MAHONING RIVER
WASTE LOAD ALLOCATION STUDY

U.S. Environmental Protection Agency
Region V
Surveillance and Analysis Division
Eastern District Office
Fairview Park, Ohio

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WASTE LOAD ALLOCATION STUDY

Prepared for the

OHIO ENVIRONMENTAL PROTECTION AGENCY

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FAIRVIEW PARK, OHIO

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SECTION I

INTRODUCTION

The lower Mahoning River remains today as one of the most severely polluted streams in the nation. Although it is a small stream, averaging only about 150 feet in width and four feet in depth, it receives tremendous use by a steel manufacturing complex including nine separate plants, a power generating station, and eight Ohio municipalities which use it as a receiving water for sanitary wastes. The Mahoning River is also an interstate stream flowing from northeast Ohio in a southeasterly direction into northwestern Pennsylvania. At its confluence with the Shenango River in New Castle, Pennsylvania, it forms the Beaver River, which discharges into the Ohio River about twenty-five miles below Pittsburgh. The forty mile stretch of the stream from Warren, Ohio to New Castle, Pennsylvania is studied herein.

In order to maintain current industrial uses, streamflow of the Mahoning River downstream of Warren, Ohio is highly regulated for low flow augmentation, temperature control, and flood control with an elaborate system of reservoirs operated by the U. S. Army Corps of Engineers. This regulation results in higher summer minimum flows than winter minimum flows, opposite that of most natural streams. Even with regulation, the total flow of the Mahoning River may be used from two to four times during the summer months and over five times during periods of winter minimum flow. It is this continual use and re-use and, more significantly, overall lack of water pollution control by basin dischargers that render the stream unfit for aquatic life and recreational uses, both within Ohio and in Pennsylvania. Pollution in the stream is characterized by extremely high temperatures, low concentrations of dissolved oxygen, high levels of ammonia-N, cyanide, phenolics, and metals, severe bacterial contamination, and gross amounts of floating oil. Only pollution tolerant benthic organisms populate the lower reaches of the stream. Needless to say, the lower Mahoning River in Ohio does not support a well-balanced, native fish population.

With abundant recreational areas in the upper portions of the basin and with the economy of the area heavily dependent upon the stream, valley residents have not looked upon the Mahoning River for recreational uses, but rather as an important economic resource to be used to its utmost capacity. Unfortunately, existing uses of the stream in Ohio are not consistent with Pennsylvania's intended uses of recreation and aquatic life and existing uses of the Beaver River as a public water supply. Efforts by state and federal regulatory agencies to implement a pollution abatement program in the Mahoning Valley have been clouded by controversy for over twenty-five years.

At this writing, a viable water pollution abatement plan for the Mahoning Valley has not yet been implemented. Ohio water quality standards are again being revised and proposed National Pollutant Discharge Elimination System (NPDES) permits of May 1976 for the major municipal and industrial dischargers have been appealed by the dischargers, the Commonwealth of Pennsylvania, and the Western Reserve Economic Development Agency. These proposed NPDES permits were based upon the preliminary findings of this analysis and were designed to begin implementation of USEPA Administrator Train's decision of March 1976 to provide economic relief to the Mahoning Valley steel industry from the full impact of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500).

The Federal Water Pollution Control Act establishes a continuous planning process for water quality improvement to be implemented by the states on a river basin scale (Section 303(e)); an areawide planning process to be implemented within the framework of the basin plans (Section 208); and, a NPDES permit program to regulate municipal and industrial wastewater discharges by means of nationwide technology-based effluent limitations and other discharge criteria necessary to achieve water quality objectives (Section 402). Ideally, NPDES permits should be consistent with and implement the results of the planning processes. This study was completed at the request of the Ohio Environmental Protection Agency to estbalish the technical basis for a Section 303(e) plan.

The major purpose of this report is to establish cost effective waste load allocations for significant Ohio municipal and industrial dischargers to achieve federally approved Pennsylvania water quality standards. The results can, and have, been used for Section 208 planning purposes, preparation of proposed NPDES permits, and development of appropriate water quality standards for the Ohio portion of the stream.

Developing waste discharge allocations for the Mahoning River is a complex task involving questions of equity, economics, waste treatment technology, mathematical water quality simulation, and a high degree of engineering judgment. Prior to assigning allowable discharge loadings to each discharger, a considerable amount of detailed information about the river system had to be developed. A review of the complex hydrology of the system was necessary. The location of each significant discharger and the amounts of wastes discharged were quantified. The relation of existing discharges and possible changes in discharges to instream water quality were established. Appropriate treatment technologies were evaluated in terms of applicability to each discharger and available estimated capital cost information was assembled. Finally, the allocations were established for several treatment technologies and were evaluated in terms of the water quality objectives.

In completing each of the above tasks an effort was made to use the best information available. Where existing information was either lacking or inadequate, substantial resources were expended to provide the necessary data. Although the mathematical water quality models employed herein were validated within reasonable limits, the results obtained were not mechanically transferred into conclusions and recommendations, but were evaluated in terms of the strengths and weaknesses of the entire analysis and the feasibility of the treatment technology considered, then formulated into an implementable water quality improvement plan.

Based upon the water quality analysis, the minimum level of waste treatment for Ohio dischargers found to be consistent with Pennsylvania water quality standards includes regionalization and secondary treatment plus nitrification for municipal sewage treatment plants; BATEA or closed dirty water quench systems for coke plants; recycle of blast furnace process waters with discharge of minimal blowdown to the stream; BPCTCA or equivalent treatment for steelmaking, hot forming, cold rolling, and finishing operations at the steel mills; and, offstream cooling and recycle of condenser cooling water at the Ohio Edison power plant. Estimated municipal capital costs associated with the above levels of treatment are about 120 million dollars, while estimated industrial capital costs range from about 104 to 128 million dollars, depending upon the type of coke plant treatment provided.

The report is presented in eight sections and separate appendices: Section I is the introduction; Sections II and III present conclusions and recommendations, respectively; the Mahoning River basin is described in Section IV with emphasis on the complicated hydrology of the stream; Section V presents background information and effluent data for the major industrial and municipal dischargers; a listing of applicable Ohio and Pennsylvania water quality standards is presented in Section VI with a historical water quality review; the mathematical water quality models employed in the waste load analysis, the results of USEPA field studies that were necessary to obtain sufficient data to use the water quality models, and the results of model verification studies are presented in Section VII; and, Section VIII presents the waste load allocation policy employed, throughout the analysis, six waste water treatment alternatives, and the water quality response and estimated capital costs associated with each alternative.

SECTION II
FINDINGS AND CONCLUSIONS

A. Hydrology

1. The lower Mahoning River is highly regulated by the U.S. Army Corps of Engineers for flood control, low flow augmentation, and temperature control, resulting in summer minimum regulated flows greater than winter minimum regulated flows. Using the Mahoning River minimum regulated flow schedules for water quality design purposes does not provide the safety inherent in using the annual minimum consecutive seven day flow with a ten year recurrence interval used for design purposes for most natural streams in Ohio. Mahoning River streamflow at the minimum regulated schedules may occur as much as twenty percent of the time on an annual basis.

2. Based upon information provided by the U.S. Army Corps of Engineers, significant increases of minimum regulated schedules are not possible with existing uses of the reservoir system in the Mahoning River Basin. Increasing streamflow to minimize or eliminate point source waste treatment requirements is not feasible as the drainage area of the basin is not capable of supporting significantly higher sustained flows.

B. Water Quality

1. With the exception of improved pH levels, stream quality of the lower Mahoning River has not appreciably improved since the early 1950's. Excessive water temperatures, minimal dissolved oxygen concentrations, gross amounts of floating oil, severe bacterial contamination, and high levels of ammonia-N, total cyanide, phenolics, and metals are still prevalent.

2. Existing Ohio and Pennsylvania water quality standards for the lower Mahoning River have been routinely violated since they were adopted in 1972 and 1971, respectively.

3. The level of aquatic life in the stream has not improved from 1965 to 1975 as measured by the diversity and numbers of benthic organisms.

C. Water Quality Management Planning

1. The mathematical water quality model RIBAM, as modified by USEPA, and an Edinger-Geyer temperature simulation model have been validated for the lower Mahoning River system. Given the complexity of the system in terms of the altered flow regime, the number of significant point sources, and existing severely polluted conditions, efforts to validate the mathematical models for water quality management planning were successful.

2. At this writing, the data base assembled for the lower Mahoning River for determining mathematical model input parameters is the most extensive, detailed, and complete data set for any river system in Ohio.

3. Except for the sensitivities of computed values of temperature, dissolved oxygen, and ammonia-N to changes in flow, and the sensitivity of computed dissolved oxygen values to changes in temperature, water quality model computations for the lower Mahoning River are not overly sensitive to anticipated ranges of input parameters supplied to the mathematical models. Mahoning River quality in Ohio, and in Pennsylvania, is primarily a function of municipal and industrial waste discharges in Ohio.

4. The waste load allocation analysis was completed with no explicit safety factors for achieving Pennsylvania water quality standards. For the most part, these standards are expressed as values not to be exceeded at any time. Monthly average vs. daily maximum discharge loadings for municipal and industrial sources were employed, and, as noted above, frequently

occuring water quality design flows were included. Allowances for expansion in steel production in the Mahoning Valley were not made. Industrial modernization, expansion, or growth must incorporate new source performance discharge standards which will result in minimal impacts in stream quality, and will most likely occur as existing production facilities with high discharges of pollution are replaced.

5. Water quality models cannot be used exclusively to develop a comprehensive water quality management plan for the Mahoning River. Important constituents having adverse impacts on stream quality including suspended solids, oil and grease, fluoride, certain nutrients, and metals must be evaluated separately. For some constituents, rough quantitative assessments of probable impacts on stream quality were made. For others only qualitative judgments could be considered; and, for oil and grease, the level of analysis was severely hampered by the very nature of oil and grease, the absence of any reasonably specific applicable criteria, and, the difficulty of relating waste discharges to such criteria.

D. Waste Treatment Technology to Achieve Pennsylvania Water Quality Standards.

1. The most cost effective method of achieving Pennsylvania water quality standards for the Mahoning River within the framework of the Federal Water Pollution Control Act Amendments of 1972 was found to be the following (Case 3, Tables VIII-3 and VIII-7):

a. Regionalization of municipal sewerage systems with secondary treatment plus nitrification (Ammonia-N removal). Estimated capital and annual operating costs (1976 dollars) for the eight municipalities included in this analysis are 120 and 4.2 million dollars, respectively, as opposed to 96 and 3.3 million dollars, respectively, for conventional secondary treatment. Of the total capital costs, 18 million dollars are for interceptor projects necessary regardless of treatment plant design. About 0.4 million dollars of the annual operating costs are associated with interceptor systems.

b. Offstream cooling and recycle of condenser cooling water at the Ohio Edison-Niles Steam Electric Generating Station. Estimated capital costs associated with this project are 8 million dollars (1976 dollars).

c. Depending upon the level of coke plant treatment provided, total capital costs of 96.2 to 120.3 million dollars are estimated for the steel industry (1975-1976 dollars). Costs associated with each process operation are summarized below:

1) Coke plants

Closed dirty water quench systems (about 1.8 million dollars), or, depending upon air pollution considerations, BATEA (25.9 million dollars).

2) Blast Furnaces

Recycle of gas wash water, direct contact gas cooling water, and miscellaneous contaminated streams with minimal blowdown to the river (26.6 million dollars). Depending upon the performance of recycle systems at the three most downstream blast furnace operations, blowdown treatment may be required (up to 3.6 million dollars assuming BATEA costs for blowdown treatment).

3) Hot Forming

Treatment of process waste water to 30 mg/l suspended solids and 10 mg/l oil and grease (49.5 million dollars). There is considerable uncertainty that this level of treatment for oil and grease (or BPCTCA (70.0 million dollars)) is sufficient to achieve designated stream uses. Estimated hot forming BATEA costs are 102.0 million dollars.

4) Cold Rolling, Finishing

Treatment to BPCTCA or equivalent (12.8 million dollars).

5) Miscellaneous

Sanitary waste improvements (1.9 million dollars).

2. The treatment technology outlined above represents the minimum basic program necessary to achieve Pennsylvania water quality standards. Relatively minor adjustments of industrial final effluent limitations for ammonia-N, total cyanide, and phenolics may be necessary after treatment controls are installed. However, selection of the basic minimum waste treatment technology at this time is not affected by these minor adjustments or by the sensitivity of water quality model computations.

3. Estimated capital costs for the Mahoning Valley steel industry to

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3. Estimated capital costs for the Mahoning Valley steel industry to

achieve Pennsylvania water quality standards (96.2 to 120.3 million dollars), are significantly less than estimated capital costs for industry-wide BPCTCA (147.4 million dollars) and industry-wide BATEA (189.1 million dollars).

E. Prospects for Stream Recovery

1. Numerical physical and chemical Pennsylvania water quality standards will be achieved with the waste treatment alternative outlined above. There is uncertainty that the Ohio and Pennsylvania general criteria for oil and grease will be achieved.

2. Taste and odor problems at the Beaver Falls water supply resulting from municipal and industrial discharges in Ohio should be abated. However, taste and odor problems associated with reservoir operations in the Beaver River Basin will continue to occur.

3. Poor sediment quality in the Mahoning River is likely to persist for some time after gross point source discharges are abated. During natural cleansing of these sediments to levels consistent with then current discharges, background water quality, and residual non-point source loadings, adverse effects upon overlying water quality will be minimal.

4. After treatment controls are installed and discharges of toxic substances are reduced, instream levels of phosphorus, and carbonaceous and nitrogenous materials, will be sufficient to result in algal growth. The extent to which nuisance conditions will occur is difficult to predict. Several factors influencing algal growth, including the high natural turbidity of the Mahoning River, reduction of extreme temperatures, and the establishment of a foraging fish population, may tend to minimize possible nuisance conditions.

5. Violations of Pennsylvania dissolved oxygen standards resulting from non-point source loadings and combined sewer overflows induced by major

precipitation events are unlikely. Such effects in the Ohio portion of the stream will be more severe.

6. After treatment controls are installed, the Mahoning River in Pennsylvania will be capable of supporting a balanced warm water fishery. Except for the most congested industrial areas just downstream of Warren and Youngstown where the entire stream is a mixing zone for waste discharges, the Ohio portion of the stream should also support a varied aquatic population. Operation and maintenance of pollution control facilities installed by dischargers located close to the Ohio-Pennsylvania state line will have a major bearing on water quality in Pennsylvania.

SECTION III
RECOMMENDATIONS

1. Engineering and construction of municipal and industrial water pollution control facilities consistent with Conclusion D. 1 be implemented simultaneously through appropriate mechanisms provided by the Federal Water Pollution Control Act and other Ohio EPA programs.

2. Additional comprehensive water quality and discharge surveys of the lower Mahoning River should not be considered until point source discharge controls are installed and operating. Existing long term ambient monitoring programs should be continued to determine progress towards achieving desired water quality objectives.

3. The design of municipal sewage treatment plants should consider supplemental sludge handling capability in the event phosphorus controls are necessary to minimize algal growth in the stream.

SECTION IV

MAHONING RIVER BASIN DESCRIPTION

The Mahoning River Basin is described below in terms of geography, geology, meteorology, land and water uses, demography, economy, and hydrology. By design, the information and data presented are of a general nature for the purpose of providing background information only. Additional detailed information concerning the description of the basin can be found in appropriate listed references. Hydrologic information is limited primarily to the lower Mahoning River downstream of Leavittsburg, Ohio.

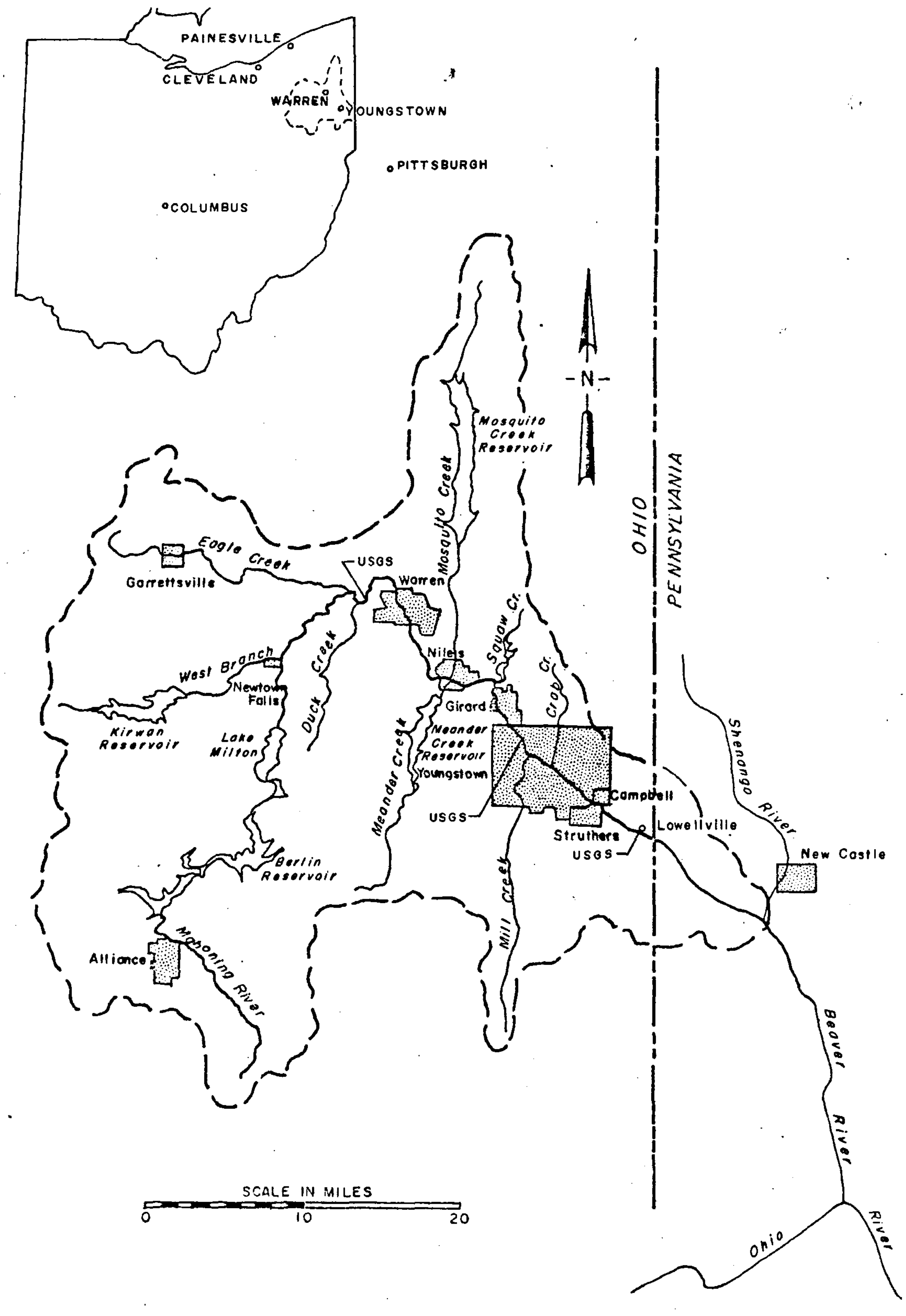
A. Geography[1, 2]

The Mahoning River is an interstate stream originating in northeastern Ohio flowing 96 miles in a southeasterly direction before crossing the Ohio-Pennsylvania State line near Lowellville, Ohio (Figure IV-1). The river flows another 12 miles in Pennsylvania prior to its confluence with the Shenango River at New Castle, Pennsylvania, forming the Beaver River. The Beaver River flows for about 21 miles in Pennsylvania to the Ohio River at mile point 942.4 (from its mouth) which is approximately 13 miles upstream of where the Ohio River crosses the Pennsylvania State line.

Total drainage area of the Mahoning River Basin is 1140 square miles, 1078 of which are in Ohio and 62 in Pennsylvania. Principal tributaries are the West Branch of the Mahoning, Eagle Creek, Mosquito Creek, Meander Creek and Mill Creek. The average stream gradient of the Mahoning River is 2.2 feet per mile from Pricetown to Leavittsburg and 2.6 feet per mile from Leavittsburg to Lowellville.

FIGURE IV-1

MAHONING RIVER BASIN



The Mahoning River Basin is located in the Southern New York section of the Appalachian Plateau Province, in the Appalachian Highlands physiographic division (Figure IV-2). The southern New York section is a mature glaciated plateau of moderate relief.

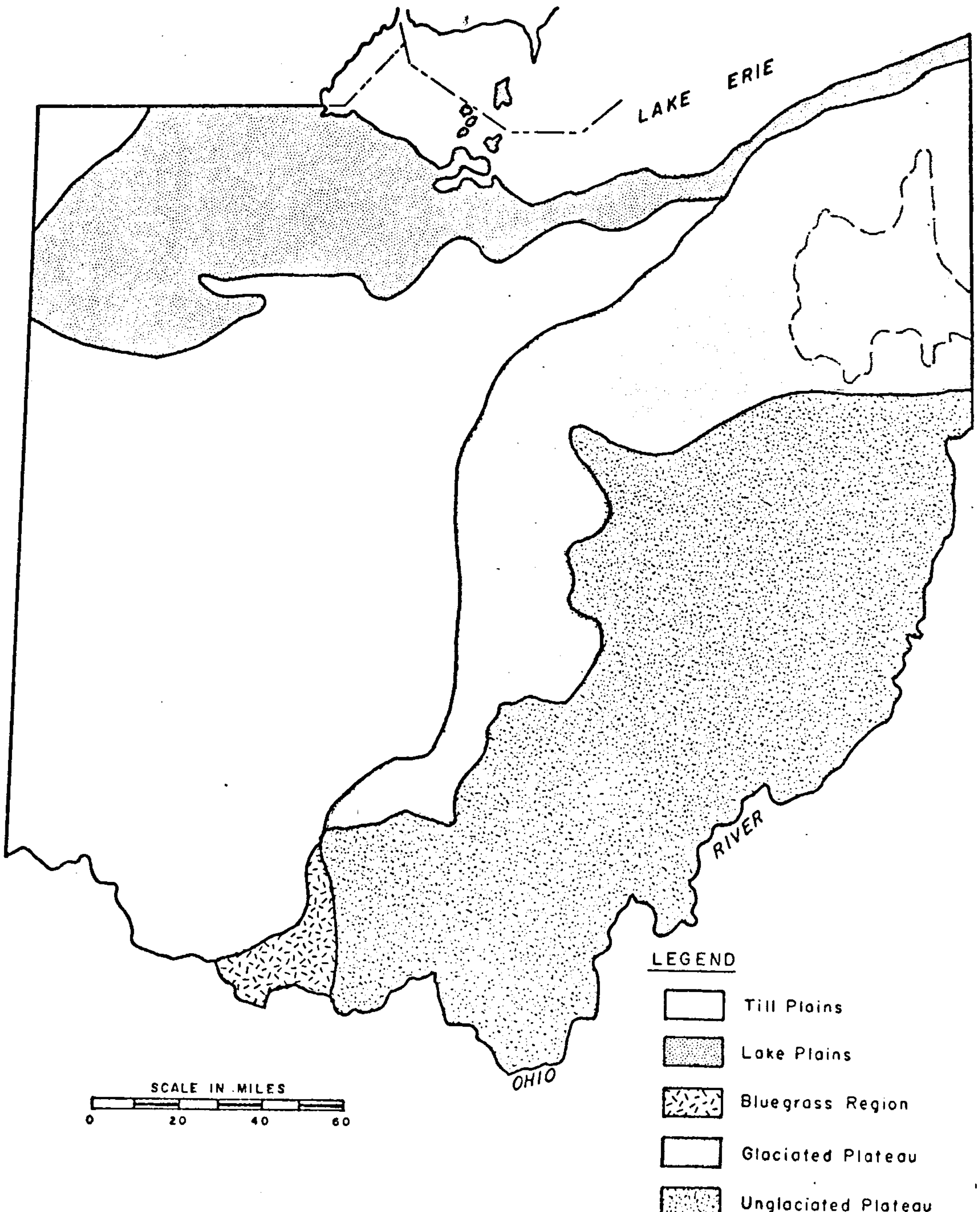
B. Geology[3, 4]

Figures IV-3 through IV-5 illustrate generalized geologic cross-sections at various locations within the Mahoning Basin. The rocks exposed in the basin dip gently toward the south, so that the formations crop out in east-west belts with successively younger formations toward the south. The Berea sandstone of Mississippian age occurs at the surface north of Warren. For several miles south of Warren, interbedded shales and sandstones of Mississippian age prevail at or near the surface. The surface of the southern portion of the Mahoning River Basin is underlain by the Pottsville and Allegheny rocks of Pennsylvanian age. Several of the sandstones and conglomerates are water bearing but the Pennsylvania strata are predominantly shale and clay with thin beds of coal and limestone. As a result, the effect of groundwater storage on streamflow is probably negligible.

Of relatively greater importance, from the hydrologic standpoint, is the covering of glacial drift. This is erratic in thickness and of variable character. The drift is mostly of late Wisconsin age, largely till, and generally is thin, averaging about 25 feet in thickness. Except in the buried valleys there is little water storage in the glacial deposits, and in these valleys the materials are generally clay and fine sand, with limited storage and permeability. The western part of the area has thicker drift, associated with the end moraines.

There is a buried valley with drift 200 feet thick, extending south to north across Portage County, and a similar one extending to the northward in the present Mahoning-Grand River valley. The glaciers blocked northward flowing streams, and filled the ancient valleys with drift, rearranging the drainage pattern, and causing such reversals in direction as the bend in the Mahoning River near Warren. Generally, the most abundant water supplies

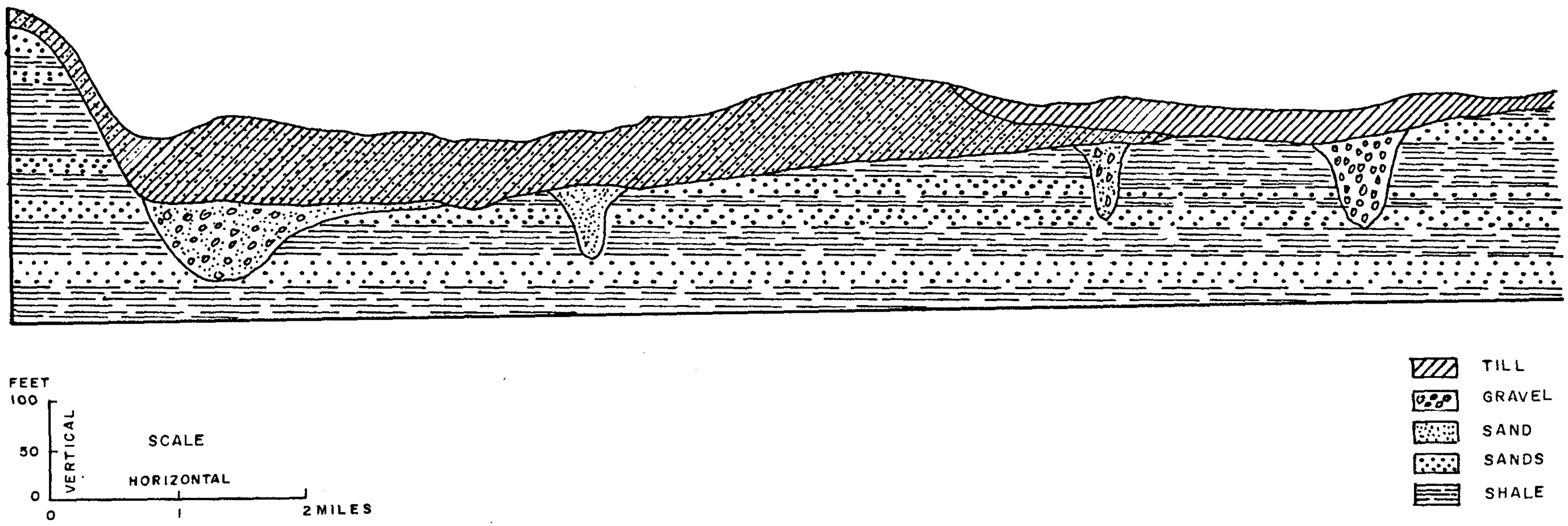
FIGURE IV-2
MAHONING RIVER BASIN
PHYSIOGRAPHIC SECTIONS OF OHIO



SOURCE: Northeast Ohio Water Plan, 1972

FIGURE IV-3

GENERALIZED CROSS SECTION SHOWING THE GEOLOGY OF THE MIDDLE MAHONING RIVER BASIN

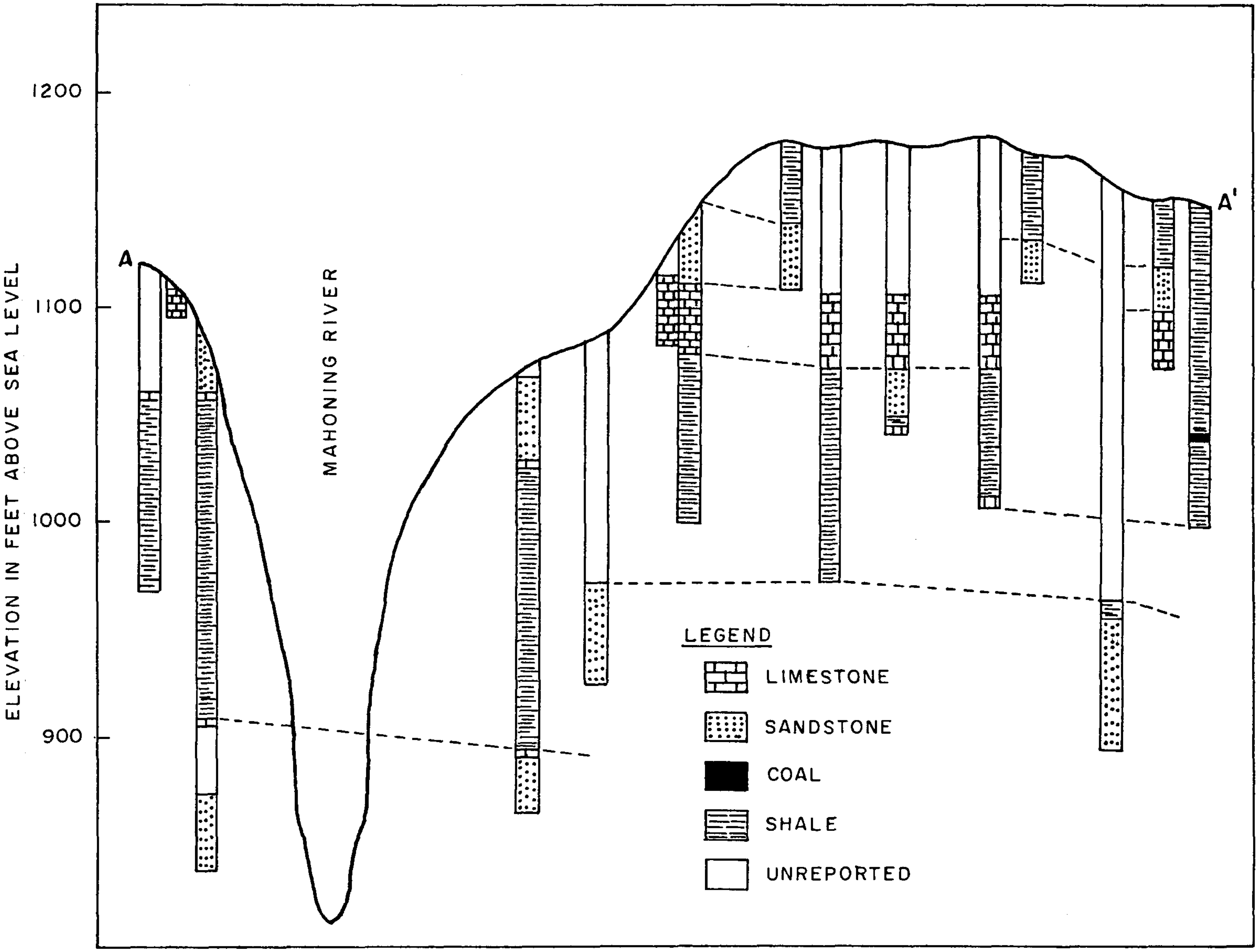


SOURCE: Ohio Water Plan Inventory, 1960

FIGURE IV-4

MAHONING RIVER BASIN

GEOLOGIC CROSS SECTION A-A'

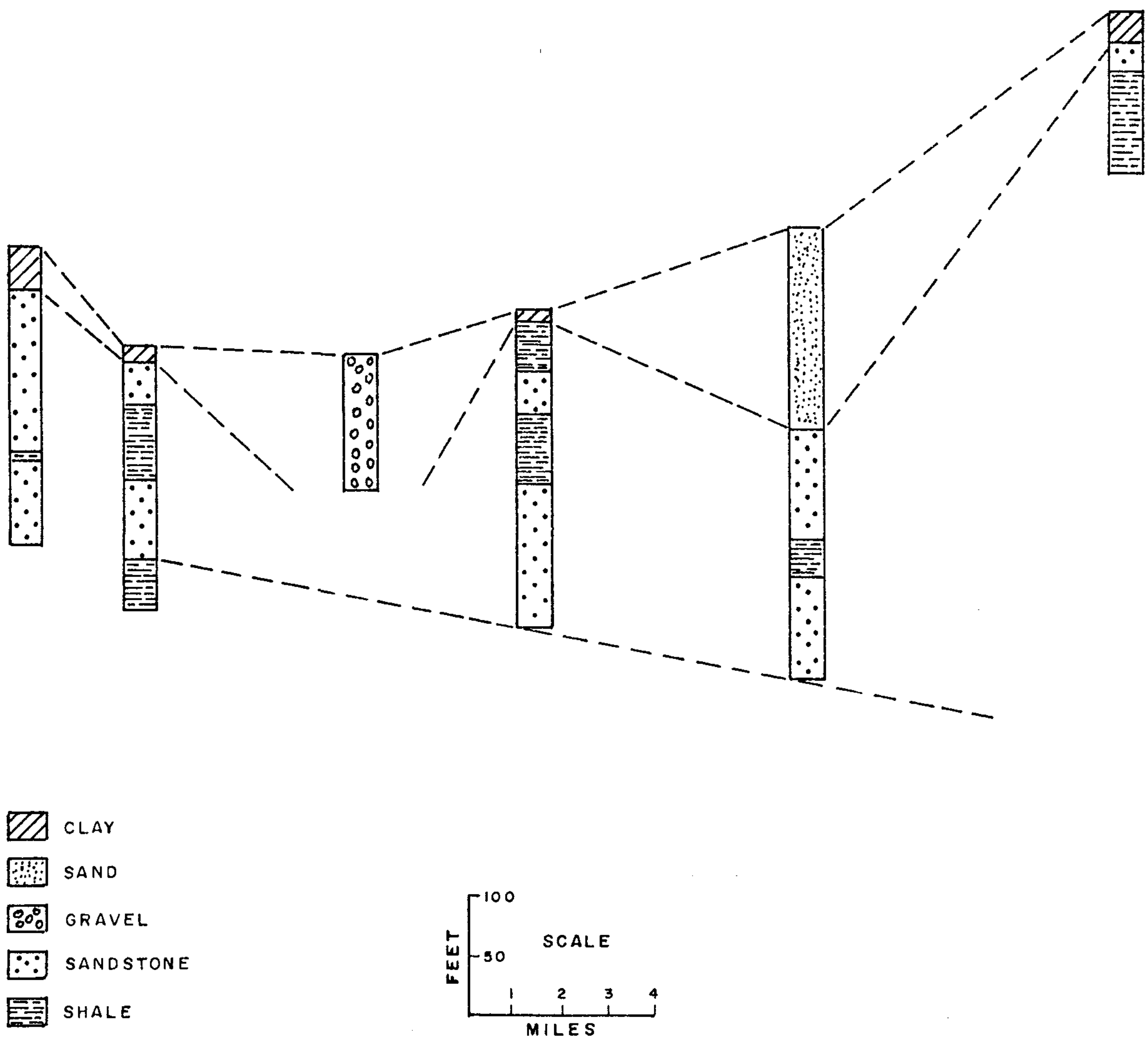


SOURCE: Ohio Water Plan Inventory, 1960

FIGURE IV-5

MAHONING RIVER BASIN

GENERALIZED GEOLOGIC CROSS SECTION, NORTH TO SOUTH ACROSS THE UPPER MAHONING RIVER BASIN



SOURCE: Ohio Water Plan Inventory, 1960

are in the underlying rocks, indicating that there is little natural groundwater storage affecting streamflows (Figure IV-6).

The groundwater of the basin is generally of poor quality due to local geological conditions. Relatively few groundwater supplies have been developed in the basin. The Ohio Department of Natural Resources reports that troublesome amounts of iron and manganese are present in most wells, many of which also contain objectionable amounts of dissolved solids and hardness. Water from most wells in the area has a pH greater than 7.0. Temperature of underground water in the area remains essentially constant throughout the year; however, wells that induce infiltration from the Mahoning River below Youngstown yield water with temperatures considerably higher than the average of 51-54°F.

As mentioned previously, the soils in the Mahoning River Basin developed generally from late Wisconsin till deposited on sandstone and shale. As is the case for areas that have experienced glaciation, the soils of the basin are varied with many abrupt changes. Table IV-1 presents generalized information on soil features and limitations for several land uses by major soils within association groups shown in Figure IV-7. The Mahoning, Ellsworth, Remsen, and Canadea soils are dominated by a silty surface layer with fine textured, clayey subsoil below 0 to 12 inches deep. These soils have a rapid runoff rate and are highly erosive. The Wadsworth, Rittman, Canfield, Ravenna, Conneaut, Chili, Loudonville, Weikert and Platea soils have a moderate erodibility factor. The restrictive subsoil layer is deeper, resulting in a better water holding capacity.

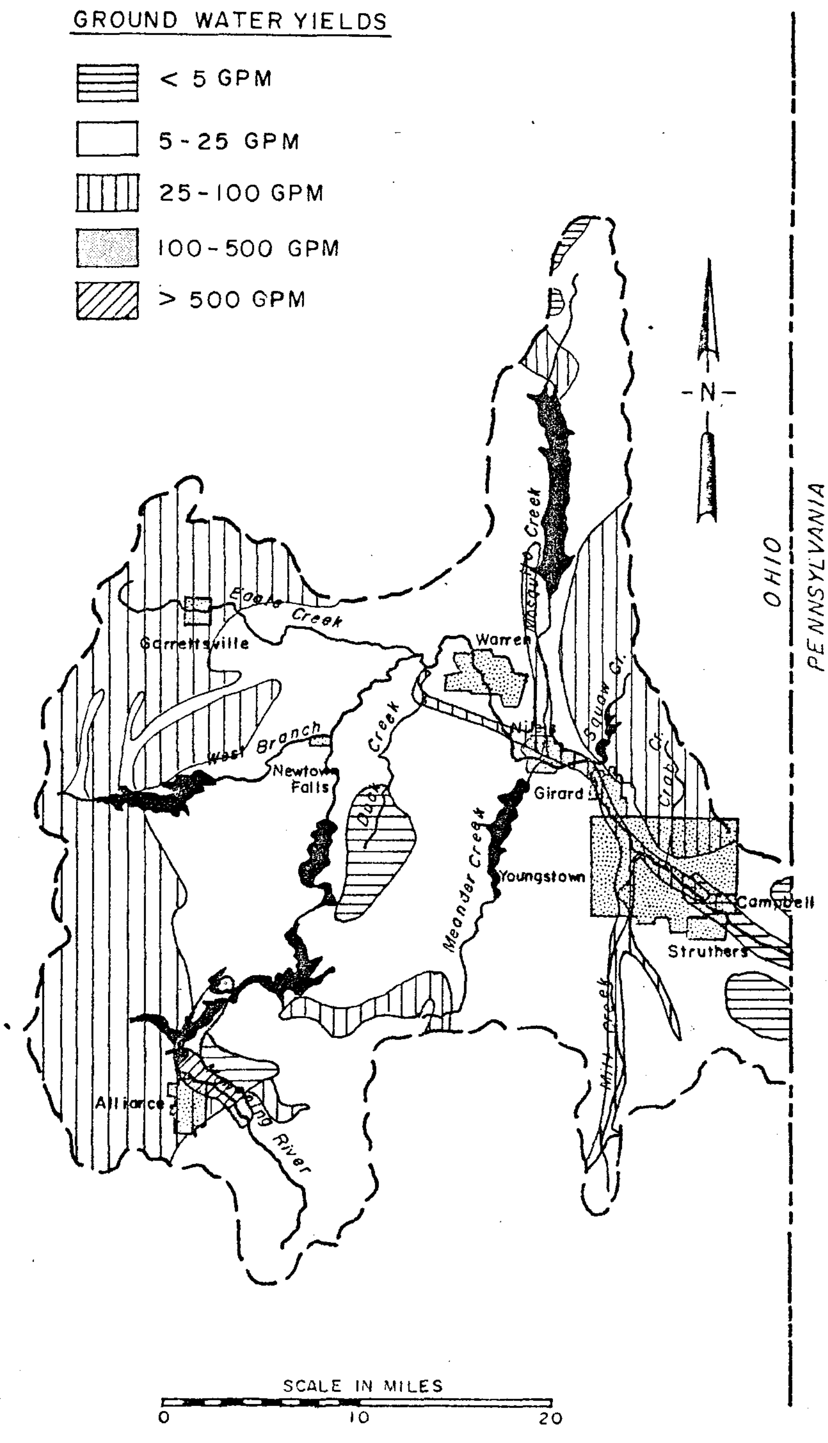
C. Meteorology[5, 6]

The climate of the Mahoning River Basin is characteristic of northern Ohio. The mean annual air temperature is approximately 50°F with maximum daily temperatures averaging 83°F during July and minimum daily temperatures averaging 28°F during January. Figure IV-8 is an isohyetal map of the basin depicting annual mean precipitation in inches; average rainfall across the basin is approximately 36.5 inches. Average annual snowfall is approximately 38 inches. The growing season for the basin averages between 140 and 150 days. Table IV-2 presents mean air temperatures,

FIGURE IV-6

MAHONING RIVER BASIN

UNDERGROUND WATER RESOURCES



SOURCE: Northeast Ohio Water Plan, 1972

TABLE IV - 1

CHARACTERISTICS OF SOIL ASSOCIATIONS

Soil Association	Slope Range	Soil Features and/or Limitations for Selected Uses					
		Septic Tank Leach Fields[1]	Agriculture and Landscaping	Recreation[2]	Ponds and Lakes	Roads and Parking Lots	Pipelines and Sewers
Mahoning Ellsworth	nearly level to strongly sloping	wetness, slow permeability	wetness, poor tilth, clayey erosion	wetness, temporary wetness	few limitations, clayey, subject to cracking	wetness, frost heave	seasonal high water table
Mahoning Remsen	nearly level to gently sloping	wetness, slow permeability	wetness, poor tilth, clayey, erosion	wetness, temporary wetness	few limitations, clayey, subject to cracking	wetness, frost heave, high shrink-swell	seasonal high water table, high shrink-swell
Wadsworth Rittman	nearly level to sloping	wetness, slow permeability	wetness, erosion	wetness, temporary wetness	few limitations	wetness	seasonal high water table
Canfield Ravenna	nearly level to sloping	wetness, slow permeability	temporary wetness	wetness, temporary wetness	few limitations	temporary wetness, frost heave	seasonal high water table, seepage above fragipan
Conneaut Painesville	nearly level to gently sloping	wetness	temporary wetness	wetness, temporary wetness	moderate seepage	temporary wetness, frost heave	seasonal high water table
Canadea Sebring	nearly level	wetness, slow permeability	wetness, poor tilth, clayey	wetness	moderate seepage	wetness, poor stability, frost heave	seasonal high water table

TABLE IV - 1 (Continued)

CHARACTERISTICS OF SOIL ASSOCIATION

Soil Association	Slope Range	Soil Features and/or Limitations for Selected Uses					
		Septic Tank Leach Fields[1]	Agriculture and Landscaping	Recreation[2]	Ponds and Lakes	Roads and Parking Lots	Pipelines and Sewers
Chili Wheeling (Muck)	nearly level to strongly sloping	few limitations, possible ground water contamination (muck) is severe	seasonal drouthiness, wind erosion on farmed	few limitations except on muck	high seepage rate	few limitations except very low stability and wetness on muck	few limitations on Chili and Wheeling, high water table in muck
Colonie-Conotton Elnora	gently sloping	few limitations, possible ground water contamination	sandy, drouthy	few limitations	high seepage rate	few limitations	possible caving
Loudonville Weikert	sloping to very steep	shallow to bedrock, steep slope	shallow to bedrock, some steep slope	steep slopes	shallow to bedrock	shallow to bedrock steep slopes	bedrock at 2 to 4 feet, stony
Platea Sheffield	level to sloping	wetness, slow permeability	wetness	wetness, temporary wetness	few limitations	wetness	seasonal high water table

[1] Applies to homes, light industrial and commercial buildings of less than four stories with basements. Soils of slow permeability are defined by percolation rates of 0.063-0.200 inches per hour.

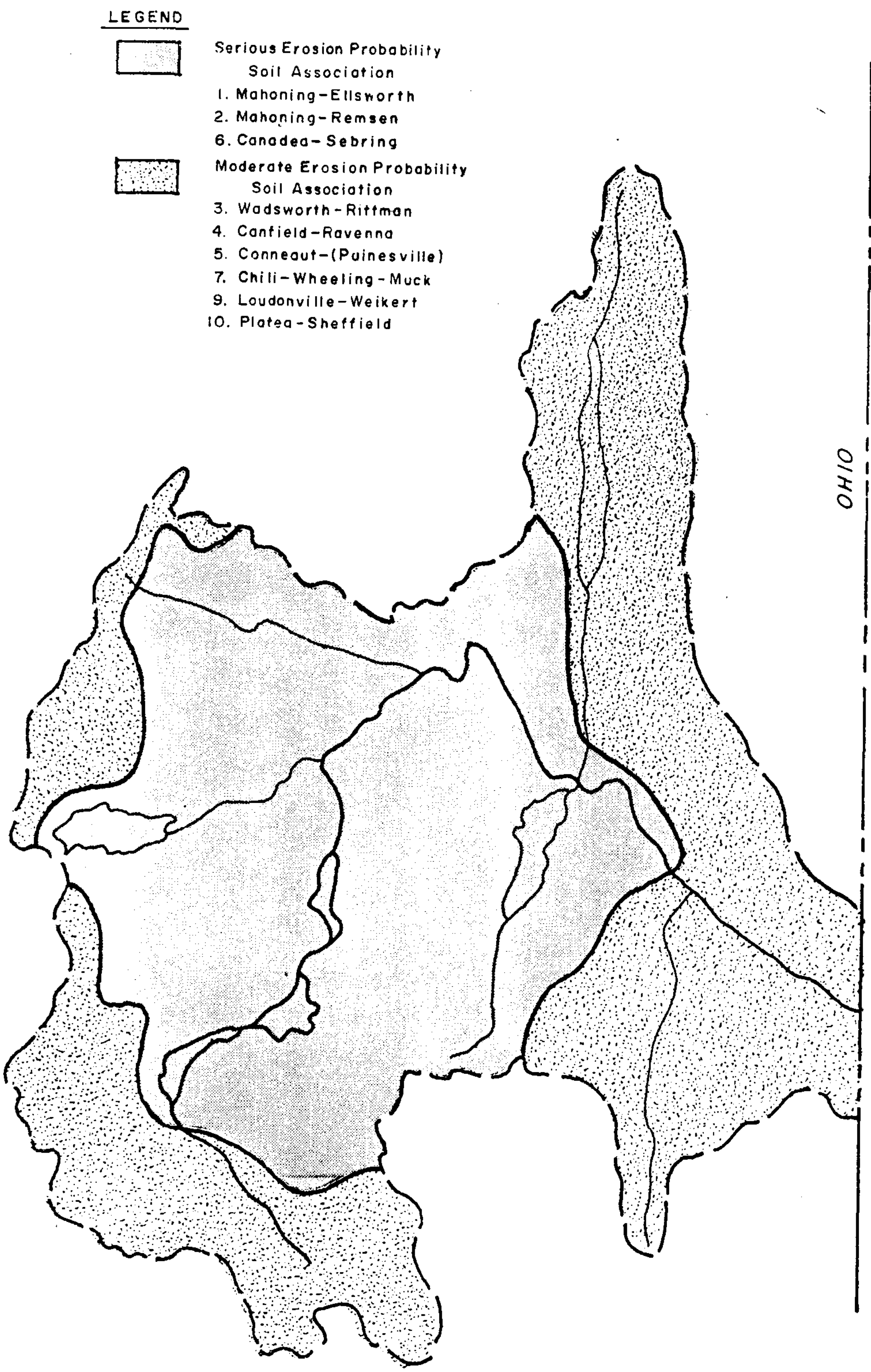
[2] Applies to athletic fields, campsites, and picnic areas.

Source: Prepared as part of the Ohio Cooperative Soil Survey by Division of Lands and Soils. Ohio Department of Natural Resources; U. S. Soil Conservation Service; and the Ohio Agricultural Research and Development Center.

FIGURE IV-7

MAHONING RIVER BASIN

SOIL ASSOCIATION AND ERODIBILITY



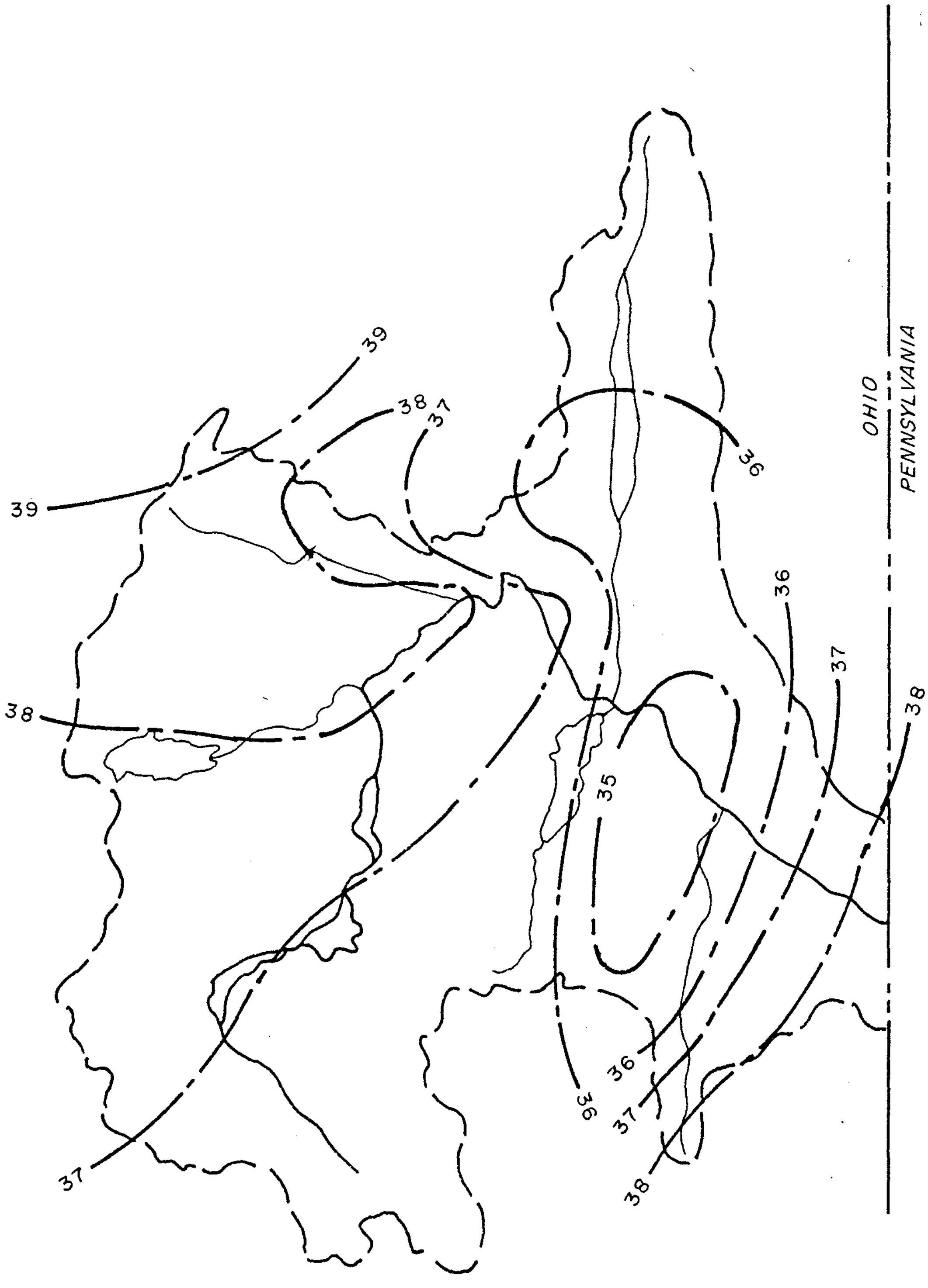
SOURCE Division of Land and Soils, Ohio Department of Natural Resource

FIGURE IV-8

MAHONING RIVER BASIN

ISOHYETAL MAP

AVG. ANNUAL PRECIPITATION IN INCHES



SOURCE: Northeast Ohio Water Plan, 1972

TABLE IV - 2

CLIMATIC DATA FOR NORTHEAST OHIO

Area	Mean Temperature, (°F) Annual	July	January	Average Dates of Killing Frost First	Last	Average Length of Growing Season (Days)	Latitude
Cleveland	49.9	72.2	27.5	Nov. 2	Apr. 21	195	41°24' N
Painesville	49.9	71.0	28.2	Nov. 4	Apr. 24	193	41°45' N
Akron	49.7	72.4	27.0	Oct. 22	Apr. 30	173	40°55' N
Chardon	48.9	70.6	26.2	Oct. 17	May 3	167	41°35' N
Hiram	48.8	71.2	26.1	Oct. 15	May 2	165	41°19' N
Youngstown	48.7	70.6	26.0	Oct. 4	May 12	145	41°16' N
Ravenna	49.2	70.6	27.1	Sept. 25	May 14	133	41°10' N
Warren	50.3	72.1	27.8	Sept. 24	May 11	148	41°12' N
Canfield	49.2	70.8	27.0	Sept. 28	May 11	142	41°01' N

Reference: Climate Guide for Selected Locations in Ohio, Division of Water, Ohio Department of Natural Resources.

U. S. Department of Commerce, Climatological Summary.

average dates of killing frost and the average length of the growing season for selected locations in the basin and other locations in northeast Ohio.

D. Land and Water Uses

Table IV-3 presents a summary of land use within the seven Ohio counties included in the Mahoning River Basin. As shown in Table IV-4, only small portions of Ashtabula, Columbiana, Geauga, and Stark counties are actually in the basin. Land uses in the basin associated with portions of these counties are primarily agricultural and residential. As shown in Table IV-3, approximately 35 percent of the land within the basin is devoted to cropland, 25 percent to forest and woodland, 17 percent to urban and developed areas, and 17 percent to various farm and nonfarm uses. Less than 0.5 percent of the basin is covered by water.

The Mahoning River Valley from Warren, in the northwest portion of the basin, to Lowellville near the Pennsylvania line, is characterized as a large urbanized area, comprising industrial, residential and commercial uses. On the 36 miles of river frontage from Newton Falls to the Pennsylvania line approximately ten miles are in open and undeveloped land. Eight miles of this open land are evident from Newton Falls to Warren and two miles near Lowellville. The reach in Pennsylvania from the State line to New Castle is mostly undeveloped, although some urban development extends into the Mahoning Valley of Pennsylvania from the outskirts of New Castle.

Approximately five miles of river frontage in the Mahoning River Valley is in intensive urban development with a mix of residential, commercial and industrial uses evident as the river pases southeast through Warren, Niles, McDonald and Girard in Trumbull County. The stretch from lower Warren to Niles is characterized by scenic, undeveloped river banks. Nearly 60 percent, or about 21 miles, of river front from Newton Falls to the Pennsylvania line is in heavy industrial use that includes several major steel mills.

Major uses of the basin's water resources are municipal, industrial, and recreational. Other uses include livestock watering, fish and wildlife propagation, and disposal of municipal and industrial wastes. Flow augmentation is practiced on the Mahoning River by the U. S. Army Corps of

TABLE IV - 3

MAHONING RIVER BASIN PLANNING AREA

1967 LAND USE
(ACRES)

	Ashtabula County	% of Total	Columbiana County	% of Total	Geauga County	% of Total	Mahoning County	% of Total	Portage County	% of Total	Stark County	% of Total	Trumbull County	% of Total
Area of County	451,340		342,103		259,080		268,160		319,320		366,720		391,145	
Urban and Developed Area	57,959	12.8	43,804	12.8	31,825	12.3	77,326	28.8	36,206	11.3	86,458	23.6	60,638	15.5
Water Area	1,100	0.2	803	0.2	1,258	0.5	754	0.3	1,332	0.4	147	< 0.1	2,000	0.5
Cropland	142,954	31.7	142,803	41.7	80,591	31.1	80,026	29.8	115,622	36.2	152,777	41.7	105,583	27.0
Pasture and Range	24,310	5.4	52,828	15.4	19,057	7.4	15.485	5.8	32,053	10.0	23,157	6.3	32,127	8.2
Forest and Woodland	135,674	30.1	88,768	25.9	100,663	38.9	31,026	11.6	89,327	28.0	67,120	18.3	86,224	22.0
Other Land in Farm	48,412	10.7	6,600	1.9	14,465	5.6	16,048	6.0	3,990	1.2	10,000	2.7	30,719	7.9
Not in Farm	40,931	9.1	6,497	1.9	11,211	4.3	46,779	17.4	17,902	5.6	25,705	7.0	64,615	16.5
Federal Non-Cropland	0	0.0	0	0.0	10	< 0.1	716	0.3	22,888	7.2	1,356	0.4	9,239	2.4

SOURCE: Ohio Soil and Water Conservation Needs Inventory, the Ohio Soil and Water Conservation Needs Committee, 1971.

TABLE IV - 4

OHIO COUNTIES IN THE MAHONING RIVER BASIN

County	Total Area (sq. mi.)	Portion in Basin Area (sq. mi.)	Portion in Basin Percent of County
Ashtabula	709	113*	16
Columbiana	535	56	10
Geauga	409	6	1.5
Mahoning	425	352*	84
Portage	505	276	55
Stark	579	57	10
Trumbull	641	496*	78

SOURCE: Water Inventory of the Mahoning and Grand River Basins and adjacent areas in Ohio, Ohio Department of Natural Resources, Division of Water, April 1961.

* Includes 285 square miles drained into Pennsylvania by the Shenango River and its tributaries.

Engineers to provide adequate cooling water for industry, for flood protection, and for recreational use.

Table IV-5 presents the average water consumption of the five largest industrial water users within the basin. With the exception of municipal water used for boiler operation and sanitary service, these facilities use the Mahoning River as their major water source. Total daily usage during normal production amounts to over 800 million gallons. Based upon minimum regulated streamflows at Youngstown for July (480 cfs) and January (225 cfs), the total flow of the river is used about 2.6 times during the summer and as much as 5.6 times during winter low flow periods. Since the Mahoning River is also a very shallow stream, several low head dams were constructed at various strategic points downstream of Leavittsburg to provide adequate depth for industrial intakes. Some of the smaller industrial water users on the Mahoning are Benada Aluminum Products Co., General Electric - Mahoning and Niles Glass Plants, Fitzsimmons Steel Company, Jones & Laughlin Steel, Reactive Metals Inc., Packard Electric Division - GMC, and the Wilkoff Company. Most of these dischargers obtain water from various municipalities and do not use surface water directly. Industrial water demand projections, by county, through the year 2020 are presented in Table IV-6A.

Current public water supplies within the basin are listed in Table IV-7 with projected demands of the major systems through the year 2020 presented in Table IV-8. Table IV-7 shows that approximately 70 mgd were processed by local water treatment plants for municipal usage in 1974. Because of its severely polluted condition, the main stem of the Mahoning River below Warren has never been used for potable water supply. However, the Beaver River is used by the town of Beaver Falls, Pennsylvania as its potable water supply. Tables IV-6B and IV-9A and B present projected rural and suburban domestic water demand, projected livestock water demand and projected crop irrigation water demand.

Major recreational areas in the basin, those 50 acres or larger in area, are located on Figure IV-9, which is keyed to Table IV-10 providing details for specific areas. Table IV-10 shows that the reservoir system in the Mahoning River Basin provides considerable recreational opportunities, however, the Lower Mahoning River itself is generally not used for

TABLE IV - 5

MAJOR INDUSTRIAL WATER CONSUMPTION
LOWER MAHONING RIVER BASIN

	Flow (mgd)	Source
Copperweld Steel Corporation Steel Bar Division	34.6	Mahoning River
Ohio Edison Company Niles Electric Steam Generating Plant	209.5	Mahoning River
Republic Steel Corporation		
Warren Plant	60.1	Mahoning River
Niles Plant	1.7	Mosquito Creek
Youngstown Plant	73.3	Mahoning River
Youngstown Sheet and Tube Company		
Brier Hill Works	55.6	Mahoning River
Campbell Works	232.8	
Struthers Division	22.9	
U. S. Steel Corporation		
McDonald Mills	43.0	Mahoning River
Ohio Works	78.8	
TOTAL	812.3	

SOURCES: Industrial Discharge Permit Applications (1971 - 1973)

TABLE IV - 6 A

MAHONING RIVER BASIN PLANNING AREA
INDUSTRIAL WATER DEMAND PROJECTIONS
IN MILLION GALLONS PER DAY (MGD)

County	1980	1990	2000	2010	2020
Ashtabula	184.6	158.8	117.0	103.6	81.9
Columbiana	2.2	2.6	3.0	3.6	4.0
Mahoning	437.6	416.1	310.5	246.4	220.7
Portage	4.0	4.2	5.2	6.1	6.6
Stark	9.8	9.6	9.0	9.6	10.3
Trumbull	120.8	123.9	126.8	130.3	129.9
TOTAL	759.0	715.2	571.5	499.6	453.4

TABLE IV - 6 B

RURAL AND SUBURBAN DOMESTIC WATER DEMAND PROJECTIONS*
IN MILLION GALLONS PER DAY (MGD)

County	1980	1990	2000	2010	2020
Ashtabula	1.80	1.84	1.99	2.02	2.17
Columbiana	2.75	2.80	3.02	3.08	3.31
Mahoning	3.46	3.07	2.85	2.44	2.15
Portage	5.02	5.02	5.32	5.32	5.61
Stark	0.60	0.69	0.76	0.77	0.83
Trumbull	2.43	2.48	2.68	2.73	2.93
TOTAL	16.06	15.90	16.62	16.36	17.00

* Principally individual sources of well water withdrawal.

Source: Northeast Ohio Water Plan, Ohio Department of Natural Resources, November 1972.

TABLE IV - 7

MAHONING RIVER BASIN PLANNING AREA
MAJOR PUBLIC WATER SUPPLIES

System	1974 Consumption (MGD)	Source
Alliance	8.3	Upper and Lower Deer Creek Reservoirs, Mahoning River and Wells
Columbiana	0.4	Wells
Cortland	0.38	Wells
Craig Beach	0.06	Wells
Garrettsville	0.37	Wells
Hiram	0.18	Wells
Mahoning Valley Sanitary District	38	Meander Creek Reservoir
Mosquito Creek Water District	0.06	Wells
Newton Falls	1.0	Mahoning River
Ohio Water Service Co.	5.7	Lake Evans (4.3 MGD) Lake Hamilton (1.4 MGD)
Ravenna Ordinance Depot	0.1	Wells
Sebring	0.9	Mahoning River
Warren	14.5	Mosquito Creek Reservoir
Windham	0.3	

SOURCE: Ohio Environmental Protection Agency, Northeast District Office, Water Supply Section, April 23, 1975.

TABLE IV - 8

MAHONING RIVER BASIN PLANNING AREA
MAJOR PUBLIC WATER SUPPLIES AND DEMAND PROJECTIONS

System	1969	1980	Average Daily Demand (MGD) 1990	2000	2010	2020
Alliance[1]	6.46	7.44	9.00	10.86	13.07	15.60
Columbiana	.37	.71	.91	1.07	1.32	1.59
Cortland	.26	.40	.55	.70	.87	1.06
Craig Beach	.08	.28	.36	.41	.47	.52
Garrettsville	.25	.33	.51	.85	1.08	1.30
Hiram	.11	.25	.45	.69	.96	1.23
Mahoning Valley Sanitary District[2]	37.13	44.00	52.25	60.75	73.20	86.50
Mosquito Creek Water District						.01
Newton Falls	1.14	1.45	1.78	2.18	2.58	3.01
Ohio Water Service Co.[3]	4.05	5.78	7.02	8.18	9.32	10.30
Ravenna Ordinance Depot	1.10	1.12	1.14	1.16	1.18	1.20
Sebring[4]	.85	1.00	1.20	1.37	1.56	1.74
Warren[5]	13.62	17.25	22.55	27.85	33.65	39.00
Windham	.25	.45	.65	.91	1.23	1.59
TOTAL	65.67	80.46	98.37	116.98	140.49	164.65

1. Includes East Alliance
2. Includes McDonald, Youngstown, Niles, part of Lordstown, Austintown, Boardman, Girard, Canfield, Coltsville Center, North Jackson, Smiths Corners, Wickliffe, and Mineral Ridge
3. Includes Campbell, Lowellville, North Lima, Poland, and Struthers
4. Includes Beloit and Maple Ridge
5. Includes part of Lordstown, Howland Corners, and Leavittsburg

SOURCE: Northeast Ohio Water Plan, Ohio Department of Natural Resources, November 1972.

TABLE IV - 9 A

MAHONING RIVER BASIN PLANNING AREA LIVESTOCK WATER DEMAND PROJECTIONS IN MILLION GALLONS PER DAY (MGD)

County	1980	1990	2000	2010	2020
Ashtabula	0.66	0.61	0.61	0.55	0.49
Columbiana	0.41	0.38	0.38	0.35	0.32
Mahoning	0.32	0.31	0.31	0.28	0.26
Portage	0.39	0.36	0.36	0.33	0.30
Stark	0.07	0.07	0.07	0.06	0.05
Trumbull	0.43	0.40	0.41	0.38	0.35
TOTAL	2.28	2.13	2.14	1.95	1.77

TABLE IV - 9 B

CROP IRRIGATION WATER DEMAND PROJECTIONS IN MILLION GALLONS PER DAY (MGD)

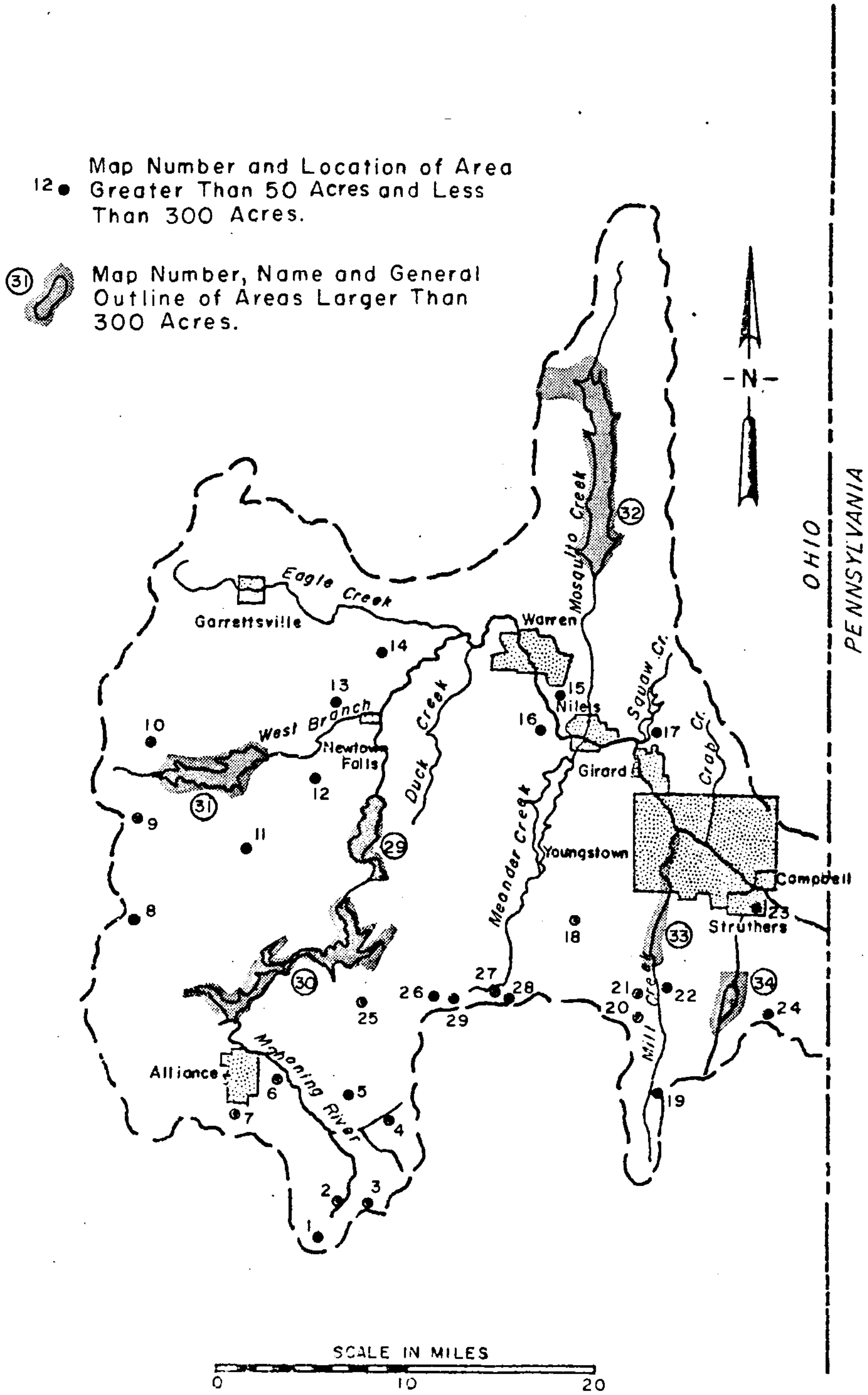
County	1980	1990	2000	2010	2020
Ashtabula	253	300	341	344	355
Columbiana	426	569	644	687	727
Mahoning	433	498	562	570	601
Portage	829	919	978	1020	1057
Stark	93	98	105	110	110
Trumbull	232	260	260	266	276
TOTAL	2266	2644	2890	2997	3126

SOURCE: Northeast Ohio Water Plan, Ohio Department of Natural Resources, November 1972.

FIGURE IV-9

MAHONING RIVER BASIN

EXISTING WATER BASIN RECREATION AREAS



SOURCE: Northeast Ohio Water Plan
Ohio Department of Natural Resources
Principal Consultant Burgess & Niple, Limited
1972

TABLE IV - 10

WATER BASED RECREATION - MAJOR RECREATIONAL AREAS

County	Key to Figure IV-9	Name of Area	Administrative Agency	Acres			Activities		
				Total	Land	Water	Boating	Fishing	Swimming
Columbiana	1	Lake Pine Sportsmen's Club	Private	65	56	9	x	x	
Columbiana	2	Paradise Lake Park	Private	130	100	30		x	x
Columbiana	3	Valley View Hunt Club	Private	338	338	0		x	
Columbiana	4	Willow Springs Lake	Private	60	53	7		x	x
Columbiana	5	Westville Lake	Alliance	160	21	139	x	x	x
Mahoning	6	Lake Park Wildlife Area	Alliance	93	73	20	x	x	
Stark	7	Silver Park	Alliance	55	54	1		x	
Portage	8	Shultz Lake	Private	60	63	37	x	x	
Portage	9	Hickory Hills Park	Private	62	47	15	x		x
Portage	10	Silver Spur Ranch Club	Private	250	244	6	x	x	x
Portage	11	Family Acres	Private	52	50	2		x	x
Portage	12	Leisure Lake Park	Private	200	187	13		x	x
Portage	13	Hideaway Woods Lake	Private	57	52	5		x	
Trumbull	14	Ridge Ranch	Private	115	100	15	x	x	x
Trumbull	15	Niles Conservation Club	Private	52	2	50		x	
Trumbull	16	Paramount Lake	Private	110	85	25		x	x
Trumbull	17	Liberty Lake	Private	119	20	99	x	x	
Mahoning	18	Lake Palmyra Park	Private	106	103	3			x
Mahoning	19	Arrowhead Lake Park	Private	300	275	25	x	x	x
Mahoning	20	Greenfield Lake	Private	80	72	8		x	
Mahoning	21	Calvins Marsh	Private	150	20	130	x	x	
Mahoning	22	Lake Wilaco	Private	200	192	8		x	

TABLE IV - 10
(continued)
WATER BASED RECREATION - MAJOR RECREATIONAL AREAS

County	Key to Figure IV-9	Name of Area	Administrative Agency	Acres			Activities		
				Total	Land	Water	Boating	Fishing	Swimming
Mahoning	23	Hamilton Lake	OH Water Svc.	104	0	104	x	x	
Mahoning	24	New Middletonn Sports Club	Private	64	60	4		x	
Mahoning	25	Rolling Meadows Lake Park	Private	80	77	3		x	
Mahoning	26	Canfield's Sports Cons. Club	Private	102	100	2	x	x	x
Mahoning	27	Western Reserve Lake	Private	95	80	15		x	x
Mahoning	28	Eastern Ohio Cons. Club Farm	Private	78	72	6		x	
Columbiana	29	Ponderosa Park	Private	87	77	10			x
Portage	31	W. Branch Reser. State Park	DNR	7873	5223	2650	x	x	x
Portage	30	Berlin Reservoir	COE	4810	3090	1720	x	x	x
Portage	30	Berlin Reser. Wildlife Area	DNR	713	709	4		x	
Stark	30	Berlin Reservoir	COE	507	215	292	x	x	
Stark	30	Deer Creek Reservoir	Alliance	323	10	313		x	
Mahoning	30	Berlin Reservoir	COE	2059	735	1324	x	x	
Mahoning	30	Berlin Reservoir Wildlife Area	DNR	570	570	0		x	
Trumbull	32	Mosquito State Park	DNR	11833	3983	7850	x	x	x
Mahoning	33	Mill Creek Park	Youngstown Township	2389	2213	176	x	x	
Mahoning	34	Evans Lake	OH Water Svc. Co.	566	0	566	x	x	
Mahoning	29	Lake Milton	Youngstown	2856	1171	1685	x	x	x

SOURCE: Northeast Ohio Water Plan, 1972.

recreational use because of its inaccessibility in most areas and the high degree of pollution that persists. With more than ample recreational areas provided by the extensive reservoir system in the basin, there has been little local interest in upgrading the Lower Mahoning River for extensive recreational uses.

E. Demography[1, 7, 8, 9]

Based upon the 1970 census, the population in the Mahoning River basin was approximately 600,000 people, or about 5.6 percent of Ohio's population of 10,650,000 people. Approximately 95 percent of the basin population resides in the Mahoning and Trumbull counties.

Population growth of the Mahoning-Trumbull counties area, as it is generally throughout the country, has been almost exclusively a function of the area's economy. Past trends in population growth have generally followed the changing pattern of demand for the area's major product -steel. Future growth will be primarily related to the steel industry and the valley's ability to attract new industrial development. Table IV-11 presents a listing of the major population centers and the relative change between 1960 and 1970. With few exceptions, the population of the basin municipalities exhibited increases between 1960 and 1970. The population of the two major urban areas, Youngstown and Warren, declined from 1960 to 1970. This loss of population reflects a lag in economic growth over the same period, especially during 1961 through 1963 and the first part of 1967, and migration to less densely populated townships and smaller cities and villages.

Table IV-12 illustrates decennial population projections for major population centers in the basin. Note that Trumbull County consistently demonstrates a higher growth rate than Mahoning County. The rapid growth of Trumbull County is projected to continue through 2020, while the growth rate of Mahoning County is moderate through 2000 and is projected to decline to slightly less than the 1970 population by the year 2020.

The Ohio Bureau of Employment reports that civilian labor forces in Mahoning and Trumbull Counties in 1974 were 133,500 and 105,500, respectively. Table IV-13 illustrates a slow steady growth in the civilian labor force for Mahoning and Trumbull Counties, between 1968 and 1974

TABLE IV - 11

MAHONING RIVER BASIN - MAJOR POPULATION CENTERS

Location	1960	1970	Change %
MAHONING COUNTY	300,480	304,057	+1.1
Campbell	13,406	12,577	-6.6
Canfield	3,252	5,468	+68.0
Craig Beach	1,139	1,532	+34.5
Lowellville	2,055	1,943	-5.8
Poland	2,766	3,117	+12.7
Struthers	15,631	15,343	-1.9
Youngstown	166,689	139,901	-19.1
TRUMBULL COUNTY	208,526	232,579	+11.5
Cortland	1,957	2,666	+36.2
Girard	12,997	14,085	+8.3
Hubbard	7,127	8,688	+21.7
McDonald	2,727	3,177	+16.5
Newton Falls	5,038	5,378	+6.7
Niles	19,545	21,489	+9.9
Warren	59,648	58,037	-2.8
PORTAGE COUNTY[1]	91,798	123,588	+34.6
Garrettsville	1,622	1,690	+4.2
Hiram	1,011	1,475	+45.9
Windham	3,777	3,200	-18.0
STARK COUNTY[1]	340,345	368,559	+8.3
Alliance	28,362	26,376	-7.5

[1] A small percentage of population of Portage and Stark Counties lie within the Mahoning River Basin.

SOURCES: U. S. Census Bureau
Northeast Ohio Water Plan

TABLE IV - 12

MAHONING RIVER BASIN - POPULATION PROJECTIONS

	1960	1970	1980	1990	2000	2010	2020
MAHONING COUNTY	300,480	304,057	316,988	326,789	330,056	320,919	302,456
Campbell	13,406	12,577	12,594	12,717	12,709	12,292	11,554
Canfield	3,252	5,468	6,151	6,808	7,112	7,030	6,680
Craig Beach	1,139	1,531	1,607	1,727	1,779	1,747	1,655
Lowellville	2,055	1,943	1,789	1,780	1,764	1,700	1,594
Poland	2,766	3,117	3,039	3,154	3,196	3,113	2,936
Struthers	15,631	15,343	15,828	16,204	16,309	15,829	14,905
Youngstown	166,689	139,901	132,575	129,240	126,777	121,442	113,595
TRUMBULL COUNTY	208,526	232,579	266,919	306,534	346,893	378,617	400,896
Cortland	1,957	2,666	3,107	3,683	4,233	4,656	4,948
Girard	12,997	14,085	16,252	18,590	20,996	22,894	24,229
Hubbard	7,137	8,688	10,377	12,155	13,890	15,233	16,169
McDonald	2,727	3,177	3,703	4,293	4,881	5,340	5,661
Newton Falls	5,038	5,378	6,025	6,837	7,692	8,370	8,849
Niles	19,545	21,489	26,413	30,600	34,780	38,043	40,325
Warren	59,648	58,037	73,264	83,547	94,212	102,646	108,589
PORTAGE COUNTY[1]	91,798	123,588	171,266	228,400	288,695	339,365	372,234
Garrettsville	1,622	1,690	2,000	2,439	2,939	3,370	3,650
Hiram	1,011	1,475	2,123	2,884	3,678	4,343	4,775
Windham	3,777	3,200	3,128	3,301	3,622	3,934	4,138
STARK COUNTY[1]	340,345	368,559	421,867	478,771	522,722	547,046	551,774
Alliance	28,362	26,376	27,709	30,038	32,026	33,114	33,198

[1] A small percentage of population of Portage and Stark Counties lie within the Mahoning River Basin.

SOURCE: Northeast Ohio Water Plan, 1960-1970 Census.

TABLE IV - 13

MAHONING RIVER BASIN
CIVILIAN LABOR FORCE MAHONING & TRUMBULL COUNTIES
1968-1974*

	Mahoning	Trumbull
1968	120,325	93,475
1969	124,075	98,125
1970	120,800	95,500
1971	123,125	97,175
% change	1.9	1.8
1972	123,100	97,300
% change	-	0.1
1973	126,825	100,375
% change	3.0	3.2
1974	133,500	105,500
% change	5.3	5.1
Percent Increase 1970-1974	10.5	10.5
Average Annual Increase	2.5	2.5

SOURCE: Division of Research & Statistics, Ohio Bureau of Employment Services

* Data for 1968-1969 represent all persons who work in each county, while 1970-1974 data represent only those persons who live and work in each county.

with an annual average increase of 2.5 percent. The manufacturing, retail trades, service and construction industries provide most of the present basin employment with the basic steel industry accounting for about 27,000 direct jobs.

F. Economy

Aside from the limited discussion of the area's economy presented earlier, a review of more detailed information is beyond the scope of this report. Additional data can be found in the following references:

1. Population and Economics - Part 1, June 1970. Mahoning-Trumbull Counties Comprehensive Transportation and Development Study.
2. Comprehensive Transportation and Development Study - Economic Inventory Report 1, March 1968.
3. Employment Trends in EDATA Planning Region - Eastgate Development and Transportation Agency, 1975.
4. EDATA Economic Trends - A Bimonthly Summary of Economic Indicators.
5. Economic Impact of Pollution Control Regulations on Steel Plants in the Mahoning River Valley - Booz, Allen & Hamilton Management Consultants for USEPA, April 1976.

G. Hydrology

The hydrology of the lower Mahoning River is extremely complex and significantly affects water pollution abatement requirements necessary to achieve desired stream standards, both within Ohio and in Pennsylvania. Natural streamflows have been altered by an extensive reservoir system constructed for low flow augmentation and temperature control, flood control, and water supply, and by several low head channel dams in the Leavittsburg-Lowellville reach of the river. Table IV-14 lists the major reservoirs in the basin and summarizes total storage capacity and the capacity allocated for low flow augmentation.[10, 11] Figure IV-1 illustrates the location of each reservoir while the location of the low head dams can be found in Figure IV-17. The discussion presented herein is limited to water quality design flow considerations and to operation of the reservoir system

TABLE IV - 14

MAJOR RESERVOIRS IN MAHONING RIVER BASIN

Reservoir	Year Completed	Owner or Operator	Tributary Drainage Area (Sq. Mi.)	Total Storage Capacity (Acre feet)	Summer low flow Storage Capacity (Acre feet)	Summer low flow Storage Capacity % of Total
Milton Reservoir	1917	City of Youngstown	273	29,770	21,500	72
Meander Creek	1931	Mahoning Valley Sanitary District	84	35,500	-	0
Berlin Lake	1943	Corps of Engineers	248	91,200	56,600	62
Mosquito Creek Lake	1944	Corps of Engineers	98	104,100	69,400	68
Michael J. Kirwan Reservoir	1966	Corps of Engineers	81	78,700	52,900	67
TOTAL				339,270	200,450	59

Note: For Berlin Lake, the amount of storage available for low flow augmentation depends upon storage withdrawn for water supply. The minimum low flow storage capacity is 37,200 acre feet.

SOURCES: (1) Water Resources Data for Ohio - 1974, Part 1. Surface Water Records, U. S. Geological Survey.
(2) Water Resources Development in Ohio, 1975, U. S. Army Corps of Engineers.
(3) Personal Communication with Max R. Janairo, Jr., Colonel, U. S. Army Corps of Engineers, Pittsburgh Dist., September 1976.

for low flow augmentation rather than expanded to a broad review of the basin hydrology encompassing annual flow duration and yield, maximum flood flows, and other hydrologic data.

Ohio water quality standards, EP-1-01 (B) (1), establish the annual minimum consecutive seven day average streamflow with a ten year recurrence interval (7 day - 10 year low flow) as the water quality design flow, or the minimum flow at which stream standards are to be achieved. Pennsylvania water quality standards do not specify a design flow, although the 7 day -10 year low flow is employed for water quality design purposes in Pennsylvania. For the lower Mahoning River at Youngstown, the natural design flow would probably be much less than 50 cfs (1 cfs = 0.646 mgd) without the construction and operation of the reservoir system.[12] However, current operation of the system by the U. S. Army Corps of Engineers is designed to provide guaranteed minimum streamflows ranging from 225 cfs at Youngstown during the months of November through March, to 480 cfs during July.[13] This schedule has been developed over the past sixty years beginning with the construction of Milton Lake by the City of Youngstown in 1917 to provide low flow augmentation for steel production during World War I. Berlin Lake and Mosquito Creek Lake were constructed during World War II, primarily for low flow augmentation and flood protection. The Michael J. Kirwan Reservoir (West Branch) was added in 1966 for additional low flow augmentation and flood protection. Meander Creek Reservoir was constructed in 1931 for water supply purposes only. (Berlin Lake can be used to augment the water supply potential of Meander Creek Reservoir.) The Corps of Engineers operates these reservoirs as a system, generally using Berlin Lake-Milton Lake and Kirwan Reservoir to maintain the schedule at Leavittsburg, and Mosquito Creek Lake to maintain the schedule at Youngstown.[14]

Figure IV-10 presents the current flow schedules the Corps of Engineers is maintaining at Leavittsburg and Youngstown, labeled BL and BY, respectively.[14] Also shown are schedules encompassing alternate releases for the Warren and Youngstown water supplies and the Kirwan Reservoir. The BY-BL schedule includes an allocation of up to 17 mgd from Berlin Lake for the Youngstown water supply and up to 16 mgd from Mosquito Creek Lake for the Warren water supply. This schedule is designed

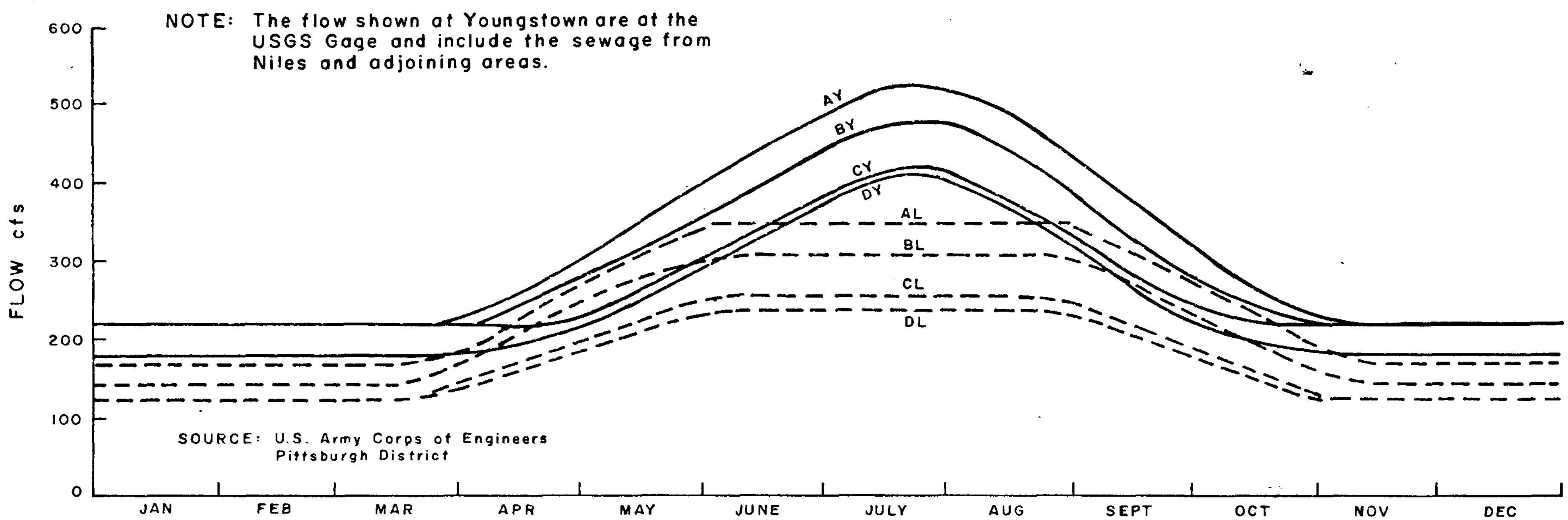
FIGURE IV-10

LOWER MAHONING RIVER

FLOW REGULATION SCHEDULES

SCHEDULES

YOUNGSTOWN	LEAVITTSBURG	
AY	AL	Berlin, Milton, Mosquito & W. Br. Mahoning River Reservoirs No Diverson for Ystn. Water Supply & 10 MGD for Warren
BY	BL	Berlin, Milton, Mosquito & W. Br. Mahoning River Reservoirs 17 MGD for Ystn Water Supply & 16 MGD for Warren
CY	CL	Berlin, Milton, Mosquito & W. Br. Mahoning River Reservoirs 34 MGD for Ystn. Water Supply & 16 MGD for Warren
DY	DL	Berlin, Milton, Mosquito Reservoirs No Diverson from Ystn. Water Supply & 10 MGD for Warren



to control mean stream temperatures in Youngstown to 98°F in July based upon 1958-1959 industrial production levels. The location of the temperature control point is at the Youngstown Sheet and Tube Company - Campbell Works river intake.

According to the Corps of Engineers, the succession of drought years from 1930 to 1934 serves as a basis for the present reservoir storage and release schedules.[14] Minimum regulated flows were determined from rainfall, runoff, evaporation, temperature, and storage computations for the 1930-1934 period. Maintenance of these schedules during a similar drought period would result in almost complete depletion of the storage in each reservoir, thereby fully consuming the water resources in the basin.

Since EP-1-01 (B) (1) also provides for consideration of hydraulically altered flow regimes in establishing water quality design flows, it is appropriate to consider the minimum regulated schedule as the design flow for the Mahoning River. The duration or percent of time the regulated flows are achieved could result in non-attainment of desired aquatic life uses, notably in Pennsylvania. Figure IV-11 illustrates the actual flow duration experienced at the Leavittsburg, Youngstown and Lowellville USGS stream gages for the 1943-1965 period.[15] While these data cannot be directly used to determine the frequency at which the BY-BL schedule was achieved prior to the construction of the Kirwan Reservoir, Figure IV-11 serves to illustrate the high frequency at which relatively low flows are encountered in the basin. For example, the annual average flow from schedule BY is about 300 cfs at Youngstown. This flow was equaled or exceeded only 77 percent of the time from 1944-1965; the maximum flow from schedule BY (480 cfs) was achieved less than 50 percent of the time. Also shown on Figure IV-11 is the simulated annual flow duration at Youngstown prepared by the Corps of Engineers for the 1930-1966 period assuming operation of existing reservoirs in the basin and no regulation for excessive stream temperatures.[16] This curve primarily reflects the addition of the Kirwan Reservoir, showing an increase over the actual 1944-1965 duration at flows less than 400 cfs. Since the 1930-1966 simulation period includes the severe drought years of 1930-1934, a simulation of the 1944-1965 period would most likely also illustrate an increase over actual duration for flows greater than 400 cfs.

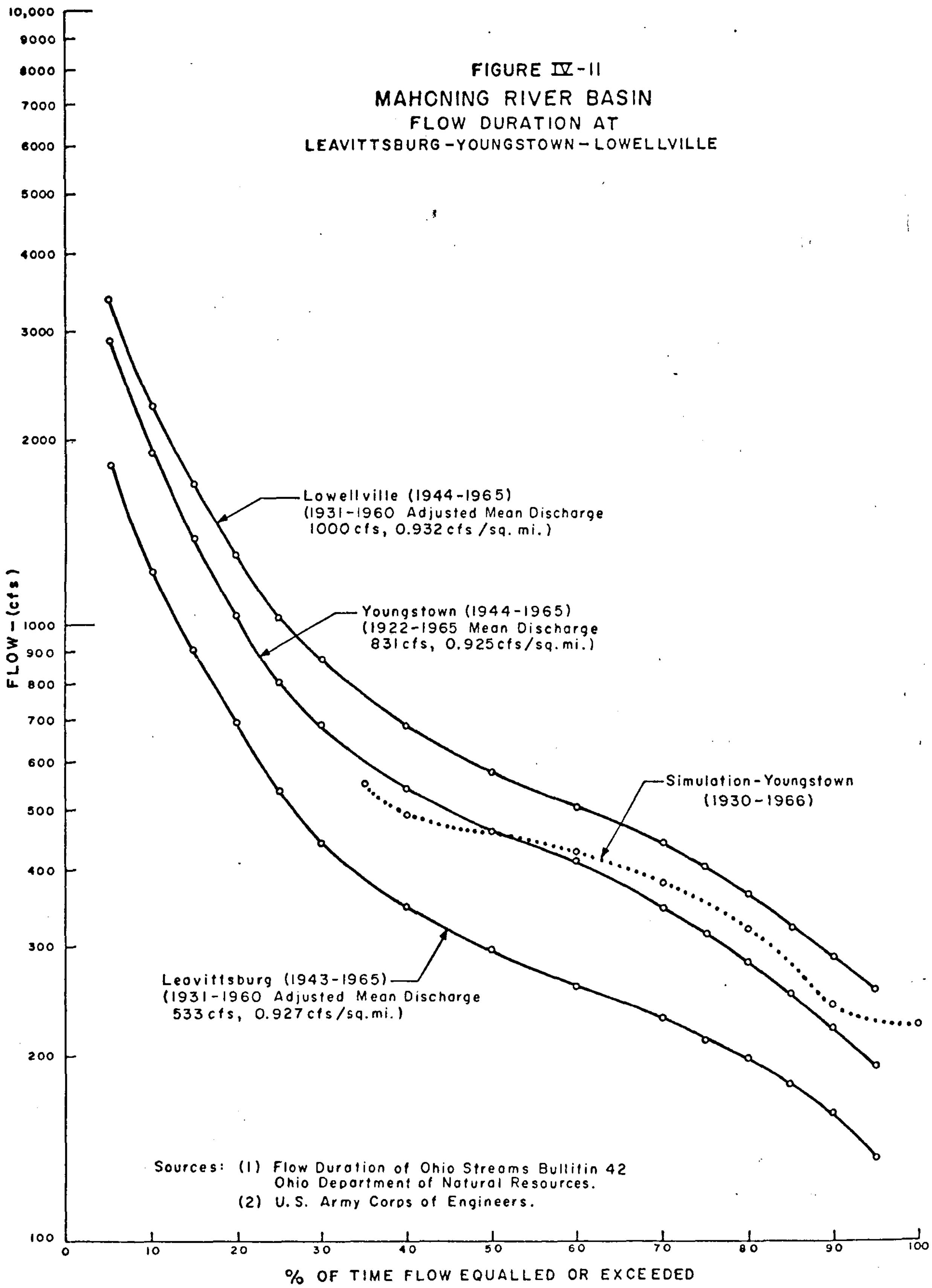


FIGURE IV-11
MAHONING RIVER BASIN
FLOW DURATION AT
LEAVITTSBURG-YOUNGSTOWN-LOWELLVILLE
Lowellville (1944-1965)
(1931-1960 Adjusted Mean Discharge
1000 cfs, 0.932 cfs/sq. mi.)
Youngstown (1944-1965)
(1922-1965 Mean Discharge
831 cfs, 0.925 cfs/sq. mi.)
Simulation-Youngstown
(1930-1966)
Leavittsburg (1943-1965)
(1931-1960 Adjusted Mean Discharge
533 cfs, 0.927 cfs/sq. mi.)
Sources: (1) Flow Duration of Ohio Streams Bullitin 42
Ohio Department of Natural Resources.
(2) U.S. Army Corps of Engineers.
FLOW-(cfs)
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
% OF TIME FLOW EQUALLED OR EXCEEDED

While Figure IV-11 provides some insight as to the occurrence of low flows at Youngstown, attainment of the BY schedule throughout the year is not addressed. Since the schedule encompasses significant annual variation which is opposite that of most natural streams, attainment of the schedule throughout the year becomes important for water quality considerations. Figure IV-12 presents a comparison of the daily minimum regulated schedule with actual monthly flow duration for the 1944-1975 period of record.[17] Since a direct comparison of daily minimum regulated schedule with monthly flow duration cannot be made, the monthly flow duration data were plotted at the beginning of each month with an ascending schedule (April, May, June, July) and at the end of each month with a descending schedule (August, September, and October); the flow duration data were plotted at the middle of each month for which the schedule is constant (November through March). Plotting the data in this fashion more clearly illustrates the flow duration trends in relation to the daily minimum schedule. The 1944-1975 period includes full operation of Mosquito Creek Lake and Berlin Lake, operation of the Kirwan Reservoir from 1968-1975, and the recent two-year period when Milton Lake was taken out of service for emergency repairs. Since the BY-BL schedule was not developed until the late 1950's and not implemented until 1968 after Kirwan Reservoir became operational,[18] it is not possible to determine actual maintenance of the schedule from the data in Figure IV-12. However, these data serve to illustrate frequent occurrence of low flows in the past. A review of the data indicate the extreme 100 percent duration flows occurred during the summer months of 1952.

To confirm the ability of the existing reservoir system to achieve the BY-BL schedule throughout the year, the Corps has also simulated monthly flow duration for the 1930-1966 period assuming operation of the current reservoir system, the actual hydrology of the basin during that time, and no regulation for excessive stream temperatures.[16] Figure IV-13 presents a comparison of the simulated monthly flow duration with the BY schedule. Since the simulated flow duration data represent monthly average values, the data were plotted in the same manner as the data presented in Figure IV-12. Figure IV-13 illustrates that simulation of the current reservoir system in the Mahoning River basin for the period 1930-1966 would have resulted in attainment of the BY schedule had the Kirwan Reservoir been in

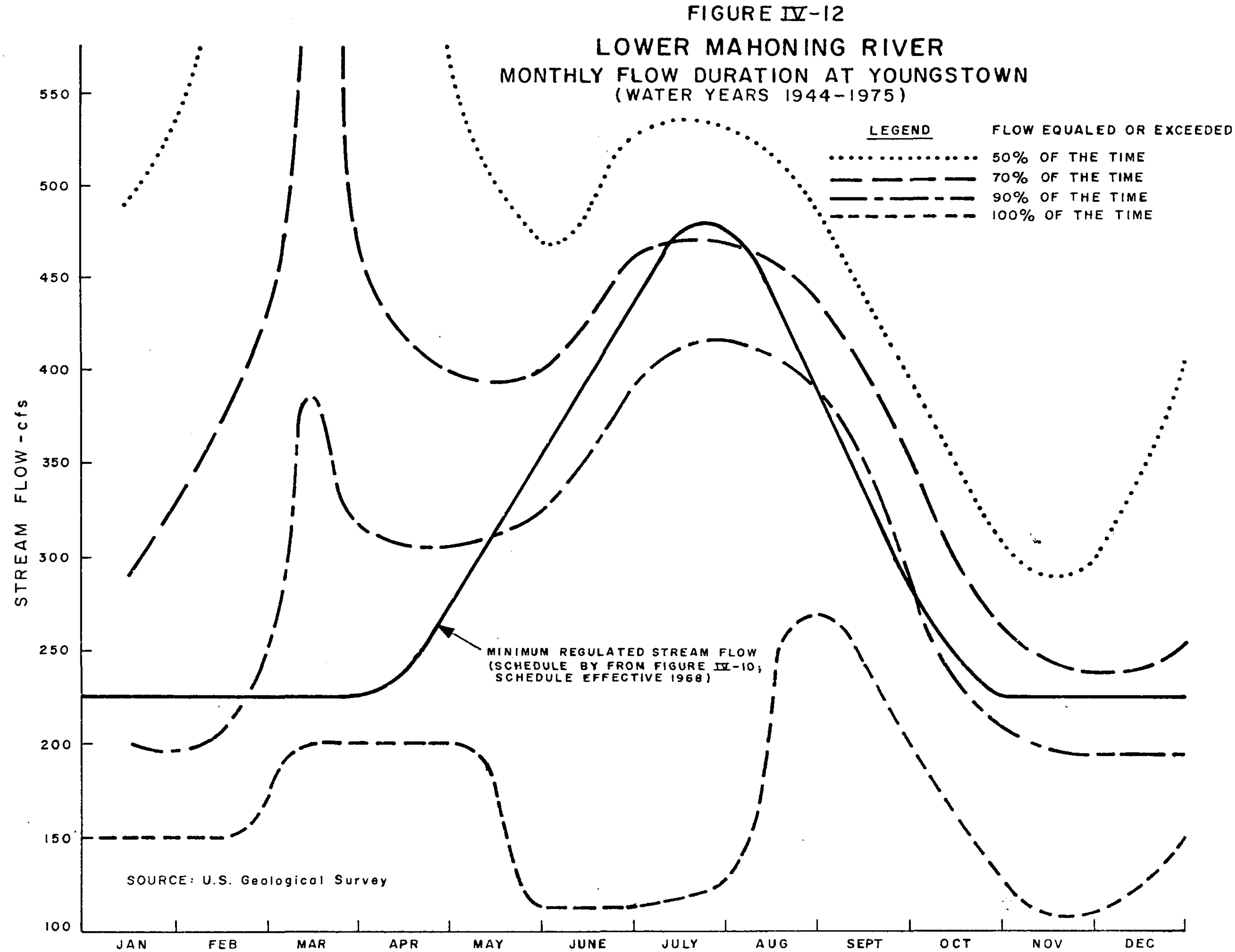


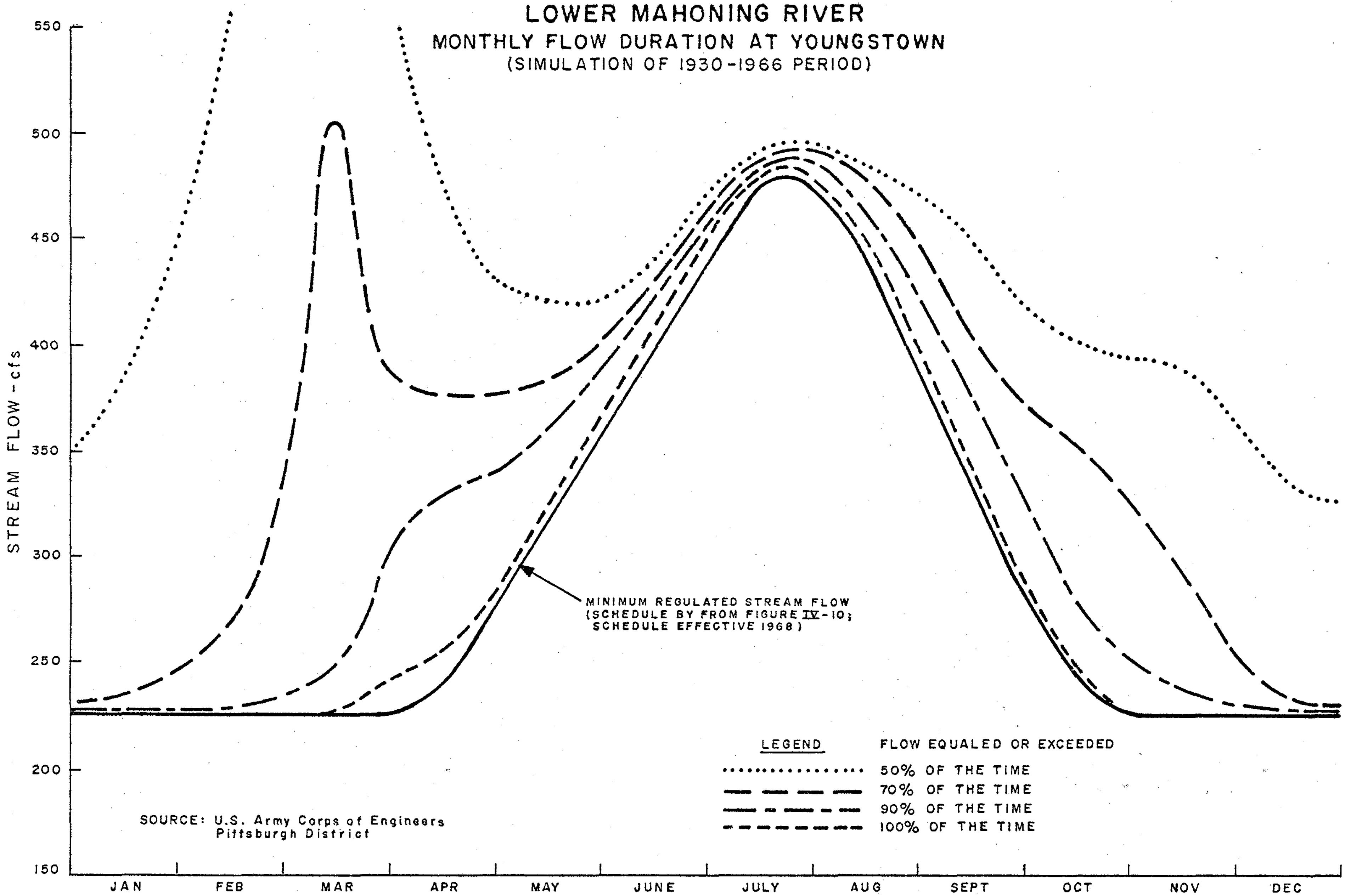
FIGURE IV-12
LOWER MAHONING RIVER
MONTHLY FLOW DURATION AT YOUNGSTOWN
(WATER YEARS 1944-1975)
LEGEND
FLOW EQUALED OR EXCEEDED
50% OF THE TIME
70% OF THE TIME
90% OF THE TIME
100% OF THE TIME
STREAM FLOW - cfs
550
500
450
400
350
300
250
200
150
100
MINIMUM REGULATED STREAM FLOW
(SCHEDULE BY FROM FIGURE IV-10;
SCHEDULE EFFECTIVE 1968)
SOURCE: U.S. Geological Survey
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC

FIGURE IV-13

LOWER MAHONING RIVER

MONTHLY FLOW DURATION AT YOUNGSTOWN

(SIMULATION OF 1930-1966 PERIOD)



operation for that time and had Mosquito Creek Lake and Berlin Lake been in operation from 1930-1944. These data lead one to conclude that the Corps can maintain the BY-BL schedule in the future although the overage above the schedule expected during the June-August period will be minimal at best.

Figure IV-14 is a similar plot encompassing the 1968-1974 water years, after operation of the Kirwan Reservoir was initiated.[16] The monthly flow duration data were plotted in the same manner as the flow duration data in Figure IV-12. These data illustrate significant shortfalls from the schedules from May through August and attainment of scheduled flows during July only about 80 percent of the time. The Corps of Engineers attributes the nonattainment of the minimum schedules for the 1968-1974 period to the lack of about 50 cfs of water for flow augmentation from Milton Lake which was taken out of service during part of this time for emergency repairs.[16]

In addition to the streamflow provided directly by the reservoir system, the municipalities which depend upon the reservoirs for potable water add flow to the stream through discharges of partially treated sewage. Table IV-15 presents discharge points for the eight municipal sewage treatment plants on or near the main stem of the lower Mahoning River, annual average discharge flow rates for 1973, 1974, 1975 and, projected design flow rates for 1985.[19, 20, 21] These data indicate that the current annual average sewage volume of 50-55 mgd amounts to about 38 percent of the regulated flow at Youngstown for the November through March period and about 18 percent of the maximum July schedule. Since only the municipalities of Warren, Niles, McDonald and Girard discharge above the Youngstown gage, actual percentages at the gage are 14 percent of the November through March schedule and about 6 percent of the maximum July schedule. Over 50 percent of the total sewage volume is discharged at Youngstown, about three miles downstream from the USGS gage.

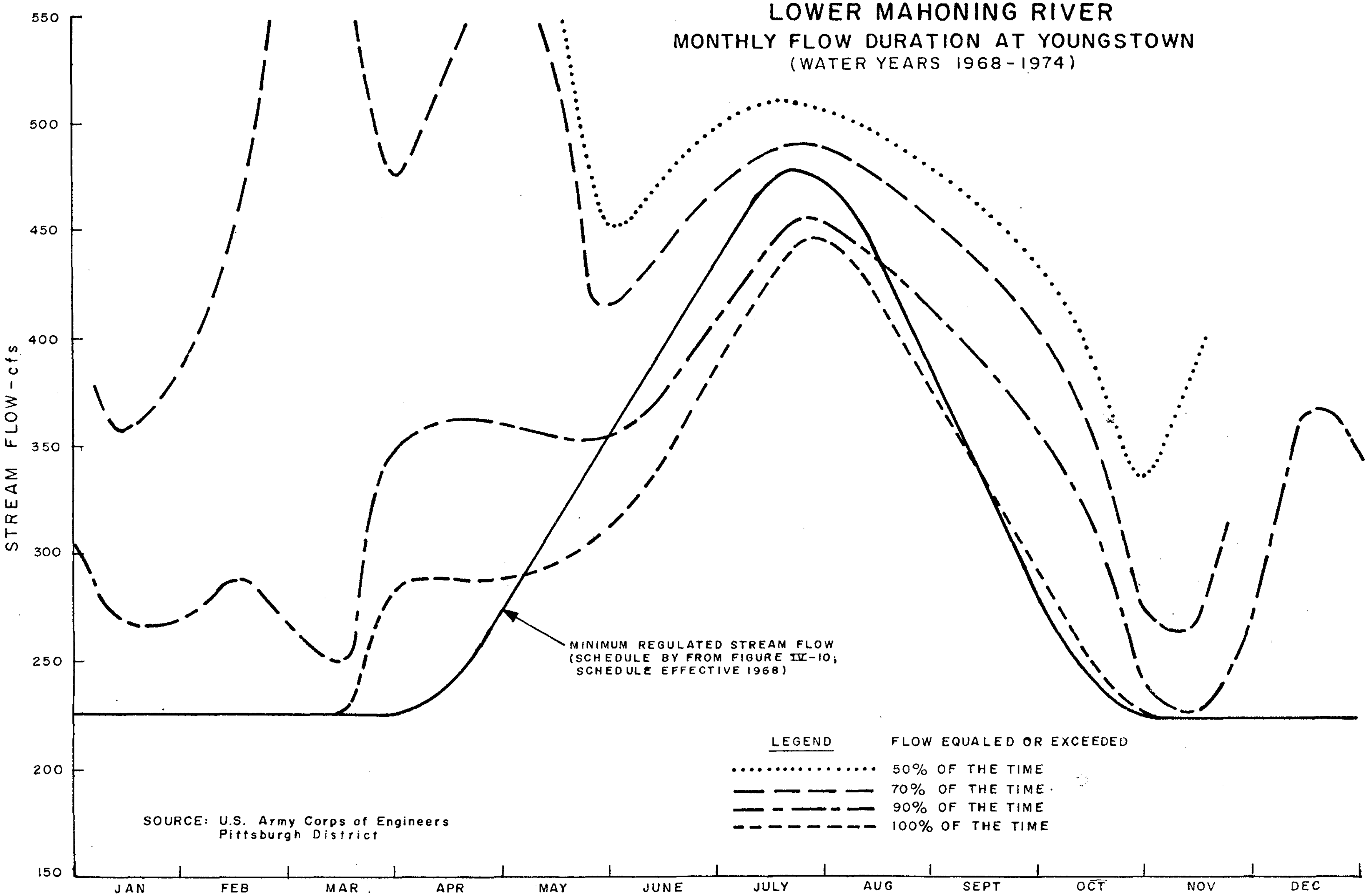
Also shown in Table IV-15 are estimated 1985 design flow rates for the most likely arrangement of regional sewage treatment systems in the valley.[20, 21] These data show a probable increase in sewage volume to about 80 mgd or an increase of about 45 percent over current levels. Included in the total are 5.8 mgd from the recently completed Meander

FIGURE IV-14

LOWER MAHONING RIVER

MONTHLY FLOW DURATION AT YOUNGSTOWN

(WATER YEARS 1968-1974)



SOURCE: U.S. Army Corps of Engineers
Pittsburgh District

TABLE IV - 15

MUNICIPAL SEWAGE TREATMENT PLANTS
LOWER MAHONING RIVER

Municipality	STP Discharge (River Mile)	Annual Average Discharge (MGD) 1973	1974	1975	Design Discharge (MGD) Current	1985 (Estimated)
USGS Stream Gage at Leavittsburg (River Mile 46.08)						
Warren	35.83	12.800	12.950	12.210	13.50	16.0
Meander Watershed	30.77	-	-	-	-	5.8
Niles	29.47	3.729	4.157	4.163	3.00	10.0 (1)
McDonald	27.32	0.529	0.605	0.805	0.61	-
Girard	25.73	3.174	2.680	1.840	1.80	-
USGS Stream Gage at Youngstown (River Mile 22.80)						
Youngstown	19.78	28.760	29.040	28.500	50.00	40.0 (2)
Campbell	16.09	2.090	2.270	2.530	2.50	-
Struthers	14.90	2.270	2.000	2.050	2.50	8.5 (3)
USGS Stream Gage at Lowellville (River Mile 12.67)						
Lowellville	12.35	0.210	0.283	0.269	0.22	0.5
TOTAL	-	53.560	53.990	52.370	74.10	80.8

Notes: (1) Regional treatment facility serving Niles, McDonald, Girard and adjacent areas located at existing Niles Treatment Plant site.
(2) Regional treatment facility serving Youngstown and adjacent areas located at Mill Creek (River Mile 22.03).
(3) Regional treatment facility serving Campbell, Struthers and adjacent areas located at existing Struthers Treatment Plant site.

SOURCES: Ohio Environmental Protection Agency
Eastgate Development and Transportation Agency

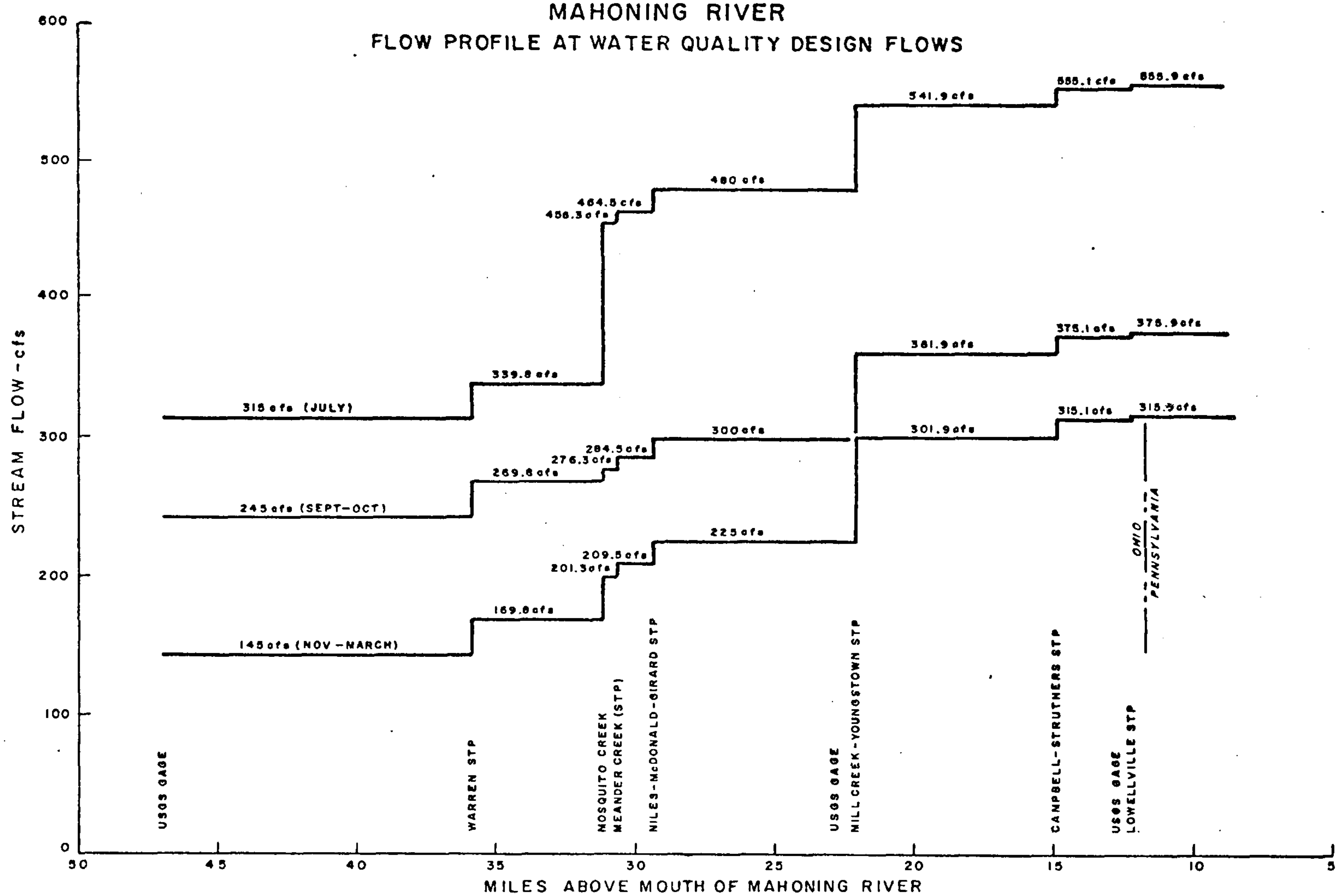
Creek Watershed Plant and increases of about 4 mgd at Warren and 2 to 3 mgd from a regional Niles-McDonald-Girard facility, all of which will be discharged above the USGS gage in Youngstown. The resultant increase in flow at the gage should be about 12-13 mgd or about 19 cfs.

According to the Corps of Engineers, increases in sewage flow above the gage would not result in alterations to the BY schedule. Because of the limited water resources of the basin, further augmentation to the regulated schedule cannot be justified since the maximum yield of the reservoir system is currently being approached at the BY schedule.[14] The Corps has indicated it could not provide increased flows during the November through March period without a downward adjustment of the summer schedule.

Although limited recent data (Figure IV-14) suggest somewhat lower design flows during the May-August period may be indicated, simulation results of the 1930-1966 period and expected increases in sewage flow by 1985 indicate use of the BY-BL schedule for water quality design flow purposes may be warranted. Figure IV-15 presents water quality design profiles from the USGS gage at Leavittsburg to the Ohio-Pennsylvania State line incorporating BY-BL schedule flows of 225 cfs (November-March), 300 cfs (September-October), and 480 cfs (July) at Youngstown. The expected 1985 municipal flows were applied to the stream at the most probable location of the regional treatment facilities. For the purpose of this analysis, it was assumed that Berlin Lake-Milton Lake and Kirwan Reservoir would be employed to maintain the schedule at Leavittsburg with Mosquito Creek Lake accounting for the difference to maintain the schedule at Youngstown. Net additions from municipal systems were incrementally added below the Youngstown gage. Contribution from minor tributaries between Leavittsburg and Lowellville was assumed to be negligible, as is usually the case during dry summer months and occasionally during the winter because of freezing. Sensitivity of the water quality response to changes in flow is reviewed in Section VIII.

It is important to note that flow in the Mahoning River will be at or close to the BY-BL schedule frequently throughout the year, more so during the June-October period and less frequently during the winter months. Hence, the safety inherent in adoption of a water quality design flow based upon rather extreme probability such as the 7 day-10 year low flow is

FIGURE IV-15
MAHONING RIVER
FLOW PROFILE AT WATER QUALITY DESIGN FLOWS



lacking for the Mahoning River. For unregulated streams adjacent to the Mahoning River basin, the ratios of design flows ($Q_{7,10}$) to annual mean flows (Q_a) are as follows:[22, 23, 24]

Stream	Drainage Area (Sq. Mi.)	$Q_{7,10}/Q_a$
Grand River near Madison	581	0.002
Ashtabula River near Ashtabula	121	0
Conneaut Creek at Conneaut	175	0.006
Little Beaver Creek near East Liverpool	496	0.036

For the Mahoning River at Youngstown, this ratio would be about 0.3 assuming the annual mean of the BY schedule as the design flow.

For comparison purposes, the USGS was requested to compute equivalent annual minimum consecutive seven day mean flows with various recurrence intervals for the period 1944 to 1975 at the Lowellville, Youngstown, and Leavittsburg gaging stations.[16] These data are presented in Table IV-16. The 1944-1975 period was selected to include the time after Berlin Lake and Mosquito Creek Lake became operational. In summary, the data show 7 day-10 year low flows of 100 cfs, 156 cfs, and 197 cfs for Leavittsburg, Youngstown, and Lowellville, respectively. For Youngstown, the value of 156 cfs represents only 69 percent of the minimum winter BY schedule of 225 cfs, less than 33 percent of the maximum July schedule of 480 cfs, and about 52 percent of the annual average schedule value of 300 cfs. Table IV-16 also demonstrates the high frequencies at which relatively low 7 day-10 year low flows have been occurring. Although the determination of a 7 day-10 year low flow for a regulated stream has little meaning in terms of Ohio Water Quality Standards the data further serve to illustrate the tight flow regulation in the basin and the lack of safety inherent in employing regulated flows for design purposes. Hence, maintenance of a water quality criterion in the lower Mahoning River will depend more upon the frequency at which design effluent discharges are achieved rather than upon the frequent and prolonged occurence of the design flow. For natural, unregulated streams design discharge levels are generally based upon flows which infrequently occur.

TABLE IV - 16

ANNUAL MINIMUM CONSECUTIVE SEVEN DAY MEAN FLOWS
PERIOD OF RECORD 1944-1975
LOWER MAHONING RIVER

Low flow Probability	Recurrence Interval (Years)	Leavittsburg (cfs)	Youngstown (cfs)	Lowellville (cfs)
0.01	100	71	125	146
0.02	50	78	132	158
0.05	20	89	144	178
0.10	10	100	156	197
0.20	5	115	173	222
0.50	2	148	213	280
0.80	1.25	189	266	350
0.90	1.11	213	301	392
0.96	1.04	242	345	443
0.98	1.02	263	377	478
0.99	1.01	282	410	512

SOURCE: U. S. Geological Survey

Figure IV-16 is a cumulative drainage area graph for the entire Mahoning River basin showing both the drainage area and location on the main stem of major and minor tributaries. Also shown are locations of USGS gaging stations and reservoirs. Significant changes in the slope of the stream and pooling effects caused by the low head dams are illustrated in Figure IV-17.

H. Mahoning River Stream Mileage

Stream mileage along the main stem of the Mahoning River from its confluence with the Shenango River near New Castle, Pennsylvania to just upstream of the Copperweld Steel river intake in Warren Township was determined from U. S. Army Corps of Engineers maps with a calibrated map measure. The Corps of Engineers maps were developed from photographs exposed during December 1961 for the Corps' Lake Erie - Ohio River Canal study (scale 1:2400 or 1" = 200'). Mileage from the most upstream point covered by these maps (River Mile 42.90) to the Leavittsburg Dam in Leavittsburg, Ohio (RM 46.08) were determined from United States Geological Survey 7.5 minute series topographic maps for the Warren, Champion, and Newton Falls quadrangles (scale 1:24000 or 1" = 2000'). Stream mileages to RM 42.90 are presented with two significant figures beyond the decimal point ($\pm$52.8 ft. or 0.264 inches on the Corps' maps), while the second decimal is estimated for mileages above 42.90. The zero mile point for the Mahoning River was selected at the center track of the Penn Central Railroad bridge nearest the confluence of the Mahoning and Shenango Rivers.

Tables IV-17, 18, and 19 present stream mileage for tributaries, bridges, dams, and USGS gages, respectively.

FIGURE IV-16
MAHONING RIVER BASIN
DRAINAGE AREA VS RIVER MILE

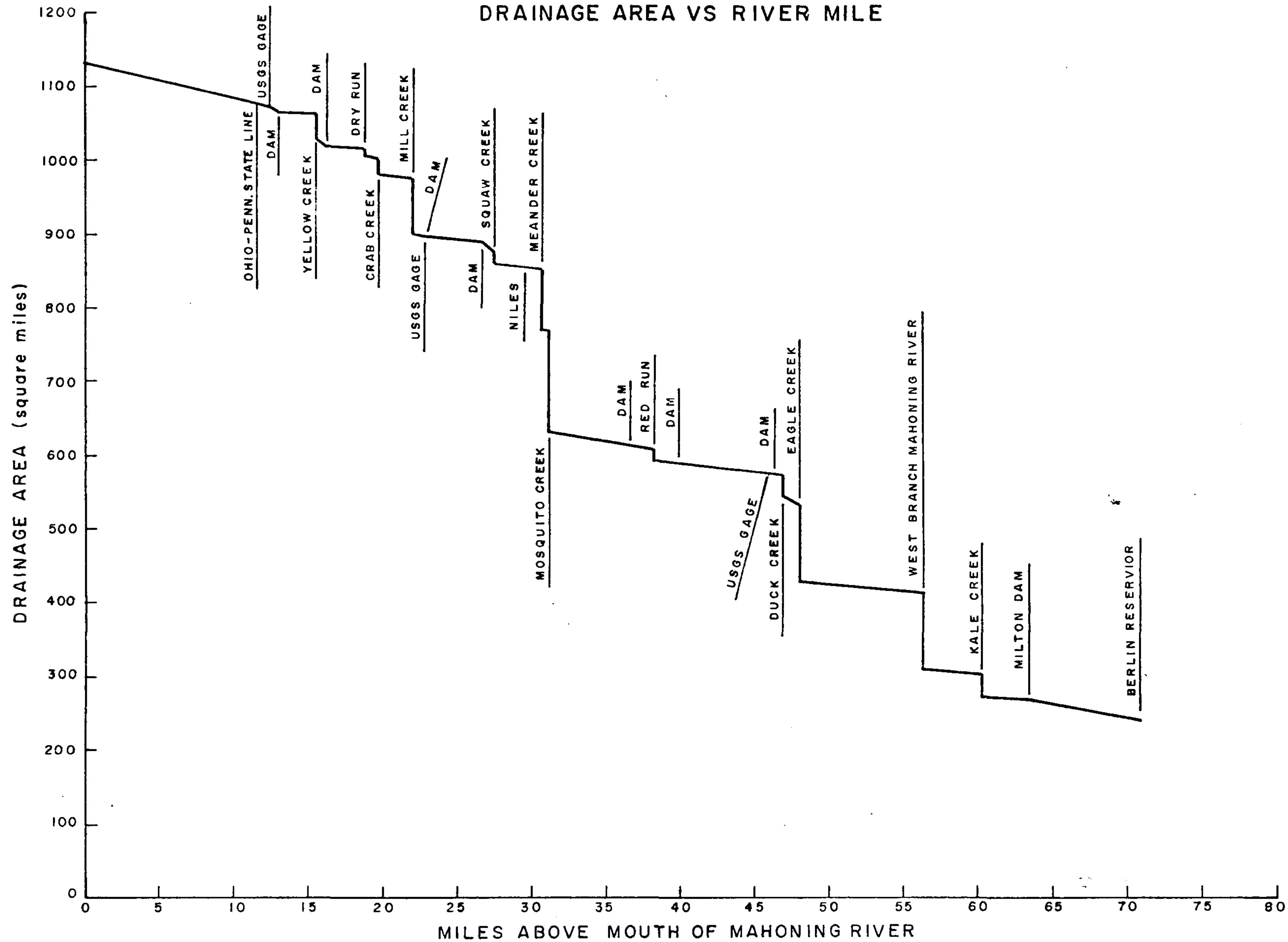


FIGURE IV-17
LOWER MAHONING RIVER
ELEVATION VS RIVER MILE

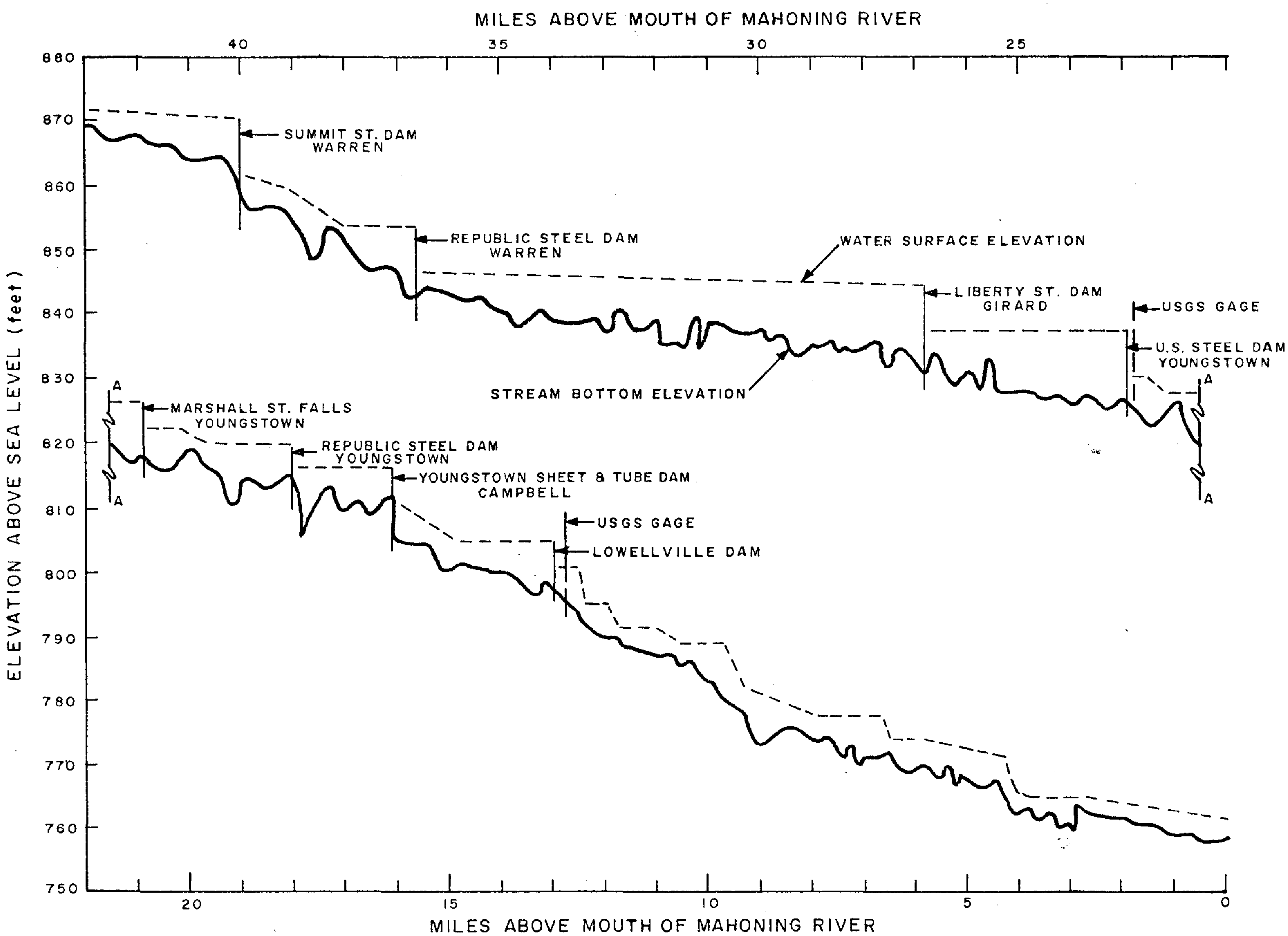


TABLE IV - 17

MAHONING RIVER STREAM MILEAGE
(River mouth to Leavittsburg, Ohio)

Tributary	River Miles Above Mouth
Hickory Run	0.02
Byers Run	2.98
Coffee Run	10.42
Grays Run	13.10
Hines Run	14.90
Yellow Creek	15.63
Dry Run	18.47
Crab Creek	19.81
Mill Creek	22.03
Fourmile Run	25.64
Little Squaw Creek	25.73
Squaw Creek	27.67
Meander Creek	30.77
Mosquito Creek	31.14
Mud Creek	33.33
Red Run	41.04
Infirmary Run	41.62

TABLE IV - 18

MAHONING RIVER STREAM MILEAGE
(River mouth to Leavittsburg)

Bridges		River Miles Above Mouth
Lawrence County, Pennsylvania		
Penn Central RR (3 tracks)	(center track)	0.00
Montgomery Av.		0.23
Route 18		0.42
Montgomery Av.		1.43
Penn Central RR (2 tracks)		1.52
Brewster Road		4.34
Route 224		6.76
Church Hill Road		9.69
Mahoning County, Ohio		
Lowellville		
Washington St.		12.64
Pittsburgh and Lake Erie RR (1 track)		13.52
Poland Township		
Pittsburgh and Lake Erie RR (1 track)		14.21
Struthers		
Bridge St. (State Route 616)		15.77
Pittsburgh and Lake Erie RR (1 track)		15.83
Penn Central RR (1 track)		16.64
Youngstown		
Oakland Av.		16.69
Penn Central RR (4 tracks)		17.82
Penn Central RR (2 tracks)		17.87
Center St.		18.29
Baltimore & Ohio RR (1 track)		16.51
Baltimore & Ohio RR (2 tracks)		19.17
Cedar St.		19.80
South Av. (State Route 164)		20.11
Market St. (State Route 57, U.S. Route 62)		20.49
Marshall St.		20.91
Mahoning Av. (State Route 18)		21.03
West Av.		21.50
Lake Erie & Eastern RR (2 tracks)		21.58
Baltimore & Ohio RR (2 tracks)		21.80
Baltimore & Ohio RR (2 tracks)		22.40
Interstate 680		22.42
Erie-Lackawanna RR (1 track)		22.43
Bridge St.		22.73
Lake Erie & Eastern RR		22.93
Lake Erie & Eastern RR (2 tracks)		23.75
Division St. (Lower)		23.84
Division St. (Upper)		23.88
Youngstown & Northern RR (1 track)		24.82

TABLE IV - 18
(continued)
MAHONING RIVER STREAM MILEAGE
(River mouth to Leavittsburg)

Bridges	River Miles Above Mouth
Trumbull County, Ohio	
Girard	
Baltimore & Ohio RR (1 track)	25.78
Interstate 80	26.20
Liberty St.	26.77
Niles	
Olive St.	29.52
Belmont Av.	30.48
Erie-Lackawanna RR (1 track)	30.76
Main St. (State Route 46)	31.30
Weathersfield Township	
Penn Central RR	33.24
West Park Av.	33.71
Warren Township	
Baltimore & Ohio RR (2 tracks)	36.94
Dover Av.	36.95
Warren	
Main Av.	38.08
Baltimore & Ohio RR (1 track)	38.66
Erie-Lackawanna RR (2 tracks)	38.70
South St.	38.71
Market St. (State Routes 5 and 82)	38.91
Summit St.	39.93
Erie-Lackawannna RR (1 track)	40.02
Dunstan Av.	41.51
Leavittsburg	
Leavitt Road	46.02

TABLE IV - 19

MAHONING RIVER STREAM MILEAGE
(River mouth to Leavittsburg, Ohio)

	Location	River Miles Above Mouth
Ohio-Pennsylvania State Line		11.61
Low Head Dams	Location	
1. Lowellville Dam	Lowellville	12.81
2. Youngstown Sheet & Tube Dam	Campbell	16.06
3. Republic Steel Dam	Youngstown	17.98
4. Marshall Street Falls	Youngstown	20.91
5. U. S. Steel Dam	Youngstown	22.96
6. Liberty Street Dam	Girard	26.82
7. Republic Steel Dam	Warren	36.69
8. Summit Street Dam	Warren	39.99
9. Leavitt Road Dam	Leavittsburg	46.08
USGS Stream Gages		
1. Lowellville		12.67
2. Youngstown		22.80
3. Leavittsburg		46.02

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SECTION V
SIGNIFICANT WASTEWATER DISCHARGERS

As noted earlier, the basic steel industry dominates the economy of the Mahoning Valley, and to a large extent, determines the quality of water in the Mahoning River. The average net discharge from the nine major steel plants may exceed 400,000 lbs/day of suspended solids, 70,000 lbs/day of oil and grease, 9,000 lbs/day of ammonia-nitrogen, 500 lbs/day of cyanide, 600 lbs/day of phenolics, and 800 lbs/day of zinc. The oil discharge is equivalent to over 200 barrels per day, or the equivalent of enough energy to heat nearly 30,000 average sized homes. Including the discharge from the Ohio Edison Power Plant, the total industrial thermal loading may exceed four billion BTU's/hr during periods of peak steel production, enough energy to heat 96,000 average sized homes. Unfortunately, this energy is not in a usable form. As noted earlier, the major plants may use the entire flow of the Mahoning River about 5.6 times during periods of winter critical flow and about 2.6 times during periods of summer critical flow. The aggregate discharge from the many smaller industrial facilities discharging to the lower Mahoning River is insignificant compared to the steel industry discharge. However, the total municipal discharge from the eight primary sewage treatment plants is significant, amounting to over 27,000 lbs/day of suspended solids, 33,000 lbs/day of BOD_5, and 3,600 lbs/day of ammonia-N. A more detailed review of the major dischargers follows. Figure V-1 illustrates the locations of the major and significant smaller dischargers along the main stem of the lower Mahoning River.

A. Industrial Dischargers

Table V-1 presents a summary of employment, water usage, and production data for the nine most significant steel plants. Tables V-2 to V-11 present summaries of available discharge data for each steel plant and

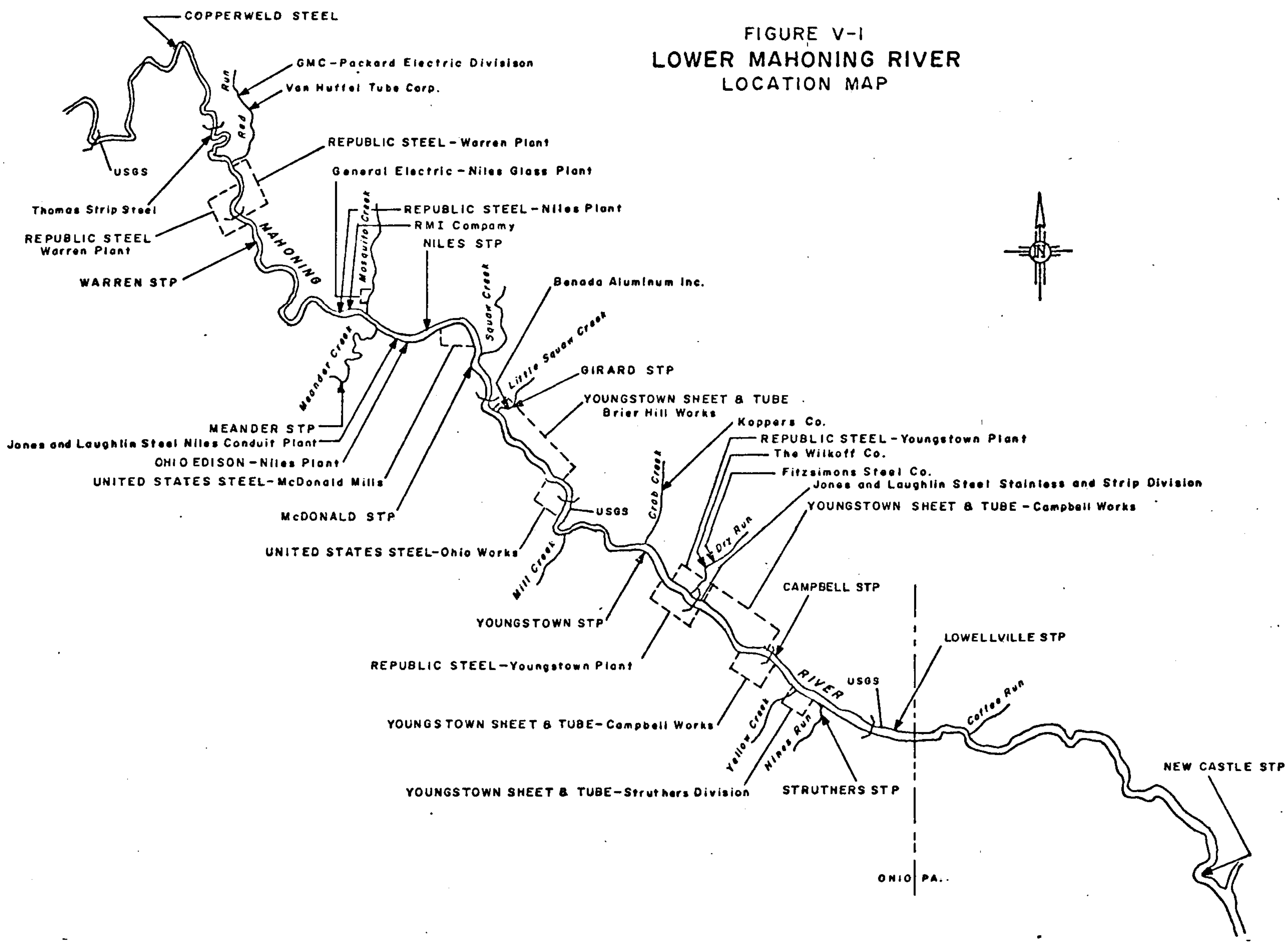

FIGURE V-1
LOWER MAHONING RIVER
LOCATION MAP

TABLE V - 1

MAJOR MAHONING RIVER STEEL PLANTS

Facility	Location	Approximate Employment	Water Usage (mgd)	Production Rates (Tons/day) Coke Plants	Iron Making	Steel Making	Hot Forming	Cold Rolling	Pickling	Coating
Copperweld Steel Corporation	Warren	2300	34.6			2030	3540		400	
Republic Steel Corporation	Warren	4600	59.1	1413	3024	6825	11733	1611	3117	1245
Republic Steel Corporation	Niles	200	1.7					990	1119	
Republic Steel Corporation	Youngstown	4100	73.9	2990	4290		7366	1605		207
U. S. Steel Corporation McDonald Mills	McDonald	2400	43.0				8640		760	
U. S. Steel Corporation Ohio Works	Youngstown	3600	78.8		4200	5600	7086			
Youngstown Sheet & Tube Co. Brier Hill Works	Youngstown	1900	55.6		1108	3850	8436	266		
Youngstown Sheet & Tube Co. Campbell Works	Campbell	7900	232.8	4013	5050	5400	16506	2306	2400	391
Youngstown Sheet & Tube Co. Struthers Division	Struthers	See Above	22.9				975			225
TOTAL		27000	602.4	8416	17672	23705	64282	6778	7796	2068

NOTES: 1. Employment data from permit applications and other industrial sources. Breakdown between U. S. Steel plants is estimated.

2. Production data supplied by industries.

the Ohio Edison power plant at Niles. Tables 1 to 9 of Appendix A present a summary of production operations, associated outfalls and existing waste treatment facilities for each facility. Table V-12 summarizes the corporate contribution of discharges to the Mahoning River.

1. Copperweld Steel Corporation

The main Copperweld Steel discharge is located just upstream from the City of Warren about 42.6 miles above the mouth of the river (Figure V-1). The company produces various alloy steels with electric furnaces and may sell either ingots or finished and semi-finished bar products.[1] Copperweld Steel accounts for about 9 percent of the raw steelmaking capacity in the Valley. As there is no coking or iron making at this facility, the primary contaminants of concern are suspended solids and oil and grease resulting from hot forming and heat treating operations. Of the nine major steel plants, Copperweld Steel accounts for about 2 percent of the aggregate suspended solids discharge and about 4 percent of the aggregate oil and grease loading. However, the Copperweld discharge is important because of its high volume in relation to critical stream flows and because it imparts turbidity and a visible oil sheen to the river in an area of good quality water and few significant dischargers (Figure V-2). Although the company uses about 37 percent of the stream during winter critical flows, the thermal loading from the plant does not result in significant increases in stream temperature.

Copperweld Steel has had an effective NPDES permit since 1974 which requires the company to treat and recycle its plant effluent with a nominal blowdown to the river by July 1, 1977.

2. Republic Steel Corporation

Republic Steel's operations in the Mahoning Valley are inter-dependent both within the Valley and with other Republic Steel operations in Ohio.[2] Of the three plants in the Mahoning Valley District, the Warren and Youngstown Plants are most significant in terms of production and waste discharges. The Warren Plant is fully integrated, producing coke, iron, steel, and semi-finished and finished products. Most of the production is devoted to hot strip with some cold rolling, galvanizing, and terne (lead) coating.[2, 3]

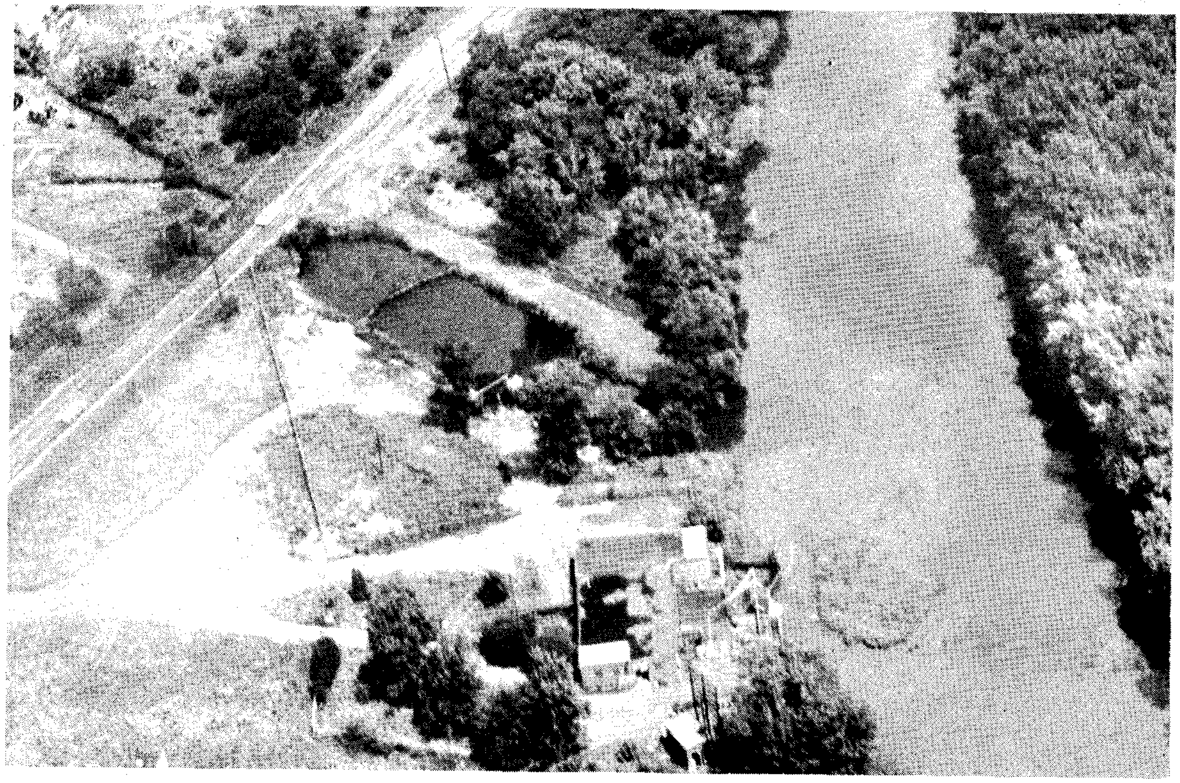

Figure V-2 Copperweld Steel Corporation river intake, effluent settling basin, outfall 002 (July 1971). Note discoloration resulting from discharge.

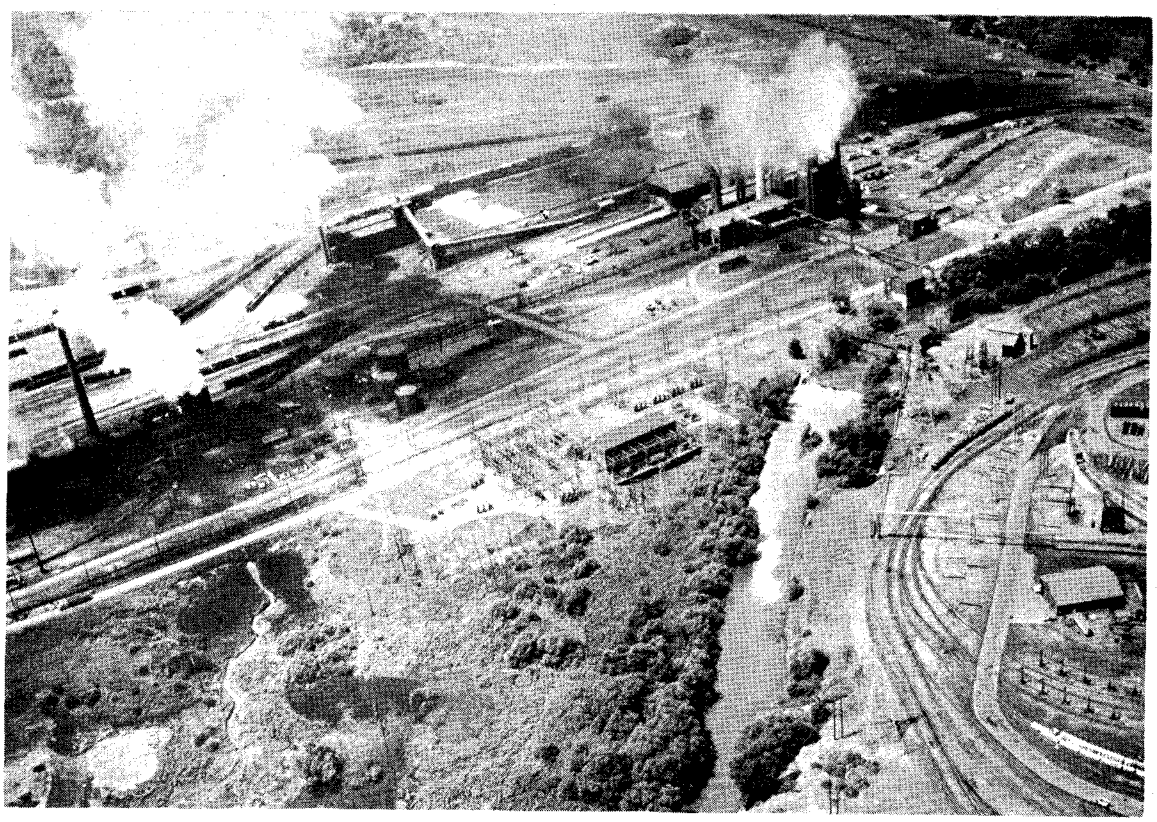

Figure V-3 Republic Steel Corporation-Warren Plant coke plant and blast furnace area; blast furnace discharge 013 at crest of dam (July 1971).

Although the plant is fully integrated, it depends upon the Youngstown Plant for supplemental coke for its blast furnace and for hot metal (molten iron) to keep its BOF steelmaking facility operating at capacity. The Youngstown Plant has no steelmaking, but receives ingots and semi-finished strip from the Warren Plant for conversion into various sections and pipes.[2, 3] A small portion of the pipe produced is galvanized. The Niles Plant is a small pickling and cold rolling operation. Republic Steel produces about 29 percent of the raw steel in the Valley.

Discharges from the Warren Plant are located just downstream from the City of Warren and just upstream from the City of Warren Sewage Treatment Plant about 36.3 to 37.9 miles above the mouth of the Mahoning River. These discharges account for about 51 percent of the total industry suspended solids loading, 14 percent of the oil loading, 21 percent of the ammonia discharge, 14 to 15 percent of the cyanide and phenolics discharges, and about 52 percent of the zinc loading. The Warren Plant blast furnace (Figure V-3) discharges more suspended solids than any other facility or entire plant in the Valley (90 tons/day), resulting in sludge banks downstream. Figure V-4 illustrates a combined discharge from the Warren Plant cold rolling, pickling, galvanizing, and terne coating operations. Emulsified oil used in cold rolling is evident in the river. Water usage can be as high as 64 percent of winter and 30 percent of summer minimum regulated streamflows. Hence, large discharge loadings of the above contaminants and a high thermal discharge have significant adverse impacts on stream quality. The Mahoning River is of fairly good quality above the Republic Steel Warren Plant.

The Niles Plant withdraws water from Mosquito Creek and discharges to the Mahoning River upstream from Mosquito Creek about 34.3 miles above the mouth of the river. Discharges from the plant account for about 1 percent of the total industry suspended solids discharge and about 4 percent of the oil discharge.

The active portion of the Republic Steel Youngstown Plant discharges downstream of the City of Youngstown Sewage Treatment Plant and just upstream from the Campbell city limits, about 17.8 to 18.5 miles above the mouth of the river (Figure V-1). The facility accounts for about 22 percent of the total industry suspended solids discharge, 13 percent of the oil

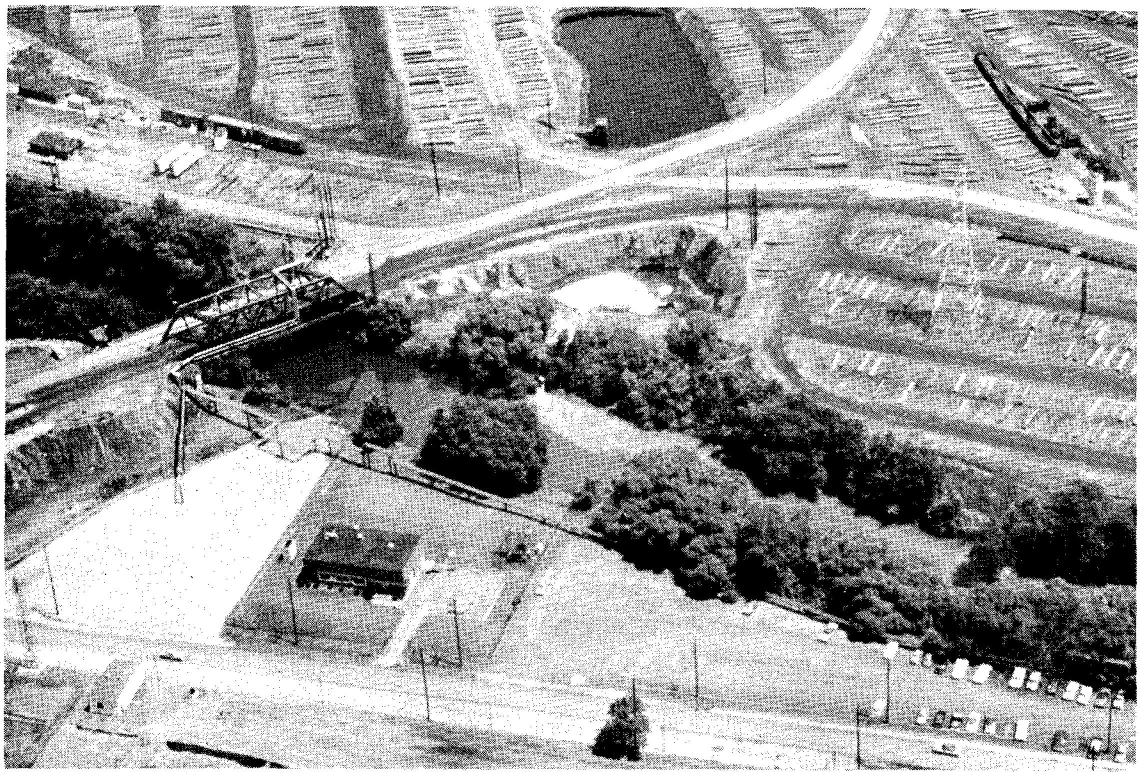

Figure V-4 Republic Steel Corporation-Warren Plant cold rolling and finishing area outfall 009 (July 1971). Note discharge of emulsified oil from lagoon.

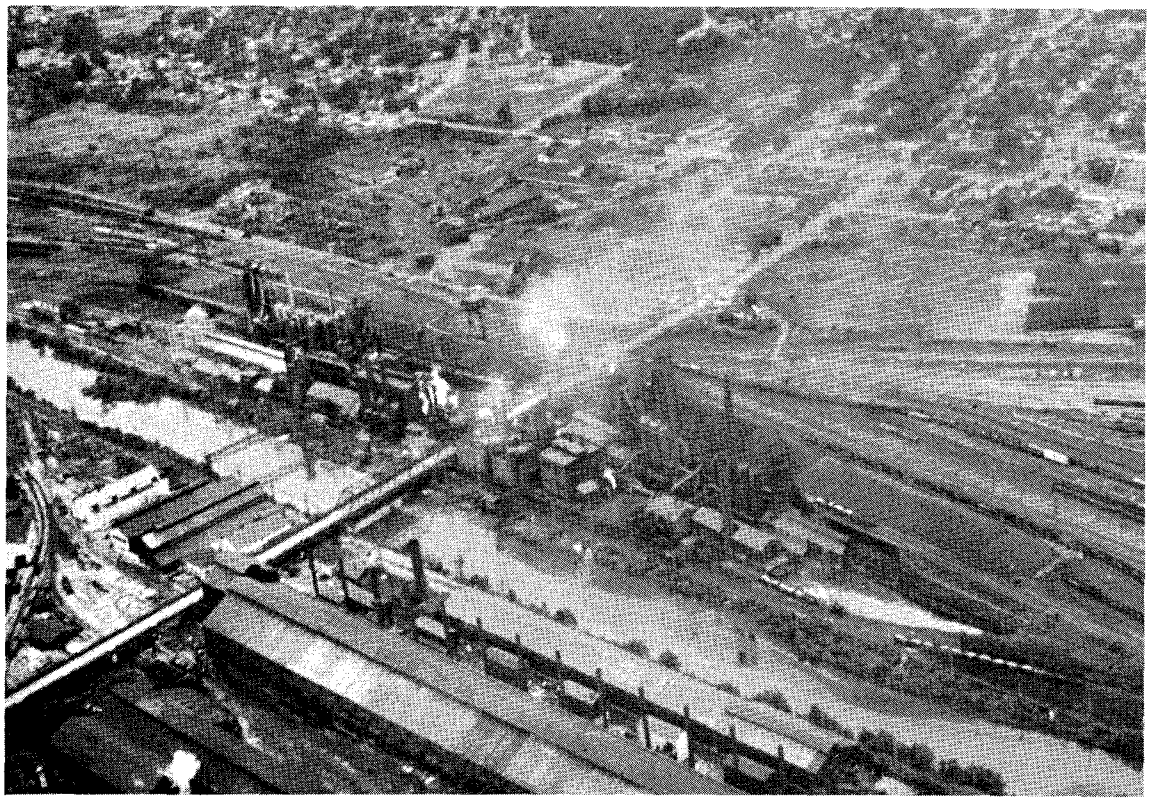

Figure V-5 Republic Steel Corporation-Youngstown Plant blast furnace area (July 1971). Note sludge banks in river formed by blast furnace discharges.

loading, 33 percent of the ammonia loading, 17 percent of the cyanide loading, and about 39 percent of the phenolics discharge. The blast furnace area contributes most of the suspended solids discharged by the plant. As illustrated in Figure V-5 sludge banks are evident below the blast furance outfalls. Although most coke plant wastes are disposed of by dirty water coke quenching, discharges of ammonia, cyanide, and phenolics are quite high. Thermal discharges from the plant are also significant in terms of resultant increases in stream temperature.

Republic Steel Corporation can be attributed with discharging the following portions of the steel industry pollution loading to the Mahoning River from its three plants:

Suspended Solids	75%	Ammonia	53%
Oil and Grease	31%	Cyanide	32%
Zinc	55%	Phenolics	53%

3. United States Steel Corporation

The Ohio Works and the McDonald Mills comprise the Youngstown Works of U. S. Steel.[4] The Ohio Works is located in Youngstown just upstream from the center of town discharging to the Mahoning River about 22.5 to 23.2 miles above its mouth (Figure V-1). The McDonald Mills is located in McDonald, about five miles upstream from the Ohio Works and about 28.7 miles above the mouth of the Mahoning River. Figure V-6 depicts the Ohio Works and Figure V-7 shows the McDonald Mills discharge.

Iron making, steelmaking, primary rolling and a small amount of pickling are carried out at the Ohio Works while the McDonald Mills produces bars, strip, and various shapes from the semi-finished products of the Ohio Works.[2, 4] Pickling is also carried out at the McDonald Mills. U. S. Steel does not operate a coke plant in the Valley, receiving coke for the Ohio Works blast furnaces from its Clairton, Pennsylvania coke plant. Because of the absence of a coke plant and in general better housekeeping and more adequate treatment facilities, discharges from the U. S. Steel facilities account for a proportionately lesser share of the total steel industry discharge than Republic Steel or Youngstown Sheet and Tube. U. S. Steel produces about 24 percent of the raw steel in the Valley, yet discharges only 4 percent of the steel industry suspended solids loading from

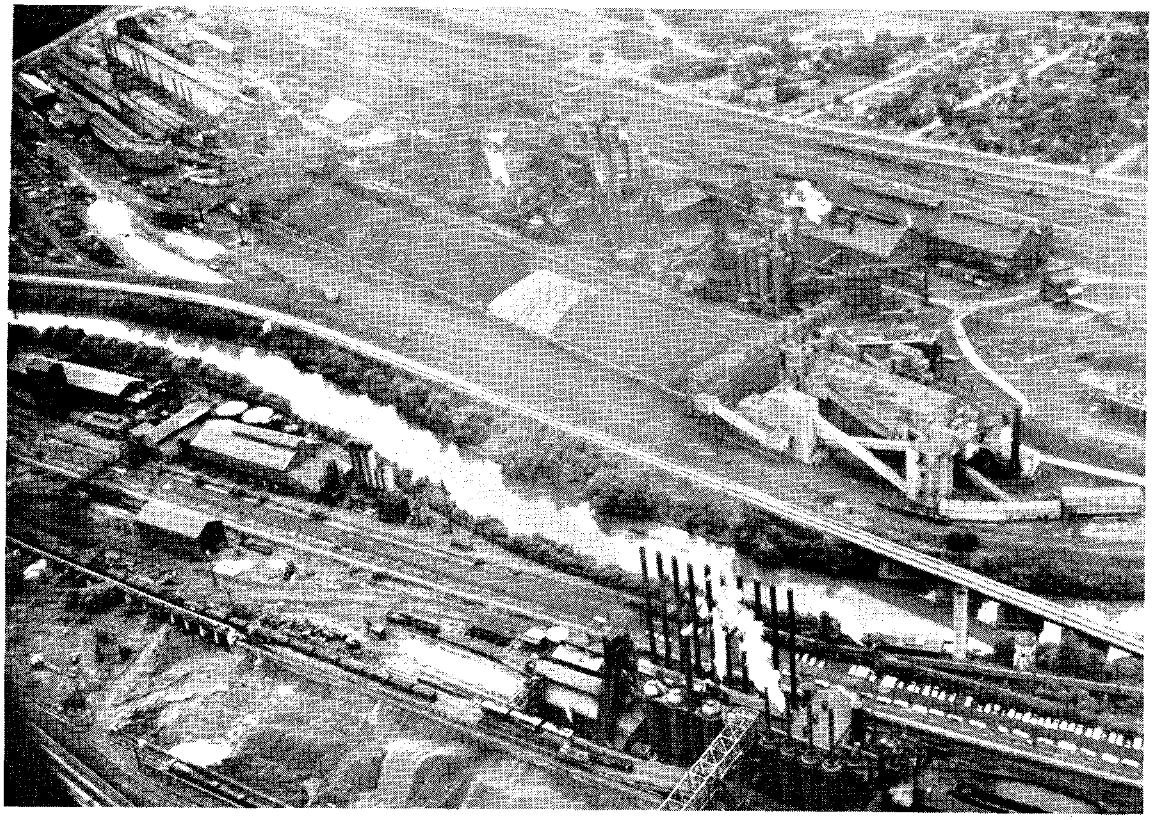

Figure V-6 U. S. Steel Corporation-Ohio Works (background), Youngstown Sheet and Tube Company-Brier Hill Works blast furnace area (foreground) (July 1971).

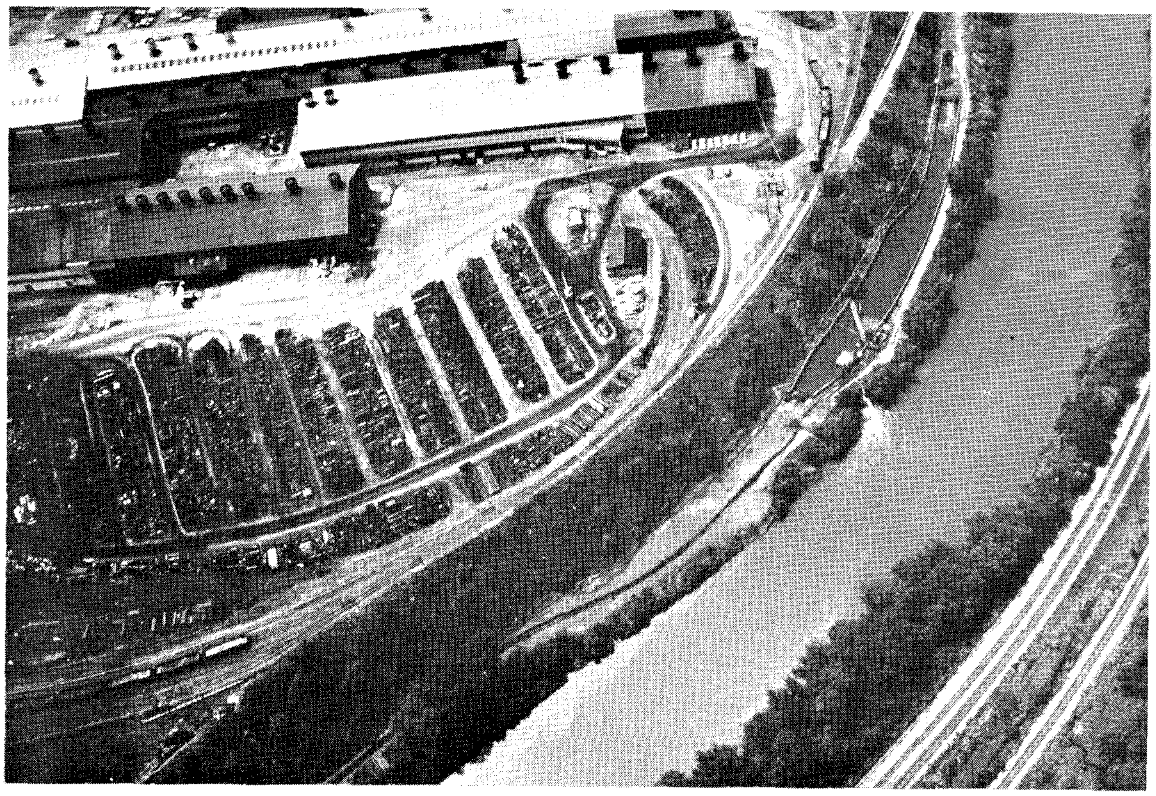

Figure V-7 U. S. Steel Corporation-McDonald Mills outfall 006 (July 1971). Note oil sheen along left bank of river resulting from discharge.

its Ohio Works and less than 2 percent from the McDonald Mills. Together both plants discharge 2 percent of the industry oil loading, although there is a severe floating oil problem at the McDonald Mills as shown in Figure V-7. The Ohio Works discharges about 18 percent, 40 percent, and 20 percent of the steel industry ammonia, cyanide, and phenolics discharges, respectively. Both plants are significant thermal dischargers. The Ohio Works uses about 54 percent of the winter critical stream flow and about 25 percent of the summer critical flow while the McDonald Mills uses about 30 percent of the winter flow and 14 percent of the summer flow.

4. Youngstown Sheet and Tube Company

The Youngstown District of the Youngstown Sheet and Tube Company (YS&T) includes the Brier Hill Works located in Girard and Youngstown, the Campbell Works located in Campbell, Struthers, and Youngstown, and the Struthers Division located in Struthers. The Campbell Works is a fully integrated facility with tubular goods and strip as main products; the Brier Hill Works produces iron, steel, electric weld pipe, cold drawn bars, and semi-finished products for finishing at the Campbell Works; and, the Struthers Division produces bars and electroplated conduit.[2, 5] The company produces about 39 percent of the raw steel in the Valley.

The Brier Hill Works receives coke, hot metal and skelp from the Campbell Works and hot rolled bars from the Struthers Division. Slabs and rounds are sent to the Campbell Works.[6] The discharges from the plant extend from 23.6 to 25.7 miles above the mouth of the Mahoning River and account for about 4 percent of the total industry suspended solids loading, and about 7 percent of the oil, ammonia, cyanide, and phenolics discharges. As shown in Figure V-1 and V-8, the Brier Hill Works is just upstream and across the river from the U. S. Steel Ohio Works. Figure V-9 illustrates a heavy oil sheen on the river between the two facilities. The total water usage amounts to 38 percent of the winter critical stream flow and about 18 percent of the summer critical flow. The Brier Hill Works is a significant thermal discharger.

The Campbell Works (Figure V-10 and V-11) uses more water than any other discharger in the Mahoning Valley, consuming up to 120 percent of the critical winter flow and 66 percent of the summer low flow. The plant

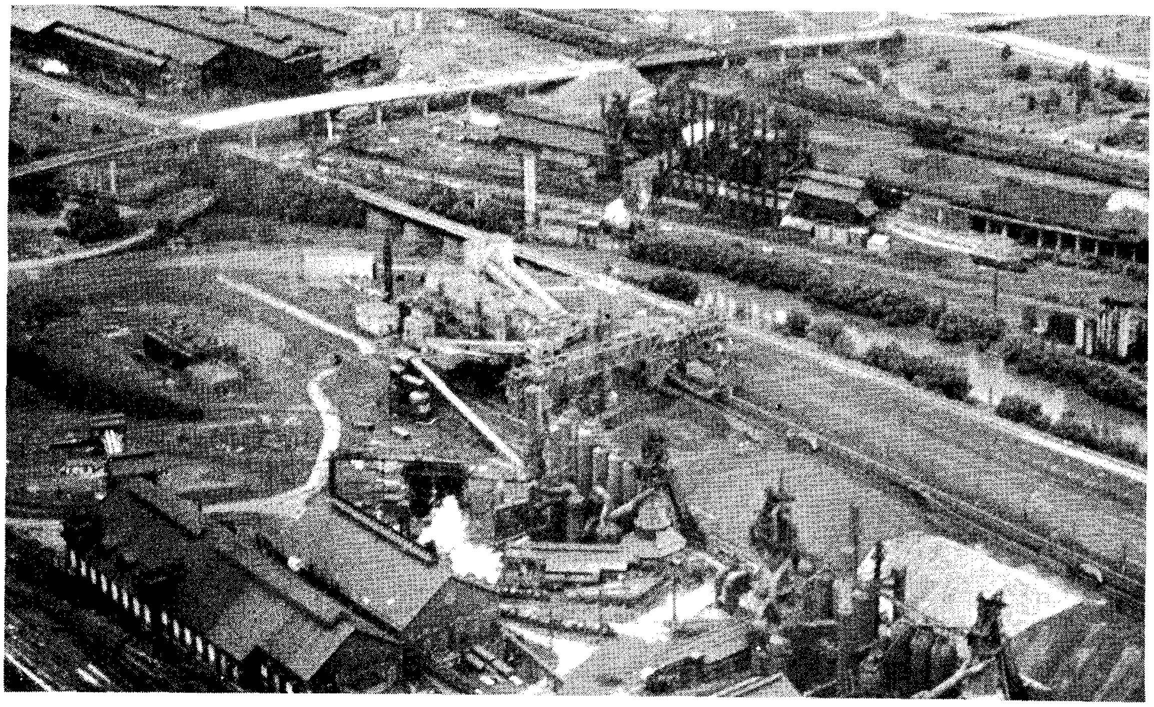

Figure V-8 U. S. Steel Corporation-Ohio Works (foreground), Youngstown Sheet and Tube Company and Brier Hill Works (background) (July 1971).

Figure V-9 Oil sheen on Mahoning River between Youngstown Sheet and Tube Company-Brier Hill Works and U. S. Steel Corporation-Ohio Works (July 1971).

discharges as much oil as all other steel plants combined, accounting for 51 percent of the total oil loading, 21 percent of the ammonia loading, 13 percent of the cyanide discharge, 20 percent of the phenolics loading, and 36 percent of the zinc discharge. The Campbell Works is also the largest steel industry thermal discharger, and discharges about 14 percent of the steel industry suspended solids loading. A reason for the relatively low suspended solids discharge is the partial blast furnace gas wash water recirculation system in operation here. With the river being highly contaminated before reaching the plant and with the tremendous loadings from the Campbell Works, the most contaminated section of the stream is found just downstream from the Campbell Works to the Ohio-Pennsylvania State Line. The Campbell Works discharges about 16.2 to 17.6 miles above the mouth of the river and only about 4.6 to 6.0 miles above the State Line.

The Struthers Division is a relatively small operation compared to the Brier Hill Works and Campbell Works, but nevertheless, contributes significant waste loadings to the stream. The plant accounts for less than 1 percent of the total industry suspended solids loading, about 5 percent of the oil discharge, 9 percent of the cyanide loading, and 9 percent of the zinc discharge. The Struthers Division is located just downstream from the Campbell Works.

Except for oil and grease, discharges from the three Youngstown Sheet and Tube Company plants generally account for less pollution than discharges from Republic Steel and more pollution than discharges from U. S. Steel. Percentages of the total major steel industry loading are shown below:

Suspended Solids	19%	Ammonia	29%
Oil and Grease	63%	Cyanide	28%
Total Zinc	45%	Phenolics	27%

5. Ohio Edison Company

Ohio Edison operates a 250MW coal fired steam electric generating station at Niles, Ohio just below the confluences of Mosquito and Meander Creeks with the Mahoning River. The condenser cooling water is discharged about 30.1 miles above the mouth of the river. Ohio Edison may use as much

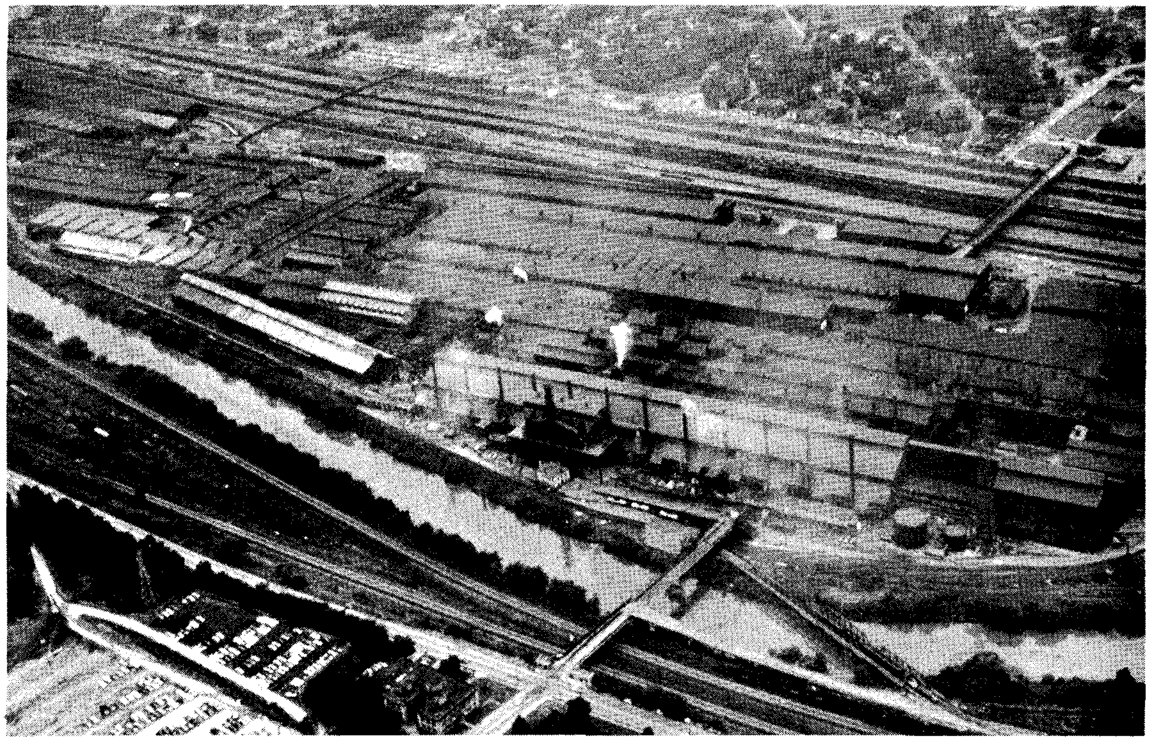

Figure V-10 Youngstown Sheet and Tube Company-Campbell Works steelmaking, primary mills and finishing mills (July 1971).

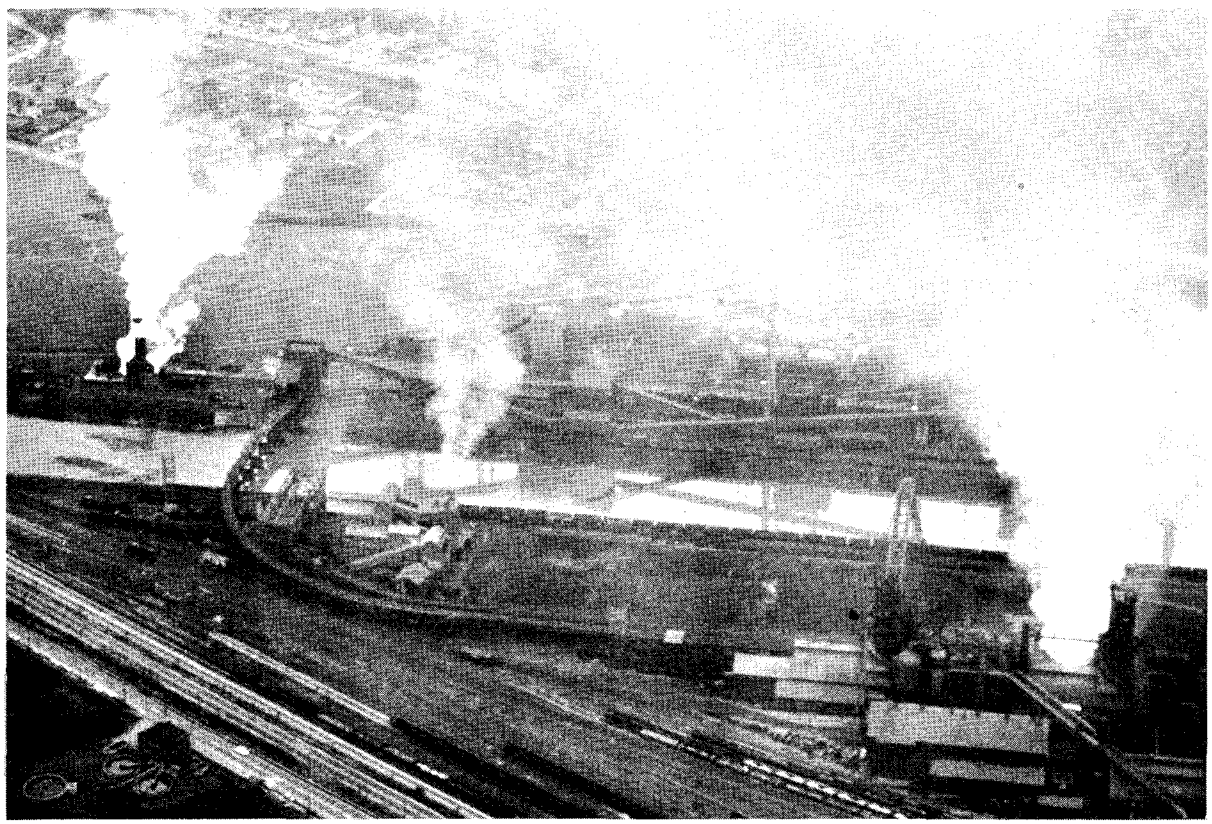

Figure V-11 Youngstown Sheet and Tube Company-Campbell Works blast furnace and sinter plant area (foreground) coke plant area (background) (July 1971).

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as 155 percent of the winter critical stream flow and 69 percent of the summer critical stream flow. Water usage in excess of actual stream flows is possible because the plant river intake withdraws water from the pool created by the Liberty Street Dam in Girard, thus recirculation of a portion of the heated effluent results.

At peak power production, Ohio Edison may discharge in excess of one billion BTU's/hr of waste heat to the river resulting in increases in stream temperatures of over $12^{o}F$ depending upon stream flow rates.

6. Other Industrial Dischargers

Figure V-1 also illustrates the locations of ten of the more significant smaller industrial dischargers to the Lower Mahoning River and its tributaries. While discharges from some of these facilities may have localized adverse impacts on stream quality, none have the far-reaching effects of the major steel plants or Ohio Edison.

TABLE V - 2

INDUSTRIAL DISCHARGE SUMMARY

COPPERWELD STEEL COMPANY

D 350*BD
OH 0011207

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	100	6050	1560					
1972 USEPA Sampling[1]	80	3010	220					
1975 USEPA Sampling[2] (February)	70	2880		9			16	5
1975 USEPA Sampling[2] (July)	60	3460		15			14	9
Ohio EPA		3300	1100					
Discharger[3]		6250	2620					

NOTES: [1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Modified NPDES permit limitations.

TABLE V - 3

INDUSTRIAL DISCHARGE SUMMARY

REPUBLIC STEEL CORPORATION
Warren Plant

D 304*AD
OH 0011274

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	670	17200	4600	980	37	250	1070	68
1972 USEPA Sampling[1]	400	31700	9000	750	12	60	310	
1975 USEPA Sampling[2] (February)	310	111700		1280	62	154	540	32
1975 USEPA Sampling[2] (July)	370	40600		670	49	55	140	10
Ohio EPA		302700	15100	1910	68	79		
Discharger[3]	400	205800	9500	1930	72	84	450	

NOTES: [1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Long-term average from comprehensive monitoring program (75-152 observations per outfall).

TABLE V - 4

INDUSTRIAL DISCHARGE SUMMARY

REPUBLIC STEEL CORPORATION
Niles Plant

D 305*AD
OH 0011266

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application		9300	3030					
1972 USEPA Sampling[1]		2280	1630					
1975 USEPA Sampling (February)		Not sampled - production curtailed						
1975 USEPA Sampling (July)		Not sampled - production curtailed						
Ohio EPA								
Discharger		9000	2870					
Discharger[2]		5100	2900					

NOTES: 1 One 8 hour or 24 hour composite sample per outfall.
2 Long-term average from comprehensive monitoring program (28-29 observations).

TABLE V - 5

INDUSTRIAL DISCHARGE SUMMARY

REPUBLIC STEEL CORPORATION
Youngstown Plant

D 306*AD
OH 0011282

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	380	66400	2150	2440	140	480	510	28
1972 USEPA Sampling[1]	350	29700	3000	990	50	260	30	
1975 USEPA Sampling[2] (February)	470	15400		3740	240	560	240	9
1975 USEPA Sampling[2] (July)	140	45700		650	138	60	150	9
Ohio EPA		161100	15490	3540	90	190		
Discharger[3]	390	88800	8950	3090	80	230	20	

NOTES:
[1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Long-term average from comprehensive monitoring program (61-112 observations per outfall).

TABLE V - 6

INDUSTRIAL DISCHARGE SUMMARY

UNITED STATES STEEL CORPORATION
McDonald Mills

D 329*AD
OH 0063215

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	15	2900	300					
1972 USEPA Sampling[1]	175	13300	1050					
1975 USEPA Sampling[2] (February)	104	8310		6				
1975 USEPA Sampling[2] (July)	44	4310		13				
Ohio EPA		3700	900					
Discharger[3]		10270	3770					

NOTES: [1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Proposed NPDES permit effluent limitations reflecting existing discharge levels (30 day average).

TABLE V - 7

INDUSTRIAL DISCHARGE SUMMARY

UNITED STATES STEEL CORPORATION
Ohio Works

D 327*AD
OH 0011916

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	115	3930						
1972 USEPA Sampling[1]	310	7700	550	520	70	-		
1975 USEPA Sampling[2] (February)	420	7050		800	430	62	160	
1975 USEPA Sampling[2] (July)	170	2870		93	7	1	24	
Ohio EPA		15000	490	1680	190	120		
Discharger[3]		37160	1550	2560	1260	240		

NOTES:
1 One 8 hour or 24 hour composite sample per outfall.
2 Average of three consecutive 24 hour composite samples at significant outfalls.
3 Proposed NPDES permit interim effluent limitations reflecting existing discharge (30 day average).

TABLE V - 8

INDUSTRIAL DISCHARGE SUMMARY

YOUNGSTOWN SHEET AND TUBE COMPANY
Brier Hill Works

D 337*AD
OH 0011312

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	330	20460	4920	200	70	18		
1972 USEPA Sampling[1]	190	4810	560	110	60	5	16	
1975 USEPA Sampling[2] (February)	270	16700		660	74	32	28	
1975 USEPA Sampling[2] (July)	120	1070		-	-	-	63	
Ohio EPA		20400	4910	150	170	18		
Discharger[3]	270	17750	4870	680	32	42		

NOTES:
[1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Long-term average discharge (observations from 1968-1975).

TABLE V - 9

INDUSTRIAL DISCHARGE SUMMARY

YOUNGSTOWN SHEET AND TUBE COMPANY
Campbell Works

D 336*AD
OH 0011321

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	1710	74600	93000	2240	30	120	420	40
1972 USEPA Sampling[1]	980	108000	53700	1150	22	110	1020	
1975 USEPA Sampling[2] (February)	720	32100		2660	490	310	640	210
1975 USEPA Sampling[2] (July)	350	16300		980	100	150	450	90
Ohio EPA		72400	94200	2060	90	190	420	
Discharger[3]	850	54720	34380	2020	60	120	310	

NOTES: [1] One 8 hour or 24 hour composite sample per outfall.
[2] Average of three consecutive 24 hour composite samples at significant outfalls.
[3] Long-term average discharge (observations from 1968-1975).

TABLE V - 10

INDUSTRIAL DISCHARGE SUMMARY

YOUNGSTOWN SHEET AND TUBE COMPANY
Struthers Division

D 334*AD
OH 0011321

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	84	6220	1140	50	45		79	
1972 USEPA Sampling[1]	22	630	40		85		360	
1975 USEPA Sampling[2] (February)		Not Sampled						
1975 USEPA Sampling[2] (July)	26	890		18	8		28	
Ohio EPA		6120	1140		46		79	
Discharger[3]	40	2590	3280		43		80	

NOTES:
1 One 8 hour or 24 hour composite sample per outfall.
2 Average of three consecutive 24 hour composite samples at significant outfalls.
3 Long-term average discharge (observations from 1968-1975).

TABLE V - 11

INDUSTRIAL DISCHARGE SUMMARY

OHIO EDISON COMPANY
Niles Steam Electric Generating Station

NET DISCHARGE LOADINGS (lbs/day)

	Thermal Loading ($x10^6$ BTU/hr)	Total Suspended Solids	Oil and Grease	Ammonia-N	Total Cyanide	Phenolics	Total Zinc	Total Chromium
Permit Application	810							
1972 USEPA Sampling	970							
1975 USEPA Sampling (February)	1160							
1975 USEPA Sampling (July)	800							
Ohio EPA								
Discharger	1300 (maximum)							

TABLE V - 12

SUMMARY OF MAJOR INDUSTRIAL DISCHARGES

MAHONING RIVER BASIN

	Thermal Discharge		Total Suspended Solids		Oil and Grease		Ammonia-N		Total Cyanide		Phenolics	
	10^6BTU/hr	% of total	lbs/day	% of total	lbs/day	% of total	lbs/day	% of total	lbs/day	% of total	lbs/day	% of tota
Copperweld Steel Corporation	70	(2)	6300	(2)	2620	(4)						
Republic Steel Corporation	790	(21)	299700	(75)	21350	(31)	5020	(53)	152	(32)	314	(53)
United States Steel Corporation	520	(14)	18700	(5)	1390	(2)	1680	(18)	190	(40)	120	(20)
Youngstown Sheet and Tube Company	1160	(31)	75100	(19)	42530	(63)	2700	(29)	135	(28)	162	(27)
Ohio Edison Company	1160	(31)										
TOTAL	3700		399800		67890		9400		477		596	

NOTE: Data for Republic Steel Corporation and Youngstown Sheet and Tube Company are long-term averages.
Data for United States Steel Corporation were obtained from the Ohio EPA, and data for Copperweld Steel Corporation reflect interim NPDES permit effluent limitations.

B. Municipal Dischargers

Tables V-13 to V-20 present summaries of available discharge data for eight sewage treatment plants discharging to the lower Mahoning River. Figure V-1 illustrates the location of the dischargers and Figure V-12 illustrates the respective service areas for each sewage treatment plant. Information pertaining to all existing municipal waste water treatment facilities in the valley are presented in Table V-21. With the exception of the newly constructed Meander Creek Sewage Treatment Plant, the eight facilities described herein provide primary treatment. Since effluent quality for these facilities falls within the range expected for primary treatment, adverse impacts on stream quality are roughly in proportion to effluent volume. The total effluent from the facilities amounted to 54 MGD on an annual average basis in 1974. The Meander Watershed plant is expected to add 4 MGD by late 1977.

1. Warren

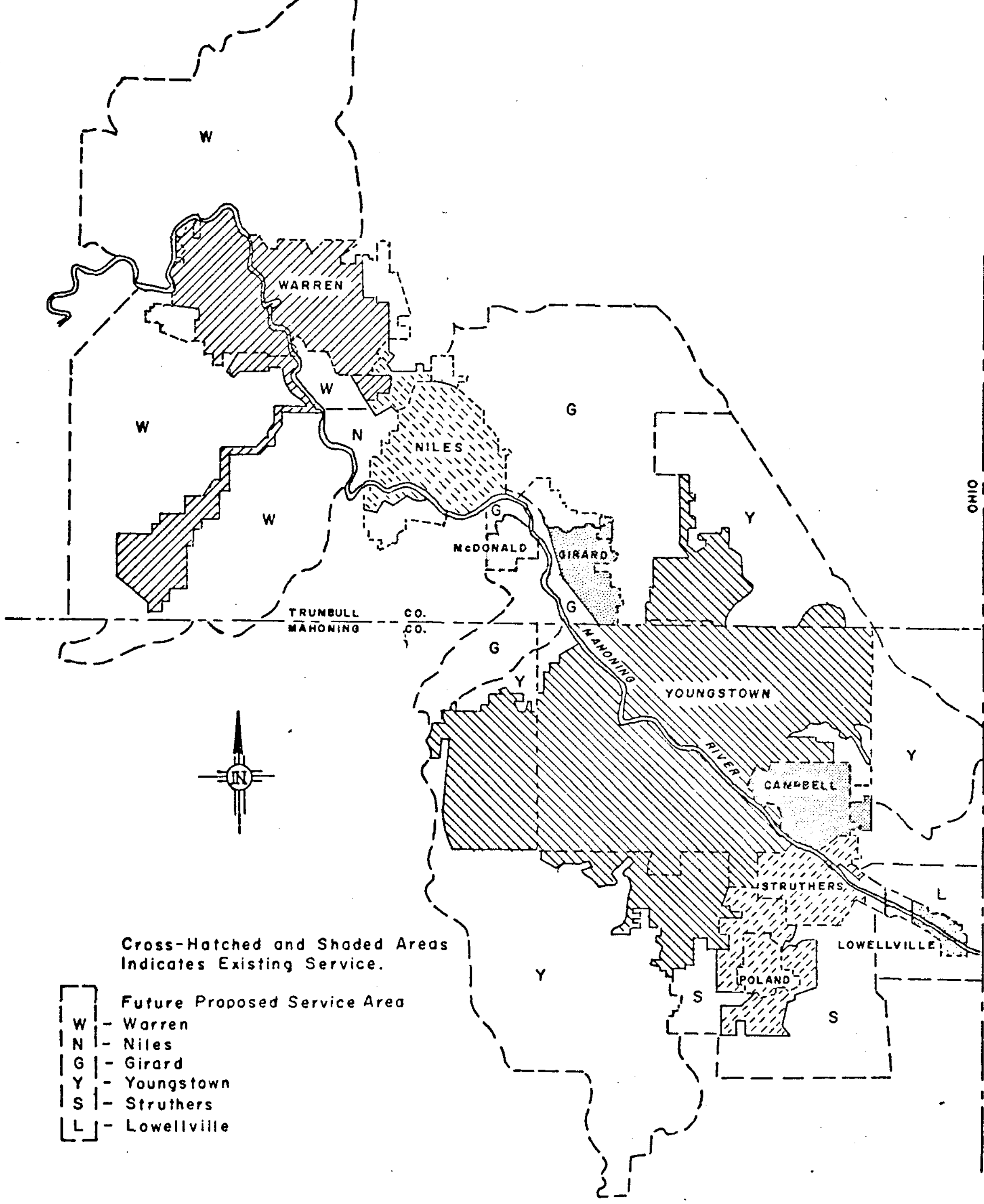
The Warren WWTP, located on 104 acres of land between the Mahoning River (M.P. 36) and South Main Street, is a primary sewage treatment plant with facilities for chemical precipitation, sludge filtration and incineration. The plant was placed in operation in 1962 and now treats an average daily flow of 12.2 MGD.[7] Average design flow of the plant is 13.5 MGD and the design population is 90,000.[7] The plant presently serves about 80,000 people including the entire population of Warren and several thousand people from Champion, Lordstown, Warren, and Howland Townships.[8]

There are three pumping stations within the service area. Most of the raw sewage is lifted to the Warren plant from the Mahoning River interceptor pumping station located approximately 0.8 miles to the north of the plant on South Main Street. The maximum capacity of this pumping station is 38.0 MGD with a firm pumping capacity of 28.5 MGD.[8] Industrial wastes (4.5 MGD) coming to the treatment plant originate from automobile, electric products, aluminum extrusion and steel manufacturing and fabrication plants.

A combined sewer system and infiltration result in excessive flows during wet weather. Bypassing occurs at the Brookside and D_2 pumping stations, the Mahoning River interceptor and at the treatment plant.[8]

FIGURE V-12

EXISTING AND PROPOSED FUTURE MUNICIPAL SERVICE AREAS



SOURCE: The Eastgate Development and Transportation Agency
NOTE: Future Service Areas May Be Modified Pending Completion of the 208 Areawide Study.

Overflows can occur at the Union Street storm sewer and at the Market Street and Republic Steel office building regulating stations.[8] With the exception of the bypass at the treatment plant, all other bypasses and overflows are discharged to the Mahoning River without treatment. Excess flow at the treatment plant is chlorinated prior to being discharged to the Mahoning River.

The Warren plant is the second largest municipal discharger to the lower Mahoning River. For 1974, the annual average effluent flow was 12.95 MGD. The plant flow amounts to about 24 percent of the total municipal contribution to the lower Mahoning River and the discharge accounts for about 21 percent (5900 lbs/day) of the municipal suspended solids discharge, 25 percent (8200 lbs/day) of the BOD_5 discharge, and about 30 percent (1000 lbs/day) of the ammonia discharge.[9]

2. Niles

The Niles WWTP is located in the southeasterly section of the City just upstream of U. S. Steel McDonald Mills, about 28.5 miles above the mouth of the Mahoning River. Niles is the third largest municipal discharger to the lower Mahoning. The plant receives and processes sanitary sewage using primary sedimentation with some chemical pretreatment, followed by chlorination of the effluent and anaerobic decomposition of sludge. The Niles plant was designed to serve a population of 25,000 by the year 1980, providing primary treatment for a design flow of 3.0 MGD. The plant presently serves the entire populaion of Niles (23,500 people) and Howland Sewer District #9 which accounts for some 1100 people.[12] In 1974, the plant treated an annual average daily flow of 4.2 MGD, which is about 40 percent higher than the design flow.[11] The hydraulic overloading can be attributed to large amounts of infiltration and storm water entering the combined sewerage system. Typically, the flow must exceed 9.2 MGD before bypassing will occur at the plant. This maximum flow has been exceeded on numerous occasions. Sewer overflows reportedly occur upstream of the treatment plant at nine different locations within the service area.[12]

The Niles discharge accounts for about 7 percent of the total municipal effluent flow and 7 percent, 6 percent, and 9 percent of the suspended solids, BOD_5, and ammonia loadings, respectively. Discharge loadings during 1974 averaged about 2300 lbs/day of BOD_5, and 1900 lbs/day of suspended solids. U. S. EPA's July 1975 survey revealed an average ammonia discharge of about 300 lbs/day over a three day period.

3. McDonald

The McDonald Sewage Treatment Plant is located just downstream of U. S. Steel McDonald Mills about 27.8 miles above the mouth of the Mahoning River. The plant receives and processes sanitary sewage, using primary sedimentation with some chemical pretreatment, followed by chlorination of the effluent and anaerobic sludge digestion. The plant was placed in operation in 1959 and now treats an average daily flow of 0.605 MGD. Design flow of the plant is 0.610 MGD average and design population is 5300.[13] The plant presently serves the entire population of McDonald, roughly 3200 people. There are no reported industrial dischargers to this facility. The collection system consists of both separate and combined sewers. The plant has infiltration/inflow problems, although bypassing is reported to be infrequent. With the exception of the Lowellville WWTP, the McDonald WWTP is the smallest municipal discharger to the lower Mahoning. The plant discharge accounts for about 1 percent of the total municipal contribution of BOD_5 (250 lbs/day), suspended solids (120 lbs/day) and flow (0.605 MGD).[14]

4. Girard

The Girard Sewage Treatment Plant is located across from the Youngstown Sheet and Tube Brier Hill Works about 25 miles above the mouth of the Mahoning River. The plant services all of Girard, with a population of about 14,000, and Liberty Township Sewer District #3, which accounts for some 6000 people.[15] The facility was placed in operation in 1963 and has a design flow of 1.8 MGD and design population of 18,000.[16] The only known industrial discharger to this facility is the Benada Aluminum Products Company.[15]

The existing sewerage system is predominantly separate with a few combined sewers in the main business district. However, inflow/infiltration has resulted in hydraulic overload problems at the treatment plant. During heavy rains, sewer overflows also occur upstream of the treatment plant.

During dry weather, the plant effluent may become the total flow of Little Squaw Creek before it reaches the Mahoning River. The Girard discharge accounts for about 5 percent of the total municipal contribution of NH_3-N (180 lbs/day), BOD_5 (18,000 lbs/day), suspended solids (1000 lbs/day) and flow (2.7 MGD) to the lower Mahoning River.

5. Youngstown

The Youngstown Wastewater Treatment Plant is located just upstream of the Republic Steel Youngstown Plant about 19.5 miles above the mouth of the Mahoning River and about 8 miles above the Ohio-Pennsylvania State Line. The Youngstown Plant provides primary treatment that can be augmented by chemical addition. The plant was placed in operation in 1965 and now treats an average daily flow of 28.5 MGD[18] while the design flow is 50 MGD with a design population of 490,000.[18] The Youngstown treatment facility presently serves about 90 percent[17] of the population of Youngstown (approximately 126,000 people) and 80,000 people from Mahoning and Trumbull Counties outside the City limits. There are numerous industrial discharges to the plant, many of which are unknown. However, the City has retained a consultant to identify all sources of industrial discharges to the plant.

The collection system includes a large number of combined sewers, resulting in wide fluctuations in flow to the plant during wet weather. Due to the large amount of excess hydraulic capacity available, bypassing at the treatment plant is infrequent and is likely to occur only during power outages. There are reportedly 117 regulators[13] and overflows upstream of the treatment plant which have discharges into every stream in the area, including Silver Creek, Crab Creek and Mill Creek which traverses an extensive park system. Ten to fifteen percent of the city, by area (Northwest section) and approximately 10 percent by population, is unsewered with septic tanks for sanitary service.[18] Projects for improving and expanding the collection system are in progress.

The Youngstown WWTP is the largest municipal discharger in the study area and can be attributed with discharging the following portions of the municipal pollution loading to the lower Mahoning River:

Flow	54%	or	28.5 MGD
Suspended Solids	63%	or	17000 lbs/day
BOD_5	52%	or	17000 lbs/day
Ammonia	46%	or	1900 lbs/day

6. Campbell

The Campbell WWTP, located about 16.5 miles above the mouth of the Mahoning River, is a primary sewage treatment plant (with provisions for chemical treatment) serving the entire population of Campbell (13,000 people). The plant was placed in operation in 1958 and between March 1974 and September 1975 treated an average daily flow of 2.274 MGD.[19] There are no reported industrial discharges to this facility, with the exception of sanitary wastes from Youngstown Sheet and Tube Company-Campbell Works.[20]

Although most of the sanitary sewage is separated from the storm water throughout the City, both are combined in a 5' x 6' concrete box sewer on Wilson Avenue, directly upstream from the treatment plant. Due to the location of the plant with respect to the City, the storm water reaches the plant in a very short time causing hydraulic overloading and resultant bypassing of much of the septic solids deposited in the interceptor during dry weather conditions. The Campbell discharge contains 4 percent, 3 percent, 4.5 percent, and 3 percent of the total municipal contributions of flow, suspended solids, BOD_5, and ammonia, respectively to the lower Mahoning River.

7. Struthers

The Struthers WWTP is located just downstream of the Youngstown Sheet and Tube Company-Struthers Division, about 14.2 miles above the mouth of the Mahoning River. The plant receives and processes sanitary sewage using primary sedimentation followed by chlorination of the effluent and anaerobic decomposition of sludge. The plant was placed in operation in 1961 and now treats an average daily flow of about 2.0 MGD.[21] Design flow of the plant is 2.5 MGD and the design population is 25,000 people.[22] The plant presently serves about 29,000 people including the entire population of Struthers and 12,000 people from Poland Township.[22] With the exception of some sanitary wastes from the Youngstown Sheet and Tube Company-Struthers Division, there are no reported industrial discharges to this facility.[21, 22]

The City has major intercepting sewers which intercept combined sewers. Sewer overflows occur upstream of the treatment plant at about four different locations during heavy rains. Bypassing of raw sewage also occurs at the plant during wet weather. However, bypassed sewage is chlorinated prior to being discharged.

The Struthers discharge accounts for about 4 percent, 2 percent, 2 percent, and 5 percent of the total municipal contribution of flow, suspended solids, BOD_5, and ammonia, respectively. Discharge loadings during 1974 averaged about 650 lbs/day of suspended solids, 918 lbs/day of BOD_5, and 207 lbs/day of ammonia.

8. Lowellville

The Lowellville WWTP, located just upstream of the Ohio-Pennsylvania State Line about 12.2 miles above the mouth of the Mahoning River, is a primary sewage treatment plant with facilities for chemical precipitation. The plant was placed in operation in 1959 and during 1975 treated an average annual flow of 0.269 MGD.[23] Design flow of the plant is 0.25 MGD and the design population is 2500.[23] The plant presently serves about 1800 people within the Village of Lowellville.[23] There are no reported industrial discharges to this facility. The sewerage system has major hydraulic overloading problems, resulting from inflow/infiltration and numerous combined sewers. Bypassing and sewer overflows occur during heavy rains.[23] The Lowellville WWTP is the smallest municipal discharger to the lower Mahoning River. The plant discharge accounts for less than 1 percent of the total municipal contribution of flow (0.269 MGD), suspended solids (170 lbs/day), BOD_5 (250 lbs/day), and ammonia (14 lbs/day).

9. Meander Creek

The Meander Creek Sewage Treatment Plant, located on Meander Creek near Niles, Ohio, has recently been completed and was placed in operation in late 1976. The plant is a secondary treatment facility (Pure Oxygen Activated Sludge) with phosphorus removal capability and disinfection by ozonation. Average design flow of the plant is 4.0 MGD and the design population is 40,000.[24] The plant will serve the City of Canfield, Mineral Ridge, and portions of the Austintown Township sewer service district.

A National Pollutant Discharge Elimination System permit for the Meander Creek facility has been issued to the Board of County Commissioners of Mahoning County. Pertinent discharge limitations of this permit which went into effect June 21, 1976 appear below:

Parameter	30 Day Average	7 Day Average	Other
BOD_5	15	25	
Suspended Solids, mg/l	20	30	
Phosphorus, mg/l	1	1.5	
Ammonia (summer), mg/l	2.5	5	
Ammonia (winter), mg/l	5	7.5	
pH su			6-9
Fecal Coliform lbs/100 ml	200	400	
Dissolved Oxygen, mg/l			minimum of 5

10. Other Municipal Dischargers

In addition to the sewage treatment plants discussed above, Table IV-20 also presents data pertaining to other municipal waste water treatment facilities in the Mahoning River Basin. Included in Table V-20 are the types of sewer systems and treatment facilities provided by the municipalities and counties along with performance data. It should be noted that nearly all of the municipal and county dischargers not previously discussed, now provide secondary treatment. Discharges from these facilities are generally of reasonably good quality. However, localized water quality problems are not uncommon.

TABLE V - 13

MUNICIPAL DISCHARGE SUMMARY

WARREN WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	11000	6100	300	1300
1975 USEPA Sampling (February)	7300	7300	500	1000
1975 USEPA Sampling (July)	9300	6400	600	700
1973 Annual Summary of Operations	9500	6200	600	1200
1974 Annual Summary of Operations	8200	5900	700	1000

TABLE V - 14

MUNICIPAL DISCHARGE SUMMARY

NILES WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	2900	2300		
1975 USEPA Sampling (February)	2700	1200	230	380
1975 USEPA Sampling (July)	2200	2200	170	300
1973 Annual Summary of Operations	2000	2000		
1974 Annual Summary of Operations	2300	1900		

TABLE V - 15

MUNICIPAL DISCHARGE SUMMARY

McDONALD WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application				
1975 USEPA Sampling (February)	200	100	30	50
1975 USEPA Sampling (July)	330	310	40	70
1973 Annual Summary of Operations	220	100		
1974 Annual Summary of Operations	250	120		

TABLE V - 16

MUNICIPAL DISCHARGE SUMMARY

GIRARD WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	2200	1600		
1975 USEPA Sampling (February)	1250	740	100	210
1975 USEPA Sampling (July)	1400	1300	100	180
1973 Annual Summary of Operations	2200	1600		
1974 Annual Summary of Operations	1800	1000		

TABLE V - 17

MUNICIPAL DISCHARGE SUMMARY

YOUNGSTOWN WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	14000	16000	1600	400
1975 USEPA Sampling (February)	10200	8000	1100	1500
1975 USEPA Sampling (July)	13900	13500	1100	1900
1973 Annual Summary of Operations	13700	16800	1400	2100
1974 Annual Summary of Operations	17000	17000	1660	2700

TABLE V - 18

MUNICIPAL DISCHARGE SUMMARY

CAMPBELL WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	1500	830		
1975 USEPA Sampling (February)	1100	380	100	130
1975 USEPA Sampling (July)	1100	1000	110	140
1973 Annual Summary of Operations	1480	750		
1974 Annual Summary of Operations	1800	850		

TABLE V - 19

MUNICIPAL DISCHARGE SUMMARY

STRUTHERS WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application	1350	720		
1975 USEPA Sampling (February)	1460	740	130	250
1975 USEPA Sampling (July)	950	900	120	200
1973 Annual Summary of Operations	1111	776		
1974 Annual Summary of Operations	900	650		

TABLE V - 20

MUNICIPAL DISCHARGE SUMMARY

LOWELLVILLE WASTEWATER TREATMENT PLANT

DISCHARGE LOADING (lbs/day)

	BOD_5	Total Suspended Solids	Total Phosphorus	Ammonia-N
Permit Application				
1975 USEPA Sampling (February)	70	60	10	6
1975 USEPA Sampling (July)	90	110	15	14
1973 Annual Summary of Operations	210	120		
1974 Annual Summary of Operations	250	170		

TABLE V - 21

DATA ON MUNICIPAL WASTEWATER TREATMENT FACILITIES

MAHONING RIVER BASIN

Entity	Receiving Stream	Type Sewer System Type Treatment Facility Design Flow MGD/PE	1970 Population	1974 Performance Data Annual Av. Flow MGD	Raw BOD Raw SS	Final BOD Final SS	Annual % Removal BOD SS
Alliance*	Beech Creek	S+C - Sec. + D 4.7/36,400	26,547	3.060	179 188	39 134	78 82
Beloit*	Tirbutary to Mahoning River	S - Sec. + D 0.1/1,000	921	0.004	186 223	3 17	98 93
Campbell	Mahoning River	S - Prim. + Chem. - D 2.5/25,000	12,577	2.270	162 109	93 45	42 59
Canfield*	Sawmill Creek	S - Sec. + D 0.75/7,500	4,997	0.700	182 177	16 20	91 88
Columbiana	Mill Creek	S - Sec. + D 0.8/8,000	4,959	0.710	101 206	3.9 4.3	96 98
Cortland*	Mosquito Creek	S - Sec. + D 0.22/2,200	2,525	0.270	130 140	47 58	64 58
Garrettsville*	Silver Creek	S - Sec. 0.15/2,000	1,718	0.128	156 62	58 34	63 45
Girard	Little Squaw Creek	S - Prim. + Chem. - D 1.8/18,000	14,119	2.680	157 132	80 46	49 65
Hiram*	Big Hollow Creek	S - Sec. 0.1/1,000	1,484	0.139	217 121	52 37	51 55

TABLE V - 21

DATA ON MUNICIPAL WASTEWATER TREATMENT FACILITIES

MAHONING RIVER BASIN

Entity	Receiving Stream	Type Sewer System Type Treatment Facility Design Flow MGD/PE	1970 Population	1974 Performance Data Annual Av. Flow MGD	Raw BOD Raw SS	Final BOD Final SS	Annual % Removal BOD SS
Lowellville	Mahoning River	S - Prim. - Chem. - D 0.22/2,640	1,836	0.283	221 157	109 71	51 55
McDonald	Tributary to Mahoning River	S - Prim. - Chem. - D 0.61/5,230	3,177	0.605	117 132	49 24	58 82
Newton Falls	Mahoning River	C - Prim. - D 1.0/7,000	5,378	0.719	65 128	38 47	42 63
Niles	Mahoning River	S-C - Prim. - Chem. - D 3.0/27,000	21,581	4.160	177 109	66 54	63 50
Sebring*	Fish Creek	S - Sec. 0.5/4,045	4,954	0.500	144 131	12 13	92 90
Struthers	Mahoning River	S - Prim. - Chem. - D 2.5/31,000	15,343	2.000	97 106	55 39	43 63
Warren	Mahoning River	S-C - Prim. - Chem. - D 13.5/90,000	63,494	12.95	100 160	76 55	24 66
Windham*	Eagle Creek	S - Sec. - D 0.6/6,000	3,360	0.370	226 68	17 11	92 84
Youngstown	Mahoning River	S-C - Prim. - Chem. - D 50/218,000	140,909	29	151 157	71 69	56 53

TABLE V - 21

DATA ON MUNICIPAL WASTEWATER TREATMENT FACILITIES

MAHONING RIVER BASIN

Entity	Receiving Stream	Type Sewer System / Type Treatment Facility / Design Flow MGD/PE	1970 Population	1974 Performance Data: Annual Av. Flow MGD	1974 Performance Data: Raw BOD / Raw SS	1974 Performance Data: Final BOD / Final SS	Annual % Removal BOD / SS
Mahohing County Milton S. D. #11 Craig Beach	Mahoning River	S - Sec. - D 0.32/3,200	650				
Mahoning County * Park S. D. #29 Boardman STP	Mill Creek	S - Sec. - D 5.0/50,000	5,000	1.430	164 164	2.6 15	98 91
Portage County * Atwater Sanitary S. D. #1	Tributary to Deer Creek	S - Sec. - D 0.2/2,000		0.044	127 231	8 6	97 94
Trumbull County * Mineral Ridge S. D.	Meander Creek	S - Sec. 0.2/2,000			136 158	18 18	87 89
Trumbull County * Mosquito Creek S. D.	Mosquito Creek	S - Sec. - D 1.5/15,000		1.973	146 100	15 17	90 83
Trumbull County * Warren-Champion S. D. Subdistrict #1-B Kuszmaul Allotment	Chocolate Run	S - Sec. 0.09/900			201 192	15 16	93 92
Trumbull County * Warren-Champion S. D. Subdistrict #1-D Meadowlane Heights Allotment	Chocolate Run	S - Sec. 0.015/150			192 229	10 13	95 94
Trumbull County * Weathersfield S. D. #1	Tributary of Mahoning River	S - Sec. 0.12/1,200			163 198	19 5	98 88

SOURCES: 1) Reference 25 2) 1974 Annual Summaries of Operations

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20. City of Campbell, NPDES Permit Application - Standard Form A - Municipal, September 1974.

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SECTION VI

WATER QUALITY STANDARDS AND HISTORICAL WATER QUALITY

A. Ohio and Pennsylvania Water Quality Standards

The history of water quality standards development for the Ohio portion of the Mahoning River is long and full of controversy. While a detailed historical review is beyond the scope of this report, the Ohio Environmental Protection Agency has made a summary of major developments from February 1965 to March 1976 from its perspective.[1] The effective standards as of this writing are those originally adopted by Ohio on July 11, 1972[2] and Federally approved on September 29, 1972.[3] These standards were re-adopted by Ohio without change on July 27, 1973 with other statewide standards[4] and again Federally approved on December 18, 1973.[5] Federal exception to a few of the statewide criteria were amended by Ohio on January 8, 1975[6] and Federally approved May 14, 1975.[7]

By these standards,[2] the Mahoning River from Warren to the Lowellville Dam is classified for secondary contact recreation, as a well balanced warm water fishery, for industrial water supply, and for agricultural use and stock watering. The reach from the Lowellville Dam to the Ohio-Pennsylvania State line is also classified for public water supply and for primary contact reaction. At this writing, the Ohio EPA is considering downgrading designated stream uses and water quality criteria for selected Ohio reaches of the Mahoning River from 1977 to 1983.[1] The post 1983 standards would be compatible with existing Pennsylvania water quality standards at the Ohio-Pennsylvania State line.

The current water quality standards for the Pennsylvania portion of the Mahoning River were adopted on September 2, 1971[8] and Federally approved on August 10, 1973.[9] These standards designate the Mahoning River in Pennsylvania for warm water fish; domestic, industrial, livestock, and irrigation water supplies; recreational uses including boating, fishing, water contact sports, natural and conservation areas; and, power (generation) and treated waste assimilation. Pennsylvania is considering minor adjustments to the numerical criteria associated with the warm water fish use designation.

Table VI-1 summarizes existing Ohio Mahoning River water quality standards, Ohio statewide water quality standards, existing Pennsylvania Mahoning River water quality standards, and possible revisions to the Pennsylvania water quality standards under consideration. The criteria association with the possible revisions to the Pennsylvania standards were obtained from recent correspondence between the Ohio Environmental Protection Agency and the Pennsylvania Department of Environmental Resources.[10, 11, 12, 13]

TABLE VI - 1

OHIO AND PENNSYLVANIA WATER QUALITY STANDARDS

LOWER MAHONING RIVER

Water Quality Constituent	Ohio Standards: Mahoning River July 11, 1972	Ohio Standards: General Statewide Standards January 8, 1975	Pennsylvania Standards: Mahoning River September 2, 1971	Pennsylvania Standards: Possible Revisions to Pennsylvania Standards
1) Temperature	Allowable increase over temperature measured at Leavittsburg, Ohio	5°F Allowable increase over natural stream temperatures and maximum values not to be exceeded:	Maximum values not to be exceeded:	Maximum values not to be exceeded:
January	10°F	50°F	50°F	56°F
February	10	50	50	56
March	10	60	60	62
April	5	70	70	71
May	5	80	80	80
June	5	90	90	90
July	5	90	90	90
August	5	90	90	90
September	5	90	90	90
October	5	78	78	78
November	5	70	70	69
December	10	57	57	58
2) Dissolved Oxygen	Minimum daily average 5.0 mg/l Minimum at any time 4.0 mg/l	Minimum daily average 5.0 mg/l Minimum at any time 4.0 mg/l	Minimum daily average 5.0 mg/l No value less than 4.0 mg/l	
3) pH	No values below 6.0 su No values above 8.5 su Daily fluctuations which exceed the range of pH 6.0 to pH 8.5 and are correlated with synthetic activity may be tolerated	No values below 6.0 su No values above 9.0 su pH may be less than 6.0 or more than 9.0 if there is no contribution of acidic or alkaline pollution attributable to human activities	Not less than 6.0 su Not more than 8.5 su	
4) Ammonia-N	See "Toxic Substances" (17) (0.02 mg/l unionized Ammonia-N)	Maximum at any time 1.5 mg/l	See "Toxic Substances" (17) (0.02 mg/l unionized Ammonia-N)	
5) Total Cyanide	See "Toxic Substances" (17)	Maximum at any time 200 µg/l	Not more than 25 µg/l	
6) Free Cyanide	-	Maximum at any time 5 µg/l	-	

TABLE VI - 1
(continued)
OHIO AND PENNSYLVANIA WATER QUALITY STANDARDS

LOWER MAHONING RIVER

Water Quality Constituent	Ohio Standards: Mahoning River July 11, 1972	Ohio Standards: General Statewide Standards January 8, 1975	Pennsylvania Standards: Mahoning River September 2, 1971	Pennsylvania Standards: Possible Revisions to Pennsylvania Standards
7) Phenolics	See "Toxic Substances" (17)	Maximum at any time 10 µg/l	Not more than 5 µg/l	Not more than 10 µg/l
8) Oil and Grease	See "General Criteria" (18)	5.0 mg/l (hexane soluble)	See "General Criteria" (18)	
9) Dissolved Solids, mg/l	Maximum monthly average 500 mg/l Maximum at any time 750 mg/l	Dissolved solids may exceed one, but not both of the following: a) 1500 mg/l b) 150 mg/l attributable to human activities	Maximum monthly average 500 mg/l Maximum at any time 750 mg/l	
10) Total Iron	-	-	Not more than 1.5 mg/l	
11) Dissolved Iron	-	Maximum at any time 1.0 mg/l	-	
12) Fluoride	-	Maximum at any time 1.0 mg/l	Not more than 1.0 mg/l	Not more than 2.0 mg/l
13) Threshold Odor Number	Daily average of 24 at 60°C	The threshold odor number attributable to human activities shall not exceed 24 at 40°C	Not more than 24 at 60°C	Not more than 24 at 40°C
14) Total Copper	See "Toxic Substances" (17)	Maximum values at any time: Total Copper (µg/l) — Hardness (mg/lCaCO$_3$) 5 — 0-80 10 — 80-160 20 — 160-240 50 — 240-320 75 — > 320	See "Toxic Substances" (17)	

TABLE VI - 1
(continued)
OHIO AND PENNSYLVANIA WATER QUALITY STANDARDS

LOWER MAHONING RIVER

Water Quality Constituent	Ohio Standards: Mahoning River July 11, 1972	Ohio Standards: General Statewide Standards January 8, 1975	Pennsylvania Standards: Mahoning River September 2, 1971	Pennsylvania Standards: Possible Revisions to Pennsylvania Standards
15) Total Zinc	See "Toxic Substances" (17)	Maximum values at any time: Total Zinc (μg/l) — Hardness ($mg/l CaCO_3$) 75 — 0-80 100 — 80-160 200 — 160-240 400 — 240-320 500 — > 320	See "Toxic Substances" (17)	
16) Bacteria	Primary Contact - (Swimming and Water-Skiing) Bacteria: The fecal coliform content (either MPN or MF count) not to exceed 200 per 100 ML as a monthly geometric mean based on not less than five samples per month; nor exceed 400 per 100 ML in more than ten percent of all samples taken during a month Secondary Contact - (Boating, Fishing and Wading) Bacteria: The fecal coliform content (either MPN or MF count) not to exceed 1,000 per 100 ML as a monthly geometric mean based on not less than five samples per month; nor exceed 2,000 per 100 ML in more than ten percent of all samples taken during a month	1. Geometric mean fecal coliform content (either MPN or MF count), based on not less than five samples within a 30-day period, shall not exceed 200 per 100 ml 2. Fecal coliform content (either MPN or MF count) shall not exceed 400 per/100 ml in more than ten percent of the samples taken during any 30-day period	The fecal coliform density in five consecutive samples shall not exceed a geometric mean of 200 per 100 ml	

TABLE VI - 1
(continued)
OHIO AND PENNSYLVANIA WATER QUALITY STANDARDS

LOWER MAHONING RIVER

Water Quality Constituent	Ohio Standards: Mahoning River July 11, 1972	Ohio Standards: General Statewide Standards January 8, 1975	Pennsylvania Standards: Mahoning River September 2, 1971	Pennsylvania Standards: Possible Revisions to Pennsylvania Standards
17) Toxic Substances	Toxic Substances: Not to exceed one-tenth of the 96-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agency.	All pollutants or combinations of pollutants shall not exceed at any time one-tenth of the 96-hour median tolerance limit for any indigenous aquatic species, except that other more stringent application factors shall be imposed where necessary to meet the minimum requirements of the National Technical Advisory Committee, "Water Quality Criteria," 1968.	The list of specific water quality criteria does not include all possible substances that could cause pollution. For substances not listed, the general criterion that these substances shall not be inimical or injurious to the designated water uses applies. The best scientific information available will be used to adjudge the suitability of a given waste discharge where these substances are involved.	
18) General Criteria	Minimum Conditions Applicable to all Waters at all Places and at all Times 1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits. 2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.	All waters of the state shall be free from substances attributable to human activities which result in sludge deposits, floating materials, color, turbidity, or other conditions in such degree as to create a nuisance.	General Water Quality Criteria: a) Water shall not contain substances attributable to municipal, industrial or other waste discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. b) Specific substances to be controlled shall include, but shall not be limited to, floating debris, oil, scum and other floating materials, toxic substances and substances which produce color, tastes, odors, turbidity or settle to form sludge deposits.	

TABLE VI - 1
(continued)
OHIO AND PENNSYLVANIA WATER QUALITY STANDARDS

LOWER MAHONING RIVER

Water Quality Constituent	Ohio Standards: Mahoning River July 11, 1972	Ohio Standards: General Statewide Standards January 8, 1975	Pennsylvania Standards: Mahoning River September 2, 1971	Pennsylvania Standards: Possible Revisions to Pennsylvania Standards
18) General Criteria	3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance. 4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.			

B. Historical Water Quality

Prior to the industrialization and urbanization of the Mahoning River Valley in Ohio, the Mahoning River supported a diverse fish population including Ohio muskellunge, redfin pickerel, smallmouth bass, largemouth bass, yellow perch, and walleye among, others.[14] Many of the migratory species were eliminated from the stream during the first half of the nineteeneth century with the construction of channel dams.[14] Virtually all species of fish were eliminated from the main stem of the lower Mahoning River during the early twentieth century by untreated municipal and industrial wastes from a growing steel producing center.[14] While there are probably no water quality data available for the pre-industrialized Mahoning River, references to the polluted state of the stream prior to World War II and numerous data from the early 1950's to the present are available. Following is an excerpt from a 1936 report concerning the then current state of the river:[15]

> "Nine communites with a 1936 population of 276,000 discharge into the stream up to 40 million gallons a day of untreated domestic sewage. Industrial wastes from many plants are also discharged without treatment directly into the Mahoning. Sewage odors in Youngstown and elsewhere are often extremely objectionable. In the mills almost crude sewage is used at times for cooling rolls, blast furnace operations, condensation, boiler feedwater, etc. and sewage odors become very offensive. During periods of low flow the river water is black and boils with putrefication. Sewage wastes clog industrial equipment."

While conditions described above no longer exist, the Mahoning River remains as one of the most polluted streams in the nation by present day standards. Municipal sewage treatment plants for the eight communities described in Section V were not installed until the late 1950's and early 1960's. The City of Youngstown did not begin operations at its plant until 1965. Prior to that time, raw sewage was discharged directly to the stream. As noted earlier, all of these facilities currently provide only primary sewage treatment. With few notable exceptions, the existing level of treatment at the steel plants remains characteristic of that found throughout the industry during the early 1950's, i.e., direct discharge of coke plant wastes or disposal through coke quenching; rudimentary solids removal for blast furnace gas wash water; scale pits with and without oil skimming for hot forming wastes; no treatment for emulsified cold rolling oils; direct discharge of spent pickling acids and rinse waters; and, no treatment for coatings wastes. The notable exceptions being the partial recirculation system for blast furnace wastes at the Youngstown Sheet and Tube Company-Campbell Works installed during the late 1960's; the recirculation system installed at the Republic Steel-Warren Plant strip mill during the early 1960's when that mill was modernized; and, the new cold rolling mill and pickle rinse water treatment system installed by Youngstown Sheet and Tube at its Campbell Works in late 1976. Two other notable improvements in steel plant waste disposal practices occurred during the past twenty years: direct discharges of spent pickling acids were generally eliminated in the mid 1960's when off-site disposal methods were adopted; and, most steel plant sanitary wastes were diverted to municipal sewerage systems as sewage treatment plants were planned and constructed, although a few direct discharges of raw sewage from the mills remain. Against this background, a brief review of water quality during the post World War II period is presented.

1. Temperature

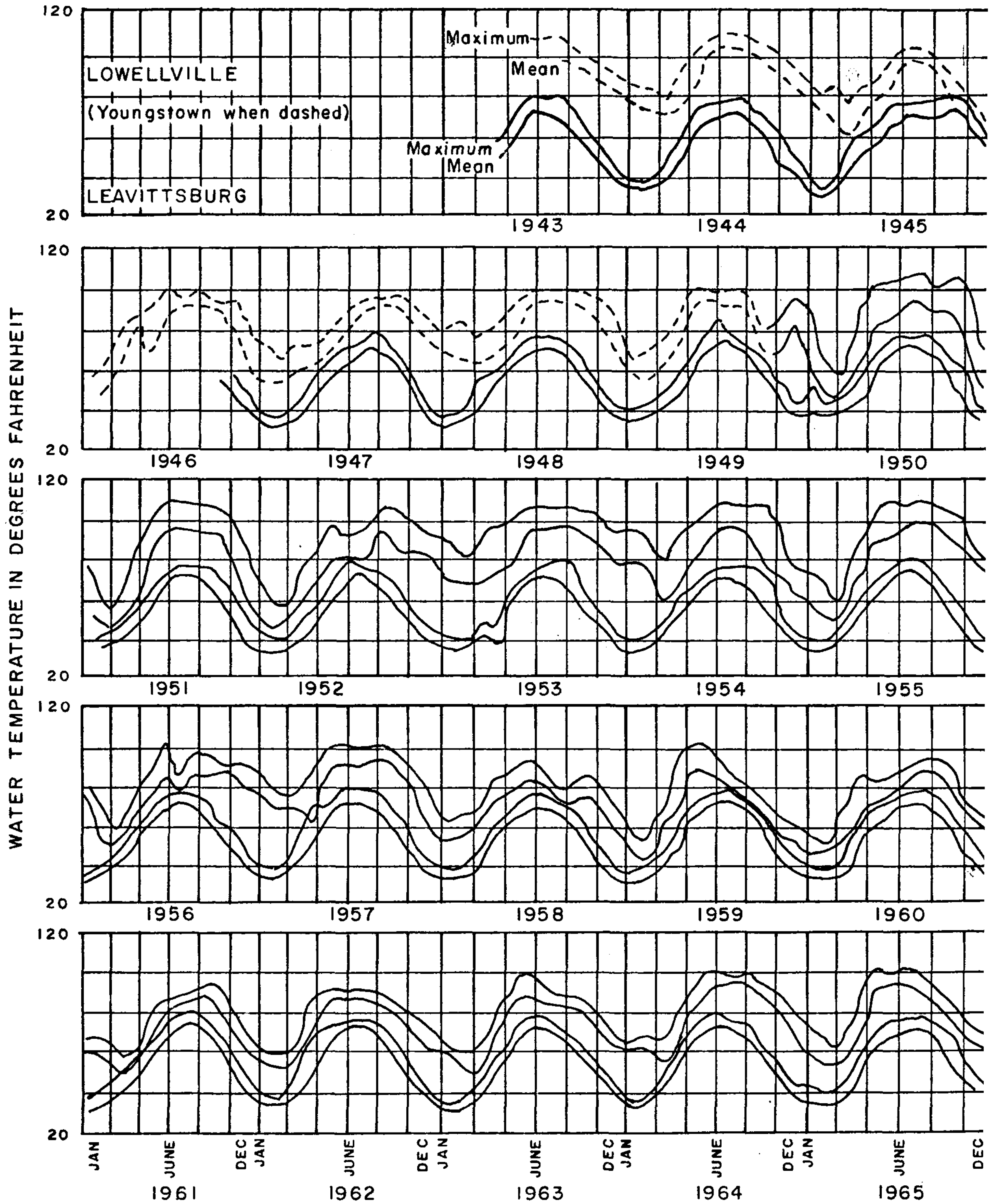
Large increases in water temperature over natural levels accelerate oxygen depletion, adversely affect fish and other aquatic life, and may intensify toxic effects of other waste constituents.

The water temperature of the Mahoning River above Leavittsburg, Ohio is governed largely by air temperatures and by releases from upstream reservoirs. Aside from seasonal variations, the water temperature downstream of Leavittsburg is controlled primarily by thermal loadings from the steel industry and the Ohio Edison-Niles Plant. The monthly maximum and mean water temperatures of the Mahoning River from 1943 through 1965 at Leavittsburg and Lowellville are illustrated in Figure VI-1.[16] These continuous thermographs illustrate excessive temperatures in terms of aquatic life uses generally prevailed during the summer months throughout the entire period of record. Monthly maximum and mean river temperatures frequently exceeded 100°F and 90°F, respectively, at Lowellville. Figure VI-2 illustrates the water temperature of the Mahoning River between 1966

FIGURE VI-1

MAHONING RIVER BASIN

MONTHLY MAXIMUM AND MEAN WATER TEMPERATURES OF THE MAHONING RIVER

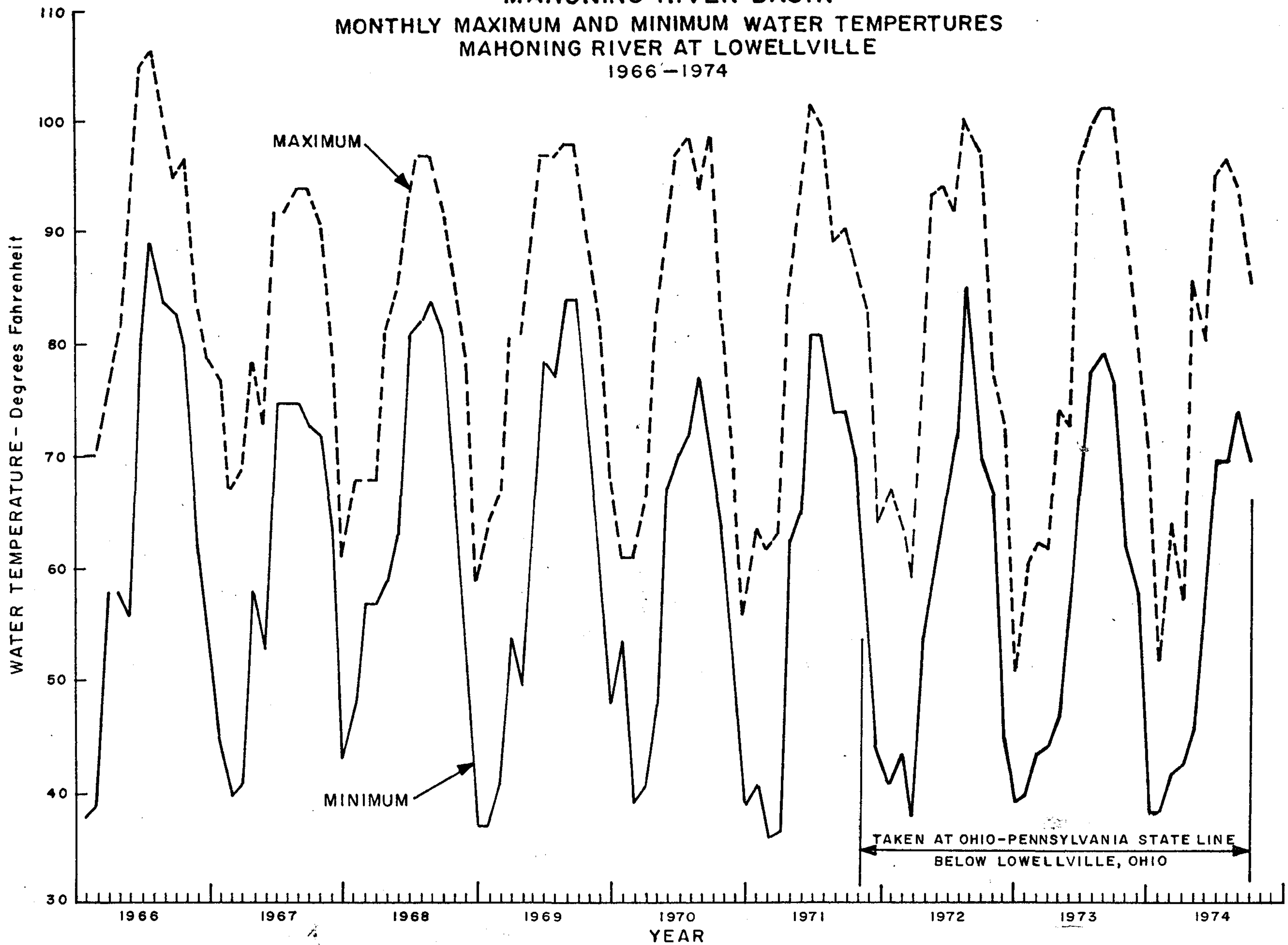


Source: Geological Survey Water-Suppy Paper 1859C

FIGURE VI-2

MAHONING RIVER BASIN

MONTHLY MAXIMUM AND MINIMUM WATER TEMPERTURES
MAHONING RIVER AT LOWELLVILLE
1966–1974



and 1974. These thermographs reveal that temperature conditions remained essentially unchanged from those observed between 1943-1965. During this entire period, these data indicate that existing Ohio and Pennsylvania water quality standards were routinely exceeded.

More recent data (Appendix B), which was obtained by the USEPA during July 1976, show some reduction of water temperatures, however, the July data were obtained during a period of very low steel production. Even under these conditions, temperature increases from Leavittsburg to Lowellville resulted in violation of the existing Mahoning River standards adopted in 1972 (maximum allowable ΔT of $5^{o}F$).[2]

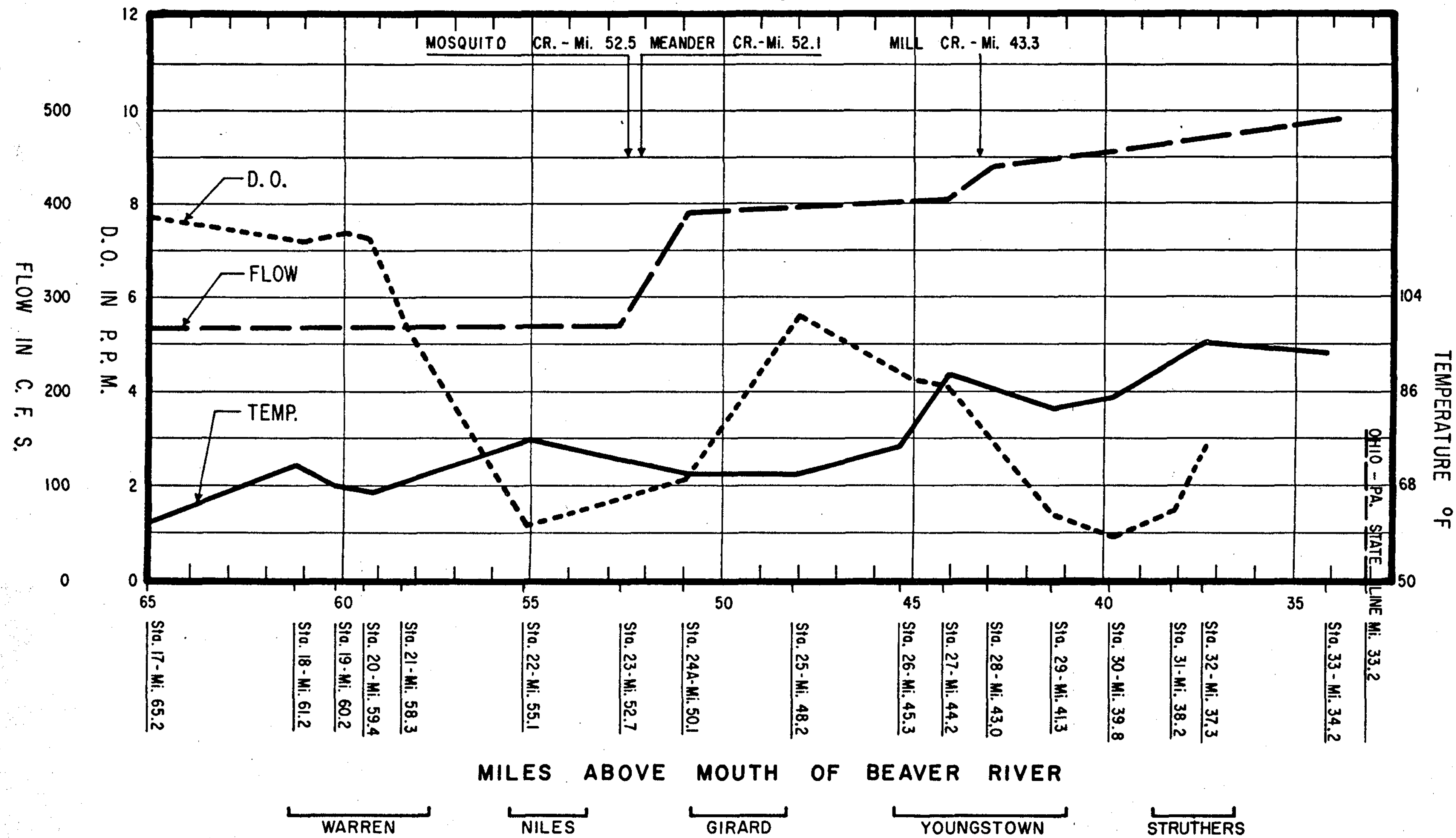
2. Dissolved Oxygen

Dissolved oxygen is required for the respiration of all aerobic life forms. Reduced dissolved oxygen concentrations disrupt the natural biological balance within a stream and result in increased toxicity of many toxic substances. A well balanced aquatic biota requires minimum dissolved oxygen concentrations above four or five mg/l.[17]

Dissolved oxygen concentrations found at Leavittsburg are generally sufficient for all designated stream uses. Downstream from Warren to Lowellville, however, the discharge of oxygen consuming materials including organic and nitrogenous matter along with thermal discharges, reduce the river's capacity to maintain natural dissolved oxygen levels. The majority of the oxygen demanding material is discharged by the municipalities of Warren and Youngstown. Loadings from industry, largely from the three by-product coke plants, blast furnaces, and finishing operations also contribute to the oxygen demand on the river.

Typical dissolved oxygen profiles are illustrated in Figures VI-3 and VI-4.[18, 19] The data presented for the summer months of 1952, 1963, 1964, 1969, 1970 and 1971 demonstrate the profile has not significantly changed during this period. As expected, the heavy concentration of oxygen demanding wastes discharged downstream of Warren resulted in almost complete depletion of oxygen at several locations. Installation of primary sewage treatment plants on the main stem of the Mahoning River during the late 1950's and early 1960's has not significantly improved dissolved oxygen levels in the stream. This is due to an increase in municipal influent loads

FIGURE VI-3



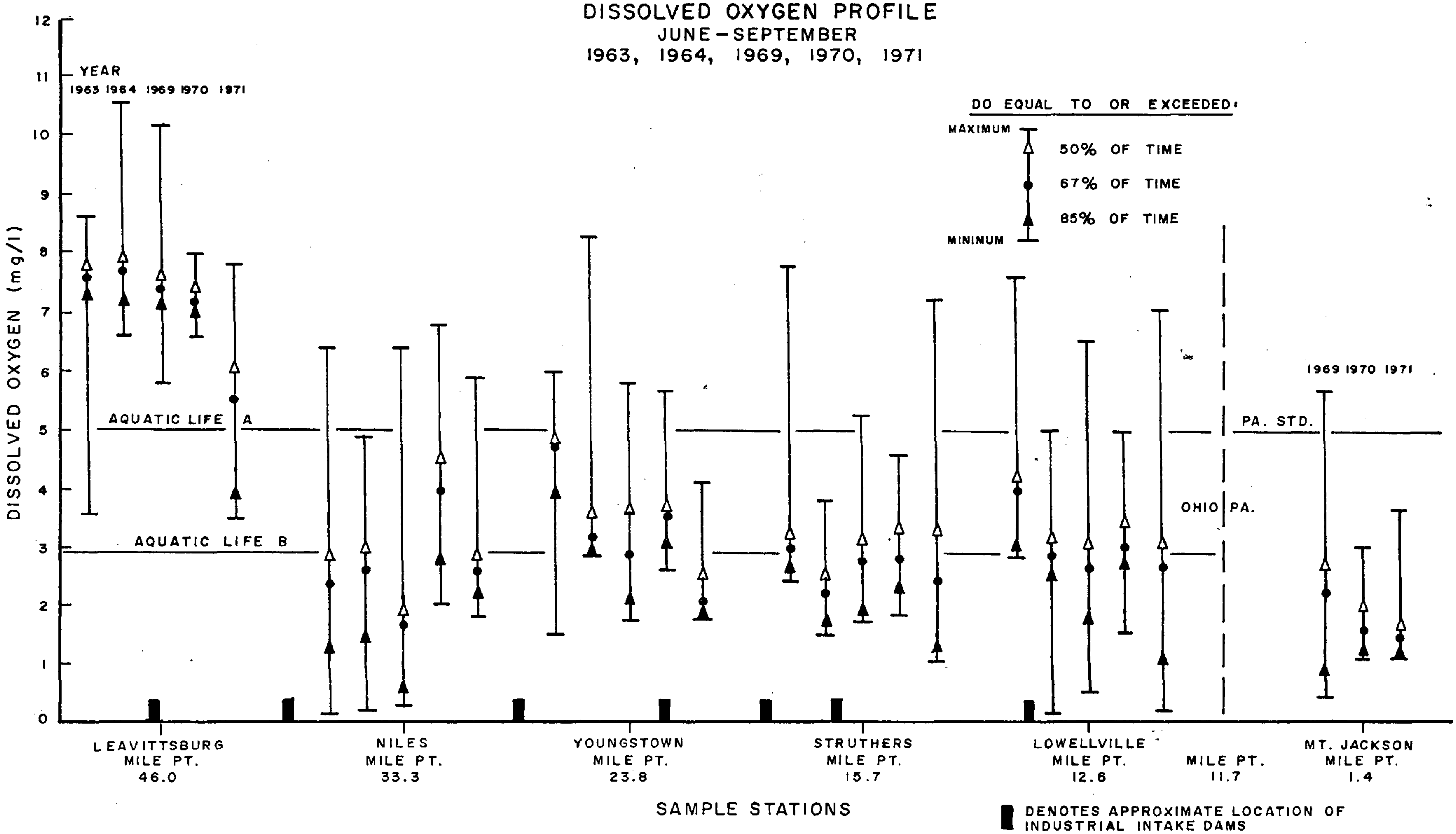
MAHONING RIVER STREAM SURVEY DATA SEPTEMBER 24, 1952

TYPICAL PROFILES OF DISSOLVED OXYGEN, TEMPERATURE,
AND FLOW DURING PERIOD OF FULL INDUSTRIAL PRODUCTION
1954 OHIO DEPARTMENT OF HEALTH SURVEY

FIGURE VI-4

MAHONING RIVER

DISSOLVED OXYGEN PROFILE
JUNE – SEPTEMBER
1963, 1964, 1969, 1970, 1971



since 1950, lack of control for soluble organic and nitrogenous matter, and lack of control for industrial discharges.

The present dissolved oxygen standards for the Mahoning River in Ohio are not less than 5.0 mg/l as a daily average value, nor less than 4.0 mg/l at any time.[2] As shown in Figure VI-4, dissolved oxygen levels in the Mahoning River have consistently violated these standards and were less than 4.0 mg/l fifty percent of the time at Lowellville during 1964, 1969, 1970 and 1971. Dissolved oxygen levels at Mt. Jackson, more than ten miles into Pennsylvania, violated the Pennsylvania standard of 5.0 mg/l from 1969 through 1971 and never exceeded 3.6 mg/l during the summer months of 1970 and 1971.

3. pH

Extreme pH values interfere with domestic and industrial water uses and adversely affect fish and other aquatic life. Changes in pH also affect toxicity of certain pollutants, notably ammonia-N and cyanide.[17]

In the past, low pH values observed in the lower Mahoning River were the result of uncontrolled discharges of spent pickle acid solutions by steel mills in the Warren-Lowellville section of the basin. The Ohio River Valley Water Sanitation Commission (ORSANCO) estimated in 1959 that approximately 400,000 pounds per day of acid (as equivalent $CaCO_3$) were discharged by the steel mills.[20] Table VI-2 is a listing of pH data for the Mahoning River compiled from 1959 through 1973. These data illustrate that extreme values of pH were recorded through 1967. Major improvements occurred in the disposal methods of pickling acids between 1968 and 1971 which resulted in a significant reduction in the amount of acid discharged to the stream. For water year 1973, the pH at the USGS Lowellville monitoring station never was less than 6.0 and on only 15 days was it less than 6.5. The maximum pH recorded was 8.2. Although rinse waters from pickling operations at Republic Steel, U. S. Steel, and Youngstown Sheet and Tube are still discharged with no treatment, the pH of the Mahoning River has generally achieved current Ohio and Pennsylvania water quality standards since 1968 (pH 6.0 to 8.5).

TABLE VI-2

MAHONING RIVER WATER QUALITY DATA

pH

	(1) Oct 1957 to Sept 1958		(1) Oct 1958 to Sept 1959		(1) Oct 1959 to Sept 1960		(2) Jan 1963 to Dec 1963		(3) Oct 1963 to Sept 1964			(2) Jan 1964 to Dec 1964		(2) Jan 1965 to Dec 1965		(3) Oct 1965 to Sept 1966			(3) Oct 1966 to Sept 1967			(3) Oct 1972 to Sept 1973		
Location	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Days <6.0/<6.5	Min	Max	Min	Max	Min	Max	Days <6.0/<6.5	Min	Max	Days <6.0/<6.5	Min	Max	Days <6.0/<6.
Leavittsburg							6.6	8.9				6.9	8.6	6.6	8.3									
Warren																								
Niles							5.3	8.9				3.5	7.3	5.4	7.7									
Youngstown							4.6	7.3				3.9	8.1	4.6	8.2									
Struthers							5.8	7.6				6.2	8.3	6.5	8.1									
Lowellville	6.1	7.0	5.3	7.3	6.6	7.2	6.1	8.0	3.8	8.5	63/149	4.4	9.0	6.3	8.5	4.0	8.1	33/81	3.0	9.5	63/107	6.0	8.2	0/15

(1) U. S. Geological Survey, Water Supply Papers, Numbers 1571, 1672, 1742.

(2) Ohio Department of Health, Stream Surveillance Report, 1963, 1964, 1965.

(3) U. S. Geological Survey, Water Resources Data for Ohio, Part 2; Water Quality Records 1964, 1966, 1967, and 1973.

4. Ammonia-N

Excessive ammonia-N concentrations contribute to several water quality problems including toxicity to fish, deoxygenation, and stream eutrophication. High levels of ammonia during the warmer months depresses the dissolved oxygen substantially below the level accounted for by the residual carbonaceous BOD. The chlorine demand of raw water for potable supplies is increased significantly by the presence of ammonia-N.

Ammonia-N in the Mahoning River is derived mostly from coke plant and blast furnace discharges and from municipal sewage. Other sources include hot dip galvanizing rinse waters and wash waters from the General Electric - Niles Plant glass bulb frosting operation. Ammonia-N data for the Mahoning River are presented in Table VI-3. As shown, the general Ohio water quality standard of 1.5 mg/l has been exceeded at Lowellville since at least 1958. As clean water rarely exceeds a few tenths of a mg/l,[21] these concentrations are indicative of gross contamination. More recent data (1971 and 1975) presented in Table VI-3, appear to show some improvement at Lowellville over previous years. Since there have been no major treatment facilities installed which would account for reduced ammonia concentrations, the improvements noted by the recent data are attributed to mitigating factors including the levels of steel production and stream flow occuring at the time of stream sampling.

5. Cyanide

Cyanide is known to be toxic to fish at relatively low concentrations. The toxicity, however, varies widely with changes in pH, temperature and dissolved oxygen.[22] Concentrations of total cyanide found in the Mahoning River result from discharges from coke plants, blast furnaces, and to a lesser extent from plating operations.

Table VI-4 presents total cyanide data for the Mahoning River measured from 1952 to 1975. These data reveal that total cyanide levels have exceeded the current Pennsylvania water quality standard[8] of 25 ug/l by wide margins since 1952. The average total cyanide concentration measured at Lowellville between November 1952 and September 1953 was 250 ug/l. In February 1975, the USEPA found an average total cyanide concentration in the river at Lowellville of 205 ug/l; the average

TABLE VI-3

MAHONING RIVER WATER QUALITY DATA

Ammonia-N, mg/l

Period of Record

Location	(1) Oct 1957-Sept 1958 Min Max Avg	(1) Oct 1958-Sept 1959 Min Max Avg	(1) Oct 1959-Sept 1960 Min Max Avg	(2) Oct 1967 Min Max Avg	(3) Oct 1970-Sept 1971 Min Max Avg	(4) Feb 1975 Min Max Avg	(5) July 1975 Min Max Avg
Below Alliance				3.28			
Below Berlin Reservoir				0.08 0.33			
Below Lake Milton				0.02 0.06			
Leavittsburg				0.01 0.71	1.2 2.6 1.7	0.15 0.18 0.17	0.03 0.12 0.06
Niles					1.2 2.8 1.8	0.66 1.02 0.85	0.40 0.79 0.66
Below Niles				3.46 4.15			
Youngstown					1.1 0.4 1.8	1.06 1.24 1.11	0.62 1.21 0.96
Struthers					1.1 3.0 2.1	2.24 2.27 2.26	1.75 2.54 2.10
Lowellville	0.0 12.0 3.5	0.0 7.8 3.5	0.2 7.4 3.3	8.64 10.02	0.8 3.7 1.9	2.37 2.40 2.38	1.50 2.37 1.90
Mt. Jackson					0.8 3.7 1.8		
Route 224						2.32 3.24 2.66	1.24 1.86 1.57

(1) U. S. Geological Survey, Water Supply Papers, Numbers 1571, 1672, 1742.

(2) Ohio Department of Health, A Report on Recommended Water Quality Standards for Interstate Waters, Mahoning River, Pymatuning, Yankee, and Little Beaver Creeks, Ohio-Pennsylvania, May 1970.

(3) USEPA, Region V, Ohio District Office, Mahoning River Enforcement Report, March 1972.

(4) USEPA, Mahoning River Survey, February 11-14, 1975.

(5) USEPA, Mahoning River Survey, July 14-17, 1975.

TABLE VI-4

MAHONING RIVER WATER QUALITY DATA

Total Cyanide, mg/l

Location	(1) Nov 1952-Sept 1953		(2) Aug 1965-July 1976			(3) 1969			(4) Oct 1971-Sept 1972			(5) Feb 1975			(6) July 1975		
	Range	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Leavittsburg												.00	.007	.006	<.005	.007	.002
Warren															<.005	<.005	<.005
Niles												.014	.028	.023	.029	.059	.040
Girard Dam						.05	.13										
Youngstown, Penn. RR						.05	.13					.184	.200	.131	.028	.088	.052
Struthers												.198	.274	.226	.066	.153	.099
Lowellville	0-1.0	.25				.05	.12					.188	.224	.205	.063	.098	.076
Ohio-Penn State Line									.00	.120	.046						
Route 224 Bridge-Edinburg			.00	.240	.047												
New Castle												.107	.190	.183	.021	.035	.026

(1) Public Health Service, U. S. Department of HEW, Report on Quality of Interstate Waters, Mahoning River, Ohio-Pennsylvania, January 1965.

(2) USEPA, data processing network, STORET, August 1965 to July 1976.

(3) Ohio Department of Health, A Report on Recommended Water Quality Standards for the Interstate Waters, Mahoning River, Pymatuning, Yankee and Little Beaver Creek, Ohio-Pennsylvania, May 1970.

(4) U. S. Geological Survey, Water Resources Data for Ohio, Part 2, Water Quality Records, 1972.

(5) USEPA, Mahoning River Survey, February 11-14, 1975.

(6) USEPA, Mahoning River Survey, July 14-17, 1975.

concentration measured at Edinburg, Pennsylvania was 183 ug/l, over seven times the Pennsylvania standard, indicating virtually no improvement in total cyanide concentrations in the Mahoning River since 1952.

6. Phenolics

High levels of phenolics cause disagreeable tastes and odors in drinking water, taint the flavor of fish flesh, and are directly toxic to fish at high concentrations. If phenolics are present in raw water supplies in sufficient concentrations to cause taste and odors, expensive water treatment procedures may be required to minimize the problems. For this reason, the National Academy of Sciences - National Academy of Engineering committee on water quality criteria recommends no more than one ug/l of phenolic compounds in streams being utilized for public water supply.[22] The Mahoning River below Leavittsburg is not used for public water supply, however, phenolics that originate from the coke plants and blast furnaces in the industrial Warren-Youngstown area, contribute to taste and odor problems in Pennsylvania water supplies on the Beaver River.[20, 23]

Table VI-5 presents the average and extreme phenolics concentration in the Mahoning River from 1952 to February of 1975. The levels of phenolics measured at Lowellville have remained relatively constant during this period, illustrating a continuing discharge of excessive amounts of phenolics since 1952. Phenolics concentrations measured in Pennsylvania are much higher than the levels recommended for public water supplies and are also much greater than the Pennsylvania water quality standard of 5 ug/l.[8] Average concentrations found during the USEPA February 1975 survey were 82 ug/l at Edinburg and 70 ug/l at New Castle, Pennsylvania.

7. Oil And Grease

There are no quantitative data for instream levels of oil and grease for the Mahoning River. However, as noted in Section V, as much as 200 barrels of oil per day have been discharged to the stream based upon industrial discharge data; and, as noted in Section VII, oil concentrations in Mahoning River sediments are measured in terms of percents. McKee and Wolf[21] indicate oils in waters used for domestic water supplies may have the following potential deleterious effects: hazards to the health of consumers;

TABLE VI-5

MAHONING RIVER WATER QUALITY DATA

Phenolics, μg/l

Period of Record

Location	(1) 1952 to 1954	(2) 1957 to 1958			(2) 1958 to 1959			(1) 1959 to 1961			(3) 1963			(3) 1964			(4) 1969			(5) 1970 to 1971			(6) 1975		
	Range	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Pricetown											14	0	4.5	7.1	0	.13									
Leavittsburg											111	0	7.4	7.1	0	0.4				70	0	30	33	12	16
Niles											1561	2	232	1656	5	162				275	0	55	62	33	43
Youngstown											166	0	28	366	0	41	81	61		165	0	55	130	110	120
Struthers											571	7	136	557	14	139				295	10	45	200	120	193
Lowellville	5-44	348	8	65	524	5	109				240	3	45	540	5	63	36	8		185	0	45	140	130	137
Mt. Jackson																				225	0	35			
Edinburg																							100	72	82
New Castle																							100	48	70
Mouth								100	0	15															
Beaver Falls								300	0	28															

(1) Public Health Service, U. S. Department of HEW, Report of Interstate Waters, Mahoning River, Ohio-Pennsylvania, January 1965.

(2) U. S. Geological Survey, Water Supply Papers Numbers 1271, 1672, 1742.

(3) U. S. Geological Survey, Water Resources Data for Ohio, Part 2, Water Quality Records, 1963 and 1964.

(4) Ohio Department of Health, A Report on Recommended Water Quality Standards for the Interstate Waters, Mahoning River, Pymatuning, Yankee and Little Beaver Creek, Ohio-Pennsylvania, May 1970.

(5) USEPA, Region V, Ohio District Office, Mahoning River Enforcement Report, March 1972.

(6) USEPA, Mahoning River Survey, February 11-14, 1975.

production of tastes and odors; presence of turbidity, films, or irridescence; and, increased difficulty of water treatment. Adverse effects upon aquatic life include interference with fish respiration; destruction of algae and other plankton; destruction of benthal organisms and interference in spawning areas; fish flesh tainting; deoxygenation; interference with photosynthesis and reaeration; and, direct toxic action.

Oil sheens are always found on the Ohio portion of the lower Mahoning River, and during periods of peak steel production, heavy oil slicks covering the entire stream surface can be found in the Campbell-Struthers area as well as in some upstream locations.

8. Heavy Metals

Heavy metals individually or in combination may be toxic to aquatic organisms and thus can have an adverse impact on the aquatic environment.[17] Iron has been found to be objectionable in public water supplies because of its effect on taste, staining of plumbing fixtures and laundered clothes and accumulation of deposits in distribution systems.[22] Table VI-6 presents available heavy metals data for the Mahoning River. With the exceptions of iron, zinc and copper, existing levels of heavy metals do not appear to present significant water quality problems.

During the period 1963-1965, iron concentrations at Leavittsburg were less than 1.5 mg/l for 90 percent of the time.[16] From Niles downstream to Lowellville, the iron concentrations increased markedly and concentrations in excess of 50 mg/l were measured frequently.[16] There has been some reduction in total iron levels since 1965 (primarily the result of pickle liquor from steel mills being hauled off-site for neutralization), however, total iron remains in excess of the maximum Pennsylvania water quality standard of 1.5 mg/l.[8]

Data for zinc and copper are too limited to exhibit any significant water quality trends, however, levels exceeding general Ohio water quality standards from Leavittsburg to the State line during April, July and October of 1969 and February of 1975 were common. Zinc is primarily discharged by plating operations, blast furnaces, and municipal sewage treatment plants. Copper is also found in plating wastes and occasionally in blast furnace discharges.

TABLE VI-6

MAHONING RIVER WATER QUALITY DATA

Heavy Metals, mg/l

Ohio Stations

April, July, Oct 1969(1)

Parameter	Youngstown Min	Youngstown Max	Youngstown Avg	Lowellville Min	Lowellville Max	Lowellville Avg
Chromium		0.02			0.02	
Copper	0.02	0.04		0.02	0.05	
Total Iron	3.0	10.2		4.8	13.0	
Soluble Iron	0.21	0.25		0.16	0.38	
Lead		0.02			0.02	
Manganese	0.15	0.50		0.22	0.61	
Zinc	0.09	0.19		0.11	0.19	

(1) Ohio Department of Health, A Report on Recommended Water Quality Standards for the Interstate Waters, Mahoning River, Pymatuning, Yankee and Little Beaver Creek, Ohio-Pennsylvania, May 1970.

TABLE VI-6

Continued

MAHONING RIVER WATER QUALITY DATA

Heavy Metals, mg/l

Pennsylvania Stations

Parameter	Route 224 Min	Route 224 Max	Route 224 Avg	Mahoning River Mt. Jackson Min	Mahoning River Mt. Jackson Max	Mahoning River Mt. Jackson Avg	Beaver River Beaver Falls Min	Beaver River Beaver Falls Max	Beaver River Beaver Falls Avg
10/70-9/71(3)									
Total Iron				0	2.7	1.1			
Ferrous Iron				0	2.7	0.2			
8/71(3)									
Arsenic, ppb			<6.0			<6.0			<6.0
Cadmium			<0.01			<0.01			<0.01
Chromium			<0.03			<0.03			<0.03
Lead			<0.1			<0.1			<0.1
Mercury			<0.1			<0.1			<0.1
Nickel			<0.1			<0.1			<0.1
2/75(4)									
Cadmium			<0.008						
Chromium	0.03	0.065	0.045						
Copper	.025	0.1	0.055						
Total Iron	2.8	4.1	3.5						
Lead			<0.05						
Zinc	0.26	0.37	0.32						

(3) USEPA, Region V, Ohio District Office, Mahoning River Enforcement Report, March 1972.

(4) USEPA, Mahoning River Survey, February 11-14, 1975.

TABLE VI-6
Continued

MAHONING RIVER WATER QUALITY DATA

Heavy Metals, mg/l

Ohio Stations

Parameter	Pricetown			Leavittsburg			Niles			Youngstown			Struthers			Lowellville		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1/63-12/65[2]																		
Total Iron		2.0		5.0			160	12		60	5.5		91	8.6		107	6.6	
10/70-9/71[3]																		
Total Iron				0.1	1.7	0.4	0.5	11.9	3.8	0.5	14.3	3.5	0.5	14.8	5.7	0.2	8.8	2.2
Ferrous Iron				0	0.2	<0.1	0	3.3	1.0	0	4.3	1.0	0	2.4	1.0	0	1.4	0.5
8/71[3]																		
Arsenic, ppb			<6.0			<6.0			<6.0			<6.0			<6.0			<6.0
Cadmium			<01			<01			<01			<01			<01			<01
Chromium			<03			<03			<03			<03			<03			<03
Lead			< .1			< .1			< .1			< .1			< .1			< .1
Mercury			< .1			< .1			< .1			< .1			< .1			< .1
Nickel			< .1			< .1			< .1			< .1			< .1			< .1
2/75[4]																		
Cadmium						<008			<008			<008			<008			<008
Chromium				<020	.025			.17		<02	.02	.011	.04	.05	.45	.03	.04	.035
Copper				<010	.075	.031	<02	.45	.16	.01	.06	.04	.02	1.08	.06	.03	.04	.035
Total Iron				.40	.590	.520	.31	7.9	4.1	2.1	2.7	2.4	3.3	5.3	4.6	3.0	3.2	3.1
Lead						<050			<05			<05			<05			<05
Zinc				<020	.05	.035	.08	.16	.12	.12	.29	.20	.26	.40	.32	.30	.36	.33

(2) U. S. Geological Survey, Water Supply Papers Number 1859C.

(3) USEPA, Region V, Ohio District Office, Mahoning River Enforcement Report, March 1972.

(4) USEPA, Mahoning River Survey, February 11-14, 1975.

9. Bacterial Conditions

High total coliform densities, especially when accompanied by high fecal coliform concentrations, indicate the presence of human or animal wastes which may contain pathogenic organisms capable of causing enteric diseases in humans.[22] The presence of these organisms above acceptable levels in streams pose potential health problems to those exposed to the water. Major bacterial sources in the Mahoning River are sewage treatment plant discharges, combined sewer overflows, and storm water runoff.

Total and fecal coliform data for the Mahoning River collected between 1939 and 1971 are contained in Table VI-7. These data are at levels indicative of gross contamination throughout the period of record. The construction of primary sewage treatment plants with chlorination during the late 1950's and early 1960's seems to have done little to improve the coliform densities found in the lower Mahoning and Beaver Rivers.[18, 24] Gross contamination continues as a result of combined sewer discharges, storm water runoff, and inadequate disinfection of primary sewage effluents because of high solids content. Data collected during August 1971 also suggests possible bacterial aftergrowth induced by high river temperatures and an abundance of organic matter. This record shows continuous violation of both Pennsylvania and Ohio water quality standards listed in Table VI-1.

10. Biological Conditions

The biotic variety in a stream is a good indicator of pollution levels. In July 1952 a lengthy steel strike curtailed industrial production along the Mahoning River and the pollution load to the stream at that time was primarily untreated municipal wastes. Industrial production was resumed in September when the strike ended. Figure VI-5 shows the differences in the number of genera of plants and animals under conditions which existed in July and September.[17] The biotic community was severely reduced with the resumption of industrial activity and the resulting increase in the industrial pollution load discharged to the stream. These data also indicate the relatively rapid repopulation of the stream once toxic discharges were abated at the outset of the strike. Seasonal variations between July and September did not affect the results as evidenced by the data obtained at the two upstream control stations.

TABLE VI-7

MAHONING RIVER BACTERIOLOGICAL DATA

(Number per 100ml)

Period of Record

	March-April 1966[2]				August 8, 1971[3]		August 17, 1971[3]		August 24, 1971[3]		August 31, 1971[3]	
	T. Coliform		F. Coliform		T. Coliform	F. Coliform	T. Coliform	F. Coliform	T. Coliform	F. Coliform	T. Coliform	F. Coliform
	Min	Max	Min	Max								
Above Alliance	20	430	10	330								
Below Alliance	3,300	5,800	2,000	19,500								
Below Berlin Res.	10	20	8	10								
Below Lake Milton	10	30	2	10								
Pricetown					5,000	2,800	9,000	690	13,000	3,200	2,200	250
Below Newton Falls	540	6,100	2,100	4,100								
Leavittsburg	2,500	6,300	360	1,000	23,000	690	64,000	3,200	24,000	2,500	54,000	3,100
Warren	390	9,200	440	1,700								
Niles	100	24,000	300	2,900	33,000	2,300	8.500	1,300	39,000	2,500	86,000	4,000
Youngstown-Div. St.	20,000	53,000	6,400	71,800	90,000	8,500	82,000	56,000	480,000	8,400	7,200	1,000
Youngstown-Rt. 18	77,000	370,000	33,000	69,000								
Struthers	61,000	161,000	11,000	36,000	370,000	60,000	680,000	74,000	690,000	14,000	170,000	22,000
Lowellville	45,000	120,000	3,900	11,800	360,000	15,000	500,000	30,000	900,000	44,000	490,000	34,000
Route 224 (Pa.)					360.000	13,000	450,000	33,000	860,000	42,000	400,000	47,000
Mt. Jackson (Pa.)					26,000	990	12,000	1,100	57,000	4,400	11,000	700
New Castle (Pa.)	4,300	210,000	1,300	12,000								
Beaver Falls (Pa.)					590,000	210	1,000	390	7,000	470	5,000	6,000

	Total Coliform			
	Min	Max	Avg	% of months avg index > 3000
Jan 1936 - March 1939[1]				
Mahoningtown (Pa.)	181	115,000	40,000	80
Jan 1948 - June 1953[1]				
Beaver Falls (Pa.)	3,020	57,100	22,500	97

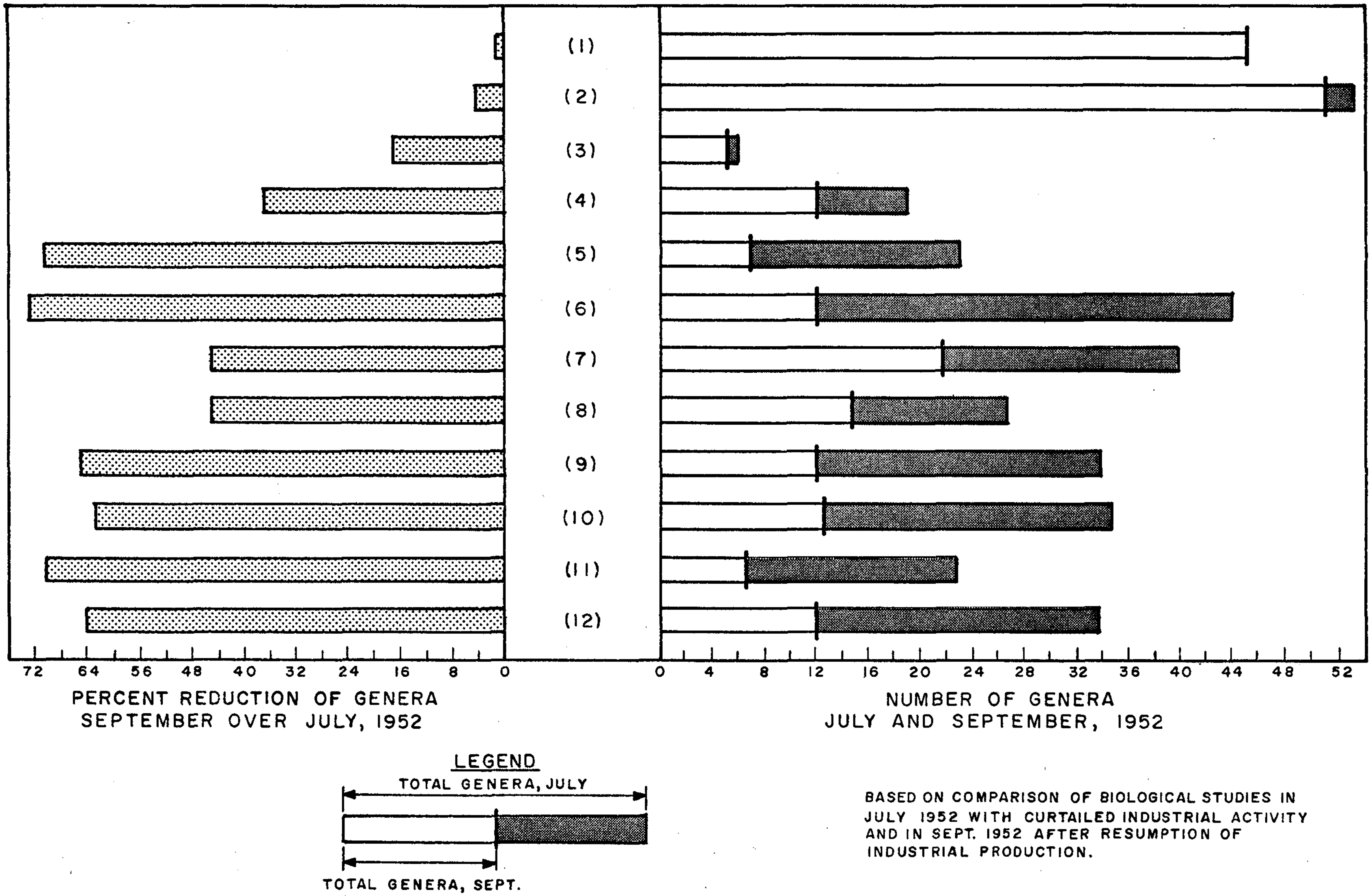
(1) Ohio Department of Health, Water Pollution Study, Mahoning River Basin, October 1954.

(2) Ohio Department of Health, A Report on Recommended Water Quality Standards for Interstate Waters, Mahoning River, Pymatuning, Yankee, and Little Beaver Creeks, Ohio-Pennsylvania, May 1970.

(3) USEPA, Region V, Ohio District Office, Mahoning River Enforcement Report, March 1972.

FIGURE VI-5

EFFECT OF INDUSTRIAL WASTES ON GENERA OF ORGANISMS IN MAHONING RIVER 1952



BASED ON COMPARISON OF BIOLOGICAL STUDIES IN JULY 1952 WITH CURTAILED INDUSTRIAL ACTIVITY AND IN SEPT. 1952 AFTER RESUMPTION OF INDUSTRIAL PRODUCTION.

A later study completed in 1965 by the U. S. Public Health Service measured the number and kinds of bottom organisms and the concentration of phytoplankton in the Mahoning River. The following excerpt from Mackenthun[17] presents the findings of this study which are nearly identical to those found by USEPA during 1975 (Section VII). (Figure numbers revised to conform to this report):

> "In a study during the week of January 4, 1965, bottom organisms were reduced in numbers from over 1,300 per square foot upstream from Newton Falls, Ohio, to about 350 per square foot upstream and downstream from Warren, 300 per square foot at Lowellville (Mile 11), and 850 per square foot at the first bridge crossing downstream from the Ohio-Pennsylvania State line (Figure VI-6). Similarly, 11 different kinds of organisms were found upstream from Newton Falls, only one kind, a pollution tolerant organism, was found at Lowellville (Mile 11), and 3 kinds were found at the first bridge crossing downstream from the State line (Figure VI-7). Although few in numbers downstream from Newton Falls, clean-water associated organisms were found to the highway 422 bridge upstream from Warren, Ohio. Cleanwater-associated organisms were not found throughout the remainder of the Mahoning River. Only pollution-tolerant sludgeworms persisted at Lowellville, and only pollution-tolerant sludgeworms and leeches and one kind of tolerant snail were found at the station downstream from the State line. The absence of clean-water associated fish food organisms in the Mahoning River downstream from Warren, Ohio, the severe decrease in the diversity of bottom organisms and the generally low numbers of stream bed animals at most sampling stations, attests to the severely polluted condition of the river and its toxicity from Warren, Ohio, to its confluence with the Shenango River in Pennsylvania.
>
> The bottom of the Mahoning River throughout the reach studied was generally rock and rubble with sludge along the shores and in many slack water areas. Such a rubble substrate would be expected to support a bountiful fish food organism population when not polluted. In many areas, oil formed a film on the water's surface, adhering to twigs, shoreline grasses and debris, and became mixed with the sludges. Substrate rocks and rubble were covered with a thick iron deposit that was harmful to bottom organisms in the Lowellville-State line reach.
>
> Conditions of existence were only slightly improved in the Beaver River. Sludgeworm populations were reduced from those found in the more polluted reaches of the Mahoning River, which indicates a reduction in the organic food supply. At New Brighton, Pa., partial stream recovery was found. The different kinds of organisms had increased and stoneflies were observed in small numbers on rocks in the shallow water near the shore. These were not found in quantitative samples taken from deeper

FIGURE VI-6

NUMBERS OF STREAM BED ANIMALS, MAHONING-BEAVER RIVERS

JANUARY 1965

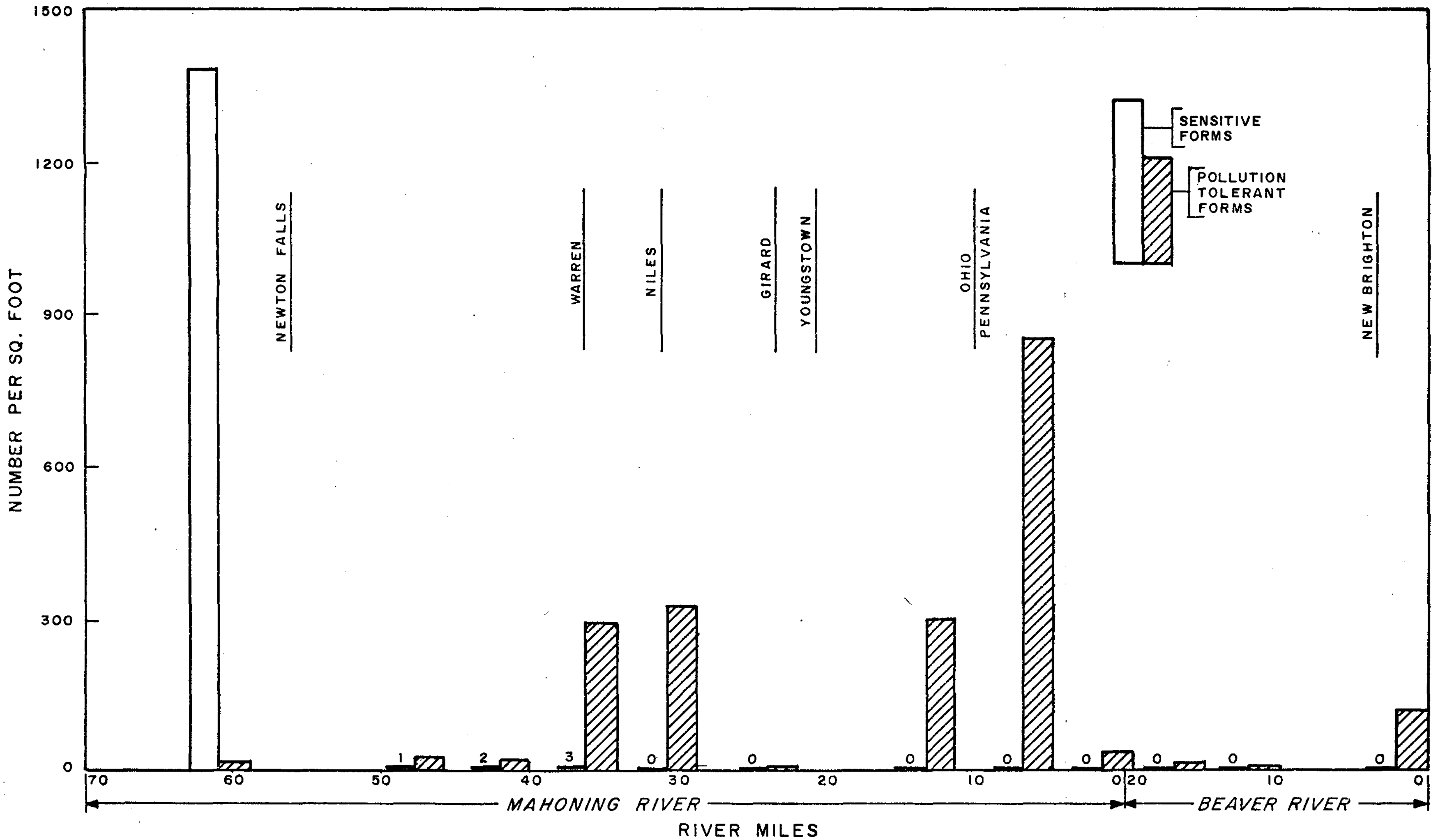
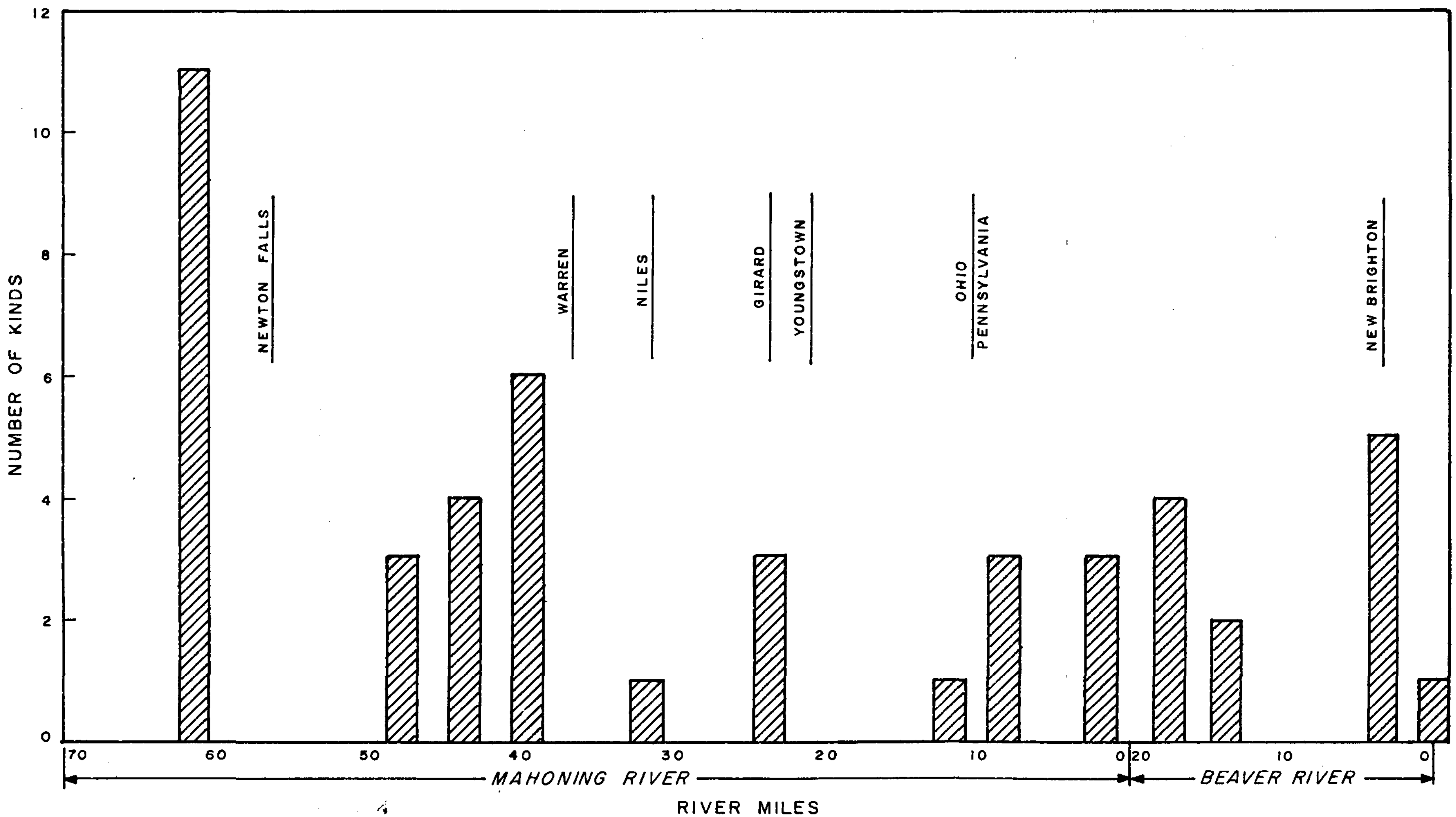


FIGURE VI-7

KINDS OF STREAM BED ANIMALS, MAHONING-BEAVER RIVERS

JANUARY 1965



water where the impact of pollution would be expected to be greatest.

Oil was also found throughout the Beaver River. Many of the bottom rock were red in color and showed evidence of an iron precipitate. Colonizing the rock's surface in shallower waters was a growth of slick, slimy algae often characteristic of polluted water.

Fisheries investigators have reported that the Mahoning River does not support a catchable fish population downstream from Warren, Ohio, to its confluence with the Shenango River, and that the Beaver River supports a catchable fish population only in its lower reach in the New Brighton area. In those areas where fishing was not reported, there were no bottom organisms on which fish normally feed.

Results of an examination of the phytoplankton population were similar to those found for the bottom organism population. Values of total counts upstream from Newton Falls, Ohio, were in a range that would be expected in an unpolluted stream during the winter months (Figure VI-8). Downstream from the U.S. Highway 5 bridge (mile 47.4) total count values were substantially reduced and remained so throughout the remainder of the Mahoning River. At Lowellville, Ohio, and at the first bridge crossing downstream from the Ohio-Pennsylvania State line, total count values were one-fourth of those upstream from Newton Falls. Some recovery was found at the highway 18 bridge upstream from the confluence of the Mahoning River with the Shenango River. Depressed algal counts demonstrate the degrading effects of pollution on this primary food source for aquatic life in the stream. The low phytoplankton total count values and the low population numbers found in the bottom organism population is strongly suggestive of the action of a toxic substance or substances to aquatic life."

While there has been little, if any, change in biological conditions in the Mahoning River from 1952 to 1975, the physical characteristics of the stream are such that a substantial fish population could be supported in the absence of toxic substances and deoxygenating wastes. There is evidence that a substantial recovery of the stream for aquatic life uses is possible once wastewater discharges are controlled.

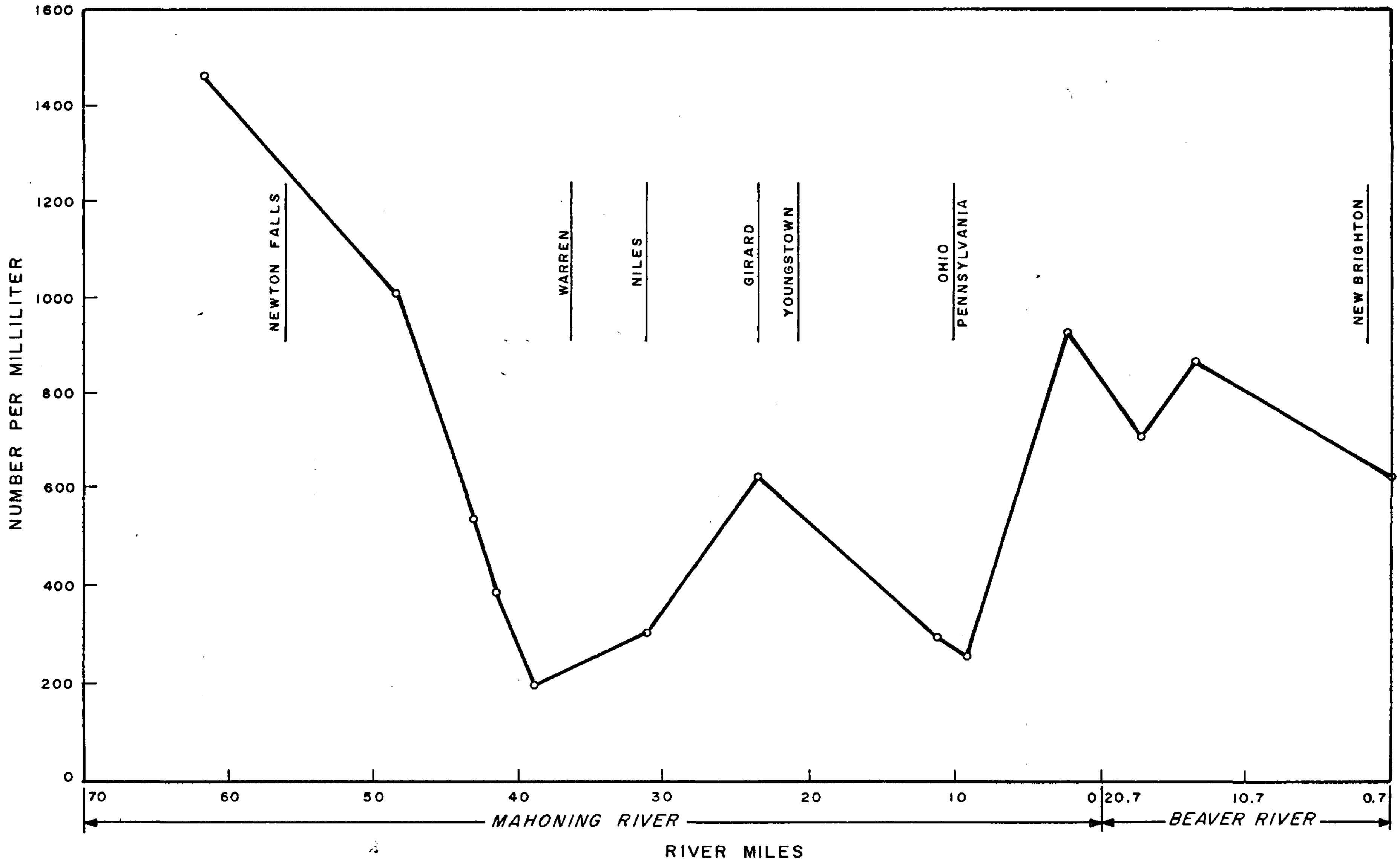
11. Taste and Odor

Taste and odor in surface waters may result from many sources. Among these are discharges of phenolics, oils, and municipal wastes, bottom river sediments, and natural odor producing substances. All of these contribute to this problem on the Mahoning River in addition to bottom releases from upstream reservoirs in the basin.

FIGURE VI-8

PHYTOPLANKTON IN MAHONING-BEAVER RIVERS

JANUARY 1965



An indication of the odor potential of water is measured by the threshold odor (T.O.) determination. The Federal Water Quality Administration and the Ohio Department of Health cooperated in a threshold odor study of the Mahoning River during 1969 and 1970. The results of that study are presented in Table VI-8. As shown, mean threshold odor number values ranged from 18 to 114 at 40°C for the stations from above Youngstown to Mt. Jackson, Pennsylvania. Similarly, mean threshold odors values of 2 to 306 were found for the five reservoirs tributary to the Mahoning River. Mean odors values at the Beaver Falls water intake during this survey ranged from 7 to 65.

The existing Ohio threshold odor limit on the main stem of the Mahoning from Warren to Lowellville, is a daily average of 24 at 60°C.[8] As shown in Table VI-10, these criteria have been exceeded in the Mahoning River and in the Beaver River at the Beaver Falls water intake.

To combat tastes and odors, the Beaver Falls water treatment plant uses large quantities of activated carbon, which add significantly to water treatment costs. Under average Mahoning River conditions, the plant uses from 35 to 100 pounds per day of powdered activated carbon.[25] However, as much as 600 pounds per day have been used on numerous occasions to combat shock loads of taste and odor causing materials.[25]

TABLE VI-8

MAHONING AND BEAVER RIVERS

Threshold Odor Data(1)

1969-1970

	Mahoning River Stations						Reservoirs Tributary to the Mahoning River				
	Alliance	Above Warren	Above Youngstown	State Line	Mt. Jackson	Beaver River at Eastvale Pa.	Below Berlin Reservoir	Below Lake Milton	Below West Branch Reservoir	Below Mosquito Reservoir	Below Meander Reservoir
April 1969											
Number of Samples	3	10	9	9	10	10	5	5	5	5	3
Range	13-30	5-66	7-35	17-57	12-57	5-10	4-10	2-35	1-4	10-125	4-8
Mean	20	12	18	32	33	7	6	10	2	39	6
July 1969											
Number of Samples	3	9	9	8	9	9	5	5	5	4	3
Range	8-24	4-58	20-100	22-99	22-150	7-43	5-23	5-70	3-162	10-43	3-75
Mean	13	20	44	59	61	18	10	26	66	32	27
October 1969											
Number of Samples	3	10	10	10	10	10	5	5	5	5	3
Range	25-76	2-7	20-50	43-200	27-171	18-87	1-3	2-200	1-3	3-59	3-6
Mean	52	5	33	114	94	43	2	42	2	19	4
February 1970											
Number of Samples	3	10	10	10	10	10	5	5	5	5	3
Range	6-9	4-481	10-121	17-181	28-181	10-150	6-1500	6-340	4-150	13-35	5-8
Mean	8	85	62	73	75	65	306	76	40	27	7

(1) Results are recorded as T.O.N. at 40°C.

Source: Ohio Department of Health, A Report on Recommended Water Quality Standards for Interstate Waters, Mahoning River, Pymatuning, Yankee, and Little Beaver Creeks, Ohio-Pennsylvania, May 1970.

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SECTION VII
WATER QUALITY MODEL VERIFICATION

A mathematical water quality model is necessary for water quality management planning in the lower Mahoning River because of the large number of point source dischargers and the unique hydrologic characteristics of the system. A computerized water quality model (BEBAM) for the entire Beaver River basin including the Mahoning and Shenango Rivers and two reservoirs in the Mahoning River system was developed by Raytheon Oceanographic and Environmental Services under contract with the USEPA.[1] Before BEBAM could be used with some degree of confidence for water quality management planning for the industrialized stretch of the Mahoning, significant modification and a more rigorous verification of the model were necessary. The BEBAM code was modified to improve the flexibility of the model with respect to interdependent constituents and to accurately incorporate the effects of sediment oxygen demand in the dissolved oxygen balance. The segmentation was adjusted to the actual distribution of dischargers, tributaries, and channel dams along the study reach, thus forcing the computational procedures in BEBAM to more closely reflect mixing and transport phenomena found in the river. Detailed physical data of the system were considered permitting more accurate water quality computations. Numerous field and laboratory studies were conducted to develop stream reaction rates specific to the Mahoning River for carbonaceous biochemical oxygen demand, ammonia–N, total cyanide, and phenolics. Because of the lack of published information concerning total cyanide and phenolics, the respective reaction rate dependence on temperature had to be determined. Also, sediment oxygen demand rates were measured in the field. Finally, two comprehensive point source and water quality surveys were conducted for model verification purposes and sediment quality and biota were investigated.

A. <u>Water Quality Model</u>

The water quality model, BEBAM, with some modifications was used throughout this study to simulate water quality in the Mahoning River. The model is composed of two major elements: a computerized model of seventeen water quality constituents, called the River Basin Model (RIBAM); and a general computerized model of river water temperatures called QUAL-1. Specialized data decks provide the two models with information descriptive of the particular river basin being studied. A second temperature prediction model was also evaluated in this study. General descriptions of the models are presented below. More detailed descriptions can be found in References 1 and 2.

1. River Basin Model

RIBAM is a far-field, one-dimensional, steady-state computer model adapted from the DOSAG[3] water quality model prepared by the Texas Water Development Board. The conceptual and theoretical approach used in the computation of the 17 water quality parameters in RIBAM is a direct extension of the approach used to model BOD and DO in DOSAG. Modifications were made by the USEPA to the RIBAM code received from Raytheon in order for the model to be more compatible with the Mahoning River system.

In RIBAM, the river is analyzed as a network consisting of four basic components:

1) Junctions - the confluence of two streams,
2) Stretches - the length of the river between junctions,
3) Headwater stretches - the length of a river from its headwaters to its first junction,
4) Reaches - the subunits that comprise a stretch.

Reach boundaries were selected at effluent sources, channel dams, tributaries or physical changes in the stream which divide a stretch into subunits of uniform physical and hydraulic characteristics. As a result, all effluent sources are considered to enter the stream at the upstream end of a reach.

To compute water quality, RIBAM assumes steady-state conditions in which each constituent behaves according to a continuous differential equation throughout a reach. At reach boundaries, effluent sources are added and stream characteristics can be changed. This approach may be used because the definition of a reach assumes that physical characteristics of the stream remain constant for the length of the reach. In addition, the mathematical model assumes stream quality is one dimensional, i.e., that concentrations vary along the length of a reach but are uniform in width and depth.

For modeling purposes, the 17 water quality constituents are grouped into three categories: 1) conservative, 2) non-conservative, non-coupled and 3) non-conservative coupled. Each constituent within a given category obeys a general equation which is characteristic of that category. The concentration of each constituent is computed for any point in a reach by evaluating the appropriate equation using the time of travel from the head of the reach to the point. Time of travel is computed by the time-rate-distance equation:

$$t = \frac{x}{v} \qquad 7.1$$

where x = the distance downstream from the head of the reach

v = average stream velocity within a reach.

The constituents of particular concern on the Mahoning River are temperature, ammonia-nitrogen, total cyanide, phenolics, and dissolved oxygen (DO). Carbonaceous biochemical oxygen demand (CBOD), and nitrite-nitrogen, were also considered in the modeling because of their effect on dissolved oxygen. Conservative constituents were not modeled in this analysis. However, mass balance relationships were reviewed for each conservative constituent studied (see Section VII-B).

In RIBAM, CBOD, ammonia-N, total cyanide, and phenolics are classified as non-conservative, non-coupled constituents and are assumed to obey the first order differential equation:

$$\frac{dc}{dt} = -KC \qquad 7.2$$

where K is the reaction rate and the C the concentration. The solution to equation 7.2 is:

$$C(t) = C_o e^{-Kt} \qquad 7.3$$

where C_o is the concentration at the head of the reach and t is the time.

The starting concentration C_o is determined by a mass balance equation, which assumes that the effluent mixes completely with the river water at the point of discharge. All tributary and municipal flows and loadings are added at this point as well as net loadings from the industrial discharges. The most significant industrial discharges generally do not add to the total flow of the stream since most steel plant process and cooling water is withdrawn and then discharged to the river.

In RIBAM, the first-order decay of ammonia-N is the first step in the three-step biological removal of ammonia-N from the system. The reactions modeled are the oxidation of ammonia-N to nitrite-N, the oxidation of nitrite-N to nitrate-N and the biological assimilation of nitrate-N. Reactions representing the bio-chemical decomposition of organic nitrogen to ammonia-N and biological assimilation of ammonia-N are not included in RIBAM. These reactions do not consume DO in the stream, however, both reactions affect ammonia-N concentrations which in turn can affect oxygen levels during nitrification. In RIBAM, the nitrification of ammonia-N to nitrite-N consumes 3.43 mg/l of dissolved oxygen for every mg/l of ammonia-N that is oxidized to nitrite-N.[4] Nitrite-N is also oxidized by bacteria to nitrate-N. Concentrations of nitrite-N are therefore increasing as a result of the ammonia-N reaction and depleting as a result of nitrification to nitrate-N. In RIBAM, nitrite-N is modeled as a non-conservative, "coupled" parameter with two first-order reactions taking place simultaneously. The differential equation for this reaction is:

$$\frac{dC_2}{dt} = K_2 C_2 + CF_{1,2} K_1 C_1 \qquad 7.4$$

where C is concentration, K is the reaction rate, CF is the conversion factor from ammonia to nitrite and the subscripts 1 and 2 refer to ammonia-N and nitrite-N, respectively. For this reaction, $CF_{1,2}$ is 1.0, indicating that one mg/l of nitrite-N is produced for each mg/l of ammonia-N that is broken down. The solution to equation 7.4 for nitrites is:

$$C_2(t) = (C_2^{o} + A_{1,2})\, e^{-K_2 t} - A_{1,2}\, e^{-K_1 t} \qquad 7.5$$

where

$$A_{1,2} = \frac{K_1 C_1^{o}}{K_1 - K_2}$$

It has been shown that the oxidation of one mg/l nitrite to nitrate consumes up to 1.14 mg/l of DO.[4] This relationship is incorporated into the DO equation. The complete nitrification of one mg/l of ammonia-N to nitrate-N therefore uses a total of 4.57 mg/l of DO, assuming a stoichiometric conversion.

RIBAM assumes dissolved oxygen is dependent upon and coupled to CBOD, ammonia-N, nitrite-N, iron, chlorophyll a, and sediment oxygen demand. However, DO in the Mahoning River is dominated by the effects of abnormally high stream temperatures, large CBOD and ammonia-N discharges from the industries and municipalities, and to a much lesser extent by the oxygen uptake of the polluted sediments. Preliminary evaluations indicated that in most cases the effects of iron and chlorophyll a on DO would be minimal and were therefore not included in this analysis. The affects of not including these constituents in modeling DO is discussed further in a subsequent review of model verification.

The resulting differential equation for the dissolved oxygen deficit is:

$$\frac{dD}{dt} = -K_R D + 3.43\, K_1 C_1 + 1.14\, K_2 C_2 + K_3 C_3 + B \qquad 7.6$$

where D is the DO deficit, K the reaction rate, C the constituent concentrations, and B is the benthic oxygen demand. The subscripts 1, 2, and 3 denote ammonia-N, nitrite-N, and carbonaceous BOD, respectively, and R denotes the reaeration rate. As modeled in this analysis, carbonaceous BOD represents the total oxygen demand less that from the nitrification of ammonia-N and nitrite-N. The RIBAM code includes additional terms for chlorophyll a and iron which are deleted in equation 7.6 because they were not included in this analysis. The solution to equation 7.6 is:

$$D(t) = (D^{o} + A_1 + A_2 + A_3 - b)\, e^{-K_R t} - A_2\, e^{-K_2 t} - A_3\, e^{-K_3 t} + b \qquad 7.7$$

where

$$A_1 = \frac{3.43\, K_1 C_1^{o}}{K_1 - K_R}$$

$$A_2 = \frac{1.14K_2C_2^{\,o}}{K_2 - K_R}$$

$$A_3 = \frac{K_3C_3^{\,o}}{K_3 - K_R}$$

$$b = B/K_R$$

The dissolved oxygen concentration is computed by subtracting the oxygen deficit computed in equation 7.7 from the saturated dissolved oxygen concentration (C_{SAT}).

$$C_{DO}(t) = C_{SAT} - D\,(t) \qquad 7.8$$

The saturation dissolved oxygen concentration is dependent on the stream water temperature, T, and the mean basin elevation, E. C_{SAT} is computed in the model by the equation:

$$C_{SAT} = \{14.62 - 0.3898*T + (0.006060*T^2) - (0.0005897*T^3)\} \quad 7.9$$
$$*\{(1-(0.00000697*E))^{5.67}\}$$

where T is in degrees centigrade and E is feet above sea level.

An important factor in maintaining dissolved oxygen levels in the Mahoning River is the many low-head channel dams located between Leavittsburg and Lowellville. The turbulent mixing which occurs as water flows over these dams substantially reduces dissolved oxygen deficits. In RIBAM, the change in the DO deficit resulting from reaeration over channel dams is computed after Owen, et al.[5]

$$Da/Db = 1 + 0.11\,ab\,(1 + 0.046\,T)\,H \qquad 7.10$$

where Da = dissolved oxygen deficit above dam (mg/l)

Db = dissolved oxygen deficit below dam (mg/l)

T = temperature (C^o)

H = height (feet which the water falls)

a = 1.25 in clear to slightly polluted water;
1.0 in polluted water;
0.80 in sewage effluents.

$b = 1.3$ for step weirs to cascades;
1.0 for weir with free fall.

Since values of 1.0 for coefficients a and b are built into the RIBAM code, adjustments were made to the values of H input to the code based upon measured data above and below each dam to compensate for the inflexibility with respect to the a and b coefficients. Adjusting the dam heights has the same effect on the computed reaeration over the dams as changing coefficients a and b to correctly account for the degree of stream pollution and dam configuration.

In RIBAM, reaction rates for non-conservative parameters are assumed to have an Ahrhenius temperature dependence. Reaction rates at 20 degrees centigrade for each reaction are adjusted for temperature by the generalized expression:

$$K(T) = K(20)\theta^{T-20} \qquad 7.11$$

$K(T)$ = reaction rate at temperature T

T = Temperature of a reach in ^{o}C

θ = temperature correction factor for a particular constituent

Values of θ were computed from data obtained on the Mahoning River or selected from recently published information.

2. River Temperature Models

Two temperature prediction models were evaluated to determine which would be more appropriate to successfully and easily simulate the temperature regime in the Mahoning River. The two models evaluated were QUAL-1, developed by the Texas Water Development Board, and the Edinger-Geyer completely mixed stream model.[2, 6] The QUAL-1 model had been received from Raytheon as the temperature modeling portion of the Beaver Basin Model (BEBAM) project. Some difficulty had been encountered by Raytheon in trying to verify QUAL-1 on the Mahoning River. It was for this reason that a second temperature model, the Edinger and Geyer formulation, was also evaluated.

a. QUAL-1

QUAL-1 contains the capability to simulate CBOD, DO, temperature and conservative constituents. Only the temperature portion of the model was evaluated in this study. The basis for temperature simulation in the QUAL-1 model is a heat budget which represents the energy transfer across the air-water surface:

$$H_N = H_{sn} + H_{an} - (H_b \pm H_c + H_e) \qquad 7.12$$

where

H_N = Net energy flux passing the air-water interface, BTU/ft^2-day

H_{sn} = Net shortwave solar radiation passing through interface, BTU/ft^2 –day

H_{an} = Net longwave atmosphere radiation flux passing through interface, BTU/ft^2-day

H_b = Outgoing longwave back radiation flux, BTU/ft^2-day

H_c = Conductive energy flux between air and water, BTU/ft^2-day

H_e = Energy loss by evaporation, BTU/ft^2-day

The heat budget equation shown above is the basis not only for QUAL–1 but for most temperature models. The basic differences between models are the particular methods used to estimate the heat terms in Equation 7.12 and the methods used to simulate the hydraulic system to which the heat budget is applied. Equations developed by Water Resources Engineers and Anderson are used to estimate both short and long wave atmospheric radiation in QUAL-1.[7, 8] Back radiation, H_b, is computed using the Stephen-Boltzman Fourth Power Radiation Law, and heat transfer due to conduction (H_c) is computed from the Bowen Ratio which relates H_c to the heat transfer due to evaporation. H_e is given by the relationship developed by Roesner.[9] The evaporation term is important because the heat transfer term is dependent on wind speed which is often quite variable and the evaporation relationship is also used to compute H_c.

The heat budget described above is applied to a control volume which is also being affected by mass transport (advection) into and out of the volume and longitudinal dispersion. The relationship for dispersion was determined from work by Elder and employs the use of Manning's roughness coefficient.[10] Because the model includes dispersion, a finite difference method is employed to solve the differential equation for the temperature flowing out of the control volume.

QUAL-1 requires as input standard hydrologic and point source loadings as well as the following meteorological data:

- Dry Bulb Temperature
- Wet Bulb Temperature
- Cloud Cover
- Barometric Pressure
- Wind Speed

Meteorological data can be supplied to the model for time intervals corresponding to the computational time step which is also input to the code.

b. EDINGER-GEYER

A non-stratified, one-dimensional, temperature distribution model was developed by Edinger and Geyer for the purpose of estimating the temperature distribution in the vicinity of a heated water discharge. In this model, increases in temperature resulting from the addition of heat to a water body decay in the downstream direction and approach an equilibrium temperature by heat exchange between the water and the atmosphere. With longitudinal advection the dominant transport mechanism, and assuming steady-state conditions, the temperature distribution downstream of a heat course is given by:

$$T = E + (T_m - E)\, e^{-KA/\rho C_p Q_r} \qquad 7.13$$

where

E = equilibrium temperature, ^oF

T_m = mixed river temperature at heat source, ^oF

K = exchange coefficient, BTU/ft^{2}day-^oF

A = surface area, ft^2

ρ = density of water, 62.4 lb/ft^3

C_p = specific heat of water, 1.0 BTU/lb

Q_r = river flow, ft^3/day

A heat budget similar to the one used in QUAL-1 was used to derive equations for the equilibrium temperature and the exchange coefficient in the above equation. The Edinger and Geyer model uses the Brunts formula for long-wave atmospheric radiation, the Anderson relationship for evaporation, and requires measured shortwave radiation as input.[8, 11] Equations representing the remaining terms in the heat budget were the same as those found in QUAL-1. Linear approximations were then made to simplify calculation procedures used to solve for the equilibrium temperature and exchange coefficient.

In reviewing the Edinger and Geyer model, Parker found some of the approximations were not necessary and modified the equations for K and E.[12] Those modified equations were applied to this study.

B. USEPA Field Studies

Data obtained during field studies conducted between February 1975 and July 1975 provided the information needed to compute the inputs and to verify the water quality models. Reaction rate studies for CBOD, ammonia–N, total cyanide, and phenolics were conducted on May 5, June 5, June 17, and June 24, 1975. Sediment oxygen demand rates were determined on May 21 and July 23, 1975 with an in situ benthic respirometer. To verify time of travel calculations, dye studies of the lower 15 miles of the Mahoning River were conducted on June 17, 1975 and for the Warren-Niles area on June 24, 1975. Additional time of travel data obtained for the entire area of study by the U. S. Geological Survey during the week of July 20, 1975 were also considered. On March 7, 1975 sediment chemistry and benthic macroinvertebrate samples were obtained at 14 locations. Sediment chemistry data were also obtained from river sediment samples collected on July 23, 1975 just downstream from the three coke plants in the valley. On February 11-14, 1975 and July 14-17, 1975, comprehensive basin surveys were conducted to obtain sufficient data to verify the water quality models for water quality simulation purposes.

Data developed through these comprehensive field efforts have been made available to the Ohio Environmental Protection Agency and the Eastgate Development and Transportation Agency (EDATA), which is the

208 Planning Agency for Mahoning and Trumbull Counties. Data pertaining to sediments have been made available to the Corps of Engineers. The Corps is studying the feasibility of dredging polluted sediments in the Mahoning River and the effect of these sediments on water quality. A discussion of the field studies to determine model input parameters and how the results were processed into the form required by the computer code are presented below followed by a discussion of the results of the February and July comprehensive surveys.

1. Hydrology and Physical Characteristics

In RIBAM, a river system must be subdivided into reaches with uniform physical and hydraulic characteristics. To maintain this uniformity and to insure that all effluent sources were correctly located at the head of a reach, the Mahoning River between Leavittsburg, Ohio and New Castle, Pennsylvania was segmented at the confluence of tributaries, the discharge point for each municipality and major industrial source, and at the channel dams. One additional reach boundary was chosen at State Route 224 bridge in Pennsylvania for comparison with measured water quality at that point. Table VII-1 gives a description of each reach and the river mile points of the boundaries. For industrial sources with multiple outfalls, one discharge located at the average river mile of major outfalls was selected. A boundary was not established at the dam at the Youngstown Sheet and Tube Campbell Works because this dam is located adjacent to the Campbell STP discharge, the next upstream reach boundary. The difference in computed dissolved oxygen levels introduced by shifting the dam location to the head of this reach is negligible.

Array sizes in the RIBAM code limit the number of reaches in a stretch to 20 and the total number of reaches in a basin to 40. The choice of boundaries described above results in a total of 37 reaches, a value within the total reach constraint but exceeding the size constraint for the number of reaches in a stretch (i.e., the length of a river between junctions). To accommodate the reach per stretch constraint, an artificial tributary with a length of .01 miles and zero flow was added to the system to form a junction below reach number 20. This results in the main stem of the Mahoning River being divided into two stretches, the headwater stretch from Leavittsburg to

TABLE VII-1

MAHONING RIVER REACH BOUNDARY DESCRIPTION

Boundary Identification	River Mile at Head of Reach	Length of Reach (Miles)
USGS Gaging Station	46.08	3.51
Copperweld Steel Company	42.57	.95
Infirmary Run	41.62	.58
Red Run	41.04	1.05
Summit Street Dam	39.99	3.28
Republic Steel Corporation-Warren Plant	36.71	.88
Warren Sewage Treatment Plant	35.83	2.50
Mud Creek	33.33	2.19
Mosquito Creek	31.14	.37
Meander Creek	30.77	.71
Ohio Edison Company-Niles Plant	30.06	.59
Niles Sewage Treatment Plant	27.47	.81
U. S. Steel Corporation-McDonald Mills	28.66	.99
Squaw Creek	27.67	.35
McDonald Sewage Treatment Plant	27.32	.50
Liberty Street Dam	26.82	1.09
Girard Sewage Treatment Plant	25.73	.09
Fourmile Run	25.64	1.79
Youngstown Sheet and Tube Company-Brier Hill Works	23.85	.76
U. S. Steel Corporation-Ohio Works	23.09	.13
U. S. Steel Dam	22.96	.93
Mill Creek	22.03	1.12
Marshall Street Falls	20.91	1.10
Crab Creek	19.81	.05
Youngstown Sewage Treatment Plant	19.76	1.29
Dry Run	18.47	.33
Republic Steel Corporation-Youngstown Plant	18.14	.16
Republic Steel Dam	17.98	1.58
Youngstown Sheet and Tube Company-Campbell Works	16.40	.31
Campbell Sewage Treatment Plant	16.09	.46
Yellow Creek	15.63	.13
Youngstown Sheet and Tube Company-Struthers Division	15.50	.60
Struthers Sewage Treatment Plant	14.90	2.09
Lowellville Dam	12.81	.46
Lowellville Sewage Treatment Plant	12.35	1.93
Coffee Run	10.42	3.66
State Route 224 Bridge	6.76	5.24
Penn Central RR, New Castle, Pa.	1.52	-

the U. S. Steel - Ohio Works and the lower stretch from the U. S. Steel - Ohio Works to New Castle, Pennsylvania. The addition of the artificial tributary increased the total number of reaches to 38 but cannot affect the water quality computations because the additional tributary has zero flow.

The flow regimes for both February and July verification studies were computed using measured flows at the three USGS gaging stations as boundary values. Flow recorded at the Leavittsburg gaging station was used to initialize the river flow. Measured flow additions from the sewage treatment plants and tributaries located between the Leavittsburg and Youngstown gages were accumulated with the initial flow and the total compared with the flow recorded at the Youngstown gaging station. During both the February and July sampling surveys, the flow recorded at Youngstown was about 10 percent greater than the sum of measured flows up to that point.

Since changes in flow through the major dischargers were not considered, unaccounted for differences in flow between the gages were assumed to be the result of surface water runoff and were apportioned on a drainage area basis. To apportion the "runoff" flow, drainage areas for all tributaries whose flow was not measured were totaled with the portion of the main stem drainage area between the gaging stations. This enabled an average runoff per square mile (cfs/mi^2) to be computed for the upper length of the river. The runoff factor was multiplied by the respective tributary drainage area and resultant flow added at the head of the river reach where the tributary joined the main stem. The remaining runoff was assumed to flow directly into the main stem (i.e., not through the tributary). Main stem runoff was divided by the length, in miles, between the two USGS gaging stations to determine the runoff per mile length along the main stem. This factor was multiplied by the length of each river segment to get the runoff per reach which was added at the head of each segment.

The same procedure described above was used between the Youngstown and Lowellville USGS gaging stations to compute unmeasured tributary flows and main stem runoff flows. To obtain runoff flows below the Lowellville gaging station, runoff rates were similarly applied to drainage areas downstream of Lowellville. For the February survey, the runoff rate was calculated using the total basin drainage area upstream of the Lowellville USGS gage and the three-day average flow at the Lowellville gage. For the July survey, the drainage area and measured flow of Coffee Run were used to calculate the runoff rate. The computed runoff flows were again added at the head of each reach. Table VII-2 lists the drainage areas employed for flow apportionment.

Stream cross-sectional data were needed to determine stream velocities and depths for input to the RIBAM code. These data were obtained from maps provided by the U. S. Army Corps of Engineers[13] which are based upon photographs exposed December 6, 1961. River soundings at intervals of approximately one-tenth of a mile from the Copperweld Steel Corporation downstream to the Beaver River and bottom elevations at about 20 foot intervals across the river are supplied, as well as the water surface elevation on December 6, 1961. Bottom elevations were averaged and subtracted from the water surface elevation to obtain an average depth at every one-tenth of a mile. River widths were measured directly with a ruler divided into hundredths of an inch. The relatively large scale on the maps, 1" = 200', enables an accuracy of ± 4 feet for stream widths. Cross-sectional areas were calculated at every sounding by multplying the width by the average depth. Cross-sectional areas and depths for each reach on the model were computed by averaging the values determined at every tenth of a mile interval. These values however, represent the physical dimensions occurring during the December 6, 1961 flow regime and had to be adjusted to the flow measured during the Feburary and July 1975 surveys.

Depth and cross-sectional area adjustments for different flow regimes were made using the 1961 USGS hydrograph for the Leavittsburg, Youngstown and Lowellville gaging stations. For a specific flow (average flow measured during February 1975 survey), the corresponding gage height was computed using the 1961 hydrograph. The difference between the computed gage height and the value measured on December 6, 1961 was considered the depth adjustment at that location. Depth adjustments were computed at all three gaging stations and a linear depth adjustment by mile point was assumed for free-flowing reaches between the gaging stations. Depth adjustments were then added (or subtracted) to the 1961 depths. Below the Lowellville gage, the depth adjustment determined at the gage was applied downstream to New Castle, Pennsylvania.

TABLE VII-2

MAHONING RIVER DRAINAGE AREAS

Tributary	Drainage Area (Square Miles)(1) Total Area	Downstream of USGS Gage
Infirmary Run	10.5	10.5
Red Run	7.2	7.2
Mud Creek	11.9	11.9
Mosquito Creek	138.0	40.5
Meander Creek	85.8	1.9
Squaw Creek	18.4	18.4
Fourmile Creek	4.7	4.7
Mill Creek	78.4	12.1
Crab Creek	21.1	21.1
Dry Run	10.1	10.1
Yellow Creek	39.4	39.4
Coffee Run	10.6	10.6
Basin		
above Leavittsburg Gage	575	
above Youngstown Gage	898	
above Lowellville Gage	1073	
above Beaver River	1140	
Mainstem Only		
Leavittsburg to Youngstown	46.5	
Youngstown to Lowellville	26.0	
Lowellville to Beaver River	29.2	

(1) Information Source: Drainage Areas of Ohio Streams, Supplement to Gazetteer of Ohio Streams, Ohio Department of Natural Resources, Report 12a, 1967.

A separate technique was used to compute depth adjustments in channel dam pools. Head heights at dams were computed using the formula for flow over a broad crested weir:

$$H = \frac{Q^{2/3}}{3.33\ xL} \qquad 7.14$$

where Q = flow, ft^3/sec

L = length of the dam, ft

H = height of water flowing over the dam, ft

The difference between the head height computed using the December 1961 flow and the head height determined using the flow from one of the field surveys was the depth adjustment applied to the entire length of the dam pool.

The average reach cross-sectional area determined from the Corps' maps was divided by the average reach depth to obtain the reach width which was multiplied by the adjusted depth to determine an adjusted cross-sectional area. In computing adjusted cross-sectional areas by this method, it is assumed that stream width remains constant with changes in flow. This assumption is reasonable for the Mahoning River because of the steep banks found along most of the study area, notably in the industrial segments.

Adjusted cross-sectional areas are used in the following equation to compute stream velocities for input to the RIBAM code:

$$V = \frac{Q}{A} \qquad 7.15$$

where A = average cross-sectional area, ft^2

Q = average flow in a reach, ft^3/sec

The average flow used in equation 7.15 was equal to the flow at the head of a reach plus one-half of the surface flow for that reach.

2. Travel Time

The time required for water in the main stem to move downstream from one location to another is important in water quality modeling of non-conservative constituents. As indicated earlier, RIBAM computes travel times using cross-sectional areas and stream flows. To verify the methods used to compute travel times, dye tracer studies were conducted by the USEPA, Michigan-Ohio District Office in two different river sections and later by the U. S. Geological Survey from Warren, Ohio to New Castle, Pennsylvania.

Both the USEPA and the USGS dye studies were conducted in the same fashion. Time was recorded when a dark-red trace dye (rhodamine B) was dumped into the river at an upstream location. At downstream measuring stations, a fluorometer sensitive to low level dye concentrations was set up to detect passage of the dye. Times were recorded when the dye was first detected and again when the maximum dye levels occurred. In the USEPA survey, water samples were collected at one-half hour intervals before dye arrival with the last grab sample collected before dye detection, saved for chemical analysis and use in reaction rate determinations.

USEPA dye studies were conducted on June 17, June 23, and June 24, 1975. The first of these studies was from the PL and E railroad bridge in Struthers (RM 15.83) to the Penn Central railroad bridge in New Castle, Pennsylvania (RM 1.52) with three intermediate sampling stations. This section of the river included the pool behind the Lowellville dam and the lower free flowing portion of the Mahoning River. Cross-sections and travel times were computed in the manner described earlier using the measured flows at the USGS gaging station at Lowellville and measured flows at Coffee Run, a tributary within the reach. Runoff per square mile, which was used in determining runoff flow in each reach, was computed from the drainage area and measured flow of Coffee Run. Computed travel times are shown in Table VII-3.

The results of this study showed excellent correllation between measured and computed values up to the State Route 224 bridge. Travel times computed using the previously described methods were within 10 percent of the measured arrival times of the maximum dye concentrations which represents the main body of water. However, below the State Route 224 bridge computed travel times were only half the measured travel time of the main body of water and only two-thirds the travel time of the leading edge. The poor agreement indicates that cross-sectional data from 1961 U. S. Army Corps of Engineers' maps are probably not representative of present stream conditions in the river segment below Route 224.

To check this conclusion, a second dye study was conducted on June 23, 1975 in the lower river segment from State Route 224 to New Castle, Pennsylvania. An additional sampling station at the Brewster Road bridge (RM 4.34) was selected to determine more precisely where 1961 cross-sectional data may no longer be representative of stream geometry. No water samples were taken during this study. Travel times were computed using the methods described above with the resulting measured and computed travel times presented in Table VII-4.

The results of the June 23, 1975 study support the conclusion that actual travel times in the lower Mahoning River are larger than computed. There was good agreement between measured and computed values downstream to the Brewster Road bridge, however, below that point the computed travel time was 1.38 hours, whereas the measured time of arrival for the maximum dye concentration was 3.37 hours. A difference of this magnitude indicates cross-sectional areas and the total segment volume in this section is significantly larger than the values determined from the Corps' maps.

The cross-sectional changes were included in the modeling by making adjustments to the total segment volumes between Brewster Road and New Castle using the ratio of the measured travel time to the computed travel time (2.44). The volume ratio was further broken down to adjustment factors for depth and width assuming two-thirds of the volume increase resulted from an increase in the depth and one-third was a result of an increase in width. The computed factors of 1.35 and 1.81 for width and depth, respectively, were multiplied times the adjusted dimensions used in computing the travel time. The adjusted depth was then corrected for flow using the method described earlier to determine the depth corresponding to the December 1961 flow regime in which the other segment depths were measured.

The corrected depth and widths for the lower segment were then used to compute travel times for the June 17 dye study. In this case, good correlation was found between measured and computed values. The travel time calculated with the corrected dimensions for the State Route 224 bridge to New Castle segment was 5.08 hours which differs from the measured value of 5.62 hours by less than 10 percent. The corrected cross-sections were therefore considered representative of the lower Mahoning River.

On June 24, 1975, the USEPA conducted a dye study of a portion of the Liberty Street dam pool from the Warren STP to the Carver-Niles Road bridge with an intermediate station at the West Park Avenue bridge. The measured corresponding computed times are presented in Table VII-5. Computed and measured values were nearly identical from Warren STP to West Park Avenue (2.42 hours vs. 2.43 hours), however the computed travel time for the reach from West Park Avenue to Carver-Niles bridge was 1.7 hours (30 percent) less than the measured time for the peak dye concentration. Although this is a significant difference, cross-sectional adjustments were not made with these data because reasonably good agreement was found between measured and computed travel times obtained with USGS data for this reach (Table VII-6).

At the request of Ohio EPA, the U. S. Geological Survey conducted a time of travel study from the Summit Street bridge in Warren, Ohio to the State Route 108 bridge in New Castle, Pennsylvania. The dye study was conducted in three separate sections over a three-day period from July 22–24, 1975. Flow rates varied widely over the study period as a result of a large rain which occurred on July 20 and 21 (410 to 1170 cfs as measured at Youngstown). Measured travel times and the corresponding computed values are reported in Table VII-6. Computed travel times agreed within 10 percent of the measured values for all segments except the 4-mile stretch below the Liberty Street dam. In this segment, computed travel times were about 20 percent (2 hours) longer than the measured time value for peak dye arrival. Considering the unsteady flows which existed during this survey, the correlation was considered good and the methodology used to compute travel times was considered verified.

3. Reaction Rates

Implicit in the use of the water quality model, RIBAM, is the assumption that the non-conservative constituents carbonaceous BOD (CBOD), ammonia–N, nitrite-N, total cyanide, and phenolics react in the stream according to first-order differential equations. While decay or

TABLE VII-3

JUNE 17, 1975 USEPA DYE STUDY

LOWER MAHONING RIVER

Station Description	River Mile	Length (Miles)	Dye Arrival Time (Hours) Leading Edge	Peak	Computed
PL&E RR, Struthers	15.83	0	0	0	0
PL&E RR, Lowellville	13.52	2.31	2.00	2.17	2.11
Church Hill Rd.	9.69	3.83	3.08	3.67	3.36
State Route 224	6.76	2.93	1.88	2.45	2.50
Penn Central RR New Castle, Pa.	1.52	5.24	4.70	5.62	* 3.10

Flow recorded at USGS Gage at Lowellville, 960 cfs.

* After width and depth correction, computed dye arrival time was 5.08 hours, see text.

TABLE VII-4

JUNE 23, 1975 USEPA DYE STUDY

LOWER MAHONING RIVER

Station Description	River Mile	Length (Miles)	Dye Arrival Time (Hours) Leading Edge	Peak	Computed
State Route 224	6.76	0	0	0	0
Brewster Rd.	4.34	2.42	1.66	1.80	1.79
Penn Central RR, New Castle, Pa.	1.52	2.82	2.50	3.37	1.38

Flow recorded at USGS Gage at Lowellville, 826 cfs.

TABLE VII-5

JUNE 24, 1975 USEPA DYE STUDY

LOWER MAHONING RIVER

Station Description	River Mile	Length (Miles)	Dye Arrival Time (Hours) Leading Edge	Peak	Computed
Warren STP	35.83	0	0	0	0
West Park Avenue	33.71	2.12	2.00	2.42	2.43
Carver-Niles Road	30.48	3.23	4.42	5.44	3.77

Flow recorded at USGS Gage in Leavittsburg, 440 cfs.

TABLE VII-6

JULY 1975 USGS DYE STUDY
LOWER MAHONING RIVER

Station Description	River Mile	Length (Miles)	Date	Discharge (cfs)	Dye Arrival Time (Hours) Leading Edge	Peak	Computed
Summit St.	39.93	0	7/24		0	0	0
Market St.	38.91	1.02	7/24	410	0.83	1.08	1.09
N. Main St.	31.30	7.61	7/24	410	10.50	12.42	12.50
Liberty St.	26.97	4.53	7/24	540	11.92	12.58	13.30
Liberty St.	26.97	0	7/23		0	0	0
Bridge St.	22.73	4.04	7/24	560	9.33	9.92	12.00
Center St.	18.29	4.44	7/24	600	6.67	8.00	8.30
South St.	20.11	0	7/22		0	0	
Center St.	18.29	1.82	7/22		1.33	1.58	0
Washington St. (Lowellville)	12.64	5.65	7/22	1020	5.17	6.25	5.80
Route 224	6.76	5.88	7/22	1030	4.33	4.92	4.40
SR 108 (New Castle, Pa.)	1.43	5.33	7/22	1170	4.33	5.08	4.60

removal of these constituents may in fact be more complex owing to the nature of the biochemical and physical processes involved, the simplification of first-order reactions is commonly employed in water quality modeling since rates of decay closely, though not always exactly, follow first-order reactions.[3, 4, 6, 14, 15, 16] Reaction rates for all of the above constituents are dependent upon the specific environment in which the reaction occurs, i.e., temperature, pH, populations of specific microorganisms, concentrations of toxic or inhibiting substances, channel geometry and bottom conditions, proximity to waste discharges, etc. Because of the uniqueness of the lower Mahoning River in terms of its highly polluted state and multitude of waste discharges, reaction rates presented in the literature for different streams or determined by laboratory studies may not be representative of those found in the Mahoning. For this reason, field and laboratory studies were conducted specifically to obtain data necessary to compute reaction rates for the Mahoning River.

Four separate sampling programs were conducted during the months of May and June 1975 to obtain rate data. Two of these sampling programs were conducted in conjunction with the travel time studies discussed earlier. Grab samples were collected during the four surveys at the sampling locations presented in Table VII-7. Samples were analyzed for the non-conservative constituents being modeled as well as other constituents. Temperature, pH and conductivity were recorded at the time samples were collected as well as river stage at the three USGS gaging stations. Samples were collected in pre-preserved bottles and thoroughly iced until analysis. Water quality data obtained during all rate surveys are presented in Appendix B, Tables 1-4.

A summary of the rates determined from the stream data is presented in Table VII-8 with the methodology for rate determination presented below.

a. Carbonaceous BOD Reaction Rate

The rate of oxidation of carbonaceous BOD (CBOD) can be computed using two general methods. Regression analysis can be applied to CBOD loadings along a stream to calculate the reaction rate, or one of several procedures developed to determine BOD rates from daily BOD bottle values can be used to calculate the CBOD rate at a given point in the stream.

TABLE VII-7

SAMPLING STATIONS FOR USEPA REACTION RATE STUDIES
MAHONING RIVER

Station Description	River Mile	Survey Date (1975) May 5	June 5	June 17	June 24
Leavitt Road Bridge	46.06	X	X		
B&O RR Bridge	38.66	X	X		
Below Warren STP	35.80				X
West Park Avenue Bridge	33.71	X	X		X
Belmont Avenue Bridge	30.48	X	X		X
Liberty Street Bridge	26.77	X	X		
Division Street Bridge	23.84	X	X		
Bridge Street Bridge	22.73	X	X		
Marshall Street Bridge	20.91	X	X		
B&O RR Bridge	19.17	X	X		
Penn Central RR Bridge	17.82	X	X		
P&LE RR Bridge	15.83	X	X	X	
Washington Street Bridge	12.64	X	X	X	
Church Hill Road Bridge	9.69	X	X	X	
Route 224 Bridge	6.76	X	X	X	
Brewster Road Bridge	4.34	X	X		
Penn Central RR Bridge	1.52	X	X	X	

TABLE VII-8

SUMMARY OF IN-STREAM REACTION RATES FOR LOWER MAHONING RIVER

Parameter	Reaction Rate at 20°C	θ*
Total Cyanide	1.350	1.050
Phenolics > 20 μg/l	3.710	1.060
Phenolics < 20 μg/l	1.580	1.060
BOD	0.300 **	1.047
Nitrite	2.000	1.060
Ammonia-N	0.276	1.100

* θ = Temperature correction factor $k(T) = k(20^{o}C)\theta^{(T-20)}$

** A value of 0.12 was used for the BOD reaction rate for water quality projections (see Section VIII).

Regression analysis (curve fitting) has the advantage of including the effects of CBOD decay, settling, and removal by attached plants and slimes; however, it has the disadvantage of requiring collection of data throughout fairly long river stretches having no major CBOD loadings. Since bottle rate determinations do not require river sampling over any given length, rates can be computed for relatively short river segments with many industrial and municipal point sources as found in the Mahoning River. Reaction rates determined from bottle studies, however, do not include the effects of settling and removal by attached growth which can be significant in streams with a large wetted perimeter in relation to streamflow. To account for greater contact with attached biological organisms, RIBAM has the flexibility to adjust input CBOD rates for stream depth as suggested by Hydroscience[17] where bottle rates are employed.

For this study, CBOD reaction rates were computed using the Tsivoglou daily difference method, a bottle rate procedure.[16] Because of the large number of major dischargers between Warren and Struthers, there are virtually no stretches of river where an adequate number of sampling points can be located to employ the curve-fitting technique. In addition, long-term BOD values measured at many sampling locations in the lower stretches of the river can be unreliable due to high concentrations of cyanide, phenolics, and metals which can create toxic conditions for BOD stabilizing organisms in the water sample. Recent surveys of the Mahoning River stream bed by the Corps of Engineers showed that sedimentation was occurring only along the stream banks and behind the larger channel dams with generally less than 30 percent of the bottom covered by sediment deposits.[18] Hence, use of the CBOD bottle rates could underestimate the total CBOD disappearance behind some dams by excluding settling.

The Tsivoglou daily difference method for BOD rate determination is an adaptation of Fair and Velz methods and gives a graphic picture of observed data and predominant rate changes with time. As described in the USEPA Water Quality Training Manual,[19] the rate calculation procedures are quite simple. The method, however, assumes that the majority of the data follow a first order reaction. Points that do not fit this assumption are considered extraneous.

When ammonia-N is present in the water sample, nitrification can substantially increase the long-term BOD bottle values. Since RIBAM handles the effects of nitrification separately from the oxidation of CBOD, oxygen depletion caused by nitrification must be subtracted from the total BOD measured in the sample bottle. Generally, the two reactions can be separated because CBOD oxidation starts immediately and ammonia-N nitrification may be delayed a few days while a sufficient population of nitrifying bacteria is being established. The daily difference method is then applied to the BOD values for the first few days before nitrification becomes significant.

As discussed by Velz,[4] the effects of nitrification on the BOD test can be controlled by chemically inhibiting nitrification. Studies by Young[20] showed nitrification could be controlled by addition of 2-chloro-6 (trichloromethyl) pyridene (TCMP) without affecting CBOD stabilization. The standard BOD test was run on samples with and without nitrification inhibited for two of the sampling programs, June 5 and July 14-17, 1975. For the other surveys, BOD samples were not analyzed with nitrification inhibited and NBOD was separated assuming a time delay as discussed above.

The calculated CBOD rates for all four rate studies, as well as the comprehensive July survey, are presented in Table VII-9. CBOD rates show variability between stations during a specific survey, as well as variability between surveys at a specific station. This variability can be attributed to many factors, including variations in BOD characteristics at different sampling locations; possible toxic conditions in highly polluted segments of the river; substantial differences in river flows between surveys; variable waste loadings; and to the different techniques employed to separate the effects of nitrification. Considering the many factors affecting BOD stabilization, the calculated rates show an overall average of 0.3 day^{-1} with most values within plus or minus 0.1 day^{-1} of the average.

The range of computed rates, as well as the average value computed rates, agree well with values presented in the literature for highly polluted streams. Klein reports CBOD rates for polluted streams between 0.3 and 0.5 day^{-1}.[21] Eckenfelder indicates untreated sewage exhibits CBOD rates between 0.35 and 0.60 day^{-1}.[22] Clean streams have been found to have CBOD rates in the range 0.10-0.12 day^{-1}.[23, 24]

Considering the variability found in the CBOD rates, the average value of 0.3 day^{-1} was applied to the Mahoning River from Leavittsburg to New

TABLE VII-9

CARBONACEOUS BOD REACTION RATES

MAHONING RIVER

(Bottle Rates in Base e, 1/day)

Station Description	River Mile	Survey Date (1975) May 5	June 5	June 17	June 24	July 14-15	July 15-16	July 16-17
Leavitt Road Bridge	46.06	*	.228			.252	.264	.261
B&O RR Bridge	38.66	.116	.225			.256	.309	.304
Below Warren STP	35.80				4.22			
West Park Avenue Bridge	33.71	.194	.329		4.22	.345	.348	.376
Belmont Avenue Bridge	30.48	.305	.233		.410			
USS McDonald Intake	28.83					.339	.337	.363
Liberty Street Bridge	26.77	.170	.267					
Division Street Bridge	23.84	.112	.277					
Bridge Street Bridge	22.73	*	.225			.229	.252	*
Marshall Street Bridge	20.91	.174	.234					
B&O RR Bridge	19.17	.485	.239			.358	.454	.320
Penn Central RR Bridge	17.82	.454	.265					
P&LE RR Bridge	15.83	.502	.289	.397		.264	.266	.329
Washington Street Bridge	12.64	.401	.245	.358		.274	.296	.320
Church Hill Road Bridge	9.69	.234	.205	.372				
Route 224 Bridge	6.76	.273	.181	.386		.270	.245	.348
Brewster Road Bridge	4.34	.126	.195					
Penn Central RR Bridge	1.52	.109	.156	.431		.337	*	.280
Survey Average		.261	.237	.388	.418	.292	.308	.322
Flow cfs								
Leavittsburg	46.02	335	2340		440	442	372	332
Youngstown	22.80	450	3323		702	557	563	479
Lowellville	12.67	566	2550	960		669	669	585

* BOD values did not readily fit first order reaction.

Castle for verification of the RIBAM code. Some of the surveys showed increase in CBOD rates in certain segments of the river. However, variability in the rates at given sampling stations was high and trends seen in the data were not consistent for all surveys. Selection of different rates for different river segments did not appear warranted.

Since BOD bottle rates are all determined at the incubation temperature of the water sample, 20°C, temperature dependence of the CBOD rate cannot be determined from these data. The temperature correction coefficient commonly presented in the literature (1.047) was used to adjust CBOD rates occurring at temperatures other than 20°C.[14]

b. Nitrogenous BOD Reaction Rate

The nitrification of ammonia-N to nitrate-N is a two-stage reaction which, if carried to completion, will consume 4.57 mg/l DO for each mg/l of ammonia-N oxidized.[4] The first stage, the oxidation of ammonia-N to nitrite-N, is the controlling reaction because the conversion proceeds at a slow rate and most of the oxygen depleted in complete nitrification is consumed in this reaction (3.43 mg/l).[4] The second stage is the oxidation of nitrite-N to nitrate-N which can proceed at a rate as much as ten times faster than the first stage and consumes 1.18 mg/l DO for each mg/l of nitrite-N oxidized.[4] Because of the differences in reaction rates, there is generally little accumulation of nitrite-N in the stream.

Since the ammonia-N decay rate is equal to the oxygen uptake rate of nitrogenous biochemical oxygen demand (NBOD), the rate can be determined from bottle BOD values or by applying regression techniques to ammonia-N data along the river. The advantages and disadvantages discussed earlier of using these two methods for CBOD rate determination apply to the use of these techniques for NBOD rate calculation as well. As a result, the Tsivoglou daily log difference procedure was also selected for NBOD rate calculations. Rates calculated with this procedure are representative of the rate for the first stage of nitrification, and could underestimate the disappearance rate of ammonia-N behind channel dams because it does not include the relatively small loss of NH_3-N from settling or direct utilization by plants.

As discussed previously, daily BOD values were determined with and without nitrification inhibited for the June 5 and July 14-17, 1975 surveys. The difference between the measured BOD values is the oxygen depletion

(BOD) resulting from ammonia-N nitrification. Tsivoglou's method was applied to the difference between the BOD values with and without nitrification inhibited to calculate the NBOD reaction rate. The daily log-difference procedure was also used to compute NBOD rates for the May 5, June 17, and June 24 surveys but only for those stations where the CBOD and NBOD reactions could be separated because of a time lag before nitrification began. The computed NBOD rates for all surveys are presented in Table VII–10.

A significant difference was found between NBOD rates computed when nitrification was chemically inhibited and when CBOD and NBOD were separated based upon the time lag. For the surveys where nitrification was not inhibited, NBOD rates show a large variability (0.2-1.2 day^{-1}). However, in the surveys when CBOD and NBOD were chemically separated, NBOD rates show only minor variations. All rates except two were within 0.1 of the mean value of 0.276 day^{-1}. Also when the BOD's were chemically separated, the data indicate that at most locations, nitrification was starting immediately. Hence, the time-lag method of separation does not appear to be a good method for correctly and consistently separating the reactions of nitrification and CBOD stabilization. For this reason, the nitrification rate calculated from the chemically inhibited samples was used as input to the RIBAM code.

Examination of the calculated rates showed no consistent trends along the river. Rates computed from the June 5 survey data indicate an increase in the reaction rate in the Youngstown area, however, the survey was conducted during a period of very high flow. No discernible trend was seen in the calculated rates determined from the three-day July survey which was conducted during a period approaching summer critical low flows. As a result, the average computed NBOD rate (0.276 day^{-1}) was applied to the river from Leavittsburg to New Castle. A temperature correction coefficient of 1.10 as shown in Eckenfelder and Thomann is used to adjust the NBOD rate input to the model.[22, 23]

The reaction rate for the oxidation of nitrite-N to nitrate-N, the second stage of the nitrification of ammonia-N, cannot be calculated from the data collected. Therefore, values found in the literature for the nitrite–N reaction rate (2.0 day^{-1}) and the temperature dependence of this reaction (1.06) were used in the model.[4, 23]

TABLE VII-10

NITROGENOUS BOD REACTION RATES

MAHONING RIVER

(Bottle Rates in Base e, 1/day)

Station Description	River Mile	Survey Date (1975) May 5	June 5	June 17	June 24	July 14-15	July 15-16	July 16-17
Leavitt Road Bridge	46.06	*	.268			-	-	-
B&O RR Bridge	38.66	.197	*			-	-	-
Below Warren STP	35.80				*			
West Park Avenue Bridge	33.71	.199	.086		*	.315	.230	.272
Belmont Avenue Bridge	30.48	.454	.218		*			
USS McDonald Intake	28.83					.265	.290	.250
Liberty Street Bridge	26.77	.726	.200					
Division Street Bridge	23.84	.569	.213					
Bridge Street Bridge	22.73	*	.222			.234	.268	.193
Marshall Street Bridge	20.91	.456	.242					
B&O RR Bridge	19.17	.469	.351			.262	.287	.245
Penn Central RR Bridge	17.82	.338	.372					
P&LE RR Bridge	15.83	.930	.313	.366		.223	.316	.282
Washington Street Bridge	12.64	.845	.310	.313		.338	.289	.362
Church Hill Road Bridge	9.69	.401	.465	.310				
Route 224 Bridge	6.76	.333	.294	.386		.245	.329	.279
Brewster Road Bridge	4.34	.587	.360	.289				
Penn Central RR Bridge	1.52	1.204	*	.288		.285	.334	.283
Survey Average		.551	.280	.325	*	.258	.292	.271
Flow cfs								
Leavittsburg	46.02	335	2340		440	442	372	332
Youngstown	22.80	450	3323		702	557	563	479
Lowellville	12.67	566	2550	960		669	669	585

* Data do not readily fit a first order reaction.
- Insufficient amount of nitrification to determine rate.

c. Total Cyanide Reaction Rate

The decay of cyanide compounds in the Mahoning River is assumed to obey a first-order reaction. This reaction is thought to be chiefly biological in nature, although instream settling may account for some removal. Linear regression analysis was employed to calculate the decay rate in conjunction with field measurements and computed travel times. Since the major sources of cyanide compounds in the Mahoning are blast furnaces and coke plants, maximum instream concentrations are found just downstream of the steel plants in Youngstown and Struthers. Hence, the segment of the Mahoning from Struthers to New Castle is an appropriate stretch to evaluate total cyanide destruction as maximum stream concentrations occur at the head of the reach and no major sources of total cyanide enter below that point. Assuming a first-order reaction, the rate is calculated by taking the natural logarithm of the flowing total cyanide loadings in the stream and plotting the values on Cartesian coordinate paper with travel time on the abscissa. The slope of the best fit line calculated by linear regression is the stream reaction rate.

Total cyanide was studied during six USEPA sampling programs conducted on the Mahoning River between February and July 1975. However, data from only three of these surveys (February 11-14, May 5, and July 14-17) were suitable for calculation of total cyanide reaction rates. Because of high streamflow and low steel production, total cyanide was not found in sufficient quantities to compute reaction rates during the June 17 and June 24, 1975 surveys. As discussed earlier, the flow regime encountered during the June 5, 1975 survey was high and did not exhibit steady-state conditions, making it impossible to calculate streamflows and travel times necessary to compute the reaction rate.

The computed rates for the remaining three surveys, along with the average measured river temperature in the reach, are presented in Table VII-11. Since these reaction rates were determined over a wide range of temperatures (7.7-26.9^{o}C), the rates and the corresponding temperatures were used to derive both the average reaction rate of 20^{o}C and the temperature correction coefficient. Assuming an Ahrrhenius temperature dependence, regression analysis was used to calculate cyanide reaction rate

TABLE VII-11

TOTAL CYANIDE REACTION RATES

MAHONING RIVER

Survey Date	Temperature (°C)	Rate (1/day) (Base e)
February 11-14, 1975	7.7	0.797
May 5, 1975	21.3	1.366
July 14-27, 1975	26.9	1.971

Computed rate at 20°C 1.35

Temperature correction factor (θ) 1.05

$$K(T) = K(20)\theta^{(T-20)}$$

at 20°C of 1.35 day^{-1} and a temperature correction factor of 1.05. The high correlation of this regression (r^2 = 0.98) indicates a good fit of the curve to the data.

Because several planned studies did not produce total cyanide data suitable for computation of reaction rates, data for the February and July comprehensive surveys had to be included in the rate determinations, notably with respect computation of rate dependence on temperature (θ). Hence, in order to verify the total cyanide reaction rate and temperature correction coefficient (θ) below Lowellville, a verification of the rates with a data set other than the February and July data was made.

d. Phenolics Reaction Rates

The destruction of phenolic compounds in a stream results from oxidation by aerobic bacteria belonging chiefly to the genera Achromobacter, Vibrio, Micrococcus, Pseudomonas, and Nocardia.[21] However, other removal mechanisms may include sedimentation with particulate matter, and possibly air stripping in turbulent reaches. The total reaction rate or removal rate of these compounds in the Mahoning River by all mechanisms was calculated using the same curve fitting techniques employed for total cyanide rate determinations. Stream data from five of the six Mahoning River sampling programs were used to compute reaction rates at measured stream temperatures (Table VII-12). The June 5, 1975 survey data could not be included because of high and unstable streamflow.

The calculated rates show a typical Ahrrhenius temperature dependence except for the rate encountered during the July 14-17, 1975 survey which appears slightly low. Excluding the July survey rate, regression techniques were applied to calculate a temperature correction coefficient (θ) of 1.06 and a phenolic reaction rate (K_p) of 3.71 at 20°C. The correlation coefficient of this regression (r^2 = 0.995) indicates that these rates closely fit the assumed temperature dependence. A slightly smaller value of θ_p was computed when the July rate was included, however a poorer fit to a single curve was found (r^2 = 0.88). Because of this, the values of θ_p and K_p, calculated by excluding the July survey rate, were employed for model verification. The lower phenolic reaction rate in July and only small rate differences in the temperature range of 21-27°C possibly indicates an attenuation of the phenol rate temperature dependence at

TABLE VII-12

PHENOLICS REACTION RATES

MAHONING RIVER

Survey Date	Temperature (^{o}C)	Rate (1/day) (Base e)
February 11-14, 1975	7.7	1.80
May 5, 1975	21.4	4.26
June 17, 1975	25.9	5.05
June 24, 1975	24.0	4.82
July 14-17, 1975	26.9	3.98

Computed rate at $20^{o}C$	Concentration > 20 μg/l	3.71 day^{-1}
Computed rate at $20^{o}C$	Concentration < 20 μg/l	1.58 day^{-1}
Temperature Correction Factor (θ)		1.06

$$K(T) = K(20)\theta^{(T-20)}$$

temperatures above 20°C. Additional rate data on the Mahoning River at temperatures in the 30-40°C range are needed to substantiate this hypothesis and determine the appropriate mathematical relationships for high stream temperatures. However, the necessity of obtaining such data may be mitigated should thermal discharge limitations be imposed which would prevent the river from reaching abnormally high temperatures.

An examination of the phenolic data used to calculate rates, shows that a large drop in concentration occurs between Struthers (RM 15.83) and Lowellville (RM 12.64), however, below Lowellville phenolic destruction appears slower. An examination of sediment quality (Table VII-21) shows no accumulation in the sediments between these points; in fact, the measured sediment phenolic concentration is less at Lowellville. Hence, biological oxidation appears to be the primary cause for the decay. Regression analysis on the data from Lowellville downstream results in significantly lower reaction rates than the values shown on Table VII-12, except for the February survey when phenolic values below Lowellville were above 50 µg/l. In discussing phenolic reactions, Klein indicates different phenolic compounds react at different rates with some compounds (nitrophenols) unable to be oxidized by bacteria.[32] It appears reasonable, therefore, that rate differences seen in the Mahoning are attributable to the presence of at least two different classes of phenolic compounds, each having different characteristic reaction rates. As the faster reacting compounds are depleted, slow reacting compounds are more readily seen oxidizing in the stream.

To incorporate the above findings into a single first order reaction equation as contained in RIBAM, it was assumed for modeling purposes that the phenolic reaction rate is dependent on stream concentrations. The data show that the phenolic concentration below which a lower reaction rate appears evident is about 20 µg/l. For concentrations less than 20 µg/l, a rate of 1.58 day^{-1} was calculated from the data. Since stream concentrations in the 5-20 µg/l range are expected after point source controls are installed, the rate of 1.58 day^{-1} was employed for modeling various waste treatment alternatives. For verification purposes, the lower reaction was used in those river segments where the computed phenolic concentrations dropped below 20 µg/l.

Although more reaction rate data were obtained for phenolics than for total cyanide, the February survey data were used to compute the rate at 20°C and temperature dependence because these data were obtained at low stream temperatures, thus providing a good range of data for computing the temperature correction coefficient (θ). A verification of the phenolics rate and temperature dependence below Lowellville with a data set other than the February and July data was also made.

e. Dissolved Oxygen Reaeration

The waste assimilation capacity of a stream for oxygen demanding materials is partially dependent upon the rate at which oxygen from the atmosphere enters the stream.[25] It is generally held that the rate of reaeration in free-flowing stream segments is governed by physical laws and is dependent upon such hydraulic parameters as velocity, depth, and energy loss in the stream.[5, 24, 25, 26] Significant dissolved oxygen reaeration also occurs as water tumbles over channel dams or natural stream falls. Insufficient data were obtained during the sampling programs on the Mahoning River to enable DO reaeration formulations to be developed for the river. Therefore, a review was made of recently published literature in order to select a reaeration formulation which can be applied to hydraulic conditions encountered on the Mahoning River.

Several methods for calculating atmospheric reaeration have been developed for use in mathematical water quality models. A review of the literature indicates that the most commonly used reaeration formulations were developed by O'Connor-Dobbins (1958), Churchill, et al. (1962), Owens, et al. (1962), and Tsivoglou (1972).[5, 24, 25, 26] O'Connor's, Churchill's and Owen's formulations assume reaeration to be a function of stream velocity and depth with all three expressions of the form:

$$K_2 = \frac{aV^b}{D^c} \qquad 7.16$$

where K = reaeration rate

V = stream velocity

D = stream depth

a,b,c = emperical constants

Values of a, b, and c were determined from field data and are different for the three formulations. Tsivoglou, on the other hand, using gas tracer techniques, concluded that the reaeration rate coefficient is directly proportional to the rate of energy expenditure in nontidal streams. To depict this relationship, Tsivoglou suggested the following equation:

$$K_2 = 0.054\ (\Delta h/t) \text{ at } 25^{o}C \qquad 7.17$$

where Δh = change in water elevation in feet
t = time in days

In a recent review of reaeration formulations, Covar indicates that considerable scatter was found in data used by Tsivoglou and that data from streams with different hydraulic characteristics were used to develop the formulations by Churchill, O'Connor and Owens.[27] Covar arrives at the conclusion that the studies by Churchill, O'Connor and Owens are the most appropriate formulation when applied to streams with a combination of depth and velocity similar to that used in the original research.

Different flow regimes were encountered on the Mahoning River during the February and July 1975 comprehensive water quality surveys. For the February survey, the average river flow was about 1060 cfs at Youngstown with the river exhibiting combinations of velocity and depth which were at the borderline between the use of O'Connor-Dobbins formulation and the Churchill formulation. Both relationships give essentially the same reaeration rate for the velocities and depths determined at this flow. In the July survey, the flow at Youngstown was much lower (530 cfs) with corresponding lower velocities and depths. For these combinations of flow and velocity, the O'Connor-Dobbins formulation appears more appropriate. Considering that the velocities and depths encountered in the Mahoning River over a large range of flow are similar to the stream characteristics reported in the original research by O'Connor, the O'Connor-Dobbins equation was used to calculate reaeration in the free-flowing segments of the Mahoning River.

The equation for the reaeration occurring at channel dams (Equation 7.10) was calibrated using data obtained on July 15 and 16, 1975.

DO measurements were taken a short distance upstream and downstream of four dams. Data were obtained far enough downstream to insure complete mixing, generally a few hundred feet. These data, along with stream temperature data, were used to compute the ratio of the DO deficit above and below each dam as well as the multiplicative factor (axb) contained in Equation 7.10. Since the factors (axb) cannot be input to the RIBAM code, dam heights input to code for the February and July verification studies were adjusted by the factors shown in Table VII-13. For the Summit Street and Republic Steel dams in Warren, height adjustments were not made because this portion of the stream is currently relatively unpolluted and such dams, according to Owens, would allow more reaeration than dams in polluted segments. Dam heights at the Liberty Street dam and the remains of the Marshall Street dam were adjusted by the average of the calibrated factors. The adjustment for the Lowellville Dam was excluded when computing the average adjustment factor because of the atypical physical structure of this dam. An adjustment factor of 1.0 for clean streams was applied for water quality projections with significant treatment.

f. Sediment Oxygen Demand

Because of the potential impact of the sediment oxygen demand (SOD) on the dissolved oxygen balance in the Mahoning River, field studies were conducted on May 21-22, 1975 and July 23-24, 1975 to roughly quantify SOD rates at selected locations along the main stem of the stream. A benthic respirometer of known volume and bottom surface area was employed to measure the change in dissolved oxygen over time. The change in dissolved oxygen over the same time period was also determined in a BOD bottle suspended in the stream containing river water. The effects of normal BOD decay and algal respiration would be accounted for in the bottle, thus permitting isolation of the sediment effect in the respirometer. Field tests were generally completed along the sides of the stream rather than in the center owing to the nature of sedimentation in the river discussed earlier and the large amount of rubble and debris found at many stations.

Table VII-14 presents SOD rates determined at ten locations in this fashion. Higher rates were generally found in the Youngstown-Lowellville area, with lesser rates in the Leavittsburg-Niles area and in Pennsylvania.

TABLE VII-13

DAM HEIGHT ADJUSTMENT FACTORS

MAHONING RIVER

Channel Dam	Actual Height (H in feet)	Da/Db*	Computed factor (ab)
U. S. Steel Ohio Works			
July 15, 1975	7.5	1.8	0.42
July 16, 1975		1.6	0.30
Republic Steel, Youngstown			
July 16, 1975	3.0	1.4	0.52
Youngstown Sheet and Tube Campbell Works			
July 16, 1975	5.7	1.6	0.45
Lowellville			
July 16, 1975	4.6	1.8	0.65**
Average			0.42

* Ratio of measured DO deficit above dam to DO deficit below dam.

** Not included in average because of atypical physical geometry of Lowellville Dam.

Equation 7.10 $Da/Db = 1 + 0.11\ ab\ (1 + 0.046T)H$

TABLE VII-14

SEDIMENT OXYGEN DEMAND

LOWER MAHONING RIVER

Station	Location	River Mile	Sample Date	Stream Temp.	SOD at Ambient Temp. (gm/m^2 day)	SOD at 20°C (gm/m^2 day)
1	Leavittsburg	46.08	5/21/75	18.5°C	1.77	1.90
-	Warren	40.02	7/24/75	23.0°C	3.24	2.80
-	Niles	30.45	5/21/75	24.5°C	0.32	0.26
-	Youngstown	23.84	7/24/75	29.0°C	8.40	5.41
8	Youngstown	22.73	5/22/75	28.0°C	1.30	0.88
10	Youngstown	19.17	7/24/75	26.0°C	6.91	5.16
12	Struthers	15.83	5/22/75	30.0°C	10.07	6.18
-	Lowellville	13.52	5/23/75	27.0°C	11.66	8.28
-	Lowellville	13.52	7/23/75	27.5°C	4.53	3.14
14	Church Hill Rd.	9.69	5/23/75	28.0°C	2.81	1.90
17	New Castle, Pa.	1.52	7/23/75	27.0°C	0.66	0.47

Rates were determined at the same station near Lowellville (RM 13.52) in May and July 1975, respectively, at different points along the cross-section of the stream. The large difference in the rates obtained at nearly the same temperature suggests high variability in the data, as expected. The rates determined at ambient temperatures (18.5-30^{o}C) were adjusted to 20^{o}C assuming an Ahrrhenius temperature dependence (θ = 1.05) after Velz.[4] For model verification purposes, these rates were adjusted to ambient temperature and applied to the percent of bottom covered with sediment as determined by the Corps of Engineers (Figure VII-48). Based upon sediment quality data, the SOD rates at certain stations may be inhibited. Hence, a longer period of time may be required in some locations than in others for the in situ demand to be satisfied once point sources of organic solids are controlled.

4. Comprehensive Basin Surveys

During February 11-14, 1975 and July 14-17, 1975, comprehensive basin surveys were completed to obtain sufficient data to verify RIBAM for water quality simulation purposes. These comprehensive surveys included 23 stream and tributary sampling stations in February and 29 in July, eight municipal sewage treatment plants, one electric power generating station, and about 40 separate discharge points from the valley steel plants. Three consecutive 24-hour composite samples were obtained by USEPA personnel at most stream and tributary stations. Three stream stations were sampled for temperature and dissolved oxygen only in February. Plant operators at the eight sewage treatment plants obtained grab samples which were composited proportional to flow by USEPA personnel. Twenty-four hour composite samples were obtained by Republic Steel with the company's automatic samplers. One U. S. Steel plant was sampled by the company and one by USEPA personnel. Twenty-four hour composite samples were obtained at each U. S. Steel facility during the February survey, while only twice daily grab samples were obtained at the Ohio Works during the July survey because of curtailed production. Twenty-four hour composite samples were obtained at the McDonald Mills in July. The Youngstown Sheet and Tube Company obtained eight-hour composite samples at its facilities. Municipal and industrial samples were obtained in pre-preserved containers provided by USEPA, and, with the exception of Republic Steel samples, all were iced or refrigerated during collection. Laboratory analyses were completed by USEPA laboratories in Cleveland and Chicago. The February survey was completed during a period of full steel production, while the July survey was completed during a period of low production.

Hourly gage heights were obtained at the Leavittsburg, Youngstown, and Lowellville USGS gages to determine main stem streamflow. Selected tributaries were gaged by USEPA personnel at least six times per day during both surveys. Effluent flows from municipal sewage treatment plants were obtained from plant flow meters while estimates or measurements of industrial effluent flow rates were provided by the respective companies.

a. February 11-14, 1975 Comprehensive Survey

1) Hydrology

The February and July surveys were designed to quantify instream quality and significant waste discharges during periods of winter and summer critical flows, respectively. Although winter critical flows have historically occurred with the greatest frequency during the month of February,[28] greater runoff and reservoir releases were experienced during February 1975 resulting in the daily hydrograph shown in Figure VII-1. Considering the day-to-day variations in streamflow that can occur, the flow was remarkably stable during the three-day survey as illustrated in Figure VII-2 and can be considered to be representative of steady-state conditions. Since the computed time-of-travel from Leavittsburg to the most downstream sampling station for the flows experienced during the survey was slightly less than two days, the sampling period of three days exceeded the time-of-travel by about 50 percent. Thus, the water flowing by the Leavittsburg sampling station at the start of the survey had completely passed through the study area. Travel time throughout the study area at flows encountered during the February and July surveys are compared with times-of-travel at winter and summer critical flows in Figure VII-3. From these data, it is apparent that the February survey results are not representative of winter critical flow conditions (1061 cfs vs 225 cfs at Youngstown), but the data obtained are nonetheless valid for model verification purposes.

FIGURE VII - 1
MOHONING RIVER BASIN
DAILY HYDROGRAPH
FEBRUARY 1975

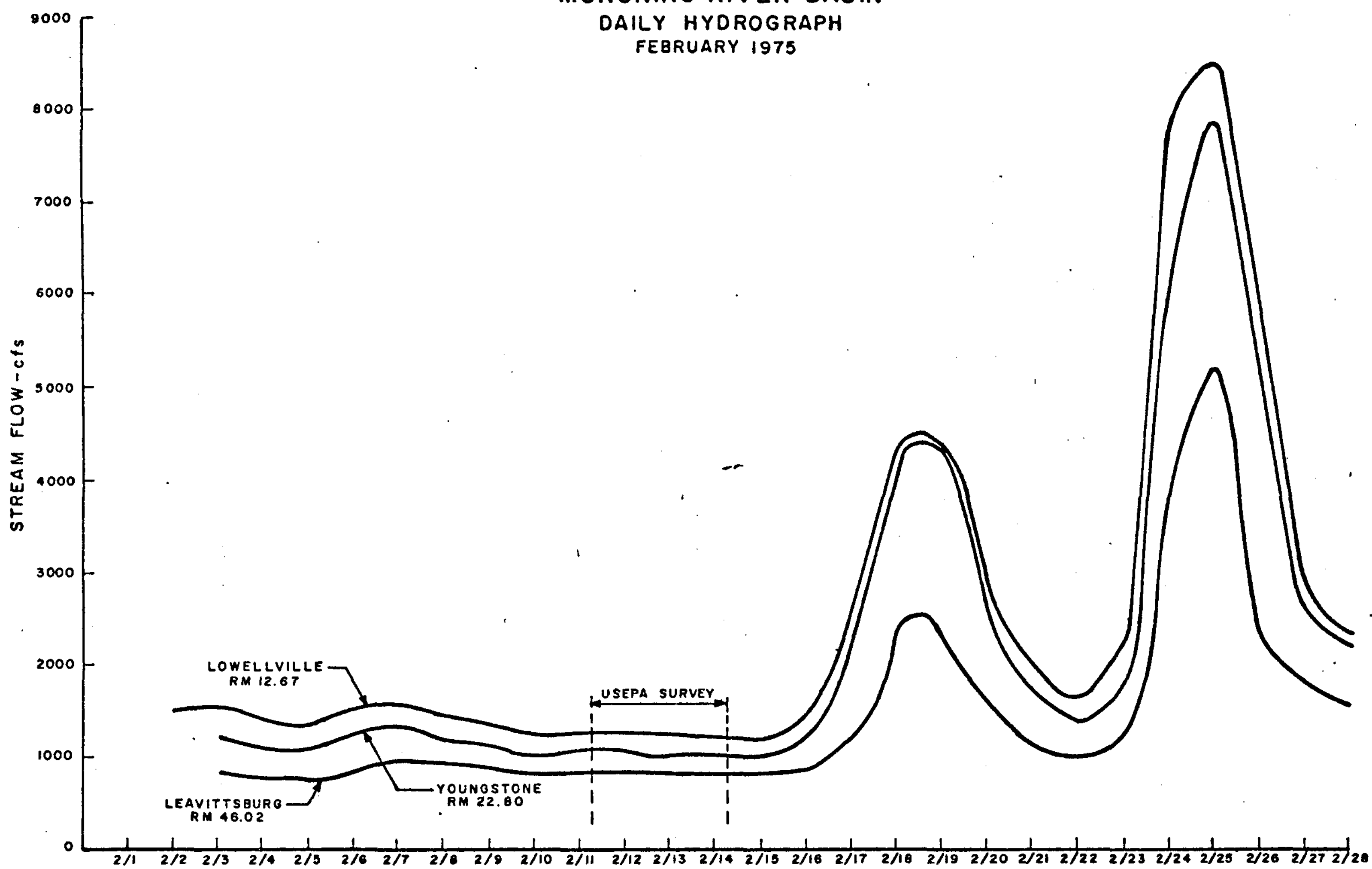
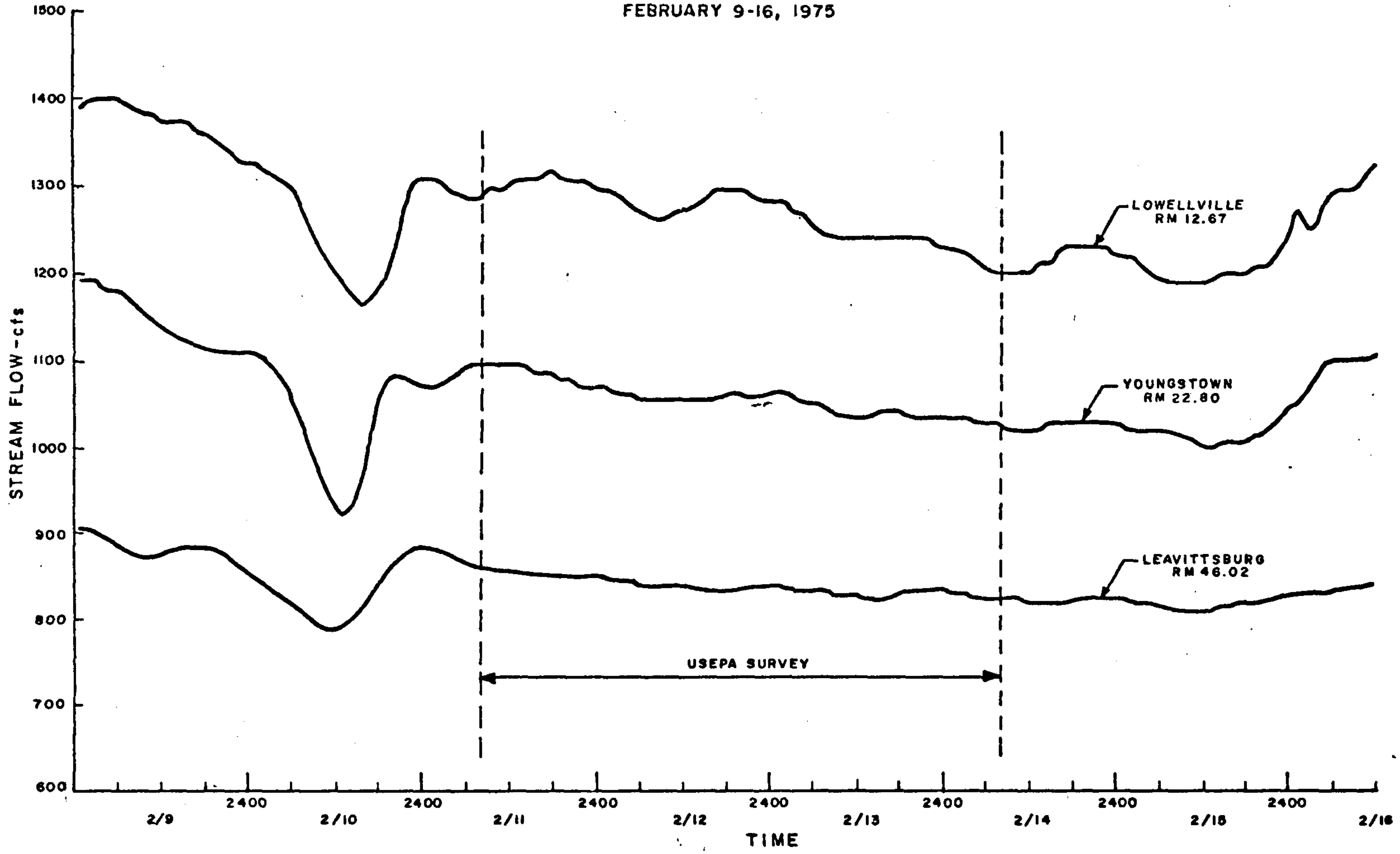


FIGURE VII-2
MOHONING RIVER BASIN
HOURLY HYDROGRAPH
FEBRUARY 9-16, 1975



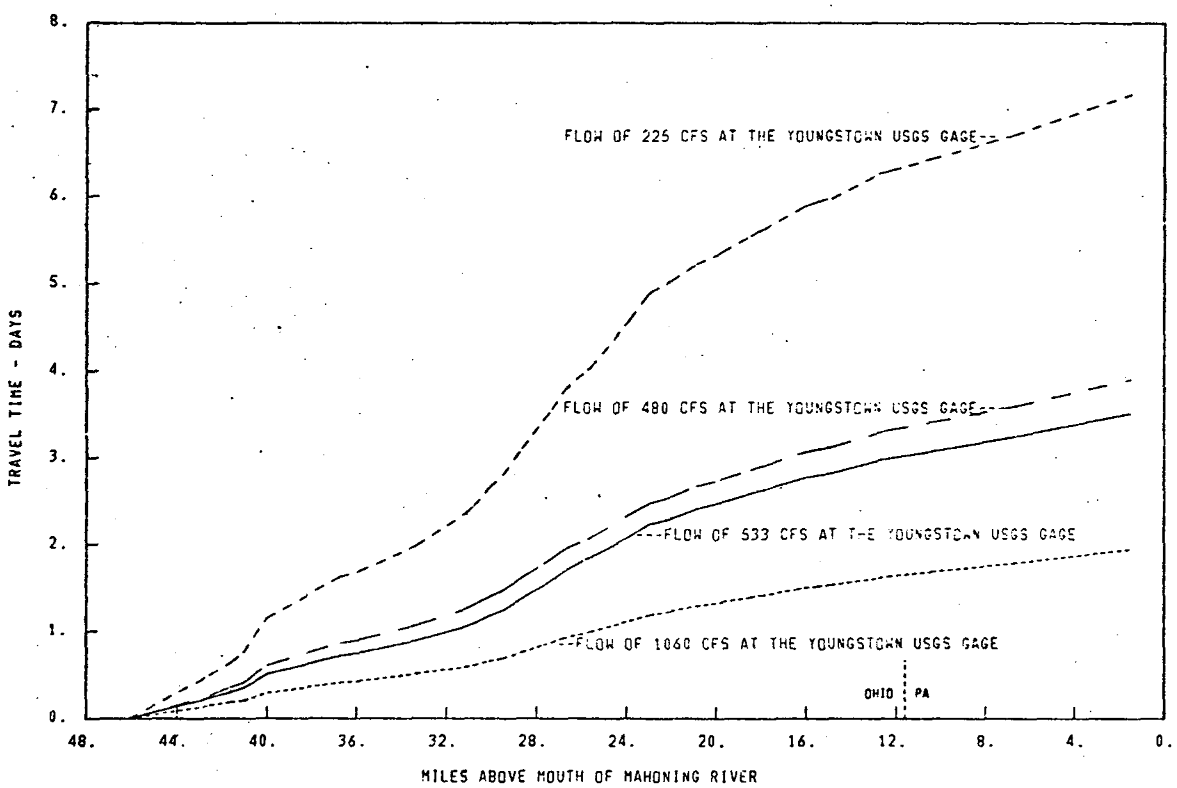


FIGURE VII-3
TRAVEL TIME VS. RIVER MILE
LOWER MAHONING RIVER

Figure VII-4 presents the three-day average main stem flow profile for the February survey and the maximum and minimum daily average flows recorded at the Leavittsburg, Youngstown, and Lowellville USGS stream gages. The distribution of flow between the gages and downstream of Lowellville was reviewed earlier.

2) Weather Conditions

The February 1975 survey was completed during a period of seasonal weather for the month of February. Air temperatures at the river (measured at the Youngstown STP) ranged from about 20 to 35°F, while air temperatures at the Youngstown Airport were slightly colder, ranging from 12 to 28°F and averaging about 21°F.[29] The Youngstown Airport is located about eleven miles north of Youngstown and is 250-300 feet higher in elevation than the river near the Youngstown STP.

Wind velocity was highly variable at the Youngstown STP ranging from calm conditions to 14 mph and averaging 4.5 mph, which is less than the average wind velocity recorded at the Youngstown Airport for the same period (12.4 mph).[29] Wind direction at both locations was also variable but winds were generally from the northwest. Barometric pressure at the Youngstown STP exhibited a generally rising trend throughout the survey ranging from 29.89 to 30.06 inches of mercury on February 11-12, from 29.83 to 30.10 inches on February 12-13, and 30.10 to 30.18 inches on February 13-14, 1975. Cloud cover exceeded 0.9 during the three-day survey and two periods of snowfall were recorded.[29] The first snowfall was relatively light and occurred during the early morning hours of February 12. However, the second snowfall occurred on February 13 and was more severe, amounting to one to three inches at places.

Aside from the snowfall and efforts by local municipalities in salting roads, the weather conditions should have had no measureable impact on streamflow. The effects of melting snow from road salting were negligible since the flow at the Youngstown and Lowellville gages showed no appreciable changes as illustrated in Figure VII-2. Possible effects of road salting on stream quality are discussed elsewhere. The cold weather necessitated a change to manual stream sampling at many stream stations from automatic sampling as the inlet tubing to the automatic sampling

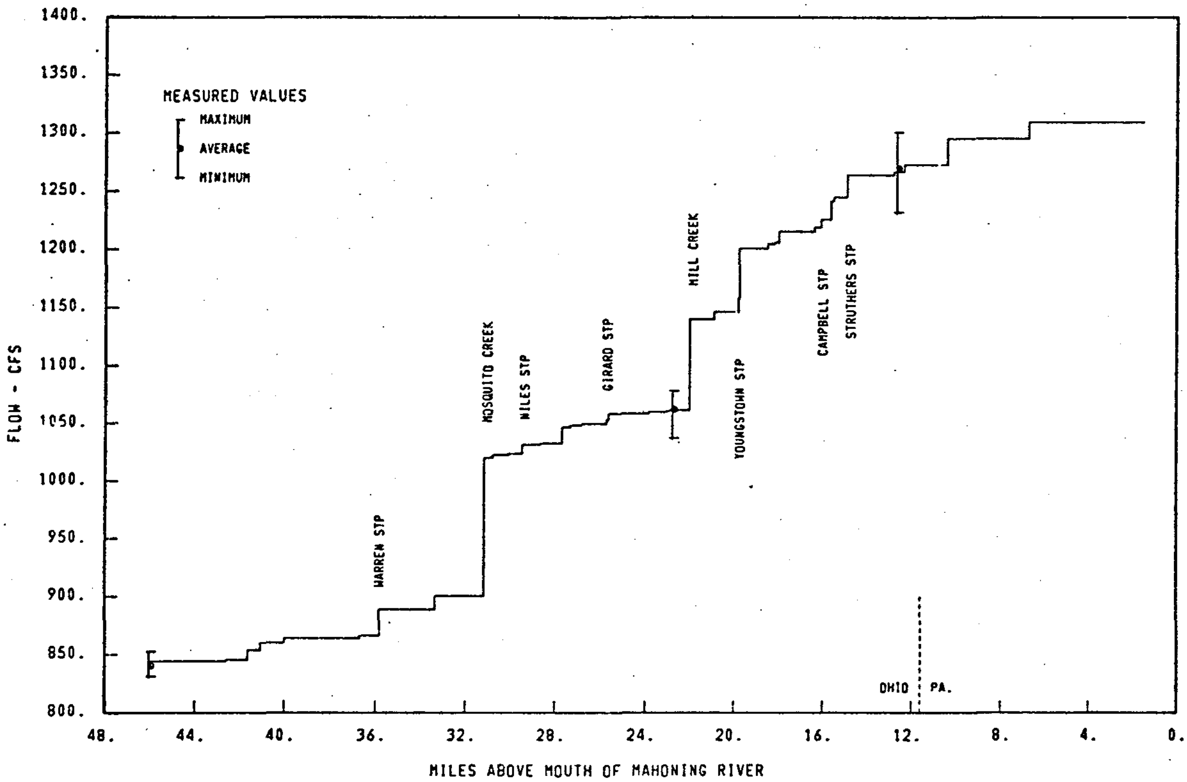


FIGURE VII-4
MAIN STEM FLOW PROFILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

devices tended to freeze. Also, air temperatures below freezing rendered the computation of wet bulb temperature from psychometric formulae imprecise at best.[30] Wet bulb temperature is an input to the Qual-1 water temperature model.

3) Sampling Stations

a) Main Stem and Tributary Stations

Figure VII-5 illustrates the location of the 17 main stem and six tributary sampling stations employed during the February survey. Table VII-15 presents station descriptions. Most main stem stations were selected at convenient highway or railroad bridges spanning the river. The design was to bracket significant municipal and industrial dischargers and significant tributaries. Industrial water supply intakes at the Republic Steel-Warren Plant, the Ohio Edison plant, and both U. S. Steel plants were selected because of their convenient locations. Also, the use of industrial water supply intakes as river stations reduced the required number of chemical analyses.

Because of the relatively shallow depth of the river (average depth about four feet), turbulence occurring at the low head dams, and moderate stream velocities, near complete vertical mixing of effluent discharges with the stream occurs rapidly. Lateral mixing is aided by the large temperature differences between most industrial dischargers and the stream; the force at which some of the larger discharges enter the river; industrial use of the total stream at flows less than 1200 cfs at Youngstown; and the many changes in the direction of the river, notably in the upper reaches. Although lateral mixing usually requires longer distances to occur than vertical mixing,[31] most stream stations were located sufficiently downstream of significant point source discharges to assure that adequate mixing has occurred. For this reason, samples were taken at only one location at each station, generally near the center of the stream. However, because of the concentration of discharges, in the lower Youngstown-Campbell-Struthers area, complete lateral mixing of the wastes discharged between sampling stations may not occur. This is probably more significant at Station 10, located less than 500 feet below the Republic Steel-Youngstown Plant coke

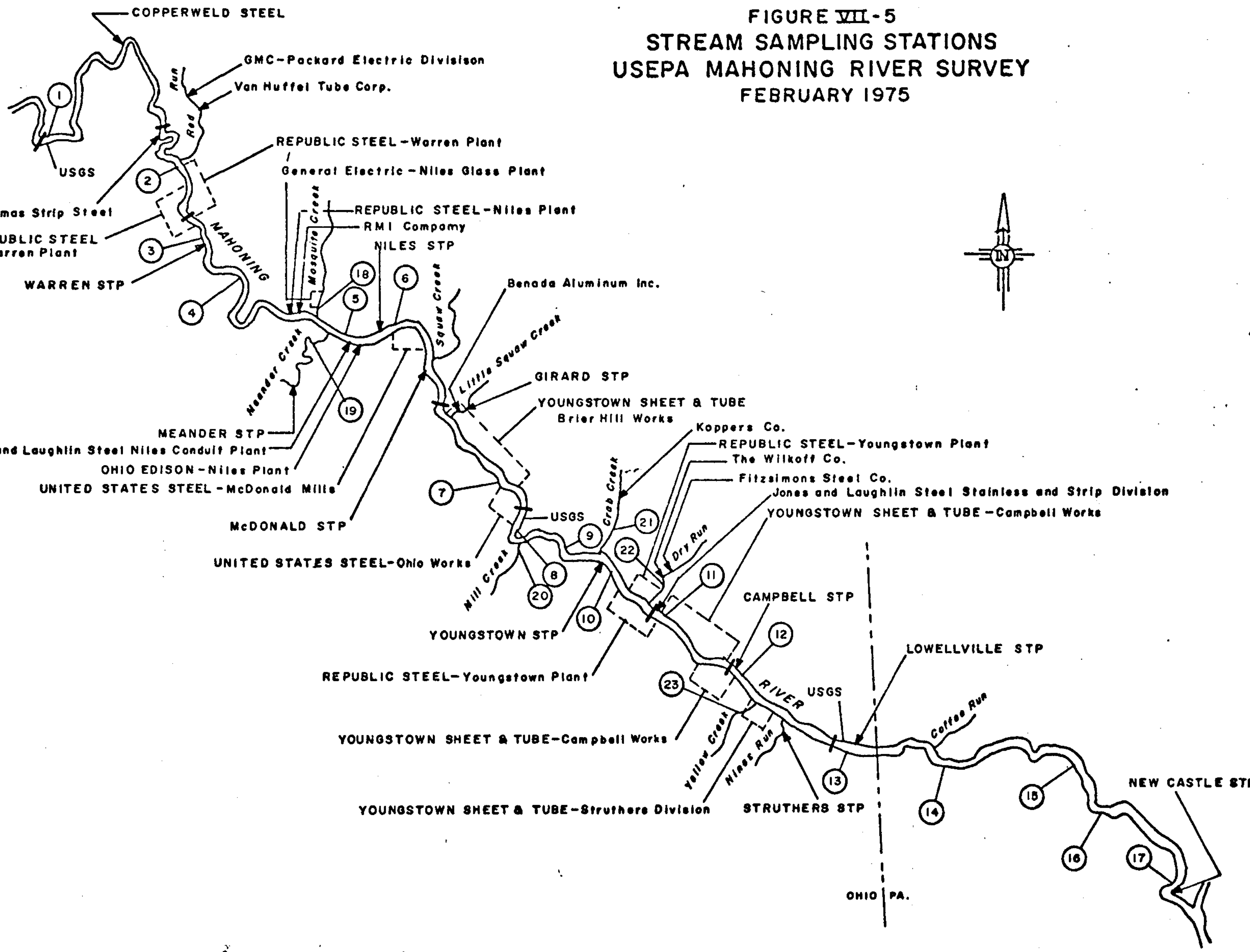


FIGURE VII-5
STREAM SAMPLING STATIONS
USEPA MAHONING RIVER SURVEY
FEBRUARY 1975

TABLE VII-15

STREAM SAMPLING STATIONS
USEPA MAHONING RIVER SURVEY
February 11-14, 1975

MAIN STEM STATIONS

Station Number	River Mile	Description
1	46.02	Leavitt Road
2	37.76	Republic Steel-Warren Plant Intake
3	35.83	100' Upstream from Warren STP
4	33.71	West Park Avenue
5	30.14	Ohio Edison Intake
6	28.83	U. S. Steel-McDonald Mills Intake
7	23.43	U. S. Steel-Ohio Works Intake
8	22.73	Bridge Street
9	20.91	Marshall Street
10	19.17	B and O RR - Youngstown
11	17.82	Penn Central RR - Youngstown
12	15.83	P and LE RR - Struthers
13	12.64	Washington Street
14	9.69	Church Hill Road (Pa)
15	6.76	Route 224 (Pa.)
16	4.34	Brewster Road (Pa.)
17	1.52	Penn Central RR (Pa.)

TRIBUTARY STATIONS

Station Number	Tributary (River Mile)		Description (Miles Above Mahoning River)	
18	Mosquito Creek	(31.14)	Penn Central RR	(0.14)
19	Meander Creek	(30.77)	Route 46	(0.81)
20	Mill Creek	(22.03)	Mahoning Avenue	(0.04)
21	Crab Creek	(19.81)	Elk Street	(0.47)
22	Dry Run	(18.47)	P and LE RR	(0.13)
23	Yellow Creek	(15.63)	Yellow Creek Park Dam	(0.44)

plant discharge, and Station 12, located less than 2000 feet below the Youngstown Sheet and Tube Company-Campbell Works coke plant and blast furnace discharges.

Of the industrial intake stations, Station 7 at the U. S. Steel-Ohio Works may not fully take into account the blast furnace discharge of Youngstown Sheet and Tube Company-Brier Hill Works located on the opposite side of the river about 1000 feet upstream for the intake, and the Niles STP discharge may not be completely mixed with the river as it passes the U. S. Steel-McDonald Mills intake at Station 6 about 3000 feet downstream. The Republic Steel-Warren Plant intake (Station 2) and the Ohio Edison intake (Station 5) are located sufficiently downstream of significant point sources and tributaries to assure near complete mixing.

Because of resource limitations, only the six largest tributaries were sampled during the February survey. These were sampled as close to the respective confluences with the Mahoning River as possible.

b) Municipal Sewage Treatment Plant Stations

Twenty-four hour composite discharge samples were obtained by sewage treatment plant personnel at Warren, Niles, Girard, Youngstown, Campbell, and Struthers. Twelve-hour and eight-hour composite samples were obtained by plant personnel at the McDonald and Lowellville plants, respectively.

c) Industrial Stations

Table VII-16 provides a summary of the industrial intake and discharge sampling stations employed during the survey. Because of laboratory resources limitations, only the most significant discharges could be sampled. Twenty-four hour composite samples were obtained by USEPA personnel at Copperweld Steel and at the U. S. Steel-McDonald Mills. The U. S. Steel-Ohio Works intake (stream Station 7) was sampled by the USEPA, while U. S. Steel personnel sampled the Ohio Works discharges.

With the exception of the most upstream intake at the Warren Plant (stream Station 2), which was sampled by the USEPA, Republic Steel obtained 24-hour composite intake and effluent samples for the Warren and Youngstown Plants employing automatic samplers. The Niles Plant was not

TABLE VII-16

INDUSTRIAL SAMPLING STATIONS

USEPA MAHONING RIVER SURVEY

February 11-14, 1975

	Republic Steel Corporation		U. S. Steel Corporation		Youngstown Sheet and Tube Co.		Ohio Edison Co.
Copperweld Steel	Warren Plant	Youngstown Plant	McDonald Mills	Ohio Works	Brier Hill Works	Campbell Works	Niles Generating Station
River Intake	River Intake G001	River Intake J002	River Intake	River Intake	River Intake	River Intake	River Intake
Outfall 002	River Intake G002	Outfall 006-008	Outfall 005	Outfall 001	Outfall 003	Outfall 002	Outfall 002
	Outfall 008	011		002	005	007	
	009	013		003		012	
	010	014				014	
	013	015				015	
	014	016				017	
						024	
						025	
						026-A	
						040	
						041	

sampled due to curtailed production. The Youngstown Sheet and Tube Company provided eight-hour composite samples for the Brier Hill Works and Campbell Works. The Struthers Division was not sampled. The Ohio Edison intake (stream Station 5) and the condenser cooling water discharge were sampled by USEPA personnel.

4) Survey Results

Table VII-17 lists the water quality constituents studied at each stream and tributary station and municipal and industrial discharge. Tables 5 and 6 of Appendix A summarize the daily municipal and industrial effluent discharge data obtained during the February survey, respectively. A complete compilation of the raw data is on file at the USEPA, Region V, Eastern District Office. Figures VII-6 through VII-22 graphically depict trends in stream quality along the main stem of the river. A tabular presentation of the water quality data, including tributary data, is made in Appendix B, Table 7. Total cyanide and phenolics were measured at only those industrial discharges where the presence of total cyanide or phenolics was either known or suspected. Although the discharge of oil and grease causes severe water quality problems, oil and grease determinations were not made during the survey because of laboratory resource limitations. Likewise, microbiological analyses of the stream and sewage treatment plant discharges and phytoplankton analyses of the stream could not be made. Table VII-18 presents sediment chemistry data obtained on March 7, 1975.

The discussion presented below is more qualitative than quantitative. Emphasis is placed upon describing general water quality trends, reviewing compliance with Pennsylvania water quality standards, and the relationship between significant discharges and stream quality. Additional discussion of those constituents modeled (temperature, dissolved oxygen, CBOD, ammonia-N, nitrite-N, total cyanide, and phenolics) is presented in Section VII-C, Verification Results. The stream data are reviewed in the following groupings:

- Temperature, dissolved oxygen, nutrients, suspended solids
- Dissolved solids, fluoride, sodium, chloride, and sulfate
- Total cyanide, phenolics
- Metals

TABLE VII-17

WATER QUALITY CONSTITUENTS

USEPA MAHONING RIVER SURVEY

February 11-14, 1975

Field Measurements

- Flow (tributaries only)
- Temperature
- Dissolved Oxygen
- Specific Conductance

Laboratory Analyses

- Total Dissolved Solids
- Sodium
- Chloride
- Sulfate
- Fluoride

- Total Suspended Solids

- BOD_5
- BOD_{20}
- COD

- Total Cyanide
- Phenolics

- Total Kjeldahl Nitrogen
- Ammonia-N
- Nitrite+Nitrate-N
- Total Phosphorus

- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Zinc

- Total Hardness (stream and tributaries only)

TABLE VII-18

MAHONING RIVER SEDIMENT CHEMISTRY

March 7, 1975

Sediment Chemistry (mg/kg - dry weight)

Station Number/Location	River Mile	Sample Number	Total Solids (%-Wet)	Volatile Solids (%)	COD	TKN	NH_3-N	Total Phosphorus	Oil and Grease	Total Cyanide	Phenolics
Main Stem											
1. Leavittsburg	46.02	7037	72.6	0.8	5,300	100	6	280	< 100	0.06	0.41
4. Niles-West Park Avenue	33.71	7038	80.0	1.3	7,500	160	17	680	800	1.40	0.75
- Niles-Belmont Avenue	30.48	7041	31.3	15.6	260,000	2,900	160	2,200	1,300	4.80	3.80
- Youngstown-Division Street	23.84	7042	50.3	6.3	120,000	2,200	110	2,400	17,000	4.20	0.60
8. Youngstown-Bridge Street	22.73	7043	34.0	7.0	150,000	870	70	1,200	17,000	8.80	1.80
11. Youngsotwn-Penn Central RR	17.82	7046	47.1	5.7	140,000	1,400	50	2,800	22,000	25.00	1.30
12. Struthers-P and LE RR	15.83	7047	50.0	11.7	180,000	2,300	68	2,400	24,000	6.40	4.20
13. Lowellville-Washington Street	12.64	7048	42.7	10.7	170,000	2,300	30	1,400	15,000	14.00	0.94
15. Edinburg-Route 224	6.76	7049	44.1	10.4	170,000	1,900	82	3,500	27,000	15.00	1.80
17. New Castle-Penn Central RR	1.52	7050	44.0	8.5	180,000	1,800	99	3,500	32,000	17.00	2.50
Tributaries	Above Mouth										
18, 21. Mosquito Creek	0.41	7039	31.8	3.4	21,000	460	92	460	1,400	0.16	3.80
19, 22. Meander Creek	0.81	7040	17.3	8.6	50,000	1,400	170	680	1,600	6.40	13.00
20, 25. Mill Creek	0.04	7044	75.2	1.7	14,000	260	75	310	800	1.20	0.53
USEPA Region V Criteria for Polluted Sediments	Non Polluted			< 5	< 40,000	< 1,000	< 75	< 420	< 1,000	< 0.1	
	Moderately Polluted			5-8	40-80,000	1-2,000	75-200	420-650	1-2,000	0.1-0.25	
	Heavily Polluted			> 8	> 80,000	> 2,000	>200	> 650	> 2,000	> 0.25	

TABLE VII-18

Continued

MAHONING RIVER SEDIMENT CHEMISTRY

March 7, 1975

Sediment Chemistry (mg/kg - dry weight)

Station Number/Location	Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
Main Stem											
1. Leavittsburg	3,560	3	< 1	15	6	7,800	15	155	< 0.1	50	36
4. Niles-West Park Avenue	8,440	19	2.0	68	210	330,000	110	1,640	< 0.1	180	650
- Niles-Belmont Avenue	295	13	4.0	370	330	200,000	670	3,220	0.2	360	1,990
- Youngstown-Division Street	14,900	12	2.0	310	170	83,000	200	2,330	0.2	150	1,000
8. Youngstown-Bridge Street	18,900	26	3.0	23	115	410,000	290	4,160	< 0.1	50	530
11. Youngstown-Penn Central RR	8,300	2	1.0	150	145	155,000	280	1,690	0.1	155	1,290
12. Struthers-P and LE RR	17,000	14	4.0	220	190	190,000	640	1,970	0.2	190	1,240
13. Lowellville-Washington Street	19,100	9	4.0	260	320	190,000	870	2,210	0.5	270	3,650
15. Edinburg-Route 224	17,200	27	5.0	110	165	147,000	520	1,690	0.4	150	2,160
17. New Castle-Penn Central RR	23,100	14	6.0	150	255	230,000	690	2,150	0.5	200	2,900
Tributaries											
18, 21 Mosquito Creek	820	1	< 1	3	4	1,400	20	92	< 0.1	40	22
19, 22. Meander Creek	4,120	< 1	2.0	18	58	7,800	45	345	< 0.1	50	134
20, 25. Mill Creek	10,000	12	1.0	27	20	27,000	160	1,190	< 0.1	25	154
USEPA Region V Criteria for Polluted Sediments	Non-Polluted	< 3		< 25	< 25	< 17,000	< 40	< 300	< 1	< 20	< 90
	Moderately Polluted	3-8		25-75	25-50	17-25,000	40-60	300-500		20-50	90-200
	Heavily Polluted	> 8	> 6	>75	>50	> 25,000	> 60	> 500	> 1	> 50	> 200

a) Temperature, Dissolved Oxygen, Nutrients, Suspended Solids

Figure VII-6 illustrates the increase in stream temperature with travel downstream. Although the flow at the USGS gage at Youngstown was nearly five times greater than the February minimum schedule of 225 cfs, an average increase in stream temperature of about 10^{o}F at the warmest part of the stream at Struthers was recorded, indicating high steel production. The maximum allowable Pennsylvania temperature water quality standard of 50^{o}F for the month of February was approached but not exceeded. As shown on Table 6, Appendix B, the most significant thermal dischargers were the Ohio Edison-Niles Plant (1160 x 10^6 BTU/hr), Youngstown Sheet and Tube Company-Campbell Works (710 x 10^6 BTU/hr), Republic Steel-Youngstown Plant (470 x 10^6 BTU/hr), U. S. Steel-Ohio Works (420 x 10^6 BTU/hr), and the Republic Steel-Warren Plant (340 x 10^6 BTU/hr). The aggregate affect of the thermal discharges resulted in decreases in dissolved oxygen concentrations of 1.8 mg/l at Station 12 (Struthers) and 1.5 mg/l at Station 17 (New Castle, Pa.), respectively. Because of increasing flow with travel downstream, the decrease in saturation flowing loads is larger than a proportional decrease in dissolved oxygen saturation concentrations. The apparent slight increase in average stream temperature at Station 16 (RM 4.34) is due to the fact that samples could only be taken during daylight hours because of hazardous road conditions. Hence, the colder nighttime temperatures were not recorded. There are no significant thermal dischargers between Stations 15 and 16.

Figure VII-7 presents the dissolved oxygen profile measured during the February survey. Maximum, minimum, and three-day average concentrations are plotted at each main stem station (Stations 1 through 17), as well as the average measured flowing stream loading and the calculated loadings at saturation. Flows from Figure VII-4 were employed to compute stream loadings. These data demonstrate a substantial decrease in dissolved oxygen concentrations from an average of about 14 mg/l (slightly above saturation) at Leavittsburg to less than 10 mg/l at New Castle, Pennsylvania. Taking saturation values into account, the measured dissolved oxygen deficit at New Castle averaged about 19,000 lbs/day. The total deficit at Station 17, including the effects of reduced saturation values because of increased stream temperatures amounted to about 30,000 lbs/day. Because of cold stream temperatures and high stream flows, the Pennsylvania dissolved oxygen standards (5.0 mg/l daily average, 4.0 mg/l daily minimum) were not violated.

Figure VII-7 illustrates that large discharges of carbonaceous and nitrogenous oxygen demanding substances in the Warren area (Warren STP, Republic Steel-Warren Plant, Tables 5, 6, Appendix B) exerted their effect in the upper Youngstown area. The slower rate of in-stream oxidation at cold temperatures and decreased travel time because of high flows caused the oxygen sag to occur further downstream than during summer low flow periods (Figures VII-3, 4). The oxygen demand from significant discharges in the Youngstown-Struthers area (Youngstown STP, U. S. Steel, Youngstown Sheet and Tube, Republic Steel, Tables VII-5, 6, Appendix B) had not been satisfied in the Mahoning River as dissolved oxygen levels were still declining near the confluence with the Shenango River. This is also illustrated in Figures VII-8 and 9 which show only partial oxidation of carbonaceous and nitrogenous oxygen demanding substances and a significant loading discharged to the Beaver River. The increase in five and twenty day biochemical oxygen demand ($BOD_{5, 20}$), from Station 16 to Station 17 is most likely the result of resuspension of settled material in this reach of the river as indicated by Figure VII-10. There are no known significant point sources in this area except the New Castle STP which is outside the study area and is downstream of Station 17.

Figure VII-9 (nitrogen series) illustrates the rising trend of total kjeldahl nitrogen (TKN), and ammonia-nitrogen (NH_3-N) with discharges in the Youngstown-Struthers area contributing most of the loadings. The increase in nitrite+nitrate nitrogen (NO_2 + NO_3 - N) with travel downstream demonstrates nitrification was occurring, although the rate of nitrification was considerably reduced by cold stream temperatures.

The effects of algal activity were also expected to be minimal owing to seasonal conditions. Based upon these data, a nitrogenous oxygen demand loading of about 90,000 lbs/day (4 x TKN) was being discharged to the Beaver River from the Mahoning River during the survey. The corresponding carbonaceous demand was about 160,000 lbs/day (BOD_{20} - 4TKN). A comparison of upstream loads at Leavittsburg, tributary loads, and the municipal and industrial point source loadings indicates that measured stream loadings of BOD_{20} are generally 15-30 percent higher than the sum of the point source and tributary loadings. However, the sum of the tributary and point source COD loadings are generally within 5-10 percent of the stream COD loadings. This is the result of toxicity problems in BOD testing for several steel plant discharges. The dilution of these wastes in the stream reduced the toxicity and most likely resulted in higher stream BOD values than the sum of the discharge values. Significant unaccounted for combined sewer overflows and non-point source loadings were not expected with the weather and runoff conditions encountered during the survey.

Figure VII-11 depicts an increase in average ammonia-N concentrations from less than 0.2 mg/l at Leavittsburg to about 2.4 mg/l at Lowellville. This value exceeds the general Ohio WQS level of 1.5 mg/l but, owing to low stream temperatures, the recommended USEPA aquatic life criterion of 0.02 mg/l un-ionized NH_3 -N (equivalent to 3.5 mg/l at pH 7.5 and $46^{\circ}F$) was not exceeded. At February design flows, the ammonia concentration could reach 6.0 mg/l considering the longer travel times and faster reaction rates at higher stream temperatures. This level would greatly exceed the recommended USEPA criterion (1.5 mg/l NH_3 -N at pH 7.5 and $66^{\circ}F$). Pennsylvania has no specific ammonia water quality standard for the Mahoning River and, as noted earlier, relies upon a general water quality criteria for control of toxic substances. The recommended USEPA aquatic life criterion for ammonia is considered a reasonable benchmark to assess compliance with Pennsylvania water quality standards.

Figure VII-12 and Tables 5 and 6, Appendix B demonstrate major sources of total phosphorus during the survey were the municipalities of Youngstown (1090 lbs/day) and Warren (490 lbs/day). The total industrial loading averaged 530 lbs/day while the total municipal loading averaged about 2200 lbs/day. Maximum stream concentrations in excess of 1.0 mg/l were recorded at Station 12 (Struthers) and approached 0.9 mg/l at Station 4 (Niles). Upstream values recorded at Leavittsburg averaged about 0.1 mg/l. The instream settling of phosphorus illustrated in Figure VII-12 is verified by the high sediment concentrations found at and below the Warren and Youngstown STP's (Table VII-18). Sediments in the Pennsylvania reach of the river are highly enriched from discharges in the Youngstown area.

Stream concentrations in the 0.3 to 0.5 mg/l range encountered for most of the stream are high from a nutrient standpoint.

b) Total Dissolved Solids, Fluoride, Sodium, Chloride, Sulfate

Analyses for total dissolved solids (TDS), fluoride, sodium, chloride, and sulfate were completed for each stream, tributary, and discharge sample obtained. Figures VII-13 through VII-17 illustrate increases in stream concentrations of these substances with travel downstream and average flowing loads at each stream sampling station employing the average flows from Figure VII-4 and the respective three-day average concentration.

Pennsylvania has water quality standards for total dissolved solids (500 mg/l monthly average, 750 mg/l maximum) and fluoride (1.0 mg/l maximum). Based upon Figure VII-13, the maximum dissolved solids criterion of 750 mg/l was not approached and it appears that the stream would be in compliance with the monthly average value of 500 mg/l. Although the average fluoride concentration increased by a factor of 2.5 from upstream levels at Leavittsburg, the Pennsylvania standard of 1.0 mg/l was not exceeded because of high stream flow. Maximum values of over 0.6 mg/l were recorded at the State line (Figure VII-14). Major sources of fluoride during the survey were the Republic Steel-Warren Plant (1440 lbs/day), the Youngstown Sheet and Tube-Campbell Works (330 lbs/day), the U. S. Steel-Ohio Works (310 lbs/day), the Republic Steel-Youngstown Plant (275 lbs/day), the Youngstown STP (200 lbs/day) and the Warren STP (105 lbs/day), (Tables 5, 6, Appendix B). Most of the steel plant discharges result from blast furnace gas washing operations. However, over 80 percent of the Republic Steel-Warren Plant discharge resulted from an intermittently run finishing operation in the galvanizing area employing a fluoride compound.[32] The municipal discharges are the result of fluoridation of potable water supplies. Although the General Electric Company-Niles Glass Plant had been considered a major source of fluorides, the data obtained for Mosquito Creek show an average gross fluoride discharge of 150 lbs/day or 0.31 mg/l which is only slightly above background levels (0.19 to 0.26 mg/l) measured at Leavittsburg and other tributaries.

There appears to have been an error in analyses or data transcription for TDS at Station 17. The three-day average concentration for Station 17 was 343 mg/l while corresponding values for Station 13 and 15 were 387 mg/l and 393 mg/l, respectively. Data for other macro constituents and total hardness do not indicate a precipitation reaction of major proportions occurred although the suspended solids concentration increased somewhat (Figure VII–10). A review of the specific conductance data for the samples taken at Stations 13, 15, and 17 show near constant values for each day. There are no significant sources of low TDS water in the area. Most of the average decrease from Station 15 to Station 17 results from values obtained on February 12–13, 1975 when 400 mg/l was recorded at Station 15 and 310 mg/l at Station 17. Had the data at Station 17 been reported as 410 mg/l vs 310 mg/l, the three-day average values would have been more in line. Hence, a laboratory or data transcription error is suspected, but a review of laboratory bench sheets, etc. could not confirm the possible error.

Figures VII-15, 16, and 17 illustrate increasing concentrations of sodium, chloride, and sulfate, respectively, with travel downstream. Comparison of tributary, industrial, and municipal discharges of sodium and chloride with flowing loads in the Youngstown area indicate significant non-point source discharges, most likely the result of road salting on two days of the survey. Downstream of Struthers, instream concentrations and loadings of these materials remained relatively constant. However, as shown on Figure VII-17, the concentration of sulfates continued to increase well into Pennsylvania. This is most probably the result of runoff from strip mines in the lower part of the basin which would be high in sulfates. Neither the chloride nor sulfate concentrations exceeded recommended drinking water criteria of 250 mg/l. With discharges of spent pickling acids no longer occurring on a regular basis, it is doubtful these criteria would be exceeded.

c) Total Cyanide, Phenolics

Large discharges of total cyanide and phenolics from coke plant and blast furnace operations resulted in the stream profiles depicted in Figures VII–18 and 19. Pennsylvania water quality standards of 25 µg/l for total cyanide and 5 µg/l for phenolics were exceeded by wide margins. Cyanide concentrations exceeding 200 µg/l near the Ohio-Pennsylvania State line (Station 13) and concentrations of phenolics in excess of 120 µg/l were recorded. As shown in Table 6, Appendix B and graphically depicted in

Figure VII-18, the major sources of cyanide are in the Youngstown-Struthers area, most notably the Youngstown Sheet and Tube-Campbell Works (490 lbs/day), U. S. Steel-Ohio Works (430 lbs/day), and the Republic Steel-Youngstown Plant (240 lbs/day). The total municipal cyanide discharge in the basin during the survey averaged about 110 lbs/day. The most significant dischargers of phenolics were the Republic Steel-Youngstown Plant (560 lbs/day), the Youngstown Sheet and Tube-Campbell Works (310 lbs/day), the Republic Steel-Warren Plant (150 lbs/day), and the U. S. Steel-Ohio Works (60 lbs/day). The total municipal discharge averaged about 20 lbs/day.

While upstream, cyanide concentrations (Station 1) were near the detectable limit of 5 µg/l, phenolics were found at 12 and 21 µg/l on the second and third days of the survey (the first day samples could not be analyzed within the recommended holding period of 24 hours after collection and were discarded). These values are in excess of Ohio's general water quality standard of 10 µg/l. The source is unknown but bottom releases from the upstream reservoirs are suspect. Nonetheless, these relatively low concentrations are far overshadowed by the downstream concentrations (100-200 µg/l) resulting from point source dischargers. Both total cyanide and phenolics exhibited relatively rapid decay in the stream despite cold temperatures and short travel time resulting from high stream flow. Considering the minimum regulated schedule for February (225 cfs at Youngstown) and the effluent loadings encountered during the February 1975 survey, total cyanide and phenolics concentrations in excess of 200 µg/l respectively, would be expected at the State line. As noted in Section VI, values in this range have been recorded.

With the exception of Crab Creek, the tributaries sampled were relatively free of cyanide and phenolics. Concentrations of 89 µg/l, 160 µg/l, and 740 µg/l for phenolics were recorded for Crab Creek (Table 7, Appendix B). The probable source of these phenolics is the Koppers Company tar distillation plant located upstream of Station 21, the Crab Creek sampling point.

d) Metals

Of the six metals studied, cadmium and lead were not found to be present in the stream above the detectable limits of 8 µg/l and 50 µg/l, respectively, although the discharge of these metals is indicated in Table 6, Appendix B. The cadmium discharges are peculiar to the Republic Steel Warren and Youngstown plants. Chromium was found above the detectable limit (20 µg/l) only on the third day of the survey. Measured discharges in the Warren area could not account for the maximum concentration of 190 µg/l recorded at Station 4 in Niles.

Figures VII-20, 21, and 22 illustrate changes in copper, iron, and zinc with travel downstream. The sharp spikes for copper and iron recorded at Station 4 (Niles) were the result of slug loadings on the second day of the survey from the Republic Steel-Warren Plant blast furnace discharge indicating a possible process or treatment system upset on that day. The peaks and valleys for copper, iron, and zinc are also reflected in the sediment chemistry data presented in Table VII-18 and generally by the suspended solids data presented in Figure VII-10. Pennsylvania's total iron standard of 1.5 mg/l was exceeded by a factor of two. At the hardness levels recorded at the State line (177-205 mg/l as $CaCO_3$), the Ohio general standards for copper (0.020 mg/l at 160-240 mg/l hardness) and zinc (0.200 mg/l at 160–240 mg/l hardness) were exceeded. Pennsylvania has no specific metals criteria, but the Ohio general standards which are based upon toxicity data are good benchmarks for comparison purposes.

The steel industry iron discharge averaged more than 35 tons per day during the survey while the zinc discharge approached one ton per day.

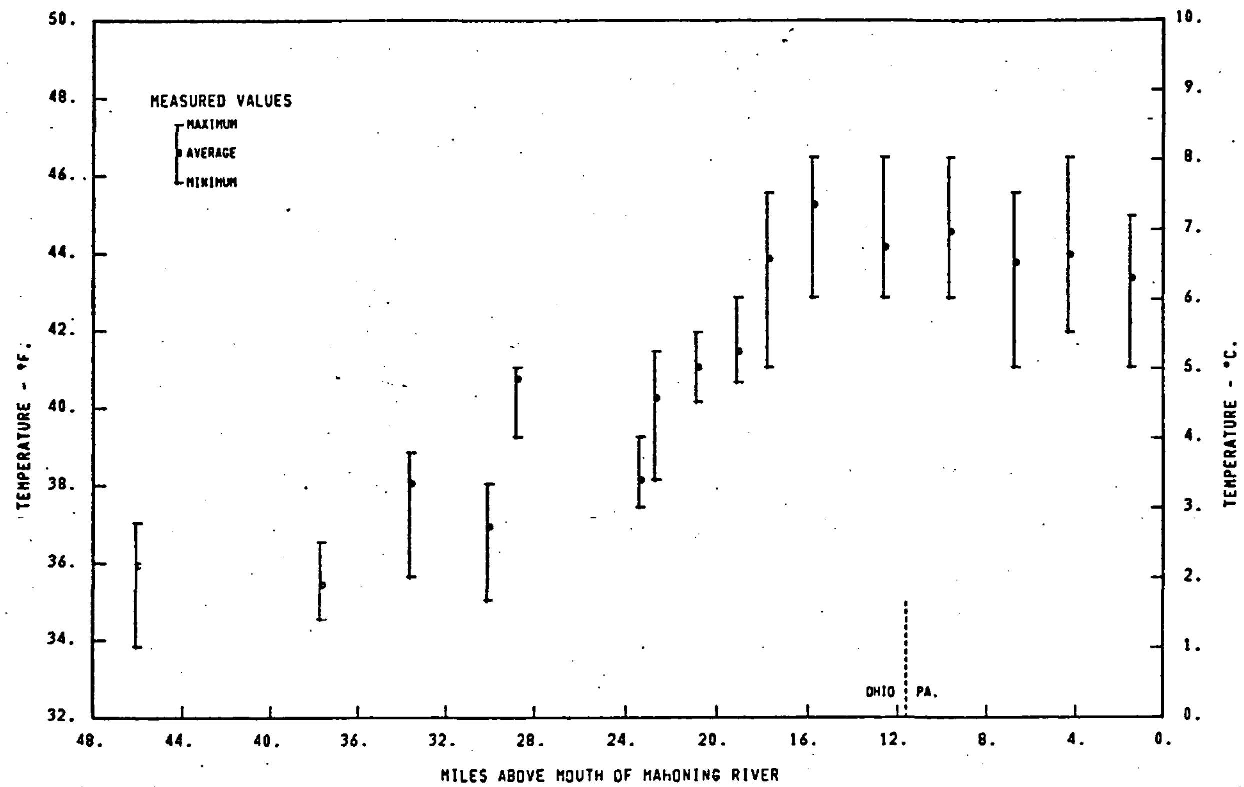


FIGURE VII-6
TEMPERATURE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

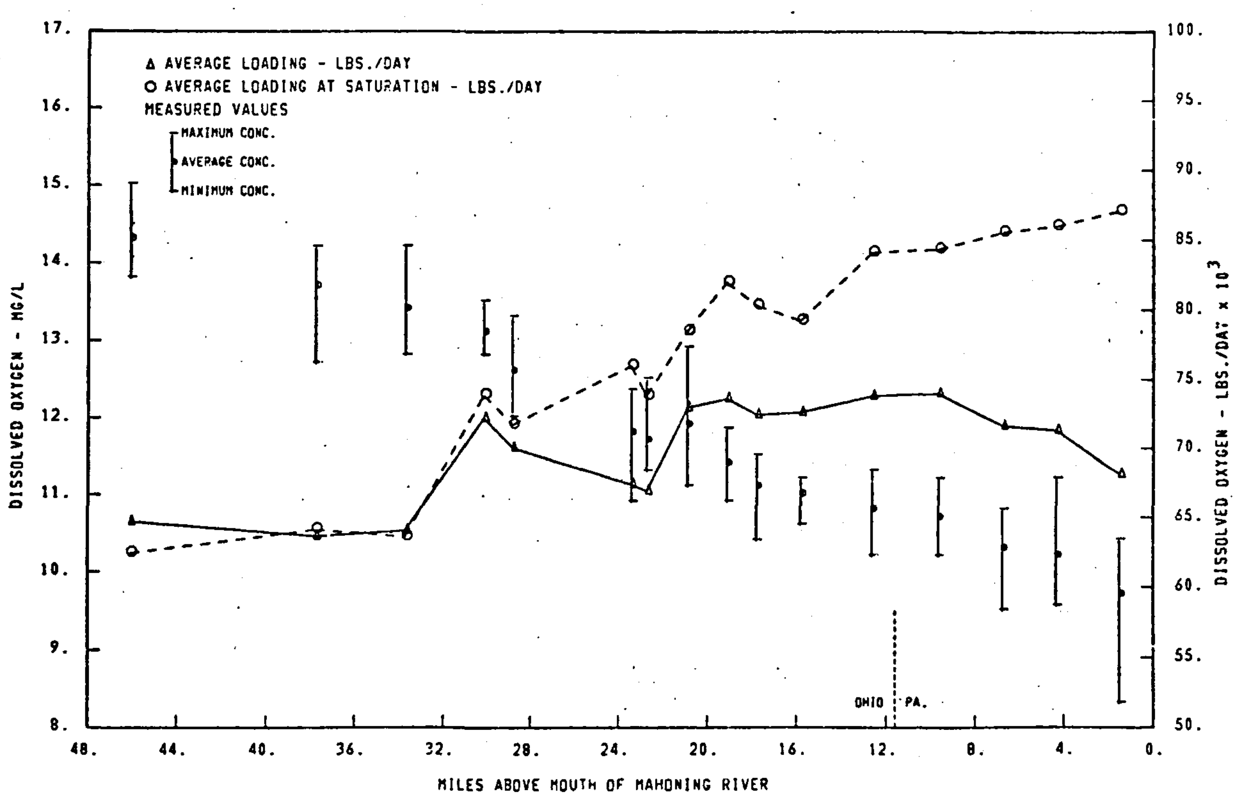


FIGURE VII-7
DISSOLVED OXYGEN VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

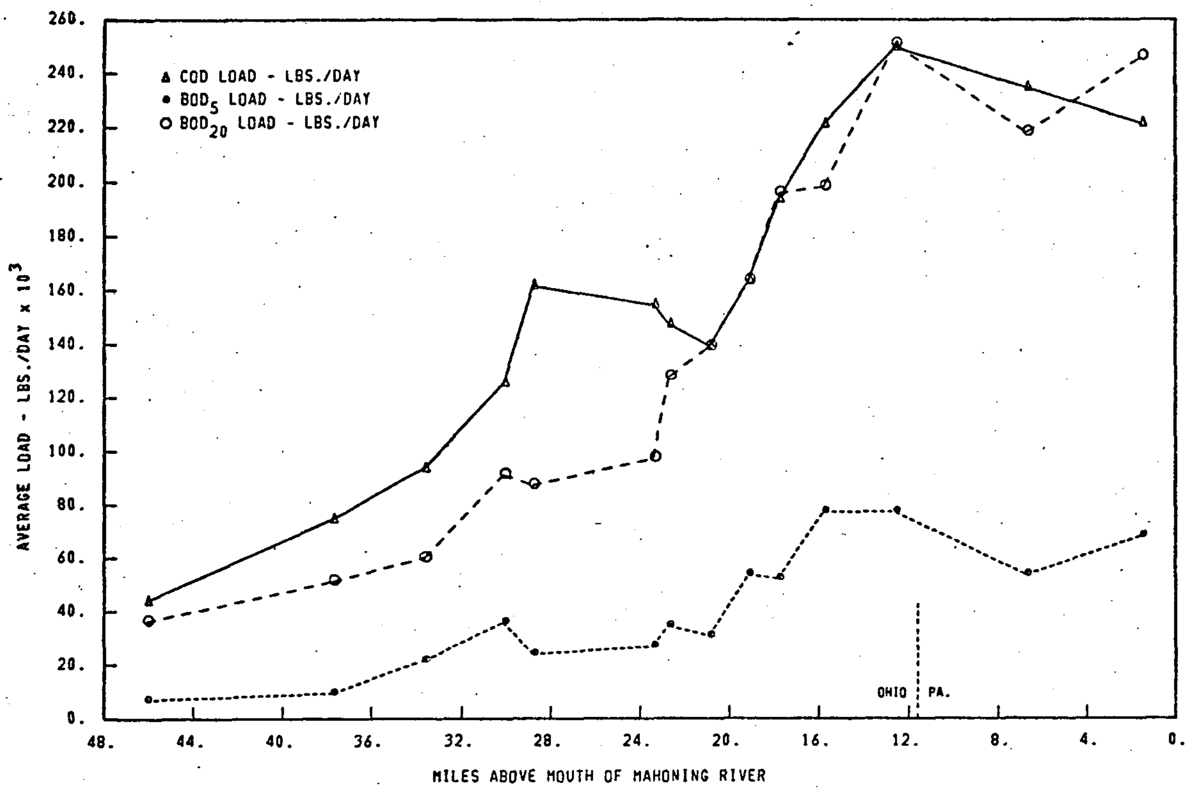


FIGURE VII-8
COD, BOD_5, BOD_{20} VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

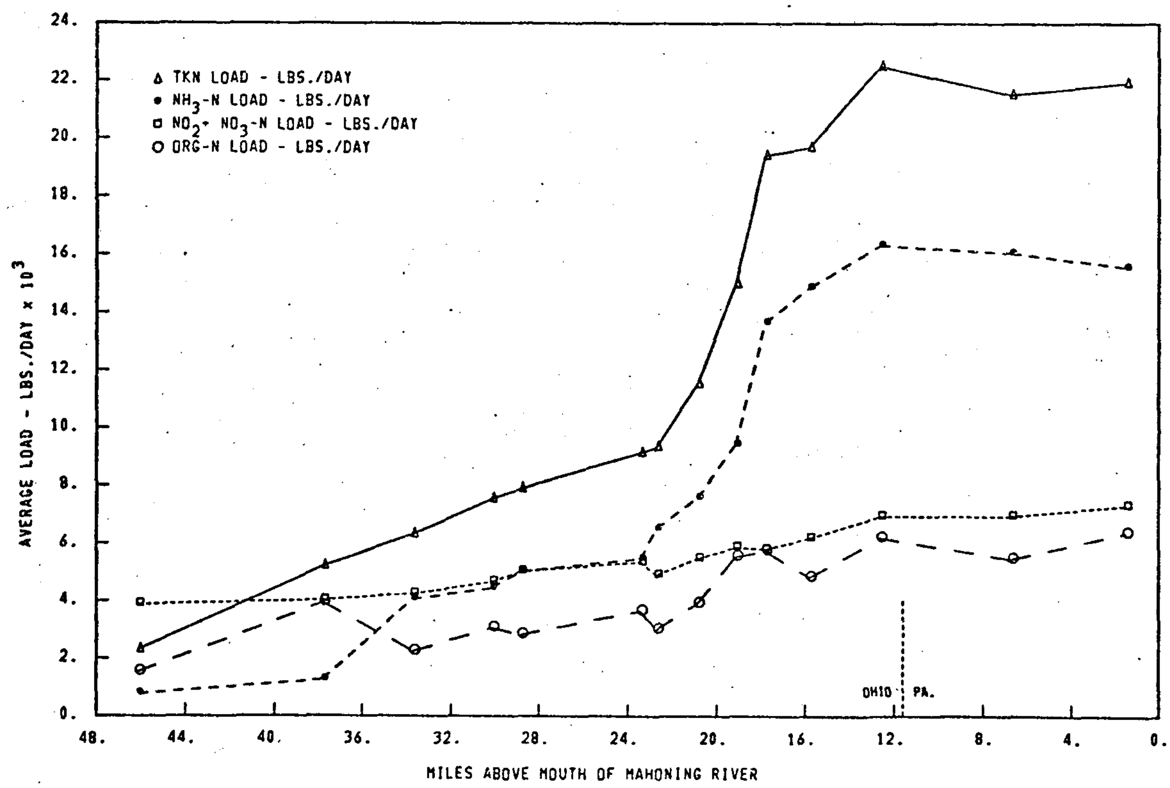


FIGURE VII-9
TKN, NH_3-N, ORG-N, NO_2+ NO_3 VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

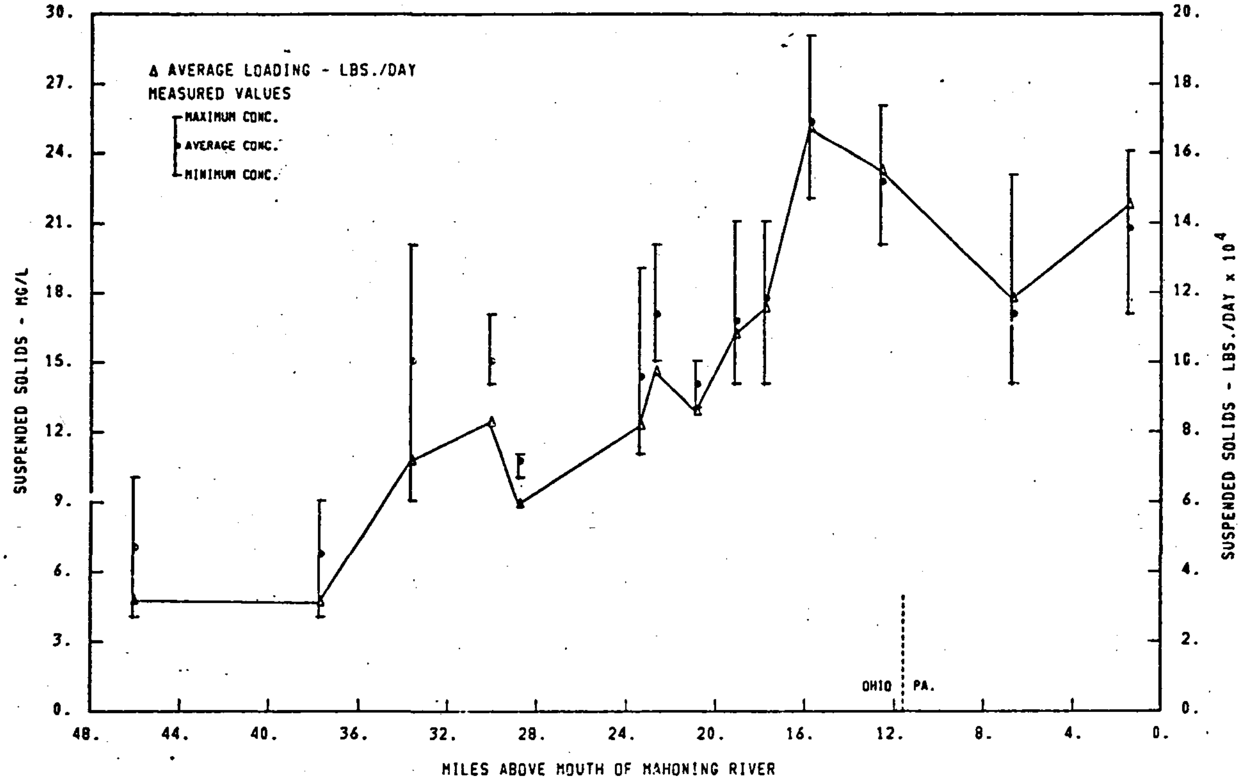


FIGURE VII-10
SUSPENDED SOLIDS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

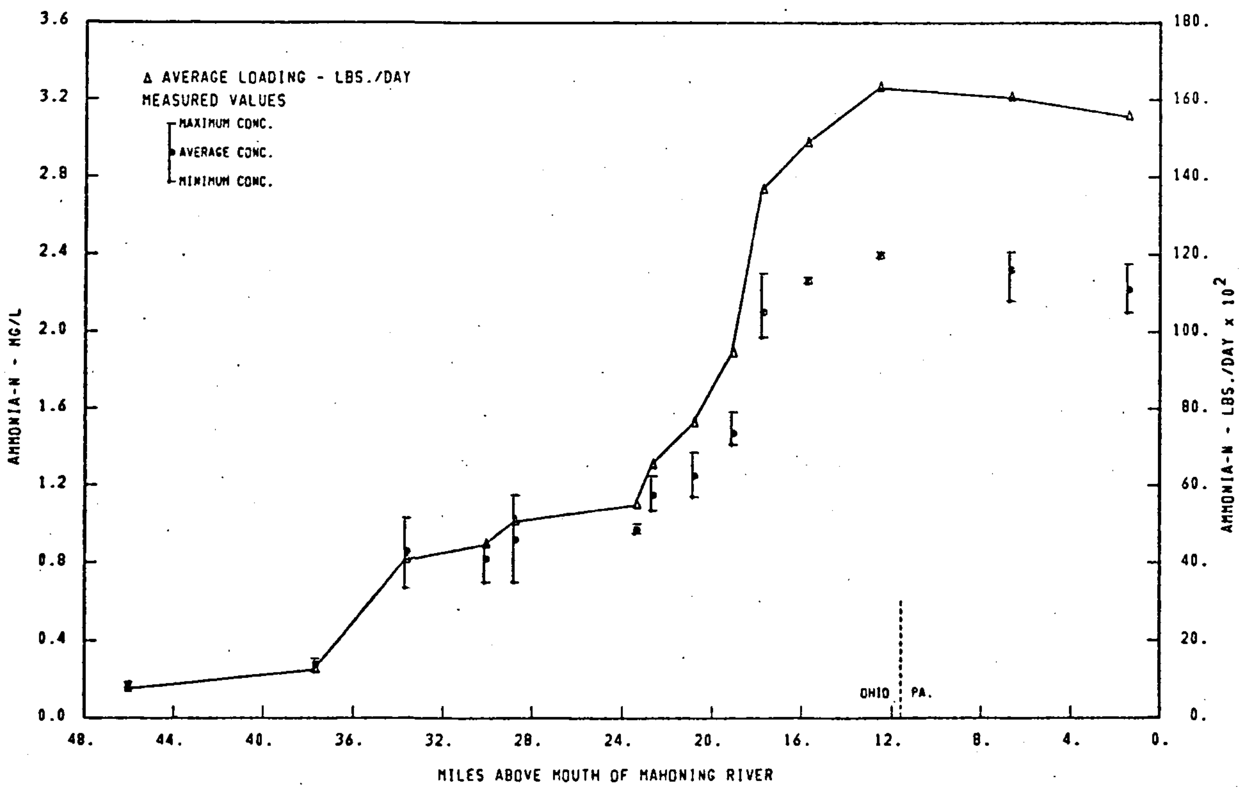


FIGURE VII-11
AMMONIA-NITROGEN VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

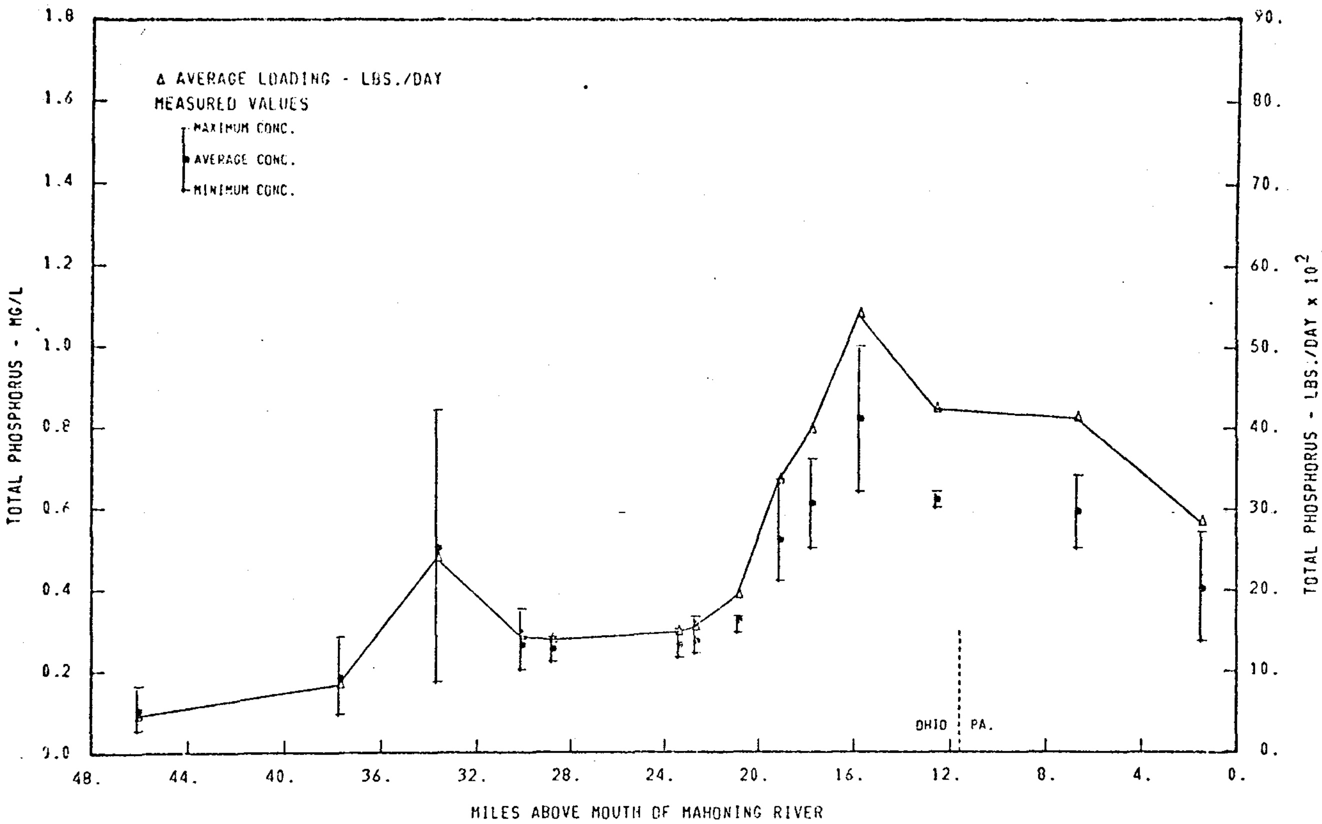


FIGURE VII-12
TOTAL PHOSPHORUS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

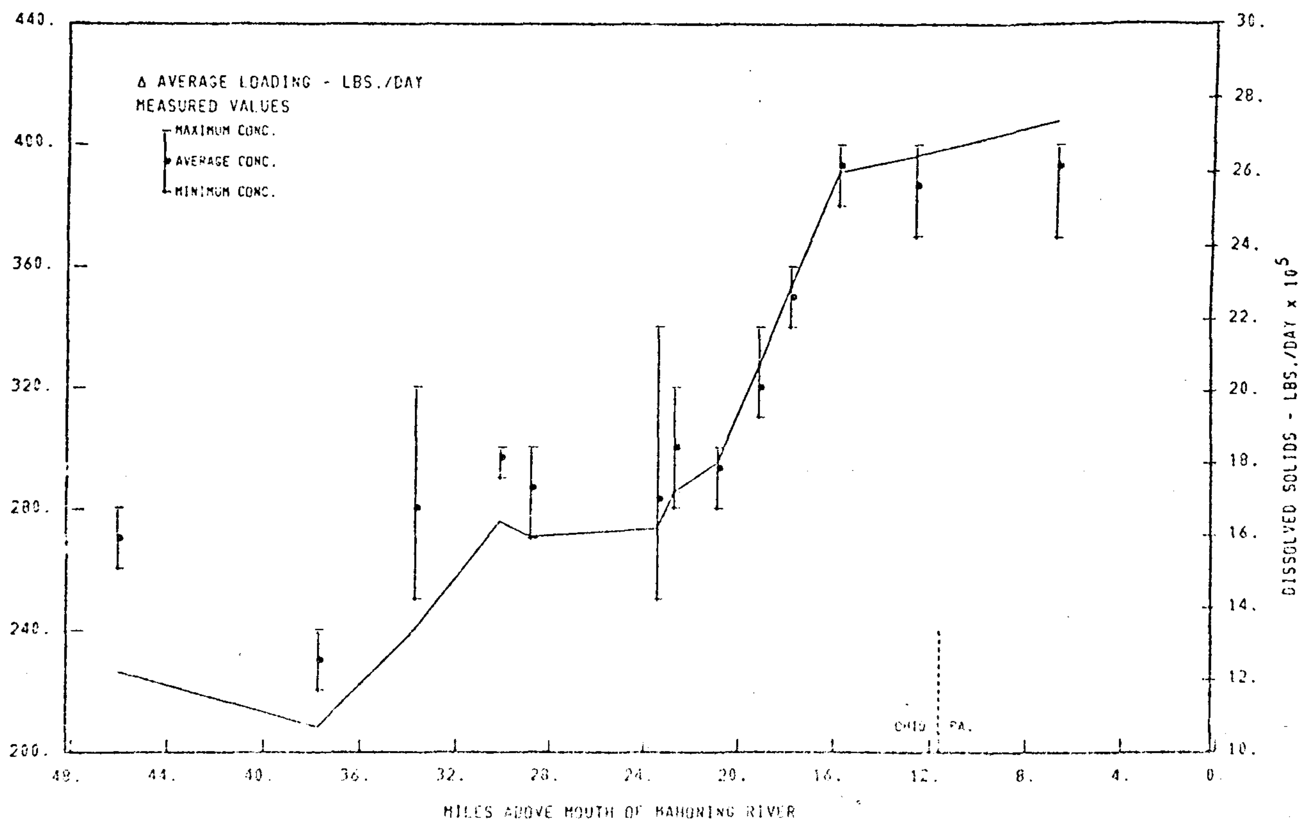


FIGURE VII-13
DISSOLVED SOLIDS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

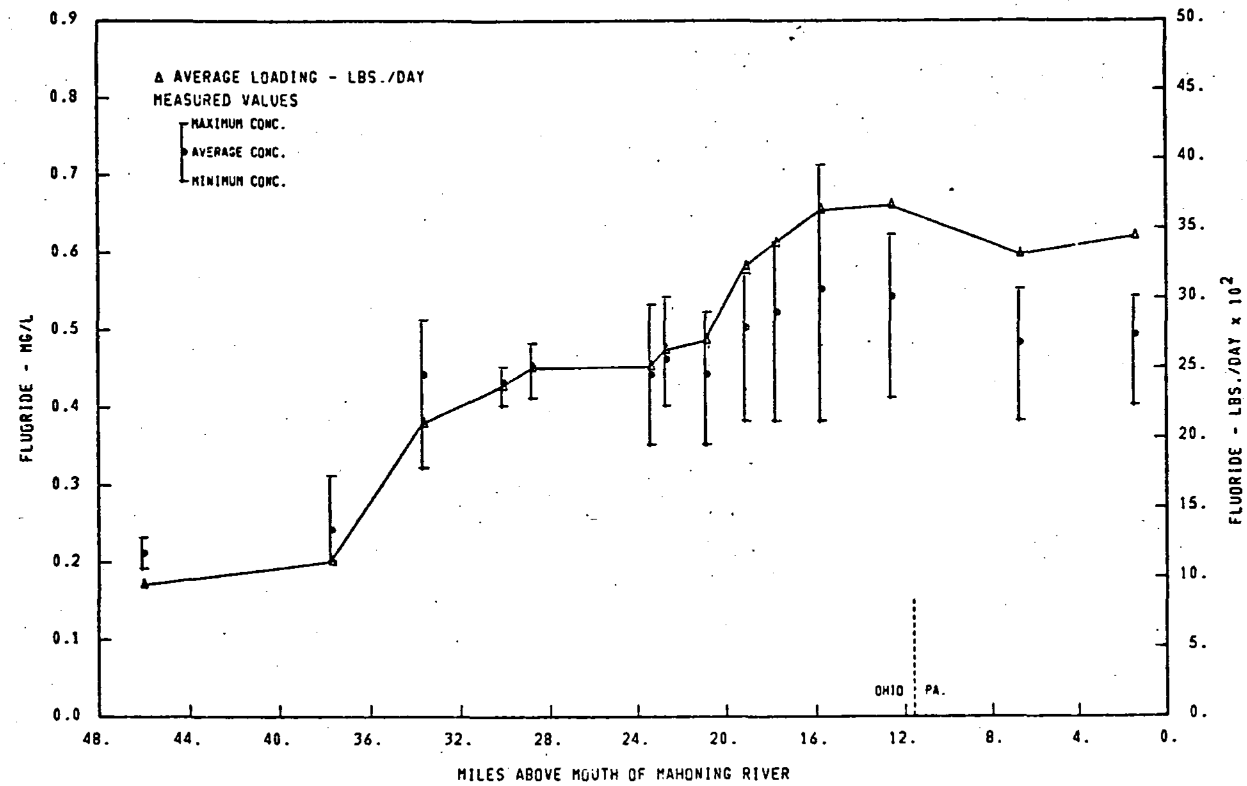


FIGURE VII-14
FLUORIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

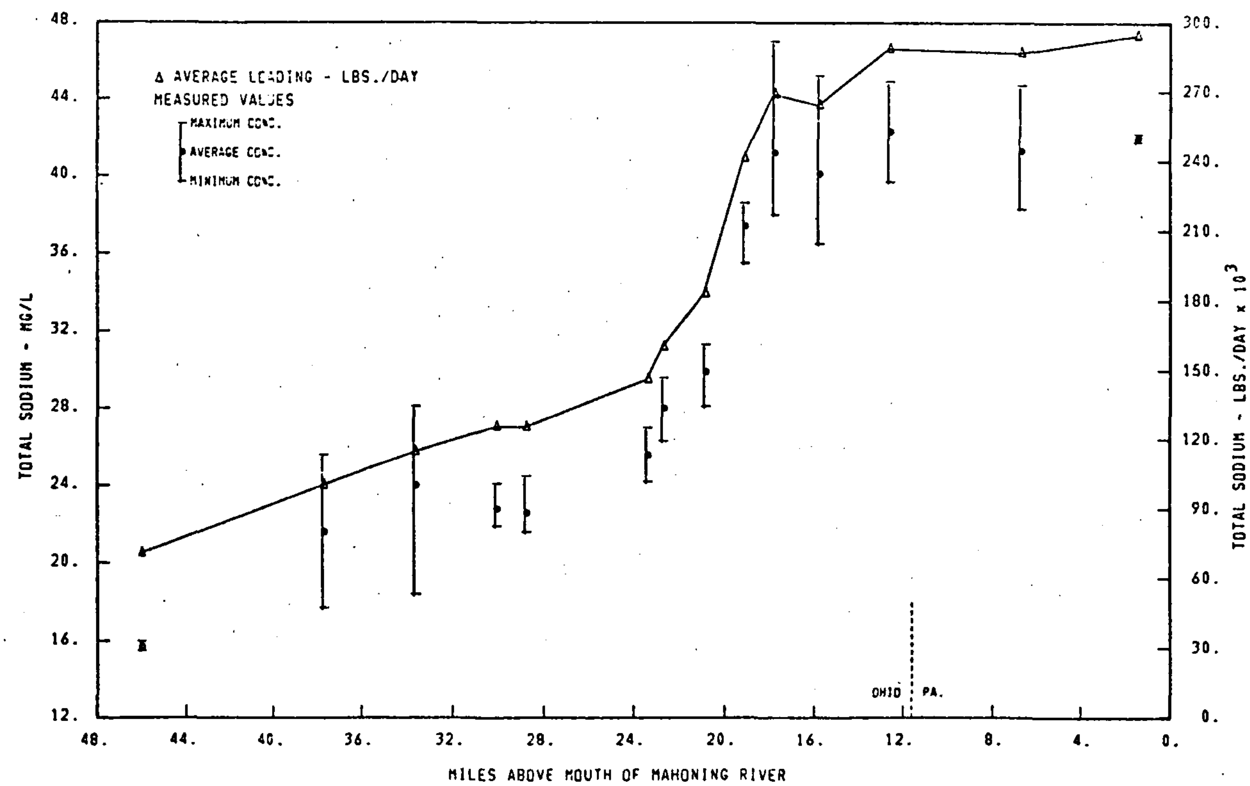


FIGURE VII-15
TOTAL SODIUM VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

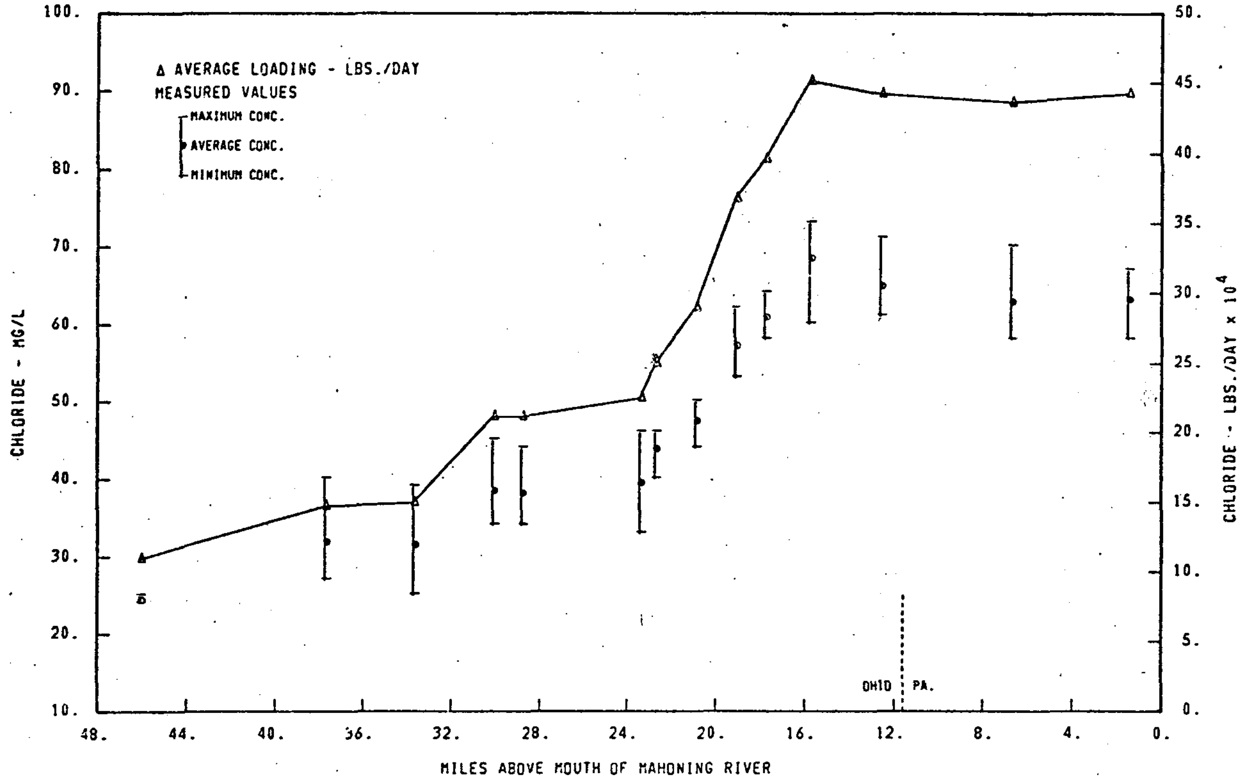


FIGURE VII-16
CHLORIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

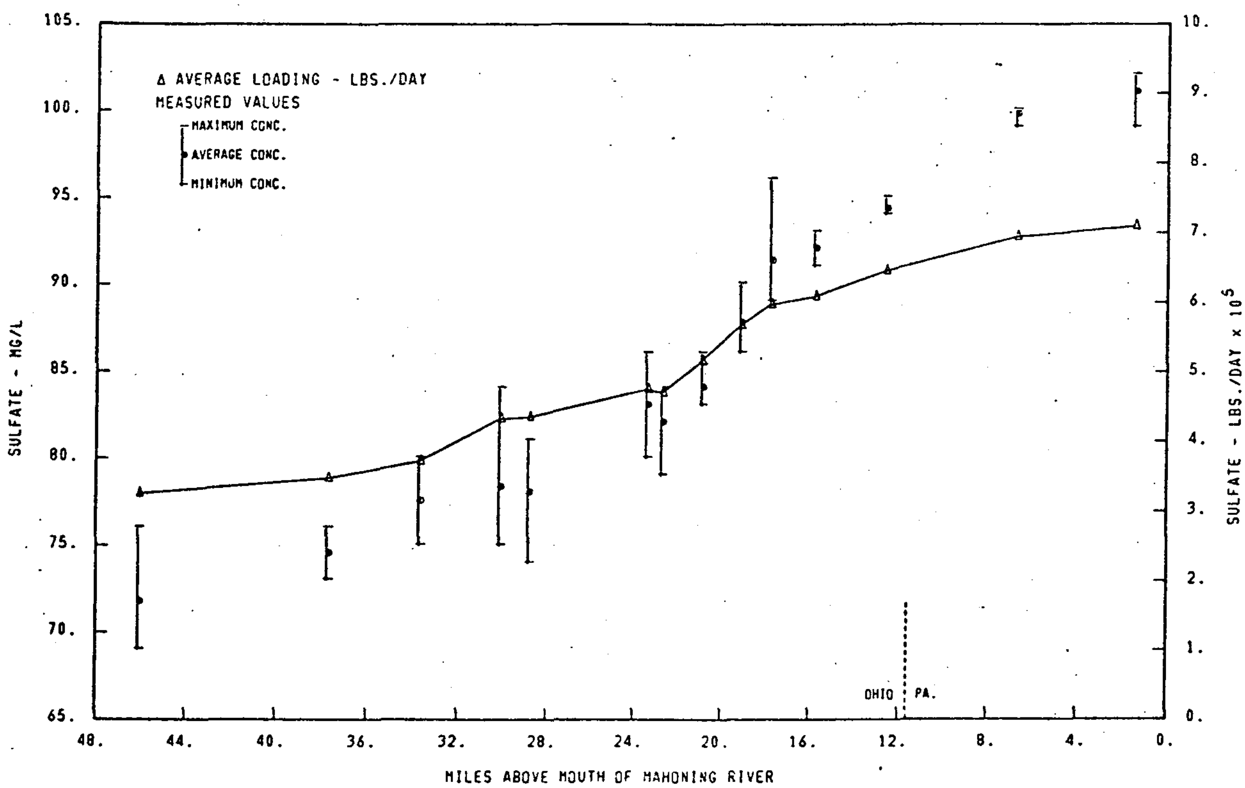


FIGURE VII-17
SULFATE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

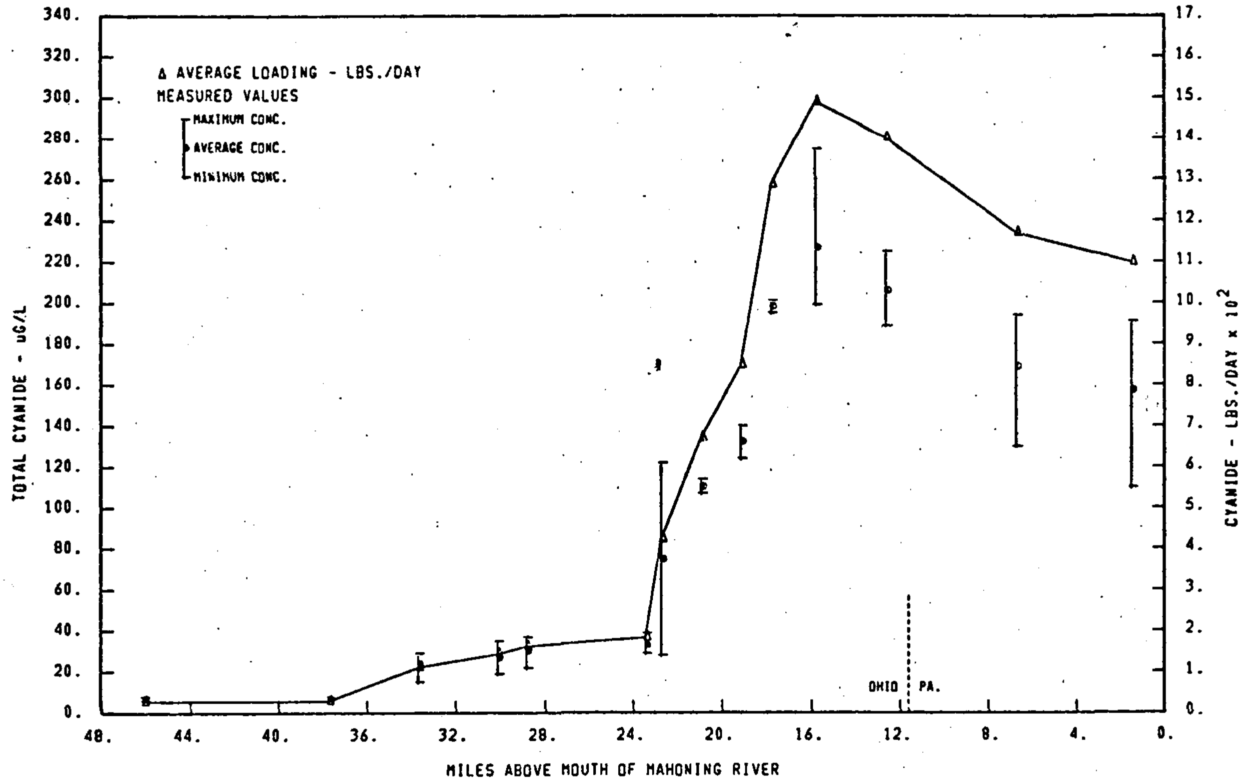


FIGURE VII-18
TOTAL CYANIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

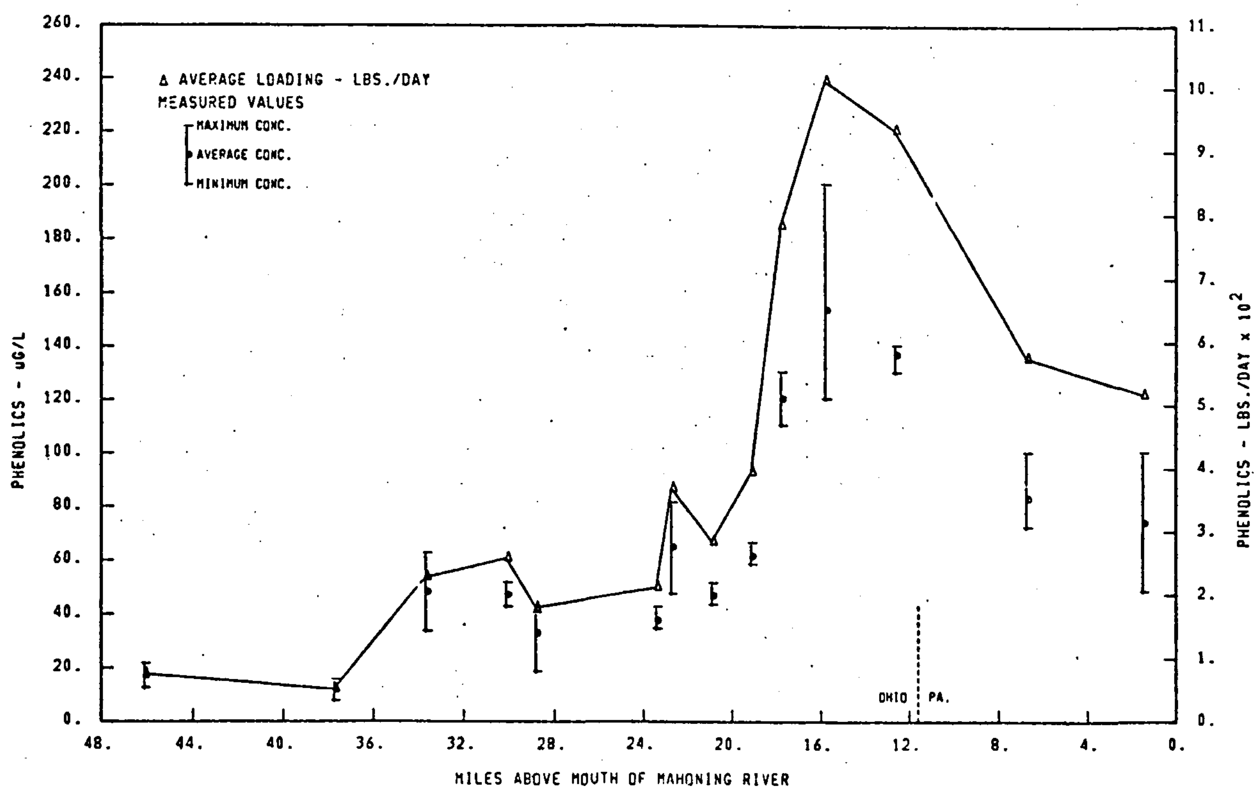


FIGURE VII-19
PHENOLICS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

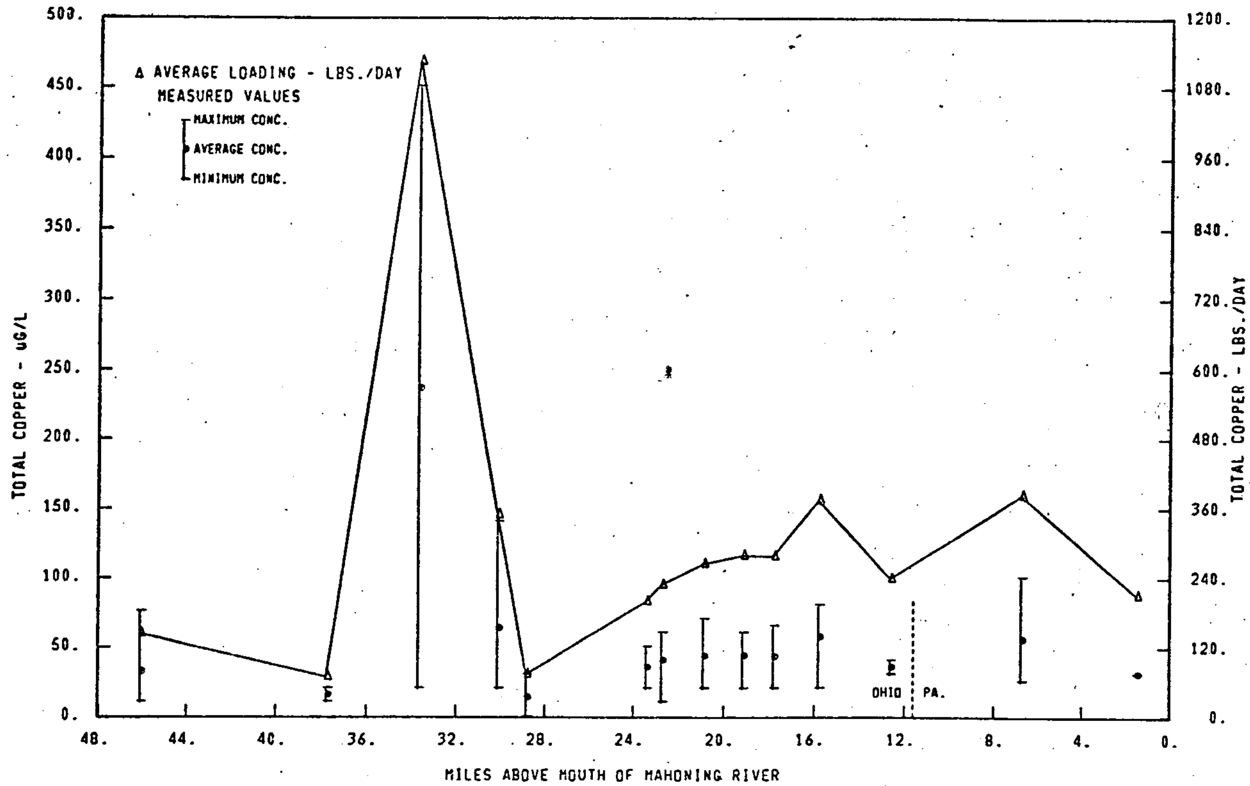


FIGURE VII-20
TOTAL COPPER VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

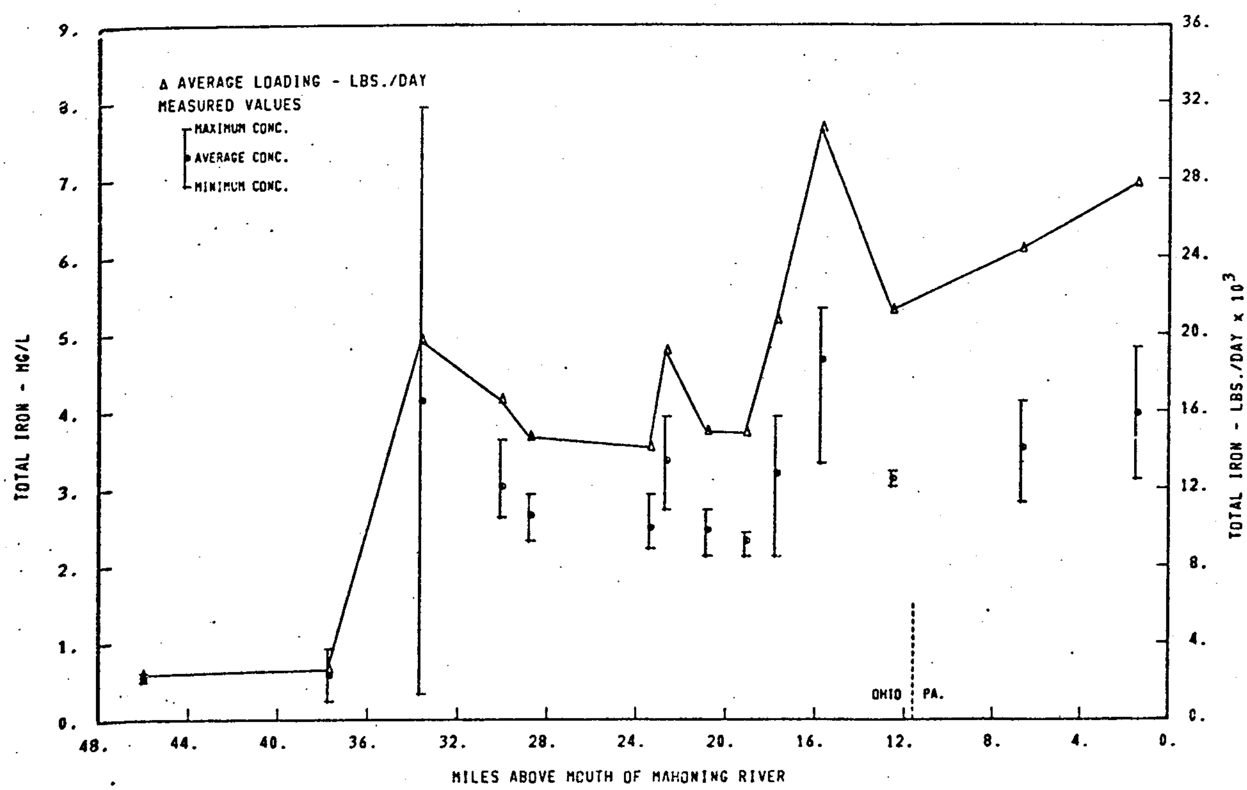


FIGURE VII-21
TOTAL IRON VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

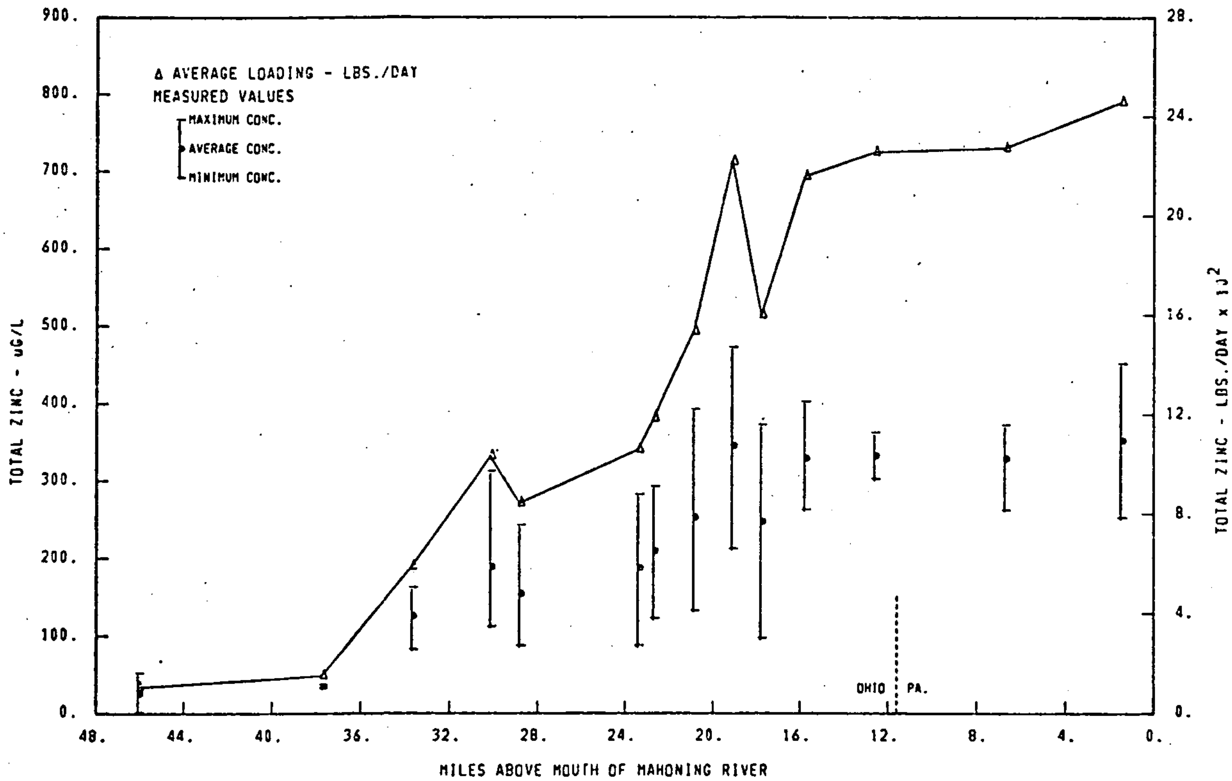


FIGURE VII-22
TOTAL ZINC VS. RIVER MILE
US EPA MAHONING RIVER SURVEY FEBRUARY 11-14, 1975

b. July 14-17, 1975 Comprehensive Survey

1) Hydrology

July was selected as the month for the second comprehensive survey in an attempt to sample the stream at the peak of the BY-BL minimum regulated schedule (480 cfs at Youngstown - Figure IV-10). During dry summers, the flow at Youngstown generally is very stable and remains in the immediate range of the BY minimum schedule. However, as shown in Figure VII-23, relatively wide fluctuations in flow were experienced throughout July 1975. Fortunately, the comprehensive survey was completed during a period of fairly steady flow considering the daily variation for the remainder of the month. Figure VII-24 presents hourly variations in flow at each USGS gage for the July 9-20, 1975 period. The effect of a severe thunderstorm is illustrated from the evening of July 10 to the early morning hours of July 11 followed by about three days of declining flow. A moderate thunderstorm occurred between Youngstown and Lowellville on July 13 preceeding the survey and a moderate, more steady rain occurred in the upper part of the basin just prior to the initiation of the survey accounting for the variation shown in Figure VII-24. The hydrograph declined slightly for the remainder of the survey and leveled out during the July 16-19 period which was immediately followed by intense thundershowers in the lower part of the basin.

The three-day average flow profile is presented in Figure VII-25. This profile was constructed in the same fashion as the flow profile for the February comprehensive survey (Figure VII-4). The average flow recorded at the Youngstown gage was 533 cfs, about 11 percent higher than the maximum BY schedule, and, as shown on Figure VII-3, the travel time experienced during the survey is close to that for the BY schedule. Although the average flow during the survey was close to the BY schedule, the significant variation just prior to the survey and the declining hydrograph during the survey did not result in near-perfect, steady-state flow conditions as experienced during the February survey. Nonetheless, there were no fluctuations in flow of such magnitude that would render a steady-state analysis employing three-day average data unreasonable.

FIGURE VII-23
MOHONING RIVER BASIN
DAILY HYDROGRAPH
JULY 1975

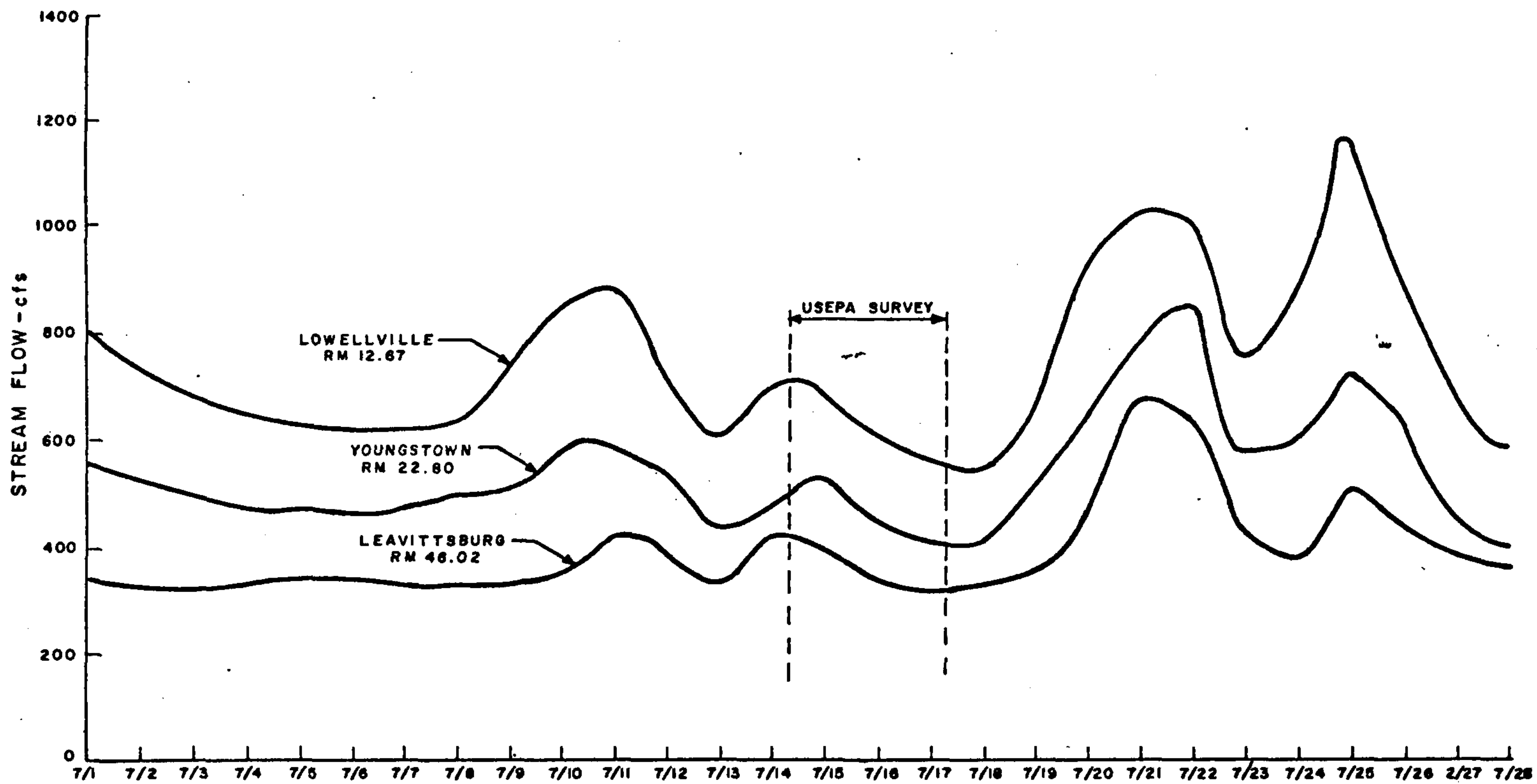
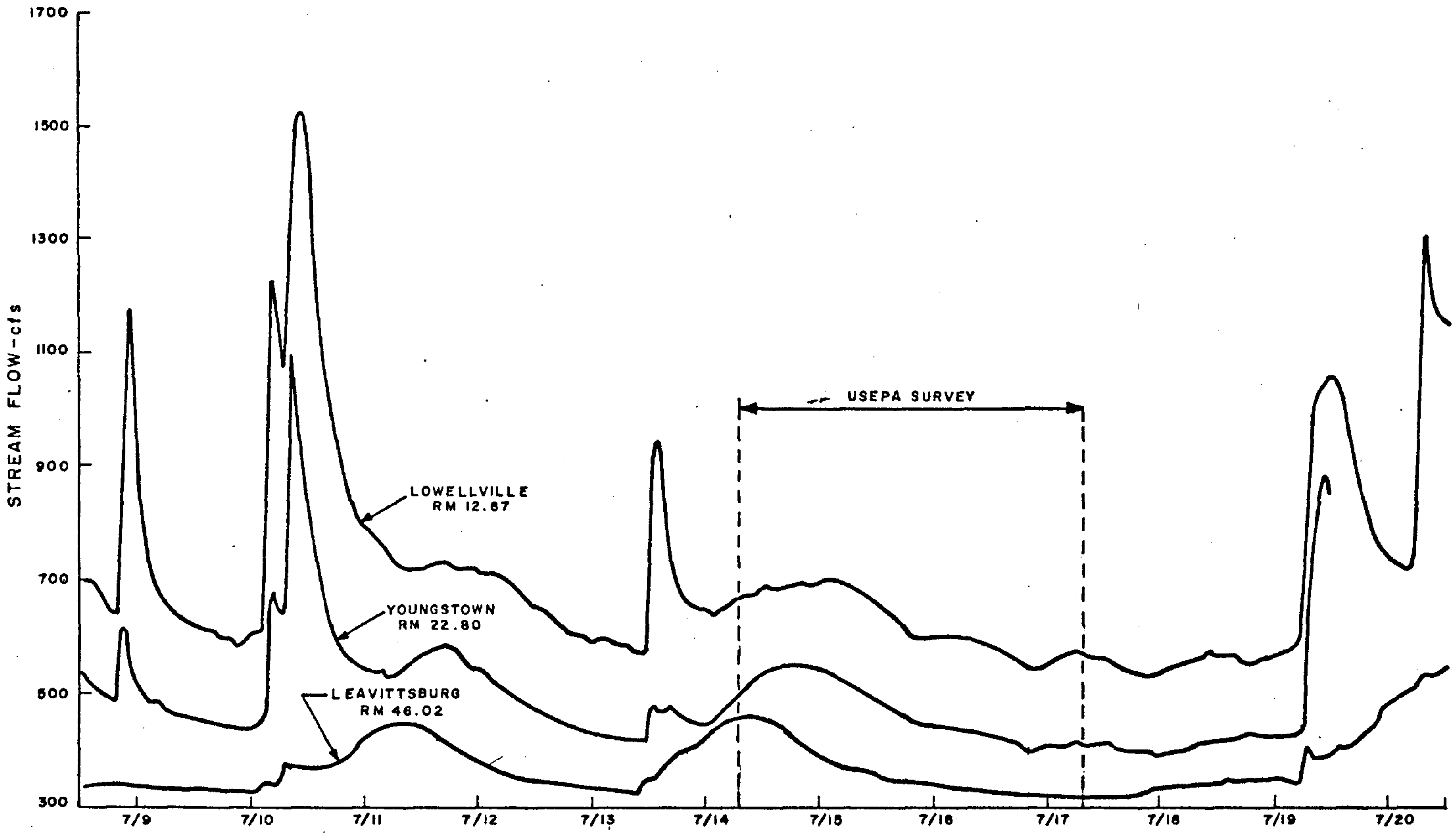


FIGURE VII-24
MOHONING RIVER BASIN
HOURLY HYDROGRAPH
JULY 9-20, 1975



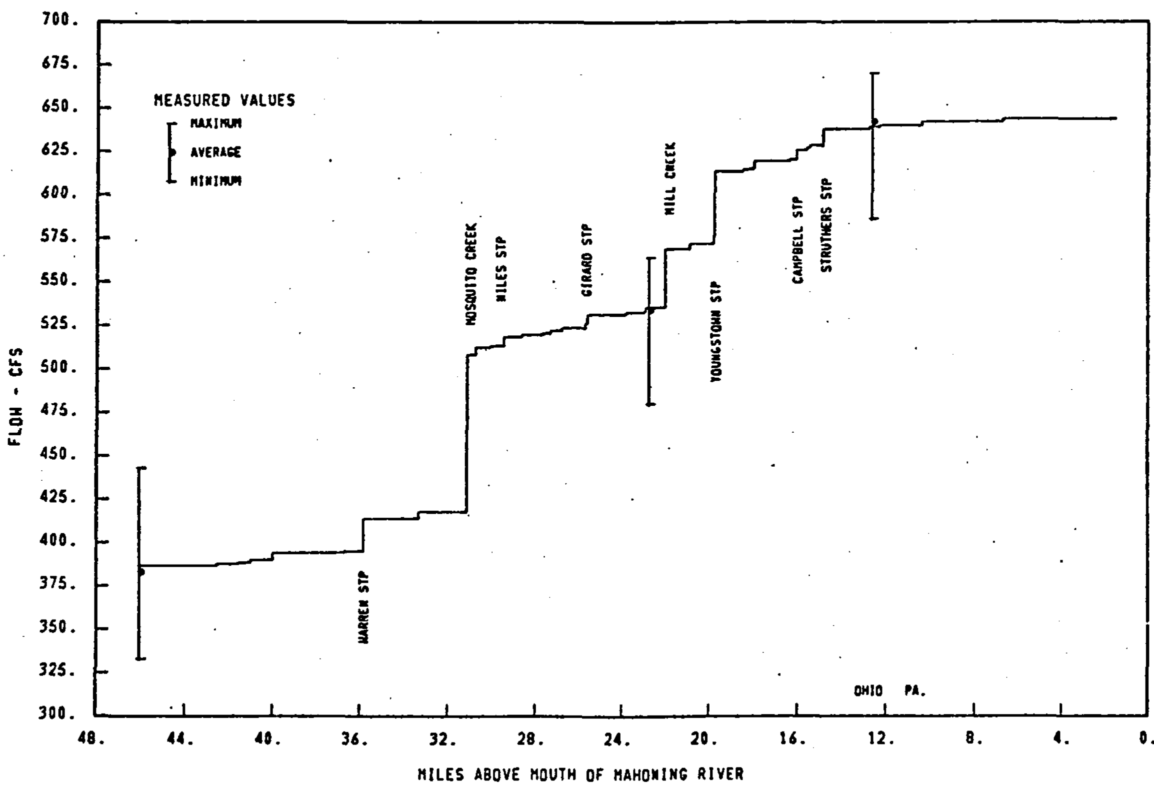


FIGURE VII-25
MAIN STEM FLOW PROFILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1976

2) Weather Conditions

As noted above, several significant precipitation events occurred during July 1975. The total monthly precipitation recorded at the Youngstown airport was 2.25 inches of rain while the long-term July average is 3.80 inches.[33] While the monthly precipitation was below normal, the intensity of the individual rainfall events resulted in wide fluctuations in stream flow. Air temperatures recorded throughout the basin were seasonably low, ranging from 59°F to 80°F at Warren, 55°F to 84°F at the Youngstown airport,[34] and 59°F to 80°F at Edinburg, Pennsylvania. Daily average temperatures at the Youngstown airport exhibited a warming trend from 66.5°F on July 14-15, to 68.8°F on July 15-16, to 72.2°F on July 16-17, 1975, corresponding to the decreasing trend of cloud cover which averaged 0.6, 0.5, and 0.4 on the three days, respectively.[34] Wind speed averaged 8.5, 4.7, and 4.9 mph at the Youngstown airport and 6.0, 2.6, and 2.2 mph at the Warren STP for the three day survey, respectively.

3) Sampling Stations

a) Main Stem and Tributary Stations

Figure VII-26 illustrates the location of the 29 stream and tributary sampling stations employed for the July 14-17, 1975 survey. Station descriptions are presented in Table VII-19. Two changes in main stem sampling stations were made from the February survey. A new Station 2 was established at the Summit Street bridge in Warren. Station 2 from the February survey was relocated to the B and O RR bridge in Warren from the Republic Steel-Warren Plant intake to provide better access. This station was renumbered to Station 3 for the July survey. Composite samples were collected at Stations 14 and 16 for the July survey in addition to field measurements. Only field measurements were made during the February survey at these stations. The tributaries Infirmary Run, Red Run, Mud Creek, Squaw Creek, and Coffee Run were also included in the July survey.

b) Municipal Sewage Treatment Plant Stations

Sewage treatment plant discharges from Warren, Niles, McDonald, Girard, Youngstown, Campbell, Struthers, and Lowellville were sampled in the same manner as was done for the February survey.

FIGURE VII-26
STREAM SAMPLING STATIONS
USEPA MAHONING RIVER SURVEY
JULY 1975

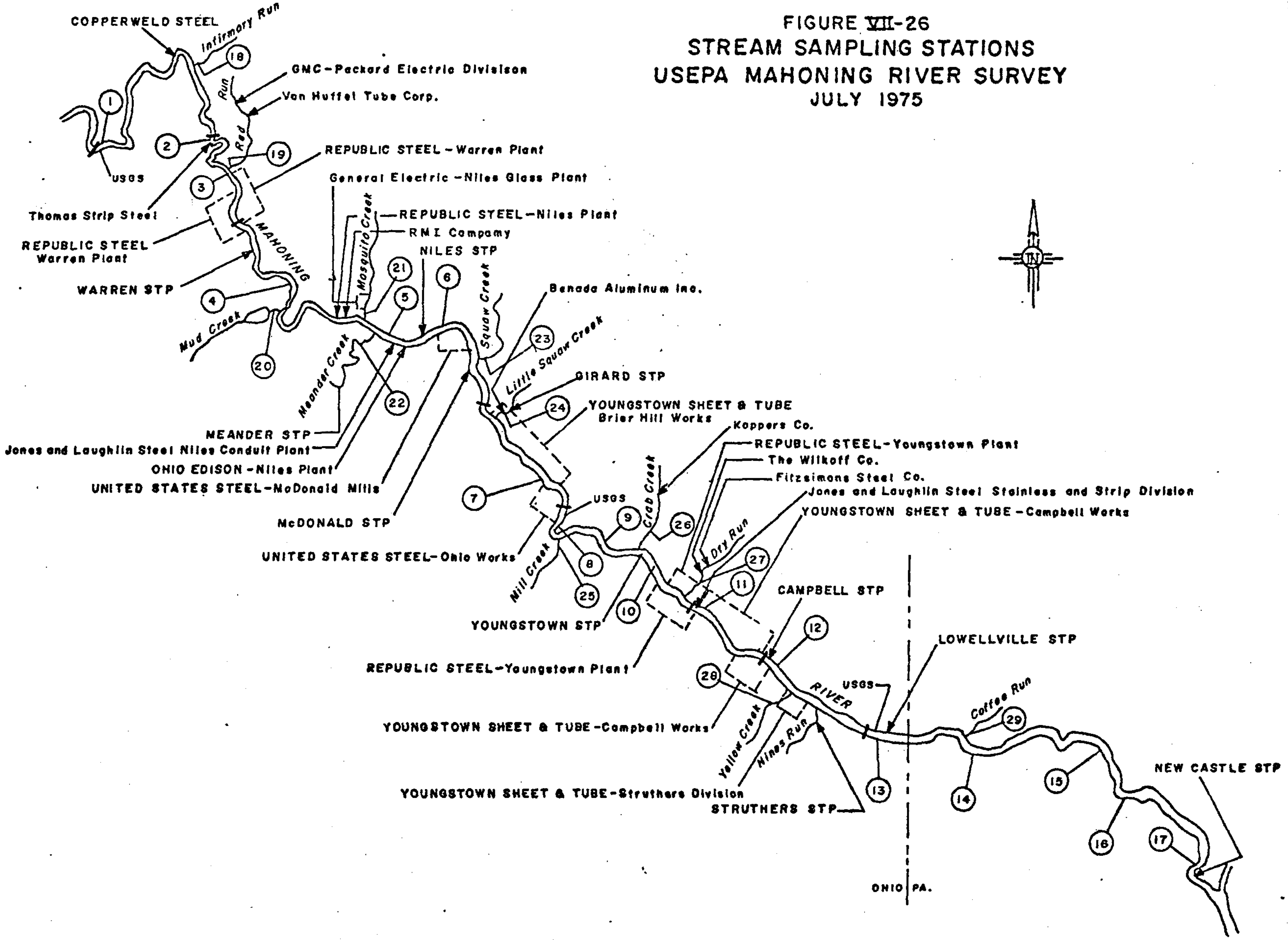


TABLE VII-19

STREAM SAMPLING STATIONS

USEPA MAHONING RIVER SURVEY

July 14-17, 1975

MAIN STEM STATIONS

Station Number	River Mile	Description
1	46.02	Leavitt Road
2*	39.93	Summit Street
3*	38.66	B and O RR - Warren
4	33.71	West Park Avenue
5	30.14	Ohio Edison Intake
6	28.83	U. S. Steel-McDonald Mills Intake
7	23.43	U. S. Steel-Ohio Works Intake
8	22.73	Bridge Street
9	20.91	Marshall Street
10	19.17	B and O RR - Youngstown
11	17.82	Penn Central RR - Youngstown
12	15.83	P and LE RR - Struthers
13	12.64	Washington Street
14	9.69	Church Hill Road (Pa.)
15	6.76	Route 224 (Pa.)
16	4.34	Brewster Road (Pa.)
17	1.52	Penn Central RR (Pa.)

TRIBUTARY STREAMS

Station Number		Tributary (River Mile)		Description (Miles Above Mahoning River)	
February	July				
	18	Infirmary Run	(41.62)	B and O RR	(0.55)
	19	Red Run	(41.04)	At Mahoning River	(0.01)
	20	Mud Creek	(33.33)	Paramount Lake	(0.03)
(18)	21	Mosquito Creek	(31.14)	Penn Central RR	(0.14)
(19)	22	Meander Creek	(30.77)	Route 46	(0.81)
	23	Squaw Creek	(27.67)	Erie Lackawanna RR	(0.04)
	24	Little Squaw Creek	(25.73)	RR Bridge	(0.35)
(20)	25	Mill Creek	(22.03)	Mahoning Avenue	(0.04)
(21)	26	Crab Creek	(19.81)	Elk Street	(0.47)
(22)	27	Dry Run	(18.47)	P and LE RR	(0.13)
(23)	28	Yellow Creek	(15.63)	Yellow Creek Park Dam	(0.44)
	29	Coffee Run (Pa.)	(10.42)	East Churchill Road	(0.30)

* Different than Stations 2 and 3 for February 1975 survey.

c) Industrial Stations

All of the industrial intake and discharge stations sampled during the February survey (Table VII-16) were also sampled during the July survey. Because of curtailed production at the U. S. Steel-Ohio Works, two effluent grab samples per day were obtained by USEPA personnel and combined for analyses. The Republic Steel-Niles Plant was again not sampled because of curtailed production. Outfall 012 of the Republic Steel-Youngstown Plant was included in the July survey, as were the river intake and Outfalls 042, 045, and 049 of the Youngstown Sheet and Tube Company-Struthers Division.

4) Survey Results

Table VII-20 is a listing of the water quality constituents studied. Tables 8 and 9 of Appendix B summarize the municipal and industrial discharge loadings, respectively. A complete compilation of the raw data is on file at the USEPA, Region V, Eastern District Office. Figures VII-27 through VII-47 illustrate trends in stream quality along the main stem of the river. A tabular presentation of the main stem and tributary data can be found in Table 10 of Appendix B. The July survey data are reviewed in the same categories as were the February data.

a) Temperature, Dissolved Oxygen, Nutrients, Suspended Solids

Figure VII-27 presents the temperature profile encountered during the July 1975 survey. Stream temperatures at Leavittsburg averaged about 70°F over the three days, while those in the Youngstown-Struthers area averaged from 78-81°F. Maximum values in the lower reaches of the stream in Ohio approached 86°F. The increase in stream temperature for the flow regime encountered is small by historical standards and is a direct result of low steel production. The aggregate steel industry thermal loading was about 1250×10^6 BTU/hr vs about 2400×10^6 BTU/hr measured in February. Overall, roughly 40 percent less heat was discharged to the stream. The significant temperature variation measured at each station is a result of declining streamflow, the cool air temperatures at night, and the variability of thermal loadings at the U. S. Steel-McDonald Mills and Ohio Works, the Youngstown Sheet and Tube-Brier Hill Works, and the Republic Steel-Warren Plant. For most stations in the Youngstown area, the range of temperatures

TABLE VII-20

WATER QUALITY CONSTITUENTS

USEPA MAHONING RIVER SURVEY

July 14-17, 1975

Field Measurements

- Flow (tributaries only)
- Temperature
- Dissolved Oxygen
- Specific Conductance
- pH

Laboratory Analyses

- Total Dissolved Solids
- Sodium
- Chloride
- Sulfate
- Fluoride

- Total Suspended Solids

- BOD_5
- BOD_{20}
- COD
- TOC

- Total Cyanide
- Phenolics

- Total Kjeldahl Nitrogen
- Ammonia-N
- Nitrite-N
- Nitrite+Nitrate-N
- Total Phosphorus
- Ortho Phosphorus

- Aluminum
- Arsenic
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Zinc

- Total Hardness (stream and tributaries only) exceeded 8°F. Because of the reduced thermal loadings, the Pennsylvania maximum temperature water quality standard of 90°F for July was not exceeded.

Despite lower steel production, the dissolved oxygen profile illustrated in Figure VII-28 demonstrates severe depletion below Warren, a moderate recovery in upper Youngstown, followed by a continual sag from lower Youngstown downstream to the mouth of the river. Dissolved oxygen concentrations averaged 8.4 mg/l (94 percent of saturation) at Station 3 above the Republic Steel-Warren Plant, 6.0 mg/l (70 percent of saturation) at Station 4 in Niles, 3.4 mg/l (42 percent saturation) at Station 6, the U. S. Steel-McDonald Mills intake, 5.9 mg/l (72 percent of saturation) at Station 9 at Marshall Street in Youngstown, 4.6 mg/l (58 percent of saturation) at Station 13 near the Ohio-Pennsylvania State line, and 3.1 mg/l (38 percent of saturation) just upstream from the New Castle STP at Station 17. The Pennsylvania water quality dissolved oxygen standards of 5.0 mg/l daily average, and 4 mg/l daily minimum were violated by wide margins. The profile illustrated in Figure VII-28 is similar to that found during the February 1975 survey (Figure VII-7), but owing to the higher stream temperatures and longer travel times, the sag below Warren is more pronounced. The measured dissolved oxygen deficits at Station 17 for both surveys were fairly close - about 20,000 lbs in February and 18,000 lbs in July. Much of the dissolved oxygen variation encountered at each station during the July survey can be attributed to the declining hydrograph (Figures VII-23, 24). Higher concentrations were generally recorded on the first day of the survey and lower values on the last day.

Figures VII-29 and VII-30 demonstrate that most of the carbonaceous and nitrogenous oxygen demanding wastes were discharged in the Youngstown area. Discharges from the municipal sewage treatment plants were close to those measured in February, while discharges from many of the steel plants were significantly different, (Tables 5, 6, 8, 9, Appendix B). The BOD_{20} values measured at the steel plants from the U. S. Steel-McDonald Mills downstream were not considered reliable since there was not nearly enough carbonaceous material (total organic carbon) or nitrogenous material present in the discharge to account for the extremely high analytical results obtained. Consistent results could not be obtained at various dilutions in the BOD testing. Station to station mass balances of COD, TOC, and BOD_5 show fairly good agreement between measured discharge loadings, while there is a consistently high imbalance in the BOD_{20} discharge loadings in concentrated industrial areas. For these reasons, TOC data were employed for all steel plant wastes to estimate carbonaceous BOD for water quality modeling. These data are also more in line with the COD effluent data obtained (Table 9, Appendix B).

The nitrogen series data are indicative of a more complex stream than was encountered in February (Figure VII-30). Increasing nitrites and nitrates with travel downstream demonstrate nitrification was occurring at a faster rate, as would be expected with higher stream temperatures. However, simple nitrification of ammonia-N to nitrate-N was not the only reaction involving the various forms of nitrogen in the stream. A mass balance between Stations 3 and 4 indicate a nitrogenous discharge load was not accounted for in the discharges from the Republic Steel-Warren Plant and the Warren sewerage system. From Station 4 to Station 5, instream settling in the upper reaches of the Liberty Street Dam pool most likely accounts for the loss of organic nitrogen. The small increase in ammonia–N is probably the result of the breakdown of organic-nitrogen. Nitrification was also occurring as evidenced by the increase in nitrate-N.

Reactions between the Ohio Edison Power Plant and the U. S. Steel-McDonald Mills intakes appear to be more complex. The power plant used about 60 percent of the total river flow for condenser cooling and virtually instantaneously raised the temperature of this water by 12-15°F. In addition, chlorination of the intake cooling water for slime control was practiced daily. These factors probably resulted in algal die-off, and, further settling in the dam pool resulted in a loss of organic nitrogen. It also appears that the rate of nitrification in the stream was exceeded by the rate of nitrate-N uptake as shown by decreasing nitrate-N. Previous data obtained at Ohio Edison indicate conversion of about 200 lbs/day of organic–N to ammonia–N through the plant.[35]

Nitrification was also occurring between the U. S. Steel-McDonald Mills intake (Station 6) and the U. S. Steel-Ohio Works intake (Station 7) as evidenced by a corresponding decrease in ammonia-N and an increase in nitrate-N. While this was occurring, the organic-N level (and TKN) also increased, possibly indicating the presence of blue-green algae behind the Liberty Street Dam. It appears that a discharge source was missed between the U. S. Steel-Ohio Works and the Marshall Street falls in Youngstown (Station 9) as evidenced by increasing nitrogenous material as well as carbonaceous material. The Youngstown sewerage system is suspect as there are numerous overflows in that area.[36]

The Youngstown STP and the Republic Steel-Youngstown Plant discharges are plainly evident between Stations 9 and 11. The data obtained above and below the Youngstown STP and Republic Steel indicate that algal growth was occurring. However, the situation reversed itself in the Youngstown Sheet and Tube dam pool as a large decrease in organic-N was accompanied by a large increase in ammonia-N not fully accounted for by discharge loadings from the Campbell STP and the Youngstown Sheet and Tube-Campbell Works. Breakdown of some of the organic nitrogen discharged by the Youngstown STP, Republic Steel, and Youngstown Sheet and Tube to ammonia-N probably accounted for most of this change. Since TKN was also lost, it appears that algal die-off may have been caused by high temperatures and high levels of toxic materials. Settling behind the dam resulted in removal of some of the organic-nitrogen from the stream.

The large increase in organic-nitrogen between Stations 12 and 13 probably resulted from the growth of blue-green and green algae in the Lowellville dam pool. The blue-green forms can use both available ammonia–N and fix nitrogen from the atmosphere, while the green forms would probably use nitrate-N for synthesis. Conditions for such growth during the survey were good, i.e., high stream temperatures and considerable sunshine. Also, toxic materials were significantly reduced at Station 13 from upstream levels. Nitrification was obviously occurring below Station 13 in Pennsylvania. However, the growth of algae and conversion of organic-N to ammonia–N complicated the nitrogen balance in the stream.

Most of the nitrogenous oxygen demand was not satisfied in the Mahoning River, but was discharged to the Beaver River. Based upon Figure VII-30, this demand averaged nearly 50,000 lbs/day during the July survey vs the 90,000 lbs/day encountered during the February survey when steel production was much higher and industrial TKN loadings were 80 percent greater.

Suspended solids concentrations in the stream were found to be highly variable as shown in Figure VII-31. This is attributed to the rainfall events described earlier. The higher values were measured on the first day of the survey immediately following the rain and the lowest values on the last day while the hydrograph was declining. It is interesting to note that the highest dissolved oxygen concentrations also coincided with high runoff, suggesting the effect of the rainfall event was an improvement in stream quality. Since the previous rainfall event was more severe (Figure VII–24) and occurred only three days earlier, it is possible that slug loadings of oxygen demanding wastes often assoicated with storm events were not discharged during the rainfall event immediately preceeding the survey.

Instream settling occurred above the major dischargers in the Warren area followed by an increase in the solids loading below the Republic Steel-Warren Plant and the Warren STP. There is a dramatic change in sediment quality above and below these dischargers (Table VII-18). Significant settling also occurred in the upper Youngstown area as well as in Pennsylvania. The effects of the loadings from the Youngsotwn STP and the steel industry in the Youngstown-Struthers area are plainly evident.

Figure VII-32 presents concentrations and flowing loads of ammonia–N at each station. As noted above, the most significant loadings were discharged in the Warren and lower Youngstown areas. Concentrations above Warren were very low, and in many instances below the limit of detection (0.03 mg/l). However downstream at Station 4, the concentration averaged about 0.8 mg/l. At Station 12 in Struthers, the average concentration was 2.1 mg/l. At the State line (Station 13) the average value of 1.9 mg/l more than doubled the recommended USEPA aquatic life criteria of 0.8 mg/l (pH 7.5 and temperature 81^{o}F) based upon 0.02 mg/l of unionized ammonia-N.

Concentrations of total phosphorus and flowing loads of total and ortho-phosphorus are illustrated in Figure VII-33. Upstream of Warren concentrations of total phosphorus in the immediate range of 0.1 mg/l were found. However, loadings from the Warren STP (590 lbs/day) and the Youngstown STP (1140 lbs/day) largely account for the increase in concentration to nearly 1.0 mg/l in Youngstown. As in February, the steel industry loading (600 lbs/day) was low in comparison to the municipal discharges (2280 lbs/day). About 70 percent of the phosphorus discharged by the municipalities was ortho-phosphorus, while about 50 percent of the industrial discharges was ortho-phosphorus. Hence, most of the phosphorus discharged is in a form that is readily assimilated for biological growth.

As noted earlier, the levels encountered in the stream are high compared to concentrations necessary to stimulate biological productivity and phosphorus controls may be warranted in the future to limit algal growth in the stream. The high turbidity in the Mahoning River resulting from the high erodability of the soils in much of the basin may serve to limit algal growth in spite of high nutrient levels due to reduced light penetration. However, high growth rates are expected.

Of the tributaries sampled, Little Squaw Creek, made up of primary effluent from the Girard STP, had the highest concentrations of carbonaceous and nitrogenous materials as well as phosphorus. Most other tributaries with known sewage discharges exhibited moderate contamination. Mill Creek was one of the cleaner tributaries during the survey.

b) Total Dissolved Solids, Fluoride, Sodium, Chloride, Sulfate

Figures VII-34 and VII-35 present dissolved solids and fluoride profiles encountered during the July survey, respectively. Pennsylvania water quality standards for these constituents were not exceeded. The maximum dissolved solids concentration in Pennsylvania was less than 370 mg/l vs. the standard of 500 mg/l and the maximum fluoride concentration detected in Pennsylvania was less than 0.6 mg/l vs. a standard of 1.0 mg/l. Industrial fluoride loadings were much higher in February (2410 lbs/day) than in July (550 lbs/day) accounting for the relatively low concentrations, while the municipal discharges were about the same (380 lbs/day in February and 470 lbs/day in July). The average loading from Mosquito Creek was about 350 lbs/day with concentrations ranging from 0.46 to 0.66 mg/l, indicating possible greater discharges from the General Electric-Niles Glass Plant than in February.

Major discharges of sodium, chloride, and sulfate in the Youngstown area are illustrated in Figures VII-36, 37, and 38, respectively. While the concentrations and flowing loads of sodium and chloride leveled off at the State Line and remained relatively constant in Pennsylvania, the concentration and loading of sulfates continued to increase, again indicating runoff from abandoned mining sites in that area of the basin.

c) Total Cyanide and Phenolics

Despite lower steel production, the concentration of total cyanide exceeded 100 µg/l in the Ohio portion of the stream and, as illustrated in Figure VII-39, exceeded the Pennsylvania water quality standard of 25 µg/l by a wide margin. Although the total industrial loading for the July survey (290 lbs/day) was considerably less than measured in February (1300 lbs/day), high stream concentrations were recorded because of reduced streamflow (533 cfs vs 1061 cfs at Youngstown). The Republic Steel-Youngstown Plant contributed nearly half of the industrial total cyanide loading in July and the Youngstown Sheet and Tube-Campbell Works contributed about one third. The municipal discharge during the July survey averaged about 110 lbs/day, over 75 percent of which was discharged by the Youngstown STP.

The industrial discharges of phenolics were also considerably lower in July than in February (260 lbs/day vs 1120 lbs/day), with the Youngstown Sheet and Tube-Campbell Works contributing nearly 60 percent of the measured total. Loadings of both total cyanide and phenolics recorded from the Republic Steel plants may be low because the samples were not iced during collection. Although samples were obtained in containers with chemical preservatives added before collection, the hot effluent temperatures and lack of icing prevented the samples from being cooled to recommended holding temperatures until several hours after collection of the composite samples. The Pennsylvania water quality standard of 5 µg/l was barely exceeded at the State line. At Station 17, the concentration was reduced to below detectable levels (2 µg/l). Phenolics were not detected above the Republic Steel-Warren Plant. The reduced loadings coupled with longer travel time and warmer temperatures resulted in much lower concentrations than measured in February. From the data presented in Figure VII-40, it appears that the rate of decay of phenolics was much faster from Station 12 to Station 13 where concentrations were relatively high than from Station 13 to Station 17 where concentrations were in the 0–15 µg/l range. This may be due to different reaction rates for the various types of phenolic compounds present in coke plant and blast furnace discharges.

Crab Creek was again found to be highly contaminated with total cyanide and phenolics, suggesting significant discharges from the Koppers Company plant located on that tributary; Little Squaw Creek contained detectable levels of cyanide and phenolics, most of which appear to be discharged from the Girard STP. Red Run also showed high concentrations of cyanide, although the rate of flow was negligible (< 0.1 cfs). The source of cyanide is among the several industrial dischargers to Red Run in Warren. The source of cyanide in Squaw Creek is unknown.

d) Metals

Figures VII-41 to 47 present measured concentrations and flowing loads of aluminum, arsenic, chromium, copper, iron, manganese, and zinc, respectively, for the July 1975 survey.

Cadmium was detected in the main stem of the river only on the third day of the survey at Stations 8 (13 μg/l), and 10 (11 μg/l), and in Crab Creek (11 μg/l), slightly above the detectable limit of 10 μg/l and above the Ohio general water quality standard of 5 μg/l {EP-1-02(J)}. It does not appear that the measured discharges of 1 lb/day and 7 lbs/day from the Republic Steel-Warren and Youngstown Plants, respectively, could account for the measured stream concentrations owing to their location and instream dilution. Aside from a minor discharge from the Warren STP (< 1 lb/day), there were no other measured cadmium discharges during the survey. Lead was found above the detectable limit of 50 μg/l and above the Ohio general water quality standard of 40 μg/l on July15-16, 1975 at Station 9 (100 μg/l), and on July 16-17, 1975 in Dry Run (110 μg/l). Although discharges of lead were measured at Copperweld Steel (84 lbs/day), the Republic Steel-Warren Plant (23 lbs/day), the Republic Steel-Youngstown Plant (44 lbs/day), the Youngstown Sheet and Tube-Campbell Works (38 lbs/day), and the Youngstown Sheet and Tube-Struthers Division (8 lbs/day), none could be found in the stream directly below these plants. However, a review of the sediment chemistry data presented in Table VII-18 reveals high concentrations from Niles downstream. Lead was not detected in municipal discharges during the July survey.

Of the other metals studied, chromium (Figure VII-43) was detected in the range of 0-30 μg/l, well below the general Ohio water quality standard of

300 μg/l. Arsenic (Figure VII-42) was found in the range of 0-7 μg/l, also well below the respective water quality standard of 50 μg/l. Although there is no stream standard for aluminum (Figure VII-41), relatively high concentrations (300-500 μg/l) were found at Leavittsburg as well as in the industrial reach of the stream. Little Squaw Creek contained 26-60 mg/l of aluminum.

At the total hardness values found in the stream (136-170 mg/l), Ohio general water quality standards for copper (Figure VII-44) and zinc (Figure VII–47) would be 10 and 100 μg/l respectively. As shown in Figures VII-44 and 47, these values were exceeded by wide margins both in Ohio and Pennsylvania. Major sources of copper were the Republic Steel-Warren Plant (239 lbs/day), Copperweld Steel (27 lbs/day), and the Republic Steel-Youngstown Plant (23 lbs/day). The total municipal discharge averaged about 15 lbs/day. Most of the steel plant loading results from blast furnace operations. Probable sources are the copper furnace cooling systems and traces in ores.

Major zinc sources were the Youngstown Sheet and Tube-Campbell Works (451 lbs/day), Republic Steel-Youngstown Plant (147 lbs/day), the Republic Steel-Warren Plant (143 lbs/day), and the Youngstown Sheet and Tube-Brier Hill Works (63 lbs/day). The total municipal discharge averaged 57 lbs/day. Steel plant zinc sources include galvanizing line rinse waters and blast furnace discharges.

Figure VII-45 depicts violations of Pennsylvania's total iron standard of 1.5 mg/l with values of the State line ranging from 2.2 to 2.6 mg/l and those at Station 17 in New Castle reduced to 1.1 - 1.3 mg/l by instream settling. Major sources of iron are blast furnace and hot forming discharges. Assuming the pickle rinse iron discharges are totally ferrous iron and other iron discharges are ferric iron, there was relatively little ferrous iron discharged to the stream. Since total manganese (Figure VII-46) never exceeded 1.0 mg/l, the general Ohio stream standard of 1.0 mg/l dissolved manganese was obviously not exceeded. The highest concentrations were recorded at Leavittsburg. Slightly increasing concentrations from Lowellville to New Castle are probably the result of runoff from mining activities in that part of the basin.

Metals contamination of the tributaries is a function of the type of discharges to the tributaries. Red Run exhibited high levels of copper (200-820 µg/l) and zinc (340-3600 µg/l) indicating plating or metal finishing wastes; Squaw Creek contained high levels of iron (13-20 mg/l) and zinc (5300-6800 mg/l), the source of which is unknown; Little Squaw Creek showed high levels of aluminum (26-60 mg/l) and chromium (1300-2400 µg/l) most probably from the Benada Aluminum Products Company discharge; Dry Run contained high concentrations of copper (510-1400 µg/l), chromium (15–600 µg/l), zinc (140-230 µg/l), and iron (46-283 mg/l), a result of pickle rinse water and other discharges from Fitzsimons Steel. The pH of Dry Run ranged from 2.8 to 3.3 standard units. Mud Creek contained detectable levels of arsenic (11-14 µg/l). Infirmary Run, Mosquito Creek, Mill Creek, Crab Creek, Yellow Creek, and Coffee Run were relatively free of metals contamination.

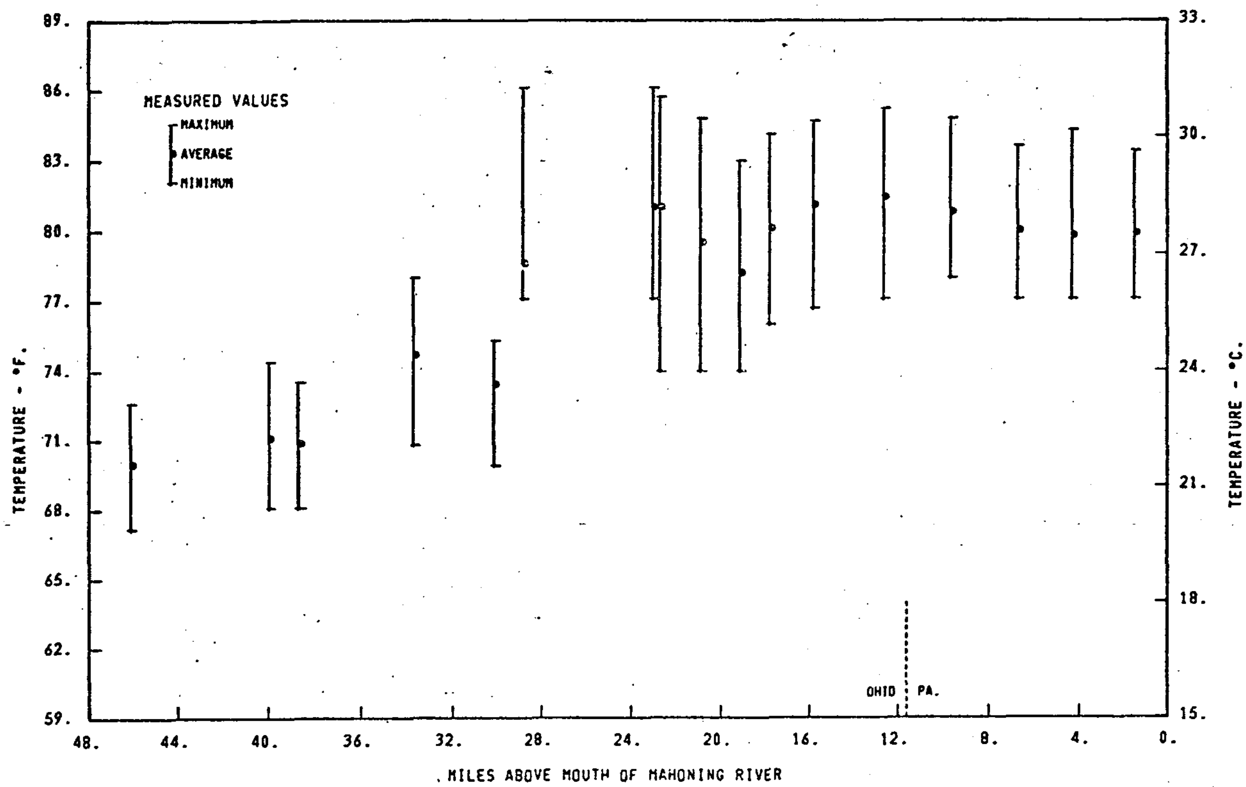


FIGURE VII-27
TEMPERATURE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

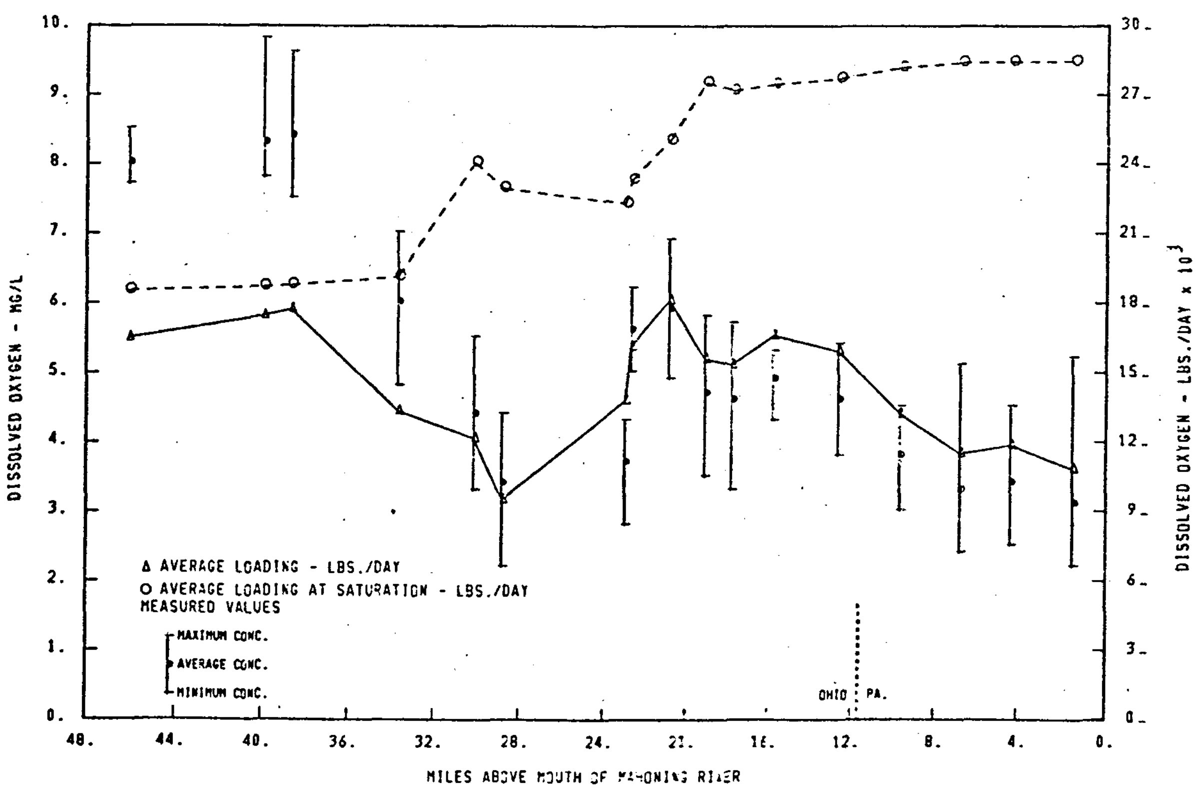


FIGURE VII-28
DISSOLVED OXYGEN VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

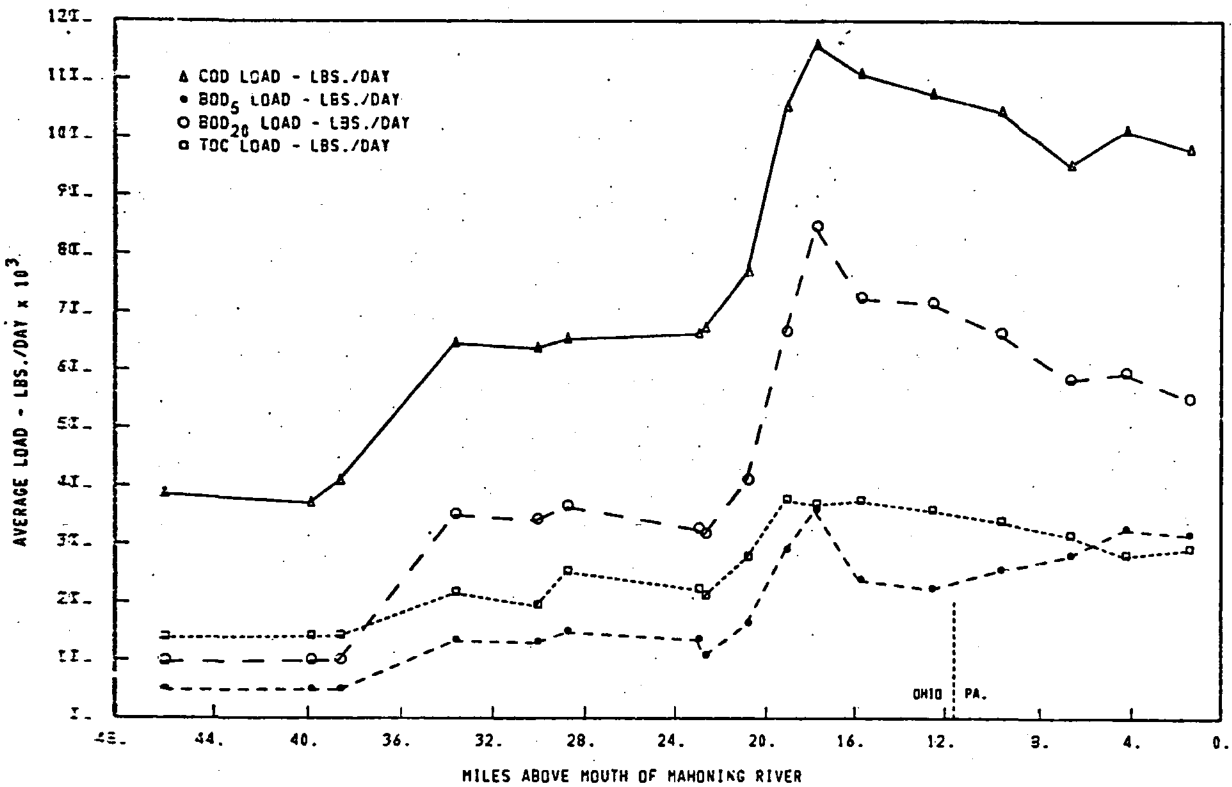


FIGURE VII-29
COD, BOD_5, BOD_{20}, TOC VS. RIVER
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

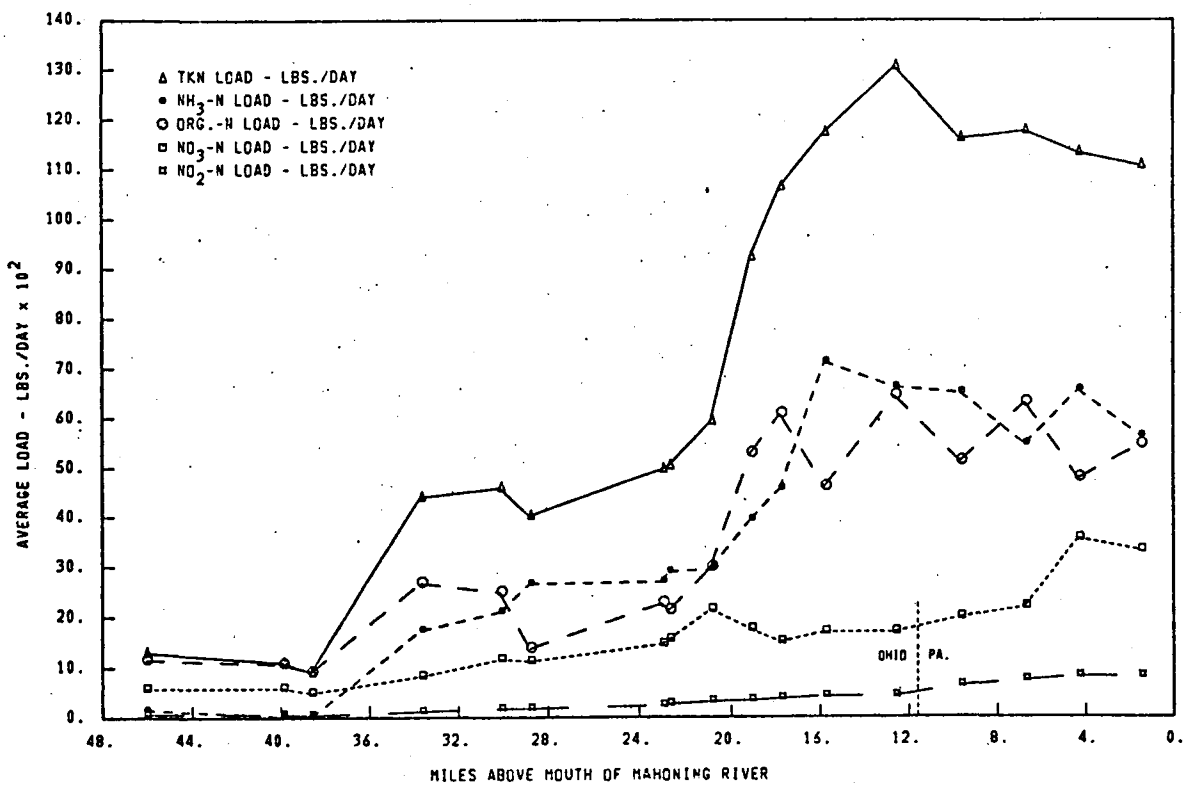


FIGURE VII-30
TKN, NH_3-N, ORG.-N, NO_3-N, NO_2-N VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

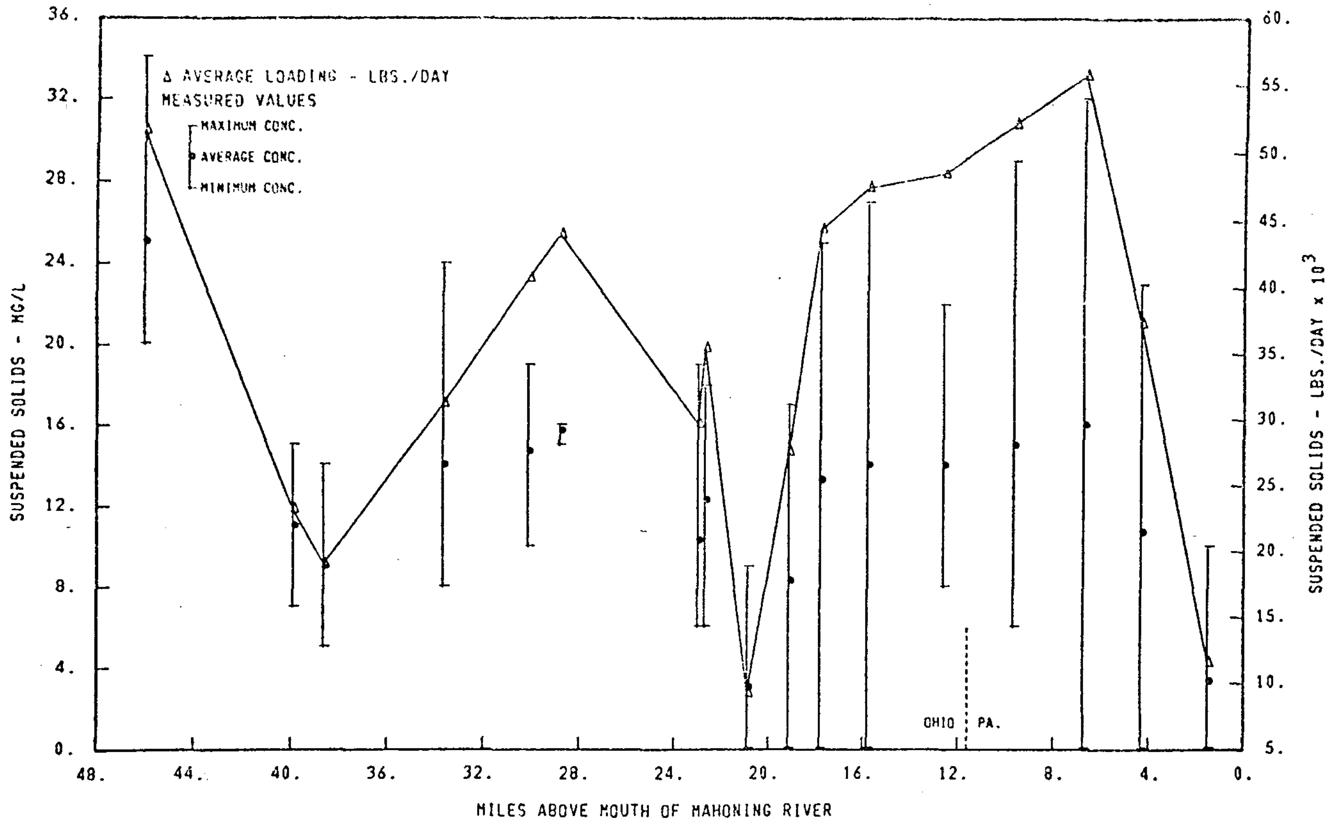


FIGURE VII-31
SUSPENDED SOLIDS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

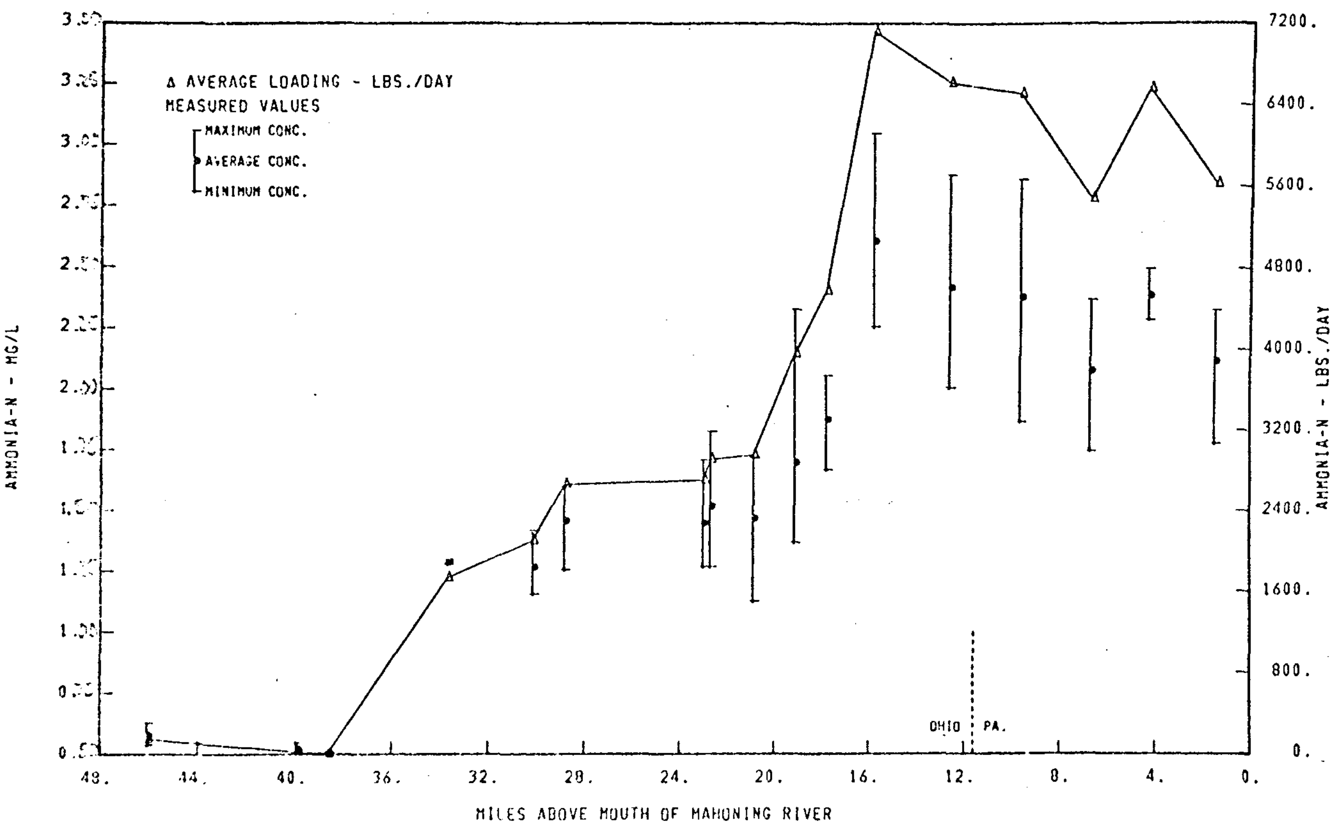


FIGURE VII-32
AMMONIA-NITROGEN VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

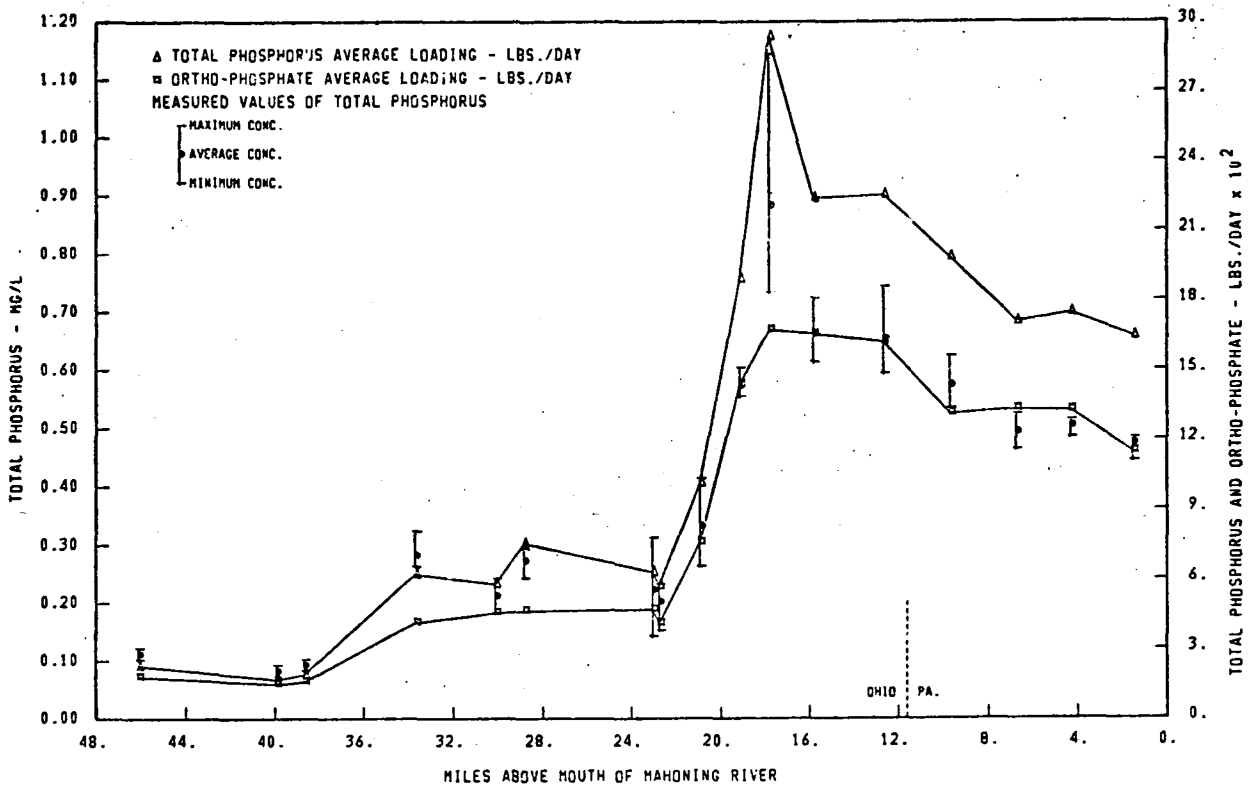


FIGURE VII-33
TOTAL PHOSPHORUS AND ORTHO-PHOSPHATE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

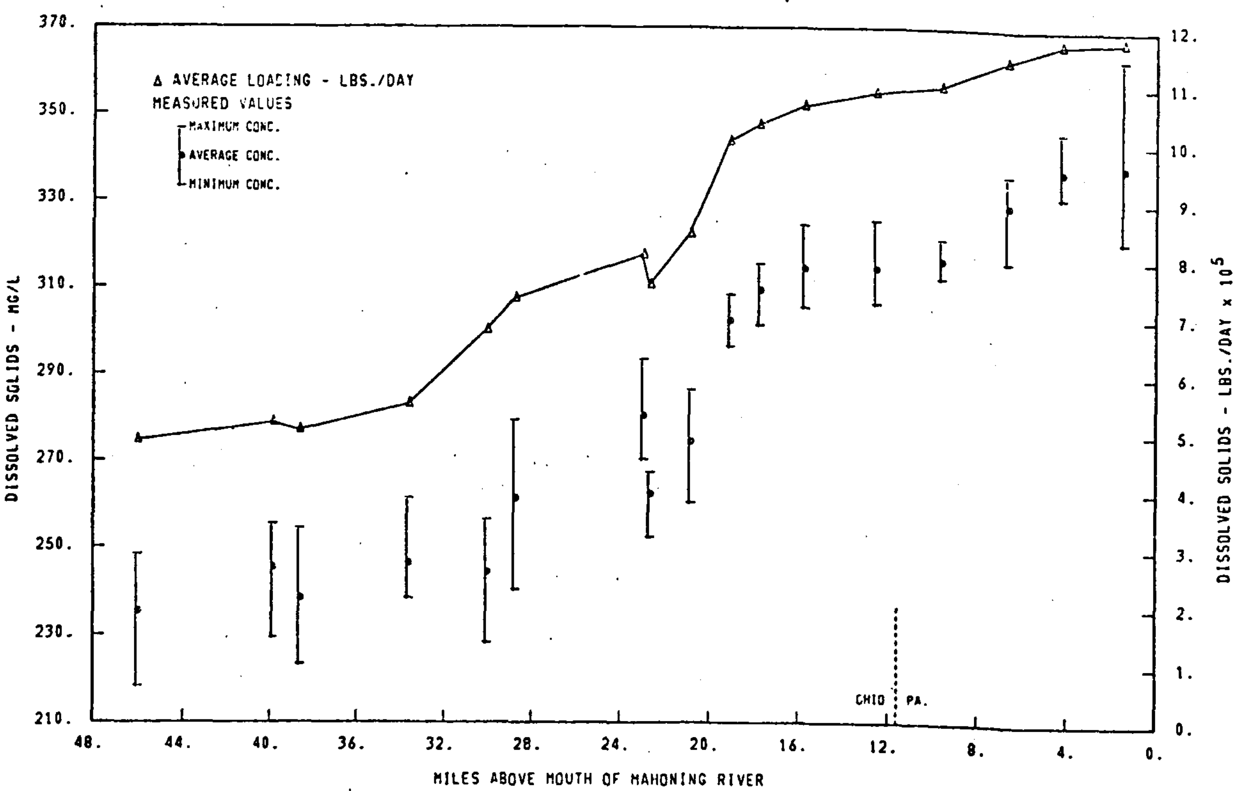


FIGURE VII-34
DISSOLVED SOLIDS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

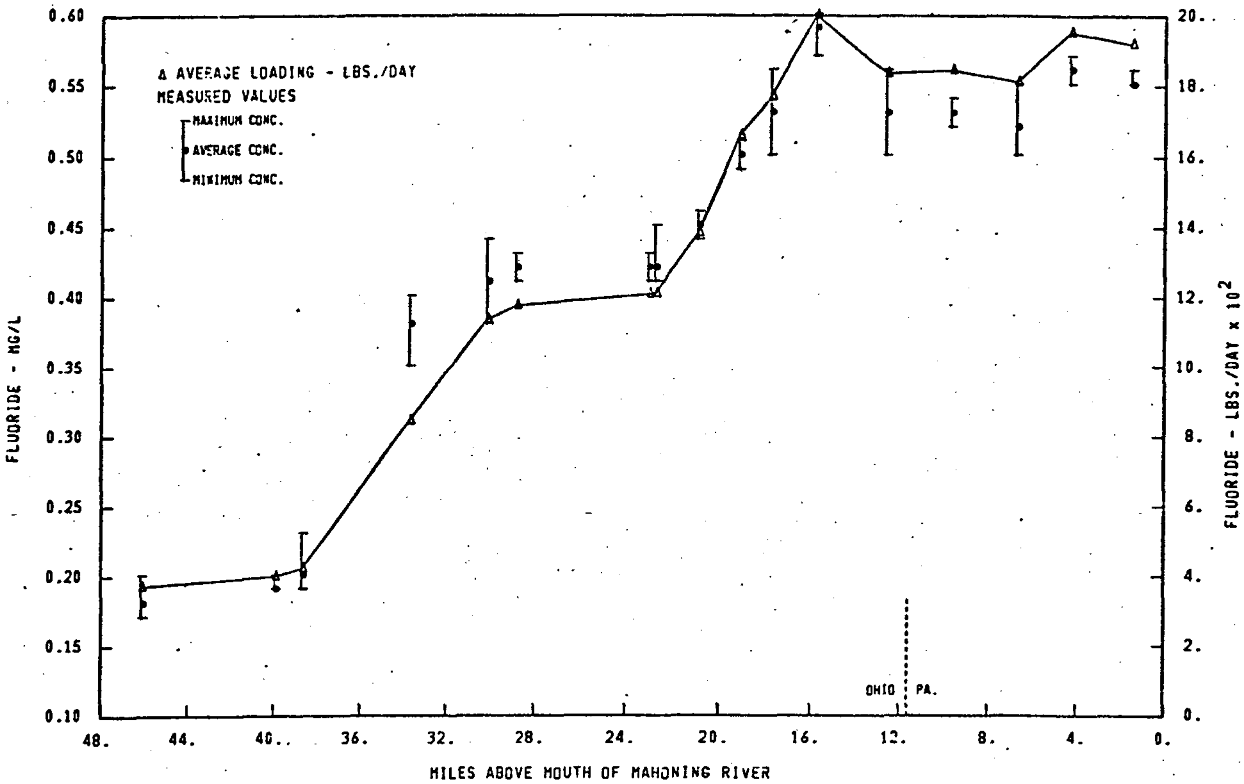


FIGURE VII-35
FLUORIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

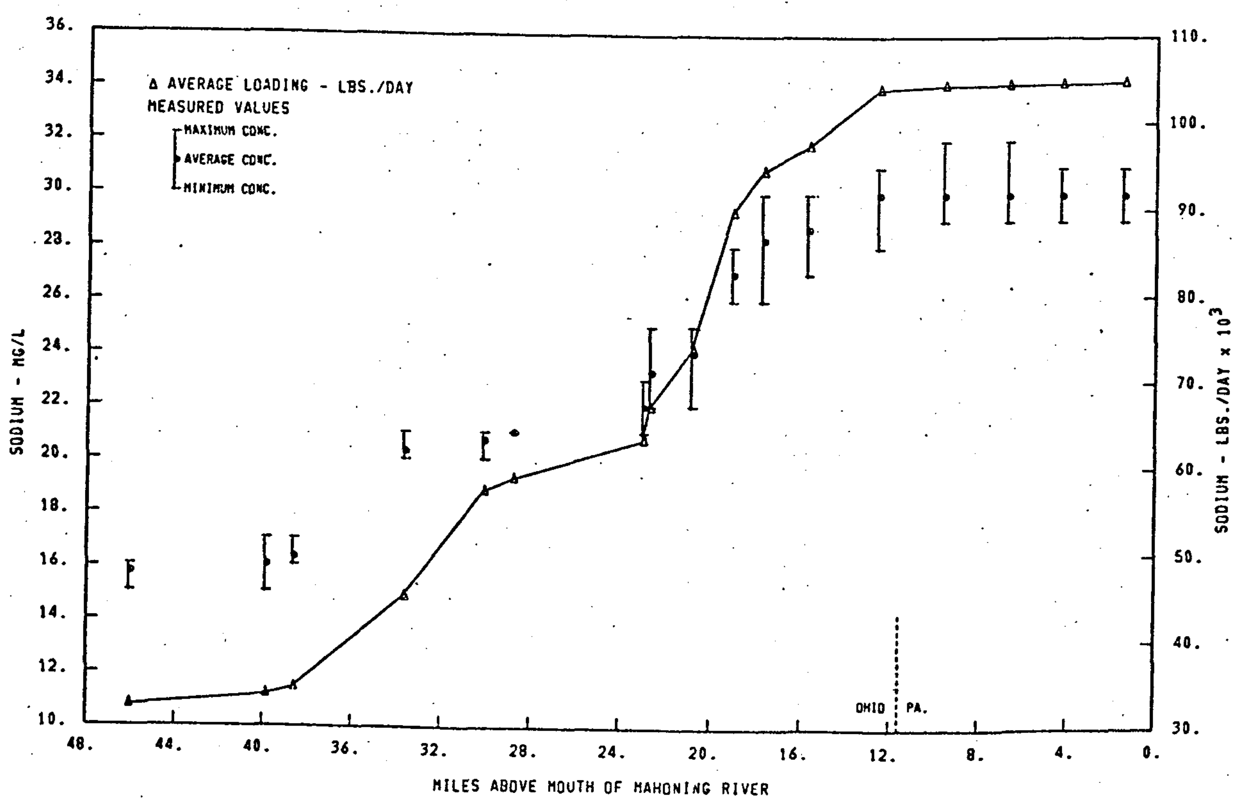


FIGURE VII-36
SODIUM VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

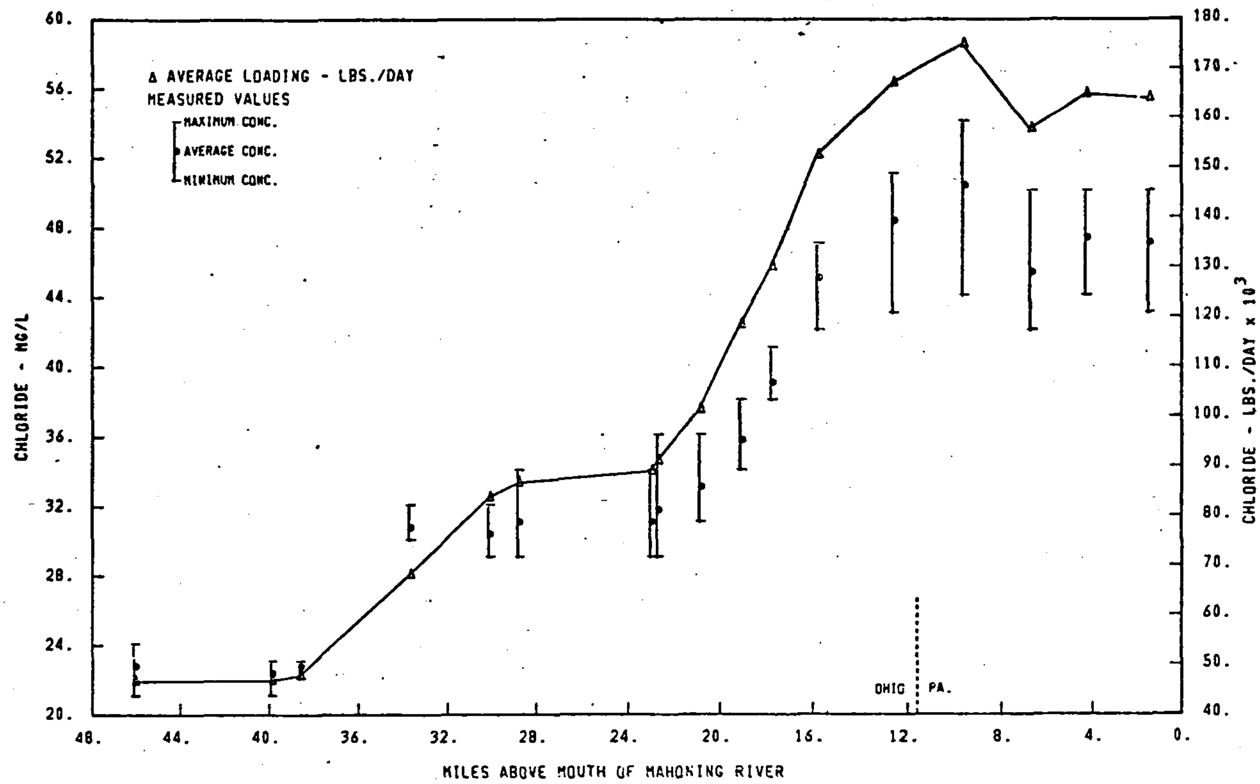


FIGURE VII-37
CHLORIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

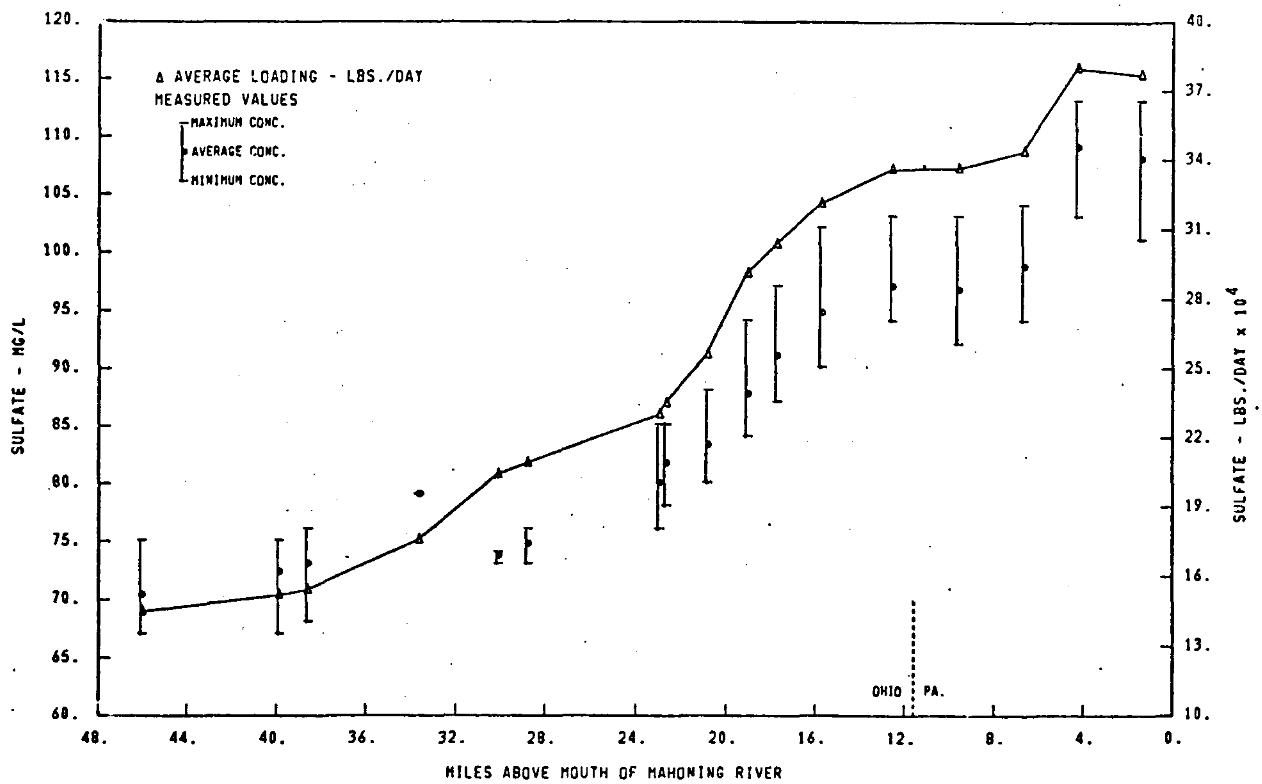


FIGURE VII-38
SULFATE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

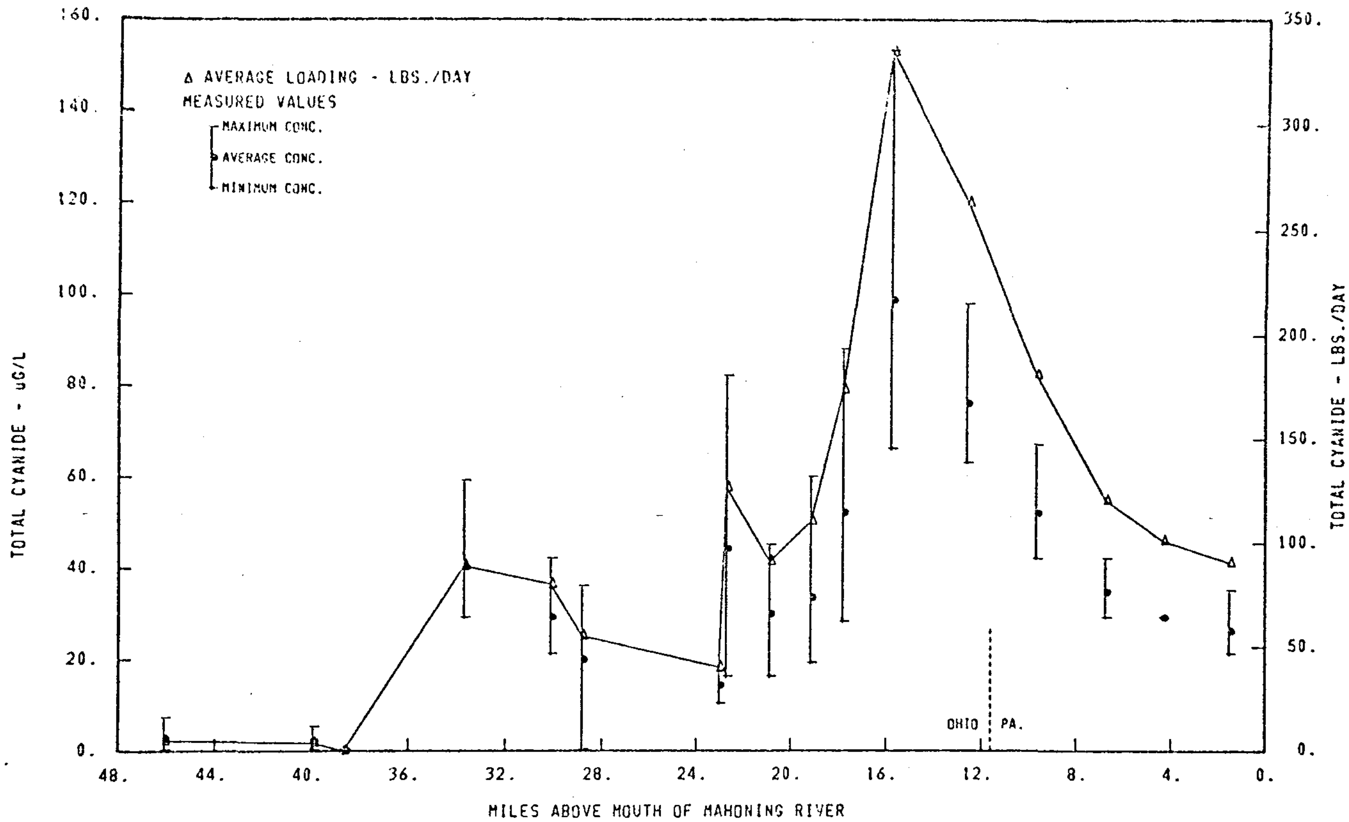


FIGURE VII-39
TOTAL CYANIDE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

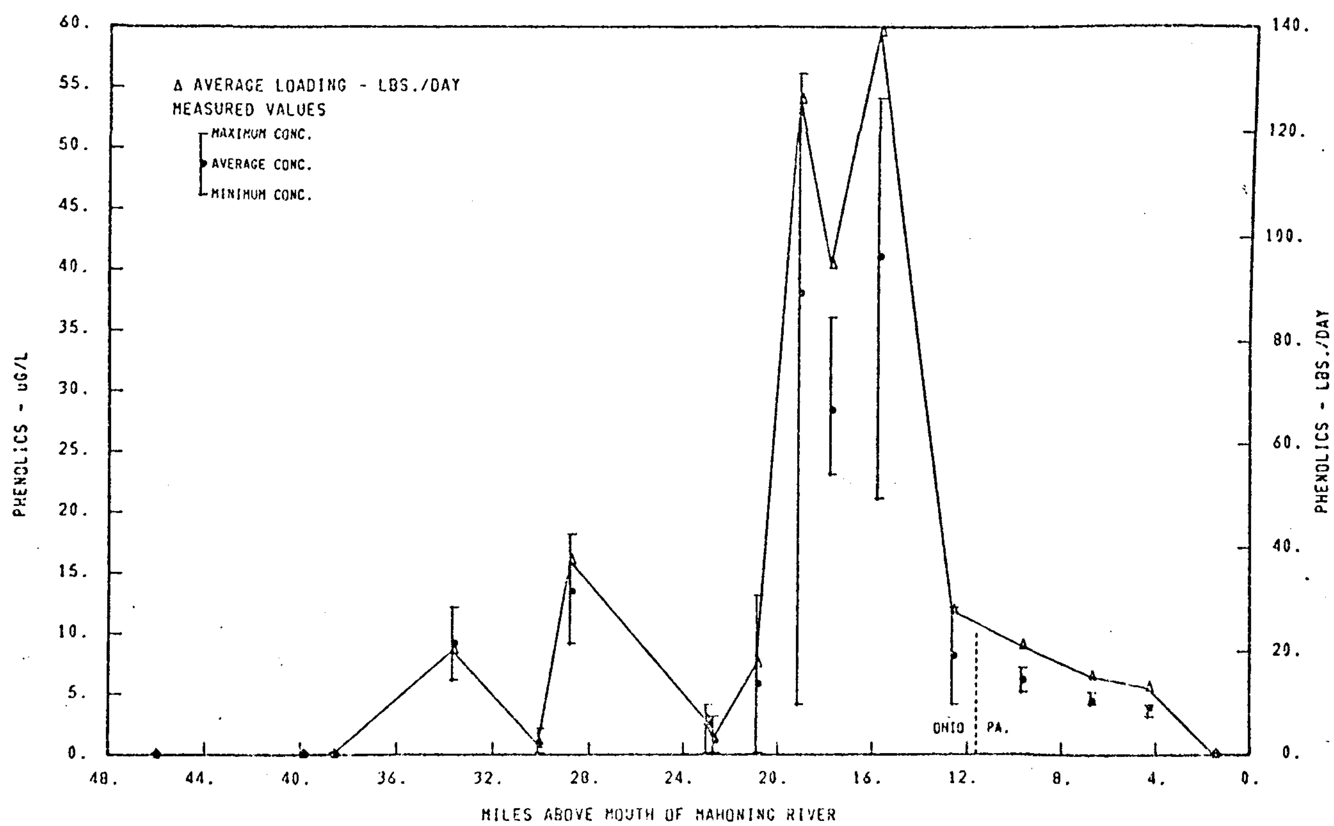


FIGURE VII-40
PHENOLICS VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

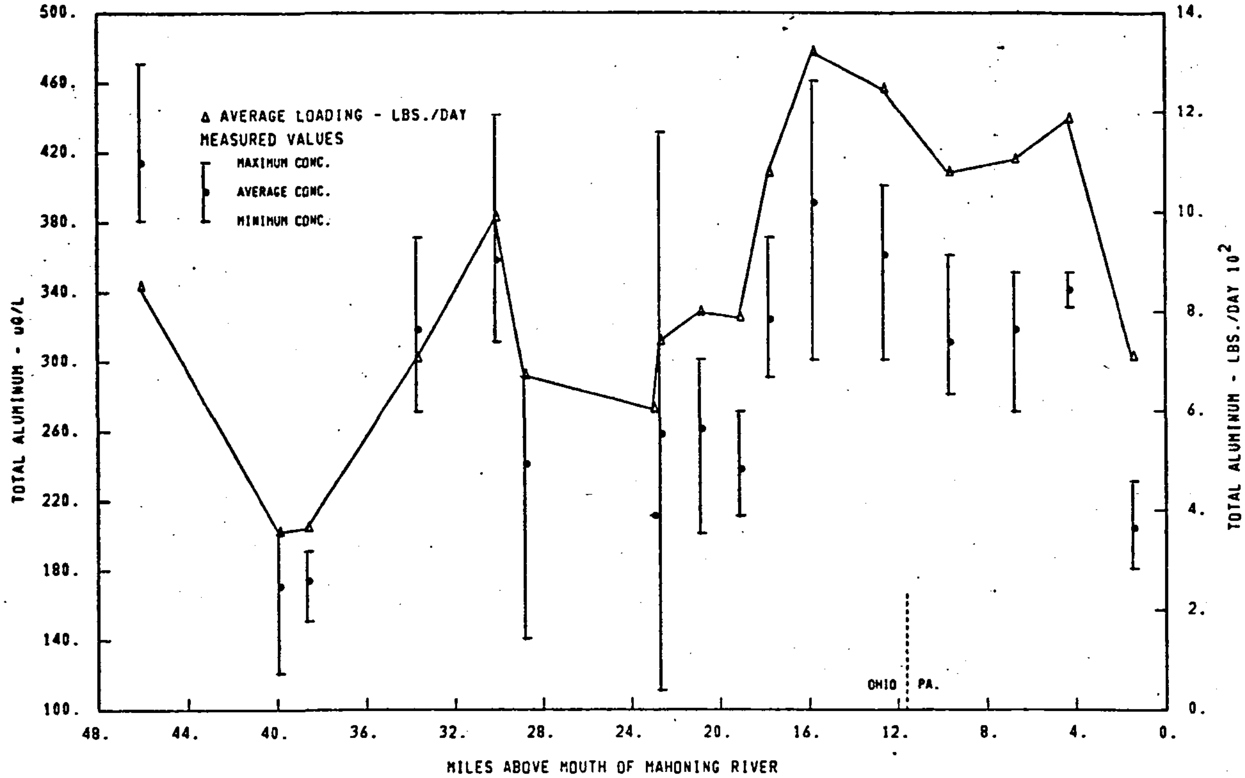


FIGURE VII-41
TOTAL ALUMINUM VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

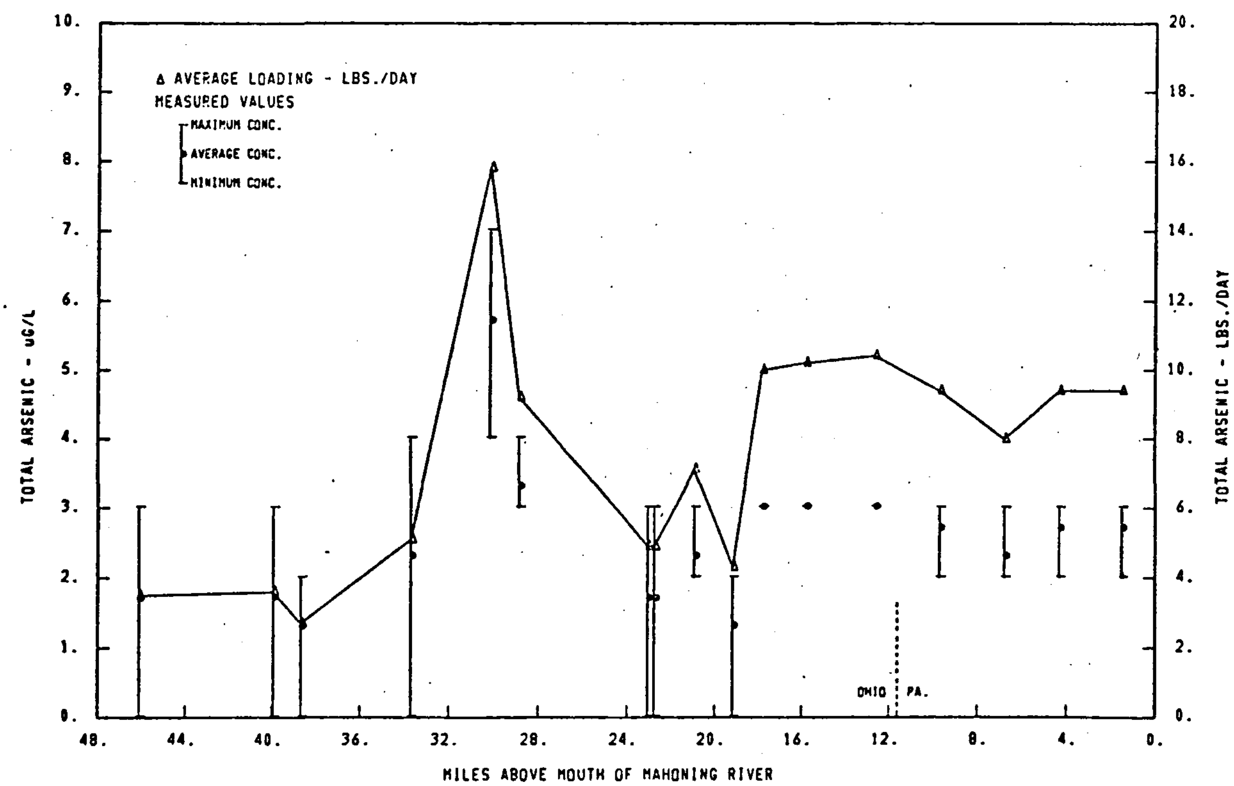


FIGURE VII-42
TOTAL ARSENIC VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

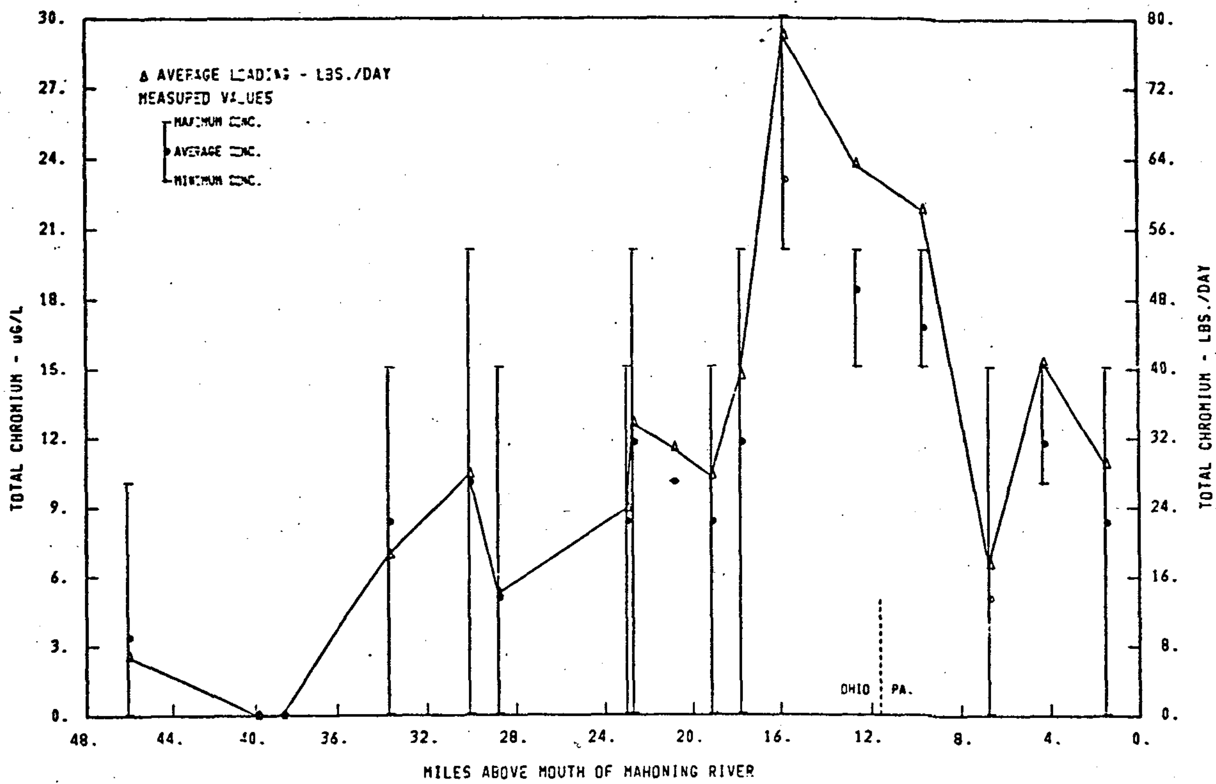


FIGURE VII-43
TOTAL CHROMIUM VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

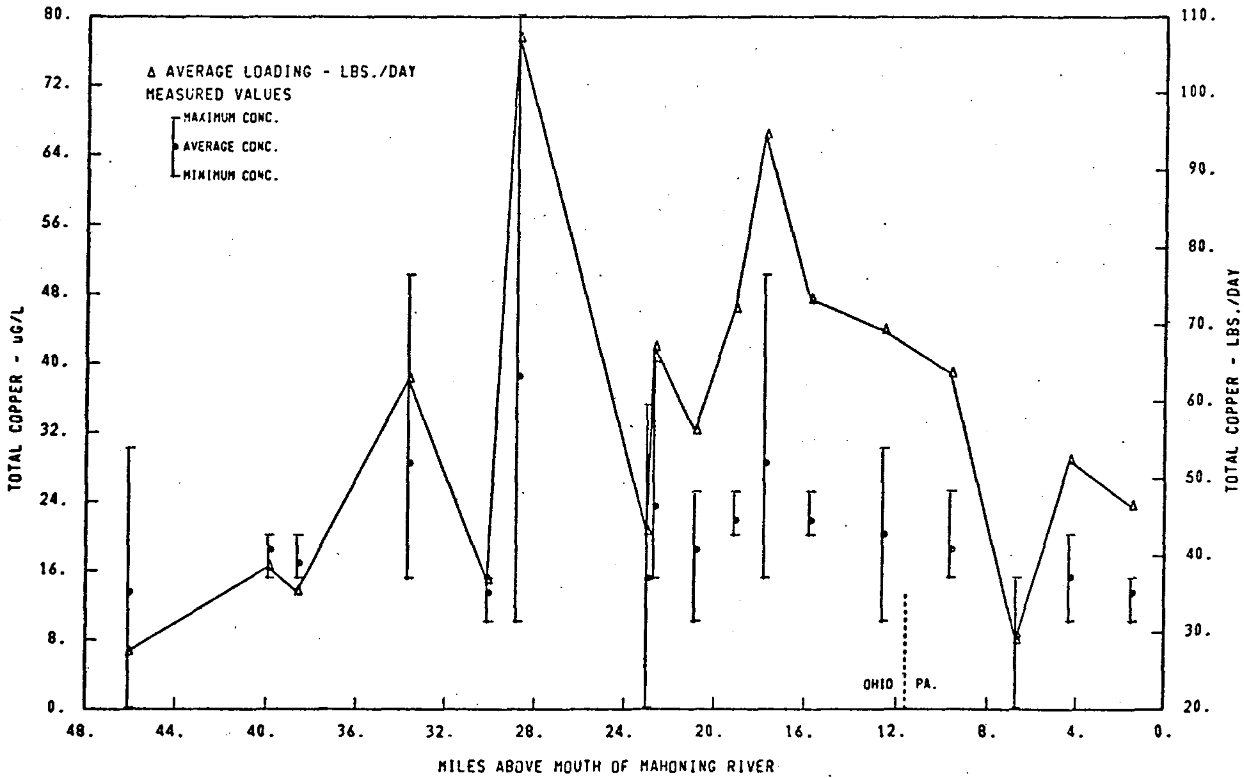


FIGURE VII-44
TOTAL COPPER VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

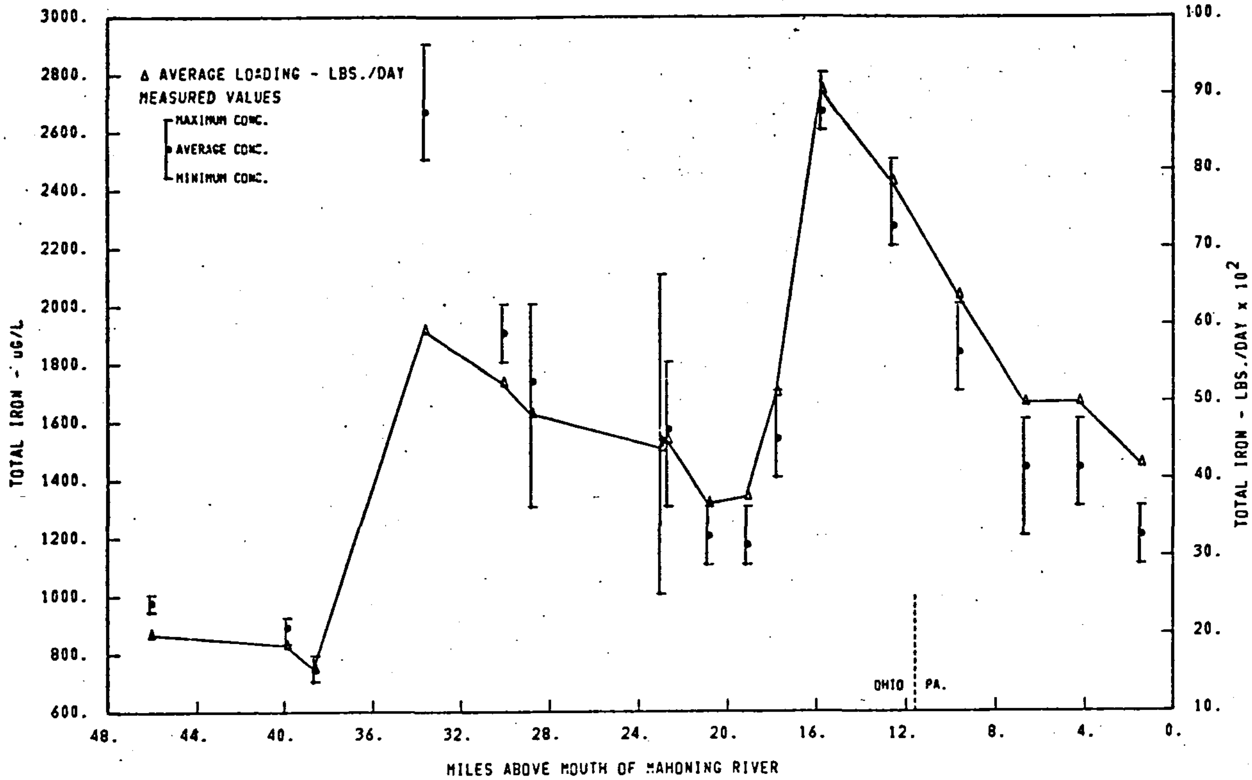


FIGURE VII-45
TOTAL IRON VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

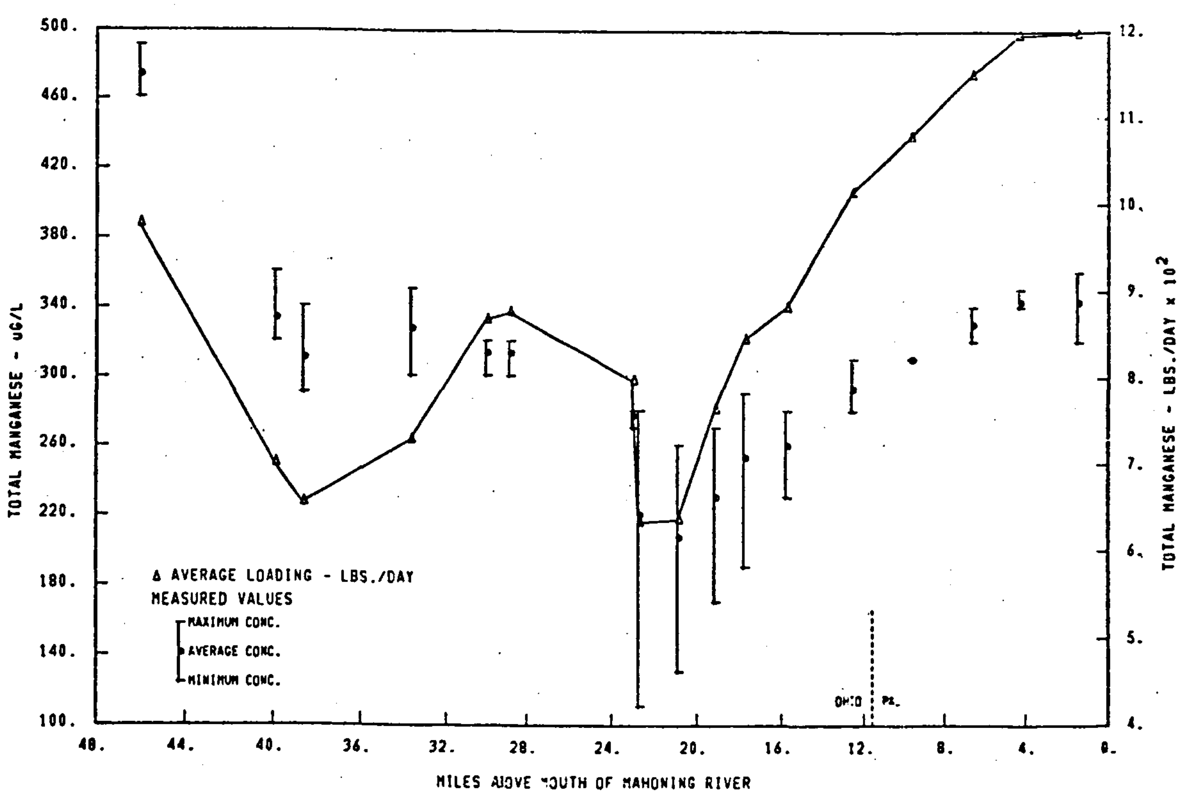


FIGURE VII-46
TOTAL MANGANESE VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

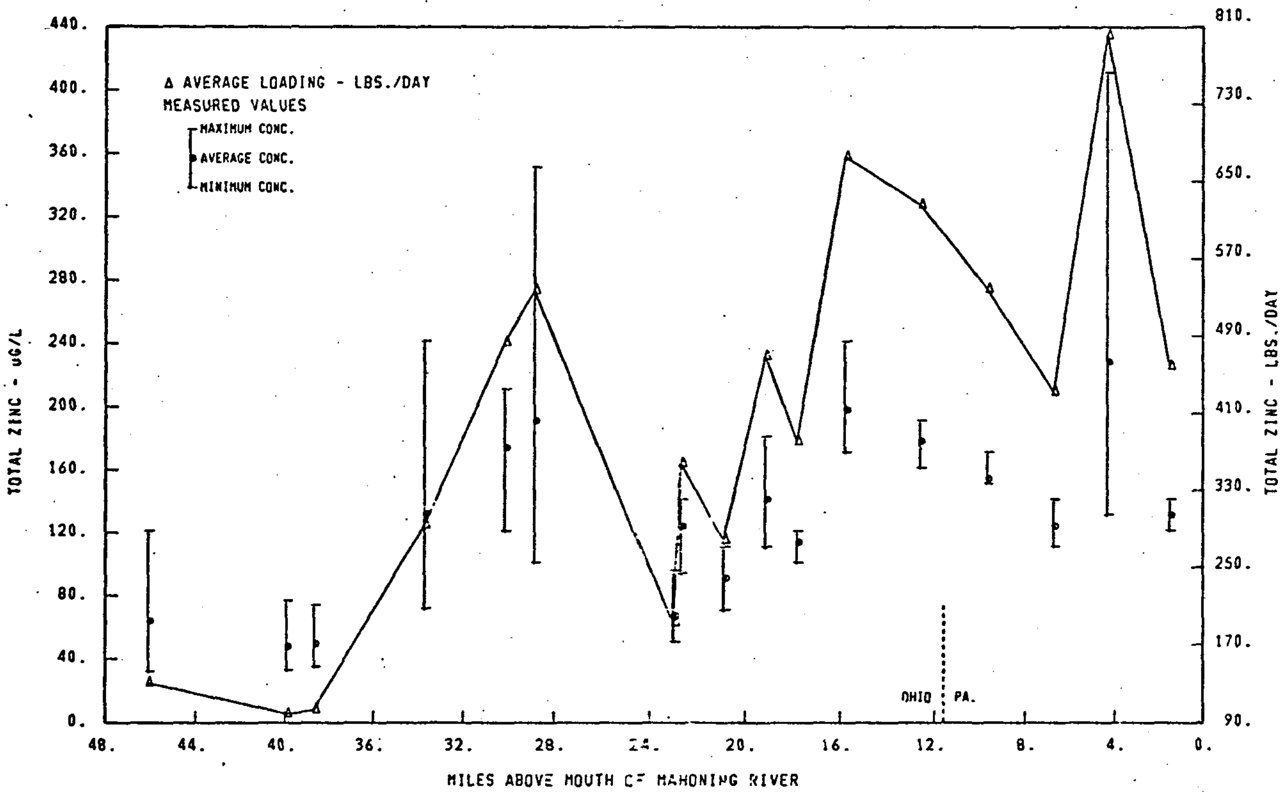


FIGURE VII-47
TOTAL ZINC VS. RIVER MILE
US EPA MAHONING RIVER SURVEY JULY 14-17, 1975

c. Mahoning River Sediment Chemistry and Biota

Tables VII-18 and 21 present sediment chemistry and benthos data obtained on March 7, 1975. Figure VII-48 illustrates the percent of bottom covered with sediment as determined by the Corps of Engineers during April 1975, the location of the low head dams, and the approximate discharge points of the major dischargers. According to information provided by the Corps of Engineers,[18] most of the sedimentation in the lower Mahoning occurs along the stream banks rather than in the center of the stream bed indicating scouring of deposited sediments at high stream flows.

As shown on Figure VII-48, about 15 percent of the bottom was found to be covered with sediment just below the Copperweld Steel discharge and over 50 percent directly behind the Summit Street dam. Little or no sedimentation was found between the Summit dam and the Republic Steel-Warren Plant. However, from 25 to 60 percent of the bottom was covered above the Republic Steel dam. Republic Steel's largest discharge (blast furnace discharge 013) occurs at the dam crest and, according to Republic Steel monitoring data, deposits about 180,000 lbs/day (90 tons/day) of suspended solids into the stream. The effect of this discharge and that of the Warren STP are evident throughout the Liberty Street dam pool which also receives discharges from Mosquito Creek, Meander Creek, the U. S. Steel-McDonald Mills, and the Niles and McDonald STPs. About 25 to 40 percent of the Liberty Street dam pool bottom was found to be covered with sediment with the maximum coverage (55-75 percent) occurring at about river mile 32 to 33 where the pooling effect begins.

Downstream from the Liberty Street dam, the percent of the bottom covered with sediment averages 12 to 15 percent. Although point source suspended solids loadings are relatively high in the Youngstown-Struthers area from the Youngstown Sheet and Tube, U. S. Steel, Republic Steel plants, and the Youngstown STP, the lesser sedimentation probably results from higher stream velocities than normally occur in the Liberty Street dam pool. The entire stream bed was covered with sediment within 0.1 miles of the Lowellville dam, but the average coverage for the Lowellville pool was found to be only 17 percent. Short reaches in Pennsylvania were found to have little or no sedimentation, while the coverage for the lower seven miles averaged about 15 percent.

TABLE VII-18

MAHONING RIVER SEDIMENT CHEMISTRY

March 7, 1975

Sediment Chemistry (mg/kg - dry weight)

Station Number/Location	River Mile	Sample Number	Total Solids (%-Wet)	Volatile Solids (%)	COD	TKN	NH_3-N	Total Phosphorus	Oil and Grease	Total Cyanide	Phenolics
Main Stem											
1. Leavittsburg	46.02	7037	72.6	0.8	5,300	100	6	280	< 100	0.06	0.41
4. Niles-West Park Avenue	33.71	7038	80.0	1.3	7,500	160	17	680	800	1.40	0.75
- Niles-Belmont Avenue	30.48	7041	31.3	15.6	260,000	2,900	160	2,200	1,300	4.80	3.80
- Youngstown-Division Street	23.84	7042	50.3	6.3	120,000	2,200	110	2,400	17,000	4.20	0.60
8. Youngstown-Bridge Street	22.73	7043	34.0	7.0	150,000	870	70	1,200	17,000	8.80	1.80
11. Youngsotwn-Penn Central RR	17.82	7046	47.1	5.7	140,000	1,400	50	2,800	22,000	25.00	1.30
12. Struthers-P and LE RR	15.83	7047	50.0	11.7	180,000	2,300	68	2,400	24,000	6.40	4.20
13. Lowellville-Washington Street	12.64	7048	42.7	10.7	170,000	2,300	30	1,400	15,000	14.00	0.94
15. Edinburg-Route 224	6.76	7049	44.1	10.4	170,000	1,900	82	3,500	27,000	15.00	1.80
17. New Castle-Penn Central RR	1.52	7050	44.0	8.5	180,000	1,800	99	3,500	32,000	17.00	2.50
Tributaries	Above Mouth										
18, 21. Mosquito Creek	0.41	7039	31.8	3.4	21,000	460	92	460	1,400	0.16	3.80
19, 22. Meander Creek	0.81	7040	17.3	8.6	50,000	1,400	170	680	1,600	6.40	13.00
20, 25. Mill Creek	0.04	7044	75.2	1.7	14,000	260	75	310	800	1.20	0.53
USEPA Region V Criteria for Polluted Sediments	Non Polluted			< 5	< 40,000	< 1,000	< 75	< 420	< 1,000	< 0.1	
	Moderately Polluted			5-8	40-80,000	1-2,000	75-200	420-650	1-2,000	0.1-0.25	
	Heavily Polluted			> 8	> 80,000	> 2,000	>200	> 650	> 2,000	> 0.25	

TABLE VII-18

Continued

MAHONING RIVER SEDIMENT CHEMISTRY

March 7, 1975

Sediment Chemistry (mg/kg - dry weight)

Station Number/Location		Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
Main Stem												
1. Leavittsburg		3,560	3	< 1	15	6	7,800	15	155	< 0.1	50	36
4. Niles-West Park Avenue		8,440	19	2.0	68	210	330,000	110	1,640	< 0.1	180	650
- Niles-Belmont Avenue		295	13	4.0	370	330	200,000	670	3,220	0.2	360	1,990
- Youngstown-Division Street		14,900	12	2.0	310	170	83,000	200	2,330	0.2	150	1,000
8. Youngstown-Bridge Street		18,900	26	3.0	23	115	410,000	290	4,160	< 0.1	50	530
11. Youngstown-Penn Central RR		8,300	2	1.0	150	145	155,000	280	1,690	0.1	155	1,290
12. Struthers-P and LE RR		17,000	14	4.0	220	190	190,000	640	1,970	0.2	190	1,240
13. Lowellville-Washington Street		19,100	9	4.0	260	320	190,000	870	2,210	0.5	270	3,650
15. Edinburg-Route 224		17,200	27	5.0	110	165	147,000	520	1,690	0.4	150	2,160
17. New Castle-Penn Central RR		23,100	14	6.0	150	255	230,000	690	2,150	0.5	200	2,900
Tributaries												
18, 21 Mosquito Creek		820	1	< 1	3	4	1,400	20	92	< 0.1	40	22
19, 22. Meander Creek		4,120	< 1	2.0	18	58	7,800	45	345	< 0.1	50	134
20, 25. Mill Creek		10,000	12	1.0	27	20	27,000	160	1,190	< 0.1	25	154
USEPA Region V Criteria for Polluted Sediments	Non-Polluted		< 3		< 25	< 25	< 17,000	< 40	< 300	< 1	< 20	< 90
	Moderately Polluted		3-8		25-75	25-50	17-25,000	40-60	300-500		20-50	90-200
	Heavily Polluted		> 8	> 6	>75	>50	> 25,000	> 60	> 500	> 1	> 50	> 200

TABLE VII-21

MAHONING RIVER BENTHIC MACROINVERTEBRATES

March 7, 1975

Main Stem Stations

Station Number Location	1* Leavittsburg Leavitt Rd.	4 Niles West Park Av.	- Niles Belmont Av.	- Youngstown Division St.	8 Youngstown Bridge St.	11 Youngstown Penn Central	12 Struthers P&LE RR	13 Lowellville Washington St.	15 Edinburg, Pa. Route 224	17 New Castle, Pa. Penn Central
River Mile	46.02	33.71	30.48	23.84	22.73	17.82	15.83	12.64	6.76	1.52
Substrate	Sand and gravel	Sand oily sludge, fly ash	Oily sludge, sewage sludge	Sand, black oily sludge ash	Black oily sludge	Black oily sludge	Black oily sludge	Black oily sludge	Sand, oily sludge	Black oily sludge
Number of Taxa	23	1	2	1	2	2	3	2	5	4
Organisms/Sq. Meter	1033	1652	369	15	516	5552	78,279	22,253	89	2264
Sludgeworms (Oligochaeta)	204	1652	369		516	5472	78,121	22,253	20	2175
Leeches (Hirudinea)				15		80	158		49	89
Snails (Gastropoda)	19								15	
Fingernail Clams (Pelecypoda)	223									
Plenaria (Turbellaria)	32									
Roundworms (Nematoda)	19									
Caddia Flies (Trichoptera)	19									
Mayflies (Ephemeroptera)	26									
Midge Flies (Tendipedidae)	440									
Other Diptera	51									
Isopoda (Asselus)										
Amphipoda (Crangongx)										
Odonata (Coenagriidae)									5	

*Benthos sample collected May 5, 1975.

TABLE VII-21

Continued

MAHONING RIVER BENTHIC MACROINVERTEBRATES

March 7, 1975

Tributary Stations

Station Number Location	18, 21 Mosquito Creek	19, 22 Meander Creek	20, 25 Mill Creek
River Mile	0.41	0.81	0.04
Substrate	Ash, sand	Greyish white chemical fines, softening sludge	Sand, gravel, silt
Number of Taxa	5	1	10
Organisms/Sq. Meter	562	15	492
Sludgeworms (Oligochaeta)	30		187
Leeches (Hirudinea)		15	
Snails (Gastropoda)			
Fingernail Clams (Pelecypoda)			
Plenaria (Turbellaria)			
Roundworms (Nemtoda)			
Caddis Flies (Trichoptera)			
Mayflies (Ephemeroptera)			
Midge Flies (Tendipedidae)	74		182
Other Diptera			
Isopoda (Asselus)	89		
Amphipoda (Crangongx)	369		123

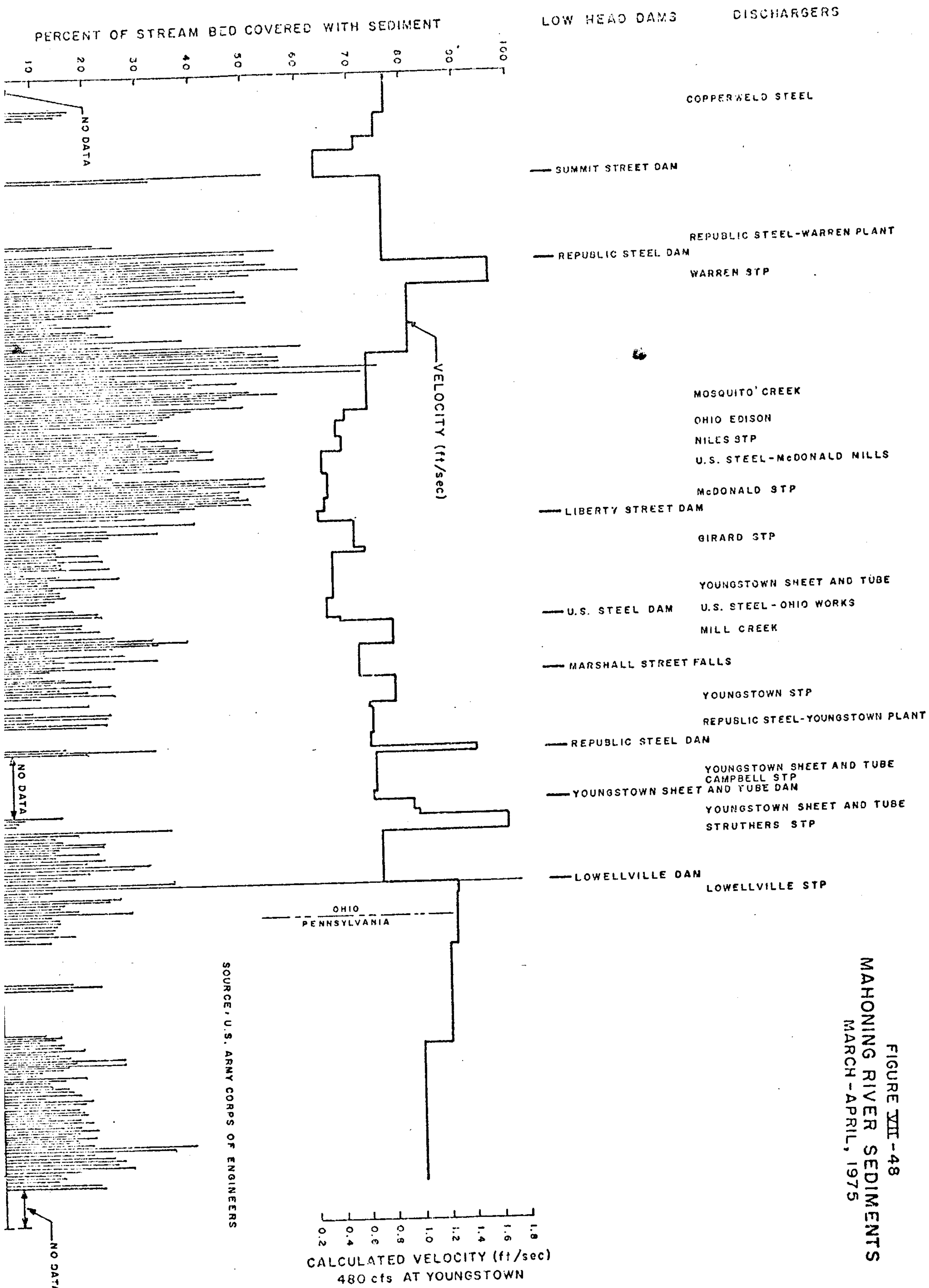


FIGURE VII-48
MAHONING RIVER SEDIMENTS
MARCH-APRIL, 1975

For comparison purposes, draft USEPA Region V criteria for open lake dumping of harbor dredgings are presented in Tables VII-18. These interim guidelines were developed from data from over 100 harbors for volatile solids, COD, TKN, oil and grease, lead, zinc, and mercury, and from 260 samples from 34 harbors for ammonia-N, total cyanide, phosphorus, iron, nickel, manganese, arsenic, cadmium, chromium, barium, and copper.[37] While these criteria are not directly based upon biological requirements of benthic organisms, they provide a means of qualitatively assessing the degree of pollution in the sediments of the lower Mahoning River.

As shown in Table VII-21, the sand and gravel substrate at Leavittsburg was found to be inhabited by a diverse benthic community suggesting clean water of good chemical quality. This is confirmed by the water quality measured during the February and July 1975 surveys and previous data (Section VI). Sediment quality can be termed non-polluted considering draft Region V criteria discussed above. The sediments were low in organic content and nitrogenous material, had no detectable oil and grease, and contained relatively low amounts of metals.

At West Park Avenue in Niles (RM 33.71), the substrate is greatly affected by discharges from the Republic Steel-Warren Plant and the Warren STP. Oily sludge and fly ash predominated making the benthic environment unsuitable for most forms of life. Only pollution tolerant sludgeworms were found. The chemical data suggests little organic deposition occurs in this immediate area as the volatile solids content and COD of the sediments were found to be quite low, 1.3 percent and 7500 mg/kg, slightly above values found at Leavittsburg. However, 800 mg/kg of oil were found and the content of most metals far exceed the draft Region V "Heavily Polluted" criteria. The iron content was found to be 23 percent. Since the river is free flowing at this point, stream velocities are apparently high enough to preclude most organic deposition, but not so high as to keep the heavier particulate matter discharged from Republic Steel blast furnace operations in suspension.

The next downstream station studied, Belmont Avenue in Niles (RM 30.48), is in the upper reaches of the Liberty Street dam pool. The chemical and biological data obtained, lower stream velocities, and the percent of bottom covered with sediments (Figure VII-48) indicate more organic deposition occurs in this area than upstream. The substrate was found to be primarily black, oily sludge. Nearly 16 percent of the sediments were found to be volative solids, and the COD was determined to be 260,000 mg/kg. The TKN increased from 160 mg/kg at West Park Avenue to 2900 mg/kg. A similar increase in phosphorus was noted and the total cyanide and phenolics levels increased by factors of nearly 4 and 5, respectively. The concentration of most metals was also increased substantially over levels found at West Park Avenue. These data suggest that lighter particulate matter settling in this area either contain or absorb cyanide and phenolics. With the high organic content found, high numbers of sludgeworms and leaches would be expected. Only sludgeworms were found in low numbers suggesting the benthic environment may be toxic in this area and possibly in most of the Liberty Street dam pool.

Benthic conditions in the tributaries of Mosquito Creek and Meander Creek were generally much better than the main stem, with Mosquito Creek being the cleaner of the two tributaries. The substrate in Meander Creek was chiefly composed of grayish-white chemical fines which tend to smother most benthic invertebrates. Only a few leaches were found. The source of this material is clearly the Mahoning Valley Sanitary District water treatment plant. The source of cyanides may be the Jones and Laughlin Niles Conduit Division located nearby, but the source of phenolics is not known; decaying vegetation is suspect. The substrate in Mosquito Creek was chiefly ash and sand. Sludgeworms, leaches, midges, and several crawling organisms were found suggesting moderately contaminated conditions. The volatile matter, COD, and metals were low while the measured ammonia–N concentration was higher than measured at most main stem stations. The General Electric Company-Niles Glass Plant is the probable ammonia source.

Benthic conditions in the upper Youngstown area (Division St., RM 23.84) were not much better than at Belmont Avenue in Niles. The substrate is basically the same black, oily sludge. Measured volatile solids and COD levels were less than at Belmont Avenue although the oil and grease level increased by more than an order of magnitude. Phosphorus and cyanide levels remained about the same while concentrations of nitrogenous material and phenolics decreased somewhat as did most metals.

Nonetheless, only leeches in low numbers were found, again suggesting toxic conditions. Ohio Edison, the U. S. Steel-McDonald Mills, the Niles, McDonald and Girard STPs, and part of the Youngstown Sheet and Tube-Brier Hill Works discharge between Belmont Avenue and Division Street . The large increase in aluminum levels at Division Street probably result from the Benada Aluminum Products Company which discharges to Little Squaw Creek. The substrate and chemical quality of Bridge Street (RM 22.73), just below the Youngstown Sheet and Tube-Brier Hill Works and U. S. Steel-Ohio Works, is about the same as that measured at Division Street. However, levels of total cyanide and phenolics increased due to upstream blast furnace discharges. The sediments were found to contain 41 percent iron, nearly 2 percent oil, and 7 percent volatile material. Only sludgeworms were found, and in low numbers.

A sample obtained just behind a spillway on Mill Creek near the mouth of the Mahoning River was composed of sand, gravel, and silt. Levels of volatile solids (1.7 percent), COD (14,000 mg/kg), NH_3-N (75 mg/kg), phosphorus (310 mg/kg), and oil and grease (800 mg/kg) are below the draft Region V polluted sediment criteria and well below values found along the main stem of the Mahoning. However, levels of arsenic, chromium, iron, lead, manganese, nickel, and zinc are above the respective draft criteria and suggest contamination by metal finishing wastes or possibly mine drainage. Sludgeworms and midge flies dominate the benthic community along with crawling organisms. The mix and numbers of organisms in the substrate found is an indication of moderate pollution.

Black, oily sludge was also encountered at the Penn Central Railroad bridge in Youngstown (RM 17.82), downstream from the Youngstown STP and the Republic Steel-Youngstown Plant. Chemical quality was like that of several upstream stations: high organics, nitrogenous materials, phosphorus, and metals. The oil and grease content exceeded 2 percent and the total cyanide level was the highest recorded in the river (25 mg/kg). This site is undoubtedly affected by the Republic Steel coke plant and blast furance discharges located just upstream of the sampling point. Benthic organisms exhibited an increase in total numbers, but the kinds of organisms found, sludgeworms and a few leeches, hardly constitute a well balanced benthic community.

The worst water quality in the Mahoning River is generally found at the P&LE Railroad bridge in Struthers (RM 17.82), just downstream from the Youngstown Sheet and Tube-Campbell Works. However, the relatively high stream velocity encountered in the free-flowing area below the Youngstown Sheet and Tube dam and settling in the dam pool probably precludes this area from having the worst sediment quality in all categories. Nonetheless, the volatile solids content was nearly 12 percent, COD - 13 percent, TKN – 2300 mg/kg, phosphorus - 2400 mg/kg, oil and grease - 2.4 percent, and iron - nearly 20 percent. The highest mercury level (0.5 mg/kg) in the basin was found here. As might be expected, the benthic community was composed of only sludgeworms in high numbers and a few leaches.

Sediment quality at Washington Street in Lowellville (RM 12.64) was close to that found at Struthers. The substrate was the same black, oily sludge first seen at Niles and the benthic community consisted only of sludgeworms. The concentrations of most chemicals far exceeded the heavily polluted criteria shown in Table VII-18, and the highest zinc level (3650 mg/kg) encountered in the basin was found here.

Considering sediment chemical quality, conditions in Pennsylvania (RM 6.76 and RM 1.52) did not improve, and for phosphorus, oil and grease, aluminum, arsenic, and cadmium, the highest concentrations in the basin were found. The substrate at Edinburg (RM 6.76) had some sand as well as black, oily sludge. A few snails were found in addition to low numbers of sludgeworms and leaches. The substrate at New Castle was black, oily sludge and only sludgeworms and leaches were found. The oil and grease content was 2.7 percent at Edinburg and 3.2 percent at New Castle vs levels ranging from 1.5 to 2.4 percent in the Youngstown-Struthers area. This indicates continued deposition of oil in Pennsylvania and, most probably, well into the Beaver River.

Table VII-22 presents additional sediment chemistry data obtained on July 23, 1975 below the three operating coke plants in the Mahoning Valley located at the Republic Steel-Warren Plant, the Republic Steel-Youngstown Plant, and the Youngstown Sheet and Tube-Campbell Works. A fourth coke plant located at the Youngstown Sheet and Tube-Brier Hill Works is not operated. These data were obtained to determine if coke plant discharges have resulted in deposits of polynuclear aromatic hydrocarbons (PAH) in the river. Studies at U. S. Steel facilities in Gary, Indiana and Lorain, Ohio have

TABLE VII-22

SEDIMENT CHEMISTRY BELOW

MAHONING RIVER COKE PLANTS

July 23, 1975

(mg/kg - dry weight)

Station	-	11	12
Location	Warren	Youngstown	Struthers
River Mile	35.87	17.82	15.83
Sample Number	76-5074	76-5075	76-5076
Total Solids (%-wet)	52.6	48.0	60.7
Volatile Solids (%)	7.8	10.8	5.7
Organic Carbon (%)	2.5	4.2	2.7
Chemical Oxygen Demand	78,000	127,000	9,600
Total Kjeldahl Nitrogen	1,100	2,100	670
Ammonia-Nitrogen	72	200	64
Total Phosphorus	630	2,400	1,400
Oil and Grease	7,000	16,000	17,000
Total Cyanide	1.1	4.0	2.3
Phenolics	3.8	5.4	7.6
Aluminum	2,700	6,800	2,200
Arsenic	6	11	5
Cadmium	< 4	< 4	< 3
Chromium	36	77	77
Copper	41	63	54
Lead	85	240	140
Manganese	760	630	390
Mercury	< 0.1	0.3	0.1
Nickel	33	34	26
Zinc	290	520	520
Polynuclear Aromatic Hydrocarbons*			
Napthalene	0.24	0.5	6.5
Methylnapthalene			3.7
Dimethylnapthalene			1.9
Fluorene		19	7.3
Anthracene		35	35
Fluoranthene		13	20
Pyrene		12	14

*Several other compounds in the 0.1 to 20 mg/kg range were present in each sample but could not be identified.

revealed the presence of PAH in sediments below coke plants[38, 39] and in coke plant wastes.[39] PAH have been included in the USEPA Office of Toxic Substances listing of chemicals of near-term interest primarily because of the carcenogenic properties of some PAH.[40] Sediment chemistry data were also obtained for most of those constituents studied during March 1975.

As shown in Table VII-22, PAH were found below each coke plant. Of the many PAH, only napthalene, methylnapthalene, dimethylnapthalene, fluorene, anthracene, fluoranthene, and pyrene could be positively identified. However, several other PAH in the 0.1 to 20 mg/kg range were found to be present in each sample but could not be identified. Only napthalene was detected below the Republic Steel coke plant in Warren while most of the above listed compounds were found below the Republic Steel-Youngstown Plant and the Youngstown Sheet and Tube Company-Campbell Works in increasing concentrations. Relatively low values below the Republic Steel-Warren Plant may result from the manner in which the coke plant discharge reaches the river. Coke plant Outfall 014 discharges to a swampy area just east of Main Street and then to the river. Hence, considerable sedimentation of particulate matter could occur before the waste reaches the stream.

Sediment chemistry data at the Youngstown and Struthers stations were generally similar to that found on March 7, 1975. However, the data obtained at Warren (RM 35.87) show much higher COD, TKN, NH_3-N, oil and grease and phenolics than found about four miles downstream at RM 33.71 on March 7, 1975.

C. Verification Results

1. Tributary and Discharge Loadings

The RIBAM code requires that discharge loadings from municipal, industrial and tributary point sources be supplied to the model in the form of a concentration and flow. In applying the February and July survey data for model verification analyses, three-day average concentrations and flows were used for municipal and tributary sources. For industrial sources the three-day average plant loads were calculated from the daily net loadings of each outfall. An average effluent concentration was then calculated using the total plant load and total plant discharge flow. As discussed earlier industrial flows input to the model are assumed to be withdrawn from the stream and returned after processing, thus not affecting streamflow.

Nonpoint source loadings and small, unmeasured tributary loadings were input to the code using the flows discussed in the hydrology section and a concentration determined by averaging the values collected at selected locations. The sampling locations selected were at the upstream survey boundary at Leavittsburg and at tributaries not severely contaminated with municipal or industrial effluent. For the February verification, the selected stations included Leavittsburg, Mosquito Creek, Meander Creek, and Mill Creek. For the July survey, the selected stations included the locations used for the February survey plus Mud Creek and Coffee Run. Nonpoint source loadings were added to the stream at the head of the appropriate river segment.

2. Temperature

As discussed earlier, two one-dimensional temperature prediction models were evaluated in order to select an applicable model for thermal load allocation. Both the QUAL-1 temperature model and a modified Edinger and Geyer completely mixed model were used to compute river temperatures for the February and July 1975 USEPA Mahoning River surveys. The meteorological, hydrologic, and thermal loading data supplied to each model were the same; however, river segmentation was somewhat different because of the different input requirements and limitations. A discussion of the inputs specific to the temperature models is presented below followed by the results of the verification.

With regard to river segmentation, the node points selected for the RIBAM model were also applied to the Edinger and Geyer model. River geometry, stream hydrology, and segment velocities in the RIBAM code were used directly in the Edinger and Geyer model. Tributary, municipal, industrial, and runoff loadings were applied at the head of each segment to compute an initial temperature which was decayed downstream to the next node point using Equation 7.13.

Computational array size constraints in QUAL-1 limited the number of reaches which could be modeled in one run to 25. However, each reach can be further subdivided into a maximum of 20 computational elements. Hence, the Mahoning River was divided into ten reaches, nine of them five miles long and one reach one mile long. Each reach was further subdivided into half mile computational elements. Stream geometries obtained for the RIBAM code were averaged over the corresponding reach lengths input to the QUAL-1 model. Manning's Roughness coefficient was calculated from the stream geometry and average stream flow. In order to ensure that travel times were the same in both temperature models, the travel times computed from RIBAM were used to calculate the appropriate reach velocities input to the QUAL-1 code. Tributary, municipal, industrial, and runoff loadings were added at the head of the nearest computational element.

The same meteorological conditions were used in both temperature models. With respect to QUAL-1, daily average meteorological data were found to give the best results even though data can be input on a more frequent basis (hourly). For the Edinger and Geyer model, Parker's computational procedures,[12] as modified by USEPA,[41] were applied to the daily average weather conditions to calculate the equilibrium temperature (E) and heat exchange coefficient (K). Daily values for E and K were then averaged to obtain values used in the temperature verification studies. As noted earlier, wind speed data obtained from the Youngstown Municipal Airport were higher than the wind speed data collected at the Youngstown

STP during the February survey and at the Warren STP during the July survey by USEPA personnel. Considering the instrumentation and sampling methodology used by USEPA personnel, wind speed data collected at the STP's are less reliable than measurements at the airport. However, since both temperature models are sensitive to wind speed, the models were applied to the river using the wind speed collected at both locations. Tables VII-23 and 24 show the average meteorological conditions during the two sampling surveys and the resultant equilibrium temperatures and heat exchange coefficients computed for the Edinger and Geyer model.

Temperatures computed by QUAL-1 for February 1975 survey are compared with measured stream temperatures in Figure VII-49. The three-day averaged computed temperatures using wind speed data from both Youngstown STP and the Youngstown Municipal Airport are plotted for each computational element in the model. Using the higher Youngstown airport wind speed data, computed temperatures steadily become lower than measured instream temperatures from Leavittsburg downstream to Ohio Edison. Just above Ohio Edison, the computed temperatures are about 3^{o}F below average stream temperatures. From below Ohio Edison to Youngstown, the model predicts about 2.0^{o}F below measured temperatures. Downstream of Youngstown, the difference between measured and computed values increases to about 5.5^{o}F. The relatively gradual but steady decline of the computed temperatures below measured values indicates that the model was not accurately simulating the exchange of heat across the air-water surface. Because computed temperatures are low, the discrepancy was caused by underestimating the energy absorbed from short and long wave radiation or overestimating the heat being lost from the water by evaporation, conduction, or back radiation. With the slower wind speed data obtained from the Youngstown STP, computed temperatures more accurately replicate measured values. Upstream of Ohio Edison the model predicts about 1.5 to 2.0^{o}F below measured values. From Ohio Edison to Youngstown computed values are generally within 1^{o}F of measured temperatures and below Youngstown computed temperatures are low by about 1.5^{o}F.

Figure VII-50 shows the results of simulations by the Edinger and Geyer model of the February survey using the airport and the Youngstown STP wind speeds. Computed values generally followed the form of the

TABLE VII-23

METEOROLOGICAL CONDITIONS

FEBRUARY 1975 USEPA SURVEY

MAHONING RIVER

Date	Air Temp (^oF)	Wind Speed (mph) Airport	Wind Speed (mph) STP[2]	Relative Humidity	Cloud Cover (Tenths)	E (^oF) Airport	E (^oF) STP	K(BTU/Ft^2-Day-^oF) Airport	K(BTU/Ft^2-Day-^oF) STP
2/11-12/75	24.2	10.0	3.1	.96	10.0	26.3	29.3	82.6	36.4
2/12-13/75	22.9	15.3	6.0	.77	9.3	24.2	27.3	118.1	55.8
2/13-14/75	15.4	11.9	4.3	.70	9.0	18.6	23.4	95.3	44.5
Average	20.8	12.4	4.5	.81	9.4	23.0	26.7	98.7	45.6

TABLE VII-24

METEOROLOGICAL CONDITIONS

JULY 1975 USEPA SURVEY

MAHONING RIVER

Date	Air Temp (^oF)	Wind Speed (mph) Airport	Wind Speed (mph) STP[3]	Relative Humidity	Cloud Cover (Tenths)	E (^oF) Airport	E (^oF) STP	K(BTU/Ft^2-Day-^oF) Airport	K(BTU/Ft^2-Day-^oF) STP
7/14-15/75	66.5	8.5	6.0	.65	5.7	67.1	69.3	133.1	98.5
7/15-16/75	68.8	4.7	2.6	.61	4.6	73.5	78.6	80.6	51.6
7/16-17/75	72.2	4.9	2.2	.58	3.8	75.7	82.9	83.4	46.1
Average	69.2	6.0	3.6	.61	4.7	72.1	76.9	99.0	65.4

1. Except as noted, all Meteorological data were obtained from the weather station located at the Youngstown Municipal Airport.
2. Wind speed collected at the Youngstown Sewage Treatment Plant.
3. Wind speed collected at the Warren Sewage Treatment Plant.

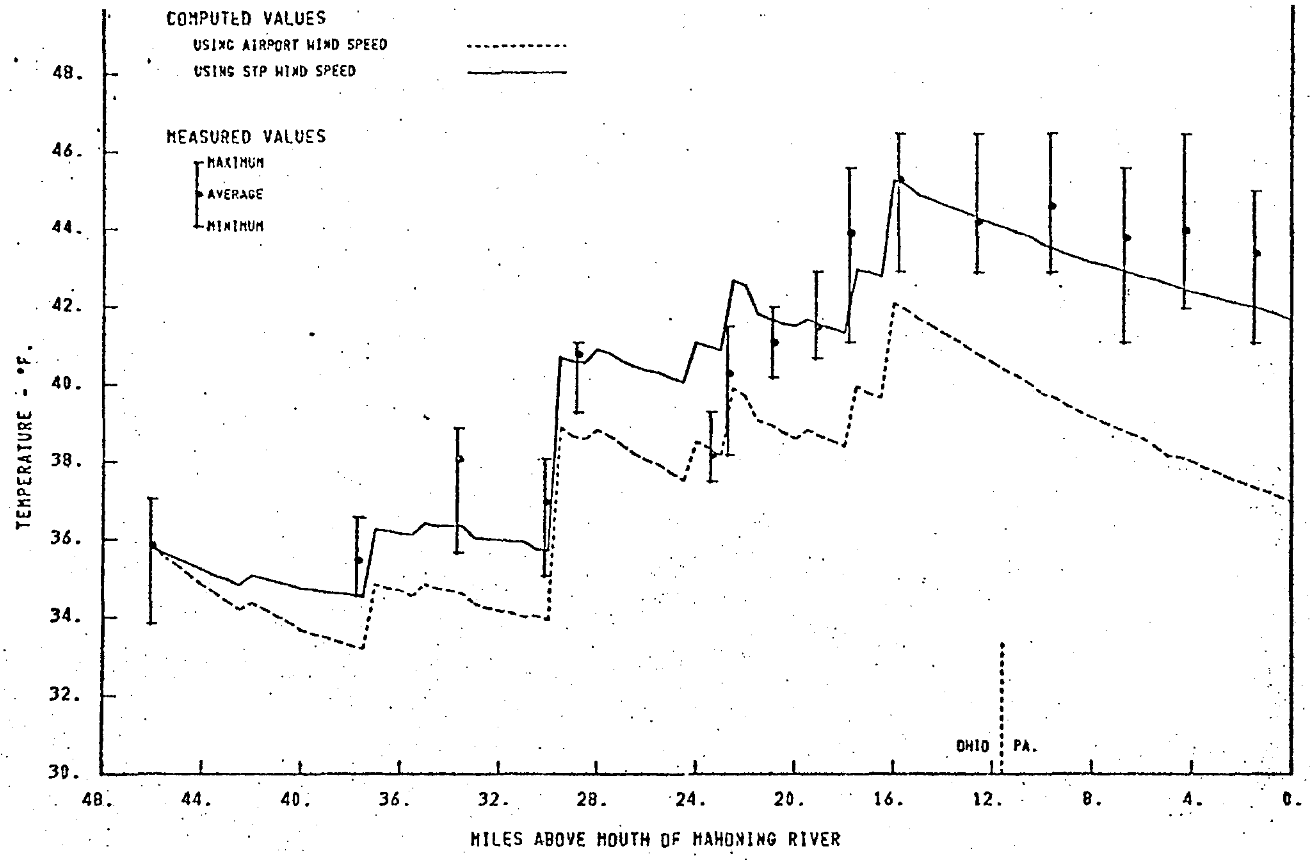


FIGURE VII-49
TEMPERATURE VS. RIVER MILE
QUAL-1 MODEL VERIFICATION USING FEBRUARY 11-14, 1975 DATA

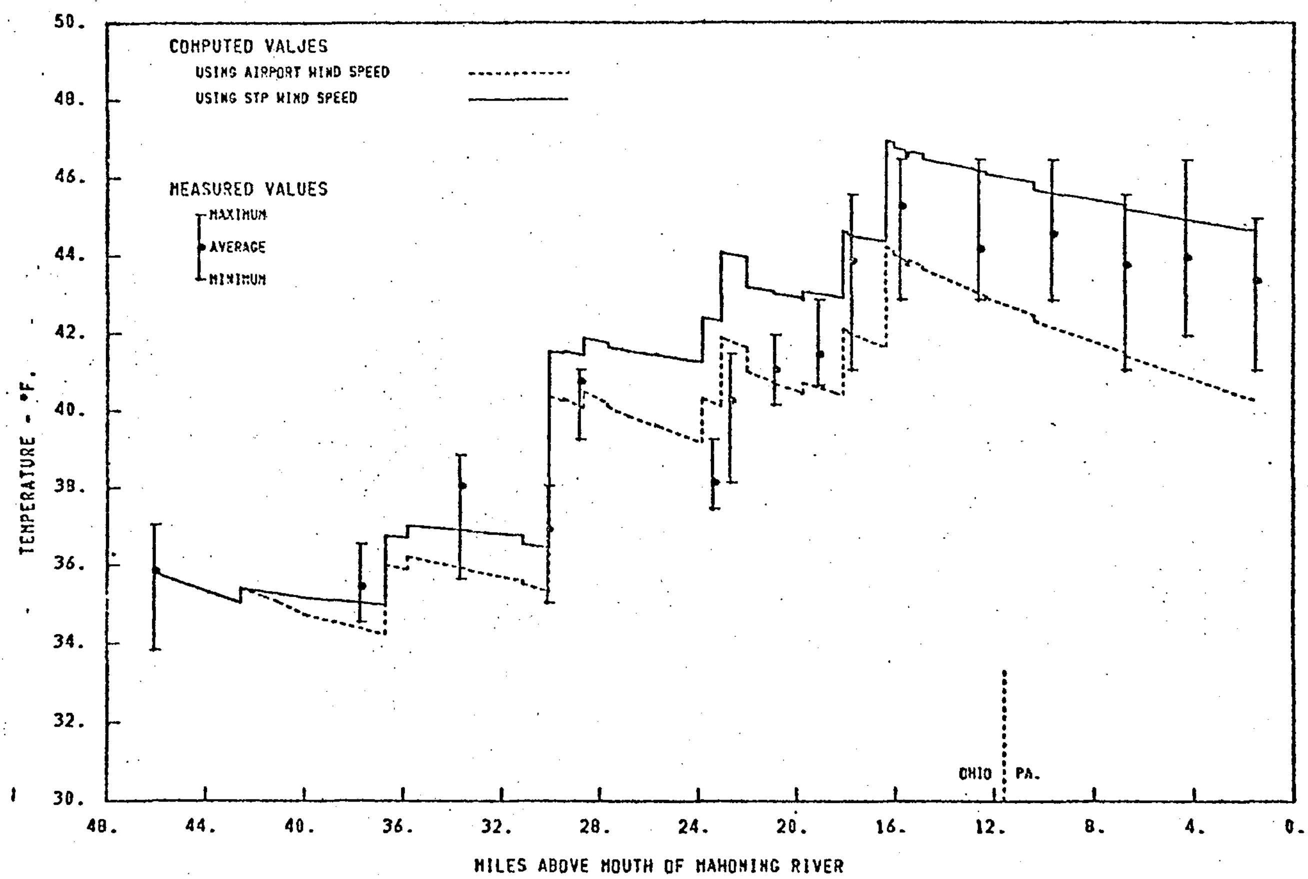


FIGURE VII-50
TEMPERATURE VS. RIVER MILE
EDINGER AND GEYER MODEL VERIFICATION USING FEBRUARY 11-14, 1975 DATA

measured temperatures with the temperatures computed using the slower STP wind speed becoming slightly high and computed temperatures using the faster airport wind speeds generally being below average measured values. The difference between the temperatures computed with the different wind speeds increases steadily in the downstream direction reaching a maximum of 4.5°F at New Castle, Pennsylvania. Downstream of Youngstown, the Edinger and Geyer temperature model predicted 1.0 to 1.5°F high using STP wind speed and 1.0 to 3.0°F low using the airport data.

Examination of stream temperature data indicates that a portion of the discrepancy between measured and computed values appears attributable to missed or unrepresentative point source thermal loadings. At the Ohio Edison-Niles Plant, the computed temperature increase of the river was about 1.0°F higher than the measured temperature increase from the Ohio Edison intake to the U. S. Steel-McDonald Works intake. There also appears to be a missed thermal loading between the Bridge Street sampling station (RM 22.73) and the Marshall Street station (RM 20.91). In this segment, average measured temperatures increased about 1.0°F, whereas computed temperatures decreased about 1.0°F primarily due to the addition of cooler water from Mill Creek. No known heated discharges enter in this river segment, however, combined sewer overflows are suspected here. Had these thermal loads been accurately measured during the February survey, computed temperatures using the airport wind speed would have more accurately replicated measured values. Between Stations 6 and 7 (RM 28.83 to 23.43), computed stream temperatures using both airport and STP wind speed did not decrease as fast as measured stream temperatures, while measured and computed values have almost identical slopes for the balance of the river. The difference in slope between Stations 6 and 7 suggests that locally different weather conditions, most likely wind speed, were prevalent in this area. A difference in wind speed can result from a funneling of wind across the water at an increased velocity not generally seen in other portions of the basin.

Temperatures computed with the QUAL-I model for the July 1975 survey are compared with measured stream temperatures in Figure VII-51. In the July survey, there was a wider range of measured temperatures than occurred in February. Generally, computed temperatures fell within the range of measured temperatures, although the temperatures computed using

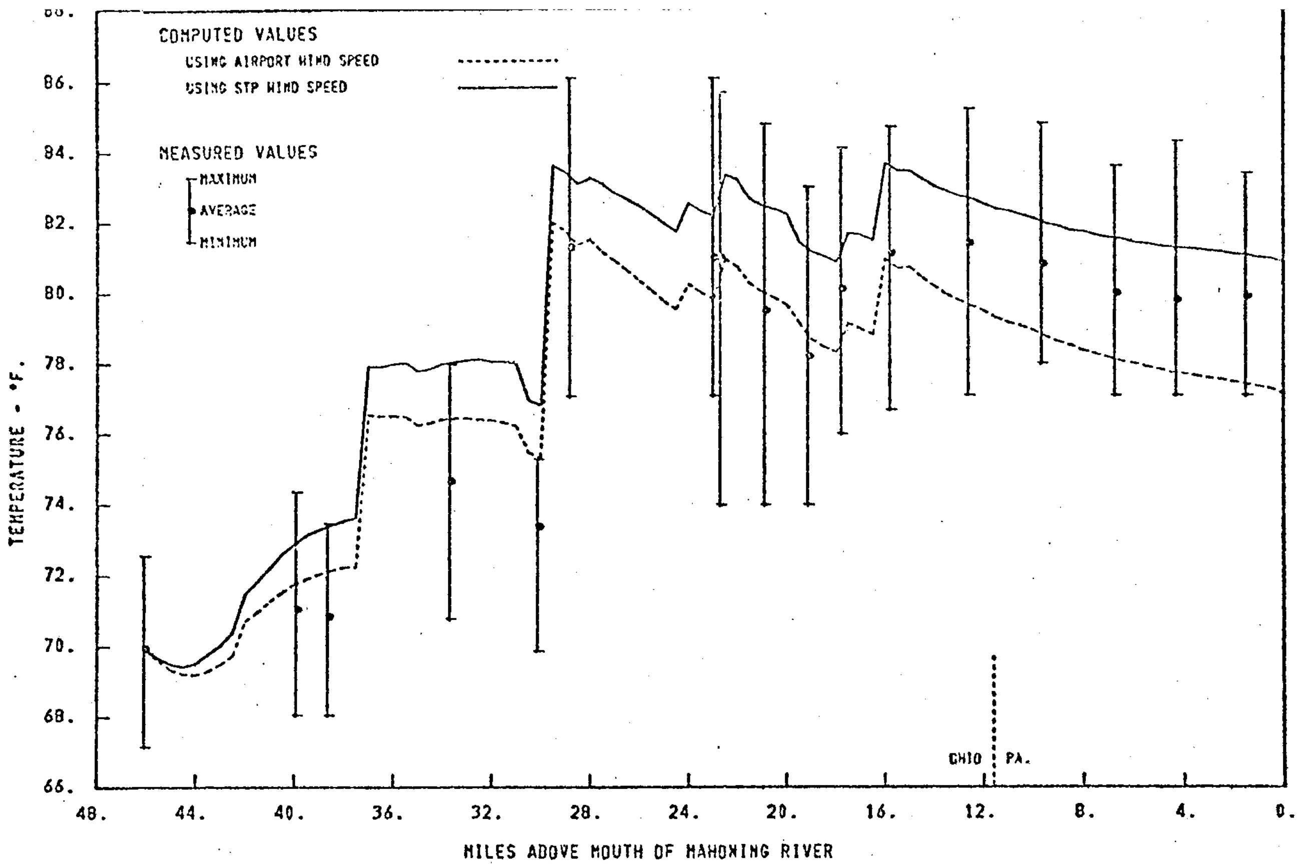


FIGURE VII-51
TEMPERATURE VS. RIVER MILE
QUAL-1 MODEL VERIFICATION USING JULY 14-17, 1975 DATA

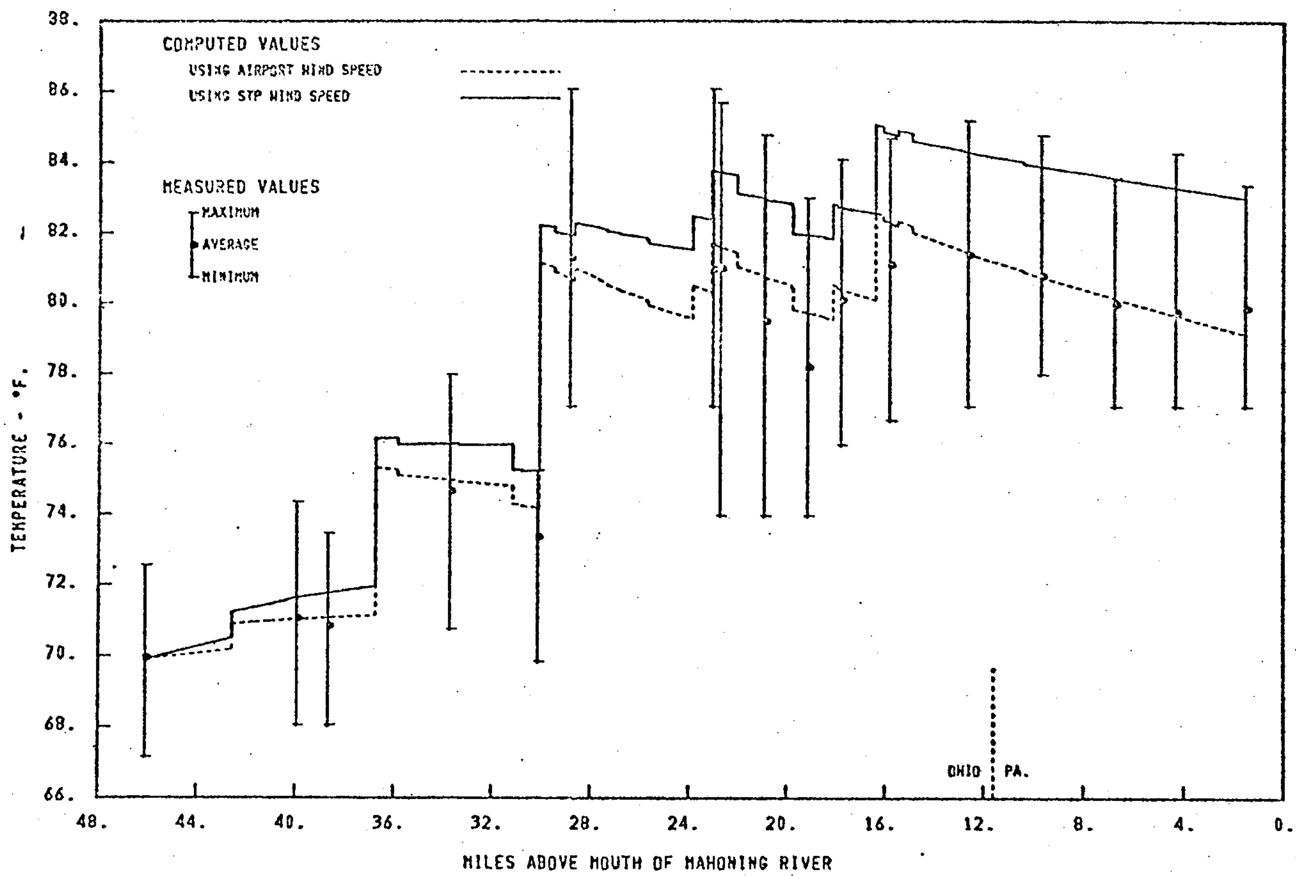


FIGURE VII-52
TEMPERATURE VS. RIVER MILE
EDINGER AND GEYER MODEL VERIFICATION USING JULY 14-17, 1975 DATA

the airport wind speed more accurately replicated average measured values upstream of Youngstown. Using the airport wind speed, computed temperatures are high by 2°F above Ohio Edison and within 1°F of measured values from Ohio Edison to Youngstown. Below Youngstown the model predicted low by about 2°F. QUAL-1 predicts about 1 to 3°F higher when wind speeds collected at the Warren STP are supplied to the model.

Temperatures computed by the Edinger and Geyer model for the July survey are illustrated in Figure VII-52. In this case, temperatures computed with the wind speed recorded at Warren STP are generally high whereas computed temperatures using the airport data accurately replicate average measured values. Applying the lower wind speed from the Warren STP results in computed temperatures gradually but steadily increasing above averaged measured values in the downstream direction to a maximum of 3°F above measured temperatures downstream of Youngstown. When higher wind speeds recorded at the airport are supplied to the model, computed temperatures are within 1°F of the three-day average measured temperatures at all but two sampling stations. Downstream of Youngstown, after temperatures have been modeled for over 30 stream miles, computed values are within two or three tenths of a degree fahrenheit of average measured temperatures. Considering the large daily fluctuations in temperature seen in the stream, the precision with which the temperature model replicated measured values is considered excellent.

After reviewing the February and July verification results for both QUAL-1 and the Edinger and Geyer model, it was evident that the modified version of Edinger and Geyer model was superior for predicting temperatures in the Mahoning River. The Edinger and Geyer model as applied in this analysis, adequately replicated stream temperatures during both a cold winter condition (February 1975) and a warm summer condition (July 1975). Using the more reliable airport wind speed data, QUAL-1 predicted stream temperatures much less accurately than the Edinger and Geyer Model. The accuracy of the QUAL-1 model improved when using the STP wind speeds but overall the verification of the Edinger and Geyer Model was superior. The results also indicate that for modeling temperature the wind speed measured at the Youngstown Municipal Airport adequately represent wind conditions in the vicinity of the river. Use of the Youngstown Municipal Airport wind speed in the Edinger and Geyer model results in the model predicting better in the summer and about the same in the winter as is achieved by using wind speed determined at the sewage treatment plants which are closer to the river. Considering the accuracy shown in the verification, the Edinger and Geyer model can be used with a high degree of confidence for predicting temperatures under varying thermal load conditions (see Section VIII).

3. Carbonaceous BOD

For the February and July verification studies, carbonaceous BOD was modeled in RIBAM as an ultimate demand exhibited by carbonaceous material. For stream quality and municipal loadings, this ultimate demand was determined as long-term BOD less the oxygen demand resulting from nitrification (CBOD = BOD_{20} - 4.57 NH_3-N). The above procedure, however, could not be applied to industrial effluents because most long-term BOD results were unreliable, most likely due to interference from toxic substances in the waste samples (see Section VII-B.3). For industrial sources, CBOD loads were calculated from TOC loadings. Assuming TOC oxidized to carbon dioxide, 2.67 mg/l of DO are consumed for each mg/l of TOC.[21] Thus, each pound of TOC is equivalent to 2.67 pounds of CBOD. Since water samples were not analyzed for TOC in the February survey because of laboratory resource limitations, TOC loads were estimated for each outfall by multiplying the TOC/COD ratio determined for the July survey by the COD load calculated from the February data. Outfall loads were totaled for each plant before converting TOC loads to CBOD values.

The stream CBOD concentrations computed by RIBAM using the February survey data are compared with measured river quality in Figure VII-53. Computed values lie within the range of measured concentrations at many sampling locations and are within 1 mg/l of average concentrations determined downstream of Lowellville, with the exception of the New Castle sampling point. Between river miles 23 and 16, the computed concentrations appear about 2 to 3 mg/l low (15-20 percent). From Figure VII-53, this difference appears attributable to a missed point source loading in the vicinity of U. S. Steel, Ohio Works (river mile 23.09) that was not sampled during the February survey. Even in this short stretch of river, the form followed by the computed values closely approximates the step increases of the measured values. At the Youngstown Sheet and Tube-increase was computed by the model as compared to the increase seen in the river from Station 11 to Station 12. In this segment, the nitrogen data indicated that large amounts of organic nitrogen were being converted to ammonia-N in the Youngstown Sheet and Tube dam pool. Also, discharge data from Youngstown Sheet and Tube show that only 8 percent of the TKN discharged was ammonia-N on one day of the survey vs over 70 percent for the other two days. Conversion of organic-N discharged from the Youngstown STP, the Republic Steel-Youngstown Plant, and the Youngstown Sheet and Tube-Campbell Works to ammonia-N in the stream would have a major impact on ammonia-N concentrations at Station 12.

Since RIBAM is not capable of modeling organic-N, the model was run with adjusted ammonia-N loadings at the Republic Steel-Warren Plant, Ohio Edison, and the Youngstown Sheet and Tube-Campbell Works to account for the organic-N. Adjusted effluent loadings at each location were determined by mass balances of ammonia-N at the sampling stations above and below each source and the measured loadings between the stations. The computed stream concentrations with the adjusted ammonia-N loadings are displayed as the dashed line in Figure VII-56. In this case, the model more accurately simulated measured concentrations throughout the river. The model appears to predict excessive amounts of decay of ammonia-N from the Warren STP downstream to the Youngsotwn STP. This discrepancy could be caused by too fast a reaction rate for ammonia-N in this stretch. However, the excellent verifications of the nitrite-N model in this segment and the continuous loss of organic-N seen in this reach indicates the difference was the result of the breakdown of organic-N thus increasing stream concentrations of ammonia-N. In the segment below Youngstown, the computed concentrations were within 15 percent of the average measured values and closely reproduced the decay of ammonia-N seen in the stream. With adjusted effluent loadings, the model appeared to adequately replicate measured concentrations for the July survey. The breakdown of organic-N into ammonia-N represented an important source of ammonia-N in the July survey and a reaction which was not included in the development of RIBAM. This reaction was not as significant in the colder February survey.

Figures VII-55 and VII-56 show that the water quality equations for ammonia-N can adequately replicate measured stream concentrations. The ammonia-N reaction rate determined from bottle rate studies when corrected for temperature appeared to reproduce the disappearance rate seen in the Mahoning River under two significantly different flow and temperature regimes. The difficulties in replicating measured concentration were primarily attributable to problems in determining point source loadings notably in Warren STP segment of the river.

The failure to include the reaction of organic-N in the RIBAM model should have a lesser effect on the water quality response of the waste treatment alternatives studied in Section VIII than it had in the July verification study. With advanced levels of treatment being considered for the municipalities, blast furnaces, and coke plants in the valley, considerably less organic-N will be discharged by the point sources. In the future, algal growth could play a more important role in the nitrogen balance in the stream under favorable sunlight and temperature conditions since availability of nutrients will not be a growth limiting factor.

5. Nitrite-Nitrogen

Unlike carbonaceous BOD and ammonia-N, the primary source of nitrite-nitrogen in the Mahoning River is the nitrification of ammonia-N to nitrite-N and not the large industrial and municipal dischargers. Since the major source of nitrite-N is a reaction and not measured point sources and since there are two simultaneous reactions affecting the concentration, nitrite-N is somewhat more difficult to simulate than standard first-order kinetic reactions.

In the February 11-14, 1975 survey, nitrite-N was not determined. For this reason, the nitrite-N model was unable to be verified separately for the February survey. Nitrite-N was however simulated for the February survey in order that the secondary affect of nitrite-N on dissolved oxygen levels would be correctly considered by RIBAM. For the February dissolved oxygen verification, nitrite-N municipal and tributary loadings were estimated based upon ratios of NO_2-N/NO_2+NO_3-N from historical data. Small industrial loadings of nitrite-N were not considered.

In the July survey, nitrite-N was measured separately and the results of the model were compared with measured stream concentrations. The computed concentrations of nitrite-N with measured and adjusted ammonia-N loading and the corresponding measured in stream concentrations for the July survey are illustrated in Figure VII-57. Computed concentrations with and without the adjusted ammonia loading have the same general shape and, with the exception of the river segment below Youngstown, the curves agree within 0.02 mg/l. Since it is more important to know the accuracy of the nitrite-N model when ammonia-N is properly simulated, the discussion on nitrite-N verification pertains primarily to the nitrite-N curve computed with adjusted ammonia-N loadings at the Republic Steel-Warren Plant, the Ohio Edison-Niles Plant, and the Youngstown Sheet and Tube-Campbell Works.

In Figure VII-57, predicted concentrations adequately replicated measured values from Leavittsburg downstream to Youngstown. In this upstream portion of the river, computed concentrations were generally within 0.02 mg/l of the three-day average measured concentrations. At approximately river mile 18 in Youngstown, computed concentrations increase sharply to a maximum of 0.26 mg/l. Average measured values however, remain at about 0.12 mg/l downstream to the Ohio-Pennsylvania state line before a significant increase was seen. At Station 16, both the measured and computed values leveled off at about the same concentration (0.24 mg/l). Within the 14 mile stretch of the river where measured and computed values do not agree, the maximum difference was 0.14 mg/l. Since the differences between measured and computed values did not begin as a sudden jump at a node point, the discrepancy does not appear attributable to an error in point source loadings of nitrite-N. The difference between measured and computed concentrations just below Youngstown was most likely caused by a high decay rate for ammonia-N or a low reaction rate for nitrite-N. However, the ammonia-N reaction does not appear too high in that segment of the river as measured and computed concentrations of ammonia-N have nearly the same slope below Youngstown (Figure VII-56). This would indicate that the nitrite-nitrogen reaction rate input to the model for this segment of the river was too slow. Nitrogen series data support this postulate in that a large amount of ammonia-N was being lost with a corresponding increase in nitrate-N.

As discussed earlier, nitrite-N is less important than other water quality constituents modeled in RIBAM and was considered in the analysis

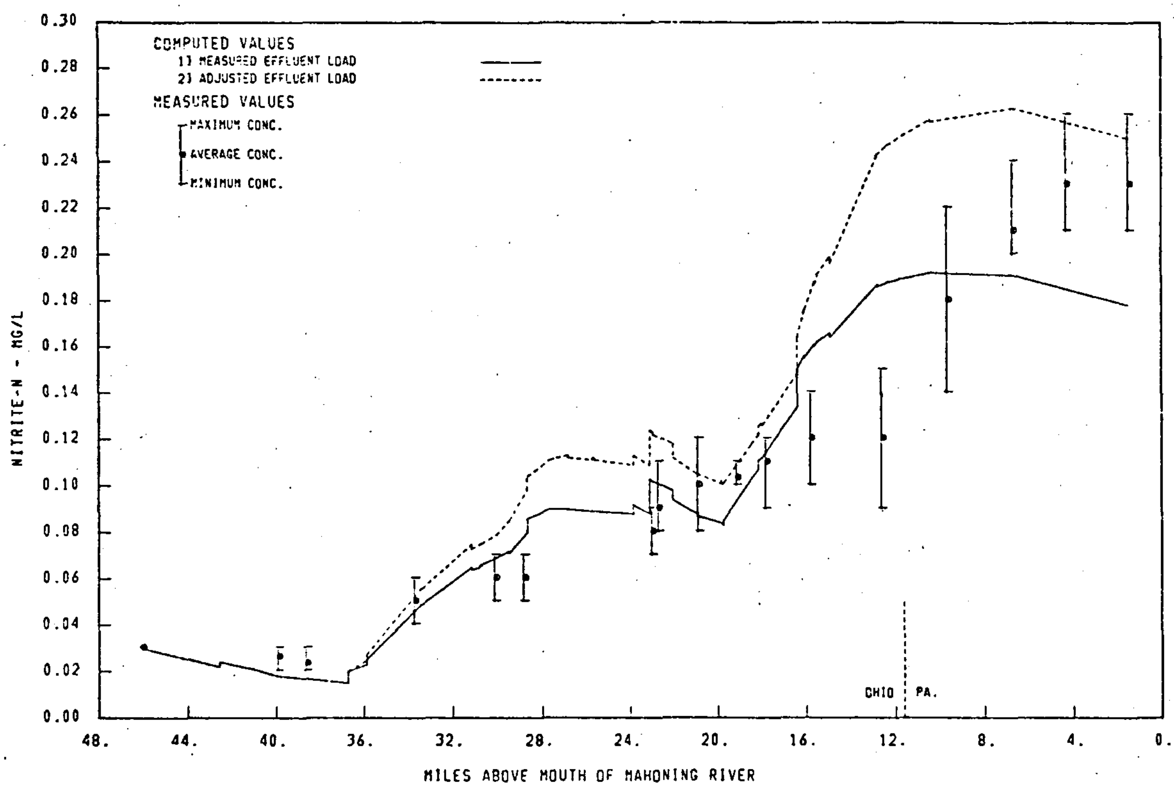


FIGURE VII-57
NITRITE-NITROGEN VS. RIVER MILE
MODEL VERIFICATION USING JULY 14-17, 1975 DATA

primarily because the reaction consumes dissolved oxygen. Also, the small accumulation of nitrite-N in the stream represents only a small oxygen demand compared to the demand resulting from high discharge levels of CBOD and ammonia-N. The nitrite-N July verification was therefore considered sufficient and the model along with the reaction rate applied in the July verification were used in the waste load allocation portion of this study.

6. Dissolved Oxygen

Dissolved oxygen is the most complex water quality constituent modeled in this analysis. In addition to the point source loadings of dissolved oxygen, concentrations are affected by reactions of carbonaceous BOD, ammonia-N, nitrite-N, and benthic oxygen demand. Dissolved oxygen is replenished by the physical process of reaeration throughout the river and by the reaeration occurring at the channel dams. Temperature affects dissolved oxygen, not only through the changes in reaction rates but also directly controlling the total quantity of oxygen the water can hold.

Computed dissolved oxygen concentrations using the February 11–14, 1975 survey data are shown in Figure VII-58 along with measured stream concentrations. Computed values closely followed the average measured concentrations throughout the river and never deviated more than 1 mg/l from the average measured concentrations. At many stations, including the sampling points downstream of Youngstown, computed values differed from the average measured concentration by less than 0.3 mg/l. The only consistent deviation of the computed values from average measured conditions was in the segment of the river from the Republic Steel-Warren Plant to Ohio Edison where the model predicted low. In this upper stretch of the river, average measured dissolved oxygen concentrations slightly exceeded theoretical saturation dissolved oxygen levels. In fact, the starting concentration of the model, which was the average value measured at Leavittsburg, exceeded the theoretical dissolved oxygen saturation level by almost 1 mg/l. Downstream of Leavittsburg, the computed DO concentrations quickly decreased to the saturation DO valve. When stream temperatures increased below Ohio Edison and measured

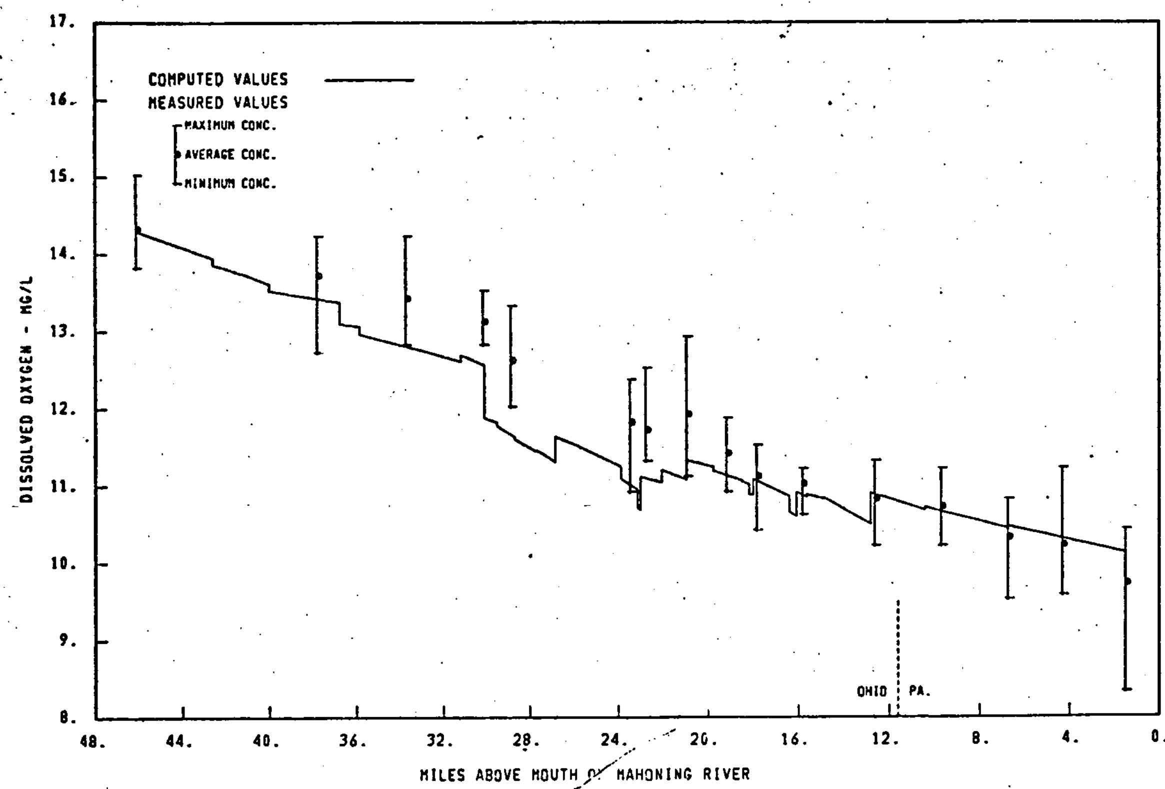


FIGURE VII-58
DISSOLVED OXYGEN VS. RIVER MILE
MODEL VERIFICATION USING FEBRUARY 11-14,1975 DATA

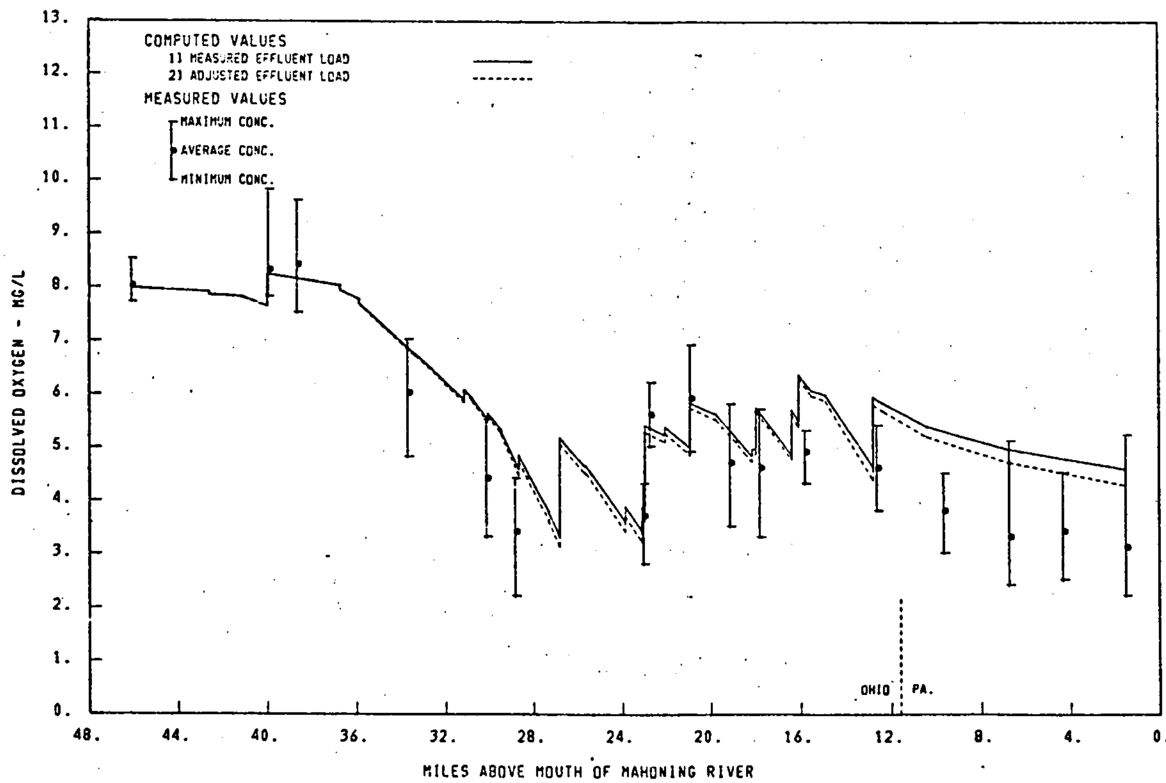


FIGURE VII-59
DISSOLVED OXYGEN VS. RIVER MILE
MODEL VERIFICATION USING JULY 14-17, 1975 DATA

stream DO levels no longer exceeded theoretical saturation values, the model quickly began to predict concentrations within a few tenths of a mg/l of average measured values. Even in this upstream portion of the river, the form of the computed values closely replicated that of the average measured values.

The results of the July verification runs of RIBAM are shown along with measured DO concentrations in Figure VII-59. The predicted DO concentrations with measured ammonia-N loadings at all outfalls are shown as the solid line in Figure VII-59. In this case, predicted DO concentrations were high throughout most of the river downstream of the Republic Steel-Warren Plant and the Warren STP. Since the DO model began predicting high in the same river segment that ammonia-N began predicting low, the difference between measured and computed values appeared to be caused by insufficient oxygen demand from ammonia-N. The DO model was therefore rerun with the adjusted ammonia-N loadings applied at the Republic Steel-Warren Plant, Ohio Edison, and the Youngstown Sheet and Tube-Campbell Works. With the adjusted ammonia-N loadings, the ammonia–N model adequately predicted measured stream concentrations but the computed values were still a little low (Figure VII–56).

The computed DO concentrations with the adjusted ammonia–N loadings are shown as the dashed line in Figure VII-59. In this case, computed concentrations fell within the range of measured concentrations at most sampling locations but were still above the three-day average stream concentrations. In Warren and Youngstown, computed concentrations were within one-half of a mg/l of average measured concentrations. However, between Warren and Youngstown and downstream of Youngstown the model predicted concentrations about one mg/l above average measured values. The tendency to predict high DO concentrations is partially attributable to underprediction of ammonia–N for the July survey. However, the affects on DO of underpredicting ammonia-N is somewhat offset by the overprediction of carbonaceous BOD.

In the segment of the river below Warren, the tendency of the model to predict high is probably caused by an overestimation of the reaeration occurring in this stretch. There are no significant changes in the stream DO due to point sources in this reach and the difference between measured and computed ammonia-N concentrations would not account for a one mg/l difference in DO in this short stretch of the river. The stream reaeration rate in the long Liberty Street dam pool was naturally low because of slow stream velocities and increased stream depths. This low rate was probably further reduced by floating oil discharged from the Republic Steel-Warren Plant and the U. S. Steel-McDonald Mills. It appears that the CBOD rate input to the model below the Warren STP was fairly accurate (Figure VII-54). Hence, the high predictions are most likely due to overestimation of reaeration capacity, and possibly to a larger than predicted sediment oxygen demand in the Liberty Street dam pool.

In the section of the river below Youngstown, the difference between computed and measured DO concentrations appears related to a point source problem (DO) and an overestimation of the reaeration capacity of the river. Measured and computed DO concentrations differ by less than 0.5 mg/l above the Republic Steel-Youngstown Plant. Downstream of the Youngstown Sheet and Tube-Campbell Works, computed concentrations exceed the three-day average measured value by about one mg/l. Some of this difference may have been caused by an overestimation of the oxygen added to the stream by the Youngstown Sheet and Tube-Campbell Works. Dissolved oxygen measurements were taken at the intake and outfalls only twice during the July survey, once on each of two days. These data indicated the Campbell Works was adding over two mg/l of oxygen to the water taken from the river. Because these measurements were taken infrequently with non-ideal sampling methods which would tend to produce high results, the values may not be representative of actual DO loadings of the facility. Reaeration above and over the Republic Steel and Youngstown Sheet and Tube dams is also an important factor in this reach. Since this area carried the heaviest covering of floating oil during the survey, reaeration was probably overestimated.

In the segment of the river downstream of Lowellville, computed concentrations consistently remain about one mg/l above measured concentrations. Since the difference in measured and computed values did not become smaller further downstream, stream reaeration may have been overestimated. Oil floating on the river was not taken into account in computing the reaeration rate in the stream.

An important factor which has not been discussed is the effect of photosynthesis and algal respiration on the DO concentrations in the Mahoning River. Undoubtedly photosynthesis during the day and the respiration of algae at night increased the range of measured DO concentrations in the Mahoning River. Apparently, the net affect of the reactions did not significantly increase average stream DO concentrations because the model, which did not include the affects of either reaction, computed DO levels close to, but above, measured values. If photosynthesis was significant measured DO concentrations would have been above computed concentrations. Since the July survey was conducted during a period of relatively sunny skies and a flow regime close to the summer design flow of the river, maximum photosynthetic effects would be expected. While photosynthesis may not be currently affecting dissolved oxygen levels in the stream, the environment after point source controls are installed may be more amenable to increased algal production under favorable light and temperature conditions.

Considering the extremely complex system involved in modeling dissolved oxygen in the Mahoning River, the RIBAM code verified well for the two surveys. Over the wide range of temperature and flow conditions, the model generally predicted within one mg/l of average measured DO concentrations throughout the river. The computed concentrations replicated the DO sag occurring behind channel dams, the DO loss resulting from increased temperatures, the reaeration through long stretches, and the point source reaeration at dams and from point source loadings. The tendency of the model to overpredict the stream reaeration in the July survey is not a significant factor when simulating the response to treatment alternatives since the gross levels of floating oil now prevalent should be substantially reduced, if not eliminated.

7. Total Cyanide

There is little, if any, information presented in the literature concerning the modeling of total cyanide in a river system. One aspect, however, that is critical to the verification of a total cyanide model is the proper handling and preservation of the water samples. Total cyanide reacts quickly at elevated water temperatures and unless samples are properly preserved and refrigerated upon collection, significant amounts of total cyanide may be lost.[42] In both the February and July 1975 surveys, stream samples were preserved and refrigerated immediately upon collection. However, because of limited manpower, municipalities and industries obtained discharge samples in bottles provided by USEPA containing the appropriate chemical preservative. These samples were picked-up daily by USEPA for analysis. The sewage treatment plants generally had provisions for refrigerating the water samples but many industrial samples were not refrigerated until after they were picked up from the plants. These procedures can cause industrial total cyanide loads to be low, notably during the July survey when air and water temperatures were quite warm.

Measured and predicted total cyanide concentrations for the February 1975 survey are displayed in Figure VII-60. Throughout the river, computed concentrations closely follow measured values, and at all but two sampling stations in Youngstown, predicted concentrations are within 10 to 15 percent of the three-day average measured value. In the portion of the river from downstream of the U. S. Steel-Ohio Works to the Youngstown Sheet and Tube-Campbell Works, computed concentrations become progressively lower than average measured values. This difference is probably attributable to a combination of incomplete mixing of the discharges at the sampling stations and underestimation of the point source loadings in this area.

At Marshall Street (river mile 20.91), the model computed about 20 µg/l below measured values. Since there are no known significant point source loadings of total cyanide between the U. S. Steel-Ohio Works and the Marshall Street sampling station and most of the reduction in computed concentration between these points resulted from dilution by Mill Creek, the difference between measured and computed concentrations probably resulted from a low total cyanide load at the U. S. Steel-Ohio Works. At the sampling stations upstream and downstream of the Republic Steel-Youngstown Plant, the model predicted low by about 40 and 60 µg/l, respectively. Because the computed total cyanide increases at Youngstown STP and at the Republic Steel-Youngstown Plant were less than the corresponding concentration increases seen in the stream, the difference again appeared attributable to low total cyanide loadings at the respective discharges. Inadequate sample refrigeration and reliance upon estimated

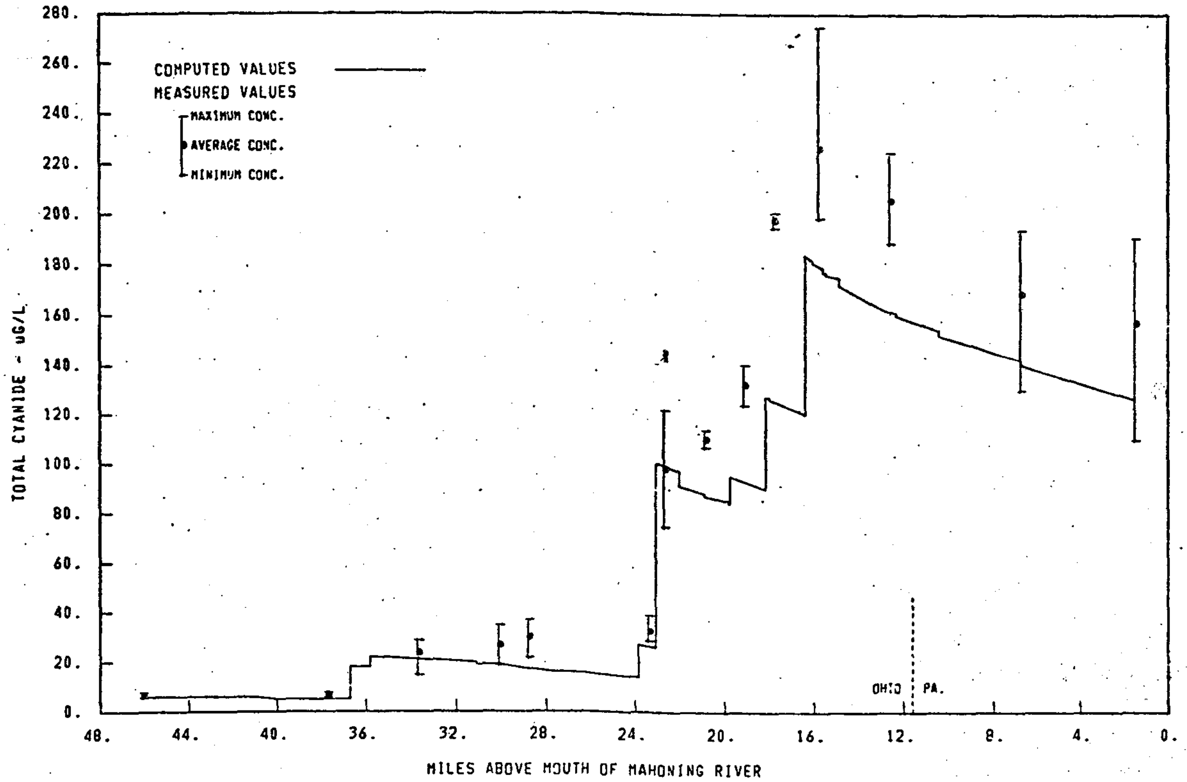


FIGURE VII-60
TOTAL CYANIDE VS. RIVER MILE
MODEL VERIFICATION USING FEBRUARY 11-14, 1975 DATA

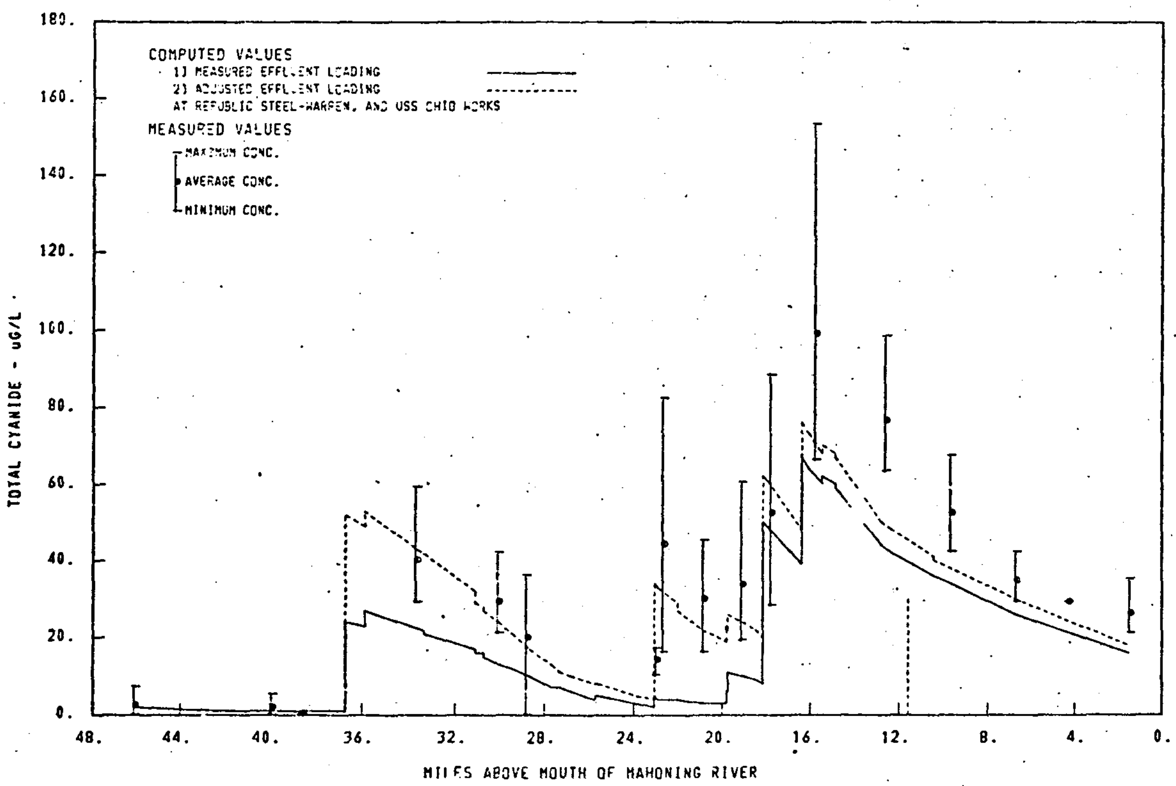


FIGURE VII-61
TOTAL CYANIDE VS. RIVER MILE
MODEL VERIFICATION USING JULY 14-17, 1975 DATA

plant flow rates most likely caused the loading-related differences between measured and computed values at all three locations. In addition, samples collected at Station 11 (river mile 17.82) and to a lesser degree at Station 10 (river mile 19.17) may have been overly affected by incomplete mixing of large point source loadings located only short distances upstream of the sampling points. As expected, computed decay of total cyanide closely followed that soon in the river downstream of Lowellville.

Computed and measured total cyanide concentrations for the July 1975 USEPA survey are shown in Figure VII-61. The solid line in Figure VII-61 represents computed values with measured total cyanide loads at all point sources. In this case, the model predicted significantly low throughout most of the river even though the shape of computed values closely matched the decay of total cyanide seen in the stream. An examination of Figure VII-61 showed that most of the difference between measured and computed values was caused by two significant increases in measured values which were not correctly accounted for in the model. The first such difference occurred in the area around the Republic Steel-Warren Plant and the Warren STP. Measured total cyanide loads for Republic Steel and the Warren STP caused an increase in the computed concentration to 27 µg/l, whereas at Station 4 two miles downstream of Warren, three-day average measured concentrations showed almost twice as much cyanide in the stream. Undoubtedly, a significant source of total cyanide was missed in the Warren segment of the river. The source is most likely the Republic Steel-Warren Plant as samples obtained by the company from this plant were not refrigerated until four to six hours after 24 composite samples were collected.

The second major total cyanide increase seen in the river which was not accounted for in the model was at the U. S. Steel-Ohio Works. During the July survey, the blast furnaces at U. S. Steel were reportedly down. Grab samples were therefore collected only twice daily on the blast furnace outfall while the remaining two outfalls were sampled six to eight times daily. The sharp increase in measured total cyanide concentrations from the U. S. Steel intake to the Bridge Street sampling point immediately downstream of U. S. Steel is attributed to a large point source loading. This loading was most likely discharged by U. S. Steel. However, a missed load at the Youngstown Sheet and Tube Company-Brier Hill Works could also account for this problem since, as noted earlier, it is doubtful that the blast furnace discharge from this plant is fully accounted for at the U. S. Steel intake (Station 6).

To determine how well the model would have replicated measured total cyanide concentrations had these two major point sources been accurately measured, the total cyanide model was rerun with adjusted total cyanide loads at the Republic Steel-Warren Plant and the U. S. Steel-Ohio Works. At Republic Steel, the adjusted total cyanide load was estimated using the difference between measured and computed concentrations at sampling Station 4 and the corresponding river flow at that point. The adjusted total cyanide load applied at the U. S. Steel-Ohio Works was calculated using the difference between the average stream concentrations upstream and downstream of the plant and the river flow at Bridge Street. The computed river concentrations with these two adjusted loadings are shown as the dashed line in Figure VII-60. As expected, the computed values much more accurately replicated measured concentration throughout the river. With the two adjusted loads, computed concentrations are within 15 percent of the three-day average measured concentration at most sampling points.

Computed values closely duplicated the slope of the average measured concentrations along the entire length of the river. This was expected below Lowellville, however, agreement of the computed and measured total cyanide decay verifies the total cyanide rate in the upstream portion of the stream. The only significant deviation of the computed concentrations from measured values was in the segment of the river immediatley downstream of the Youngstown Sheet and Tube Company-Campbell Works. Again the difference appeared related to a low total cyanide loading at the Campbell Works. As with the total cyanide load for the Republic Steel-Warren Plant and the U. S. Steel-Ohio Works, the low total cyanide load may be caused by inadequate refrigeration of the samples or the use of unrepresentative discharge flow estimates in calculating plant loadings. In addition, the Youngstown Sheet and Tube-Campbell Works was sampled only during the daytime work shift. Loadings computed from these data may not be representative of actual daily average loadings which may have been higher depending upon discharges over the remaining two-thirds of the day.

Overall, the total cyanide model only did a fair job of replicating measured values in the July survey. When missed input loadings were considered, the model agreed well by predicting within 10 to 15 percent of average measured concentrations throughout the river. However, using only the loads determined from the data, the predicted concentrations were low by as much as 40 µg/l. The loading problems do not reflect upon the accuracy of computational procedures but rather indicate deficiencies in a portion of the data base used to verify the model.

Because stream data obtained during the comprehensive February and July surveys downstream of Lowellville were used in computing reaction rates, a seperate data set was used to verify the total cyanide rate downstream of Lowellville. Raytheon Company made seven travel time measurements from Lowellville to New Castle on August 24 and 25, 1973.[43] In addition to travel time, stream temperature, total cyanide, and phenolics were determined at both ends of the study segment at the time of water passage. Analytical procedures were identical to those used in the USEPA surveys. The data obtained from the Raytheon study are presented in Table VII-25 and the corresponding computed and measured stream concentrations are illustrated in Figure VII-64.

Computed concentrations in Figure VII-64 were determined using the average measured travel time, the total cyanide reaction rate adjusted for temperature, and the average concentration at Lowellville. The resulting computed concentration at New Castle was well within the range of measured values. Hence, the total cyanide reaction rate and temperature correction coefficient adequately replicated the decay rate seen in the stream.

Reviewing the results of the February and July verification runs, the water quality model appears to adequately simulate stream concentrations of total cyanide. The first order differential equation when applied using a single temperature adjusted reaction rate adequately duplicated the reaction of total cyanide throughout the Mahoning River during both high flow-low temperature and low flow-high temperature conditions. Difficulties in replicating average measured stream concentrations encountered in the verification were caused by inaccurate point source loadings which indicate deficiencies in the sampling program and not with the model.

8. Phenolics

Little has been written about modeling phenolic compounds in a river system. Like total cyanide, phenolics break down quickly at the elevated temperatures seen in the Mahoning River. Therefore, proper handling and preservation of water samples are critical for verification in order that significant amounts of phenolics not be lost before analysis.[44] As discussed earlier in this report, two reaction rates were used in simulating phenolics. The faster reaction rate was applied to all river segments where the computed concentration of phenolics exceeded 20 µg/l and the slower reaction rate was applied to the segments where computed concentrations were less than 20 µg/l.

The computed and measured phenolics concentrations for the February 1975 survey are displayed in Figure VII-62. For the February survey, the model predicted concentrations of phenolics within about 15 percent of the three-day average measured value at most sampling stations. In the upper Youngstown portion of the river near the U. S. Steel-Ohio Works, the computed concentrations were about 20 to 30 µg/l low and remained consistently below measured values downstream of this point. It appeared that the model underpredicted the concentration increases seen at the Youngstown Sheet and Tube-Brier Hill Works, the U. S. Steel-Ohio Works and the Youngstown STP. This was the same area where significant total cyanide loadings were missed in the February survey. Had the concentration increases at these facilities been properly accounted for in the model, computed concentrations would have been within about ten percent of the three-day average measured stream concentrations throughout the river. Even though there was apparently missed loadings of phenolics, the model closely duplicated the decay of phenolics seen in the stretches of the river below Warren and, as expected, below Youngstown.

The computed and measured phenolics concentrations for the July 14–17, 1975 survey are shown in Figure VII-63. The solid line in Figure VII-63 represents predicted concentrations with measured loadings at all point sources. In this case, predicted concentrations followed the average measured values throughout the river but with the computed values being

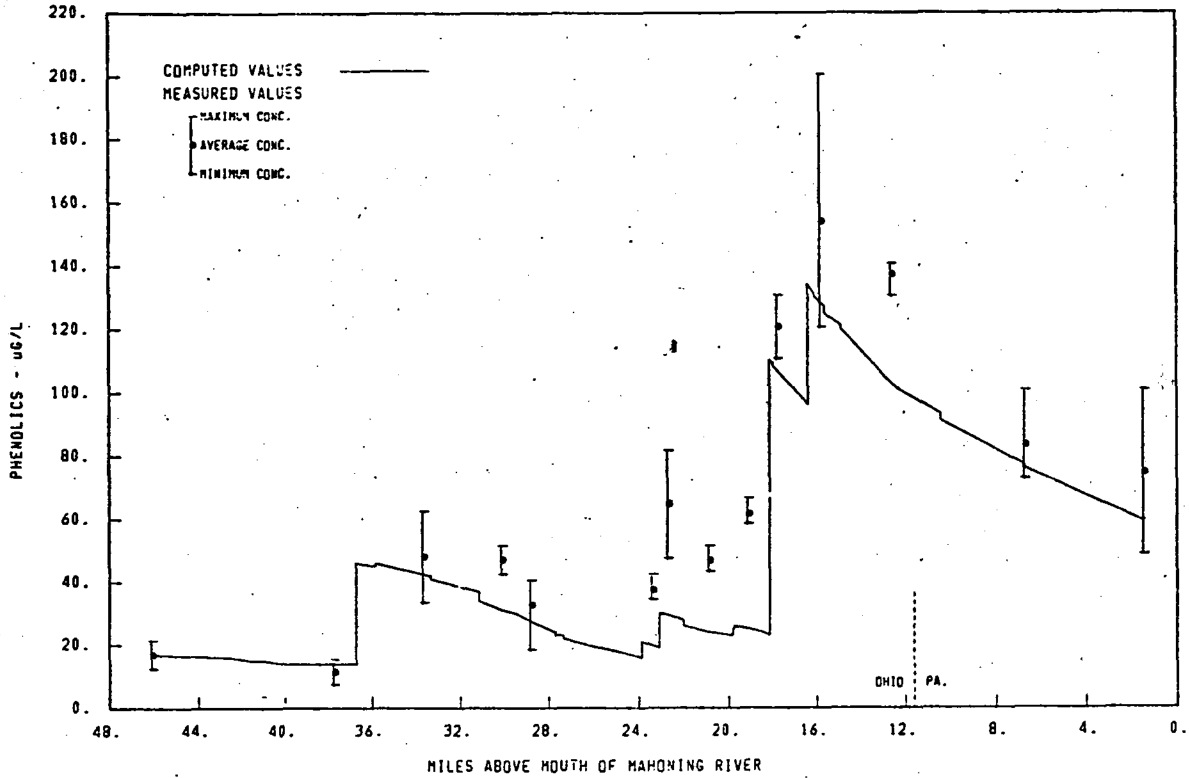


FIGURE VII-62
PHENOLICS VS. RIVER MILE
MODEL VERIFICATION USING FEBRUARY 11-14,1975 DATA

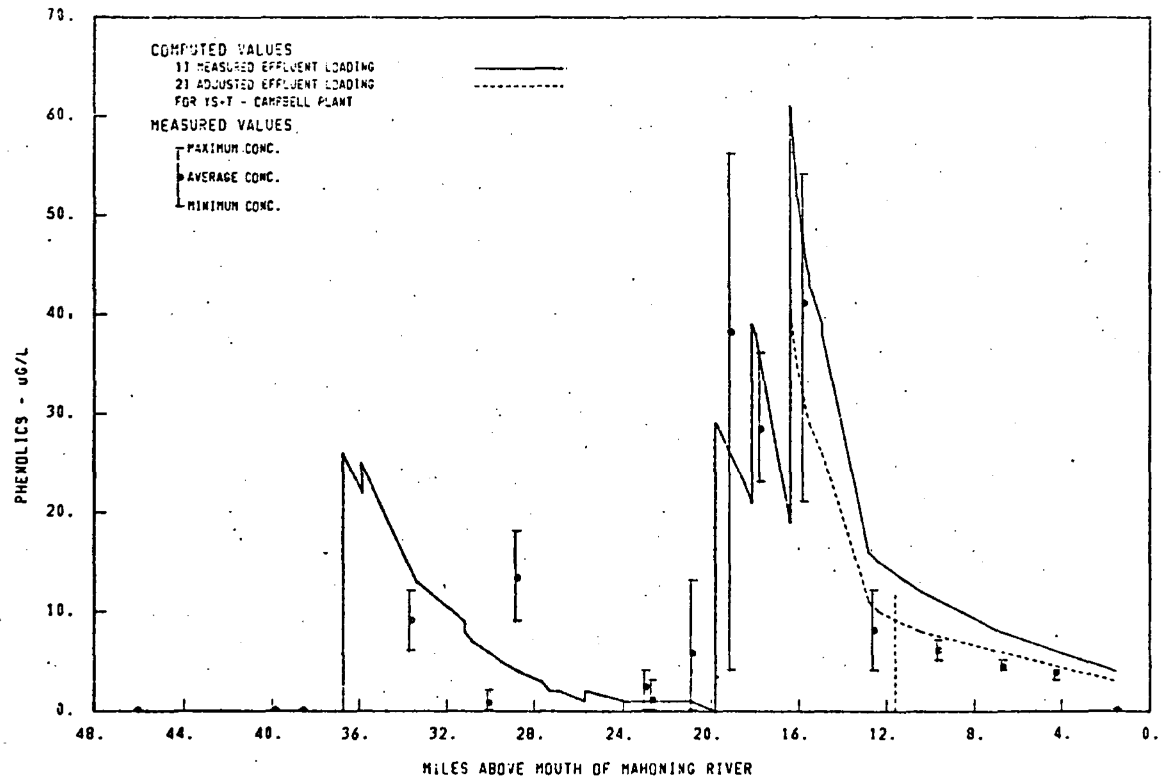


FIGURE VII-63
PHENOLICS VS. RIVER MILE
MODEL VERIFICATION USING JULY 14-17, 1975 DATA

TABLE V I I - 25
TOTAL CYANIDE AND PHENOLICS
LOWER MAHONING RIVER
August 24, 25, 1973

Sampling Point	Date Sampled	Time Sampled	Water Temp. (°F)	Total Cyanide ug/l	Phenolics ug/l
Lowellville	8/24	800	84.5	146	7
New Castle	8/24	1420	84.5	60	7
Lowellville	8/24	1200	85.0	143	19
New Castle	8/24	2000	83.5	60	7
Lowellville	8/24	1600		134	11
New Castle	8/24	2400	82.6	40	8
Lowellville	8/24	2100	87.5	113	12
New Castle	8/25	500		48	5
Lowellville	8/25	100	88.0	80	13
New Castle	8/25	900		31	8
Lowellville	8/25	600	86.0	89	10 *
New Castle	8/25	1400		21	22 *
Lowellville	8/25	1200	88.5	62	9
New Castle	8/25	2000	88.0	26	7
Averages					
Lowellville				110	12
New Castle				41	7
Travel Time (hours)		7.8			
Temperature (°F)		85.9			

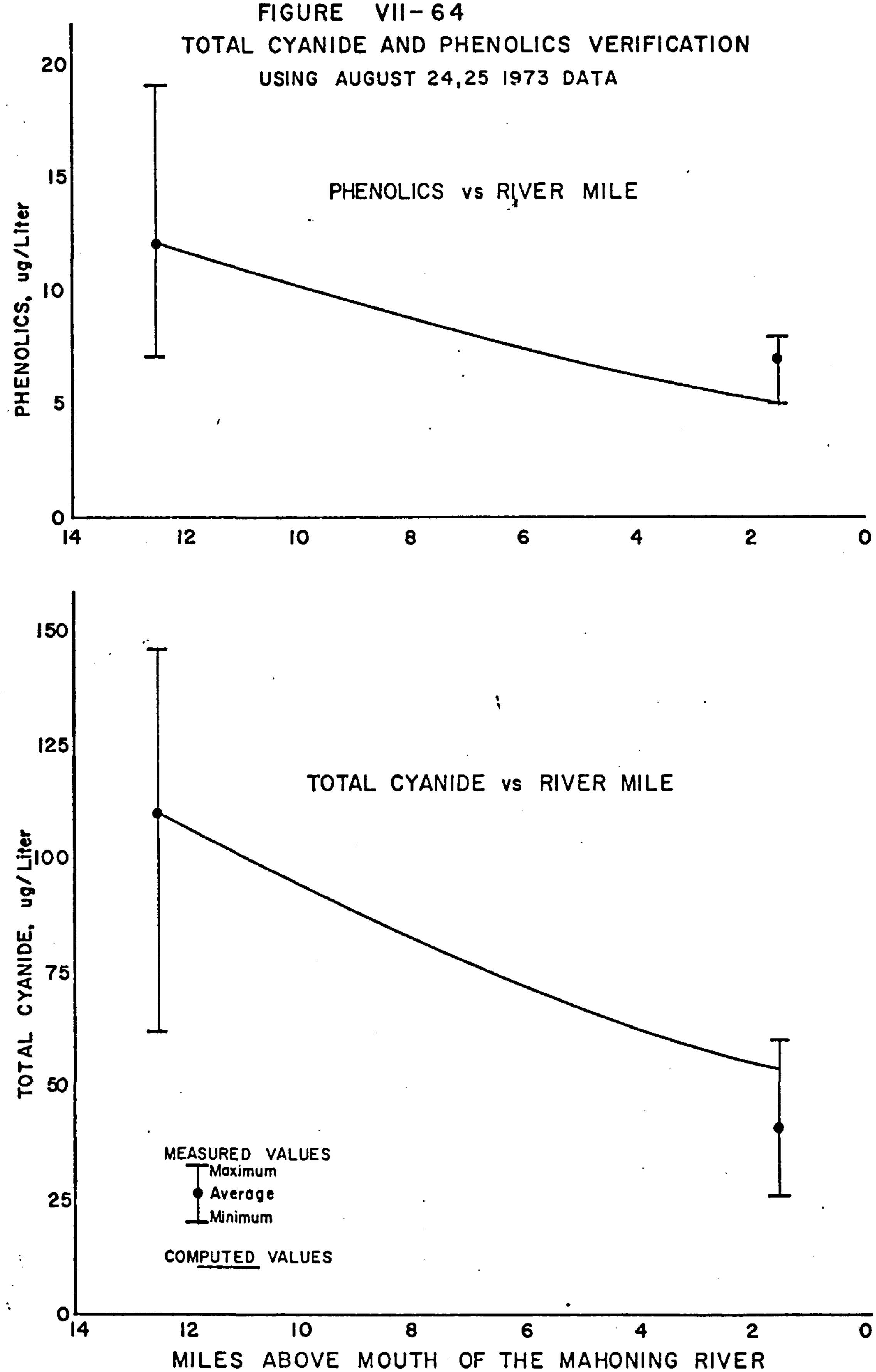
* Data excluded from averages.

Source: Raytheon Company, Expanded Development of BEBAM-A Mathematical Model of Water Quality for the Beaver River Basin, US EPA Contract No. 68-01-1836, May 1974.

FIGURE VII-64

TOTAL CYANIDE AND PHENOLICS VERIFICATION

USING AUGUST 24,25 1973 DATA



slightly high downstream of both Warren and Youngstown. Below Warren, the model predicted high by only about 5 µg/l downstream to the Ohio Edison intake. This difference probably resulted from an overestimated load at the Republic Steel-Warren Plant, as the temperature adjusted reaction rates in that area adequately reflect the decay in the stream. Between the sampling station at the Ohio Edison intake and the U. S. Steel-McDonald Mills intake, average stream concentrations increased by 14 µg/l. Since no known sources of phenolics were sampled in this area, except the Niles STP, the model did not duplicate this concentration increase. At the next downstream sampling station (U. S. Steel-Ohio Works intake) phenolics had decayed sufficiently that measured and computed concentrations were again in agreement.

Downstream of Youngstown, the predicted concentrations were as much as 14 µg/l above measured concentrations. Since the measured and computed concentration difference quickly reduced to less than 5 µg/l in Pennsylvania the difference appeared attributable to an overestimated load in the Youngstown area. A review of the daily discharge data for phenolics from the Youngstown Sheet and Tube-Campbell Works, revealed that the discharge from outfall 041 of the coke plant was ten times higher on the second day than it was on the first or third days of the survey. Apparently there was a slug discharge on the second day that was not seen during the rest of the survey. Because the Youngstown Sheet and Tube-Campbell Works was sampled only during the daytime work shift, the daily composite sample may be overly affected by one or two highly contaminated grab samples while the remaining samples were at lower levels. Had the sample been a 24-hour composite additional low level grab samples would have diluted the slug load.

To determine the effects of this overestimated phenolics load the model was rerun with an adjusted load at the Campbell Works. The adjusted load was computed by averaging only the first and third day's load from Outfall 041 and adding this load to the total of the three-day average loads for the other outfalls. The dotted line in Figure VII-63 represents the predicted phenolic concentration with the adjusted phenol load. In this case, the predicted concentrations came within 1 or 2 µg/l of the three-day average measured concentration downstream of Youngstown. Considering the number of outfalls and the sample handling and preservation problems, the verification of the model for the July survey was considered excellent.

In the segment of the stream below Lowellville, an additional verification of the model was made using the Raytheon data discussed earlier. In this case, the lower phenolic rate corrected for temperature was applied in the verification because measured stream concentrations were less than 20 ug/l. The results, shown in Figure VII-64, indicate good agreement between measured and computed values at New Castle. Hence, the phenolic reaction rates and the temperature correction coefficient adequately replicate decay in the stream.

The results of the February and July verification runs show that the phenolic model adequately replicated concentrations in the Mahoning River. The two rates used in the analysis represent a simplification of the complex reactions occurring in the stream. However, considering that the two-rate system accurately predicted the decay of phenolics during the cold winter condition when concentrations were relatively high and during warm summer conditions when in-stream concentrations were frequently below 20 µg/l, the simplification appears warranted. As with the other water quality constituents, some difficulties were encountered in the verification in accurately determining point source loadings, especially for the industrial discharges. When applying the model for load allocations, point source loadings are selected first, with the model being used to determine the water quality response to the selected loadings. Effluent loadings are therefore known quantities in water quality allocations. Difficulties encountered in accurately determining loadings for a particular water quality survey do not reflect on prediction capabilities of the model.

9. Verification Summary

In general, the Edinger and Geyer temperature model and the RIBAM water quality model adequately simulated conditions in the Mahoning River. As applied in this study, the one dimensional Edinger and Geyer temperature model predicted stream temperatures within two degrees fahrenheit of three-day average measured temperatures occurring during two completely different weather and flow conditions (February and July). RIBAM successfully modeled the reaction of CBOD throughout the Mahoning during February. However, some difficulty was encountered reproducing measured

CBOD values in the July survey in the Youngstown area. For ammonia-N, during winter conditions RIBAM accurately predicted average measured concentrations. A far more complex nitrogen system was found in the July survey, and after adjusting point source loadings to account for organic-nitrogen, the model predicted within about 15 percent of average measured values. The nitrite-N model was not evaluated for the February survey, however, in the July survey the model predicted well downstream to Youngstown where computed values became high for about 14 miles, then agreed well with measured values at the downstream end of the river. The dissolved oxygen model which includes the simulated reaction of CBOD, ammonia-N and nitrite-N generally predicted within about 0.5 mg/l of average measured concentrations in the winter survey and after ammonia-N loads were adjusted in the July survey, the model was within about 1.0 mg/l of measured values. The high dissolved oxygen results obtained in July are primarily attributed to floating oil seen on much of the river which reduced reaeration from computed values. Some loading related discrepancies were discovered in modeling total cyanide and phenolics. However, both models predicted within about 10 to 15 percent of average measured concentrations for both surveys. Based upon the ability of the computational procedures to reproduce measured stream concentrations, the models were considered verified on the Mahoning River.

During the verification studies, some difficulties were found in accurately reproducing stream concentration increases caused by point source loadings. The discrepancies in loadings primarily occurred at industrial sources where stream concentration showed larger increases than those computed with measured plant loadings. The major reasons for the discrepancies were that estimated flow rates and not measured values had to be used to compute industrial loadings, not all outfalls were sampled at each steel plant, and finally, sample handling was not always ideal. As pointed out earlier, errors in loadings do not indicate inadequacies in the model, but deficiencies in portions of the data set used for verification purposes.

The reaction rates and temperature correction coefficients supplied to the model accurately replicated the disappearance rates seen in the Mahoning River at widely varying flows and temperatures. The single rates determined for CBOD, ammonia-N, and total cyanide, and the two rates applied to the phenolics model successfully predicted the decay downstream of both industrial and municipal sources. Different reaction rates were not required for each river segment. The only significant rate problem seen in the verification was for the reaeration rate which appeared somewhat high for the July survey (see above). The good agreement for the other reaction rates was undoubtedly related to the fact that travel times and velocities were computed from procedures which had verified accurately with dye studies conducted on the Mahoning River.

It is also important to note that the accurate verification of the RIBAM model supports the use of the simplifying assumptions made during model development. Steady-state conditions for stream flow and discharge loadings were not fully obtained during either the February or July survey. However, the methods of compositing effluent samples and averaging data over the three-day sampling period produced model results which were in good agreement with measured values. The assumption that effluent loadings mix instantaneously and completely in the river at the point of discharge, produced no significant discrepancies except at the sampling stations which were located in congested areas. Incomplete mixing of the effluent at these stations generally produced larger concentration variations and sometimes average measured values which were not consistent with sampling stations further downstream. This problem points out the need for careful selection of sampling points.

As discussed in the ammonia-N verification, the hydrolysis of organic-N to ammonia-N is not included in the model. Failure to include this reaction will cause predicted ammonia-N to be low and dissolved oxygen to be high in the warm summer months. Because organic-N loadings to the Mahoning River will be substantially reduced when proposed waste treatment controls are installed, the error introduced by not including organic-N will also be substantially reduced.

A statistical comparison of measured and computed concentrations, or an error analysis, was not made in this study. Many of the inputs required for an error analysis, such as the standard deviation or standard error of the input parameters were not readily obtainable. Also the calculation

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SECTION VIII
WASTE LOAD ANALYSIS

Establishing allowable wastewater discharge levels to achieve any desired water quality objective for the lower Mahoning River can easily become unmanageable owing to several factors, not the least of which is the long and volatile history of water pollution abatement, or lack thereof, in the Valley. There are virtually an unlimited number of combinations of treatment alternatives for the 20 or so significant municipal and industrial dischargers. At this writing, water quality standards for the Ohio portion of the stream are again being revised and final best practicable control technology currently available (BPCTCA) and best available technology economically achievable (BATEA) effluent guidelines for the steel industry are as yet uncertain as a result of industry challenges. Hence, this effort is primarily directed at developing waste load allocations to achieve Pennsylvania water quality standards at the Ohio-Pennsylvania State line. The fact that significant dischargers are located between five and thirty miles upstream from the State line further complicates the analysis. Although Ohio's intention is to downgrade water quality standards for certain segments of the river, water quality in Ohio is important since it basically determines the quality in Pennsylvania. Also, future upgrading uses and standards of the Ohio portion of the stream may be desired.

The balance of Section VIII presents the waste load allocation policy employed in developing treatment alternatives; water quality-related and treatment technology-related effluent criteria; major treatment alternatives and resultant water quality in Ohio and at the Ohio-Pennsylvania State line; estimated capital costs associated with each alternative; and, the sensitivity of the water quality analysis and its relation to the selection of a treatment alternative.

A. <u>Waste Load Allocation Policy</u>

Simply stated, the waste load allocation policy employed in this analysis incorporates roughly equivalent levels of treatment for industrial process operations in a given manufacturing category and the same degree of sewage treatment for municipalities and regional treatment systems. The equivalent treatment approach was adopted after considering several others, including working directly from the Pennsylvania WQS to determine acceptable treatment levels. However, depending upon how allocations were made, this policy could result in severely penalizing dischargers located close to the State line while permitting virtually uncontrolled discharges well upstream. The policy employed herein was applied with several levels of treatment to determine those that would result in compliance with Pennsylvania WQS. Nonetheless, there are alternate methods of allocating waste loads and the selection of a particular method could be debated ad infinitum. The concept of roughly equivalent treatment for the various corporate and municipal entities is probably the most equitable, more cost effective, and , politically more feasible to implement.

Conventional secondary treatment and an advanced level of treatment incorporating nitrification (ammonia-N removal) were considered for municipalities. Proposed, remanded, and interim-final BPCTCA and BATEA effluent guidelines were considered for the steel industry, and, no treatment and offstream cooling with complete recycle of condenser cooling water were considered for Ohio Edison. Six major treatment alternatives were developed incorporating the above treatment levels in various combinations and were evaluated in terms of compliance with Pennsylvania water quality standards.

Use of effluent guidelines for the steel industry which have not been finally promulgated by the USEPA has certain limitations. However, these guidelines do provide an equitable method of determining waste loadings within a given process subcategory based upon production rates of Mahoning Valley operations within that subcategory. Of the various steel industry effluent guidelines, those for coke plants and blast furnaces are critical in terms of specific numerical criteria contained in Pennsylvania water quality standards.

In the past, various schemes to treat the entire Mahoning River near the Ohio-Pennsylvania State line have been proposed. More recently, the Ohio EPA has considered cooling the entire Mahoning River near Lowellville to achieve Pennsylvania water quality standards for temperature. Aside from the obvious technical problems assoicated with these proposals, they have been rejected by the USEPA as being outside the Federal Water Pollution Control Act, and thus illegal.[1] Hence, "treat-the-river" schemes are not considered.

B. Water Quality and Technology Based Discharge Criteria

Table VIII-1 presents a summary of the basis for NPDES permit effluent limitations for major Mahoning River municipal and industrial dischargers. The steel industry discharges are classified according to production operation. As shown, limitations for suspended solids, oil and grease, and metals are classified as technology-based while those for thermal discharges, dissolved oxygen, biochemical oxygen demand, ammonia-N, total cyanide, phenolics, and fecal coliform/residual chlorine are water quality-based. Although Pennsylvania has no numerical water quality criteria for suspended solids, oil and grease, and metals, general water quality criteria contained in Pennsylvania WQS,[2] clearly prohibit the current gross discharge of these materials:

> "93.4 General Water Quality Criteria
>
> (a) Water shall not contain substances attributable to municipal, industrial or other waste discharges in concentrations or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant, or aquatic life.
>
> (b) Specific substances to be controlled shall include, but shall not be limited to floating debris, oil, scum and other floating materials, toxic substances and substances which produce color, tastes, odors, turbidity or settle to form sludge deposits."

Section 311 of the FWPCA also restricts the discharge of oil to amounts which will not " . . . cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines."[3] Also, Ohio WQS "Four Freedoms" criteria, which are similar to the Pennsylvania General Water Quality Criteria, prohibit the gross discharge of these materials.[4]

TABLE VIII-1

BASIS FOR EFFLUENT LIMITATIONS

MAHONING RIVER BASIN

Principal Pollutants	Basis for Limitation
Municipal Sewage Treatment Plants	
Total Suspended Solids	Treatment Technology
Biochemical Oxygen Demand	Water Quality
Ammonia-N	Water Quality
Dissolved Oxygen	Water Quality
Fecal Coliform/Residual Chlorine	Water Quality
Steel Industry	
Thermal Discharge	Water Quality
Coke Plants	
Total Suspended Solids	Treatment Technology
Oil and Grease	Treatment Technology
Ammonia-N	Water Quality
Total Cyanide	Water Quality
Phenolics	Water Quality
Blast Furnaces	
Total Suspended Solids	Treatment Technology
Ammonia-N	Water Quality
Total Cyanide	Water Quality
Phenolics	Water Quality
Steelmaking	
Total Suspended Solids	Treatment Technology
Hot Forming	
Total Suspended Solids	Treatment Technology
Oil and Grease	Treatment Technology
Cold Rolling	
Total Suspended Solids	Treatment Technology
Oil and Grease	Treatment Technology
Metals	Treatment Technology
Coatings and Finishing	
Total Suspended Solids	Treatment Technology
Oil and Grease	Treatment Technology
Metals	Treatment Technology
Power Industry	
Total Suspended Solids	Treatment Technology
Thermal Discharge	Water Quality
Residual Chlorine	Water Quality

For temperature, oxygen consuming materials, ammonia-N, total cyanide, and phenolics, discharge loadings can be evaluated in terms of expected water quality with some degree of confidence using the mathematical water quality models reviewed earlier. It is not possible to do so for suspended solids and oil and grease. Hence, discharge limitations for these materials are based more upon qualitative than quantitative effects on stream quality. Gross discharges of suspended solids will generally be eliminated with the installation of technology to control other substances. Installation of BPCTCA-type treatment for steel industry finishing operations should preclude water quality problems with respect to metals. Acceptable discharge levels of oil and grease are more difficult to define.

Based upon information presented by McKee and Wolf,[5] the discharge of oil can have deleterious effects on Pennsylvania's major designated water uses for the Mahoning and Beaver Rivers. For public water supplies, oils can create health hazards to consumers, produce taste and odors, result in turbidity, films, or irridescence, and increase difficulty of water treatment. Adverse effects upon aquatic life include interference with fish respiration, destruction of algae and plankton, destruction of benthic organisms and interference with spawning, tainting fish flesh, inteference with reaeration and photosynthesis, direct chronic or acute toxic action, and deoxygenation.

Data presented earlier indicate some of the above adverse effects are obviously occurring (taste and odor, presence of turbidity and films, destruction of benthic environment) while others may be less obvious (increased difficulty of water treatment, destruction of algae and other plankton, fish-flesh tainting, interference with reaeration and photosynthesis, toxicity, and contribution to deoxygenation). There are no known data that suggest health hazards due to oil for those using the Beaver Falls water supply. Nonetheless, the current gross discharge of oil must be abated to achieve Ohio's and Pennsylvania's designated water uses. Aside from establishing a "no discharge" policy, the minimum degree of abatement required at each discharger to achieve those uses is not easily determined and may, in fact, not be determinable in a quantitative fashion.

Currently, steel industry hot forming operations contribute most of the oil discharged to the Mahoning River, and estimated capital expenditures necessary to treat those wastes comprise about 48 percent of the total estimated cost to achieve BPCTCA for the eight major facilities. Hence, any reduction in hot forming treatment costs due to region-specific effluent criteria which would result in discharges close to BPCTCA could be significant, provided designated water uses were achieved. Attachments A to the proposed NPDES permits issued in May 1976 for the steel industry reflect a deviation from nationwide hot forming BPCTCA discharge levels in order to provide maximum cost savings to the steel industry while attempting to achieve the Ohio and Pennsylvania designated water uses.

For the purposes of this analysis, three levels of treatment for oil from hot forming mills are considered: (1) Interim-Final Phase II BPCTCA (March 29, 1976); (2) Existing process discharges treated to 10 mg/l (proposed NPDES permits), and (3) Proposed Phase II BATEA (March 29, 1976). Oil limitations for cold rolling and finishing operations were established at either BPCTCA or BATEA. The aggregate discharge of oil from all plants with each of these alternatives and the respective estimated capital cost of treatment is compared with the existing full production discharges. The relatively small contribution of oil from coke plants is included in the existing discharge total, but coke plant treatment costs are not considered.

		Estimated Capital Cost of Treatment (Millions)	
	lbs/day of Oil	Hot Forming, Cold Rolling, Finishing	Hot Forming
Existing net discharge	70,000 (long-term average)	0	0
10 mg/l at existing process flows	15,400 (30-day average)	$ 62.3	$ 47.7
BPCTCA	12,200 (30-day average)	$ 82.8	$ 70.0
BATEA	500 (30-day average)	$ 118.1	$ 102.0

Based upon the above, the more cost effective approach appears to be treatment to 10 mg/l of oil at existing process flows rather than treatment to BPCTCA levels, assuming an oil discharge in the 12–15,000 lbs/day range is acceptable from a water quality viewpoint. The BATEA level would be required if 301(c) economic demonstrations by the respective discharges were unsuccessful or if water quality objectives were not achieved with higher levels of discharge. (Tables VIII-10 to VIII-12 present capital cost estimates and list cost references for each facility.)

C. Waste Treatment Alternatives

The six major waste treatment alternatives selected for evaluation are outlined in Table VIII-2. While there are virtually an unlimited number of possible combinations, these alternatives generally represent the significant differences in treatment levels specified in PL 92-500 and are consistent with the waste load allocation policy presented earlier. Each alternative was evaluated for compliance with Pennsylvania water quality standards over a wide range of stream flows for temperature, dissolved oxygen, ammonia–N (toxicity criteria), total cyanide, and phenolics using the water quality models reviewed in Section VII.

Table VIII-3 presents a summary of municipal discharge loadings for each treatment alternative considered, and Table VIII-4 presents estimated capital and annual operating costs for the respective 201 areas. Interceptor costs for all cases and capital and operating costs for Cases 2a, 2b, 3, and 5 were obtained from the 208 Agency municipal consultant.[6] Treatment facility capital and operating costs for Case 1 were estimated by similar methods by USEPA.[7, 8] The general configuration of regional treatment facilities considered herein was found to be the least cost alternative by the 208 Agency.[9] Note that costs for the Meander Creek plant are not included as this facility has been completed and is in operation. Also, municipal costs include only those facilities discharging to the lower Mahoning River. Municipal costs estimates and the locations of regional facilities may be modified somewhat once 201 Step 1 facilities plans are complete and design flows are firmly established.

Tables VIII-5 to VIII-9 present industrial effluent discharges summaries for Cases 1 to 5, and Tables VIII-10 to 12 present industrial capital cost estimates and were taken from the USEPA economic analysis of the Mahoning Valley. Appropriate references are listed in Tables VIII-10 to 12. Table VIII-13 summarizes municipal and industrial costs for each alternative. Most industrial cost data were current as of early 1975. A brief description of each treatment alternative follows:

TABLE VIII-2

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

Case	Title	Municipalities	Steel Industry	Power Industry
1	BPCTCA-Secondary	Secondary Treatment	Coke Plants Blast Furnaces } Phase 1 BPCTCA (6/24/74) Steelmaking Hot Forming Cold Rolling } Phase 2 BPCTCA (3/29/76) Finishing	No Treatment
2a	Proposed NPDES Permits (5/20/76)	Nitrification	Coke Plants - Dirty Quench (or Phase 1 BATEA) Blast Furnaces Steelmaking } Phase 1 BPCTCA Hot Forming - 10 mg/l oil, 30 mg/l suspended solids with existing process flow rates Cold Rolling Finishing } Phase 2 BPCTCA	No Treatment
2b	Proposed NPDES Permits (5/20/76) with Thermal Controls	Nitrification	Coke Plants - Dirty Quench (or Phase 1 BATEA) Blast Furnaces Steelmaking } Phase 1 BPCTCA Hot Forming - 10 mg/l oil, 30 mg/l suspended solids with existing process flow rates Cold Rolling Finishing } Phase 2 BPCTCA	Offstream Cooling and Recycle of Condenser Cooling Water
3	Pennsylvania WQS	Nitrification	Coke Plants - Dirty Quench (or Phase 1 BATEA) Blast Furnaces - Phase 1 BPCTCA for Rep-W, YS and T-BH; Phase 1 BPCTCA Ammonia-N and 30% of Phase 1 BPCTCA total cyanide and phenolics for others. Steelmaking - Phase 1 BPCTCA Hot Forming - 10 mg/l oil, 30 mg/l suspended solids with existing process flow rates Cold Rolling Finishing } Phase 2 BPCTCA	Offstream Cooling and Recycle of Condenser Cooling Water

TABLE VIII-2

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

Case	Title	Municipalities	Steel Industry	Power Industry
4	Joint Municipal Industrial Treatment (Warren and Youngstown)	Nitrification	Coke Plants, Blast Furnaces } Pretreatment to Phase 1 BPCTCA and discharge to Warren or Youngstown sewerage systems Steelmaking - Phase 1 BPCTCA Hot Forming - 10 mg/l oil, 30 mg/l suspended solids with existing process flow rates Cold Rolling, Finishing } Phase 2 BPCTCA	Offstream Cooling and Recycle of Condenser Cooling Water
5	BATEA-Nitrification	Nitrification	Coke Plants, Blast Furnaces, Steelmaking } Phase 1 BATEA Hot Forming, Cold Rolling, Finishing } Phase 2 BATEA	No Treatment

1. Case 1 BPCTCA - Secondary Treatment

As shown in Table VIII-3, conventional secondary treatment effluent criteria were specified for the municipal systems (30 mg/l suspended solids and 30 mg/l BOD_5). Existing ammonia-N discharge levels were assumed. Of the total capital cost of 96 million dollars, 18 million dollars are for interceptors which would be needed regardless of treatment plant design. Estimated annual operating costs associated with the interceptor systems amount to 0.41 million dollars of the total annual operating cost of 3.28 million dollars.

Final effluent limitations contained in the effective NPDES discharge permit for Copperweld Steel and the existing thermal discharge for Ohio Edison were included (Table VIII-5). Phase I and Phase II BPCTCA Effluent Guidelines were employed for the major steel facilities in the Valley. The total Case I industrial cost of 147.4 million dollars is categorized by process operation and by corporation as follows:

	Millions of Dollars	% of Total
Coke Plants	24.1	16
Blast Furnaces	26.6	18
Hot Forming	70.0	48
Cold Rolling, Finishing	12.8	9
Acid Regeneration	12.0	8
Cooling	0	0
Miscellaneous (Sanitary)	1.9	1
Total	147.4	
Copperweld Steel	0.8	1
Republic Steel	67.0	45
U. S. Steel	26.9	18
Youngstown Sheet and Tube	52.7	36
Ohio Edison	0	0
Total	147.4	

2. Case 2a Proposed NPDES Permits (May 1976)

Case 2a reflects the municipal and industrial NPDES permits proposed by the Ohio EPA during May 1976. Municipal treatment includes more stringent BOD_5 removal and ammonia control to 3 mg/l during the summer months and 5 mg/l during the winter. While Case 1 and 2a interceptor costs are identical, the treatment facility costs for Case 2a are increased by about 25 million dollars and annual operating costs by 0.9 million dollars to reflect the advanced treatment provided.

Copperweld Steel's effective NPDES permit and the existing thermal discharge at Ohio Edison were included. No discharge of process wastes from coke plants was assumed. This would be achieved by improving existing dirty water coke quenching systems at the Republic Steel-Warren and Youngstown Plants, and at the Youngstown Sheet and Tube-Campbell Works. However, depending upon air quality considerations, this practice may have to be discontinued in the future. In the event dirty water coke quenching is not allowed, BATEA treatment would be required for discharge of coke plant wastes to the river. Blast furnace discharges were set at BPCTCA levels as were cold rolling and finishing operations. Hot forming discharge levels were established at 10 mg/l of oil at existing process flows as discussed earlier. Total estimated industrial costs of 92.6 million dollars (dirty water coke quench) and 116.7 million dollars (coke plant BATEA) are summarized by process operation and corporation:

	Dirty Water Coke Quench		Coke Plant BATEA	
	Millions of Dollars	% of Total	Millions of Dollars	% of Total
Coke Plants	1.8	2	25.9	22
Blast Furnaces	26.6	29	26.6	23
Hot Forming	49.5	53	49.5	42
Cold Rolling, Finishing	12.8	14	12.8	11
Acid Regeneration	0	0	0	0
Cooling	0	0	0	0
Miscellaneous (Sanitary)	1.9	2	1.9	2
Total	92.6		116.7	
Copperweld Steel	0.8	1	0.8	1
Republic Steel	33.8	37	50.1	43
U. S. Steel	15.7	17	15.7	13
Youngstown Sheet and Tube	42.3	46	50.1	43
Ohio Edison	0	0	0	0
Total	92.6		116.7	

3. Case 2b Proposed NPDES Permits with Thermal Control at Ohio Edison

Municipal and steel plant treatment levels are the same as presented in Case 2a. However, offstream cooling and complete recycle of condenser cooling water at the Ohio Edison-Niles Plant is included. The capital cost summary is shown below:

	Dirty Water Coke Quench		Coke Plant BATEA	
	Millions of Dollars	% of Total	Millions of Dollars	% of Total
Coke Plants	1.8	2	25.9	21
Blast Furnaces	26.6	26	26.6	21
Hot Forming	49.5	49	49.5	40
Cold Rolling, Finishing	12.8	13	12.8	10
Acid Regeneration	0	0	0	0
Cooling	8.0	8	8.0	6
Miscellaneous (Sanitary)	1.9	2	1.9	2
Total	100.6		124.7	
Copperweld Steel	0.8	1	0.8	1
Republic Steel	33.8	34	50.1	40
U. S. Steel	15.7	16	15.7	13
Youngstown Sheet and Tube	42.3	42	50.1	40
Ohio Edison	8.0	8	8.0	6
Total	100.6		124.7	

4. Case 3 Pennsylvania Water Quality Standards

Case 3 incorporates most of the municipal and industrial discharge loadings presented in Case 2b. Total cyanide and phenolics discharges from blast furnace operations at the U. S. Steel-Ohio Works, the Republic Steel-Youngstown Plant, and the Youngstown Sheet and Tube-Campbell Works were reduced because of their proximity to the Ohio-Pennsylvania State line and the magnitude of the Case 2a and 2b discharges. Total cyanide and phenolics limitations for these blast furnace systems were set at 30 percent of BPCTCA discharge levels. This reduction was determined by reviewing the Case 2b total cyanide and phenolics responses at the most critical flow condition. For capital cost estimating purposes, BATEA, costs were employed for the three affected blast furnace operations.

Although this approach represents a slight departure from the waste load allocation policy employed throughout this analysis, each of the three major steel producers in the Valley was treated equally. It is more cost effective to obtain additional total cyanide and phenolics removal from those large dischargers located close to the State line, rather than from those upstream. The increase in the estimated total industrial cost over Case 2b is about 3.6 percent. A breakdown by process operation and by corporation is shown below:

	Dirty Water Coke Quench		Coke Plant BATEA	
	Millions of Dollars	% of Total	Millions of Dollars	% of Total
Coke Plants	1.8	2	25.9	20
Blast Furnaces	30.2	29	30.2	24
Hot Forming	49.5	48	49.5	39
Cold Rolling, Finishing	12.8	12	12.8	10
Acid Regeneration	0	0	0	0
Cooling	8.0	8	8.0	6
Miscellaneous (Sanitary)	1.9	2	1.9	1
Total	104.2		128.3	
Copperweld Steel	0.8	1	0.8	1
Republic Steel	34.4	33	50.7	40
U. S. Steel	17.8	17	17.8	14
Youngstown Sheet and Tube	43.2	41	51.0	40
Ohio Edison	8.0	8	8.0	6
Total	104.2		128.3	

5. Case 4 Joint Treatment

Case 4 represents joint treatment of municipal wastes with coke plant and blast furnace wastes pretreated to the Phase 1 BPCTCA level. Coke plant and blast furnace wastes from the Republic Steel-Warren Plant would be treated at the Warren STP and coke plant and blast furnace wastes from all other steel mills at the Youngstown STP. Other regional schemes in the upper Youngstown area and in the Campbell-Struthers area may be possible. However, the volume and strength of coke plant and blast furnace wastes may result in treatability problems at the smaller facilities, notably the proposed Campbell-Struthers facility. Hence, joint treatment at the Youngstown STP is considered the most feasible for it would provide greater dilution of industrial wastes with municipal sewage, be more resistant to treatment upsets due to fluctuating raw waste loads, and provide more time-of-travel in the stream above the Ohio-Pennsylvania State line. The respective flow and effluent concentration increases for the Warren and Youngstown facilities are shown in Table VIII-3.

Case 4 incorporates treatment of the ammonia loadings from coke plants at the municipal facilities, but allocates blast furnace ammonia loadings to the respective municipalities in the form of increased effluent concentrations. A recent summary of the literature concerning biological treatment of coke plant wastes[24] indicates near complete removal of phenolic compounds, but somewhat less successful total cyanide removal. Based upon this information, no increase in the municipal phenolics discharge of 10 mg/l and 75 percent total cyanide removal are projected (Table VIII-3). Only non-contact cooling water would be discharged from coke plants and blast furnaces at the steel plants. Other steel plant process discharges would be identical to those contained in Cases 2a, 2b, and 3. Offstream cooling is considered for Ohio Edison. The industrial cost summary presented below does not include municipal capital cost recovery for the increased size of necessary treatment facilities, cost of tie-in to municipal systems, and the increased operating cost that would be chargeable to the steel industry. These costs, which can be considerable, can only be developed during the 201 facility planning process.

	Millions of Dollars	% of Total
Coke Plant	24.1	20
Blast Furnace	26.6	22
Hot Forming	49.5	40
Cold Rolling, Finishing	12.8	10
Acid Regeneration	0	0
Cooling	8.0	7
Miscellaneous	1.9	2
Total	122.9	

	Millions of Dollars	% of Total
Copperweld Steel	0.8	1
Republic Steel	48.9	40
U. S. Steel	15.7	13
Youngstown Sheet and Tube	49.5	40
Ohio Edison	8.0	7
Total	122.9	

6. Case 5 BATEA - Nitrification

Case 5 reflects the same level of treatment for the municipalities as presented in Cases 2a, 2b, and 3 while all steel plant discharges are upgraded to BATEA. No treatment for thermal discharges is considered for Ohio Edison. The industrial cost data summary presented below does not include BATEA costs for treatment of miscellaneous steel plant runoffs (coal and ore storage, etc.).

	Millions of Dollars	% of Total
Coke Plants	25.9	14
Blast Furnaces	31.0	16
Hot Forming	102.0	54
Cold Rolling, Finishing	16.1	9
Acid Regeneration	12.2	6
Cooling	0	0
Miscellaneous (Sanitary)	1.9	1
Total	189.1	1
Copperweld Steel	0.8	1
Republic Steel	91.6	48
U. S. Steel	31.1	16
Youngstown Sheet and Tube	65.6	35
Ohio Edison	0	0
Total	189.1	

TABLE VIII-3

MUNICIPAL DISCHARGE LOADINGS

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

Case	Flow MGD	Suspended Solids mg/l	Suspended Solids lbs/day	BOD_5 mg/l	BOD_5 lbs/day	UCBOD lbs/day	Ammonia-N Summer mg/l	Ammonia-N Summer lbs/day	Ammonia-N Winter mg/l	Ammonia-N Winter lbs/day	Dissolved Oxygen Summer mg/l	Dissolved Oxygen Winter mg/l	Total Cyanide µg/l	Total Cyanide lbs/day	Phenolics µg/l	Phenolics lbs/day	Nitrite-N mg/l	Nitrite-N lbs/day
1																		
Warren	16.0	30	4006	30	4006	6009	10.2	1362	10.2	1362	4	6	50	6.7	10	1.3	0.5	66.8
Niles-McDonald-Girard	10.0	30	2504	30	2504	3756	11.3	943	11.3	943	4	6	10	0.8	10	0.8	0.5	41.7
Meander Creek	5.3	20	885	15	663	995	2.5	111	5.0	221	5	7	10	0.4	10	0.4	0.5	22.1
Youngstown	40.0	30	10014	30	10014	15021	7.9	2637	7.9	2637	4	6	50	16.7	10	3.3	0.5	166.9
Campbell-Struthers	8.5	30	2128	30	2128	3192	6.8	482	6.8	482	4	6	10	0.7	10	0.7	0.5	35.5
Lowellville	0.5	30	125	30	125	188	3.5	15	3.5	15	4	6	10	< 0.1	10	< 0.1	-	2.1
TOTAL	80.3	-	19662	-	19440	29161	-	5550	-	5660	-	-	-	25.4	-	6.6	-	335.1
2a, 2b, 3, 5																		
Warren	16.0	20	2670	15	2003	3005	3	401	5	668	5	7	50	6.7	10	1.3	0.5	66.8
Niles-McDonald-Girard	10.0	20	1669	15	1252	1878	3	250	5	417	5	7	10	0.8	10	0.8	0.5	41.7
Meander Creek	5.3	20	885	15	663	995	2.5	111	5	221	5	7	10	0.4	10	0.4	0.5	22.1
Youngstown	40.0	20	6676	15	5007	7511	3	1001	5	1669	5	7	50	16.7	10	3.3	0.5	166.9
Campbell-Struthers	8.5	20	1419	15	1064	1596	3	213	5	355	5	7	10	0.7	10	0.7	0.5	35.5
Lowellville	0.5	20	83	15	63	94	3	13	5	21	5	7	10	< 0.1	10	< 0.1	0.5	2.1
TOTAL	80.3	-	13402	-	10052	15079	-	1989	-	3351	-	-	-	25.4	-	6.6	-	335.1
4																		
Warren	16.63	20	2775	15	2081	3122	5.7	795	7.7	1062	5	7	200	27.4	10	1.4	0.5	69.4
Niles-McDonald-Girard	10.0	20	1669	15	1252	1878	3	250	5	250	5	7	10	0.8	10	0.8	0.5	41.7
Meander Creek	5.3	20	885	15	663	995	2.5	111	5	133	5	7	10	0.4	10	0.4	0.5	22.1
Youngstown	43.06	20	7186	15	5390	8084	8.1	2910	10.0	3578	5	7	370	133.9	10	3.6	0.5	179.7
Campbell-Struthers	8.5	20	1419	15	1064	1596	3	213	5	355	5	7	10	0.7	10	0.7	0.5	35.5
Lowellville	0.5	20	83	15	63	94	3	13	5	21	5	7	10	< 0.1	10	< 0.1	0.5	2.1
TOTAL	84.0	-	14017	-	10513	15769	-	4292	-	5399	-	-	-	163.3	-	7.0	-	350.5

TABLE VIII-4

ESTIMATED CAPITAL AND ANNUAL OPERATING COSTS

MAHONING RIVER MUNICIPAL TREATMENT ALTERNATIVES

(Millions of Dollars)

	Estimated Capital Costs			Estimated Annual Operating Costs		
	Interceptor	Treatment Facility	Total	Interceptor	Treatment Facility	Total
Case 1						
Warren	7.17	15.49	22.66	0.05	0.89	0.94
Niles-McDonald-Girard	4.00	17.32	21.32	0.19	0.66	0.85
Youngstown	3.81	39.78	43.59	-	0.93	0.93
Campbell-Struthers	2.58	4.68	7.26	0.15	0.33	0.48
Lowellville	0.45	0.37	0.82	0.02	0.06	0.08
TOTAL	18.01	77.64	95.65	0.41	2.87	3.28
Case 2a, 2b, 3, 5						
Warren	7.17	20.65	27.82	0.05	1.19	1.24
Niles-McDonald-Girard	4.00	22.20	26.20	0.19	0.84	1.03
Youngstown	3.81	53.05	56.86	-	1.23	1.23
Campbell-Struthers	2.58	6.00	8.58	0.15	0.43	0.58
Lowellville	0.45	0.46	0.91	0.02	0.08	0.10
TOTAL	18.01	102.36	120.37	0.41	3.77	4.18

NOTE: (1) Lowellville costs reflect tie in to Campbell-Struthers regional facility

TABLE VIII - 5

CASE I BPCTCA - SECONDARY TREATMENT

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Copperweld Steel	0	360	320	-	-	-	320	-
Republic Steel-Warren Plant								
Coke Plant		103	31	258	61.9	4.3		-
Blast Furnace		157	-	394	47.1	12.7		-
Hot Forming		4870	2657	-	-	-		-
Central Treatment		1458	374	-	-	-		BPCTCA
Total	350	6588	3062	652	109.0	17.0	3062	BPCTCA
Republic Steel-Niles Plant	-	323	106	-	-	-	106	BPCTCA
Ohio Edison-Niles Plant	1160	-	-	-	-	-	-	-
U. S. Steel-McDonald Mills	100	4210	1905	-	-	-	1905	BPCTCA
Youngstown Sheet and Tube Co.								
Brier Hill Works								
Blast Furnace		58	-	144	17.3	4.7		-
Hot Forming		2667	1290	-	-	-		-
Cold Rolling		272	109	-	-	-		BPCTCA
Total	250	2997	1399	144	17.3	4.7	1399	BPCTCA
U. S. Steel-Ohio Works								
Blast Furnace		218	-	547	65.5	17.6		-
Hot Forming		526	408	-	-	-		-
Total	350	744	408	547	65.5	17.6	408	-
Republic Steel-Youngstown Plant								
Coke Plant		218	65	545	131.0	9.0		-
Blast Furnaces		223	-	559	66.9	18.0		-
Hot Forming		1708	822	-	-	-		-
Cold Rolling		60	19	-	-	-		BPCTCA
Total	240	2209	906	1104	197.9	27.0	906	BPCTCA

TABLE VIII - 5
(continued)
CASE I BPCTCA - SECONDARY TREATMENT

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Youngstown Sheet and Tube-Campbell Works								
Coke Plant		295	88	738	177.1	12.1		-
Blast Furnaces		263	-	658	78.8	21.2		-
Hot Forming		7231	3636	-	-	-		-
Cold Rolling		795	301	-	-	-		BPCTCA
Total	690	8584	4025	1396	255.9	33.3	4025	BPCTCA
Youngstown Sheet and Tube-Struthers Division								
Hot Forming		457	207	-	-	-		-
Finishing		212	-	-	5.3	-		BPCTCA
Total	40	669	207	-	5.3	-	207	BPCTCA
TOTAL - ALL PLANTS	3180	26664	12338	3843	650.9	99.6	12338	BPCTCA

TABLE VIII - 6

CASES 2a, b PROPOSED NPDES PERMITS

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Copperweld Steel	0	360	320	-	-	-	320	-
Republic Steel-Warren Plant								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnace		157	-	394	47.1	12.7		-
Hot Forming		1230	410	-	-	-		-
Central Treatment		1458	374	-	-	-		BPCTCA
Total	350	2845	784	394	47.1	12.7	784	BPCTCA
Republic Steel-Niles Plant	-	323	106	-	-	-	106	BPCTCA
Ohio Edison-Niles Plant	2a 1160 2b 0	-	-	-	-	-	-	-
U. S. Steel-McDonald Mills	100	10715	3572	-	-	-	3572	-
Youngstown Sheet and Tube								
Brier Hill Works								
Blast Furnace		58	-	144	17.3	4.7		-
Hot Forming		2370	790	-	-	-		-
Cold Rolling		272	109	-	-	-		BPCTCA
Total	250	2700	899	144	17.3	4.7	899	BPCTCA
U. S. Steel-Ohio Works								
Blast Furnaces		218	-	547	65.5	17.6		-
Hot Forming		1502	500	-	-	-		-
Total	350	1720	500	547	65.5	17.6	500	-
Republic Steel-Youngstown Plant								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnaces		232	-	559	66.9	18.0		-
Hot Forming } Cold Rolling }		4410	1470	-	-	-		BPCTCA
Total	240	4642	1470	559	66.9	18.0	1470	BPCTCA

TABLE VIII-6
(continued)
CASES 2a, b PROPOSED NPDES PERMITS
MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Youngstown Sheet and Tube-Campbell Works								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnaces		263	-	658	78.8	21.2		-
Hot Forming } Cold Rolling		20040	6680	-	-	-		BPCTCA
Total	690	20303	6680	658	78.8	21.2	6680	BPCTCA
Youngstown Sheet and Tube-Struthers Division								
Hot Forming		3720	1090	-	-	-		-
Finishing		212	-	-	5.3	-		BPCTCA
Total	40	3932	1090	-	5.3	-	1090	BPCTCA
TOTAL - ALL PLANTS	2a 3180 2b 2020	47540	15421	2302	280.9	74.2	15421	BPCTCA

TABLE VIII - 7

CASE 3 - PENNSYLVANIA WATER QUALITY STANDARDS

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Copperweld Steel	0	360	320	-	-	-	320	-
Republic Steel-Warren Plant								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnace		157	-	394	47.1	12.7		-
Hot Forming		1230	410	-	-	-		-
Central Treatment		1458	374	-	-	-		BPCTCA
Total	350	2845	784	394	47.1	12.7	784	BPCTCA
Republic Steel-Niles Plant	-	323	106	-	-	-	106	BPCTCA
Ohio Edison-Niles Plant	0	-	-	-	-	-	-	-
U. S. Steel-McDonald Mills	100	10715	3572	-	-	-	3572	-
Youngstown Sheet and Tube								
Brier Hill Works								
Blast Furnace		58	-	144	17.3	4.7		-
Hot Forming		2370	790	-	-	-		-
Cold Rolling		272	109	-	-	-		BPCTCA
Total	250	2700	899	144	17.3	4.7	899	
U. S. Steel-Ohio Works								
Blast Furnaces		218	-	547	19.6	5.3		-
Hot Forming		1502	500	-	-	-		-
Total	350	1720	500	547	19.6	5.3	500	-
Republic Steel-Youngstown Plant								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnaces		112	-	559	20.1	5.4		-
Hot Forming } Cold Rolling		4410	1470	-	-	-		BPCTCA
Total	240	4522	1470	559	20.1	5.4	1470	BPCTCA

TABLE VIII - 7
(continued)
CASE 3 - PENNSYLVANIA WATER QUALITY STANDARDS

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Youngstown Sheet and Tube-Campbell Works								
Coke Plant		No Discharge of Process Wastes (or BATEA)						
Blast Furnaces		131	-	658	23.6	6.4		-
Hot Forming } Cold Rolling		20040	6680	-	-	-		BPCTCA
Total	690	20171	6680	658	23.6	6.4	6680	BPCTCA
Youngstown Sheet and Tube-Struthers Division								
Hot Forming		3720	1090	-	-	-		-
Finishing		212	-	-	5.3	-		BPCTCA
Total	40	3932	1090	-	5.3	-	1090	BPCTCA
TOTAL - ALL PLANTS	2020	47288	15421	2302	133.0	34.5	15421	BPCTCA

TABLE VIII-8

CASE 4 - JOINT TREATMENT

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Copperweld Steel	0	360	320	-	-	-	320	-
Republic Steel-Warren Plant								
Coke Plant		0	0	0	0	0		-
Blast Furnace		0	-	0	0	0		-
Hot Forming		1230	410	-	-	-		-
Central Treatment		1458	374	-	-	-		BPCTCA
Total	350	2688	784	0	0	0	784	BPCTCA
Republic Steel-Niles Plant	-	323	106	-	-	-	106	BPCTCA
Ohio Edison-Niles Plant	0	-	-	-	-	-	-	-
U. S. Steel-McDonald Mills	100	10715	3572	-	-	-	3572	-
Youngstown Sheet and Tube								
Brier Hill Works								
Blast Furnace		0	-	0	0	0		-
Hot Forming		2370	790	-	-	-		-
Cold Rolling		272	109	-	-	-		BPCTCA
Total	250	2642	899	0	0	0	899	BPCTCA
U. S. Steel-Ohio Works								
Blast Furnaces		0	-	0	0	0		-
Hot Forming		1502	500	-	-	-		-
Total	350	1502	500	0	0	0	500	-
Republic Steel-Youngstown Plant								
Coke Plant		0	0	0	0	0		
Blast Furnaces		0	-	0	0	0		
Hot Forming }		4410	1470	-	-	-		BPCTCA
Cold Rolling }				-	-	-		
Total	240	4410	1470	0	0	0	1470	BPCTCA

TABLE VIII-8
(continued)
CASE 4 - JOINT TREATMENT

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Total Cyanide (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Youngstown Sheet and Tube-Campbell Works								
Coke Plant		0	0	0	0	0		
Blast Furnaces		0	-	0	0	0		
Hot Forming		20040	6680	-	-	-		
Cold Forming				-	-	-		BPCTCA
Total	690	20040	6680	0	0	0	6680	BPCTCA
Youngstown Sheet and Tube-Struthers Division								
Hot Forming		3720	1090	-	-	-		-
Finishing		212	-	-	5.3	-		BPCTCA
Total	40	3720	1090	-	5.3	-	1090	BPCTCA
TOTAL - ALL PLANTS	2020	46612	15421	0	5.3	0	15421	BPCTCA

TABLE VIII-9

CASE 5 - NITRIFICATION - BATEA

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Cyanide-A (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Copperweld	0	6	6				6	
Republic Steel-Warren Plant								
Coke Plant		29	12	12	0.3	0.6		-
Blast Furnace		79	-	31.5	0.8	1.6		-
Hot Forming		11	11	-	-	-		-
Central Treatment		195	55	-	-	-		BATEA
Total	250	314	78	43.5	1.1	2.2	78	BATEA
Republic Steel-Niles Plant	-	229	92	-	-	-	92	BATEA
Ohio Edison-Niles Plant	1160	-	-	-	-	-	-	-
U. S. Steel-McDonald Mills	0			No Discharge				
Youngstown Sheet and Tube								
Brier Hill Works								
Blast Furnace		29	-	11.5	0.3	0.6		-
Hot Forming		8	8	-	-	-		-
Cold Rolling		272	109	-	-	-		BATEA
Total	200	309	117	11.5	0.3	0.6	117	BATEA
U. S. Steel-Ohio Works								
Blast Furnaces		109	-	43.7	1.1	2.2		-
Hot Forming		16	16	-	-	-		-
Total	330	125	16	43.7	1.1	2.2	16	-
Republic Steel-Youngstown Plant								
Coke Plant		62	25	25	0.6	1.2		-
Blast Furnaces		112	-	44.6	1.1	2.2		-
Hot Forming }		21	14	-	-	-		BATEA
Cold Rolling }								
Total	140	195	39	69.6	1.7	3.4	39	BATEA

TABLE VIII-9
(continued)
CASE 5 - NITRIFICATION - BATEA

MAHONING RIVER INDUSTRIAL DISCHARGES

Plant	Thermal Discharge (10^6 BTU/hr)	Suspended Solids (lbs/day)	Oil and Grease (lbs/day)	Ammonia-N (lbs/day)	Cyanide-A (lbs/day)	Phenolics (lbs/day)	UCBOD (lbs/day)	Metals (lbs/day)
Youngstown Sheet and Tube-Campbell Works								
Coke Plant		84	34	34	0.8	1.6		-
Blast Furnaces		131	-	52.5	1.3	2.6		-
Hot Forming } Cold Rolling		491	202	-	-	-		BATEA
Total	350	706	236	86.5	2.1	4.2	236	BATEA
Youngstown Sheet and Tube-Struthers Division								
Hot Forming		No Discharge			Total Cyanide			
Finishing		212	-	-	5.3	-		BATEA
Total	0	212	0	-	5.3	-	0	BATEA
					Cyanide-A			
TOTAL - ALL PLANTS	2430	2096	584	254.8	6.3	12.6	584	BATEA

TABLE VIII-10

REPUBLIC STEEL CORPORATION

ESTIMATED CAPITAL COST SUMMARY

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

(Millions of Dollars)

Alternative	1	2a	2b	3	4	5
Warren Plant						
Coke Plant	8.0	-/8.4	-/8.4	-/8.4	8.0	8.4
Blast Furnace	7.3	7.3	7.3	7.3	7.3	7.8
Hot Forming	9.7	0.4	0.4	0.4	0.4	20.2
Central Treatment	5.3	5.3	5.3	5.3	5.3	8.5
Acid Regeneration	8.8	-	-	-	-	8.8
TOTAL	39.1	13.0/21.4	13.0/21.4	13.0/21.4	21.0	53.7
Niles Plant	1.8	1.8	1.8	1.8	1.8	1.8
Youngstown Plant						
Coke Plant	7.7	0.6/8.5	0.6/8.5	0.6/8.5	7.7	8.5
Blast Furnaces	7.5	7.5	7.5	8.1	7.5	8.1
Central Treatment	10.9	10.9	10.9	10.9	10.9	19.5
TOTAL	26.1	19.0/26.9	19.0/26.9	19.6/27.5	26.1	36.1
Republic Steel						
TOTAL	67.0	33.8/50.1	33.8/50.1	34.4/50.7	48.9	91.6

NOTES: (1) BPCTCA cost estimates based upon data supplied by Republic Steel Corporation.[10, 11, 12]

(2) Lesser coke plant cost reflects upgraded dirty water quench. Higher cost reflects BATEA for coke plants. Warren coke plant dirty water quench costs to be included in cost for new coke battery.[13]

(3) Case 4 coke plant and blast furnace costs do not include cost of tie in to municipal systems and municipal cost recovery.

(3) Case 2a, 2b, and 3 Warren Plant hot forming costs and Youngstown coke plant costs based upon information provided by Republic Steel Corporation.[13]

(4) Republic Steel BATEA costs based upon estimates by C. W. Rice Division of NUS Corporation.[14]

TABLE VIII-11

YOUNGSTOWN SHEET AND TUBE COMPANY
ESTIMATED CAPITAL COST SUMMARY
MAHONING RIVER TREATMENT ALTERNATIVES
(Millions of Dollars)

Alternative	1	2a	2b	3	4	5
Brier Hill Works						
Blast Furnace	1.3	1.3	1.3	1.3	1.3	1.6
Hot Forming	4.2	4.2	4.2	4.2	4.2	6.4
EWT	1.0	1.0	1.0	1.0	1.0	1.1
Sanitary	0.8	0.8	0.8	0.8	0.8	0.8
TOTAL	7.3	7.3	7.3	7.3	7.3	9.9
Campbell Works						
Coke Plant	8.4	1.2/9.0	1.2/9.0	1.2/9.0	8.4	9.0
Blast Furnaces	1.2	1.2	1.2	2.1	1.2	2.1
Hot Forming - S	2.8	2.8	2.8	2.8	2.8	3.7
Hot Forming - C	20.7	20.7	20.7	20.7	20.7	25.5
Cold Rolling	3.5	3.5	3.5	3.5	3.5	3.5
Acid Regeneration	3.2	-	-	-	-	3.4
Sanitary	1.1	1.1	1.1	1.1	1.1	1.1
TOTAL	40.9	30.5/38.3	30.5/38.3	31.4/39.2	37.7	48.3
Struthers Division						
Hot Forming	3.3	3.3	3.3	3.3	3.3	6.2
Finishing	1.2	1.2	1.2	1.2	1.2	1.2
TOTAL	4.5	4.5	4.5	4.5	4.5	7.4
Youngstown Sheet and Tube						
TOTAL	52.7	42.3/50.1	42.3/50.1	43.2/51.0	49.5	65.6

NOTES: (1) BPCTCA AND BATEA cost estimates based upon data supplied by Youngstown Sheet and Tube Company.[15, 16, 17]

(2) Lesser coke plant cost reflects upgraded dirty water quench. Higher cost reflects BATEA for coke plant.

(3) Case 4 coke plant and blast furnace costs do not include cost of tie in to municipal systems and municipal cost recovery.

(4) Breakdown of BPCTCA and BATEA costs for hot forming operations based upon information provided by Youngstown Sheet and Tube Company.[18]

TABLE VIII-12

UNITED STATES STEEL, COPPERWELD STEEL, AND OHIO EDISON

ESTIMATED CAPITAL COST SUMMARY

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

(Millions of Dollars)

Alternative	1	2a	2b	3	4	5
United States Steel						
Ohio Works						
Blast Furnaces	9.3	9.3	9.3	11.4	9.3	11.4
Hot Forming	5.8	5.8	5.8	5.8	5.8	6.3
TOTAL	15.1	15.1	15.1	15.1	15.1	17.7
McDonald Mills	11.8	0.6	0.6	0.6	0.6	13.4
United States Steel						
TOTAL	26.9	15.7	15.7	17.8	15.7	31.1
Copperweld Steel						
TOTAL	0.8	0.8	0.8	0.8	0.8	0.8
Ohio Edison Company						
TOTAL	0	0	8.0	8.0	8.0	0

NOTES: (1) U. S. Steel BPCTCA and BATEA cost estimates based upon information supplied by U. S. Steel.[19,20] Blast furnace cost supplied by U. S. Steel reduced by 2.0 million dollars to delete cost of dismantling No. 1 blast furnace.[21]

(2) U. S. Steel Case 4 blast furnace cost does not include costs of tie in to municipal system and municipal cost recovery.

(3) U. S. Steel Case 2b, 3, 4 cost estimates based upon information provided by C. W. Rice Division of NUS Corporation.[14]

(4) Copperweld Steel Corporation based upon communication with Copperweld Steel Corporation.[22]

(5) Ohio Edison Company cost estimate based upon information provided by Ohio Edison Company.[23]

TABLE VIII-13

MUNICIPAL AND INDUSTRIAL CAPITAL COST SUMMARY

MAHONING RIVER TREATMENT ALTERNATIVES

(Millions of Dollars)

Alternative	1	2a	2b	3	4	5
Municipal 201 Areas						
Warren	22.7	27.8	27.8	27.8	27.8	27.8
Niles-McDonald-Girard	21.3	26.2	26.2	26.2	26.2	26.2
Youngstown	43.6	56.9	56.9	56.9	56.9	56.9
Campbell-Struthers	7.3	8.6	8.6	8.6	8.6	8.6
Lowellville	0.8	0.9	0.9	0.9	0.9	0.9
Municipal Total	95.7	120.4	120.4	120.4	120.4	120.4
Industrial						
Copperweld Steel	0.8	0.8	0.8	0.8	0.8	0.8
Republic Steel	67.0	33.8/50.1	33.8/50.1	34.4/50.7	48.9	91.6
U. S. Steel	26.9	15.7	15.7	17.8	15.7	31.1
Ohio Edison	0	0	8.0	8.0	8.0	0
Youngstown Sheet and Tube	52.7	42.3/50.1	42.3/50.1	43.2/51.0	49.5	65.6
Industrial Total	147.4				122.9	189.1
a) Dirty Water Coke Quench		92.6	100.6	104.2		
b) Treatment for Coke Wastes		116.7	124.7	128.3		

NOTE: (1) Alternative 4 Joint Treatment costs do not include increased municipal capital costs for introduction of industrial wastes, or increased industrial costs for tie in to municipal systems and municipal cost recovery.

D. Water Quality Analyses

1. Water Quality Modeling of Waste Treatment Alternatives

a. Flow Regime

The streamflow used for water quality design purposes directly affects the selection of a basinwide waste treatment alternative. As noted in Section IV, the minimum regulated streamflows provided by the U.S. Army Corps of Engineers were selected for design purposes, but, because of the complex hydrology in the basin and the important flow/temperature/time-of-travel relationships, the water quality response for each alternative was studied over a wide range of expected flows for the months of February and July. The water quality design flows presented in Section IV and the flows encountered during the verification studies reviewed in Section VII are within the range of flows studied herein. In addition, Cases 2b and 3 were studied at flows exceeded 90 percent of the time during each month to determine other periods of the year that may be critical from a water quality viewpoint.

Figure VIII-1 illustrates the actual February and July flow duration as measured at the USGS gage in Youngstown for the 1945-1975 period of record. The February duration was selected as being typical of those winter months with minimum regulated flows of 225 cfs. The 90 percent duration flow for each month for the same period of record is illustrated in Figure IV-12. Actual flow duration in the future (and achievement of the minimum regulated streamflows) may be slightly higher because of the installation of the Kirwan Reservoir in 1968. Flow profiles for the length of the study area and stream velocities for each segment were developed from the flows at Youngstown by methods described earlier. To simplify the calculations, minor tributaries were assumed to contribute no flow, Mill Creek was assumed to contribute no flow during the summer and 15 cfs during the winter, and Mosquito Creek was assumed to supplement the flow at Leavittsburg and the upstream sewage treatment plants to provide the flow at Youngstown. Table VIII-14 presents a listing of the specific flows studied and the respective flow durations.[25] All references to flow in evaluating waste treatment alternatives are to the USGS gage in Youngstown.

FIGURE VIII-1

MAHONING RIVER FLOW DURATION AT YOUNGSTOWN

FEBRUARY AND JULY

PERIOD OF RECORD 1945-1975

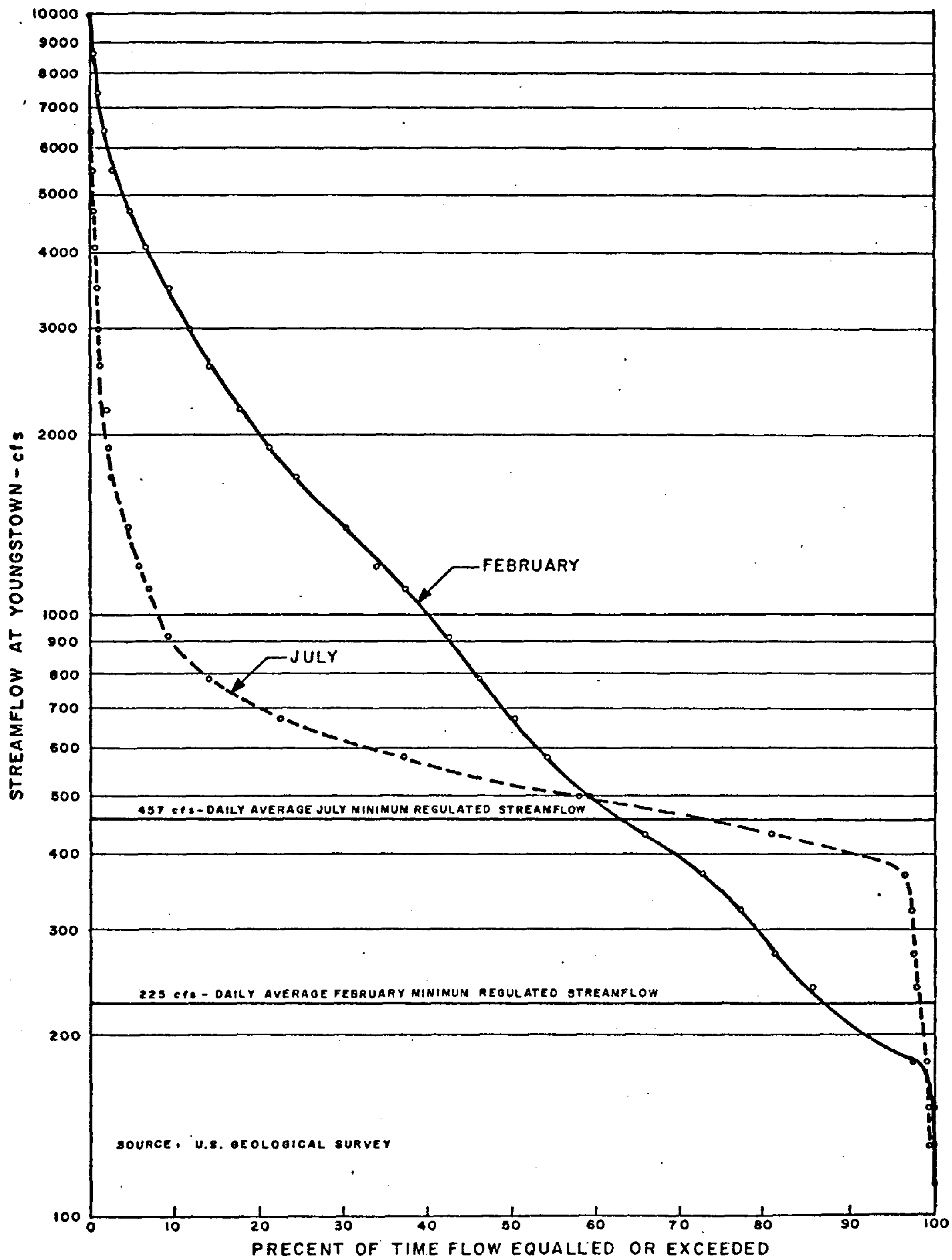


TABLE VIII-14

MAHONING RIVER FLOW DURATION AT YOUNGSTOWN

(1944-1975 Period of Record)

Flow (cfs)	Percent of Time Equaled or Exceeded		Month	Flow Equaled or Exceeded 90% of Time (cfs)
	February	July		
175	97		January	200
225	86		February	200
300	79	97	March	380
400	68	94	April	315
480	60	61	May	315
675	50	22	June	330
900	43	10	July	420
1200	34	5.8	August	380
1500	26	4.0	September	285
			October	200
			November	200
			December	200

SOURCE: U. S. Geological Survey

TABLE VIII-15

MAHONING VALLEY INDUSTRIAL THERMAL DISCHARGERS

(10^6BTU/HR)

	Existing Full Production Thermal Discharge	Case 1 BPCTCA Secondary	Case 2a Proposed NPDES Permits - No Thermal Control	Case 2b Proposed NPDES Permits - With Thermal Control	Case 3 Pennsylvania WQS	Case 4 Joint Treatment	Case 5 BATEA Nitrification
Copperweld Steel	70	0	0	0	0	0	0
Republic Steel Warren Plant	400	350	350	350	350	350	250
Ohio Edison	1160	1160	1160	0	0	0	1160
U. S. Steel McDonald Mills	100	100	100	100	100	100	0
Youngstown Sheet and Tube Brier Hill Works	270	250	250	250	250	250	200
U. S. Steel Ohio Works	420	350	350	350	350	350	330
Republic Steel Youngstown Plant	390	240	240	240	240	240	140
Youngstown Sheet and Tube Campbell Works	850	690	690	690	690	690	350
Youngstown Sheet and Tube Struthers Division	40	40	40	40	40	40	0
TOTAL	3700	3180	3180	2020	2020	2020	2430

b. Temperature and Thermal Loadings

The thermal discharge conditions resulting from the six treatment alternatives selected for evaluation are presented in Table VIII-15. The existing thermal discharges for Copperweld Steel, Ohio Edison, and U. S. Steel are those measured under high production during the February 1975 USEPA survey. Existing thermal discharges for Republic Steel and Youngstown Sheet and Tube Company were obtained from the respective dischargers. The existing thermal discharges are assumed to represent total plant 30-day average loadings that would be expected during periods of high steel production and not daily maximum discharges which could be considerably higher. As shown by the difference in loadings experienced during the February and July USEPA surveys (Appendix B, Tables 6 and 9), the level of steel production in the Valley can have a significant impact upon thermal discharges to the stream.

Table VIII-16 summarizes equilibrium temperature, heat transfer coefficient, and municipal sewage temperature data employed in the stream temperature analyses for each month. Monthly average equilibrium temperature and heat transfer coefficient data were computed from meteorological data obtained at the Youngstown Weather Station[26] by methods described by Parker[27] and modified by USEPA.[28] Extreme conditions were estimated from average and extreme conditions at Cleveland, Ohio. Since the thermal discharge data are taken to approximate monthly average loadings, the stream temperature profiles developed from an analysis incorporating average meteorological conditions more closely represents expected monthly average conditions at a given streamflow rather than daily maximum values. Pennsylvania WQS for temperature are maximum values not to be exceeded. The results of the thermal analysis are presented in Section VIII-D-2.

c. Waste Loadings

To fully evaluate a given waste treatment alternative, adjustments to the standard constituents limited in NPDES permits are necessary. For example, in Ohio, municipal discharges are generally limited in terms of five-day biochemical oxygen demand (BOD_5) whereas the ultimate carbonaceous oxygen demand (UCBOD) is needed for input to the model. Municipal UCBOD levels for each alternative were determined by multiplying the

TABLE VIII-16

EQUILIBRIUM TEMPERATURES, HEAT TRANSFER COEFFICIENTS, AND MUNICIPAL SEWAGE TREATMENT PLANT TEMPERATURES

MAHONING RIVER WASTE TREATMENT ALTERNATIVES

	Average Condition		Extreme Condition		
Month	Equilibrium Temperature (°F)	Heat Transfer Coefficient (BTU/FT^2-day-°F)	Equilibrium Temperature (°F)	Heat Transfer Coefficient (BTU/FT^2-day-°F)	Municipal STP Temperature (°F)
January	31	85	40	70	50
February	33	80	41	60	50
March	40	95	46	80	55
April	49	105	57	90	60
May	60	105	68	95	65
June	69	115	76	105	70
July	74	115	80	105	75
August	73	110	79	95	75
September	67	110	73	95	70
October	58	100	65	85	65
November	43	100	50	80	60
December	33	85	42	75	50

Notes:

(1) Mahoning River at Leavittsburg and tributaries assumed to be at equilibrium temperature or, based upon data at Leavittsburg, at 33°F when equilibrium temperature is below 32°F.

(2) Extreme condition obtained from relation of average and extreme conditions for Cleveland, Ohio.

(3) Municipal sewage temperatures obtained from City of Youngstown data and USEPA surveys.

BOD_5 effluent limitations by a factor of 1.5 which generally represents the inverse of the ratio of BOD_5/BOD_{20} during normal BOD amortization where BOD_{20} is close to the ultimate demand.[24, 30]

Estimates of UCBOD discharges from the steel plants were based upon data obtained at plants outside the Mahoning basin with operating treatment systems similar to those contemplated for the Mahoning Valley.[31, 32, 33, 34] As noted earlier, the existing discharge of wastewaters from hot forming and cold rolling operations contributes a carbonaceous oxygen demand to the stream. To estimate the UCBOD from treated wastes, limited oil and grease and BOD data were evaluated from hot forming wastes treated by large lagoons with oil skimming,[31] large diameter clarifiers,[32] and large diameter clarifiers followed by pressure filters.[33] The highest UCBOD/oil ratio was 0.8 for the lagoon system and the lowest was indeterminate since no measurable oil (, 1 mg/l) was being discharged from the pressure filter system. This system also discharged less BOD than contained in the river intake water. The ratio for the large diameter clarifier system was 0.43 on one day of a survey and -0.43 on the second day. Less UCBOD was discharged from the facility than was taken in from the river on the second day. Based upon these limited data, a conservative value of one pound of UCBOD per pound of oil discharged was selected to account for the carbonaceous demand associated with oily waste discharges. It is important to note that application of this factor is not the basis for oil and grease limitations. Any oxygen demand associated with oily waste discharges is probably associated with breakdown products of oil rather than oil itself, the exception being emulsified oils which would be more amenable to biological oxidation.

The UCBOD discharge from a blast furnace gas wash water recirculating system was found to be negligible.[34] However, the nitrogenous demand associated with the ammonia discharge was substantial. Nearly all of the TKN discharged was in the form of ammonia-N. Based upon these results, no UCBOD was assigned to blast furnace discharges. The above factor for oil was used to estimated the UCBOD discharges for coke plants. Since either BATEA or dirty water quench (no discharge of process wastes) are envisioned for treatment, the effect of coke plant discharges on the stream should be negligible.

As noted in the verification studies and previous work,[31] steel and power plant and cooling and process discharges tend to contain less dissolved oxygen than intake waters when the intakes are relatively close to saturation and the discharges are elevated in temperature. Conversely, when intake dissolved oxygen levels are severely depleted, the effect of the discharges is to add significant amounts of dissolved oxygen by turbulence and mixing. There appears to be little change when the intake dissolved oxygen levels were in the middle range of five to eight mg/l. For the purpose of analyzing waste treatment options, no direct effect of industrial discharges on dissolved oxygen was assumed since middle range dissolved oxygen levels are expected for most of the industrialized stretch of the river after treatment under both summer and winter conditions.

BPCTCA cyanide discharge criteria for coke plants and blast furnaces are specified as total cyanide while BATEA criteria are specified as cyanide–A (cyanide amendable to chlorination). As noted in Section VII, stream reaction rate studies and the verification analyses were based upon total cyanide only. Cyanide-A was not studied since Pennsylvania WQS are based upon total cyanide, due to laboratory and resource limitations, and, because of the poor reproducibility of cyanide-A determinations. Although total cyanide was not modeled for Case 5, the levels of discharge should be quite low and would be expected to result in compliance with the Pennsylvania total cyanide standard.

The oxygen demand associated with the oxidation of organic nitrogen is not explicitly included in the RIBAM model. However, it was implicitly included in the February verification analysis by the methods used to determine stream and discharge UCBOD values. These were generally determined with the following formula:

$$\text{UCBOD} = \text{BOD}_{20} - 4.57\ \text{NH}_3\text{-N}$$

Any organic nitrogen oxidized during the BOD test would thus be included as UCBOD and not associated with the nitrogenous demand from ammonia–N. Since the rates of decay of UCBOD and ammonia-N were found to be very close (0.3 day^{-1} vs 0.276 day^{-1}), any error introduced in the verification studies by including the demand associated with organic nitrogen as UCBOD would be small. The respective rates employed in the evaluation of waste treatment alternatives (Cases 2a, 2b, 3, 4, 5) are not close (0.12 day^{-1} vs 0.276 day^{-1}). However, as indicated earlier, coke plant discharges should be negligible, blast furnaces discharges should not contain appreciable amounts of organic nitrogen, and nitrified municipal treatment plant effluents should be relatively low in organic nitrogen.[35, 36] Hence, the error introduced by not including organic nitrogen in the dissolved oxygen balance is expected to be small although the effect will be to overestimate stream dissolved oxygen levels and underestimate ammonia-N levels. Municipal sewage treatment disharges were assumed to contain 0.5 mg/l of nitrite–N and, based upon survey results, industrial discharges were assumed to contain no nitrite-N. The dissolved oxygen balance in the stream is not sensitive to the estimated total nitrite-N discharge of 300-400 lbs/day.

Use of monthly average discharge loadings for waste load allocation purposes rather than daily maximum loadings is considered to be reasonable for the lower Mahoning River system. Typically, waste load allocations are based upon daily maximum effluent loadings necessary to meet water quality standards just downstream of a discharge. In these cases, the maximum daily load is simply determined by computing the maximum permissible stream loading at the water quality design flow at the point in question, assuming there are no upstream loadings. For the Mahoning River, the primary objective is to achieve a stream standard downstream of a large number of dischargers. With properly designed and operated treatment systems, it is highly unlikely that each discharger will achieve the respective daily maximum discharge simultaneously. Total system performance is expected to be closer to the total daily average loading of all dischargers. Hence, the use of daily maximum discharges for waste load allocation purposes for this system tends to be overly restrictive in terms of treatment requirements. However, implicit in the use of monthly average loadings is some risk of violating Pennsylvania water quality standards when dischargers close to the State line discharge significantly above allowable monthly average loadings.

Safety factors or reserve allocations for industrial effluent discharges were not made. Significant growth in the Mahoning Valley steel industry is unlikely owing to the economic conditions in the area. Curtailment of production at some plants is possible. Any new production facilities or plant expansions would have to be treated to new source performance standards which are at least equivalent to BATEA, thus having little or no impact on stream quality. Municipal growth is considered in terms of the dissolved oxygen response of various alternatives at the State line.

With the frequent occurrence of the water quality design flow of the river, the use of monthly average vs daily maximum loadings for allocation purposes, and no explicit safety factors or reserve allocations for industrial growth, the allocations made are not considered to be overly conservative in terms of stream quality.

d. Stream Reaction Rates

Table VIII-17 presents a summary of stream reaction rates and temperature correction coefficients considered in the evaluation of waste treatment alternatives. With the exception of the UCBOD rate, these rates and coefficients were also employed in the verification analysis. A lower UCBOD rate (0.12 day^{-1} vs 0.30 day^{-1}) was used for evaluating treatment alternatives since these alternatives, notably 2a, 2b, 3, 4 and 5, encompass a high degree of municipal treatment. The residual carbonaceous material discharged to the stream should be slower reacting than that contained in the primary sewage effluents currently being discharged.[37, 38]

Aside from the change in the UCBOD reaction rate, it is difficult to estimate changes in the stream reaction rates for other constituents after treatment controls are installed. With higher dissolved oxygen levels, much lower concentrations of toxic materials, and with highly nitrified municipal effluents providing seed organisms, the instream nitrification rate may be expected to increase somewhat. However, the reaction rate studies reviewed earlier indicate rates close to the value of 0.276 day^{-1} used in the verification studies were found in relatively clean stretches of the river. Hence, that value was used in evaluating waste treatment alternatives.

Some of the cyanide discharged from blast furnace systems after recycle of gas wash water may be in the form of ferro- or ferri-cyanides.[39] Although less toxic than simple cyanides, ferro-ferri-cyanides can be photochemically decomposed by ultraviolet light to hydrocyanic acid and simple soluble cyanides.[40, 41, 42] One source indicates as much as 75 percent of ferro-cyanide was oxidized in five days upon exposure to sunlight and complete removal occurring in 10 to 12 days.[40] No data for temperature, pH, or other environmental conditions were presented. The

TABLE VIII-17

STREAM REACTION RATES AND TEMPERATURE CORRECTION COEFFICIENT
MAHONING RIVER WASTE TREATMENT ALTERNATIVES

	Reaction Rate K at 20°C (base e)	Temperature Correction Coefficient (θ)
UCBOD	0.12	1.047
NO_2-N	2.00	1.06
NH_3-N	0.276	1.10
Total Cyanide	1.35	1.05
Phenolics (< 20 μg/l)	1.58	1.063
Phenolics (> 20 μg/l)	3.71	1.063
Reaeration (K_2)	*	1.024

$$K_T = K_{20}\ \theta^{(T-20)}$$

T in °C

* O'Connor-Dobbins Formulation

$$K_2 = \frac{12.9\ u^{0.5}}{H^{1.5}}$$

Where u = velocity, ft/sec
H = depth, ft

same reference, indicates the conversion occurs "rapidly" and complex cyanides should be considered the same as simple cyanides for discharge purposes.[40] Research currently underway[41, 42] confirms the photodecomposition of ferri- and ferrocyanides and documents that chronic low level exposure to cyanide interferes with fish spawning. There are currently only limited data available concerning the relative amounts of ferri- ferrocyanides in recycled blast furnace discharges, and these data are highly variable.[39] Hence, there is considerable uncertainty concerning the type of cyanide that will be discharged and the rate of instream decomposition. Since the Mahoning River is a highly turbid stream, instream decomposition of ferrocyanides may be slower than measured by USEPA for existing total cyanide discharges. Because of the lack of sufficient information to estimate the instream cyanide reaction rate and temperature correction coefficient which might occur after treatment controls are installed, the rate and correction coefficient determined from USEPA field studies were employed for evaluating waste treatment alternatives. Based upon limited information presented above, the rate may be somewhat high, possibly producing overly optimistic results. Since reaction rates for total cyanide and phenolics were determined when stream dissolved oxygen levels were fairly high for the Mahoning River (four to nine mg/l), increases in these rates due to increased dissolved oxygen levels after treatment controls are installed are not anticipated.

Owing to the relatively minor effects of sediment oxygen demand (SOD) on the dissolved oxygen balance in the stream, SOD was not included in the evaluation of waste treatment alternatives. This has the effect of slightly overestimating dissolved oxygen concentrations (generally from , 0.1 to 0.3 mg/l) throughout the study area. However, the slight difference obtained in the dissolved oxygen response was not worth the effort to obtain temperature adjusted sediment oxygen demand rates for each of the 38 stream segments modeled at the numerous stream temperature conditions evaluated. In any event, SOD will probably remain the same until point source controls are installed, exhibit some increase for a period of time as in-place toxicants are gradually degraded, then revert to a level reflecting residual waste loadings, normal background, and non-point source effects. While this process could take several years to occur after the existing gross discharges are abated, the effect on ambient dissolved oxygen concentrations should not be severe.

e. Tributary and Upstream Initial Conditions

In addition to temperature which was reviewed earlier, initial stream concentrations of dissolved oxygen, CBOD, ammonia-N, nitrite-N, total cyanide, and phenolics for the most upstream segment of the study area (Mahoning River at Leavittsburg) and for the two tributaries included (Mosquito Creek and Meander Creek) must be specified. Based upon USEPA survey results and historical data, the data presented in Table VIII-18 were selected as initial conditions at Leavittsburg and for Mosquito and Mill Creeks.

f. Non-Point Source Considerations

As the Mahoning Valley is a highly urbanized and industrialized area, non-point source pollution is expected to consist of combined sewer overflows containing raw sewage (high in suspended matter, CBOD, ammonia-N, fecal coliform); urban runoff (high in suspended matter, containing some oil, heavy metals, and organic matter); and industrial runoff (high in suspended matter, containing some oil and organic matter, and possibly ammonia-N, cyanide, phenolics and sulfides from coke plant and blast furnace areas). Runoff high in nutrients associated with agricultural runoff is not expected for the lower Mahoning River.

A review of available data for the Mahoning River reveals that no intensive surveys were conducted specifically to gather non-point source loadings and evaluate effects on stream quality. The only continuous historical record of water quality below the Youngstown area is maintained by the USGS at Lowellville, and then only for flow, temperature, dissolved oxygen, pH, and specific conductance. Of these, only dissolved oxygen and possibly specific conductance would be significantly affected by non-point source pollution. Since adverse non-point source effects on water quality constituents for which there are criteria (i.e., dissolved oxygen, ammonia-N, total cyanide, phenolics, fecal coliform), are most likely to occur at the outset of major precipitation events, an analysis of changes in water quality at Lowellville for 39 major precipitation events from 1966 to 1974 was

TABLE VIII-18

INITIAL UPSTREAM CONDITIONS AND TRIBUTARY CONCENTRATIONS
MAHONING RIVER WASTE TREATMENT ALTERNATIVES

	Concentration, mg/l					
	Dissolved Oxygen	CBOD	Ammonia-N	Nitrite-N	Total Cyanide	Phenolics
January	13.0	3.5	0.2	0.01	0.010	0.010
February	13.0	3.5	0.2	0.01	0.010	0.010
March	11.7	3.5	0.2	0.01	0.010	0.010
April	10.3	3.5	0.2	0.01	0.005	0.005
May	9.0	3.5	0.2	0.01	0.005	0.005
June	8.2	3.5	0.2	0.01	0.000	0.000
July	7.8	3.5	0.2	0.01	0.000	0.000
August	7.8	3.5	0.2	0.01	0.000	0.000
September	8.4	3.5	0.2	0.01	0.000	0.000
October	9.3	3.5	0.2	0.01	0.005	0.005
November	11.2	3.5	0.2	0.01	0.010	0.010
December	13.0	3.5	0.2	0.01	0.010	0.010

made. Unfortunately, only changes in dissolved oxygen could be evaluated as there are no continuous data for ammonia-N, total cyanide, phenolics, or fecal coliform.

A major precipitation event was defined in terms of streamflow as a day-to-day increase in the flow at Lowellville of at least 25 percent. It is highly doubtful that normal operation of the reservoir system would result in day-to-day increases in flow of 25 percent at Lowellville. Hence, changes of such magnitude would most likely be the result of precipitation or a quick thaw which would have roughly the same effect. Since the USGS records both daily minimum and daily maximum dissolved oxygen concentrations, the changes in both were considered. A summary of the results is presented in Table VIII-19. These data show that daily minimum concentrations decreased after about 67 percent of the events with an average decrease of 0.70 mg/l, while daily maximum concentrations decreased after about 28 percent of the events with an average decrease of 0.35 mg/l. Daily minimum and maximum concentrations actually increased during 25 percent and 69 percent of the events, respectively. The average day-to-day change for all events was -0.33 mg/l for daily minimum concentrations and +0.42 mg/l for daily maximum concentrations. Assuming a similar response after point source controls are installed, violations of dissolved oxygen standards at the State line would occur only in extreme cases as a result of storm-inducted, non-point source pollution. Effects in the Ohio reach of the river would most likely be more severe. Hopefully, conditions in the future would improve with construction of planned major interceptor sewers in the heavily populated urban areas, and with supplementary storm-water management and land-use practices to be considered as part of the 208 program.

Based upon the data presented in Table VIII-19, a reserve allocation or safety factor for oxygen demanding substances from combined sewer discharges, urban runoff, and industrial runoff was not made in this analysis. Unfortunately, data are not available to determine the effects of other critical constituents at the State line. Since adverse effects of these constituents will generally be at least partially mitigated by higher flows, reserve allocations for these constituents in terms of more stringent point source controls were also not made.

TABLE VIII-19

CHANGES IN DISSOLVED OXYGEN CONCENTRATIONS WITH MAJOR PRECIPITATION EVENTS

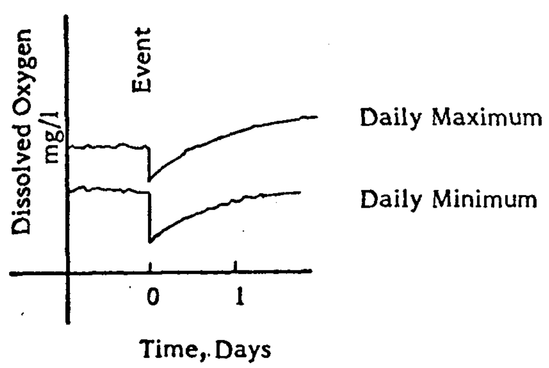
MAHONING RIVER AT LOWELLVILLE, OHIO

1966-1974

	Dissolved Oxygen			
	Daily Minimum Concentration		Daily Maximum Concentration	
Events with Decreasing Concentrations	26/39	67%	11/39	28%
Events with No Change in Concentration	3/39	8%	1/39	3%
Events with Increasing Concentration	10/39	25%	27/39	69%

	Number of Events	Change in Daily Minimum Concentration	Number of Events	Change in Daily Maximum Concentration
Maximum Increase	1	+1.60 mg/l	1	+2.40 mg/l
Average Increase	10	+0.54 mg/l	27	+0.76 mg/l
Average Change	39	-0.33 mg/l	39	+0.42 mg/l
Average Decrease	26	-0.70 mg/l	11	-0.35 mg/l
Maximum Decrease	1	-3.00 mg/l	1	-1.10 mg/l

TYPICAL DISSOLVED OXYGEN RESPONSE



Source: U. S. Geological Survey, Water Resources Data for Ohio, Part 2. Water Quality Records.

2. Water Quality Response

The discussion of the water quality response to the treatment alternatives studied herein includes projected water quality at the Ohio-Pennsylvania State line, a sensitivity analysis of the response to changes in model inputs, and resultant water quality in the Ohio portion of the stream.

a. Response at the Ohio-Pennsylvania State Line

Figures VIII-2 to VIII-4 present expected water quality at the State line for each alternative at the February stream flows presented in Table VIII-14; Figures VIII-5 to VIII-7 present the respective results for the month of July. Figure VIII-8 presents the stream temperature response at the State line to Case 3 thermal discharges at monthly flows equaled or exceeded 90 percent of the time and with monthly average and extreme meteorological conditions (Table VIII-16). Figures VIII-9 to VIII-12 present the respective Case 2b and Case 3 dissolved oxygen, ammonia-N, total cyanide, and phenolics results at the monthly average temperature condition illustrated in Figure VIII-8.

1) February Conditions

As noted in Table VI-1, the current Pennsylvania temperature standard for February is 50°F maximum; an upward revision to 56°F is being considered. Data presented in Figure VIII-2 demonstrate that the 50°F standard would be exceeded at streamflows up to 660 cfs during February with the average thermal discharges associated with Cases 1 and 2a. Flows less than 660 cfs occur about 51 percent of the time during February. The proposed standard of 56°F would be exceeded at flows up to 400 cfs, or those occurring about 32 percent of the time in February. Reduced thermal discharges associated with Cases 2b, 3, and 4 would permit compliance with the 50°F standard at streamflows greater than 400 cfs (exceeded 68 percent of the time) and with the 56°F proposed standard at flows greater than 200 cfs (exceeded 92 percent of the time). The temperature response of Case 5 is slightly different but indicates compliance with the 50°F standard at flows greater than 420 cfs (54 percent of the time) and with the 56°F

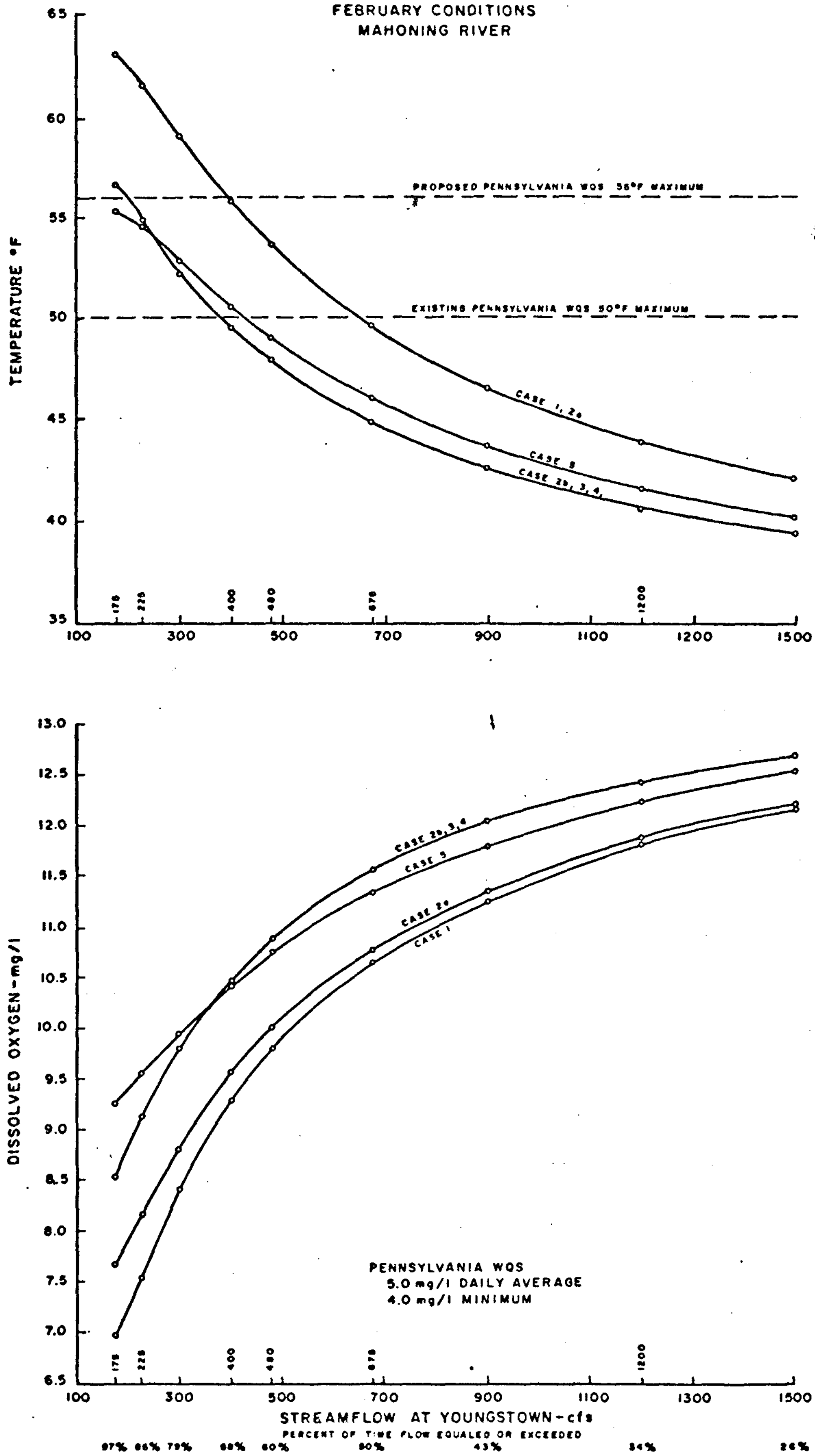
FIGURE VIII - 2

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

TEMPERATURE AND DISSOLVED OXYGEN vs FLOW

FEBRUARY CONDITIONS

MAHONING RIVER



standard at the lowest flow studied (175 cfs), which has been exceeded 97 percent of the time.

As indicated earlier, the predicted temperatures are based upon monthly average meteorological conditions and what are considered to be monthly average industrial thermal discharges at relatively high production levels. Extreme meteorological conditions would result in significantly higher State line temperatures as would maximum, or peak, industrial thermal discharges. Conversely, low steel production would result in significantly lower State line temperatures. While the probability of each steel plant operating at either high or low production at the same time is relatively high based upon the production history in the Valley, the probability of each discharge at each plant simultaneously achieving a maximum thermal discharge is remote. The temperature response of Cases 2b, 3, and 4 and that of Case 5 indicates that compliance with proposed revisions to Pennsylvania temperature standards could be achieved by complete cooling at Ohio Edison (Cases 2b, 3, 4) or by no cooling at Ohio Edison and significant cooling at each steel plant (Case 5).

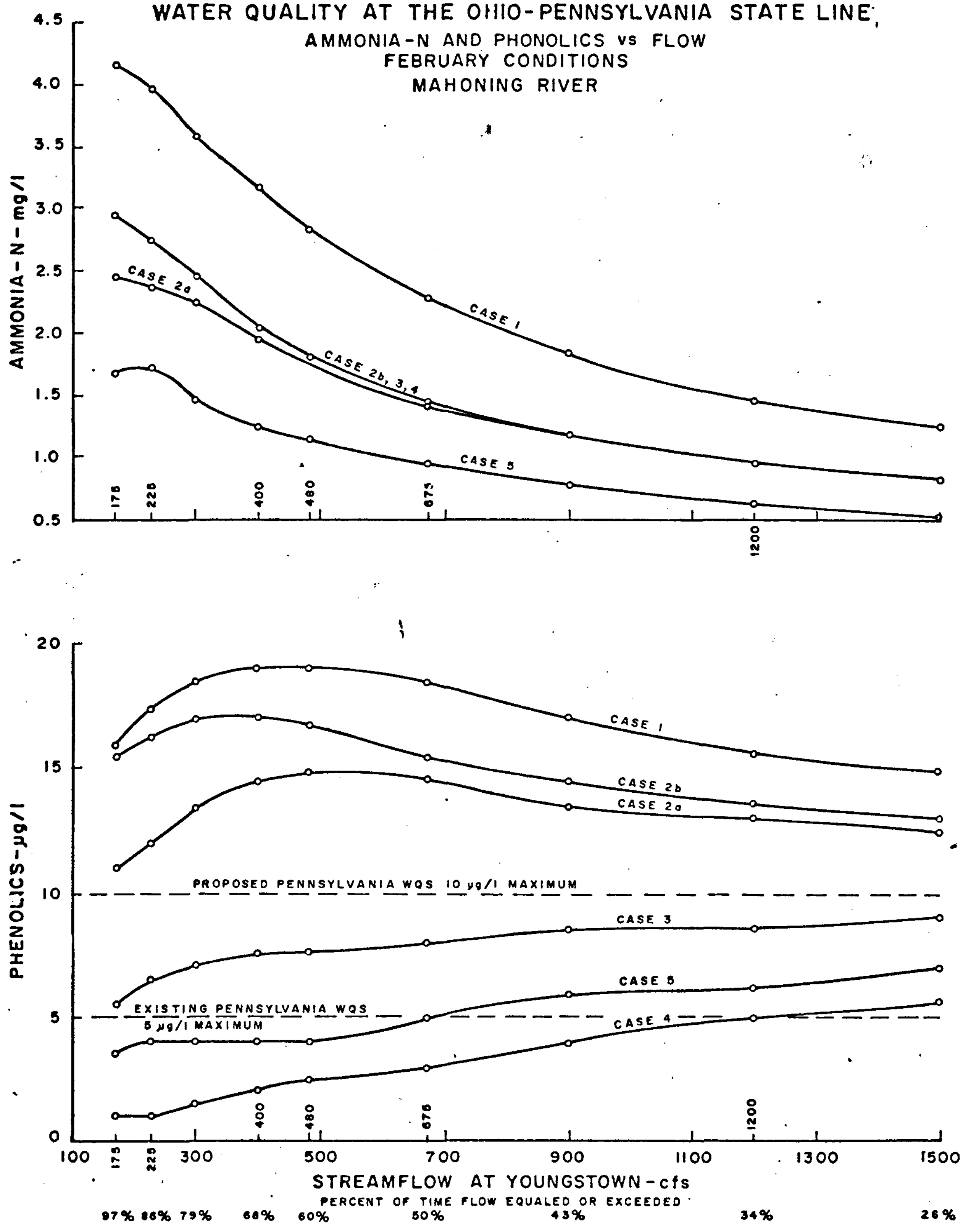
With the relatively low stream temperatures expected during February, compliance with the Pennsylvania 5.0 mg/l dissolved oxygen standard is anticipated with any treatment alternative as illustrated in Figure VIII-2.

Depending upon the pH of the stream, compliance with the recommended aquatic life criterion (0.02 mg/l of unionized ammonia-N) would not be achieved with Case 1 discharges at low flow-high temperature conditions. The permissible ammonia-N level would be about 1.8 mg/l at pH 7.5 and the expected temperature of 62°F and flow of 225 cfs. At pH 7.0, the permissible level would be about 5.0 mg/l, but at pH 8.0, only about 0.6 mg/l. Predicted values at the State line are in the 4.0 to 4.5 mg/l range at low flows for Case 1 discharges. Expected ammonia-N values at the State line for Cases 2b, 3, and 4 are slightly above the permissible level at pH 7.5, temperature 56°F and flow 225 cfs, (2.7 mg/l vs 2.3 mg/l); while well below the permissible level at pH 7.0 (2.7 mg/l vs 7.0 mg/l); and significantly above the permissible level at pH 8.0 (2.3 mg/l vs 0.7 mg/l). Case 2a ammonia-N levels are about 0.5 mg/l lower than levels for Cases 2b, 3, and 4 at low flows owing to faster reaction at higher stream temperatures. Case 5

FIGURE VIII - 3

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

AMMONIA-N AND PHONOLICS vs FLOW
FEBRUARY CONDITIONS
MAHONING RIVER



values are the lowest of all. Based upon Figure VIII-3, it is apparent that only marginal compliance with the recommended aquatic life criterion for ammonia-N would be achieved under a wide range of flow conditions for Cases 2a, 2b, 3, and 4. Expected concentrations for Case 1 would be out of compliance for most flows studied whenever pH values approached or exceeded 7.5 standard units.

With a background phenolics concentration of 10 ug/l for the Mahoning River at Leavittsburg and major tributaries, Cases 3, 4, and 5 are projected to achieve compliance with the proposed Pennsylvania standard of 10 ug/l at all flows studied (Figure VIII-3); Cases 1, 2a, and 2b are projected to result in non-compliance at all flows with levels at most flows for within 5 ug/l of the 10 ug/l proposed standard. Only Case 4 is projected to achieve the existing 5 ug/l standard over a wide range of flows under winter conditions. The response for each case is nearly flat over the range of flows studied, with flows of 300 - 480 cfs presenting maximum values due to the flow-temperature-time of travel relationships for the system from Youngstown to the Ohio-Pennsylvania State Line.

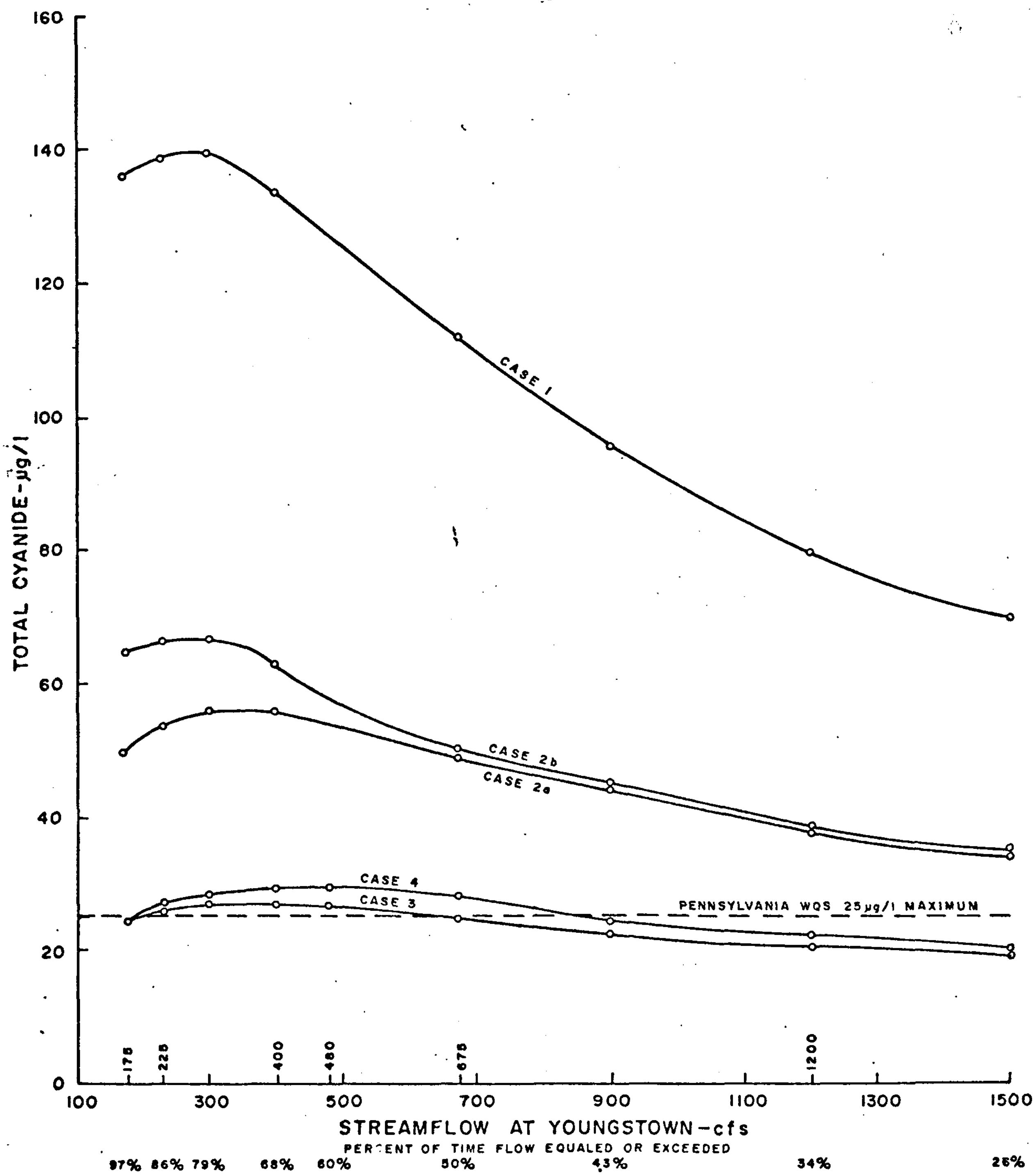
The total cyanide response presented in Figure VIII-4 illustrates that Cases 3 and 4 are projected to achieve marginal compliance with the maximum total cyanide standard of 25 ug/l while projected values for Cases 2a and 2b are significantly above the standard for all flows studied under winter conditions. Case 1 values are extremely high owing to the BPCTCA coke plant discharges at the Republic Steel-Youngstown Plant, and the Youngstown Sheet and Tube-Campbell Works. The effect of achieving the proposed Pennsylvania temperature standard of 56°F is shown by differences in the responses for Cases 2a and 2b over the lower flow range studied. Although Case 5 (BATEA) was not modeled for total cyanide, low stream concentrations are expected.

In summary, under February conditions, Cases 2b, 3, 4, and 5 are projected to achieve compliance with proposed Pennsylvania temperature standards; all cases would be in compliance with dissolved oxygen standards; only marginal compliance with recommended ammonia-N criteria is expected with Cases 2a, 2b, 3, 4, and 5; Cases 3, 4, and 5 would result in compliance with the proposed phenolics standard; and, only Cases 3 and 4

FIGURE VIII-4

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

TOTAL CYANIDE vs FLOW
FEBRUARY CONDITIONS
MAHONING RIVER



(and 5) are projected to achieve the Pennsylvania total cyanide standard. It is important to note that Pennsylvania standards for temperature, total cyanide, and phenolics are values not to be exceeded. A minimum dissolved oxygen standard is also included. The discharge loadings used for evaluating compliance with Pennsylvania WQS are 30 day average NPDES discharge limitations. Hence, the variability of the discharges, notably of those close to the State Line, can have a significant impact on achievement of water quality standards.

2) July Conditions

As illustrated in Figure VIII-5, the projected monthly average July temperature at the Ohio-Pennsylvania State Line for Cases 1 and 2a is expected to exceed the 90^{O}F maximum Pennsylvania WQS at flows less than 500 cfs which occur more than 40 percent of the time. The projected monthly average temperatures for Cases 2b, 3, 4, and 5 are about 3^{O}F below the 90^{O}F maximum standard at flows in the 400 to 480 cfs range and well below the standard at flows in excess of 700 cfs. Flows in excess of 700 cfs only occur about 20% of the time in July.

The July dissolved oxygen response for Case 1 includes state line concentrations in the 5.0 to 5.5 mg/l range at flows from 400 to 500 cfs and greater than 6.0 mg/l at flows exceeding 700 cfs. Expected state line concentrations for the other alternatives are generally in the 6.0 to 7.0 mg/l range at the lower flows studied and slightly greater than 7.0 mg/l in the higher flow range. It is important to note that the state line is just downstream of the Lowellville Dam and reaeration over the dam significantly impacts state line dissolved oxygen levels.

With higher stream temperatures resulting in faster reaction of ammonia-N, total cyanide, and phenolics, state line concentrations of these constituents illustrated in Figures VIII-6 and 7 for all cases are significantly lower than those expected for February conditions. Aside from Case 1, ammonia-N concentrations which range from about 1.5 ug/l at lower flows to about 1.1 ug/l at higher flows, expected July ammonia-N levels are in the range of the recommended 0.02 ug/l unionized ammonia-N criterion at pH 7.5. Of particular interest is the flat response to changes in streamflow.

The phenolics responses of all cases are below the proposed Pennsylvania standard of 10 ug/l and in the immediate range of the existing 5 ug/l

FIGURE VIII-5

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

TEMPERATURE AND DISSOLVED OXYGEN vs FLOW

JULY CONDITIONS

MAHONING RIVER

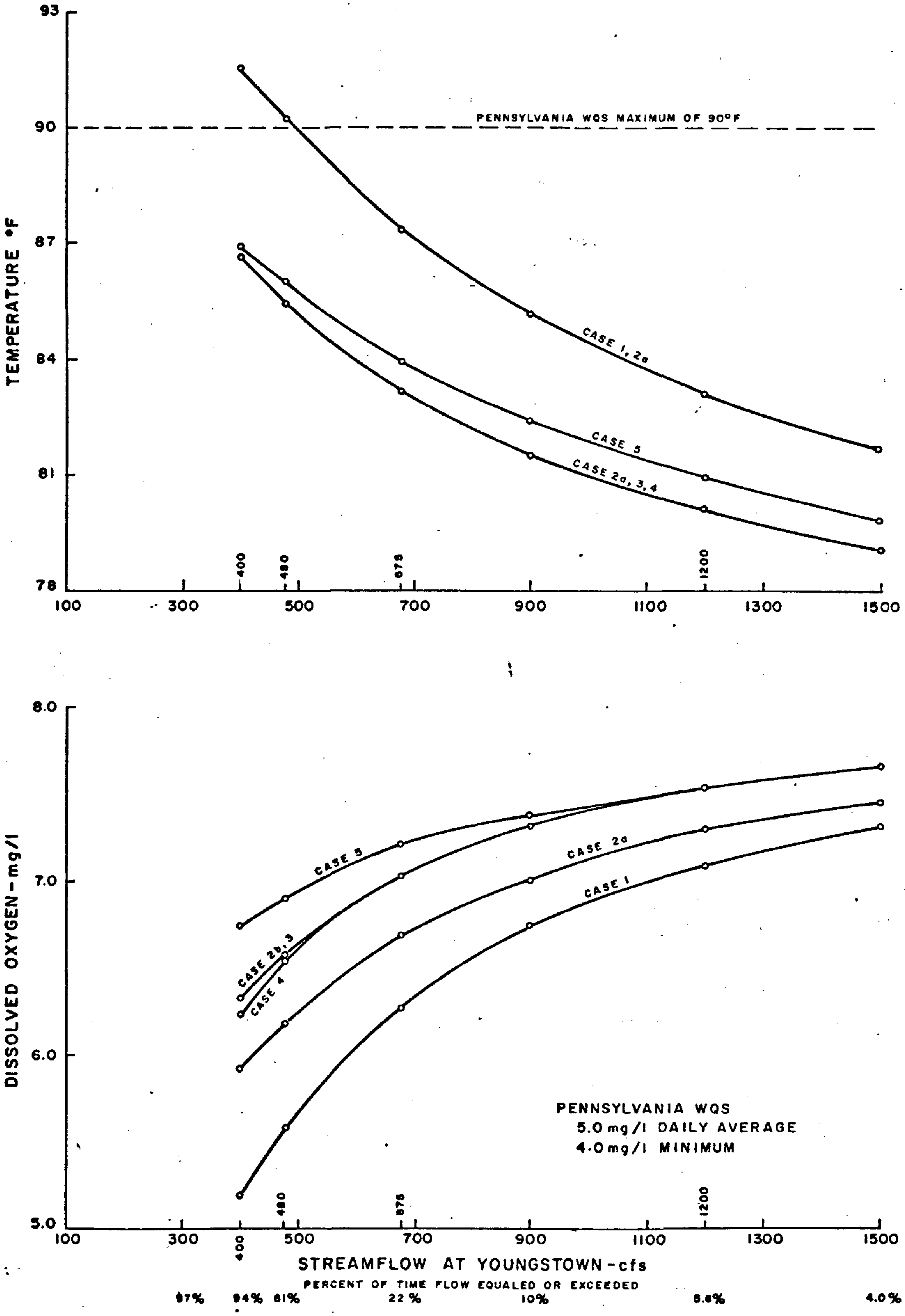


FIGURE VIII-6

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE
AMMONIA-N AND PHONOLICS vs FLOW
JULY CONDITIONS
MAHONING RIVER

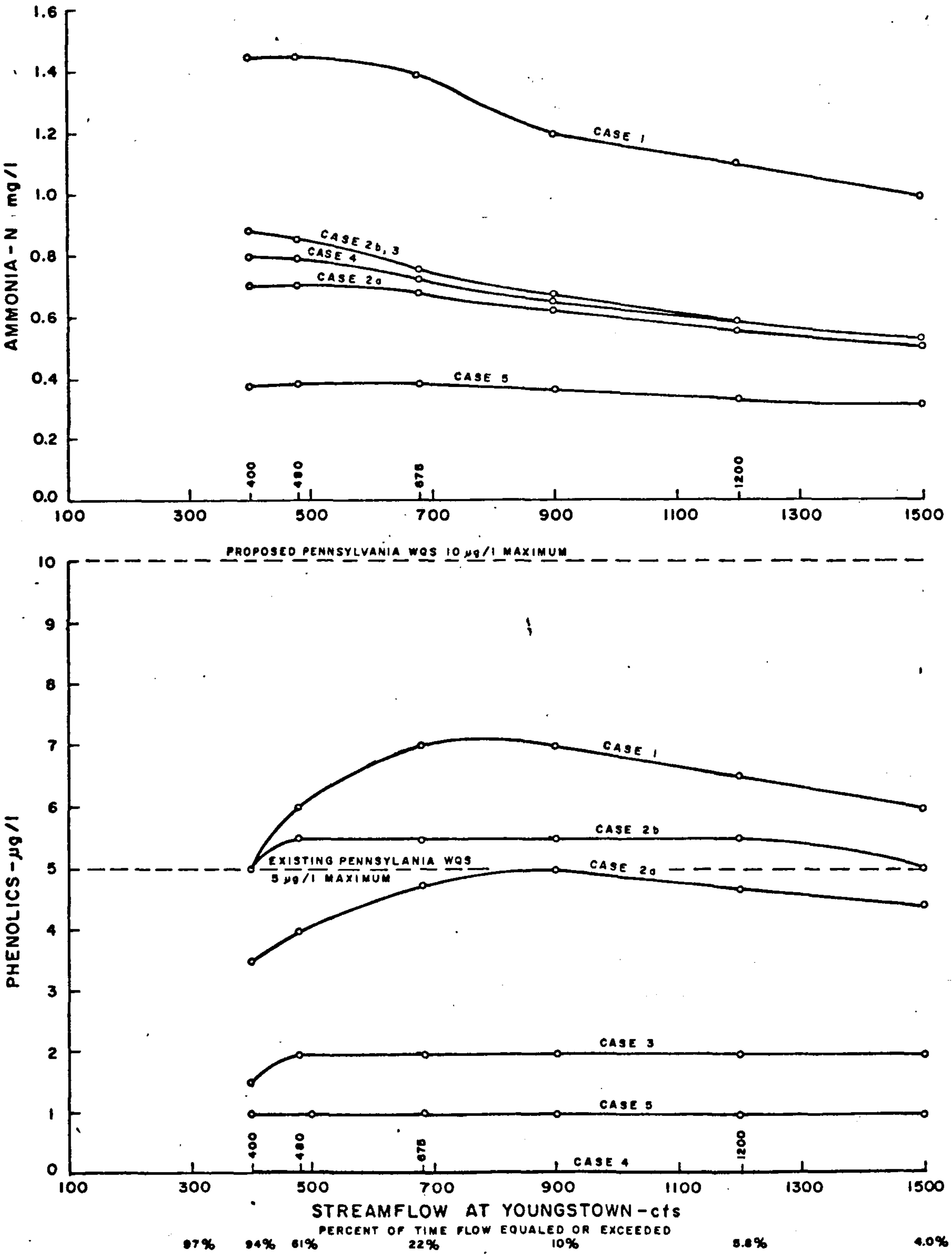
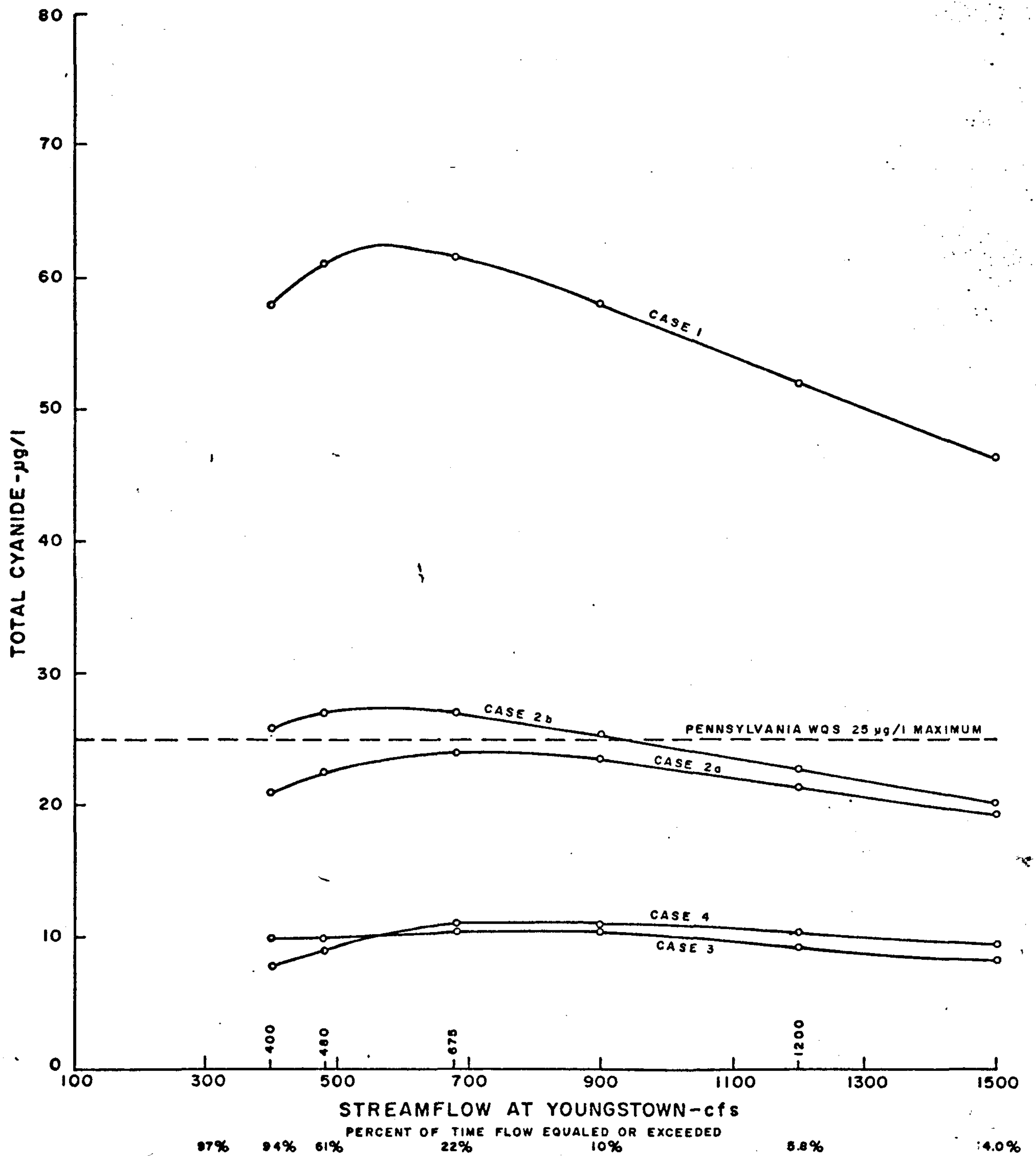


FIGURE VIII-7

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE
TOTAL CYANIDE vs FLOW
JULY CONDITIONS
MAHONING RIVER



standard. Only the Case 1 total cyanide response illustrated in Figure VIII-7 is significantly above the maximum Pennsylvania WQS of 25 ug/l. Responses for the other cases are in the immediate range or below the standard for all flows studied. Again, both the expected phenolics and total cyanide levels at the state line are relatively constant with increases in flow. It is noteworthy that the Pennsylvania WQS are maximum values not to be exceeded while the projected state line concentrations represent levels less than expected maximum values.

3) Monthly Conditions

From the results obtained over a wide range of flows under February and July conditions it is apparent that Case 1 is unacceptable because of high winter and summer stream temperatures, ammonia-N, and total cyanide; high winter phenolics; and, marginal summer dissolved oxygen. Case 2a is not projected to comply with winter or summer temperature standards and the total cyanide and phenolics standards under winter conditions. The total cyanide and phenolics responses for Case 2b under February conditions are also above the respective standards. Cases 3, 4, and 5 are projected to comply with all standards under both summer and winter conditions.

Since compliance with Pennsylvania temperature standards is necessary, and the likelihood of extensive joint municipal-industrial treatment and/or installation of BATEA on a large scale is small, Cases 2b and 3 were selected for further analysis at flows exceeded 90% of the time for each month. As noted earlier, Case 2b reflects implementation of the May 1976 proposed NPDES permits and offstream cooling at the Ohio Edison-Niles Plant. Case 3 discharges of heat and most constituents are identical to those included in Case 2b. However, total cyanide and phenolics discharges are reduced for certain steel plants.

Figure VIII-8 illustrates monthly average and extreme equilibrium water temperatures computed by methods described earlier with meteorological data obtained at the Youngstown Airport. These values represent the expected water temperatures that would occur with no artificial inputs of heat. Data obtained at the USGS water quality monitor at Leavittsburg are in the immediate range of these values. Also shown in Figure VIII-8 are monthly maximum existing and proposed Pennsylvania water quality stand-

FIGURE VIII - 8

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

WATER TEMPERATURE vs MONTH

MAHONING RIVER

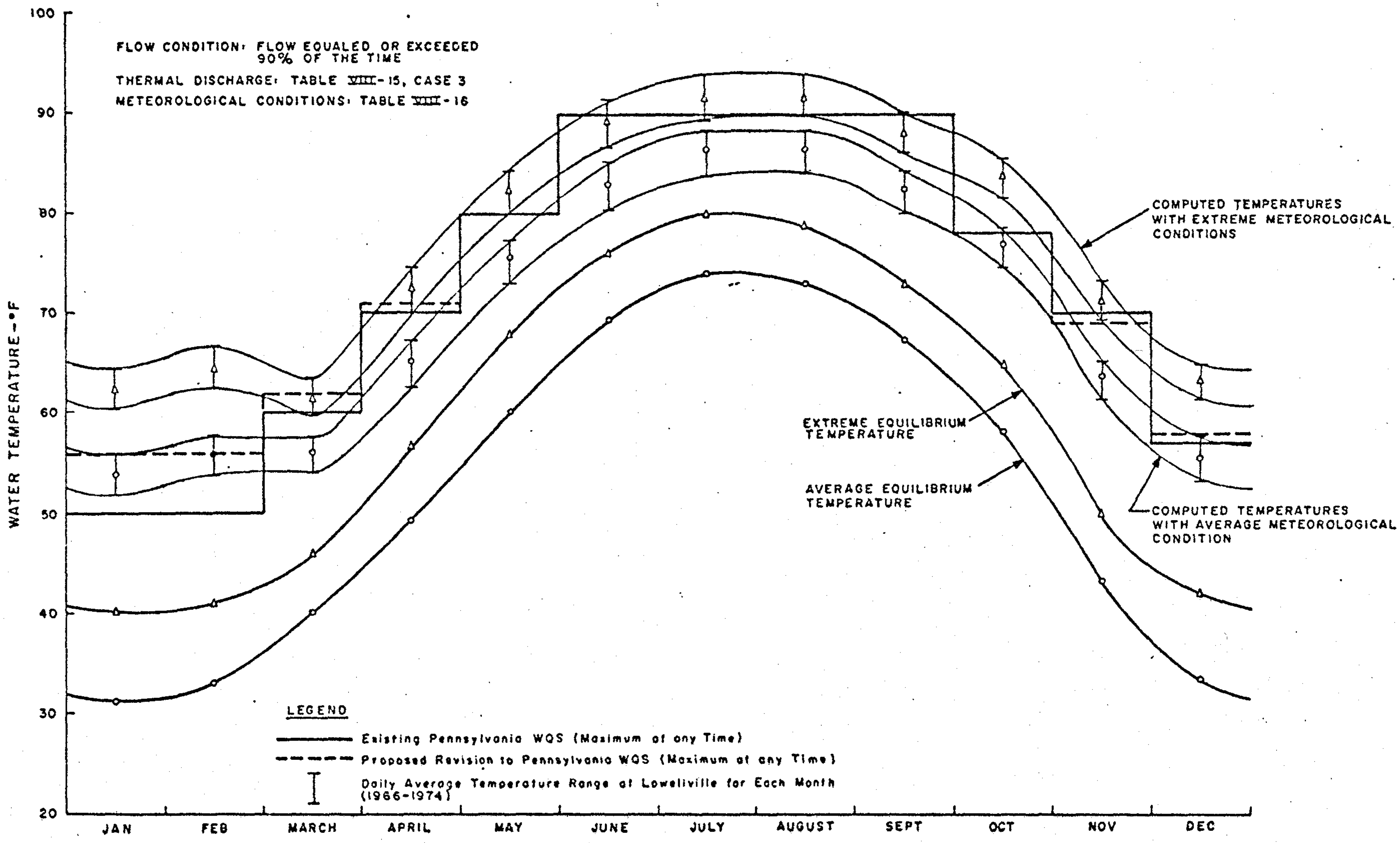


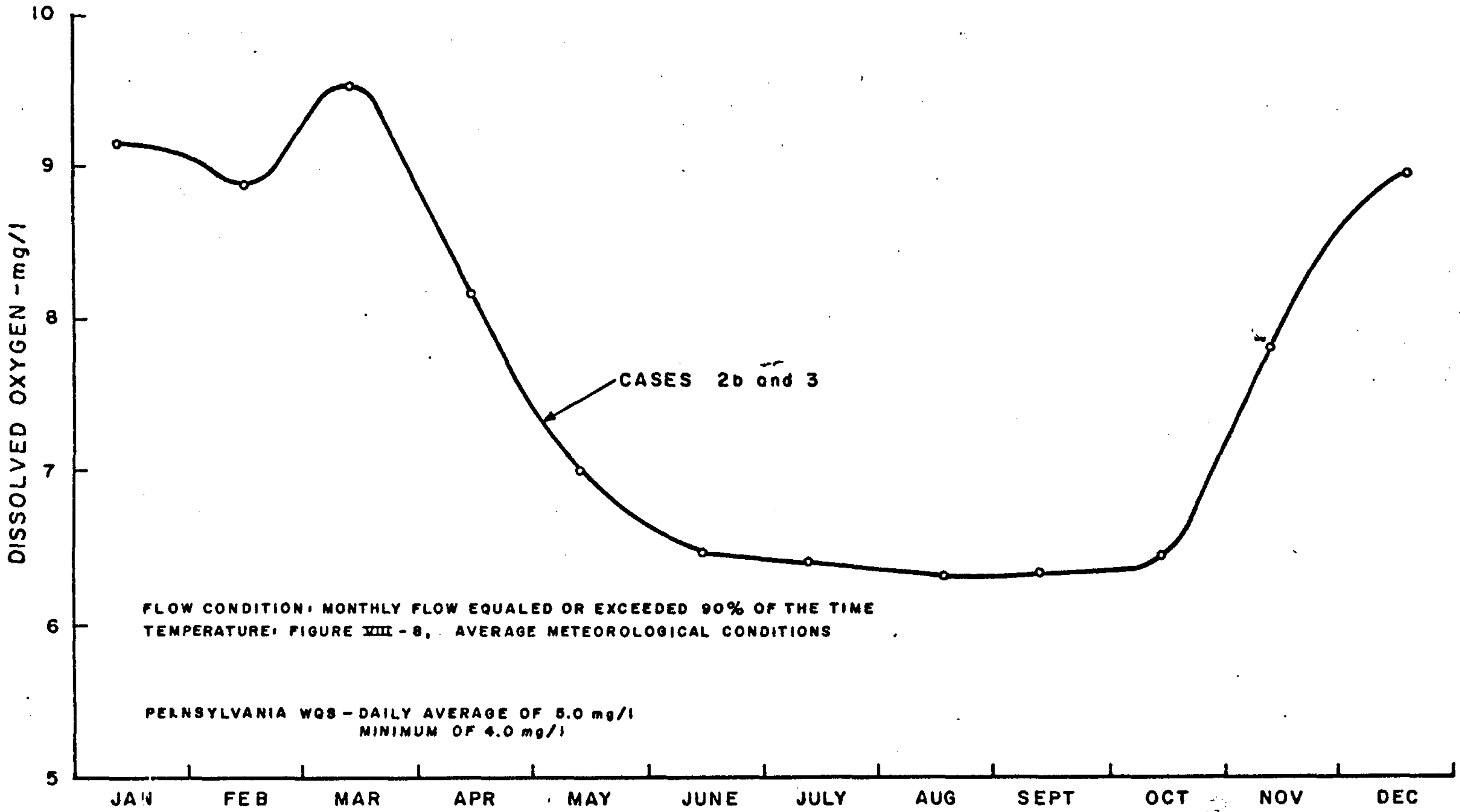
Figure VIII-8 are monthly maximum existing and proposed Pennsylvania water quality standards for temperature. Projected state line temperatures computed with Case 3 monthly average thermal discharges, at monthly flows equaled or exceeded 90% of the time, and, with average and extreme equilibrium temperatures, are compared with the WQS. As shown, the computed temperatures with average meteorological conditions are generally below the proposed revisions to existing Pennsylvania WQS by one to three degrees Fahrenheit, the exception being February where the projected temperature is the same as the proposed maximum standard of $56^{o}F$. The range about the projected values for each month represents the actual daily average temperature range recorded for each month at Lowellville from 1966 to 1974. Owing to the averaging of large amounts of data, these ranges, generally within $2.5^{o}F$, do not adequately reflect extreme daily fluctuations of more than $10^{o}F$ which have occasionally occurred.

Projected temperatures with extreme meteorological conditions are generally above the proposed revisions to the WQS, the exceptions being March, June, and September, where the projected value is less than 1 to $2^{o}F$ below the respective standards. Projected increases over the proposed and existing standards range from 6 to $9^{o}F$ during the winter months to 1 to $2^{o}F$ during July and August. Daily fluctuations in temperature will tend to exacerbate the problem.

These data serve to illustrate that only marginal compliance with proposed revisions to Pennsylvania WQS for temperature can be expected throughout the year during low flow, high production periods. Since the flow rates employed in this analysis are close to the minimum regulated schedule maintained by the Corps of Engineers, attainment of the state line temperature standards will probably be more closely related to the production level in the valley than to streamflow which frequently occurs.

The dissolved oxygen response for Cases 2b and 3 at the above temperatures (average meteorological conditions) and flows is presented in Figure VIII-9. Full compliance with the Pennsylvania WQS is projected throughout the year with concentrations in the 6.0 ug/l range expected during the summer months. Considering the data presented in Table VIII-19, concentrations approaching the minimum Pennsylvania dissolved oxygen standard of 4.0 ug/l resulting from non-point source and combined sewer overflow effects are not expected. However, as noted earlier, non-point

FIGURE VIII-9
WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE
DISSOLVED OXYGEN vs MONTHS
MAHONING RIVER



effects in the Ohio portion of the stream could be more severe.

The ammonia-N responses of Cases 2b and 3 illustrated in Figure VIII-10 are identical, as the same point source discharges are included in each case. The projected quality at the state line at the flow and temperature conditions reviewed for dissolved oxygen is compared with the recommended aquatic life criterion of 0.02 ug/l unionized ammonia-N at pH values of 7.0, 7.5, and 8.0 standard units. The Mahoning River is generally in the pH 7.0 to 7.5 range. However, values in the 7.5 to 8.0 range are not uncommon, and values above 8.0 are recorded. As shown in Figure VIII-10, the responses of Cases 2b and 3 are close to the recommended criteria associated with pH 7.5, well below those associated with pH 7.0 and significantly above those associated with pH 8.0. Considering the existing pH range found in the river and the species of fish desired for the Pennsylvania section of the stream, compliance with ammonia-N toxicity criteria appears adequate for the Case 2b and 3 discharge loadings.

The total cyanide and phenolics responses for Cases 2b and 3 at the Ohio-Pennsylvania state line are illustrated in Figures VIII-11 and 12, respectively. Case 2b discharges are projected to exceed the maximum Pennsylvania total cyanide standard by wide margins in the winter, spring, and fall months and only marginally during the summer months. Case 3 discharges are expected to achieve the total cyanide standards on a monthly average basis throughout the year. Large variations in waste discharges above the monthly average discharge loadings specified herein, notably at those plants located closest to the Ohio-Pennsylvania state line, will result in state line concentrations well above those illustrated in Figure VIII-11.

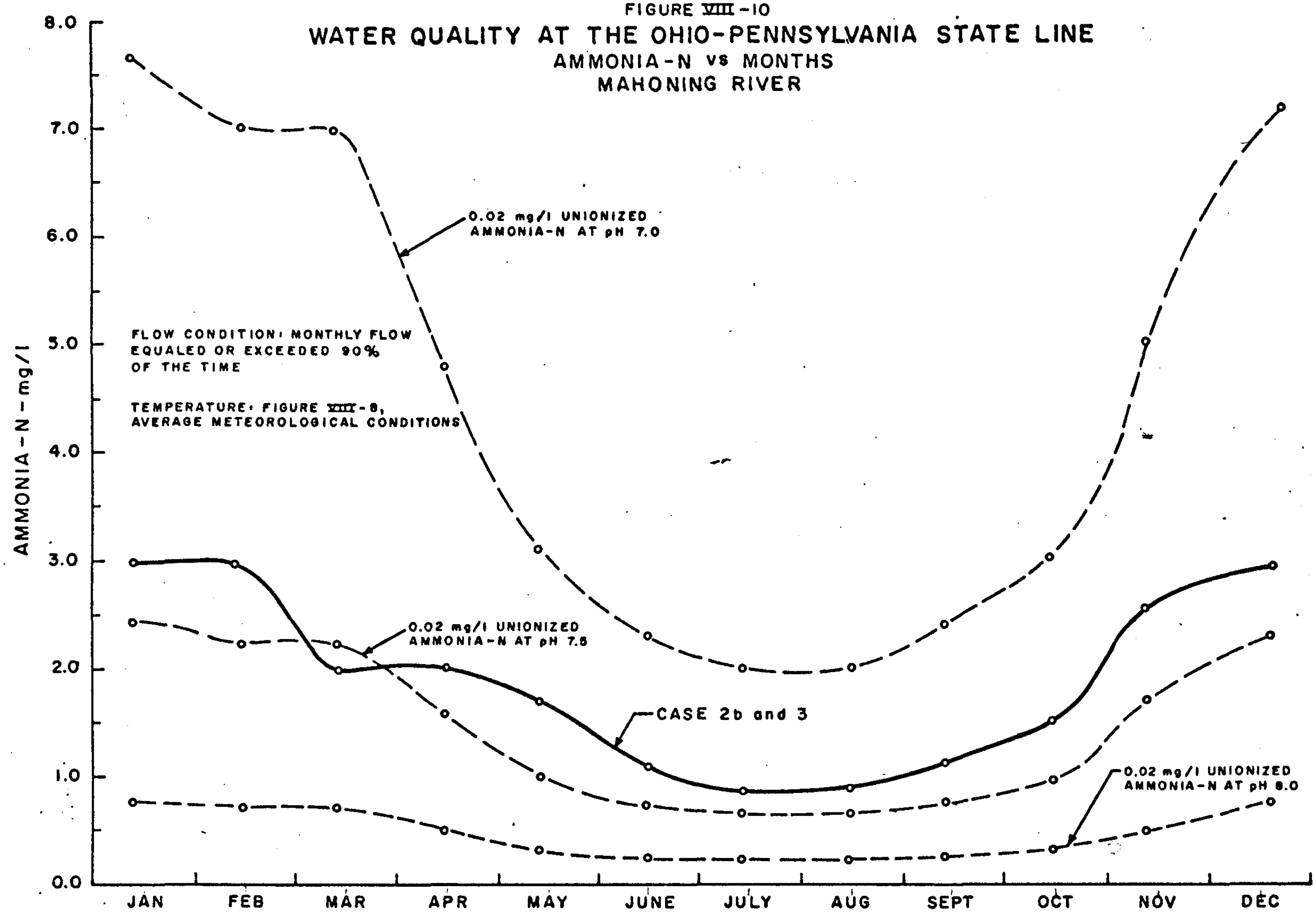
The phenolics responses are similar in form to the total cyanide responses. However, the Case 2b phenolics discharge loadings result in attainment of the existing and proposed revisions to the Pennsylvania WQS of 5 and 10 ug/l, respectively, more of the time. The widest variations from the 10 ug/l revised criterion are projected for the winter months when values 5 to 8 ug/l above the limit are shown. The Case 3 discharges are projected to comply with the proposed 10 ug/l standard throughout the year. However, as noted above for total cyanide, large fluctuations in waste discharges near the state line can result in significant violations of the WQS.

FIGURE VIII-10

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

AMMONIA-N vs MONTHS

MAHONING RIVER



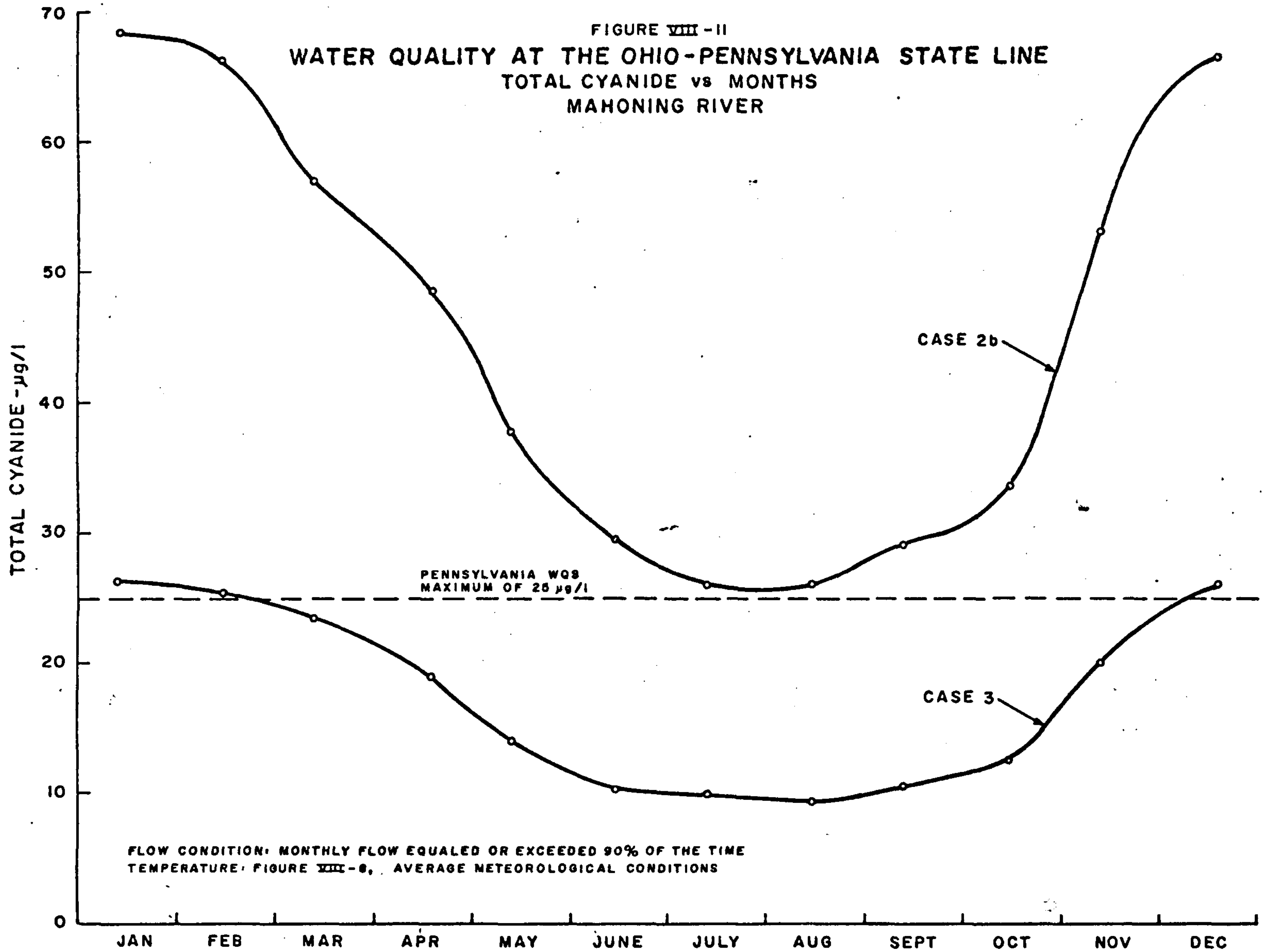


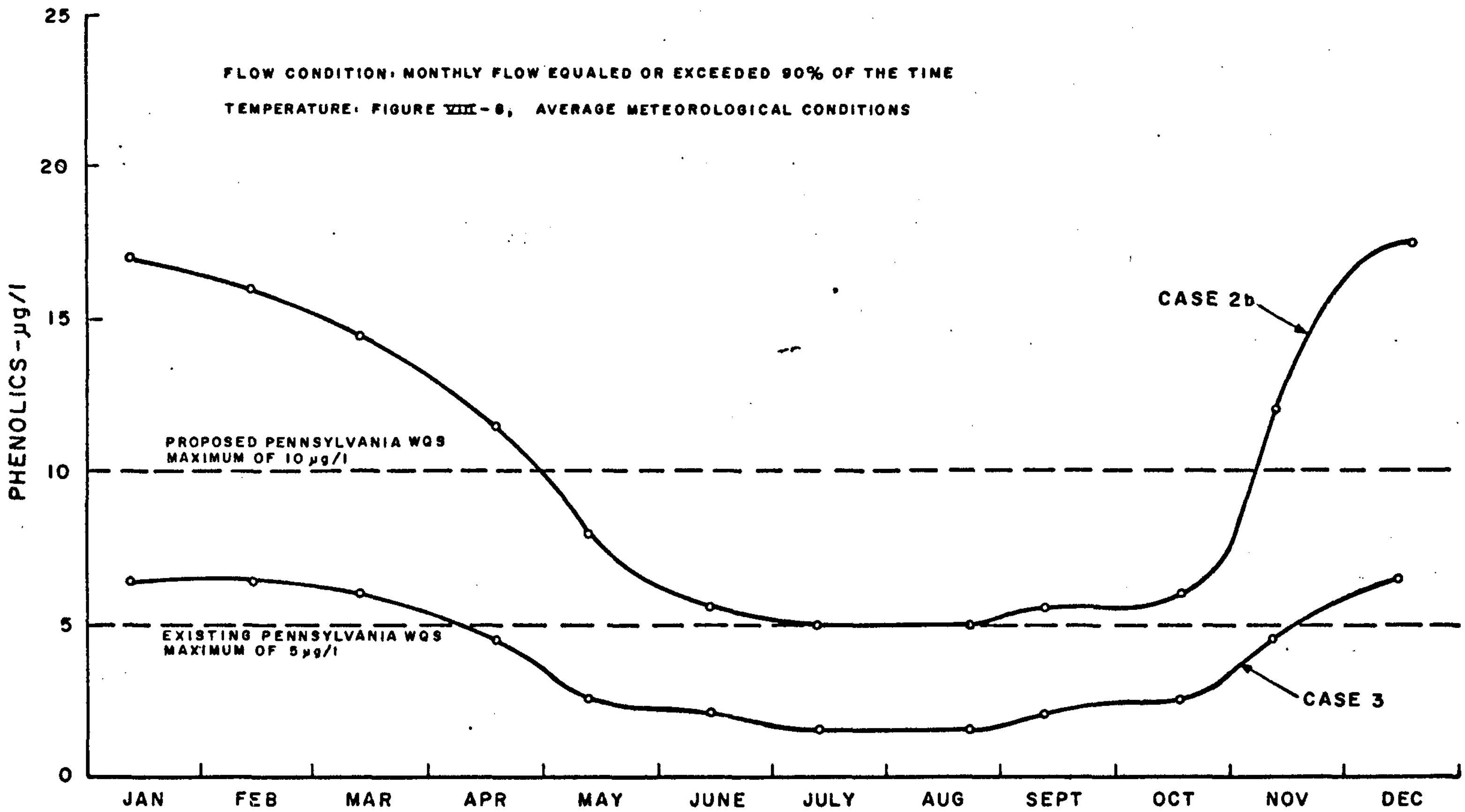
FIGURE VIII - 11
WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE
TOTAL CYANIDE vs MONTHS
MAHONING RIVER
TOTAL CYANIDE - µg/l
70
60
50
40
30
20
10
0
CASE 2b
CASE 3
PENNSYLVANIA WQS
MAXIMUM OF 25 µg/l
FLOW CONDITION: MONTHLY FLOW EQUALED OR EXCEEDED 90% OF THE TIME
TEMPERATURE: FIGURE VIII-8, AVERAGE METEOROLOGICAL CONDITIONS
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC

FIGURE VIII-12

WATER QUALITY AT THE OHIO-PENNSYLVANIA STATE LINE

PHONOLICS vs MONTHS

MAHONING RIVER



b. Sensitivity Analysis

Sensitivities of water quality responses to several mathematical model inputs were determined to evaluate effects of naturally occuring changes in flow and temperature, and to evaluate possible errors in certain specified inputs including reaction rates, stream velocity, travel time, temperature, reaeration rate, stream depth, and sediment oxygen demand. The discharge loadings associated with Case 2b were selected as the base case. The February design flow of 225 cfs at Youngstown was used as the base flow as the worst water quality generally occurs at lower design flows, the exception being dissolved oxygen which achieves minimum concentrations during the warm summer months. A flow of 400 cfs at Youngstown was used for evaluating the sensitivity of dissolved oxygen to certain related inputs under July conditions. The sensitivity results are illustrated in Figures VIII-13 to VIII-36 and summarized in tabular form in Table VIII-20.

1) Sensitivity of Temperature

Computed stream temperatures are affected by meteorological and hydrologic variables. The sensitivity of temperatures to meteorological inputs is discussed below, while the sensitivity of temperatures to velocity and flow is presented later. Air temperature, wind speed, relative humidity and cloud cover are used to calculate the equilibrium temperature (E) and the heat exchange rate (K) for the temperature model employed in this analysis. The sensitivity of computed temperatures to E and K was evaluated rather than determining the response of the model to each meteorological variable used to compute E and K.

The value of E was increased and decreased 5°F resulting in a 10°F range, three times larger than the range of E computed for the February verification study using wind speeds which differed by more than a factor of two. Computed temperatures with the changes in E are displayed in Figure VIII-13 and the response at three locations in the stream are presented in Table VIII-20. The results indicate that stream temperatures are relatively sensitive to changes in E. With E increased 5°F, computed temperatures exceeded temperatures for the base case by 2.9°F at Youngstown, by 3.1°F at the state line, and by 3.7°F at New Castle. Similar decreases in computed temperatures resulted when E was decreased by 5°F. Computed temperatures at the state line under winter low flow conditions changed by about 0.6°F for each degree of change in the equilibrium temperature. At higher design flows encountered during the summer, the sensitivity of computed temperatures to E remains about the same since the heat exchange rate is generally higher in the summer and offsets the effects of reduced travel time caused by higher flows.

Values of K were increased and decreased 25 percent (± 20 BTU/Ft^2-Day-°F). This range of K is twice as large as the difference in K values computed using average and extreme meteorological conditions for the month of February (Table VIII-16). Figure VIII-14 illustrates the sensitivity of computed temperatures to this range of K and the results at three stream locations are presented in Table VIII-20. With the higher heat exchange rate, computed temperatures were below the values for the base case by 2.1°F at the state line and 2.7°F at New Castle. With K decreased, computed temperatures exceeded the base case values by 2.5°F at the state line and 3.4°F at New Castle. Calculated stream temperatures are about one-half as sensitive to changes in K during summer low flow conditions since travel times are about fifty percent lower.

2) Sensitivity to Temperature

The sensitivity of computed concentrations to temperature was determined by running RIBAM with calculated temperatures for the base condition increased and decreased 5°F. A 5°F shift in temperature is twice as large as the maximum difference between measured and computed values in the verification of the Edinger and Geyer temperature model. The resulting 10°F range in temperature includes most temperatures seen during the winter months, as well as most variations caused by extreme weather conditions. Since the initial temperature at Leavittsburg was set at 33°F, the temperature from Leavittsburg to the Republic Steel-Warren Plant could only be lowered to 32°F, and, by the full 5°F below Republic Steel. Computed concentrations of ammonia-N, dissolved oxygen, total cyanide and phenolics with adjusted temperatures are illustrated in Figures VIII-15 through VIII-18, respectively.

The results for ammonia-N, Figure VIII-15 and Table VIII-20, indicate that stream concentrations are relatively insensitive to changes in temperature throughout Ohio and at the Ohio-Pennsylvania state line. The difference in ammonia-N concentrations for the 10°F temperature range never exceeded 0.3 mg/l or about 10 percent of the instream concentration. The maximum range in computed values was only 0.36 mg/l at New Castle. At higher summer design flows, the range of expected ammonia-N concentrations for a 10°F range in temperature would be about 10% less since the reduction in travel time more than offsets the higher reaction rates resulting from higher temperatures.

Computed dissolved oxygen concentrations were fairly sensitive to changes in temperature (Figure VIII-16 and Table VIII-20). At the Ohio-Pennsylvania state line, a 5°F shift in temperature caused a 0.7 mg/l (8 percent) change in DO from base level concentrations. Unlike ammonia-N, the range of DO concentrations remains fairly constant throughout the river since it primarily results from a 0.7 mg/l shift in the DO saturation concentrations. At the water temperatures encountered during the summer months, a 5°F change in water temperature causes changes in the DO saturation concentrations of only ± 0.4 mg/l.

Total cyanide and phenolics were relatively insensitive to changes in temperature during winter low flow conditions (Figures VIII-17, VIII-18 and Table VIII-20). As with ammonia-N, the range of total cyanide and phenolics concentrations corresponding to the 10°F range in temperatures started small and gradually increased with travel downstream. At the Ohio-Pennsylvania state line, computed total cyanide concentrations with the adjusted temperatures were within ± 7 μg/l (about 10 percent) of the computed values for the base case. For phenolics, the computed concentrations at the state line were within ± 2.5 μg/l, or about 15 percent, of the base case. Both constituents would be about half as sensitive to temperature during the warmer summer conditions.

3) Sensitivity to Velocity

Stream temperatures were computed with stream segment velocities increased and decreased twenty five percent. These computed temperatures and the adjusted velocities were then supplied to RIBAM to evaluate changes in other constituents. The percent change applied to velocities is over twice as large as differences between measured and computed velocities during the three dye studies conducted on the Mahoning River (Section VII).

Figure VIII-19 shows the sensitivity of computed temperatures to changes in velocity. Adjustments in stream velocities caused steadily increasing temperature ranges in the downstream direction. With increased velocities, thermal loadings had less time to decay and thus stream temperatures were higher; conversely, with velocities decreased, stream temperatures decreased. At the state line, the velocity adjustments caused less than a 3.0^{o}F change in temperature from the base case or about 10 percent of the thermal loading remaining in the stream at that point (Table VIII-20).

Concentrations of ammonia-N, dissolved oxygen, total cyanide and phenolics were relatively insensitive to changes in velocity (Figures VIII-20 to VIII-23). With stream velocities adjusted as above, ammonia-N concentrations changed about 0.1 mg/l at the state line (5 percent) and less than 0.1 mg/l throughout the Ohio portion of the stream. For dissolved oxygen, the effects of changes in velocities were offset by resulting changes in temperature. Throughout Ohio, the DO concentrations showed little variability for 25 percent changes in velocity, with the largest range in DO values being 0.5 mg/l (4 percent) behind the Liberty Street Dam. At the Ohio-Pennsylvania state line there was a 0.3 mg/l range in computed DO concentrations which increased to about $\pm$ 0.5 mg/l at New Castle. Both total cyanide and phenolics showed steadily increasing ranges of computed values throughout the study area. At the state line the range of computed concentrations for both constituents is about $\pm$ 15 percent of the base case concentration at that point, i.e., $\pm$ 10 μg/l for total cyanide and $\pm$ 3 μg/l for phenolics.

4) Sensitivity to Travel Time and Reaction Rates

The sensitivity of computed concentrations to travel time is the same as the sensitivity to reaction rates. Since stream concentrations are simulated with first order differential equations, the product of the reaction rate and the travel time is contained in the exponent of the water quality equations. Changing the travel time by a fixed percentage has the same effect as changing the reaction rate by the same percentage. RIBAM was run with travel times increased and decreased by twenty-five percent. In this instance, temperatures input to the model were not adjusted to reflect the change in travel time so that the sensitivity to reaction rates could be separately evaluated. The results are illustrated in Figures VIII-24 to VIII-27. The water quality responses at three locations are presented in Table VIII-20.

As seen in Table VIII-20, ammonia-N and dissolved oxygen concentrations were relatively insensitive to $\pm$ 25 percent adjustments in travel times. Ammonia-N concentrations changed by only 0.06 mg/l at Youngstown and 0.14 mg/l (5 percent) at the state line with adjusted travel times. The range of computed dissolved oxygen concentrations with the increase and decrease in travel time was less than 0.4 mg/l throughout Ohio and was less than 0.3 mg/l at the Ohio-Pennsylvania line. The range of computed concentrations remained fairly constant at 0.3 mg/l downstream to New Castle. Although travel time adjustments are equivalent to simultaneous changes in all reaction rates affecting DO, the computed concentrations changed by only a few tenths of a mg/l.

Total cyanide and phenolic concentrations were found to be more sensitive to travel time or reaction rates. The twenty-five percent increase in travel time caused 12 µg/l (18 percent) decrease in total cyanide and about a 3 µg/l (17 percent) decrease in phenolics at the Ohio-Pennsylvania state line. The twenty-five percent decrease in travel times resulted in total cyanide and phenolic increases of 15 µg/l (21 percent) and 4 µg/l (22 percent), respectively, at the state line. Computed concentrations in Ohio were less sensitive to travel time. On a percentage basis, total cyanide and phenolics were more sensitive to travel time and reaction rates than other constituents.

The reaction rates of total cyanide and phenolics are much faster than those for other constituents and therefore larger percentages of the effluent loadings decay in the stream. Concentrations of both constituents would be about one half as sensitive to twenty-five percent adjustments in travel time or reaction rates at summer critical flow conditions when shorter travel times occur.

5) Sensitivity to Flow

Of the parameters supplied to the water quality models, stream flow exhibits the largest fluctuations and directly affects all other hydrologic variables in the model. Hence, a more detailed examination was made of the sensitivity of the models to flow. Numerous runs were made using different flow regimes for both winter and summer conditions and the treatment alternatives discussed earlier. February flow regimes ranged from a low value of 175 cfs at the Youngstown gage, (exceeded 97 percent of the time) to a high value of 1,500 cfs at Youngstown (exceeded only 26 percent of the time). The flow regimes and initial conditions applied in the analysis were reviewed earlier. (Section VIII, D, Table VIII-14). For each flow, velocities and depths were calculated using previously describe procedures and the Edinger and Geyer temperature model was used to compute water temperatures for the different treatment alternatives. Calculated velocities, depths and temperatures were input to RIBAM to compute water quality.

Figures VIII-28 to 30 illustrate computed stream profiles for temperature, ammonia-N, and dissolved oxygen for Case 2b effluent loadings during winter (February) conditions with Table VIII-20 presenting the results at three stream locations. Each figure presents computed values for three flows at the Youngstown gage, 225 cfs, 675 cfs, and 1500 cfs. For temperature, ammonia-N, and DO, the results indicate that as stream flow increases the effects of point source discharges decrease and the water quality improves along the entire length of the river. Computed temperatures showed a substantial decrease as flows were increased from 225 cfs to 675 cfs and again when flows were increased to 1500 cfs. At the Ohio-Pennsylvania state line, computed temperatures decreased by about 10°F when flow was increased from 225 cfs to 675 cfs, and temperatures decreased an additional 5°F as stream flow was increased to 1500 cfs. Computed ammonia-N concentrations showed similar responses to stream flow with concentration profiles becoming much flatter, and less decay occuring in the stream because of reduced temperatures and travel times at higher flows. At the state line, there was a 1.4 mg/l (50 percent) decrease in ammonia-N concentrations when flow was increased from 225 cfs to 675 cfs and an additional 0.6 mg/l (21 percent) decrease when flow was increased to 1500 cfs. Dissolved oxygen concentrations, plotted in Figure VIII-30, also showed a substantial flattening as flow was increased.

At higher flows the sag in computed concentrations was much less and the sudden changes in DO at point sources (i.e. dams or outfalls) was also reduced. DO concentrations at the state line increased by 2.5 mg/l when stream flow was increased from 225 cfs to 675 cfs and an additional 1.2 mg/l when flow was increased to 1500 cfs. A substantial portion of the improvement in DO concentration as flow increases is directly related to the increase in DO saturation concentrations caused by reductions in temperature.

The sensitivities of total cyanide and phenolics to flow are illustrated in Figures VIII-32 and VIII-33, respectively. As with other constituents, increased flows resulted in flatter computed concentration profiles, but in these cases, the highest flow does not result in the best water quality at all points in the stream. Immediately downstream of the large industrial dischargers, computed concentrattions at 225 cfs are significantly higher than the values computed at 675 cfs or 1500 cfs. However, computed values at 225 cfs are less than the concentrations computed at the higher flows in two river segments. At the Ohio-Pennsylvania state line, less than five miles downstream of the Youngstown Sheet and Tube-Campbell Works, there is only 14 μg/l (20 percent) difference in total cyanide concentration between the 225 cfs and 675 cfs cases and a 18 μg/l difference between the 675 cfs and 1500 cfs. Similar results were seen for phenolics at the state line. The computed concentration decreased only 1 μg/l (6 percent) when flows increased from 225 cfs to 675 cfs and 3 μg/l as flows increased from 675 cfs to 1500 cfs. Hence, a sixfold increase in flow resulted in a decrease in phenolics concentration of less than 4 μg/l at the state line.

As stream flow increases, stream velocities and depths increase, travel time and computed temperatures decrease, the effects of point source loadings are diluted, and, the decay of non-conservative constituents is reduced. The simultaneous effects of these factors at the Ohio-Pennsylvania state line are presented in Figures VIII-2 to VIII-7. Computed temperatures and dissolved oxygen concentrations at the state line with February conditions showed consistent improvement as flows were increased. Temperatures at the state line dropped significantly and steadily with increases in flow for all treatment alternatives. Of the three thermal control alternatives evaluated, Case 5 temperatures were slightly less sensitive to flow than the other alternatives because the major thermal loadings are located well upstream from the state line. Differences in dissolved oxygen concentrations between the treatment alternatives generally decreased with increasing flow from a maximum of 2.3 mg/l at 175 cfs to 0.7 mg/l at 1500 cfs.

Computed ammonia-N concentrations at the state line decreased steadily with increases in flow for all alternatives except Case 5 (Figure VIII-3). Under February conditions, computed concentrations for Case 5 increased slightly when the flow was increased from 175 cfs to 225 cfs. At flows greater than 225 cfs, concentrations at the state line declined steadily. At flows above 675 cfs all treatment alternatives showed a decline in the sensitivity of computed concentrations to flow.

Computed phenolics concentrations at the state line using winter conditions were found to be relatively insensitive to changes in flow. Also, the maximum concentration at the state line for each treatment alternatives did not occur at the lowest flow. For Cases 1 and 2a the maximum concentration was found to occur at a flow of 480 cfs, while for Case 2b the maximum concentration close to 400 cfs. For Cases 3, 4 and 5, computed concentrations steadily increased with increasing flow to the maximum at 1500 cfs. These steady increases were the result of the initial concentration of the river being set at 10 μg/l (Section VIII D). For each case, however, computed concentration at the state line fluctuated by less than 5 μg/l over the entire range of flows studied.

Computed total cyanide concentrations at the state line are also relatively insensitive to changes in flow. Over the wide range of flows computed concentrations for Case 2a changed by less than 20 μg/l and concentrations for Cases 3 and 4 changed less than 10 μg/l. As was the case for phenolic concentrations, maximum concentrations at the state line did not occur at the lowest stream flows. For alternatives 1 and 2b maximum concentrations at the state line are achieved at 300 cfs. With alternative 2a the maximum value was obtained at 400 cfs, and for Cases 3 and 4 the maximum concentration occurred at 480 cfs.

Under summer conditions water quality response at the state line to increasing flow was similar to that seen in winter conditions, with the exception that stream temperatures were higher and concentrations of DO, ammonia-N, phenolics and total cyanide were lower (Figures VIII-6 and 7).

Also with summer conditions, the sensitivity of ammonia-N, total cyanide and phenolics to increasing flows was somewhat reduced. Ammonia-N concentrations at the state line for Cases 2a, 2b, 3, 4 and 5 fluctuated by less than 0.2 mg/l (20 percent) for the four-fold increase in flow. Computed phenolic concentrations for Cases 1 and 2a changed by less than 2 µg/l while concentrations for the other cases changed by less than 1 µg/l over the entire range of flow. The maximum phenolic concentration at the state line also occurred at a different flow in the summer time (900 cfs) than under winter conditions (480 cfs). Computed total cyanide concentrations for Cases 2a, 2b, 3 and 4 fluctuated by less than 5 µg/l when flows were increased from 400 cfs to 1500 cfs. Generally, computed concentrations at the state line using summer conditions were insensitive to large changes in stream flow.

6) Dissolved Oxygen Sensitivity

The response of computed DO concentrations to changes in reaeration rate, depth and sediment oxygen demand was also studied. Summer critical flow conditions were used in conjunction with the Case 2b treatment alternative as the base case. The critical summer flow conditions represent the period of minimum expected DO levels.

Throughout this report, the O'Conner-Dobbsin reaeration formulation has been successfully used to compute stream reaeration[43]. In determining the sensitivity of DO to reaeration, RIBAM was run with the computed reaeration rates for each segment increased and decreased by twenty-five percent. The results indicate that throughout most of the river DO concentrations are relatively insensitive to the reaeration rate (Figure VIII-33, Table VIII-20). In the Ohio portion of the river a maximum difference of only 0.4 mg/l between concentrations computed with reaeration rates increased and decreased twenty-five percent was predicted. Throughout most of Ohio, including at the state line, the range of computed values was generally less than 0.2 mg/l. From Figure VIII-33 it is evident that the channel dams maintain fairly consistent DO concentrations in the stream, such that when the reaeration rates are reduced, and DO values decrease, additional reaeration occurs at the channel dams. Downstream of the Ohio-Pennsylvania state line, where there are no dams, the computed DO range increased to 0.65 mg/l.

In RIBAM, stream depths are used in computing the reaeration rates and to adjust the BOD reaction rates (Section VII, A). When stream depths were increased and decreased twenty-five percent, velocities were not adjusted so that the effects of depth could be evaluated separately from changes in velocity. Figure VIII-34 shows the computed DO concentration profiles with the adjusted depths. The results indicate that computed DO concentrations are relatively insensitive to change in depth. When stream depths were increased, DO concentrations decreased. Likewise, when depths were decreased, computed DO values increased. The maximum difference in computed DO concentration in Ohio using the different depths was 0.4 mg/l, while many segments had ranges in DO of less than 0.2 mg/l. Again, the dams tend to equalize DO concentrations. At the state line there was only a 0.2 mg/l range in computed DO concentrations, however, the range increased rapidly below the state line to a maximum of 0.9 mg/l at New Castle.

The final parameter evaluated was the sensitivity of DO to sediment oxygen demand. In the verification of the RIBAM model, measured sediment oxygen demand rates were applied to the stream areas where the Corps of Engineers found sediment. The resulting sediment oxygen demand was adjusted for temperature and input to the RIBAM code (Section VII, B). However, sediment oxygen demand was not considered in waste load allocations. To determine the sensitivity of computed DO concentrations to the sediment oxygen demand, the model was run for both summer and winter low flow conditions with no SOD load (base case), the SOD loads used in the verification, and the measured sediment demand rates applied to the total bottom area of the river. All SOD loads were adjusted for temperature as was done in the verification analysis. The results presented in Figures VIII-35 and VIII-36 demonstrate that SOD has very little effect on dissolved oxygen concentrations in the stream. With the measured sediment oxygen demand rates applied to 100 percent of the river bottom, computed DO concentrations in July decreased a maximum of 0.3 mg/l behind the Lowellville dam from the base case. In most of the remaining portions of the river DO decreased less than 0.1 mg/l. Using the SOD loads determined for the verification runs, dissolved oxygen levels in July never decreased more than 0.1 mg/l from the base case. Using Feburary low flow conditions and assuming the entire river bottom covered with sediment, DO decreased less than 0.2 mg/l throughout most of the river and decreased a maximum of 0.4 mg/l behind the Lowellville dam. With the SOD loads used in the verification studies, DO decreased less than 0.2 mg/l (2 percent) throughout the river in February. Clearly DO levels in the Mahoning are insensitive to existing SOD loads.

7) Sensitivity Analysis Summary

Aside from the effects of large fluctuations in stream flow upon stream temperatures and concentrations of dissolved oxygen and ammonia-N, and of temperature upon dissolved oxygen, water quality model computations for the lower Mahoning River are not overly sensitive to a fairly wide range of input values for equilibrium water temperature, heat transfer coefficient, stream velocity, travel time, reaction rates, reaeration rate, and sediment oxygen demand. Given the physical characteristics of the stream in terms of widths, depths, and length, and the stream velocities and travel times resulting from the regulated flow regime, water quality in the lower Mahoning River is primarily a function of municipal and industrial effluent discharges rather than of any particular water quality model input.

The sum of sensitivities of the water quality model to each variable is not the overall sensitivity of the water quality model. In many cases, as one input was changed causing computed values to increase, a related variable changes in a manner to cause computed concentrations to decrease, thus partially offsetting the effects of each change.

Owing to the different distribution of discharge loadings for each treatment alternative studied herein, the magnitude (percent) change of the water quality response at the state line to changes in input variables will not be exactly the same for each case. However, with the exceptions of Cases 1 and 4, neither of which are likely to be fully implemented, the distribution of effluent loadings along the length of the stream are somewhat similar to that of Case 2b. Hence, the sensitivity results of Case 2b can be reasonably applied to Cases 2a, 3, and 5.

TABLE VIII-20

SUMMARY OF SENSITIVITY ANALYSES

Constituent and Tested Parameters	Adjustment to Input Parameters	Water Quality Response at February Design Flow Conditions (response with parameter increased/response with parameter decreased): Youngstown, Ohio River Mile 23.0 Concentration	% of base level	Ohio-Pa State Line River Mile 11.61 Concentration	% of base level	New Castle, Pa River Mile 1.52 Concentration	% of base level
Temperature (°F)							
E	±5°F	+2.9/-2.9	+16/-16 *	+3.1/-3.1	+14/-14 *	+3.7/-3.7	+25/-25 *
K	±25%	-1.0/+1.1	-5/+5 *	-2.2/+2.5	-10/+11 *	-2.7/+3.4	-18/+23 *
Velocity	±25%	+0.8/-1.2	+4/-6 *	+1.9/-2.7	+9/-12 *	+2.5/-3.3	+17/-22 *
Flow	675 cfs, 1500 cfs	-11.2, -15.1	-60, -81 *	-10.0, -15.5	-46, -71 *	-4.5, -8.8	-31, -60 *
Dissolved Oxygen (mg/l)							
Temperature	±5°F	-0.8/+0.8	-7/+7	-.75/+.75	-8/+8	-0.8/+0.8	-9/+9
Velocity	±25%	0.0/0.0	0/0	-0.1/+0.2	-1/+2	-0.3/+0.5	-3/+5
Travel Time (Rate)	±25%	0.0/+.1	0/+1	0.0/+0.2	0/+2	+.3/+.1	+2/+1
Flow	675 cfs, 1500 cfs	+2.0, +2.6	+19, +24	+2.6, 3.7	-29, +41	2.1, +3.3	+23, +35
K_2 Note 1	±25%	0.0/0.0	0/0	+0.1/-0.1	+2/-2	+0.3/-0.4	+5/-7
Depth Note 1	±25%	0.0/0.0	0/0	-0.1/+0.1	-2/+2	-0.4/+0.5	-7/+8
SOD Note 1	Note 2	0.0, 0.0	0, 0	0.0, -0.1	0/-2	0.0/-0.1	0/-2
SOD	Note 2	0.0, -0.1	0, -1	0.0, -0.2	0, -2	0.0, -0.1	0, -1
Ammonia-N (mg/l)							
Temperature	±5°F	-0.06/+0.06	-3/+3	-0.16/+0.12	-6/+4	-0.2/+0.16	-8/+6
Velocity	±25%	+.05/-.04	+3/-2	+.12/-.08	+4/-3	+.12/-.10	+4/-4
Travel Time (Rate)	±25%	-.06/+.06	-3/+3	-.12/+.14	-4/+5	-.16/+.20	-6/+8
Flow	675 cfs, 1500 cfs	-1.0, -1.3	-56, -72	-1.4, -2.0	-50, -71	-1.2, -1.8	-46, -68
Total Cyanide (μg/l)							
Temperature	±5°F	-3/+3	-4/+4	-7/+7	-10/+10	-7/+7	-20/+20
Velocity	±25%	+4/-4	+6/-6	+9/-11	+13/-16	+9/-10	+26/-29
Travel Time (Rate)	±25%	-3/+5	-4/+7	-12/+15	-18/+22	-11/+15	-31/+43
Flow	675 cfs, 1500 cfs	-37, -50	-51, -69	-15, -32	-22, -47	+5, -4	+15, -12
Phenolics (μg/l)							
Temperature	±5°F	-1/+1	-5/+5	-2.5/+2.5	-15/+15	-2/+2	-25/+25
Velocity	±25%	+1/-1	+5/-5	+2.5/-3	+15/-17	+2/-2	+25/-25
Travel Time (Rate)	±25%	-2/+2	-10/+10	-3/+4	-17/+22	-3/+4	-38/+50
Flow	675 cfs, 1500 cfs	-8, -9	-40, -45	-1, -4	-6, -24	+4, +3	+50, +38

1) Sensitivity determined for July design flow conditions (480 cfs at Youngstown).

2) First value given is with measured SOD rates applied to the portion of the river bottom where sediments were found by the Corps of Engineers. Second value is with SOD rates applied to 100% of river bottom (see text).

* Percentages are based on the difference between the computed and the equilibrium temperature for the base case.

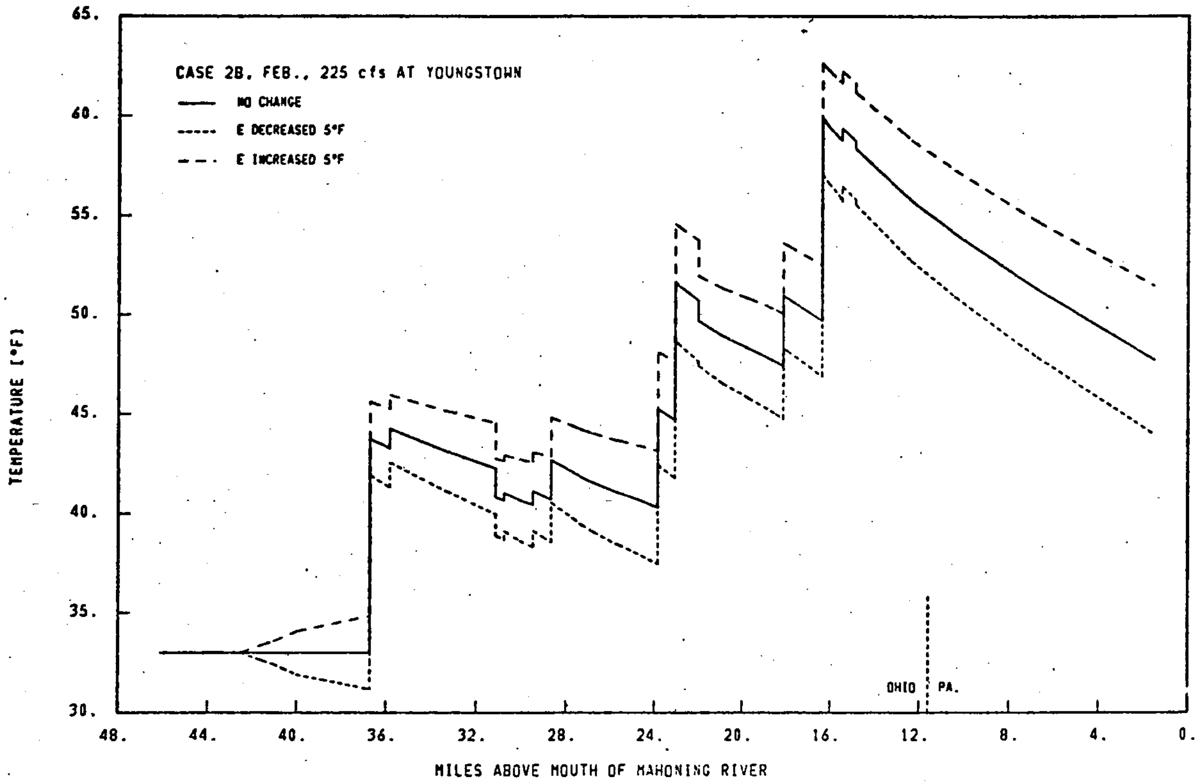


FIGURE VIII-13
MAHONING RIVER - SENSITIVITY TO EQUILIBRIUM TEMPERATURE
TEMPERATURE VS. RIVER MILE

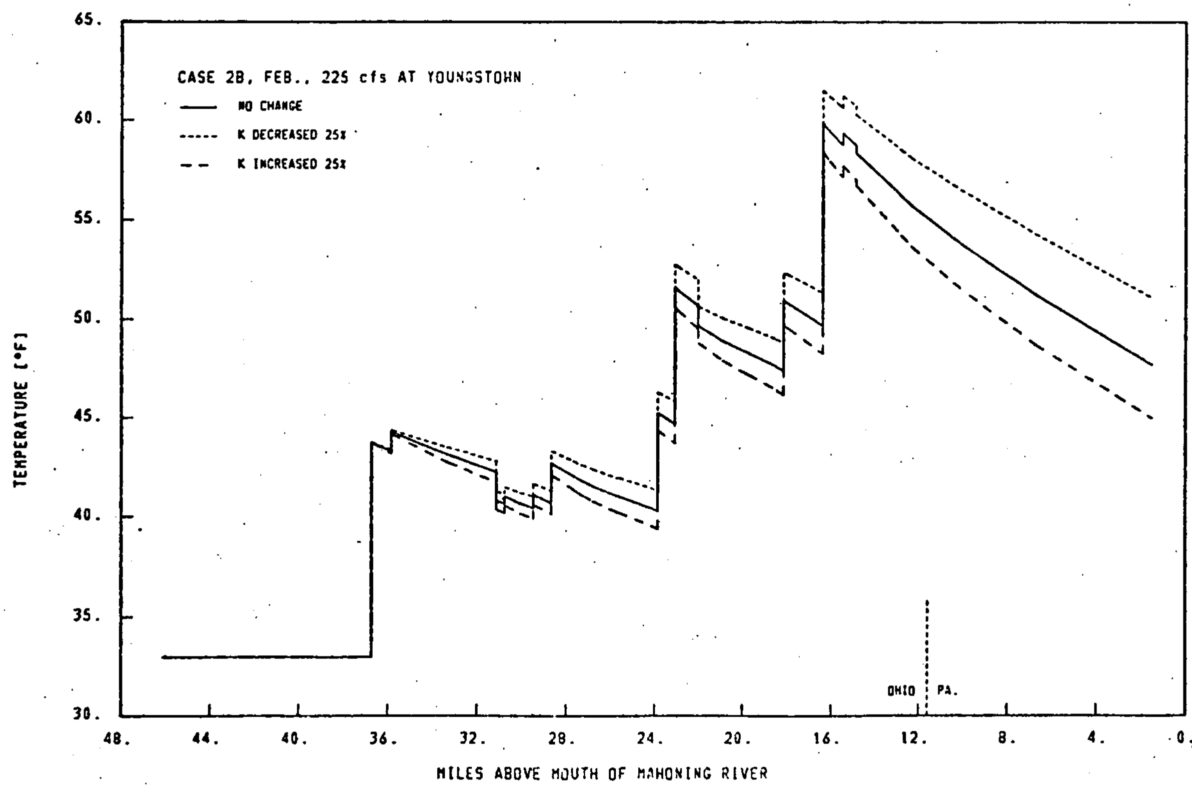


FIGURE VIII-14
MAHONING RIVER - SENSITIVITY TO HEAT TRANSFER RATE
TEMPERATURE VS. RIVER MILE

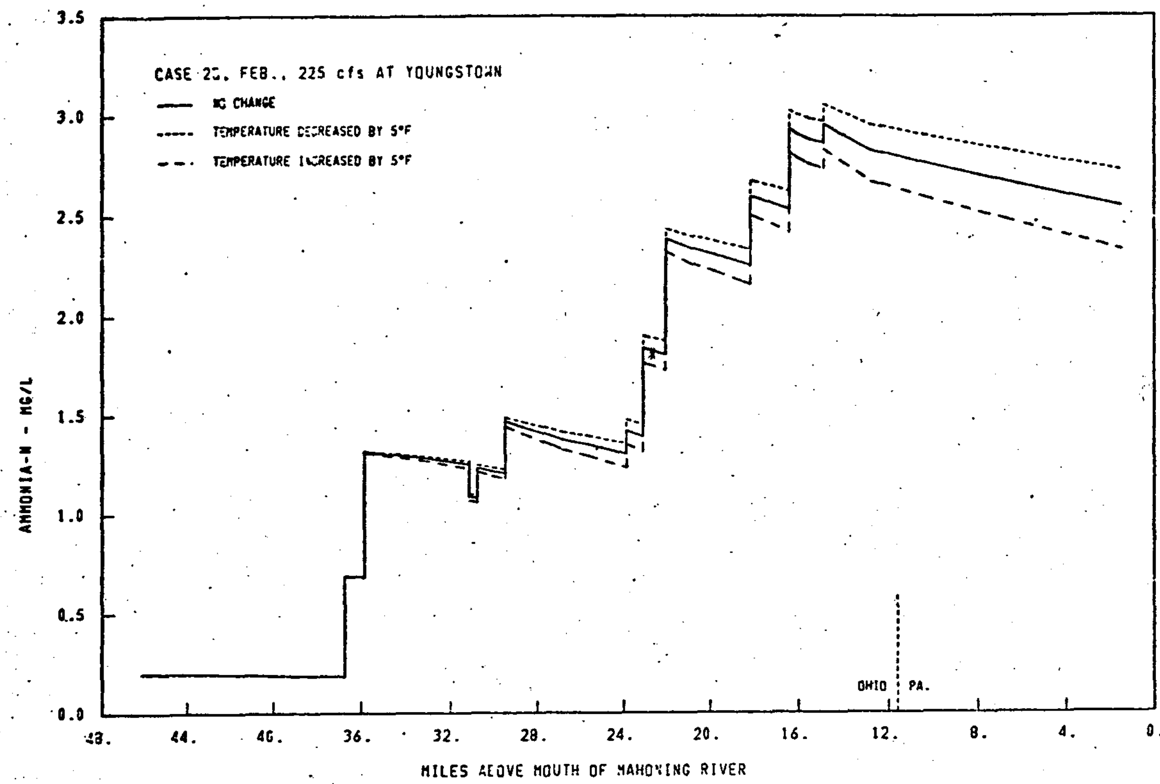


FIGURE VIII-15
MAHONING RIVER - SENSITIVITY TO TEMPERATURE
AMMONIA-NITROGEN VS. RIVER MILE

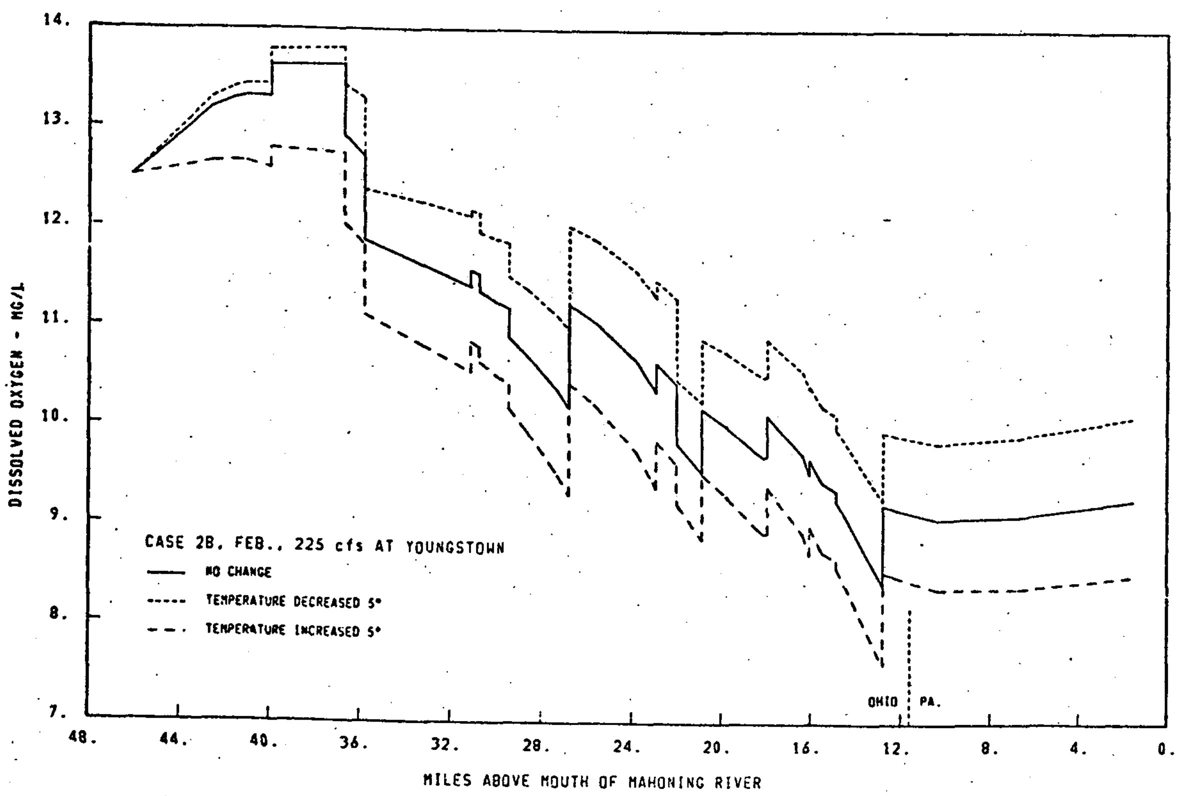


FIGURE VIII-16
MAHONING RIVER - SENSITIVITY TO TEMPERATURE
DISSOLVED OXYGEN VS. RIVER MILE

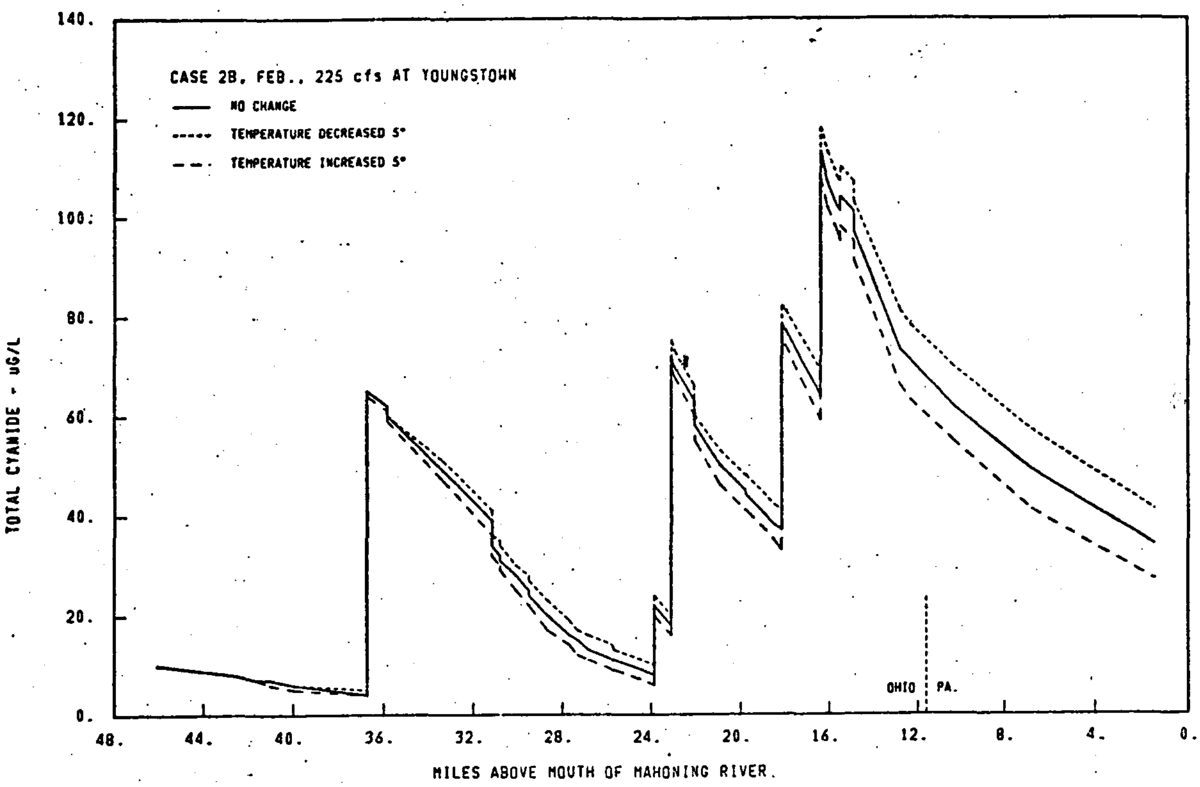


FIGURE VIII-17
MAHONING RIVER - SENSITIVITY TO TEMPERATURE
TOTAL CYANIDE VS. RIVER MILE

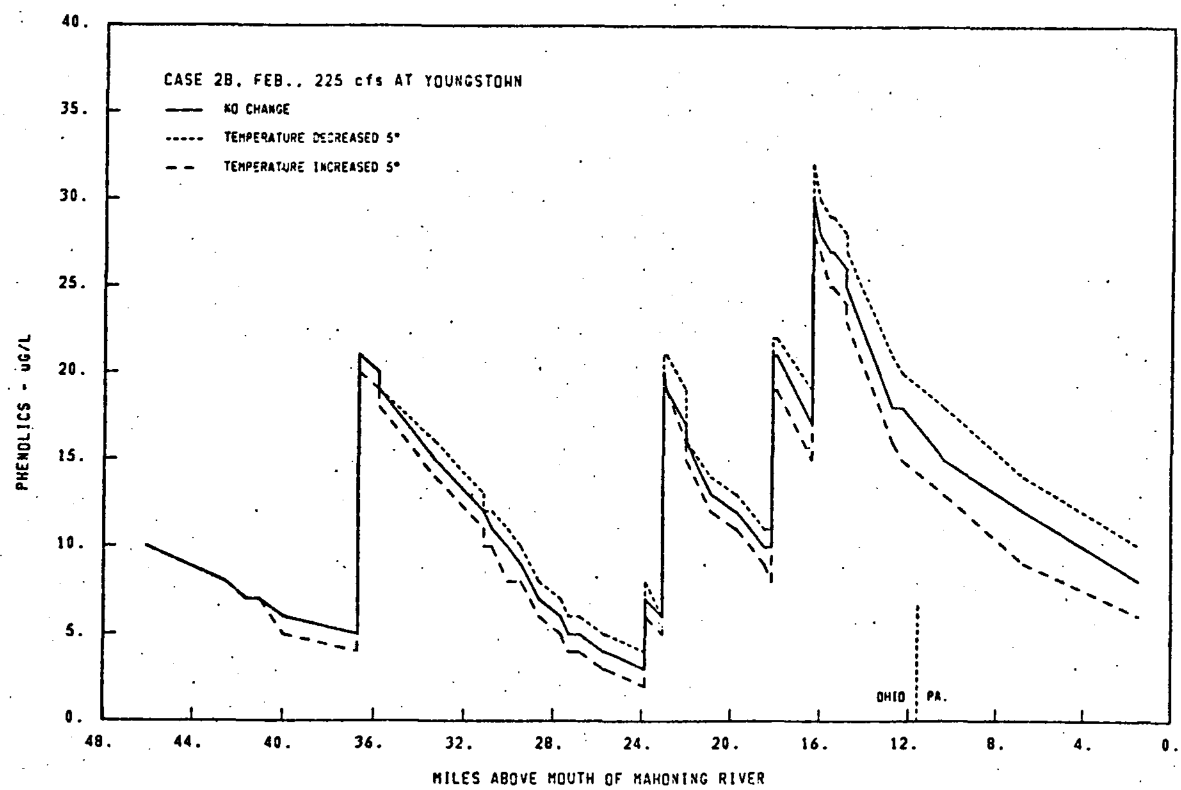


FIGURE VIII - 18
MAHONING RIVER - SENSITIVITY TO TEMPERATURE
PHENOLICS VS RIVER MILE

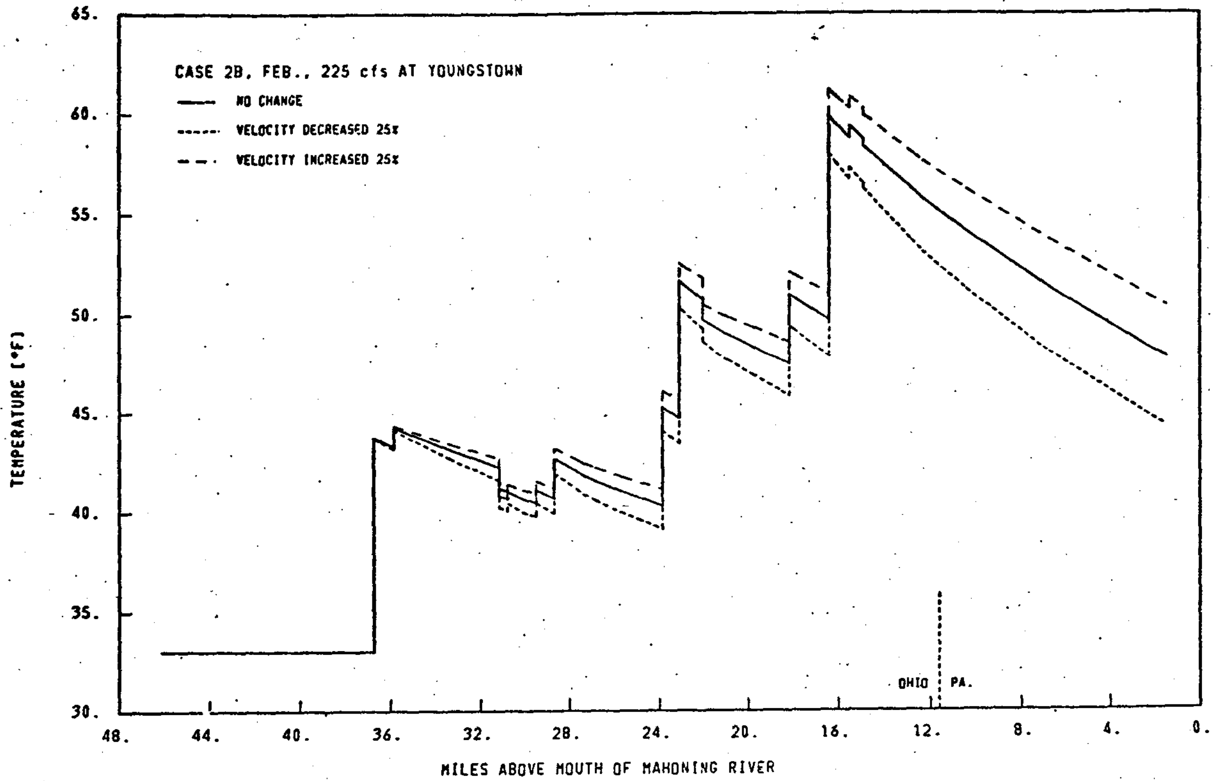


FIGURE VIII-19
MAHONING RIVER - SENSITIVITY TO VELOCITY
TEMPERATURE VS. RIVER MILE

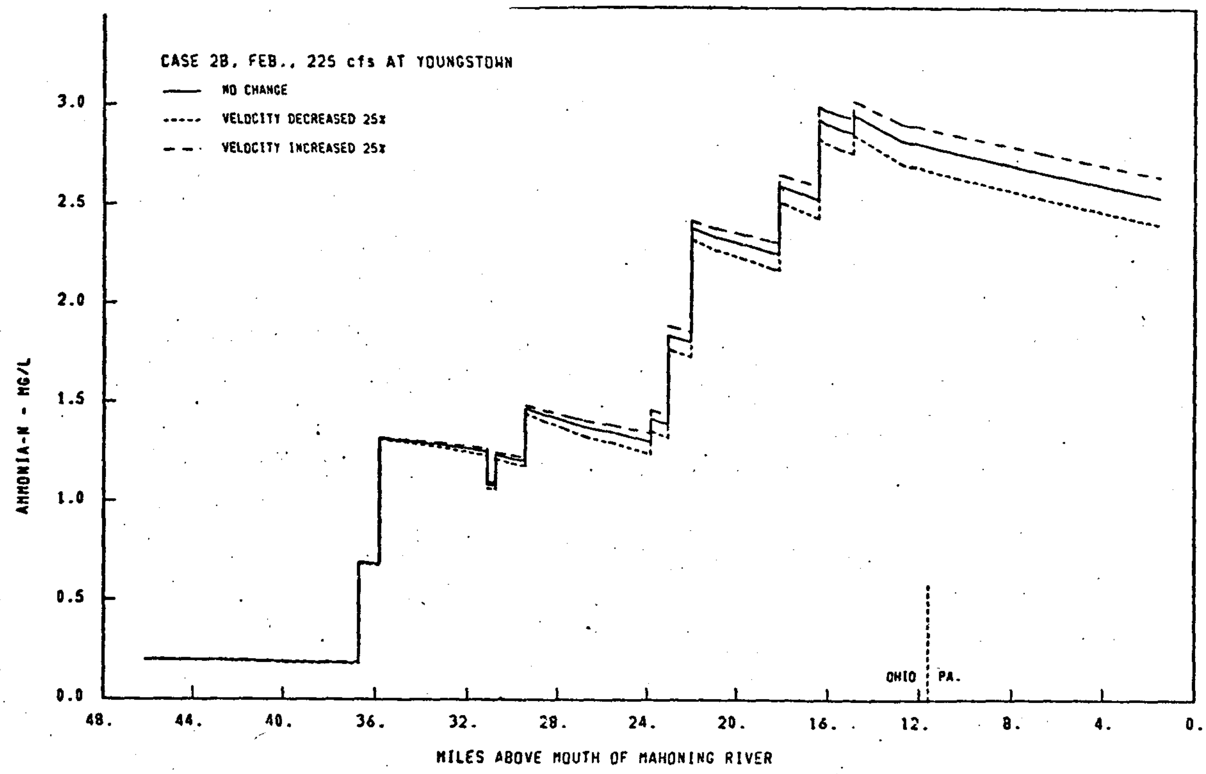


FIGURE VIII-20
MAHONING RIVER - SENSITIVITY TO VELOCITY
AMMONIA-NITROGEN VS. RIVER MILE

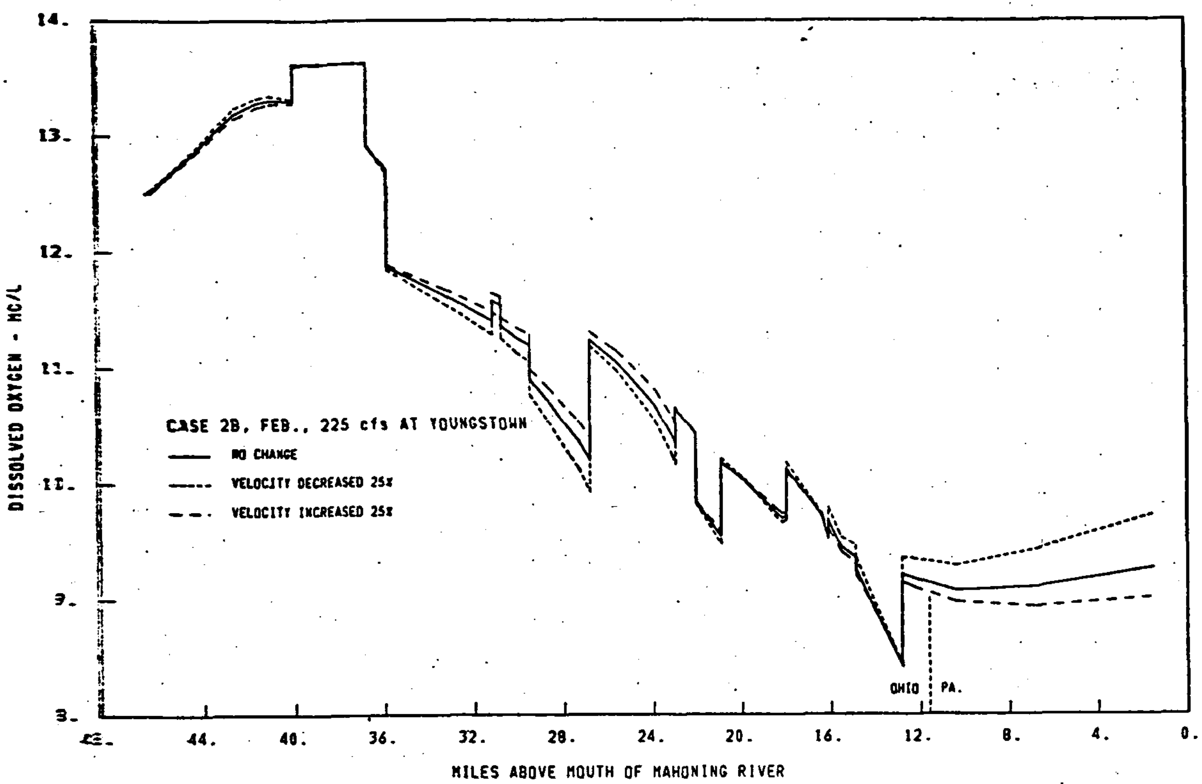


FIGURE VIII-21
MAHONING RIVER - SENSITIVITY TO VELOCITY
DISSOLVED OXYGEN VS. RIVER MILE

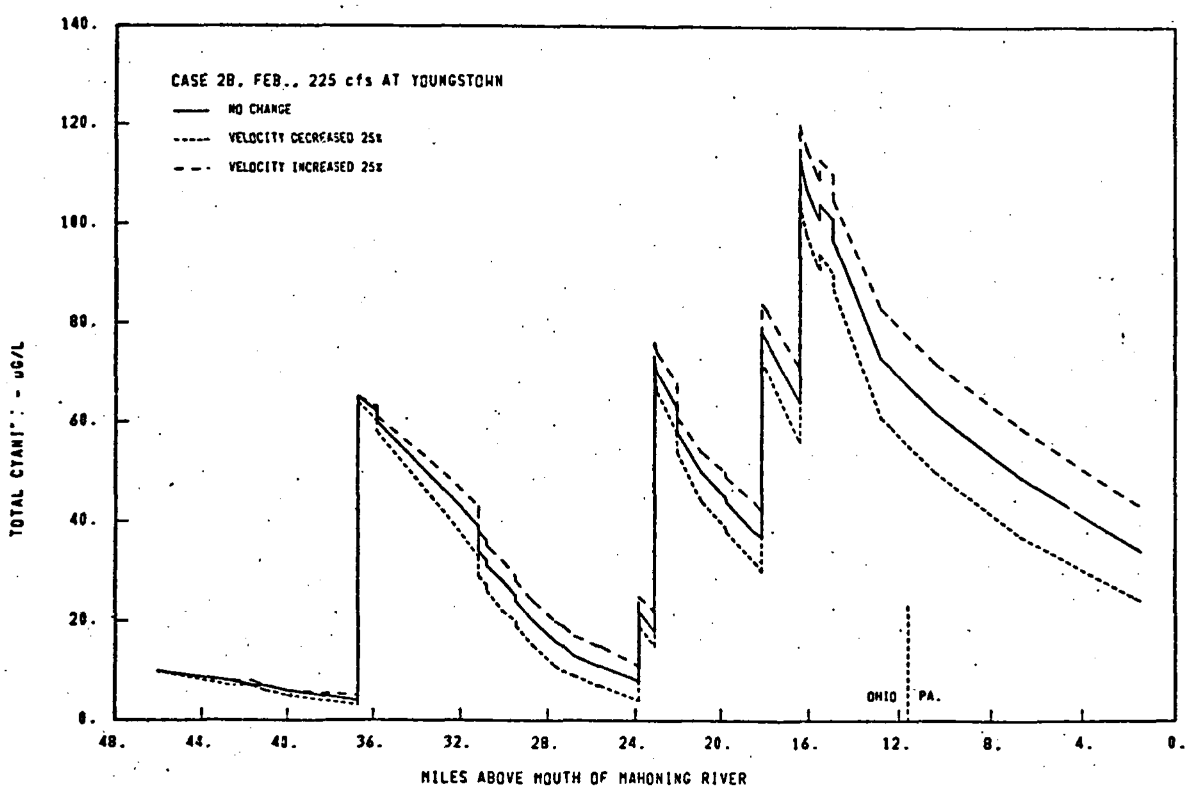


FIGURE VIII-22
MAHONING RIVER - SENSITIVITY TO VELOCITY
TOTAL CYANIDE VS. RIVER MILE

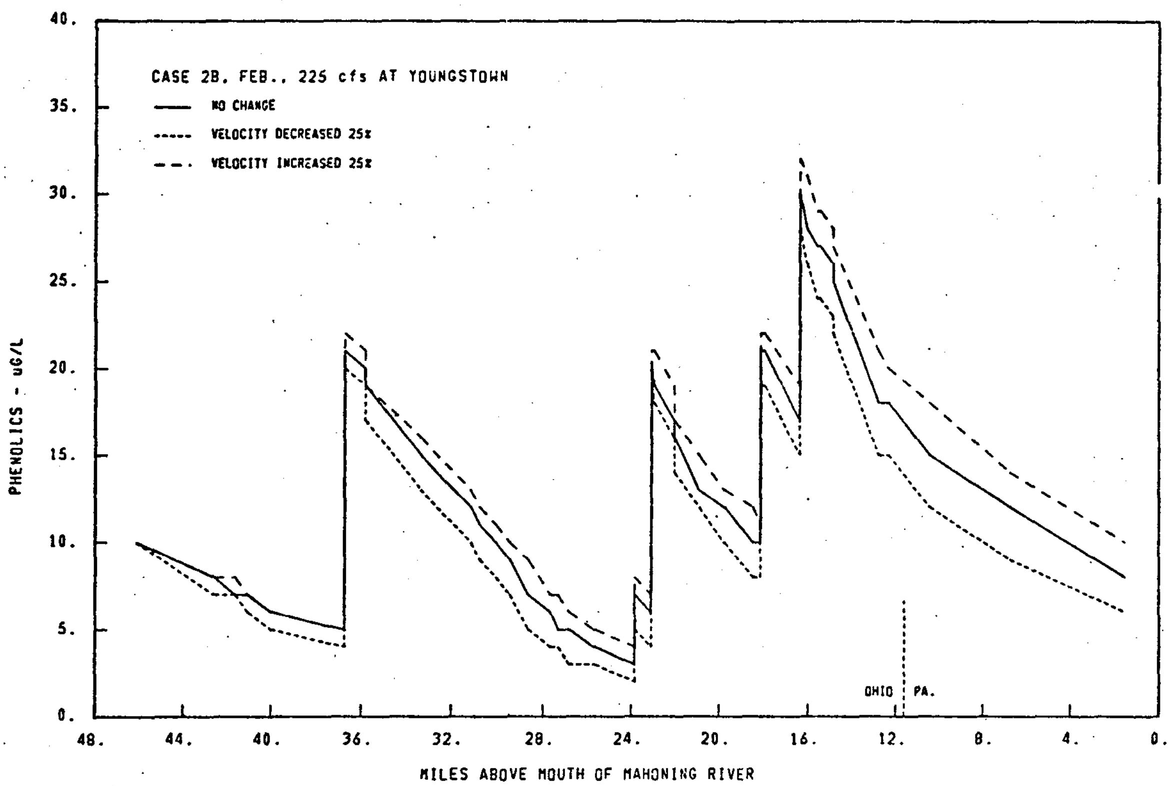


FIGURE VIII-23
MAHONING RIVER - SENSITIVITY TO VELOCITY
PHENOLICS VS. RIVER MILE

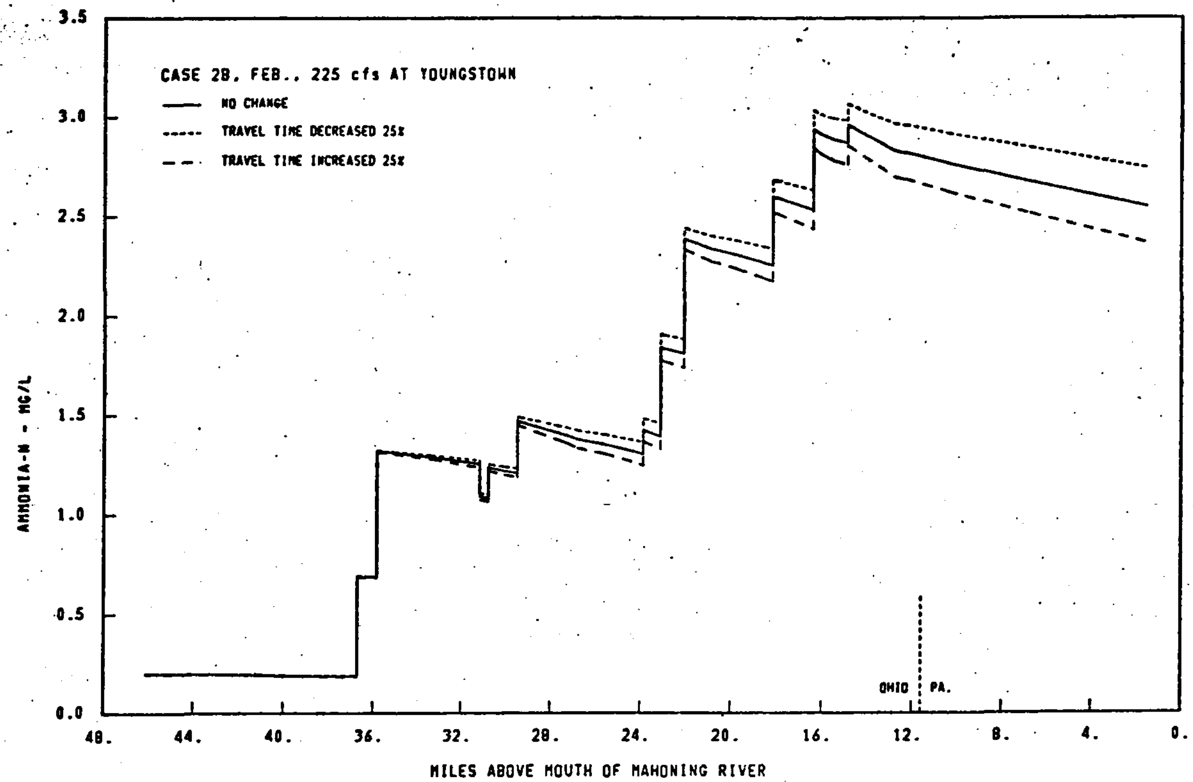


FIGURE VIII-24
MAHONING RIVER - SENSITIVITY TO TRAVEL TIME
AMMONIA-NITROGEN VS. RIVER MILE

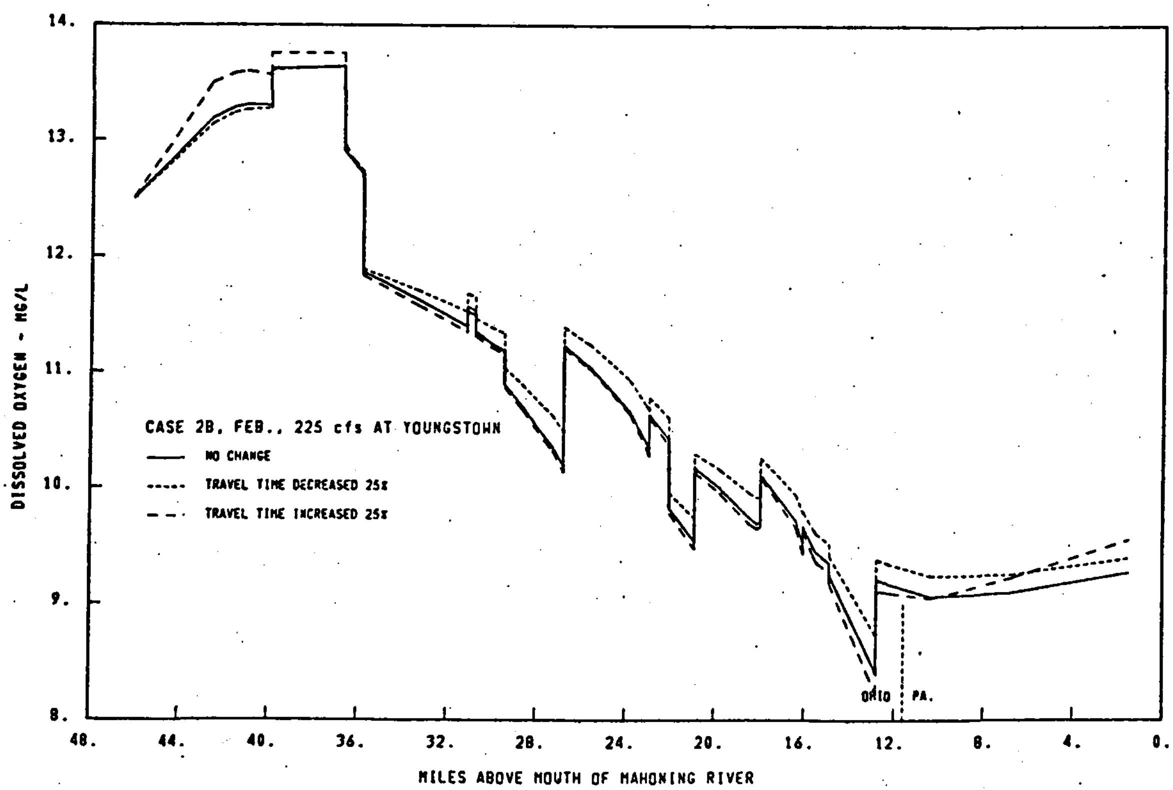


FIGURE VIII-25
MAHONING RIVER - SENSITIVE TO TRAVEL TIME
DISSOLVED OXYGEN VS. RIVER MILE

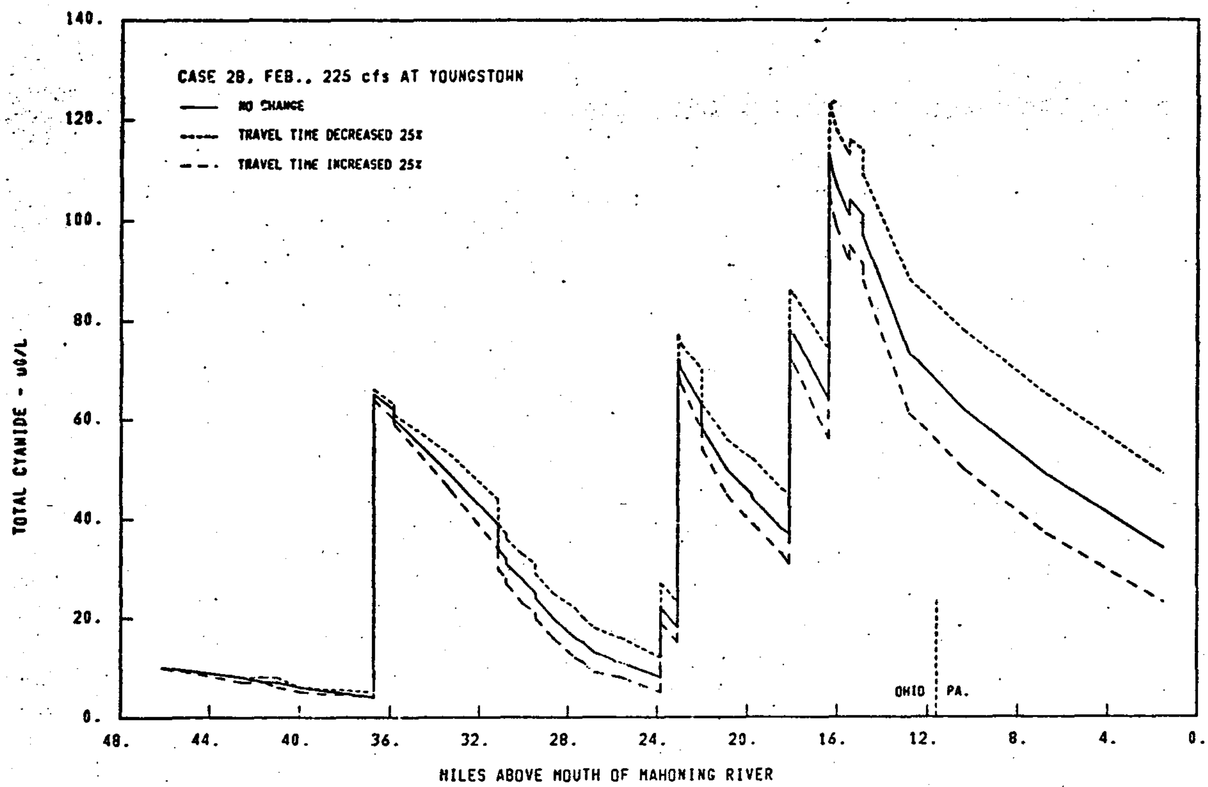


FIGURE VIII-26
MAHONING RIVER - SENSITIVITY TO TRAVEL TIME
TOTAL CYANIDE VS. RIVER MILE

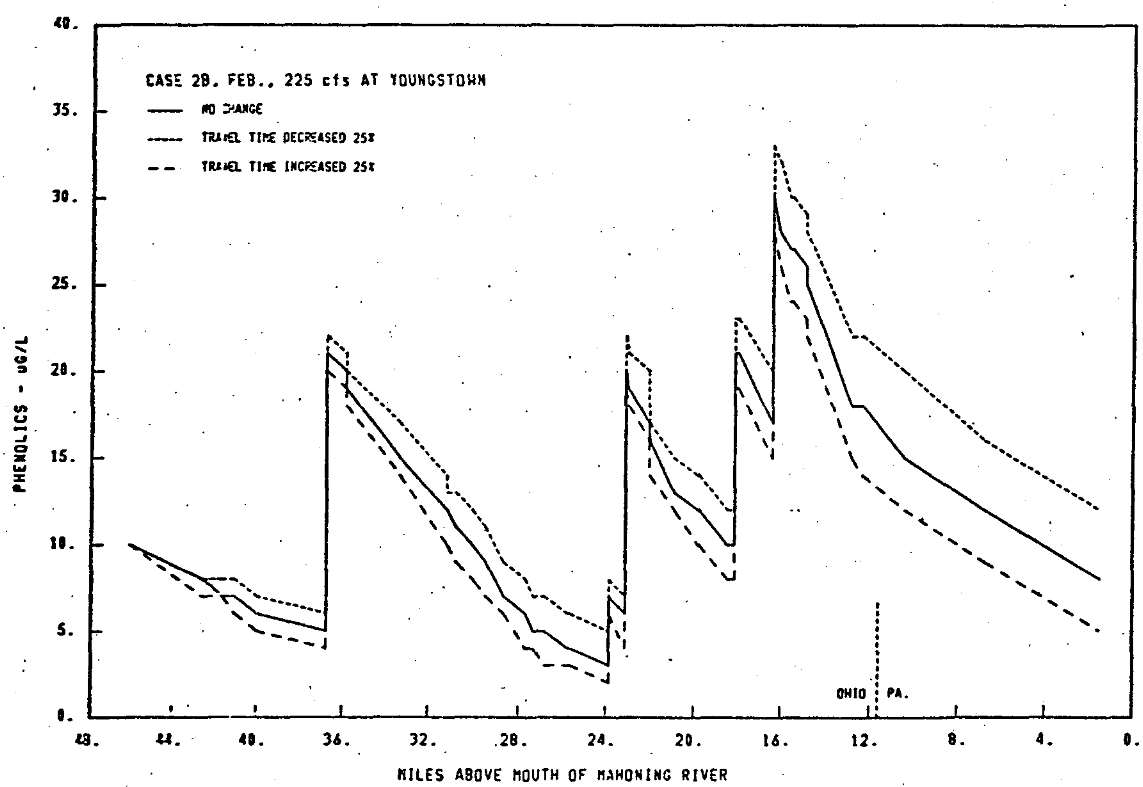


FIGURE VIII-27
MAHONING RIVER - SENSITIVITY TO TRAVEL TIME
PHENOLICS VS RIVER MILE

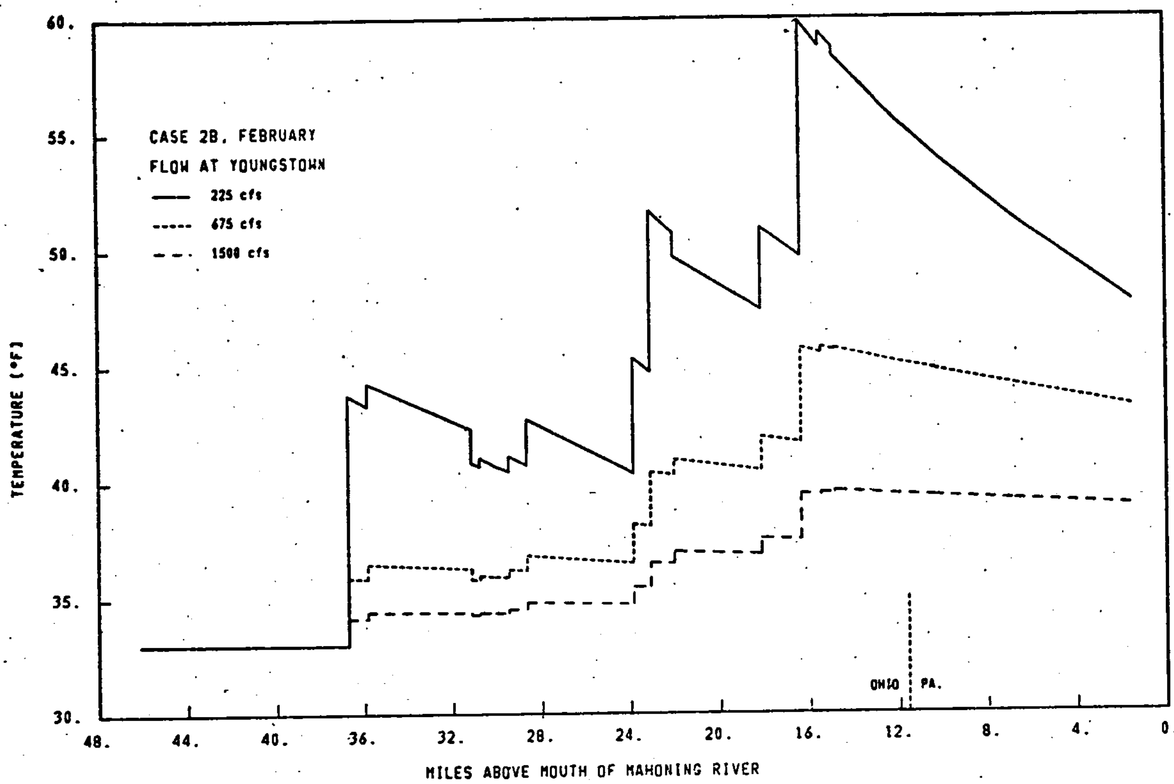


FIGURE VIII-28
MAHONING RIVER - SENSITIVITY TO FLOW
TEMPERATURE VS. RIVER MILE

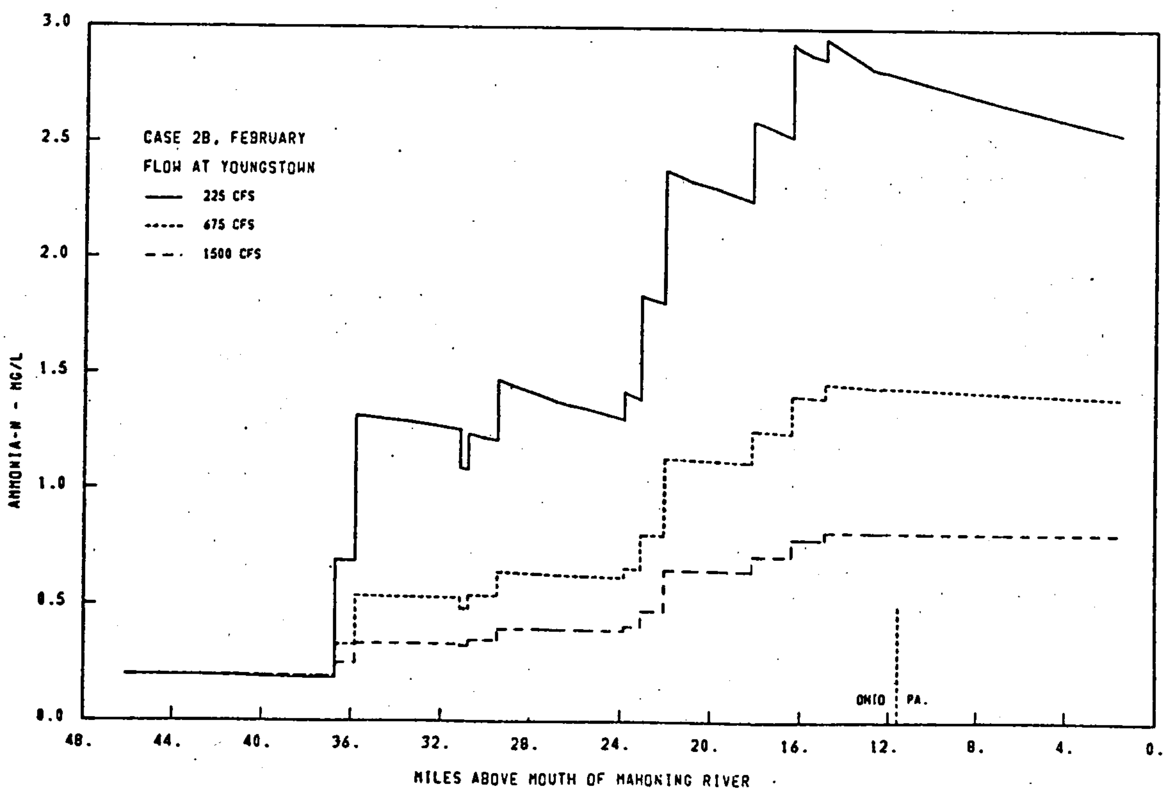


FIGURE VIII-29
MAHONING RIVER - SENSITIVITY TO FLOW
AMMONIA-NITROGEN VS. RIVER MILE

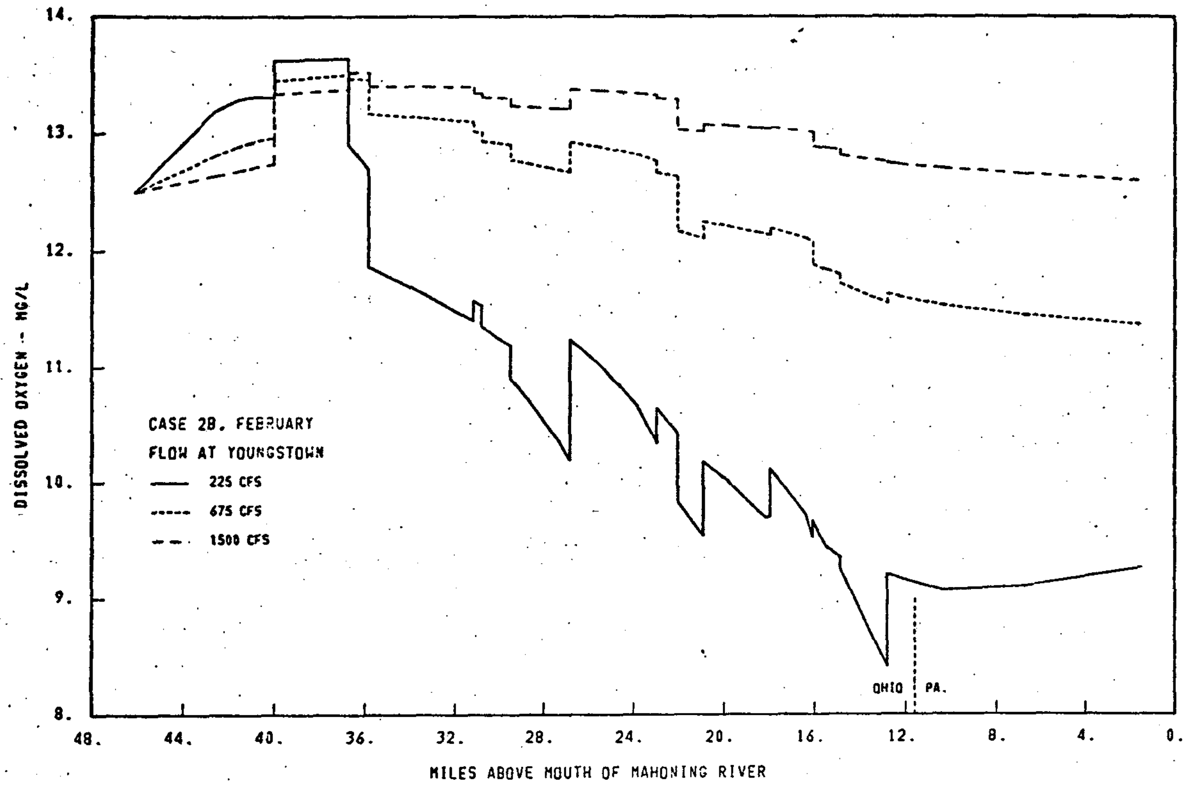
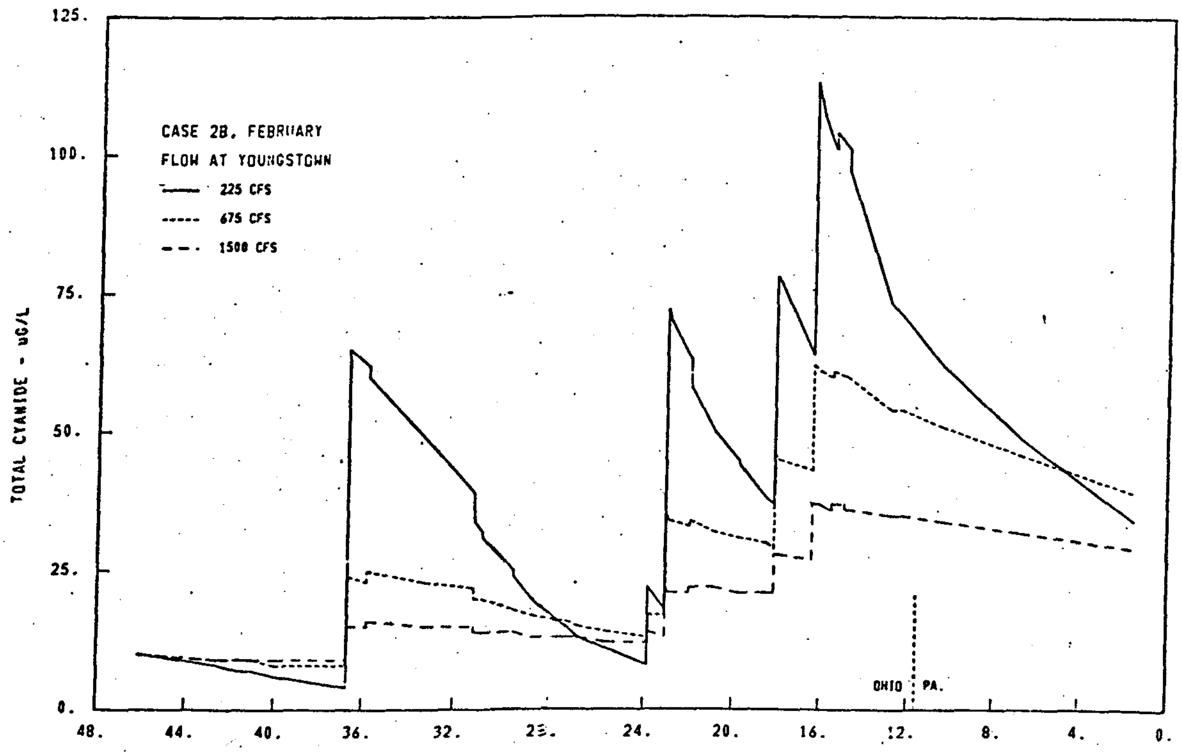


FIGURE VIII-30
DISSOLVED OXYGEN VS. RIVER MILE
MAHONING RIVER - SENSITIVITY TO FLOW



MILES ABOVE MOUTH OF MAHONING RIVER

FIGURE VIII-31
MAHONING RIVER - SENSITIVITY TO FLOW
TOTAL CYANIDE VS. RIVER MILE

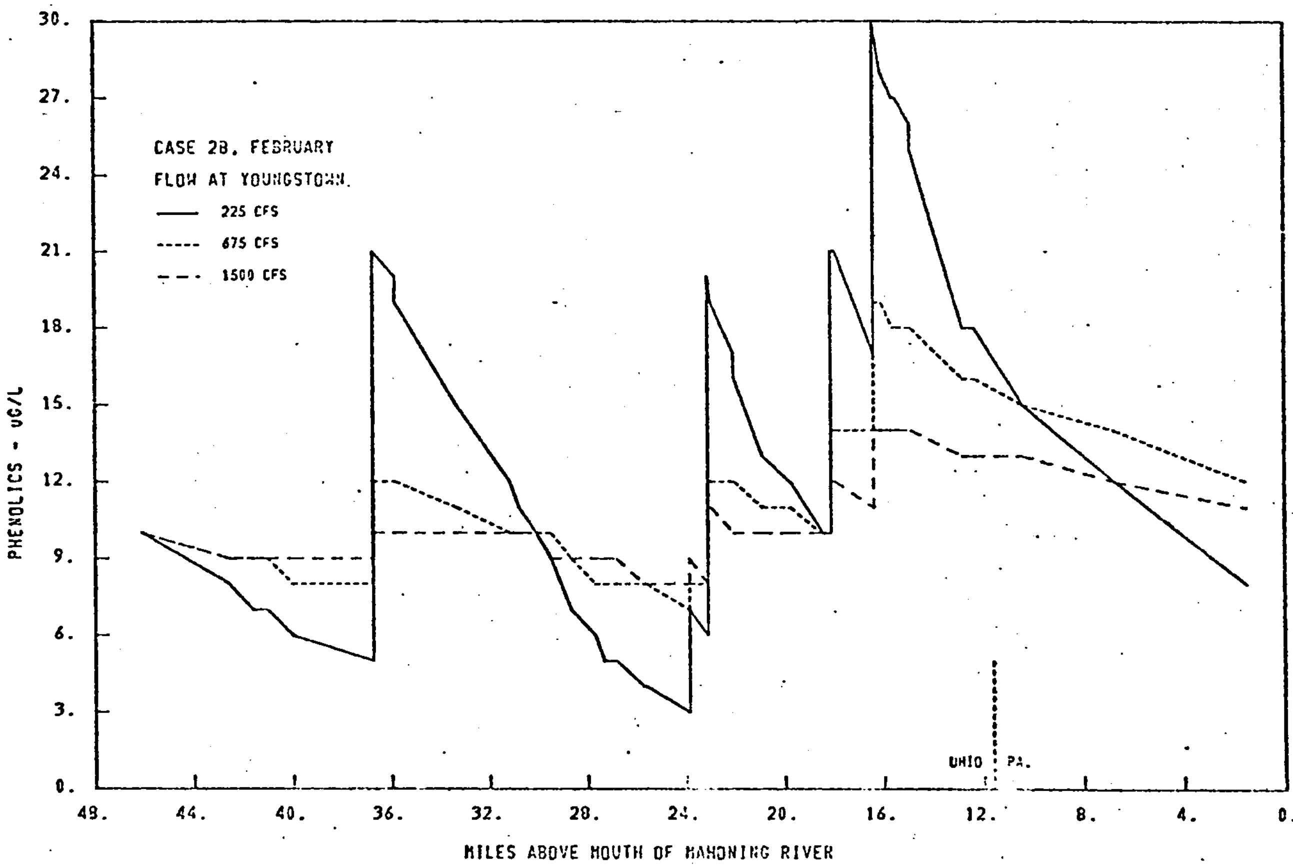


FIGURE VIII-32
MAHONING RIVER - SENSITIVITY TO FLOW
PHENOLICS VS. RIVER MILE

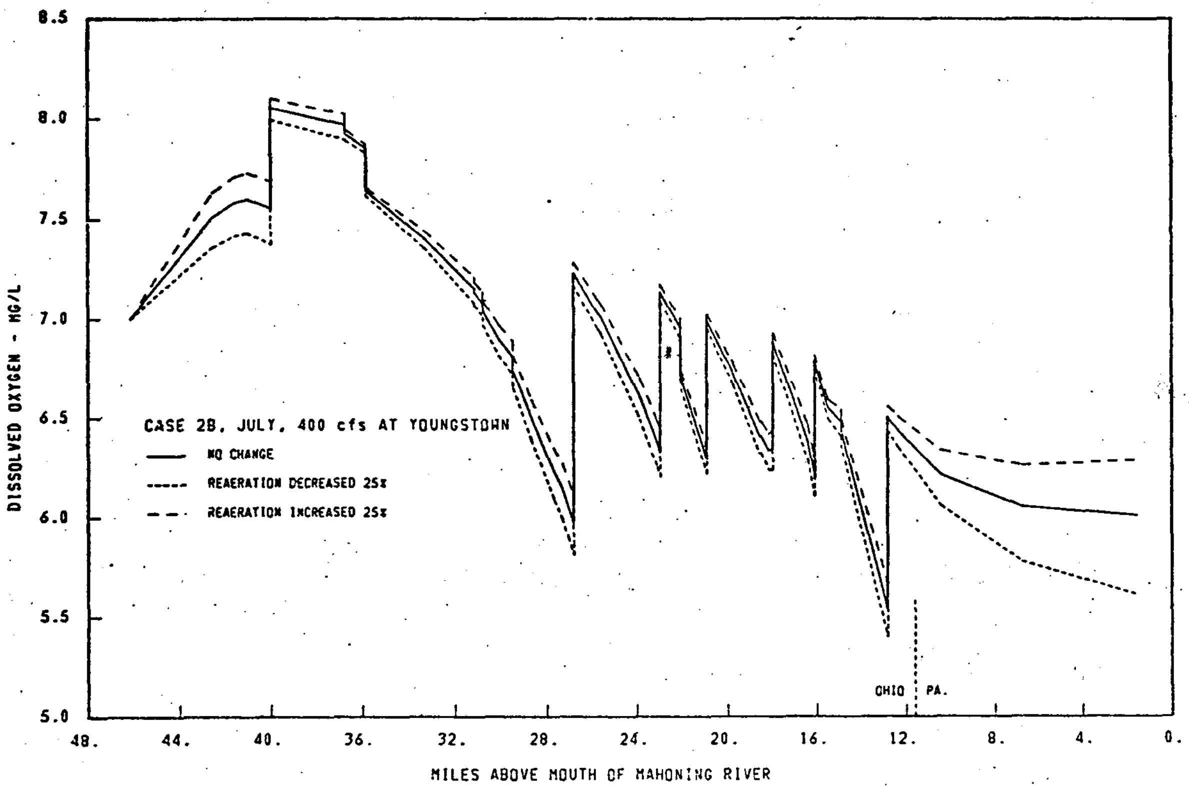


FIGURE VIII-33
MAHONING RIVER - SENSITIVITY TO REAERATION
DISSOLVED OXYGEN VS. RIVER MILE

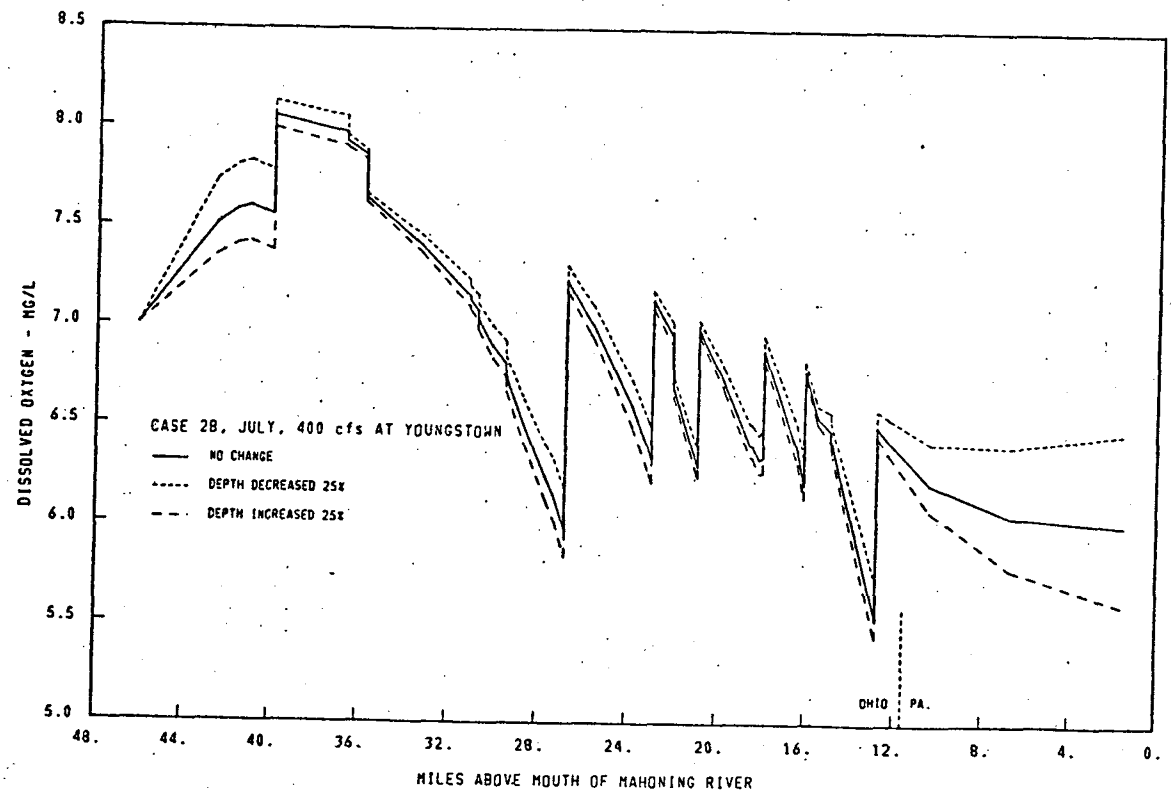


FIGURE VIII-34
MAHONING RIVER - SENSITIVITY TO DEPTH
DISSOLVED OXYGEN VS. RIVER MILE

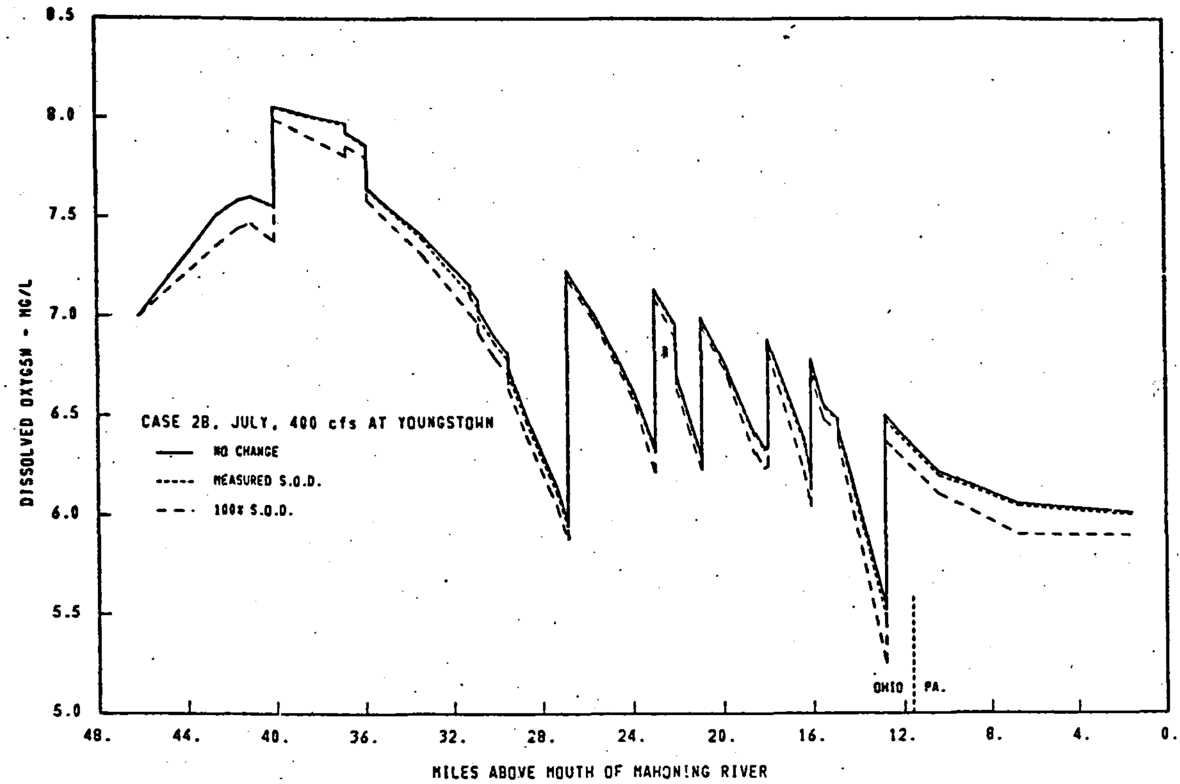


FIGURE VIII-35
MAHONING RIVER - SENSITIVITY TO SEDIMENT OXIDATION DEMAND
DISSOLVED OXYGEN VS. RIVER MILE

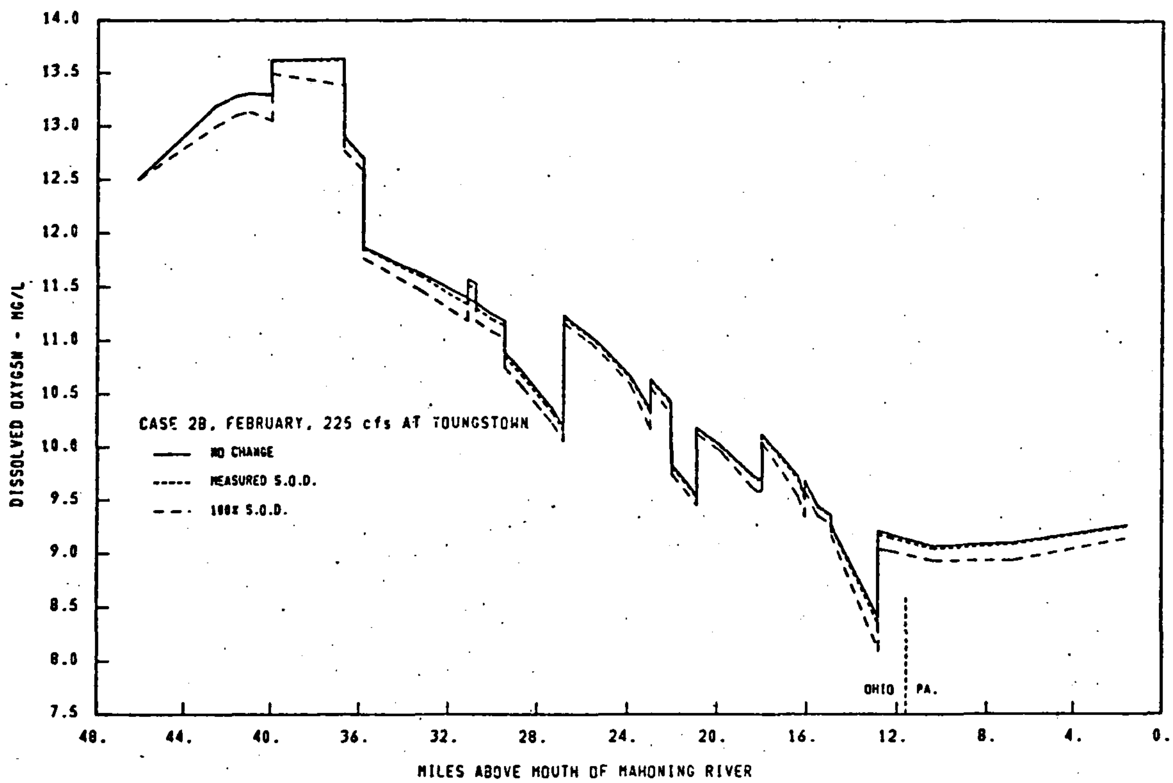


FIGURE VIII-36
MAHONING RIVER - SENSITIVITY TO SEDIMENT OXIDATION DEMAND
DISSOLVED OXYGEN VS. RIVER MILE

c. Projected Water Quality in Ohio

1) February Conditions

Figures VIII-37 to VIII-41 illustrate profiles of temperature, dissolved oxygen, ammonia-N, total cyanide, and phenolics, respectively, for the entire study area at the winter critical flow of 225 cfs for Cases 1, 2b, 3, and 5. Cases 2a and 4 were not included.

As shown in Figure VIII-37, stream temperatures in the range of 38 to 45°F are expected from the Republic Steel-Warren Plant to the Ohio Edison-Niles Plant for each case studied. The lower values reflect BATEA treatment at Republic Steel. Temperatures near 65°F, 30°F above natural levels, are predicted downstream of Ohio Edison with no cooling at that facility. The Case 1 and Case 5 responses are separated only by the reduction in thermal loads for BATEA treatment of hot forming wastes at steel plants downstream of Ohio Edison. The much lower Case 3 temperatures (about 40°F) reflect cooling at Ohio Edison. Downstream of the Youngstown Sheet and Tube-Campbell Works, the responses for Cases 3 and 5 are nearly identical. While the differences between Case 3 and Case 5 are small downstream of Struthers, the differences from Ohio Edison to upper Youngstown (River mile 24) are substantial, with the Case 3 response providing temperatures low enough for all stream uses. Temperatures above the proposed Pennsylvania standard of 56°F are only seen for a short reach of stream in Ohio downstream of the Youngstown Sheet and Tube-Campbell Works with the Case 3 thermal discharges.

The dissolved oxygen and ammonia-N responses for Case 2b and Case 3 are identical as only discharge loadings of total cyanide and phenolics were modified for Case 3. The differences in the Case 3 and Case 5 dissolved oxygen profiles illustrated in Figure VIII-38 primarily result from the large differences in stream temperatures reviewed above. Figure VIII-38 also indicates about half of the differences in the dissolved oxygen responses between Cases 1 and 3 result from thermal effects and half from the higher degree of municipal treatment contemplated for Case 3. Although values above the 5.0 mg/l Pennsylvania water quality standard are projected for all cases, deficits of three to seven mg/l from upstream saturation values are shown.

Ammonia-N profiles illustrated in Figure VIII-39 demonstrate significant differences in the Warren area between Cases 1 and 3 due to

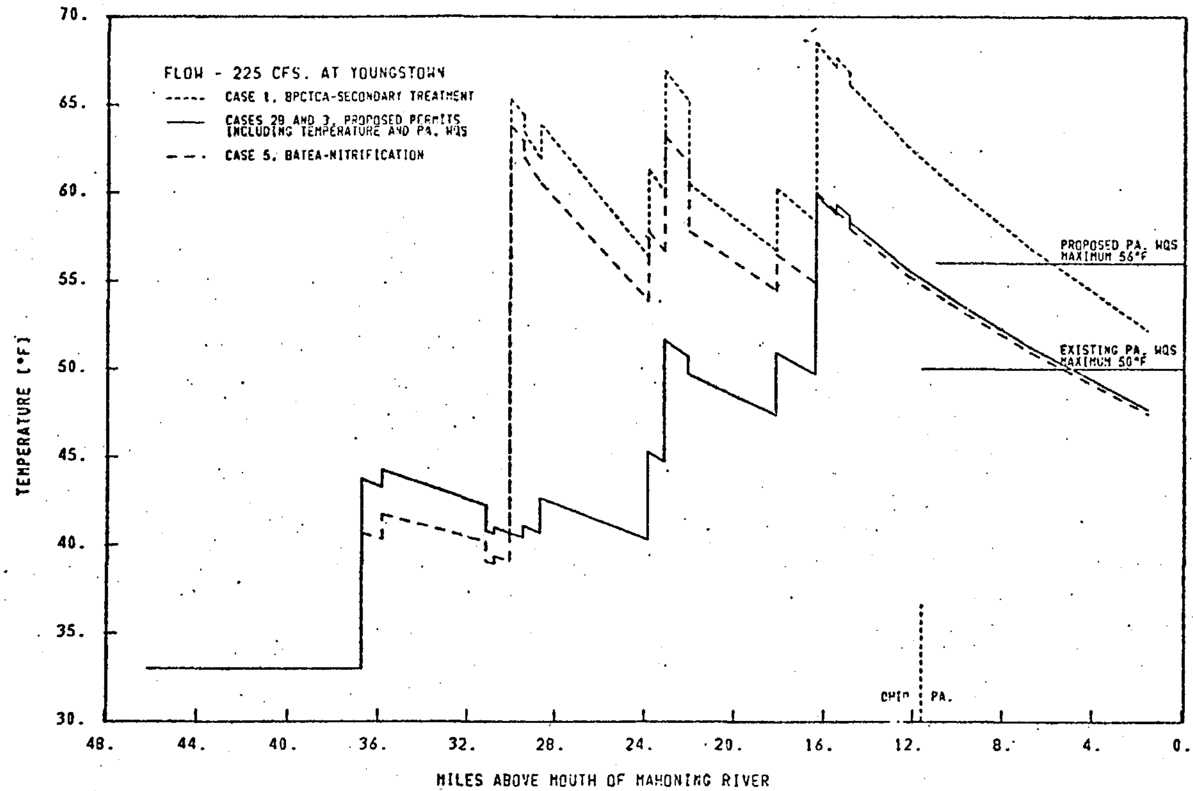


FIGURE VIII-37
MAHONING RIVER - WINTER CRITICAL FLOW (FEBRUARY)
TEMPERATURE VS. RIVER MILE

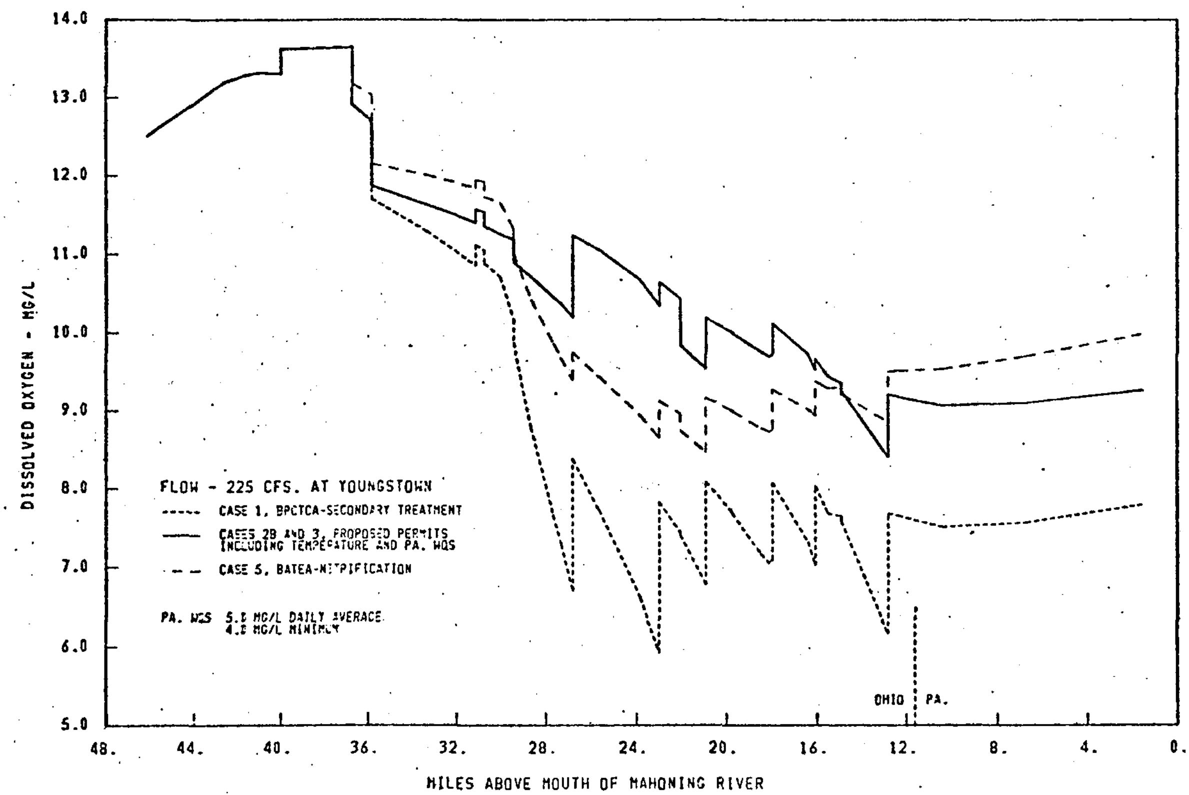


FIGURE VIII-38
MAHONING RIVER - WINTER CRITICAL FLOW (FEBRUARY)
DISSOLVED OXYGEN VS. RIVER MILE

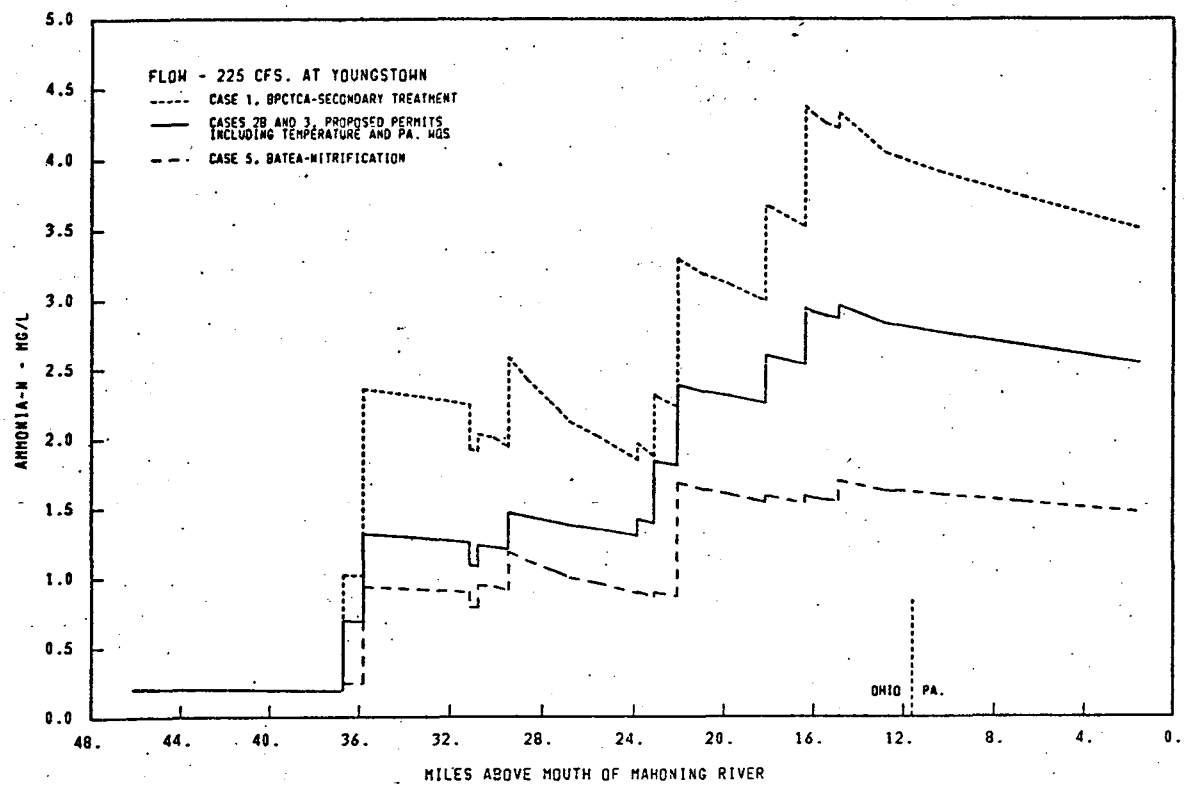


FIGURE VIII-39
MAHONING RIVER - WINTER CRITICAL FLOW (FEBRUARY)
AMMONIA-N VS. RIVER MILE

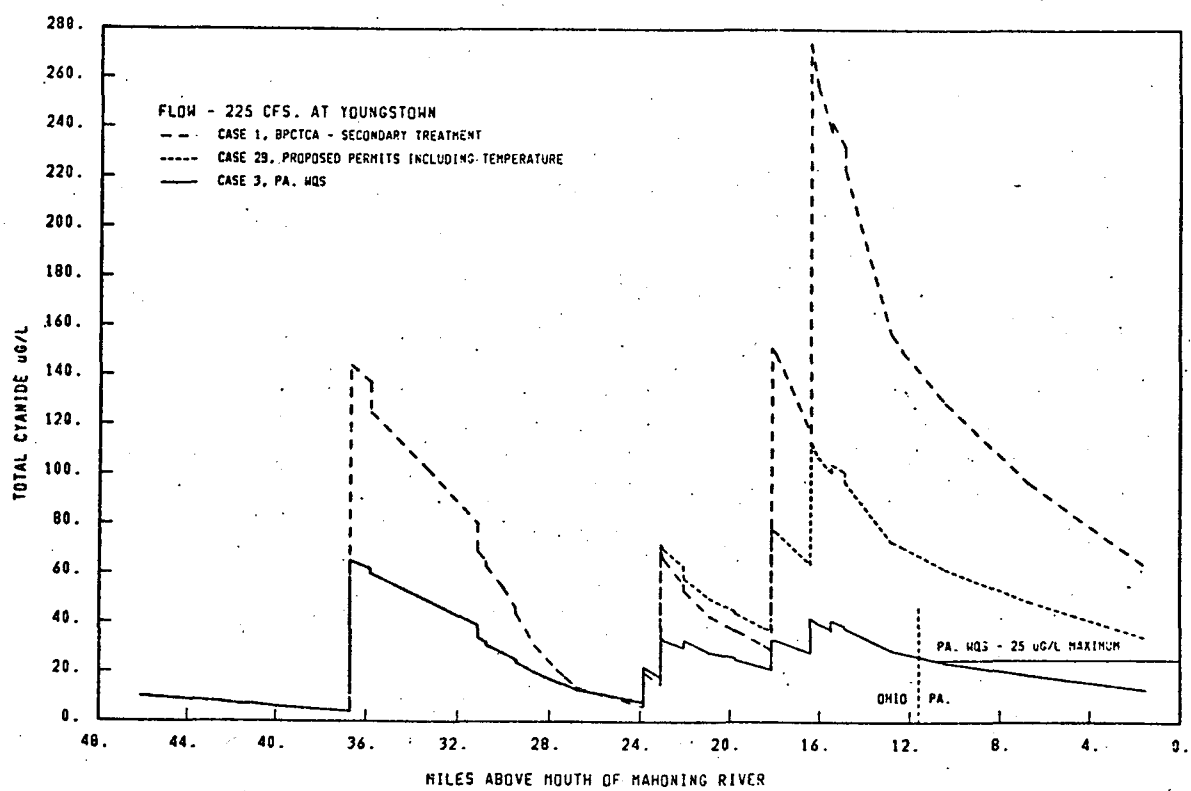


FIGURE VIII - 40
MAHONING RIVER - WINTER CRITICAL FLOW (FEBRUARY)
TOTAL CYANIDE VS. RIVER MILE

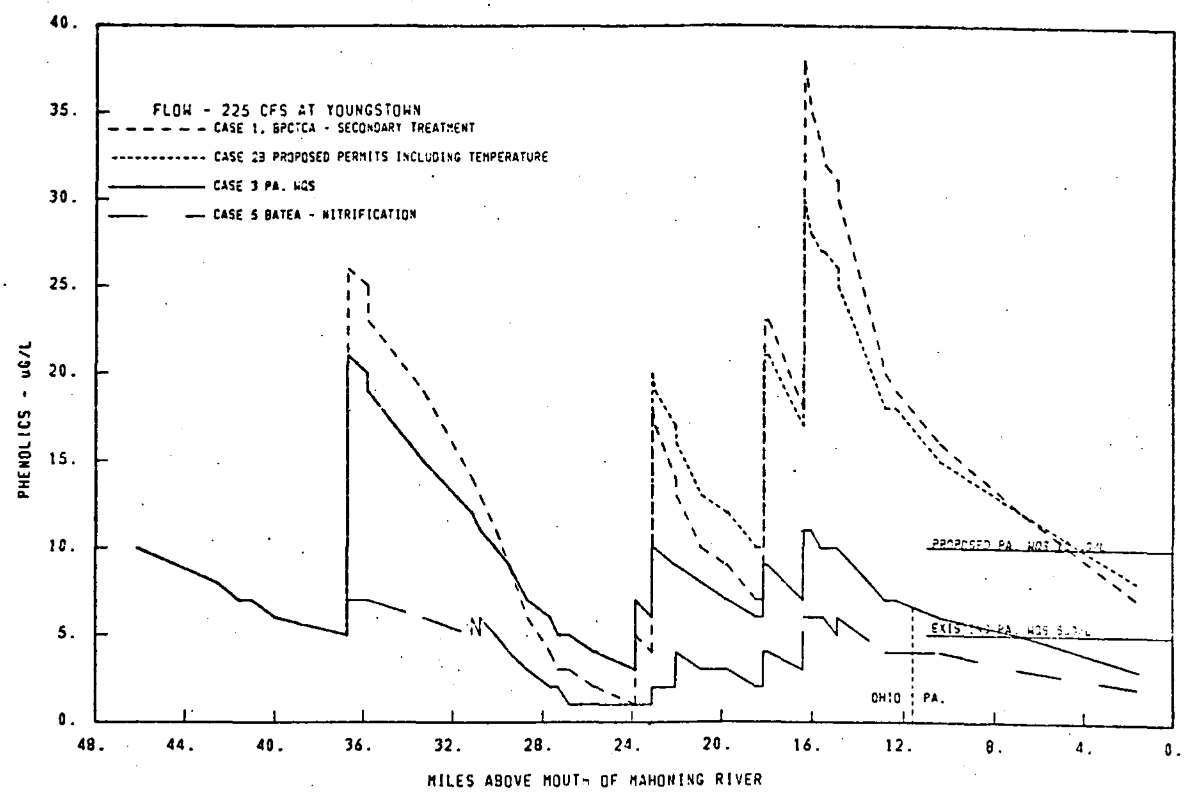


FIGURE VIII - 41
MAHONING RIVER - WINTER CRITICAL FLOWS (FEBRUARY)
PHENOLICS VS. RIVER MILE

nitrification at the Warren STP and the absence of coke plant wastes at the Republic Steel-Warren Plant. The difference just below the Warren STP amounts to over 1 mg/l in the stream. Case 5 (BATEA at the Republic Steel blast furnace) represents another 0.4 mg/l instream decrease below the Warren STP. Similar differences at downstream dischargers are shown for each case. For the pH and temperature conditions expected, the Case 3 profile represents marginal attainment of the recommended ammonia-N criterion.

Figure VIII-40 illustrates the extremely high total cyanide concentrations for Case 1 occurring at Warren, upper Youngstown, and in the stretch of the stream below Youngstown. Major differences between Case 1 and Case 2b are the result of coke plant dishcarges at the Republic Steel-Warren and Youngstown Plants, and the Youngstown Sheet and Tube-Campbell Works. Aside from the seven mile reach from the Republic Steel-Warren Plant to just downstream of Ohio Edison, the Case 3 total cyanide levels should be acceptable for most aquatic life uses throughout the stream.

The phenolics responses for each case shown in Figure VIII-41 are similar to the respective total cyanide responses. Again, aside from relatively short reach below Warren, instream levels associated with Case 3 should be adequate for most aquatic life uses throughout the stream. Concentrations associated with Cases 1 and 2b generally range from two to four times the recommended 10 ug/l criterion downstream of significant dischargers.

2) July Conditions

Figures VIII-42 to VIII-46 present computed profiles for temperature, dissolved oxygen, ammonia-N, total cyanide, and phenolics, respectively, for Case 1, 2b, 3 and 5. The maximum flow of 480 cfs included in the Corps of Engineers regulated schedule for late July was employed.

As shown in Figure VIII-42, temperature profiles associated with Cases 3 and 5 are acceptable for most aquatic life uses throughout the stream while the Case 1 values are above 90^{o}F from lower Youngstown to just below the Ohio-Pennsylvania state line. From Ohio Edison to the Youngstown Sheet and Tube-Campbell Works, the Case 3 thermal profile provides temperatures nearly 10^{o}F lower than Case 5, with values only

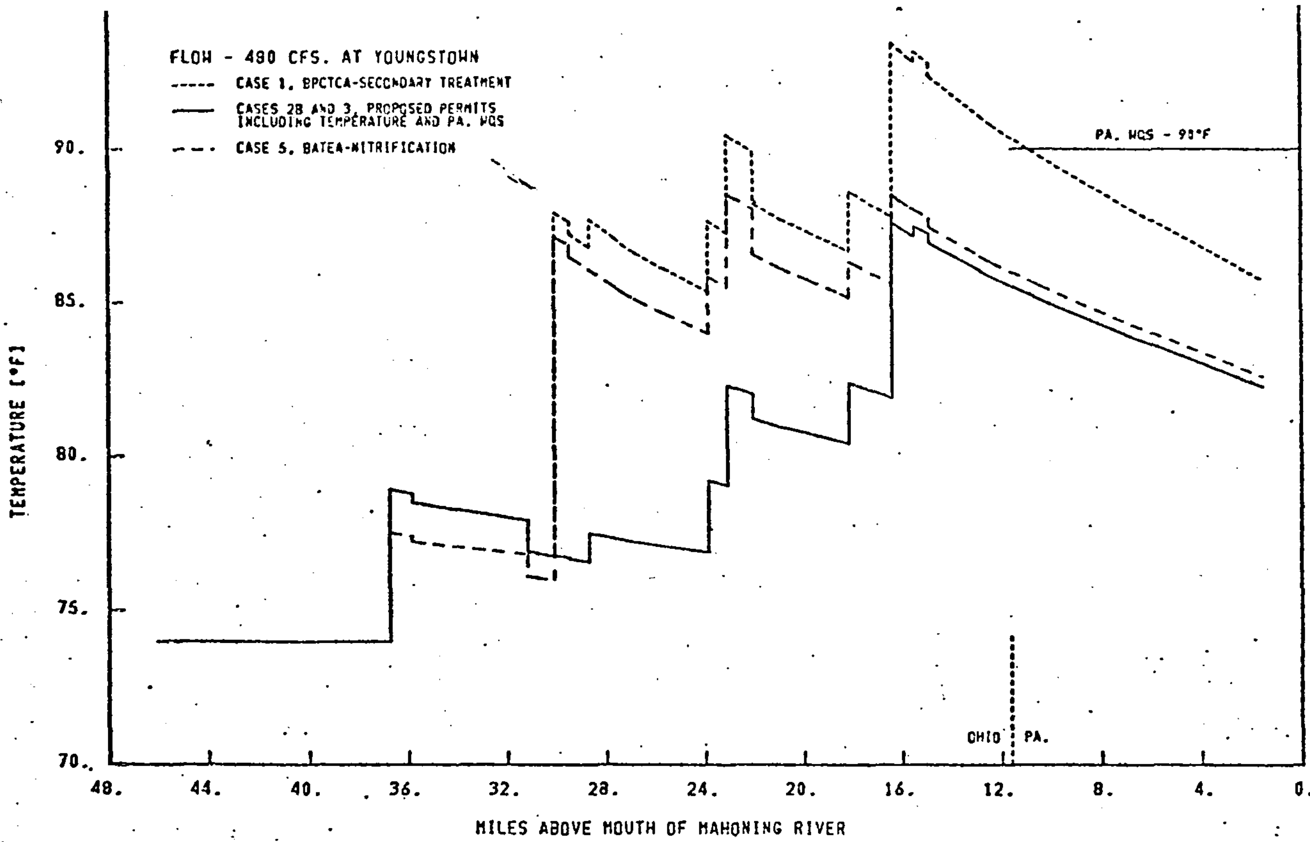


FIGURE VIII-42
MAHONING RIVER - SUMMER CRITICAL FLOW (JULY)
TEMPERATURE VS. RIVER MILE

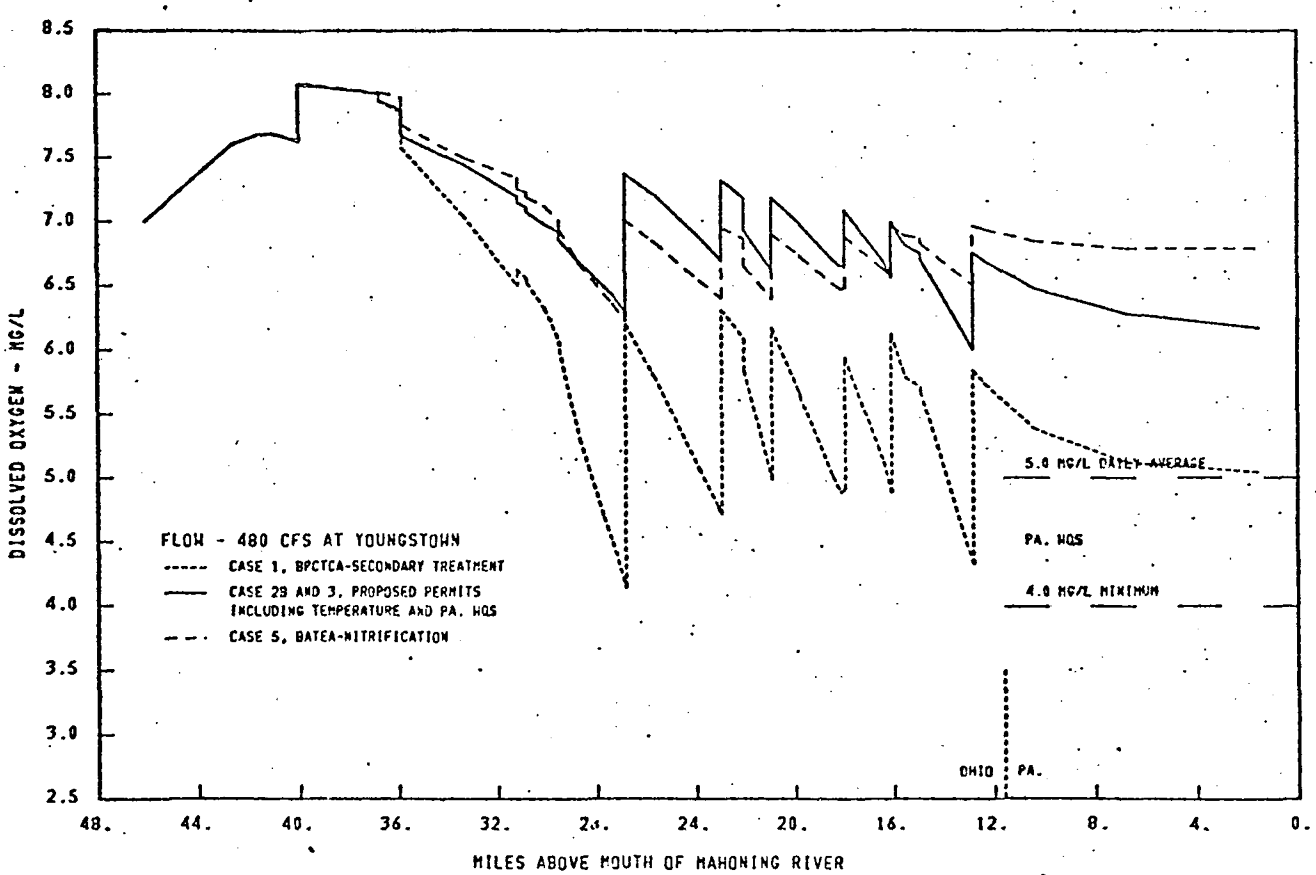


FIGURE VIII-43
MAHONING RIVER - SUMMER CRITICAL FLOW (JULY)
DISSOLVED OXYGEN VS. RIVER MILE

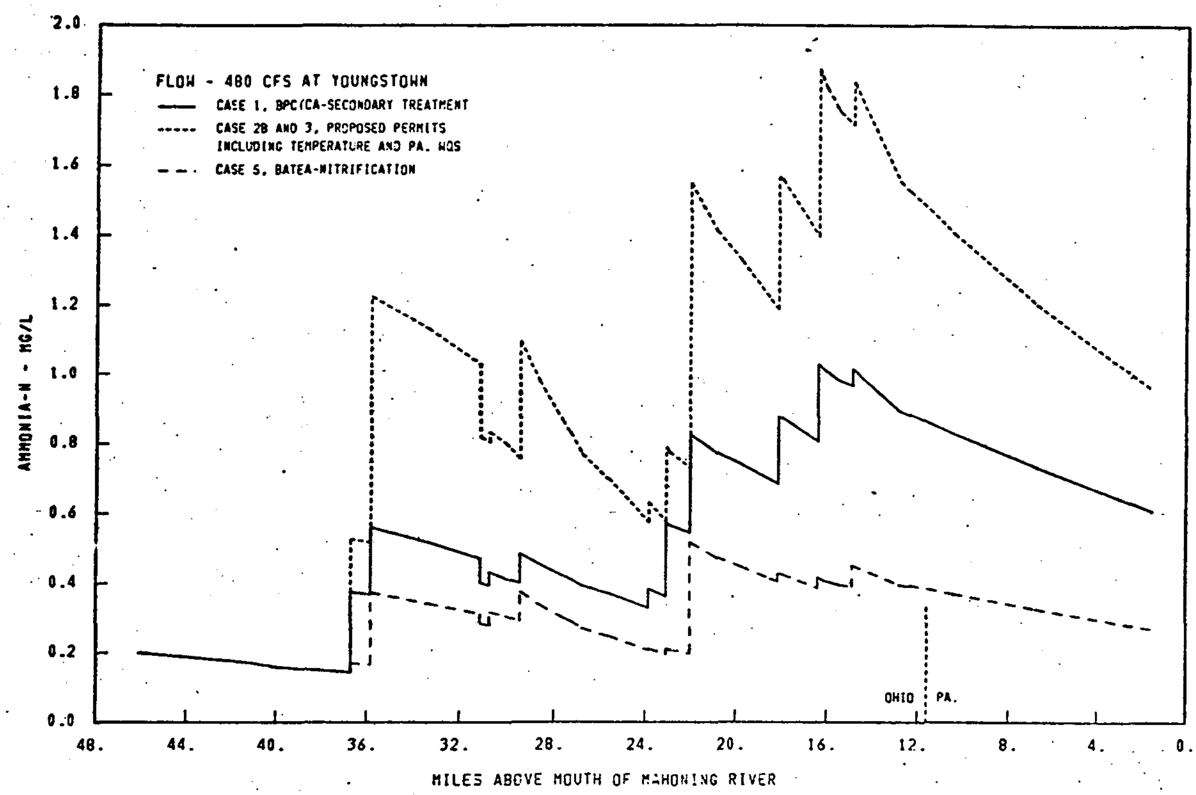


FIGURE VIII-44
MAHONING RIVER - SUMMER CRITICAL FLOW (JULY)
AMMONIA-N VS. RIVER MILE

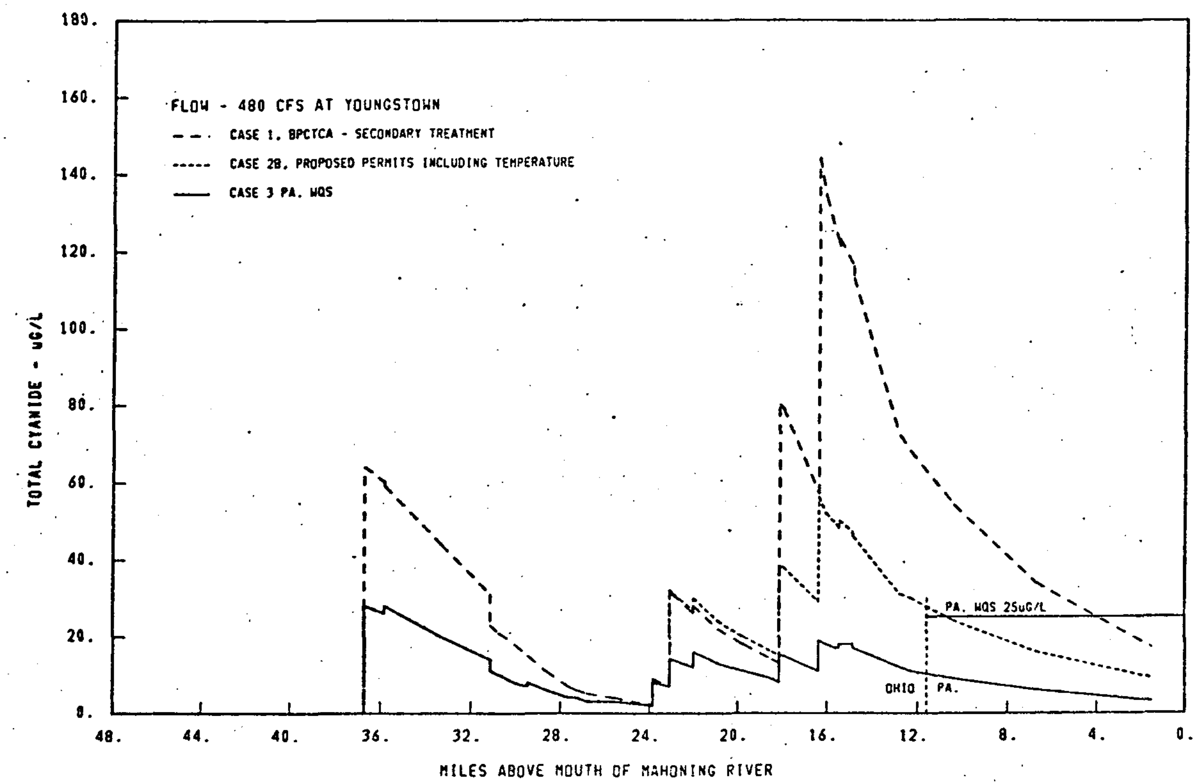


FIGURE VIII-45
MAHONING RIVER - SUMMER CRITICAL FLOW (JULY)
TOTAL CYANIDE VS. RIVER MILE

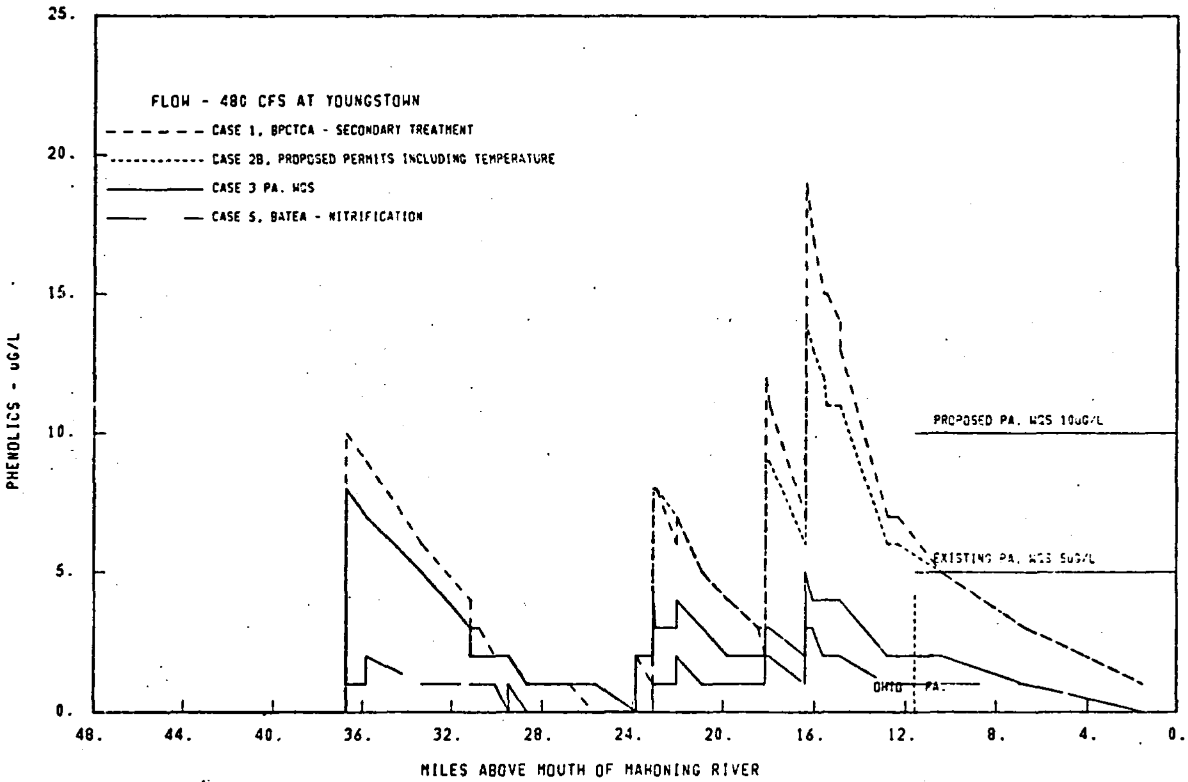


FIGURE VIII-46
MAHONING RIVER - SUMMER CRITICAL FLOW (JULY)
PHENOLICS VS. RIVER MILE

slightly above 80°F upstream of Youngstown Sheet and Tube, and slightly above 85°F downstream of Youngstown Sheet and Tube where the Case 3 and Case 5 profiles converge.

The dissolved oxygen profiles for Case 1 and Case 3 presented in Figure VIII-43 clearly illustrate the effects of high carbonaceous and nitrogenous loadings in the Warren area compounded by a significant decrease in saturation values caused by Ohio Edison. Average values below 4.0 mg/l are predicted for Case 1 behind the Liberty Street Dam in Girard vs. average values of about 6.0 mg/l for Case 3. Similar differences are seen downstream with only marginal compliance with the Pennsylvania WQS of 5.0 mg/l projected for Case 1. The difference in the profiles associated with Cases 3 and 5 are largely due to differences in the distribution of thermal discharges illustrated in Figure VIII-42, except for downstream of Struthers where differences in discharge loadings are more in effect.

The ammonia-N profiles shown in Figure VIII-44 are similar in form to those illustrated in Figure VIII-39 for winter conditions, but lower concentrations associated with higher streamflow are projected. Nonetheless, with the pH and temperature conditions expected, Case 3 is estimated to provide marginal compliance with the recommended ammonia-N criterion of 0.02 mg/l unionized ammonia-N.

Case 1 is projected to provide unacceptable total cyanide levels throughout most of the stream for summer conditions. Those associated with Case 2b are marginal in the Warren and Youngstown areas while the total cyanide profile associated with Case 3 shows marginal values for most aquatic life purposes in the Warren area during July. Only Case 1 provides high phenolics concentrations with respect to aquatic life uses for July conditions.

E. Discussion of Results

Of the six waste treatment alternatives studied herein, Case 3 provides the most cost effective means of achieving Pennsylvania water quality standards, and, with the exception of Case 5 (BATEA), provides the best water quality for the Ohio portion of the stream. Municipal waste treatment technology associated with this alternative includes secondary treatment plus nitrification. Aside from treatment of wastes from the

General Electric-Niles Plant in a regional municipal facility serving the Niles area, extensive joint municipal-industrial treatment is not anticipated. The degree of municipal treatment is sufficient to achieve Pennsylvania dissolved oxygen standards and marginally acceptable levels of ammonia-N at estimated twenty year design flows for the respective regional treatment facilities.

There are several methods of achieving Pennsylvania water quality standards for temperature. Each involves reducing the existing thermal discharge to the river by a significant amount. If only Pennsylvania temperature standards were being violated, an equal percentage reduction of existing full production thermal discharges from each facility would appear to be an equitable means of allocating discharge loadings. However, considering overall industrial waste treatment costs to achieve other Pennsylvania WQS, offstream cooling and recycle of condenser cooling water at Ohio Edison coupled with thermal load reductions at the steel mills incidental to other treatment provided is the more equitable means of achieving the Pennsylvania temperature standards. It is more cost effective to remove waste heat from one large source with relatively high increases in temperature, than from numerous diffuse sources with relatively low temperature increases over river intakes. A cost to Ohio Edison of about eight million dollars vs steel industry costs ranging up to a probably maximum of fifty million dollars (assuming thermal load reduction from recycling hot forming operations) clearly illustrates this point. For Case 3, Ohio Edison's cost of treatment represents about six to eight percent of total industrial capital costs and about three to four percent of total municipal and industrial costs. Although Ohio Edison is about eighteen miles upstream from the State line and not all of the instream temperature increase at the plant would be removed at the State line, the improvement in the Ohio portion of the stream is important and substantial.

Depending upon air pollution considerations, coke plant treatment can be as rudimentary as dirty water quenching for disposal of aqueous wastes, or as sophisticated as BATEA. In any event, significant discharges of contaminants associated with coking operations are not compatible with Pennsylvania water quality standards.

The basic level of blast furnace treatment required includes recycle of blast furnace gas wash water, direct contact gas cooling water, and miscellaneous contaminated streams, with minimal blowdown to the river. Use of blowdown for slag cooling or quenching at the furnaces is recommended to minimize discharges. The steel industry maintains that it is not possible to predict discharge levels of ammonia-N, total cyanide, and phenolics from recycle blast furnace facilities until they are constructed and operating. However, data at several existing blast furnace recycle systems indicate discharge levels of these contaminants well below the Phase 1 BPCTCA effluent guideline values, and also for total cyanide and phenolics, well below the Case 3 discharge levels allocated to the three blast furnace systems located closest to the Ohio-Pennsylvania State line.[34,39,44] In addition, zero discharge has been achieved at a few systems by controlling the blowdown to levels consistent with disposal by slag quenching.[39] Based upon this information, it is doubtful that blowdown treatment will be necessary at any or all Mahoning Valley blast furnaces to achieve Pennsylvania WQS. If such treatment is necessary, however, it is relatively low in cost compared to the basic BPCTCA recycle facilities. Should additional blast furnace blowdown treatment be required because of contaminant carry over from coke quenched with dirty water, the cost of blowdown treatment is small compared to the alternate, coke plant BATEA, which is estimated to cost about twenty-five million dollars more than upgraded coke plant dirty water quench systems.

Although oil and grease loadings in the range of BPCTCA for the steel industry are included in Case 3, there is considerable uncertainty that designated stream uses will be achieved at this level of discharge, (12-15,000 lbs/day). A conservative environmental approach would call for BATEA treatment of oil bearing wastes (500 lbs/day), but owing to the incremental cost of nearly sixty million dollars, this is not justified at this time. Although unlikely, BATEA for oil bearing wastes may be installed at some or all facilities in the Mahoning Valley, depending upon Section 301(c) economic demonstrations by the dischargers.

Installation of the above waste treatment technology is projected to result in compliance with numerical existing and proposed revisions to Pennsylvania water quality standards for temperature, dissolved oxygen, total cyanide, and phenolics. Marginal compliance with recommended ammonia-N criterion (0.02 mg/l unionized ammonia-N) is also projected. Existing standards for pH and dissolved solids are currently being achieved. With suspended solids discharges reduced by over ninety-five percent, notably from blast furnace operations, full compliance with the total iron and fluoride standards is expected. Discharges of copper and zinc will be reduced in like manner and, based upon the range of total hardness values found in the stream, recommended aquatic life criteria for those substances will also be achieved. To the extent that existing municipal and industrial waste water discharges in Ohio contribute to taste and odor problems in downstream potable water supplies, these problems will be greatly alleviated. However, taste and odor problems resulting from operation of the reservoir system in the Beaver River Basin are likely to continue. As noted above, there is uncertainty regarding compliance with Ohio and Pennsylvania general criteria for oil and grease with Case 3 discharges.

While improvements in stream quality will occur as soon as treatment facilities are brought on line, improvement in sediment quality is likely to occur slowly. Except for areas directly behind channel dams, the center of the stream is currently not heavily covered by sediment and will improve prior to the stream banks which are not easily scoured by freshets and sustained high runoff. Leaching of metals, oil and grease, etc., from existing deposits will occur, possibly reducing toxic conditions and causing sediment oxygen demand rates to increase for a period of time. However, leaching of these materials will not significantly adversely affect overlying water quality to the extent of resulting in violations of stream standards[45], and, as noted earlier, the dissolved oxygen balance in the stream is not sensitive to sediment oxygen demand.

As water quality improves and toxic discharges are eliminated, the Mahoning River will become biologically more productive at all trophic levels. Depressed phytoplankton counts in the industrialized stretch of stream will improve. With the high nutrient levels expected, algal blooms will occur during periods of optimal environmental conditions. The extent to which nuisance conditions develop can be mitigated by several factors including the high turbidity of the stream, zooplankton grazing, and the establishment of fish populations which feed on algae. Phosphorus controls at regional sewage treatment facilities would also tend to reduce the occurrence of nuisance conditions. However, since it is difficult to precisely predict what will happen based upon the current condition of the stream, a prudent approach to municipal sewage treatment plant design should include provisions for supplementary sludge handling capacity in the event phosphorus controls are warranted.

In summary, implementation of the treatment controls discussed herein will allow the Mahoning River to support designated stream uses in Pennsylvania. A varied aquatic population will also be supported in most of the Ohio portion of the stream, with areas directly below Warren and from lower Youngstown to Struthers somewhat stressed during periods of low flow.

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LIST OF FIGURES

ACKNOWLEDGMENTS

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