WATER QUALITY CONTROL NEEDS, Connoquenessing Creek and Lower Beaver River, Beaver River Basin, Pennsylvania

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
WHEELING, WEST VIRGINIA

WATER QUALITY CONTROL NEEDS
CONNOQUENESSING CREEK AND
LOWER BEAVER RIVER
BEAVER RIVER BASIN
PENNSYLVANIA

Prepared at the request of the District Engineer
U.S. ARMY ENGINEER DISTRICT, PITTSBURGH
Corps of Engineers
Pittsburgh, Pennsylvania

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
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I. INTRODUCTION

Request and Authority

This study was requested by the District Engineer, U. S. Army Corps of Engineers, Pittsburgh, Pennsylvania in a letter dated April 22, 1968. They reported that studies were being conducted to determine the feasibility of providing flood protection to areas on Connoquenessing Creek downstream from Butler, Pennsylvania. Preliminary investigations by the Corps revealed that there are two multiple-purpose reservoirs, one located on Little Connoquenessing Creek just above the mouth of Yellow Creek and the other located on Glade Run near its mouth, which have a potential of storing water for low flow augmentation to enhance downstream water quality conditions. The Federal Water Pollution Control Administration (FWPCA) was requested to investigate the feasibility of providing water quality control storage in the two proposed reservoirs.

Authority to conduct this study is provided in the Federal Water Pollution Control Act, as amended (33 USC 466 et seq.).

Purpose and Scope

The purpose of this study is to determine the need for and value of storage for water quality control in Connoquenessing Creek and the lower portion of the Beaver River downstream from Connoquenessing Creek.

In addition to the two reservoir sites originally proposed, the

Corps of Engineers is considering a site which is located on Thorn Creek, a tributary to Connoquenessing Creek. All three sites have the potential of providing limited amounts of storage for water quality control purposes. Pertinent data related to the three sites is presented in Table 1.

TABLE 1

PHYSICAL DATA OF POTENTIAL RESERVOIR SITES
(Corps of Engineers)

Name	Mile Point	Drainage Area (Square Miles)	Maximum Potential Storage (1000 acre ft.)
Little Connoquenessing Creek	3.3	44	140
Glade Run	0.2	41	95
Thorn Creek	9.6	11.2	11.5

The Soil Conservation Service has under investigation, several sites on tributary streams to Connoquenessing Creek above Zelienople, Pennsylvania. The study is being conducted under Public Law 566 and preliminary data indicates that some of the sites could potentially store additional water for low flow augmentation needs in Connoquenessing Creek. The local watershed sponsors, however, have not yet been approached with a concrete proposal of water resource development. In this study, consideration has been given to the use of the potential reservoirs as supplementary sources of storage to satisfy water resource needs in Connoquenessing Creek.

The area included in the study encompasses the watershed which drains Connoquenessing Creek, with the exception of Slippery Rock

Creek; the main stem of Connoquenessing Creek below the mouth of Slippery Rock Creek; and the Beaver River from the mouth of Connoquenessing Creek to the Ohio River. This area is located within the Beaver River Basin and includes portions of Butler, Allegheny, Lawrence, and Beaver Counties, Pennsylvania.

Water quality control storage needs and associated benefits have been evaluated under present and projected conditions to the year 2020.

Acknowledgements

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U. S. Army Corps of Engineers, Pittsburgh District

U. S. Geological Survey, Pittsburgh, Pennsylvania

U. S. Soil Conservation Service, Harrisburg, Pennsylvania

Pennsylvania Department of Health

Pennsylvania State Fish Commission

Butler Area Joint Sewer Authority, Butler, Pennsylvania

Butler County Planning Commission, Butler, Pennsylvania

Beaver County Planning and Zoning Commission, Beaver, Pennsylvania

Shenango Valley Regional Planning Commission, Sharon, Pennsylvania

Southwestern Pennsylvania Regional Planning Commission, Pittsburgh, Pennsylvania

Armco Steel Corporation, Butler, Pennsylvania

Special recognition is given to the Pennsylvania Department of Health, the Pennsylvania State Fish Commission, the Butler Area Joint

Sewer Authority and the Armco Steel Corporation for contributing personnel and pertinent facilities during special field investigations conducted in the summer and fall of 1968.

II. SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Findings

1. The Pittsburgh District, U. S. Army Corps of Engineers is investigating the feasibility of constructing multiple-purpose reservoirs in the Connoquenessing Creek Basin. The three sites under consideration are located on the following tributaries to Connoquenessing Creek: Little Connoquenessing Creek, Glade Run and Thorn Creek.

2. Each of the three sites has potential storage available for downstream water quality control.

3. Typical, seasonal low streamflows in Connoquenessing Creek between Butler and Ellwood City consist primarily of municipal and industrial waste waters.

4. The four-county economic study area (Beaver, Butler, Lawrence, and Mercer Counties) had a total population of 562,071 in 1960, an average density of 277 people per square mile.

5. Industrial establishments engaged in the manufacture of primary metals, fabricated metal products, and stone, clay, and glass dominate the types found in the economic study area.

6. Except for emergency use at Zelienople, Pennsylvania, the main stem of Connoquenessing Creek below Butler, Pennsylvania, is not currently being utilized as a source for municipal or industrial water supply. The Beaver River serves as a source of water for municipal and industrial use.

7. The water quality standards adopted by the Pennsylvania

Sanitary Water Board for the Beaver River have been approved by the Secretary of the Interior. In the absence of state standards for Connoquenessing Creek (an intrastate stream), water quality criteria commensurate with current national and state objectives was utilized in the assessment of pollution abatement needs in this study.

Conclusions

1. The total population of the economic study area is projected to increase 3.6 percent annually from 562,071 in 1960 to 1,793,000 in 2020. Total employment is expected to increase from 191,079 in 1960 to 671,000 in 2020, an average increase of 4.2 percent per year.

2. The main stem of Connoquenessing Creek, downstream from Butler, Pennsylvania, is degraded by residual municipal and industrial wastes originating primarily in the Butler and Zelienople areas. The high concentration of oxygen consuming wastes and nutrients cause undesirable dissolved oxygen depletions and excessive growth of rooted and floating aquatic plants. The water quality problems will become more severe as industrial and municipal growth continues.

3. An evaluation of alternative pollution abatement plans for Connoquenessing Creek included consideration of low flow augmentation, through reservoir releases, in combination with various levels of advanced waste treatment at the sources; the use

of a pipeline to transport treated wastes from the Butler and Zelienople areas to the Beaver River; and expansion of the existing inter-basin water transfer system to facilitate low flow augmentation needs. Presently water is brought in from the Allegheny River for water supply purposes.

4. With regard to the alternatives involving low flow augmentation, an evaluation of the total stream flow requirements for maintenance of the 5.0 mg/l dissolved oxygen standard throughout Connoquenessing Creek indicated that solution of the problem at Butler, Pennsylvania would provide protection to the entire stream. Stream flow augmentation is therefore limited to the immediate vicinity of the Butler municipal and industrial complex.

5. A cost analysis of pollution abatement alternatives indicates that the least costly method of attaining the water quality objectives in Connoquenessing Creek is the use of reservoir storage in the Thorn Creek site for water quality control, in combination with advanced waste treatment facilities at all organic waste sources which discharge to Connoquenessing Creek in the Butler and Zelienople areas.

6. There are several significant municipal and industrial waste discharges to the Connoquenessing Creek below the confluence of Slippery Rock Creek and to the Beaver River portion of the study area. The implementation of existing pollution abatement requirements is expected to insure achievement of the water quality

objectives in these streams.

Recommendations

Based on the results of this study, it is recommended that:

1. The least costly combination of pollution abatement measures be implemented to achieve the water quality objectives in Connoquenessing Creek. The most favorable pollution abatement plan includes the combination of reservoir storage in the Thorn Creek site and advanced waste treatment of all organic wastes discharged to Connoquenessing Creek in the Butler and Zelienople areas.

2. The advanced waste treatment facilities include removal of phosphorus as well as the oxygen demanding wastes. Effluent waste concentrations should be limited to the following:

Area	Allowable Effluent Concentration (mg/l)		Minimum Treatment Requirements (Percent Removal)	
	BOD_{20}	Total Phosphorus-P	BOD_{20}	Total Phosphorus-P
Butler Complex 1/	10.5	0.5	95	95
Zelienople and Harmony	30	0.5	90	95

1/ Combined municipal and industrial wastes in Butler area.

3. Streamflow augmentation be provided to Connoquenessing Creek from the proposed Thorn Creek reservoir. The projected low flow augmentation needs during the period June through October are as follows:

	1980	2000	2020
Total Flow Required (cfs)	19	33	41
Estimated Return Flow (cfs)	15	24	32
Net Flow Required (cfs)	4	9	9

4. The minimum average annual benefits of reservoir storage for low flow augmentation are $140,000, based on the least costly alternative of a single purpose water quality control reservoir. Since additional water quality control benefits are not readily identifiable, a maximum average annual benefit of $610,000 could be credited to water quality control storage in the proposed Thorn Creek Reservoir.

5. Multi-level outlets be provided at sufficient locations and of adequate size on all high-level reservoirs in order to provide for flexibility of operation so that adequate water quality control can be maintained.

III. DESCRIPTION OF STUDY AREA

Location and Geography

Connoquenessing Creek is the lower-most major tributary to the Beaver River and drains 833 square miles or about one-fourth of the Beaver River basin. Two streams, the main stem of Connoquenessing Creek and Slippery Rock Creek, join just before Connoquenessing Creek enters the Beaver River. Water quality investigations in this study excluded the Slippery Rock Creek drainage (404 square miles) since all the potential reservoirs are located in the main stem branch watershed.

The main stem of Connoquenessing Creek originates in the mountainous divide between the Beaver and Allegheny River Basins in western Pennsylvania. Several small tributaries enter the main stem before the creek approaches the community of Butler, Pennsylvania. The remaining portion of the creek meanders through a valley of moderate gradient as it flows westward through the communities of Renfrew, Harmony and Zelienople before it joins Slippery Rock Creek near its mouth. The stream contains a series of pools, both natural and man-made, and riffles for most of its length between Butler and Ellwood City, a distance of 43 stream miles. Just before joining with Slippery Rock Creek at Ellwood City, the stream enters a gorge and becomes quite steep in gradient. Major tributaries in the study portion of the watershed include Brush Creek, Little Connoquenessing Creek, Breakneck Creek, Glade Run, Thorn Creek, Bonnie Brooke, Thorn Run, and Stony Run.

The southern portion of the study area lies within the northern part of Allegheny County, a major metropolitan area which includes the city of Pittsburgh, Pennsylvania.

The twelve miles of the Beaver River included in the study area consist of two pools, one created by a dam at Beaver Falls and the other from backwater of the Ohio River.

Climate

The area experiences moderate temperature extremes with a recorded low of $-19^{o}F$ and summer high of $101^{o}F$ at Butler, Pennsylvania during the period 1942 to 1961. Precipitation averages just under 40 inches a year with the amount increasing toward the eastern portion of the study area.

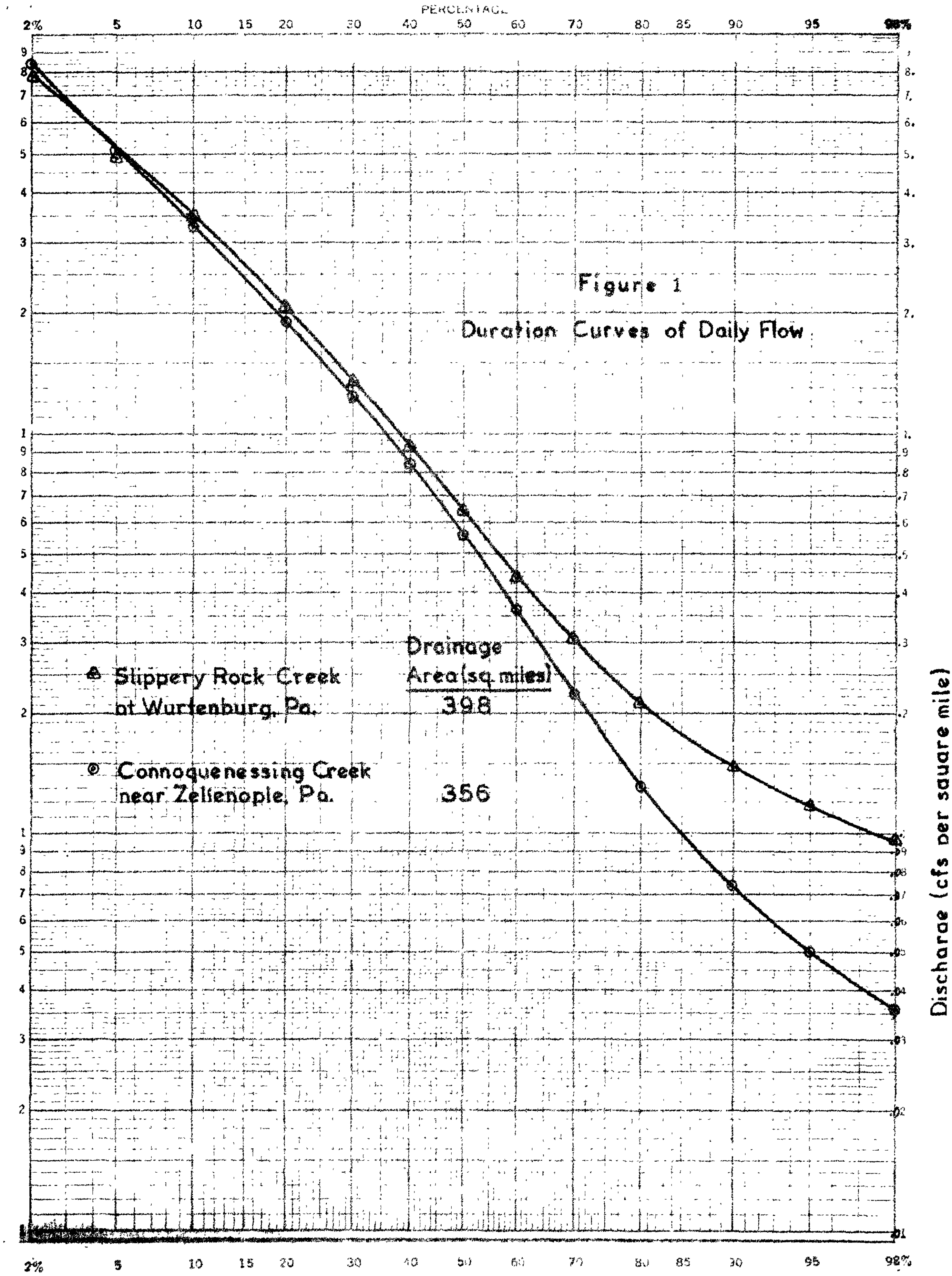
IV. WATER RESOURCES OF THE STUDY AREA

Streamflow

There is only one streamflow measuring station located in the study area which provides a long record of continuous data. The gage is operated by the U. S. Geological Survey and is located on the main stem of Connoquenessing Creek between Zelienople and Ellwood City. Long term streamflow records of other nearby areas are available on Slippery Rock Creek at Wurtemburg and the Beaver River at Wampum. Pertinent data relative to these stations is presented in Table 2.

The main stem of Connoquenessing Creek upstream from Slippery Rock Creek experiences unusually low streamflows during the summer months. When compared to other areas adjacent to this stream, the low flow characteristics of the main stem are as much as 50 percent less in magnitude. The comparison of daily flow duration curves for Connoquenessing Creek and Slippery Rock Creek in Figure 1 reveals the striking difference in low flow conditions.

Most of the streamflow in the main stem of Connoquenessing Creek originates from municipal and industrial waste water during the summer and fall low flow periods. The municipal-industrial complex at Butler, Pennsylvania, obtains most of its water supply from reservoir releases in the headwater areas. Three reservoirs with a total combined storage capacity of 890 million gallons are presently used to store and regulate the natural runoff from the



PERCENTAGE
Figure 1
Duration Curves of Daily Flow
Drainage Area (sq. miles)
Slippery Rock Creek at Wurtenburg, Pa. 398
Connoquenessing Creek near Zelienople, Pa. 356
Discharge (cfs per square mile)
Percent of Time Discharge was Equalled or Exceeded

TABLE 2

LONG TERM PERMANENT STREAM FLOW MEASURING STATIONS

U.S.G.S. Station Number	Station Name	Drainage Area (square miles)	Period of Record	Average Flow (cfs)	Instantaneous Minimum Flow (cfs)	7-day, 10 yr. Low Flow (cfs) 2/
3-1055	Beaver River at Wampum, Pennsylvania	2235	1914-1918 1932-1968	2294 1/	74	600 3/
3-1060	Connoquenessing Creek near Zelienople, Pennsylvania	356	1919-1968	462	6	9.8
3-1065	Slippery Rock Creek at Wurtemberg, Pennsylvania	398	1911-1968	552	16	30

Source: Water Resources Data for Pennsylvania, Part 1. Surface Water Records, 1968, USGS

1/ Adjusted for storage since 1932.
2/ The seven-consecutive-day annual low flow with recurrence interval of 10 years.
3/ Estimated minimum flow assuming existing reservoirs on the Mahoning and Shenango River systems are operated as currently scheduled.

watersheds above them plus water that i[s p]umped at a maximum rate of 5.5 million gallons per day (mgd) from the Allegheny River to augment needs during relatively dry periods. Although there is some natural flow from uncontrolled streams above Butler, Pennsylvania, the bulk of Butler's water needs is satisfied from regulated releases during the summer-fall seasons. The stream below Butler normally contains at least 50 percent wastewater with little additional dilution water available from other tributary streams. It is not until Slippery Rock Creek enters Connoquenessing Creek at Ellwood City that base flows are increased significantly.

Low flow frequency data for Connoquenessing Creek near Zelienople, Pennsylvania, are presented below:

Magnitude and Frequency of Annual Low Flow (Period 1920-59)

Consecutive Days	Discharge (cfs) for Indicated Recurrence Interval- 2 years	5 years	10 years	20 years	40 years
7	15	11	9.8	8.8	8.0
14	19	12	11	9.8	8.8
30	24	14	13	11	10
60	35	19	16	13	12
120	71	31	22	17	14

Source: Water Resources Bulletin No. 1, Pennsylvania Streamflow Characteristics, Low-Flow Frequency and Flow Duration, Pennsylvania Department of Forests and Waters, and U. S. Geological Survey, April, 1966.

The Beaver River streamflows are, of course, much greater in volume than Connoquenessing Creek. Since there are several existing reservoirs which provide storage for low flow augmentation in the Beaver River system, the dry-season flows are relatively high and are expected to exceed 600 cfs at all times if scheduled releases are maintained.

Water Use

With the exception of the Butler area, Connoquenessing Creek is not used as a source of municipal and industrial water supply. The municipalities and industries located along Connoquenessing Creek obtain water from wells or tributary streams of suitable quality.

The Butler Water Company withdraws water directly from Connoquenessing Creek at a point upstream from Butler. As previously mentioned, the stream is augmented by reservoir releases and interbasin transfer from the Allegheny River.

Several large industrial establishments use the Beaver River as the primary source of water supply. Some of the municipalities also withdraw water directly from the Beaver River.

Existing Water Quality

The Upper Ohio Basin Office, FWPCA, Wheeling, West Virginia, collected water quality samples at a few locations in the Connoquenessing Creek drainage during general surveys in the Beaver River basin in 1966. Comprehensive water quality investigations were conducted during 1968, along the entire length of Connoquenessing Creek. The study was done as a cooperative effort with the

Pennsylvania State Fish Commission and the Pennsylvania Department of Health. Municipal and industrial effluent samples were collected in addition to water quality samples from various stream locations. Examination of samples included chemical, bacteriological and plankton analysis. Benthic and fish studies were conducted by State personnel at a few key locations on Connoquenessing Creek and at the two potential reservoir locations on Little Connoquenessing Creek and Glade Run.

Analysis of the available data reveals that there are pollution problems in many sections of Connoquenessing Creek and some of its tributaries caused by excessive residual organic and nutrient waste discharges from municipalities and industries in the area. The major contributor of such wastes is the Butler municipal and industrial complex.

Connoquenessing Creek, upstream from Butler, is relatively free of organic pollution but at times has been known to show effects of mining activities during periods of low runoff and drainage. However, the stream did not contain excessive amounts of acidity at the time samples were collected.

Bonnie Brooke, which enters Connoquenessing Creek just upstream of Butler, Pennsylvania, at times is polluted by organic wastes introduced to the stream in its lower reaches. Dissolved solids concentrations were above normal during low flow conditions. Specific conductivity was observed in excess of 900 micromhos.

Connoquenessing Creek, downstream from the Butler complex, is degraded by residual municipal and industrial wastes. The stream contains high nutrient loads which are continuously contributed from municipal sources and intermittently from industrial sources. Dissolved solids are usually above normal levels and excessive amounts of organic wastes are discharged to the stream as a residual load from the Butler sewage treatment facilities, from lagoon discharges of the Armco Steel Corporation and from the many untreated sanitary waste discharges in the area.

A most significant pollution problem in Connoquenessing Creek below Butler, is the excessive growth of rooted and floating aquatic plants. The abundance of these plants causes fluctuations in the dissolved oxygen levels of the stream, impairs the recreational value by congestion of the stream, and increases the oxygen demanding load when die-off and decay occur. It is believed that carbon, nitrogen, and phosphorus are the nutritional elements most utilized by green plants. Since phosphorus is recognized by many researchers as the element which is easiest to control in streams and lakes, an important objective of recent water quality studies has been to determine the sources and amounts of phosphorus being introduced to Connoquenessing Creek.

The most recent water quality studies show that a major portion of the total phosphorus load found in the stream is contributed by the Butler Area Joint Sewage Authority system and at times the

Armco Steel Corporation. Concentrations of total phosphorus ranged between 0.04 and 7.3 mg/l in the creek just downstream from the Butler complex. Most nutrients introduced into the stream at Butler are available immediately for biological uptake, while some are absorbed by the bottom deposits. A substantial portion of this load remains in the stream at Zelienople. Additional nutrients are added to the stream at Zelienople and produce algal problems from this point to the mouth of Connoquenessing Creek. Inspection of Figure 2 reveals the relative magnitude of the phosphorus contributions from the Butler area. Although the phosphorus levels decrease rapidly below Butler, sufficient quantities are available to cause the nutrient-associated problems throughout the remainder of Connoquenessing Creek. This is evidenced by the high plankton counts, at times reaching proportions considered as algae blooms, in the stream below Butler (see Table 3).

A summary of the total phosphorus levels found during the recent surveys is presented in Table 4.

The large residual organic load which enters Connoquenessing Creek at Butler, Pennsylvania, cannot be adequately assimilated under existing low flow conditions. The limited field investigations conducted by the Upper Ohio Basin Office, Wheeling, during the summer of 1968 revealed that the average twenty-day Biochemical Oxygen Demand (BOD_{20}) load from the effluent of the Butler Area Joint Sewage Authority treatment facilities plus the effluent of the

Figure 2

Total Phosphorus Levels in Connoquenessing Creek
(Aug. 27 - Aug. 30, 1968)

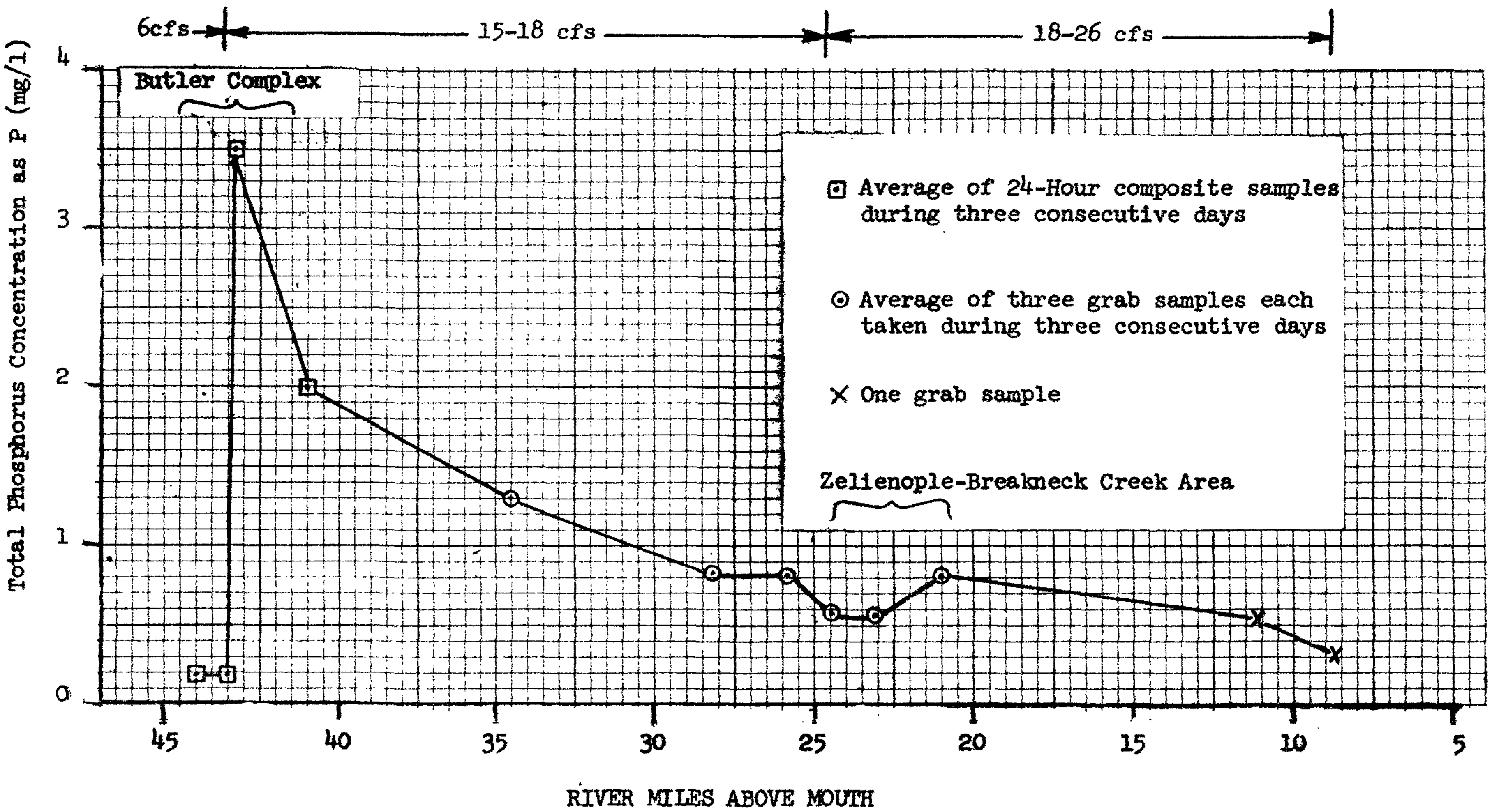


TABLE 3

PLANKTON COUNTS - CONNOQUENESSING STUDY, 1968

Station Number	Station Description	Number of Plankton Per ml of Sample 7/30 & 7/31	8/29 & 8/30
-	Connoquenessing Creek at Rt. 38 Bridge above Butler	2,040	1,665
0526	Connoquenessing Creek at McCalmont Rd. Bridge	18,870	8,325
0844	Connoquenessing Creek above Confluence with Glade Run	7,215	4,995
0538	Glade Run at Bridge above mouth	7,770	1,110
0839	Connoquenessing Creek at Bridge below Confluence with Glade Run	18,315	3,330
0472	Breakneck Creek at Eidenau, Pennsylvania	23,310	7,215
0847	Connoquenessing Creek below Breakneck Creek	22,200	20,535
0843	Little Connoquenessing Creek at Mouth	1,665	1,110
0470	Connoquenessing Creek above Zelienople, Pennsylvania	50,505	17,760
0469	Connoquenessing Creek below Zelienople, Pennsylvania	55,500	15,540
0840	Connoquenessing Creek at Hazen, Pennsylvania	25,530	12,765
0841	Brush Creek at Bridge above Mouth	3,330	2,220
-	Connoquenessing Creek at Rt. 65 Bridge above Ellwood City, Pennsylvania	41,625	21,090
0475	Slippery Rock Creek at 488 Bridge	4,995	5,550
0467	Connoquenessing Creek at Mouth	8,325	2,775
	Stream Flow (cfs)	20-50	17-25

TABLE 4

PHOSPHORUS LEVELS IN CONNOQUENESSING CREEK STUDY AREA

Station Number	Location	No. of Samples	Total Phosphorus as P (mg/1)		
			Maximum	Minimum	Average
0473	Connoquenessing Creek above Butler	2	1.45	0.04	---
0474	Bonnie Brooke near mouth	2	0.27	0.05	---
0836	Sullivan Run	5	1.00	0.04	0.25
0848	Connoquenessing Creek above Armco Plant 1	7 1/	0.22	0.07	0.15
0849	Connoquenessing Creek above Butler STP	7 1/	0.22	0.14	0.18
0534	Connoquenessing Creek below Butler	9 1/	7.30	0.04	2.95
0526	Connoquenessing Creek below Butler	9 1/	3.21	0.08	1.75
0837	Thorn Creek near mouth	2	0.39	0.08	---
0838	Connoquenessing Creek @ Renfrew Br.	2	0.05	0.17	---
0844	Connoquenessing Creek above Glade Run	3	1.45	1.22	---
0842	S. F. Glade Run in Headwater	3	0.25	0.05	---
0538	Glade Run at mouth	5	0.19	0.03	---
0839	Connoquenessing below Glade Run	2	1.03	0.04	---
0845	Connoquenessing at Wahlville	3	0.88	0.46	---
0472	Breakneck Creek at mouth	5	1.50	0.53	1.14
0847	Connoquenessing Creek between Breakneck and Little Connoquenessing	3	0.63	0.49	---

TABLE 4 (Continued)

PHOSPHORUS LEVELS IN CONNOQUENESSING CREEK STUDY AREA

Station Number	Location	No. of Samples	Total Phosphorus as P (mg/1)		
			Maximum	Minimum	Average
0843	Little Connoquenessing at Dam Site	5	0.12	0.03	0.08
0470	Connoquenessing above Zelienople	5	0.78	0.50	0.64
0469	Connoquenessing below Zelienople	5	0.82	0.51	0.70
0840	Connoquenessing at Hazen	3	0.45	0.07	---
0841	Brush Creek at mouth	3	0.32	0.05	---
0468	Connoquenessing at Rt. 488 Bridge	3	0.64	0.33	---
0475	Slippery Rock Creek	3	0.99	0.12	---
0467	Connoquenessing below Ellwood City	3	1.20	0.59	---

1/ Includes 24 hour Composite Data

Armco Steel Corporations' lagoons is 1275 pounds per day. Streamflow and water temperatures encountered during the most recent surveys were representative of average late summer conditions which normally reflect the worst organic pollution problems. Industrial and municipal discharge volumes also represented average summer conditions. High nutrient contributions stimulate an excessive and undesirable growth of aquatic plants. Dissolved oxygen depletions, normally encountered as organic waste materials are assimilated in the receiving streams, are disguised, particularly during daylight hours, because of the oxygen generated by the aquatic plants. This is probably why the dissolved oxygen levels in the stream below Butler were found to be near saturation during regular daytime sampling. If nutrient loads were minimized to a level which would practically eliminate excessive aquatic plant growth, dissolved oxygen levels could approach 4.4 mg/l during average summer conditions. Maximum oxygen depletion probably would occur in Connoquenessing Creek near the mouth of Glade Run. Oxygen depletions of less than 4.4 mg/l could be expected during periods of extremely low flows.

Other types of wastes are discharged to the stream in the vicinity of Butler, Zelienople and Ellwood City. Some waste materials common to the steel and metal fabricating industries are found throughout the entire length of Connoquenessing Creek below Butler. The effects of coal mining activities are also present.

An analysis of water quality data reveals that most locations sampled on Connoquenessing Creek displayed concentrations of dissolved solids, including aluminum, manganese, sulfate and iron, and conductivity and hardness values above desirable levels. (See Table 5).

Toxic materials were found in Connoquenessing Creek in the vicinity of the steel mills at Butler, Pennsylvania. Hexavalent chromium concentrations of as high as 1.29 mg/l were detected in the stream; but, the recent installation of process waste treatment facilities at the steel mills is expected to eliminate the discharge of these wastes to the stream.

The water quality of Glade Run near the location of the proposed reservoir is generally acceptable for intended reservoir uses. There are some organic wastes from individual homes and farms in the area as evidenced by slightly high bacterial counts. Key water quality characteristics found during 1966 and 1968 are shown in Table 6.

Water quality data from two locations on Little Connoquenessing Creek, near the mouth and at the dam site, indicates the water is relatively free from pollutants. Intermittent mine drainage problems have occurred on some tributaries to the Creek, particularly Yellow Creek. However, it appears that such problems are insignificant at the proposed reservoir. The limited amount of bacteriological data reveals some problems which are caused by raw waste

TABLE 5

SUMMARY OF PERTINENT WATER QUALITY DATA
CONNOQUENESSING CREEK

RANGE OF VALUES

Location	River Mile	No. Samp.	pH (units)	Specific Conductance (micromhos)	Sulfate (mg/1)	Total Iron (mg/1)	Fecal Coliform (organisms/100ml)	Hexavalent Chromium (mg/1)	Phenols (mg/1)	Hardness (mg/1)
Above Butler	48.2	5	6.7-8.6	225-675	37-225	0.3-1.0	30-190	-	-	66-20[illegible]
Below Butler	41.0	9	7.2-8.8	580-2200	285-450	1.0-5.0	100-690	0.04-0.19	0-0.009	168-48[illegible]
Above Zelienople	23.1	14	6.8-9.0	260-1200	54-290	0.4-3.8	48-4000	-	-	90-49[illegible]
Below Zelienople	21.0	13	6.9-9.0	263-1300	52-375	0.5-3.8	60-2500	-	-	94-48[illegible]
Above Ellwood City	8.7	12	6.8-9.8	233-1400	7-375	0.5-7.7	4-5700	-	-	96-42[illegible]
Below Ellwood City	1.7	11	6.7-8.3	240-850	66-230	0.2-6.5	100-420,000	-	0-0.01	102-47[illegible]

TABLE 6

SUMMARY OF PERTINENT WATER QUALITY DATA
GLADE RUN AND LITTLE CONNOQUENESSING CREEK

Constituent	Units	Number Samples	Glade Run at Dam Site		Little Connoquenessing Creek at Dam Site	
			Maximum	Minimum	Maximum	Minimum
pH	units	7-5	7.7	6.7	7.4	6.3
Specific Conductivity	micromhos	7-5	405	340	875	480
Hardness	mg/l	4-2	114	96	190	163
Total Coliform	organisms/ 100 ml	4-1	25,000	610	26,000	-
Fecal Coliform	organisms/ 100 ml	4-1	1,500	100	630	-
Fecal Streptococci	organisms/ 100 ml	4-1	4,000	80	730	-
Dissolved Oxygen	mg/l	7-5	9.8	7.2	8.5	6.5
Total Phosphorus (as P)	mg/l	5-5	0.19	0.03	0.12	0.04

discharges from individual rural homes and farms located in the watershed. Pertinent water quality characteristics found at the dam site during the summer of 1968 are shown in Table 6.

Water quality studies were not conducted on Thorn Creek at the proposed reservoir site. A limited amount of water quality data from samples collected near the mouth of Thorn Creek indicates that there is slight organic pollution, at times, which is probably caused by inadequately treated sanitary wastes from individual homes and the community of Saxonburg, Pennsylvania.

The lower Beaver River is degraded by inadequately treated municipal and industrial wastes, most of which originate from the tributary areas and river reaches outside of the study area. Inspection of a tabulation of pertinent water quality data (see Table 7) reveals the fact that undesirable levels of specific conductance, dissolved oxygen, hardness, sulfates, total iron, fecal coliform, phenols and cyanide occurred occasionally during the 1966 and 1968 surveys.

The results of benthic biology studies conducted in the study area during 1965 indicate that polluted conditions prevail in Connoquenessing Creek downstream of Butler, and near the mouth below Ellwood City. Similar conditions were found in the Beaver River between its mouth and the junction with Connoquenessing Creek. Connoquenessing Creek upstream of Butler, supported a variety of forms, but of low densities. The benthic fauna downstream of Butler

TABLE 7

SUMMARY OF PERTINENT WATER QUALITY DATA
BEAVER RIVER

Range of Values

Location	River Mile	No. Samp.	Specific Conductance (micromhos)	Dissolved Oxygen (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Fecal Coliform 1/	Phenols (mg/1)	Cyanide (mg/1)
At Wampum, Pennsylvania	15.2	12	50-700	3.5-11.0	101-250	65-190	1.1-3.6	890-13,000	0-0.016	0-0.05
Below Connoquenessing C.	11.3	9	400-760	5.5-8.1	166-255	110-275	0.2-6.5	1200-19,000	0-0.058	0-0.04
At Beaver Falls, Pa.	5.6	12	340-700	5.9-10.5	109-260	38-228	0.2-4.3	60-3800	0.001-0.013	0-0.03
Near Mouth	3.0	25	339-800	5.8-12.0	83-272	70-200	0.1-5.6	50-16,000	0-0.14	0-0.2

1/ organisms/100 ml

was predominated by large numbers of pollution tolerant snails, midge larva and very tolerant sludgeworms. The stream did show gradual recovery through to Ellwood City. The substrate of the Beaver River at the sampling stations appeared to be conducive to benthic development; however, the benthos consisted of sludgeworms, snails, midge larva, and fingernail clams. No pollution sensitive forms were collected in the Beaver River.

Biological investigations conducted by the Pennsylvania Department of Health and the Pennsylvania Fish Commission in 1968 also indicate that pollution problems exist in certain sections of Connoquenessing Creek. At each of nine stations in the Connoquenessing Creek watershed, benthic organisms, fishes, and periphyton scrapings were collected and the number and type categorized by pollution tolerance classifications. A report of these investigations appears in Appendix A. An adequate and diverse community of aquatic life, indicative of clean to relatively clean stream conditions, was found at stations located on Connoquenessing Creek above Butler and upstream from Ellwood City and on Glade Run and the Little Connoquenessing Creek in the vicinity of the dam sites. Stations located below Butler and above and below Zelienople yielded benthic and aquatic life tolerant to polluted conditions. The most severely degraded condition existed at the station on Connoquenessing Creek below Butler, where a low number of pollution tolerant benthic fauna was found. Pollution tolerant fish species dominated the total population and the periphyton community reflected organic and nutrient input to the stream. Although slightly less pollution was indicated in the Zelienople area, the predominant benthic fauna and fish population were tolerant of polluted conditions.

V. THE ECONOMY

Population

The principal population centers of the study area are located along the main stem of Connoquenessing Creek and the Beaver River. They include the municipalities of Butler, Zelienople, Ellwood City, Beaver Falls, and New Brighton which had a combined 1960 population of over 60,000. Butler is the largest city in the study area. Other smaller communities are located along the network of highways which connect the major municipalities with Pittsburgh, Pennsylvania. A sizable suburban population is encountered in a few areas close to Pittsburgh.

The total population of the four-county economic study area (Beaver, Butler, Lawrence, and Mercer Counties) increased from 442,260 in 1940 to 562,071 in 1960, an average annual growth rate of 1.35 percent. Although this growth rate was substantially larger than that experienced by the State of Pennsylvania (0.7%), it fell slightly behind the national average of 1.78 percent. The average population density of the economic area was 277 people per square mile in 1960.

Industry

The majority of the manufacturing establishments are located in or near the major communities along Connoquenessing Creek and the Beaver River. Several industries are also found on Breakneck Creek, a small tributary to Connoquenessing Creek.

Industrial establishments engaged in the manufacture of primary metals, fabricated metal products, stone, clay, and glass dominate the types found in the study area. Most of the large factories which have an employment of more than 500 are engaged in the steel-making and metal fabrication businesses. Several basic steel mills are located along the Beaver River and in the City of Butler. Table 8 presents a summary of the size and type of manufacturing establishments found in the Counties of Beaver, Butler and Lawrence.

Transportation

The Connoquenessing Creek area is served by three interstate highways: I-80S traverses Beaver and Lawrence Counties in a north-west to south-east direction; I-79 runs north-south through Butler, Lawrence, and Mercer Counties; and I-80 runs east-west through Mercer County.

Five railroads provide both freight and passenger service in the economic study area.

Three small airports provide limited air service, but no commercial air lines serve the area.

Agriculture

Agriculture has been an important enterprise in the study area, but the impact of urban and suburban development has created a steady decline in farming operations. The area is an important producer of dairy products, beef, hogs, field crops, poultry and

TABLE 8

NUMBER AND EMPLOYMENT SIZE OF
MANUFACTURING PLANTS
(BEAVER, BUTLER, AND LAWRENCE COUNTIES)

SIC	Manufacturing Industry	Number of Plants with Employment of 1-19	20-49	50-99	100-249	250-499	500- or more	Total
20	Food and Kindred Products	62	14	2	2	0	0	80
22	Textile Mill Products	0	0	0	0	1	0	1
23	Apparel	1	0	0	2	0	0	3
24	Lumber and Wood Products	27	1	0	1	0	0	29
25	Furniture and Fixtures	6	1	1	0	0	0	8
26	Paper and Allied Products	3	1	0	0	0	0	4
27	Printing and Publishing	31	3	2	2	0	0	38
28	Chemicals	14	3	4	3	0	1	25
29	Petroleum Refining	8	1	0	1	2	0	12
30	Rubber and Misc. Plastics	5	1	4	0	1	0	11
31	Leather	0	0	0	0	1	0	1
32	Stone, Clay, and Glass	44	9	9	10	6	1	79
33	Primary Metal	8	10	5	5	8	8	44
34	Fabricated Metal Products	31	8	5	6	3	2	55
35	Machinery, except Electrical	39	12	3	6	1	3	64
36	Electrical Machinery	4	0	0	0	1	2	7
37	Transportation Equipment	1	0	0	0	1	1	3
38	Professional, Scientific Instruments	1	2	0	1	0	0	4
39	Miscellaneous	5	2	1	0	0	0	8
	Totals	290	68	36	39	25	18	476

Source: Location of Manufacturing Plants by County, Industry, and Employment Size, Census of Manufacturing, 1963, U. S. Dept. of Commerce.

nursery stock. Most of these farming operations are now part-time, with the operator holding full or part-time employment elsewhere.

About one-third of the area is suitable for agriculture production. Although the southern half of the Connoquenessing Creek drainage contains the best farmland, scattered agricultural developments are also found in the north central region.

A few highly developed, irrigated farms are found in the mid-section of the Connoquenessing Creek drainage. These operations usually obtain their water supply from surface sources for supplemental irrigation during the occasional dry periods experienced in the summer and early fall seasons.

A few conifer plantations are being managed for Christmas tree production. Only five percent of the forested area is being utilized for the commercial tree enterprises. Approximately one-third of the Connoquenessing Creek drainage is forest land.

Future Growth

A major portion of the study area has experienced a steady economic growth at a rate close to the rest of the nation. Its ideal location--in the center of western Pennsylvania between the Pittsburgh-Youngstown-Cleveland metropolitan complex--is partly responsible for the rapid growth. Other factors which have contributed to the favorable climate for growth include the abundance of natural resources, adequate transportation facilities and a progressive populace. Economic growth is expected to continue at an accelerated rate.

Several local and regional planning commissions have studied the economic trends and they have formulated population and industrial projections for the area. This information, plus the Appalachia Developmental Benchmark Projections developed by the U. S. Army Corps of Engineers, Pittsburgh District, were utilized in establishing the economic projections for the study area. The "developmental benchmarks" were conceived by the Office of Appalachian Studies, Corps of Engineers to describe the population, employment, and income growth required to meet the goals of the Appalachian Act, Public Law 89-4. To achieve these goals, it was assumed that the rate of economic growth in the Appalachian area would be accelerated over that of the national norm. The economic projections for the Connoquenessing Creek study reflect the accelerated growth concept of the Appalachian Study.

The economic projections were formulated under the basic assumption that water quantities would not limit potential economic developments in the Connoquenessing Creek portion of the study area.

The total population of the economic area is projected to increase 3.6 percent annually from 562,071 in 1960 to 1,793,000 in 2020. Butler County is projected to have an annual increase of 5.1 percent for the period 1960 to 2020.

County population projections were disaggregated to the municipality level to reflect the anticipated growth at each source of waste. Tables 9 and 10 summarize the predicted population growth for the years 1980, 2000, and 2020.

Employment in the Connoquenessing Creek economic area is projected to increase at a faster rate than occurred between 1940 and 1960. Total employment is expected to increase from 191,079 in 1960 to 671,000 in 2020, an average increase of 4.2 percent per year. Projected employment for the major industrial groups is presented in Table 9.

The manufacturing group will remain the largest employer in the area, although its share of total employment is projected to decline from 40 percent (1960) to 25 percent in 2020. Employment in manufacturing will increase from 85,218 in 1960 to 186,640 in 2020.

Industrial gross output projections were determined for the manufacturing industries which normally utilize significant quantities of water. These indices were applied to the existing industrial waste loads to arrive at the industrial waste contributions under projected conditions. Industrial gross output indices are presented in Table 11.

TABLE 9

CONNOQUENESSING CREEK ECONOMIC AREA
HISTORICAL AND PROJECTED POPULATION AND EMPLOYMENT
(BEAVER, BUTLER, LAWRENCE, AND MERCER COUNTIES)

	1940	1950	1960	1980	2000	2020
Total Population	442,260	489,586	562,071	776,500	1,469,000	1,793,000
Total Employment	130,799	173,912	191,079	271,900	530,000	671,000
Agriculture[1]	12,128	9,207	5,382	2,800	2,120	2,030
Mining	4,507	3,896	1,959	1,210	1,060	900
Construction	3,681	7,553	8,320	14,260	32,130	40,100
Manufacturing	(56,421)	(81,209)	(85,218)	(104,030)	(153,400)	(186,640)
Durable Goods		(7,418)	(75,647)	(92,500)	(136,900)	(165,100)
Furn. Lumber, Wood	1,039	876	974	700	600	550
Primary Metals		42,242	42,058	42,100	44,000	46,000
Fabricated Metals		6,391	8,756	14,300	29,800	42,700
Mach., Ind., Elec., Equip.	5,499	14,894	13,681	21,600	45,100	57,800
Trans. Equip. & Mtr. Veh.	1,427	1,546	3,421	2,900	2,400	1,500
Other Durables	45,172	8,231	6,857	10,900	15,000	16,550
Non-Durables		(7,029)	(9,571)	(11,530)	(16,500)	(21,540)
Food	1,389	1,568	2,556	3,130	4,100	5,600
Textiles & Apparel	741	825	834	750	660	600
Printing & Publishing	683	1,073	2,075	2,300	2,540	3,000
Chemicals	471	1,486	2,097	3,450	7,500	10,740
Other Non-Durables		2,077	2,009	1,900	1,700	1,600

TABLE 9 (Continued)

CONNOQUENESSING CREEK ECONOMIC AREA
HISTORICAL AND PROJECTED POPULATION AND EMPLOYMENT
(BEAVER, BUTLER, LAWRENCE, AND MERCER COUNTIES)

	1940	1950	1960	1980	2000	2020
Trans., Comm., & Util.	9,966	14,618	13,624	15,300	24,750	25,660
Wholesale & Retail Trade	18,369	25,128	29,527	49,800	114,730	137,050
Finance, Insurance & R. Est.	2,191	2,977	4,551	12,450	30,000	42,160
Personal & Business Service	18,970	22,979	31,957	60,500	142,350	190,450
Government	2,737	3,477	4,578	11,550	30,460	46,050
Unreported	1,829	1,868	3,961	-	-	-
TOTAL	130,799	173,912	191,079	271,900	530,000	671,000
Population	442,260	489,586	562,071	776,500	1,469,000	1,793,000

[1]Includes forestry and fisheries

TABLE 10

POPULATION PROJECTIONS FOR STUDY AREA

Community or Township (Twp.)	1960	1980	2000	2020
Beaver County	206,948	301,000	520,000	600,000
Koppel	1,389	2,000	3,300	3,900
New Brighton	8,397	11,000	14,000	17,000
Beaver Falls	16,240	22,000	30,000	41,000
Butler County	114,639	166,000	384,000	465,000
Evans City	1,875	2,600	5,600	6,400
Harmony	1,142	1,700	4,000	4,800
Mars	1,522	2,100	4,600	5,200
Zelienople	3,284	5,200	12,800	16,500
Butler	20,975	27,000	47,000	57,000
Butler Twp.	15,219	23,400	59,000	77,000
Center Twp.	4,303	6,400	17,500	24,000
Cranberry Twp.	3,596	5,500	20,200	24,500
Lawrence County	112,965	152,500	275,000	328,000
Elwood City	11,310	15,000	25,000	28,000
Mercer County	127,519	157,000	290,000	400,000

Note: County totals include population outside of the study area.

TABLE 11

PROJECTED INDUSTRIAL GROSS OUTPUT FOR STUDY AREA

(1960=100)

SIC Code	Manufacturing Industry	Index of Gross Output 1980	2000	2020
20	Food and Kindred Products	230	525	1280
22,23	Textiles and Apparel	150	220	360
24,25	Lumber and Wood Products including Furniture	155	315	475
27	Printing and Publishing	200	380	750
28	Chemicals and Allied Products	470	2655	7450
33	Primary Metals	190	320	550
34	Fabricated Metal Products, except Ordnance, Machinery and Transportation Equipment	290	1040	2575
35	Machinery, except Electrical	255	885	1895
37	Transportation Equipment	170	230	250

VI. WATER QUALITY CONTROL

Sources of Pollution

The major sources of pollution found in Connoquenessing Creek are inadequately treated municipal and industrial wastes.

Several industries located in the study area are not providing a sufficient level of waste treatment to meet the existing regulations of the Pennsylvania Sanitary Water Board. Table 12 summarizes the current status of individual waste treatment facilities for the industrial waste permitees in the study area.

There are several municipalities which discharge significant quantities of organic wastes to the streams in the study area (see Figure 3). The existing sewerage facilities and estimates of their untreated load contributions under present and projected conditions are summarized in Table 13.

In the Butler, Pennsylvania area the most significant contributors of wastes include the large Armco Steel Corporation complex and the Butler Area Joint Sewage Authority. Although many of the individual homes located in the vicinity of Butler are discharging untreated wastes to the stream, the large residual organic loads from the sewage treatment facilities and the lagoon discharge of the steel manufacturing plant account for the bulk of the oxygen demanding wastes found in Connoquenessing Creek below Butler.

The Armco complex is currently engaged in an expansion program

TABLE 12

SUMMARY OF INDUSTRIAL WASTE PERMITTEES

Plant Name	Location	Receiving Stream	Type of Industry	Status of Waste[1/] Treatment Facilities
Beaver County				
Babcock & Wilcox Co.	Koppel Boro.	Beaver River	Steel Tubing	1
Babcock & Wilcox Co.	W. Mayfield	Beaver River	Blast Furnace & Rolling Mill	2
Calgon Corp.	Ellwood City	Connoquenessing Creek	Water Treatment Chemicals	1
Ceramic Color & Chemical Manufacturing Co.	New Brighton	Blockhouse Run	Pigments, ceramic colors	3
Ellwood Knitting Mills	Ellwood City	Connoquenessing Creek	Knit Outerwear	1
Ellwood Stone Co.	Big Beaver Boro.	Beaver River	Silica Sand	3
Leopardi Products	N. Sewickley Twp.	Connoquenessing Creek	Potato Chips	2
Mayer China Co.	Beaver Falls	Beaver River	Vitrified China	2
Moltrup Steel Products	Beaver Falls	Beaver River	Steel plates	2
Townsend Company	Fallston Boro.	Beaver River	Steel wire, nails, spikes	3
Townsend Company	N. Sewickley Twp.	Connoquenessing Creek	Metal fasteners	3
Butler County				
American Plating	Zelienople	Connoquenessing Creek	Electro-plating	1
Anderson Asphalt Co.	Adams Twp.	Breakneck Creek	Asphalt	1

TABLE 12

SUMMARY OF INDUSTRIAL WASTE PERMITTEES (Continued)

Plant Name	Location	Receiving Stream	Type of Industry	Status of Waste Treatment Faciliti[1/]
Armco Steel No. 1	Butler Twp.	Connoquenessing Creek	Primary Steel	3
Armco Steel No. 2	Butler	Connoquenessing Creek	Stainless Steel	2
Austins Household Prod.	Adams Twp.	Breakneck Creek	Detergents, Cleaners	1
Castle Rubber Co.	E. Butler	Bonnie Brooke	Industrial Rubber	1
Comaco Inc.	Middlesex Twp.	Glade Run Trib.	Precoated Aluminum and Steel Coils	3
Country Bell Company	Center Twp.	-	Powdered Milk	1
Eagle Coal Company	Center Twp.	Stony Run Trib.	Coal Washery	1
Halstead and Mitchell	Zelienople	Connoquenessing Creek	Copper Tubing	1
Mine Safety Appliances	Callery	Breakneck Creek	Safety Appliances	1
Warrendale Plating Co.	Adams Twp.	Breakneck Creek	Metal Bumpers	2
Lawrence County				
U. S. Steel, National Tube Division	Ellwood City	Connoquenessing Creek	Steel Pipe and Tubes	1 [2/]

1/ 1-Compliance
2-Violation, satisfactory progress
3-Violation, unsatisfactory progress
Source: Pennsylvania Department of Health, Pittsburgh District Office. (December, 1969)

2/ Source: Pennsylvania Department of Health, Meadville District Office. (December, 1969)

TABLE 13

EXISTING SEWERAGE FACILITIES AND PROJECTED UNTREATED LOADS

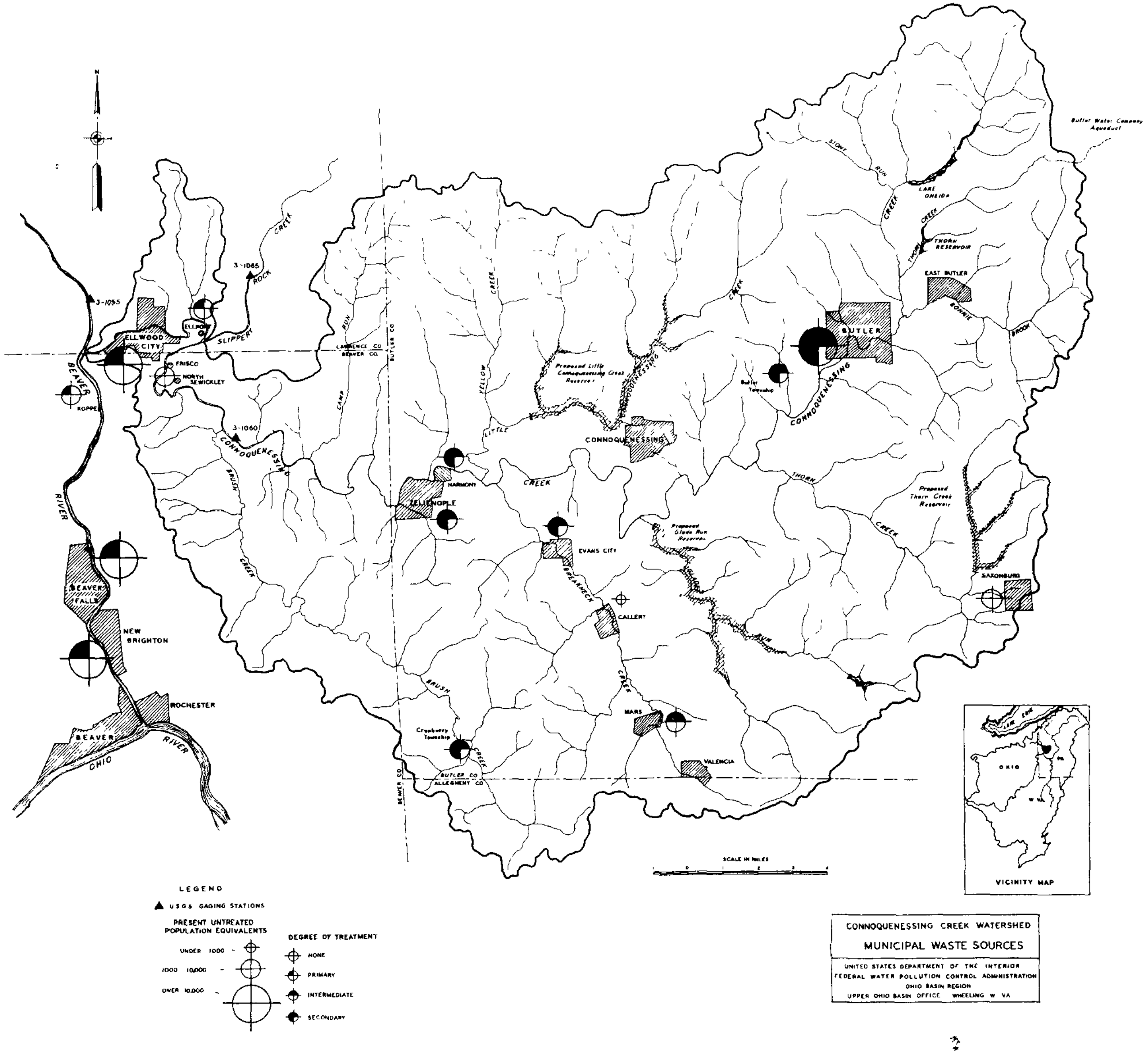
Community	Present Treatment 1/	Population Served	Receiving Stream	Untreated Population Equivalents Present	1980	2000	2020
Beaver County							
Beaver Falls	P	26,000	Beaver River	36,400	49,100	67,300	98,300
Koppel	P 4/	1,400	Beaver River	1,400	2,020	3,330	3,930
New Brighton	P	11,500	Beaver River	13,800	18,100	23,000	27,900
Butler County							
Butler Twp.	S 3/	4,000	Sawmill Run	4,000	4,000	4,000	4,000
BAJSA 2/	S	36,000	Connoquenessing Cr.	36,900	65,000	121,000	147,000
Callery	None	419	Breakneck Creek	420	580	1,250	1,430
Cranberry Twp.	S	1,720	Brush Creek	1,720	2,630	9,670	14,000
Evans City	S	1,500	Breakneck Creek	1,500	2,080	4,480	5,120
Harmony	S	1,500	Connoquenessing Cr.	1,500	2,230	5,250	6,300
Mars	I	1,550	Breakneck Creek	1,550	2,140	4,680	5,300
Saxonburg	S	1,000	Rockdale Creek	1,000	1,540	3,880	5,060
Zelienople	S	4,200	Connoquenessing Cr.	4,200	6,640	19,600	25,300
Lawrence County							
Ellport	P	1,400	Connoquenessing Cr.	1,400	1,890	3,400	4,060
Ellwood City	P	15,000	Connoquenessing Cr.	18,000	23,900	46,400	52,100
N. Sewickley and Frisco	None	1,500	Connoquenessing Cr.	1,500	2,020	3,640	4,350

1/ P - Primary, I - Intermediate, S - Secondary

2/ Butler Area Joint Sewage Authority

3/ Overloaded at times from infiltration

4/ Not operable



CONNOQUENESSING CREEK WATERSHED

MUNICIPAL WASTE SOURCES

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO BASIN REGION
UPPER OHIO BASIN OFFICE WHEELING W VA

to modernize their overall steel-making capabilities and increase the productive capacity at the Butler Works. During the 1968 field surveys, the old open hearth melting furnaces and rolling mills, with their many process waste discharges, were in operation. Several new electric furnaces and a large, continuous slab casting unit are being installed, and should be in operation in 1970. Although some of the older rolling mills and stainless steel production facilities will continue operation, recently added waste treatment facilities will eventually eliminate most of the process waste outfalls that are discharging water with high concentrations of various dissolved solids and toxic materials. The lagoons, which receive large quantities of neutralized pickle liquor and wash water wastes, will continue to be operated as in the past.

The lagoon discharge was found to contain significant quantities of oxygen consuming wastes when sampled in 1968. An average BOD_{20} load of 657 lbs/day was measured during the three-day sampling period in late August, 1968. BOD_{20} concentrations ranged from 44 to 67 mg/l in the estimated 2.2 cfs lagoon discharge. The source of these oxygen consuming wastes is unknown.

Although the existing effluent BOD_{20} load from the Butler Sewage treatment plant was found to be slightly lower than that from the Armco lagoon discharge, Butler's raw load was much greater than the estimated Armco raw load. For the purpose of evaluating the pollution abatement requirements in this study, it was assumed that the existing Armco effluent load approximates their raw contribution.

Most of the large phosphorus load found in the stream at the Butler complex is contributed by the Butler Sewage Authority system. Analysis of several composite samples of Butler's effluent indicated that the average contribution was 10 lbs/day total phosphorus (as P) for every 1000 population served. During one of the field surveys, the Armco process effluents contained large quantities of phosphorus that were apparently being discharged in batches. It is believed that the use of phosphate addatives for the control of scaling in the water distribution system at Armco was responsible for the intermittently high loads. Since the Armco phosphorus contributions are quite irregular in frequency and magnitude, the overall average contribution was quite small as compared to the municipal sources. The Armco phosphorus contribution to Connoquenessing Creek is expected to be significantly reduced when the current expansion program is completed.

Using the predicted economic growth patterns for the Butler area, future untreated wastes generated in the Butler complex would approach the following:

Source	Waste	1980	2000	2020
Butler Sanitary Systems	BOD_{20} (Population Equivalents)	69,000	125,000	151,000
Armco Lagoon	BOD_{20} (Population Equivalents)	4,000	5,000	9,000
Totals		73,000	130,000	160,000
Butler Sanitary Systems	Total Phosphorus as P (lbs/day)	690	1,250	1,500

Breakneck Creek introduces significant residual wastes to Connoquenessing Creek. Several industries and small municipalities located on this Creek do not have sufficient waste treatment to provide the desired protection to stream quality. The residual wastes from Breakneck Creek plus the municipal discharges of Zelienople and Harmony further degrade Connoquenessing Creek just as it is recovering from degradation caused by wastes introduced from the Butler complex, twenty stream miles upstream.

Connoquenessing Creek begins to recover only to be subjected to a similar pattern of degradation in the Ellwood City area. Residual municipal wastes entering via Brush Creek and the industrial and municipal contributions in the Ellwood City area combine to once more alter the water quality conditions of Connoquenessing Creek before it enters the Beaver River. Dissolved oxygen deficiency and nutrient associated problems are not as severe in this reach because of the vast increase in the waste assimilative capacity of the Creek. The extremely high natural reaeration capacity along with the introduction of additional dilution water from Slippery Rock Creek influence the stream's ability to assimilate residual organic wastes.

Water Quality Criteria

Pennsylvania's first comprehensive Clean Streams Law was adopted in 1937. The law provides for the establishment of water quality criteria for all streams in the State. The Pennsylvania Sanitary

Water Board has adopted water quality criteria for interstate streams in conformance with the Federal Water Quality Act of 1965 as amended. The proposed standards for the Beaver River have been approved by the Secretary of the Interior and are presented in Table 14.

The State of Pennsylvania has been actively engaged in the process of establishing water quality criteria for intrastate waters. Connoquenessing Creek is one of the few intrastate streams where specific criteria has not yet been developed. In the absence of state standards, water quality criteria commensurate with current national and state objectives will be utilized in the assessment of pollution abatement needs. The water quality objectives proposed in this report for the Connoquenessing Creek drainage will provide protection for all legitimate water uses to meet both existing and anticipated needs. The standard water uses established by the Pennsylvania Water Board for most waters of the Commonwealth include the following:

- 1.0 - Aquatic Life
  - 1.2 Warm Water Fish
- 2.0 - Water Supply
  - 2.1 Domestic
  - 2.2 Industrial
  - 2.3 Livestock
  - 2.4 Wildlife
  - 2.5 Irrigation

TABLE 14

WATER QUALITY CRITERIA-BEAVER RIVER

Parameter	Criteria
pH	Not less than 6.0; not to exceed 8.5.
Dissolved Oxygen	Minimum daily average 5.0 mg/1; no value less than 4.0 mg/1.
Iron	Total iron - not to exceed 1.5 mg/1.
Temperature	Not to exceed 5°F rise above ambient temperature or a maximum of 87°F, whichever is less; not to be changed by more than 2°F during any one hour period.
Dissolved Solids	Not to exceed 500 mg/1 as a monthly average value; not to exceed 750 mg/1 at any time.
Bacteria (Coliforms/100 ml)	For the period 5/15 - 9/15 of any year; not to exceed 1000/100 ml as an arithmetic average value; not to exceed 1000/100 ml in more than two consecutive samples; not to exceed 2400/100 ml in more than one sample.
	For the period 9/16 - 5/14 of any year; not to exceed 5000/100 ml as a monthly average value, nor to exceed this number in more than 20% of the samples collected during any month; nor to exceed 20,000/100 ml in more than 5% of the samples.
Threshold Odor Number	Not to exceed 24 at 60°C.

3.0 - Recreation

3.2 Fishing

3.3 Water Contact Sports

3.4 Natural Area

3.5 Conservation Area

4.0 - Other

4.1 Power

4.3 Treated waste assimilation

The water quality criteria established for the Beaver River were designed for the protection of the above water uses, and are also applicable to Connoquenessing Creek.

Pollution Abatement Alternatives

Several pollution abatement alternatives were considered in the evaluation conducted to determine the most favorable plan for meeting the water quality objectives in Connoquenessing Creek. The principal alternatives included the use of low flow augmentation, through reservoir releases, in combination with various levels of advanced waste treatment at the municipal and industrial sources; the use of a pipeline to transport treated wastes from the Butler and Zelienople areas to the Beaver River; and expansion of the existing inter-basin water transfer system to facilitate low flow augmentation needs in lieu of reservoir releases for water quality control.

It was assumed that all wastes would receive at least the

degree of treatment set forth below as the definition of secondary waste treatment or its equivalent:

> Substantially complete removal of all floatable and settleable materials, a minimum removal of 85 percent of the 5-day BOD and suspended solids based on design flow, disinfection or other methods that result in substantial reduction of microorganisms and such additional treatment as may be necessary to meet applicable water quality standards, and to meet recommendations of the Secretary of the Interior or orders of a court pursuant to Section 10 of the Federal Water Pollution Control Act.

With regard to the alternatives involving low flow augmentation, an evaluation of the total streamflow requirements needed to maintain 5.0 mg/l dissolved oxygen throughout Connoquenessing Creek indicated that solution of the problem at Butler would provide protection to the entire stream. That is, if additional streamflow were provided to Connoquenessing Creek in the immediate vicinity of Butler, the 5.0 mg/l dissolved oxygen level would be maintained throughout the remainder of the Creek. The hydraulic and hydrologic characteristics of the receiving stream, the relative spacing of significant, organic waste discharges and the fact that the present and projected raw waste loads from the Butler area are much greater in magnitude than other sources influenced the selection of the primary area of streamflow augmentation need.

Utilizing the basic Streeter-Phelps equations for dissolved oxygen dynamics in streams, the total streamflow requirements were computed for Connoquenessing Creek under varying degrees of twenty-day Biochemical Oxygen Demand (BOD_{20}) removal efficiencies of wastes originating from the Butler municipal and industrial complex. The results of this analysis are presented in Table 15.

TABLE 15

TOTAL FLOW REQUIREMENTS IN CFS AT BUTLER, PENNSYLVANIA, NEEDED TO MAINTAIN 5.0 MG/L DISSOLVED OXYGEN (JUNE THROUGH OCTOBER)

Year	Waste Flow cfs 1/	Ultimate Biochemical Oxygen Demand (BOD_{20}) Removal Efficiencies 85%	90%	95%
1968	9	36	24	12
1980	15	56	37	19
2000	24	100	68	33
2020	32	124	84	41

1/ Estimated total waste flow discharged by municipal and industrial water users in the Butler area.

It was assumed that all communities and industries which discharge organic wastes to tributary streams would provide sufficient treatment to meet the water quality objectives for all streams in the area. Since many of these tributary streams are virtually dry during the summer and fall seasons, the minimum waste treatment requirements were assumed to be above the conventional secondary level. It is, however, not the purpose of this study to determine the precise minimum treatment requirements for the small communities whose residual wastes have little influence on the water quality

of Connoquenessing Creek.

In order to insure that water quality enhancement is achieved throughout the entire length of Connoquenessing Creek, it is essential that augmented flows be introduced to the stream in the immediate vicinity of the Butler municipal and industrial complex. This eliminates consideration of the proposed Little Connoquenessing Creek Reservoir and certainly reduces the desirability of utilizing the proposed Glade Run Reservoir for water quality control storage. The most favorable locations for such storage appear to be in the tributaries immediately above and below Butler. The potential Thorn Creek site is in an ideal location for meeting the flow augmentation needs. In analyzing the pollution control options involving reservoir storage, the Thorn Creek site was given prime consideration while the Glade Run site was considered as a supplementary source of storage when quantities above Thorn Creek's maximum available potential were required.

Estimates of reservoir storage requirements to meet the net flow augmentation needs were obtained through extrapolation of a curve which relates storage amounts to streamflow demands with a failure frequency of one-in-ten years. This relationship was developed by the Hydrology Branch of the U. S. Army Corps of Engineers, Pittsburgh District Office. The storage-streamflow relationship was developed under the assumption that the future water supply needs of the Butler municipal and industrial complex could be

supplied by potential developments in upstream areas. This appears to be the most rational approach since the Soil Conservation Service has identified preliminary sites upstream from Butler with potential water supply storage and there is the possibility that the existing inter-basin water transfer system from the Allegheny River could be expanded to satisfy projected needs.

An assessment of the existing assimilative capacity of the Beaver River indicates that a minimum of secondary treatment (as previously defined) of all municipal and industrial wastes in the study reach is required to meet the 5.0 mg/1 dissolved oxygen level under present and projected to the year 2020 conditions. In arriving at this conclusion, it was assumed that sufficient treatment will be provided to the upstream waste sources in order that the existing water quality objectives will be achieved.

The 5.0 mg/1 dissolved oxygen objective may be obtained throughout the study area without the use of additional streamflow to increase the assimilative capacity of the streams. Table 16 summarizes the minimum treatment requirements of significant organic wastes for achievement of the water quality objectives.

TABLE 16

SUMMARY OF MINIMUM WASTE TREATMENT
REQUIREMENTS NEEDED TO MAINTAIN 5.0 mg/1
DISSOLVED OXYGEN WITHOUT LOW FLOW AUGMENTATION

Area	Percent BOD_{20} Removal		
	1980	2000	2020
Connoquenessing Creek			
Butler	96%	96%	96%
Zelienople & Harmony	92%	92%	92%
Ellwood City & Vicinity	85%	85%	85%
Beaver River			
All communities 1/	85%	85%	85%

1/ Those organic waste sources which discharge to the Beaver River within Beaver County, Pennsylvania.

Another alternative considered in this study is the use of a pipeline to transport the residual wastes after secondary treatment, from the Butler and Zelienople areas to the Beaver River. The pipeline would be designed to carry the volume of wastes expected by the year 2020. Since there are existing nutrient-associated problems in the Beaver River, it was assumed that a high degree of nutrient removal would be required at the waste sources prior to pipeline transportation.

One of the prime pollution control objectives in Connoquenessing Creek is to substantially reduce the nuisance growths of aquatic plants. A review of current literature on the subject indicates that there is no phosphorus standard applicable to all situations. It has been suggested by some scientists [13/] that inorganic phosphorus levels be limited to 0.01 mg/l (P) to prevent algae blooms in lakes. Others have concluded that phosphorus levels below 0.5 mg/l (PO_4) or 0.16 mg/l (P) would control nuisance growths and that algae growth would almost stop at levels below 0.05 mg/l (PO_4) or 0.016 mg/l (P).

The Report of the National Technical Advisory Committee on Water Quality Control [14/] recommends, as a guideline, that the concentration of total phosphorus should not be increased to levels exceeding 0.1 mg/l (P) in flowing streams for control of nuisance algae growths. The Report also recommends that the addition of all organic wastes containing nutrients, vitamins, trace elements, and growth stimulants should be carefully controlled and that a biological monitoring system should be utilized to determine the effectiveness of the control measures put into operation.

Since excessive nutrients are partly responsible for the pollution problems in Connoquenessing Creek, an attempt was made to analyze the effectiveness of each pollution abatement alternative in terms of residual nutrient levels in the stream. In addition to the principal plans, consideration was given to the use of reservoir releases for low flow augmentation to provide dilution of the residual phosphorus to a level which would meet the Committee's criteria. This abatement method was, however, found to be highly unreliable since the potential dilution water was found to contain, at times, quantities of nutrients significantly above the desired phosphorus concentration in the stream.

Another water quality characteristic which required attention in this study was the high level of dissolved solids found in Connoquenessing Creek in the vicinity of Butler, Pennsylvania. The source of the pollutant appears to be a combination of several industrial waste discharges in and above Butler. It is speculated that part of the problem stems from the discharges from abandoned coal mines located on tributaries to Connoquenessing Creek upstream from Butler. Most of the problem, however, appeared to be caused by inadequately treated industrial waste discharges. Although reservoir releases designed to provide dilution of these dissolved solids could be utilized in solving this particular problem, it is believed that installation of the minimum required industrial treatment facilities set forth by the Pennsylvania Sanitary Water Board will provide adequate protection to the stream.

VII. COST AND BENEFIT ANALYSIS

Selection of A Pollution Abatement Plan

The basis for selecting the most favorable alternative means of maintaining the water quality objectives over the project design life is that the plan should achieve these goals at a minimum total cost and be consistent with the minimum treatment requirements. The least costly alternative is independent of the distribution of cost between the local, State and Federal Governments.

Each of the pollution abatement alternatives was evaluated for the 100-year study period. All costs for waste treatment facilities, reservoir storage, and pipelines include estimates of annual operation and maintenance and are in July 1968 dollars. The 4-7/8 percent interest rate was utilized in estimating the average annual cost of each facility.

Treatment levels of 85, 90, 95, and 98 percent BOD_{20} removal were selected as points to determine the comparative cost of combinations of reservoir storage for low flow augmentation and waste treatment. The treatment methods used as a basis for the comparative costs in this analysis are as follows:

1. 85 percent treatment consists of a secondary plant utilizing the trickling filter process.
2. 90 percent treatment consists of a secondary plant utilizing the activated sludge process.

3. 95 percent treatment consists of activated sludge plus coagulation and sedimentation with lime and rapid sand filtration.

4. 98 percent treatment consists of activated sludge plus coagulation and sedimentation with lime, nitrogen removal rapid sand filtration and granular carbon adsorption.

It was assumed that each waste treatment facility would have a fully effective life of 25 years. Although the advanced waste treatment processes may not necessarily be operated throughout the entire year, for the purpose of this cost analysis, cost estimates of operation and maintenance were based on continuous operation.

Estimates of the cost of providing the required reservoir storage for low flow augmentation to meet the total stream flow requirements were taken from preliminary cost data supplied by the Planning Division of the Pittsburgh District, U. S. Army Corps of Engineers. Figure 4 presents a graphical representation of the average annual cost per acre foot of storage for the Thorn Creek and Glade Run sites. These costs represent the total annual cost of a single-purpose reservoir designed to provide the flow schedule for downstream water quality control needs.

A comparison of the alternative total costs (see Table 17) reveals that the least costly combination occurs at the 95 percent BOD_{20} level.

Figure 4 Reservoir Cost Estimates

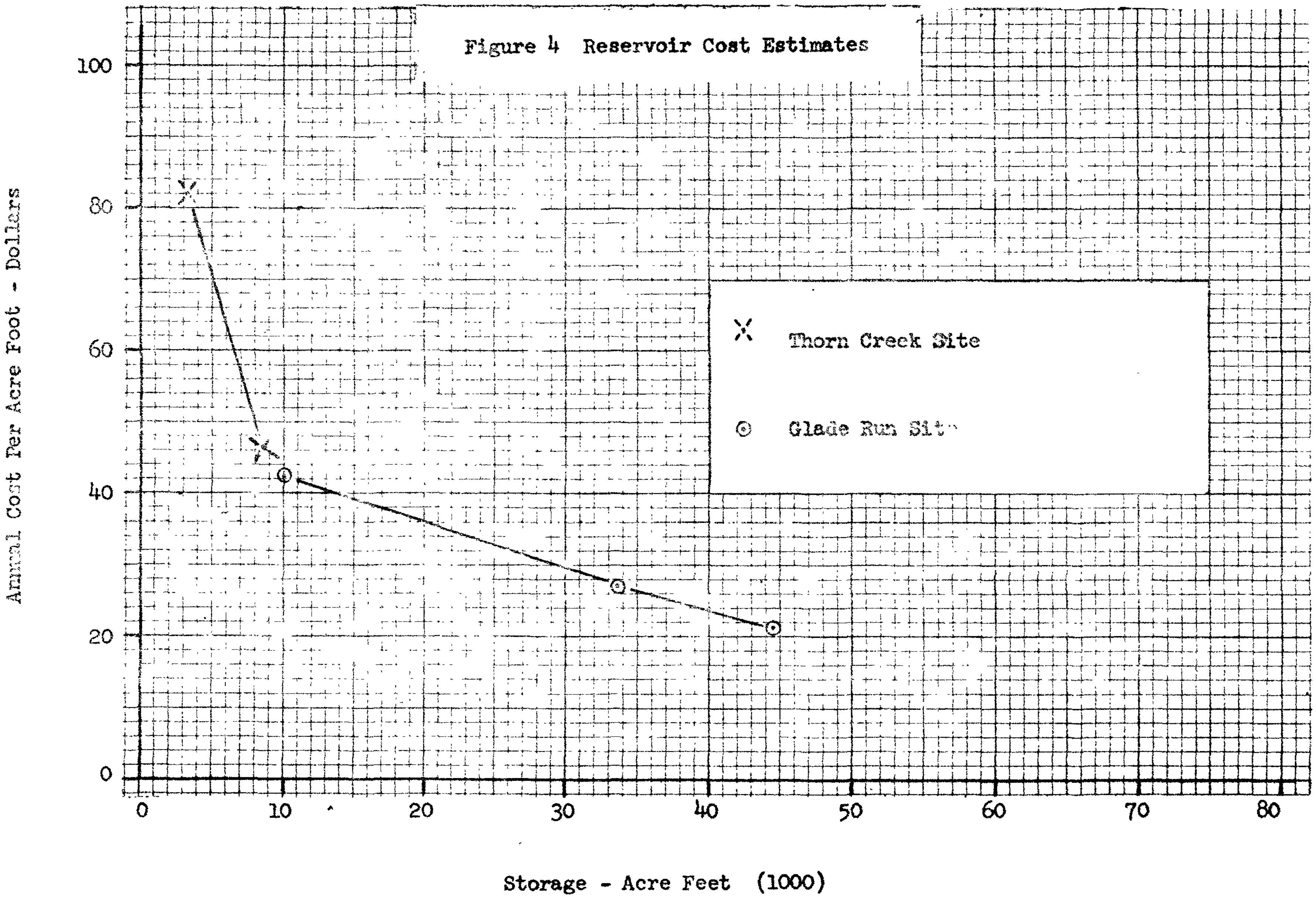


TABLE 17

COST COMPARISON OF LOW FLOW
AUGMENTATION AND WASTE TREATMENT SYSTEMS
REQUIRED TO MAINTAIN 5.0 mg/1 DISSOLVED OXYGEN

	Degree of Treatment (% BOD_{20} removal)			
	85	90	95	98
Annual Cost of waste treatment				
Butler area	$480,000	$690,000	$950,000	$1,700,000
Zelienople area	$130,000	$170,000	$260,000	$ 260,000 1/
Totals	$610,000	$860,000	$1,210,000	$1,960,000
Estimated storage requirements (acre feet)	(52,000)	(13,000)	(1,500)	(0)
Annual cost of storage	$1,220,000	$740,000	$140,000	0
Total annual cost of water quality control	$1,830,000	$1,600,000	$1,350,000	$1,960,000

1/ The maximum treatment needs at Zelienople are 92% BOD_{20} removal; therefore, the cost for 95% BOD_{20} was considered for this alternative.

Since there are two potential sources of water which could be used to satisfy the net streamflow requirements for water quality control, the respective cost estimates were compared so that the most favorable method could be identified. In lieu of reservoir storage, the low flow augmentation needs could be satisfied by transporting additional flows from the Allegheny River to the headwaters of Connoquenessing Creek. Such a system would require a permit from the State of Pennsylvania to increase the existing withdrawal rate from the Allegheny River. These types of permits are normally granted if it can be shown that the withdrawal will have an insignificant effect on downstream water users. It is doubtful that a permit would be granted for a large increase in the withdrawal rate because of the fact that existing low flows in the Allegheny River are augmented by releases from the Allegheny River Reservoir for water quality control in the Pittsburgh area. Without knowing the probable limitation on potential withdrawal increases, it was assumed, for the purpose of the alternative cost analysis, that the required flows could be transferred to Connoquenessing Creek.

Estimates of the total annual cost for this alternative included the initial construction cost of an eleven-mile pipeline with appurtenant pumping facilities, and the annual operation and maintenance. The annual cost of existing augmentation in the Allegheny River was not considered. The pipeline was designed to supply the low flow augmentation needs through to the year 2020. Table 18 presents a summary of the comparative costs for the two sources of low flow augmentation water.

TABLE 18

COST COMPARISON OF THE TWO
SOURCES OF LOW FLOW AUGMENTATION WATER

Net Flow Required (cfs)	Annual Cost - Dollars Reservoir Releases	Annual Cost - Dollars Inter-basin Transfer
9	$140,000 1/	$300,000
52	$740,000 2/	$1,200,000
92	$1,220,000 2/	$2,100,000

1/ Thorn Creek site. 2/ Thorn Creek and Glade Run sites.

Inspection of the comparative costs reveals that reservoir storage is the least costly source of water for low flow augmentation to Connoquenessing Creek.

Another pollution abatement method given consideration in this study is the transportation of treated wastes to the Beaver River. Such a pipeline would convey the waste effluent from treatment facilities in the Butler and Zelienople areas to the Beaver River, a total distance of approximately 44 miles. The pipeline was designed to carry the projected waste flows to the year 2020. Table 19 summarizes the comparative costs of these alternatives. The effluent pipeline alternative would be more costly than the plan utilizing reservoir storage for low flow augmentation. In addition to being costlier, the effluent pipeline is less favorable because it would substantially reduce

TABLE 19

COST COMPARISON OF LOW FLOW
AUGMENTATION AND EFFLUENT PIPELINE

	Annual Cost - Dollars	
	Pipeline	Low Flow Augmentation 1/
Annual cost of treatment		
Butler Area	$690,000	$950,000
Zelienople Area	$170,000	$260,000
Totals	$860,000	$1,210,000
Annual cost of effluent pipe	$820,000	$ 0
Annual cost of reservoir storage	$ 0	$ 140,000
Total annual cost of water quality control	$1,680,000	$1,350,000

1/ 1500 Acre Feet in Thorn Creek Site.

the dry season stream flows in Connoquenessing Creek to the point where other recreational type benefits would be minimized in the 44 miles of stream.

Since excessive nutrients are partly responsible for the pollution problems in Connoquenessing Creek, an attempt was made to analyze the effectiveness of each pollution abatement alternative in terms of residual nutrient levels in the stream.

One of the water quality objectives in Connoquenessing Creek is to control the excessive algal growths through limitation of phosphorus levels. Of the three alternative abatement plans, the effluent pipeline would provide the most reduction in stream phosphorus concentrations. Since this plan is undesirable because of cost considerations and its detrimental affect on dry weather stream flows, the residual phosphorus levels were computed for each of the waste treatment-low flow augmentation combinations considered in the study. In this analysis it was assumed that all potential dilution water contained insignificant amounts of phosphorus. Table 20 summarizes the results of this analysis. The least costly combination of water quality control measures (1500 acre feet reservoir storage plus 95% BOD_{20} treatment at Butler) displayed the most efficient means of providing maximum reduction of stream phosphorus levels. The advanced waste treatment processes of Coagulation and Sedimentation with Lime and Rapid Sand Filtration were considered the most favorable combination for maximizing

TABLE 20

ESTIMATED RESIDUAL PHOSPHORUS IN
CONNOQUENESSING CREEK

Pollution Abatement Combinations: 2020 Reservoir Storage (acre ft.)	Waste Treatment Process	Residual Stream Phosphorus-P 1/ (mg/l)
52,000	Trickling Filter	1.8
13,000	Activated Sludge	2.8
1,500	Activated Sludge, Coagulation & Sedimentation with Lime and Rapid Sand Filtration.	0.35
0	Activated Sludge, Coagulation and Sedimentation with Lime, Nitrogen Removal, Rapid Sand Filtration and Granular Carbon Adsorption.	0.40

1/ Assuming all potential reservoir releases contained insignificant amounts of phosphorus.

phosphorus reductions of municipal wastes. These processes, plus the low flow augmentation constitute the most favorable plan for maintaining the water quality objectives through the year 2020.

The analysis of the various pollution abatement alternatives utilized specific advanced waste treatment processes without consideration of the practicability of application to existing facilities in the Butler and Zelienople areas. One reason for this rationale is the fact that these areas are expected to experience such rapid growth that existing treatment facilities would most likely become unable to manage the higher flow volumes in the near future. If existing facilities were replaced, the processes used in the analysis are considered to be the most practical available under current technology. Also, it is not the intent of this study to design the most desirable treatment facilities at each individual source of organic type wastes. The recommended pollution abatement plan should not necessarily stipulate the application of specific waste treatment processes, but rather it should provide limitations on the chemical and biological characteristics of projected waste effluents to Connoquenessing Creek.

The formulation of a pollution abatement plan was influenced by the fact that the combined municipal and industrial waste discharges from the Butler complex constitute the bulk of the streamflow in

Connoquenessing Creek under low natural flow conditions. Since the streamflow will contain such a high proportion of waste water even with the implementation of low flow augmentation, the pollution abatement plan should contain limitations on the concentration of waste effluents as well as minimum treatment requirements. It is therefore suggested that the recommended waste treatment requirements and effluent limitations presented in Table 21 be established for the study area.

TABLE 21

RECOMMENDED WASTE TREATMENT REQUIREMENTS NEEDED TO MEET WATER QUALITY OBJECTIVES IN CONNOQUENESSING CREEK WITH LOW FLOW AUGMENTATION

AREA	ALLOWABLE EFFLUENT CONCENTRATION (mg/1)		MINIMUM TREATMENT REQUIREMENTS (PERCENT REMOVAL)	
	BOD_{20}	TOTAL PHOSPHORUS-P	BOD_{20}	TOTAL PHOSPHORUS-P
Waste discharges in the vicinity of Butler, Pennsylvania	10.5	0.5	95	95
Waste discharges in the vicinity of Zelienople and Harmony, Pennsylvania	30	0.5	90	95

The recommended pollution abatement measures will require the installation of advanced waste treatment facilities in the Butler and Zelienople areas. As previously discussed in this report, there are many unsewered areas in the vicinity of these communities. There are also a few small sanitary waste treatment systems which cannot provide the high degree of treatment recommended. In view of these conditions, it is highly desirable that consideration be given to the use of a regional waste collection system which would transport the wastes to a central treatment plant at Butler and Zelienople. Such a system normally minimizes per capita treatment costs.

Although the raw oxygen consuming waste load from the Armco lagoon is relatively small when compared to the other sources in the Butler complex, this load must be substantially reduced to meet the recommended water quality objectives in Connoquenessing Creek. Isolation of the oxygen consuming wastes may simplify their treatment at either an in-house treatment facility or a regional sanitary-industrial waste treatment system. Also, all measures should be taken by Armco to insure that the intermittent phosphate wastes are collected and treated.

In summary, the most favorable pollution abatement plan includes the use of reservoir storage in the proposed Thorn Creek site for water quality control in combination with the specified degree of advanced waste treatment for all organic wastes discharged to Connoquenessing Creek in the Butler and Zelienople

areas. Potential releases should be scheduled so that the minimum flow requirements presented in Table 22 are met during the period June through October.

TABLE 22

RECOMMENDED FLOW AUGMENTATION
FOR WATER QUALITY CONTROL, CONNOQUENESSING CREEK
BELOW BUTER, PENNSYLVANIA
(JUNE THROUGH OCTOBER)

	1980	2000	2020
Total Flow Required (cfs)	19	33	41
Estimated Return Flow (cfs) 1/	15	24	32
Net Flow Requirement (cfs)	4	9	9
Estimated Storage Required (Acre Feet)	1000	1500	1500

1/ Total waste flow discharged by municipal and industrial water users in the Butler area.

Experience has shown that the physical and chemical characteristics of water vary with depth in many of the deeper reservoirs. During periods of thermal stratification, which normally occur during the summer months, the bottom layers of the reservoir may contain water low in dissolved oxygen, high in iron and manganese content, and of objectionable taste and odor. In order to insure that downstream water quality is not adversely affected by release of poor quality water, it is recommended that all deep reservoirs constructed in the study area be provided with multi-level outlet structures capable of providing for adequate water quality control and facilities for monitoring such releases.

Benefits

Benefits associated with implementation of the recommended water quality enhancement plan would accrue throughout the length of Connoquenessing Creek below Butler, Pennsylvania. The achievement of the water quality objectives would enhance recreational activities in and along the Creek and increase the potential for sport fishing which is quite limited at the present time. Water quality enhancement would also increase the value of property adjacent to the stream.

The provision of low flow augmentation would enhance and protect the water quality of Connoquenessing Creek in a 44 mile reach thereby benefiting many communities and private property owners along the Creek. Since the recreation potential of the stream will be substantially increased, other more distant communities located outside of the immediate study area will benefit from the enhancement of stream water quality. The effects of the provision of storage for water quality control are therefore considered to be widespread in nature.

Since these benefits are quite difficult to evaluate quantitatively, the cost of providing the same effects of water quality improvement by the most likely alternative will be utilized as an approximation of benefits. The least costly alternative means of achieving water quality objectives is the use of a single-purpose reservoir, located on Thorn Creek, designed to meet the flow requirements as previously outlined. From preliminary cost data supplied by the Pittsburgh District, U. S. Army Corps of Engineers, it is estimated that the average annual cost of providing the comparable storage is $140,000. This may be considered as the minimum benefit.

Since additional water quality control benefits are not readily identifiable, the maximum benefit attributable to water quality control storage is actually the difference of the total annual cost of water quality control between the least costly alternative and the cost of the highest degree of waste treatment required to meet the water quality objectives without additional storage. From Table 17, a maximum average annual benefit of $610,000 could be credited to the proposed Thorn Creek Reservoir.

Probably the recommended low flow augmentation levels will not necessarily provide maximum recreation and fishing benefits in Connoquenessing Creek. Although water quality conditions are expected to be favorable for such stream uses, guaranteed additional streamflows would certainly further enhance the recreation potential of Connoquenessing Creek. Consideration should be given to the use of potential reservoir storage for this purpose.

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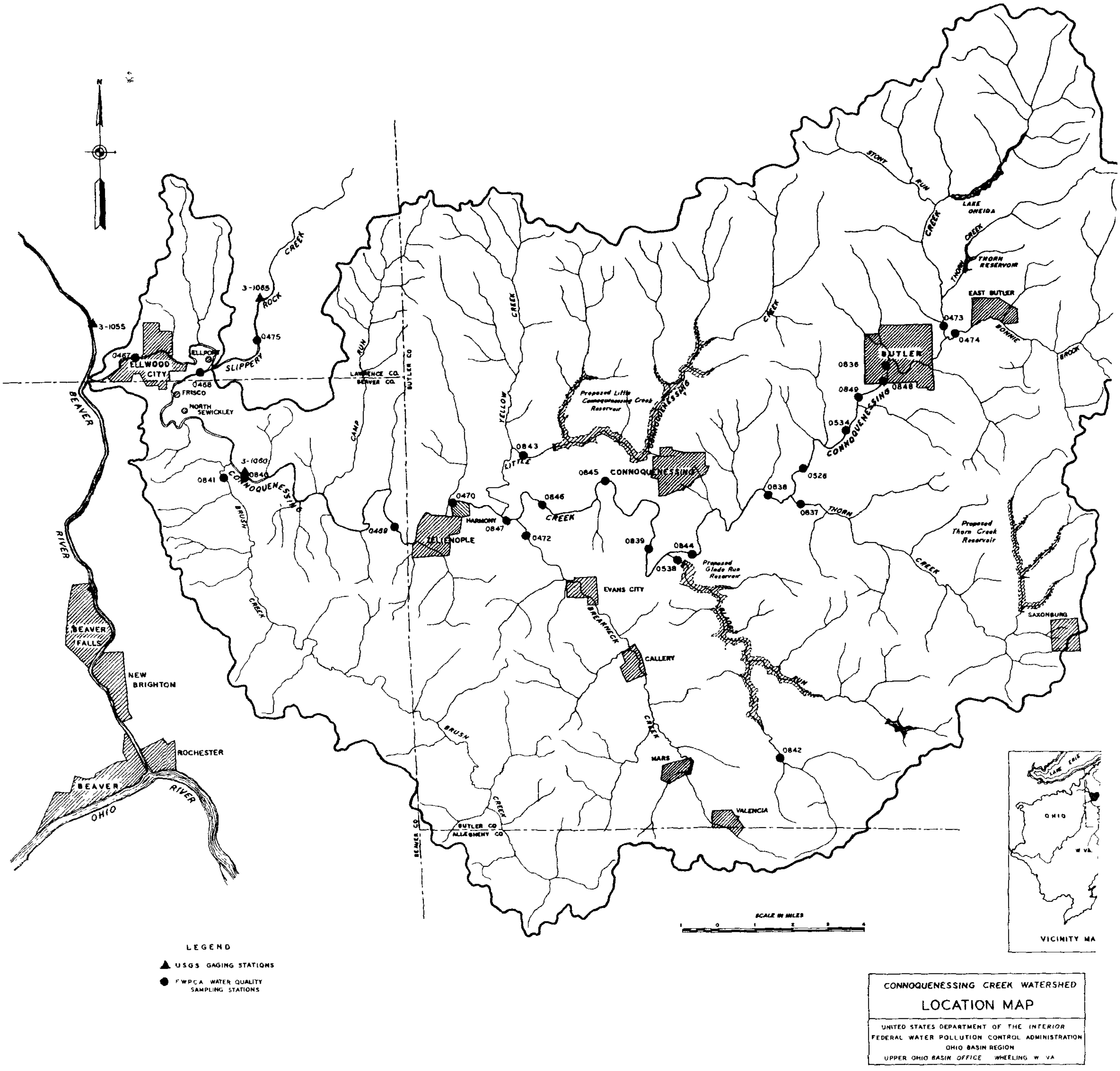

CONNOQUENESSING CREEK WATERSHED
LOCATION MAP
UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO BASIN REGION
UPPER OHIO BASIN OFFICE WHEELING W. VA.
LEGEND
USGS GAGING STATIONS
FWPCA WATER QUALITY SAMPLING STATIONS
SCALE IN MILES
VICINITY MA
ELLWOOD CITY
ELLPORT
FRISCO
NORTH SEWICKLEY
BEAVER FALLS
NEW BRIGHTON
ROCHESTER
BEAVER
OHIO RIVER
BEAVER RIVER
SLIPPERY ROCK CREEK
CONNOQUENESSING
ZELIENOPLE
HARMONY
EVANS CITY
CALLERY
MARS
VALENCIA
BUTLER
EAST BUTLER
SAXONBURG
LAKE ONEIDA
THORN RESERVOIR
Proposed Little Connoquenessing Creek Reservoir
Proposed Glade Run Reservoir
Proposed Thorn Creek Reservoir
LITTLE CREEK
YELLOW CREEK
BREAKNECK CREEK
BRUSH CREEK
THORN CREEK
BONNIE BROOK
STONY RUN
CAMP RUN
LAWRENCE CO.
BEAVER CO.
BUTLER CO.
ALLEGHENY CO.
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CONNOQUENESSING CREEK STUDY

APPENDIX A

AQUATIC BIOLOGY INVESTIGATION

LETTER REPORT

Prepared by

Pennsylvania Department of Health
Division of Water Quality

January 8, 1969

Aquatic Biology Investigation
Connoquenessing Creek Survey
Butler and Beaver Counties
July 29-30, 1968

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An intensive chemical and biological investigation of Connoquenessing Creek was carried out on July 29-30, 1968, in cooperation with the FWPCA (Ohio River Basin Project) of Wheeling, West Virginia; Pennsylvania Fish Commission; and the Meadville Regional Health Department office. The Wheeling Field Station of the FWPCA was requested by the U.S. Army Corps of Engineers to determine the need for, and value of, two potential multiple-purpose reservoirs to be located on tributaries of Connoquenessing Creek. Analysis of existing water quality conditions revealed that pollution problems (mainly high organic and nutrient loads and poor low flow characteristics) existed along some sections of Connoquenessing Creek. In order to better define the extent and magnitude of the problems, the present field investigations were conducted.

This report summarizes the results of the biological investigations. The biological investigation was conducted by E. R. Brezina and R. Bushick of the Pennsylvania Department of Health and R. Hesser of the Pennsylvania Fish Commission. During a two day reconnaissance on July 18 and 19, 1968, nine biological sampling stations were selected as representative of existing stream conditions (Table I and Figure 1). Benthic organisms were collected quantitatively using a 1 sq. foot Surber stream bottom sampler. Fishes were collected with a portable stream electro-shocker apparatus. Periphyton was qualitatively sampled by scraping deposits from the surface of several rocks at each location.

Results and Discussion: A summary of the biological data is presented in Tables II, III, and IV. From analysis and interpretation of the data, the following conclusions were drawn:

Station 1: Connoquenessing Creek above Butler

Clean stream conditions; relatively low standing crop of benthic fauna and fishes reflect physiographic conditions and productivity of stream; benthic and fish populations dominated by pollution sensitive organisms; some evidence of iron precipitates on stream bottom resulting from limited acid mine drainage inflow.

Station 2: <u>Connoquenessing Creek below Butler</u>

Moderate to severe stream degradation; benthic fauna represented by three taxa, all pollution tolerant; presence of tolerant species resulting from organic input from Butler sewage treatment plant; relatively low numbers of tolerant organisms indicates some toxic chemical or waste discharge, possibly pickling liquor or metal ions from Amco Steel Company. Periphyton community reflects organic and nutrient input to stream. Fish population poorly represented in numbers and species and dominated by pollution tolerant individuals.

Station 3: <u>Below Proposed Dam Site on Glade Run</u>

Clean stream conditions; good diversity of benthic and fish fauna; abundance of caddis fly, <u>Hydropsyche</u>, suggests nutrient and organic enrichment; complete absence of periphyton possibly related to abundance of needle-like crystalline structures (possibly calcium carbonate or some other mineral) and/or physical (habitat) conditions.

Station 4: <u>Connoquenessing Creek at Eidenau and upstream from Zelienople</u>

Intermediate stream conditions; dominance of pollution tolerant organisms (benthic fauna) with moderate abundance of <u>Simulium</u> and Tendipedidae suggest organic and nutrient enrichment. Fish populations represented by 15 species with more than 50% (by species) tolerant of polluted conditions.

Station 5: <u>Downstream from Zelienople</u>

Moderately polluted conditions; dominance (both species and numbers) of pollutional tolerant benthic invertebrates and fishes. Attached alga, <u>Cladophora</u>, very abundant; this alga responds to increased organics and nutrients. Ideal habitat conditions for benthic populations somewhat lacking due to abundance of <u>Cladophora</u> occupying available suitable substrate.

Station 6: <u>At Hazen and upstream from Ellwood City</u>

Relatively clean stream conditions; large abundance of caddis fly, <u>Hydropsyche</u>, suggest organic enrichment; broad diversity of fish life.

Station 7: <u>Directly below dam site on Little Connoquenessing Creek</u>

Clean stream conditions; adequate species diversity, yet low number of individuals possibly due to low flow, siltation, and a heavy diatom coating on rocks. Excellent species diversity in relation to fish populations. Low numbers of fishes possibly reflect on the low standing crop of benthic fauna.

Station 8: Above proposed dam site on Glade Run

Relatively clean stream conditions; very large numbers of caddis fly, Hydropsyche, suggest organic input from surrounding farmland. Low number of species of benthic fauna and fishes reflects on lack of suitable and diverse habitats associated with headwater areas.

Station 9: Upstream from proposed reservoir on Little Connoquenessing Creek

Relatively clean stream conditions; some abundance of Spirogyra and Cladophora. Low numbers of individuals associated with a headwater habitat displaying characteristics of low productivity.

Summary: From the preceding discussion three major areas can be distinguished receiving moderate to severe pollution along the 41 miles of stream surveyed. These three areas are:

Station 2: Downstream from Butler
Station 4: At Eidenau; upstream from Zelienople
Station 5: Directly downstream from Zelienople

At the above three stations, the major pollutional problems stem from an excessive amount of organics and nutrients. There also appears to be some toxic waste entering the stream directly below Butler.

At all other stations surveyed, there existed an adequate and diverse community of aquatic life indicating relatively clean stream conditions.

In relation to the proposed reservoir sites on Little Connoquenessing Creek and Glade Run, the data indicates that moderate organic and nutrient loads enter Glade Run. Construction of the mutiple-purpose reservoir on Glade Run will retard the nutrients and eutrophic conditions may proceed at accelerated rates. To inhibit or retard eutrophication, the following conditions should be taken into consideration:

1. That the reservoir should not have large areas less than five feet deep.

2. That complete retention time be relatively short so as not to allow for accumulation of nutrients. Should the reservoir be shallow and clear with a relatively long detention time, eutrophication would probably result with a change in species composition and a shifting of population density to an unbalanced state. The result of accelerated eutrophication might possibly be the development of nuisance algae and aquatic vegetation.

Little Connoquenessing Creek appears to be an excellent site for the construction of a multiple-purpose reservoir from the standpoint of aquatic life diversity.

One important factor to consider in relation to the proposed reservoir sites is the very poor low flow characteristics of Connoquenessing Creek. What effect the construction of dams on two of the major tributaries to the

Connoquenessing Creek will have on the flow characteristics cannot be established from available data. However, it might be hypothesized that reducing the inflow of water to Connoquenessing Creek, especially during summer months when poor flow conditions normally exist, might increase the effect of high organic and nutrients loads on the aquatic life of the stream, unless flow release is regulated to reduce the nutrient concentration through dilution.

Recommendations: It is recommended that:

1. A more intensive biological and chemical survey be conducted within each of the three problem areas listed above.

2. Detailed information on the location of waste treatment facilities, type of waste and discharge points for all facilities located in the drainage basin surrounding the three problem areas should be gathered and a copy forwarded to the Aquatic Biology Unit so that the proposed survey can be conducted next spring.

FIGURE I.

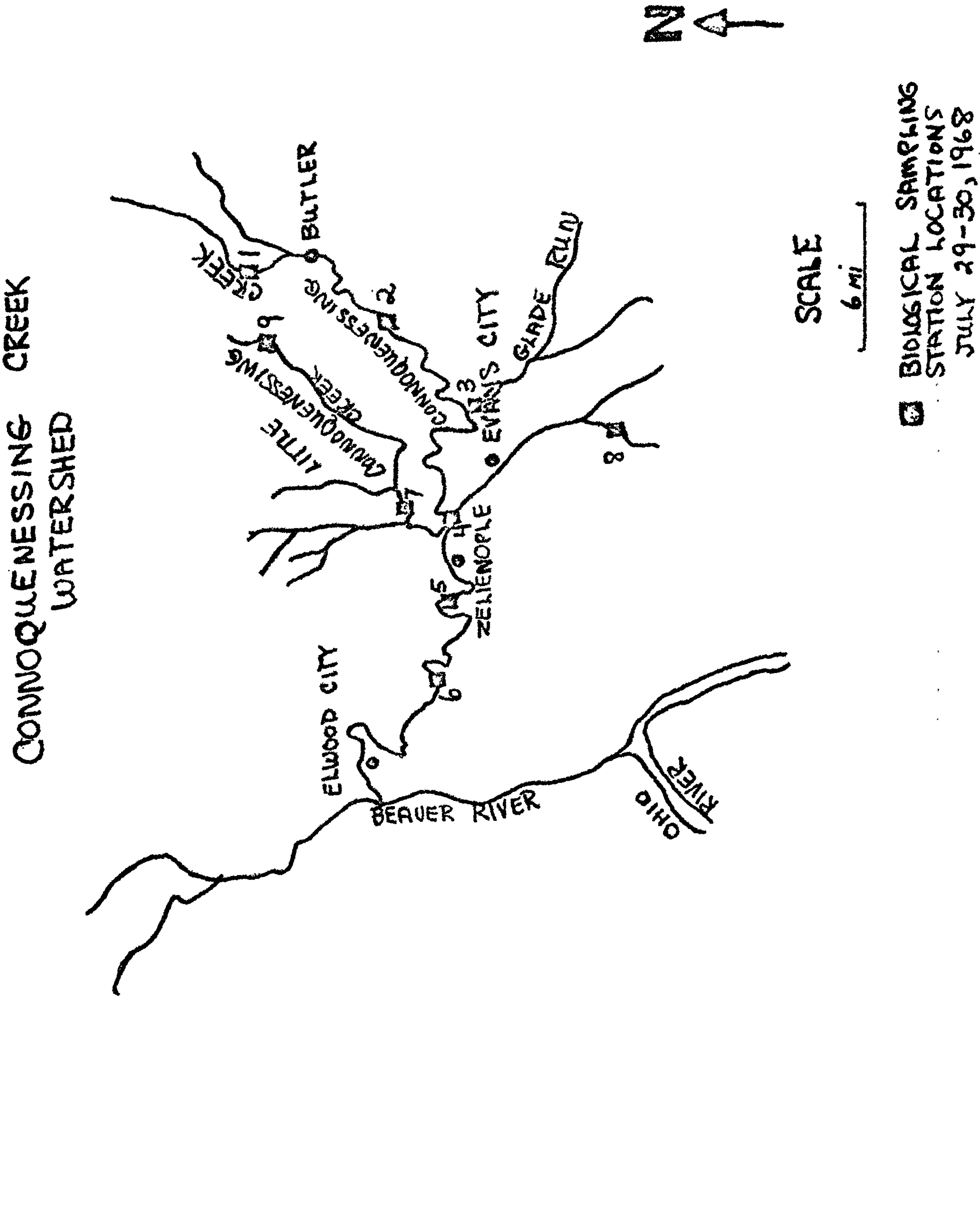
CONNOQUENESSING CREEK
WATERSHED
N
BUTLER
CREEK
CONNOQUENESSING
EVANS CITY
GLADE RUN
LITTLE
CONNOQUENESSING
CREEK
ZELIENOPLE
ELWOOD CITY
BEAVER RIVER
OHIO
RIVER
1
2
3
4
5
6
7
8
9
SCALE
6 MI
BIOLOGICAL SAMPLING
STATION LOCATIONS
JULY 29-30, 1968

TABLE I

CONNOQUENESSING CREEK

7/29/68 - 7/30/68

Biological
Sampling Station Locations

Station No.	County	Location
1	Butler	Bridge at 10119 - 3 miles N of Butler off Highway 38.
2	Butler	Bridge at 10151 - West of Rt. #8 N.E. of Renfrew.
3	Butler	0.6 miles below bridge at T-354 and below proposed dam site - N.E. of Evans City.
4	Butler	10042 at Eidenau - 1/8 mile N of Rt. 68.
5	Beaver	Bridge at 588 - 1/2 mile west of junction of 288.
6	Beaver	04078 at bridge and junction with 04055.
7	Butler	Bridge at 10041 - on Little Connoquenessing below dam site.
8	Butler	Bridge at T-384 - Jct with T-382 on Glade Run.
9	Butler	Bridge at 10015 and T-410 - South of Rt. 422 on Little Connoquenessing.

All fishes, benthos, and algae were sampled at above locations.

Distance of stream worked with electro fishing gear.

Station	Distance
1	35 feet
2	250 feet
3	40 feet
4	100 feet
5	100 feet
6	30 feet
7	100 feet
8	50 feet
9	100 feet

TABLE II

CONNOQUENESSING CREEK

7/29/68 - 7/30/68

Algae
Qualitative--Scrapings off Rocks

Station 1 -

1. Spirogyra
2. Navicula

Station 2 -

1. Potomogeton cripus
2. Vorticella
3. Navicula
4. Cladophora
5. Ulothrix
6. Rhizoclonium
6. Needle-like, crystalline structure - very abundant.

Station 3 -

1. Needle-like crystalline structure - very abundant.

Station 4 -

1. Cladophora
2. Navicula
3. Fragellaria
4. Rhizoclonium
5. Ulothrix

Station 5 -

1. Cladophora
2. Navicula
3. Unknown diatom

Station 6 -

1. Fragellaria
2. Rhizoclonium
3. Enteremorpha

Station 7 -

1. Spirogyra

Station 9 -

1. Spirogyra
2. Gladophora
3. Rhizoclonium
4. Cymbella
5. Navicula

TABLE III

CONNOQUENESSING CREEK

7/29/68 - 7/30/68

Biological Stream Survey

Aquatic Invertebrates ORGANISM	Stations 1	2	3	4	5	6	7	8	9
Turbellaria (Flatworms)									
Planariida									
Planaria sp.					1 *				
Nematoda (Roundworms)							2		
Isopeda (Aquatic Sow Bugs)									
Asellidae									
Asellus sp.									1
Decapoda (Grayfishes)									
Astacidae									
Cambarus sp.			1		1		1		
Hydracarina (Water Mites)									
Unionicolidae									
Koenikea sp.				1					
Ephemeroptera (Mayflies)									
Baetidae	1								
Ameletus sp.			10	2	12	18	1	29	1
Baetis sp.					3		1		
Isonychia sp.									3
Heptageniidae									1
Stenonema sp.							12		
Heptagenia sp.			40						
Hemiptera (Bugs)									
Gerridae									
Trepobates sp.			3						

* no./sq. ft.

Biological Stream Survey (continued)

Aquatic Invertebrates ORGANISM	Stations 1	2	3	4	5	6	7	8	9
Trichoptera (Caddis Flies)									
Hydrepaychidae									
Hydrepsyche sp.	88		189	86	18	241	11	426	24
Petamyla sp.			1						
Limnephilidae									
Limnephilus sp.									1
Rhyacophilidae									
Rhyacophila sp.	1			1	2		4		
Coleoptera (Beetles)									
Elmidae	1								
Promoreaia sp.			2			2	1	3	3
Paephenidae									
Psephemus sp.			1						
Unidentified	1								
Diptera (Flies, Midges)									
Tipulidae									
Antocha sp.			15					3	3
Simuliidae									
Simulium venustum			2	45	11	3			
Tendipedidae	5	67	22	38	35	12	8	7	20
Rhagionidae									
Atherix variegata	1	1	2	1				4	5
Unidentified				1					
Gastropoda (Snails)									
Physidae									
Physa sp.		2			1		1		
Aneylidae				1	4				
Ferrissia sp.									

Biological Stream Survey (continued)

Aquatic Invertebrates ORGANISM	Stations 1	2	3	4	5	6	7	8	9
Pelecypoda (Clams)									
Sphaeridae									
Pisidium sp.				1	2				
Sphaerium sp.			3						
No. of organisms	98	70	291	177	90	276	42	508	63
No. of taxa	7	3	13	10	11	5	10	6	11
Diversity Index $\left(\frac{S-1}{\ln N}\right)$	1.31	0.47	2.12	1.74	2.22	0.71	2.41	0.803	2.41

TABLE IV

CONNOQUENESSING CREEK

7/29/68 - 7/30/68

Fishes

Common Name	Scientific Name	Stations 1	2	3	4	5	6	7	8	9
Hogsucker	*Hypentelium nigricans*	2		15	9	4	5	2	2	3
White Sucker	*Catostomus commersoni*	10				4	1	1	51	16
Golden Redhorse	*Moxostoma erythrurum*							1		
Creek Chno	*Semetilus atromaculatus*	12		3				7	37	10
Redside Dace	*Clinostemus elongatus*								54	1
Golden Shiner	*Notemigonus crysoleucas*			3						
Silverjaw Minnow	*Ericymba buccata*	1		7	5				15	
Common Shiner	*Notropis cornutus*	23			23	3	38	3		
Bigeye Shiner	*Notropis boops*						9	1		
Mimic Shiner	*Notropis volucellus*			5	1	25	84	4		
Rosyface Shiner	*Notropis rubellus*				1	5	2	4		
Bluntnose Minnow	*Pimephales notatus*		69	54	22	48	24	27		
Stoneroller	*Campostoma anomalum*	29	2	6	23		107		20	22
Carp	*Cyprinus carpio*							4		
Banded Killifish (Western)	*Fundulus diaphanus*		18							
Blackside Darter	*Percina maculata*			4				1		

Fishes (continued)

Common Name	Scientific Name	Stations 1	2	3	4	5	6	7	8	9
Logporch	*Percina caprodes*				1			1		
Johnny Darter	*Etheostoma nigrum*	3			2		3		4	4
Fantail Darter	*Etheostoma flabellare*							2		
Greenside Darter	*Etheostoma blennioides*			19	5		4	2		
Greenbanded Darter	*Etheostoma zonale*							1		
Mottled Sculpin	*Cottus bairdii*									2
Smallmouth Bass	*Micropterus dolomioui*			1	2	2	7	1		
Largemouth Bass	*Micropterus salamoides*		4			2				
Bluegill	*Lapomis macrochirus*			1	7			1		
Rock Bass	*Ambloplites rupestris*				1	2				
Pumpkinseed	*Lepomis gibbosus*				1			5		
Yellow Bullhead	*Ictalurus natalis*					1				
	Total No. of Fishes --	80	93	115	106	96	284	68	183	58
	Total No. of Species --	7	4	10	15	10	11	18	7	7

Total No. of Fishes = 1063
Total No. of Species = 28