UNITED STATES
DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
State, Federal & Constituent Programs Division

COMPLETION REPORT

Grantee: **PENNSYLVANIA FISH AND BOAT COMMISSION**

Project No: **N/A**

Grant No: **NA46FU0218**

Project Title: **SUSQUEHANNA TRIBUTARY BLOCKAGE STUDY**

Period Covered: **07/01/94 - 06/30/95**

Prepared by: **ROBERT F. CARLINE**

Approved by: **RICKALON HOOPES**

Date: **NOVEMBER 6, 1995**

Statutory Funding Authority:
___Anadromous Fish Conservation Act (P.L. 89-304)
_X_Chesapeake Bay Studies
___Endangered Species Act
___Interjurisdictional Fisheries Act (Title III of P.L. 99-659)
___Magnuson Act
___Oyster Disease Research
___Saltonstall-Kennedy
___Unallied Industry Projects
___Unallied Science Projects

SFC
APPROVED
BY Susan Olsen
DATE 5/02/96

Final Report Phase II
NOAA Grant Award #NA46FU0218

Submitted by:

Robert F. Carline
Ted Bukowski

The Pennsylvania State University
College of Agricultural Sciences
School of Forest Resources

Impediments to Fish Passage and Habitat Suitability for Anadromous Fish in Pennsylvania Tributaries to the Susquehanna River - Phase II

Submitted to:
The Pennsylvania Fish and Boat Commission
1225 Shiloh Road
State College, PA 16801-8495
Atten: R. Hoopes

Period Covered:

July 1, 1994 to June 30, 1995

Table of Contents

PROJECT TITLE
Impediments to Fish Passage and Habitat Suitability for Anadromous Fish in Pennsylvania Tributaries to the Susquehanna River - Phase II

INTRODUCTION

Since construction of four hydropower dams in the early part of the 20th century, migration of anadromous fish from the Chesapeake Bay into the Susquehanna River has been restricted. In 1991, a fish lift was opened at Conowingo Dam, MD, the first of the four dams (Fig. 1). In June 1993, agreement was finalized among resource agencies and utilities that own and operate the next three dams. The agreement calls for provision of passageways at these dams to enable migratory fish to reach historical spawning grounds on the Susquehanna River. However, fish access to many tributaries of the Susquehanna River is blocked by smaller dams and other obstructions. Currently, more than 200 blockages on tributaries prevent migratory fishes from reaching potential spawning areas. There is no complete inventory of existing blockages on these tributaries nor is there any measure of the amount of suitable spawning and rearing habitat that would be available to migratory fishes, if passages were provided at these blockages.

Removal of tributary blockages would allow migratory fish access to potential spawning and rearing areas. However, successful colonization of these areas is dependent upon a host of factors, some of which are related to suitability of physico-chemical habitat features.

The objectives of this project are to: (1) inventory blockages to fish passage on tributaries to the Susquehanna River and (2)

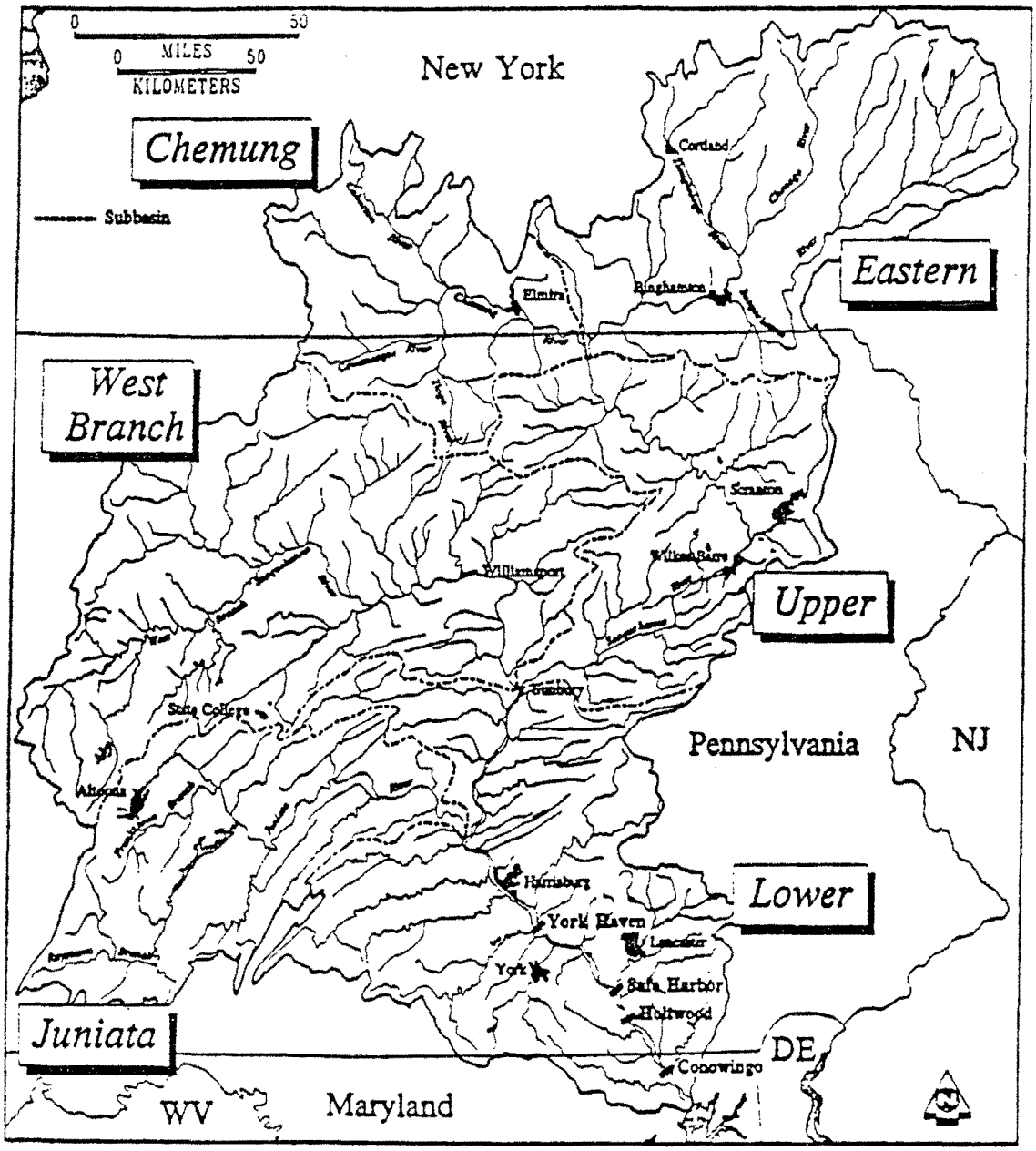

Figure 1. The Susquehanna River basin (from Southerland, et al., 1993).

identify the quantity and quality of habitat that could be made available to various anadromous fish species, if passage was provided at the blockages. The information derived from this study will contribute to the establishment of priorities for fish passage construction.

FISH SPECIES OF INTEREST

This project focused on river herring -- alewife and blueback herring. These species typically spawn in small streams, whereas American shad and striped bass tend to spawn in large streams similar to mainstem habitats.

GEOGRAPHIC SCOPE

Blueback herring can migrate more than 300 miles into freshwater and spawn in streams with flows as low as 5 cfs. Thus, their potential range includes nearly the entire Pennsylvania portion of the Susquehanna River basin. If all tributaries with such small flows were surveyed, the entire project could take many years to complete. Rather, we surveyed a portion of tributaries that may provide habitat for river herring. The following criteria were used to determine locations at which tributary surveys end.

(a) A natural blockage is encountered. Normally surveys would end here because presumably, river herring were not able to pass over or through natural blockages such as waterfalls or cataracts. If we were uncertain that a natural feature would constitute a blockage to migration, the survey continued upstream.

(b) A dam $\geq$ 40 ft. Providing passage facilities for fish

over dams this high is rather expensive and technically difficult. Such dams on tributaries in this inventory would have a low priority for removal or construction of passage facilities.

(c) Change from third order to second order. For tributaries in the lower basin, this corresponds to a watershed area of about 10 mi^2 and a summer flow of about 8 cfs. If a blockage is encountered and summer flows are $\pm$20% of 8 cfs, the survey ended at the blockage. We also ended surveys on third order streams when baseflow was less than 8 cfs.

Streams surveyed during Phase II (See Fig. 2)

Stream County	Susquehanna River Mile	Approx. Mileage Including 3rd Order Tributaries
Conestoga River Lancaster Co.	31.3	114
Chickies Cr. Lancaster Co.	42.0	31
Conewago Cr. Lancaster Co.	52.2	13
Kreutz Cr. York Co.	40.0	3
Codorus Cr. York Co.	47.8	53
Conewago Cr. York Co.	51.6	139

SURVEY METHODS

We assembled a list of blockages from data provided by the Pennsylvania Department of Environmental Protection (DEP) and from

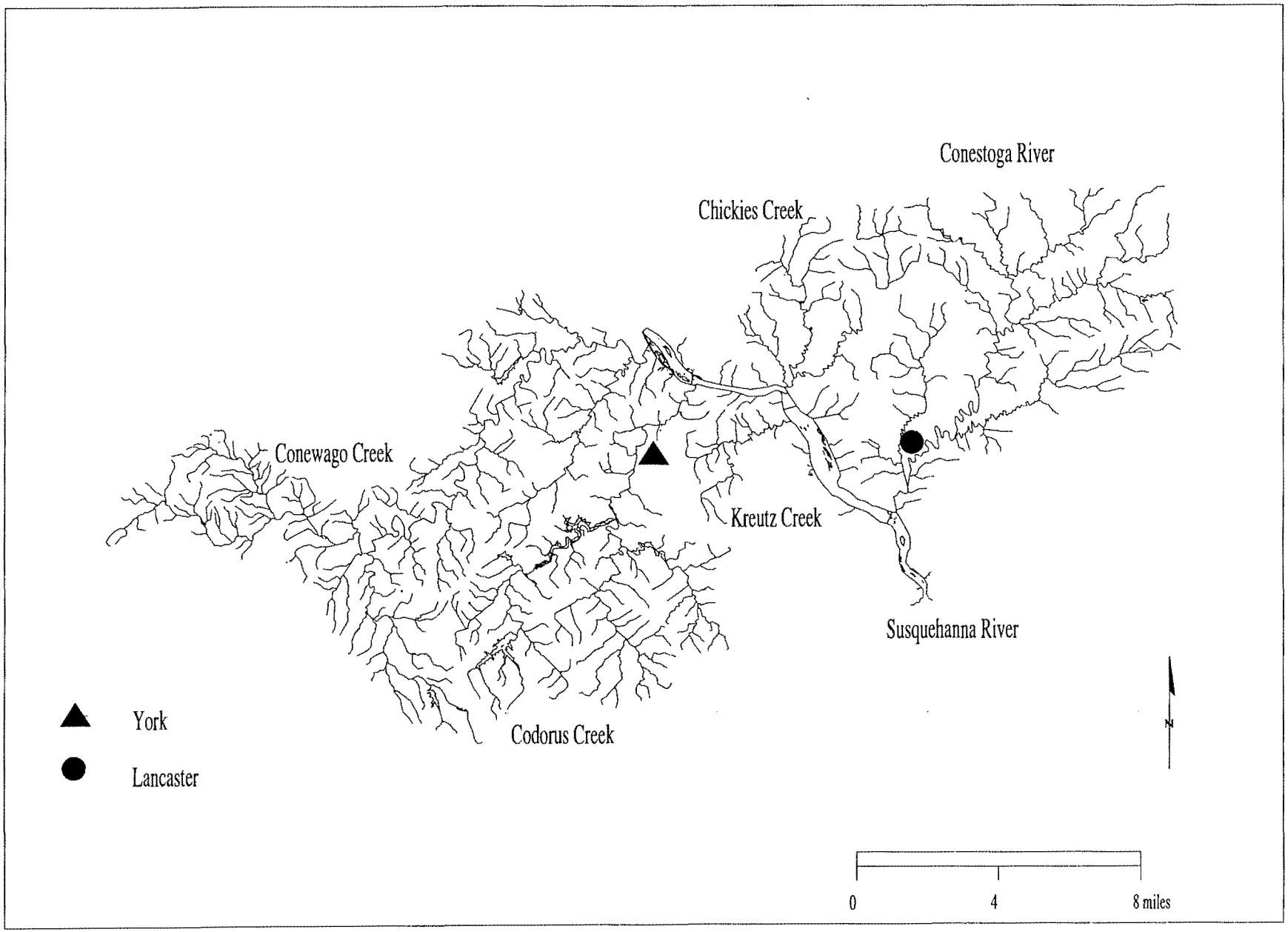

Figure 2. Streams surveyed during Phase II.

a recently published report by the U.S. Army Corps of Engineers. Some of these blockages may no longer exist.

Reconnaissance Surveys. To confirm the locations of blockages, we first inspected a set of 1992 aerial photographs (1:14,000) that cover the larger tributaries in the lower Susquehanna River basin. Not all candidate tributaries have been photographed. For these, we conducted on-ground visual surveys. For tributaries in which blockages are located, on-ground surveys began at the downstream most blockage and proceeded to the mouth to ensure that any natural blockages were identified.

Among the tributaries with blockages, we noted the relative distribution of riffle-run and pool habitats. This information was used to select sampling sites for habitat suitability surveys.

Blockage Characterization. The Living Resources Subcommittee's Fish Passage Work Group selected a set of criteria to be used for blockage characterization. These criteria were employed during this survey and are to be used by all jurisdictions in the Chesapeake Bay drainage.

Habitat Surveys. All tributaries of the appropriate size that have one or more blockages were included in habitat surveys. Tributaries without blockages were not surveyed.

Habitat Suitability Index (HSI) models were used to assess the quantity of suitable habitat for spawning and juvenile rearing for alewife and blueback herring. Physical data (i.e. river depth, current velocity, substrate) were collected along transects set perpendicular to streamflow. At each transect, measurements were made at five equally-spaced points. Transects were established at a frequency of four per river mile and distributed among the two

major habitat types (riffle-run and pool) in proportions equal to the relative occurrence of these habitat types (estimated during reconnaissance of stream blockages). Dissolved oxygen, temperature, turbidity, and pH also were measured at each transect. Survey crews measured physico-chemical variables along transects by wading in the smaller tributaries or from a boat in the larger tributaries.

Streambanks were categorized as forest, brush, grasses, wetland, riprap, or erosion prone.

A Global Positioning System (GPS) receiver was used to locate transects in accordance with EPA guidelines (Region III Order 5361.5 Site Location Identification Policy and Responsibilities; Sept. 14, 1988). The GPS receiver also was used to delineate the tributaries into habitat types and total area of each habitat type was computed for each tributary.

Water Quality History. For each of the candidate tributaries, we reviewed Pennsylvania Department of Environmental Protection (PADEP) water quality records to determine point source discharges and available water quality data. Our intent here was to identify tributary reaches with poor water quality, which might influence habitat suitability, particularly during juvenile rearing periods. This information will be used when assigning priorities to blockage removal.

RESULTS

Conestoga River (Lancaster County)

Blockages. There are 28 blockages on the Conestoga River and 45 blockages on the Conestoga River tributaries (Figs. 3A and

3b). See Appendix I for the size and location of the blockages.

Habitat. The Conestoga River and tributaries flow through a mix of agricultural and residential lands. Eroding streambanks (31%) were the most common condition found, followed by grasses, forest, brush, and riprap (Table 1).

The predominant substrate in the riffle/run sections was cobble. The predominant substrate in the pool sections was sand/gravel (Table 2). The mean depth was 1.79 feet.

Water Quality. We measured water quality variables at more than 360 transects throughout the basin. The median pH was 8.2 and the range was 7.4 to 8.9 (Appendix II). Values from one of our pH meters tended to drift upward as the day progressed. This behavior was not discovered until data were summarized. On certain days we noted a suspiciously large number of values greater than 9.0 and one greater than 10.0. Therefore, throughout this report we report only those values less than 9.0.

The median dissolved oxygen was 8.0 mg/L; lowest values (5-6 mg/L) were measured in Mill Creek on the day after a heavy downpour. On days when Mill Creek flow was normal, dissolved oxygen was typically more than 7 mg/L. Overall, dissolved oxygen in this basin was uniformly high. The median turbidity in the basin was 17.5 NTU. Values over 100 were rare except during days following heavy rainfalls. The median turbidity should be considered typical for normal flows.

According to the Pennsylvania Department of Environmental Protection (PADEP), the Conestoga River watershed has 75 permitted discharges. Twenty-six of the permitted discharges are industrial waste and the other 49 are domestic wastewater discharges.

Agricultural runoff may also be a serious source of pollution.

HSI Scores. The overall HSI scores for the Conestoga River are listed in Table 3. HSI scores by blockage and stream reach are listed in Table 4. HSI scores of less than 50 typically resulted from shallow depths, low velocities, or both.

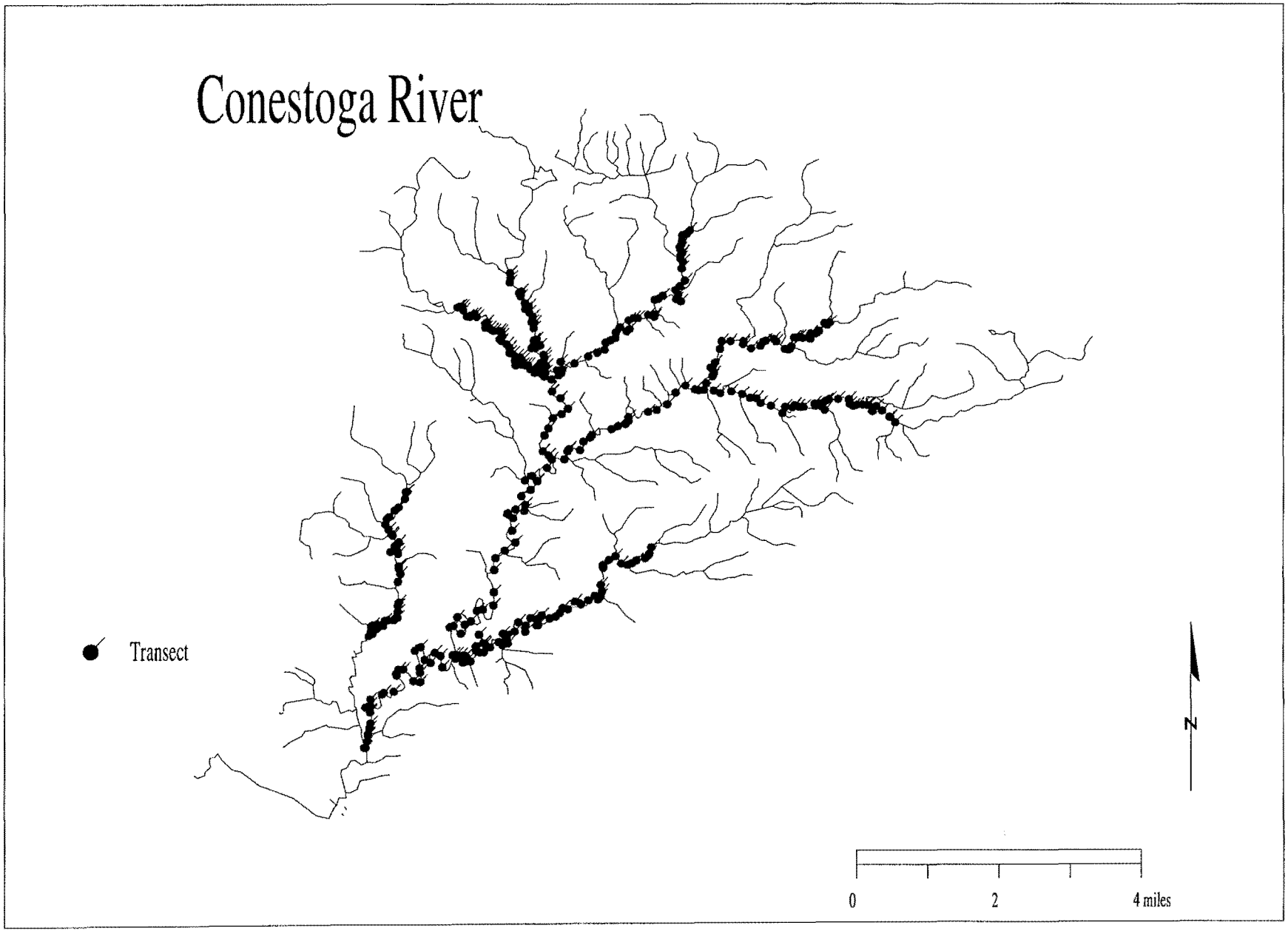

Figure 3a. Transects surveyed on Conestoga River, Lancaster County.

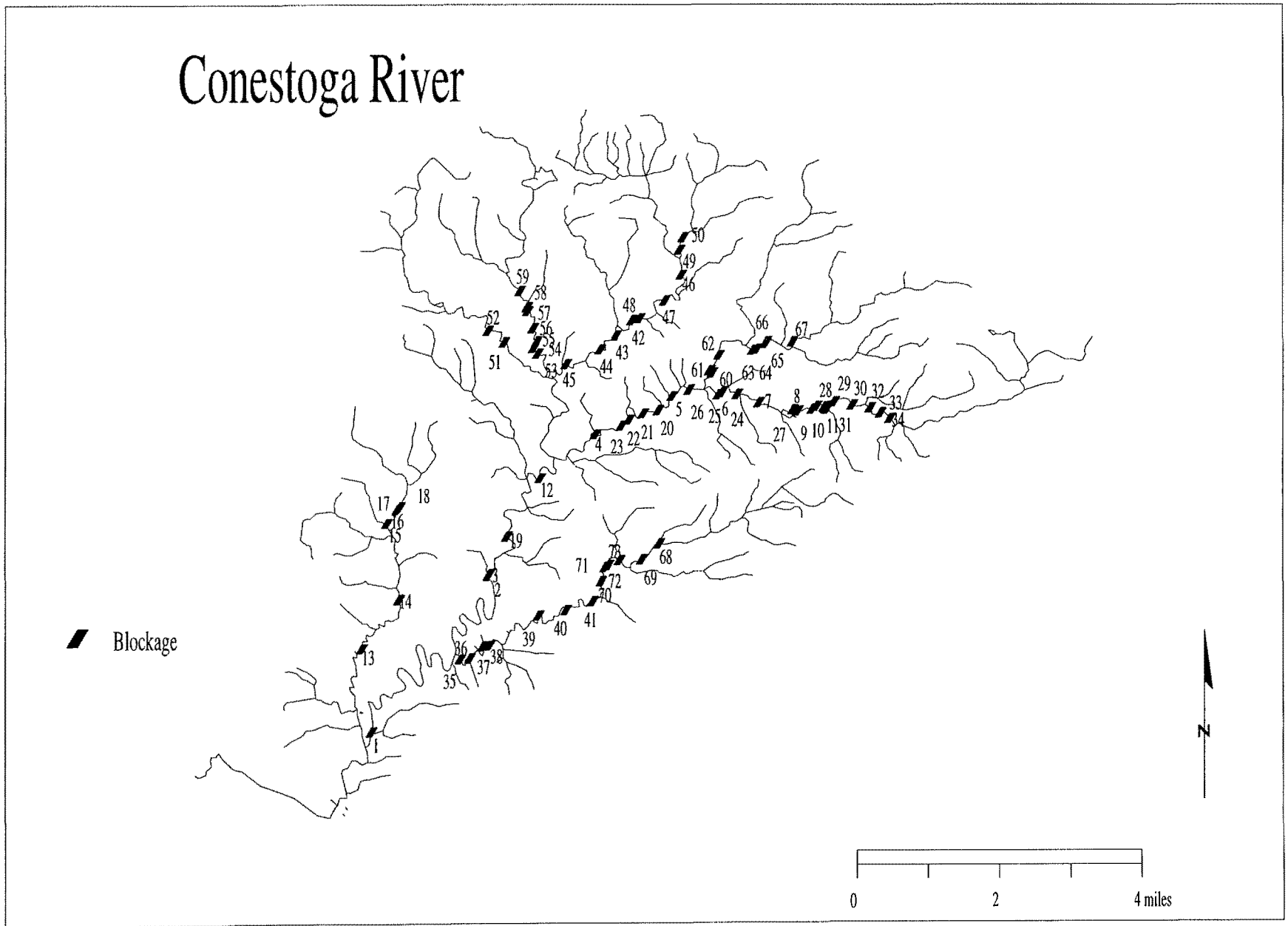

Figure 3b. Blockages surveyed on Conestoga River, Lancaster County. Blockage numbers correspond with blockage identification numbers, e.g., 1=PACNS001.

Table 1. Stream bank conditions in the Conestoga River drainage, Lancaster County.

Bank Condition	Percent of Total
Forest	21
Brush	15
Grasses	22
Riprap	11
Eroding	31

Table 2. Summary of substrate composition by habitat type in Conestoga River, Lancaster County.

		Habitat type (%)	
		Riffle-run	Pool
Surveyed reach total habitat		35	65
Substrate:	Fines	2	13
	Sand/gravel	33	42
	Cobble	49	26
	Boulder	11	17
	Other	5	2

Other= bedrock or vegetation

Table 3. Habitat composition and weighted habitat suitability index (HSI) scores for drainages surveyed.

Drainage and County	Reach Surveyed (acres)	Vegetated Banks (%)	Habitat type (%)		Habitat-weighted HSI scores			
					Alewife		Blueblack herring	
			Riffle/ run	Pool	S[A]	R[B]	S[A]	R[B]
Conestoga River Lancaster County	947	58	35	65	42	34	55	25
Chickies Creek Lancaster County	180	77	45	55	43	36	55	30
Kreutz Creek York County	33	44	42	58	46	31	61	25
Codorus Creek York County	175	73	32	68	58	41	71	38
Conewago Creek York County	295	95	34	66	44	39	58	34

A=Spawning
B=Rearing

Table 4. Blockages with habitat suitability data by reach for Conestoga River, Lancaster County. Reaches are reported with the blockage at their downstream end. Tributaries that enter a mainstem reach are listed with the downstream blockage of that mainstem reach. The downstream limit of a reach is a blockage or the mouth of a tributary, while the upstream limit is a blockage or the point where the stream changes from third to second order.

Blockage				Reach					
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACNS001	Conestoga River	4.0	8.0	Conestoga River	328	60	48	73	44
PACNS002	Conestoga River	21.7	2.0	Conestoga River	2	36	31	56	20
PACNS003	Conestoga River	21.8	5.0	Conestoga River	47	41	47	55	44
PACNS019	Conestoga River	24.3	2.0	Conestoga River	72	51	40	69	35
PACNS012	Conestoga River	28.6	6.5	Conestoga River	110	47	41	56	35
PACNS004	Conestoga River	32.8	5.0	Conestoga River	20	45	38	55	33
PACNS023	Conestoga River	35.1	1.5	Conestoga River	3	32	52	63	36
PACNS022	Conestoga River	35.4	2.0	Conestoga River	8	39	46	58	39
PACNS021	Conestoga River	36.2	0.7	Conestoga River	5	43	38	56	30
PACNS020	Conestoga River	36.8	7.0	Conestoga River	8	24	17	64	41
PACNS005	Conestoga River	37.7	3.0	Conestoga River	10	48	43	55	41
PACNS026	Conestoga River	38.7	5.0	Conestoga River	9	48	43	58	39
PACNS025	Conestoga River	39.8	4.0	Conestoga River	2	38	35	58	20

Table 4. (continued)

Blockage				Reach					
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACNS006	Conestoga River	40.1	4.0	Conestoga River	4	44	31	61	25
PACNS024	Conestoga River	40.8	7.0	Conestoga River	7	44	32	53	25
PACNS007	Conestoga River	41.8	8.1	Conestoga River	11	44	32	55	27
PACNS027	Conestoga River	43.5	2.0	Conestoga River	1	46	36	66	35
PACNS008	Conestoga River	43.8	4.5	Conestoga River	6	40	37	54	22
PACNS010	Conestoga River	44.5	1.4	Conestoga River	1	36	29	61	22
PACNS009	Conestoga River	44.6	2.0	Conestoga River	3	46	32	55	18
PACNS028	Conestoga River	45.0	2.2	Conestoga River	1	46	36	66	35
PACNS030	Conestoga River	45.3	1.8	Conestoga River	3	38	36	37	34
PACNS011	Conestoga River	45.8	8.0	Conestoga River	5	47	41	61	34
PACNS031	Conestoga River	46.6	1.3	Conestoga River	3	52	40	73	36
PACNS032	Conestoga River	47.1	4.5	Conestoga River	1	57	33	72	33
PACNS033	Conestoga River	47.5	0.3	Conestoga River	3	49	37	65	29
PACNS034	Conestoga River	48.2	3.0	Conestoga River	1	47	28	46	26
PACNS013	Little Conestoga	4.9	9.6	Little Conestoga	24	50	40	61	28
PACNS014	Little Conestoga	9.7	4.0	Little Conestoga	12	46	38	57	28

Table 4. (continued)

Blockage				Reach					
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACNS015	Little Conestoga	12.9	2.0	Little Conestoga	2	43	33	56	16
PACNS016	Little Conestoga	13.5	1.0	Little Conestoga	1	33	16	56	11
PACNS018	Little Conestoga	13.6	1.5	Little Conestoga	3	47	39	53	21
PACNS035	Mill Creek	0.4	6.0	Mill Creek	4	47	46	59	30
PACNS037	Mill Creek	1.1	1.5	Mill Creek	5	7	13	14	3
PACNS036	Mill Creek	2.1	2.0	Mill Creek	12	38	35	53	22
PACNS039	Mill Creek	4.0	2.5	Mill Creek	27	44	36	56	27
PACNS038	Mill Creek	8.4	6.0	Mill Creek	13	34	40	50	37
PACNS041	Mill Creek	10.3	5.0	Mill Creek	11	34	38	51	32
PACNS040	Mill Creek	11.9	1.0	Mill Creek	6	49	36	65	29
PACNS073	Mill Creek	13.0	6.0	Mill Creek	6	40	23	63	24
PACNS072	Mill Creek	13.8	1.5	Mill Creek	3	42	25	559	3
PACNS071	Mill Creek	14.2	4.0	Mill Creek	9	37	32	50	21
PACNS070	Mill Creek	15.5	3.0	Mill Creek	6	39	30	54	21
PACNS069	Mill Creek	16.7	2.5	Mill Creek	2	40	25	51	16
PACNS045	Cocalico Creek	6.2	2.0	Cocalico Creek	15	41	29	62	27
PACNS044	Cocalico Creek	8.0	4.7	Cocalico Creek	8	41	35	56	34

Table 4. (continued)

Blockage				Reach					
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACNS043	Cocalico Creek	9.3	6.5	Cocalico Creek	9	36	34	51	22
PACNS042	Cocalico Creek	10.6	1.4	Cocalico Creek	2	44	29	50	20
PACNSO48	Cocalico Creek	11.0	4.0	Cocalico Creek	10	34	41	56	22
PACNS047	Cocalico Creek	12.9	1.5	Cocalico Creek	8	15	11	16	6
PACNS046	Cocalico Creek	14.8	7.5	Cocalico Creek	3	35	30	57	19
PACNS049	Little Cocalico Ck	0.2	3.0	Little Cocalico Ck	2	33	29	48	16
PACNS050	Little Cocalico Ck	0.6	2.0	Little Cocalico Ck	1	33	24	53	15
PACNS053	Middle Creek	1.1	0.8	Middle Creek	1	40	40	52	27
PACNS054	Middle Creek	1.4	3.0	Middle Creek	1	41	43	55	25
PACNS055	Middle Creek	1.7	1.0	Middle Creek	4	42	38	58	26
PACNS056	Middle Creek	2.5	1.2	Middle creek	3	39	47	53	31
PACNS057	Middle Creek	3.2	1.0	Middle Creek	1	60	42	69	28
PACNS058	Middle Creek	3.4	3.5	Middle Creek	4	43	26	51	25
PACNS059	Middle Creek	4.2	1.0	Middle Creek	3	40	40	53	24
PACNS051	Hammer Creek	3.2	1.0	Hammer Creek	3	42	39	54	23
PACNS052	Hammer Creek	4.0	1.8	Hammer Creek	8	49	45	60	28
PACNS061	Muddy Creek	0.9	3.5	Muddy Creek	2	43	27	59	22

Table 4. (continued)

Blockage				Reach				
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACNS060	Muddy Creek	1.2	2.0	Muddy Creek	2	42	34	52	27
PACNS063	Muddy Creek	1.4	5.5	Muddy Creek	15	42	34	52	27
PACNS064	Muddy Creek	3.8	1.0	Muddy Creek	2	46	28	59	22
PACNS065	Muddy Creek	4.3	1.0	Muddy Creek	1	34	18	57	14
PACNS066	Muddy Creek	4.3	3.0	Muddy Creek	8	30	21	44	11
PACNS067	Muddy Creek	5.7	2.5	Muddy Creek	8	35	26	48	15

A=Spawning
B=Rearing

Chickies Creek (Lancaster County)

Blockages. There are 18 blockages on Chickies Creek and 7 blockages on the tributaries to Chickies Creek (Fig. 4). See Appendix I for size and location of dams.

Habitat. Chickies Creek flows through mostly agricultural lands. Forested streambanks were most common (40%), followed by grass cover and eroding slopes (Table 5). The predominant riffle/run substrate was cobble. The primary pool substrate was fines (Table 6). The mean depth of the stream was 1.60 feet.

Water Quality. We measured water quality variables at more than 60 transects in the basin. The median pH was 8.1 and the range was 7.7 to 8.5 (Appendix II). The median dissolved oxygen was 10.3 mg/L and it ranged from 8.4 to 13.0 mg/L. The median turbidity was 6 NTU and the maximum value was 100 NTU, which was measured the day after a thunderstorm. Overall, water quality in this basin appears to be quite good.

According to the Pennsylvania Department of Environmental Protection (PADEP), the Chickies Creek watershed has 21 permitted discharges. Six of the permitted discharges are industrial waste and the other 15 are domestic wastewater discharges. Agricultural runoff may also be a serious source of pollution.

HSI Scores. The overall HSI scores for Chickies Creek are listed in Table 3. HSI scores by blockage and reach are given in Table 7. HSI scores less than 50 resulted from shallow depths, low velocities, or both.

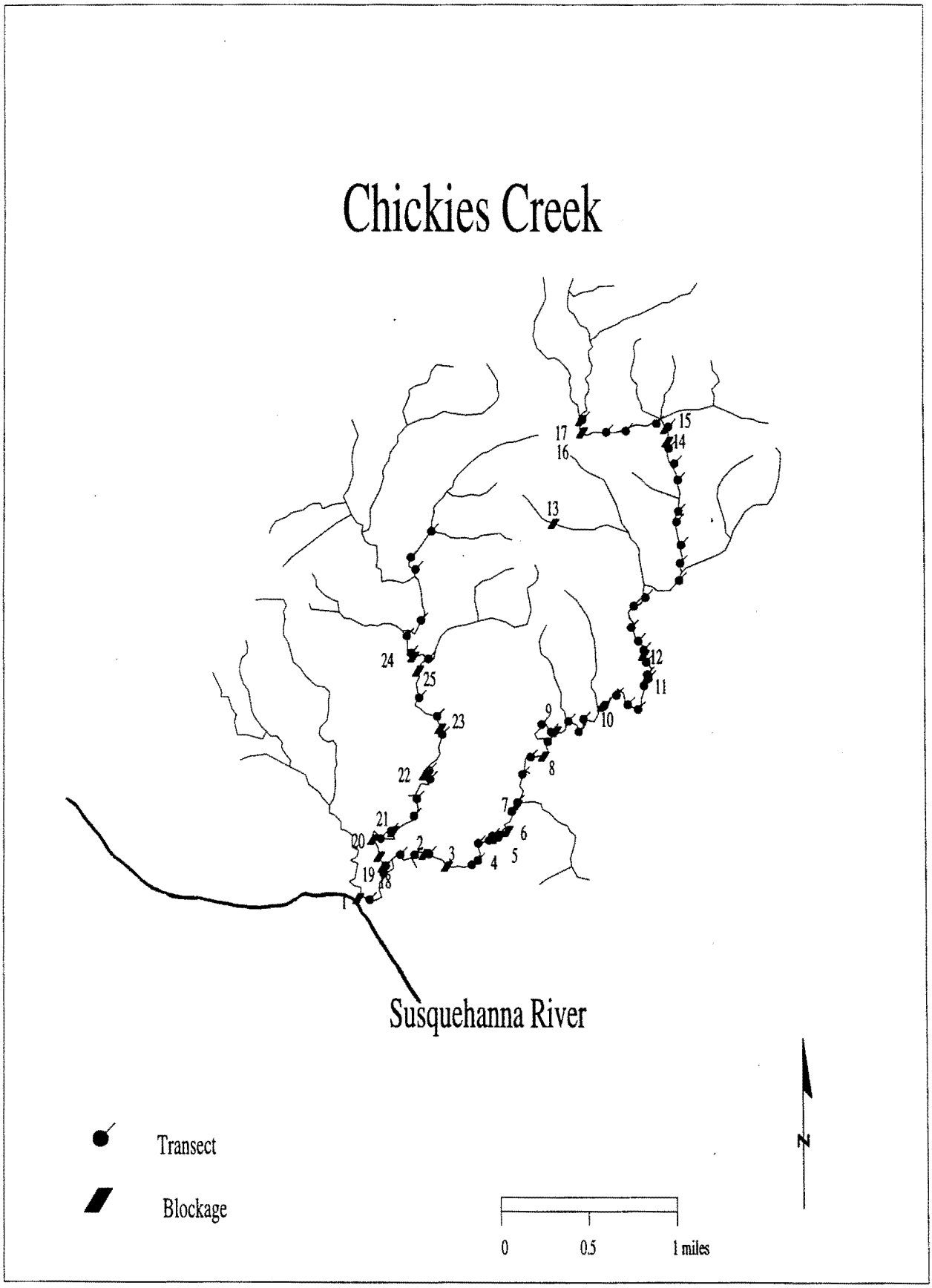

Figure 4. Tansects and blockages surveyed on Chickies Creek, Lancaster County. Blockage numbers correspond with blockage identification numbers, e.g., 1=PACHI001.

Table 5. Stream bank conditions in the Chickies Creek drainage, Lancaster County.

Bank Condition	Percent of Total
Forest	40
Brush	8
Grasses	29
Riprap	2
Eroding	21

Table 6. Summary of substrate composition by habitat type in the Chickies Creek drainage, Lancaster County.

		Habitat type (%)	
		Rifle-run	Pool
Surveyed reach total habitat		45	55
Substrate:	Fines	8	46
	Sand/gravel	23	24
	Cobble	58	19
	Boulder	1	3
	Other	10	8

Other= bedrock or vegetation

Table 7. Blockages with habitat suitability data by reach for Chickies Creek, Lancaster County. Reaches are reported with the blockage at their downstream end. Tributaries that enter a mainstem reach are listed with the downstream blockage of that mainstem reach. The downstream limit of a reach is a blockage or the mouth of a tributary, while the upstream limit is a blockage or the point where the stream changes from third to second order.

Blockage				Reach		HSI Score			
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACHI001	Chickies Creek	0.1	8.0	Chickies Creek	13	54	38	62	39
PACHI002	Chickies Creek	1.9	4.5	Chickies Creek	12	56	29	71	30
PACHI003	Chickies Creek	3.6	4.0	Chickies Creek	14	45	37	49	30
PACHI005	Chickies Creek	5.9	3.0	Chickies Creek	3	39	29	48	28
PACHI006	Chickies Creek	6.1	1.0	Chickies Creek	5	45	46	63	41
PACHI007	Chickies Creek	7.1	7.0	Chickies Creek	15	43	44	42	39
PACHI008	Chickies Creek	9.1	7.0	Chickies Creek	11	44	31	53	28
PACHI009	Chickies Creek	10.6	8.0	Chickies Creek	11	48	38	56	36
PACHI010	Chickies Creek	13.0	1.0	Chickies Creek	10	40	31	53	27
PACHI011	Chickies Creek	15.2	2.5	Chickies Creek	4	33	28	47	27
PACHI012	Chickies Creek	15.9	3.0	Chickies Creek	16	41	36	49	23
PACHI013	Chickies Creek	20.7	1.0	Chickies Creek	5	15	35	32	&9

Table 7. (continued)

Blockage				Reach						
						HSI Score				
						Alewife		Blueback		
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACHI014	Chickies Creek	22.1	2.0	Chickies Creek	1	40	31	48	26
PACHI015	Chickies Creek	22.5	2.0	Chickies Creek	4	34	33	50	19
PACHI016	Chickies Creek	24.6	1.2	Chickies Creek	0	29	39	41	24
PACHI019	L. Chickies Creek	0.3	1.1	L. Chickies Creek	1	52	35	64	33
PACHI020	L. Chickies Creek	0.6	2.0	L. Chickies Creek	9	35	21	49	21
PACHI021	L. Chickies Creek	2.1	1.5	L. Chickies Creek	16	43	38	62	35
PACHI022	L. Chickies Creek	4.5	4.0	L. Chickies Creek	6	62	40	76	37
PACHI023	L. Chickies Creek	5.8	7.0	L. Chickies Creek	11	56	41	63	35
PACHI025	L. Chickies Creek	8.1	2.5	L. Chickies Creek	12	53	42	58	33

A=Spawning
B=Rearing

Conewago Creek (Lancaster County)

Two natural blockages were found below any dams on the Conewago Creek, therefore, no habitat surveys were conducted. The first natural blockage was located 5.7 miles above the mouth; it is about 1/8 mile downstream of the Deodate Road bridge: lat:40° 09′ 42", long:76° 39′ 58". The second blockage was located 6.0 miles above the mouth; it is immediately upstream of the Deodate Road bridge: lat:40° 09′ 46", long:76° 36′ 46". Both blockages were stone ledges with vertical drops greater than 1.5 feet.

Kreutz Creek (York County)

Blockages. There are 8 blockages on the Kreutz Creek (Fig. 5). See Appendix I for size and location of blockages.

Habitat. Most of Kreutz Creek flows through residential land. Eroding streambanks (48%) was the most common condition (Table 8). The predominant riffle/run substrate was cobble. The predominant pool substrate was sand/gravel (Table 9). The mean depth of the stream was 1.03 feet.

Water Quality. We measured water quality variables at 34 transects in this basin. The median pH was 8.0 and it ranged from 7.2 to 8.3 (Appendix II). The median dissolved oxygen was 8.8 mg/L and the range was 6.9 to 11.3 mg/L. The median turbidity was 5 NTU and the range was 3 to 24. Water quality in this basin appears to be adequate for cool and warmwater fishes.

According to the Pennsylvania Department of Environmental Protection (PADEP), the Kreutz Creek drainage has two permitted

discharges; one is a domestic wastewater plant and the other is an industrial waste discharge.

HSI Scores. The overall HSI scores for Kreutz Creek are listed in Table 3. HSI scores by blockage and reach are listed in Table 10. HSI scores of less than 50 resulted from shallow depths, low velocities, or both.

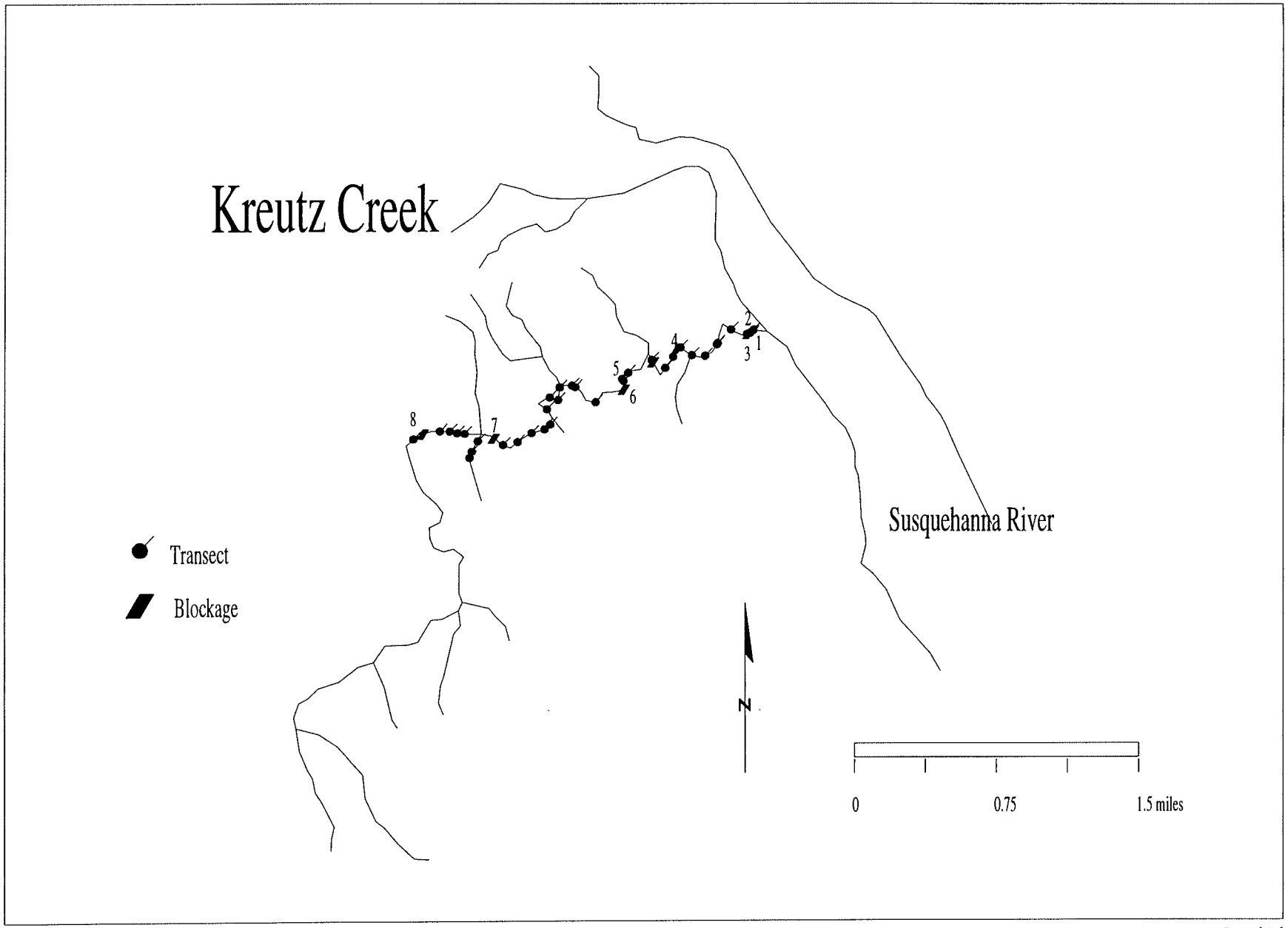

Figure 5. Transects and blockages surveyed on Kreutz Creek, York County. Blockage numbers correspond with blockage identification numbers, e.g., 1=PAKRE001.

Table 8. Stream bank conditions in the Kreutz Creek drainage, York County.

Bank Condition	Percent of Total
Forest	6
Brush	32
Grasses	6
Riprap	8
Eroding	48

Table 9. Summary of substrate composition by habitat type in Kreutz Creek, York County.

		Habitat type (%)	
		Riffle-run	Pool
Surveyed reach total habitat		42	58
Substrate:	Fines	0	4
	Sand/gravel	25	47
	Cobble	62	12
	Boulder	9	33
	Other	4	4

Other= bedrock or vegetation

Table 10. Blockages with habitat suitability data by reach for Kreutz Creek, York County. Reaches are reported with the blockage at their downstream end. Tributaries that enter a mainstem reach are listed with the downstream blockage of that mainstem reach. The downstream limit of a reach is a blockage or the mouth of a tributary, while the upstream limit is a blockage or the point where the stream changes from third to second order.

Blockage				Reach		HSI Score			
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PAKRE001	Kreutz Creek	0.2	1.0	Kreutz Creek	0.4	46	24	65	24
PAKRE002	Kreutz Creek	0.3	2.0	Kreutz Creek	0.6	38	24	61	20
PAKRE003	Kreutz Creek	0.5	0.8	Kreutz Creek	5.7	45	32	59	26
PAKRE004	Kreutz Creek	1.7	1.0	Kreutz Creek	3.3	47	34	59	26
PAKRE005	Kreutz Creek	2.4	5.0	Kreutz Creek	4.8	46	30	57	20
PAKRE006	Kreutz Creek	3.4	7.0	Kreutz Creek	11.2	46	40	57	25
PAKRE007	Kreutz Creek	6.3	1.0	Kreutz Creek	6.2	49	31	61	27

A=Spawning
B=Rearing

Codorus Creek (York County)

Blockages. There are four blockages on Codorus Creek and three blockages on the South Branch of Codorus Creek (Fig. 6). See Appendix I for size and location of blockages.

Habitat. The lower half of Codorus Creek flows through the city of York and the upper half of Codorus Creek and the South Branch flow through mostly agricultural lands. Forest and brush were the most common streambank condition; 18% of banks were eroding (Table 11). Cobble was the predominant substrate type in riffle/run habitat. Cobble was also the predominant substrate type in pool habitat (Table 12). The mean depth was 1.54 feet.

Water Quality. We measured pH and turbidity at 77 transects in this basin. Fewer temperature and dissolved oxygen measurements were made because of problems with the dissolved oxygen meter. The median pH was 7.7 and the range was 7.3 to 8.9 (Appendix II). The median dissolved oxygen was 8.8 and the range was 8.0 to 10.9. The median turbidity was 18 and the range was 4 to 40 NTU. High turbidity values were measured the day following a thunderstorm.

According to the Pennsylvania Department of Environmental Protection (PADEP), the Codorus Creek watershed has 33 permitted discharges, 23 of which are industrial waste. Below the mouth of the South Branch of the Codorus Creek, an industrial discharge adds a stained color and a rancid smell to the water of the mainstem of the Codorus Creek that persists to the Susquehanna River. The ten other permitted discharges are from domestic wastewater plants.

HSI Scores. The overall HSI scores for Codorus Creek are listed in Table 3. HSI scores by blockage and reach are located in Table 13. HSI scores less than 50 resulted from shallow depths.

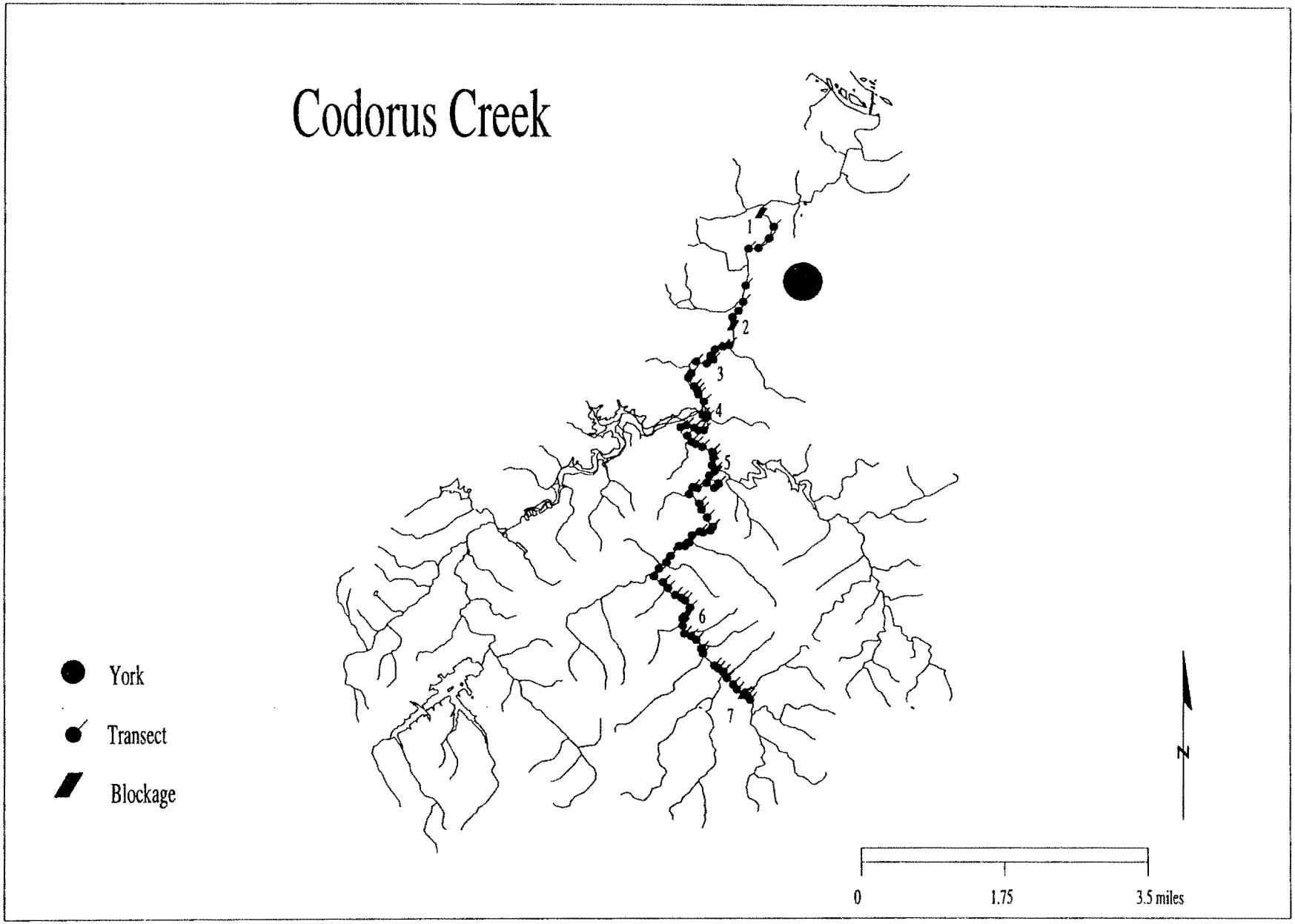

Figure 6. Transects and blockages surveyed on Codorus Creek, York County. Blockage numbers correspond with blockage identification numbers, e.g., 1=PACOD001.

Table 11. Stream bank conditions in the Codorus Creek drainage, York County.

Bank Condition	Percent of Total
Forest	25
Brush	39
Grasses	9
Riprap	9
Eroding	18

Table 12. Summary of substrate composition by habitat type in Codorus Creek, York County.

		Habitat type (%)	
		Riffle-run	Pool
Surveyed reach total habitat		32	68
Substrate:	Fines	0	4
	Sand/gravel	18	31
	Cobble	46	48
	Boulder	30	12
	Other	6	5

Other= bedrock or vegetation

Table 13. Blockages with habitat suitability data by reach for Codorus Creek, York County. Reaches are reported with the blockage at their downstream end. Tributaries that enter a mainstem reach are listed with the downstream blockage of that mainstem reach. The downstream limit of a reach is a blockage or the mouth of a tributary, while the upstream limit is a blockage or the point where the stream changes from third to second order.

Blockage				Reach		HSI Score			
						Alewife		Blueback	
ID	Stream	Miles from mouth	Ht (ft)	Stream	Area (ac)	S[A]	R[B]	S[A]	R[B]
PACOD001	Codorus Creek	6.4	4	Codorus Creek	51	57	46	72	43
PACOD002	Codorus Creek	10.5	4	Codorus Creek	21	60	36	74	40
PACOD003	Codorus Creek	12.0	4	Codorus Creek	26	61	42	76	41
PACOD004	Codorus Creek	14.9	4	Codorus Creek	23	58	40	72	38
PACOD005	Codorus Ck. S. Br.	0.1	1	Codorus Ck. S. Br.	39	62	42	77	44
PACOD006	Codorus Ck. S. Br.	8.6	4.6	Codorus Ck. S. Br.	14	58	40	69	36
PACOD007	Codorus Ck. S. Br.	12.2	1	Codorus Ck. S. Br.	1	50	43	59	23

A=Spawning
B=Rearing

Conewago Creek (York County)

Blockages. There are three dams within the area that habitat surveys were conducted and 11 more dams in the watershed (Fig. 7). See Appendix I for size and location of the blockages.

Habitat. Conewago Creek flows through residential and farm lands. Forest and brush were the predominant streambank conditions (Table 14). The predominant riffle/run substrate was boulder. Sand/gravel was the predominant pool substrate (Table 15). The mean depth was 2.38 feet.

Water Quality. We measured water quality variables at more than 70 transects, except for dissolved oxygen, which was measured at 63 transects (Appendix II). Erratic readings from the pH meter resulted in 56 useable values. The median pH was 7.9 and the range was 7.4 to 8.9. The median dissolved oxygen was 7.7 mg/L and the range was 3.8 to 11.8. The lowest dissolved oxygen values were taken on days of high streamflow when turbidity values were also high. Median turbidity was 13 and the range was 5 to 52.

According to the Pennsylvania Department of Environmental Protection (PADEP), the Conewago Creek watershed has 56 permitted discharges. Forty-eight of these discharges are from domestic wastewater treatment plants and the other eight are industrial waste. All but one of these discharges are into tributaries, thus the mainstem of Conewago Creek has better water quality than would be expected. Appendix II contains a summary of the water quality data gathered during the habitat survey.

HSI Scores. The overall HSI scores Conewago Creek are listed in Table 3. HSI scores by blockage and reach are listed in Table 16. HSI

scores less than 50 resulted from shallow depths, low velocities, or both.

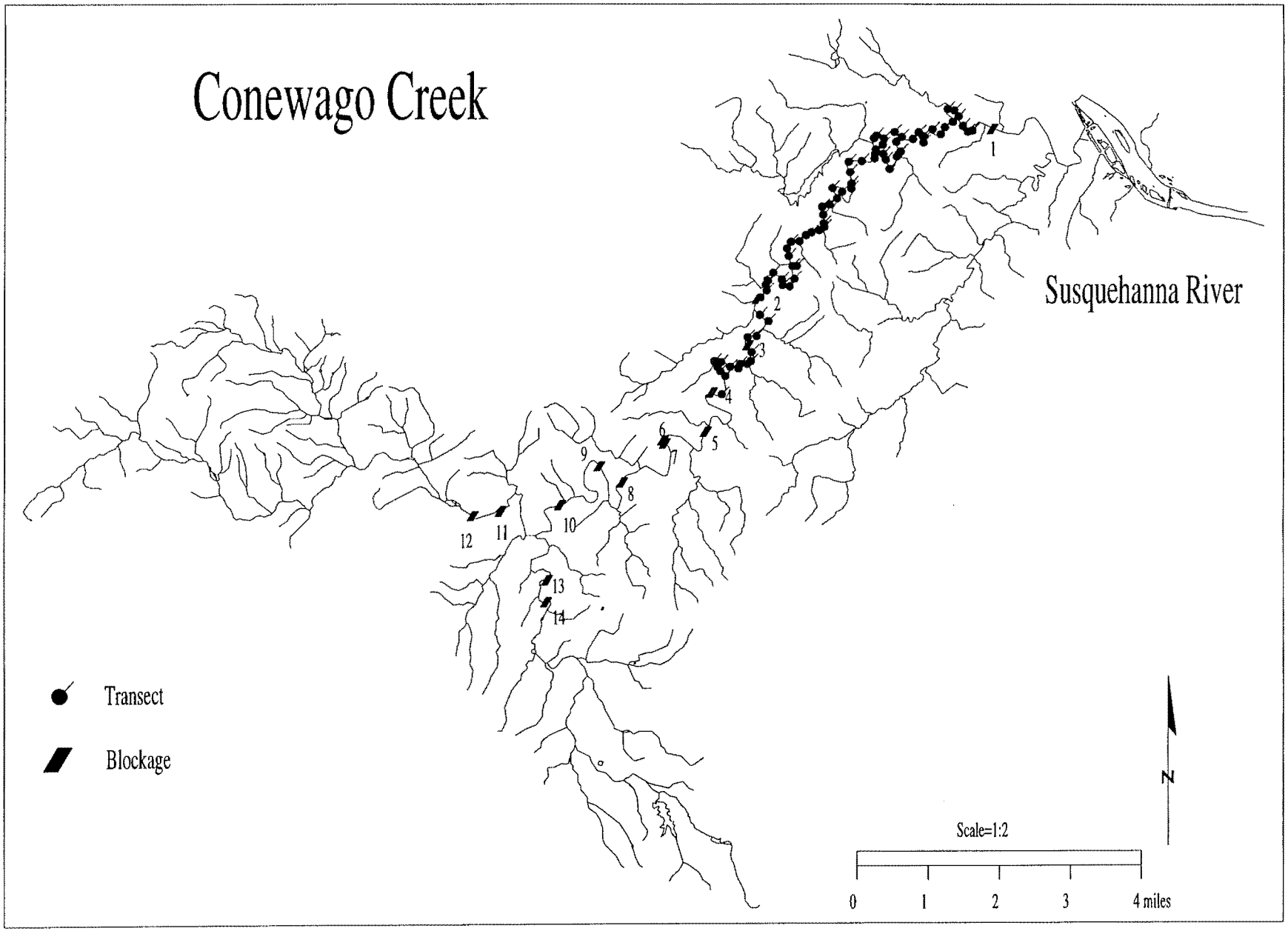

Figure 7. Transects and blockages surveyed on Conewago Creek, York County. Blockage numbers correspond with blockage identification numbers, e.g., 1=PACWW001.

Table 14. Stream bank conditions in the Conewago Creek drainage, York County.

Bank Condition	Percent of Total
Forest	45
Brush	35
Grasses	15
Riprap	5
Eroding	0

Table 15. Summary of substrate composition by habitat type in Conewago Creek, York County.

		Habitat type (%)	
		Riffle-run	Pool
Surveyed reach total habitat		34	66
Substrate:	Fine	0	2
	Sand/gravel	14	45
	Cobble	16	19
	Boulder	60	32
	Other	10	2

Other= bedrock or vegetation

Appendix I

Blockage locations and characteristics

ID	Stream Name	River Mile	Height (feet)	Type[a]	Comment
PACNS001	Conestoga River	4.0	8.0	DM	
PACNS002	Conestoga River	21.7	2.0	DM	
PACNS003	Conestoga River	21.8	5.0	DM	
PACNS004	Conestoga River	32.8	5.0	DM	
PACNS005	Conestoga River	37.7	3.0	DM	
PACNS006	Conestoga River	40.1	4.0	DM	
PACNS007	Conestoga River	41.8	8.1	DM	
PACNS008	Conestoga River	43.8	4.5	DM	
PACNS009	Conestoga River	44.6	2.0	DM	
PACNS010	Conestoga River	44.5	1.4	DM	
PACNS011	Conestoga River	45.8	8.0	DM	
PACNS012	Conestoga River	28.6	6.5	DM	
PACNS013	Little Conestoga River	4.9	9.6	DM	
PACNS014	Little Conestoga River	9.7	4.0	DM	
PACNS015	Little Conestoga River	12.9	2.0	DM	
PACNS016	Little Conestoga River	13.5	1.0	DM	
PACNS017	Little Conestoga River	13.5	0.7	DM	
PACNS018	Little Conestoga River	13.6	1.5	DM	
PACNS019	Conestoga River	24.3	2.0	DM	
PACNS020	Conestoga River	36.8	7.0	DM	
PACNS021	Conestoga River	36.2	0.7	OT	Concrete ford
PACNS022	Conestoga River	35.4	2.0	DM	
PACNS023	Conestoga River	35.1	1.5	DM	

Appendix I (continued)

Blockage locations and characteristics

ID	Stream Name	River Mile	Height (feet)	Type[a]	Comment
PACNS024	Conestoga River	40.8	7.0	DM	
PACNS025	Conestoga River	39.8	4.0	WF	Water fall w/turbine on right bank
PACNS026	Conestoga River	38.7	5.0	DM	
PACNS027	Conestoga River	43.5	2.0	DM	
PACNS028	Conestoga River	45.0	2.2	DM	
PACNS029	Conestoga River	45.2	1.4	OT	Concrete ford
PACNS030	Conestoga River	45.3	1.8	DM	
PACNS031	Conestoga River	46.6	1.3	OT	Concrete ford
PACNS032	Conestoga River	47.1	4.5	DM	
PACNS033	Conestoga River	47.5	0.3	PC	Three culverts
PACNS034	Conestoga River	48.2	3.0	DM	
PACNS035	Mill Creek	0.4	6.0	DM	
PACNS036	Mill Creek	2.1	2.0	DM	
PACNS037	Mill Creek	1.1	1.5	PX	Sewage pipe
PACNS038	Mill Creek	8.4	6.0	DM	
PACNS039	Mill Creek	4.0	2.5	DM	
PACNS040	Mill Creek	11.9	1.0	DM	
PACNS041	Mill Creek	10.3	5.0	DM	
PACNS042	Cocalico Creek	10.6	1.4	DM	

Appendix I (continued)

Blockage locations and characteristics

ID	Stream Name	River Mile	Height (feet)	Type[a]	Comment
PACNS066	Muddy Creek	4.3	3.0	DM	
PACNS067	Muddy Creek	5.7	2.5	DM	
PACNS068	Muddy Creek	17.4	8.5	DM	
PACNS069	Muddy Creek	16.7	2.5	DM	
PACNS070	Muddy Creek	15.5	3.0	DM	
PACNS071	Muddy Creek	14.2	4.0	DM	
PACNS072	Muddy Creek	13.8	1.5	DM	
PACNS073	Muddy Creek	13.0	6.0	DM	
PACHI001	Chickies Creek	0.1	8.0	DM	
PACHI002	Chickies Creek	1.9	4.5	DM	
PACHI003	Chickies Creek	3.6	4.0	OT	Multiple islands w/debris piles
PACHI004	Chickies Creek	5.8	3.0	DM	
PACHI005	Chickies Creek	5.9	3.0	OT	Cattle crossing
PACHI006	Chickies Creek	6.1	1.0	OT	Cattle crossing
PACHI007	Chickies Creek	7.1	7.0	DM	
PACHI008	Chickies Creek	9.1	7.0	DM	
PACHI009	Chickies Creek	10.6	8.0	DM	
PACHI010	Chickies Creek	13.0	1.0	DM	
PACHI011	Chickies Creek	15.2	2.5	DM	
PACHI012	Chickies Creek	15.9	3.0	DM	
PACHI013	Chickies Creek	20.7	1.0	DM	

Appendix I (continued)

Blockage locations and characteristics

ID	Stream Name	River Mile	Height (feet)	Type[a]	Comment
PACHI014	Chickies Creek	22.1	2.0	DM	
PACHI015	Chickies Creek	22.5	2.0	BC	Man made waterfall
PACHI016	Chickies Creek	24.6	1.2	DM	
PACHI017	Chickies Creek	24.7	1.0	DM	
PACHI018	Little Chickies Creek	0.1	1.0	DM	
PACHI019	Little Chickies Creek	0.3	1.1	DM	
PACHI020	Little Chickies Creek	0.6	2.0	DM	
PACHI021	Little Chickies Creek	2.1	1.5	DM	
PACHI022	Little Chickies Creek	4.5	4.0	DM	
PACHI023	Little Chickies Creek	5.8	7.0	DM	
PACHI024	Little Chickies Creek	7.5	4.0	DM	
PACHI025	Little Chickies Creek	8.1	2.5	OT	Cattle Crossing
PAKRE001	Kreutz Creek	0.2	1.0	DM	
PAKRE002	Kreutz Creek	0.3	2.0	DM	
PAKRE003	Kreutz Creek	0.5	0.8	DM	
PAKRE004	Kreutz Creek	1.7	1.0	DM	
PAKRE005	Kreutz Creek	2.4	5.0	DM	
PAKRE006	Kreutz Creek	3.4	7.0	DM	
PAKRE007	Kreutz Creek	6.3	1.0	DM	
PAKRE008	Kreutz Creek	8.0	1.5	DM	
PACOD001	Codorus Creek	6.4	4.0	DM	
PACOD002	Codorus Creek	10.5	4.0	DM	

Appendix I (continued)

Blockage locations and characteristics

ID	Stream Name	River Mile	Height (feet)	Type[a]	Comment
PACOD003	Codorus Creek	12.0	4.0	DM	
PACOD004	Codorus Creek	14.9	4.0	DM	
PACOD005	S. Br. Codorus Creek	0.1	1.0	DM	
PACOD006	S. Br. Codorus Creek	8.6	4.6	DM	
PACOD007	S. Br. Codorus Creek	12.2	1.0	DM	
PACWW001	Conewago Creek	7.0	3.0	DM	
PACWW002	Conewago Creek	19.7	6.0	DM	
PACWW003	Conewago Creek	22.0	4.0	DM	
PACWW004	Conewago Creek	25.8	5.0	DM	
PACWW005	Conewago Creek	29.0	7.0	DM	
PACWW006	Conewago Creek	31.3	1.1	DM	
PACWW007	Conewago Creek	31.5	6.0	DM	
PACWW008	Conewago Creek	34.2	3.0	DM	
PACWW009	Conewago Creek	38.0	8.0	DM	
PACWW010	Conewago Creek	41.8	8.0	DM	
PACWW011	Conewago Creek	46.9	8.0	DM	
PACWW012	Conewago Creek	47.9	7.0	OT	Cattle Crossing
PACWW013	S. Br. Conewago Creek	3.2	7.5	DM	
PACWW014	S. Br. Conewago Creek	5.5	3.7	DM	

a= blockage type: DM= dam, OT= other, BC= box culvert, PX= pipeline crossing, PC= pipe culvert, WF= water fall.

Appendix II. Summary of physico-chemical measurements streams surveyed during Phase II.

Basin, county, and statistic	Temperature (°C)	pH	Dissolved oxygen (mg/L)	Turbidity (NTU)
Conestoga R. Lancaster Co.				
N	365	359	365	365
Median	22.5	8.2	8.0	17.5
Mean	22.5	8.2	8.0	34.8
Minimum	17.1	7.4	5.3	0
Maximum	28.3	8.9	12.6	384
Chickies Cr. Lancaster Co.				
N	64	63	64	63
Median	11.4	8.1	10.3	6
Mean	11.3	8.1	10.5	16.6
Minimum	7.8	7.7	8.4	1
Maximum	13.3	8.5	13.0	100
Kreutz Cr. York Co.				
N	34	28	34	34
Median	18.9	8.0	8.8	5
Mean	19.0	7.9	8.9	7.4
Minimum	17.3	7.2	6.9	3
Maximum	21.1	8.3	11.3	24
Codorus Cr. York Co.				
N	60	77	47	77
Median	17.4	7.7	8.8	18
Mean	13.5	7.9	9.1	19.3
Minimum	14.3	7.3	8.0	4

Appendix II (continued)

Basin, county, and statistic	Temperature (°C)	pH	Dissolved oxygen (mg/L)	Turbidity (NTU)
Maximum	18.9	8.9	10.9	40
Conewago Cr. York Co.				
N	78	56	63	79
Median	22	7.9	7.7	13
Mean	21.9	8.1	7.8	17.3
Minimum	18	7.4	3.8	5
Maximum	26	8.9	11.8	52