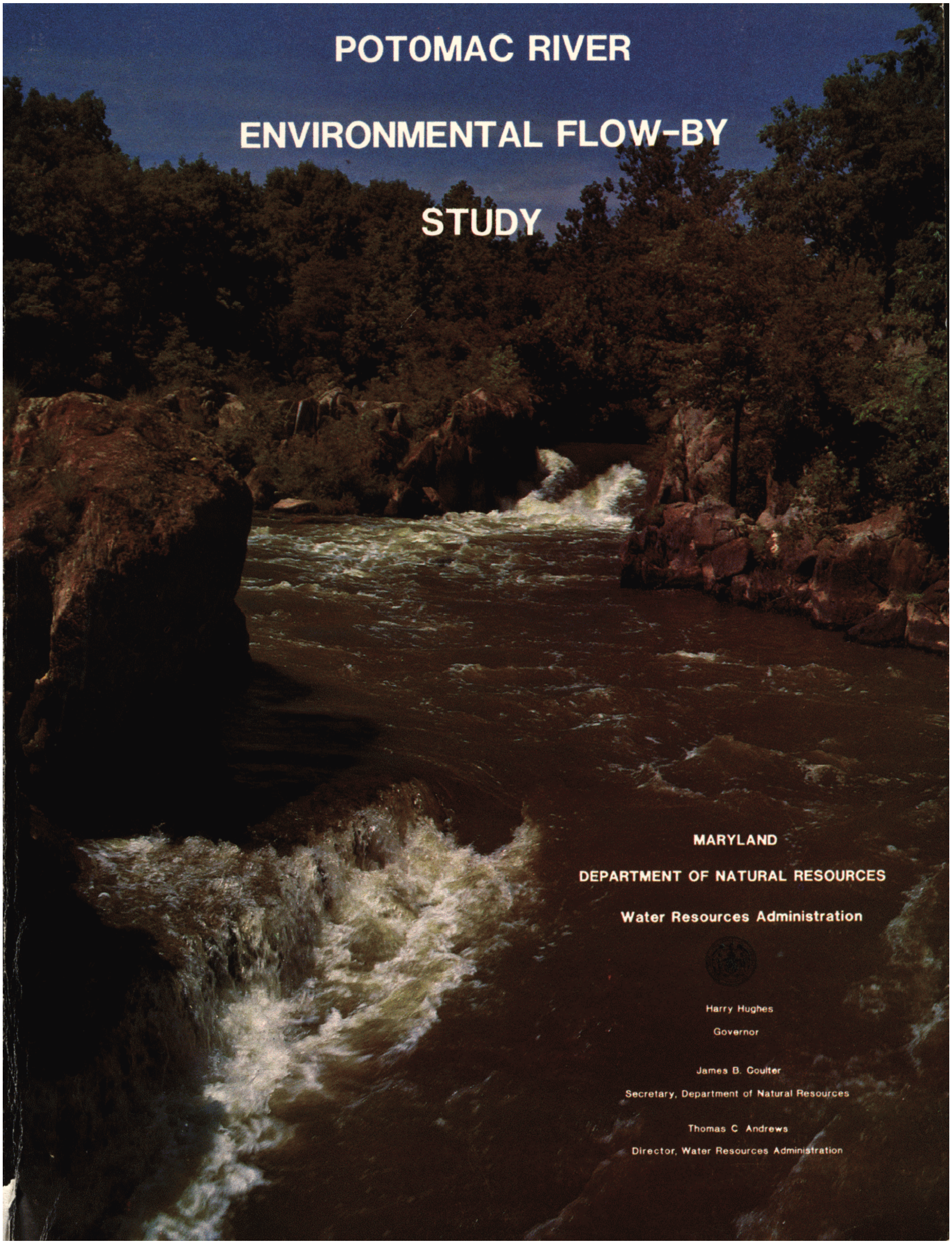


POTOMAC RIVER ENVIRONMENTAL FLOW-BY STUDY

MARYLAND

DEPARTMENT OF NATURAL RESOURCES

Water Resources Administration

Harry Hughes
Governor

James B. Coulter
Secretary, Department of Natural Resources

Thomas C. Andrews
Director, Water Resources Administration

W K Hodges

POTOMAC RIVER ENVIRONMENTAL FLOW-BY STUDY

Submitted to
The United States Army Corps of Engineers
in
Fulfillment of the Requirements of
Article 2.C of
The Potomac River Low Flow Allocation Agreement

Prepared By:

MARYLAND DEPARTMENT OF NATURAL RESOURCES
Water Resources Administration
Water Supply Division
Water Supply Planning Section

Annapolis, Maryland
1981

ACKNOWLEDGEMENTS

The Potomac River Environmental Flow-by Study was made possible by close cooperation of individuals from federal, state, interstate and academic institutions. The following organizations were instrumental in providing funding and/or information to the project:

U.S. Fish and Wildlife Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
Interstate Commission on the Potomac River Basin
Washington Suburban Sanitary Commission
Virginia State Water Control Board
Fairfax County Water Authority
Maryland Department of Natural Resources

General project guidance and advice was provided by members of an interagency technical task force. The task force included:

Charles Wheeler - Maryland Department of Natural Resources
Ernest Rebuck - Maryland Department of Natural Resources
Allan Dietemann - currently, North Carolina Dept. of Natural Resources
Ken Taylor - U.S. Geological Survey
Herb Freiberger - U. S. Geological Survey
Dave Smith - U.S. Fish & Wildlife Service
Steve Goodbred - U.S. Fish & Wildlife Service
Jim Nolke - U. S. Fish & Wildlife Service
Glenn Kinser - U. S. Fish & Wildlife Service
Tom Pheiffer - Environmental Protection Agency
Leo Clark - Environmental Protection Agency
Jane Massey - Environmental Protection Agency
Robert Davis - Environmental Protection Agency
Howard Echlund - Corps of Engineers
Norman Edwards - Corps of Engineers
Robert Pace - Corps of Engineers
Robert Morris - Potomac River Fisheries Commission
James McNeal - Virginia State Water Control Board
Al Willett - Virginia State Water Control Board
Duane Geuder - D.C. Government
John Brink - D.C. Government
David Conlin - D.C. Government
Jim Rasin - Interstate Commission on the Potomac River Basin
Gordon Wolman - Johns Hopkins University
Michael S. Haire - Office of Environmental Programs
George H. Harman - Office of Environmental Programs

Special recognition is due to Allan Dietemann, the original study leader, responsible for initial project design and coordination, formation of the technical task force, and primary data collection in 1978. Others involved in field data collection in 1978 and 1980 included; Steve Goodbred and Dave Smith of the U.S. Fish and Wildlife Service, Albert E. Sanderson, Jr., Kenneth Miller, Cynthia Barnes, of the Maryland Water Resources Administration, James Allison and Walter Butler of the Maryland Office of Environmental Programs and W. R. Carter III, Harley Speir and Steven Early of the Maryland Tidewater Administration.

The U.S. Fish & Wildlife Service's Instream Flow Group (IFG) Model methodology portion of the study (both data collection and subsequent computer analysis) was the result of a close working relationship between Steve Goodbred and Dave Smith of the U.S. Fish & Wildlife Service, Daniel P. Sheer of the Interstate Commission on the Potomac River Basin and staff members of the Maryland Water Resources Administration. Special thanks is due to Daniel Sheer and Steve Goodbred for their hard work and persistance in refining and obtaining IFG computer model results necessary for fishery analysis.

Special equipment for primary data collection was provided by the U.S. Geological Survey. Tabulation of benthic organism data was conducted by Ms. Betty Jo Phipps.

Much thanks and appreciation is extended to Charles A. Wheeler, Chief, Water Supply Division of the Maryland Water Resources Administration for coordinating field data collection in 1980 and for providing advice and inspiration during development of this document.

This document was written and prepared by the Water Supply Planning Section of the Maryland Water Resources Administration:

Robert D. Miller, Chief
Richard C. Lucas
Cynthia E. Troxell
Albert E. Sanderson, Jr.

Document typing was done by Elaine M. Patterson.

Cover photo by Charles A. Wheeler.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

RECOMMENDATIONS FOR AN ENVIRONMENTAL FLOW-BY AND EXECUTIVE SUMMARY

I. Recommendations for an Environmental Flow-by and Executive Summary

A. Environmental Flow-by Recommendations

The primary "charge" to the State of Maryland in conducting the Environmental Flow-by Study was to assess the environmental effects of various increments of low flow and make recommendations to the U.S. Army Corps of Engineers for the establishment of "any amount needed for flow in the Potomac River downstream from the Little Falls dam for the purpose of maintaining environmental conditions" (See Chapters II and V and Appendix D, Potomac River Low Flow Allocation Agreement). To specifically and adequately address the study "charge" in the context of available water management alternatives, the environmental flow-by recommendation will be presented as two separate recommendations:

RECOMMENDATION #1: Establish a minimum daily environmental flow-by of 100 million gallons a day (mgd) below Little Falls dam. Recommendation #1 will form the basis for implementing the Potomac River Low Flow Allocation AGreement formula.

RECOMMENDATION #2: At a calculated flow of 500 mgd just above the Great Falls intake, begin shifting Aqueduct withdrawals to the Little Falls dam intake to maintain at least 100 mgd plus the Washington Aqueduct's allocation up to 200 mgd between Great Falls and Little Falls dam.

A broad spectrum of Potomac River resources and uses including, the fishery, macroinvertebrates, wildlife, recreation and water quality were analyzed in an effort to gain an understanding of the potential impacts associated with low river flows from zero to 1100 mgd. The impacts of historical low river flow on non-fishery resources and uses, such as boating or wildlife were found to be negligible or of a short term nature, thus are only of minor concern. The fishery resource will be most affected by low river flow.

In establishing the recommended 100 mgd flow-by below Little Falls dam, a few of the factors taken into consideration were:

1. Practical water management realities including historical flow frequency, water supply demand, and water use restriction capabilities, presently limit the amount of water available for a minimum environmental flow-by. A daily average flow below Little Falls dam of 100 mgd is nearly the limit of what the current system can provide during extreme drought conditions.

2. The integrity of the fishery can be protected by establishing a flow-by as a daily minimum rather than a weekly average minimum. In addition, the current low flow allocation formula is calculated on a daily basis.

3. The area of potential impact extends approximately one mile from Little Falls dam to Little Falls -- however, the only area of significant concern is a small 22 acre backwater (See Zone 3 fishery discussion in Chapter V.)

4. Of all areas of the Potomac analyzed, the section from Little Falls dam to Little Falls was found to contain the poorest fishery habitat (averaging six to ten times less habitat available per 1,000 feet than is found above the dam) and is the least accessible for fishing.

5. The species of most concern (and most adversely affected) in the fluvial area below the dam is the juvenile life stage of the smallmouth bass -- estimated to number only 3500 juveniles (0 to 3 years of age) in any given year under average flow conditions in the 22 acre backwater.

6. Low flows at the level and duration necessary for a significant decline in the juvenile smallmouth bass population below the dam would be expected to occur only about once in twenty years. It is estimated that the smallmouth bass population would fully recover in approximately 4 years.

After weighing the above factors in terms of existing water supply needs and natural flow frequencies, it was determined that a minimum daily environmental flow-by of 100 mgd is reasonable and will be sufficient to protect the integrity of the fishery below Little Falls dam.

A considerably different environmental and use situation exists above Little Falls dam -- necessitating formulation of Recommendation #2. A very productive and highly used fishery exists between Great Falls and Little Falls dam. Even at the lowest flows, there is six to ten times more ideal habitat available per 1000 feet of stream above the dam than below the dam. The gross wetted area per 1000 feet of much of the river above Little Falls dam is more than two times that found below the dam. In addition, thousands of fishermen converge on the area each year as a result of easy access and the challenges offered by a varied and productive fishery.

Based on analysis of low flow related impacts in relation to water management opportunities, an effort should be made to maintain a minimum 100 mgd plus the Washington Aqueduct withdrawals up to 200 mgd between Great Falls and Little Falls dam. Washington Aqueduct withdrawals are usually at or near 200 mgd during late summer and early fall. The integrity of the fishery can be maintained at such a flow that lasts no longer than the recorded historical duration for that flow. By gradually shifting Aqueduct withdrawals to the Little Falls dam Intake when 500 mgd is observed just above the Great Falls intake, up to an additional 200 mgd would be available for environmental purposes down to the dam. Although pumping costs at Little Falls are high (approximately $8,000 a day) such pumping for environmental purposes would only occur on estimated average of one day in seven years.

B. Future Environmental Considerations

RECOMMENDATION: Upon completion and operation of Bloomington Reservoir, establish a monthly flow schedule, based on existing information regarding water management opportunities, that will optimize in-stream values while meeting water supply needs.

Bloomington Reservoir was constructed for such multiple purposes as water quality control in the North Branch of the Potomac and enhancement of water storage/supply capabilities. According to one management strategy developed by ICPRB CO-OP, operation of Bloomington Reservoir could mean that with "year 2000 demands" and water use restrictions in place, an additional 70 mgd could be made available on a daily basis for environmental concerns, bringing the total environmental flow to 170 mgd. If operated on a weekly average basis a environmental flow of 200 mgd (weekly average) could be maintained. Since there is flexibility in releases from the Bloomington Reservoir, a monthly flow schedule could be maintained in an effort to manage and optimize the fishery environment.

A plan development permit has been issued by the Maryland Water Resources Administration for the proposed construction of Little Seneca Reservoir. ICPRB CO-OP indicates that under certain management strategies, Little Seneca, if constructed and operated on a regional basis, could mean that, with year 2000 demands and water use restrictions in place, an additional 130 mgd could be made available (beyond that which is possible with Bloomington) to meet environmental management objectives. This could bring the total environmental management flow to 300 mgd.

Designation of a specific monthly optimization flow management schedule is beyond the protection oriented scope of this study. As Bloomington becomes fully operational, a monthly flow schedule is recommended to optimize in-stream and out-of-stream needs to the extent practically possible.

Establishment of a monthly flow schedule could be based on:

1) Additional in-depth analysis and refinement of existing data.

2) "Trade-off" considerations between fish species and life stages as well as among other in-stream values and uses (The decline in low flow associated habitat availability for certain life stages of some key fish species below Little Falls dam is off-set by a corresponding increase in availability of habitat above the dam during low flows -- See Chapter VII).

3) Collection of additional needed information on fish life stage requirements.

4) Refinement of system management modeling capabilities.

5) Other management and institutional considerations that may become evident as efforts are made to fully manage the Potomac.

CHAPTER II

INTRODUCTION

II. Introduction

In 1978, the Potomac River Low Flow Allocation Agreement was developed to provide an interjurisdictional mechanism for allocating water among the various Potomac water suppliers during periods of critical low flow. Signatories to the "Agreement" include the United States of America acting by the Secretary of the Army through the Chief of Engineers, the State of Maryland acting by the Governor and the Secretary of the Department of Natural Resources, the Commonwealth of Virginia acting by the Governor and the Chairman of the State Water Control Board, the District of Columbia acting by its Mayor, the Washington Suburban Sanitary Commission acting by its chairman and the Fairfax County Water Authority acting by its chairman. The portion of the Potomac covered by the "Agreement" extends from Little Falls dam to the farthest upstream limit of the pool of water behind the Chesapeake and Ohio Canal Company rubble dam at Seneca, Maryland.

The need for maintaining sufficient water in the Potomac to protect in-stream values during periods of critical natural low flow is established in Article 2.C of the "Agreement" (See Appendix D). Article 2.C reads as follows:

> "Whenever the Restriction Stage [total daily withdrawal is equal to or greater than eighty percent of total daily flow] or the Emergency Stage [projected total daily withdrawal in excess of daily flow] is in effect, the Aqueduct shall daily calculate and advise each user, and the Moderator, of each user's allocated fair share of the water available from the subject portion of the Potomac River in accordance with this Section C. In calculating the amount of water available for allocation, the Aqueduct will determine, in consultation with the parties, and based upon then current conditions and information, <u>any amount needed for flow in the Potomac River downstream from the Little Falls dam for the purpose of maintaining environmental conditions (environmental flow-by)</u>*, and shall balance such need against essential human, industrial and domestic requirements for water. The Aqueduct's determination shall be based upon the data and shall give substantial weight to conclusions for environmental flow-by submitted by the State [of Maryland]."

In July of 1978, the U.S. Army Corps of Engineers developed a "Memorandum of Intent" for clarification of the environmental flow-by/allocation formula portion of the "Agreement" (See Appendix D). The "Memorandum of Intent" stated that "the Washington Aqueduct will include along with the amount of water withdrawn from the subject portion of the river that amount designated as the environmental flow-

*Emphasis Added

by. Thus, when the Washington Aqueduct determines that the amount withdrawn, combined with the environmental flow-by amount, is equal to or greater than eighty (80) percent of the total daily flow, the Restriction Stage will be put into effect and allocation will begin."

It is Article 2.C that establishes the primary "charge" and objective of the environmental flow-by study conducted by the State of Maryland -- that is, the development of "conclusions" (environmental flow-by recommendations and impact associated with low flows) for the establishment of an "amount needed for flow in the Potomac River downstream from Little Falls dam for the purpose of maintaining environmental conditions." Beyond the primary study "charge" and objective, data collection and analysis was expanded in an effort to make a thorough examination of low flow effects on a broad range of environmental values and recreational activities from Seneca Pool to Little Falls, including a portion of the extreme upper estuary. Expansion of the study scope provided an information base that will enable the development of future management alternatives for the Potomac beyond the immediate and necessary need for the establishment of a flow-by below Little Falls dam.

During the early phase of study design it was determined that only the lower fluvial portion of the Potomac (between Little Falls and Seneca Pool) would be measurably affected by potential low flows and water withdrawals. Previous federal and state modeling efforts, as well as, some modeling done in conjunction with the flow-by study, indicate that the tidal Potomac Estuary is not adversely affected by cyclic low flow conditions. Tidal influence, estuary size, and the natural break-down of nutrients and BOD were found to have a far greater impact on the tidal Potomac than low freshwater in flows. Thus, the data collection and analysis focused on the fluvial Potomac. See Chapter VI, Section B, for a quantitative discussion of the focus of the flow-by study in relation to water quality in the tidal Potomac.

Primary data collection for the study was conducted in the summers of 1978 and 1980 during periods of low flow. Velocity, depth and substrate data was obtained at various locations for fishery analysis utilizing the U.S. Fish and Wildlife Services Instream Flow Group (IFG) Model (See Chapter IV). The model, developed initially for use on small western streams, predicts changes in ideal habitat availability per 1,000 feet of stream for various fish species. The model proved to be a useful tool for analyzing relative changes in habitat availability at various flows, however, its application was limited by the following constrictions:

1. The model would not provide results below flows of 300 mgd with any acceptable degree of confidence.

2. The model had never been applied to a stream as large or complex as the Potomac -- thus data collection was hampered, certain data collected had to be discarded or greatly adjusted because of lack of uniformity, and the amount of data collected was insufficient for thorough analysis of all habitat types.

3. Necessary data is not available for eastern streams to determine the full significance of square feet of available ideal habitat per 1,000 feet -- that is, whether or not 100,000 sq. ft. of available habitat is in fact excellent habitat or only marginal habitat when compared to some regional standard of suitability.

4. The model does not provide a direct indication of changes in sub-ideal or marginal habitat availability nor does it establish a direct relationship to changes in water quality.

Beyond the IFG model methodology, secondary data was collected and analyzed for flow related impacts on recreation, wildlife, macroinvertebrates, and water quality.

The document that follows is organized first, to familiarize the reader with the study portion of the river and data collection procedures, and second, to provide an understanding of low-flow associated effects on the fluvial and upper estuary portion of the Potomac. The fishery section of Chapter V is divided into two segments, impacts below Little Falls dam and impacts above Little Falls dam, to facilitate flow-by recommendations that specifically address the study "charge." The "Study Area Map" in the back cover and the "Summary Impact Matrix" should be referred to for orientation and comparison of low flow impacts.

The study was developed to establish a minimum acceptable environmental flow-by in what is essentially an unregulated river. It is recognized that with the completion of the Bloomington Reservoir and the pending development of the Little Seneca Reservoir, more water will be available in the Potomac for both environmental and water supply purposes (See Chapter VII). Future options may exist for managing the Potomac in an effort to optimize in-stream values. Specific recommendations for optimization management, while recognized in this document, are beyond the charge and scope of the environmental flow-by study and should be addressed in the future.

CHAPTER III

DESCRIPTION OF THE FLUVIAL POTOMAC RIVER

III. Description of the Fluvial Potomac River

A. Physical

The Potomac River drains 11,560 square miles of the Middle Atlantic Coastal Region. The river is a free flowing stream for 186 miles from its headwaters in the Appalachian Mountains to Little Falls near Washington D.C.; there becoming an estuary extending 114 miles to the Chesapeake Bay.

The Upper Potomac River watershed (see figure 3-1) is a mountainous region where the river flows through long flat reaches, occasionally interrupted by rapids. In the Appalachian Mountains, the river developed a trellised drainage pattern along lines of least resistance. There the river flows in a north-east direction along belts of weak rock, turning at right angles to cut through ridges. From Hancock, the river meanders in a south-east direction following a dendritic drainage pattern until it reaches Washington D.C.

The study portion of the river, from Seneca Pool to Little Falls, is entirely within the Piedmont Province, which is characterized by rolling terrain (see figures 3-2 and 3-3). Elevations of the river bed range from 180 feet a.s.l. (above sea level) to about 20 feet a.s.l. at Little Falls. Above Blockhouse Falls, located about one mile down stream from Seneca Pool, (see figure 3-4) the gradient averages 4.0 feet/mile (Parker, et al, 1907). From Blockhouse Falls to Little Falls, the river contains many falls and rapids, and has an average gradient of 8.5 feet/mile.

The regional geology through which the Potomac River flows is illustriated in figure 3-5. At Seneca Pool, the river cuts through Triassic sandstones and shales. Between Seneca Breaks and Little Falls, the river slices through granitic and gneissic rocks of Precambrian and Lower Paleozoic Age. In some places a veneer of Pleistocene and recent alluvial sediment has been deposited along the river banks and on some of the river's small islands. Bottom composition appears to consist primarily of rock, gravel and coarse sand with accumulations of fine materials in low velocity flow areas (Cloos, et al, 1964).

Most of the bedrock in the Piedmont is covered with a regolith. Water is stored in, and moves through, both the regolith and fractures in the underlying rock, providing base flow to parts of the Potomac River and its tributaries.

B. Hydrological

Stream flow in the Potomac River and its tributaries is provided by a combination of direct runoff from the land surface and subsurface discharge from groundwater storage. During periods between storms, river flow is provided from water stored in the channel and from groundwater base flow (Trainer, 1975).

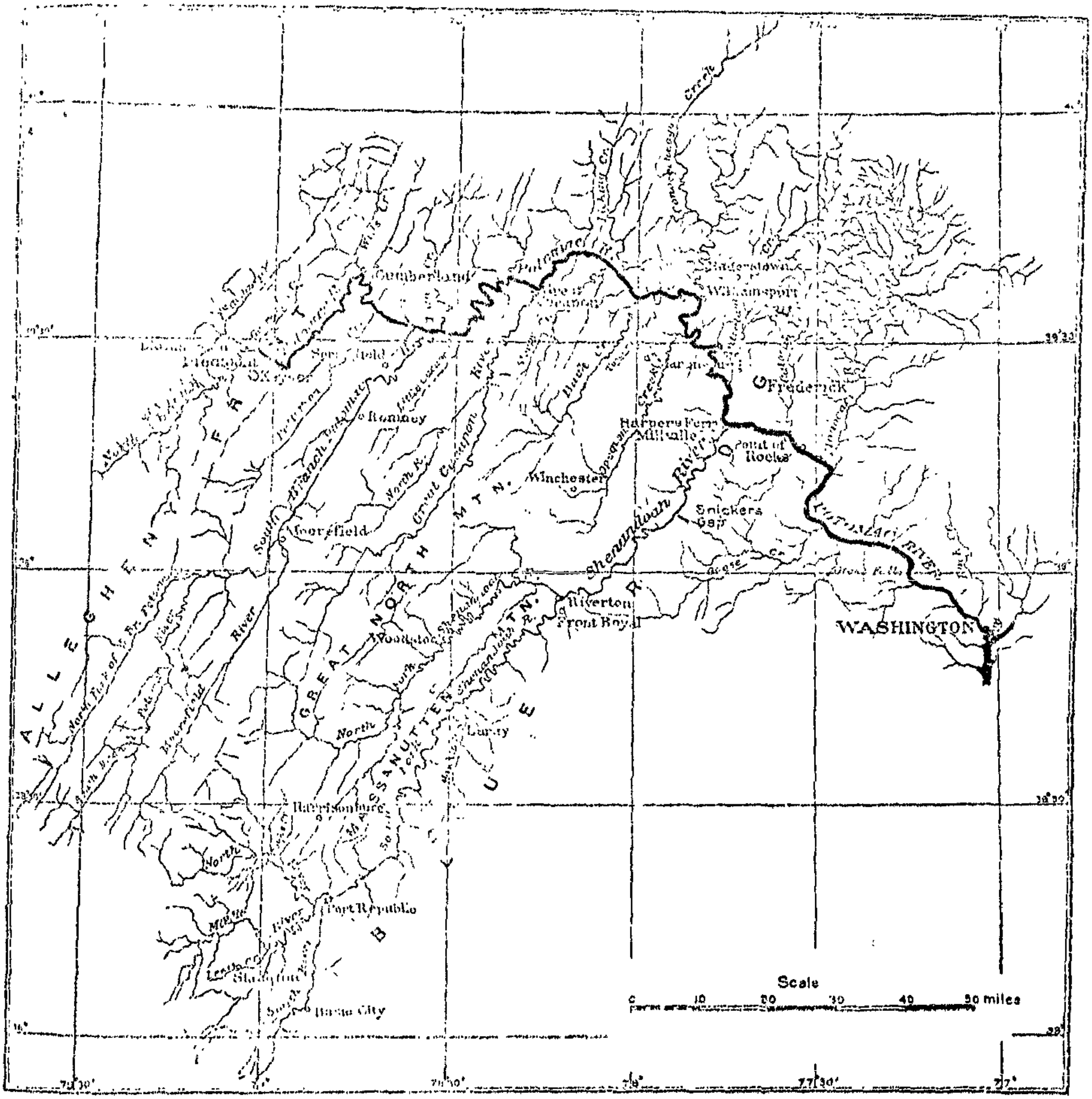


Figure 3-1 Map of the Potomac River Drainage Basin
(adapted from Parker, et al, 1907)

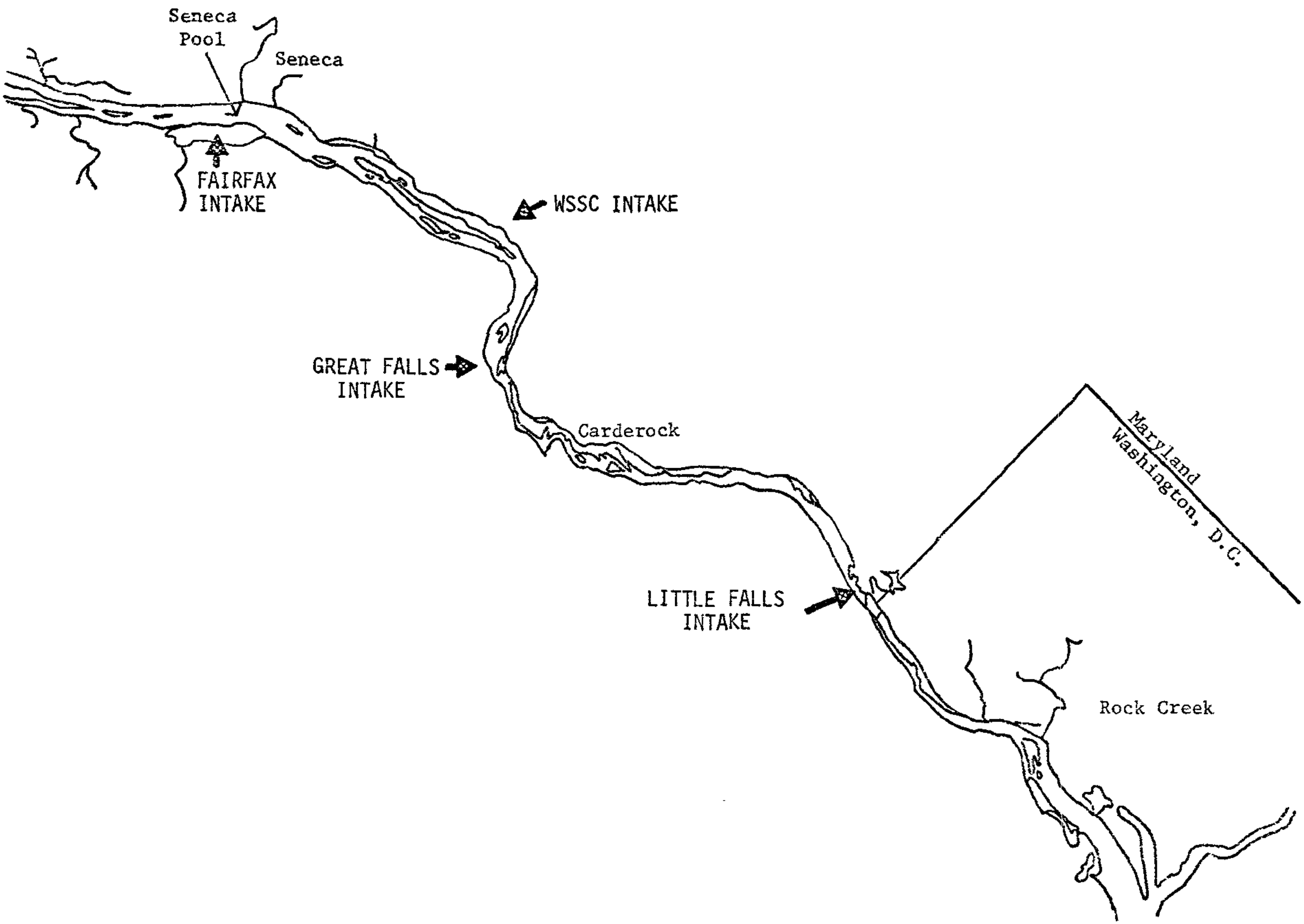


Figure 3-2 Map of Study Area Showing Intake Locations

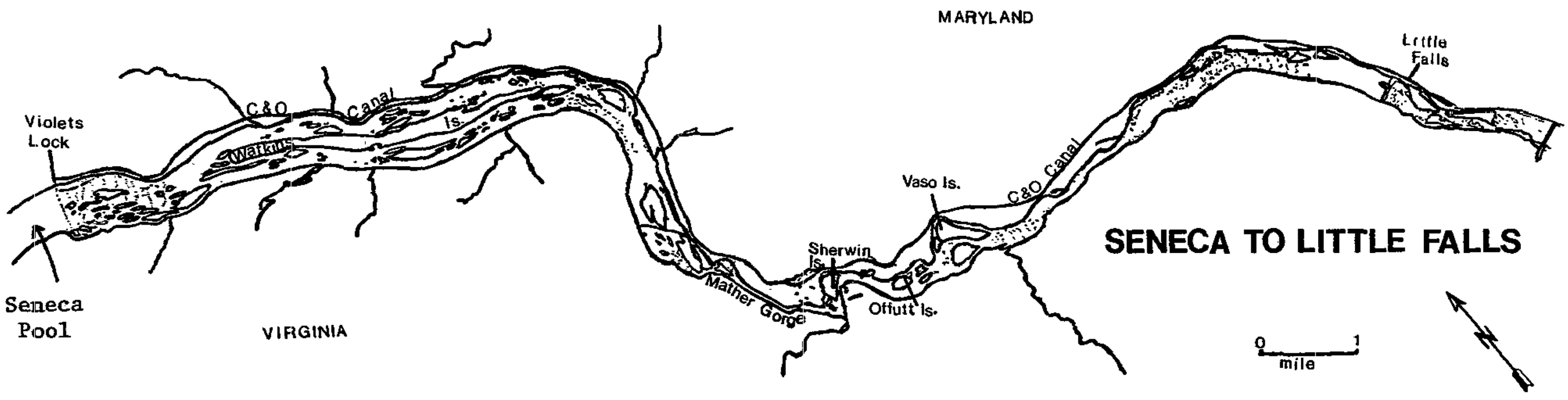


Figure 3-3 Map of Study Area

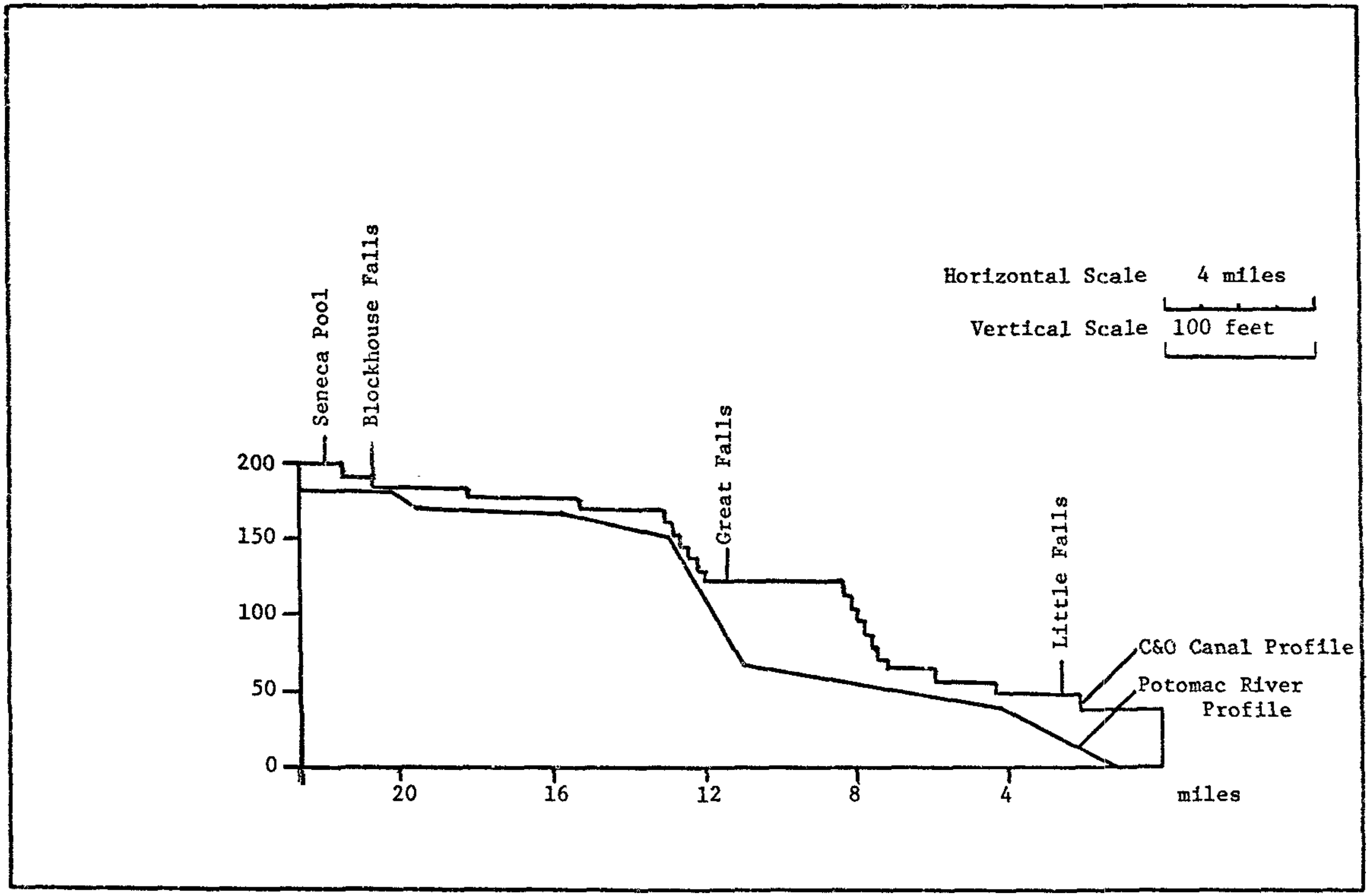


Figure 3-4 Profile of the Potomac River from Seneca Creek to Little Falls (adapted from Parker, et al, 1907)

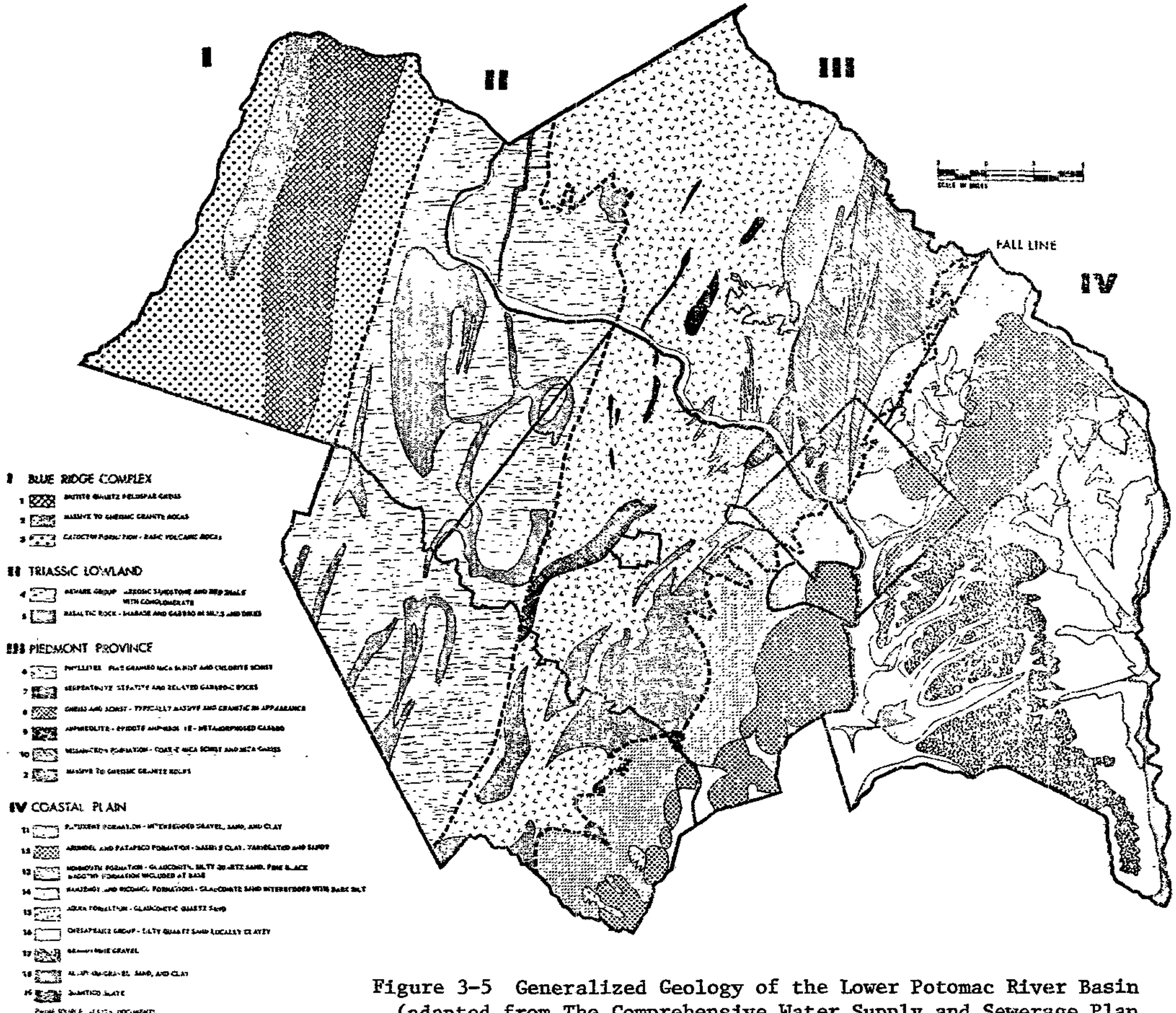


Figure 3-5 Generalized Geology of the Lower Potomac River Basin (adapted from The Comprehensive Water Supply and Sewerage Plan for Montgomery County; June 1979)

The amount of water in the river depends upon the amount of precipitation that either enters the ground or becomes runoff. Typically snow melt and winter rain provide high runoff and a large part of the groundwater recharge. Both groundwater base flow and runoff greatly diminish during summer because of higher rates of evaporation and transpiration, leading to noticable declines in river flow.

Decline in flow is especially conspicuous during extended dry periods when groundwater provides almost all of the river flow as illustrated in Figure 3-6. As the groundwater reserve becomes depleted, the amount of water available for base flow decreases. If the water table becomes low enough, water may seep out of the channel into the ground, further reducing river flow.

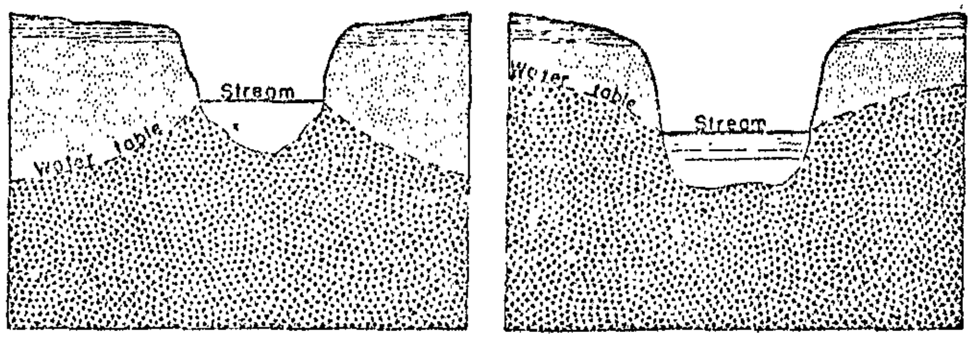
Flows in the Potomac River fluctuate greatly depending upon the amount of precipitation that falls in the river basin. Precipitation varies for different parts of the watershed within the study area, averaging between 40 and 45 inches per year. Figure 3-7 indicates average rainfall in the Maryland portion of the Potomac River watershed.

The average adjusted River flow at Little Falls is 7,358 mgd (million gallons per day)*. A maximum adjusted recorded daily flow of 315,564 mgd occurred on March 19, 1936 and a minimum flow of 394 mgd*, occurred on September 10, 1966. The observed flow at Little Falls on September 9, 1966 was only 78 mgd. As illustrated in Figure 3-8, the maximum mean yearly flow was 13,824 mgd in 1972 and the lowest mean yearly flow was 3,549 mgd in 1969 (Walker, 1971).

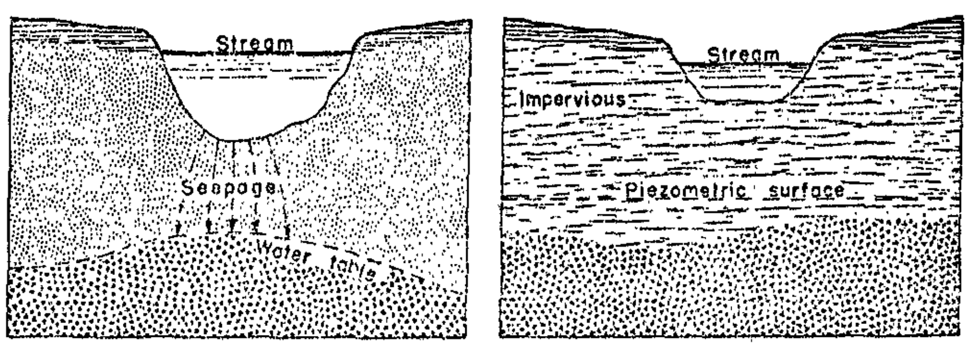
Low flows can be described by their magnitude, duration and frequency. Table 3-1 shows the relationship between these properties for Little Falls Dam on the Potomac River near Washington D.C.

The Potomac River is the only major surface source of potential, additional, non-saline water supply available (without resorting to massive inter-basin transfer), for the Washington Metropolitan Area. Average annual regional withdrawals per year ranged from 187 mgd in 1960 to 325 mgd in 1980. As indicated in figure 3-9, the general trend has been one of steadily increasing annual regional withdrawals per year since the 1960's. During each year, maximum usage usually occurs between June and September, (see Figure 3-10) with monthly averages ranging from 320 to 390 mgd. Minimum regional withdrawals usually take place between November and March and range from a monthly average of 280 to 310 mgd.

*Total flow = flow observed at Little Falls plus adjustments for diversions and municipal withdrawals.



Influent stream on the left loses water to the aquifer; effluent stream on the right gains water from the aquifer because water table is above the stream bed.



Stream on the left flows only following periods of surface runoff, but is dry during droughts. Stream on the right is isolated hydraulically from artesian aquifer below it.

Figure 3-6 The Effect of the Water Table on Base Flow (adapted from Johnson Division, Universal Oil Products Co., 1972)

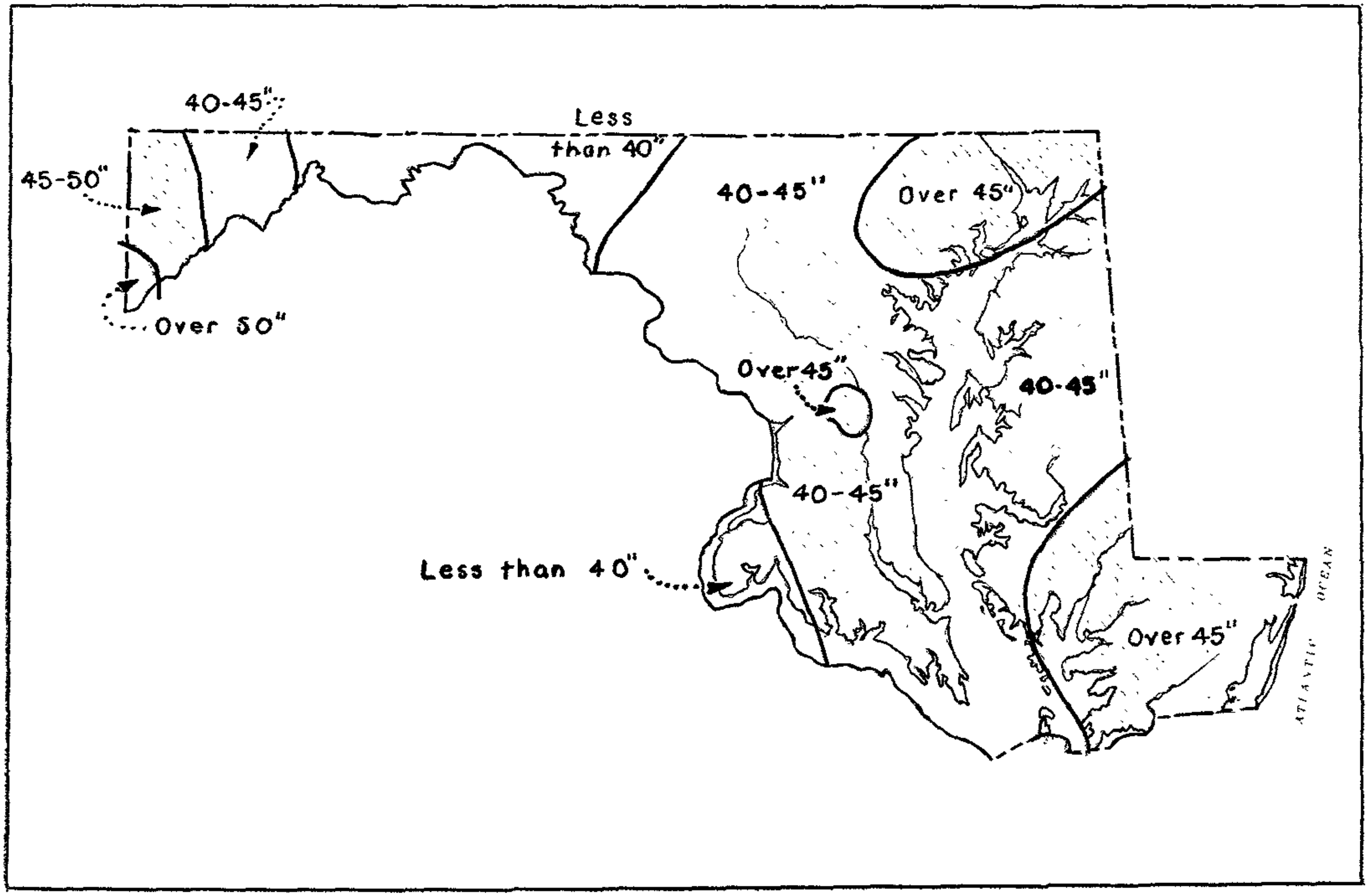


Figure 3-7 The Average Yearly Precipitation in Maryland
(adapted from Walker, 1970)

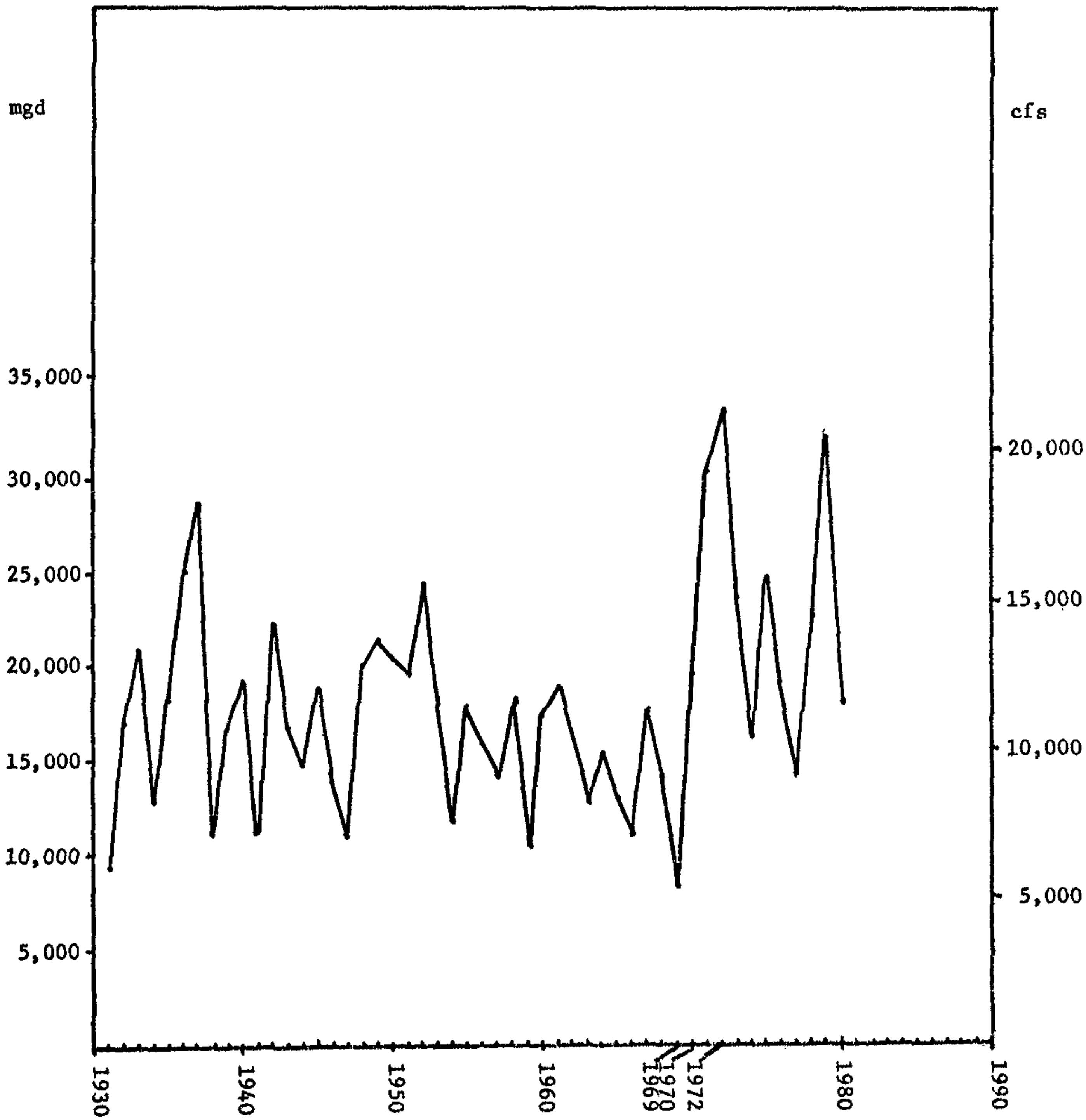


Figure 3-8 Average Yearly Discharge, per Calendar Year, of the Potomac River at Little Falls Dam, near Washington, D.C. (data from the U.S. Geological Survey, 1964, 1981)

Magnitude and Frequency of Annual Low Flow

(Based on Observed Flow during the Period Apr. 1, 1930, to Mar. 31, 1967)

Annual Minimum	Discharge, in mgd*, for Indicated Recurrence Interval, in Years				
	2-year	5-year	10-year	20-year	50-year
7-day	859	506	362	266	-
14-day	911	543	395	295	-
30-day	1,008	635	492	397	-
60-day	1,273	762	574	453	-
90-day	1,499	898	691	556	-
120-day	1,796	1,111	853	691	-

Magnitude and Frequency of Annual Low Flow

(Based on Adjusted Flow during the Period Apr. 1, 1930, to Mar. 31, 1967)

Annual Minimum	Discharge, in mgd*, for Indicated Recurrence Interval, in Years				
	2-year	5-year	10-year	20-year	50-year
7-day	1,047	743	614	523	-
14-day	1,098	782	646	556	-
30-day	1,121	866	730	633	-
60-day	1,486	995	814	691	-
90-day	1,718	1,124	917	782	-
120-day	2,009	1,330	1,079	904	-

* 0.646 mgd = 1 cfs (cubic feet per second)

Table 3-1 Magnitude and Frequency of Annual Low Flows at Little Falls Dam Gage near Washington, D.C. (adapted from Walker, 1971)

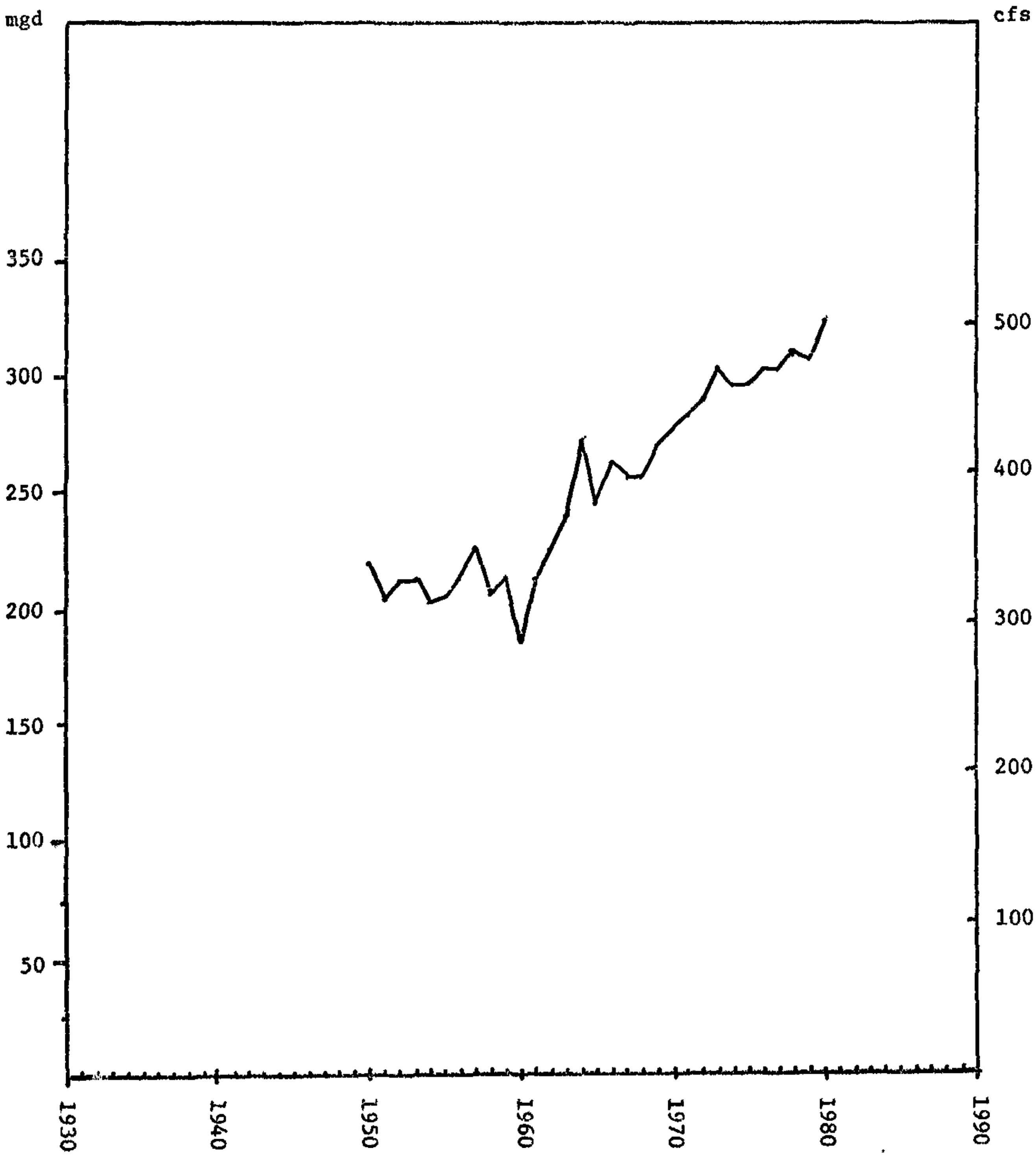


Figure 3-9 Average Yearly Withdrawals, per Calendar Year, of the Potomac River prior to Little Falls Dam, near Washington, D.C. (data from the U.S. Geological Survey, 1964, 1981)

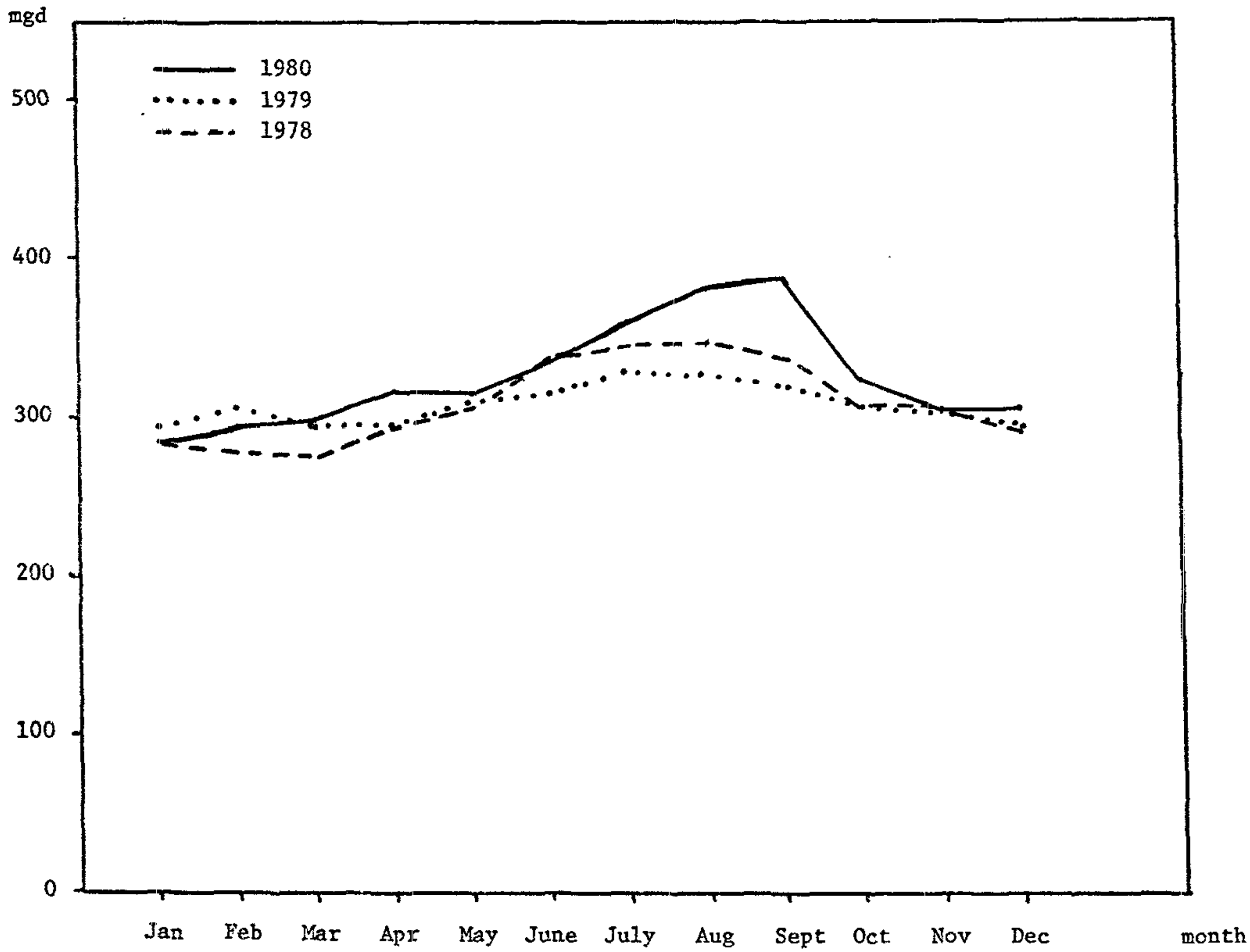


Figure 3-10 Graph of Average Withdrawals from Study Portion of the Potomac per Month from January 1978 to December 1980 (Data from U.S. Army Corps of Engineers, Washington Aqueduct Division, 1978-1980)

The cyclic increases and decreases in water use contrast the yearly occurrences of high and low river flows. Peak flows usually occur between February and early May (see figure 3-11), whereas minimum flows tend to be between June and October. As a result of tropical storms and hurricanes, there may occasionally be high flows in September or October. During periods of unusually low flow, such as occurred in September 1966, withdrawals could potentially equal or exceed total river flow, as indicated in figure 3-12.

C. Biological

The Potomac River supports a large and diverse biologic community. The number and variety of species within the community is far too great to permit a description of all species within this report. However, those species and biotic types which inhabit the study area and which have been deemed to be important, conspicuous, or dominant, or which were specifically observed and identified in the course of field investigation, are described herein. For the purpose of this report, the biota are divided into the following categories; Wildlife, Fish, Aquatic Vegetation, Microbiota, and Macroinvertebrates.

1. Wildlife

For the purpose of this study, the wild animals and birds living within the sphere of the Potomac ecosystem from Seneca Pool to the upper estuary, have been divided into three groups. These groups, which in part reflect the animals dependence on the flowing river, are aquatic dependent animals, partially aquatic dependent animals and non-aquatic dependent animals.

An aquatic dependent animal is defined herein as one which lives and feeds in the river most of the time. Aquatic dependent animals are totally dependent upon the river for survival during at least part of their life cycle. In the study area, aquatic dependent mammals include the rare river otter and the more common beaver and muskrat. These species spend much of their time in the water and partially depend upon the river as a source of food. Aquatic reptiles, including snapping turtle, mud turtle, spotted turtle, painted turtle, red bellied turtle and the northern water snake, are common throughout the study area and frequent both the water and the near shore. Aquatic amphibians which primarily inhabit the overflow pools of the Potomac floodplain, include the two-lined salamander, marbled salamander, spotted salamander, dusty salamander, red-backed salamander, shiney salamander, mud salamander, green frogs, leopard frogs, bullfrog and red spotted newt. Green treefrogs, spring peepers, northern cricket frogs, pickerel frogs, eastern wood frogs and American toads also depend upon the overflow

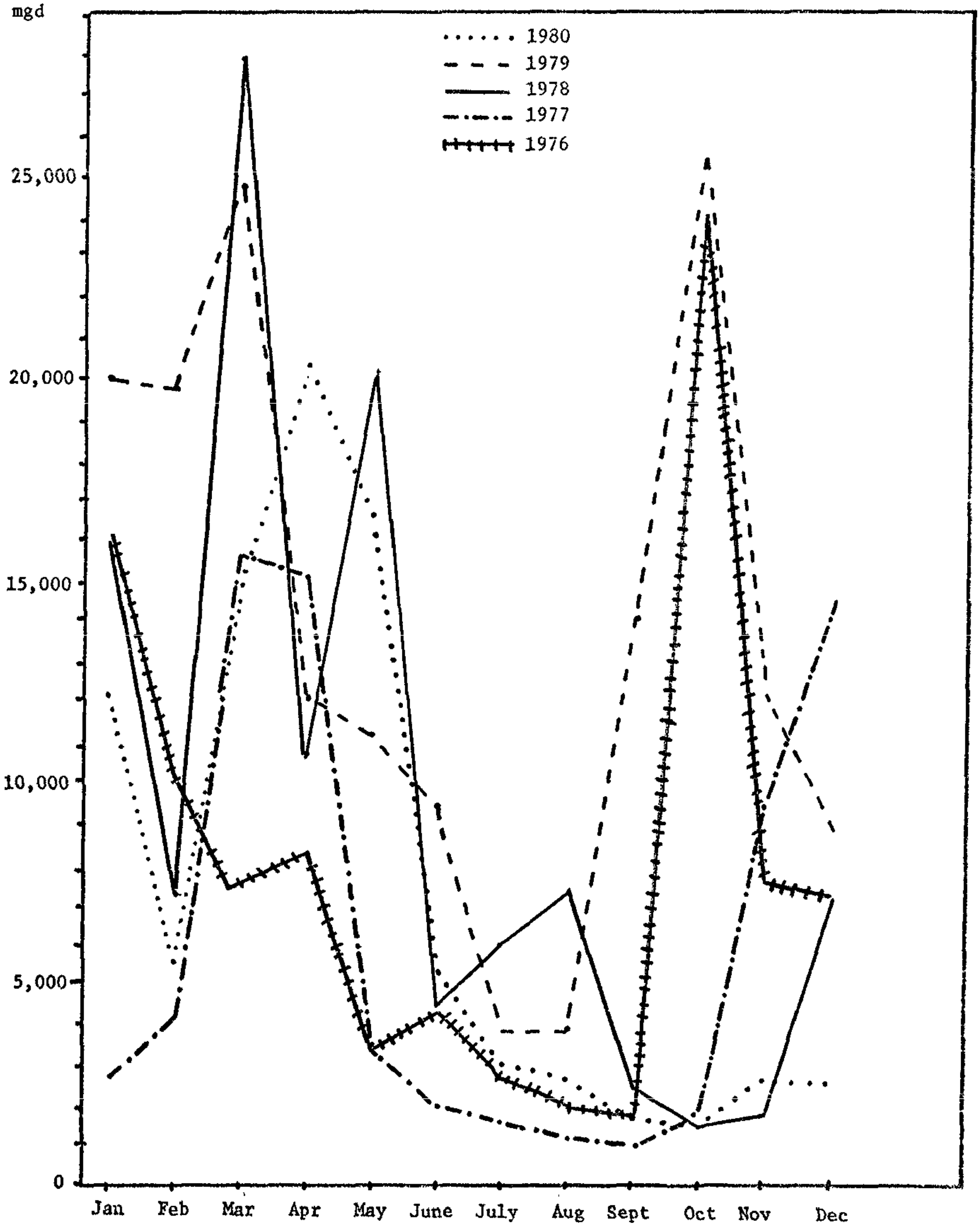


Figure 3-11 Average Total Flow at Little Falls Dam Gage (Including Withdrawals from Study Portion of Potomac) per Month for January 1976 to December 1980 (data from U.S. Geological Survey, 1981, and U.S. Army Corps of Engineers, 1978-1980)

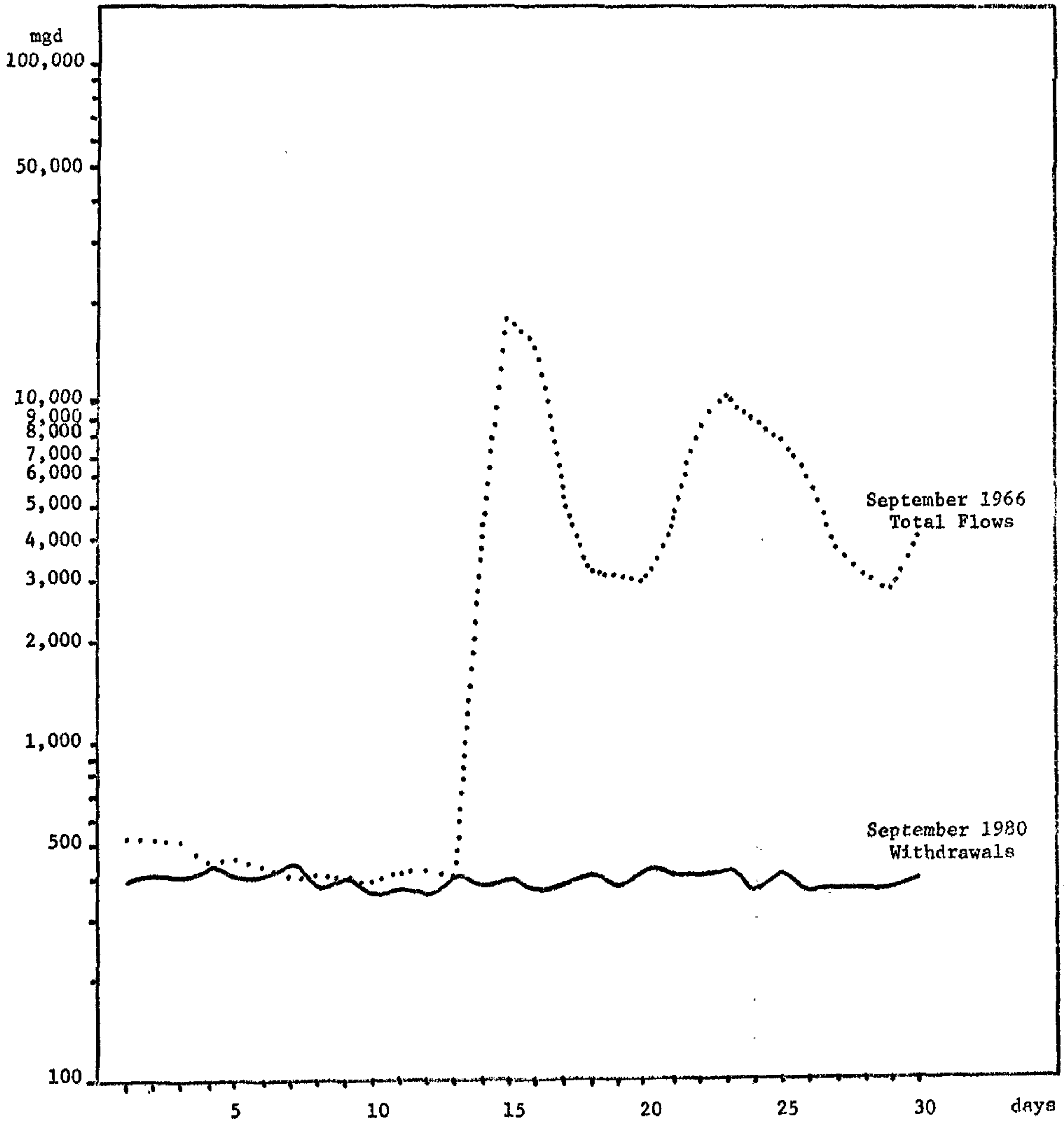


Figure 3-12 Semi-logarithmic Graph of September 1980 Withdrawals and September 1966 Flows (data from the U.S. Army Corps of Engineers and the U.S. Geological Survey, 1981)

pools during their early life stages. The young ducklings of resident nesting waterfowl are totally dependent upon the riverine environment for food and shelter. The adults also depend on the river for food and protection. Resident waterfowl which nest in the study area are mallards, black ducks and wood ducks. Ospreys and occasionally southern bald eagles, both rare and endangered species, use the riverine environment and the upper estuary as a food source and nesting area.

A partially aquatic dependent animal is defined herein as one which either feeds in part on aquatic life or which spends a significant portion of its time in the water. However, these animals are not totally dependent on the river as a food source. The most common partially aquatic mammals are raccoon and mink. Both are partially dependent on river animals and invertebrates as a source of food. There are also several types of birds that are partially dependent such as great blue herons and green herons. Belted kingfishers and several species of waterfowl, such as pied billed grebes, goldeneye and mergansers, commonly visit the study area during the cooler months.

Non-aquatic dependent animals are those which inhabit or frequently visit the lands comprising the near shore flood plain of the river or the river's many islands. These species may occassionally enter the river but are not directly dependent upon it for food, shelter or reproduction. Mammals that are included in this group are grey fox, opossum, skunk, weasel, whitetail deer, squirrels, rats, mice, woodchucks and rabbits. Most song birds which visit the river's shores are considered to belong in this category. Over 108 species of birds have been identified. The peregrine falcon, an endangered species, was observed along the river upstream of the study area in 1978 (Sanderson, 1981). Another sighting has been reported in the vicinity of Violets Lock in the study area.

The Maryland Wildlife Administration's management program includes wild turkey, dove, waterfowl, and squirrel within parts of the study area in Mongtomery County.

2. Fish

The <u>Fishery of the Piedmont Potomac</u>, by Dietemann and Sanderson (1978), includes a compilation of 63 fish species (See Table 3-2) which have been identified by researchers as inhabitants of the Piedmont region of the Potomac. Most of these species may be found in the study portion of the river. Several other fish species have been identified as residents of the study area. These include the hickory shad, quillback carpsucker, white catfish, chain pickerel and several minnow species.

Species / Location (see Figure 1)	Monocacy R. A	Dickerson B	Seneca C	Md. tribs. D	Va. tribs. F	Mather Gorge F	References
PETROMYZONTIDAE							
Sea lamprey *Petromyzon marinus*						0	24
ANGUILLIDAE							
American eel *Anguilla rostrata*	X		X	X	X	X	4,6,15
SALMONIDAE							
Brook trout *Salmo fontinalis*				X	X		5,16
CLUPEIDAE							
Gizzard shad *Dorosoma cepedianum*		X				X	1,21
Alewife *Alosa pseudoharengus*						X	9,14
American shad *Alosa sapidissima*						X	9,14
Blueback herring *Alosa aestivalis*						X	14
AMIIDAE							
Bowfin *Amia calva*	X						21
ACIPENSERIDAE							
Atlantic sturgeon *Acipenser oxyrhynchus*						X	21
CYPRINIDAE							
Blacknose dace *Rhinichthys atratulus*	X			X	X		5,6,13,16
Longnose dace *Rhinichthys cataractae*	X	X	X	X	X	X	1,4,13,16,21
Rosyside dace *Clinostomus funduloides*				X	X		5,6,16
Creek chub *Semotilus atromaculatus*	X	X	X	X	X		1,5,9,13,16
Fallfish *Semotilus corporalis*	X	X	X	X			1,5,9,13
Cutlips minnow *Exoglossum maxillingua*	X	X	X	X	X	X	1,4,5,6,13,16
Golden shiner *Notemigonus crysoleucas*	X	X	X	X	X		1,5,13,16
Silverjaw minnow *Ericymba buccata*	X	X		X			1,5,13
Bluntnose minnow *Pimephales notatus*	X	X	X	X	X	X	1,4,5,9,16,21
River chub *Nocomis micropogon*	X	X	X	X		X	1,4,5,13,21
Stoneroller *Campostoma anomalum*	X	X	X	X			1,4,5,13
Fathead minnow *Pimephales promelas**	X						26
Silvery minnow *Hybognathus nuchalis*	X	X					1,13,
Goldfish *Carassius auratus**	X	X	X			X	1,9,13,21
*Carp Cyprinus carpio**	X	X	X			X	1,4,13,21
Comely shiner *Notropis amoenus*	X	X	X	X			1,4,5,13
Rosyface dace *Notropis rubellus*	X		X	X			4,5,6,13
Swallowtail shiner *Notropis procne*	X	X	X	X	X	X	1,4,5,9,16,21
Satinfin shiner *Notropis analostanus*				X	X	X	5,12,16,21
Common shiner *Notropis cornutus*	X	X	X	X	X		1,4,5,9,13,16
Spottail shiner *Notropis hudsonius*	X	X		X			1,4,5
Spotfin shiner *Notropis spilopterus*	X	X	X	X			1,4,5,9,13
CATOSTOMIDAE							
White sucker *Catostomus commersoni*	X	X	X	X	X	X	1,4,5,6,13,15,21
Hogsucker *Hypentelium nigricans*	X	X		X			1,4,5,6,13
Redhorse sucker *Moxostoma macrolepidotum*	X	X	X			X	1,4,13,21
Creek chubsucker *Erimyzon oblongus*	X	X				X	1,4,21
ICTALURIDAE							
Yellow bullhead *Ictalurus natalis*	X	X		X		X	1,4,13,21,24
Brown bullhead *Ictalurus nebulosis*	X	X			X	X	1,13,16,21
Channel catfish *Ictalurus punctatus**		X	X	X		X	1,5,6,9,21,24
Blue catfish *Ictalurus furcatus**						0	2
Margined madtom *Noturus insignis*	X	X	X	X		X	1,5,12,21
PERCOPSIDAE							
Trout-perch *Percopsis omiscomaycus*			0	0		0	9,12,24
COTTIDAE							
Mottled sculpin *Cottus bairdi*				X			5,6,24
PERCICHTHYIDAE							
White perch *Morone americana*						X	14,21,24
Striped bass *Morone saxatilus*						X	21,24
POECILIIDAE							
Mosquitofish *Gambusia affinis*	X						13
CYPRINODONTIDAE							
Banded killifish *Fundulus diaphanus*	X	X					1,21
CENTRARCIDAE							
Rock bass *Ambloplites rupestris**	X	X	X	X			1,4,5,6,12,13,24
Redbreast sunfish *Lepomis auritus*	X	X		X		X	1,4,6,13,18
Green sunfish *Lepomis cyanellus**	X	X	X	X	X		1,6,9,13,16
Warmouth *Lepomis gulosus**		X				0	1,24
Pumpkinseed sunfish *Lepomis gibbosus*	X	X	X	X		X	1,4,6,9,13
Bluegill sunfish *Lepomis macrochirus**	X	X	X	X	X	X	1,6,9,13,15,16,21
Longear sunfish *Lepomis megalotis**		X			X		1,15,16
Smallmouth bass *Micropterus dolomieui**	X	X	X	X		X	1,4,6,9,13,21,24
Largemouth bass *Micropterus salmoides**	X	X	X	X		X	1,6,9,13,21,24
White crappie *Pomoxis annularis**	X	X	X			X	1,9,21
Black crappie *Pomoxis nigromaculatus**		X			X		1,16
PERCIDAE							
Tessellated darter *Etheostoma olmstedi*	X	X		X	X	X	1,5,13,16,21
Shield darter *Percina peltata*		X	X			X	2,21
Fantail darter *Etheostoma flabellare*	X	X	X	X			1,5.6,12,13
Greenside darter *Etheostoma blennioides*	X	X	X	X		X	1,5,13,21
Walleye *Stizostedion vitreum**						0	1,21
Yellow perch *Perca flavescens*						X	1,21
TOTAL SPECIES = 63	42	42	31	37	19	38	

* *introduced*

X = present
0 = no recent collections

Table 3-2 Fishes Reported in the Potomac River and Tributaries from Washington, D.C. to the Monocacy River (Dietemann and Sanderson, 1978)

The study area provides a high quality fishery with an abundance of two of the more popular game species, the smallmouth black bass and the largemouth black bass. In recent years studies have determined that reproduction of young bass has been exceptionally high and large catches of adults have been reported (Kreh, 1980). Channel catfish have also become increasingly popular sport fish and the Potomac River has become nationally recognized for its high quality cat fishery (Almy, 1981). Other highly desirable game and pan species which are abundant in the study area of the river are white crappie, black crappie and several varieties of sunfish.

Several anadromous species of fish are also in the study area of the Potomac during portions of each year. These include blueback herring, alewife, American shad, hickory shad, striped bass, white perch, yellow perch and american eel. With the exception of the eel, these species enter the lower fluvial portion of the Potomac below Little Falls Dam each year for spawning purposes. While in the upper estuary and lower fluvial portion of the river, the adults of some species provide a viable sport fishery. The young inhabit the lower fluvial river during their early life cycle and eventually migrate downstream to the Potomac estuary and beyond.

During the 1930's, walleyes were reported to be commonly caught by fishermen in the lower fluvial river and the upper estuary. However, more recently, reports of catches of this species have become exceedingly rare and recent fish sampling studies have not been able to confirm the continued presence of this species in the river. At this time the Maryland Wildlife Administration is attempting to restore this fishery.

The fluvial Potomac River is capable of supporting approximately 180 lbs of harvestable size fish per acre (Sanderson, 1958). Game fish and panfish, preferred by anglers, form about 52 percent of the total fish population. So called "rough fish" or less desirable fish species, constitute 48 percent of the population. By weight, however, the popular game fish and panfish constitute only 40 percent of total fish biomass (See Appendix A for data derived from fishery sampling efforts in: 1975, 1976, 1978 and 1980 conducted in coordination with the Potomac Low Flow Study).

3. Aquatic Vegetation

Lowell Keup and Delbert Hicks (1978) sampled rooted aquatic plants from Great Falls upstream to the confluence of the Savage River, a distance of about 220 miles. Investigations also were made of the Monocacy, Antietam, Conococheague, South Branch Potomac, Cacapon and Shenandoah tributaries.

Rooted aquatic plants store nutrients during the spring and summer growing season. In autumn these plants decay and the stored nutrients are released and pass downstream. These nutrients provide only a small part of the total chemical load carried annually by the river. These rooted aquatics seasonally provide for some measure of erosion control as well as cover for fish and wildlife. Some species of plants serve as foods for fish and wildlife, especially waterfowl and muskrats.

During low-flow study data collection conducted in 1978 and 1980, rooted aquatic plants were noticeably sparse within the study reach, with the exception of a profuse stand of water willow, Justicia americana, which covered Seneca Dam. Seneca Dam, a low rubble dam that feeds water to the Chesapeake and Ohio Canal is constructed of rock, gravel and coarse sand. The dam's construction makes it an ideal substrate for this species of rooted aquatic plant. Associated with the rooted aquatic vegetation and this substrate is an abundance of aquatic insects which serve as food organisms for smallmouth bass, channel catfish, and red breasted sunfish. Water willow was the only rooted aquatic plant species observed in the study portion of the river.

4. Microbiota

Microbiota are those living organisms which are too small to be seen individually without magnification. In the natural aquatic environment these consist primarily of phytoplankton, small zooplankton, benthic microbes and bacteria. Other land and air dwelling microbes enter the aquatic environment via eroding sediment, sewerage plant effluent, airborne dust, etc., and survive for a period of time. These organisms provide food for the larger zooplankton and benthic macroinvertebrates, both of which are ultimately eaten by fish.

Phytoplankton appear to be the base of the aquatic food chain in the fluvial Potomac River because turbidity and scouring action of flow tend to severely depress the populations of benthic photosynthetic organisms (i.e. benthic algae, mosses, etc.), zooplankton and the larger rooted vegetation. The major phytoplankton that inhabit the river are coccoid blue green algae, filamentous blue green algae, coccoid green algae, filamentous green algae, green flagellates, other coccoid algae, other pigmented flagellates, centric diatoms, and pennate diatoms (See Tables 3-3, 3-4 and 3-5). Within these groups, the species composition and abundance of phytoplankton generally reflect the concentration of organic and inorganic nutrients in the river water. However, water temperature, light, turbidity and other chemical water quality factors effect species composition and abundance (Weber, Mason and Rasin, 1978). Weber, Mason, and Rasin (1978) studied the phytoplankton at Great Falls and other

	Year									
Genus	58	59	60	61	62	63	64	65	66	67
Coccoid Blue Green Algae										
Anacystis	X	X	X	X	X	X				
Gomphosphaeria		X								
Filamentous Blue Green Algae										
Anabaena	X									
Lyngbya					X					
Oscillatoria	X	X			X	X				
Phormidium		X			X	X				
Raphidiopsis				X	X	X				
Coccoid Green Algae										
Actinastrum				X		X	X		X	X
Ankistrodesmus	X	X	X	X		X	X	X	X	X
Characium		X								
Chlorella (type)	X	X			X	X				
Chlorococcum	X									
Coelastrum				X	X			X		
Cosmarium	X				X		X			
Crucigenia					X				X	
Dictyosphaerum				X		X		X	X	
Golenkinia				X	X			X		
Kirchneriella					X	X	X		X	X
Lagerheimia					X	X	X		X	X
Micractinium				X			X		X	X
Oocystis			X	X	X			X	X	X
Palmellococcus		X	X							
Pediastrum	X						X			
Scenedesmus	X	X	X	X	X	X	X	X	X	X
Schroederia		X			X					
Selenastrum	X									
Staurastrum		X								
Tetradesmus		X		X	X	X				
Treubaria					X					
Filamentous Green Algae										
Mougeotia						X	X			
Green Flagellates										
Chlamydomonas	X	X		X	X	X	X	X	X	X
Euglena	X	X		X	X	X	X	X	X	
Phacus				X			X			
Trachelomonas				X			X		X	
Other Coccoid Algae										
Chrysocapsa					X					
Other Pigmented Flagellates										
Chromulina	X		X		X					
Chrysococcus						X	X	X		X
Dinobryon				X						
Gymnodinium		X								
Peridinium	X					X				
Centric Diatoms										
Cyclotella	X	X	X	X	X	X	X	X	X	X
Melosira	X	X	X	X	X	X	X		X	X
Stephanodiscus	X	X	X	X	X	X	X	X	X	X
Pennate Diatoms										
Achnanthes	X		X	X	X	X	X	X	X	X
Amphipleura						X	X		X	
Amphora		X	X	X	X	X			X	
Anomoeoneis									X	
Asterionella	X			X		X	X		X	X
Bacillaria						X	X			
Caloneis				X	X					
Ceratoneis	X		X				X			
Cocconeis	X	X	X	X	X	X	X	X	X	
Cymatopleura		X	X	X						
Cymbella	X	X	X	X	X	X	X	X	X	X
Denticula			X	X	X					
Diatoma	X	X	X	X	X	X	X	X	X	X
Diploneis			X	X	X	X				
Epithemia			X	X	X	X		X	X	
Eunotia		X	X	X	X	X	X	X	X	
Fragilaria	X	X	X	X	X	X	X	X	X	X
Frustulia		X	X	X	X					
Gomphonema	X	X	X	X	X	X	X	X	X	X
Gyrosigma		X	X	X	X	X	X			
Meridion	X		X	X	X	X	X	X	X	
Navicula	X	X	X	X	X	X	X	X	X	X
Neidium			X	X	X					X
Nitzchia	X	X	X	X	X	X	X	X	X	X
Pinnularia	X	X	X	X	X	X	X		X	
Pleurosigma	X	X			X					
Rhoicosphenia	X	X		X	X		X		X	X
Rhopalodia									X	
Surirella		X	X	X	X	X	X	X	X	
Synedra	X	X	X	X	X	X	X	X	X	X
Tabellaria	X		X	X	X				X	

Table 3-3 Plankton Genera in the Potomac River at Williamsport (Weber, Mason and Rasin, 1978)

Genus	58	59	60	61	62	63	64	65	66	67
					Year					
Coccoid Blue-green Algae										
Agmenellum	X	X	X		X	X			X	
Anacystis	X	X	X	X	X	X	X			
Gomphosphaeria		X	X		X		X			
Filamentous Blue-green Algae										
Anabaena	X					X				
Aphanizomenon						X				
Calothrix		X								
Gleotrichia	X									
Oscillatoria	X	X								
Phormidium	X	X								
Rhaphidiopsis				X	X	X				
Coccoid Green Algae										
Actinastrum	X	X	X	X	X	X	X	X	X	X
Ankistrodesmus	X	X	X	X	X	X	X	X	X	X
Characium		X								
Chlorella (type)	X	X		X	X	X				
Chlorococcum	X			X						
Closteriopsis	X									
Closterium		X	X	X		X				
Coelastrum	X	X	X	X	X	X	X		X	
Cosmarium				X						X
Crucigenia	X	X	X	X	X	X	X		X	
Dictyosphaerium	X	X	X	X	X	X	X	X	X	
Dimorphococcus						X				
Elakatothrix						X				
Gleocystis	X		X						X	
Golenkinia		X			X	X	X	X	X	
Kirchneriella		X	X	X	X	X	X	X	X	X
Lagerheimia		X		X	X	X	X	X	X	X
Micractinium		X	X		X	X	X	X	X	X
Nannochloris					X					
Nephrocytium							X			
Oocystis		X	X	X	X	X	X		X	X
Ophiocytium					X					
Palmellococcus			X		X					
Pediastrum	X	X		X		X	X		X	X
Planktosphaeria					X					
Polyedriopsis						X				
Scenedesmus	X	X	X	X	X	X	X	X	X	X
Schroederia		X		X	X	X				
Selenastrum				X						
Sphaerocystis	X	X			X					
Staurastrum		X								
Tetradesmus		X		X	X	X				
Tetraedon	X		X		X	X			X	X
Tetrastrum		X		X			X		X	
Treubaria				X	X	X	X			
Westella					X					
Filamentous Green Algae										
Spirogyra					X					
Green Flagellates										
Chlamydomonas	X	X	X		X	X	X	X	X	X
Chlorogonium		X			X					
Eudorina							X			
Euglena		X		X	X	X	X		X	
Xephyrion									X	
Pandorina				X		X	X			
Phacotus		X	X	X	X	X	X		X	
Trachelomonas		X	X	X	X	X	X		X	
Other Pigmented Flagellates										
Chromulina			X	X	X	X				
Chrysococcus						X	X		X	
Gymnodinium		X			X					
Mallomonas	X									
Peridinium		X								
Centric Diatoms										
Cyclotella	X	X	X	X	X	X	X	X	X	X
Melosira	X	X	X	X	X	X	X		X	
Stephanodiscus		X	X	X	X	X	X	X	X	X
Pennate Diatoms										
Achnanthes		X	X	X	X	X	X	X	X	X
Amphipleura		X								
Amphora	X	X	X	X		X	X		X	X
Asterionella	X				X			X		X
Bacillaria					X					
Caloneis				X			X	X		
Ceratoneis					X				X	
Cocconeis		X	X	X	X	X	X	X		
Cymatopleura		X	X							
Cymbella	X	X	X	X	X	X	X	X	X	X
Denticula			X							
Diatoma	X	X	X	X	X	X	X		X	X
Diploneis			X	X					X	X
Epithemia		X		X						
Eunotia			X	X	X	X		X	X	
Fragilaria	X	X	X	X	X		X		X	X
Frustulia			X	X	X			X		
Gomphoneis		X			X	X				
Gomphonema	X	X	X	X	X	X	X	X	X	X
Gyrosigma		X	X	X	X	X	X			
Hantzschia				X						
Meridion	X		X	X	X			X	X	X
Navicula	X	X	X	X	X	X	X	X	X	X
Neidium		X		X						
Nitzschia	X	X	X	X	X	X	X	X	X	X
Opephora		X								
Pinnularia	X	X	X	X	X	X	X		X	X
Pleurosigma		X			X					
Rhoicosphenia	X	X	X	X	X	X	X	X	X	X
Rhopalodia				X			X			
Stauroneis		X								
Surirella	X	X	X	X	X			X	X	X
Synedra	X	X	X	X	X	X	X	X	X	X
Tabellaria	X	X	X		X					

Table 3-4 Plankton Genera in the Potomac River at Great Falls (Weber, Mason and Rasin, 1978)

Genus	Year				
	63	64	65	66	67
Coccoid Blue-green Algae					
Agmenellum	X	X	X		
Anacystis		X			
Gomphosphaeria		X			
Filamentous Blue-green Algae					
Oscillatoria	X			X	
Coccoid Green Algae					
Actinastrum	X	X	X	X	X
Ankistrodesmus	X	X	X	X	X
Coelastrum	X		X	X	
Cosmarium			X		X
Crucigenia	X	X	X	X	X
Dictyosphaerium	X	X	X	X	X
Elakatothrix	X		X		
Franceia			X	X	
Golenkinia	X	X	X	X	
Kirchneriella	X	X	X	X	X
Lagerheimia		X	X	X	X
Micractinium	X	X	X	X	X
Nephrocytium		X			
Oocystis	X	X	X	X	X
Pediastrum	X	X	X	X	X
Polyedriopsis				X	
Scenedesmus	X	X	X	X	X
Schroederia					X
Sphaeroscystis			X		
Staurastrum		X		X	
Tetrastrum		X	X	X	
Tetraedron	X	X	X	X	X
Treubaria	X	X		X	
Filamentous Green Algae					
Binuclearia				X	
Mougeotia				X	
Green Flagellates					
Chlamydomonas	X	X	X	X	X
Eudorina		X	X		
Euglena	X	X	X	X	
Pandorina	X	X		X	
Phacus				X	
Pteromonas		X	X	X	
Trachelomonas	X	X		X	
Other Pigmented Flagellates					
Chrysococcus		X	X		
Dinobryon			X		
Kephyrion				X	
Lagynion			X		
Mallomonas	X		X		
Peridinium	X		X		
Centric Diatoms					
Cyclotella	X	X	X	X	X
Melosira	X	X	X	X	X
Stephanodiscus	X	X	X	X	X
Pennate Diatoms					
Achnanthes	X	X	X	X	X
Amphora	X	X	X	X	
Asterionella	X	X	X		
Caloneis				X	
Cocconeis	X	X	X	X	X
Cymbella	X	X	X	X	X
Diatoma	X	X	X	X	X
Epithemia		X			
Eunotia				X	
Fragilaria	X	X	X	X	X
Frustulia		X		X	
Gomphonema		X	X	X	X
Gyrosigma		X		X	
Meridion		X		X	
Navicula	X	X	X	X	X
Nitzschia	X	X	X	X	X
Opephora	X				
Pinnularia	X	X			
Rhoicosphenia				X	X
Stauroneis				X	
Surirella	X	X	X	X	X
Synedra	X	X	X	X	X

Table 3-5 Plankton Genera in the Potomac River at Washington, D.C. (Weber, Mason and Rasin, 1978)

sites on the Potomac. They have concluded that the total counts and taxonomic compositions of the phytoplankton in the river are characteristic of water which contain high concentrations of organic and inorganic nutrients. Changes in the dominant organisms during the period of operation of the National Water Quality Network from 1958-1967 are indicative of increasing concentrations of nutrients. These changes were also observed by Bartsch (1954), and Jaworski (1972).

Bacteria play an important role in waste decomposition within the river ecosystem. They are capable of tolerating a wide range of physical and chemical variability within the aquatic environment.

5. Benthic Macroinvertebrates

Benthic Macroinvertebrates are herein defined as a miscellaneous group of macroscopic animals which do not have backbones and which inhabit the river bottom or substrate during a substantial portion of their life cycles. These animals feed primarily on living microinvertebrates, plants and detritus and in turn are an extremely important element in the food chains of larger fish and wildlife.

Quantitative sampling of benthic macroinvertebrates at nine individual one-square-foot sites across each of three riffle areas sampled on the Potomac River at Seneca, Carderock and Little Falls, showed these areas to be highly productive and diverse habitats for these organisms. Aquatic insects are the dominant benthic macroinvertebrates representing 81 of the 95 different types of organisms collected and 93 percent of the total number of organisms. The non-insect benthic macroinvertebrates are for the most part molluscs including clams and snails and representing 7 taxa and 6.2 percent of total numbers. The remaining non-insect forms included flatworms, leeches, amphipods, isopods and aquatic earthworms comprising 8 taxa and 0.8 percent of total numbers.

Caddisflies are the dominant riffle inhabitants constituting about 60 percent of total organisms. Dipterans ranked second, mayflies third and aquatic beetles fourth. The molluscs ranked fifth with clams and snails about equally represented. Ubiquitous organisms found at all 27 riffle transect sites were the caddisflies, Hydropsyche phalerata and macronema sp. and the larval aquatic moth, Parargyractis fulicalis.

In terms of total numbers, number of genera, and diversity indices at individual one square foot sampling sites, a few sites showed slight stress while the majority appeared normal. This indicates good to excellent stream quality. Combining sites into three square-foot composites suggested an excellent stream quality with some enrichment indicated. The number of taxa at all sample locations remained relatively constant with most of the differences involving rarer forms.

There was some variability in total numbers of organisms across and down the river. At the Seneca transect minimal numbers occurred on the Maryland side whereas the reverse was true at the Little Falls transect, with maximum and relatively uniform numbers occurring across the Carderock transect. The Virginia side showed a downriver decline in total numbers while at mid-river and on the Maryland side numbers increased from Seneca to Carderock and then decreased at the Little Falls transect. Most of these differences can be accounted for by reductions in the dominant caddisflies and dipterans, and it is difficult to determine the significance of these reductions (30 to 40 percent) due to the possible effects of emergence, competition and predation along with the vagaries of sampling small portions of an extremely large habitat.

Two exotic molluscs, the Asiatic clam, Corbicula fluminea and the faucet snail, Bithynia tentaculata appear to be well established in the study portion of the Potomac.

Qualitative sampling in shallow and deep pool areas, and in water willow stands, generally showed a much less diverse and abundant benthic macroinvertebrate fauna with forms more tolerant of siltation and enrichment. The water willow (Justicia americana) habitat appeared to be the more diverse of these qualitative sample sites.

There was no quantitative benthic macroinvertebrate data collected in similar large riffle areas of the Potomac with which to compare present findings. Prior routine monitoring work was done with artificial substrate samplers placed closer to shore in the quieter, slow-moving waters, reflective of the less diverse conditions of the pool areas. Similar macroinvertebrate communities in terms of number and diversity have previously been found in riffle areas sampled near the mouth of Conococheague Creek and the Monocacy River.

A complete test of "Potomac River Low Flow Study Benthic Macroinvertebrate Findings" is presented in Appendix B (See Figure 3-13 for maps of the Benthic Macroinvertebrate sampling sites).

D. Chemical

"Despite its reputation, the fluvial Potomac and its freshwater streams are among the cleanest of those in America's major river basins. Some pollution from small municipalities -- all are relatively small except those in the Metropolitan Washington Area -- remains to be corrected. Most of the relatively few major industries are in compliance with or on schedule to meet, effluent and water quality requirements" (Interstate Commission on the Potomac River Basin, 1978).

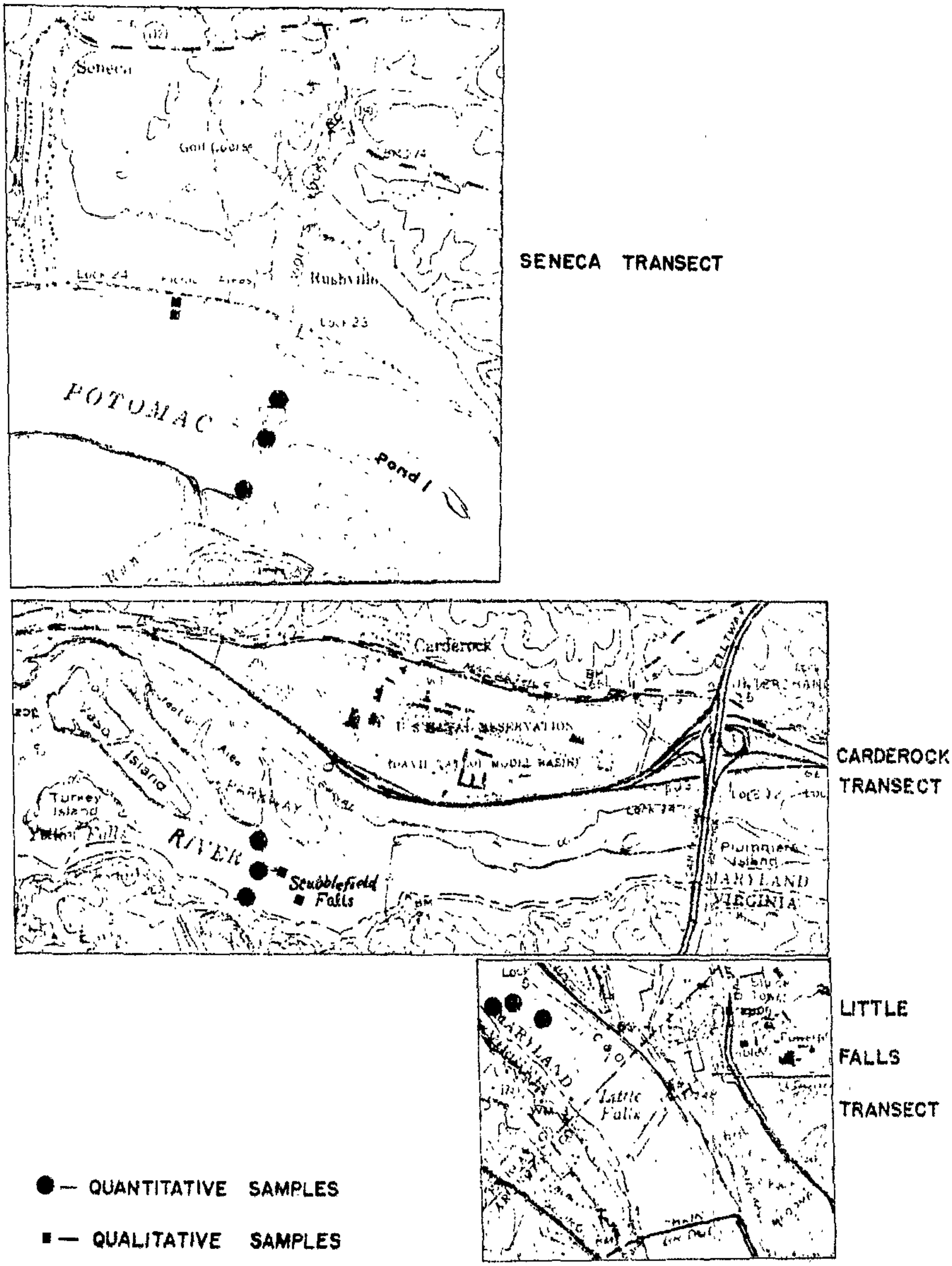


Figure 3-13 Benthic Macroinvertebrate Sample Sites

Documented at the symposium was the status of fish and other inhabitants of the aquatic communities of the fluvial river which have responded to the improved and generally adequate water quality for aquatic life that occurs as a result of environmental quality control efforts within the river basin.

The Interstate Commission on the Potomac River Basin summarized the Potomac River basin water quality status and prepared a trend assessment for the years 1962-1973 (ICPRB, 1975). The ICPRB concluded that during the period 1962-1973 the mainstream from 10 miles below Cumberland to Great Falls (150 river miles) was generally of good quality and supported recreation and aquatic life. In the 20 mile free flowing reach of the river from Great Falls to the estuary it was reported that increasing nutrient levels, oxygen demanding wastes, and silt and bacteria were present. A "Water Quality Status and Trend By Station" analysis for the lower fluvial portion of the river and some of its major tributaries, which appeared in Potomac River Basin Water Quality 1978-79 (Interstate Commission on the Potomac River Basin, 1980) is presented in Table 3-6.

Erosion at construction sites within the river basin also adds to the heavy sediment load carried annually by the Potomac River. The U.S. Geological Survey reported that in 1979 approximately 2.03 million tons of sediment was carried by the river past Point of Rocks upstream of the study area. Heavy sediment loading by itself may limit the biologic productivity of desirable aquatic life, adversely effect recreational use of the river and add to the cost of water purification at the downstream public water supply intakes.

The following brief summary description of the important water quality parameters of the reach of the Potomac between Harpers Ferry and Chain Bridge (Washington D.C.) is quoted from the Metropolitan Washington Water Quality Management Plan published by the Metropolitan Washington Council of Governments (1978) (COG). Figures 3-14 through 3-23, are also adapted from the COG plan. The figures graphically demonstrate the effects of low vs. high flows on chemical constituents at various sampling stations within the study area.

Dissolved Oxygen

Samplings indicated excellent conditions during both the 1972 high flow and the 1976 low flow years. Values for average daily dissolved oxygen rarely dropped below 7 mg/l, and uniformly met state standards of 4.0 mg/l minimum and 5.0 mg/l.

BOD_5

Summer BOD_5 values averaged approximately 3 mg/l and winter values averaged approximately 1.5 mg/l. Both of these values were well under the 5 mg/l level generally viewed as indicating polluted waters.

Table 3-6

Water Quality Status and Trend by Station (1978-1979)*

<u>Seneca Creek at River Road</u>

Status: Fair-Good Water Quality
Limiter: Bacteria, NO_3, pH
Source: Runoff
Trend: Not discernible

<u>Cabin John Creek at Macarthur Blvd.</u>

Status: Fair-Good Water Quality
Limiter: Bacteria, NO_3
Source: Runoff
Trend: Improving

<u>Potomac River at Little Falls Dam, MD</u>

Status: Fair Water Quality (<u>Poor at low flows</u>)
Limiter: Bacteria, NO_3
Source: Municipal Wastewater, Urban and Ag. runoff, water treatment plant wastes
Trend: Not discernible

<u>Potomac River at Fletcher's Boat House</u>

Status: Fair-Good Water Quality
Limiter: Bacteria
Source: Delapidated Sanitary Sewer, Runoff

<u>Rock Creek at Virginia Avenue</u>

Status: Fair-Poor Water Quality
Limiter: Bacteria, Sediment
Source: Runoff, Combined Sewer Systems
Trend: Not descernible

*Potomac River Basin Water Quality 1978-79 (Interstate Commission on the Potomac River Basin, 1980)

Figure 3-14

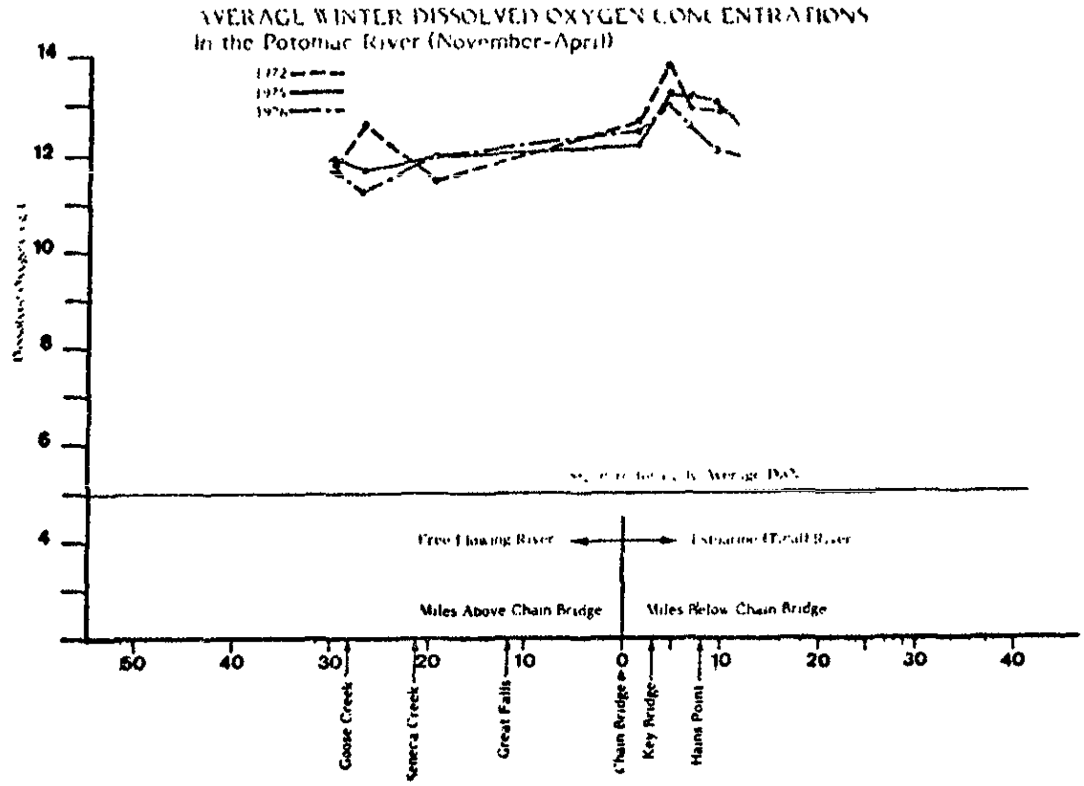


Figure 3-15

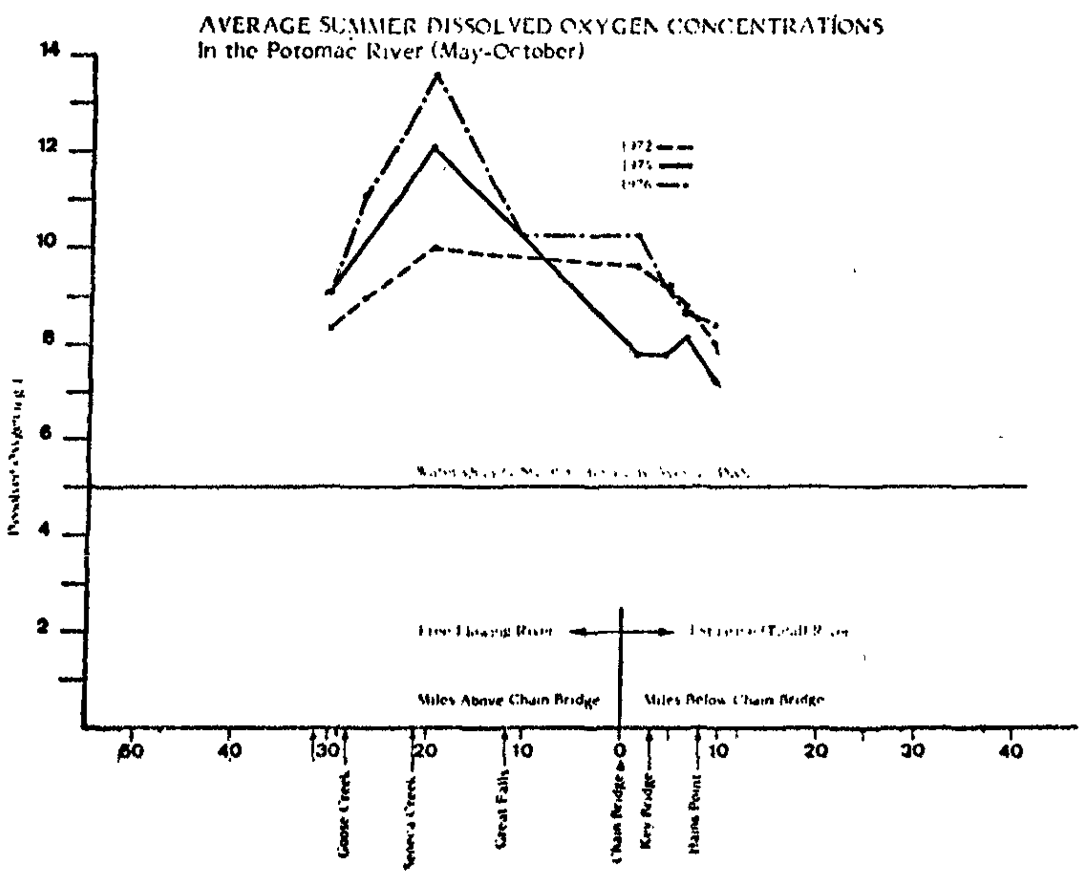


Figure 3-16

1977 LOW FLOW DISSOLVED OXYGEN CONCENTRATIONS
In the Potomac River (June - November)

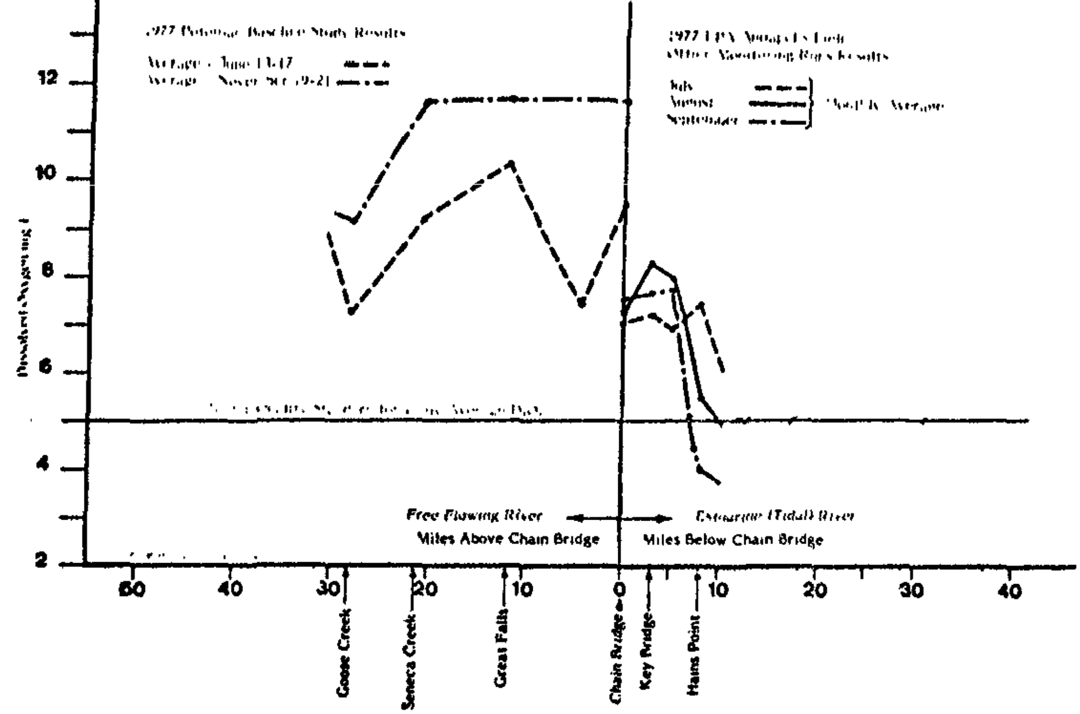


Figure 3-17

1972 HIGH FLOW SUMMER DISSOLVED OXYGEN (May - October)

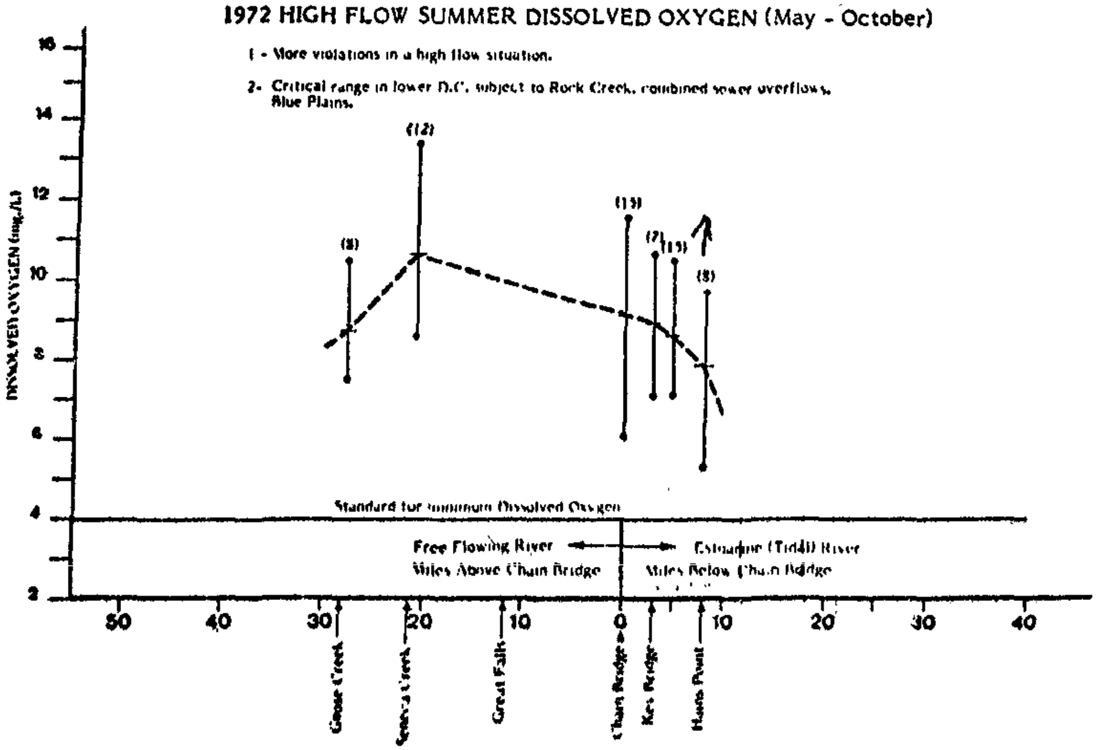


Figure 3-18

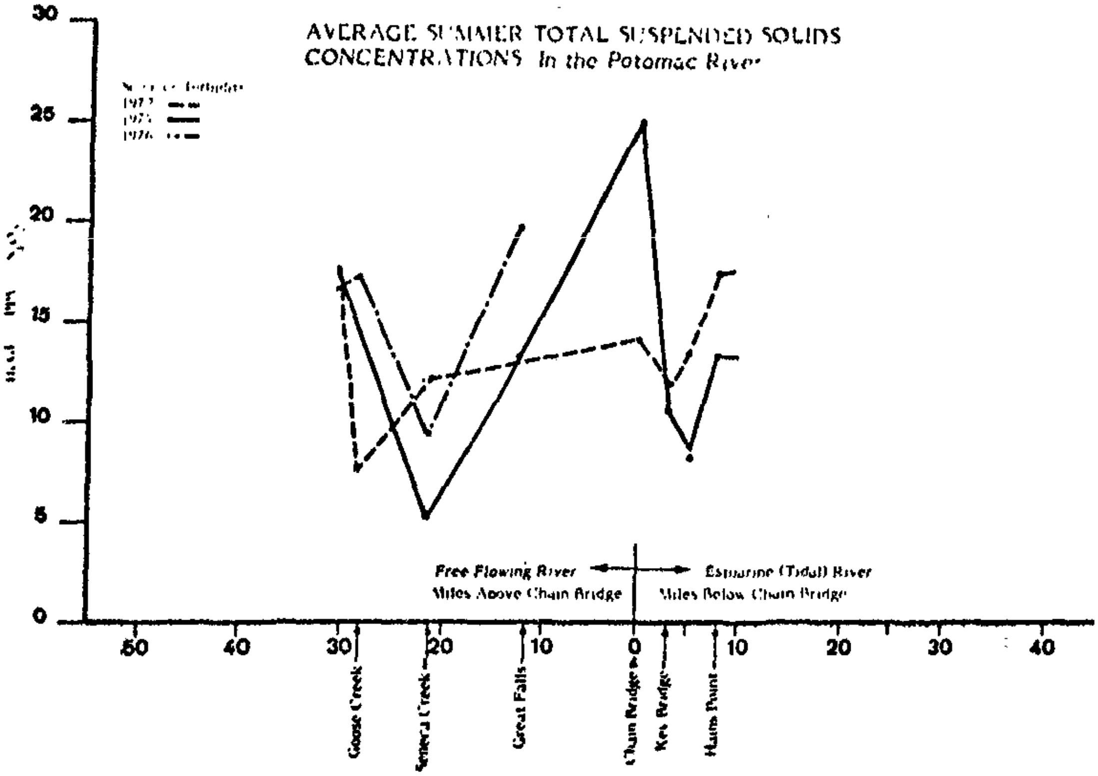


Figure 3-19

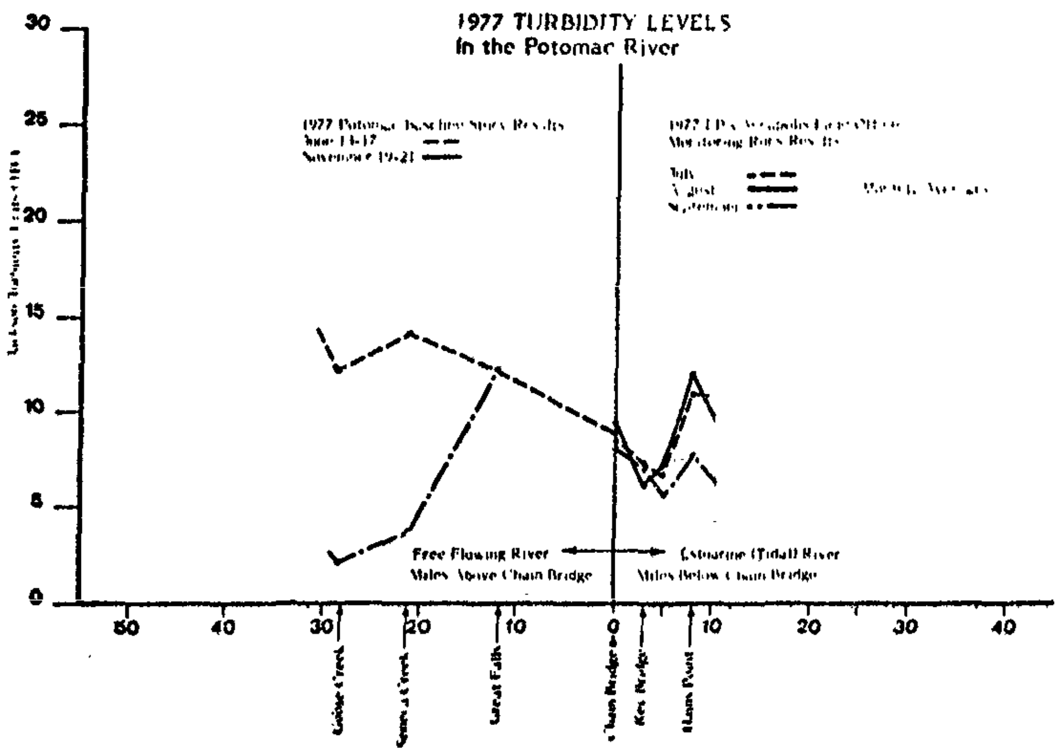


Figure 3-20

AVERAGE SUMMER TEMPERATURES
In the Potomac River (June-November)

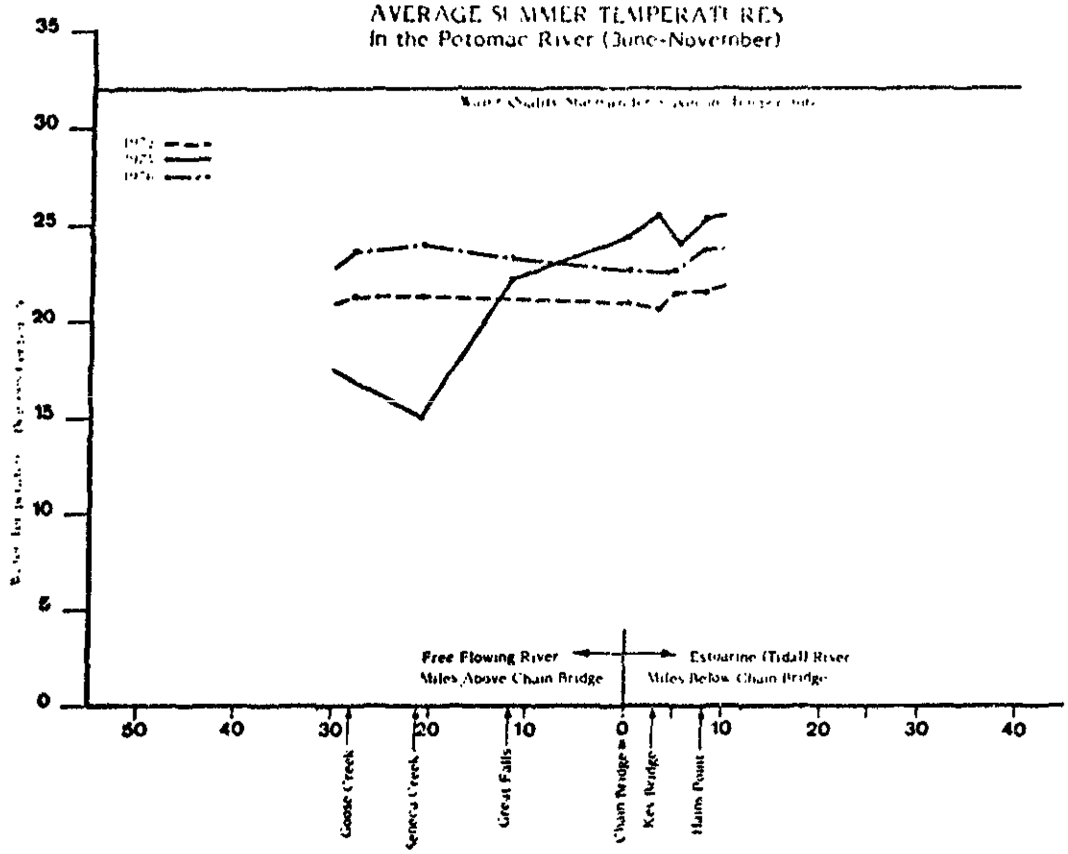


Figure 3-21

SUMMER BOD_5
In the Potomac River (June-November)

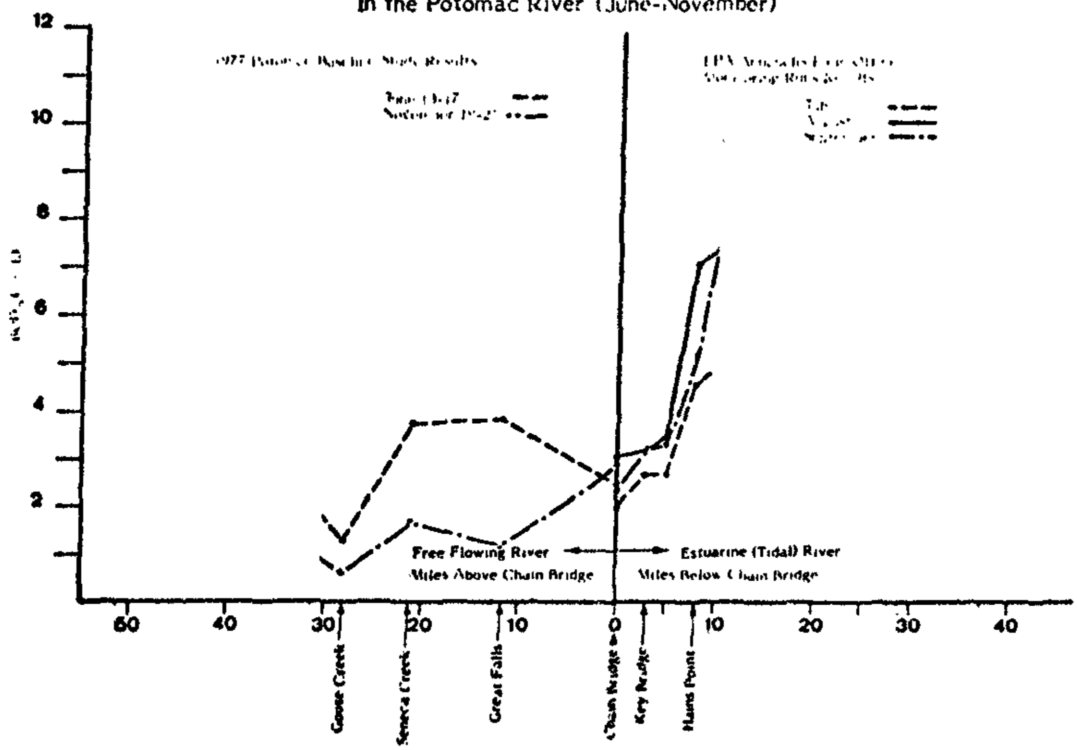


Figure 3-22

AVERAGE SUMMER pH LEVELS
In the Potomac River

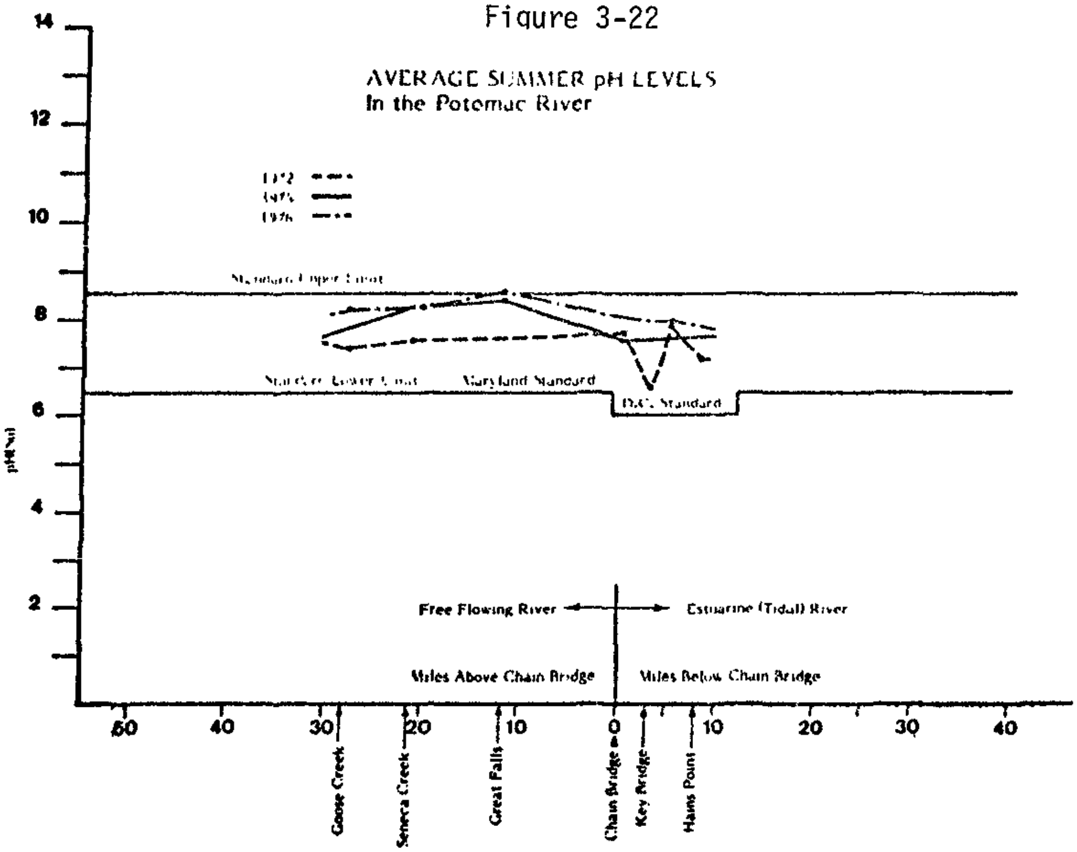
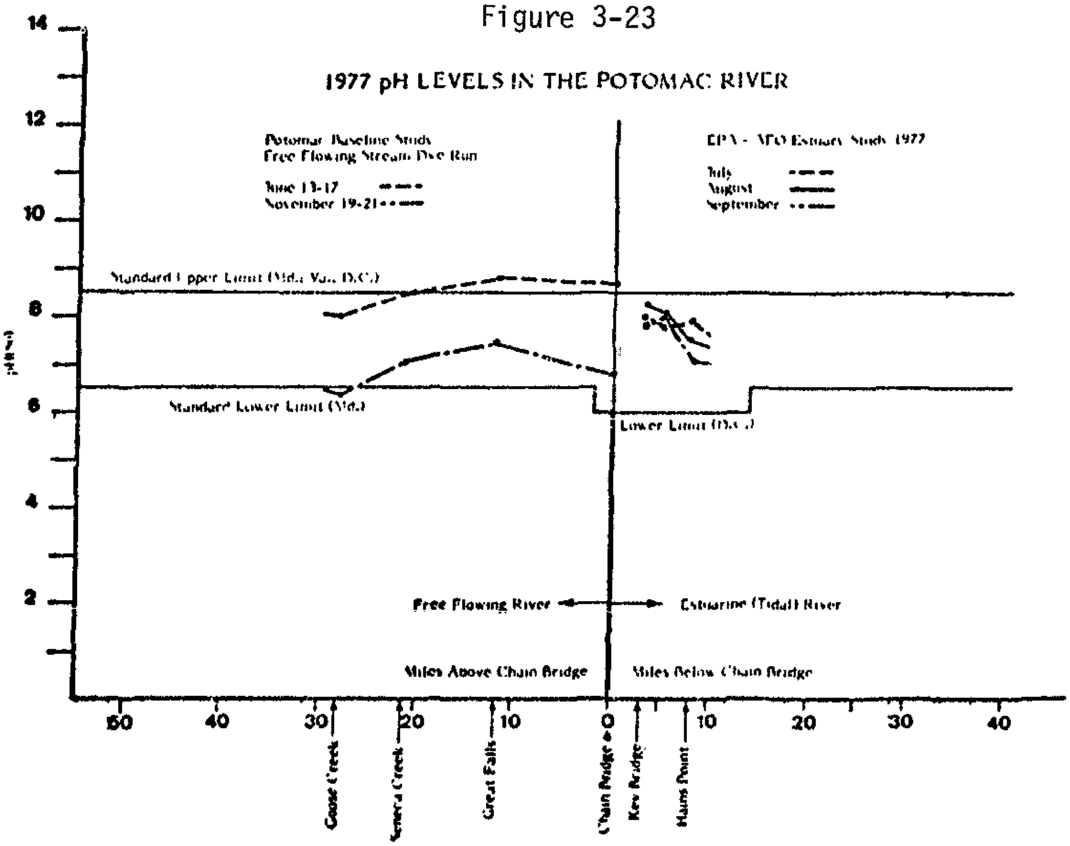


Figure 3-23

1977 pH LEVELS IN THE POTOMAC RIVER



pH

pH concentrations generally stayed within the 6.0-8.5 range established by Virginia and Maryland for general aquatic life and wildlife. During 1976 and 1977 samplings, the standards were exceeded in the section between Seneca Creek and Chain Bridge, indicating alkaline conditions above 8.5 mg/l.

Temperature

The 90° F maximum state standard for general aquatic life and wildlife was not exceeded.

Suspended Solids

In 1974 average concentrations of suspended silicon-dioxide ranged from a low of 5 ppm at Seneca Creek in 1974 to a high of 26 ppm at Chain Bridge. Accordingly, water conditions appear to have met 1972 NAS/NAE criterion for total suspended solids, which estimated that aquatic communities would receive a high level of protection if maximum concentrations of suspended solids did not exceed 25 mg/l and a moderate level of protection at 80 mg/l (National Academy of Sciences, 1972).

Consideration of average suspended solids or turbidity conditions falls short of being an accurate reflection of water quality conditions for every instant of time. For example, most sampling programs are of the grab sample type collected when it is not raining, and average data will probably reflect conditions during dry weather flows. By contrast the free flowing Potomac River near Washington is subject to large, "flashy" increases in total suspended solids, especially during and after summer thunder showers and when spring rain follows the freezing and thawing of winter ground. It has been estimated that the Potomac River near Point of Rocks, Maryland transports 70 percent of its annual sediment load in 10 days of each year (McCaw and Grambell, 1977). During those periods, maximum concentrations of suspended solids probably exceed average conditions many times over.

E. Recreational Uses

From Seneca Pool to Little Falls, the Potomac River is the setting for many forms of water-related recreation. The most popular of these are fishing, aesthetic viewing and boating. Recreational activities that occur along this section of the river are discussed below. Each activity is described in relation to the areas where it occurs, the principal season of its occurrence and its general level of use (as described by Maryland Department of Natural Resources, 1979).

low - means that the recreational activity occurs to only a light extent in this river section and that there are no problems of congestion or conflicts among the participants of that particular activity resulting from the number of participants engaged in that activity.

medium - means that the recreational activity occurs to a moderate extent in this river section but that there are few if any problems of congestion or conflicts amongst the participants of that particular activity resulting from the number of participants engaged in the activity.

high - means that the recreational activity occurs at a heavy level in this river section and that problems of congestion or conflicts amongst the participants of that particular activity resulting from the number of participants engaged in that activity do, at times, occur.

Fishing: Bank fishing and small boat fishing are among the most popular forms of recreation on the river. Both take place year-round, but are less popular during the winter. Bank fishing occurs at high levels throughout the stretch from Seneca Pool to Little Falls, although concentrations generally take place at those places offering parking and access. In contrast, small boat fishing occurs at lower levels because of lack of access to navigable portions of the river. The only area where there is a high concentration of small boat fishing is Seneca Pool. The principal sport fish are smallmouth bass, largemouth bass, sucker, catfish, and sunfish, (Maryland Department of Natural Resources, 1979).

Canoeing: Both white water canoeing and flat water canoeing occur at high levels on a year-round basis, although they are less popular during winter. The most popular white water stretches are from Dam 2 at Violets Lock to Watkins Island and from Great Falls to Little Falls. Most canoeists make single day trips, but others prefer to extend the trip by camping along the river.

Since 1970, instruction in white water boating and water safety has been available on the Potomac River. The area around Angler's Inn, near Cropley, is a popular instruction site because of its variety of water types that range from slow moving deep pools to faster runs and rapids.

Flat water canoeing is popular in Seneca Pool and in the C & O Canal, but there are a few suitable stretches between Dam 2 at Violets Lock and Little Falls. Roundtrip circuits are possible for those who endeavor both white water and flat water canoeing. Roundtrips are accomplished by a combination of white water and flat water canoeing downstream in the river and returning in the canal. The number of canoeists has doubled in the last ten years. There are several large canoeing associations in the area (Department of Natural Resources, 1979).

Kayaking: Kayaking occurs at somewhat lower levels than canoeing, from Seneca Pool to Little Falls, but does take place at many of the same locations. It occurs year-round with less popularity during the winter (Department of Natural Resources, 1979).

Hunting: Hunting, allowed only in certain restricted areas along the River, occurs at high levels during the Fall. It is prohibited within the boundaries of the C & O Canal Park and at the Dierssen Waterfowl Sanctuary, but is a major activity at McKee - Beshers Wildlife Management Area and is also allowed directly in the river (Department of Natural Resources, 1979).

Aesthetic Viewing: There are several types of aesthetic viewing along the Potomac, all of which occur at high rates all year-round. Some major areas of interest are history, geology, nature study and bird watching. The study portion of the Potomac River is one of the most scenic areas in the Washington Metropolitan region.

Swimming: Swimming occurs at high levels in Seneca Pool. Downstream from Seneca, swimming may be good in places, but is generally dangerous and occurs at much lower levels of use. Summer is the principal use season (Department of Natural Resources, 1979).

High Speed Power Boating and Water Skiing: Both of these occur at high levels in Seneca Pool from late spring, through early fall (Department of Natural Resources, 1979).

F. Chesapeake and Ohio Canal Uses

The Chesapeake and Ohio Canal stretches 184.5 miles along the Potomac River from Cumberland to Washington D.C. This relic has been out of commercial use since 1924, but it is now preserved in the 20,239 acre Chesapeake and Ohio National Historical Park under the custody of the National Park Service. The lower 23 miles of the park are administered by the National Capital Parks System (Parsons, 1976). Most of this lower portion boarders the "study" stretch of the Potomac River from Seneca Pool to Little Falls.

The major park resources are the physical remains of the C & O Canal including its bed, tow path, aqueducts, culverts, locks, lock houses and other associated structures. The park has been divided into five types of land use zones. The three that are described below (Parsons, 1976) occur in the stretch from Seneca Pool to Little Falls.

Zone A: National Interpretive Zone

A designated Interpretive Zone defines areas containing major historic restoration opportunities where the park visitor is able to see a functioning canal in a historic setting. Interpretive areas are easily accessable and have available park land for development of visitor facilities. Visitor centers are expected to support large density, short term (1-2 hours) visitor use. Each of these areas represents a different setting and therefore a different theme.

Area	Setting	Length
Seneca	Industrial stone quarrying and Seneca Aqueduct	1.6 miles
Great Falls	Rural with a tavern and 6 locks	4.2 miles

Zone B: Cultural Interpretive Zone

Cultural zones define areas that contain historic resources but cannot support high density visitor use. The historic resources may spread along the canal, producing longer term visitation than Zone A (estimate 1-3 hours). Cultural zones are not necessarily completely restored for the main objective of these areas is tow path use.

Area	Length
Lock 8 to Anglers Inn	4.0 miles

Zone C: Short Term Recreational

Short Term Recreational sections are designed for the general tow path user seeking a leisurely stroll of 2 to 6 hours in a natural setting. Zone C areas are limited in historic resources and available land for visitor facilities. The sections are usually short and often link two zones of higher density. The objective is to ensure a leisurely recreational experience in a natural setting.

Area	Length
Swains Lock to Violet's Lock	5.6 miles
Alexandria Aqueduct to Lock 8	7.2 miles

Due to the narrow boundaries of the park, most facilities and activities are located on or near the canal. The major recreational activities are canoeing and fishing on the canal, use of tow path and aesthetic viewing.

In 1980, about three million people visited the portion of the park covered by this report. It is estimated that 80% of the visitors used the tow path (McMann, 1981). The tow path is primarily used for activities such as, hiking, biking, walking, horseback riding, jogging, cross country ski lessons, nature and history study and aesthetic viewing.

The portion of the C & O Canal between Violets Lock and Georgetown was rewatered in the late 1930's and since then has served as a major recreational resource. Several forms of water recreation, such as canoeing, fishing and Canal clipper rides have become popular in recent years. Each of these activities will be described below.

Fishing: Bank fishing is popular all year-round, except when the canal is frozen. Concentrations usually occur at places offering parking and access. It is estimated that about 10,000 fishermen use the canal each year (McMann, 1981).

Canoeing: Flat water canoeing has become a major activity on the canal all year round, but is restricted during the winter when the water in the canal is frozen. Users include both canoe clubs and individual canoeists. In 1980, about 7,500 people participated in canoe classes that were offered by the Canoe Cruisers Association (McMann, 1981). The total number of canoeists using the canal each year is estimated to be 20,000 (McMann, 1981).

Canal Clipper Rides: During late spring, summer and early fall, Canal Clipper rides are offered on the canal in the vicinity of Great Falls. In 1980, about 20,700 people rode the Canal Clipper (McMann, 1981).

The park has been designed and developed such that many forms of aesthetic viewing are possible. Zone A areas are especially popular with those who are interested in history, whereas Zone C areas are more conducive to bird watching and nature study.

The amount of time visitors spend in the park ranges from a few hours to a few days. Most of the short term users live near the park and use it frequently. Long term users are those who spend at least one night at either the group campground or the hiker-biker site. Group camping, especially Boy Scouts, constitute the bulk of the long term users. During 1980, about 7,400 people participated in group caming at the park (McMann, 1981).

Other facilities that are offered to the visitor include; parking facilities, picnic sites, canoe rentals, boat ramps and access to the Potomac River.

CHAPTER IV

STUDY DESIGN AND PROCEDURES

IV. Study Design and Procedures

A. Primary data collection and Transect Descriptions

The methodology employed in the Potomac River Low Flow Study consists of three major components.

1. Collection of data - Including measurements of depth, velocity, substrate type, water quality, biology, aesthetic factors, benthic macroinvertebrates, and recreational use at selected locations in the study portion of the river (See Appendix B for detailed discussion benthic data collection methodology and results).

2. Utilization of the Instream Flow Group (IFG) Computer Model - The IFG model was used to manipulate field data for analysis of physical habitat changes that result from various increments of low river flow.

3. Aggregation and analysis of data - Historical flow data was combined with output from the IFG Model and aesthetic and recreational use data. Relationships were developed between physical, chemical, biological and recreational resources.

The initial design of the low flow study was developed by an interagency task force led by the Maryland Department of Natural Resources which incorporated multidisciplinary perspectives and view points. The plan was to collect as much empirical data as was needed to formulate conclusions on environmental impacts of low flows, and to supplement this data with more subjective evaluations from experts on fisheries, biology, recreation, etc. Data collection for the U.S. Fish & Wildlife Service's Instream Flow Group (IFG) model was considered a top priority and planning was conducted to determine the kind of data needed and how it could be obtained.

After field reconnaissance of the river and study of topographic maps, the task force concluded that four sets of transects would be adequate for the Instream Flow model. In 1978, with the aid of the United States Geological Survey, eight specific transect locations were established and permanently marked. Initial data collection began in the summer of 1978. At that time river flow was approximately 2000 cfs (1292 mgd) and was selected as a medium flow for the model. Lower flows did not occur in 1979 so no data was taken. In 1980 flow dropped to about 1,300 cfs (840 mgd) and data was collected at all transects. A transect at Seneca Breaks was deleted in 1980 due to its complex hydraulic nature and was replaced by two riffle transects (6 & 7) below Carderock. Two backwater transects (2 & 3) were also added in 1980 to better understand how these valuable fisheries habitat change in relation to discharge. In the fall of 1980, high flow data was obtained for the model. Discharge was approximately 3500 cfs (2261 mgd). Ideally the three flows needed for the IFG methodology should be an order of magnitude apart or at least 3 to 4 times apart. The difficulty in measuring ideal flows in the Potomac is that above 4000 cfs (2584 mgd) working in the river becomes increasingly dangerous. The chance of a low flow (>1000 cfs) is remote. The methodology does allow estimations of fisheries habitat at discharges 60 percent below the lowest measured flow.

Within the study area, from Seneca Pool to Little Falls, twelve transect sites were chosen as being representative of habitat and hydrology and for having easy access. Each site is described in detail below. The location and cross section of each transect are indicated in figures 4-1 and 4-2.

Transect 1: Transect 1 is located in Seneca Pool, about halfway between the mouth of Seneca Creek and Seneca Dam. There are three large pool areas and many small pools between Seneca and Little Falls. Assuming that all pools are similar biologically and hydrologically, Seneca Pool was chosen as a representative transect site because it is easily accessable. Data was collected at both medium and high flows.

Transects 2 and 3: Transect 2 is located between Sherwin Island and the Maryland Shore and Transect 3 is located in a small inlet of the Virginia Shore. Both transects are representative of backwater areas that are important nursery habitat for larval and juvenile fish. Currents are usually imperceptable and the water only flows when the river is at flood stage, consequently data was taken at medium and high river flows only. These transects were "attached" to transect 4 for computer analysis since they are all in the same vicinity.

Transect 4: Transect 4 is located between Sherwin Island and the Virginia Shore. It is representative of Mather Gorge, the only gorge in the study portion of the river. Velocities are high which reduces the value of habitat for many fish. Data was taken at low, medium and high flows.

Transect 5: Transect 5 is located just upstream from Offutt Island and is representative of a deep riffle. It is a very diverse and productive habitat that is typical of the Potomac River. Riffles are easily dewatered and therefore, may be adversely impacted by low river flows. Data was taken at high; medium and low flows.

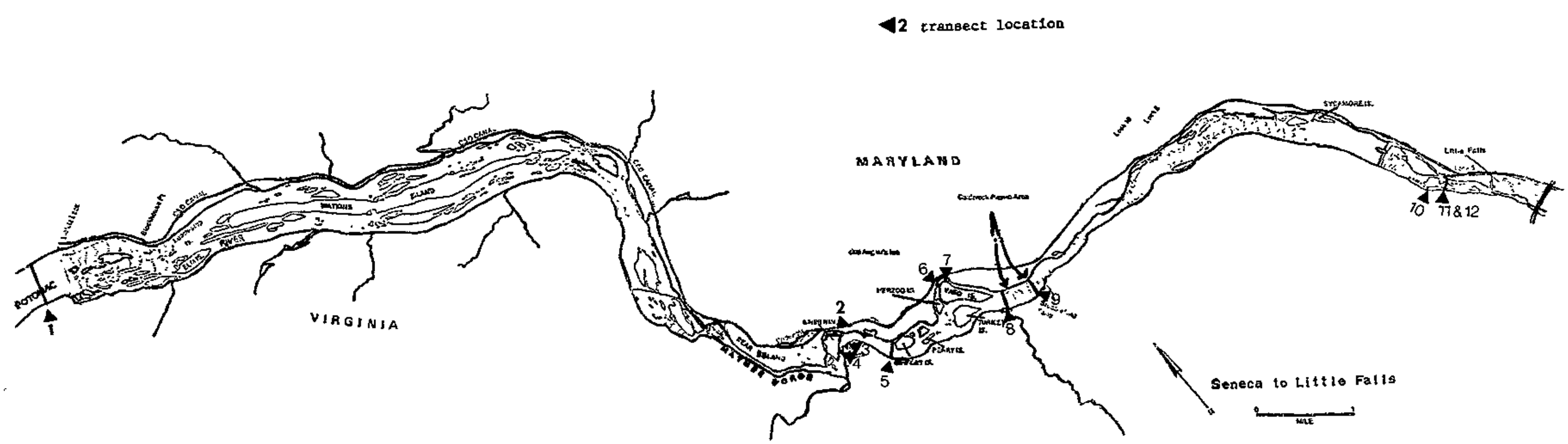


Figure 4-1 Transect Locations (adapted from Thompson, 1974)

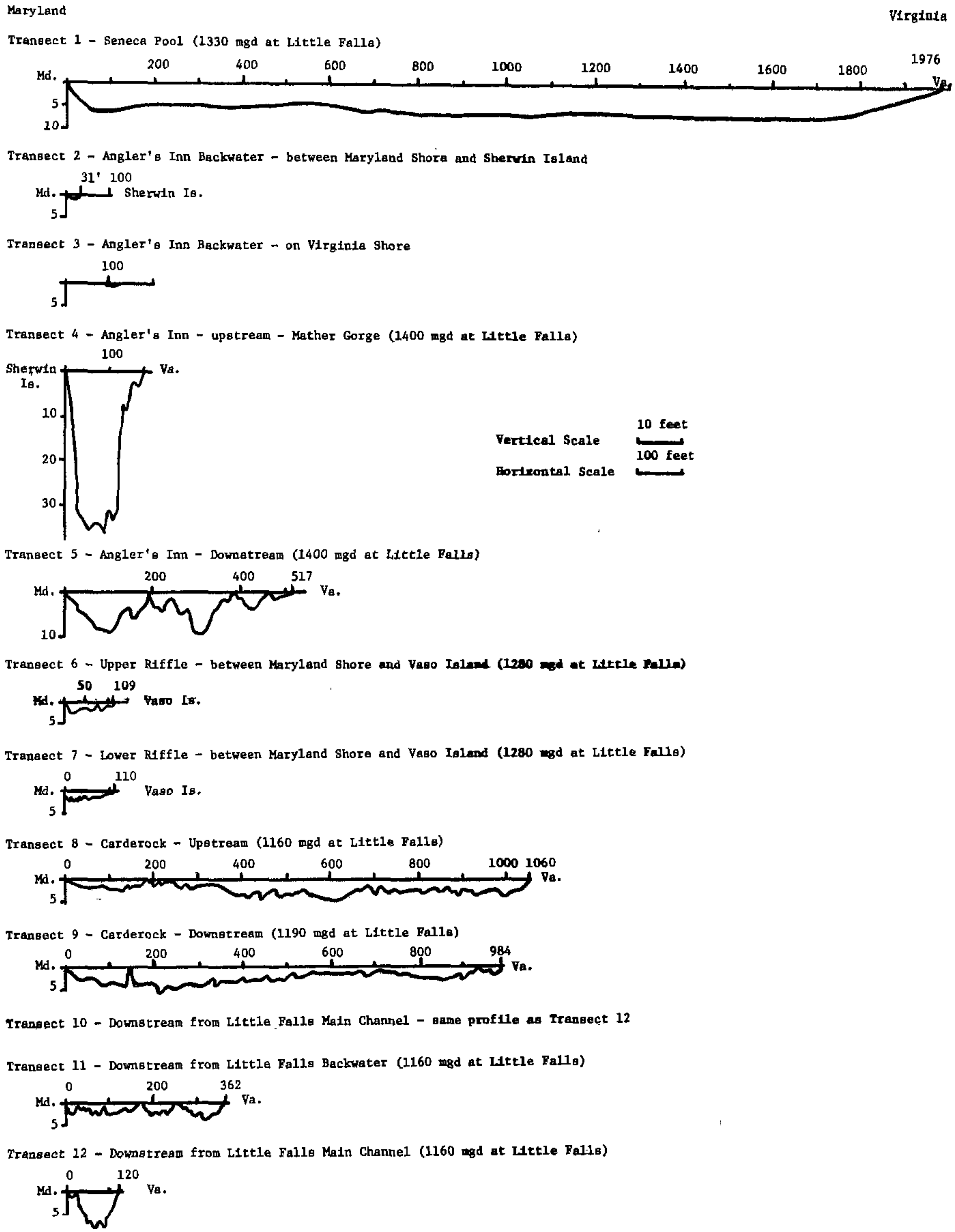


Figure 4-2 Cross Sections of Transects - River Profiles at Medium Flow

Transects 6 and 7: Transects 6 and 7 are located between Vaso Island and the Maryland Shore and both are representative of riffle areas. Transect 7 is downstream from transect 6. As in transect 5, they are important, easily impacted fish habitats. Data was taken at low, medium and high flows.

Transects 8 and 9: Transects 8 and 9 are located at Carderock and are representative of one of the most diverse habitats on the river. A combination of pools, runs and riffles, offers quiet water areas for resting and areas with current for feeding. Data was taken at low, medium and high flows.

Transect 10: Transect 10 is located about ½ mile downstream from Little Falls Dam in the main channel which flows on the Virgina side of the river bed. The channel is about 10 feet deep and velocities are too high to be good fisheries habitat for most species. Data was taken at low and high flows.

Transects 11 and 12: Transects 11 and 12 actually constitute a single transect that crosses two distinctly different habitats. They are located about 1/10 mile downstream from transect 10. Transect 11 passes through a flowing backwater along the Maryland shore and transect 12, like transect 10, is in the main channel along the Virginia Shore. Data was taken at low, medium and high flows. Table 4-1 summarizes transect description.

Transect sites were surveyed for water surface elevation, and velocity and depth measurements were taken at selected intervals. Water quality measurements, including dissolved oxygen, and temperature were obtained at selected locations during summer stress conditions of low flow and high temperature. Fish sampling was conducted using electrofishing, seining, gill netting and trapping techniques. Grabs for invertebrate organisms were taken with a surber sampler.

B. Data Analysis Procedures[1]

The major analytical tool used in this study was the U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (also refered to as the IFG model).

The first step in using the IFG model was to select one of two different hydraulic simulation sub-models; either the stage backwater (IFG4) or the water surface profile (IFG2).

---

[1]Section written by: Steven Goodbred, U.S. Fish and Wildlife Service Annapolis, Maryland.

Each sub-model has certain advantages. IFG4 requires much less calibration, is easier to use, is not as sensitive to field measurement errors and does not need to include all hydraulic control points, whereas IFG2 has none of the preceding advantages but requires considerably less data collection. Because of its greater flexibility and ease of use, the IFG4 sub-model was selected for use in the study.

Data for the hydraulic sub-model was collected at selected transects in representative habitats within the study reach of the river. Along each transect selected intervals were chosen to take hydraulic measurements. These measurements consisted of both depth and velocity readings. Where depths were greater than 2.6 feet velocities were taken at 0.2 and 0.8 of the depth.

The next major step was to use this field collected hydraulic data to calibrate the chosen hydraulic sub-model. This was accomplished in the following manner.

Initially, raw data from field notes was organized into a computer compatable format. A computer program was written locally to transform raw data from flow meter readings (expressed as revolutions per second) into velocity readings (feet per second). An average velocity was computed at each hydraulic measurement station for which more than one velocity measurement was taken per sampling.

Velocities at low, medium and high flow stages for each station were then compared. If it was apparent that a regression of velocities versus flow would be negative (predicted velocities decrease as flow increases), then that station was omitted. Also, if any apparent discrepancies existed in the water surface elevation between different flows they were calculated by taking the average of the depths and subtracting that from 100. Depth readings were subtracted from water surface elevations to obtain bottom elevations for each station.

Horizontal distances between stations at each transect were not measured in a consistent manner from year to year. These distances were measured from two different datum points, one being the waters edge and the other being the vertical (elevation) control point on the river bank. To obtain data that was consistent, all horizontal measurements were corrected to read from the vertical control points. All stations were then displayed on a computer printout and realigned so that for each transect there were an equal number of stations, at all three flow stages. Then corresponding stations were averaged to obtain an average station number.

In order to compute discharge each transect was compartmentalized into cells. These cells consisted of an area, ½ the distance from a station to both adjacent stations times the depth at that station. A discharge for each cell was then computed by multiplying cell area by velocity. These were then summed up to obtain a total discharge at each transect for each flow. The computed discharge (Dc) was then compared to the actual discharge (Da) based on the USGS Little Falls gauging station. Actual discharges were corrected to reflect any municipal withdrawals which affect flow past a transect. A ratio was obtained, Da/Dc=R, which was then used to multiply actual velocities (Va) to produce a calibration velocity (Vc), R(Va)=Vc. These new velocities were then used to recompute the discharge. Once the computed and actual discharges were similar, the data was formated according to the IFG4 program and processed through a Boeing Corporation computer in Seattle, Washington.

When the hydraulic model was calibrated and results from the desired range of flows was determined, fish electivity curves for pertinent representative species and life stages were processed with the hydraulic output. This program (HABTAT) printed out the area of weighted useable habitat per 1000 ft of stream for each transect, species and life stage, over the desired range of flows. This data was the final output used to evaluate impacts from various low flows.

Table 4-1 Transect Description Summary

Transect Number	Location	Type of Habitat Represented	Flows Where Data was Collected			Comments
			Low	Medium	High	
1	Seneca Pool (halfway between mouth of Seneca Creek and rubble dam)	Pool		x	x	Rubble dam at Seneca Breaks is a hydrologic control point; few intakes above Seneca Pool; one of the areas least impacted by low flows.
2	Between Sherwin Island and Md. Shore - near Angler's Inn	Backwater (nursery habitat)		x	x	Biologically important to larval & juvenile fish; low velocities and imperceptible currents; water flows at flood stage.
3	In backwater on Va. Shore - near Angler's Inn	"		x	x	"
4	Between Sherwin Island and Va. Shore	Gorge or Run	x	x	x	Not a productive fishery, because velocities are too high.
5	Upstream side of Offutt Island	Multiple Island Deep Riffle	x	x	x	Very productive & diverse fishery, most typical habitat; easily dewatered area.
6	Between Vaso Island and Md. Shore	Riffle	x	x		Important fish habitat (feeding area); easily dewatered.
7	Between Vaso Island and Md. Shore, downstream from #6)	Riffle	x	x		"
8	Carderock Scott Run Falls	Combination of pools, riffles and runs	x	x	x	Contains large amount of food for fish; variation in habitat (current areas for feeding, pools for rest).
9	Carderock Stubblefield Falls	"	x	x	x	"
10	Below Little Falls Main channel on Va. side	Run	x		x	High velocity; limited fish habitat.
11	Below Little Falls	Backwater	x	x	x	Low velocity and imperceptible currents; biologically important for larval & juvenile fish.
12	Below Little Falls Main channel on Va. side	Run	x	x	x	High velocity; limited fish habitat.

CHAPTER V

EFFECTS OF VARIOUS LOW FLOWS ON THE FREE FLOWING POTOMAC RIVER

V. Effects of various low flows on the free flowing Potomac River

A. Effects on the Fishery

As noted in Chapters I and II, the primary charge of the environmental flow-by study outlined in the Potomac River Low Flow Allocation Agreement was to establish "any amount needed for flow in the Potomac River downstream from the Little Falls dam* for the purpose of maintaining environmental conditions." In an effort to specifically and adequately address the study "charge," for the purpose of fishery analysis, the study portion of the river was divided into two segments; 1) Little Falls dam down to Little Falls and 2) Great Falls down to Little Falls dam. It was determined that separating the river into two segments was both logical and desirable for the following physical, hydrological and water management reasons:

1) Little Falls dam has physically separated the river since the 1940's by creating a barrier to fish passage. The inoperability of the Snake Island fishway has prevented the movement upstream of anadromous and other fish beyond the dam.

2) Little Falls dam, and the rubble dam just downstream, create hydrologic conditions below the dam that are unique to that portion of the river. In addition, the river bottom configuration below the dam is composed of backwater areas that become dewatered rapidly (while other areas remain watered) as water flows in a diagonal direction toward the deep main channel along the Virginia Shore.

3) Little Falls dam marks the downstream terminus of the water supply intakes. An environmental flow below the dam provides the basis for the low flow allocation formula to all intakes. In addition, the option exists for alternative water management schemes between Great Falls and Little Falls dam that could provide more water in that area to improve environmental values.

The fishery habitat between Seneca Pool and Little Falls varies considerably in terms of quantity and quality. The best habitat for most fish species occurs between Seneca Pool and Great Falls. The section below Great Falls down to Little Falls dam is less productive than the upper area, although it is still considered an area of prime fishery habitat (Sanderson, 1981). The area below Little Falls dam down to Little Falls is considered the least productive fishery habitat of the study portion of the river.

*Emphasis added

As noted in Chapter III, fishing is an important recreational activity in the study portion of the river. By far, the heaviest concentration of fishing takes place between Great Falls and Little Falls dam as a result of excellent fishing opportunities combined with easy access. Fishing declines significantly between Little Falls dam and Little Falls because of poorer fishery habitat and very limited access to the area.

1. Effects of Low Flow on the Fishery from Little Falls Dam to Little Falls

The mile stretch of river between Little Falls dam and Little Falls can be subdivided into three hydrologically distinct fishery habitat zones as follows: (See Figure 5-1)

1. Zone 1, located just below the dam, is approximately 47 acres in size. It is a relatively shallow riffle area considered to be the best fishery habitat below the dam.

2. Zone 2 is a narrow, deep main channel that runs along the Virginia Shore from the dam to Little Falls. The linear shaped Zone 2 covers approximately 21 acres.

3. Zone 3 is a backwater area downstream from Zone 1 and adjacent to Zone 2. It is approximately 22 acres in size and represents an important fishery during incubation, fry and juvenile life stages of species such as the smallmouth bass.

Utilizing the IFG model, availability of <u>ideal</u>* habitat (as reflected by depth, velocity and substrate) in relation to flow was analyzed for six key species -- smallmouth bass, channel catfish, white sucker, greenside darter, bluegill and gizzard shad. The IFG model was discovered to reflect changes in river hydrology, and hence fishery habitat, <u>only</u> in the 22 acre Zone 3 backwater and the 21 acre Zone 2 main channel. The 47 acre Zone 1 just below the dam is <u>not</u> reflected in the results of the IFG model. The unique hydrology and bottom configuration below the dam results in Zone 1 being the last area to be significantly dewatered during low flows. Even during the 1966 drought, with a flow below the dam of 78 mgd, the area remained watered. The remaining river flow passed over the Maryland side of Little Falls dam (which is lower than the Virginia side) and "fanned" out across the rubble dam and Zone 1 on its way to the deeper main channel on the Virginia side.

*ideal habitat in the IFG methodology refers to that habitat which is most preferred and suitable for individual species and life stages.

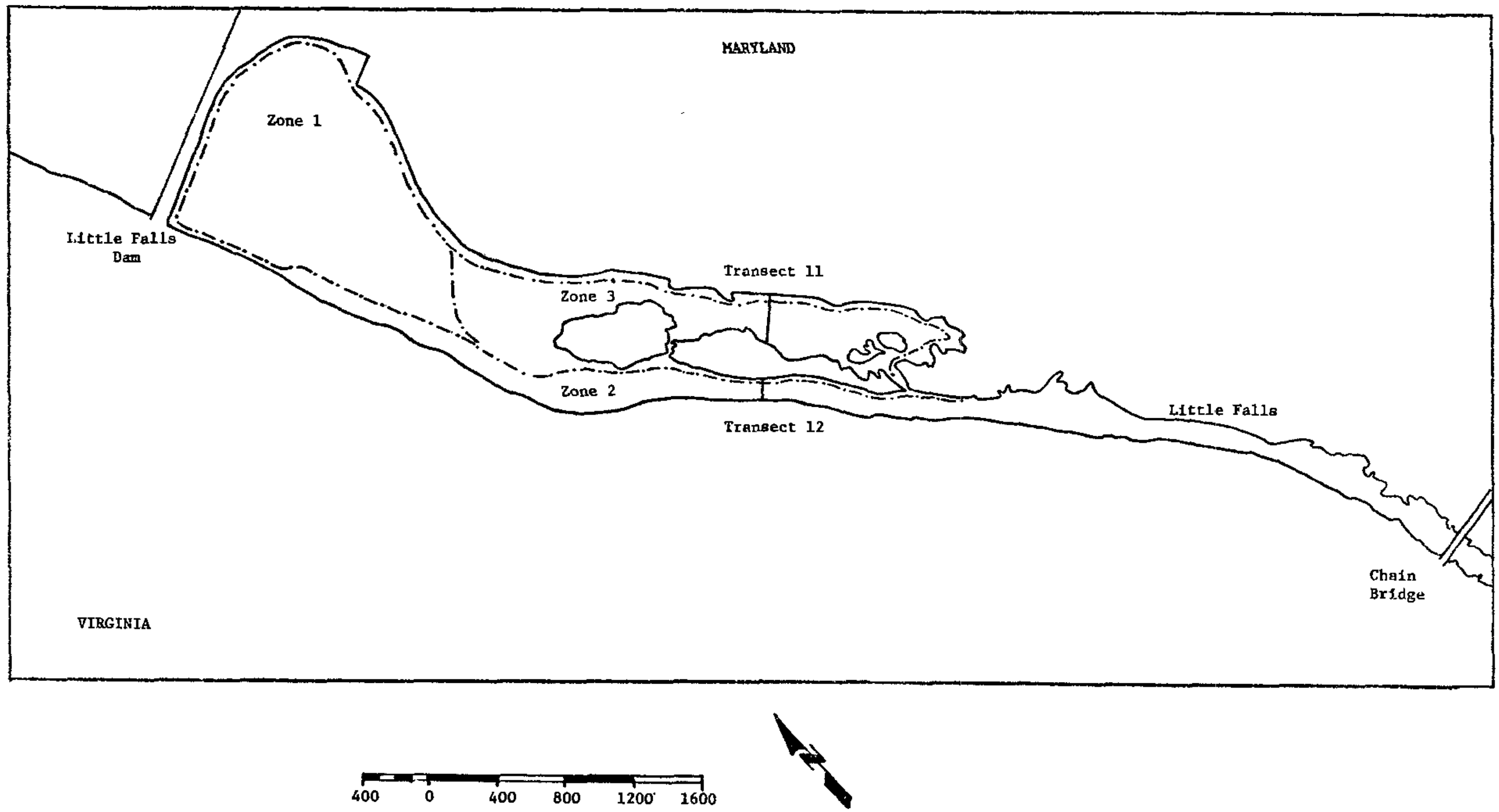


Figure 5-1 Little Falls Dam to Little Falls, Hydrologic/Fishery Habitat Zones and Transect Locations

Figure 5-2 indicates the effects of flow on gross wetted area per 1,000 feet of river at transects 11 and 12 (Zones 3 and 2 respectively). As river flow decreases from 1,800 mgd to 500 mgd there is a 27 percent reduction in gross wetted area. At 500 mgd the shallow Zone 3 becomes dewatered as flow is concentrated in the Zone 2 deep main channel -- thus resulting in a rather steady and dramatic decline in gross wetted area. As a result of below dam hydrology and bottom configuration described above, the dewatering of Zone 3 at 500 mgd, indicated in Figure 5-2, does not occur in Zone 1.

The effect of low flows on the fishery between Little Falls dam and Little Falls varies widely depending upon the species in question and its life stages. Figures 5-4 through 5-9 relate habitat availability at the incubation, fry, juvenile, adult, and spawning life stages of various key species. Historical river flow frequencies (see Table 5-1) indicate that only the juvenile and adult life stages could possibly be affected by low flows since it is only during these life stages that such flows are likely to occur.

Figure 5-3, included for purpose of flow comparison, shows the flows observed below Little Falls dam during the 1966 drought months of August and September. The lowest 7 day consecutive flow for September 1966 was 404 mgd before withdrawals and 117 after withdrawals. Such flows, at the 1966 withdrawal level*, represent a 7-day in 100-plus year occurence. Observed flows of 300 mgd (the lowest limit of the IFG model) for a 7-day period in September could be expected to occur approximately every 20 years.

Of all species and life stages analyzed utilizing the IFG model, the juvenile life stage of the smallmouth bass is of most concern in relation to potential low flows below Little Falls dam. As Figure 5-4 indicates, there is nearly an 88 percent reduction in juvenile smallmouth bass habitat availability from 900 mgd to 300 mgd. The 88 percent reduction indicated by the model occurs primarily in the 22 acre Zone 3 backwater. It appears that the juvenile smallmouth bass habitat loss at low flow is considerably less in the larger 47 acre Zone 1. It should be noted that there is not a one to one relationship between habitat reduction and numbers of fish lost. Fish loss is dependent upon a multitude of variables including, flow duration, water quality, predation and the general quality of the remaining habitat.

In an effort to put smallmouth bass habitat availability into perspective in terms of numbers of fish, estimations of population distributions were made. Calculations based on earlier studies indicate that in the late summer and early fall of any given year there are approximately 160 juvenile

*1980 withdrawals average approximately 500 mgd higher than in 1966.

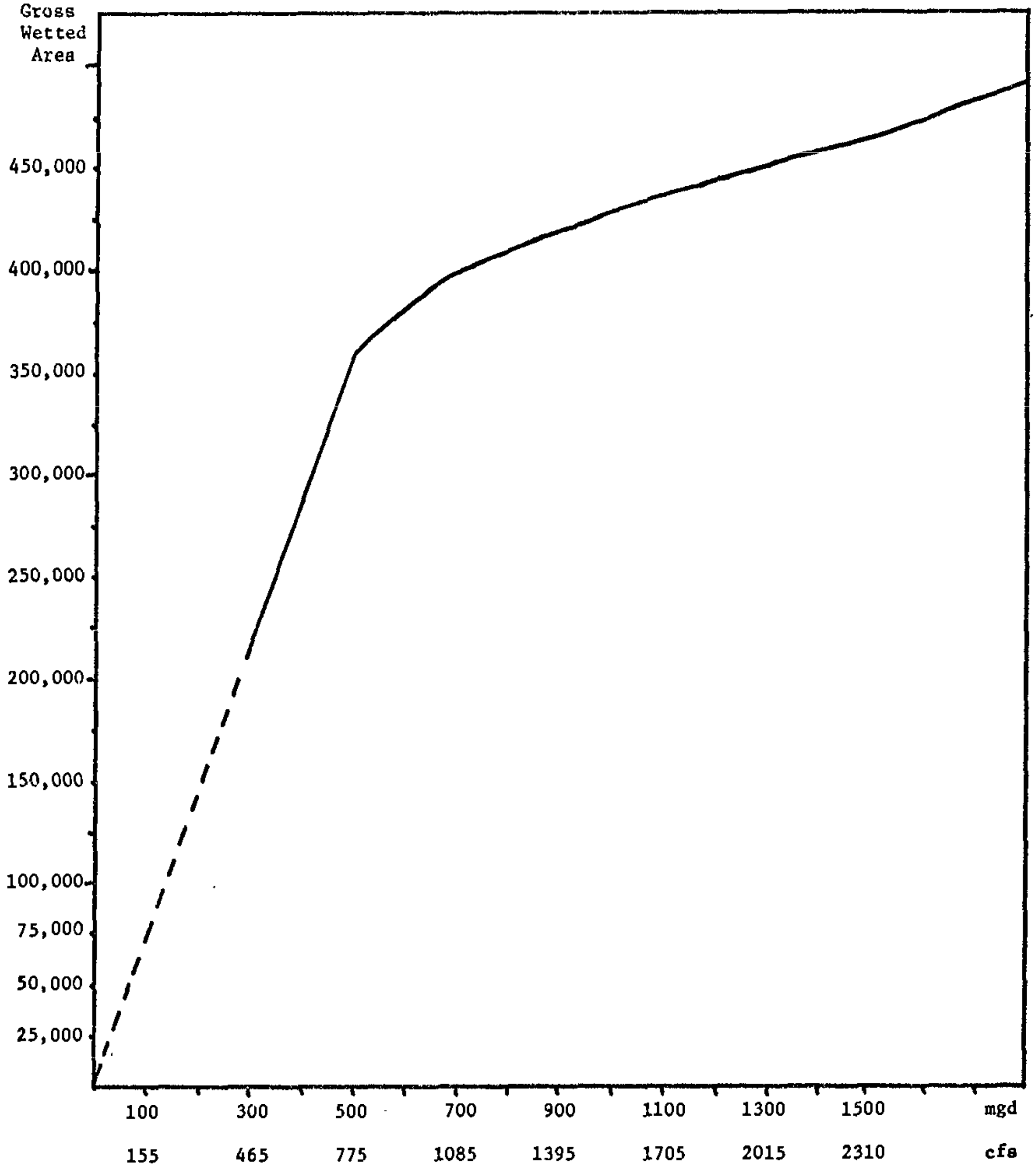


Figure 5-2 Graph of Flow vs Gross Wetted Area ($ft.^2$/1000 ft. of river) at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

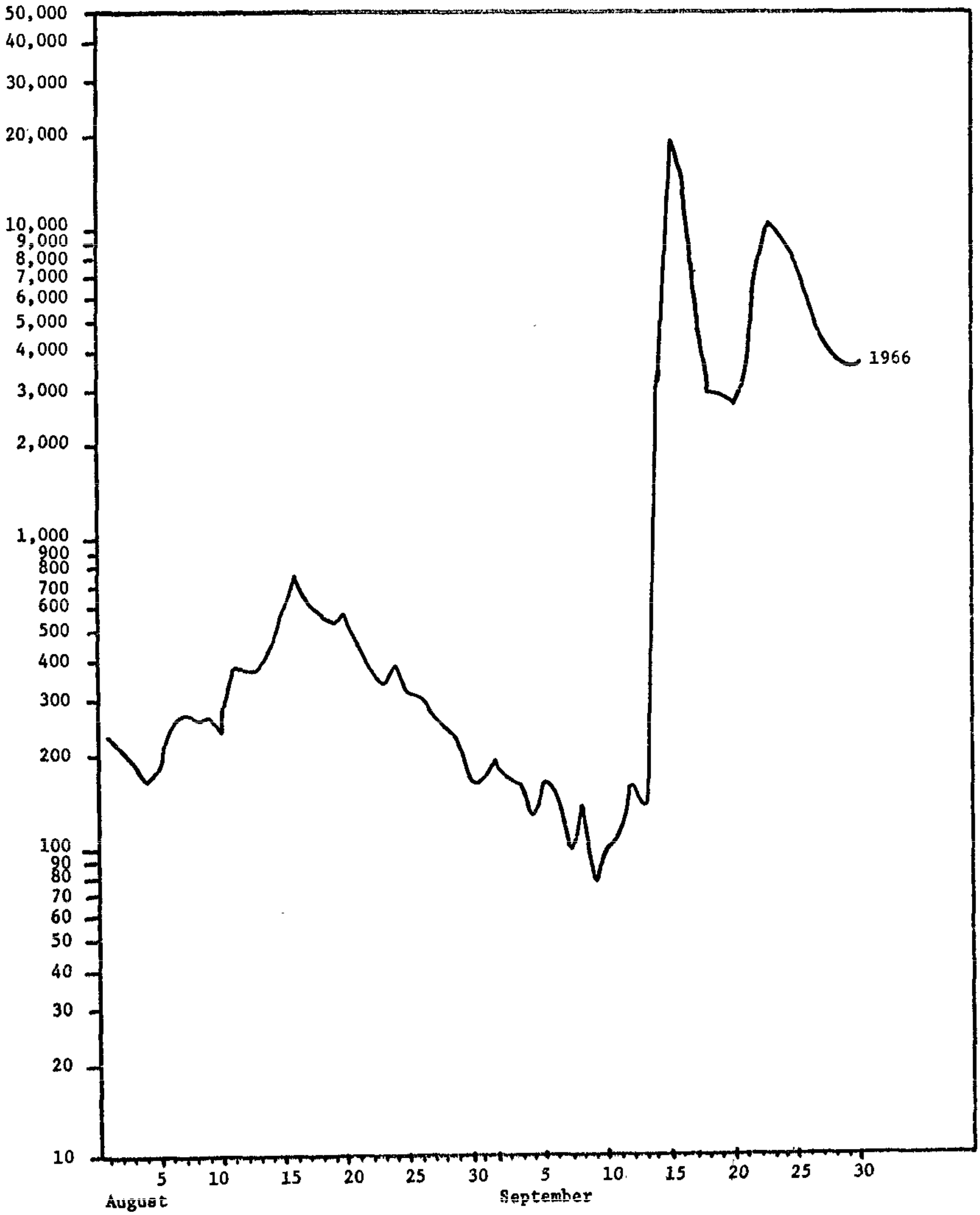


Figure 5-3 Observed Flows for August and September, 1966, at Little Falls Dam

smallmouth bass (one to three years of age) present per acre (Lucas and Sanderson, 1981). The 22 acre backwater most affected by low flow can be expected to contain approximately 3,500 juvenile smallmouth bass. Analysis of population dynamics and juvenile age classes indicate that the smallmouth bass population in Zone 3 would take approximately four years to fully recover from an extreme low flow of a week or longer. Such flows can be expected to occur once every twenty years (See Table 5-1).

The following discussion summarizes the effects of flow upon availabiliy of <u>ideal</u> habitat in <u>Zones 2 and 3</u> for each life stage of the six key indicator species. Table 5-1 should be referred to for relating flow frequencies to critical times for life stages.

<u>Smallmouth Bass</u> - See Figure 5-4

<u>Incubation</u> - Critical time, April 20 - June 10 [May]*

From 1,800 mgd to 900 mgd, habitat availability per 1,000 feet of stream declines 62 percent from 105,000 sq. ft. to 40,000 sq. ft. Below 900 mgd no further habitat reduction occurs down to 300 mgd.

<u>Fry</u> - Critical time, May 1 to June 15 [May]

From 1,800 mgd to 700 mgd habitat availability per 1,000 ft. stream declines 87 percent from 185,000 sq. ft. to 25,000 sq. ft. Below 700 mgd no further habitat reduction occurs.

<u>Juveniles</u> - Critical time, June 15 until maturity at ages 2 to 4 years but most commonly 3 years.

From 1,800 mgd to 900 mgd habitat availability per 1,000 ft. of stream declines 15.5 percent. From 900 mgd to 300 mgd habitat declines 88 percent from 220,000 sq. ft. to 25,000 sq. ft. per 1,000 ft. of stream. This juvenile habitat reduction occurs primarily in Zone 3. Juveniles do not have the ability to survive longer than one week in the fast moving main channel (Sanderson, 1981). It is believed that those capable of doing so will move to Zone 1. Historical evidence indicates that low flows are possible during the juvenile life stage. Since the decline in available juvenile habitat in relation to flow is dramatic to Zone 3 at flows lower than 900 mgd and since bass of this size are particularly susceptable to both predation and competition for food and habitat, it can be presumed that the actual number of juvenile bass will be reduced at lower flows beyond reductions that normally occur at higher flows.

*Brackets indicate month of most concern.

Table 5-1 Natural Low Flow Frequency (Adjusted for Withdrawal) at Little Falls Dam - Monthly Series

		2 yr.	5 yr.	10 yr.	20 yr.	50 yr.	100 yr.
January	1-day	3,134	1,911	1,467	1,176	914	771
	7-day	3,763	2,255	1,716	1,364	1,050	880
	30-day	7,224	4,103	2,968	2,237	1,601	1,267
February	1-day	4,056	2,500	1,904	1,505	1,142	944
	7-day	4,722	2,828	2,124	1,659	1,244	1,020
	30-day	N/A	N/A	N/A	N/A	N/A	N/A
March	1-day	5,063	3,351	2,661	2,184	1,733	1,478
	7-day	6,215	4,049	3,213	2,646	2,117	1,820
	30-day	12,271	8,229	6,745	5,752	4,833	4,318
April	1-day	4,758	3,444	2,910	2,531	2,164	1,949
	7-day	5,483	3,867	3,252	2,831	2,435	2,207
	30-day	10,557	6,855	5,460	4,522	3,655	3,168
May	1-day	3,485	2,507	2,100	1,810	1,527	1,363
	7-day	4,053	2,884	2,425	2,107	1,807	1,626
	30-day	7,406	4,545	3,522	2,855	2,253	1,925
June	1-day	2,270	1,639	1,388	1,213	1,044	946
	7-day	2,670	1,908	1,613	1,410	1,218	1,107
	30-day	4,773	2,924	2,312	1,923	1,581	1,396
July	1-day	1,573	1,071	866	722	584	505
	7-day	1,826	1,237	1,007	849	698	613
	30-day	2,746	1,749	1,400	1,172	966	853
August	1-day	1,256	879	729	624	526	468
	7-day	1,456	1,007	840	725	619	558
	30-day	2,300	1,365	1,074	895	741	659
September	1-day	1,082	730	593	499	411	361
	7-day	1,234	842	690	587	488	432
	30-day	1,846	1,124	904	772	659	600
October	1-day	1,058	758	646	573	505	467
	7-day	1,249	873	741	654	576	529
	30-day	2,103	1,143	876	722	597	541
November	1-day	1,397	919	749	637	535	478
	7-day	1,648	1,068	866	736	618	552
	30-day	2,770	1,497	1,099	858	653	564
December	1-day	2,063	1,211	940	766	612	528
	7-day	2,383	1,406	1,078	868	684	587
	30-day	4,547	2,344	1,647	1,225	875	698

Source: Adapted from U.S. Army Corps of Engineers, Baltimore District. 1978. Final Environmental Impact Statement Concerning Proposed Potomac River Water Supply Structures.

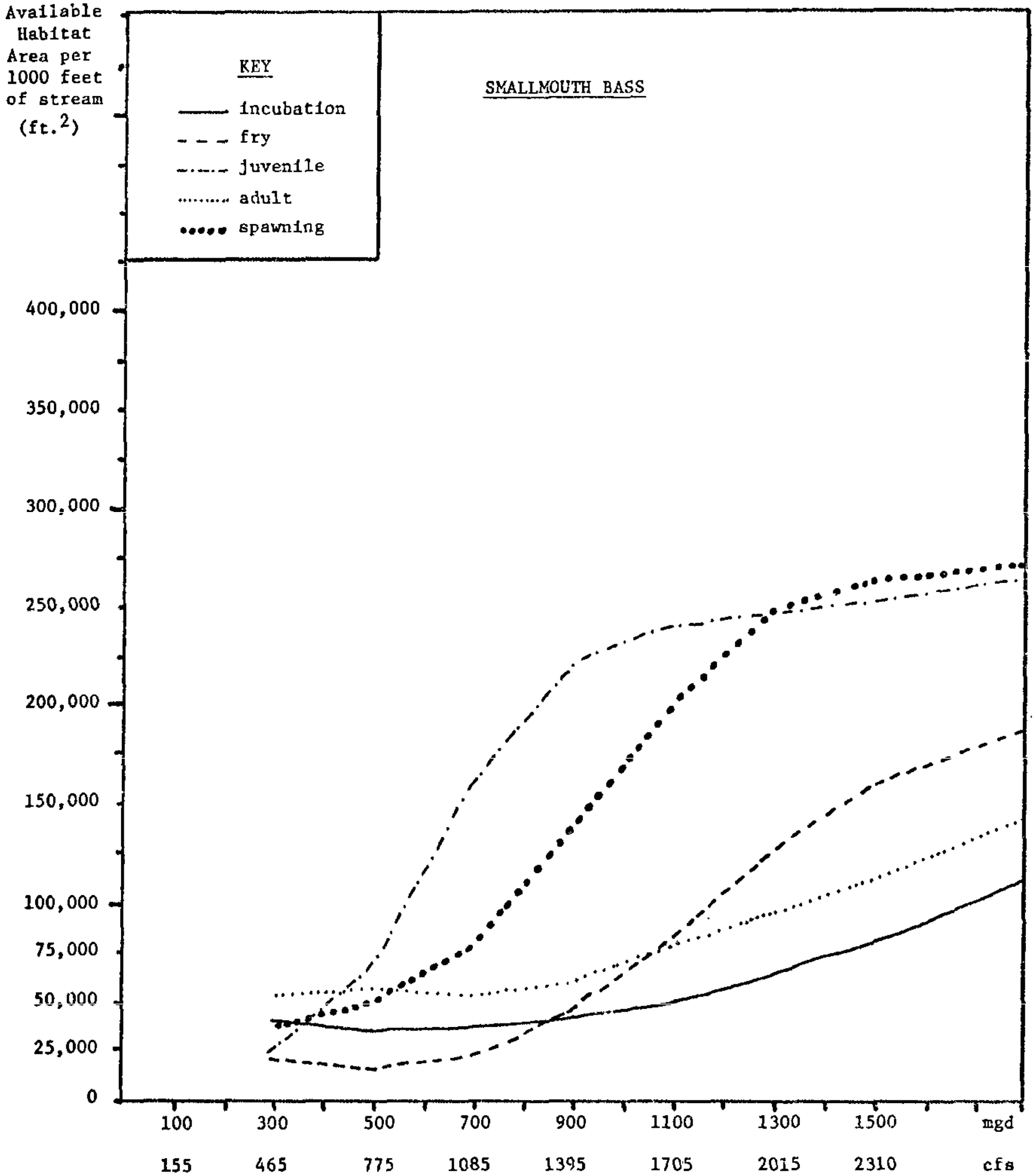


Figure 5-4 Smallmouth Bass Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

Adults - Critical time, all year.

From 1,800 mgd to 900 mgd habitat availability declines 42 percent, from 145,000 sq. ft. to 60,000 sq. ft. per 1,000 ft. of stream. Below 900 mgd no significant additional habitat loss occurs. Adult smallmouth bass are large, strong swimmers and are not nearly as susceptible to predation and competition as are juvenile bass. It is felt that most adults can survive all but the most catastrophic low flows of long duration.

Spawning - Critical time, April 20 - June 10 [May]

From 1,800 mgd to 300 mgd habitat availability per 1,000 ft. of stream declines 86 percent from 270,000 sq. ft. to 40,000 sq. ft.

Catfish - See Figure 5-5

Fry - Critical time June 1 - June 30 [June]

Decline in ideal habitat, 1,800 mgd to 300 mgd is 67 percent from 430,000 sq. ft. to 140,000 sq. ft.

Juvenile - Critical time, July 1 until maturity at age 3

Habitat remains relatively stable, declining gradually from 58,000 sq. ft. at 1,800 mgd to 20,000 sq. ft. at 300 mgd. Though low flows are possible during juvenile life stages, the channel catfish is rather tough and adaptable so it is assumed actual numbers of juvenile catfish will only be moderately reduced as a result of such flows. The extent of population reduction will depend upon the duration and severity of the low flow.

It should be noted that at 1,800 mgd, the total available ideal habitat for juvenile and adult channel catfish is relatively small (58,000 sq. ft./1,000 ft. and 61,000 sq. ft./1,000 respectively) between Little Falls Dam and Little Falls.

Adults - Critical time - all year

Ideal habitat loss between 1,800 mgd and 1,100 mgd is approximately 46 percent. Below 1,100 mgd no further habitat reduction occurs. The adult life stage of the channel catfish is extremely durable and is believed to be very resistant to low flow. Historical flow frequency indicates that flow declines below 1,100 mgd as often as 7 days every 2 years without adversely affecting the channel catfish population.

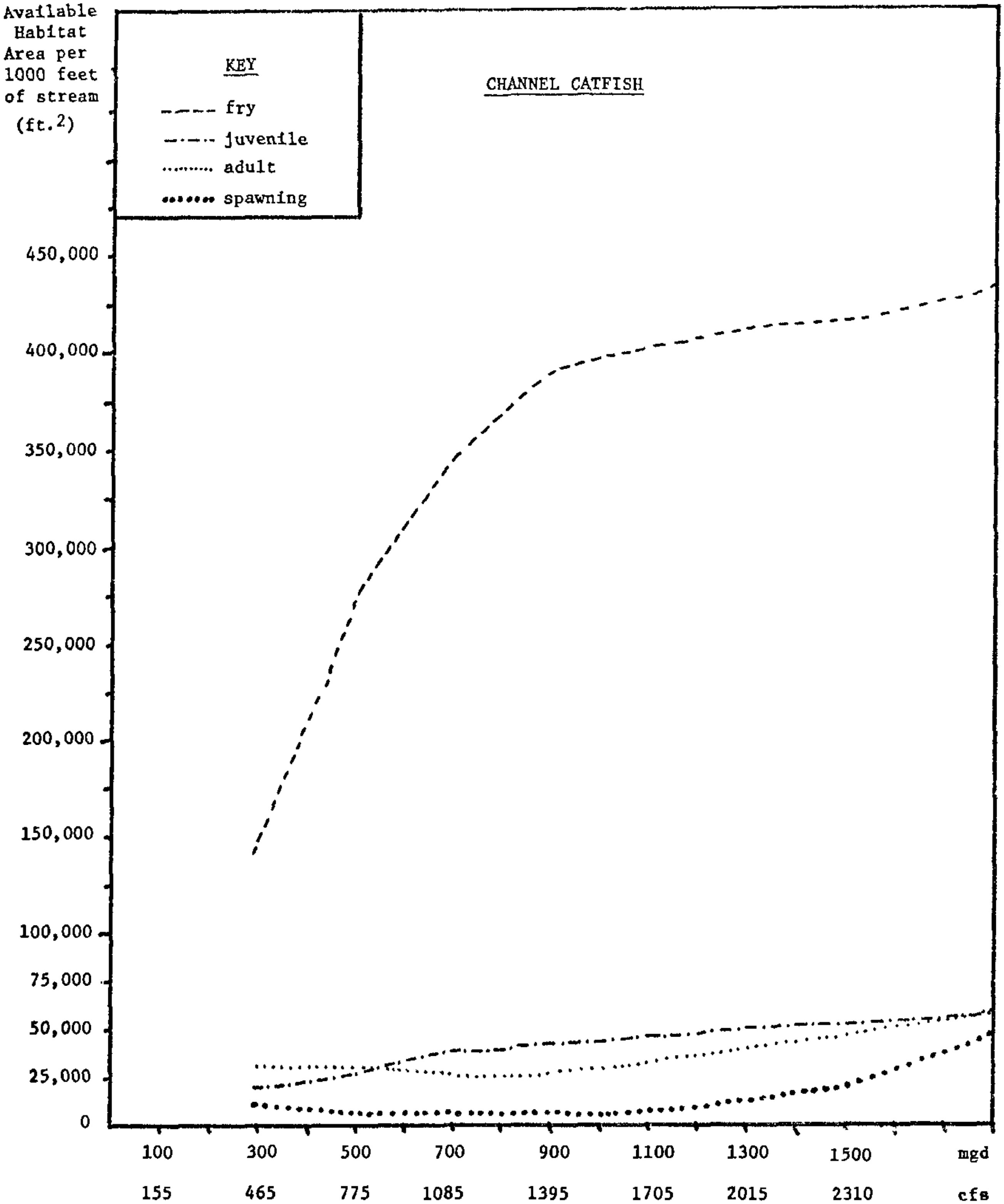


Figure 5-5 Channel Catfish Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

Spawning - Critical time, May 15 - June 15

Between 1,800 mgd to 1,300 habitat available per 1,000 ft. of stream declines 70 percent from 45,000 sq. ft. to 15,000 sq. ft. Below 1,300 mgd no further habitat reduction occurs.

White Sucker - See Figure 5-6

Suckers and gizzard shad appear to constitute a large portion of the forage fish in the Potomac. The habitat of the river below Little Falls favors suckers by a wide margin. In the study area the redhorse and guillback suckers are present in greater numbers than the white sucker indicating that they are better adapted to the environment of the lower Potomac. During the 1966 drought, massive dieoffs of suckers were observed at several locations such as Seneca Pool (Sanderson, 1981). It is not known whether the dieoffs were related to deteriorating water quality or reduction in physical habitat, or a combination of both. At any rate, the sucker population made a rapid recovery to its present high levels.

Fry - Critical time May 15 - June 15

10 percent habitat reduction from 1,800 mgd to 1,100 mgd. From 1,100 mgd to 300 mgd there 92 percent decline in habitat from 185,000 sq. ft. to 15,000 sq. ft.

Juveniles - Critical time, June 15 until maturity at 2 to 3 years of age.

From 1,800 to 700 only 16 percent reduction in habitat occurs. Below 700 mgd to 300 mgd habitat availability declines by 75 percent from 285,000 sq. ft. to 70,000 sq. ft. Since juvenile white suckers are susceptible to both increased predation and competition for food and habitat, that occur during low flow it is assumed that the actual number of juveniles will decline during sustained low flows of more than two weeks. Historical flow frequencies indicate that such flows are likely to occur on an average of once every twenty years.

Adults - Critical time - all year

A 72 percent reduction in ideal habitat occurs from 1,800 mgd to 300 mgd. Adult white suckers are large and much less susceptible to predation than are juvenile suckers. Most adult suckers could survive low flows other than those of long duration. Historical flow frequencies indicate that such flows are likely to occur on an average of once every twenty years.

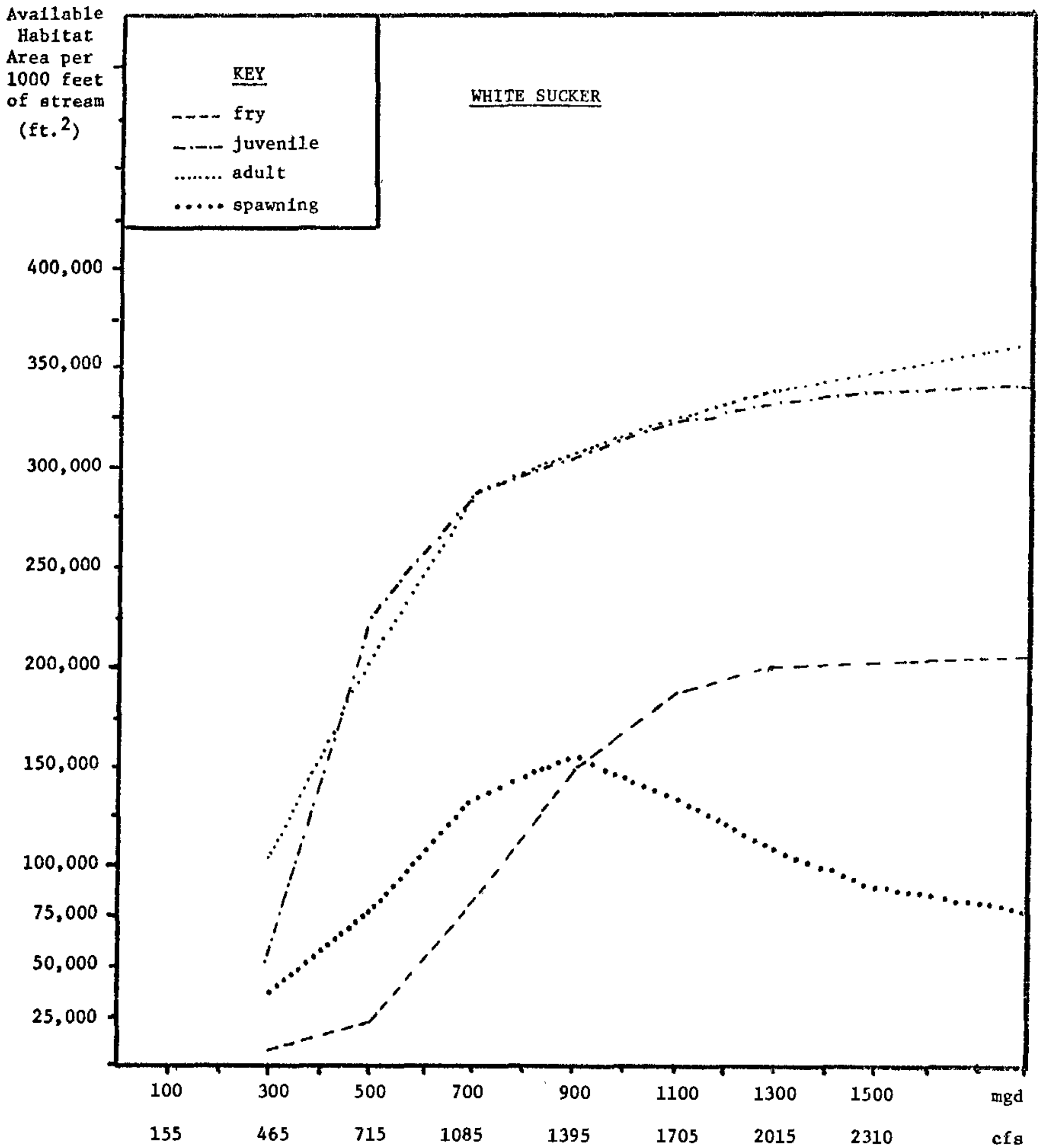


Figure 5-6 White Sucker Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

Spawning - Critical time, April - May 15

There is actually a 100% increase in habitat availability from 1,800 mgd to 900 mgd. From 900 mgd to 300 mgd habitat declines to near original levels.

Bluegill - See Figure 5-7

Fry	1800 - 1300 mgd	no change in habitat availability
	1300 - 300 mgd	100% loss in habitat availability
Adults	1813 - 500 mgd	98% loss in habitat availability
	500 - 300 mgd	100% gain in habitat availability
Juveniles	1800 - 1490 mgd	3% loss in habitat availability
	1490 - 1100 mgd	5% gain in habitat availability
	1100 - 300 mgd	100% loss in habitat availability

Greenside Darter - See Figure 5-8

Juvenile	1800 - 500 mgd	233% gain in habitat availability
	500 - 300 mgd	25% loss in habitat availability
Adult	1800 - 700 mgd	71% gain in habitat availability
	700 - 500 mgd	no change in habitat availability
	500 - 300 mgd	25% loss in habitat availability
Spawning	1800 - 1300 mgd	25% gain in habitat availability
	1300 - 900 mgd	7% loss in habitat availability
	900 - 300 mgd	40% loss in habitat availability

In general, ideal habitat availability appears to be low for the Greenside Darter from Little Falls dam to Little Falls -- averaging less than 50,000 sq. ft./1,000 ft. However, Green Darter habitat improves considerably as flows decrease until 500 mgd. At 500 mgd habitat availability begins to decline.

Gizzard Shad - See Figure 5-9

Fry	1813 - 1490 mgd	2% loss in habitat availability
	1490 - 300 mgd	95% loss in habitat availability
Juveniles	1813 - 1000 mgd	65% loss in habitat availability
Adults	1000 - 300 mgd	75% gain in habitat availability
Spawning	1813 - 1490 mgd	2% loss in habitat availability
	1490 - 500 mgd	84% loss in habitat availability
	500 - 300 mgd	0 loss in habitat availability

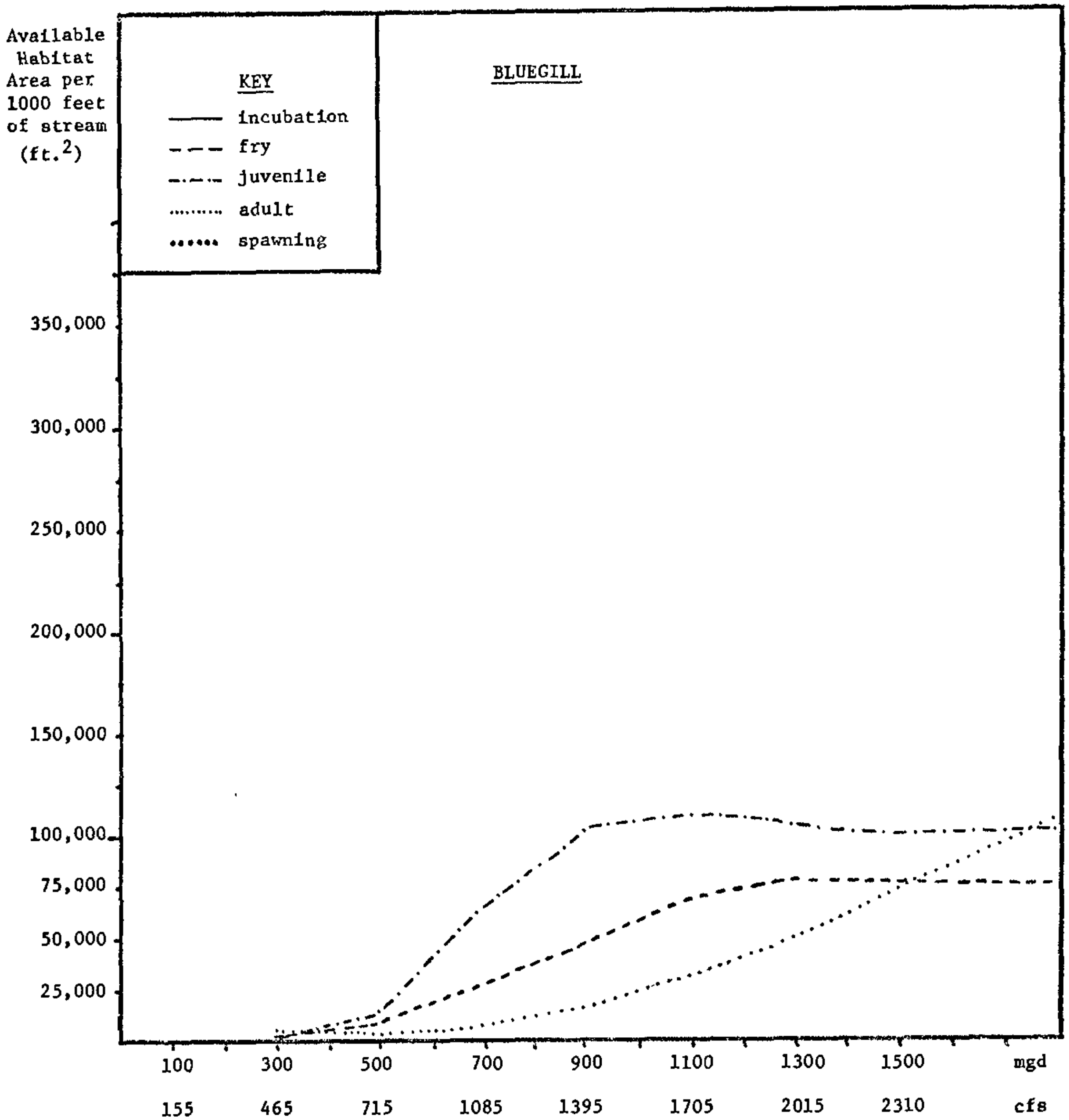


Figure 5-7 Bluegill Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

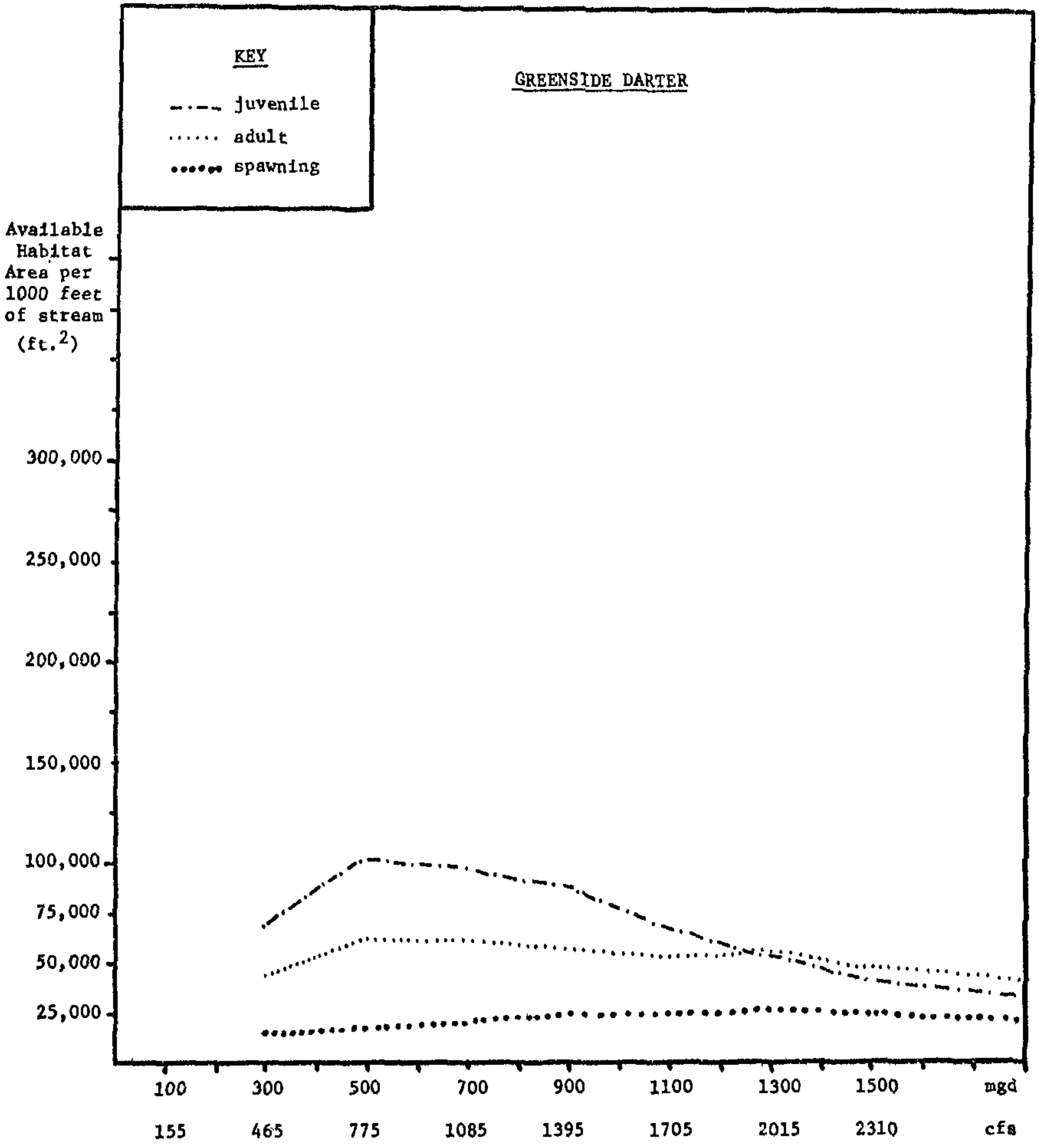


Figure 5-8 Greenside Darter Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

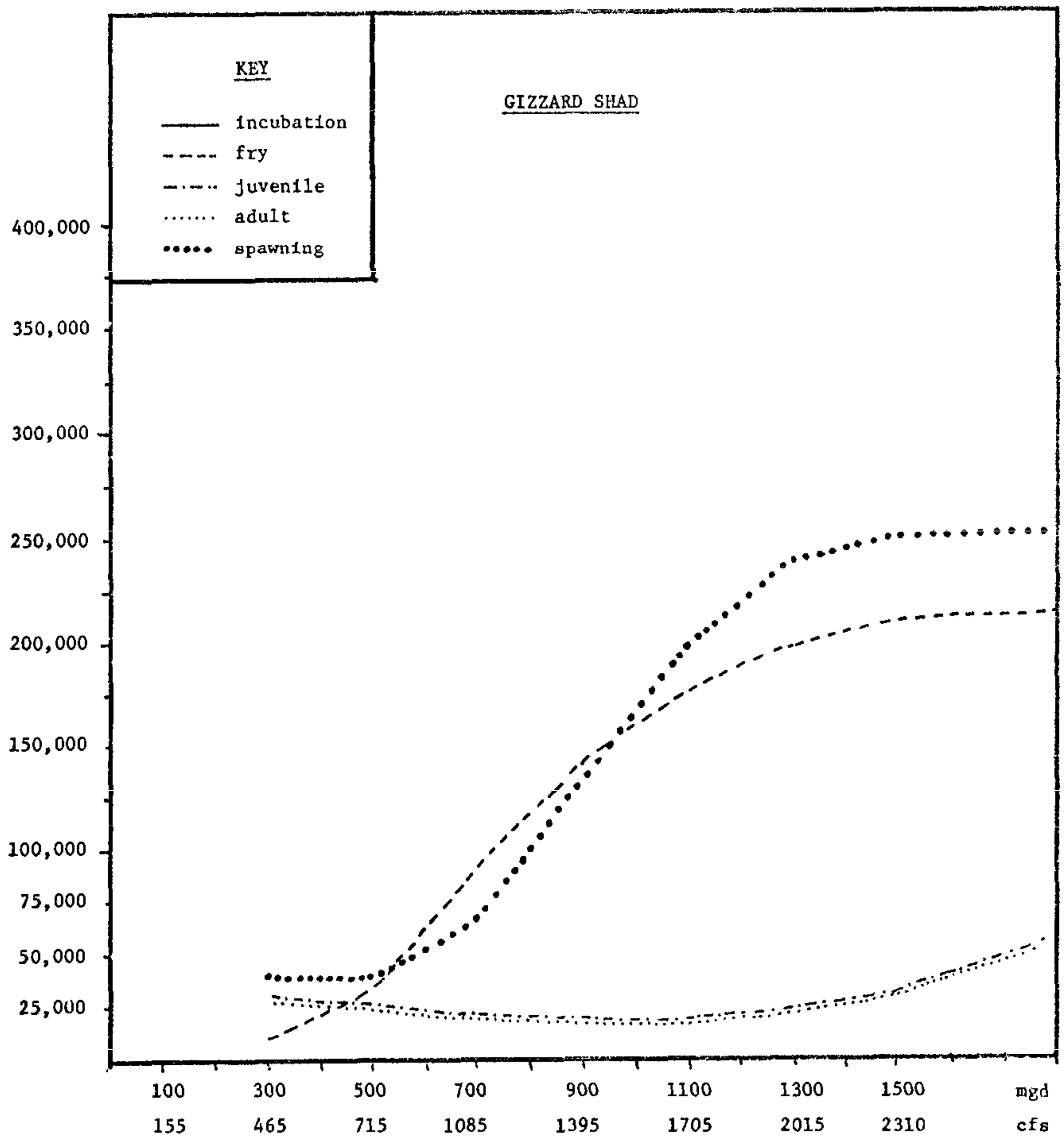


Figure 5-9 Gizzard Shad Habitat Availability at Various River Flows at Transect Locations 11 and 12. Fluvial Area below Little Falls Dam.

Life stage critical timing is an important factor in relation to low flow fishery analysis. As indicated by above discussion, the only life stages that are of concern in relation to historical low flows are the juvenile and adult. Without exception, the other life stages occur during periods of historical high flow -- mid to late spring.

Another important consideration deals directly with how the IFG model results are to be interpreted. The model predicts physical changes in <u>ideal</u> habitat availability. It does not provide a direct indication of changes in sub-ideal or marginal habitat availability nor does it establish a direct relationship to changes in water quality. In addition, declines or increases in habitat availability only infer relative changes. Necessary data is not available for eastern streams to determine the full significance of square feet of available ideal habitat per 1,000 feet -- that is, whether or not 100,000 sq. ft. of available juvenile smallmouth bass habitat is in fact excellent habitat or only marginal habitat when compared to some regional standard of suitability. The model is however, a useful tool for analyzing relative changes in ideal habitat of various species in relation to flow.

2. Effects of low flow on the fishery from Great Falls to Little Falls Dam

Unlike the river below Little Falls dam, the Potomac above the dam to Great Falls is both a very productive and popular fishing area. Even at the lowest flows, there is six to ten times more ideal habitat available per 1,000 feet of stream above the dam than below the dam. The gross wetted area per 1,000 feet of much of the river above Little Falls dam is more than two times that found below the dam (See Figure 5-10). Thousands of fishermen converge on the area each year as a result of easy access and the challenges offered by a varied and productive fishery.

Transects 8 and 9 (See Figure 4-1 and Study Area Map) were selected for detailed analysis because they represent riffle and run areas considered to be the best year-around fishery environment. Such riffle and run areas are not only important fishery zones but also readily reflect variations in physical habitat that occur as a result of changes in flow. Transects 2 and 3 were found to represent critical spring incubation and fry backwater areas, however, these locations become dewatered nearly every year in late summer and early fall and thus are of no consequence in low flow analysis. Transect 4 primarily reflects habitat changes in Mather Gorge; however, the deep, fast moving Gorge was found to be poor fishery habitat when compared to the riffle and run areas.

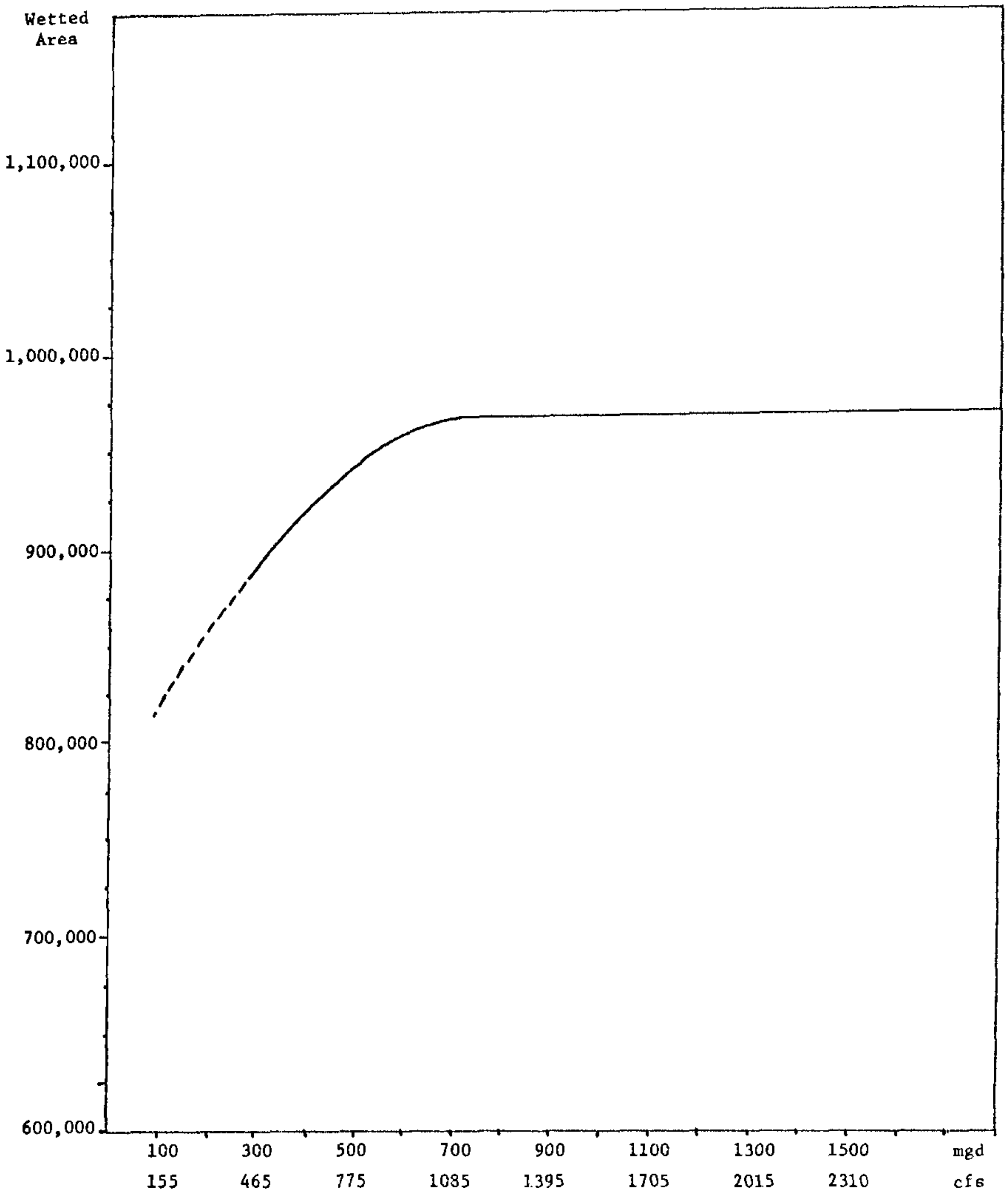


Figure 5-10 Graph of Flow vs Gross Wetted Area (ft.^{2}/1000 ft. of river) at Transect Locations 8 and 9. Run and Riffle Areas above Little Falls Dam.

Analysis of fishery habitat from Great Falls to Little Falls dam reveals some interesting occurrences. At low flows, ideal habitat availability for many fish species actually improves. For example, habitat availability for the juvenile and adult bluegill improves substantially as flows decrease, reaching levels above 275,000 sq. ft./ 1,000 ft. The same low flow "off-setting" situations occurs with juvenile smallmouth bass above Little Falls dam.

Of most concern above Little Falls dam is the apparent decline in juvenile channel catfish ideal habitat availability as a result of low river flow. From 1,800 mgd to 300 mgd habitat availability per 1,000 feet of stream declines 76 percent from 105,000 sq. ft. to 25,000 sq. ft. However, it must be pointed out that juvenile channel catfish habitat availability in this area is relatively low to begin with when compared to other species. Also, as noted in earlier discussions, the channel catfish is a very hardy species and its numbers would not be expected to decline significantly except during the lowest flow of sustained duration.

The following discussion summarizes the effects of flow upon availability of ideal habitat in riffle and run areas above Little Falls dam for each life stage of the six key indicator species (See Figures 5-10 through 5-14). Table 5-1 should be referred to for relating flow frequencies to critical times for life stages.

Smallmouth Bass - See Figure 5-11

Incubation - Critical time, April 20 - June 10 [May]

Between 1,800 mgd and 300 mgd, habitat availability declines 85 percent from 636,000 sq. ft. to 94,000 sq. ft. -- however, 94,000 sq. ft./1,000 ft. is relatively high for a flow of 300 mgd. Historical records reveal that low flows have not occurred during incubation.

Fry - Critical time, May 1 - June 15 [May]

Habitat availability remains high at 430,000 sq. ft., first increasing and then decreasing as flows decline.

Juveniles - Critical time, June 15 until maturity at ages 2 to 4 years (most commonly 3 years)

Between 1,800 mgd and 700 mgd juvenile smallmouth bass habitat improves significantly from 460,000 sq. ft./1,000 ft. to over 700,000 sq. ft./1,000 ft., an increase of 52 percent. At 700 mgd habitat availability declines somewhat to 650,000 sq. ft./1,000 ft. at 300 mgd, but is still 41 percent higher than at 1,800 mgd.

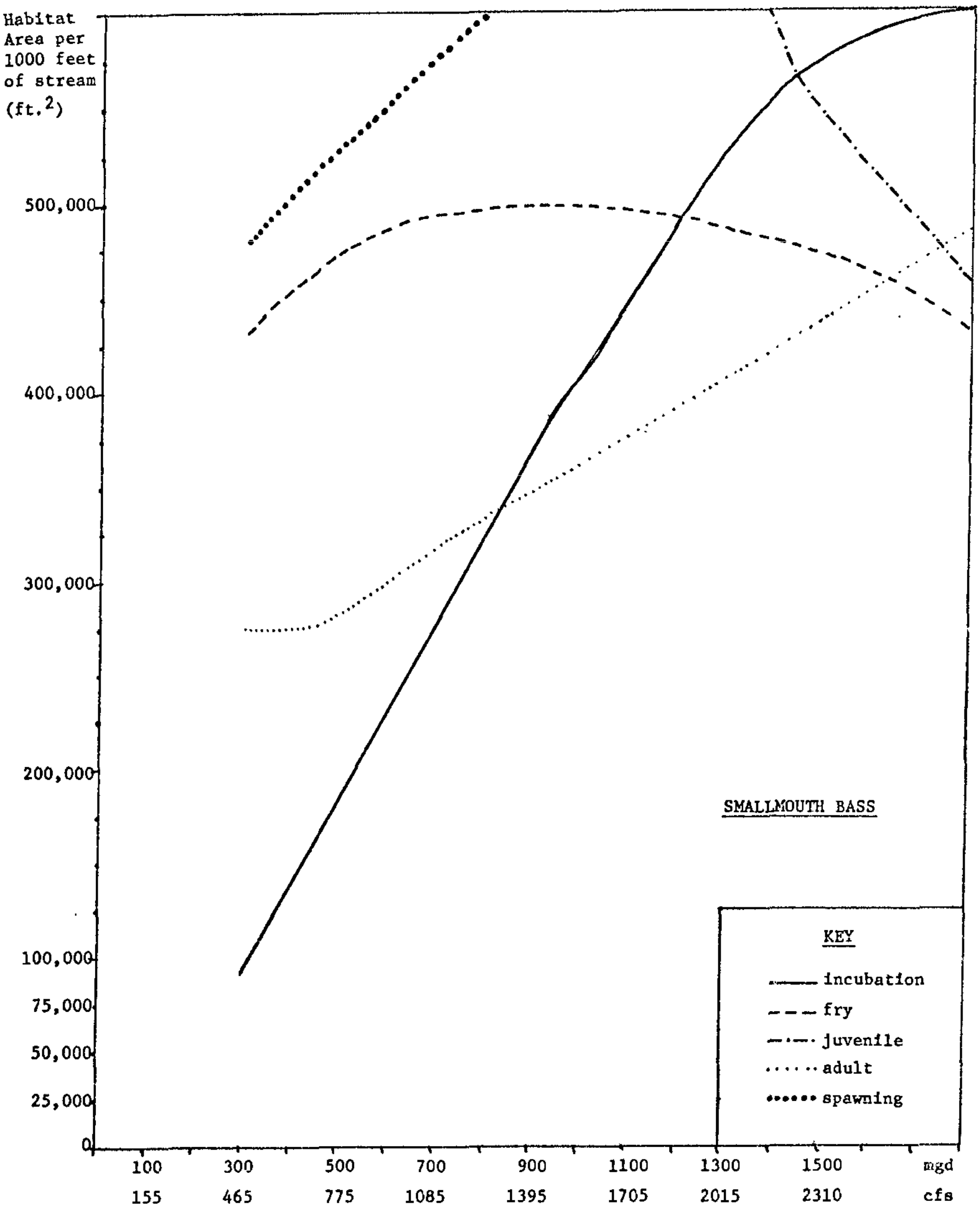


Figure 5-11 Smallmouth Bass Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

Adults - Critical time, all year

Between 1,800 mgd and 300 mgd habitat availability declines 48 percent from 480,000 sq. ft./1,000 ft. to 250,000 sq. ft./1,000 ft. The decline begins to lessen somewhat as 300 mgd is approached.

Spawning - Critical time, April 20 - June 10 [May]

From 1,800 mgd to 700 mgd habitat availability remains fairly constant. At 700 mgd, habitat declines 23 percent from 625,000 sq. ft./ 1,000 ft. to 480 sq. ft./1,000 ft. at 300 mgd.

Channel Catfish - See Figure 5-12

Juveniles - Critical time, July 1 until maturity at age 3

Between 1,800 and 300 habitat availability declines steadily from 105,000 sq. ft./1,000 ft. to 25,000 sq. ft./1,000 ft. (76 percent). It should be noted that juvenile catfish habitat is low even at high flows compared to habitat availability of other important species.

Adults - Critical time, all year

Adult ideal habitat availability declines from 275,000 sq. ft./1,000 ft. at 1,800 mgd to 204,000 sq. ft./1,000 ft. at 300 mgd, a 26 percent decrease. Adult channel catfish are extremely durable and hardy. It is felt that their numbers would not decline significantly as a result of low flows of moderate duration.

Bluegill - See Figure 5-13

Fry - Critical time May 1 - June 15 [May]

Habitat availability improves substantially from 226 sq. ft./1,000 ft. at 1,800 mgd to 225,000 sq. ft./1,000 ft. at 300 mgd, an increase of 995 times original available habitat.

Juveniles - Critical time, July 1 until maturity at age 3

Juvenile habitat availability improves dramatically from 7,537 sq. ft./1,000 ft. at 1,800 to 292,949 sq. ft./1,000 ft. at 300 mgd, an increase of 39 times the original available habitat.

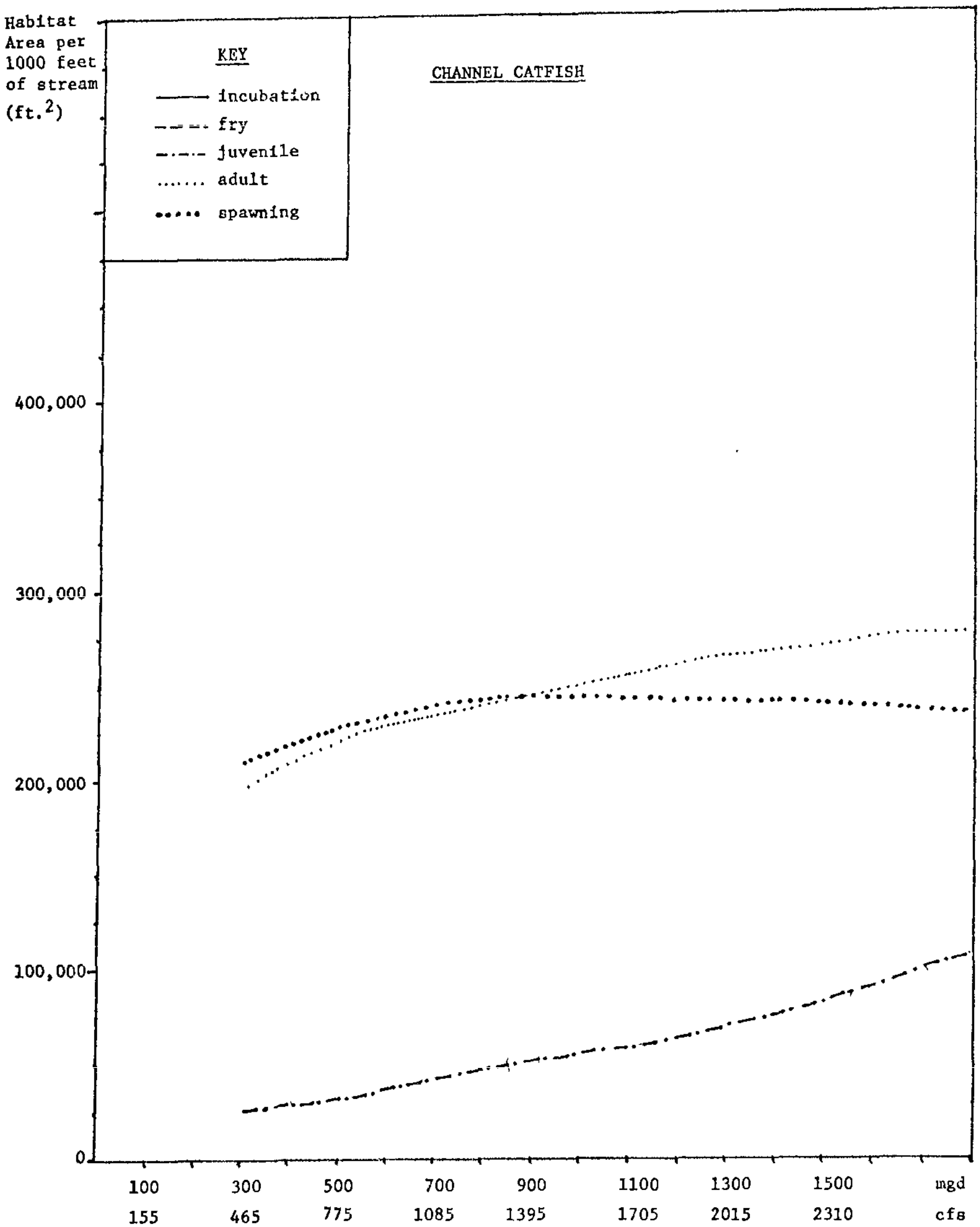


Figure 5-12 Channel Catfish Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

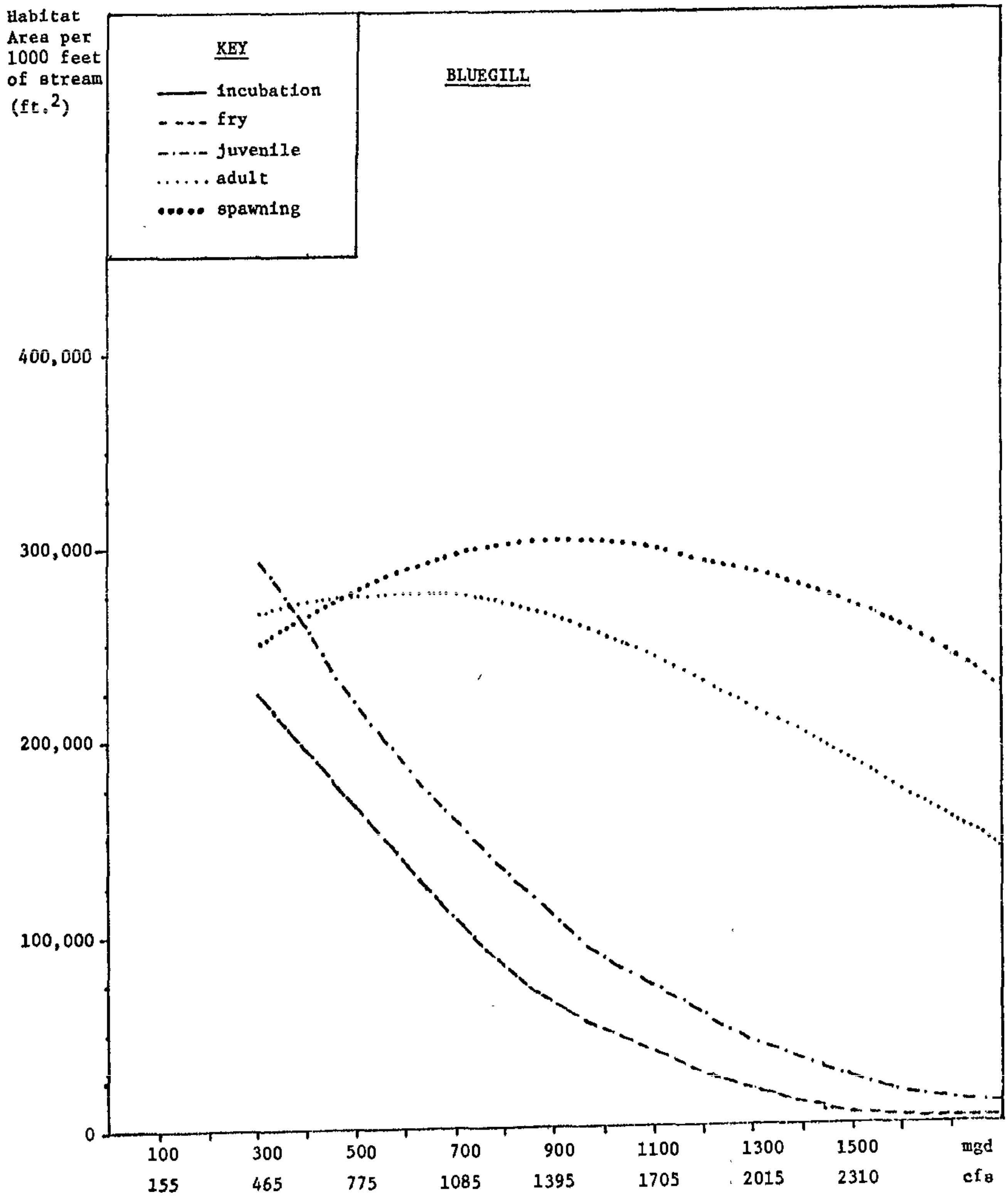


Figure 5-13 Bluegill Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

The improved juvenile bluegill habitat availability between Great Falls and Little Falls dam that occurs as a result of low flow more than off-set the decline in juvenile habitat noted below the dam.

Adults - Critical time, all year

Between 1,800 mgd and 500 mgd habitat availability increases significantly from 149,000 sq. ft./1,000 ft. to 276,000, an increase of nearly 200 percent. At 500 mgd habitat begins to decline slightly to 269,000 at 300 mgd.

Greenside Darter - See Figure 5-14

Juvenile	1800 - 700 mgd	100% gain in habitat availability
	700 - 500 mgd	no change in habitat availability
	500 - 300 mgd	20% decrease in habitat availability
Adult	1800 - 300 mgd	57% decrease in habitat availability
Spawning	1800 - 300 mgd	74% decrease in habitat availability

Gizzard Shad - See Figure 5-15

Fry	1800 - 500 mgd	111% gain in habitat availability
	500 - 300 mgd	1% decrease in habitat availability
Juvenile	1800 - 300 mgd	33% decrease in habitat availability
Adult	1800 - 300 mgd	33% decrease in habitat availability
Spawning	1800 - 300 mgd	22% decrease in habitat availability

White Sucker - See Figure 5-16

Fry	1800 - 500 mgd	154% gain in habitat availability
	500 - 300 mgd	2% loss in habitat availability
Juvenile	1800 - 700 mgd	20% gain in habitat availability
	700 - 300 mgd	10% loss in habitat availability
Adult	1800 - 1500 mgd	no change in habitat availability
	1500 - 300 mgd	29% loss in habitat availability
Spawning	1800 - 1100 mgd	57% gain in habitat availability
	1100 - 300 mgd	39% loss in habitat availability

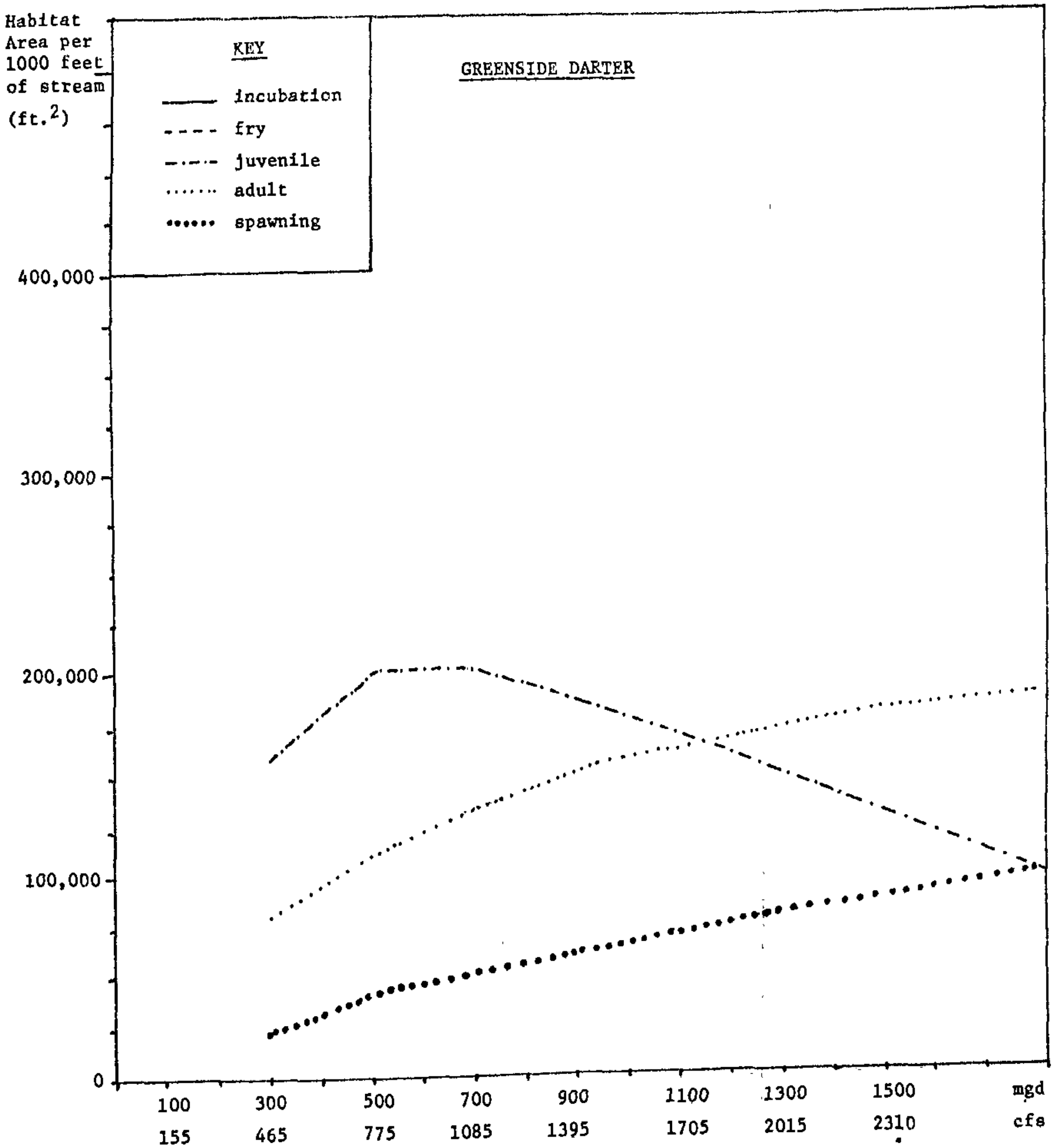


Figure 5-14 Greenside Darter Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

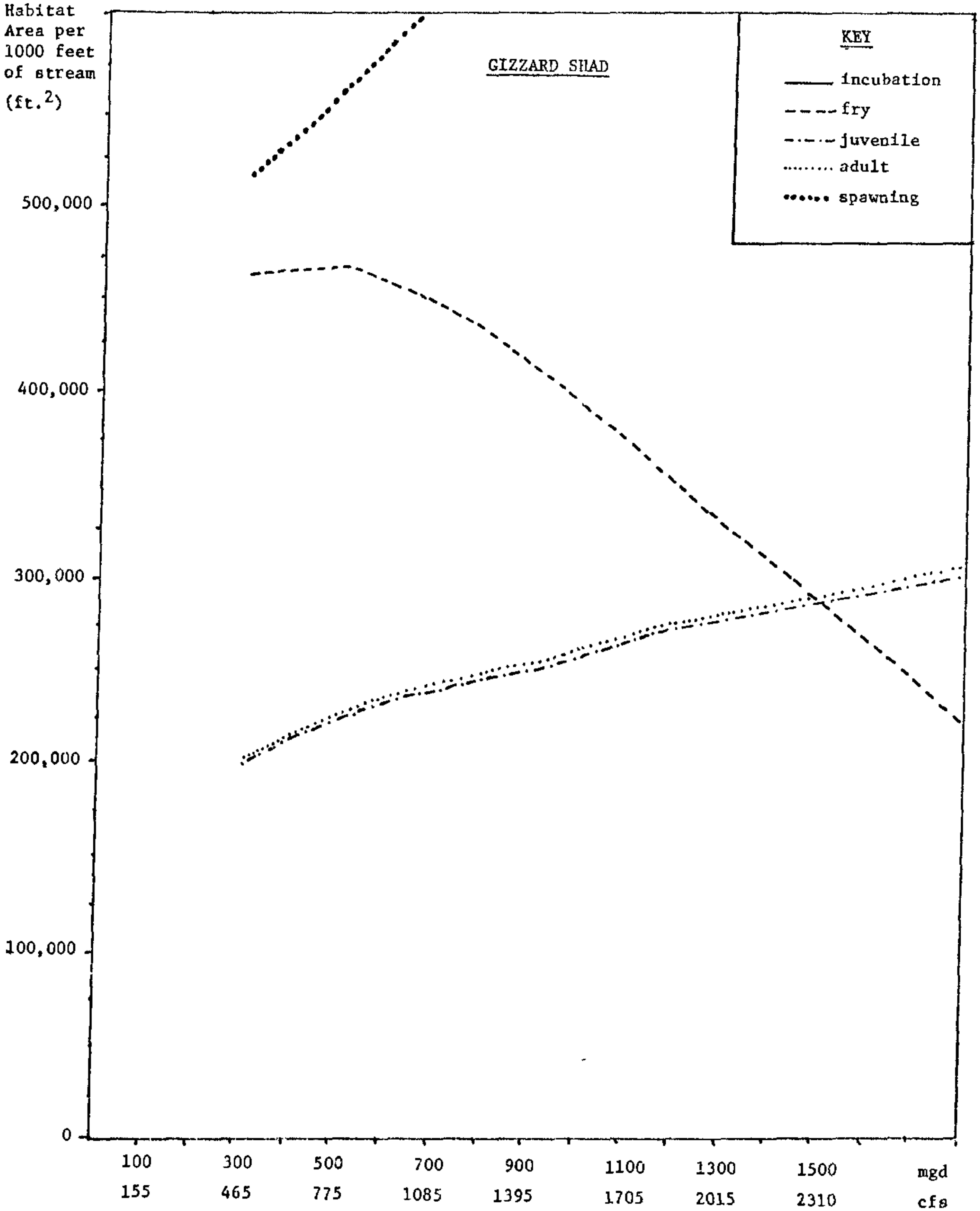


Figure 5-15 Gizzard Shad Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

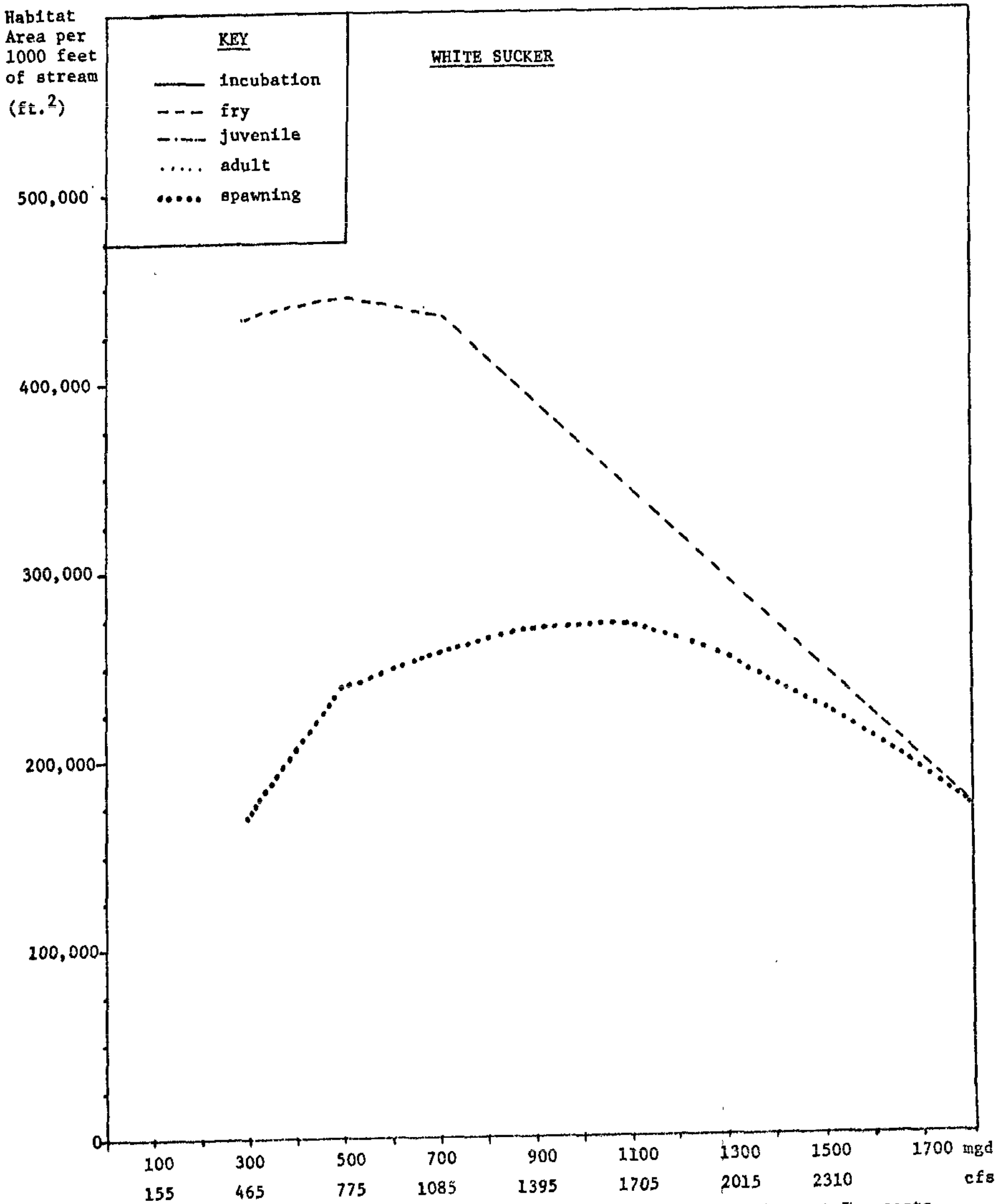


Figure 5-16 White Sucker Habitat Availability at Various River Flows at Transects 8 and 9. Run and Riffle Areas above Little Falls Dam.

The IFG model results demonstrate that low flows can have either a positive or negative effect on the fishery depending upon the species involved, its life stage and its location in the river. As indicated in the preceding discussion, some important negative effects of low flow below Little Falls dam occur at the same time as corresponding improvements in habitat above the dam.

The occurrence of greatest concern in relation to low flow is the decline in ideal habitat availability for juvenile smallmouth bass in a small area below Little Falls dam and for juvenile channel catfish in the runs and riffles above the dam. As previously stated, declines in juvenile smallmouth bass habitat availability in a 22 acre area below the dam containing approximately 3,500 juveniles is more than offset by low flow related increases in substantially better juvenile habitat availability above the dam. Channel catfish numbers above the dam are not expected to decline significantly in the face of ideal habitat loss at low flows of historical duration because of the hardiness and durability of the species.

B. Effects on Macroinvertebrates

The macroinvertebrate population of 1980 reported by Allison for the study area was diverse and abundant indicating a history of recent acceptable flows and water quality. The discharge at the time of collection of microbiota was about 2550 mgd referenced to the Little Falls gaging station. The macroinvertebrates are largely responsible for the existing fast growth rate of the fish population, particularly those centrarchids up to three years old.

Based on analysis of primary data collected, estimates of the effects of low flows on the macroinvertebrate community are as follows:

At flows down to 500 mgd the macroinvertebrate community should be able to sustain a viable population of most species for at least two to three months in the remaining fluvial areas.

At flows below 500 mgd down to 100 mgd, the macroinvertebrate population would be increasingly stressed from a habitat in which the volume, depth and area are progressively reduced. Siltation effects would also increase (see page 124).

At a flow of 100 mgd, the population as a whole would be severely stressed with survival of one month or less depending upon the location, species, and fluvial areas remaining. However, flows of such duration are historically unprecedented.

C. Effects on Wildlife

Water oriented wildlife may be placed in one of three categories: 1) those which are almost totally aquatic, 2) those which are partially aquatic and 3) those which are secondarily dependent on the aquatic habitat. Water oriented wildlife generally will be negatively impacted by long term low flows. Short term low flows can have positive and negative impacts depending upon the species and duration of the low flow. Recovery of all animal populations would be largely dependent upon restoration of higher flows or mitigation of extreme low flows. Reduced animal populations in the Potomac Valley and River, which still retains a diverse natural ecosystem, would translate into a loss of recreational and aesthic value for many people.

Aquatic Animals

Several effects upon aquatic populations can be expected from increasing the frequency of low river flows within the study area. First, habitat dimensions of depth, width and certain substrates would be reduced according to the magnitude of reduction of flows. It is not presently predictable what the effects of this reduced habitat size would have on existing population numbers except for short term crowding until river levels rose. During the times of reduced habitat, otter, beaver, and muskrat lodges would be more easily observed and accessible to man. Beaver and muskrat are more adaptable to the physical nearness and presence of man than otter. Except for excessive predation which might occur by man or disturbance or destruction of lodges, beaver and muskrat populations would likely not be eliminated or reduced beyond recovery.

River otter, in contrast to beaver and muskrat, are much more secretive and less adaptable to the presence of man and his disturbances. Thus improved access for man at low river flows combined with a reduced habitat would be expected to impact more severely on the otter population which is presently a small one. Otters are residents occasionally on the larger islands and along sections of the river banks which are infrequently visited by man. Otters are dependent upon the Potomac River's fish, crustacean and molluscan life. A reduction in seasonally low stream flows could initially make food organisms more easily available, and thus have a positive impact. However, unless flows are reestablished soon, food organisms would die and reduce total available food later. The long term effects of reduced populations of aquatic life upon which otters feed is difficult to predict without further study.

There are sizeable populations of mallard, black ducks and wood ducks between Little Falls and the upper end of Seneca Pool. In addition to being part of the local ecosystem, these ducks provide pleasure to bird watchers and game for hunters. Critical to perpetuation of the resident duck populations is successful nesting and survival of the ducklings to the flight stage after plumage has developed. Further reductions from the naturally occuring low river flows would further reduce critical habitat. Egg losses would likely increase from predation by animals such as raccoons, opossums, foxes, and snakes which are common to the study area. Ducklings would be more vulnerable to the above predators and to hawks and owls. The loss of riverine habitat would result in crowding of ducklings, loss of protective cover and easier availability to predators. Adult ducks would not be expected to be as adversely affected as ducklings since they could fly to other locations where foods are available. However, if adults were forced to abandon either nests or pre-flight ducklings, duck reproduction could fall to a level which would not sustain the local population.

Aquatic turtles in the study area include the snapping, spotted, painted and red bellied varieties. Female snapping turtles are known to leave the water body they inhabitat to deposit the fertilized eggs on land above the river, selecting a moist sandy or soft soil site where the eggs may be buried or covered. Further flow reductions during the summer can be expected to diminish reproductive success and to further reduce the aquatic habitat for these reptiles.

The northern watersnake is common throughout the study area frequenting both the water and shoreline. Foods of the northern watersnake are small fish, aquatic insects, terrestrial insects, and frogs. The impact of further low flow reductions in summer and autumn would be to reduce the food supply upon which it depends.

<u>Partially Aquatic Animals</u>
Ringtailed raccoon

Raccoons are water loving animals. They are strong swimmers and agile climbers. They usually find a den in a hollow of a large sycamore or other tree near the bank of the Potomac. Raccoons are common residents on the larger and vegetated islands within the study area. They depend upon the river environment for much of their food. Fish, frogs, salamanders, crayfish, fresh water mussels are prominent items in their diet. They also depend upon seeds and fruits of shoreline plants in season. A reduced river flow might make the aquatic life left in some stranded shallow pools more readily available to adult raccoons, and in late summer and autumn also to young raccoons of the family. Quite frequently the foot prints of raccoons are observable around isolated pools. Remnants of food organisms are often left along the pool bank as further evidence of their nocturnal forays.

Because raccoons are largely nocturnal in feeding and movement and are highly adaptable to the presence of man it is hardly likely that the population within the study area will be severly reduced as a result of increasing the frequency of lower river flows.

Birds

Increasing the frequency of low flows during summer will result in loss of shallow water feeding areas for great blue and green herons. Less productive, formerly deeper areas would then become available as water levels decline. Most of the food organisms that herons depend upon are found on the shallow wadable flats which will then be exposed and dry. Some remaining shallow pools should produce limited quantities of food organisms but food will decline as the low flow period continues. As the river level continues to drop, water will remain only in the unusable deeper channels. Repeated extreme low flows would have a negative effect upon the population.

The pied billed grebe, goldeneye and mergansers are migratory water fowl that visit to the study area during the colder months from September to May. They are less likely to be adversely affected than resident birds by low flows because they nest to the north of Maryland.

The bald eagle and osprey, while formerly common to the study area, now are uncommon. Both species prefer large dead trees for nesting sites. The osprey population in Maryland has been increasing in numbers the last five years. Except for conditions where only 25% or less of the river habitat remained, it is not clear the degree to which future reduced flows could affect the bald eagle and osprey populations Both of these water dependent birds of prey are habitually found on the larger rivers and estuaries of the Chesapeake Bay. They are seldom observed nesting along the smaller fresh water rivers or streams of the Bay system. The marsh hawk and peregrine falcon are only rarely seen in the study area.

Amphibians

Although associated with the riverine environment, amphibians depend more on high spring flows which fill and sometimes overflow the near-shore ponds and river backwaters. Later in spring and summer these waters become isolated from the main river. A reduced summer flow should have no serious consequences on most of these species, except for the occasional amphibian who would be a visitor to the shoreline of the river proper. There it would be more likely to predation by snakes and herons.

Secondarily Dependent Animals

Secondarily dependent animals are defined as those animals who frequently utilize the river edge habitat for cover, food, travel and refuge. Included in this group are white-tail deer, red fox and gray fox. They are only partially dependent upon the river for drinking water and not totally dependent upon it for food or reproduction. These animals, while presently utilizing the river-land interface corridor, could exist to nearly the same degree despite a major protracted low river flow.

Evaluation Procedure

The basic requirements of water oriented wildlife species are food, cover and water. How well an area supplies these requirements can be indexed through interpretation of three major factors: (1) quantity of land-water use remaining, (2) interspersion or undulation of the boundary between land and water, and (3) the quantity of interdependent land-water uses available. While it is recognized that habitat components differ somewhat for each water oriented wildlife species, the importance of each of the three major factors listed above has been quantified as a weight in the evaluation procedure. The relative value of each habitat condition or type of vegitation, and the magnitude of weights is only indirectly available from the literature on most species. Ultimately the assignment of weights must be derived from the experience and knowledge of wildlife biologists and others familiar with the habitat under study and with the species involved.

The degree of disturbance to wildlife by man is an additional factor which affects the ability of the habitat to sustain wildlife. This factor was recognized and weighted in the development of instream flow requirements.

The study area is now heavily used for recreation in both the land and aquatic habitats. Predictions of human population increase in the adjoining counties and states, combined with predictions of increased visitations in the future to the residual "natural" environmental corridor formed by the river and its adjacent lands, weighed heavily in the assessment of likely behavioral impacts and changes upon wildlife populations. As an example of wildlife behavioral impacts caused by man; consider two closely related duck species within the study zone--the black duck and the mallard. The black duck is truly wild, exceedingly alert and wary of human presence. It avoids the presence of man even to the exent of abandoning an area if too frequently disturbed. On the other hand, mallard ducks quite easily adapt to man's presence. They frequently visit parks where they look for handouts of food from visitors.

D. Effects on Recreation

The most popular forms of water-oriented recreation on the study segment of the Potomac River are fishing, canoeing, kayaking, hunting, aesthetic viewing, swimming, water skiing, and power boating, all of which are affected to some extent by low flows. The effects of low flows on each activity are described below.

Fishing: The best fishing areas in the Potomac River are pools, riffles and multiple island habitats. As flow decreases, riffles and parts of the multiple island habitats may become dewatered, thus trapping fish in isolated pools where fishing success may initially improve. After about a week of low river flow, pools tend to heat up and become stagnant, dissolved oxygen levels decrease, water quality deteriorates, food becomes scarce and, as a result, the fish begin to die and angling success declines.

Bank fishing and small boat fishing are both potentially affected by low flows. Small boat fishing is more readily impacted because a minimum amount of water is required for navigation. A small motorized boat requires a water depth of 2.5 feet and a small non-power boat requires about 0.5 feet of water (Interagency Task Force, 1979). Most motorized boat fishing is done in Seneca Pool where only an unusually low flows of exceptional duration would have a detrimental effect on the sport. At river flows below 700 mgd it becomes difficult to navigate small non-power boats on most of the river between Seneca and Little Falls. Small boat fishing is still possible in isolated pools, but navigation between pools is difficult.

Low flow impacts on bank fishing are minimal because access to fishing spots is not limited by low flow. In an unusually low flow of sufficient duration, fishing areas could become aesthetically unpleasant, poor water quality could kill the fish, and some fishing areas could totally dry up.

As river flow decreases, each part of the river will be affected differently. Riffles, the most quickly impacted areas, are easily dewatered and become unnavigable to the small boat fisherman. Portions of multiple island areas quickly dewater leaving small isolated pools in which bank fishing is possible as long as it is aesthetically pleasing and the fish survive. If there is good access to the river, it may be possible to get small boats into these isolated pools but navigation between the pools may be poor. Least impacted are large pools like Seneca Pool. Both bank fishing and small boat fishing are possible during all but the most severe low flows in these areas.

Canoeing and Kayaking: Flat water canoeing, and white water canoeing and kayaking are popular activities in most parts of the Potomac River study area. Pools are used for flat water canoeing, whereas areas with sufficient flow to produce rough surface conditions, such as stretches near Carderock, are popular for white water canoeing and kayaking.

Both kayaks and canoes require a passage channel with a minimum depth of about 0.5 feet (Interagency Task Force, 1979). During most low flows, pool areas which tend to be the areas of least impact, remain usable for flat water canoeing--although an exceptionally low flow of long duration could render these pools aesthetically unpleasant because of deteriorating water quality. Very low flows may dewater riffles, leaving them impassable to all boating. As flows decrease, some stretches that are usable for white water canoeing and kayaking remain, but at exceptionally low flows the size and number of stretches become greatly reduced. When the gage of Little Falls measures less than 2.7 feet (700 mgd at Little Falls) the bulk of the study area becomes unusable for canoeing and kayaking. Best canoeing/kayaking conditions usually occur at gauge heights from 3.5 to 4.5 feet (2,000 to 3,000 mgd), (Gertler, 1981).

Hunting and Trapping: Most hunting and trapping within the study area takes place at the McKee-Beshers Wildlife Management area. Hunting and trapping also occur on the river proper and on some of the river's numerous islands. Small boats provide a major means of access for these activities so that hunting and trapping on the river might be inhibited if river flow becomes too low for navigation. Small boat navigation becomes difficult in much of the study area (except at Seneca and other large pools) at flows below 700 mgd.

Low river flows can also increase competition and predation among those animals which are dependent or semi-dependent on the riverine environment. These include some fur bearing animals, such as muskrat, beaver, mink and river otter and locally breeding water fowl. The stress induced on these populations by low flows over an extended period of time may reduce their numbers and consequently adversely effect hunting and trapping. However, the majority of game and fur bearing animals are not particularly dependent on the aquatic environment and thus a long period of essentially zero river flow would be necessary to significantly reduce their numbers.

Aesthetics: The study portion of the Potomac River is one of the most scenic areas in the Washington Metropolitan Region. The aesthetic quality of the river will be negatively impacted when river flow is reduced below the level at which large areas of river bed are exposed and stagnant pools become numerous.

Swimming, Power boating and Water Skiing: Swimming, power boating and water skiing occur almost exclusively in Seneca Pool because they require deeper water than most other forms of recreation on the Potomac River. Swimming and power boating both require a minimum depth of water of 2.5 feet and water skiing requires water about 5 feet deep (Interagency Task Force, 1979). Most low flows have little impact on recreational activities in Seneca Pool but, an unusually low flow of sufficient duration could cause water quality in the pool to deteriorate and thus make recreational activity there unpleasant.

E. Effect on the C & O Canal

The C & O Canal has 2 intake sites along the study portion of the Potomac River. The feeder dam at Violets Lock supplies the canal with water down to Lock 5, at Little Falls dam, where additional water is added to supply the canal down to the Georgetown area. The average water use of the canal is unknown, but in 1975, the U.S. Geological Survey conducted flow tests at Lock 5 that indicated a standard (preferred) flow of 42 mgd (Sipes, 1981). It has been estimated (Foster, 1981) that 25-30 mgd is the standard inflow at Violets Lock, although no flow tests have been made.

Water level in the C & O Canal is monitored and maintained on a daily basis. Ideally, the water level should be 2 feet below the top of the tow path. If the water level drops below the 2 foot mark, action is immediately taken to control and contain the canal water. As Potomac River flow decreases, less water is available to the feeder canals. Actions are first taken to clear the feeder canals of debris in order to allow entrance of as much water as possible. If flow becomes low enough (estimated to be about 100 mgd flowing over Little Falls dam), water level is controlled and contained by slowing "outflow" at the canal's waste weirs. The weirs are closed, thus retarding the flow of water from the canal to the river. Some water is lost to seepage and evaporation, but sufficient water is available to maintain acceptable water levels (Foster, 1981).

Exceptionally low river flows, could potentially adversely affect the Canal's historical structures, recreational activities and local aesthetics. These effects are discussed below.

Historical structures: The Canal's historical structures, such as the wooden locks, gates and weirs, deteriorate quickly if exposed to air or to repeated wetting and drying (Young, 1981). In past years, efforts to control water level in the canal have been sufficient to preserve the structures (Foster, 1981). A drought of sufficient duration (estimated to be a month or more) could dewater the canal and expose the structures.

Recreational activities: The most popular recreational activities on the canal are canoeing, clipper rides at Great Falls and fishing. In previous years, canoeing and clipper rides in the canal have not been affected by low river flows because of efforts to control and contain canal water level by park service personnel (Foster, 1981). In the process of maintaining the water level, circulation and dissolved oxygen are decreased. After prolonged periods (estimated to be a week or more), the canal fish begin to die and fishing becomes more difficult (Sipes, 1981). If the canal becomes totally dewatered as the result of a sustained low river flow (estimated to be a month or longer), all three of the above recreational activities would cease. Non-water oriented canal activities such as bicycling, walking, and running are not adversely affected by Potomac River low-flows.

Aesthetics: During prolonged low flow periods (greater than a week in duration), water may become stagnant and, as a result, aestheticly unappealing. Should the canal become totally dewatered, it would probably be less appealing to the history and canal enthusiasts.

During periods of high and medium river flow, only approximately one mgd of water is returned to the Potomac at the canal's terminus in the estuary near Georgetown. Virtually no water enters the estuary from the canal during periods of low river flow. Most of the 20 to 30 mgd entering the canal at Violets Lock, plus the water added at Little Falls Dam, is lost through seepage, evaporation and the canals waste weirs (Sipes, 1981).

Since the C & O Canal was rewatered in the 1930's, it has never been damaged or incapacitated by low flow of the Potomac River. In previous years, including the unusually low flow of 1966, sufficient water level in the canal has been maintained to preserve its historic structures and recreational activities. The potential exists that a low flow of sufficient magnitude and duration could damage the historical structures and inhibit recreational activities in the canal.

F. Effects on Water Quality

1. Bacteria

Bacterial water quality in the fluvial river is a result of discharges from point sources, agricultural runoff, and urban storm water runoff. Recent bacterial information for the years 1978-1979 has been compiled by Rasin, Brooks and Flynn (1980) in Interstate Commission on the Potomac River Basin (ICPRB) Technical Publication 80-1.

Characteristically, coliform and fecal coliform bacteria counts rise as a result of flushing from the land and overflow of some waste treatment facilities following storms. At low stable flows below 1100 MGD with an extended period of several weeks to a month with little rainfall, coliform and fecal coliform bacterial levels in the fluvial portion of the offshore river tend to decrease. The ICPRB has characterized bacteria as a limit to water quality at Whites Ferry upstream of the study area, at Goose Creek, a Virginia tributary to the upper end of Seneca Pool, at Seneca Creek (MD) at River Road, at Cabin John Creek at Mar Arthur Boulevard, and the Potomac at Little Falls Dam.

Low river flows of themselves are not a cause of bacterial pollution.

2. Dissolved Oxygen

Dissolved oxygen was measured within the study area on July 23 and July 25, 1980 (See figure 5-17 for station locations). The flow recorded at Little Falls was 2520 mgd on July 23, and 2560 mgd on July 25. Depths sampled varied from the surface to 35 feet. Water temperatures ranged from 28.5°C at the surface to 23.0°C at the bottom. Thirty-two (32) of the samples analyzed exceeded the D.O. standard of 5.0 ppm. Five (5) of the samples did not meet the standard. The samples which did not meet the D.O. standard were collected from slack water areas of the river and were from below the surface (See Table 5-2).

At flows below 2500 mgd with typical summer water temperatures, dissolved oxygen will continue to decline in slack water areas. The proportion of slack water to fluvial areas will increase. At 300 mgd it is estimated that dissolved oxygen levels in much of the study area will become marginal for support of some species of aquatic life. At flows approaching 100 mgd only short time survival can be expected for some species.

During the summer drought of 1966 with flows of about 119 mgd (185 cfs) recorded at Little Falls, dead and dying fish were observed within the study area. These fish, principally red horse and white suckers and channel catfish succumbed to the combined stress of high water temperatures and low dissolved oyxgen. It was observed that many species of fish exhibited unusual behavior by crowding into riffle areas even during daylight hours when normally they would be under the shaded cover of trees which line the bank. There was a noticeable increase in the number of diseased and moribund fish. However, no long term impact on fish populations is believed to have occurred as a result of the 1966 drought (See tables 5-2 and 5-3 for water temperature and dissolved oxygen data collected in the study portion of the river).

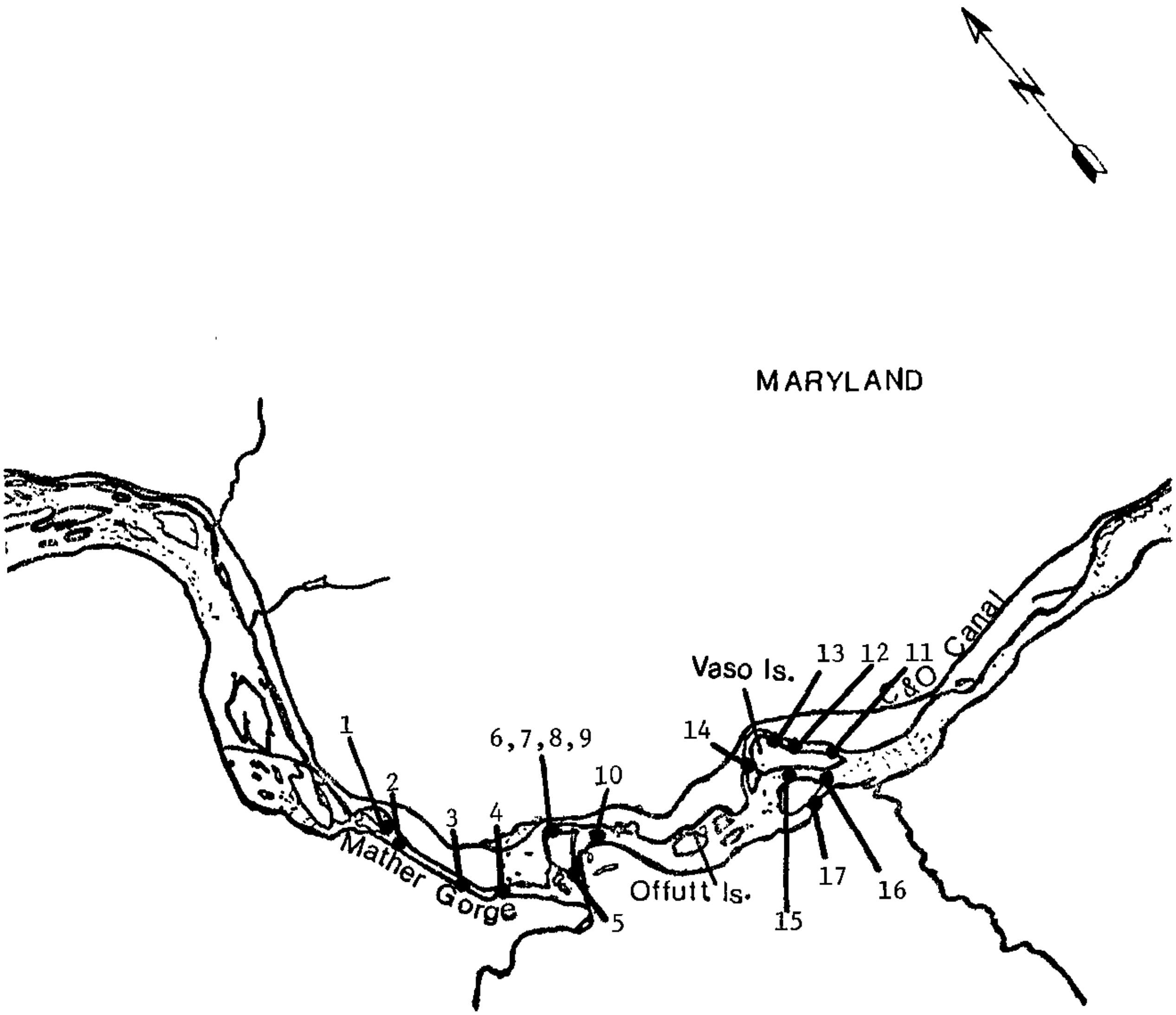


Figure 5-17 Locations of Water Temperature and Dissolved Oxygen Stations, 1980.

Table 5-2

WATER TEMPERATURE - DISSOLVED OXYGEN

Great Falls to Cropely (Anglers Inn)

July 23, 1980 (1:00 pm. to 3:30 p.m. EDT)*

Station Number	Depth Feet	Water Temp °C	Dissolved Oxygen ppm	Current or Slack
1	Surface	28.0	7.5	Current
	4.0 (bottom)	28.0	6.5	Current
2	Surface	28.5	8.0	Slight/Current
	27 (bottom)	28.0	6.8	Slight/Current
3	Surface	28.0	6.6	Slack
	3.5 (bottom)	28.0	5.5	Va. Side
4	Surface	28.2	7.1	Slack
	5.0 (bottom)	28.2	6.8	Md. Side
5	Surface	28.0	7.5	Strong current
	35.0 (bottom)	28.0	6.5	middle of river Upper Cropely Depth Velocity Transect
6	Surface	28.0	6.6	Slack just inside
	5.0 (bottom)	27.0	4.2	entrance to backwater on Md. side upstream of boat landing
7	Surface	28.0	7.6	Slack middle of Cove
	2 (bottom)	27.5	6.0	lower 1/3 of back water
8	Surface	28	7.0	Slack off rockey point,
	5	-	4.6	Md. side
	10 (bottom)	23.0	N/A	
9	Surface	28.0	6.8	Slack 50 feet upstream
	5	-	4.8	of station 8
	10 (bottom)	23.0	3.5	
10	Surface	28.0	8.0	Slack just outside
	7.5 (bottom)	28.0	5.8	mouth of backwater

*Flow at Little Falls 2520 MDG on July 23, 1980

Table 5-3

WATER TEMPERATURE - DISSOLVED OXYGEN

Above Carderock Rapids

July 25, 1980 (10:00 a.m. to 12:00 p.m.)*

Station Number	Depth Feet	Water Temp °C	Dissolved Oxygen ppm	Current or Slack
11	Surface 10 (bottom)	28.0 27.5	7.7 7.6	Slack R fork of river MD side 1/4 mile above transect
12	Surface 3 (bottom)	27.9 27.9	7.8 7.8	Current - Riffle at head of pool above
13	Surface 4 (bottom)	27.5 27.5	7.8 7.8	Slight current pool above Riffle
14	Surface 4 (bottom)	27.7 27.7	7.7 7.7	Slight current Pool between Herzog & Vaso Island
15	Surface 5 (bottom)	28.0 28.0	7.8 7.7	Current Bottom of Riffl[illegible] between Vaso & Turkey Islands
16	Surface 10 (bottom)	27.8 27.5	7.8 7.9	Slight current between lower end of Turkey Island and Vaso Island
17	Surface 15 (bottom) 30	27.6 27.5 27.0	7.6 7.2 7.6	Slack Backwater below yellow falls between Turkey Island and Virginia shore.

*See map - for station locations.

Flow at Little Falls 2560 MGD on July 25, 1980

3. Sedimentation

The total impact of various low flows and resulting depths upon river sedimentation remains to be documented by further on site study and by modeling. However, some general conclusions from this study are obvious. As flows decrease in velocity from drought, sedimentation will occur over a larger portion of the remaining study area. Stretches of the river which once had flows scouring, suspending and transporting much of the finer sediments will become very slow moving (low velocity) or become stagnant pools with zero velocity. When this occurs a blanket of silt will precipitate upon the bottom. Bottom dwelling and bottom dependent organisms will be adversely affected. Macroinvertebrate and fish populations will be stressed. Figure 5-17 from the American Society of Civil Engineers (1975) publication <u>Sedimentation Engineering</u> shows critical water velocities for quartz sediment as a function of mean grain size.

The crews wading along the bottom of the transects during the study observed this occurrence many times near the shore lines and behind islands where velocities were reduced.

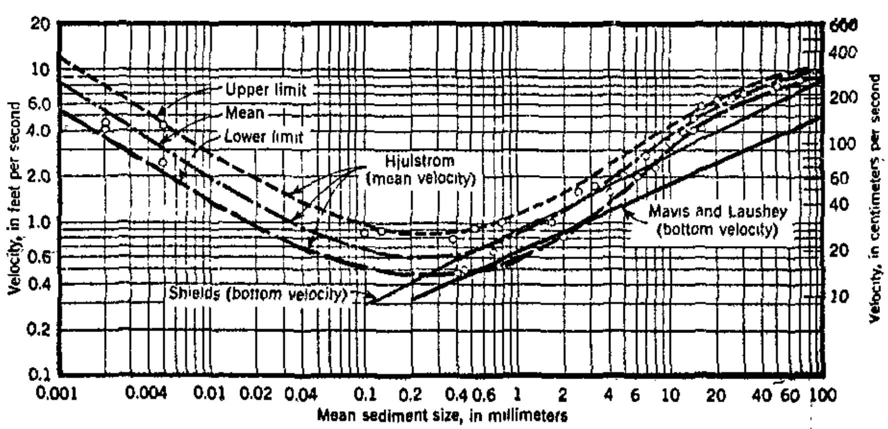


FIG.5-18 -Critical Water Velocities for Quartz Sediment as Function of Mean Grain Size

CHAPTER VI

EFFECTS OF VARIOUS LOW FLOWS ON THE UPPER POTOMAC ESTUARY

VI. Effects of Various Low Flows on the Upper Potomac Estuary

A. Description of the Potomac Estuary

The estuarine portion of the Potomac River extends 114 miles (108 nautical miles) from Little Falls, near Chain Bridge to the Chesapeake Bay. The Potomac Estuary is relatively shallow averaging 18 feet in depth (Champ, 1978).

This area is dominated by two major hydrodynamic features, the reversal of flow due to the tides and the associated change in water level. These two factors, as well as distribution of saline waters, are modified by the level of discharge from the fresh water portion of the river. Proceeding downstream from Chain Bridge, river discharge over Little Falls becomes a smaller part of total water movement. At mean discharge (7,358 mgd), tidal movement exceeds river drainage at a point 12 miles below Chain Bridge. As discharge from the free flowing portion of the river decreases, the extent of the tidal influence increases. The upper 30 miles of the Potomac Estuary is essentially a dynamic fresh water lake. From Indian Head to the Chesapeake Bay, the water becomes increasingly salty (Champ, 1978). In a partially mixed estuary such as the Potomac, non-tidal circulation resulting from the fresh water-saline water interaction is also significant.

The portion of the estuary of principal concern in this report extends from Little Falls to Rock Creek a distance of about 4.5 miles (see figure 3-2). Even though the water in this zone is relatively fresh, the habitat is much different from that of the free flowing part of the river. Some of the life forms in the upper estuary are described below:

Fish: Several anadromous and resident species, such as bass, perch, catfish, shad, alewife and herring, utilize the upper estuary at some stage of their life cycle. It is an important spawning area and is a preferred nursery for many species that feed on the abundant phytoplankton population. Striped bass, *Morone saxatilis*, according to Merriner (1976), migrate into Chesapeake Bay from the ocean, ascend the Potomac and spawn in tidal freshwater. Mainstream spawning occurs in the area from Hallowing Point to Sandy Point with some fish traveling all the way to Little Falls.

Net sampling for spawning fish of all species in the area from Little Falls or Great Falls downstream to the mouth of Rock Creek in Washington D.C. is particularly difficult in spring and early summer because the bottom has many rocks and boulders. There is much floating and submerged debris and strong fluvial currents that frequently prohibit the setting of fishing nets for collecting samples for population analysis. However, the considerable recreational fishery which takes place in that reach of the study area between Little Falls and Rock Creek during March, April, May and June reveals sizeable catches of white perch, Morone Americana; herrings, Alosa aestivalis and Alosa pseudoharengus; with smaller catches in numbers of striped bass, American shad, Alosa sapidissima; and hickory shad, Alosa mediocris (Sanderson, 1981). These anadramous species are on the annual run to their spawning grounds. Some fish caught are in prespawning condition, some are active spawners and a few have finished spawning. During the years since 1970 there has been a fluctuation in the recreational catch of striped bass, American shad and hickory shad in the area just downstream of Little Falls. A noticeable concurrent fluctuation in the catch of herrings has also occurred.

Strictly freshwater species found in the upper estuary are generally late-spring to early summer spawners with extended or multiple spawning periods. The anadramous and semianadramous species, American shad, hickory shad, alewife, blueback herring, striped bass, white perch, yellow perch, and gizzard shad have all been identified during the spawning season of spring and/or early summer in the upper estuary past the District of Columbia to the vicinity of Little Falls. The head of the estuary is essentially a "fresh water lake." Occasional catches of striped bass and white perch have been observed in the vicinity of Cropely about 1 mile below Great Falls. The only obstruction to migratory spawning fish from the estuary moving upstream into the fluvial river is Little Falls dam constructed by the Corps of Engineers to provide part of the water supply for the Washington Metropolitan area. The fishway in the Little Falls dam at Snake Island has not been maintained and some minor modifications are needed to facilitate passage of fish (Dietemann and Sanderson, 1978, Dalley, 1980).

In the past five years (1975 - 1980) there has been a resurgence in sportfishing for freshwater species in the upper estuary from Piscataway Creek upstream to Little Falls. Largemouth black bass, chain pickerel, black and white crappies, channel catfish, yellow perch, and several species of sunfish form most of the catch. The resurgence of fishing is associated with changes in fish species sought due to the decline of shad and striped bass in the upper estuary, to less costly travel expenses for the nearby residents who formerly were able to travel farther afield and improved water quality in recent years. The sport fishery is conducted from the bank and from boats.

Benthic Invertebrates: The fresh water environment of the upper estuary is not suitable for commercially important shellfish. Since the water is continually fresh (not a transition zone) only a few species can survive. Their populations are also limited because of occasional organic pollution and low dissolved oxygen levels in or near the sediment. Algal blooms also cause a decrease in population (Lippson et al, 1979).

Zooplankton: Zooplankton are a very important group of organisms in an estuarine environment because they provide a major food source for other organisms, especially larval fish. Estuaries, such as the Potomac, have nutrients to support denser zooplankton populations than oceanic habitats, however, relatively fewer species have been able to adapt to the rigorous estuarine habitat (Lippson et al, 1979).

Primary Production: Tidal fresh water regions, such as the Upper Potomac Estuary, have high nutrient levels. Primary production flourishes in such an environment. Fresh water algal species (phytoplankton), such as blue-green algae, proliferate during spring, summer and early fall and diatoms are prolific during late fall and winter (Lippson et al, 1979).

The quality and quantity of life in the Upper Potomac Estuary is directly related to its water quality. Water quality depends on the interaction of carbon, nitrogen, phosphorus, dissolved oxygen (D.O.) and phytoplankton. Concentrations are a function of sedimentation, waste water loading, temperature, fresh water inflow, tidal flow and biologic activity (U.S. Army Corps of Engineers, 1978).

Water quality is generally acceptable in the upper estuary, but it decreases from Chain Bridge downstream to Rock Creek. The primary water quality problem is excessive enrichment with organic material, and phosphorus. Concentrations of nitrogen and phosphorus are lowest during high flows that occur from February to April when temperatures and algal blooms are low. Concentrations increase during the lower flow periods in July, August and September when temperatures are high and algal blooms are more prolific (Jaworski, et al, 1972). The average range of summer conditions are as follows:

pH = 7.5 - 8.0
total phosphorus = 0.05 - 0.10 mg/l
$NO_2 + NO_3$ = 0.1 - 1.0 mg/l (flow related)
NH_3 = 0.0 - 0.10 mg/l
BOD_5 = 2.0 - 4.0 mg/l

The effects of various low flows below Little Falls on dissolved oxygen (D.O.), salinity and water quality are discussed in the following sections.

B. Focus of the Flow-by Study in Relation to Water Quality in the Potomac Estuary

In response to questions concerning the focus of the flow-by study in relation to the Potomac Estuary, Mr. Daniel Sheer of the Interstate Commission on the Potomac River Basin, stated, in a letter to Thomas C. Andrews, Director, Maryland Water Resources Administration, the following:

> The easiest analysis to do is one that overestimates the impact of flow-by on the water quality of the tidal Potomac. Simply assume the tidal Potomac is a lake where the volume is equal to the volume of the estuary from Little Falls downstream to the point of interest. Further, assume that all the flow over Little Falls into the tidal Potomac is distilled water. This ignores significant and, in fact, dominant impact of tide on water quality and the impact of pollutants brought in by the flow-by.
>
> During dry periods most pollutants enter the tidal Potomac with the effluent from the treatment plants. Assume that is about 350 million gallons a day. Pollutants leave the tidal Potomac (in this simplified analysis) one of two ways. The first is by transport downstream. Water entering the tidal Potomac equals the effluent flow plus the flow-by. This must also equal the water going out of the tidal Potomac. The total amount of pollutant transported out is simply equal to the flow times the concentration of the pollutant in the tidal Potomac.
>
> Pollutants are also removed by biological processes. In most of our models these processes are assumed to remove a certain percentage of the total pollutant in the estuary per day. That percentage is called the decay rate. For equilibrium (which is a worst case) what goes in equals what goes out. The following simple equation says this in mathematical terms.
>
> a) $P=(F+350)X + DVX$
>
> Where P in this equation is the total pollutant load per day to the estuary and X is the concentration of the pollutant in the estuary. F is the flow-by, V is the Volume of the estuary, and D is the decay rate.

Rearranging,

b) $$X = \frac{P}{F+350+DV}$$

Because we assumed that the water coming over Little Falls was distilled water, the amount of pollutant entering the tidal Potomac is fixed. Therefore we can use this equation to see how the concentration of a pollutant in the tidal Potomac would change with changing flow-by. I have done this for both BOD and nutrients.

For the BOD analysis it is appropriate to take the lower end of the fresh water portion of the tidal Potomac somewhere below Woodrow Wilson Bridge. Most of the impact of BOD will be felt upstream of this point. The volume of the tidal Potomac would then be about 20 billion gallons (EPA Annapolis Field Office Tech. Report #43 by Jaworski and Clark). An appropriate decay rate for BOD is about 25 percent per day according to EPA Annapolis Field Office Technical Report #35.

For these figures, DxV is the equivalent of 5,000 mgd. Therefore, the DxV term dominates the denominator in b). Decay is much, much more important in reducing pollutant concentrations than even substantial flow-by.

Figure 1 shows the percent reduction in BOD concentration as a function of the flow-by. Note that even for a flow-by as large as 500 million gallons a day the reduction is less than 10 percent. This is equivalent to changing the efficiency of BOD removal at the treatment plant from 90 percent ot 91 percent. Further, considering the impact of tide which causes ten times more water movement past Woodrow Wilson Bridge than the net downstream flow and the fact that the water coming over the Falls is not distilled water, I might expect to see a change in BOD concentration on the order of two or three percent, not ten. The corresponding change in DO would be even smaller.

To find an increase of two to five percent of BOD concentration in the estuary it would be necessary to measure in a statistically significant sense an increase of about a quarter mg/l. This is impossible given the natural variation of BOD levels in the tidal Potomac.

More important, at the levels of DO which will be maintained in the tidal Potomac, a fish won't be able to tell the difference either.

Turning our attention to nutrients, the analysis can be repeated. We must take the estuary at least down to Indian Head and probably further, before the full impact of the nutrients is apparent. The same plot of reduction in nutrient concentration versus flow-by is presented for the reach down to Indian Head with a volume of 90 billion gallons and the decay rate of three percent per day. The results are rather similar. In the real world you could not measure a difference due to flow-by. There is no reason to believe there would be any substantial impact on aquatic life.

Because of the relatively small magnitude of the expected changes, any study of the impact of flow-by on the tidal freshwater Potomac would be like trying to split hairs with a meat cleaver. Aquatic communities are just not sensitive to changes this small.

As the flow-by study clearly shows, changes in flow have a significant impact on habitat in the free-flowing Potomac. It is important to maximize this flow consistent with maintaining reliable water supply. In contrast, I believe the effect of changes in flow-by on the freshwater tidal Potomac will be small. Further studies of this issue are likely to be of little immediate value for water resources management."

C. Dissolved Oxygen

Stakhiv (1976), of the U.S. Army Corps of Engineers, used a computer model to examine the chemical and biological effects on the upper estuary, near Chain Bridge, that would be produced by low flows over Little Falls. He estimated the concentrations of dissolved oxygen (DO) that would result from 119 mgd flow over Little Falls, no flow over Little Falls and no flow over Little Falls plus 100 mgd withdrawal from the upper estuary.

As indicated in figure 6-1, a flow of approximately 119 mgd over Little Falls would produce a DO concentration of 6.0 ppm after 30 days. Stakhiv (1978) assumed a possible modeling error of 2 ppm, --thus the, true DO content may be as low as 4 ppm which does not meet the 5.0 ppm minumum average daily requirement that has been established for aquatic life by both Washington D.C. and Maryland.

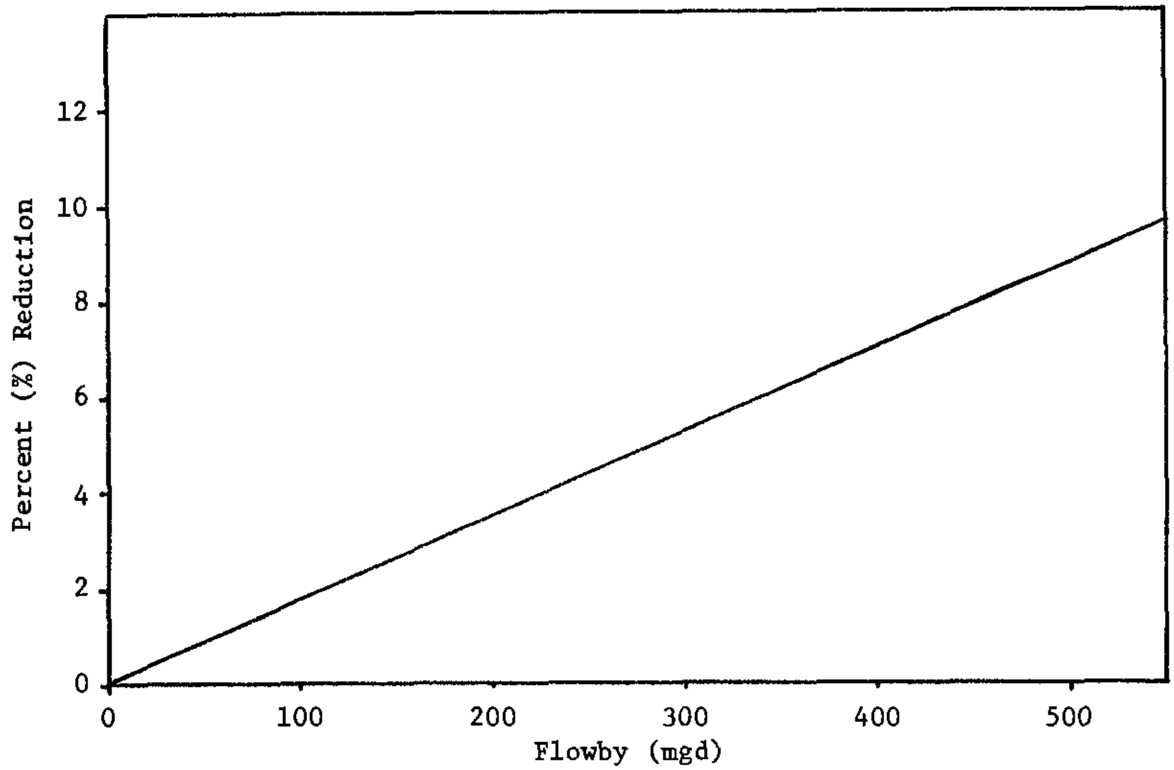


Figure 6-1 Upper Bound on BOD Concentration Reduction Vs Flowby

Note: In Figures 6-1 and 6-2, the estuary is treated as a lake with no tide and no pollutants in the flow-by.

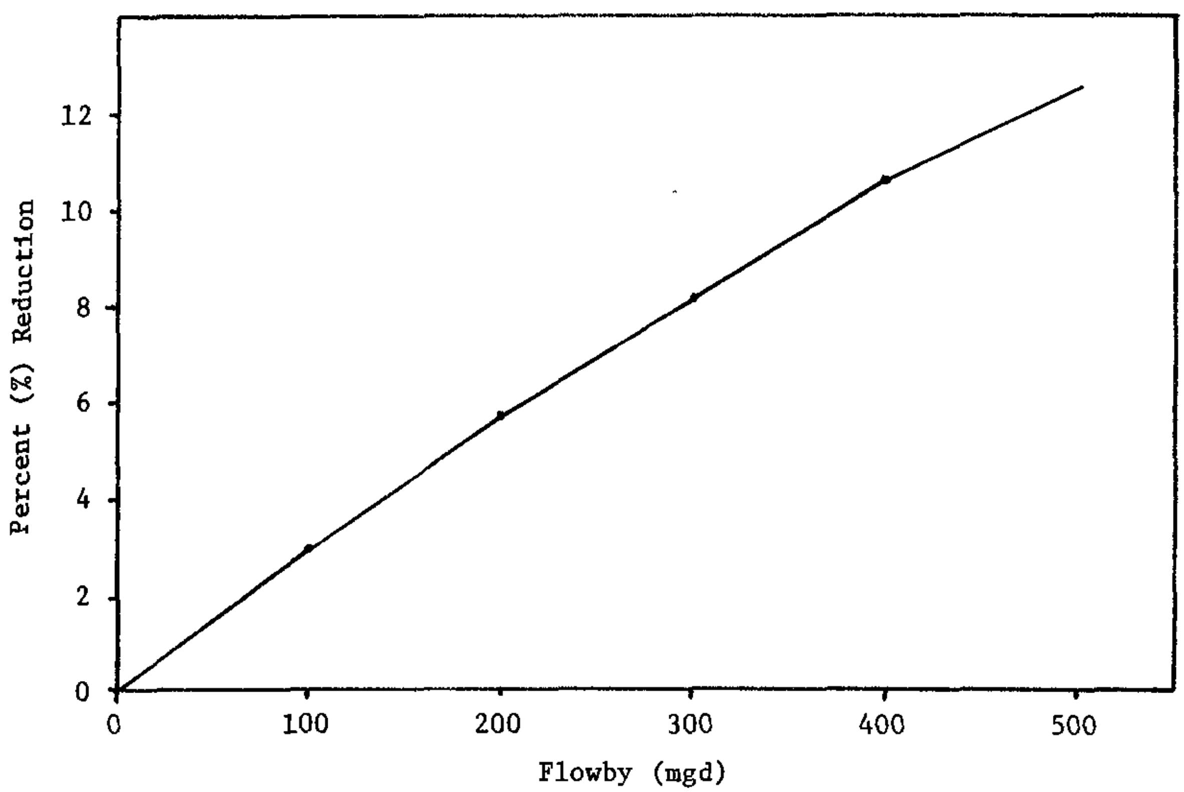


Figure 6-2 Upper Bound Nutrient Concentration Reduction Vs Flowby

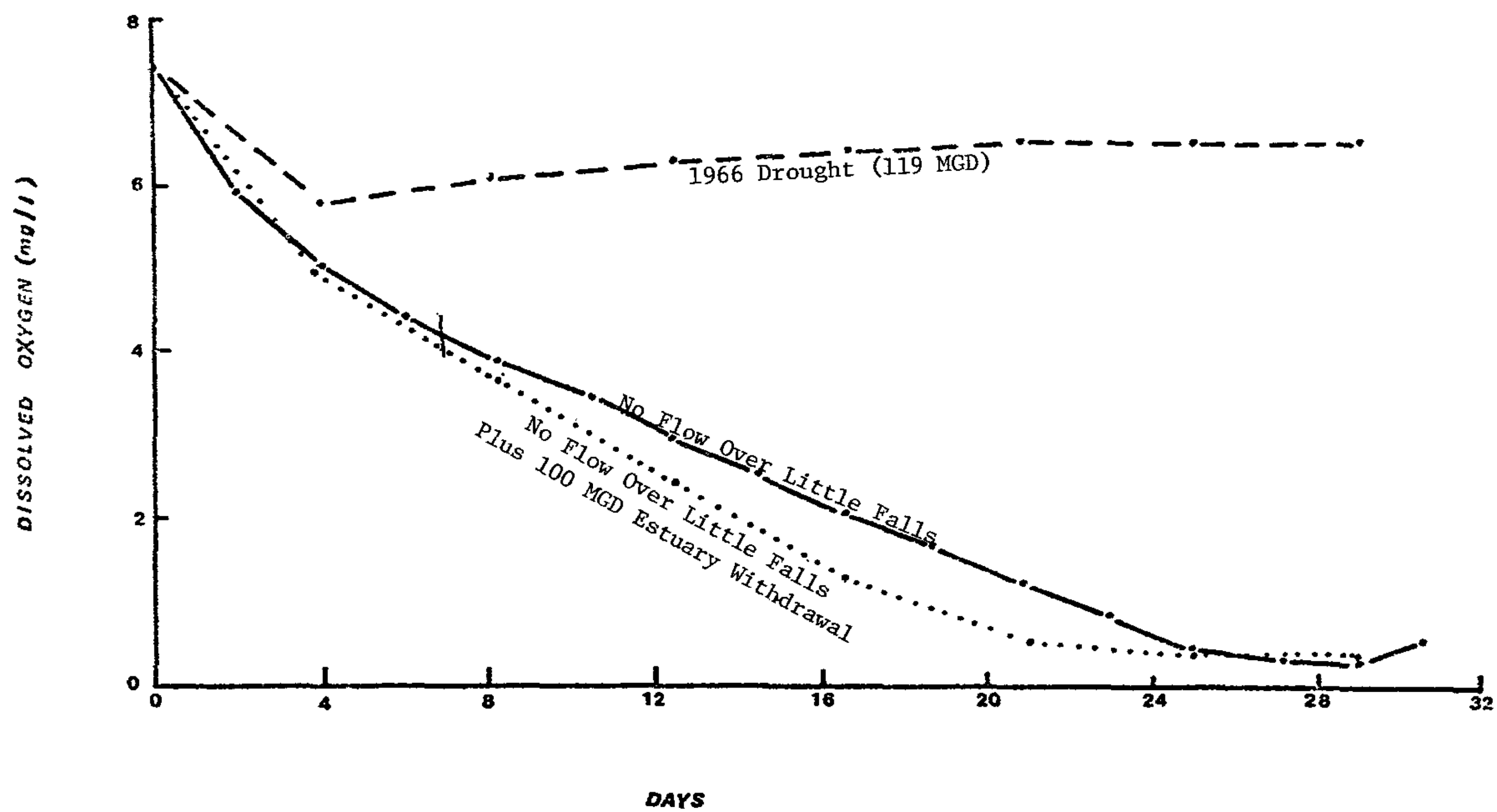


Figure 6-3 Low Flow Dissolved Oxygen vs Time

Stakhiv estimated that if there was no flow over Little Falls, DO would decrease to 5.0 ppm within 5 days, to 2.0 ppm within 18 days and approach zero ppm within 24 days. For conditions of no flow over Little Falls plus 100 mgd withdrawal from the upper estuary, DO concentration decrease somewhat more rapidly and may approach zero after 21 days. These two no flow situations combined with high summer water temperatures may produce unacceptable conditions for aquatic life.

D. Salinity

The U.S. Army Corps of Engineers has conducted a series of eight tests with the Chesapeake Bay Model to estimate the changes that might occur in upper salinity as a result of various low flows over Little Falls, sewage treatment plants discharge to the upper estuary and withdrawal from a possible permanent water supply intake. This intake would be located at the head of the upper estuary about 1,000 feet upstream from Chain Bridge.

In order to reproduce the correct salinities that would have occurred in nature prior to the drought conditions being tested, a weekly stepped hydrograph was introduced at each of the freshwater inflow points on the model prior to the start of each test. This hydrograph simulated the 19 weekly averaged flows that occurred from April 15, 1964 through August 19, 1964. After the last week of the hydrograph, it was assumed that the natural flow of the Potomac River would have decreased to a point such that in order to maintain a flow over Little Falls, the flow of the river would have to be controlled.

At this point in time, one of the series of test flows over Little Falls was introduced into the Potomac River and maintained at a constant rate for a 6 month sampling period. At the same time, simulation of the appropriate sewage treatment flows and water supply withdrawals was begun. During the testing period, flows in the remaining tributaries were maintaned at a level which simulated the August to October 1964 average.

Table 6-1 shows the test conditions for each of the eight tests conducted and the resultant salinities at Corps station PO-16-1, the nearest sampling station to Chain Bridge and Little Falls.

TABLE 6-1

Salinity at Washington Aqueduct Proposed Water Supply Intake at Various Low Flows Over Time (Summary of Preliminary Results from Chesapeake Bay Model Project U.S. Army Corps of Engineers)*

Test Number	Test Conditions			Bottom Salinity (Parts Per Thousand) near Chain Bridge at Various Fluvial Low Flows, after approximately							
	Potomac Flow (MGD) Over Little Falls	Sewage Treatment Flow (MGD)	Potomac Estuary Withdrawal (MGD)	2.5 months	3 months	3.5 months	4 months	4.5 months	5 months	5.5 months	6 months
03P04A	0	418	0	1		2		3		4	
03P05A	100	418	0			1			2	3	4
03P06A	500	418	0								
03P03A	900	418	0								
03P04B	0	705	0	1					2	3	
03P05B	100	705	0			1		2		3	
03P03B	900	705	0								
03P04C	0	705	100	1		2			3		4

*Corps Station PO 16 1

NOTE: Time is measured from start of test on 19 August 1964.

Based on an evaluation of preliminary data from the model, it was discovered that in the extreme upper estuary near Chain Bridge, at zero flow-by and a sewage treatment flow (STF) of 418 mgd, a bottom salinity of 1 ppt will occur after 2.5 months; 2 ppt at 3.5 months, 3 ppt at 4.5 months, and 4 ppt at 5.5 months. At a low flow of 100 mgd and 418 mgd STF, a salinity of 1 ppt will occur at 3.5 months; 2ppt at 5 months, and 4 ppt at 6 months. If the STF is increased to the project year 2020 output of 705 mgd the following salinity will result:

1 ppt at 3.5 months
2 ppt at 4.5 months
3 ppt at 5.5 months

At a fluvial flow of 500 mgd and above over Little Falls, salinity is zero or less than 1 ppt for at least 6 months.

CHAPTER VII

OTHER FACTORS THAT MAY AFFECT RECOMMENDATIONS OF FLOW-BY

VII. Other Factors that may affect Recommendations of Flow-by

A. Stream Flow Regulation

According to conclusions of ICPRB CO-OP, the filling of Bloomington Reservoir, will provide opportunities for improvement in fisheries habitat during extreme low flows occurring under natural conditions. Construction of Little Seneca Reservoir may further increase the opportunity to control flow-by on a daily basis without adversely affecting water supply.

ICPRB CO-OP maintains that together, these two facilities could regulate stream flow so that projected year 2000 water supply requirements are met and a minimum flow-by of over 300 mgd could be maintained. Alternatively, a higher flow-by could be maintained earlier in the year (e.g. 400-500 mgd in July and August) provided a lower flow-by (e.g. 200 mgd) was allowed in the fall. Such a sliding flow-by schedule would minimize the frequency of habitat reduction.

Runs of ICPRB CO-OP simulation models, analyzed in light of the results of the IFG metholology, indicate that flow regulation can increase the frequency of habitat availability in the river between the water supply intakes to levels higher than would occur in the absence of withdrawals.

As these facilities become operational, and as better management data becomes available, the flow-by could be adjusted upward in an effort to improve fisheries conditions consonant with maintaining other uses.

B. Waste Water Management

A long term strategy for wastewater management in the Washington Metro area has been developed by the Metropolitan Washington Council of Governments, Water Resources Planning Board (1980). The planning process established an important and continuing political and technical forum to evaluate present and future wastewater treatment needs. The plan has been adopted by each jurisdiction of the Washington area and a commitment has been made to work within that forum to resolve remaining or subsequent problems of providing adequate wastewater treatment.

Considerable progress has been made in resolving the few persistent capacity problems that remain. In addition to examination of treatment alternatives, alternatives will be evaluated through implementation of EPA's Potomac Strategy (U. S. Environmental Protection Agency, 1979). The long term strategy incorporates specific water resources studies that will also include the results of Water Resources Planning Board's (WRPB) regional nonpoint source investigations, the District of Columbia's Combined Sewer Overflow Study, and related estuary monitoring and modeling results. The integrated consideration of point, nonpoint, and combined sewer overflow impacts should identify cost effective means of wastewater management. The WRPB intends to use the Potomac Strategy investigations and Blue Plains Feasability Study to further assess wastewater treatment options and reach agreement on cost-effective plans for the Blue Plains service area.

The long term waste management strategy has and will contribute to minimizing the environmental and instream use impacts associated with low flows throughout the fluvial study area and into the upper estuary.

C. Restoration of Habitat and Natural Recovery of Biota

The Potomac River over the centuries has been exposed to both droughts and floods. Drought conditions (defined here as a flow equal to the seven day continuous low flow with a reoccurrence interval of once in ten years (Q 7-10) is a naturally occurring phenomenon to which most of the fauna and flora have adapted over time. This Q 7-10 with its related habitats dimensions of velocities, depths, areas and volumes for hydraulic reaches of the river is a predictable natural stress which limits the capacity of the river to provide for aquatic life.

Most modern waste control programs are designed to maintain the integrity of the fluvial environment and its inhabitants for flows down to the Q 7-10. Until about a decade ago most waste control programs considered only point discharge sources. More recent basin programs for the Potomac also consider non point sources, including urban runoff and agricultural runoff.

In the river from Seneca upstream to Harpers Ferry the fluvial ecosystem has not exhibited any serious permanent damages from the reoccurrence of Q 7-10 flows.

The occurrence of 7 day duration flows below the Q 7-10 of course occur less frequently. These lower flows exhibit a greater stress upon the ecosystem.

The effects of flows below the 7 day in 10 year low flow Q 7-10 upon biota are a result of:

1) The degree to which habitat size has been reduced in area, depth, and fluvial portions,

2) The sensitivity of the various species of aquatic life to the degree and duration of the stress imposed,

3) The home range of the species involved,

4) The stage of the life cycle of particular species involved and the season of the year during which the low flow conditons occurs, and

5) The effects of waste loads upon the physical, chemical and biological characteristics of the system.

The fluvial Potomac ecosystem is known to have recovered from the drought flows of summer 1966 which averaged 185 cfs (119 MGD) below Little Falls for two weeks. Fish mortalities were observed in 1966. The time which was required for recovery of fish and other populations to pre-drought conditions was not documented. However, the recovery time for some species of fish can be predicted from age and growth analysis of fish from the fluvial Potomac (Sanderson, 1958). Figures 7-1 through 7-4 depict the growth rate of fish species highly ulitized in the fluvial river fishery (Sanderson, 1958). Table 7-1 summarizes the number of growing seasons (years) to reach harvestable size.

Table 7-1
Fish Length and Age to Harvestable Size

Species	Minimum Length Harvestable Inches	Age in Years
Smallmouth Bass	12 (minimum legal size)	4 - 6
Largemouth Bass	12 (minimum legal size)	4 - 6
Channel Catfish	15	4 - 5
Yellowbelly Sunfish	6 - 7	3 - 5

For the most sought after species, smallmouth and largemouth bass, four years would be required to reestablish the fishable population. This prediction is based upon the assumption that replacement of adult spawners, spawning conditions, and food supplies for larval and juvenile fish would be easily available and adequate in numbers in the first and succeeding years following depression of the population.

D. Restoration of Little Falls Dam Fishway

The Potomac River has historically been a popular spawning ground for many types of anadromous fish such as striped bass, American shad, hickory shad, sturgeon, yellow perch, white perch, alewife and blueback herring. Upstream from Little Falls, the river has water quality parameters, such as high dissolved oxygen content, that are especially well suited for egg and larval development of anadromous fish species. The fishery has declined greatly in the past forty years due to obstruction of fish passage in the Little Falls dam area (Dietemann and Sanderson, 1978).

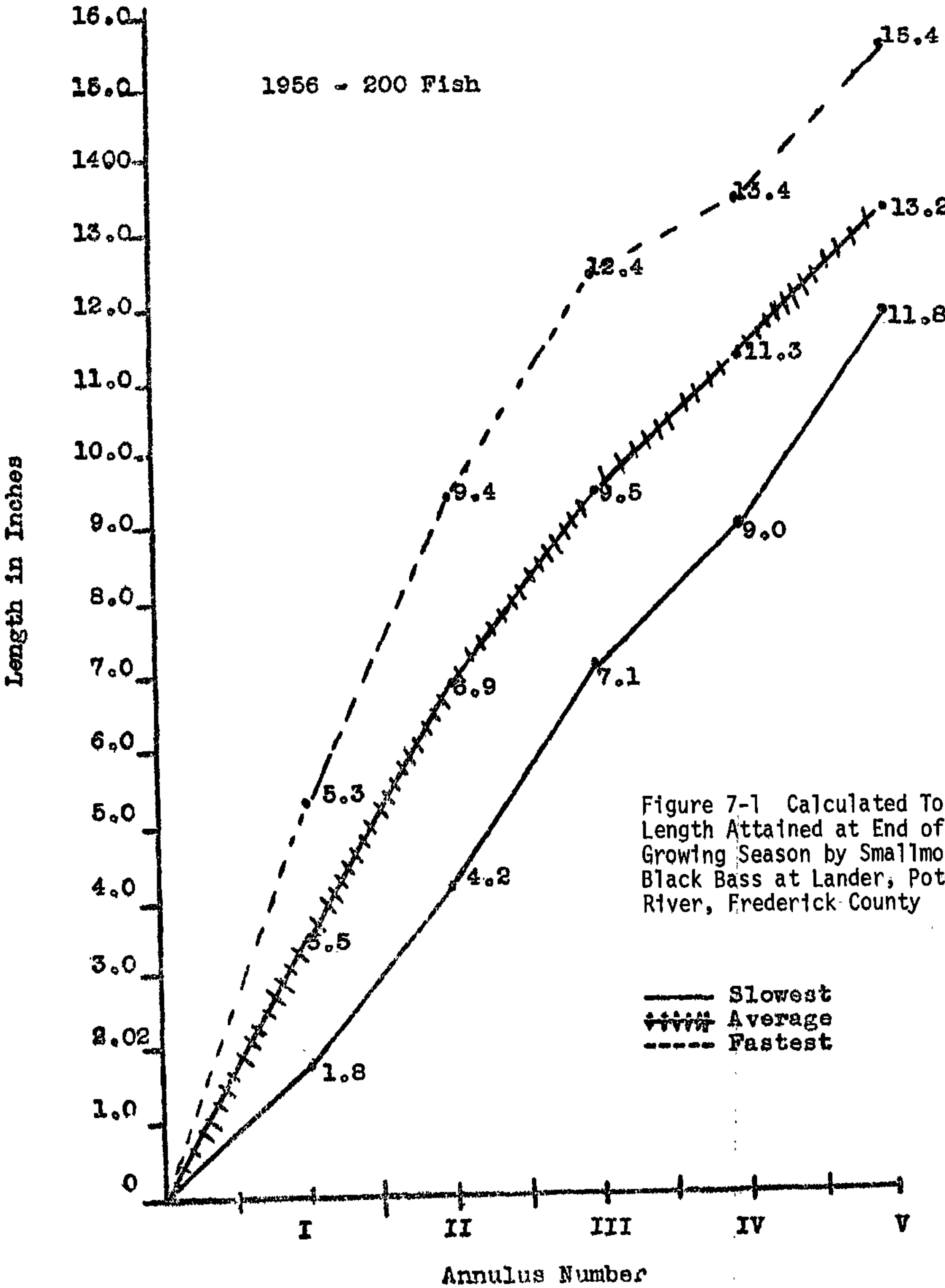


Figure 7-1 Calculated Total Length Attained at End of Each Growing Season by Smallmouth Black Bass at Lander, Potomac River, Frederick County

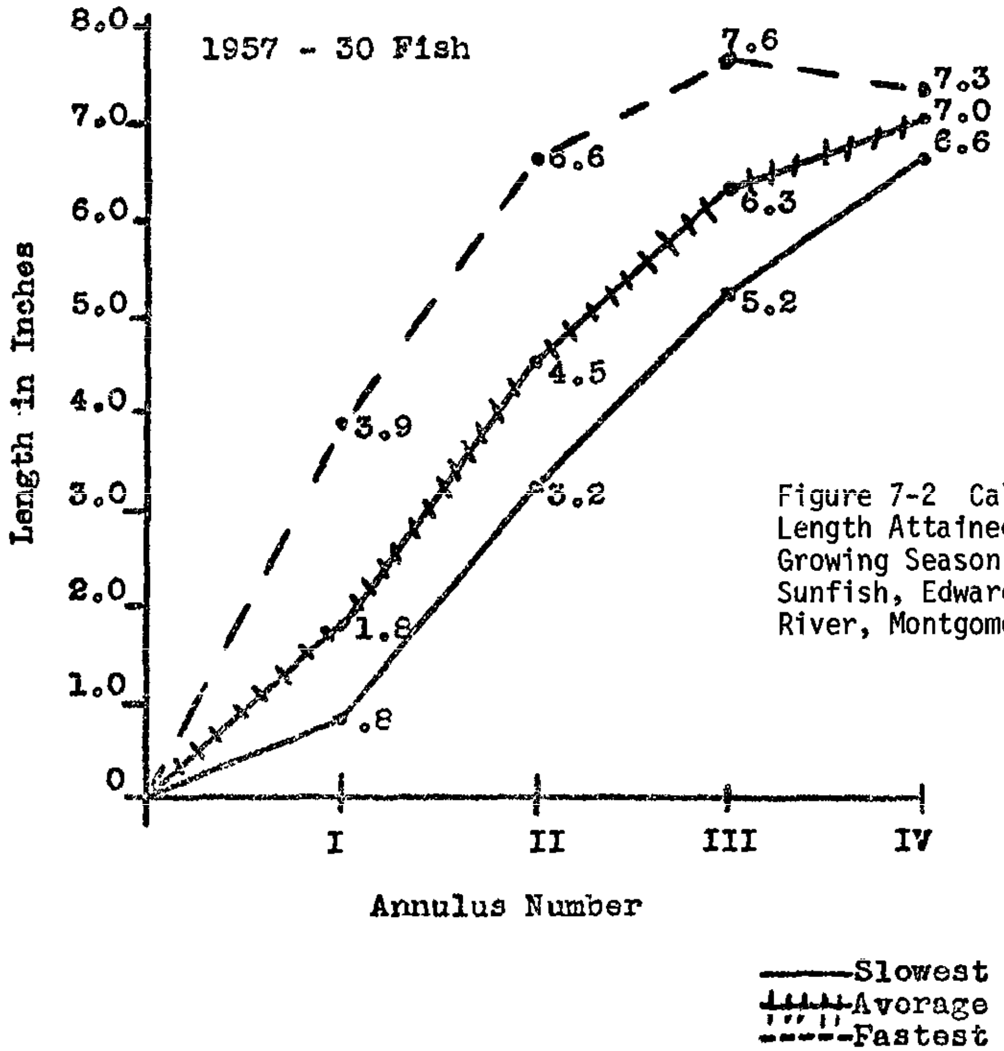


Figure 7-2 Calculated Total Length Attained at End of Each Growing Season by Yellowbelly Sunfish, Edward's Ferry, Potomac River, Montgomery County

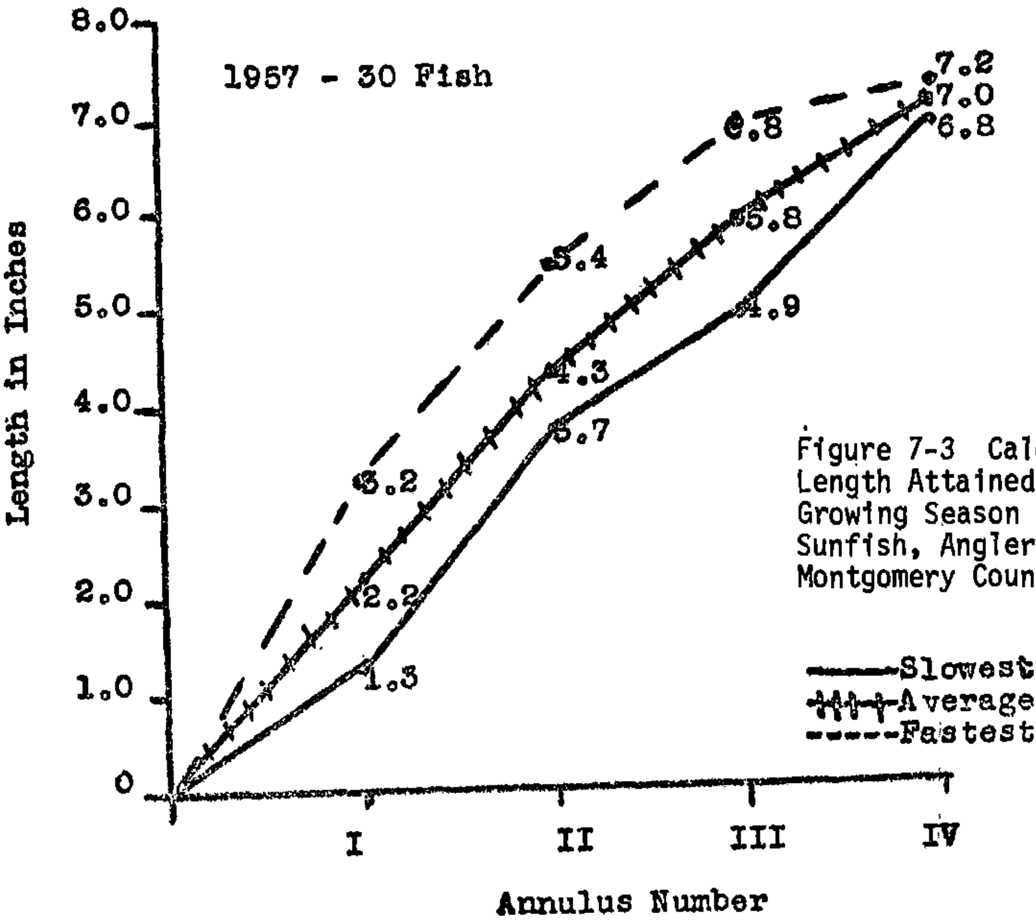


Figure 7-3 Calculated Total Length Attained at End of Each Growing Season by Yellowbelly Sunfish, Anglers Inn, Montgomery County

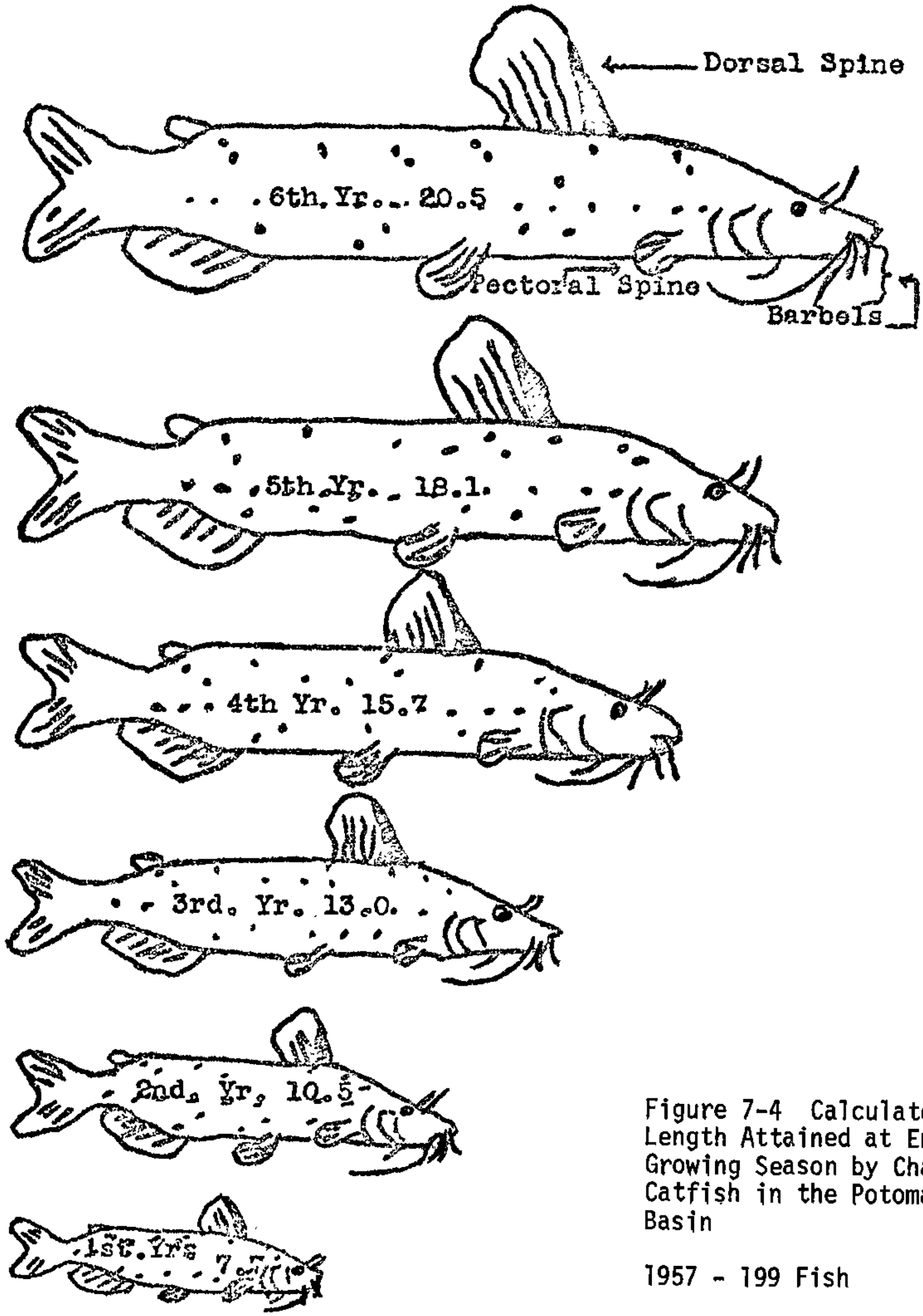


Figure 7-4 Calculated Total Length Attained at End of Each Growing Season by Channel Catfish in the Potomac River Basin

1957 - 199 Fish

Total Length in Inches

In 1831 a loose rock fill feeder dam was constructed to divert water to the C & O Canal. Until 1943 to 1949, when major repairs were made and a concrete cap was placed on the crest of the rock fill, anadromous fish were able to pass through periodic breaks in the dam. The Snake Island Fishway was completed in 1959 along with the Little Falls Dam, which was constructed to divert water to the Washington aqueduct system. No anadromous fish passed the fishway during its first four seasons (1960 - 1963), so the operation and maintenance of the fishway was abandoned (Dalley, 1980).

In recent years, a decline in numbers of anadromous fish have renewed interest in fish passage facilities to utilize the historic spawning and rearing area upstream from Little Falls. The reason why no anadromous fish have passed the fishway is not clearly understood. It may be due to poor design or operation of the fishway or it may be due to other biologic factors in the vicinity of Little Falls. The appropriate repairs and adjustments to Sanke Island Fishway can not be affected and the fishway can not resume operation until the problem is better understood. Further research is presently being contemplated although no study has been initiated (Goodbred, 1981).

The Snake Island Fishway is a vertical slot fishway that was designed for operation when flows range between 1940 mgd and 20,670 mgd. An additional 260 mgd to 550 mgd of attraction water is needed to supplement the flow through the fishway (Dalley, 1980). Therefore a minimum flow of 2,200 mgd at Little Falls dam is the minimum requirement for operation of the fishway. Most anadromous fish spawn between late March and early June, which are usually high flow months. Examination of past records of both observed and adjusted flow at Little Falls (U.S. Geological Survey, 1981) indicates that flows normally exceed 2,200 mgd throughout the spawning season, with the exception of rare low flows of short duration that may occur in June. The fishway will not be adversely affected by low flows that normally occur from July to October.

CHAPTER VIII

SUMMARY MATRIX OF LOW FLOW IMPACTS

Flow-by Little Falls Dam MGD	RECREATION					CHESAPEAKE & OHIO CANAL			
	Canoeing/ Kayaking	Hunting & Trapping	Aesthetics	Fishing	Swimming Power Boating Skiing	Physical/ Historical Structures	Recreational Uses	Smallmouth Bass*	Channel Catfish*
Zero									
100			At 100 mgd and below water quality begins to deteriorate at a level that will adversely affect aesthetics of the river. (3)						
300						At a flow estimated to be approximately 300 mgd the Park Service must change canal operations in an effort to contain water. After approximately one week the contained water will become stagnant resulting in depletion of dissolved oxygen and fish kills. (7)	Fishing deteriorates because of stagnant water fish kills over extended periods of extreme low flow. Other recreational use is not adversely effected by low flows. (8)	A) Juvenile habitat availability is 2[illegible],000 ft²/1000 ft (8[illegible]% decline from 900 mgd). Adult habitat availability does not significantly decline between 900 & 300 mgd. Below 300 mgd habitat decline is not predicted. ------------------------ B) Adult habitat availability declines [illegible] from 1800 to 300 mgd.	A) Juvenile habitat availability has gradu declined from 58,000 f at 1800 mgd to 20,000 ft² at 300 mgd. ------------------------ B) Juvenile habitat availability declines 76% from 1800 to 300 mgd. Adult habitat availability decreases 26% from 1800 to 300 mgd.
500									
700	700 mgd at Little Falls Dam is the minimum flow necessary for canoeing/kayaking in the study portion of the Potomac. Below 700 mgd navigation is greatly impaired. The optimum flows for canoeing/kayaking range between 2000 mgd and 3000 mgd. (1)	700 mgd at Little Falls Dam is the minimum flow necessary for small boat navigation. Below this flow hunting from a boat becomes difficult downstream from Seneca Pool. At flows below 700 mgd, of sustained duration during hunting & trapping season (Sept-Jan), non-boat hunting opportunities decline. (2)		700 mgd at Little Falls Dam is the minimum flow necessary for small boat fishing in most of the river downstream from Seneca Pool. At lower flows it becomes difficult to navigate a small boat. (4)				B) Juvenile habitat availability increases 53% from 1800 to 700 mgd. At 700 mgd habitat availability declines somewhat to 550,000 sq. ft. at 300 mgd, but is still 41% higher than at 1800 mgd.	
900				Fishing Opportunities begin to decline below 900 mgd (10% of average river flow) (5)	At 900 mgd, power boating in Seneca Pool is restricted to an area from the Seneca [illegible] to the lower end of the first island above Seneca Creek. This is 50% of the normal pool size. (6)			A) Juvenile habitat availability is 222,000 ft²/1000 ft. (16.5% decline is from 1800) Adult habitat availability is 60,000 ft²/1000 ft (42% decline from 1800 mgd)	
1100									A) Adult habitat availability has decreased 46% from 1800 mgd to 1100 mgd

Indicates that in-stream activity or resource can not occur or is severely inhibited because of low flow

Indicates increasing impact on in-stream activity or resource with declining flows

Indicates that activity or resource is not adversely affected by low flows

Key

1) Source: Review of literature and personal communication with Edward Gertler, author of Maryland and Delaware Canoe Trails, 1979. 700 mgd equates to 2.7 feet gauge height at Little Falls Dam.

2) Source: Review of literature, "Guidelines for Determining Instream Flow Needs." Interagency Task Force Report, 1979. Calculations relate water depth to minimum flows necessary for small boat navigation. Wildlife population stressed at low flows of long duration, resulting in a decline in hunting opportunities.

3) Personal observations made of declining aesthetics in relation to low flow.

4) Source: Review of literature and accepted standards for small boat navigation. "Guidelines for Determining Instream Flow Needs."

LOW-BY STUDY
FLOWS

	FLUVIAL WILDLIFE (MAJOR SPECIES)					FLUVIAL MACRO-INVERTEBRATES	FLUVIAL WATER QUALITY		UPPER ESTUARY WAT (LITTLE FALLS TO R	
Gizzard Shad*	Ducks	Turtles	Raccoon	Mink	Wading Birds		Dissolved Oxygen	Bacteria	Dissolved Oxygen	Salinity
				Food supply of the mink is adversely affected at zero flow (10)	Food supply of wading birds is adversely affected by zero flow. (12)				Dissolved Oxygen of 5 ppm (necessary for most aquatic life) will be met for about five days. From 5 to 14 days, dissolved oxygen will begin to decline rapidly and aquatic life will be increasingly stressed. From 14 to 30 days aquatic life mortalities can be expected. (18)	In the extreme upper estuary, near Chain Bridge, at zero flo a sewage treatment of 418 mgd or 70% m or 100 mgd withdraw from the estuary in a salinity of 1 PPT occur after 4 mos; 2 at 5 mos, 3 PPT at 6 and 4 PPT at 7 mos.
						At 100 mgd, severe stress occurs with survival of one month or less depending on location, species and fluvial areas. (14)	Below 100 mgd, dissolved oxygen is marginal for short term survival of most aquatic life. (15)		Flows of 185 cfs, circa 120 mgd (1966 drought) will result in dissolved oxygen levels that are acceptable for most aquatic life for approximately 30 days. (19)	Chain Bridge area: A flow of 100 mgd and mgd sewage treatmen (STF), a salinity o PPT will occur at 5 2 PPT at 6.5 mos, 3 at 7 mos, 4 PPT at mos. With a 70% STF 1 PPT at 5 mos, 2 P mos, 3 PPT at 7 mos
A) Adult habitat availability increases 75% from 1000 to 300 mgd. B) Both Adult & Juvenile habitat availability decreases 33% from 1890 to 300 mgd.				Short duration (less than one month) low flows actually improve the availability of food for mink, if the fish population survives. (11)	Short duration (less than one month) low flows (300 mgd) actually improve the availability of food for wading birds. (13)		At 300 mgd, dissolved oxygen and the remaining fluvial habitat creates severe stress conditions for fish at summer water temperatures. (27)		362 mgd (7-day, 10 year low flow) is the Council of Governments current recommended margin of safety for water quality in the upper estuary. (20)	
		Aquatic turtles must move to sandy banks or smooth soil sites to deposit eggs. Below 500 mgd during the spring, access to nesting is restricted in some parts of the study area. (9)								At 500 mgd and abov salinity is zero or less than 1 PPT for at least 7 months.
A) Juvenile habitat availability decreases 65% from 1813 to 1000 mgd.							At flows below 2500 mgd with summer water temperatures (approximately 25°C) dissolved oxygen begins to decline in areas of slack water. The dissolved oxygen standards (5.0 ppm) are met in areas of strong current. The D.O. standard is not met in some slack water areas. As flow decreases sub-standard D.O. areas increase. (16)	Bacterial water quality is a reflection of storm water run-off and discharges from point sources. Increments of low-flow will not appreciably affect bacterial water quality. (17)		

12) Review of literature concerning water quality.

13) Same as 11.

14) Based on analysis of primary data collection and reports of Maryland Department of Natural Resources.

15) Based on analysis of primary data collection and a review of literature.

16) Based on analysis of primary data collection for dissolved oxygen, summer 1980.

17) General review of reports from Council of Governments, ICPRB and other sources.

18) Conclusions of Eugene Z. Stakhiv. 1976. "Alternatives for water supply and their biological impacts." U.S. Army Corps of Engineers, published in The Potomac Estuary Biological Resources, ICPRB and Maryland Department of Natural Resources. Model accuracy is ± 2 ppm. Any value below 5 ppm is considered a stress condition.

19) Same as 18.

20) Same as 18.

21) Literature review. "The Potomac Estuary, Biological Resources" - article "Alternatives for water supply and their biological impacts" and "Final Environmental Impact Statement, Emergency water pumping station, Potomac Estuary, Washington D.C." U.S. Army Corps of Engineers, see page 60.

22) Same as 21

23) Metropolitan Washington Water Quality Management Plan.

24) Summary of preliminary results from the Chesapeake Bay Model, U.S. Army Corps of Engineers.

25) Same as 24.

26) Same as 24.

27) Based on 1966 observations and analysis by Albert Sander Department of Natural Resources.

*A) Indicates IFG Model predicted impacts of low flows on ideal habitat availability betwe Little Falls dam and Little Falls in the 22 a Zone 3 backwater and the 21 acre Zone 2 main

B) Indicates IFG Model predicted impacts of l flows on ideal habitat availability between Great Falls and Little Falls dam in the riffl run areas.

Literature Cited

Almy, Gerald. 1981. The neglected sportfish in Sports afield magazine.

American Society of Civil Engineers. 1975. Sedimentation Engineering, ASCE - Manuals and reports on engineering practice-NO 54. p 102. New York. 745 P.

Bartsch, A. F. 1954. Bottom and plankton conditions in the Potomac River in the Washington Metro area. Interstate Commission on the Potomac River Basin.

Champ, Michael A., Dorothy L. Darden, Robert A. Noland. 1978. The nature of the Potomac Estuary in The Potomac Estuary: a potential water supply. Proceedings of the 1977 Fall Public Meetings. Interstate Commission on the Potomac River Basin, Rockville, Maryland. General Publication 78-1. p 10-14.

Clark, Leo J., Stephen E. Roesch and Molly M. Bray. 1980. Assessment of 1978 Water Quality conditions in the Upper Potomac Estuary. U.S. Environmental Protection Agency, Region III, Annapolis, Maryland. Report Number 903/9-80-002. 91p.

Cloos, Ernst, G. W. Fisher, C. A. Hopson and Emery T. Cleaves. 1964. The geology of Howard and Montgomery Counties. Maryland Geological Survey, Baltimore, Maryland. 373 p.

Colwell, R. R. and M. R. Belas. 1978. Microbiological studies in The fresh water Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 78-2. p. 9-14.

Dalley, P. J. 1980. Investigation of Snake Island Fishway at Little Falls Dam, Potomac River, Maryland - Virginia. U.S. Fish and Wildlife Service, Region 5. 19 p.

Dietemann, Allan and Albert Sanderson, Jr. 1978. The fishery of the Piedmont Potomac in The freshwater Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland Technical Publication 78-2 pp 70-75.

Dingman, R. J.; Gerald Meyer and Robert O. R. Martin. 1954. Water resources of Howard and Montgomery Counties. Maryland Geological Survey Bulletin 14, Baltimore, Maryland. 260 p.

Foster, Donald. 1981. Personal Communication. Great Falls Foreman.

Gertler, Edward. 1981. personal communication. author of Maryland and Delaware canoe trails. 1979. Seneca Press, Maryland. 180 p.

Goodbred, Steve. 1981. personnal communication. U.S. Fish and Wildlife Service.

Harman, George H. 1978. Benthic macroinvertebrates in The fresh water Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 78-2. p 29-35.

Interagency Task Force -- Instream Flows. 1979. Guidelines for determining instream flow needs.

Interstate Commission on the Potomac River Basin. 1975. Potomac River Basin water quality status and trend assessment, 1962-1973. Interstate Commission on the Potomac River Basin, Bethesda, Maryland.

Interstate Commission on the Potomac River Basin. 1978. The Potomac Estuary - a potential water supply, proceedings from the fall 1977 public meeting. Interstate Commission on the Potomac River Basin, Bethesda, Maryland. General Publication 78-1. 46 p.

Jaworski, N. A., D. W. Lear and O. Villa Jr. 1972. Nutrient Management in the Potomac Estuary, in Nutrients and eutrophications, special symposium, Volume 1. American Society of Limnology and Oceanography, Allen Press. p 246-273.

Jaworski, Norbert A., Leo Clark and Kenneth D. Feigner. 1972. Upper Potomac Estuary eutrophication control requirements. Environmental Protection Agency, Region III, Annapolis Field Office, Technical Report 53. 41 p.

Johnson Division, Universal Oil Products Company. 1972. Groundwater and Wells. Saint Paul, Minnesota, 432 p.

Kreh, Lefty. 1980. The Potomac now contains hoards of small bass. Baltimore Sun Newspaper. July 29, 1980 issue.

Kuep, Lowell and Delbert B. Hicks. 1978. Rooted aquatic plants. in The freshwater Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 78-2. p 25-28.

Lippson, Alice J., Michael S. Haire, A. Fredrick Holland, Fred Jacobs, Jorgen Jenson, R. Lynn Moran-Johnson, Tibor T. Polgar and William A. Richkus. 1979. Environmental Atlas of the Potomac Estuary. Prepared by Environmental Center, Martin Marietta Corporation, Baltimore Maryland for Power Plant Siting Program, Maryland Department of Natural Resources. 280 p.

Lucas, Richard C. and Albert Sanderson. 1981. personal communication

Maryland Department of Natural Resources, Capital Programs Administration, Land Planning Services. 1979. Recreational use of the Upper Potomac River. Annapolis, Maryland. 132 p.

Maryland Register, May 1980.

McCaw, William J. and Ernest L. Gambell. 1979. Conserving the Potomac's soil and water resources. Interstate Commission on the Potomac River Basin, Bethesda, Maryland 91p.

Merriner, John V. 1975. Anadramous fishes of the Potomac Estuary in the Potomac Estuary: biological resources: trends and opinions. Interstate Commission on the Potomac River Basin, Bethesda, Maryland p 105-109.

Metropolitan Washington Council of Governments, Water Resource Planning Board. 1978. Draft Metropolitan Washington water quality management plan.

Metropolitan Washington Council of Governments, Water Resource Planning Board. 1980. Metropolitan Washington water quality management plan supplement. Washington, D.C.

McMann, Mac. 1981. personal communication. C & O Canal Park office.

Montgomery County, Maryland. 1979. Comprehensive water supply and sewerage systems plan, fys 1979 to 1988. Adopted by Montgomery County Council. 896 p.

National Academy of Science and National Academy of Engineering. 1972. Water Quality Criteria, 1972.

Parker, Horatio; Bailey Willis, R. H. Bolster, W. W. Ashe and M. C. Marsh. 1907. The Potomac River basin. U.S. Geological Survey Water Supply Paper 192. U.S. Government Printing Office, Washington D.C. 364 p.

Parsons, John G. 1976. Chesapeake and Ohio Canal National Historical Park - general plan. U.S. Government Printing Office, Washington D.C. 106 p.

Rasin, V. James Jr. Keith M. Brooks. Kevin C. Flynn. William C. McCaw III. 1980. Potomac River Basin water quality 1978-1979. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 80-1. 77 p.

Sanderson, Albert E., Jr. 1958. Smallmouth bass management in the Potomac River Basin in Transactions of the twenty-third North American Wildlife Conference. Wildlife Management Institute, Washington, D.C. p. 248-262.

Sanderson, Albert. 1981. personal communication. Fisheries Biologist Maryland Department of Natural Resources.

Sipes, Dale. 1981. personal communication. Head of Maintenance C & O Canal Park

Stakhiv, Eugene Z. 1976. Management of water supply and its impact on biological resources in The Potomac Estuary, biological resources / trends and opinions. Interstate Commission on the Potomac River Basin, Bethesda, Maryland. Technical Publication 76-2. p 118-122.

Stotts, V. D. J. R. Longwell. 1962. Potomac River biological investigation 1959, supplement to technical appendix of Part VII. in Potomac River Basin studies. U.S. DHEW, Washington, D.C.

Thompson, John Seabury. 1974. Potomac whitewater: a guide to safe canoeing above Washington. Appalacian Books, Oakton, Virginia. 44 p.

Trainer, Frank W. and Frank A. Watkins. 1975. Geohydrologic reconnaissance of the Upper Potomac River basin. U.S. Geological Survey Water Supply Paper 2035. U.S. Government Printing Office, Washington, D.C. 68 p.

Tsai, Chu-fa. 1978. Impact of waste water discharges in the freshwater Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 78-2 p. 147-151.

U.S. Army Corps of Engineers, Baltimore District. 1977. Impacts of proposed Washington Suburban Sanitary Commission intake, summary document, supplement 2. U.S. Army Corps of Engineers Baltimore, Maryland.

U.S. Army Corps of Engineers, Baltimore District. 1978. Final Environmental impact statement concerning proposed Potomac River water supply structures. U.S. Army Corps of Engineers, Baltimore, Maryland. 304 p.

U.S.Army Corps of Engineers, Washington Aqueduct Division. 1981. Flow records from Little Falls 1978 to 1981.

U.S. Environmental Protection Agency, Region III. 1979. Draft Potomac strategy. U.S. Environmental Protection Agency, Phildelphia, Pennsylvania.

U.S. Geological Survey. 1964. Compilation of records of surface waters of the United States, October 1950 to September 1960, Part 1-B North Atlantic Slope Basins, New York to York River. U.S. Geological Survey Water Supply Paper 1722. U.S. Government Printing Office, Washington D.C. 578 p.

Walker, Patrick N. 1970. Water in Maryland: a review of the free state's liquid assets. Maryland Geological Survey Educational Series #2, Baltimore, Maryland. 52 p.

Walker, Patrick N. 1971. Flow characteristics of Maryland streams. Maryland Geological Survey Report of Investigations 16, Baltimore, Maryland. 160 p.

Weber, Cornelius I, William T. Mason and V. James Rasin. 1978. Phytoplankton. in The freshwater Potomac: aquatic communities and environmental stresses. Interstate Commission on the Potomac River Basin, Rockville, Maryland. Technical Publication 78-2. p 15-24.

Young, J. D. 1981. personal communication. C & O Canal Park Office - National Capital Park Service.

APPENDIX A

RESULTS OF FISHERY SAMPLING ON THE STUDY PORTION OF THE POTOMAC RIVER

Fish Species Collected in the Potomac River. 1975.

Scientific Names	Common Names	3	4	5	6	7	8	9	10	11	12	13	14	15	16a	16b	17	18
Amia calva	Bowfin									x						x		
Anguilla rostrata	American Eel						x	x	x	x							x	
Dorosoma cepedianum	Gizzard Shad															x	x	x
Esox niger	Chain Pickerel				x			x										
Campostoma anomalum	Stoneroller			x	x		x		x		x							
Carassius auratus	Goldfish															x	x	x
Cyprinus carpio	Carp				x					x		x		x		x	x	
Ericymba buccata	Silverjaw			x	x													
Exoglossum maxillingua	Cutlips Minnow			x														
Hybognathus nuchalis	Silvery Minnow															x		x
Nocomis micropogon	River Chub				x	x	x	x	x	x	x	x		x	x	x	x	x
Notemigonus crysoleucas	Golden Shiner	x		x			x											
Notropis amoenus	Comely Shiner						x	x	x	x	x	x	x		x	x	x	x
Notropis cornutus	Common Shiner			x	x		x	x						x		x		x
Notropis hudsonius	Spottail Shiner			x	x		x		x	x	x	x	x	x	x	x	x	x
Notropis procne	Swallowtail Shiner				x			x		x		x	x	x	x	x	x	x
Notropis rubellus	Rosyface Shiner											x				x	x	
Notropis spilopterus	Spotfin Shiner			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pimephales notatus	Bluntnose Minnow		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rhinichthys atratulus	Blacknose Dace		x													x		
Rhinichthys cataractae	Longnose Dace			x	x	x	x								x		x	x
Semotilus atromaculatus	Creek Chub	x	x	x			x					x	x			x		
Semotilus corporalis	Fallfish			x	x		x	x	x	x	x							x
Catostomus commersoni	White Sucker	x		x	x		x	x	x					x	x			x
Erimyzon oblongus	Creek Chubsucker						x	x										

1. [illegible], Edward and Robert M. Davis. 1976. An investigation of the physical-chemical characteristics, macro-invertebrates, and fish populations of the Upper Potomac River Basin. Study title: Fish fauna studies. Maryland Fisheries Admin. Fed. Aid Proj. F-29-R-1. Job 3.

Fish Species Collected in the Potomac River. 1975.

Scientific Names	Common Names	3	4	5	6	7	8	9	10	11	12	13	14	15	16a	16b	17	1
ypentelium nigricans	Northern Hogsucker		x				x	x	x	x					x	x		
oxostoma macrolepidot	Shorthead Redhorse			x			x	x	x	x			x	x	x	x	x	x
ctalurus natalis	Yellow Bullhead			x	x		x	x	x			x		x	x	x	x	x
ctalurus nebulosus	Brown Bullhead		x	x			x		x					x	x	x	x	x
ctalurus punchatus	Channel Catfish			x					x	x		x		x		x	x	x
oturus insignis	Margined Madtom						x											
undulus diaphanus	Banded Killifish															x		
mbloplites rupestris	Rock Bass			x	x	x	x	x	x	x				x	x		x	x
epomis auritus	Redbreast Sunfish			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
epomis cyanellus	Green Sunfish				x		x					x		x		x	x	x
epomis gibbosus	Pumpkinseed						x		x		x	x	x	x	x	x	x	x
epomis gulosus	Warmouth								x						x		x	
epomis macrochirus	Bluegill		x	x		x	x	x	x			x	x	x	x	x	x	x
epomis megalotis	Longear						x	x	x	x		x			x	x	x	x
icropterus dolomieui	Smallmouth Bass			x	x	x	x	x	x	x	x	x	x	x				x
icropterus saloides	Largemouth Bass		x		x		x		x		x	x	x	x	x		x	x
omoxis annularis	White Crappie														x		x	
omoxis nigromaculatus	Black Crappie								x					x		x		x
theostoma blennioides	Greenside Darter						x			x		x						
theostoma flabellare	Fantail Darter						x											
theostoma olmsteidi	Tessellated Darter				x			x	x			x	x	x	x		x	
erca flavesceus	Yellow Perch														x			
ottus bairdi	Mottled Sculpin						x											

..hmait and Davis. 1976.

RESULTS OF FISH COLLECTIONS FROM THE POTOMAC RIVER BELOW GREAT FALLS ON JULY 6-7, 1976

The three mile scenic canyon of the Potomac River below Great Falls is known as Mather Gorge. It is characterized by roaring white water and long deep pools, with steep rock cliffs on each riverbank.

Because of the high average velocity and the deep gorge streambed, the area forms a unique fish habitat uncharacteristic of the majority of the Potomac River.

On July 6-7, 1976, the Maryland Department of Natural Resources conducted a fisheries investigation of the River in the vicinity of Cropely (Old Anglers Inn) near the confluence of Difficult Run (Va.) with the Potomac River. A combination of one 100 yard gill net; two 3X3X6 foot wire "D" fish traps (placed over-night at a depth of 40 feet); one 20 ft. haul seine; and hook and line were used to collect specimens. A total of nineteen species and 278 specimens were collected.

Depth soundings were conducted in the long deep pool in the Potomac River immediately downstream from the Difficult Run confluence. Depths averaged about 30 ft., however a drop-off was located about 100 yards downstream from this confluence which averaged 40 ft. in depth with one sounding reaching 48 ft. During this measurement, the flow in the Potomac River was at slightly below "normal" water stage levels. A temperature profile of the deep pool revealed a uniform temperature gradient from surface to bottom and side to side of 71 to 73°F. The cool waters of Difficult Run (64°F.) mixed and sloped downward along the bottom of the pool. Walleye, Stizostedion vitreum, have been reportedly caught by fishermen in this pool, however sampling with traps and gill net yeilded no specimens of this species. A beaver and an otter were observed near this pool on the morning of July 7. An additional sampling trip is planned in August for this area.

List of Fishes Collected from the Potomac River Below Great Falls on July 6-7, 1976*

ANGUILLIDAE	No. of Specimens	Weight in pounds
American Eel *Anguilla rostrata*	3	.2
CYPRINIDAE		
Longnose dace *Rhinichthys cataractae*	8	.1
Swallowtail shiner *Notropis procne*	75	.3
Satinfin shiner *Notropis analostanus*	75	.5
Bluntnose minnow *Pimephales notatus*	3	.1
River chub *Nocomus micropogon*	5	.1
Goldfish *Carassius auratus*	2	1.0
Carp *Cyprinus carpio*	12	24.0
CATOSTOMIDAE		
White sucker *Catostomus commersoni*	2	2.1
Redhorse *Moxostoma macrolepidotum*	15	17.0
CLUPEIDAE		
Gizzard shad *Dorosoma cepedianum*	16	16.0
ICTALURIDAE		
Margined madtom *Noturus insignis*	1	.01
Yellow bullhead *Ictalurus natalis*	2	2.0
Channel catfish *Ictalurus punctatus*	14	21.0
CENTRARCHIDAE		
Smallmouth bass *Micropterus dolomieu*	4	3.5
Redbreast sunfish *Lepomis auritus*	1	.5
White crappie *Pomoxis annularis*	1	.8
PERCIDAE		
Tessellated darter *Etheostoma olmstedi*	35	.3
Shield darter *Percina peltata*	1	.01
TOTALS		
19 Species	278 specimens	89.51 pounds

*By gill net variable mesh

ADDITONAL RESULTS OF FISH COLLECTIONS FROM THE POTOMAC RIVER IN THE AREA NEAR MATHER GORGE

On November 18-19, 1976, the Department of Natural Resources sampled a backwater of the Potomac River north of Sherwin Island, near Cropley, Montgomery County, Maryland. Approximately 100 yards of two inch stretched gill net (six feet deep) was set overnite in water varying from five to fifteen feet in depth. The net was set near a deep hole known to be a wintering area for fish.

Two species, the largemouth bass, and the brown bullhead, were collected during this date but not previously recorded on the July 6-7 survey of this general area. The addition of these two species brings the new total for this area of the Potomac River to 21 species.

All fish collected were quite active and in excellent condition. The water temperature was 41°F. in the backwater and 39°F. in the mainstream Potomac River. Water clarity was excellent, over four feet visability, more than could ever be recalled for this part of the Potomac River in many years. This unsual clarity was probably due to snow melt condtions in the upper Potomac River watershed.

LIST OF FISHES COLLECTED NOV. 18-19, 1976, IN THE BACKWATER NORTH OF SHERWIN ISLAND IN THE POTOMAC RIVER BELOW GREAT FALLS AT A LOCATION NEAR CROPLEY, MD.

		No. of Specimens	Weight in lbs.
CYPRINIDAE			
Carp *Cyprinus carpio*		2	13.
CATOSTOMIDAE			
White Sucker *Catostomus commersoni*		1	1.5
Redhorse *Moxostoma macrolepidotum*		33	40.0
CLUPEIDAE			
Gizzard Shad *Dorosoma cepedianum*		1	1.0
ICTALURIDAE			
Brown Bullhead *Ictalurus nebulosus*		1	.25
Channel Catifish *Ictalurus punctatus*		2	2.0
CENTRARCHIDAE			
White crappie *Pomoxis annularis*		4	2.5
Largemouth Bass *M. salmoides*		3	2.5
TOTALS	Eight Species	47	62.75

POTOMAC RIVER FISH SAMPLES

SITE: Potomac R. b'twn Little Falls & Brookmont Dam
DATE: 3-5 October 1970
SAMPLING METHOD: All

SPECIES	NUMBER	% of TOTAL	WEIGHT (lbs)	% of TOTAL	$\overline{X}$ CONDITION FACTOR (LENGTH GROUP)
Anguilla rostrata	1	1.85	0.25	0.59	
Catostomus commersoni	1	1.85	0.44	1.04	
Carpiodes cyprinus	1	1.85	2.25	5.30	
Cyprinus carpio	3	5.56	16.25	38.27	
Dorosoma cepedianum	3	5.56	1.5	3.53	
Ictalurus punctatus	5	9.26	2.13	5.02	
Lepomis auritus	16	29.63	3.57	8.41	10.02 (6-6.9")
L. gibbosus	1	1.85	0.19	0.45	
Micropterus salmoides	1	1.85	0.19	0.45	
Moxostoma macrolepidotum	11	20.37	14.76	34.76	
Nocomis micropogon	3	5.56	0.62	1.46	
Notropis hudsonius	7	12.96	0.28	0.66	
N. procne	1	1.85	0.03	0.07	
	54	100	42.46	100	

Note: 37 additional fish were caught which are not included in this table.

POTOMAC RIVER FISH SAMPLES

SITE: Carderock, Potomac R.
DATE: 10-12 October 1978
SAMPLING METHOD: All

SPECIES	NUMBER	% of TOTAL	WEIGHT (lbs)	% of TOTAL	$\overline{X}$ CONDITION FACTOR (LENGTH GROUP)
Anguilla rostrata	5	4.27	0.57	0.50	
Carpiodes cyprinus	1	0.85	1.81	1.59	
Catostomus commersoni	1	0.85	1.06	0.93	
Cyprinus carpio	7	5.98	35.06	30.87	
Hypentelium nigricans	1	0.85	0.81	0.71	
Ictalurus catus	1	0.85	2.19	1.93	
I. natalis	1	0.85	0.31	0.27	
I. punctatus	23	19.66	7.87	6.93	3.3 ([illegible])
Lepomis auritus	19	16.24	3.85	3.39	7.9 ([illegible])
Micropterus dolomieui	3	2.56	1.29	1.14	
Moxostoma macrolepidotum	47	40.17	58.42	51.43	3.9 ([illegible])
Notropis hudsonius	7	5.98	0.29	0.26	
Noturus insignis	1	0.85	0.06	0.05	
	117	100	113.59	100	

POTOMAC RIVER FISH SAMPLES

SITE: Potomac R. at Anglers Inn
DATE: 16-17 October 1978
SAMPLING METHOD: All

SPECIES	NUMBER	% of TOTAL	WEIGHT (lbs.)	% of TOTAL	$\bar{X}$ CONDITION FACTOR (LENGTH GROUP)
Carpiodes cyprinus	19	11.24	30.25	25.30	4.6 (14-14.9")
Catostomus commersoni	2	1.18	1.40	1.17	
Cyprinus carpio	3	1.78	10.32	8.63	
Dorosoma cepedianum	3	1.78	1.28	1.07	
Hypentelium nigicans	2	1.18	1.16	0.97	
Ictalurus natalis	7	4.14	2.04	1.71	
I. punctatus	16	9.47	6.26	5.23	3.0 (9-9.9")
Lepomis auritus	29	17.16	3.33	2.78	9.9 (4-4.9")
L. gibbosus	6	3.55	0.78	0.65	7.1 (6-6.9")
L. macrochirus	5	2.96	0.76	0.64	
Micropterus dolomieui	3	1.78	0.40	0.33	
M. salmoides	1	0.59	0.44	0.37	
Mcxostoma macrolepidotum	69	40.83	60.68	50.74	3.9 (14-14.9")
Nocomis micropogon	3	1.78	0.38	0.32	
Notropis hudsonius	5	2.96	0.20	0.17	
Pomoxis sps.	2	1.18	0.69	0.58	
	169	100	119.60	100	

POTOMAC RIVER FISH SAMPLES

SITE: Seneca, Potomac R.
DATE: Oct. 20, 1978
SAMPLING METHOD: All (electroshock, gill net, D-trap)

SPECIES	NUMBER	% of TOTAL	WEIGHT	% of TOTAL	$\bar{X}$ CONDITION FACTOR (LENGTH GROUP)
Carassius auratus	1	0.58	1.38	0.71	
Catostomus commersoni	5	2.89	4.95	2.56	
Cyprinus carpio	10	5.78	43.45	22.45	
Hypentelium nigricans	4	2.31	3.17	1.64	
Ictalurus natalis	1	0.58	0.25	0.13	
Ictalurus punctatus	12	6.94	12.52	6.47	2.2 (11-11.9")
Lepomis auritus	28	16.18	4.81	2.49	2.0 (6-6.9")
Lepomis gibbosus	8	4.62	0.85	0.44	
Lepomis macrochirus	10	5.78	1.57	0.81	
Micropterus dolomieui	14	8.09	15.65	8.09	
Micropterus salmoides	5	2.89	3.23	1.67	
Moxostoma macrolepidotum	60	34.68	98.97	51.14	
Nocomis micropogon	3	1.73	-	-	
Notropis hudsonius	8	4.62	0.33	0.17	
Pomoxis annularis	2	1.16	1.44	0.74	
Pomoxis nigromaculatus	2	1.16	0.94	0.49	
	173	100.00	193.51	100.00	

Comparison of percentage composition of Potomac fish population. Sanderson 1955[1] and collections made in October 1978.

Species	Percent by number 1955	Percent by number 1978	Percent by weight 1955	Percent by weight 1978
Ambloplites rupestris	3 5	0	1.2	0
Anguilla rostrata	0	1.15	0	0.17
Carassius auratus	0	0.19	0	0.29
Carpiodes cyprinus	0	4.04	0	7.64
Catostomus commersoni	7.5	1.73	11.6	1.67
Cyprinus carpio	0.5	4.43	7.0	22.33
Dorosoma cepedianum	0	1.15	0	0.58
Hypentelium nigricans	10.2	1.34	9.8	1.09
Ictalurus catus		0.19		0.47
(Sanderson-I. furcatus?)	1.9		9.0	
Ictalurus natalis	1.0	1.73	1.0	0.55
Ictalurus punctatus	5.2	10.78	9.8	6.12
Lepomis auritus	13.3	17.72	4.2	3.31
Lepomis gibbosus	2.4	2.89	0.7	0.39
Lepomis macrochirus	4.0	2.89	1.5	0.50
Micropterus dolomieui	13.7	3.85	8.2	3.69
Micropterus salmoides	1.0	1.34	1.7	0.82
Moxostoma macrolepidotum	7.6	36.03	28.9	49.48
Nocomis micropogon	0	1.73	0	--
Notropis hudsonius	0	5.20	0	0.23
oturus insignis	0	0.19	0	0.01
Pomoxis annularis	0	0.77	0	0.45
Pomoxis nigromaculatus	0.3	0.38	0.1	0.20
Semotilus atromaculatus	6.1	0	1.82	
Semotilus corporalis	2.8	0	1.8	0
Notemigonus crysoleucas	2.8	0	0.8	0
Notropis procne	0	0.19	0	0.01

1. Sanderson, Albert E. 1955. Summary of Potomac River investigations, 1955. Data report Maryland Game and Inland Fish Commission. Mimeo. n.p.

Ranking of fish species by poundage collected. Potomac River. Oct 1978

Species	Poundage rank by site (% of sample poundage) Little Falls	Carderock	Anglers Inn	Seneca
Anguilla rostrata	10(0.6%)	10(0.5%)		
Carassius auratus				11(0.7%)
Carpiodes cyprinus	4(5.3%)	6(1.6%)	2(25.3%)	
Catastomus commersoni	8(1.0%)	8(0.9%)	7(1.2%)	5(2.6%)
Cyprinus carpio	1(38.3%)	2(30.9%)	3(8.6%)	2(22.5%)
Dorosoma cepedianum	6(3.5%)		8(1.1%)	
Hypentelium nigricans		9(0.7%)	9(1.0%)	8(1.6%)
Ictalurus catus		5(1.9%)		
Ictalurus natalis		11(0.3%)	6(1.7%)	15(0.1%)
Ictalurus punctatus	5(5.0%)	3(6.9%)	4(5.2%)	4(6.5%)
Lepomis auritus	3(8.4%)	4(3.4%)	5(2.8%)	6(2.5%)
Lepomis gibbosus	11(0.5%)		10(0.7%)	13(0.4%)
Lepomis macrocnirus			11(0.6%)	9(0.8%)
Micropterus dolomieui		7(1.1%)	14(0.3%)	3(8.1%)
Micropterus salmoides	12(0.5%)		13(0.4%)	7(1.7%)
Moxostoma macrolepidotum	2(34.8%)	1(51.4%)	1(50.7%)	1(51.1%)
Nocomis micropogon	7(1.5%)		15(0.3%)	
Notropis hudsonius	9(0.7%)	12(0.3%)	16(0.2%)	14(0.2%)
Notropis procne	13(0.1%)			
Noturus insignis		13(0.1%)		
Pomoxis annularis			12(0.6%)	10(0.7%)
Pomoxis nigromaculatus				12(0.5%)

Potomac River Low Flow Study - Fish Collection Data

Sampling Station Location - Potomac River backwater (just above Old Anglers Inn)
Sampling Date - 20 November 1980
River Length Sampled - 91.4 meters (300 feet)
Method of Sampling - Electrofishing with 120v AC shocker - representative collection obtained
Collectors - G. Harman, J. Allison, W. Butler, S. Goodbred, B. Folker, G. Ruddy

COMMON NAME/SCIENTIFIC NAME[1]	TOTAL COUNT	TOTAL WEIGHT (gms)*	TOTAL LENGTH (cm)
Rosyside dace/ *Clinostomus funduloides* Girard	1	0.9	5.3
Swallowtail shiner/ *Notropis procne* (Cope)	1	0.5	4.3
Spotfin shiner/ *Notropis spilopterus* (Cope)	272	510.2	3.3 - 9.4
Bluntnose minnow/ *Pimephales notatus* (Rafinesque)	60	127.6	3.0 - 8.1
Shorthead redhorse/ *Moxostoma macrolepidotum* (Lesueur)	1	12.9	10.9
Yellow bullhead/ *Ictalurus natalis* (Lesueur)	2	222.0	20.6 - 21.1
Redbreast sunfish/ *Lepomis auritus* (Linnaeus)	15	118.0	3.0 - 15.5
Pumpkinseed/ *Lepomis gibbosus* (Linnaeus)	16	31.2	3.3 - 6.1
Longear sunfish/ *Lepomis megalotis* (Rafinesque)	2	27.9	1.7 - 26.2
Bluegill/ *Lepomis macrochirus* (Rafinesque)	22	23.2	3.0 - 5.1
Largemouth bass/ *Micropterus salmoides* (Lacepede)	2	58.0	12.7 - 14.2

1 - American Fisheries Society-Special Publication No. 6, Third Edition, 1970.
* - see attached page for length and weight distribution of more abundant species.

Potomac River Low Flow Study - Fish Collection Data

Sampling Station Location: Potomac River backwater just above Old Anglers Inn
Sampling Date: 20 November 1980

Length and weight distribution of more abundant species

Spotfin shiner-T.L.(cm)	<3.3	3.6-4.1	4.3-4.8	5.1-5.6	5.8-6.4	5.6-7.1	7.4-7.9	8.1-8.6	8.9-9.4
Count	6	41	76	49	30	29	25	13	3
T. weight (gms)	1.9	23.2	66.2	68.3	65.7	88.0	106.4	70.5	20.0
$\bar{x}$ weight (gms)	0.3	0.6	0.9	1.4	2.2	3.0	4.3	5.4	6.7

Bluntnose minnow T.L.(cm)	3.0	3.3-3.6	3.8-4.1	4.3-4.6	4.8-5.1	5.3-5.6	5.8-6.1	6.4-6.6	6.9-7.1	7.4-7.6	7.9-8.1
Count	1	2	4	5	5	15	10	5	8	4	1
T. weight (gms)	0.2	0.8	2.2	4.5	6.4	24.8	21.9	14.7	28.9	18.0	5.2
$\bar{x}$ weight (gms)	0.2	0.4	0.6	0.9	1.3	1.7	2.2	2.9	3.6	4.5	5.2

Redbreast sunfish T.L.(cm)	3.0	3.3	4.1	4.6	4.8	5.1	5.6	6.6	7.6	9.9	15.5
Count	2	3	2	1	1	1	1	1	1	1	1
T. weight (gms)	1.0	2.4	3.0	2.0	2.4	2.6	4.0	6.0	8.9	17.7	68.0
$\bar{x}$ weight (gms)	0.5	0.8	1.5	2.0	2.4	2.6	4.0	6.0	8.9	17.7	68.0

Pumpkinseed T.L.(cm)	3.3	4.1	4.3	4.6	4.8	5.1	5.3	5.8	6.1
Count	1	4	4	1	1	2	1	1	1
T. weight (gms)	0.7	4.9	5.6	2.1	2.3	4.8	3.0	3.5	4.3
$\bar{x}$ weight (gms)	0.7	1.2	1.4	2.1	2.3	2.4	3.0	3.5	4.3

Bluegill T.L.(cm)	3.0	3.3	3.6	3.8	4.1	4.3	4.6	4.8	5.1
Count	2	6	2	2	1	3	1	2	3
T. weight (gms)	0.5	3.3	1.3	1.7	1.2	3.8	1.5	3.6	6.3
$\bar{x}$ weight (gms)	0.25	0.55	0.65	0.85	1.2	1.3	1.5	1.8	2.1

$\bar{x}$ = average weight/fish

Potomac River Low Flow Study - Fish Collection Data

Sampling Station Location - Potomac River along northwest bank in the region northwest of Vasco Island
Sampling Date - 20 November 1980
River Length Sampled - 230 meters (755 feet)
Method of Sampling - Electrofishing with 120v AC shocker - representative collection obtained
Collectors - G. Harman, J. Allison, W. Butler, S. Goodbred, B. Folker, G. Ruddy

COMMON NAME/SCIENTIFIC NAME[1]	TOTAL COUNT	TOTAL WEIGHT (gms)*	TOTAL LENGTH (cm)
American eel/ Anguilla rostrata (Lesueur)	11	308.4	18.0 - 33.3
Rosyside dace/ Clinostomus funduloides Girard	1	1.5	5.6
River chub/ Nocomis micropogon (Cope)	2	14.9	7.6 - 9.1
Spottail shiner/ Notropis hudsonius (Clinton)	268	405.6	3.6 - 10.7
Rosyface shiner/ Notropis rubellus (Agassiz)	7	12.9	4.8 - 7.6
Spotfin shiner/ Notropis spilopterus (Cope)	841	1557.1	2.3 - 9.7
Bluntnose minnow/ Pimephales notatus (Rafinesque)	108	173.4	2.5 - 7.6
Northern hogsucker/ Hypentelium nigricans (Lesueur)	1	12.0	10.7
Redbreast sunfish/ Lepomis auritus (Linnaeus)	2	5.6	5.3 - 5.8
Pumpkinseed/ Lepomis gibbosus (Linnaeus)	1	1.7	5.1
Tesselated darter/ Etheostoma olmstedi Storer	2	4.3	6.1 - 7.1

1 - American Fisheries Society-Special Publication No. 6, Third Edition, 1970

* - see attached page for length and weight distribution of more abundant species.

POTOMAC RIVER LOW FLOW STUDY - FISH COLLECTION DATA

Sampling Station Location: Potomac River along northwest bank in the region northwest of Vasco Island
Sampling Date : 20 November 1980

Length and Weight Distribution of More Abundant Species

American eel T.L. (cm)	18.0	20.1	20.3	23.1	24.1	24.4	26.9	28.2	28.4	30.0	33.3
Count	1	1	1	1	1	1	1	1	1	1	1
T. weight (gms)	8.7	11.6	13.3	20.3	17.7	22.7	28.5	35.5	36.0	45.0	69.1

Spottail shiner T.L. (cm)	3.6	3.8-4.6	4.8-5.3	5.6-6.1	6.4-6.9	7.1-7.6	7.9-8.4	8.6-9.1	9.4-9.9	10.2-10.7
Count	1	66	113	33	28	16	9	1	-	1
T. weight (gms)	0.1	48.0	128.7	54.5	62.0	56.5	42.2	5.6	-	8.0
$\bar{x}$ weight (gms)	0.1	0.7	1.1	1.7	2.2	3.5	4.7	5.6	-	8.0

Rosyface shiner T.L. (cm)	4.8	5.8	6.4	6.6	6.9	7.6
Count	1	1	1	1	2	1
T. weight (gms)	0.5	1.4	1.7	1.8	4.6	2.9

Spotfin shiner T.L. (cm)	2.3-2.5	2.8-3.0	3.3-3.6	3.8-4.1	4.3-4.6	4.8-5.1	5.3-5.6	5.8-6.1	6.4-6.6	6.9-7.1	7.4-7.6	7.9-8.1
Count	2	8	30	36	84	119	146	163	91	77	46	20
T. weight (gms)	0.1	1.5	10.0	24.4	60.7	128.3	215.5	303.9	214.5	227.1	171.5	92.8
$\bar{x}$ weight (gms)	0.05	0.2	0.3	0.7	0.7	1.1	1.5	1.9	2.4	2.9	3.7	4.6
T.L. (cm)	8.4-8.6	8.9-9.1	9.4-9.7									
Count	14	4	1									
T. weight (gms)	74.0	25.5	7.3									
$\bar{x}$ weight (gms)	5.3	6.4	7.3									

Bluntnose minnow T.L. (cm)	2.5-2.8	3.0-3.3	3.6-3.8	4.1-4.3	4.6-4.8	5.1-5.3	5.6-5.8	6.1-6.4	6.6-6.9	7.1-7.6
Count	1	-	3	8	27	29	30	3	2	5
T. weight (gms)	0.3	-	1.5	5.5	28.2	41.2	59.6	8.3	7.0	21.8
$\bar{x}$ weight (gms)	0.3	-	0.5	0.7	1.0	1.4	2.0	2.8	3.5	4.4

$\bar{x}$ = average weight/fish

APPENDIX B

BENTHIC MACROINVERTEBRATE DATA COLLECTION METHODOLOGY AND RESULTS

APPENDIX B

Benthic Macroinvertebrate Data Collection Methodology and Results *

On August 14 and 20, 1980 the Biological Monitoring Section of the Office of Environmental Programs initiated a cooperative sampling effort with the Water Supply Division of the Department of Natural Resources (DNR-WRA) and the U.S. Fish and Wildlife Service for the purpose of inventorying the benthic macroinvertebrates as a part of the Potomac River Low Flow Study.

Methods

Benthic macroinvertebrates were collected at three transects in the Potomac River (see attached map). These included the Seneca area, the Carderock area and the Little Falls area. Quantitative sampling was conducted in shallow riffle areas (12 to 18 inches) with a Surber square foot sampler. Nine individual square foot samples were collected along each transect with three representing the Maryland side, 3 mid-river, and 3 the Virginia side. These riffles are erosional areas of turbulent, rapid flow characterized by bedrock and coarse sediments such as cobbles and boulders. They are well oxygenated areas inhabited by organisms possessing special adaptations allowing them to attach or avoid the main thrust of the current.

An additional minimal effort was expended to qualitatively sample shallow inshore (2 feet or less) and deeper (6 to 7 feet) pools or depositional areas in an effort to characterize the benthic macroinvertebrate fauna of these areas which are subject to less desirable water quality conditions during critical flow and temperature periods of the year. For these purposes sieving devices were utilized to sample bottom areas by immersion of the sample taker with the sieving device to the bottom. The exact areas sampled under these difficult circumstances were not quantifiable but are felt to be representative. Two samples were taken at Seneca Pool about halfway between the riffle sampled and the mouth of Seneca Creek ten feet from shore in 2 feet of water and

*Prepared by: James T. Allison, Biological Monitoring, Office of Environmental Programs.

50 feet from shore at a depth of 6 to 7 feet. Two qualitative samples were also taken in the Carderock area in a slow, shallow, sandy area below a Willow Island and in a shallow water willow (*Justicia americana*) area. Qualitative sampling sites are noted on attached maps.

Benthic macroinvertebrate samples were labeled and preserved in the field with 70 percent ethanol and returned to the laboratory for sorting and identification. A species list was prepared which included number of taxa, number of organisms and computed diversity indices using the Shannon-Weaver Function. The use of diversity indices to assess stream quality has limitations which must be tempered by subjective judgement and professional interpretation. Estimates of diversity increase with sample size and samples with less than 100 individuals should be evaluated with caution. Index values from 0 to 1 indicate a stressed, polluted condition and values between 1 and 3 indicate intermediate conditions which can be subjectively broken down to fair (1 to 2) and good (2 to 3) with 3 and over suggesting an excellent stream quality. The index used is one recommended by EPA for purposes of uniformity and it uses the number of species in a sample along with the distribution of the individuals among the various taxonomic groups. Equally important in evaluating the data are the number of taxa along with the total number of organisms and their status with regard to tolerance to pollution and function within the community.

Results

A total of 12,621 benthic macroinvertebrate organisms were collected at Potomac low flow sampling stations. These were distributed among 5 phyla, 14 Orders and contained 95 species of which 81 were aquatic insects. In examining the species by taxonmmic Orders it is found that six Orders constitute about 90 percent of the total organisms. In descending order of abundance these are Trichoptera (caddisflies) 24.2 percent, Diptera (true flies) 23.2 percent, Ephemeroptera (mayflies) 18.9 percent, Coleoptera (aquatic beetles) 11.6 percent, Gastropoda (snails) 5.3 percent, and Odonata (dragonflies) 3.2 percent.

Seneca Creek Transect

At the Seneca Creek transect (see attached map) 56 taxa were collected among a total of 4,164 organisms combining nine one square-foot samples across the transect. The species diversity index was 4.10 suggesting an excellent stream quality. Caddisflies were dominant representing 57 percent of total numbers and 12 taxa. The dominant caddisflies were Cheumatopsyche campyla, Macronema sp., and Hydropsyche phalerata. These are retreat builders with nets as fine as 5 to 40 microns used to strain out fine suspended particulate material including phytoplankton and bacteria as sources of food. The second most abundant organisms were dipterans or aquatic larvae of true flies (13 taxa) comprising as dominants the chironomid midge Polypedilum sp. and Rheotanytarsus sp. and the dancefly larvae Hemerodromia sp. The majority of the dipterans are omnivores with some herbivores and predators represented. Mayflies (14 taxa) and beetles (6 taxa) each represented close to 10 percent of total organisms. The remaining 10 percent were distributed among 8 Orders including 11 taxa. Two Orders containing stoneflies and leeches were represented by only one organism. Numbers of organisms in the remaining 6 Orders included 3 damselflies, 10 fishflies, 17 flatworms, 75 clams, 132 snails and 167 aquatic moth larvae. The latter is a clinger and silk retreat maker which functions as a scraper feeding on algae and vascular plants and is very ubiquitous being present at all 9 sampling sites on this transect. The clams were represented by the exotic Asiatic clam, Corbicula fluminea (22) and the Fingernail clam, Sphaerium transversum (53). The snails included the exotic Faucet snail, Bithynia tentaculata (124), the Freshwater limpet, Ferrissia rivularis (2), and the native river snail, Goniobasis virginica (6). Five other ubiquitous species appearing at all 9 sites along this transect are the caddisflies, Hydropsyche phalerata and Macronema sp., the mayflies Caenis sp. and Stenonema exiguum and the elmid beetle Stenelmis mera.

Examining cross-transect differences at Seneca Creek showed the average number of taxa and organisms per square foot to range from 14 to 35 and 63 to 896 respectively. Maximum numbers of taxa per three square feet were found at the mid-river transect (43) with intermediate numbers on the Virginia side (40) and minimal numbers on the Maryland side (38). The maximum number of organisms per three square feet occurred on the Virginia side (1964) with mid-values at midstream (1477) and minimal value on the Maryland side (723). There was generally a cross-stream reduction in numbers of many of the dominant taxa from the Virginia side toward the Maryland side with the caddisflies exhibiting the most pronounced differences going from 1407 to 579 to 395 representing respectively Virginia, mid-river, and the Maryland side. Species diversity indices per square foot ranged from 2.99 to 3.80 with maximum mean diversity per three square feet found at mid-river (3.66), minimal mean diversity at the Maryland side (3.40) and intermediate mean diversity on the Virginia side (3.49). There was generally a good mixture of tolerant, intolerant and facultative organisms with respect to tolerances to siltation, organic enrichment and eutrophication with many of unknown tolerances which would suggest overall that the riffle community is a very productive community reflecting generally an excellent stream quality. The Virginia side of the river appears to be more productive at this transect.

Seneca Ceeek Pool

Qualitative samples taken in the Seneca Pool area at a shallow mud and detrital substrate site and a deeper sand and gravel substrate site revealed contrasting results. A good diversity (30 taxa) and abundance (520 organisms) of benthic macroinvertebrates was taken in the shallow area with dominants consisting of dipterans (11 taxa - 315 organisms - 60.6% of total), bivalves (1 taxa - 76 organisms - 14.6% of total), mayflies (4 taxa - 65 organisms - 12.5% of total), and aquatic beetles (4 taxa - 46 organisms - 8.8% of total). The dipteran dominance was divided evenly by two taxa which represented 73 percent of all dipterans. These were Tanytarsus sp. and Polypedilum sp. The dominant mayflies were Hexagenia atrocaudata and Caenis sp., burrowing forms found in bottom mud or submerged debris. Only one bivalve, the asiatic clam, Corbicula fluminea was present. The dominant beetles were the larval elmids, Dubiraphia sp. and Stenelmis sp. The remaining taxa consisted of alderflies, dragonflies, amphipods and aquatic oligochaetes comprising as a whole 2.4 percent of total numbers. The entire community appears to be one more adapted to slow current and the resultant deposits of silt and detrital material which accumulate in these areas.

In contrast to the shallow, mud and detrital substrate pool area, the deeper sand and gravel substrate pool near midchannel revealed a paucity of organisms (34) comprising only 10 taxa. Forty percent of these were dipterans (6 taxa), 30 percent bivalves (1 taxa) and 15 percent mayflies (1 taxa). The two remaining taxa represented at this site were the aquatic earthworm, Limnodrilus sp. and the alderfly, Sialis sp. The single bivalve was the asiatic clam Corbicula fluminea and the single mayfly was Tricorythodes sp. The reduced diversity and numbers of benthic macroinvertebrates at this site probably results for the most part from a lack of diverse habitat and also to a lesser degree from the inadequacies of sampling techniques in this depth and habitat type.

Carderock Transect

The Carderock sample sites were located in a riffle area 0.34 miles upstream from Stubblefield Falls (see attached map). Again combining 9 one-square foot samples across the transect, a total of 56 taxa of benthic macroinvertebrates were collected among a total of 4,523 organisms. The species diversity index was 3.98 suggesting an excellent stream quality.

Caddisflies were again dominants of the riffle community representing 15 taxa and 61.7 percent of total numbers. Within this group the prominent taxa were Hydropsyche sp., Macronema sp. and Cheumatopsyche campyla. The mayflies with 15 taxa and the dipterans (true flies and midges) with 11 taxa each represented about 11 percent of total numbers. Dominant mayflies were Heterocloen curiosum and Stenonema exiguum and dominant dipterans included Polypedilum sp., Cardiocladius sp. and Rheotanytarsus sp. Elmid beetles with 4 taxa represented 9 percent of total organisms with Stenelmis mera the dominant. Clams represented 3.8 percent of total numbers and were represented by the dominant asiatic clam (163) and the subordinate Fingernail clam (9). A single taxa, the small net-spinning larvae of the aquatic moth constituted 2.2 percent of total numbers (99). The remaining groups present which together represented less than one percent of total numbers included the helgrammite or Dobsonfly, Corydalus cornutus, the damselfly Argia sp., the dragonfly Gomphus sp., the scud Gammarus fasciatus, the flatworm

Dugesia tigrina and three snails. The gill-bearing Faucet snail was dominant (15) with the less common air breathing Freshwater limpet (2) and Tadpole snail Physa sp. (1) also found. Ubiquitous taxa found at all transect stations included two dipterans (Cardiocladius sp. and Polypedilum sp.), three hydropsychid caddisflies (Hydropsyche phalerata, Macronema sp. and Potamyia flava), one mayfly (Stenonema mediopunctatum), one elmid beetle (Stenonema mera), the aquatic moth larvae and the asiatic clam.

Examination of statistics across transect at each square foot sampling site revealed variations of from 15 to 37 taxa, 98 to 860 organisms and diversities from 2.98 to 3.87. Maximum numbers of taxa per three square feet were found on the Virginia side (43) with 40 and 41 found on the Maryland side and at mid-river respectively. The maximum numbers of organisms per three square feet occurred at mid-river (1625) with 1537 on the Maryland side and 1361 on the Virginia side. Again the principal difference in numbers of organisms was associated with hydropsychid caddisflies which showed a reduction in numbers across transect opposite to that at the upstream Seneca transect going from 1133 caddisflies on the Maryland side to 964 mid-river to 686 on the Virginia side. Other changes from the upstream Seneca transect included two less taxa of dipterans, 3 additional taxa of caddisflies, absence of stoneflies, 1 additional mayfly, 2 less beetles, 1 additional odonate and amphipod and no leeches. The number of snail taxa remained the same but the native river snail, Goniobasis virginica, was replaced by the Tadpole snail, Physa sp. Overall the number of taxa remained the same at the two transects (56) along with similar total numbers (4523-Seneca, 4164-Carderock) and diversities (4.10-Seneca, 3.98-Carderock).

Carderock Qualitatives

Qualitative benthic macroinvertebrate samples were collected at two sites in the Carderock transect area (see attached map). One sample was taken in a slow, shallow area (1 foot or less) with a sandy bottom located below a willow island and the second sample was taken in stands of the water-willow, Justicia americana, in an area with water depths of six to eight inches.

At the sandy bottom site only 17 taxa distributed among a total of 40 organisms were collected. No dipterans were represented and only 1 caddislfy, Neuroclipsus sp., was present. Five taxa and 12 specimens of mayflies were present. Four taxa and 12 specimens of aquatic beetles were taken, two for the first time, the riffle beetle, Macronychus glabratus, and the water-penny beetle, Psephenus herricki. The Faucet snail and Freshwater limpet were found here along with two taxa of leeches and one taxa each of damselflies, aquatic moths and clams (asiatic). The distribution of individuals among the various taxonomic groups creates a high species diversity index, however, the low number of taxa and organisms contravene this inflated value. The lack of diverse habitat here combined with low current flows and resultant siltation account in part for the diminished community of benthic macroinvertebrates.

The qualitative sample collected in the water willow area was much more diverse than the sandy bottom site as might be expected. A total of 213 organisms divided among 28 taxa included 6 taxa of dipterans, 9 taxa of caddisflies, 4 taxa of mayflies, 3 taxa of elmid beetles, 2 taxa of snails and 1 taxa each of damselflies, aquatic moths, amphipods and clams (asiatic). This area is similar in diversity to riffle sites. Differences include a 25 percent reduction in dipteran taxa and more than a 50 percent reduction in mayflies taxa. The caddisflies which dominated the riffle community were replaced as dominants by dipterans in the water willow community.

Little Falls Transect

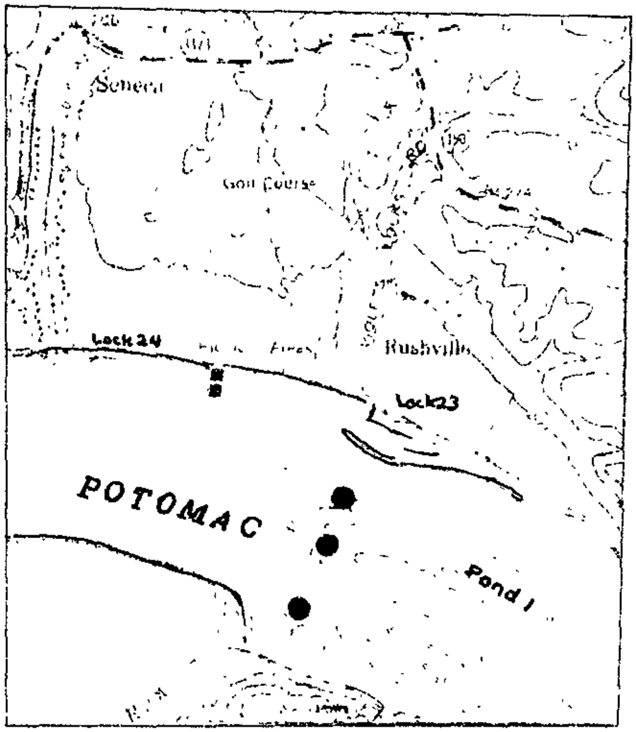
The Little Falls transect was located in a riffle area about seven tenths of a mile above Chain Bridge (see attached map). A total of 58 taxa of benthic macroinvertebrates among a total of 3,127 organisms were collected at the combined nine one-square foot sites along the transect. The overall species diversity index across the riffle of 3.99 again suggested an excellent stream quality. Caddisflies continued to dominate the riffle community with 19 taxa representing 60.5 percent of total numbers. Macronema sp. was the dominant caddisfly with Hydropsyche sp. and Cheumatopsyche sp. as sub-dominants. The dipterans ranked second in variety and abundance with 11 taxa dominated by the midges Cardiocladius sp. and Polypedilum sp. The mayflies ranked third in variety (9 taxa) but only fifth in abundance. There was a 40 percent reduction in mayfly taxa from the upstream Carderock transect, however, the majority of missing taxa were rare forms. The reduction in mayfly numbers resulted primarily from reductions in Heterocloeon curiosum, Stenonema exiguum, Caenis sp. and Tricorythodes sp. The most pronounced downstream decline among the mayflies occurred with Stenonema exiguum dropping from 197 at Seneca to 63 at Carderock to 20 at Little Falls. Some of these differnnces in taxa and numbers may have resulted from emergence. The beetles and snails at the Little Falls transect were each represented by 5 taxa; clams and crustaceans by 2 and dobsonflies, aquatic moths, damselflies, flatworms and aquatic earthworms by 1 taxa each. Abundant in numbers among these latter groups were the aquatic moth (226), the Faucet snail (184), the Asiatic clam (125) and the elmid beetle, Stenelmis mera (124). Ubiquitous taxa at this transect occurring at all sample sites included the midge, Polypedilum sp., the caddisflies, Cheumatopsyche campyla, Hydropsyche phalerata and Macronema sp. and the aquatic moth, Parargyractis fulicalis.

Examining cross-transect differences at Little Falls showed the average number of taxa and organisms per square foot to range from 21 to 29 and 138 to 916 respectively. Maximum numbers of taxa and organisms per three square feet occurred at mid-river (48 and 1330) with intermediate values on the Maryland side (40 and 1024) and minimal values on the Virginia side (33 and 778) where the majority of missing taxa were rare forms.

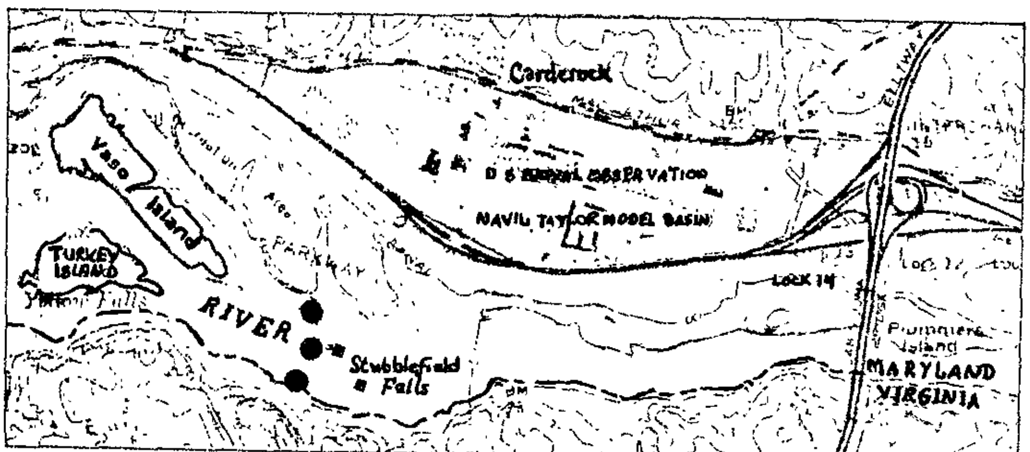
Although there was a slight increase in number of taxa (2) at the Little Falls transect there was also a reduction in the total number of organisms from upstream levels. Much of the difference in the numbers of organisms can be accounted for by decreases in the dominant dipterans, Polypedilum sp. and Rheotanytarsus sp. and the caddisflies, Hydropsyche (scalaris group) and H. phalerata and the mayflies Stenonema exiguum and Tricorythodes sp. It is difficult to attach too much significance to this drop in numbers due to the possible effects of emergence, competition and predation and the vagaries of sampling extremely small portions of an extremely large habitat. The same is true also in terms of the number of taxa. It is quite easy to miss the rarer forms. The riffle area at this site is highly productive and diverse and indicative of an excellent stream quality.

POTOMAC RIVER LOW FLOW STUDY

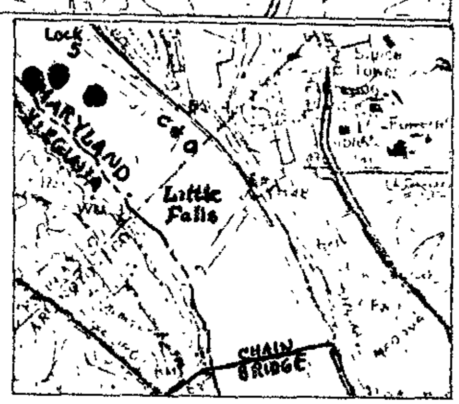
BENTHIC MACROINVERTEBRATE SAMPLE SITES



SENECA TRANSECT



CARDEROCK TRANSECT



LITTLE FALLS TRANSECT

● — QUANTITATIVE SAMPLES

■ — QUALITATIVE SAMPLES

MACROINVERTEBRATES COLLECTED AT RIFFLE BELOW SENECA CREEK
ON THE POTOMAC RIVER USING THE SURBER SAMPLER

SAMPLES COLLECTED AUGUST 14, 1980

ORGANISMS	Md. Side 1	Md. Side 2	Md. Side 3	Total # for 3 sq. ft.	Mid River 1	Mid River 2	Mid River 3	Total # for 3 sq. ft.	Va. Side 1	Va. Side 2	Va. Side 3	Total # for 3 sq. ft.	Total # entire sec. of river
DIPTERA													
Chironomidae													
Ablabesmyia sp.	-	-	-	-	-	-	-	-	-	-	1	1	1
Cardiocladius sp.	1	-	-	1	-	-	-	-	1	-	-	1	2
Conchapelopia sp.	4	1	-	5	1	4	-	5	1	3	1	5	15
Cricotopus sp.	1	-	-	1	1	1	-	2	-	1	-	1	4
Dicrotendipes sp.	-	-	-	-	-	2	-	2	-	-	1	1	3
Glyptotendipes sp.	2	-	2	4	7	8	5	20	1	4	11	16	40
Parachironomus sp.	-	-	-	-	-	2	-	2	-	-	-	-	2
Polypedilum sp.	22	7	-	29	14	63	12	89	17	50	26	93	211
Psectrocladius sp.	-	-	-	-	-	2	-	2	-	1	-	1	3
Rheotanytarsus sp.	7	15	-	22	25	12	19	56	35	32	22	89	167
Empididae													
Hemerodromia sp.	27	-	7	34	21	46	8	75	1	2	-	3	112
Rhagionidae													
Atherix variegata	-	-	-	-	-	-	-	-	-	1	-	1	1
Tipulidae													
Antocha sp.	-	1	-	1	-	-	-	-	-	-	-	-	1
TRICHOPTERA													
Hydropsychidae													
Cheumatopsyche campyla	100	29	3	132	-	230	21	251	57	154	175	386	769
Hydropsyche scalaris	-	-	-	-	-	2	1	3	-	5	2	7	10
H. dicantha	-	-	-	-	-	-	-	-	-	10	90	100	100
H. hageni	16	-	1	17	13	6	9	28	6	10	8	24	69
H. hoffmani	8	-	-	8	5	3	3	11	8	34	28	70	89
H. phalerata	89	24	15	128	36	64	44	144	85	71	55	211	483
H. (scalaris grp)?	-	-	-	-	-	-	-	-	15	129	-	144	144
Macronema sp.	63	24	2	89	4	65	42	111	76	170	188	434	634
Potamyia flava	11	8	-	19	2	15	7	24	8	11	7	26	69
Hydroptilidae													
Hydroptila spatulata	1	-	-	1	-	-	-	-	-	-	-	-	1
Leptoceridae													
Ceraclea spongillovorax	-	-	-	-	1	4	1	6	-	4	1	5	11
Ceraclea sp.	1	-	-	1	1	-	-	1	-	-	-	-	2
PLECOPTERA													
Perlidae													
Acroneuria sp.	1	-	-	1	-	-	-	-	-	-	-	-	1
EPHEMEROPTERA													
Baetidae													
Baetis sp.	2	-	-	2	2	2	1	5	-	-	-	-	7
Centroptilum sp.	-	1	-	1	-	-	-	-	-	-	-	-	1
Heterocloeon curiosum	3	-	-	3	4	7	2	13	-	-	2	2	18
Pseudocloeon sp.	-	1	-	1	-	-	-	-	-	-	-	-	1
Caenidae													
Brachycercus sp.	-	-	-	-	-	-	-	-	-	1	1	2	2
Caenis sp.	1	8	1	10	4	32	8	44	3	10	2	15	69
Ephemerellidae													
Ephemerella deficiens	2	-	-	2	-	5	-	5	-	-	1	1	8
Heptageniidae													
Heptagenia sp.	-	-	-	-	-	1	-	1	-	-	-	-	1
Stenacron interpunctatum	-	-	-	-	2	-	-	2	-	4	-	4	6
Stenonema exiguum	42	13	2	57	23	16	3	42	29	54	15	98	197
S. mediopunctatum	2	1	1	4	3	8	-	11	-	4	-	4	19
S. terminatum	-	3	-	3	-	3	-	3	-	-	-	-	6
Potamanthidae													
Potamanthus walkeri	-	6	-	6	-	5	3	8	2	1	2	5	19
Tricorythodidae													
Tricorythodes sp.	10	2	1	13	11	20	-	31	1	2	-	3	47
COLEOPTERA													
Elmidae													
Microcylloepus pusillus	4	-	-	4	13	42	1	56	-	-	3	3	63
Optioservus trivittatus	-	1	-	1	-	-	-	-	-	-	-	-	1
Promoresia elegans	-	-	-	-	1	-	-	1	-	-	-	-	1
Stenelmis crenata	-	-	-	-	-	8	-	8	-	11	4	15	23
S. markeli	-	1	-	1	-	-	-	-	1	-	-	1	2
S. mera	18	43	20	81	25	56	68	149	24	53	17	94	324
MEGALOPTERA													
Corydalus cornutus	1	1	-	2	2	-	-	2	1	2	3	6	10
LEPIDOPTERA													
Parargyractis fulicalis	7	9	4	20	34	31	44	109	7	24	7	38	167
ODONATA													
Argia sp.	-	-	-	-	-	-	1	1	-	1	1	2	3
TURBELLARIA													
Dugesia tigrina	-	-	-	-	15	-	-	15	-	-	2	2	17
GASTROPODA													
Bithynia tentaculata	1	-	-	1	118	5	-	123	-	-	-	-	124
Ferrissia rivularis	-	-	1	1	1	-	-	1	-	-	-	-	2
Goniobasis virginica	1	1	-	2	1	3	-	4	-	-	-	-	6
PELECYPODA													
Corbicula fluminea	5	7	3	15	-	3	1	4	1	2	-	3	22
Sphaerium transversum	-	-	-	-	3	3	-	6	-	35	12	47	53
HIRUDINEA													
Erpobdellidae	-	-	-	-	1	-	-	1	-	-	-	-	1
Total # of Organisms	453	207	63	723	394	779	304	1,477	380	896	688	1,964	4,164
Total # of Taxa													
Generic level	27	20	12	33	27	29	19	36	19	25	24	32	46
Species level	30	23	14	38	31	35	22	43	22	32	29	40	56
Diversity Index													
Ordinal level	1.66	2.24	2.30	1.97	2.69	2.02	2.11	2.46	1.52	1.66	1.14	1.48	2.08
Generic level	3.30	3.53	2.86	3.01	3.53	3.64	3.25	3.94	2.95	3.09	2.73	3.00	3.62
Species level	3.56	3.64	2.99	3.79	3.75	3.80	3.44	4.14	3.31	3.70	3.20	3.65	4.10

MACROINVERTEBRATES COLLECTED IN THE CARDEROCK AREA
OF THE POTOMAC RIVER
SAMPLES WERE COLLECTED WITH THE SURBER SAMPLER
Samples were collected August 20, 1980 (Numbers per sq. ft. unless otherwise noted)

	Md. Side			Total # for	Mid River			Total # for	Va. Side			Total # for	Total # for
ORGANISMS	1	2	3	3 sq. ft.	1	2	3	3 sq. ft.	1	2	3	3 sq. ft.	entire section
DIPTERA													
Chironomidae													
Ablabesymia mallochi	1	4	-	5	-	-	-	-	2	-	1	3	8
Cardiocladius sp.	10	12	4	26	2	33	32	67	37	34	5	76	169
Conchapelopia sp.	1	-	-	1	1	-	-	1	1	-	-	1	3
Cricotopus sp.	1	-	-	1	-	-	-	-	-	5	1	6	7
Dicrotendipes sp.	1	-	-	1	1	-	-	1	-	-	-	-	2
Eukiefferiella sp.	10	5	-	15	4	-	-	4	8	3	1	12	31
Polypedilum sp.	36	16	1	53	43	12	14	69	22	24	3	49	171
Rheotanytarsus sp.	66	2	2	70	24	1	6	31	1	6	-	7	108
Empididae													
Hemerodromia sp.	2	1	-	3	-	6	1	7	-	3	-	3	13
Simuliidae													
Simulium sp.	1	-	-	1	3	-	-	3	-	1	-	1	5
Tipulidae													
Antocha sp.	-	-	-	-	-	-	-	-	1	-	1	2	2
TRICHOPTERA													
Glossosomatidae													
Protoptila sp.	-	-	-	-	-	-	-	-	-	2	-	2	2
Hydropsychidae													
Cheumatopsyche campyla	20	9	2	31	86	-	41	127	38	51	22	111	269
Hydropsyche scalaris	-	1	-	1	6	1	1	8	2	1	-	3	12
H. betteni	-	-	-	-	-	-	-	-	1	-	-	1	1
H. dicantha	2	1	-	3	-	-	-	-	2	-	-	2	5
H. hageni	60	26	-	86	24	-	6	30	11	3	-	14	130
H. hoffmani	14	16	-	30	78	2	38	118	10	28	1	39	187
H. leonardi	10	2	4	16	8	-	4	12	3	4	2	9	37
H. phalerata	89	48	3	140	64	9	28	101	47	92	10	149	390
H. (scalaris grp)?	288	254	-	542	64	1	140	205	63	35	-	98	845
Macronema sp.	119	128	20	267	204	40	77	321	126	70	51	247	835
Potamyia flava	10	9	3	22	32	2	7	41	3	7	1	11	74
Hydroptilidae													
Hydroptila waubesiana	-	-	-	-	-	1	-	1	-	-	-	-	1
Leptoceridae													
Nectopsyche pavida	-	-	-	-	-	-	-	-	-	1	-	1	1
Polycentropodidae													
Neureclipsis	1	-	-	1	-	-	-	-	-	1	-	1	2
EPHEMEROPTERA													
Baetidae													
Baetis sp.	2	1	3	6	-	6	1	7	1	8	-	9	22
Centroptilum sp.	-	-	-	-	-	-	-	-	1	-	-	1	1
Heterocloeon curiosum	20	15	-	35	86	2	27	115	38	84	-	122	272
Isonychia sp.	1	-	-	1	-	-	1	1	-	-	-	-	2
Pseudocloen sp.	-	4	-	4	-	-	-	-	-	-	-	-	4
Caenidae													
Caenis sp.	3	-	-	3	1	2	1	4	-	1	-	1	8
Ephemerellidae													
Ephemerella deficiens	1	-	-	1	2	-	2	4	-	-	-	-	5
Heptageniidae													
Heptagenia sp.	-	-	-	-	-	1	-	1	-	-	1	1	2
Stenacron interpunctatum	-	-	-	-	-	18	-	18	-	-	-	-	18
Stenonema exiguum	14	5	8	27	18	4	12	34	-	-	2	2	63
S. mediopunctatum	3	3	1	7	5	5	8	18	1	1	2	4	29
S. modestum	-	-	-	-	-	-	-	-	-	1	-	1	1
S. terminatum	-	-	-	-	-	-	-	-	-	10	1	11	11
Potamanthidae													
Potamanthus walkeri	-	1	-	1	1	5	-	6	-	-	-	-	7
Tricorythodidae													
Tricorythodes sp.	4	1	-	5	5	12	12	29	6	9	7	22	56
COLEOPTERA													
Elmidae													
Microcylloepus pusillus	4	-	-	4	33	-	9	42	8	-	-	8	54
Stenelmis crenata	1	-	-	1	-	1	-	1	-	4	2	6	8
S. markeli	-	-	-	-	-	2	-	2	-	-	-	-	2
S. mera	8	33	4	45	46	49	15	110	81	68	38	187	342
MEGALOPTERA													
Corydalus cornutus	-	-	1	1	1	-	1	2	1	2	-	3	6
ODONATA													
Argia sp.	1	-	-	1	-	2	-	2	-	-	-	-	3
Gomphus sp.	1	-	-	1	-	-	-	-	-	-	-	-	1
LEPIDOPTERA													
Parargyractis fulicalis	9	10	33	52	2	8	19	29	5	11	2	18	99
AMPHIPODA													
Gammarus fasciatus	-	-	-	-	-	5	-	5	-	-	-		5
TURBELLARIA													
Dugesia tigrina	1	-	-	1	-	-	-	-	-	-	1	1	2
PELECYPODA													
Corbicula fluminea	4	11	9	24	9	13	3	25	16	88	10	114	163
Sphaerium transversum	-	-	-	-	6	-	3	9	-	-	-	-	9
GASTROPODA													
Bithynia tentaculata	-	-	-	-	1	5	8	14	-	-	1	1	15
Ferrissia rivularis	2	-	-	2	-	-	-	-	-	-	-	-	2
Physa sp.	-	-	-	-	-	-	-	-	-	1	-	1	1
Total # of Organisms	821	618	98	1537	860	248	517	1625	536	659	166	1361	4523
Total # of Taxa													
Generic level	30	19	13	33	24	22	22	32	21	24	18	32	44
Species level	37	26	15	41	30	28	28	40	28	32	23	43	56
Diversity Index													
Ordinal level	1.23	1.15	2.27	1.38	1.57	2.58	1.67	1.86	1.82	2.19	1.95	2.07	1.82
Generic level	2.45	2.24	2.95	2.57	3.11	3.68	3.03	3.46	3.06	3.38	2.97	3.35	3.28
Species level	3.35	2.98	3.07	3.39	3.74	3.87	3.70	4.08	3.57	3.84	3.16	3.84	3.98

MACROINVERTEBRATES COLLECTED AT LITTLE FALLS ON THE POTOMAC RIVER USING THE SURBER SAMPLER

SAMPLES COLLECTED AUGUST 20, 1980
(Numbers per square foot unless otherwise noted)

ORGANISMS	Md. Side 1	Md. Side 2	Md. Side 3	Total # for 3 sq. ft.	Mid River 1	Mid River 2	Mid River 3	Total # for 3 sq. ft.	Va. Side 1	Va. Side 2	Va. Side 3	Total # for 3 sq. ft.	Total for entire section of river
DIPTERA													
Chironomidae													
Ablabesmyia mallochi	-	-	-	-	1	-	-	*1*	-	-	-	-	*1*
Cardiocladius sp.	13	58	33	*104*	-	5	1	*6*	1	8	11	*20*	*130*
Cricotopus sp.	-	-	-	-	4	-	-	*4*	2	2	1	*5*	*9*
Dicrotendipes sp.	-	-	-	-	1	-	-	*1*	-	-	-	-	*1*
Eukiefferiella sp.	-	-	-	-	-	-	3	*3*	-	2	-	*2*	*5*
Polypedilum sp.	2	6	14	*22*	1	5	10	*16*	22	12	10	*44*	*82*
Rheotanytarsus sp.	1	-	3	*4*	2	-	-	*2*	2	-	1	*3*	*9*
Psectrocladius sp.	-	-	-	-	-	-	-	-	1	-	-	*1*	*1*
Empididae													
Hemerodromia sp.	-	-	-	-	-	2	2	*4*	-	-	-	-	*4*
Tipulidae													
Antocha sp.	1	-	2	*3*	-	1	-	*1*	1	-	-	*1*	*5*
Simuliidae													
Simulium sp.	-	-	-	-	-	-	1	*1*	-	-	-	-	*1*
TRICHOPTERA													
Brachycentridae													
Micrasema sp.	-	-	-	-	-	-	-	-	-	-	1	*1*	*1*
Hydropsychidae													
Cheumatopsyche campyla	20	34	17	*71*	7	33	131	*171*	17	17	15	*49*	*291*
Hydropsyche scalaris	-	2	-	*2*	-	-	1	*1*	-	-	-	-	*3*
H. dicantha	16	6	-	*22*	-	-	41	*41*	-	-	-	-	*63*
H. hageni	23	4	4	*31*	-	4	20	*24*	13	19	3	*35*	*90*
H. hoffmani	4	4	1	*9*	-	1	49	*50*	4	9	1	*14*	*73*
H. leonardi	-	9	-	*9*	-	4	54	*58*	-	-	-	-	*67*
H. phalerata	21	24	13	*58*	1	17	46	*64*	55	42	22	*119*	*241*
H. (scalaris grp)?	-	3	-	*3*	-	2	9	*11*	45	28	6	*79*	*93*
Macronema sp.	41	209	57	*307*	15	100	362	*477*	37	46	46	*129*	*913*
Potamyia flava	4	4	2	*10*	-	7	6	*13*	8	1	-	*9*	*32*
Hydroptilidae													
Hydroptila spatulata	-	-	-	-	-	-	1	*1*	-	-	-	-	*1*
H. waubesiana	1	-	-	*1*	3	-		*3*	-	-	-	-	*4*
Leucotrichia pictipes	3	-	5	*8*	-	-	-	-	-	-	-	-	*8*
Leptoceridae													
Ceraclea spongillovorax	-	-	-	-	-	1	-	*1*	-	-	-	-	*1*
Oecetis cinerascens	1	-	-	*1*	1	1	-	*2*	-	-	-	-	*3*
Polycentropidae													
Cyrnellus fraternus	-	-	1	*1*	2	-	-	*2*	-	-	-	-	*3*
Neureclipsis	1	-	1	*2*	2	-	-	*2*	-	-	-	-	*4*
Psychomyiidae													
Psychomyia flavida	-	-	-	-	-	1	-	*1*	-	-	-	-	*1*
EPHEMEROPTERA													
Baetidae													
Baetis sp. 2	1	7	3	*11*	5	-	-	*5*	3	2	4	*9*	*25*
Heterocloeon curiosum	15	2	5	*22*	1	1	24	*26*	9	15	2	*26*	*74*
Caenidae													
Caenis sp.	-	-	-	-	2	-	1	*3*	-	-	-	-	*3*
Potamanthidae													
Potamanthus walkeri	-	-	-	-	1	7	-	*8*	3	-	-	*3*	*11*
Heptageniidae													
Stenacron interpunctatum	-	-	-	-	1	-	-	*1*	-	1	1	*2*	*3*
Stenonema exiguum	2	3	4	*9*	3	3	4	*10*	1	-	-	*1*	*20*
S. mediopunctatum	-	5	-	*5*	2	6	2	*10*	2	-	-	*2*	*17*
S. terminatum	-	1	-	*1*	-	-	-	-	-	-	-	-	*1*
Tricorythidae													
Tricorythodes sp.	2	1	8	*11*	5	-	1	*6*	-	2	6	*8*	*25*
COLEOPTERA													
Elmidae													
Microcylloepus pusillus	1	9	5	*15*	-	-	2	*2*	1	5	1	*7*	*24*
Optioservus trivittatus	-	1	-	*1*	-	-	-	-	-	-	-	-	*1*
Stenelmis crenata	-	1	-	*1*	-	-	1	*1*	-	-	-	-	*2*
S. markeli	-	1	4	*5*	10	-	-	*10*	-	2	-	*2*	*17*
S. mera	2	21	18	*41*	10	10	48	*68*	12	-	3	*15*	*124*
MEGALOPTERA													
Corydalus cornutus	-	-	-	-	-	-	4	*4*	1	-	-	*1*	*5*
LEPIDOPTERA													
Parargyractis fulicalis	10	58	65	*133*	15	35	12	*62*	9	11	11	*31*	*226*
ODONATA													
Argia sp.	-	-	-	-	2	-	-	*2*	-	-	-	-	*2*
CRUSTACEA													
Gammarus fasciatus	-	-	4	*4*	-	-	-	-	-	-	-	-	*4*
Asellus communis	-	-	5	*5*	-	-	-	-	-	-	-	-	*5*
TURBELLARIA													
Dugesia tigrina	2	3	7	*12*	-	1	-	*1*	5	10	3	*18*	*31*
PELECYPODA													
Corbicula fluminea	-	9	2	*11*	18	9	80	*107*	3	-	4	*7*	*125*
Sphaerium transversum	-	6	-	*6*	-	2	-	*2*	-	-	-	-	*8*
GASTROPODA													
Bithynia tentaculata	-	2	40	*42*	11	11	-	*22*	26	45	49	*120*	*184*
Ferrissia rivularis	5	-	12	*17*	11	7	-	*18*	-	-	-	-	*35*
Goniobasis virginica	-	-	1	*1*	1	-	-	*1*	-	-	-	-	*2*
Anculosa carinata	-	-	3	*3*	-	-	-	-	1	-	-	*1*	*4*
Physa sp.	-	-	-	-	-	-	-	-	3	3	-	*6*	*6*
OLIGOCHAETA													
Limnodrilus sp.	-	-	-	-	-	-	-	-	-	-	3	*3*	*3*
Total # of Organisms	192	493	339	*1024*	138	276	916	*1330*	287	282	204	*773*	*3127*
Total # of Taxa													
Generic level	21	18	26	*30*	26	21	19	*37*	23	18	19	*28*	*47*
Species level	24	28	29	*40*	28	26	27	*48*	27	21	22	*33*	*58*
Diversity Index													
Ordinal level	1.52	1.86	2.67	*2.23*	2.80	1.91	1.20	*1.69*	1.91	1.95	2.25	*2.08*	*2.08*
Generic level	3.08	2.83	3.78	*3.46*	3.98	3.18	2.50	*3.08*	3.11	3.03	3.24	*3.27*	*3.48*
Species level	3.69	3.12	3.88	*3.79*	4.16	3.38	3.10	*3.60*	3.76	3.66	3.44	*3.81*	*3.99*

QUALITATIVE SAMPLING OF THE SENECA POOL AREA

SAMPLES COLLECTED AUGUST 14, 1980

ORGANISMS	Maryland Side Shallow Mud & detritus	Middle Seneca Pool Sand & gravel
DIPTERA		
Chironomidae		
Ablabesymia mallochi	2	-
Ablabesymia sp.?	13	2
Chironomus sp.	2	1
Cryptochironomus fulvus	28	-
Diamesinae	1	-
Dicrotendipes sp.	4	-
Glyptotendipes sp.	3	-
Paracladopelma sp.	-	3
Polypedilum sp.	113	2
Procladius sp.	21	2
Tanytarsus sp.	117	4
Ceratopogonidae	11	-
TRICHOPTERA		
Hydropsychidae		
Cheumatopsyche campyla	1	-
Hydropsyche dicantha	1	-
H. phalerata	1	-
Macronema sp.	2	-
Potamyia flava	1	-
Leptoceridae		
Oecetis cinerascens	5	-
EPHEMEROPTERA		
Baetidae		
Centroptilum sp.	1	-
Caenidae		
Caenis sp.	19	-
Ephemeridae		
Hexagenia atrocaudata	43	5
Tricorythodidae		
Tricorythodes sp.	2	-
COLEOPTERA		
Elmidae		
Dubiraphia sp. (larvae)	26	-
Microcylloepus pusillus	2	-
Stenelmis sp. (larvae)	11	-
Hydrophilidae		
Berosus sp.	2	-
MEGALOPTERA		
Sialidae		
Sialis sp.	5	1
ODONATA		
Gomphidae		
Gomphus sp.	1	-
AMPHIPODA		
Gammaridae		
Crangonyx sp.	1	-
PELECYPODA		
Corbicula fluminea	76	10
OLIGOCHAETA		
Limnodrilus sp.	5	4
Total # of Organisms	520	34
Total # of Taxa		
Generic level	28	10
Species level	30	10
Diversity Index		
Ordinal level	1.79	1.97
Generic level	3.43	2.98
Species level	3.45	2.98

MACROINVERTEBRATES COLLECTED IN THE CARDEROCK AREA OF THE POTOMAC RIVER

SAMPLES COLLECTED QUALITATIVELY ON AUGUST 20, 1980

ORGANISMS	Slow Shallow Area Below A Willow Island Sandy Bottom	Sample Collected In Water Willow Area
DIPTERA		
Chironomidae		
Cardiocladius sp.	-	10
Conchapelopia sp.	-	1
Polypedilum sp.	-	38
Rheotanytarsus sp.	-	18
Empididae		
Hemerodromia sp.	-	12
Simuliidae		
Simulium sp.	-	1
TRICHOPTERA		
Hydropsychidae		
Cheumatopsyche campyla	-	22
Hydropsyche scalaris	-	1
H. hageni	-	2
H. phalerata	-	11
Hydropsyche (scalaris grp)?	-	1
Macronema sp.	-	2
Potamyia flava	-	3
Hydroptilidae		
Hydroptila spatulata	-	1
Polycentropodidae		
Neureclipsis sp.	1	1
EPHEMEROPTERA		
Baetidae		
Heterocloeon curiosum	-	4
Heptageniidae		
Stenacron interpunctatum	4	-
Stenonema mediopunctatum	1	2
S. terminatum	1	3
Potamanthidae		
Potamanthus walkeri	5	-
Tricorythodidae		
Tricorythodes sp.	1	17
COLEOPTERA		
Elmidae		
Macronychus glabratus	1	-
Microcylloepus pusillus	-	3
Stenelmis markeli	6	14
S. mera	4	2
Psephenidae		
Psephenus herricki	1	-
ODONATA		
Argia sp.	3	-
Hetaerina sp.	-	2
LEPIDOPTERA		
Parargyractis fulicalis	1	2
AMPHIPODA		
Gammarus fasciatus	-	16
PELECYPODA		
Corbicula fluminea	1	3
GASTROPODA		
Bithynia tentaculata	6	16
Ferrissia rivularis	1	5
HIRUNDINEA		
Erpobdella sp.	1	-
Placobdella sp.	2	-
Total # of Organisms	40	213
Total # of Taxa		
Generic level	15	23
Species level	17	28
Diversity Index		
Ordinal level	2.44	2.51
Generic level	3.39	3.88
Species level	3.69	4.03

DEPARTMENT OF HEALTH AND MENTAL HYGIENE

OFFICE OF ENVIRONMENTAL PROGRAMS
Division of Water Quality Monitoring
Biological Services Section

Potomac River Low Flow Study - Fish Collection Data

Sampling Station Location	-	Potomac River along northwest bank in the region northwest of Vasco Island
Sampling Date	-	20 November 1980
River Length Sampled	-	230 meters (755 feet)
Method of Sampling	-	Electrofishing with 120v AC shocker - representative collection obtained
Collectors	-	G. Harman, J. Allison, W. Butler, S. Goodbred, B. Folker, G. Ruddy

COMMON NAME/SCIENTIFIC NAME[1]	TOTAL COUNT	TOTAL WEIGHT (gms)*	TOTAL LENGTH (cm)
American eel/ *Anguilla rostrata* (Lesueur)	11	308.4	18.0 - 33.3
Rosyside dace/ *Clinostomus funduloides* Girard	1	1.5	5.6
River chub/ *Nocomis micropogon* (Cope)	2	14.9	7.6 - 9.1
Spottail shiner/ *Notropis hudsonius* (Clinton)	268	405.6	3.6 - 10.7
Rosyface shiner/ *Notropis rubellus* (Agassiz)	7	12.9	4.8 - 7.6
Spotfin shiner/ *Notropis spilopterus* (Cope)	841	1557.1	2.3 - 9.7
Bluntnose minnow/ *Pimephales notatus* (Rafinesque)	108	173.4	2.5 - 7.6
Northern hogsucker/ *Hypentelium nigricans* (Lesueur)	1	12.0	10.7
Redbreast sunfish/ *Lepomis auritus* (Linnaeus)	2	5.6	5.3 - 5.8
Pumpkinseed/ *Lepomis gibbosus* (Linnaeus)	1	1.7	5.1
Tesselated darter/ *Etheostoma olmstedi* Storer	2	4.3	6.1 - 7.1

1 - American Fisheries Society-Special Publication No. 6, Third Edition, 1970

* - see attached page for length and weight distribution of more abundant species.

POTOMAC RIVER LOW FLOW STUDY - FISH COLLECTION DATA

Sampling Station Location: Potomac River along northwest bank in the region northwest of Vasco Island
Sampling Date : 20 November 1980

Length and Weight Distribution of More Abundant Species

American eel											
T.L. (cm)	18.0	20.1	20.3	23.1	24.1	24.4	26.9	28.2	28.4	30.0	33.3
Count	1	1	1	1	1	1	1	1	1	1	1
T. weight (gms)	8.7	11.6	13.3	20.3	17.7	22.7	28.5	35.5	36.0	45.0	69.1

Spottail shiner										
T.L. (cm)	3.6	3.8-4.6	4.8-5.3	5.6-6.1	6.4-6.9	7.1-7.6	7.9-8.4	8.6-9.1	9.4-9.9	10.2-10.7
Count	1	66	113	33	28	16	9	1	-	1
T. weight (gms)	0.1	48.0	128.7	54.5	62.0	56.5	42.2	5.6	-	8.0
$\bar{x}$ weight (gms)	0.1	0.7	1.1	1.7	2.2	3.5	4.7	5.6	-	8.0

Rosyface shiner						
T.L. (cm)	4.8	5.8	6.4	6.6	6.9	7.6
Count	1	1	1	1	2	1
T. weight (gms)	0.5	1.4	1.7	1.8	4.6	2.9

Spotfin shiner												
T.L. (cm)	2.3-2.5	2.8-3.0	3.3-3.6	3.8-4.1	4.3-4.6	4.8-5.1	5.3-5.6	5.8-6.1	6.4-6.6	6.9-7.1	7.4-7.6	7.9-8.1
Count	2	8	30	36	84	119	146	163	91	77	46	20
T. weight (gms)	0.1	1.5	10.0	24.4	60.7	128.3	215.5	303.9	214.5	227.1	171.5	92.8
$\bar{x}$ weight (gms)	0.05	0.2	0.3	0.7	0.7	1.1	1.5	1.9	2.4	2.9	3.7	4.6
T.L. (cm)	8.4-8.6	8.9-9.1	9.4-9.7									
Count	14	4	1									
T. weight (gms)	74.0	25.5	7.3									
$\bar{x}$ weight (gms)	5.3	6.4	7.3									

Bluntnose minnow										
T.L. (cm)	2.5-2.8	3.0-3.3	3.6-3.8	4.1-4.3	4.6-4.8	5.1-5.3	5.6-5.8	6.1-6.4	6.6-6.9	7.1-7.6
Count	1	-	3	8	27	29	30	3	2	5
T. weight (gms)	0.3	-	1.5	5.5	28.2	41.2	59.6	8.3	7.0	21.8
$\bar{x}$ weight (gms)	0.3	-	0.5	0.7	1.0	1.4	2.0	2.8	3.5	4.4

$\bar{x}$ = average weight/fish

APPENDIX C

IFG MODEL OUTPUT FOR TRANSECTS 11 AND 12 (BELOW LITTLE FALLS DAM) AND TRANSECTS 8 AND 9 (ABOVE LITTLE FALLS DAM)

HABTAT PROGRAM VERSION NUMBER 2-3
LAST UPDATED ON 5 NOVEMBER 1979.

IOC 10000 01101 00000 00000

HEADER 24 10 10 10 0.00 0.00 0.00 0.00 0.00 0.00

VELOCITY BRACKETS 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

DEPTH BRACKETS 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

SUBSTRATE BRACKETS 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

CURVE ID NUMBERS 20111 20112 20113 20114 20115 100200 100201 100202 100203 30100 30101 30102
30110 20400 20401 20402 20410 51201 51202 51203 60100 60101 60102 60110

CURVE SET DEFINITION DATA WAS OBTAINED FROM THE FILE --
IFG FILE OF SUITABILITY CURVES
LAST UPDATED ON 79/01/03. 15.57.50.

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR SMALL MOUTH BASS (TURBID WATER)

MONTH	Q	INCUBATION	FRY	JUVENILES	ADULT	SPAWNING
1	2810.00	111313.81	188469.13	264911.71	144406.63	271355.22
2	2310.00	79445.86	159103.28	252315.12	112091.75	262619.47
3	2015.00	64911.31	126514.25	247632.37	95893.78	248132.51
4	1705.00	50675.44	83319.46	240776.82	78866.85	200593.33
5	1395.00	42583.41	46386.53	222758.31	60881.42	138441.00
6	1085.00	38088.22	24669.03	163798.65	53860.23	79111.29
7	775.00	35182.49	17042.21	69089.13	58015.43	50690.83
8	465.00	41202.43	21691.18	26738.19	53610.55	37461.13

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR SMALL MOUTH BASS (TURBID WATER)

MONTH	Q	GROSS	INCUBATION	FRY	JUVENILES	ADULT	SPAWNING
1	2810.	490114.	22.71	38.45	54.05	29.46	55.37
2	2310.	462721.	17.17	34.38	54.53	24.22	56.76
3	2015.	450352.	14.41	28.09	54.99	21.29	55.10
4	1705.	435698.	11.63	19.12	55.26	18.10	46.04
5	1395.	418756.	10.17	11.08	53.20	14.54	33.06
6	1085.	398468.	9.56	6.19	41.11	13.52	19.85
7	775.	359179.	9.80	4.74	19.24	16.15	14.11
8	465.	215470.	19.12	10.07	12.41	24.88	17.39

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WHITE SUCKER

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	205229.02	339970.44	361884.25	77147.17
2	2310.00	202493.50	336962.04	347101.06	89794.48
3	2015.00	200025.99	331046.11	337838.50	107758.97
4	1705.00	185496.66	322209.94	324330.29	134092.81
5	1395.00	147379.98	305134.10	304943.91	154665.82
6	1085.00	81305.64	285694.17	285301.37	132324.45
7	775.00	22122.12	227037.23	205491.98	76458.96
8	465.00	8781.90	57994.74	102431.51	36473.28

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR WHITE SUCKER

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	490114.	41.87	69.37	73.84	15.74
2	2310.	462721.	43.76	72.82	75.01	19.41
3	2015.	450352.	44.42	73.51	75.02	23.93
4	1705.	435698.	42.57	73.95	74.44	30.78
5	1395.	418756.	35.19	72.87	72.82	36.93
6	1085.	398468.	20.40	71.70	71.60	33.21
7	775.	359179.	6.16	63.21	57.21	21.29
8	465.	215470.	4.08	26.92	47.54	16.93

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR CHANNEL CATFISH

MONTH	Q	FRY	JUVENILES	ADULTS	SPAWNING
1	2810.00	432269.52	58838.92	58956.74	40130.43
2	2310.00	415649.98	53883.83	46451.90	21873.36
3	2015.00	410581.00	49975.35	40416.77	13651.12
4	1705.00	400714.84	47494.51	32171.06	7950.89
5	1395.00	379493.19	43018.18	26134.35	5939.16
6	1085.00	344111.37	37034.99	26172.79	7232.90
7	775.00	273529.59	32635.88	30350.69	8327.87
8	465.00	141442.67	19785.86	31881.31	13425.05

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR CHANNEL CATFISH

MONTH	Q	GROSS	FRY	JUVENILES	ADULTS	SPAWNING
1	2810.	490114.	88.20	12.01	12.03	8.19
2	2310.	462721.	89.83	11.64	10.04	4.73
3	2015.	450352.	91.17	11.10	8.97	3.03
4	1705.	435698.	91.97	10.90	7.38	1.82
5	1395.	418756.	90.62	10.27	6.24	1.42
6	1085.	398468.	86.36	9.29	6.57	1.82
7	775.	359179.	76.15	9.09	8.45	2.32
8	465.	215470.	65.64	9.18	14.80	6.23

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BLUEGILL

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	75491.58	104022.98	109231.51	132860.24
2	2310.00	76389.32	101546.08	71988.85	89529.44
3	2015.00	77523.19	105161.81	49845.01	59539.32
4	1705.00	63719.21	110568.12	30630.58	30980.53
5	1395.00	47607.82	103723.26	15946.77	10024.77
6	1085.00	26537.33	65520.10	6190.21	860.83
7	775.00	8257.11	13896.81	2631.19	5109.67
8	465.00	0.00	523.41	5489.83	8613.02

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR BLUEGILL

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	490114.	15.40	21.22	22.29	27.11
2	2310.	462721.	16.51	21.95	15.56	19.35
3	2015.	450352.	17.21	23.35	11.07	13.22
4	1705.	435698.	15.77	25.38	7.03	7.11
5	1395.	418756.	11.37	24.77	3.81	2.39
6	1085.	398468.	6.66	16.44	1.55	.22
7	775.	359179.	2.30	3.87	.73	1.42
8	465.	215470.	0.00	.24	2.55	4.00

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR GREENSIDE DARTER

MONTH	Q	JUVENILES	ADULTS	SPAWNING
1	2810.00	33879.64	41783.60	24359.42
2	2310.00	42481.60	47753.87	25097.59
3	2015.00	52334.37	51617.07	25715.18
4	1705.00	67708.16	54611.97	25629.12
5	1395.00	83109.52	57927.72	25057.94
6	1085.00	97218.57	61510.25	23171.73
7	775.00	102629.64	62383.78	18067.42
8	465.00	69973.10	44514.76	17069.90

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR GREENSIDE DARTER

MONTH	Q	GROSS	JUVENILES	ADULTS	SPAWNING
1	2810.	490114.	6.91	8.53	4.97
2	2310.	462721.	9.18	10.32	5.42
3	2015.	450352.	11.62	11.46	5.71
4	1705.	435698.	15.54	12.53	5.88
5	1395.	418756.	19.85	13.83	5.98
6	1085.	398468.	24.40	15.44	5.82
7	775.	359179.	28.57	17.37	5.03
8	465.	215470.	32.47	20.66	7.92

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR GIZZARD SHAD

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	214538.70	57856.12	57856.12	257281.02
2	2310.00	210305.81	33671.60	33671.60	251525.18
3	2015.00	199038.15	24505.90	24505.90	240182.62
4	1705.00	178733.30	19964.74	19964.74	199836.65
5	1395.00	145020.97	20604.86	20604.86	135248.37
6	1085.00	94275.65	23226.49	23226.49	67829.43
7	775.00	33862.58	27408.84	27408.84	40265.16
8	465.00	10585.98	31517.64	31517.64	40799.16

LITTLE FALLS PRODUCTION RUN BACKWATER & MAIN CHANNEL SPLICED
DOWNSTREAM TRANSECT DUMMIED FROM UPSTREAM TRANSECT

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR GIZZARD SHAD

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	490114.	43.77	11.80	11.80	52.49
2	2310.	462721.	45.45	7.28	7.28	54.36
3	2015.	450352.	44.20	5.44	5.44	53.33
4	1705.	435693.	41.02	4.58	4.58	45.87
5	1395.	418756.	34.63	4.92	4.92	32.30
6	1085.	398468.	23.66	5.83	5.83	17.02
7	775.	359179.	9.43	7.63	7.63	11.21
8	465.	215470.	4.91	14.63	14.63	18.93

HABTAT PROGRAM VERSION NUMBER 2-3
LAST UPDATED ON 5 NOVEMBER 1979.

```
IOC      10000     01101     00000     00000

HEADER   24   10   10   10      0.00      0.00      0.00      0.00      0.00      0.00

VELOCITY BRACKETS      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

DEPTH BRACKETS      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00·

SUBSTRATE BRACKETS      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.0C      0.00      0.00      0.00

CURVE ID NUMBERS   20111   20112   20113   20114   20115  100200  100201  100202  100203   30100   30101   30102
                   30110   20400   20401   20402   20410   51201   51202   51203   60100   60101   60102   60110
```

CURVE SET DEFINITION DATA WAS OBTAINED FROM THE FILE -
IFG FILE OF SUITABILITY CURVES
LAST UPDATED ON 79/01/03. 15.57.50.

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR SMALL MOUTH BASS (TURBID WATER)

MONTH	Q	INCUBATION	FRY	JUVENILES	ADULT	SPAWNING
1	2810.00	636936.10	433897.91	460874.28	482290.98	697368.79
2	2310.00	576298.15	470301.02	542144.18	439834.05	700783.02
3	2015.00	527618.06	481574.56	585823.78	412502.61	691246.59
4	1705.00	458882.62	490262.32	628375.66	382460.20	665897.26
5	1395.00	374221.81	496186.90	667564.24	351332.82	625819.30
6	1085.00	279435.65	493580.98	700717.67	319297.55	579954.60
7	775.00	188422.42	474656.70	696421.19	285703.13	534210.27
8	465.00	94298.08	431381.72	651613.06	249489.92	480538.43

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR SMALL MOUTH BASS (TURBID WATER)

MONTH	Q	GROSS	INCUBATION	FRY	JUVENILES	ADULT	SPAWNING
1	2810.	970044.	65.66	44.73	47.51	49.72	71.89
2	2310.	969352.	59.45	48.52	55.93	45.37	72.29
3	2015.	968884.	54.46	49.70	60.46	42.58	71.34
4	1705.	968327.	47.39	50.63	64.89	39.50	68.77
5	1395.	967680.	38.67	51.28	68.99	36.31	64.67
6	1085.	966902.	28.90	51.05	72.47	33.02	59.98
7	775.	948570.	19.86	50.04	73.42	30.12	56.32
8	465.	890465.	10.59	48.44	73.18	28.02	53.96

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR WHITE SUCKER

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	170225.22	629331.60	943663.68	182139.22
2	2310.00	247322.96	674379.95	945550.99	227428.78
3	2015.00	295703.91	699830.16	941392.25	255883.43
4	1705.00	344414.00	722741.67	930152.22	272707.51
5	1395.00	388660.75	743717.02	905902.20	270512.86
6	1085.00	423770.08	753919.71	858989.48	257040.02
7	775.00	445248.78	727250.37	788054.47	239412.95
8	465.00	438259.24	678866.59	674963.42	172019.59

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR WHITE SUCKER

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	970044.	17.55	64.88	97.28	18.78
2	2310.	969352.	25.51	69.57	97.54	23.46
3	2015.	968884.	30.52	72.23	97.16	26.41
4	1705.	968327.	35.57	74.64	96.06	28.16
5	1395.	967680.	40.16	76.86	93.62	27.95
6	1085.	966902.	43.83	77.97	88.84	26.58
7	775.	948570.	46.94	76.67	83.08	25.24
8	465.	890465.	49.22	76.24	75.80	19.32

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR CHANNEL CATFISH

MONTH	Q	FRY	JUVENILES	ADULTS	SPAWNING
1	2810.00	944205.12	105529.38	275831.14	236419.44
2	2310.00	941411.23	84412.70	267518.34	241588.53
3	2015.00	938362.75	72818.73	262031.80	243283.78
4	1705.00	933284.19	61757.22	255028.50	244533.25
5	1395.00	923249.76	51390.45	247202.22	243910.95
6	1085.00	902862.78	41873.21	237887.28	239189.79
7	775.00	860499.60	33129.16	224747.96	229083.98
8	465.00	788718.44	25220.87	204146.85	210754.30

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR CHANNEL CATFISH

MONTH	Q	GROSS	FRY	JUVENILES	ADULTS	SPAWNING
1	2810.	970044.	97.34	10.88	28.43	24.37
2	2310.	969352.	97.12	8.71	27.60	24.92
3	2015.	968884.	96.85	7.52	27.04	25.11
4	1705.	968327.	96.38	6.38	26.34	25.25
5	1395.	967680.	95.41	5.31	25.55	25.21
6	1085.	966902.	93.38	4.33	24.60	24.74
7	775.	948570.	90.72	3.49	23.69	24.15
8	465.	890465.	88.57	2.83	22.93	23.67

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR BLUEGILL

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	226.34	7537.50	148999.59	233434.56
2	2310.00	7655.32	21843.28	191583.17	270467.53
3	2015.00	19885.98	39368.58	216740.73	286815.38
4	1705.00	38369.16	66371.01	242431.41	298629.30
5	1395.00	64194.74	103635.80	262970.59	301395.23
6	1085.00	106425.26	151031.42	275240.11	292806.54
7	775.00	171890.20	214789.30	276518.27	275249.28
8	465.00	225097.06	292949.82	269000.97	248736.02

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR BLUEGILL

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	970044.	.02	.78	15.36	24.06
2	2310.	969352.	.79	2.25	19.76	27.90
3	2015.	968884.	2.05	4.06	22.37	29.60
4	1705.	968327.	3.96	6.85	25.04	30.84
5	1395.	967680.	6.63	10.71	27.18	31.15
6	1085.	966902.	11.01	15.62	28.47	30.28
7	775.	948570.	18.12	22.64	29.15	29.02
8	465.	890465.	25.28	32.90	30.21	27.93

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR GREENSIDE DARTER

MONTH	Q	JUVENILES	ADULTS	SPAWNING
1	2810.00	97611.40	185878.35	97675.96
2	2310.00	127869.16	177595.08	84657.85
3	2015.00	147377.39	170091.22	77843.04
4	1705.00	168460.86	159662.33	69996.64
5	1395.00	186735.51	147037.08	60725.18
6	1085.00	200943.04	131367.04	50263.99
7	775.00	198062.96	109640.79	38957.55
8	465.00	160669.66	80903.49	24505.93

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR GREENSIDE DARTER

MONTH	Q	GROSS	JUVENILES	ADULTS	SPAWNING
1	2810.	970044.	10.06	19.16	10.07
2	2310.	969352.	13.19	18.32	8.73
3	2015.	968884.	15.21	17.56	8.03
4	1705.	968327.	17.40	16.49	7.23
5	1395.	967680.	19.30	15.19	6.28
6	1085.	966902.	20.78	13.59	5.20
7	775.	948570.	20.88	11.56	4.11
8	465.	890465.	18.04	9.09	2.75

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR GIZZARD SHAD

MONTH	Q	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.00	221017.78	297330.92	297330.92	659556.51
2	2310.00	283805.85	283516.04	283516.04	678472.66
3	2015.00	325344.62	274579.00	274579.00	681201.97
4	1705.00	369866.69	264269.92	264269.92	670223.92
5	1395.00	412352.86	252443.37	252443.37	645384.56
6	1085.00	444998.85	238387.95	238387.95	610076.47
7	775.00	465050.81	221686.67	221686.67	565690.56
8	465.00	460699.95	201633.44	201633.44	514702.31

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR GIZZARD SHAD

MONTH	Q	GROSS	FRY	JUVENILE	ADULTS	SPAWNING
1	2810.	970044.	22.78	30.65	30.65	67.99
2	2310.	969352.	29.28	29.25	29.25	69.99
3	2015.	968884.	33.58	28.34	28.34	70.31
4	1705.	968327.	38.20	27.29	27.29	69.21
5	1395.	967680.	42.61	26.09	26.09	66.69
6	1085.	966902.	46.02	24.65	24.65	63.10
7	775.	948570.	49.03	23.37	23.37	59.64
8	465.	890465.	51.74	22.64	22.64	57.80

APPENDIX D

LOW FLOW ALLOCATION AGREEMENT

AND

MEMORANDUM OF INTENT

11 January 1978

POTOMAC RIVER LOW FLOW ALLOCATION AGREEMENT

THIS AGREEMENT, made and entered into this 11th day of January 1978, by and among the UNITED STATES OF AMERICA (hereinafter called "the Government") acting by the Secretary of the Army through the Chief of Engineers, the STATE OF MARYLAND (hereinafter called "the State") acting by the Governor and the Secretary of the Department of Natural Resources, the COMMONWEALTH OF VIRGINIA (hereinafter called "the Commonwealth") acting by the Governor and the Chairman of the State Water Control Board; the DISTRICT OF COLUMBIA (hereinafter called "the District") acting by its Mayor, the WASHINGTON SURBURBAN SANITARY COMMISSION (hereinafter called "the Commission") acting by its Chairman; and the FAIRFAX COUNTY WATER AUTHORITY (hereinafter called "the Authority") acting by its Chairman;

PREFACE

WHEREAS, the Chief of Engineers is charged with the operation and maintenance of the Washington Aqueduct for the primary purpose of providing an adequate supply of potable water for distribution to and consumption by the agencies and instrumentalities of the Government situate in the District of Columbia and its environs, and thereafter of providing a public water supply for the inhabitants of the District of Columbia; and

WHEREAS, the Secretary of the Army is authorized, subject to certain conditions, to supply treated water from the Washington Aqueduct to any competent state or local authority in the Washington Metropolitan Area in Virginia, and to that end has entered into agreements with the County of Arlington and the City of Falls Church, Virginia; and

WHEREAS, the sole source of raw water treated by the Washington Aqueduct and dispensed therefrom is the Potomac River, and the Washington Aqueduct is now maintaining intake facilities for this purpose at Little Falls and Great Falls, Maryland; and

WHEREAS, the State of Maryland has enacted an appropriation permit statute which requires that all non-exempt jurisdictions obtain a permit from the Water Resources Administration of the State's Department of Natural Resources (hereinafter called "the Administration") to appropriate or use the water of the Potomac River; and

WHEREAS, the parties to this Agreement recognize that other riparian interests, such as communities located in Virginia, may in the future desire to withdraw and use water from the segment of the Potomac River which is the subject of the within Agreement, and provision is made herein requiring that access by any of them to such water be made subject to the provisions of this Agreement; and

WHEREAS, the Commission is charged with the responsibility of providing a safe and adequate public water supply within the Counties of Montgomery and Prince George's, Maryland and is also authorized to enter into agreements to provide water, and for that purpose is operating and maintaining water treatment facilities and a water distribution system; and

WHEREAS, the Commission maintains a water treatment plant and an intake therefrom on the Potomac River, which intake is upstream from the Washington Aqueduct intakes and within the limits of the River covered by this Agreement, and in addition the Commission maintains a water treatment plant with intake on the Patuxent River, and requires water from both sources in order to fulfill its abovementioned responsibilities for providing a public water supply; and

WHEREAS, the City of Rockville, Maryland, is operating and maintaining water treatment facilities and a water distribution system and maintains an intake facility about one mile upstream from Great Falls on the Potomac River, which intake is upstream from the Washington Aqueduct intakes and within the limits of the River covered by this Agreement; and

WHEREAS, the Fairfax County Water Authority is an authority in the Commonwealth of Virginia proposing to withdraw water from that portion of the Potomac River which is covered by this Agreement and has applied for a permit to construct a water intake structure for such purpose; and

WHEREAS, in the absence of adequate upstream impoundments and associated flow regulation, the quantity of water which may flow in the Potomac River between Little Falls Dam and the farthest upstream limit of the pool of water behind the Chesapeake and Ohio Canal Company rubble dam at Seneca, Maryland, during periods of low flow in that portion of the River, may be less than the quantity needed to meet the demand for all customary public water supply purposes during such periods; and

WHEREAS, in light of the Federal legislative enactments providing for the Corps of Engineers to supply water to the District of Columbia, enactment of legislation was deemed by the Government to be a prerequisite to its participation in a Potomac River Low Flow Allocation Agreement; and

WHEREAS, the consent of Congress to a Potomac River Low Flow Allocation Agreement is expressly stated in Section 181 of the Water Resources Development Act of 1976, Public Law 94-587; and

WHEREAS, the consent of Congress, pursuant to Section 9 of the Rivers and Harbors Act of 1899, to the construction of a water diversion structure by the Commission from the north shore of the Potomac River at the Commission's water filtration plant to the north shore of Watkins Island is conditioned in Section 181 of the aforesaid Water Resources Development Act of 1976 upon an enforceable Low Flow Allocation Agreement; and

WHEREAS, it is the judgment of the Chief of Engineers and the Secretary of the Army, acting pursuant to Section 10 of the Rivers and Harbors Act of 1899, that the public interest requires that such a Low Flow Allocation Agreement be a requirement for issuance of the permits for the construction of water intake structures in the subject portion of the Potomac River by the Commission and the Fairfax County Water Authority;

NOW, THEREFORE, in consideration of the premises and of the public and governmental interests deemed to be served hereby, the parties hereto do mutually agree as follows:

ARTICLE 1. Enforcement.

A. Certain Definitions:

1. Pertinent Portion of the River. The portion of the Potomac River subject to this Agreement is that located

between Little Falls Dam and the farthest upstream limit of the pool of water behind the Chesapeake and Ohio Canal Company rubble dam at Seneca, Maryland. This portion is referred to herein as "the defined portion" or, alternately "the subject portion" of the Potomac River.

2. Parties. The Government, the State, the Commonwealth, and the District shall be termed "the governing parties." All other parties hereto shall be termed "member parties." The term "parties" shall mean all parties, both governing and member, except when the context otherwise requires.

B. Moderator. Authority to enforce the provisions of this Agreement shall be vested in an unbiased Moderator. It shall be the duty of the Moderator and he shall have the authority:

1. To take all actions necessary to enforce the provisions of this Agreement and his decisions hereunder, and for this purpose he may sue in his own name.

2. To decide all disputes between or among the parties arising under this Agreement not disposed of by consent.

The authority of the Moderator shall not restrict those powers reserved to the parties, including those specified in Article 3, Section C.

C. The decision of the Moderator shall be final and conclusive unless determined by a court of competent jurisdiction to have been fraudulent, capricious, arbitrary, or not supported by substantial evidence. All parties agree to accept and implement every decision of the Moderator unless and until said decision is overturned by a court of competent jurisdiction.

D. The parties specifically grant to the Moderator the authority to inspect documents, records, meters, facilities, and other items necessary to decide any question or verify reports made by any party as a consequence of this Agreement. Upon the request of any party, the Moderator shall provide said party any or all of the information held by him relevant to this Agreement.

E. Should the Moderator decide to commence or defend any action or otherwise have need of legal services relating to this Agreement, he shall have the right to contract with counsel for such purpose, and the cost of such services shall be repaid in equal shares by the governing parties. In the interest of prompt action, the Moderator may accept legal services, or an advance of funds, for such purpose from any party. Nothing herein shall require a party being sued by the Moderator to advance funds for such purpose.

F. The Moderator shall not be liable for injury or damage resulting from any decision or action taken in good faith without malice under apparent authority of this agreement, even though such decision or action is later judicially declared to be unauthorized or invalid.

G. The Moderator shall be selected, and may be relieved of his duties for any reason, by unanimous action of the governing parties expressed in a signed memorandum. Should the office of Moderator become vacant through death, resignation, or otherwise, a new Moderator shall be selected as soon as practicable by such unanimous action. During any period in which the office of Moderator remains vacant through a failure of unanimous action or otherwise, the full functions of the office of Moderator shall be exercised by a Standby Moderator who shall, except as expressly otherwise provided, be treated as the Moderator for all purposes under the provisions hereof. The duty to designate the Standby Moderator shall rotate annually among the Government, the State, the Commonwealth, and the District in the order stated, beginning on the date this agreement becomes effective and rotating thereafter on the first day of each calendar year. Written notice of such annual designation shall be sent to all other parties by January 15 of each year. The first Moderator for this Agreement is designated in Annex A hereto.

H. Subject to the availability of funds, the reasonable expenses, including legal fees, and compensation of the Moderator shall be paid in equal shares by the governing parties. Any expense shall be deemed reasonable if at least three of the governing parties so agree or if so determined by a court. If any such party accepts as reasonable a particular expense not accepted as reasonable by the other such parties, that party may pay that expense, in addition to that party's proportionate share of all other expenses. At the time of each annual review as provided in Article 4 of this agreement, the governing parties shall set, by majority vote, the per diem fee to be paid a Moderator in the event his services shall be necessary. A Standby Moderator, who is an employee of the designating party or one of its political subdivisions or agencies, shall serve without fee in exercising the functions of the Moderator.

I. The Moderator or any party may bring an action against any one or more other parties to enforce this Agreement or a decision of the Moderator made hereunder. Such action shall be brought in the United States District Court for the District of Columbia, and each party consents to venue in said court and to service of process upon it from said court, provided that if the action is between two states of the United States, such action may be commenced in the Supreme Court of the United States. In any such action the joinder of all parties hereto shall not be deemed necessary or indispensable merely because they are parties to this Agreement. Application for or receipt of a determination by the Moderator shall not be a prerequisite to the maintenance of an action by a party, but any decision made by the Moderator on a matter involved in said action, whether before or after commencement thereof, shall be given the effect set forth in Article I, Section C. Nothing herein shall be deemed to be a waiver of any immunity any party may have from a claim for monetary damages or a claim which has substantial fiscal impact, except for the fees and expenses which are provided to be paid pursuant to the agreement. It is the intention of the parties that any matters involving the technical aspects of maintenance of litigation be resolved in a manner which ensures rapid and certain enforcement of this Agreement.

ARTICLE 2. Administration.

A. Washington Aqueduct. The Government will provide a communication control center at the Washington Aqueduct for the administration of the allocation plan as provided herein. The Washington Aqueduct Division, U. S. Army Engineer District, Baltimore ("the Aqueduct"), will collect, receive, record and accumulate daily reports regarding the flow of the Potomac River and the quantities of water being withdrawn from the defined portion of the Potomac River, and the quantities of water withdrawn and available from all other sources for use within the Washington Metropolitan Area, by the parties and the political subdivisions, authorities, and permittees of any of them, and by any other water with-drawing entity which may formally be added or made subject to this Agreement subsequent to its initial execution. Subject to the parties rights of appeal to the Moderator, the parties grant to the Aqueduct, and to each other, the right to inspect documents, records, meters, facilities and other items necessary to decide any question or verify reports made by any party as a consequence of this agreement. Beginning with the Alert Stage, the Aqueduct will keep the Moderator informed as to the stage of flow in the Potomac River, and, during the Restriction and Emergency Stages the fair share allocated to each user, and all information utilized for determining the allocation. The Aqueduct will provide all parties with the same information relating to allocation, the quantities of water being withdrawn by all users from any and all sources, and the flow of the Potomac River. To permit uniformity of reports and to implement the administrative measures specified herein, reports and calculations, by or to the Aqueduct, of daily withdrawals or daily flows, will be based on the twenty-four hour period from one midnight to the following midnight, unless the parties subsequently agree to a different twenty-four hour measuring period. The Aqueduct will calculate the total daily flow by adding the withdrawals during the previous 24 hours at all withdrawal points and the remaining daily flow over the Washington Aqueduct Dam at Little Falls, as determined by the readings recorded on the USGS gage at Little Falls during the preceding twenty-four (24) hours. The average reading will determine the flow over the dam for the previous day.

B. Stages of Flow in the Potomac River. The Aqueduct will determine from the information accumulated when the following stages exist in the defined portion of the Potomac River.

1. Alert Stage. When the total daily withdrawal from the subject portion of the Potomac River is equal to or greater than fifty percent (50%) of the total daily flow, but less than 80%, the Aqueduct will declare an "Alert Stage" to be in effect.

2. Restriction Stage. When the total daily withdrawal from the subject portion of the Potomac River is equal to or greater than eighty percent (80%) of the total daily flow, the Aqueduct will declare a "Restriction Stage" to be in effect and the Aqueduct will request the U. S. Park Service to discontinue putting Potomac River water into the C&O Canal.

3. Emergency Stage. When the estimated total daily withdrawal for any day within the ensuing five (5) days

from the subject portion of the Potomac River is expected to exceed the daily river flow anticipated, the Aqueduct will declare an "Emergency Stage" to be in effect.

C. Allocation of Flow. Whenever the Restriction Stage or the Emergency Stage is in effect, the Aqueduct shall daily calculate and advise each user (as defined herein), and the Moderator, of each user's allocated fair share of the water available from the subject portion of the Potomac River in accordance with this Section C. In calculating the amount of water available for allocation, the Aqueduct will determine, in consultation with the parties and based upon then current conditions and information, any amount needed for flow in the Potomac River downstream from the Little Falls dam for the purpose of maintaining environmental conditions ("environmental flow-by"), and shall balance such need against essential human, industrial and domestic requirements for water. The Aqueduct's determination shall be based upon the data and shall give substantial weight to conclusions for environmental flowby submitted by the State.

1. For the purposes of this Section C, the term "users" refers to the following entities which are or may be appropriating water for public water supply purposes from the subject portion of the Potomac River; namely, the Government (including its water customers), the Commonwealth for and on behalf of herself and each of her political subdivisions and

authorities (including the Authority), the State and the Administration (for and on behalf of its permittees whether or not parties to this Agreement), the District of Columbia, the Commission, and such entities which may formally be added or made subject to this Agreement subsequent to its initial execution.

2. Each user shall report to the Aqueduct (and to each other) the number of gallons of processed water pumped daily to all its customers from all sources during each winter period (the months of December through February), commencing with the winter period 1977-78. The amounts pumped during the 5 most recent winter periods which have elapsed as of the time of allocation, or less than 5 if fewer have so elapsed, shall be combined for the purpose of computing each user s average daily winter use; except that, in the case of a user first withdrawing water subsequent to the initial execution of the Agreement, the average daily winter use of such user shall be the average of the amounts of water pumped during all of the winter periods, commencing December 1 of the year immediately prior to its first withdrawal from the subject portion of the river, which have elapsed as of the time of allocation, but not exceeding the 5 most recent winter periods. The ratio which the average daily winter use of each user bears to the average daily winter use of all users will be applied to the daily amount of water available at the

time of allocation from the subject portion of the Potomac River (after deduction for environmental flow-by) and all other sources as specified in Paragraph 5 below (calculated at maximum capacity practicable). The resulting amount, less the amount then available to said user by use of the maximum capacity practicable from all such other sources, will be such user s allocated fair share of the flow of the Potomac River.

3. a. The formula set forth in Article 2.C.2. shall continue in effect unless changed by unanimous consent of the governing parties or as set forth below. After January 1, 1988, any of the governing parties which desires to change the allocation formula shall give written notice to all other parties. Within 60 days thereafter, both the governing and member parties shall meet for the purpose of negotiating a replacement formula. In the event that no such replacement formula is agreed on by the governing parties within one year after receipt of the aforesaid notice, the allocation ratio which would have been in effect for the summer of the year in which the notice was given shall be used as an interim allocation ratio for the withdrawal of water during subsequent periods of low flow until such time as the governing parties agree upon a replacement formula. Any governing party, at any time after the expiration of one year from the receipt of such notice and after the exhaustion of such administrative procedures as may be applicable if it is a permittee for

water appropriation or withdrawal, may apply to a court of competent jurisdiction for an adjudication of such rights, if any, as it or users associated with it may have to a greater share of water than set by the interim allocation ratio, provided that all parties shall adhere to the interim allocation ratio until and unless altered by a decision of such court. Applications for intakes or other modifications to water works shall continue to be received and processed during periods in which the interim allocation ratio is in effect, but such ratio shall be recalculated only in the event of the grant of an application to a new user as set forth in Section E of Article 3.

b. Any formula negotiated pursuant to subparagraph a hereof shall allocate water on a fair and equitable basis and shall take into consideration, among other things, (a) steps taken by parties which can do so to minimize dependence upon the Potomac River during periods of low flow, (b) the nature and effectiveness of water conservation methods put into effect, (c) steps taken to increase the water supply available for the Washington Metropolitan Area, (d) then current population growth and planning for future growth, (e) feasibility and availability of new sources of water, and (f) technological advances in water treatment and water quality measurement.

c. In any court proceeding instituted pursuant to subparagraph a, neither the signing of this agreement nor the passage of time thereafter shall be asserted as a waiver or diminution of any party's rights to, or right to seek, a greater share of water from the subject portion of the river. Such action shall be brought in the United States District Court for the District of Columbia, and each party consents to venue in such court and to service of process upon it from such court, provided that if the action is between two states of the United States, such action may be commenced in the Supreme Court of the United States.

4. In the event the applicable allocation formula results in an allocation exceeding the proposed withdrawal of any user, the excess amount shall be reported by said user to the Aqueduct for reallocation.

5. The water subject to the allocation formula under the terms of this Agreement includes the maximum capacity practicable from Patuxent and Occoquan as it exists in each case on December 31, 1977, and both the natural flow and the augmented flow from existing upstream reservoirs, in addition to Bloomington Lake, of the subject portion of the Potomac River. Any other augmentation to flow, reservoir storage, or treating capacity developed by a user after December 31, 1977, shall not be made subject to the allocation formula, but those users who incur, or participate in the payment of, the expenditures for such augmentation may agree as to how it is to be divided and shall file a copy of said agreement with

the other parties. In recognition that the sole source of water supply for the District of Columbia is the Potomac River, each other party will offer the District an opportunity to participate in a portion of any additional augmentation for use during the Restriction and Emergency stages on reasonable terms, unless such party shows that it is infeasible to do so.

6. In the event a disaster, such as a major fire or water main brèak, results in an abnormal loss of a significant portion of any user's water supply, the Aqueduct shall determine suitable adjustments in low flow allocation during the emergency period created by the disaster only, taking into consideration all sources available to the users.

7. Water from the emergency pumping station having its intake at the estuary of the Potomac shall not be considered as water available from other sources for the purposes of Section 2.C.2. or otherwise included in computations made under this agreement.

ARTICLE 3. Obligations of the Parties.

A. The Government agrees to cause the Aqueduct as the operating agency to perform the functions and requirements which are required of the Government and the Aqueduct in this Agreement, including the furnishing of information to the other parties relating to the Aqueduct's water withdrawal and use, the same as required by other parties to be furnished to the Aqueduct under Subparagraphs B and D, of this Article. These functions and responsibilities of the Aqueduct shall be carried out under the supervision of the District Engineer, U.S. Army Engineer District, Baltimore, or his designee, who shall be responsible for making the determinations required in the discharge of these responsibilities.

B. The parties agree to provide the Aqueduct with all the information relating to the withdrawal and use by them, their permittees, entities reporting through them and their political subdivisions, as applicable, of the waters of the subject portion of the Potomac River and availability from other sources which is needed for the administration of the allocation system.

C. The State agrees that all appropriation permits granted by the Administration for any appropriation of water from the subject portion of the Potomac River shall include a provision subjecting the permittee to the provisions of this Agreement. Nothing herein shall restrict or limit such authority as the Administration may properly have to issue permits or impose low flow allocation requirements upon any other water appropriating permittee withdrawing water from other segments of the Potomac River, or to enforce provisions of its permits in the subject portion of the Potomac River; nor any such authority as the Commonwealth may have; nor the authority of the Government with respect to navigable waters, including the regulation of commerce among the states and with foreign nations.

D. The parties will comply with the determinations made by the Aqueduct pursuant to this Agreement, unless and until overturned pursuant to the terms of Article 1.

E. Any community or entity which seeks to appropriate water from the subject portion of the Potomac River shall either become a member party to this Agreement or shall be governed by a permit which includes the low flow allocation formula and such other provisions as are necessary to effect the purposes of this Agreement. Any such community or entity may apply for permits necessary to build water intake structures or to appropriate water, and such permits shall be processed in accordance with the rules and regulations of the permit-issuing agency, notwithstanding the pendency of negotiations or the imposition of an interim allocation ratio pursuant to Section 2.C.3. If the necessary permits are granted to a community or entity not previously withdrawing water from the subject portion of the river, the existing interim allocation ratio shall be recalculated based on winter period use for the year immediately prior to the first withdrawal from the subject portion of the river by such new user. The average daily winter use of the new user for such winter period and those of the other users employed in determining the interim allocation ratio shall be employed to compute a revised interim allocation ratio which shall remain in effect until a replacement formula is determined pursuant to Section 2.C.3.

F. This Agreement does not affect such rights as parties or others subject to this agreement may have to grant or obtain permits to appropriate additional amounts of water during periods other than the Restriction or Emergency stages, but except as specifically provided in Article 2, Section C and Article 3, Section E, any additional water use resulting therefrom shall not affect any user's allocated fair share during such stages.

ARTICLE 4. Review

In the month of April in each year during the term of this Agreement the parties shall convene for the purpose of reviewing the provisions of this Agreement and considering any modifications thereof, and make such modifications as the governing parties agree upon. Upon agreement among the governing parties, review and modifications as might be agreed upon can occur at any time and not be necessarily limited to the annual, April consideration. Entities shall be admitted as new member parties upon unanimous agreement of the governing parties.

ARTICLE 5. Revocation.

This Agreement shall not be revoked without the unanimous consent of the governing parties.

ARTICLE 6. Effective Date.

This Agreement shall become binding when: (1) it is executed by the parties, and (2) a Moderator has been selected as provided in Article 1.G, and (3) the Government issues one or more permits for the construction of any water diversion structure or water intake in the subject portion of the Potomac River to any party hereto or political subdivision or authority thereof, and (4) all acts have been taken by each of the parties hereto necessary to make this agreement binding and enforceable with respect to each of them, including, if necessary, ratification by the legislatures of the signatory states. Notice that all such necessary acts have been taken by each of the parties shall be delivered to the other parties along with the opinion of its respective counsel or attorney general that the acts taken are sufficient to cause this agreement to become effective, binding and enforceable under the laws or charter of such parties. The parties will, however, commence to record and maintain the consumption figures and other base data called for under the foregoing provisions of this Agreement, at the time they execute this Agreement. This Agreement may be executed in one or more counterparts.

ARTICLE 7. Severability.

The provisions of this agreement shall be severable and if any phrase, clause, sentence or provision of the agreement is declared to be unconstitutional or the applicability thereof to any party is held invalid, the remainder of such agreement shall not be affected thereby.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement as of the day and year first above written, except as a different date of execution may be noted following any party`s signature.

ATTEST:

Charles I McGinnis

THE UNITED STATES OF AMERICA

BY Clifford L. Alexander, Jr.
Secretary of the Army

J W Morris
Chief of Engineers

Herbert M Sachs

THE STATE OF MARYLAND

BY Blair Lee
Governor

James B Coulter
Secretary of Natural Resources

THE COMMONWEALTH OF VIRGINIA

BY Mills E. Godwin, Jr.
Governor

J. Leo Bourassa
Vice Chairman, State Water Control Board

Albertine K. Schaller
EXECUTIVE SECRETARY, D. C.

THE DISTRICT OF COLUMBIA

BY Walter Washington
Mayor.

Herbert L. Tucker
Director of Environmental Services

THE WASHINGTON SUBURBAN SANITARY COMMISSION

BY Vera Berkman
Chairman

FAIRFAX COUNTY WATER AUTHORITY

BY ____________________
Chairman

NABOP-F/4 (Washington Suburban Sanitary Commission) 76-328
NABOP-F/4 (Washington Suburban Sanitary Commission) 76-804
NABOP-F/4 (Fairfax County Water Authority) 76-1126

Honorable James A. Joseph
Under Secretary of the Interior
Washington, D. C. 20240

Memorandum of Intent

Dear Mr. Joseph:

This memorandum clarifies the intent of the parties with respect to implementation of the Low Flow Allocation Agreement in response to the concerns expressed by the United States Fish and Wildlife Service and the Department of the Interior with respect to the captioned permit applications. The problem at issue is to assure that there will be enough water remaining in the Potomac River after withdrawals by the proposed intake structures to avert severe and irreparable damage and disruption to the Potomac River ecosystem, and to recognize the need to avoid damage to properties of the National Park Service.

This will be addressed as follows:

1. Until any of the proposed intakes has begun to withdraw water, there will be no change in the current water withdrawal situation. Thus, there is no need for an "environmental flow-by" amount until at least one such intake has become operational, there being no such amount in effect now.

2. The Low Flow Allocation Agreement of January 11, 1978, provides that in calculating the amount of water available for allocation, an amount shall be set aside for the maintenance for environmental conditions. Specifically, Article 2.C. states in part:

> "In calculating the amount of water available for allocation, the Aqueduct will determine, in consultation with the parties and based upon then current conditions and information, any amount needed for flow in the Potomac River downstream from the Little Falls dam for the purpose of maintaining environmental conditions ("environmental flow-by"), and shall balance such need against essential human, industrial and domestic requirements for water. The Aqueduct's determination shall be based upon the data and shall give substantial weight to conclusions for environmental flow-by submitted by the State."

3. In calculating the total daily withdrawal to determine whether the Restriction and Emergency Stages are to be put into effect pursuant to Article 2.B. of the LFAA, the Washington Aqueduct will include along with the amount of water withdrawn from the subject portion of the river that amount designated as the environmental flow-by. Thus, when the Washington Aqueduct determines that the amount withdrawn, combined with the environmental flow-by amount, is equal to or greater than eighty (80) percent of the total daily flow, the Restriction Stage will be put into effect and allocation will begin. During the Restriction or Emergency Stages, the Washington Aqueduct will (subject to the availability of funds) reduce withdrawal from the Great Falls intake and increase withdrawal from the Little Falls intake consistent with maintaining favorable environmental conditions between Great Falls and Little Falls.

4. A joint study proposed by the State of Maryland and conducted in cooperation with the Department of the Interior, the Army Corps of Engineers, the Environmental Protection Agency, and the Commonwealth of Virginia ("the joint study") is currently underway for the purpose of determining an environmental flow-by amount for the aforesaid provision of the Low Flow Allocation Agreement. When the results of that study are complete, it will constitute the data and conclusions to which reference is made in the aforesaid provision of the Agreement. The study will automatically, therefore, become the basis for execution of that provision of the Agreement.

5. Should the joint study, for any reason, not be completed by the time any intake becomes operational, the Washington Aqueduct, as initial administrative authority under the Low Flow Allocation Agreement, will utilize such environmental flow-by amount as shall be set by the Secretary of the Army in consultation with the Secretary of the Interior. The Secretary of the Army shall also solicit the views of the signatories to the Agreement.

6. It is expected that the joint study will determine, among other things, (a) an environmental flow-by amount, and (b) a schedule of the ecological consequences of each level of flow below the environmental flow-by amount. In administering the above-quoted provision of the Low Flow Allocation Agreement, the Washington Aqueduct will not invade such an amount absent essential need. In determining such need, the Washington Aqueduct shall assure itself that the localities and jurisdictions affected have made maximum use of other sources of water and imposed maximum conservation measures. The decisions of the Washington Aqueduct will be appealable to the Moderator under Article 1 of the Agreement. Any objection of the Department of the Interior or other Federal agency to any such decision of the Washington Aqueduct will be raised by appeal to the Moderator by the Department of the Army.

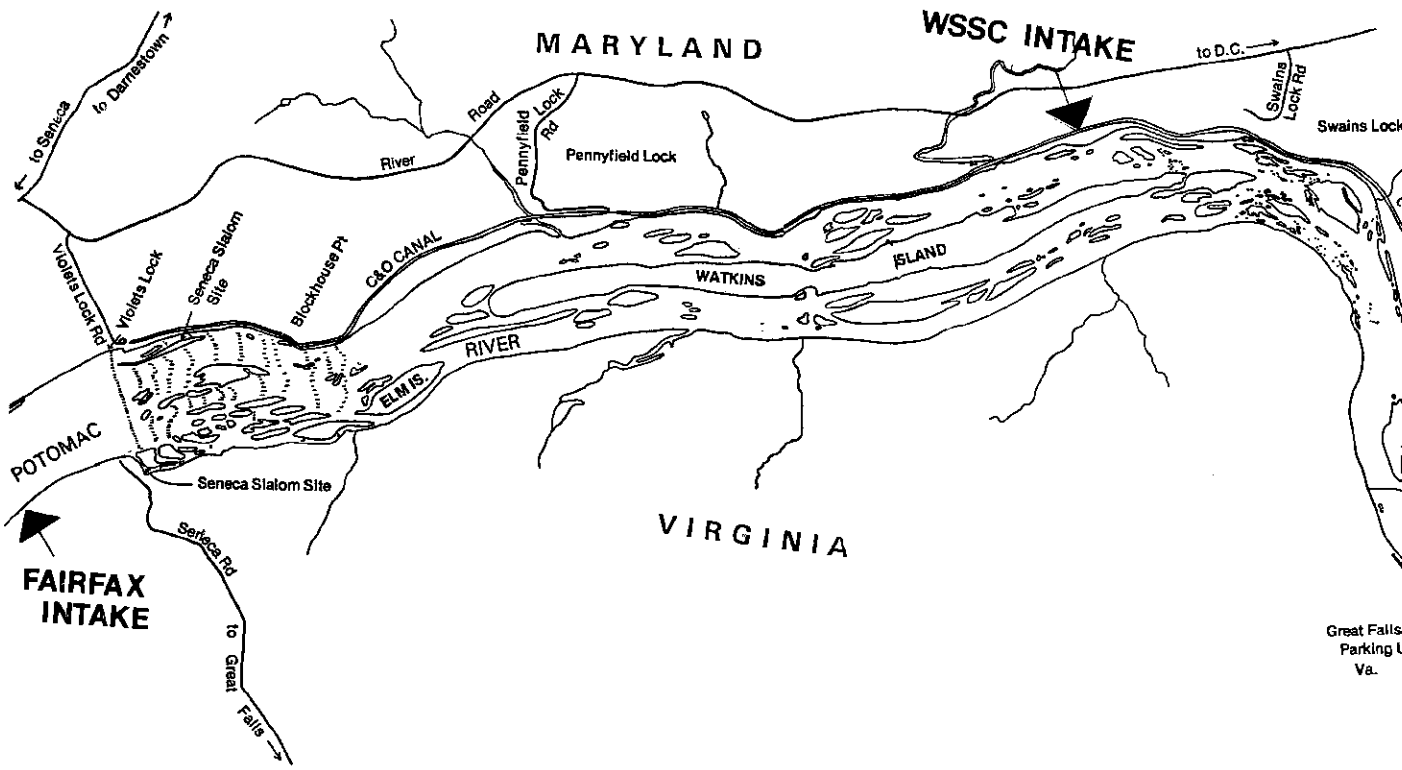
7. In recognition of the need of the C & O Canal National Historic Park for minimal amounts of water to maintain the integrity of structures, the National Park Service will not be obligated to consider a complete cutoff of its intakes until such time as the Washington Aqueduct determines it necessary to invade the environmental flow-by amount. Whenever the Restriction Stage is in effect and following a request by the Washington Aqueduct, the National Park Service will consider means of reducing the demand for water withdrawal by the C & O Canal National Historic Park from the subject portion of the river consistent with the preservation of the Park's resources.

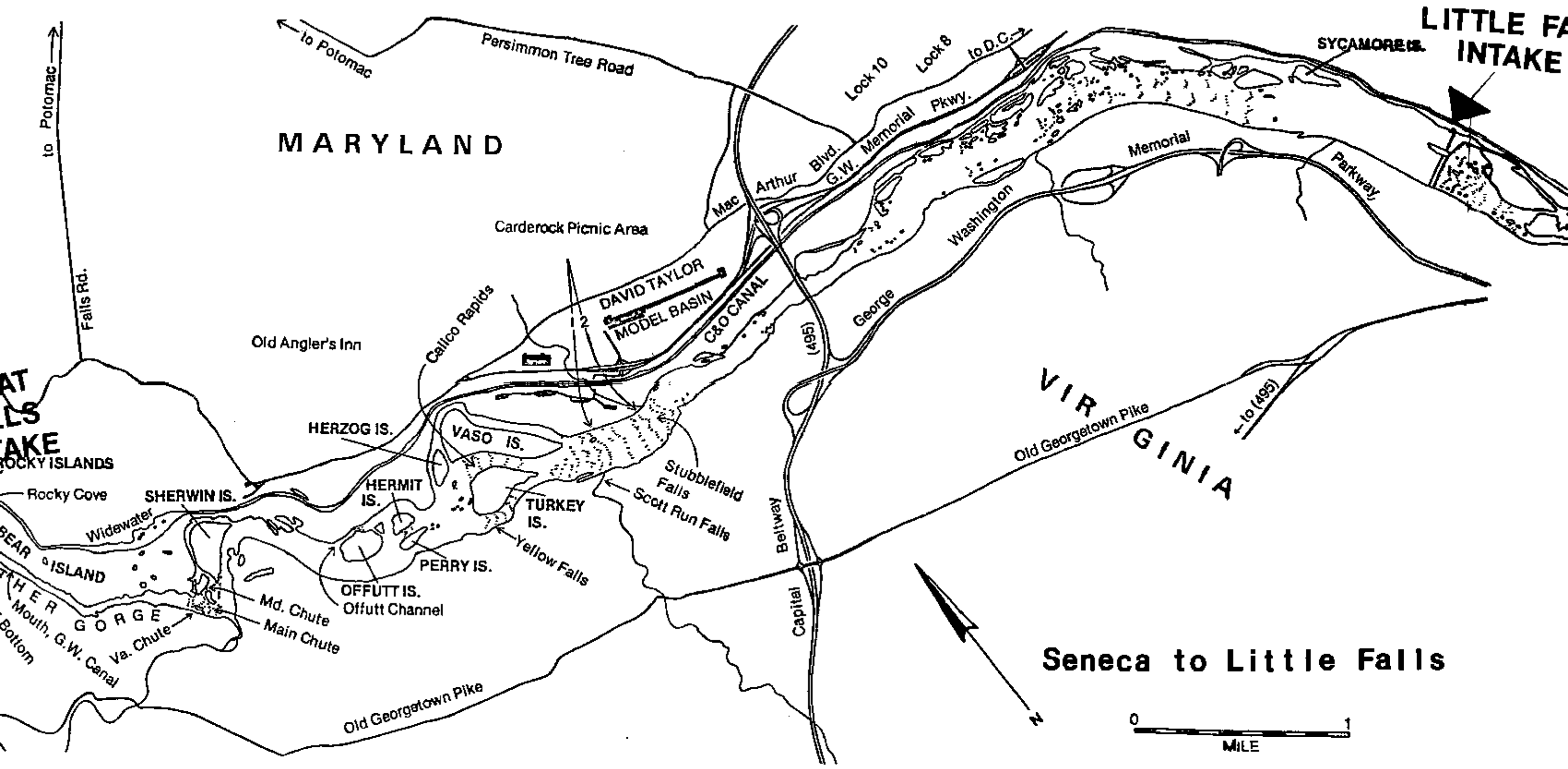
8. Nothing in this memorandum shall be construed as purporting (a) to diminish the rights of the Secretary of the Interior to meet his statutory responsibilities to protect the National Park along the river, or (b) to alter Article 3.C of the Low Flow Allocation Agreement.

The signatories to the Low Flow Allocation Agreement have been consulted with respect to this interpretation and application of the Agreement, and they concur in it. Reference to this memorandum shall be placed in any of the captioned permits granted and in any future permits for withdrawal structures from the affected portion of the Potomac River.

Sincerely,

DRAKE WILSON
Brigadier General, USA
Acting Director of Civil Works


MARYLAND
WSSC INTAKE
to D.C.
Swains Lock Rd
Swains Lock
to Seneca
to Darnestown
River Road
Pennyfield Lock Rd
Pennyfield Lock
Violets Lock Rd
Violets Lock
Seneca Slalom Site
Blockhouse Pt
C&O CANAL
WATKINS ISLAND
RIVER
ELM IS.
POTOMAC
Seneca Slalom Site
FAIRFAX INTAKE
Seneca Rd
to Great Falls
VIRGINIA
Great Falls
Va.



Seneca to Little Falls