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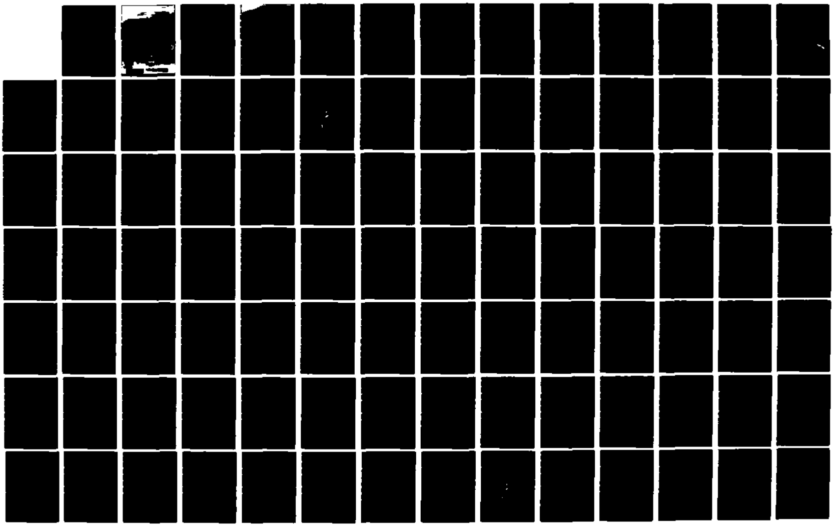

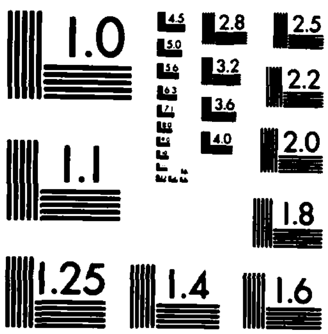

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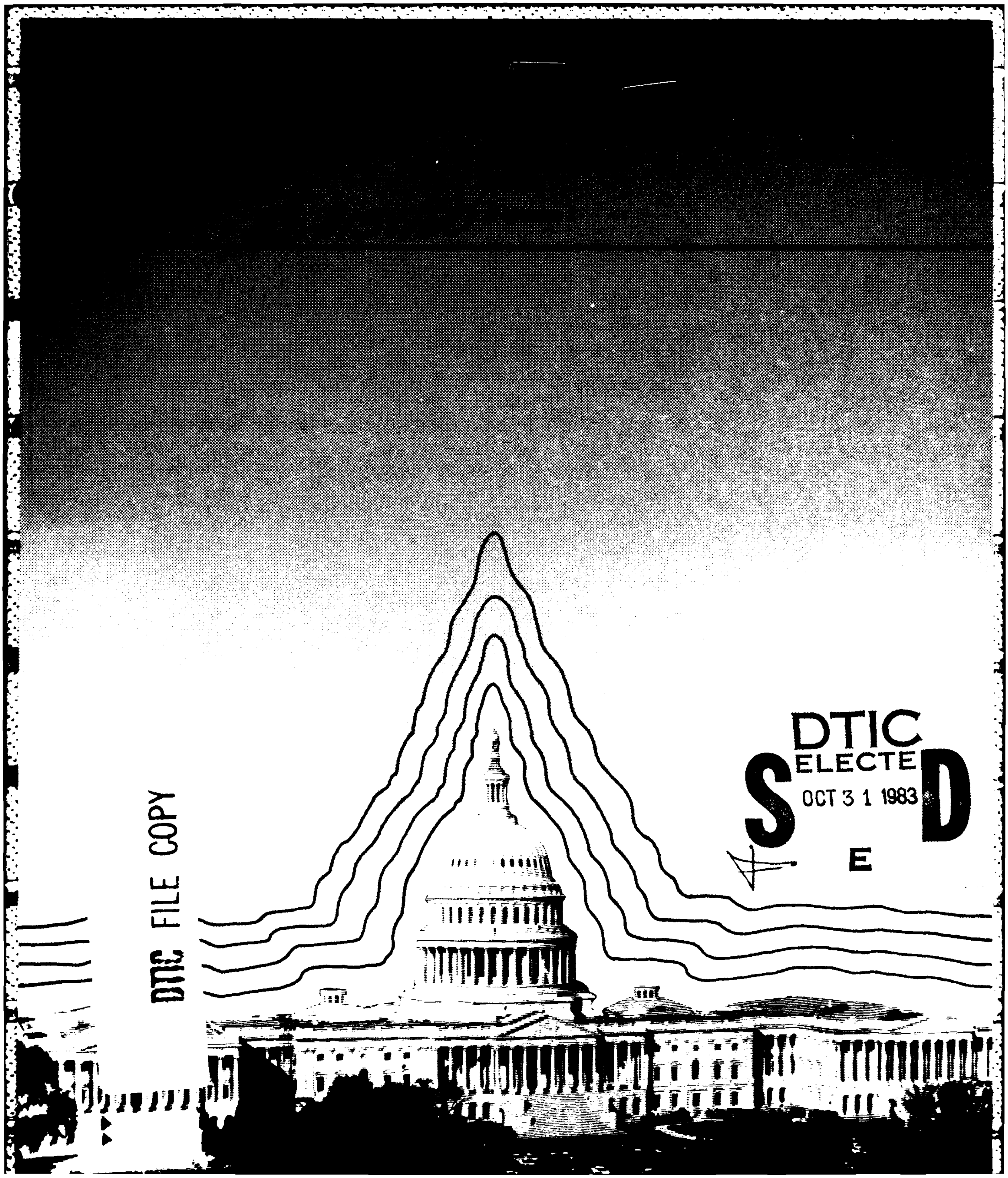

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
In response to the Water Resources Development Act of 1974, the Baltimore District of the U.S. Army Corps of Engineers conducted a comprehensive water supply analysis of the Metropolitan Washington Area (MWA). Severe water supply shortages had been forecast for the MWA and the study was undertaken to identify and evaluate alternative methods of alleviating future deficits. Initiated in 1976, the study was conducted in two phases over a 7-year period. The first, or early action phase, examined the most immediate water supply problems and proposed solutions that could be implemented locally. The second or long

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water shortage; reregulation; finished water interconnection; Occoquan Reservoir; Patuxent Reservoir; Potomac Estuary; Water Supply Coordination Agreement; Verona Lake

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range phase included an analysis of the full spectrum of structural and nonstructural water supply alternatives. In addition to such traditional water supply alternatives as upstream reservoir storage, groundwater and conservation, the study also considered such innovative measures as wastewater reuse, raw and finished water interconnections between the major suppliers, the use of the upper Potomac Estuary, reregulation and water pricing. A key tool in the study was the development and use of a basin-specific model that was used to simulate the operation of all the MWA water supply systems and sources under various drought scenarios. As the study progressed, local interests used the technical findings of the Corps' study to make great strides toward a regional solution to their water supply problems. The Corps' study concluded that with the implementation of a series of regional cooperative management agreements, contracts, selected conservation measures, and the construction of one local storage project to be shared by all, severe water supply shortages could effectively be eliminated for the next 50 years. The Final Report of the study is comprised of eleven volumes which provide documentation of both the study process and the results of all the technical analyses conducted as part of the study.

METROPOLITAN WASHINGTON AREA
WATER SUPPLY STUDY

APPENDIX H

BLOOMINGTON LAKE REFORMULATION STUDY

VOL. I

SUMMARY REPORT AND ANNEXES H-I & H-II

Department of the Army
Baltimore District, Corps of Engineers
Baltimore, Maryland

September 1983

REPORT ORGANIZATION*

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

Appendix Letter	Appendix Title	Annex Number	Annex Title
	Main Report		
A	Background Information & Problem Identification		
B	Plan Formulation, Assessment, and Evaluation	B-I	Water Supply Coordination Agreement
		B-II	Little Seneca Lake Cost Sharing Agreement
		B-III	Savage Reservoir Operation and Maintenance Cost Sharing Agreement
C	Public Involvement	C-I	Metropolitan Washington Regional Water Supply Task Force
		C-II	Public Involvement Activities - Initial Study Phase
		C-III	Public Opinion Survey
		C-IV	Public Involvement Activities - Early Action Planning Phase
		C-V	Sample Water Forum Note
		C-VI	Public Involvement Activities - Long-Range Planning Phase
		C-VII	Citizens Task Force Resolutions
		C-VIII	Background Correspondence
		C-IX	Coordination with National Academy of Sciences - National Academy of Engineering
		C-X	Comments and Responses Concerning Draft Report
D	Supplies, Demands, and Deficits	D-I	Water Demand Growth Indicators by Service Areas
		D-II	Service Area Water Demand & Unit Use by Category (1976)
		D-III	Projected Baseline Water Demands (1980-2030)
		D-IV	Potomac River Low Flow Allocation Agreement
		D-V	Potomac River Environmental Flowby, Executive Summary
		D-VI	PRISM/COE Output, Long-Range Phase
E	Raw and Finished Water Interconnections and Reregulation	E-I	Special Investigation, Occoquan Interconnection Comparison
F	Structural Alternatives	F-I	Digital Simulation of Groundwater Flow in Part of Southern Maryland
G	Non-Structural Studies	G-I	Metropolitan Washington Water Supply Emergency Agreement
		G-II	The Role of Pricing in Water Supply Planning for the Metropolitan Washington Area
		G-III	Examination of Water Quality and Potability
H	Bloomington Lake Reformulation Study	H-I	Background Information
		H-II	Water Quality Investigations
		H-III	PRISM Development and Application
		H-IV	Flood Control Analysis
		H-V	US Geological Survey Flow Loss and Travel Time Studies
		H-VI	Environmental, Social, Cultural, and Recreational Resources
		H-VII	Design Details and Cost Estimates
		H-VIII	Drawdown Frequency and Yield Dependability Analyses
		H-IX	Bloomington Future Water Supply Storage Contract
		H-X	Novation Agreement
I	Outlying Service Areas		

*The Final Report for the Metropolitan Washington Area Water Supply Study consists of a Main Report, nine supporting appendices, and various annexes as outlined above. The Main Report provides an overall summary of the seven-year investigation as well as the findings, conclusions, and recommendations of the District Engineer. The appendices document the technical investigations and analyses which are summarized in the Main Report. The annexes provide detailed data or complete reports about individual topics contained in the respective appendices.

APPENDIX H
BLOOMINGTON LAKE
REFORMULATION STUDY REPORT

APPENDIX H
BLOOMINGTON LAKE
REFORMULATION STUDY REPORT

TABLE OF CONTENTS

Table of Contents (Con't)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF ANNEXES

APPENDIX H
BLOOMINGTON LAKE REFORMULATION STUDY
REFORMULATION STUDY REPORT

INTRODUCTION

The recently completed Bloomington Lake Project in Garrett County, Maryland, and Mineral County, West Virginia, was constructed by the Corps of Engineers. The project is located on the North Branch Potomac River, about 8 miles upstream of its confluence with the Savage River. Construction was initiated in 1971 and the project was operationally completed in July 1981. The Bloomington Lake Project provides water quality control in the North Branch Potomac River, industrial and municipal water supply, flood protection to all of the downstream communities along the North Branch Potomac River, as well as limited recreational facilities for area residents.

AUTHORIZATION OF BLOOMINGTON LAKE PROJECT

The Bloomington Lake Project was recommended in the report of the Chief of Engineers, dated April 1961 entitled Potomac River Review Report - North Branch Potomac River above Cumberland, Maryland, published as House Document No. 469, 87th Congress, Second Session. The Chief of Engineers recommended construction of a dam on the North Branch Potomac River above its confluence with the Savage River to provide for the purposes of flood control, industrial and municipal water supply, water quality control, and recreation. The project was authorized by the Flood Control Act of 23 October 1962, Public Law 874, 87th Congress, Second Session, and required a non-Federal sponsor to agree to repay all costs allocated to water supply, amounting to 33.2 percent of the total project construction costs.

AUTHORITY FOR REFORMULATION STUDY

On 13 April 1978, five Metropolitan Washington Area (MWA) Congressional Representatives (Herbert E. Harris, Joseph L. Fisher, Gladys N. Spellman, Newton I. Steers, and Walter E. Fauntroy) requested, through the House Public Works and Transportation Committee, that a restudy of the Bloomington Lake Project be undertaken to determine if additional storage could be made available for water supply. Other agencies such as the Interstate Commission on the Potomac River Basin (ICPRB) also supported an investigation of the full water supply potential of the Bloomington Lake Project.

In response to the Congressional request, the Office of the Chief of Engineers notified the House Public Works and Transportation Committee that a reformulation examination of the Bloomington Lake Project could best be accomplished as an integral part of the ongoing MWA Water Supply Study authorized by Section 85 of the Public Law 93-251 - the Water Resources Development Act of 1974. This previous authorization directed the Secretary of the Army, acting through the Chief of Engineers, to: (1) make a detailed study of future water supply needs in the MWA and identify feasible water supply alternatives and their impacts; and (2) make recommendations to the Congress on a course of action for meeting both short-range and long-range water supply needs of the MWA.

Subsequently, the study was assigned to the Baltimore District to be included in the on-going MWA Water Supply Study.

REASONS FOR REFORMULATION

The Congressional interest, as indicated by the aforementioned letter from the MWA Congressional Representatives and the support provided by other agencies, including ICPRB, led to a detailed examination of the full water supply potential of the Bloomington Lake.

Even before the Congressional interest, however, results of two independently conducted investigations (one by the Johns Hopkins University and the other by the Corps of Engineers, Baltimore District), indicated that Bloomington Lake had the potential to furnish more flow to the MWA during low flow periods than was cited in the authorization document, without significantly affecting the other project purposes. Both of the studies were preliminary and warranted further detailed investigations.

An additional reason for conducting a reformulation study was that Bloomington Lake's storage was allocated to various purposes based on the needs and in accordance with the water resources management policies of the 1960's. Since then, the project's objectives, needs, and management policies have changed significantly. Moreover, the MWA does not have an upstream storage project other than Bloomington Lake to provide near-term water supply needs. Construction of another major reservoir within the headwaters of the Potomac River Basin in the near future does not seem likely due to widespread opposition to large reservoirs. It is, therefore, important that Bloomington Lake be operated in the most efficient manner possible to serve today's needs as well as to reduce projected future water supply shortages in the MWA.

PURPOSES OF REFORMULATION STUDY

The purposes of the Bloomington Lake Reformulation Study were twofold: (1) to investigate the full water supply capability of the recently completed Bloomington Lake Project using the authorized low flow augmentation storage (water supply and water quality) and to determine an optimum reservoir regulation strategy given the current conditions; and (2) to determine the feasibility of reallocating part of the water quality storage and/or a portion of flood control storage to water supply storage to furnish additional storage capability for MWA water demands.

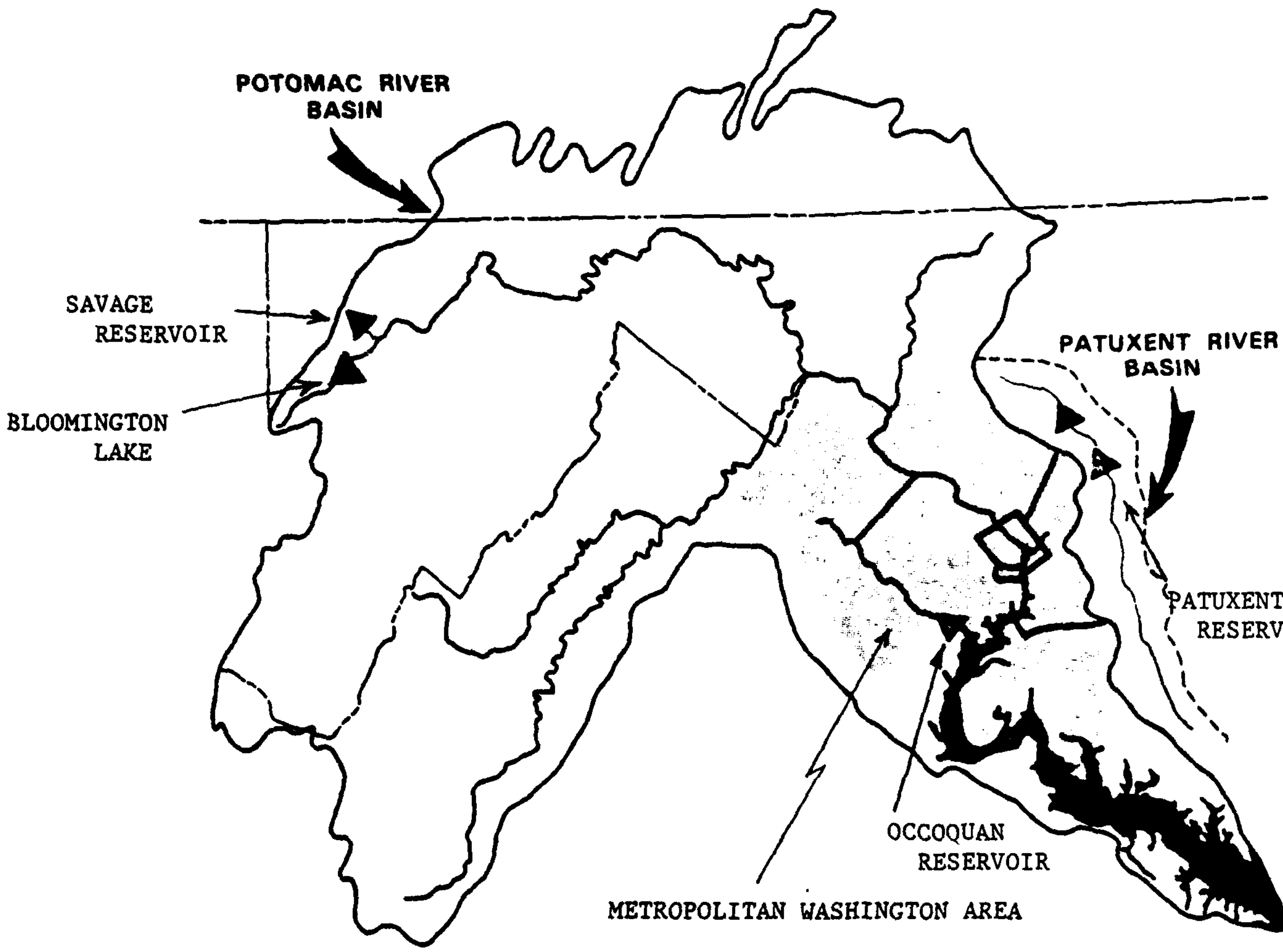
SCOPE OF STUDY

STUDY AREA

While the Bloomington Lake Project was the primary focus of this study, the project was also considered as part of a system which included the Savage River Reservoir, the Occoquan Reservoir, and the Patuxent Reservoirs (see Figure H-1). These reservoirs, plus the Potomac River, furnish over 95 percent of the MWA's water supply.

Thus, the Bloomington Lake Reformulation Study actually addressed two study areas, the North Branch Potomac River Basin and the MWA. The North Branch Potomac River, where Bloomington Lake is located and which is the principle beneficiary in terms of

FIGURE H-1
SCHEMATIC REPRESENTATION OF
RESERVOIR SYSTEM SERVING THE MWA



water quality control, flood control, and recreation, was the obvious focal point of the study. On the other hand, the MWA is the water demand area which would receive major benefits from Bloomington water supply releases. Both of these areas were considered, where appropriate, in conducting the Bloomington Lake Reformulation Study. Further discussions of the North Branch Potomac River Basin study area are given throughout Appendix H and its various annexes. Descriptions of the MWA study area are provided in Appendix A - Background Information and Problem Identification and Appendix D - Supplies, Demands, and Deficits.

LEVEL OF DETAIL

The level of detail of the Bloomington Lake Reformulation Study was generally considered to be of framework scope. Modifications to the project facilities as a result of storage reallocation were identified and preliminary design details of these modifications were prepared. Cost estimates were based on construction costs at the project and similar facilities elsewhere. Where necessary, prior costs were updated using Engineering News-Record indices.

Only the feasibility of storage reallocation within the existing Bloomington Lake Project was investigated; no consideration was given to raising the height of the Bloomington dam to increase its total storage capacity. However, modifications to the project appurtenances (such as the spillway, control tower and recreation facilities) were considered as part of all of the storage reallocation schemes.

PRIOR STUDIES

JOHNS HOPKINS UNIVERSITY STUDY

In September 1977, the Johns Hopkins University, Baltimore, Maryland, initiated an investigation to analyze the operation of the reservoirs which serve the MWA and to develop an operating strategy that addressed the interests of all major water users in the MWA. The investigation assessed the combined regulation of the low flow augmentation storage in the Bloomington Lake Project and other reservoirs in the system (Figure H-1 shows the relative location of these reservoirs). The primary conclusion of this investigation was that combined cooperative operation of the four reservoirs as an integral system could furnish significantly more flow in the Potomac River at Washington, D.C., during low flow periods than if each reservoir were operated independently. The product of these efforts was a computer simulation model titled "Potomac River Interactive Simulation Model (PRISM)." PRISM was developed as a site-specific, flow balance model for the MWA which allowed the user to test different reservoir operating scenarios and then observe the impacts on river flows and reservoir storage. This model was later modified for use in the Bloomington Lake Reformulation Study; detailed descriptions of the development and application of PRISM are discussed in Annex H-III - PRISM Development and Application.

CORPS' PRELIMINARY INVESTIGATION

Concurrent with the Johns Hopkins University study, a preliminary investigation was made by the Corps of Engineers, Baltimore District, to analyze the water supply potential of the Bloomington Lake . Using HEC-3 and HEC-5, (computer models developed by the Hydrologic Engineering Center, Davis, California), the investigation concluded that a portion of project's flood control storage could be reallocated to water supply storage without significantly impacting the flood protection provided by the project. Subsequently, enough additional flow could be provided in the Potomac River during low flow periods to eliminate the projected MWA water supply shortages.

It is important to note at this point the difference between the investigations conducted by Johns Hopkins University and the preliminary analyses performed by the Corps of Engineers. The Hopkins study examined methods to better utilize the existing conservation storage in Bloomington Lake (and throughout the system), whereas the Corps' study investigated the possibility of providing additional conservation storage in Bloomington Lake. The positive findings in both of these preliminary studies ultimately led to the detailed Bloomington Lake Reformulation Study which examined both possibilities.

RELATIONSHIP TO MWA STUDY

The results of the Bloomington Lake Reformulation study are presented in this report entitled, "Appendix H - Bloomington Lake Reformulation Study." This report is an appendix to the overall MWA Water Supply Report and is comprised of a summary Reformulation Study Report and ten technical annexes. Figure H-2 shows the organization of Appendix H and its associated annexes. The summary Reformulation Study Report documents the planning process for the Bloomington Lake Reformulation Study plus the results and conclusions regarding more efficient reservoir regulation for water supply and possible storage reallocation. The annexes contain detailed information on the various technical subjects and provide the backup data supporting the findings and conclusions.

Because the Bloomington Lake Reformulation Study was conducted as part of the long-range phase of the MWA Water Supply Study, this appendix is incorporated into the larger MWA Water Supply Study Report. The Bloomington Lake Reformulation Study was an integral part of the overall study, particularly in regard to the development and application of the PRISM model. The PRISM model, although developed as part of the Bloomington Lake Reformulation Study, had wide-ranging application to the overall study as the effects of various regional water supply management scenarios on the total system were examined. Additionally, the PRISM model was used extensively to help develop a "baseline" regulation plan for Bloomington Lake which was significantly different than the regulation plan originally set forth in the Bloomington authorization document (1962). This new "baseline" regulation plan for Bloomington was then used to redefine the "without condition" for the long-range portion of the MWA study. This redefinition of the water supply problem for the long-range phase, in light of the results of the early-action phase and the commitment to regional water supply management, was instrumental in determining that water supply shortages would not occur before 2030.

COORDINATION

A continuous effort was made to solicit public participation during the course of the Bloomington Lake Reformulation Study. Public participation and coordination efforts for the study were combined with similar efforts for the MWA Water Supply Study. These

FIGURE H-2

APPENDIX H - BLOOMINGTON LAKE REFORMULATION STUDY

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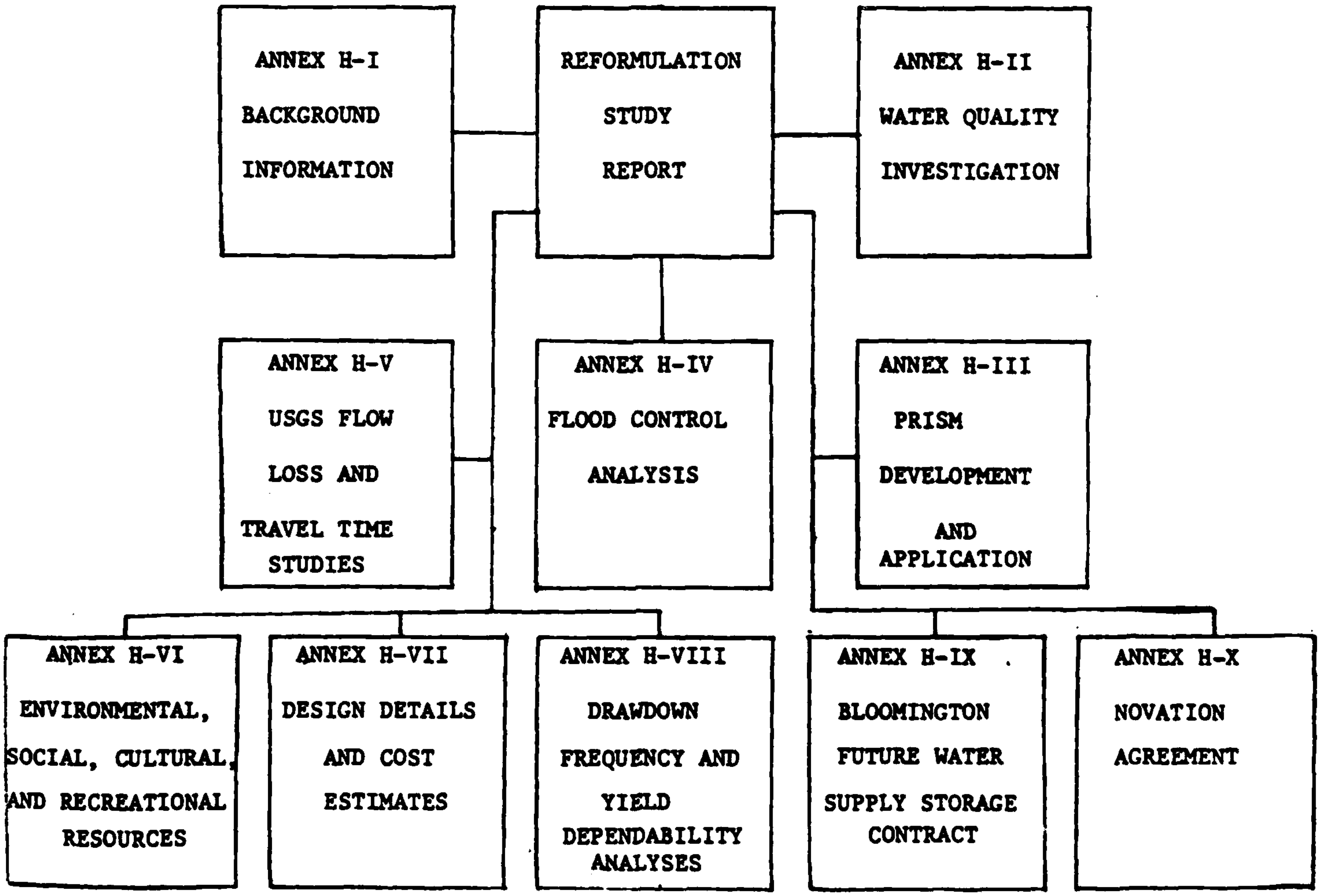


efforts were devised to assure that the desires and viewpoints of agencies, organizations, and individuals responsible for or interested in the water supply planning and management in the MWA were incorporated in the study findings and conclusions.

A public announcement of study initiation was distributed in February 1980 which explained the study purpose and study schedule. A progress report concerning the Bloomington Lake Reformulation Study was prepared in November 1980 and mailed to members of the Federal - Interstate - State - Regional Advisory Committee (FISRAC), ICPRB, members of the Citizen Task Force to review the MWA Water Supply Study, water supply utilities, and others interested in the study.

The Bloomington Lake Reformulation Study was closely coordinated with the CO-OP Section of the ICPRB. The CO-OP Program was initiated to develop a river flow forecasting procedure and to establish a mechanism by which multiple reservoir releases and river withdrawals could be efficiently managed on a day-to-day basis. The water supply utilities in the MWA have since adopted the CO-OP Program as a means to establish daily reservoir regulation policies for the joint operation of the reservoirs serving the MWA.

As part of the MWA Water Supply Study, the Bloomington Lake Reformulation Study has been discussed with various committees, at public workshops, and with other local officials and interested groups including the National Academy of Sciences - National Academy of Engineering (NAS-NAE). The NAS-NAE is responsible for final review of the MWA Water Supply Study Report including the Bloomington Lake Reformulation Study, as directed by Section 85-b(3) of P.L. 93-251. The Bloomington Lake Reformulation Study results were presented to the Citizens Task Force established for the MWA Water Supply Study for a non-technical review of the study's planning process. More details regarding the overall study coordination are presented in Appendix C - Public Involvement.

EXISTING CONDITIONS

This section provides a brief description of the present conditions given the existing Bloomington Lake Project and other water supply facilities which serve the MWA. Other pertinent Federal projects within North Branch Potomac River Basin are also discussed. This section also outlines the Baseline Condition (without Bloomington reformulation) and identifies problems, needs, and opportunities in terms of the North Branch Potomac River Basin's resource base and MWA's water supply needs. Study objectives and planning contraints are also described. The various annexes provide more detailed information.

EXISTING PROJECTS

BLOOMINGTON LAKE PROJECT

Project Description

The Bloomington Lake Project is located on the North Branch Potomac River, 7.9 miles upstream from the confluence with Savage River, partly in Garrett County, Maryland, and Mineral County, West Virginia. Figure H-3 shows the location of the project.

The project area is within the Appalachian Highlands. The watershed above the dam has a drainage area of 263 square miles and contains no natural lakes. The major tributaries above the dam site include Stony River and Abrams Creek. Much of the land around the project area has been stripped for coal and the water which drains from the surrounding areas is heavily polluted with acid mine waste caused by both active and abandoned mines. There are two small reservoirs upstream from the Bloomington Lake Project, and both are located on Stony River. (See Appendix D - Supplies, Demands, and Deficits for further description of the Stony River projects.)

The Bloomington Lake Project consists of a rolled earth and rockfill embankment about 296 feet high, a 90 foot high dike, a gated spillway, a controlled outlet works, recreational facilities, and access roads. The project provides 2,700 acre-feet of storage for sediment, 92,000 acre-feet for low flow augmentation and recreation, and 36,200 acre-feet for flood control. The low flow augmentation storage is further sub-divided into 41,000 acre-feet for water supply and 51,000 acre-feet for water quality control. Detailed project data are given in Table H-1.

The construction of the Bloomington Lake Project was initiated in 1971 and the project was operationally completed in July 1981 at a cost of $174,300,000. In accordance with the provisions of the authorization, 33.2 percent of the project construction costs allocated to water supply, estimated at $57,867,600, are to be a non-Federal responsibility and be repaid in accordance with the provisions of the Water Supply Act of 1958, as amended. A water supply contract between the Federal Government and Maryland Potomac Water Authority (MPWA) for repayment of initial water supply costs was signed on 4 November 1970. Under terms of the contract, the initial water supply storage available to MPWA would have been 7.78 percent of the low flow augmentation storage (totalling 92,000 acre-feet) or 7,158 acre-feet. Subsequently, as part of a regional operating agreement, the Potomac River users have agreed to purchase the future or remaining uncontracted water supply storage (33,837 acre-feet) as well as to take over from the MPWA all of the responsibilities and obligations resulting from its contract for the initial water supply storage. A contract for the future water supply storage was signed on 22 July 1982 and Annex H-IX provides a copy of the contract. A Novation Agreement to relieve the MPWA of its repayment responsibilities for the initial water supply contract was also signed on 22 July 1982 and a copy of this Agreement is provided in Annex H-X.

FIGURE H-3

LOCATION OF EXISTING PROJECTS IN
NORTH BRANCH POTOMAC RIVER BASIN

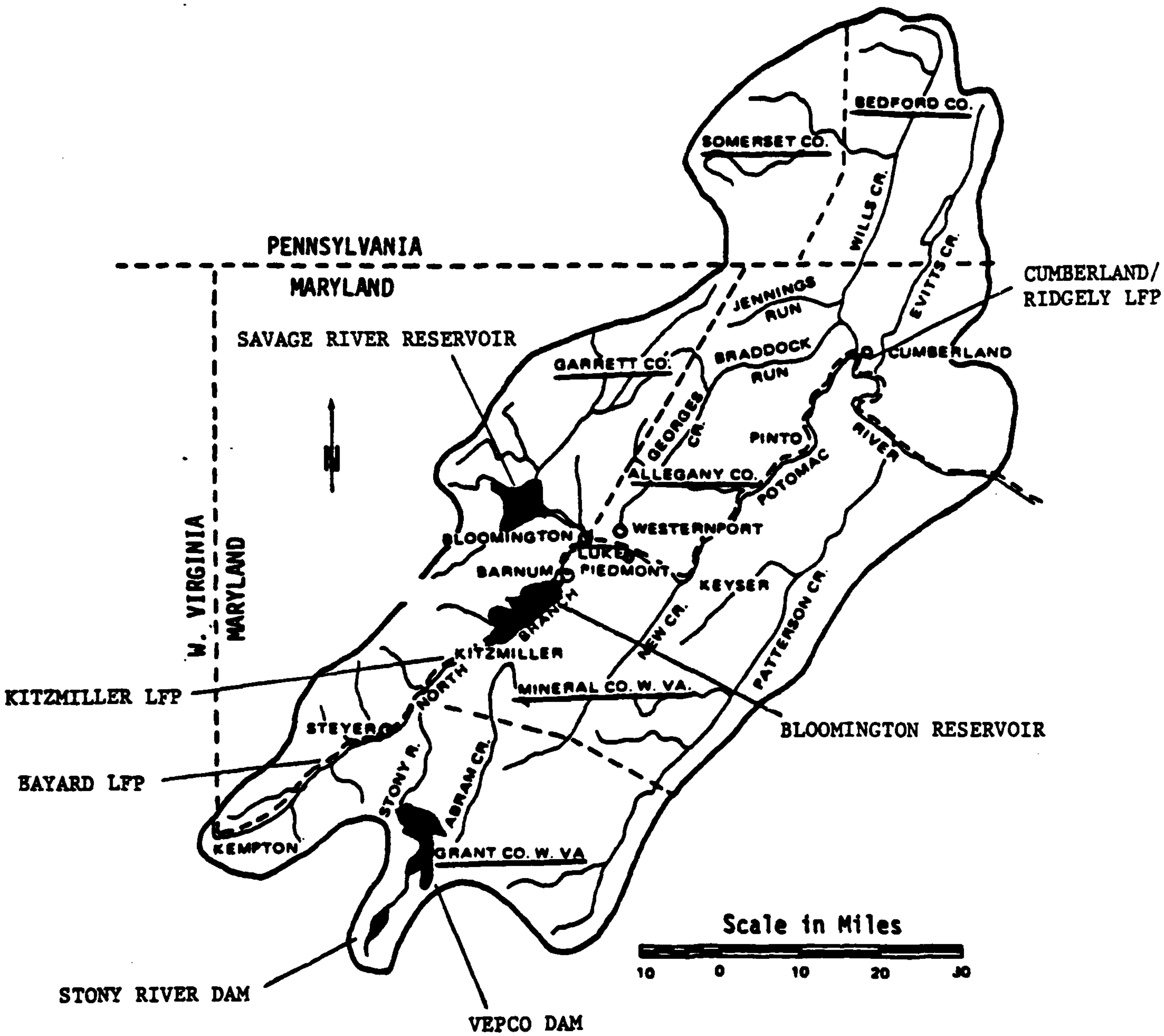


TABLE H-1
BLOOMINGTON LAKE PROJECT
PERTINENT DATA

DRAINAGE AREA (square miles)	
North Branch Potomac River at Bloomington Dam	263
North Branch Potomac River above confluence with Savage River	287
ELEVATIONS (feet above mean seal level)	
Top of dam	1,514
Spillway design flood (max pool)	1,508.9
Guide-taking line for fee acquisition	1,508 *
Guide-taking line for flowage easements for utility acquisition	1,500
Static full pool (top of closed crest gates)	1,500
Upper limit of clearing	1,469
Spillway crest	1,468
Conservation lake	1,466
Winter lake	1,410
Gate Sill	1,255
Streambed at centerline of dam	1,218
DAM	
Type	Rolled earth and rockfill
Length (ft)	2,130
Height above streambed (ft)	296
Top width (ft)	25
Maximum width at base (ft)	1,640
DIKE	
Type Rolled earth and random fill	
Length (ft)	900
Height (maximum, ft)	90
Top width (ft)	25
Maximum width at base (ft)	845
SPILLWAY	
Type	Chute
Crest length (ft)	210
Number of tainter gates	5
Size of tainter gates (ft)	32 x 42

* Elevation 1508 or a line measured 300 feet horizontally from the 1500 contour, whichever provides the greater area.

TABLE H-1 (Cont'd)

OUTLET WORKS

Type	Tunnel in rock
Length of tunnel (ft)	1,619
Inside diameter of tunnel	16'4"
Number of service gates	2
Size of gates	7'2" x 16'4"
Type of gates	Hydraulically opened
Number of emergency gates	2
Multi-level ports for water quality control	5

RESERVOIR

Length of conservation lake (airline, mi)	2.8
(along riverbed, mi)	5.5
Length of flood control pool (airline, mi)	3.5
(along riverbed, mi)	6.6
Shoreline of conservation pool (mi)	13.6

STORAGE	Acre-feet Net	Cumulative	Elevation ft above msl
Sediment reserve	2,700	2,700	--
Conservation	92,000	94,700	1466
Flood control	36,200*	130,900	1500
Design surcharge	10,800	141,700	1508.9
Top of dam	6,500	148,200	1514

POOL AREAS (ACRES)

Dead storage (below gate sill)	42
Conservation and recreation lake	952
Pool at spillway crest	965
Static full pool (top of closed crest gates)	1,184
Spillway design flood (maximum pool)	1,247

LANDS ACQUIRED (ACRES)

Dam and reservoir area	4,298
Public access area	146
Relocations	254
Total	4,698

RELOCATIONS

	Abandonment	Relocation
Western Maryland Railway (miles)	13.3	11.6
West Virginia Route 46 (miles)	2.5	3.3
Telephone lines (miles)	2.5	0

TABLE H-1 (Cont'd)

Powerlines (miles)	2.8	2.0
Pipelines (miles)	1.3	1.5
Cemeteries (42+graves)	2	2

*In addition, a minimum of 44,400 acre-feet of conservation storage will be available seasonally for flood control.

The Bloomington Lake Project is regulated to provide flood protection for communities such as Luke, Westernport, and Cumberland in Maryland and Piedmont, Keyser, and Ridgely in West Virginia, all along the North Branch Potomac River. The project is operated in conjunction with the Savage River Reservoir which, although most of its 20,000 acre-feet storage capacity is for low flow augmentation, does provide some incidental flood control storage.

During low flow periods, the Bloomington Lake Project is used for supplementing flows in the North Branch Potomac River for both water supply and water quality control. As calculated in the authorization document, the Bloomington Lake Project, in conjunction with the Savage River Reservoir and the Potomac's natural flow, could provide a maximum safe yield of 305 cfs (197 mgd) during low flow periods. The Bloomington Lake Project could contribute up to 212 cfs (137 mgd) during a severe drought and the remaining 93 cfs (60 mgd) would come from the natural flow in the North Branch Potomac River and the releases from the Savage River Reservoir.

Because of the changes which have taken place since project authorization, water supply and water quality releases have been reexamined in light of today's conditions. These studies are described in a later section, and concluded that a flow of at least 120 cfs (78 mgd) should pass Luke, Maryland at all times in order to satisfy certain minimum water quality targets. This flow would be made up of a proper mix of Bloomington Lake and Savage Reservoir releases, depending on the water quality conditions in the rivers and the remaining water quantity in the respective reservoirs. These investigations are documented in detail in Annex H-II - Water Quality Investigations and Annex H-III - PRISM Development and Application.

Hydropower Potential

The hydropower potential for the Bloomington Lake Project was identified in both the project authorization report and the 1963 Potomac River Basin Report. A detailed evaluation of hydropower potential, however, was also made during the preliminary design phase prior to construction. The reevaluation for including hydropower was made by the Federal Power Commission and concluded that the Bloomington Lake Project could be used as a lower pool for a pumped storage project that included a reservoir in nearby Piney Swamp as the upper pool. The project would provide an estimated installed capacity of 600 MW under an average head of 1,180 feet. Further, the project could also be used as a conventional peaking powerplant. For this, the Bloomington Lake Project would have to maintain a year-round conservation pool at elevation 1466 feet msl. If the project was operated as planned for full drawdown of the conservation pool to elevation 1410 feet msl, a conventional peaking power plant would not be economically justified. A conventional peaking powerplant with a year-round conservation pool at elevation 1466 feet msl could provide an installed capacity of 30 MW under an average head of 210 feet and an average annual energy production of 6500 MW - HR. The project would require steel-lining of the tunnel and construction of a low reregulating dam to minimize peaking discharges from the powerplant.

Additional evaluations of the optimum pumped storage and conventional peaking alternatives indicated that both of the aforementioned projects were of marginal justification and based on these reevaluations, hydropower was not included as a project purpose in the Bloomington Lake Project.

Because of the rise in energy prices due to imported oil and the Nation's desire to become energy self-sufficient during the 1970's, the hydropower potential of the Bloomington Lake Project was reinvestigated as part of the National Hydroelectric Power Resources Study conducted under the Water Resources Development Act of 1976. The conclusions of this study indicated that the project had potential for a run-of-river powerplant with a marginal economic feasibility and further investigations were warranted in light of the changed energy prices. For further details regarding the hydropower potential investigation, see Annex H - I.

OTHER PROJECTS

Federal Projects

Savage River Reservoir

Savage River Reservoir is located on the Savage River in Garrett County, Maryland, approximately five miles upstream from its confluence with the North Branch Potomac River (see Figure H-3). The project was initiated in 1935 by the Upper Potomac River Commission (UPRC) for the purposes of increasing low flow for industrial use and water quality control downstream of Luke, Maryland. Project construction was stopped due to World War II, but resumed in March 1949 under the direction of the U. S. Army Engineer District, Washington, D.C. The project was operationally completed in January 1952, and was transferred for operation and maintenance to UPRC in 1953. The project provides a 184-foot high dam with a storage capacity of 20,000 acre-feet, primarily for maintaining a constant minimum flow of 93 cfs (60 mgd) at Luke, Maryland, during low flow periods in the North Branch Potomac River. This 93 cfs flow includes the natural flow in the North Branch Potomac River and releases from the Savage River Reservoir. Of the 20,000 acre-feet of conservation storage, approximately 2,000 acre-feet is reserved for the Town of Westernport which withdraws its water supply directly from the reservoir for subsequent treatment and distribution. Table H-2 provides pertinent data for the project.

Until recently, the UPRC operated and maintained the project in accordance with Federal regulations with the costs paid by Allegany County. Now, however, the Potomac River users in the MWA have agreed to share these costs with Allegany County and to make Savage River Reservoir part of the system which serves the MWA. The cost sharing agreement was signed on 22 July 1982 and a copy of the agreement is provided in Annex B-III - Savage Reservoir Maintenance and Operation Cost Sharing Agreement.

TABLE H-2

SAVAGE RIVER RESERVOIR
PERTINENT DATA

DRAINAGE AREA (square miles)	105
ELEVATION (feet above mean sea level)	
Top of Dam	1497.5
Spillway Crest	1468.5
DAM	
Type	Earth and Rockfill
Length (feet)	1050
Height of dam above streambed (feet)	184
Top width (feet)	20
RESERVOIR	
Area at spillway crest	360 acres
Storage at spillway crest	20,000 acre-feet
SPILLWAY	
Type of spillway	side channel
Length at crest elevation	320 feet
Discharge capacity - 24.3 feet depth on crest	97,200 cfs
OUTLET STRUCTURE	
a. Tunnel	
Type	Horseshoe-shaped
Diameter	10 feet
Length	1,170 feet
Discharge capacity (reservoir water surface at spillway crest)	4,850 cfs
b. Slide Gates	
Type	Hydraulically operated
Number	2 twin scts.
Size	4 ft. x 10 ft.

Local Flood Projects

The North Branch Potomac River watershed has three local flood protection projects (LFP): a small LFP in Bayard, West Virginia , on Buffalo Creek; an LFP in Kitzmiller, Maryland, and Blaine, West Virginia, on the North Branch Potomac River; and an LFP in Cumberland, Maryland, and Ridgely, West Virginia on the North Branch Potomac River. Locations of these projects are shown in Figure H-3 and pertinent data have been summarized in Annex H - I - Background Information.

Non-Federal Projects

There are three non-Federal water supply reservoirs located within the MWA, (two in Maryland and one in Virginia) which were considered in the Bloomington Lake Reformulation Study. Figure H-1 shows the location of these projects in relation to Bloomington Lake. The Patuxent River reservoirs in Maryland (Triadelphia and Rocky Gorge) and the Occoquan Creek Reservoir in Virginia are part of the system providing water supply to the MWA which were considered in proposing changes to Bloomington Lake. Technical details about the Patuxent and Occoquan Reservoirs are given in Appendix D - Supplies, Demands, and Deficits.

BASELINE PROFILE

For the purposes of the Bloomington Lake Reformulation Study, existing or baseline conditions were defined as those physical, ecological, demographic, and economic characteristics of the region which were prevailing at the time of the study. These baseline conditions provided the basis against which any proposed changes were measured. The following paragraphs describe the baseline profile, first in general terms for the overall North Branch Potomac River Basin and then in more specific terms for both the Bloomington Lake and Savage Reservoir Projects.

NORTH BRANCH POTOMAC RIVER

Location

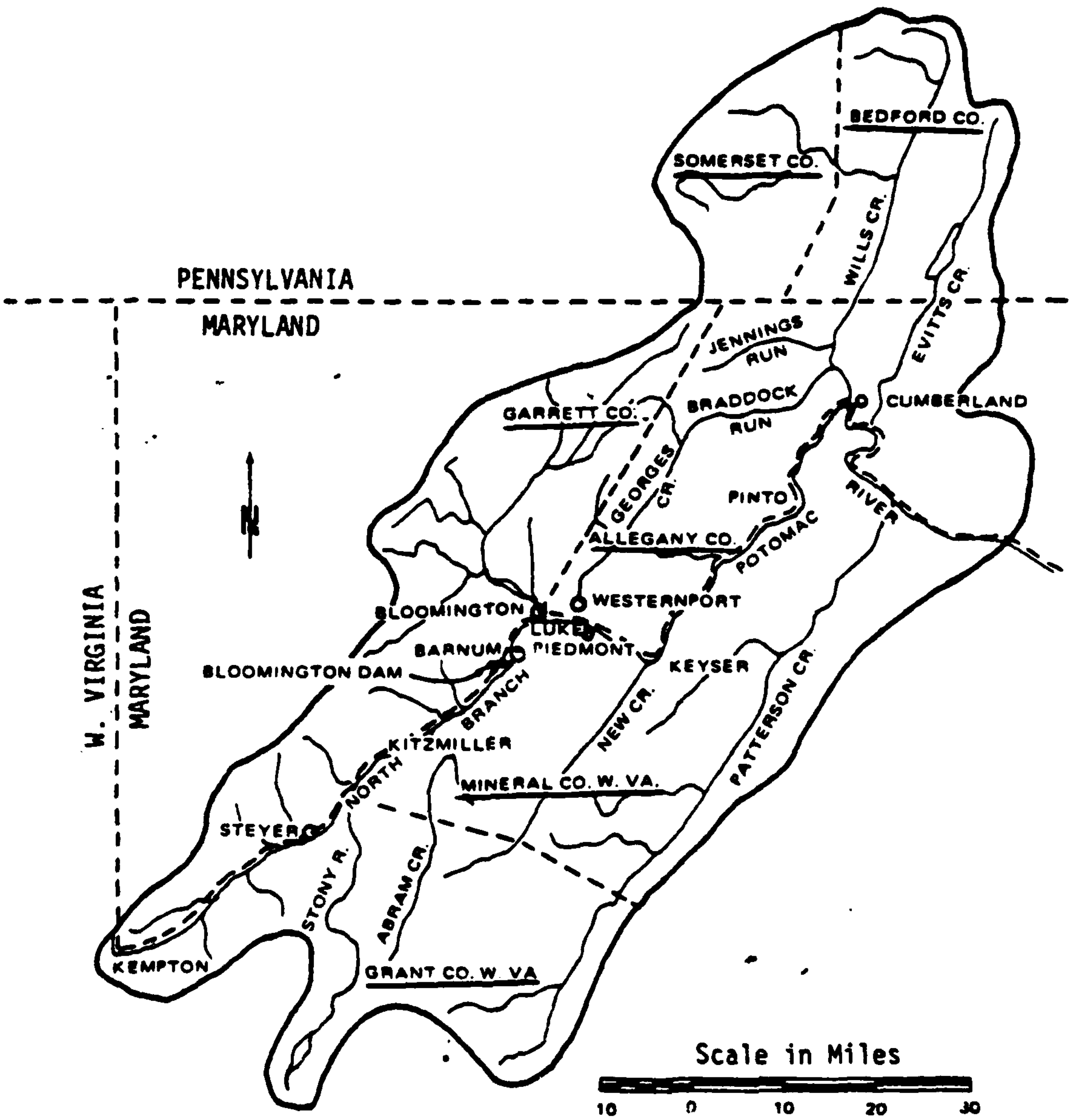
The North Branch Potomac River Basin is located partly in three states, Maryland, West Virginia, and Pennsylvania. It includes Garrett and Allegany Counties of Maryland, Grant and Mineral Counties of West Virginia, and Somerset and Bedford Counties of Pennsylvania. Figure H-4 shows the location of the North Branch Potomac River in relation to the rest of the Potomac River Basin. The North Branch Potomac River originates near the historic Fairfax Stone in West Virginia and flows about 98 miles to meet the South Branch Potomac River near Oldtown, Maryland to form the Potomac River.

Land Use

The North Branch Potomac River Basin is within two physiographic regions. The eastern half of the basin is in the Ridge and Valley Province where severe topography limits

FIGURE H-4

LOCATION OF NORTH BRANCH POTOMAC RIVER



development to the narrow, northeast-southwest stream valleys. The western half of the basin lies in the Allegheny Plateau Province, a deeply dissected plateau which generally has flat, developable land in both stream valleys and upland areas.

In Garrett County approximately seven of every ten acres of land is forested. About twenty-five percent is open farmland with one percent being classified as urban. Approximately 4,000 acres are actively mined or have been previously disturbed by strip mining.

The area of Garrett County east of the ridge of Backbone Mountain is almost completely forested. This section of the basin includes most of the 12,000 acres of the Potomac State Forest and many large stands of private forest. The communities of this area are Kempton, Vindex, Gorman, Kitzmiller, and Bloomington.

The area around the Savage River is distinctive for its rugged terrain. The majority of the land is owned by the State of Maryland and is known as the Savage River State Forest. The main feature of this area is the Savage River Reservoir which supplies water to the City of Westernport and helps to regulate the flow of the North Branch Potomac River.

The section of Allegany County included in the North Potomac River Basin can be considered an industrial region. The Upper Potomac Industrial Park is located south of Cumberland, Maryland. The major industries are Allegany Ballistics Laboratory, Celanese Fibers Co., and Kelly-Springfield Tire Company.

Approximately sixty percent of Grant and Mineral Counties in West Virginia are covered by forest. The remainder of the land is utilized for mining, farming, manufacturing and small rural communities. The mountain ridges and plateaus are not suitable for any commercial use except the hardwood saw timber industry. There are approximately 850 farms in the two counties.

Bedford and Somerset Counties in Pennsylvania are generally rural in nature. In Somerset County there are 693 square miles (sq. mi.) of forest land, 200 sq. mi. of crop land, 66 sq. mi. of pasture land. Of the 100 sq. mi. devoted to state parks and forest, approximately 4 sq. mi. have been disturbed by coal mining activity. Bedford County has a total land area of 1,018 sq. mi. of which 657 sq. mi. are devoted to forest land, 201 sq. mi. to crop land and 69 sq. mi. to pasture land.

Socio - Economic Characteristics

In general, the socio-economic characteristics of the North Branch Potomac River Basin are similar to the characteristics of the Appalachian Region in which it is located and include a high percentage of people over the age of 65, low in-migration ratios, and high out-migration levels.

The economic base of the area is comprised of four main activities: 1) mining, 2) agriculture - including forestry, 3) manufacturing, and 4) tourism. In terms of absolute numbers, manufacturing dominates the economic base of the area. The industries are mainly concentrated in the metropolitan areas and produce a diverse set of products. As is the case in the Appalachian region, there is a high concentration of work activity in a few economic sectors. Any fluctuations in the regional or national demand for their products leads to serious fluctuations in the local economy.

Income levels in the study area generally follow the dependence on manufacturing employment. However, in all cases, income levels are below the median income levels for the nation.

Archaeological and Historic Resources

Numerous archaeological and historic resources are associated with the area. Several sites, buildings, and structures have been listed in the Federal Register of Historic Places to include the Chesapeake and Ohio Canal, National Historical Park, the La Vale Tollgate House (U.S. Route 40), the Michael Cresap House in Oldtown, Maryland, and Fort Ashby in Mineral County, West Virginia.

Water Quality

The water of the North Branch Potomac River is of generally poor quality. The major sources of pollution in the basin are acidic drainage from both active and abandoned coal mines along with some wastewater discharges from industries and municipalities. The major contaminants of mine drainage are sulfuric acid, heavy metals, and high dissolved solids. At present, about 40 miles of the North Branch and 100 miles of its tributary streams are severely affected by acid mine discharges, primarily upstream of Luke, Maryland. Because of better management of coal mine discharges recently, water quality in the North Branch has shown slight improvement within the last several years.

The water quality in the North Branch will be further improved with the joint operation of the Savage River Reservoir and the recently completed Bloomington Lake Project. The new impoundment will alter water quality by changing the character of the North Branch above Luke from a free-flowing stream to a lake environment. The project will moderate pH fluctuations downstream of the dam and eliminate acid slugs from moving downstream unchecked. Joint operation with the alkaline Savage River Reservoir will further dilute any acid releases which may be made from Bloomington Lake. A detailed discussion of water quality in the North Branch Potomac River is provided in Annex H-II - Water Quality Investigations.

Environmental Resources

The North Branch Potomac River Basin provides a diverse environment including a variety of forests, river and stream communities, and extremes in topography. The climate of the basin is considered temperate, even though freezing temperatures occur about 150 days per year. About sixty percent of the North Branch Potomac River Basin's land area is in forest. The humid and temperate low-lying valleys are covered with mixed deciduous forest. The rich and diverse vegetation provides abundant food and cover for the basin's wildlife. The varied topography and diverse vegetation also provide suitable environmental conditions for the bird life which includes wild turkey, golden eagle, and a variety of hawks.

According to the information available from the Department of Interior's Office of Endangered Species, there are no species of wildlife in the North Branch Potomac River Basin listed on the National Register as being endangered. The Maryland Department of Natural Resources, however, has designated seven animal species as "threatened with statewide extinction" to include the bobcat, black bear, hellbender, Jefferson Salamander, green salamander, coal skink, and the mountain earth snake.

The North Branch Potomac River currently does not support a healthy aquatic community due to the seriousness of the acid mine drainage problem. The river supports a very limited number of species with those represented in only a few numbers. The organisms which are present are either indigenous to acid steams or are acid-tolerant forms which have become acclimated to the prolonged stress or are little affected by low pH. The North Branch does not begin to recover biologically until Oldtown, Maryland. At this point, the water quality is such that it supports a moderately diverse community. Even this area is periodically subjected, however, to acid slugs which can result in fish kills.

The operation of Bloomington Lake is expected to result in some water quality improvements in the downstream reaches. The impoundment should trap iron and aluminum which exist in the river in high concentrations because of acidic conditions. Dissolved oxygen in the downstream reach, which sometimes reaches low levels during low flows because of high BOD from some industrial and municipal discharges, will be enhanced by the augmented flows from Bloomington Lake containing relatively high levels of dissolved oxygen. The most significant water quality impact of the dam revolves around the moderation of the pH fluctuations downstream. As a result, there should be an expansion in the biotic community, both in numbers of individuals and species in stretches of the river that now have a marginal population.

From the headwaters to Bloomington Lake, the flow of the river will not be altered; therefore, this reach will remain very much the same as it was before the dam was built. The pH level and associated constitutes of acid mine drainage will not permit the development of healthy stream flora and fauna. Higher species of fish, even the more tolerant forms such as brook trout, while sucker, and river chub, would not be able to survive.

At the dam site, water quality will vary depending on the time of year but it is expected that the reservoir resulting from the impounding of the North Branch will be too acidic to support a resident lenthic community. There is the possibility that some of the vascular plants that are relatively pH-independent may become established in shallow areas; but the plants would not contribute to the improvement of the aquatic community. Also, there is the possibility that several arms of the lake will have relatively good water quality due to feeder streams, and small fisheries could be established.

As a result of the dam, areas downstream of Bloomington Lake to Piedmont, West Virginia, will no longer be subjected to acid slugs. However, the overall water quality of this reach will not be significantly altered. The elimination of acid slugs will facilitate minimal colonization in the downstream portion of this reach by some acid-tolerant forms, but fish populations of any significance are not expected. The downstream segment of the reach is characterized by an increase in pH but overall water quality is still below the limits required for a healthy stream community. This reach will still be subjected to organic pollution from domestic and industrial waste in addition to acid mine drainage. Thus, water quality and hence stream life will remain poor.

The aquatic community from Piedmont, West Virginia to Pinto, West Virginia will most likely show a gradual increase in species and numbers of individuals; however, it is not expected to show any appreciable improvement over the existing conditions before the Bloomington Lake Project. The pH level of this reach often approaches neutrality but the overall water quality is very poor. The acid slugs will be eliminated by the presence of the dam; however, these slugs only intensify the existing stress which will continue to persist.

Between Pinto and Oldtown the river should demonstrate a significant improvement over the present conditions. The community structure should become slightly more complex due to the absence of acid slugs and the loss of moderately acid-tolerant macroinvertebrates and microorganisms. The reestablishment of a more diversified community will be further facilitated by the recolonization of organisms from nearby unpolluted sources such as the South Branch Potomac River below Oldtown. The distance over which recolonization will be effective is dependent upon the extent of improvement in water quality upstream from Oldtown. A small fish population will probably develop in the river between Pinto and Oldtown, an area which now supports a limited aquatic community except near Oldtown.

Recreation Resources

The North Branch Potomac River Basin offers a variety of recreational opportunities in addition to those provided at the Bloomington Lake Project. Allegany and Garrett counties in Maryland have numerous State Parks and Forests that offer a range of recreational activities. In addition to the State parks and forests, Deep Creek Lake is located in Garrett County. Deep Creek Lake was constructed in 1925 as a source of hydroelectric power. It is 12 miles long and has approximately 65 miles of shoreline and 3,673 surface acres. The area offers boating, camping, fishing, swimming, and related activities. In Grant and Mineral Counties, West Virginia, the extent of public recreation facilities is limited to the Petersburg and Spring Run trout hatcheries and the Spruce Knob-Seneca Rock National Recreation Area.

BLOOMINGTON LAKE

The Bloomington Lake Project provides a 952-acre impoundment approximately 8 miles upstream of Luke, Maryland. The area is typical of the conditions previously described for the North Branch Potomac River Basin. The project area is characterized by steep, forested slopes. A mixed deciduous forest type predominates with oak, yellow poplar, red maple, and beech being common species. Mountain laurel is the common understage shrub. The fauna is typical of the temperate forest biome. Mammals present include whitetail deer, red fox, gray fox, red squirrel, and bobcat.

Because of the acid-polluted waters and low flows, the North Branch has limited recreation use at present, although some canoeing is done. There are presently no fishing or water-contact activities of any significance in the river, the latter probably due to the social unacceptance of acid water for swimming rather than from a health standpoint. At the present time, hunting and hiking are the only activities of any significance.

The major attractions offered at Bloomington Lake are sightseeing, picnicking, overnight camping, and boating. The initial plan of development provides facilities to accommodate an initial annual visitation of 110,000. Additional development is planned to accommodate an ultimate annual visitation of 150,000 by about the year 2005.

The High Timber Camping area, which is located on the West Virginia shore on a high ridge overlooking the dam site, has approximately 70 campsites. Below the High Timber area, and between Route 46 and the shoreline, the Howell Run picnic area and the Howell Run boat launch are located. The picnic area has approximately 100 tables with several of the tables located under a pavilion. The boat launch has approximately 60 car-trailer parking spaces.

In addition to the camping, picnicking, and boat launching areas, there are three overlooks providing various views of the project. Two overlooks are on the Maryland side and one is on the West Virginia side. One of the overlooks in Maryland provides a view of the gated spillway and lake from the downstream side of the dam. The other overlook in Maryland provides a view of the lake and the upstream sides of the gated spillway and dam. The overlook in West Virginia provides a view of the dam, lake, and stilling basin.

SAVAGE RIVER RESERVOIR

The Savage River is located within the Allegheny Plateau physiographic province and the upland resources are similar to those described for the North Branch Potomac River. Unlike the North Branch Potomac River, however, the drainage area for the Savage River has not been mined for coal, and consequently, does not have the water quality problems found in many of the other tributaries of the North Branch.

The Savage River Reservoir provides about 450 acres of surface area. The lake has a maximum depth of 150 feet, and because of the steep sides there are relatively few shallow areas. It supports both cold-water and warm-water species.

The free-flowing river above the reservoir has good water quality and supports an excellent cold-water trout fishery. However, downstream from the dam to Aaron Run the species diversity is significantly reduced possibly due to temperature changes caused by reservoir operation.

The land surrounding the Savage River Reservoir is part of the Savage State Forest and New Germany State Park. The State Forest and State Park provide various recreational facilities including hiking trails, primitive camping, and a canoe launch.

PROBLEMS, NEEDS, AND OPPORTUNITIES

FLOOD CONTROL

The North Branch Potomac River and its tributaries have been subjected to frequent and severe floods. The notable floods of record occurred in May-June 1889, March 1924, March 1936, October 1942, October 1954, and August 1955. These floods have produced stages of 15 to 20 feet above normal low water, and have inundated urban areas to depths of up to 10 feet. The largest flood in the North Branch Potomac River watershed at Kitzmiller, Maryland, for the period of record October 1949 to September 1979, occurred in October 1954. This flood was also the flood of record at Luke, Maryland. The largest flood of record at Cumberland, Maryland, occurred in March 1936. These two floods are prime examples of the two distinct types of floods which can occur in the North Branch Potomac River Basin. The March 1936 flood was a typical early springtime flood caused by snow melt and moderate to heavy coincident rainfall, while the October 1954 flood was caused by extremely heavy rainfall associated with Tropical Storm Hazel.

The Bloomington Lake Project provides the North Branch Potomac River Basin communities with protection against such floods. The estimated average annual flood control benefits associated with Bloomington Lake are $1,498,000 (October 1981 price levels). During the summer, the project provides a capacity of 36,200 acre-feet allocated to flood control storage which would control a total runoff of 2.58 inches over the upstream watershed. Additionally, the lake level is drawn down during the winter to provide extra seasonal runoff control for high volume floods in the early spring. During the drawdown season, the project provides 80,600 acre-feet of flood control storage or 5.74 inches of runoff control.

Reductions in flood stages attributable to the flood control storage in Bloomington Lake are shown in Table H-3 at various downstream damage centers for two representative large floods. Had Bloomington Lake been constructed when these floods occurred, the last column shows the stage reductions which could have been achieved.

Under any flood control reallocation plan, some of the existing flood control storage would be reallocated to water supply storage, thereby decreasing the project's runoff control potential. Such alterations to the presently existing storage allocation could affect the estimates of stage and damage reduction resulting in some foregone flood control benefits. The flood control benefits that are foregone would have to be balanced against the increased water supply benefits.

RECREATION

Because of the acid waters, the North Branch Potomac River has limited recreation use at present, although some canoeing is done. There are presently no fishing or water contact activities of any significance in the river. Hunting and hiking are the only activities of any significance in the North Branch Potomac River Basin.

The major activites offered at Bloomington Lake are sightseeing, picnicking, overnight camping, and boating. The initial plan of development provides facilities to accomodate an initial annual visitation of 110,000 with an ultimate annual visitation of 150,000 within 25 years after the project is constructed.

A higher lake level associated with storage reallocation (transferring flood control storage to water supply storage) would inundate a portion of the recreation facilities, primarily the boat launch. These facilities would have to be raised to the level of the higher pool. At the same time, however, a larger lake might offer some new recreational

TABLE H-3

FLOOD STAGE REDUCTION WITH BLOOMINGTON LAKE PROJECT

Damage Center	Flood	Stage (feet) Observed*	With Project	Reduction
Luke, MD	October 1954	17.2	10.4	6.8
Pinto, MD	October 1954	23.2	13.3	9.9
Cumberland, MD	October 1954	24.0	19.5	4.5
Luke, MD	August 1955	15.5	11.0	4.5
Pinto, MD	August 1955	22.6	13.7	8.9
Cumberland, MD	August 1955	23.2	15.2	8.0

* includes effect of Savage River Reservoir.

opportunities. Additionally, a revised regulation plan using Bloomington Lake more efficiently in light of present conditions might increase the recreation opportunities downstream of the dam.

WATER SUPPLY

The Bloomington Lake Project presently provides 41,000 acre-feet of water supply storage which was recently contracted to the major MWA water supply utilities (see Annex H-IX for a copy of the contract). Currently, the MWA depends on the Potomac River, supplemented by releases from Bloomington Lake, plus other water supply reservoirs (Patuxent and Occoquan) in Maryland and Virginia. Withdrawals from the Potomac River furnish about two-thirds of the MWA's water supply needs. Thus, the MWA is highly dependent on flows in the Potomac River, and in turn on how Bloomington Lake is regulated to provide water supply and water quality control.

With the exception of the Bloomington Lake Project and the Savage River Reservoir, there are no large reservoir projects on the Potomac River from its source to the Chesapeake Bay. Strong opposition to other large reservoirs within the Potomac River Basin most likely precludes the possibility of such new water supply sources in the near future. Because of the MWA's dependence on the Potomac River as its primary source, the potential coincidence of low flow in the Potomac River and high MWA demands within some time frame suggests the possibility of a water supply shortage and the attendant adverse consequences. The Potomac River flow record shows that the daily withdrawals from the Potomac River for water supply purposes first exceeded the historical low flow in 1971, and subsequently it has happened more than 80 times. With the construction of the Bloomington Lake Project, the dependable flow in the Potomac River has been increased somewhat; however, future water supply shortages could still potentially occur should low flows occur during periods of seasonally high water demands.

For all of these reasons, it is imperative that optimum use be made of Bloomington Lake's existing conservation storage to provide releases for downstream water supply needs. Furthermore, any additional storage which could be reallocated from other purposes would increase the project's water supply capability and possibly reduce or negate the need for other projects.

WATER QUALITY

As noted earlier, the North Branch Potomac River contains water of very poor quality. The major sources of pollution in the Basin are acid mine drainage and poorly treated effluent from municipalities and industries. The acid mine drainage problem streams from active and abandoned projects including both deep and surface mines. Recent environmental regulations have helped to control discharges from active mines, but discharges from abandoned mines continue to present a problem. Generally, acid mine drainage contains low pH, high total dissolved solid concentrations, and high sulfate levels.

Improvements in municipal and industrial waste treatment have been observed in recent years. Presently, the Upper Potomac River Commission (UPRC) operates a secondary sewage treatment plant in Westernport, Maryland while discharges about 33.5 cfs year-round. Of this total, almost 97 percent comes from the WESTVACO Pulp and Paper Mill located in Luke, Maryland with the remainder coming from the towns of Luke and Westernport. The UPRC plant effluent has a neutral pH, moderate 5-day biochemical oxygen demand (BOD), considerable total dissolved solids, high turbidity, and high color.

Upstream of Bloomington Lake, the North Branch Potomac River exhibits all the characteristics of an acid-laden stream. The pH ranges from 3.4 to 4.0 during low flow periods, and from 4.5 to 6.5 during high flow periods effectively eliminating most biological activity. Within the reservoir itself, several layers or zones of water develop especially during the summer. Generally, the water in the deeper layers exhibits a slightly higher pH than surface water, but no biological activity is expected in either zone. The lake is equipped with a multi-level outlet structure so that water can be withdrawn from any level for downstream releases. Thus, the reservoir acts as a large averaging device, allowing the system operator to capture and slowly dissipate periodic acid slug which might be moving downstream.

Savage River Reservoir is regulated in conjunction with Bloomington Lake to help diminish the effects of acid mine drainage. Because Savage Reservoir normally contains alkaline water its releases tend to buffer the acidic Bloomington Lake releases. At Luke, the discharge from the UPRC's wastewater treatment plant helps to further raise the pH, but complete biological recovery does not take place until many miles downstream near Paw Paw, West Virginia where the South Branch Potomac River contributes large quantities of good quality water.

Thus, water quality in the North Branch Potomac River and in Bloomington Lake is the product of many factors. Any reformulation study of Bloomington Lake should consider present water quality conditions, recently enacted standards and regulations, and the interaction of the many variables influencing water quality in the North Branch Potomac River. Furthermore, any reformulation study should investigate methods or regulation policies that would improve water quality in the North Branch without adversely affecting Bloomington Lake's other project purposes.

PLANNING CONSTRAINTS

Planning constraints are those physical, environmental, social, economic, and institutional boundaries which define the limits of the study. The broad institutional constraints on the planning process are embodied in a large volume of law, regulations, and policies. These constraints provide a framework in which plans are conceived, developed, and evaluated.

For the Bloomington Lake Reformulation Study, the study area was limited to the Bloomington Lake Project lands and the affected areas both upstream and downstream, including the MWA. Detailed studies of other Federal and non-Federal reservoirs and local flood protection projects were outside the scope of the Bloomington Lake Reformulation Study except for the operation of the reservoirs serving the MWA as part of the water supply system.

Two physical constraints at the existing project were identified. First, the raising of the Bloomington Dam to increase its total storage capacity was not considered as it would require extensive modifications and relocations at a prohibitive cost. Second, recreational facilities at higher pool elevations should provide at least equivalent recreational activities and opportunities as provided at the existing project.

STUDY PLANNING OBJECTIVES

Planning objectives are expressions of public and professional concerns about the future use of water and related land resources. They are derived through an analysis of the existing resource base and the expected future conditions within the study area. The purpose in defining planning objectives was to establish "targets" which guide the formulation of alternative plans and to enable an evaluation of plan effectiveness. Planning objectives may sometimes conflict with each other, reflecting different perceptions of how the water resource should be managed in the future.

Since the Bloomington Lake Reformulation Study was an integral part of the MWA Water Supply Study, the broad objectives of the Reformulation Study were the same as of those of the MWA Water Supply Study. The primary objective of the MWA Water Supply Study was to provide an adequate water supply base for the MWA; the Bloomington Lake Reformulation Study investigated the Bloomington Lake Project as one possible element to help achieve this objective.

The specific planning objectives for the Bloomington Lake Reformulation Study were identified as follows:

- To optimize the regulation of the Bloomington Lake Project in light of current and projected future conditions.

- To maximize the water supply potential of the recently completed Bloomington Lake Project.

- To enhance the water quality in the North Branch Potomac River.

- To maintain the existing level of flood damage protection for the North Branch Basin communities.

- To maintain or increase the level of recreational opportunities associated with the Bloomington Lake Project.

- To provide increased levels of flowby for the Potomac Estuary.

REDEFINITION OF WITHOUT CONDITION USING BLOOMINGTON LAKE

REASONS FOR REDEFINITION

Because Bloomington Lake is likely to be the only major headwater reservoir in the Potomac River Basin in the near future, it is imperative that the project be regulated in the most efficient possible manner to achieve its multiple purposes of water supply, water quality, flood control, and recreation. The way in which Bloomington Lake is regulated also affects how other components in the MWA's water supply system should be used as well. Therefore, determining an optimum reservoir regulation strategy using Bloomington Lake's existing conservation storage was viewed as a necessary first step before considering other options such as: (1) storage reallocation for additional water supply in Bloomington Lake or (2) implementation of other water supply programs to supplement the existing MWA sources. The following sections describe the efforts to devise a reservoir regulation strategy for Bloomington Lake which would maximize the water supply available to the MWA, yet not adversely affect other resources in the MWA's water supply system. This strategy then became the basis from which the MWA's water supply problem was redefined for the long-range phase of the overall study (see Main Report).

PREVIOUS ASSUMPTIONS

As described earlier, the authorization document for Bloomington Lake calculated the safe yield of the Bloomington Lake/Savage Reservoir system to be 305 cfs (197 mgd) at Luke, assuming a recurrence of the worst drought of record (1930-31). Of this total, the low flow augmentation storage in Bloomington Lake (92,000 acre-feet) was estimated to furnish up to 212 cfs (137 mgd).

This information was used throughout the Northeastern United States Water Supply (NEWS) Study and was also used during the early-action phase of the MWA Water Supply Study. All plans in the Progress Report published in August 1979, for instance, assumed that Bloomington Lake would provide a constant release of 135 mgd to the MWA. No efforts were made to refine this release strategy during the early-action phase, in order to avoid "wasting" Bloomington water during high flow periods or to furnish additional water during low flow periods. (Studies by others, released about the same time as the Progress Report, concluded that the constant release of 135 mgd from Bloomington Lake was very inefficient from a water supply viewpoint.) Likewise, no reservoir simulations were accomplished during the early-action phase to determine the timing and magnitude of drawdowns in Bloomington Lake, nor were any studies performed to determine the effects of the constant release strategy on water quality in Bloomington Lake and downstream.

ADDITIONAL INVESTIGATIONS REQUIRED

In 1980 at the outset of the Bloomington Lake Reformulation Study, several factors suggested that an immediate examination be conducted to determine the full potential of the existing Bloomington Lake Project. These factors included the following: the shortcomings of earlier efforts with regard to Bloomington Lake's water supply capability, the need to reexamine the water supply and water quality needs in light of today's conditions (20 years after project authorization), and the desire to regulate Bloomington Lake as efficiently as possible as part of the larger water supply system for the MWA.

To accomplish this examination of the project's full potential within the existing authorization, detailed investigations and further data development were required in several areas. These additional efforts were needed to provide the information necessary to logically formulate and evaluate different reservoir regulation schemes to optimize the use of the existing Bloomington Lake Project. Some of the more important work efforts which were identified and then accomplished are listed below:

- Development and application of a numerical (computer) model which would be capable of quickly simulating the response of the entire MWA water supply system (Potomac River and the Patuxent, Occoquan, Bloomington, and Savage Reservoirs) to different regulation strategies, water demands, flowby levels, low flow allocation ratios, and other parameters.

- Determination of the proper ratio of releases from Bloomington Lake and Savage Reservoir such that water quality conditions would be improved downstream of Luke, Maryland.

- Determination of a minimum flow target at Luke which would reflect both water quality and water quantity concerns in the North Branch Potomac River.

- Estimation of the transit time and losses for Bloomington Lake releases traveling downstream to the MWA.

- Determination of an acceptable balance between use of the upstream reservoirs (Bloomington and Savage) and the downstream reservoirs (Patuxent and Occoquan) such that the system's overall flexibility would be enhanced.

These tasks, and others, are briefly described in the next section on technical studies, and are described in greater detail in the various annexes. It should be noted at this point that much of the work on maximizing Bloomington Lake's existing water supply potential was accomplished concurrently with the development of the reservoir regulation manual for the existing Bloomington Project. Additionally, much guidance and assistance was provided through ICPRB's CO-OP Program which was also considering system operation along the Potomac River.

TECHNICAL STUDIES

SIMULATION MODEL

With the recent advances in operations research and the improved capability for computer simulation of complex systems, it became apparent that a computer model of the MWA water supply system would be useful. Such a model would allow the user to "test" different assumptions and regulation strategies to determine the best methods of managing the overall MWA water supply system.

Fortunately, a research team at Johns Hopkins University had developed such a model in the late 1970's. Their model, titled "Potomac River Interactive Simulation Model" (PRISM), was subsequently reviewed, modified, and adopted for use in the long-range phase of the MWA Water Supply Study. The Corps' version of the model, titled "PRISM/COE", became the primary tool for evaluating different regulation schemes for Bloomington Lake as well as the overall system. Details concerning model development and application are contained in Annex H-III. It should be noted that PRISM/COE was strictly a water quantity model and did not explicitly consider water quality concerns; these concerns were addressed in a related but separate examination as discussed in the next section.

PRISM/COE was a basin-specific model which simulated the operation of the MWA water supply system on a weekly (7-day) basis. It included important data on the supply sources (Potomac River and the Occoquan, Patuxent, Bloomington, and Savage Reservoirs), demands of the major users (WAD, FCWA, and WSSC) by benchmark year, allocation ratios from the Potomac Low Flow Allocation Agreement, water treatment plant capacities, streamflow targets, and 50 years of historic flow records from area streams. In all, PRISM/COE contained 43 input variables as listed in Table H-4 which the user could alter to test different operating strategies and assumptions.

TABLE H-4

PRISM/COE INPUT PARAMETERS

Parameter Description		Variable Name
1.	Capacity of Bloomington, mg	CAPB
2.	Capacity of Savage, mg	CAPS
3.	Capacity of Occoquan, mg	CAPO
4.	Capacity of Patuxent, mg	CAPP
5.	Potomac Withdrawal Capacity, FCWA, mgd	CWFCWA
6.	Potomac Withdrawal Capacity, WSSC, mgd	CWWSSC
7.	Potomac Withdrawal Capacity, WAD, mgd	CWWAD
8.	Environmental Flowby at Little Falls, mgd	ENFB
9.	Treatment Capacity of Occoquan, mgd	COCC
10.	Treatment Capacity of Patuxent, mgd	CPAT
11.	Upstream Consumptive Withdrawal, mgd	WIRG
12.	Minimum Release for Bloomington, mgd	RBMIN
13.	Minimum Release for Savage, mgd	RSMIN
14.	Environmental Flowby at Occoquan, mgd	SOMINI
15.	Environmental Flowby at Patuxent, mgd	SPMINI
16.	Bloomington Savage Flow-Dependent Ratios (0=No,1=Yes)	IBSANS
17.	Maximum Bloomington: Savage Release Ratio	BSRAT
18.	Upstream Release Fraction, 1st Week	PER1
19.	Upstream Release Fraction, 2nd Week	PER2
20.	Year of Investigation	YEAR
21.	Downstream Factor, %	DSTF
22.	Upstream Target at Luke, mgd	TARGU
23.	Year of LFAA Freeze	IYEAR
24.	Minimum Draft from Occoquan, mgd	ROMINI
25.	Minimum Draft from Patuxent, mgd	RPMINI
26.	Initial Bloomington Storage, mg	SB(1)
27.	Initial Savage Storage, mg	SS(1)
28.	Initial Occoquan Storage, mg	SO(1)
29.	Initial Patuxent Storage, mg	SP(1)
30.	Streamflow Prediction (0=Model, 1=Perfect Foresight)	LD
31.	Type of Conservation (1=Baseline, 2=Scenario 3)	ICONS
32.	Weekly Demand Coefficients (1=8-Year Monthly Average 2=1966 Actual 3=Hypothetical)	IDMD
33.	Initial Bloomington Water Supply Storage, mg	SBWS(1)
34.	Initial Bloomington Water Quality Storage, mg	SBWQ(1)
35.	Bloomington Water Supply Capacity, mg	CAPBWS
36.	Bloomington Water Quality Capacity, mg	CAPBWQ
37.	Separation of Bloomington Storage (0=No, 1=Yes)	IWSWQ
38.	Bloomington Winter Drawdown (0=No, 1=Yes)	IWTDRB
39.	Savage Winter Drawdown (0=No, 1=Yes)	IWTDRS
40.	Downstream Target (0=No, 1=Yes)	T
41.	Weekly Reports (0=No, 1=Yes)	IWEEKY
42.	Years of Weekly Reports	IWEEKR
43.	Summary Reports (0=No, 1=Yes)	SUMRPT

In simplified terms, PRISM/COE was an "accounting" mechanism for the regional water system. Given a set of operating conditions and assumptions, the PRISM/COE reported the consequences of these decisions on a week-by-week basis. PRISM/COE calculated the storage remaining in each reservoir within the system, the flow at Luke, the flowby level at Little Falls, the demand of each user, the allocated share of Potomac River water, and the nature and magnitude of any deficits. Figure H-5 provides a simplified flow chart of PRISM/COE.

Because PRISM/COE was a simulation model, it merely reported the consequences of a given set of conditions. It did not "optimize" system operation in the truest sense of the word. However, repeated application of the model with slightly different parameters during each repetition allowed the user to determine very good, if not optimal, operating strategies. It was in this manner that PRISM/COE provided its greatest utility; many different assumptions and input values were tested, both quickly and inexpensively, to observe Bloomington Lake's response and the overall system's response to various management strategies.

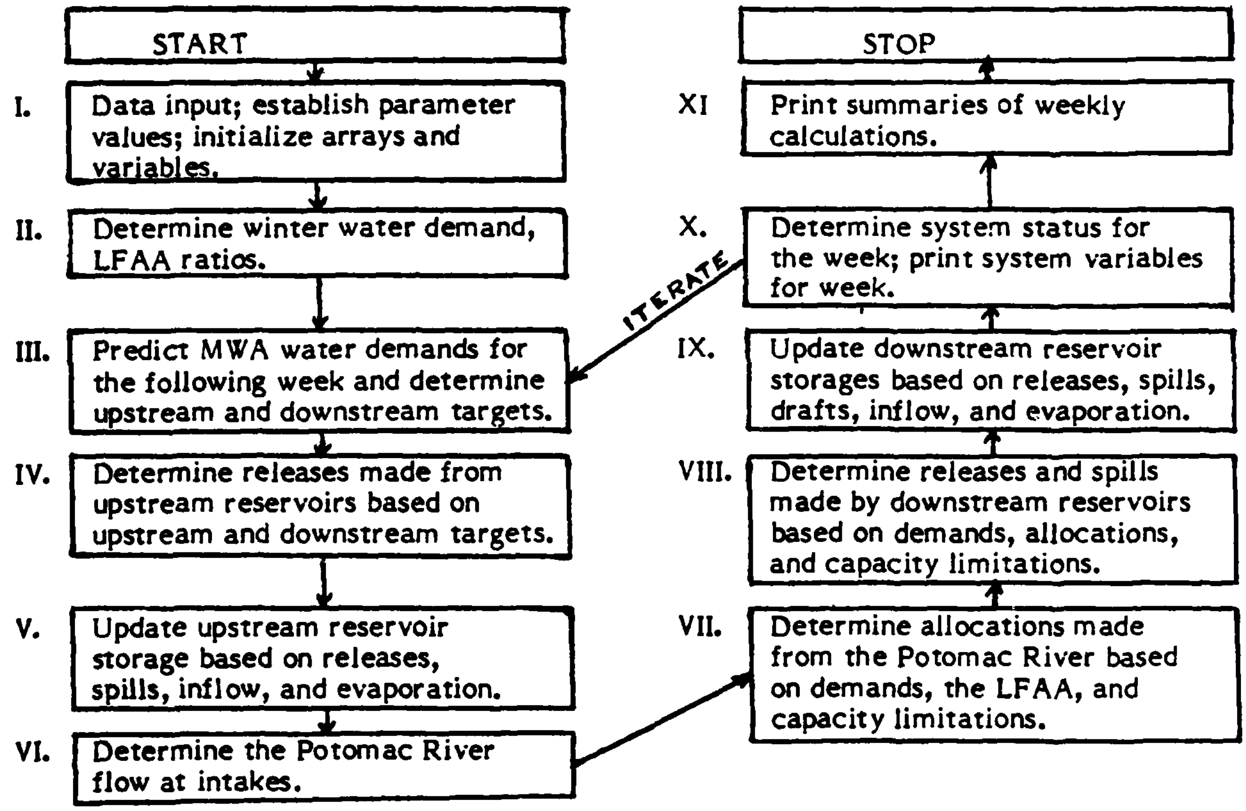
Thus, PRISM/COE was a key element in redefining the MWA's water supply problem for the long-range phase in that it provided a mechanism to examine the regional benefits of coordinated water supply management. And because Bloomington Lake was a major component of the system, investigations using PRISM/COE also furnished some valuable insights as to how that project should be regulated to provide maximum water supply benefits for the MWA. Most of the technical studies discussed in the following paragraphs were conducted to determine appropriate values for the input parameters to PRISM/COE. Where a single number could not be derived, PRISM/COE was used to test the sensitivity of the system to a range of values for that particular parameter.

WATER QUALITY INVESTIGATIONS

One of the primary purposes of the Bloomington Lake Project is to provide water quality control in the North Branch Potomac River Basin. As described earlier, acid mine drainage is a severe problem upstream of Luke, Maryland, but coordinated releases from Bloomington Lake and Savage River Reservoir are expected to improve water quality conditions downstream from Luke. More than half of Bloomington Lake's conservation storage of 92,000 acre-feet is presently allocated to water quality purposes. Two related questions needed to be answered with regard to water quality so that proper values could be entered into PRISM/COE: (1) What was the minimum flow at Luke which would produce acceptable downstream water quality and still meet North Branch needs? and (2) What was the proper ratio for balancing Bloomington Lake and Savage Reservoir releases? Details concerning these investigations are provided in Annex H-II - Water Quality Investigations.

Figure H-5

FLOW DIAGRAM OF PRISM/COE



Flow Target at Luke

The authorization document for Bloomington Lake estimated the maximum safe yield of the Bloomington/Savage system at Luke, Maryland to be 305 cfs. Improvements in biochemical oxygen demand (BOD), dissolved oxygen (DO), and temperature were projected in the authorization report, all assuming a minimum flow of at least 305 cfs at Luke, Maryland.

Since the time of authorization, though, conditions in the North Branch have changed substantially with the construction of municipal and industrial wastewater treatment plants and the enactment of environmental regulations for active mines. In light of these changes and the increased emphasis on pH and conductivity as important North Branch water quality parameters, the flow target at Luke was reexamined to determine if a value other than 305 cfs might be advantageous.

Numerical water quality models were developed for both Bloomington Lake and the North Branch Potomac River from Luke, Maryland, to Paw Paw, West Virginia to simulate water quality changes brought about by various reservoir regulation strategies. Releases from the normally alkaline Savage River Reservoir and effluent from the WESTVACO Pulp and Paper Mill and the UPRC's sewage treatment plant in Westernport, Maryland, were considered as well. It was determined that a continuous flow target at Luke higher than 305 cfs would not improve downstream water quality during drought years and, in fact, might be detrimental.

Efforts were made to investigate a range of flow targets, and a minimum flow target of 120 cfs (78 mgd) at Luke was eventually established. This value was the result of a trade-off analysis among several interrelated objectives, including (1) achieving stream water quality standards (particularly for pH and conductivity); (2) maintaining or improving aquatic habitat in the lower reaches of the North Branch near Paw Paw; (3) providing sufficient flow for industrial uses; (4) maintaining a certain volume of buffering storage in Bloomington Lake; and (5) minimizing drawdowns at the two upstream reservoirs.

It was further determined that the Luke flow target should be achieved through releases from Bloomington Lake's water quality storage (51,000 acre-feet), buffered as necessary by releases from Savage River Reservoir. Water supply releases from Bloomington Lake would be in addition to the water released to satisfy the Luke flow target, and would come from the 41,000 acre-feet of water supply storage.

It should be noted that the 120 cfs target was a minimum flow to be achieved and was determined using data from very low flow years. During most years of normal rainfall in the North Branch Potomac River, streamflow past Luke would be well in excess of the minimum 120 cfs. In those rare low flow years, it was estimated that about 46,000 acre-feet of the water quality storage in Bloomington Lake would be needed to furnish adequate water quality control. This 46,000 acre-feet was broken down as follows: 29,000 acre-feet for maintaining the Luke flow target of 120 cfs, 3000 acre-feet for vacant storage, 4000 acre-feet for periodic flushing of downstream pond areas, and 10,000 acre-feet for buffering. The remaining 5,000 acre-feet could potentially be available for other purposes, such as reallocation to water supply storage as discussed in a later section.

Bloomington/Savage Release Ratio

At the same time that the investigation was being conducted to establish the minimum flow target at Luke, efforts were also being made to determine the proper balance of releases from the expected acidic water in Bloomington Lake and the normally alkaline water in Savage River Reservoir in order to provide acceptable downstream water quality. The investigations for the flow target and release ratio proceeded concurrently, as the results of one examination directly affected the outcome of the other. The objectives listed in the previous section were also used in evaluating the trade-offs associated with various release ratios.

Initially, the ratio was tentatively set as 4 to 1 (four parts Bloomington water to one part Savage water). Subsequent water quality investigations soon demonstrated, however, that neither stream water quality or reservoir water quality was maximized with this approach. Hence, further studies were made and a revised release strategy was devised for the two reservoirs. Rather than a single ratio, the conjunctive operation of the two reservoirs was established as a series of flow-dependent ratios as shown in Table H-5. This sliding scale of ratios provided a better means of regulating the reservoirs to provide acceptable water quality, both in-lake and downstream.

TRAVEL TIME AND FLOW LOSS STUDY

Previous studies had made a variety of assumptions regarding the travel time and transit loss of water supply releases flowing from Luke to the MWA. The NEWS Study, for example, assumed that the travel time was approximately 30 days and that Bloomington Lake would not be a viable project for satisfying short-term (less than 30 days) fluctuations in supplies and demands. Other studies such as the Hopkins' PRISM effort assumed a 7-day travel time with no losses.

To determine the appropriate values to enter into PRISM/COE, the Corps of Engineers contracted with the U.S. Geological Survey (USGS) to perform routing studies. The USGS used existing Potomac flow data and similar modelling efforts for other basins to develop a flow-routing model directly applicable to the Potomac River during low flow situations. Model development, calibration, verification, and application are described in USGS's report included as Annex H-V.

The results of the USGS modelling efforts were as follows: (1) insignificant losses would occur to supplemental water supply releases travelling from Bloomington Lake to the MWA; (2) 47 percent of the flow released from the Bloomington/Savage system would reach the MWA between 4 and 7 days later; and (3) 53 percent of the flow released from the upstream reservoir system would reach the MWA between 7 and 14 days later. These values were incorporated into PRISM/COE.

SYSTEM REGULATION

Once the parameters for the Luke flow target, the release ratios, and the travel time had been established, an important remaining step was to determine how the upstream reservoirs (Bloomington and Savage) and downstream reservoirs (Patuxent and Occoquan) could best be managed as a system to provide maximum water supply. In other words, could the conjunctive regulation of the entire system of reservoirs be managed such that the yield would be greater than if each reservoir were regulated independently?

TABLE H-5

BLOOMINGTON/SAVAGE RATIOS FOR FLOW VALUES AT LUKE, MARYLAND

Flow Range (cfs)*	Bloomington/Savage Ratio
0 to 173	6.67
173 to 352	5.71
352 to 540	5.00
540 to 812	4.00
812 to 1301	3.33
1301 to 2027	2.86
2027 to 2170	2.50
2170 and above	2.50

* Combined releases from Bloomington and Savage Reservoirs. As an example for a target of 173 cfs, 150 cfs would come from Bloomington and 23 cfs from Savage, $\frac{150}{23} = 6.67$

The PRISM/COE model had been structured to help answer this question, primarily through the examination of different values for the downstream target factor (DSTF). Explained in simplest terms, the DSTF was a percentage value which reflected how much or how little the system manager wanted to use the two downstream reservoir systems. A high DSTF (close to 100 percent) would mean heavy reliance on the maximum output of the two downstream reservoir water treatment plants, with little reliance on upstream reservoir releases. This strategy would conserve water supply storage in Bloomington Lake, but might result in deficits if the Potomac River's natural flow dropped below its predicted value sometime during the following week since upstream releases would arrive between 4 and 14 days later. This strategy would also result in large drawdowns in the downstream reservoirs during a drought. On the other hand, a low DSTF (close to 0 percent) would mean very little reliance on the downstream reservoirs, with greater releases required from the upstream reservoirs and accompanying larger drawdowns. This strategy would offer significant flexibility for operating the downstream reservoirs early in a drought because they could furnish more water immediately if the Potomac's natural flow dropped unexpectedly. Because of the required lead time for travel to the MWA, however, Bloomington storage might be wasted if water was released and subsequently not needed in the following week due to poor streamflow prediction, rainfall during the time interval between upstream release and downstream withdrawal, or any other combination of factors. This early "wastage" could have adverse consequences later if a severe drought persisted for several months. Further discussion concerning the DSTF's development and application is contained in Annex H-III.

Following some preliminary PRISM/COE runs examining the DSTF, three values (20%, 60% and 100%) were selected for further investigation so that a range of effects could be evaluated. It was clear that some significant trade-offs were necessary to establish the appropriate DSTF that would provide adequate water for the MWA needs without degrading the water quality in the North Branch Potomac River. Table H-6 provides a comparison of storage remaining in the different reservoirs under different target factors.

Because the value of the DSTF could also affect the fish and aquatic resources in the various reservoirs (due to more or less drawdown), the U.S. Fish and Wildlife Service (USFWS) was requested to evaluate the potential consequences of selecting different downstream target factors. Based on their work, the USFWS concluded that heavy dependence on the downstream reservoirs would cause drawdowns to low levels during droughts, which would result in significant adverse impacts to fishery resources. On the other hand, trying to save water in the downstream reservoirs by relying more heavily on the upstream reservoirs would also cause adverse impacts. Since there are expected to be minimal fishery resources in Bloomington Lake, a drawdown would have little biological impact there. However, large releases and subsequent drawdowns would likely affect the degree to which the impoundment could maintain its ability to moderate the water quality of the North Branch. Also, since releases from Bloomington Lake are made concurrently with releases from Savage Reservoir for water quality reasons, high dependence on Bloomington for water supply releases would result in a drawdown of Savage Reservoir which would be detrimental to its fine fishery resources. Therefore, it appeared that the best DSTF from a fish and wildlife perspective would be one which produces a balanced use of the upstream and downstream reservoirs in order to minimize the possibility of severe drawdowns in any one of them.

TABLE H-6

COMPARISON OF STORAGE REMAINING (MG) WITH DIFFERENT DOWNSTREAM TARGET FACTORS

	DOWNSTREAM TARGET FACTOR		
	0.2	0.6	1.0
1930 Drought			
Bloomington (Water Supply)	6,337	11,607	13,370
Downstream Reservoirs	9,770	6,391	4,702
1966 Drought			
Bloomington (Water Supply)	5,915	10,431	12,985
Downstream Reservoirs	15,591	13,054	12,180

Simulation constants: 2030 Demands, Conservation Scenario 3, Bloomington: Savage ratio 4:1, Upstream target flow 71 mgd (110 cfs), Bloomington Conservation Storage 92,000 acre-feet (30,000 mg), and flowby 100 mgd.

From the output of the various PRISM/COE runs and the information provided by the USFWS, the following observations were made:

- From an environmental viewpoint, the DSTF should be one which balances the use of upstream and downstream reservoirs;

- Higher values of the DSTF and the subsequent lesser reliance on Bloomington Lake storage would produce better water quality conditions in the North Branch Potomac River below Luke, Maryland.

- In terms of water supply, maximum system flexibility would be achieved with a DSTF in the mid-range. High values of the DSTF would save water in Bloomington Lake for long-term droughts but would cause downstream reservoirs to use their storages more quickly, thus losing the ability to respond adequately to large short-term fluctuations in either supply or demand. On the other hand, a low DSTF would require more reliance on Bloomington Lake storage with possible water wastage due to inaccurate flow predictions for the Potomac River, while saving water in downstream reservoirs.

- The selected downstream target factor should allow some margin of error for imperfect prediction of streamflow, so that the system has enough remaining flexibility to compensate for such prediction errors.

Considering all of these concerns, observations, and results, it was concluded that a downstream target factor of 0.6 would be reasonable. This value of 0.6 would assume a 60 percent reliance on the downstream reservoirs for the water supply release determination.

At the same time the Corps was using PRISM/COE as a planning tool to reflect weekly system regulation, the CO-OP Program of ICPRB was developing a more detailed daily version of PRISM as an actual operational tool for coordinated system management. A significant portion of CO-OP's work was aimed at improving flow prediction techniques using antecedent moisture conditions, long-range weather forecasts, vegetative cover throughout the various watersheds, and other factors so that predictive errors would be minimized. The Corps' efforts and the CO-OP's efforts proceeded along somewhat parallel paths, both benefitting and sharing in each other's work concerning overall management of the system.

REDEFINITION OF THE WITHOUT CONDITION

Having examined more efficient ways of managing Bloomington Lake's storage than outlined in the authorization document and having developed PRISM/COE as a simulation tool, a revised "without condition" was defined for the long-range phase of the MWA Water Supply Study. This redefinition not only considered a revised regulation strategy for Bloomington Lake, but also considered a slightly different approach to problem identification. Whereas the early-action phase examined primarily the rate of supply and demand in certain critical weeks, the long-range phase was reoriented more toward the investigation of the volume of supply and demand over a long-term drought. A volumetric analysis such as this was able to more readily display the advantages of the recent commitment to regional cooperation which was a major result of the early-action phase. Additionally, a redefinition of the water supply problem was necessary because certain actions had been or were being taken by the MWA water suppliers as a direct consequence of the August 1979 Progress Report (see Appendix B). The complete redefinition of the "without condition" for the long-range phase is described in Appendix D - Supplies, Demands, and Deficits and summarized elsewhere in the report. The following paragraphs briefly describe the assumptions and results of the "without condition" redefinition, particularly in regard to Bloomington Lake, as it provided the basis for evaluating storage reallocation which is discussed in a later section.

The important assumptions and data incorporated into the revised "without condition" were the following:

- Conservation Scenario 3 monthly demands.
- Application of the Potomac Low Flow Allocation Agreement to allocate water from the Potomac River among the various users.
- Environmental flowby of 100 mgd to the Potomac Estuary.
- Reregulation by WSSC and FCWA.
- Conjunctive or joint operation of Bloomington and Savage Reservoirs to satisfy a minimum flow target of 120 cfs at Luke, using the ratios set forth in Table H-5.
- Downstream target factor of 0.6 and operation of all reservoirs as a single system.
- No flow loss (volume) between the upstream reservoirs and the MWA. Arrival rates would be 47 percent within one week from the date of release and the remaining 53 percent during the second week.
- 51,000 acre-feet of storage in Bloomington to be used for water quality purposes (both in-lake and downstream).
- 41,000 acre-feet of storage in Bloomington to be available for water supply upon request by the purchasers.
- Availability of Savage River Reservoir storage to dilute water supply releases from Bloomington Lake.
- Adherence to the numerous regional cooperation agreements signed in July 1982 by the MWA water supply interests.
- Availability of streamflow records from 1929 to 1979.

These assumptions and others used for the redefinition of the "without condition" for the long-range phase are listed in Table H-7. It should be noted that Little Seneca Lake was not included in PRISM/COE because construction of this project did not appear imminent when the model was being developed. However, it was decided to include the effects of Little Seneca Lake in the redefined "without condition" by separate calculations when it became apparent that the project would be constructed and operated as a regional water

TABLE H-7

WITHOUT CONDITION ASSUMPTIONS
FOR LONG-RANGE PHASE

Assumption	Value
Bloomington Lake	
Total Conservation Storage	92,000 acre-feet (30,000 mg)
Water Supply Storage	41,000 acre-feet (13,370 mg)
Water Quality Storage	51,000 acre-feet (16,630 mg)
Minimum Release	32 mgd (50 cfs)
Water Supply Release	variable
Seasonal Drawdown for Flood Control	yes
Savage River Reservoir	
Available Storage	18,000 acre-feet (5,900 mg)
Minimum Release	13 mgd (20 cfs)
Seasonal Drawdown for Flood Control	yes
Flow Target at Luke, Maryland	78 mgd (120 cfs)
Bloomington: Savage Release Ratios	time-dependent, flow-dependent
Water Supply Target Factor (Downstream)	0.6
Transit Factor, First Week	47%
Transit Factor, Second Week	53%
Flow Loss Between Luke and MWA Intakes	0 mgd
Occoquan Reservoir	
Water Supply Storage	31,600 acre-feet (10,300 mg)
Environmental Flowby	0 mgd
Minimum Withdrawal	30 mgd
Maximum Withdrawal	95 mgd
Patuxent Reservoirs (Triadelphia & Rocky Gorge)	
Water Supply Storage	31,000 acre-feet (10,000 mg)
Environmental Flowby	10 mgd
Minimum Withdrawal	20 mgd
Maximum Withdrawal	55 mgd
Little Seneca Lake	
Water Supply Storage	12,400 acre-feet (4,020 mg)
Environmental Flowby	1.12 mgd
Minimum Withdrawal	0 mgd
Maximum Withdrawal	275 mgd
Potomac Withdrawal Capacity	
WAD	650 mgd
WSSC	450 mgd
FCWA	200 mgd
Potomac Estuary Flowby	100 mgd
LFAA Provisions	No Freeze
Demand Year	2030
Level of Conservation	Scenario 3

supply facility for the benefit of all Potomac users in the MWA. More details concerning reasons for including Little Seneca Lake in the "without condition" are contained in Appendix B.

Given these assumptions, PRISM/COE (with supplemental calculations for Little Seneca Lake) was used to determine the water supply system's response to the most severe droughts in the Potomac, Patuxent, and Occoquan Basins. Such application of the model established the extent of the water supply problem as redefined for the long-range phase, facing the MWA. The results of the simulation for both the 1930-31 drought and the 1966 drought are listed in Table H-8 showing maximum deficit, cumulative deficits, remaining storages in the various reservoirs, and number of weeks at the minimum flowby level. This analysis demonstrated that the addition of Little Seneca Lake and the conjunctive operation of other reservoirs in the system, including Bloomington Lake, would alleviate potential water supply problems until at least year 2030. Thus, it was concluded that the reregulation of Bloomington Lake in a manner different than originally proposed in the original authorization document could substantially reduce or eliminate projected water supply deficits within the 50-year planning horizon.

STORAGE REALLOCATION POTENTIAL

Following the investigation of potential operating schemes and the redefinition of the "without condition," the potential for reallocating Bloomington water quality and flood control storage was examined in detail. This investigation was designed to identify the trade-offs associated with storage reallocation, given the redefinition of the base condition. These trade-offs were viewed from several angles, including the major project purposes of flood control, water quality, water supply, and recreation, as well as environmental, social, cultural, and economic concerns.

Since the earlier "without condition" analysis indicated that the projected MWA demands could be satisfied for the next fifty years with the 100 mgd flowby requirement, the effects of higher flowbys were analyzed in conjunction with the storage reallocation investigation. In particular, the study examined flowbys of 300 and 500 mgd. This afforded a more thorough study of the water supply capabilities of a reallocated project. Also, in the end it provided its own set of trade-offs and allowed an analysis of the flowby sensitivity of the MWA supply base.

In addition to these two analyses, a possible change in the normal regulation of the Bloomington project was considered in the Reformulation Study. Since the study was investigating the expanded water supply use of Bloomington Lake, there was some concern that the springtime flows in the North Branch Potomac River might not furnish a sufficient volume of runoff to refill the reservoir every year in time for MWA water supply releases. Consequently, analyses were undertaken to determine whether a constant pool for water supply operations should be provided throughout the year (year-round operation), or a lower lake elevation should be maintained during the winter and early spring to furnish additional flood runoff control, as the project is currently regulated (seasonal operation). The impacts of both types of operation were investigated from several perspectives, and a subsequent trade-off evaluation ensued.

TABLE H-8

SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE* WITHOUT CONDITION - 100 MGD FLOWBY

	1930-31	1966
Maximum Deficit, mgd		
WSSC	0	0
FCWA	0	0
WAD	0	0
Region	0	0
Cumulative Deficit, mg		
WSSC	0	0
FCWA	0	0
WAD	0	0
Total	0	0
Available Storage Remaining, mg		
Water Supply		
Bloomington	11,822	12,255
Occoquan	1,780	6,181
Patuxent	4,758	7,033
Little Seneca	3,797	3,082
Total	22,157	28,551
% of Capacity (37,790 mg)	58.6%	75.6%
Non-Water Supply		
Bloomington	13,275	13,645
Savage	4,801	4,731
Total	18,076	18,376
% of Capacity (22,530 mg)	80.2%	81.6%
Total Storage Remaining	40,233	46,927
% of Capacity (60,320 mg)	66.7%	77.8%
Weeks at Minimum Flowby Level	13	7

* Table assumes year 2030 Conservation Scenario 3 Demands.

APPROACH TO REALLOCATION FORMULATION

For the Bloomington Lake Reformulation Study, two types and several levels of storage reallocation were considered. First, reallocation of existing water quality storage to water supply storage was examined. This type of reallocation would involve modifying the existing allocations of storage without changing the permanent pool elevation or any of the project structures, as shown in Figure H-6. Thus, the current allocation of 51,000 acre-feet for water quality storage was reviewed to see if some of its storage could be designated to water supply purposes. Toward this end, the projected storage needs for maintaining adequate water quality in the North Branch Potomac River were developed during the course of the study. This water quality analysis determined that a minimum of 46,000 acre-feet of Bloomington storage would be required for proper water quality control. This total includes 29,000 acre-feet to maintain the minimum flow of 120 cfs at Luke, Maryland, 3,000 acre-feet for vacant storage, 4,000 acre-feet for downstream flushing, and 10,000 acre-feet to maintain the lake's acid-averaging ability. The vacant storage (3,000 acre-feet) will be used to drop the summer pool below 1466 feet msl so that minor flood events can be controlled and thus, instream water quality improved. Additional flow will be released periodically during low flow periods to flush out the industrial pond located near Cumberland, Maryland. This should dissipate the industrial sediments and water which is low in dissolved oxygen. This flushing will require the 4,000 acre-feet of storage as noted. As a result of this analysis, it was determined that a maximum of 5,000 acre-feet (51,000 minus 46,000 acre-feet) of water quality storage could potentially be reallocated to water supply storage. Accordingly, a total of 46,000 acre-feet (41,000 plus 5,000 acre-feet) of water supply storage would be available with a Bloomington water quality storage reallocation plan. Considering the limited volume of this available storage, no intermediate reallocation plans were evaluated for the "surplus" Bloomington water quality storage.

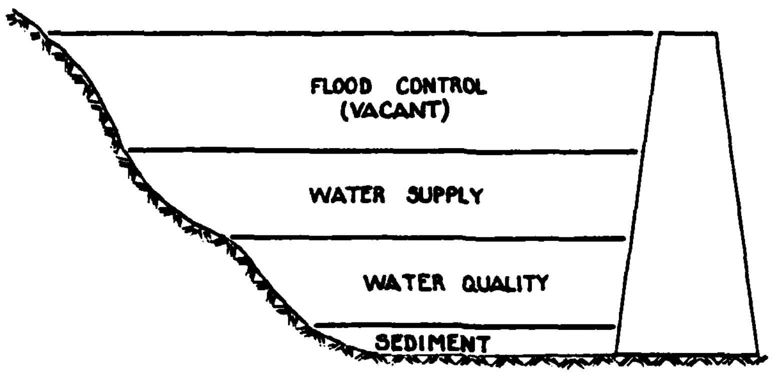
The second type of reallocation scheme considered was the reallocation of flood control storage to water supply. Under this plan the vacant flood control storage would be filled and become available for water supply releases. This would entail raising this permanent pool to an elevation above the existing lake elevation of 1466 feet msl. A schematic of the flood control storage reallocation plans is depicted in Figure H-6. With this in mind, a number of higher lake elevations were examined to identify the range of impacts and additional water supply capability.

Initially, four higher lake elevations between 1468 and 1492 feet msl were evaluated for flood control storage reallocation. The first alternative, the 1468 pool, would raise the existing pool by two feet from elevation 1466 feet msl, and add about 1,900 acre-feet of water supply storage to the project. The resultant lake would be about 13 acres larger than the current lake of 952 acres. As a result of this level of reallocation, the project would lose 1,900 acre feet of flood control storage, leaving an available flood control storage of 34,300 acre-feet.

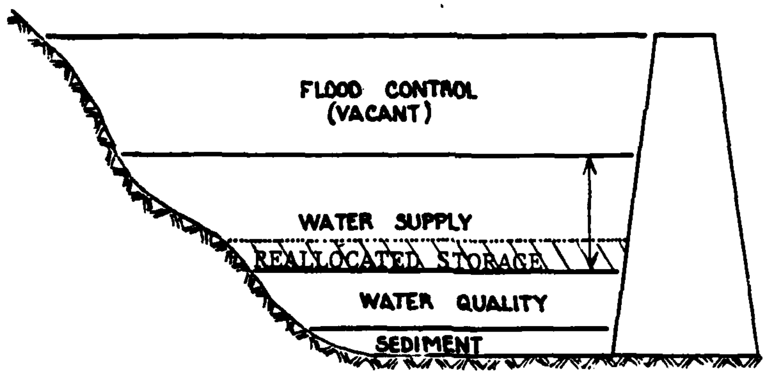
The 1475 pool was also selected as a flood control storage reallocation alternative. This plan would involve raising the existing lake by nine feet, creating a lake of 1,009 acres (an increase of 57 acres). This plan would call for reallocation of 8,800 acre-feet of flood control storage to water supply storage. The loss of flood control storage represents about 25 percent of the project's total flood control storage.

FIGURE H-6

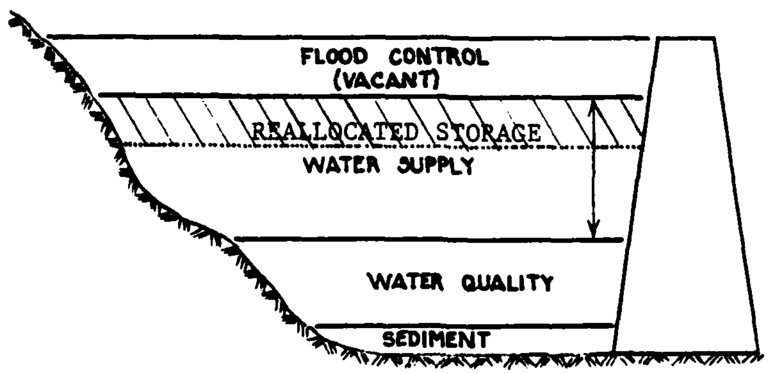
SCHEMATIC OF STORAGE REALLOCATION



EXISTING ALLOCATION



WATER QUALITY STORAGE REALLOCATION



FLOOD CONTROL STORAGE REALLOCATION

Elevation 1484 feet msl was the third lake elevation investigated. This lake would be 18 feet higher than the current pool. The lake's surface area would cover 1,069 acres, an increase of 117 acres over the existing lake. This reallocation plan would provide an additional 18,200 acre-feet of water supply storage by reducing the project's flood control storage by 50 percent. About 18,000 acre-feet of storage would remain as a flood control allocation.

The final reallocation alternative was the 1492 pool. This plan would increase the lake elevation by 26 feet and the lake size by 175 acres to 1127 acres. To do this, 27,000 acre-feet of flood control storage or about 75 percent of the current allocation would be designated as additional water supply storage.

These five plans, one water quality storage reallocation and four flood control storage reallocation, were analyzed from several technical perspectives. During this process, it became evident that two of the alternatives were deficient, and were subsequently deleted from further consideration in the remaining analyses. The reasons for these actions will be related in the appropriate technical discussions. The advantages and disadvantages of the remaining three plans were then balanced, yielding a final determination of the feasibility of Bloomington storage reallocation.

TECHNICAL ANALYSES

The evaluation of the advantages and disadvantages of Bloomington storage reallocation were accomplished through a number of technical analyses. The impacts of storage reallocation, as well as varying use of the water supply storage and year-round vs. seasonal operations, were investigated from flood control, water supply, environmental, water quality, and recreation perspectives. These analyses then provided the basis for an assessment of the reallocation alternatives. Summaries of the analyses and their conclusions are presented in the following sections.

FLOOD CONTROL

Reallocating a significant percentage of Bloomington's flood control storage could have a large impact on the reservoir's flood control capability. This impact was investigated for both upstream and downstream communities for the four levels of flood control storage reallocation noted earlier. In addition, the flood control analysis also addressed the issue of a seasonal versus year-round pool. A detailed description of the methodology and results is given in Annex H-IV, Flood Control Analysis.

Using standard hydrologic procedures, storage-frequency curves were developed for five lake levels (1466, 1468, 1475, 1484, and 1492) and two conditions of operation (seasonal and year-round). For seasonal operation, the same storage differential between summer and winter pools (44,500 acre-feet) was assumed as in the existing plan. This value corresponded to winter pools of 1410, 1413, 1423, 1436, and 1447 feet msl, respectively. For these analyses, the starting pool elevation was always assumed to be at the normal rule curve elevation in order to indicate the largest potential effect on the project's flood control capability (it is possible that the lake would be lower due to water supply or water quality releases). A comparison of these curves is summarized in Table H-9. As noted on the table, the Probable Maximum Flood (PMF) would cause the reservoir to rise

TABLE H-9

COMPARISON OF RESERVOIR FLOOD RESPONSE

MAXIMUM RESERVOIR ELEVATION (Feet, msl)*

Frequency	Return Period (Years)	1466 Pool (Existing Conditions) Seasonal	1466 Pool (Existing Conditions) Year-Round	1468 Pool Seasonal	1468 Pool Year-Round	1475 Pool Seasonal	1475 Pool Year-Round	1484 Pool Seasonal	1484 Pool Year-Round	1492 Pool Seasonal	1492 Pool Year-Round
0.10	10	1481.2	1484.6	1484.3	1486.3	1488.6	1491.9	1496.7	1497.6	1498.8	1499.4
0.04	25	1492.9	1494.2	1494.0	1495.4	1497.5	1497.5	1499.4	1500.4	1501.4	1501.4
0.02	50	1495.8	1496.5	1496.3	1497.6	1499.2	1499.2	1500.8	1501.7	1502.3	1502.5
0.01	100	1498.0	1498.6	1498.3	1499.5	1500.6	1500.7	1502.2	1502.8	1503.3	1503.4
0.005	200	1500.0	1500.4	1500.3	1501.1	1502.1	1502.2	1503.4	1503.7	1504.3	1504.3
0.002	500	1502.5	1502.7	1502.8	1503.1	1503.9	1503.9	1504.8	1504.8	1505.3	1505.3
PMF	—	1509.2	1509.2	1509.4	1509.4	1510.2	1510.2	1510.8	1510.8	1511.4	1511.4

* All entries in table are in feet, msl, and represent the highest pool elevation attained durng the given flood conditions. These values were derived from the storage-frequency curves in Figures H-IV-40 and H-IV-41 which were based on 55 years of record. The seasonal pool values represent reservoir regulation with a winter drawdown of 44,500 acre-feet.

to 1510 or 1511 feet msl with a significant reallocation of storage. Since the top of dam is at elevation 1514 feet msl, only three or four feet of freeboard would be provided for a flood of that magnitude. Currently, the project has five feet of freeboard.

In addition, peak flow-frequency curves were developed for the potential plans of operation. These curves are shown in Figures H-IV-65 to H-IV-70 of Annex H-IV for the three nearby gaging stations, Luke, Pinto, and Cumberland, Maryland. Significant data from these curves are tabulated in Table H-10. These curves show that the effects of reallocation up to the 1484 pool are relatively minor. However, the 1492 reallocation plan could have significant consequences on the degree of flood protection at Luke and Pinto.

In addition to the downstream communities, the area upstream of the project could be affected by increasing the permanent pool elevation of Bloomington Lake. This potential impact was specifically addressed for the town of Kitzmiller, Maryland, since it is the closest damage center upstream from Bloomington Lake. To determine the impacts at Kitzmiller, a series of water surface profiles was computed for a range of starting lake elevations and North Branch Potomac River flows. The hydraulic analyses indicated that none of the flow-starting elevation combinations, including the most severe case, 227,000 cfs and a starting elevation of 1510 feet msl (this is about the reservoir level peak with the PMF), had any effect on the water surface elevation at Kitzmiller. The most upstream point that is affected by the reallocation of storage is approximately two miles downstream from the Kitzmiller gage. Consequently, there would be no effect on any upstream damage center as a result of raising the permanent pool elevation at Bloomington Lake.

Raising the normal pool elevation of the Bloomington Lake, as a result of flood control storage reallocation, could have other effects besides the reducing the of freeboard for the PMF and reducing the degree of downstream flood protection. More frequent and higher discharges would occur over the gated spillway. This might cause increased concern about possible erosion at the toe of the dike to the left of the spillway. Also, at the higher pool elevations it would become more difficult to regulate the reservoir for flood control. While trying to prevent the lake from overtopping the tainter gates (elevation 1500 feet msl) with a reasonable factor of safety, it would be possible to increase downstream flooding over what would have occurred under natural conditions.

These hydrologic findings relative to the effects on the project's flood control capability were then translated into a monetary measure of the impact via an analysis of the foregone flood control benefits. This analysis determined the reduction, if any, in benefits which would be attributed to the loss in flood control storage.

A key component of the flood control benefit analysis was an estimate of flood damages that could be expected for various flood stages. To obtain this estimate, a field survey was made of the current floodplain development, including all properties up to the largest flood of record plus an additional eight feet. This data was compiled for the communities of Luke, Westernport, and Cumberland in Maryland, and Piedmont, Keyser and Ridgeley in West Virginia, as well as for the floodplain areas along the North Branch Potomac River from Savage River to the South Branch Potomac River junction. As discussed earlier, there would be no flood impacts in the upstream areas due to storage reallocation; therefore, these areas were not included in the damage survey. The

TABLE H-10

COMPARISON OF DOWNSTREAM FLOW EFFECTS

PEAK FLOW (cfs) *

Downstream Location	Frequency	Return Period (Years)	1466 Pool (Existing Conditions) Seasonal	1466 Pool (Existing Conditions) Year-Round	1468 Pool Seasonal	1468 Pool Year-Round	1475 Pool Seasonal	1475 Pool Year-Round	1484 Pool Seasonal	1484 Pool Year-Round	1492 Pool Seasonal	1492 Pool Year-Round
Luke, MD	0.10	10	11,700	11,700	11,700	11,700	11,700	11,700	11,700	11,700	11,900	11,900
	0.02	50	12,000	12,000	12,000	12,000	12,000	12,000	13,400	13,400	18,300	19,200
	0.01	100	12,000	12,000	12,000	12,000	12,000	12,800	17,100	19,100	23,000	24,400
	0.002	500	23,700	23,800	23,900	24,800	27,800	29,100	34,000	36,000	42,000	43,000
Pinto, MD	0.10	10	13,700	13,700	13,700	13,700	13,700	13,700	13,700	13,700	14,600	16,800
	0.02	50	19,900	20,000	19,900	20,000	19,900	21,500	23,700	23,700	26,800	31,700
	0.01	100	25,900	26,000	25,900	26,000	25,900	28,100	31,100	31,100	35,000	40,200
	0.002	500	47,500	47,600	47,500	47,600	47,500	51,000	57,000	57,000	63,000	70,000
Cumberland, MD	0.10	10	23,000	23,000	23,000	23,000	23,000	23,000	23,000	23,000	26,000	27,600
	0.02	50	41,000	41,000	41,000	41,000	42,000	42,000	43,000	43,000	47,000	50,000
	0.01	100	52,000	52,000	52,000	52,000	53,000	53,000	54,500	54,500	61,000	64,000
	0.002	500	88,000	88,000	88,000	88,000	93,000	93,000	98,000	98,000	106,000	107,000

* All entries in tables are in cfs and represent the highest flow attained during the given flood conditions. These values were derived from the peak *flow-frequency curves in Figures H-IV-65 through Figure H-IV-70*, which were based on 30 years (Luke), 44 years (Pinto), and 50 years (Cumberland) of record. The seasonal pool values represent reservoir regulation with a winter drawdown of 44,500 acre-feet.

potential damages for each stage of river flow were noted and then combined to form a stage-damage curve for three river reaches. The reference point for each reach was the nearby stream gage (at Luke, Pinto, or Cumberland, Maryland).

Once the stage-damage curve was constructed, this information was combined with the peak flow-frequency curves discussed earlier and established stage-discharge relationships for the gages, to generate a damage-frequency relationship for each reach. The damage-frequency data were then summed to determine the average annual damages for each river reach associated with the particular plan of operation. The total for the three reaches then provided an estimate of the total average annual damages. A summary of the estimates is tabulated in Table H-11. For the Reformulation Study analysis, future conditions benefits were excluded because the major flood-impacted areas downstream of the project are enrolled in the Federal flood insurance program, and thus the required floodplain regulations of that program should prevent any significant future increases in the damage base.

The foregone benefits, that is, the reduction in prevented flood damages, were then computed for each pool level, as noted in Table H-11. An examination of the peak flow-frequency curves showed that there was not a significant difference in downstream flood flows between year-round and seasonal operations; therefore, the benefit analysis was limited to the year-round plans since this analysis reflected the "worst case" condition for flood impacts. Seasonal operation for each level would have slightly less foregone benefits (that is, more prevented flood damages) but the difference would be less than ten percent.

As noted in Table H-11, reallocation of storage to 1468 feet msl would not reduce the flood protection capability of Bloomington Lake. The 1475 and 1484 reallocation plans would have average annual foregone benefits of $49,000 and $108,000, respectively, corresponding to a 3 and 7 percent reduction of the existing project's benefits. On the other hand, reallocating the flood control storage up to elevation 1492 would cause an estimated loss of $467,000 of the project's annual flood control benefits. This is approximately 31 percent of the existing project benefits. A reduction in benefits of this magnitude was considered unacceptable, and the 1492 plan was dropped from further consideration.

Table H-11 also demonstrates that a great majority of the foregone benefits would occur in the two rural sections designated as Savage River to Cumberland and Cumberland to the South Branch Potomac River. The majority of the damages in these sections are to transportation facilities which are scattered over 54 miles of river on both sides. It would be impractical to mitigate these losses by offering alternative means of protection, such as levees, walls, floodproofing, and structure-raising.

WATER SUPPLY

Using the PRISM/COE model, the study team evaluated the water supply potential of three levels of storage reallocation - 5,000 acre-feet of water quality storage, 8,800 acre-feet of flood control storage (1475 pool), and 18,200 acre-feet of flood control storage (1484 pool) - as well as the existing project allocation. The 1468 pool was not considered further due to the limited amount of additional storage contribution. Reallocation to 1468 feet msl would add only 1,900 acre-feet of storage, providing an

TABLE H-11

SUMMARY OF AVERAGE ANNUAL FLOOD CONTROL BENEFITS*
(October 1981 Prices)

Location	1466 Pool (Existing Conditions)	1468 Pool	1475 Pool	1484 Pool	1492 Pool
Luke, MD	$45,000	$45,000	$45,000	$44,000	$35,000
Westernport, MD	8,000	8,000	8,000	8,000	6,000
Piedmont, WV	37,000	37,000	36,000	33,000	27,000
Keyser, WV	78,000	78,000	76,000	70,000	51,000
Savage River to Cumberland, MD	567,000	567,000	555,000	529,000	408,000
Cumberland, MD - Ridgeley, WV	21,000	21,000	21,000	19,000	12,000
Cumberland, MD to South Branch Potomac River Junction	742,000	742,000	708,000	687,000	492,000
TOTAL	$1,498,000	$1,498,000	$1,449,000	$1,390,000	$1,031,000
Average Annual Foregone Benefits Due to Storage Reallocation		$0	$49,000	$108,000	$467,000
Percent of Existing Benefits Foregone	—	0%	3%	7%	31%

* These estimates reflect the existing level of development only.

estimated additional supply of only 4 mgd in a long-term drought. To get this limited yield, extensive project modifications would still be required. Consequently, the 1468 pool was eliminated from further consideration.

For the water supply analysis, the "without condition" as defined in Table H-7 was assumed with two important exceptions. First, the water supply storage and subsequently, the total Bloomington storage, was varied to reflect the different plans for reallocation. Secondly, the reallocation analysis considered three levels of flowby - 100, 300, and 500 mgd. These values provided a range of water supply demand for a sensitivity analysis of Bloomington's water supply potential.

Given these conditions and assumptions, fifty years of historical flow records were simulated for the MWA system using 2030 demands with Scenario 3 conservation. These simulations showed that only three flow sequences (1930, 1963, and 1966) would cause any deficits in the MWA system with any of the possible twelve scenarios (4 Bloomington conditions, 3 levels of flowby). For 100 mgd flowby, no deficits would occur, even with the existing project allocation. For a recurrence of the 1930-31 drought, the 300 mgd flowby scenario would cause a cumulative deficit of about 2,100 million gallons as the project is now allocated. Reallocation of 5,000 acre-feet of water quality storage would alleviate about 60 percent of this deficit, while either of the flood control storage reallocation plans would eliminate the deficit completely. With a flowby of 500 mgd, deficits would occur for a recurrence of the 1930-31, 1963, and 1966 flows under the existing system. The 1963 deficit is less than 200 mg, and could be satisfied by any of the storage reallocation plans. The 1966 deficit of about 5,900 mg is mainly a result of poor flow prediction and a sudden drop in river flow. Storage reallocation could reduce the deficit by a maximum of 60 percent. The 1930-31 flow recurrence would cause severe deficits in the MWA, reaching a total of 32,000 mg by the end of the drought. Storage reallocation at Bloomington Lake could reduce this deficit only somewhat. Water quality storage reallocation would satisfy only 6 percent of the deficit, while flood control storage reallocation would eliminate 12 percent (1475 pool) or 23 percent (1484 pool) of the MWA shortages. A summary of the estimated deficits for the fifty years of flow simulation is presented in Table H-12.

In order to ascertain the effects of using varying levels of Bloomington water supply storage, drawdown-frequency curves were developed from the PRISM/COE simulations. For the frequency analysis, the climatological year (1 April - 31 March) was used as the basic time unit so that each annual drawdown would be shown independently from earlier drawdowns. The resultant curves are graphed in Annex H-VIII, Drawdown Frequency and Yield Dependability Analyses. Table H-13 compares the drawdown frequencies for the four allocation plans and the three levels of flowby. The drawdowns noted in the table reflect year-round pools. Seasonal operation of Bloomington Lake would have similar results during the water supply release period, but would then draw down to its winter pool level. Extrapolation of the drawdown-frequency curves beyond the 2 percent chance of occurrence may not yield valid results due to the unusual shape and occasional slope changes of some of the curves.

Table H-13 indicates the severe impacts of meeting higher flowbys on the use of the reservoir regardless of the permanent pool elevation. Once in ten years, approximately ten feet of drawdown would be expected with the 100 mgd flowby scenario. For a 300

TABLE H-12

SUMMARY OF ESTIMATED MWA DEFICITS* FOR 2030 DEMANDS

CUMULATIVE REGIONAL DEFICIT (Million Gallons)

Flow Data	100-mgd Flowby				300-mgd Flowby				500-mgd Flowby			
	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)
1930	0	0	0	0	2,089	773	0	0	31,952	30,033	27,947	24,650
1931 . . 1962												
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	5,869	5,480	4,809	2,448
1967 . . . 1979	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	2,089	773	0	0	37,988	35,513	32,756	27,098
Number of Flow Years with Deficits	0	0	0	0	1	1	0	0	3	2	2	2
Average Deficit (mg) per Flow Year	0	0	0	0	42	15	0	0	760	710	655	542

* Major assumptions of analysis: Conservation Scenario 3 demands for 2030, Little Seneca Lake (4,020 mg), Patuxent Reservoirs (10,100 mg) Occoquan Reservoir (10,300 mg), LFAA freeze invoked in 1988, regional management of supply system, 120 cfs (78 mgd) flow target at Luke.
The allocation of Bloomington storage is noted for each pool (Water Supply/Water Quality) in 1,000 acre-feet.

TABLE H-13

COMPARISON OF BLOOMINGTON DRAWDOWNS FOR 2030 DEMANDS

MAXIMUM RESERVOIR DRAWDOWN (Acre-feet/Feet)*

		100 mgd flowby				300 mgd flowby				500 mgd flowby			
Frequency	Return Period (Years)	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)	1466 Pool (41/51)	1466 Pool (46/46)	1475 Pool (53/48)	1484 Pool (62/48)
0.20	5	5,000/5	5,000/5	5,000/5	5,000/5	9,000/10	10,000/11	9,000/9	10,000/10	48,000/61	48,000/61	47,000/55	47,000/52
0.10	10	9,500/10	9,500/10	9,500/10	9,500/9	20,000/22	22,000/25	24,500/23	22,900/20	52,000/68	57,000/77	65,500/81	71,400/84
0.05	20	14,500/16	14,500/16	14,500/15	14,500/14	36,000/43	39,000/47	41,500/44	40,900/40	58,000/79	64,000/91	74,500/98	82,900/105
0.02	50	21,000/24	21,000/24	21,000/22	21,000/21	71,000/107	76,000/119	81,500/113	88,900/117	75,000/119	80,000/131	89,500/134	97,900/140

* The drawdowns shown in the table reflect a year-round pool. Seasonal operation would include winter drawdowns of a minimum of 44,500 acre-feet of storage. The allocation of Bloomington storage is noted for each pool (Water Supply/Water Quality) in 1,000 acre-feet.

mgd flowby, this drawdown would be about 20 to 25 feet, while the 500 mgd flowby scenario would cause a 70 to 80-foot drawdown in the reservoir once every ten years. With severe low flow periods, the use of the reservoir would be further increased. The 100 mgd flowby scenario would cause reservoir drawdowns in the neighborhood of 20 to 25 feet once every 50 years. Similarly, flowbys of 300 and 500 mgd would result in drawdowns exceeding 100 feet. The effect of flowby on the reservoir is clearly depicted in the graph of Bloomington storage vs. time for the 1930-31 flows and the 1466 pool (Figure H-7). In this "worst" case, the Bloomington water supply storage would be completely exhausted with the 300 and 500 mgd flowby scenarios. The 1475 and 1484 pools would exhibit similar timing, duration, and magnitude of drawdowns. (It is important to note that these estimates of drawdown are based on maintaining a minimum flow of 120 cfs at Luke during all periods. Recent operating experience has indicated that it would be desirable to provide a higher flow rate during most non-drought years. Therefore, the drawdowns may be slightly greater during the more frequent drawdown years).

As noted in Figure H-7, the lake refilled to its summer pool for all of the flowby levels. The PRISM/COE simulations revealed that refilling Bloomington Lake in time for the summer water supply season should not be a problem for either year-round or seasonal pool at the elevations studied. In addition, the fall drawdown would most likely not interfere with water supply operations. Further discussion of these conclusions and other PRISM/COE results are provided in Annex H-III, PRISM Development and Application.

PROJECT MODIFICATIONS

Since the Bloomington project was not originally designed for permanent pools above 1466 feet msl, several structural analyses were undertaken to determine what modifications would be necessary to accommodate the higher lake levels. These analyses included assessments of the main dam embankment, the dike embankment, the railroad and highway embankments, the recreational facilities, the intake tower, and the spillway. The results of these analyses are summarized in the next few paragraphs. Additional details can be found in Annex H-VII, Design Details and Cost Estimates.

New stability analyses for the partial pool condition were performed for both the dam and the dike embankments for the two higher pool elevations (1475 and 1484 feet msl). In both cases, the analysis obtained safety factors greater than the required minimum. In addition to the partial pool investigation, a check was made on the seismic stability of the dam with the higher pools. The safety factors from this analysis were greater than the 1.00 requirement. Also, since the maximum design flood surcharge pool would increase by less than two feet with higher conservation pools, the original limiting design calculations for sudden drawdown and steady seepage were considered valid for a reformulated project at Bloomington Lake; consequently, no modifications for this condition were considered necessary. Given these findings, it was concluded that higher permanent pools would not cause any stability problems on the dam or dike embankments, and therefore, no embankment modifications would be required.

The reservoir slopes, including the adjacent railroad and highway embankments, were analyzed for potential problems at higher permanent pools. Using low-altitude, aerial photography, previously identified landslides were examined for their current status. In addition, new zones of probable instability were noted, and then confirmed by field inspections. This investigation concluded that there were no deep-seated, large land

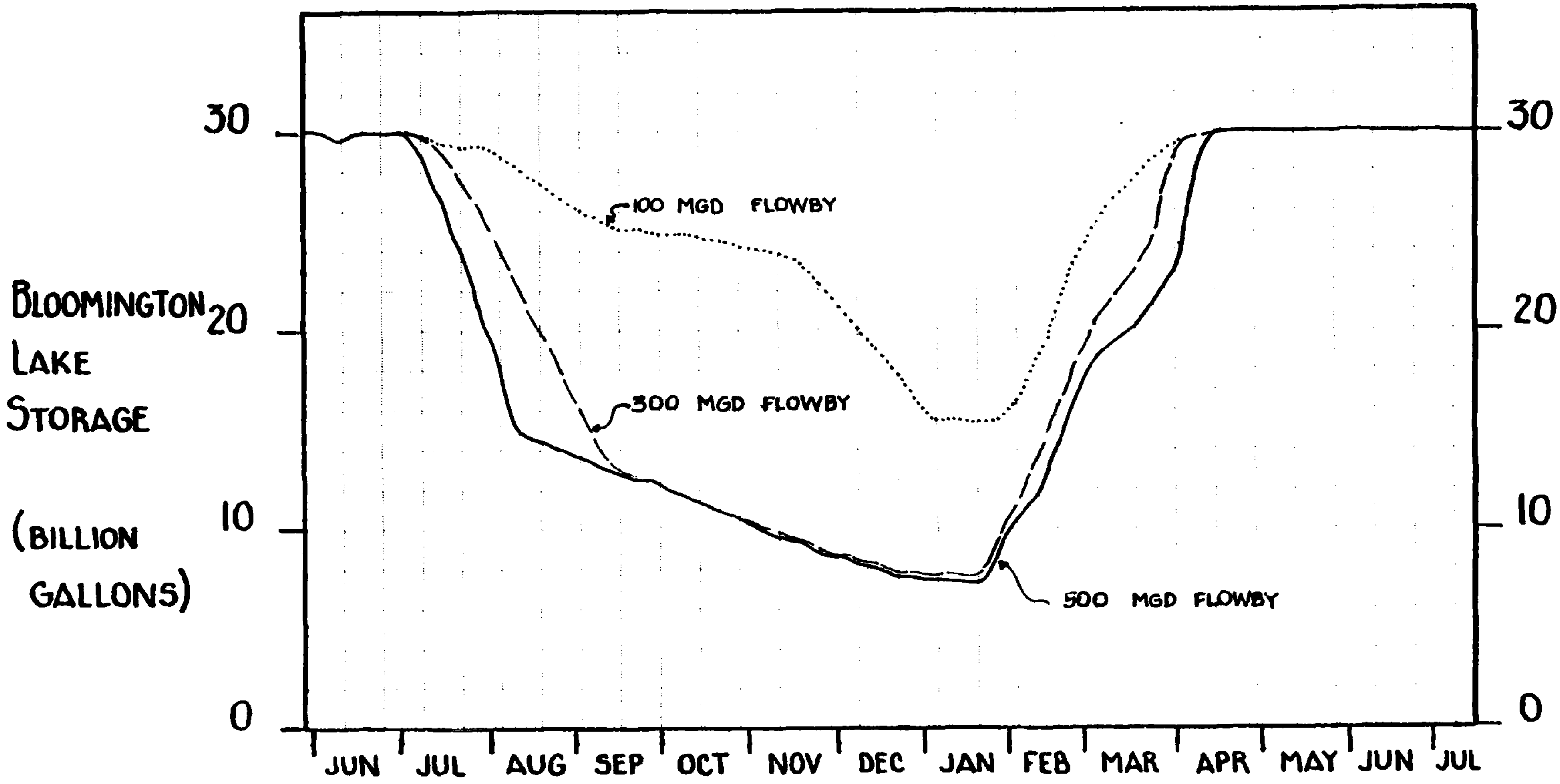


FIGURE H-7

BLOOMINGTON LAKE DRAWDOWN FOR VARYING LEVELS OF FLOWBY 1930-31 DROUGHT slides in the vicinity of Bloomington Lake. However, the 1484 lake would be very close to the railroad/highway fill in some locations. Although the existing slope protection in these areas might be adequate for repeated drawdowns, further analysis would be necessary if reallocation of flood control storage were recommended. In addition to these slope analyses, typical railroad embankments had been evaluated earlier in the design process for sudden drawdowns from a 1500 pool as well as long-term stability at a static pool at that lake level. The results of these studies showed acceptable factors of safety; therefore, the railroad embankments should pose no problems at the higher pools.

An increase in the conservation storage of Bloomington Lake would require additional clearing in the main part of the reservoir project. Trees, stumps, and brush would have to be removed from the existing upper limit of clearing at elevation 1469 feet msl to three feet above the proposed water supply pool elevation. Reallocation to the 1475 pool would require clearing approximately 80 acres from the existing project site at an estimated cost of $50,000. Similarly, 1484 reallocation would require about 140 acres of clearing, costing about $60,000.

The intake control tower would require several modifications to accommodate the increased selective withdrawal requirements at higher pools. With a water supply pool of 1475 feet msl, new intake ports would be installed at elevation 1461 feet msl. For the 1484 lake, new intake ports would be required at 1479 feet msl as well as at 1461. Associated with the portal additions would be the extension of the existing wet well, installation of a new floor slab and additional isolators, as well as modifications to the elevator and electrical systems. For the 1475 reallocation, these work items would cost an estimated $744,000. For the 1484 pool, the intake tower modifications would nearly double to approximately $1,435,000.

Raising the conservation pool to 1475 or 1484 feet msl would result in a permanent pool against the spillway tainter gates, since the existing sill only extends to 1468 feet msl. Therefore, bottom seal and side seal heaters for all five tainter gates, as well as an emergency power source and a generator building, would have to be provided if the permanent pool were raised. These spillway modifications would amount to an estimated $85,000 for either flood control storage reallocation plan.

In addition, reallocation to the higher permanent pool elevations would require relocation of a considerable portion of the existing boat launch facility. Reconstruction of the ramp, permanent docks, turnaround area, and a portion of the access road would be necessary. This construction work was estimated to cost $405,000 for the 1475 pool, and $459,000 for the 1484 pool.

A summary of the estimated costs for the project modifications is tabulated in Table H-14. The total cost for the 1475 facility modifications is approximately $1,540,000, including a contingency factor. Similarly, the modifications for the 1484 reallocation would cost an estimated $2,447,000. These costs would be incurred over an estimated engineering, design, and construction period of three years.

The analyses for this investigation also revealed that any advanced engineering studies of a reformulated project at Bloomington Lake would require additional study of the potential for downstream erosion, the adequacy of the existing low flow air vents, and the maintenance requirements of the tainter gates.

TABLE H-14

ESTIMATED COSTS OF PROJECT MODIFICATIONS
FOR REALLOCATION OF FLOOD CONTROL STORAGE
(October 1981 Prices)

Item	1475 Pool	1484 Pool
Reservoir Clearing	$50,000	$60,000
Tower Modifications	744,000	1,435,000
Spillway Modifications	85,000	85,000
Boat Launch Modifications	405,000	459,000
Subtotal	$1,284,000	$2,039,000
Contingencies (20 percent)	256,000	408,000
Total	$1,540,000	$2,447,000

WATER QUALITY

For evaluation of the reallocation plans, extensive water quality investigations were undertaken. As part of these investigations, the Baltimore District, Corps of Engineers developed mathematical models to simulate the water quality in both the reservoir and downstream in the North Branch Potomac River. A complete description of the models and their results is provided in Annex H-II, Water Quality Investigations. The reservoir model tracked several parameters, including acidity, conductivity, sulfate, manganese, and total suspended solids, within a fully mixed, two-layered system. The stream model simulated water quality at six stations between Bloomington Dam and Paw Paw, West Virginia. The stream model analyzed seven water quality parameters: temperature, pH, acidity, alkalinity, conductivity, sulfate, and total dissolved solids (TDS).

Using these two models, the projected water quality conditions for the existing project were modelled for several sets of flow data and release scenarios. The modelling analysis determined that the lake water quality was dependent on two factors, the water quality of the inflow and the discharge pattern. Since the lake provides a natural averaging mechanism, the smaller the volume of storage in Bloomington, the more it is affected by the water quality of the inflow. Thus, the impact of an acid slug would be much greater for a drawn down Bloomington Lake (i.e., after an extended series of water supply releases) than for a full pool. Additional results and conclusions of the existing condition analysis can be found in Annex H-II.

Similarly, the stream water quality model was used to project forth expected water quality conditions downstream of Bloomington Lake. The modelling results indicated that the North Branch water quality depends on the operation of the WESTVACO Pulp and Paper Mill, the discharge quality from the Upper Potomac River Commission's sewage treatment plant, the operation of the Bloomington-Savage system, and to some extent, the enforcement of mining regulations. A complete description of the projected downstream water quality is presented in Annex H-II.

Given these base conditions, the effects of higher pools (storage reallocation) and greater use of storage (flowby sensitivity) were analyzed. It was determined that higher pool elevations would affect the water quality both in the lake itself and in the stream below Bloomington Lake.

First, if Bloomington Lake were raised to 1475 or 1484 feet msl, several physical charateristics which affect water quality would change. First, the surface area would increase by 57 acres (1475 pool) or by 117 acres (1484 pool). This surface area increase is small compared to the storage increase for the higher pools. In addition, the mean depth would increase from 99.4 feet to either 102.6 feet (1475 pool) or 105.6 feet (1484 pool). The hydraulic retention time would also increase from 102.5 days to 112.4 days (1475 pool) or 122.9 days (1484 pool).

Higher pools would result in slightly higher levels of acidity, pH, and conductivity in the lower lake zones, particularly during the late spring. The upper layer of the lake would not change with higher lake elevations due to the small change in lake surface area. An increase in pool elevation would result in a larger volume of lower zone storage (during the summer), which is noted for better water quality. Overall, however, the water quality differences between the 1466 pool and higher pools would be negligible in the lake itself.

The outflow water quality from Bloomington Lake would change slightly with flood control storage reallocation. Since the higher pools would have an increased percentage of lower layer water, the Bloomington releases, particularly during the summer and fall, would reflect the mixture change. As a result, the outflows would be slightly colder and have slightly better water quality. The addition of several intake ports would also improve the ability to control the water quality of Bloomington discharges. However, higher permanent pools would discharge higher flows through the flood gates, and subsequently uncontrolled flow would occur more frequently than with the 1466 pool.

Since the Savage storage capacity would remain the same, the buffering ability of Savage would decrease with higher storages in Bloomington; consequently, a lower percentage of Savage storage would be released. However, the resultant water quality from the combination of better outflow quality and less Savage flow would be similar to the projected conditions for the 1466 pool. The increased probability of uncontrolled Bloomington releases would also impact Savage's ability to maintain a desirable Bloomington-Savage flow ratio. Generally, then, the water quality at Luke would not be impacted by storage reallocation except during high flow years when the risk of uncontrolled flow would increase. The same conclusions would apply to points further downstream. The impacts would diminish with distance downstream.

Although reallocating some water quality storage to water supply storage would not increase the lake's conservation volume, its impact on lake water quality was investigated. The decrease in water quality storage would reduce the averaging ability of the lake, and would subsequently result in slightly lower outflow quality. However, the resultant water quality differences would be minor.

The effects of increased flowby levels were also examined. For most years (ninety percent or more), higher levels of Potomac estuary flowby (up to 500 mgd) would not require releases from Bloomington water supply storage. Consequently, in those years, Bloomington would maintain the same operational scheme regardless of the downstream flowby requirements.

It would only be in extremely low flow years that there would be any difference. During those periods (e.g., a recurrence of the 1930-31 drought), extended use of the Bloomington water supply storage would alter the projected water quality conditions. With higher levels of flowby, more water supply storage would be needed; therefore, the potential for releasing less desirable water (in terms of quality) would be increased. Additionally, since Savage's dilution capacity would be taxed more frequently and for a longer duration with higher levels of flowby, the risk of depleting the Savage storage would increase and with it, the risk of losing control of the water quality in the North Branch Potomac River. Larger releases of Bloomington storage would cause a decrease in water temperature below the dam and further downstream, since more water would have to be drawn from the lower lake layer. The pH in the lake and below the dam would be lowered slightly (more acidic) with more extensive water supply releases. At Luke, this impact would be counteracted by Savage releases which would dilute the North Branch flow. Consequently, beyond Luke, greater use of Bloomington storage would not affect the pH parameter except if Savage were emptied.

Conductivity in the North Branch would exhibit similar characteristics. Large Bloomington releases would lower the conductivity levels below the dam slightly during the release period. Once Savage releases mix with the North Branch flow, then the concentrations would return to the projected "normal" levels. However, depletion of the Savage reservoir would result in lower conductivity levels at Luke and further downstream.

In general, the increases or decreases in parameter concentrations would be slight as long as the Bloomington-Savage system is able to maintain control of the water quality situation. However, once this control is lost, then the water quality would deteriorate significantly. This situation could occur under severe low flow conditions and high flowby levels as exemplified by the 500 mgd scenario during the 1930-31 drought.

The effects of year-round versus seasonal operation were also evaluated. Maintenance of a year-round pool would cause a significant impact on the water quality in the North Branch Potomac River. The reservoir and stream modelling indicated that year-round pools would frequently result in large volumes of Bloomington release during the spring snowmelt period. With seasonal operation, this runoff would have been stored to refill the lake. Since Savage River Reservoir has seasonal regulation, it cannot release much flow during the spring. Without adequate dilution of the Bloomington releases, the water quality at Luke and points downstream would be severely impacted during the spring season. Therefore, from a water quality perspective, maintenance of a year-round pool would be highly undesirable.

RECREATION IMPACTS

The impacts of Bloomington storage reallocation and higher levels of flowby were investigated for the recreation areas at Bloomington Lake as well as at the downstream MWA reservoirs. This analysis found that the recreation impacts would be primarily associated with raising the Bloomington conservation pool and the increased frequency of drawdowns due to increased use of water supply storage.

Of the existing and proposed future recreational facilities at Bloomington Lake, only the Howell Run Boat Launch would be affected by higher permanent pools. Both the High Timber Campground and Howell Run Picnic Area are located well above the proposed 1475 and 1484 pools, and consequently there would be no significant impacts to these facilities. Similarly, the proposed future sites in the project master plan are located at a higher elevation than the flood pool, or downstream of the dam. The Howell Run Boat Launch, on the other hand, would require some modification if flood control storage were reallocated. These modifications are detailed in Annex H-VII, Design Details and Cost Estimates.

An analysis of new potential recreation sites for the higher lake levels was also performed. At the 1484 pool, a potential boat launch site could be created at the western end of the lake. Use of this site would require construction of a new access road of almost one mile in length along the existing abandoned railroad bed. Both of the higher pools (1475 and 1484 feet msl) would have potential for a boat-in campground to be located on a large peninsula uplake of Deep Run. This facility could be constructed with minimal site modification and improvements.

The use of Bloomington Lake as a water supply source could affect the use of the boat launch facilities as well as the aesthetic character of the lake. Adding more water supply storage to the project, however, would not itself change this impact significantly since the timing, duration, frequency, and depth of reservoir drawdowns are generally independent of the permanent pool elevation. This was demonstrated earlier in Table H-13. However, the higher flowby values which resulted in extended water supply releases and subsequently more severe reservoir drawdowns, would have an impact on the project's recreation use.

The extent of this impact was indicated by drawdown-frequency curves developed specifically for the recreation season. As discussed earlier, the PRISM/COE simulations were used to develop several reservoir drawdown-frequency curves. Following the same technique, the peak reservoir drawdown during the recreation season (defined as 1 May to 30 September) was noted for each year of simulated flow, and then frequency curves were developed for several scenarios, representing the three levels of flowby with the 1466 pool. The resultant curves are shown in Figures H-VIII-7 and H-VIII-8. Table H-15 compares the drawdown frequencies for the three scenarios. From the frequency curves, it was determined that a 25-foot drawdown which represents the extent of the existing boat launch (1441 feet msl), had a frequency of occurrence of less than 2 percent for the 100 mgd scenario, about 8 percent for the 300 mgd scenario, and about 27 percent with 500 mgd flowby. Although the data does not reflect the 1475 and 1484 pools, the expected drawdowns and subsequent conclusions would be similar as determined for the annual frequency curves.

From this data, it was concluded that the higher flowby scenarios, particularly the 500 mgd scenario, would seriously impact the recreation resources of Bloomington Lake causing more frequent and longer periods when the boat launch would be unusable and large shoreline areas would be dewatered. The Savage River Reservoir would also be similarly affected by higher flowby values since it would be used in conjunction with Bloomington. The Patuxent and Occoquan Reservoirs, because they are located off the Potomac River and are somewhat limited by system treatment capacities, would not be as sensitive to changes in flowby as Bloomington Lake. However, the overall adverse impacts on recreation at the downstream reservoirs would still be significant with higher flowbys, particularly when considering the duration of the drawdowns.

ENVIRONMENTAL IMPACTS

The environmental analyses for the Bloomington Lake Reformulation Study concentrated on describing the existing natural resources and how they would be affected by storage reallocation and by greater use of the water supply storage. The environmental impacts which were determined by these analyses can be classified as: (1) changes due to a larger lake, (2) resultant reservoir drawdowns, and (3) changes due to water quality effects. More detailed discussion of these impacts is presented in Annex H-VI, Environmental, Social, Cultural, and Recreational Resources.

TABLE H-15

COMPARISON OF RECREATION SEASON DRAWDOWNS

Frequency	Recurrence Interval (Years)	Reservoir Drawdown (Feet)* 100-mgd Flowby	300-mgd Flowby	500-mgd Flowby
0.50	2	2	2	6
0.20	5	5	7	46
0.10	10	9	7	46
0.05	20	12	49	31
0.02	50	17	82	85

* Drawdown analysis assumed 2030 Conservation Scenario 3 Demands, a recreation season from 1 May to 30 September, and the Baseline supply conditions for the MWA Water Supply Study. Drawdowns are shown for the 1466 pool; the 1475 and 1484 pools would show similar patterns of drawdown.

The reallocation of flood control storage to water supply storage would raise the permanent pool elevation up to a maximum of 18 feet (1484 feet msl). This would result in the conversion of terrestrial habitat to aquatic habitat. Since the Bloomington Lake water quality is expected to preclude fish habitation, the ecological benefits associated with the creation of additional aquatic habitat would be negligible. On the other hand, the higher pool elevations would result in a loss of terrestrial habitat. The land which would be inundated consists primarily of steep, wooded terrain which provides habitat for various local mammals and birds. Because of the steepness of the Bloomington Lake terrain, the loss of upland habitat would be relatively small. At elevation 1475 feet msl, the pool would be enlarged from 952 acres to 1009 acres, a 57-acre increase (about 6 percent). The 1484 pool would encompass 1069 acres, an increase of 117 acres (12 percent) over the existing pool at elevation 1466 feet msl. Accordingly, the ecological impact of raising the conservation pool would be relatively minor.

Reservoir drawdowns could affect the existing fisheries resources depending on several factors. These factors include the size and depth configuration of the lake, the temperature profile, the fish species composition, and fishery management goals. The magnitude, timing, duration, and frequency of the drawdown would also affect the degree of impact. These factors were considered for Bloomington Lake as well as the other MWA system reservoirs. The other reservoirs (Savage, Occoquan, and Patuxent) were included because the use of Bloomington water supply storage could directly impact their storage levels.

For the drawdown analysis, the investigation centered on the 1966 and 1930-31 low flow conditions as measures of severe drawdown impacts. With higher flow conditions in the Potomac River Basin, the effects of storage reallocation would be inconsequential since supply and demand conditions would not require extensive use of reservoir storage even with higher levels of flowby (i.e., 500 mgd). Therefore, the drawdown impacts discussed below should be viewed with their low probability in mind.

The PRISM/COE simulations were used as basis for the drawdown analysis. For 1966 flow conditions which included a sudden drop in flow for a short duration, the PRISM/COE model indicated that storage reallocation and/or the level of flowby would not have a significant effect on the Occoquan and Patuxent drawdowns. However, higher flowby targets depleted both Bloomington and Savage reservoirs earlier and at a faster rate. Since Bloomington is not expected to support a fishery, the biological impact to the Lake due to these drawdowns would be minimal. For Savage, the drawdowns would not take effect until mid-July which is after the primary spawning time for most species; also, the loss of aquatic habitat would be relatively small since Savage River Reservoir is steep-sided. Given these findings, the fish population in Savage would most likely tolerate this level of drawdown without problem. However, a large summer drawdown could alter the thermal regime of the reservoir and downstream areas by depleting the cold water in the hypolimnion; this could be detrimental to the existing downstream trout fishery.

For a long, severe drought such as the 1930-31 flows, the PRISM/COE simulations concluded that regardless of the required level of flowby or storage reallocation, all of the MWA reservoirs would experience very large drawdowns. With 100 mgd flowby and 2030 demands, the Occoquan Reservoir would drop to less than 20 percent of normal capacity while the Patuxent Reservoirs would have only about one-half of their conservation pools remaining. With higher levels of flowby, the Savage and Occoquan Reservoirs would be emptied during the drought duration, and the Patuxent Reservoirs nearly so. These trends would not be substantially altered by either changing the water supply/water quality storage ratio in Bloomington Lake, or by increasing the Bloomington conservation pool by 9 or 18 feet, as shown earlier in the drawdown analysis in Table H-13. The large drawdowns caused by 1930-31 flow conditions would be so severe that extensive depletion of the fishery resources would be expected in the reservoirs other than Bloomington Lake, even though the drawdowns would occur after the major fish spawning period.

In general, then, reallocation of Bloomington Lake storage, water quality or flood control, would have minimal impact on the fishery resources within the system reservoirs. Drawdowns in the reservoirs would be most affected by the system demands, as signified by varying levels of flowby. However, this impact would be significant only during long, severe low flow conditions.

Storage reallocation and/or higher levels of flowby could possibly change the water quality conditions and thus, the aquatic community in the North Branch Potomac River. Using the reservoir and stream modelling techniques discussed earlier, the water quality investigations concluded that storage reallocation alone would have a minimal effect on the water quality conditions immediately downstream, except that acid slugs would be moderated somewhat. Therefore, the aquatic community would be expected to remain at the levels projected for the existing project.

Higher flowby requirements could result in extended water supply release periods under severe drought conditions. The large magnitude of this Bloomington release would effect downstream water quality by reducing the moderation effect on pH and other water quality parameters that Bloomington Lake achieves. The greater the flowby value, the more significant the fluctuations in pH would be, and thus the effect on the downstream aquatic ecosystem. Also, with higher levels of flowby, the potential for depleting the Savage storage would increase. Any undiluted Bloomington release would cause severe adverse downstream impacts due to the shock of highly acidic flow on a previously moderate pH environment. However, the frequency of extended Bloomington water supply releases would be rare; therefore, the impacts of higher flowby values would be minimal in the long run.

SOCIAL AND CULTURAL IMPACTS

For the Bloomington Lake Reformulation Study the social and cultural resources of the Bloomington project area were identified. In addition, the impacts of storage reallocation were assessed for the three potential plans. The results of these analyses are outlined below.

From a cultural perspective, storage reallocation as proposed would not effect the existing resource base. A literature survey and field reconnaissance were conducted for the Reformulation Study. Subsequently, no intact prehistoric or historic cultural resources were found in the project area. Also, most of the habitable areas had already been greatly disturbed by strip mining and dam-related construction. Therefore, the cultural investigation concluded that no significant features or structures would be impacted by raising the conservation pool from 1466 feet msl up to a maximum of 1484 feet msl.

The loss of flood control protection could have an adverse social impact within the downstream areas. However, the hydrologic analyses performed for the Reformulation Study indicated that the loss of protection was not very significant. In terms of economic benefits, the loss due to storage reallocation was 3 percent for the 1475 pool and 7 percent for the 1484 pool. There would be no loss of flood protection capability with water quality storage reallocation since the permanent pool would not be raised. The flood control analysis identified two rural stretches between the Savage River and the South Branch Potomac River as the major damage-prone areas. Flood damages in these river reaches would mainly affect the transportation network and not residential properties. Given these findings, the social impact of storage reallocation should be minimal. However, some residents downstream of Bloomington could perceive a significant reduction in the project's flood control capability. Although not supported by technical analyses, this public perception could represent an important adverse social impact.

COST ALLOCATION

Since Bloomington Lake is a multiple purpose project, its construction costs have been divided among its primary purposes, flood control, water quality, water supply, and recreation. Subsequently, the non-Federal interests who own Bloomington water supply storage are reimbursing the Federal government for a portion of the project's costs. Likewise, any further storage reallocated to water supply would also have to be paid for by a water supply purchaser. The cost of this storage is determined by its share of the original project's cost, plus any costs incurred to provide that storage as the new purpose. The former cost (the project share) is governed by Federal laws and regulations as outlined below, while the latter cost was detailed earlier in the Project Modifications section. The sum of these two costs would then be the repayment responsibility of the storage purchaser.

For the Bloomington reallocation plans, a preliminary calculation of the reallocated storage's project share was performed. Several methods for allocating project costs to project purposes were available for Federal projects, including the Separable Costs Remaining Benefits method, the Alternative Justifiable Expenditure method, and the Use of Facilities method. Of these, the Use of Facilities method was determined to be the most applicable because storage reallocations as proposed for the 1466, 1475, or 1484 pools would have insignificant effects on Bloomington Lake's other authorized project purposes. In the case of the Use of Facilities method, the reallocated storage cost to the non-Federal interests is established as the higher of either benefits or revenues foregone, or the estimated cost of storage in the Federal project. Earlier analyses indicated that the cost of storage in Bloomington Lake would exceed the foregone flood control benefits (a maximum of $108,000 per year); therefore, the storage cost served as the basis for determining the non-Federal costs for reallocated water supply storage with the Use of Facilities method.

The calculation of the storage cost involved several steps. First, the total project cost at the time of construction was computed. For Bloomington Lake, this cost was $174,300,000. From this total construction cost, the direct purpose-related costs were subtracted. For Bloomington Lake, these costs were $5,926,000 for construction of the project's recreation facilities. This then yielded the construction cost subject to allocation. Next, the reallocated storage's share of this cost was determined using the ratio of the reallocated storage to the total usable storage of 128,200 acre-feet (sediment storage was considered unusable). For water quality storage reallocation, this ratio was 3.900 percent, based on reallocating 5,000 acre-feet to water supply storage. Similarly, the reallocated storage increment for the 1475 and 1484 pools was 6.864 and 14.197 percent, respectively. A summary of the potential storage volumes and the increment calculation is presented in Table H-16. The calculation of the reallocated share cost can be summarized by the following formula:

$$\text{Cost of Reallocated Storage} = (\text{Total Construction Costs} - \text{Specific Costs}) \times \frac{\text{Reallocated Storage}}{\text{Total Usable Storage}}$$

Following this calculation, the allocated cost share was updated to current price levels by use of the Engineering News-Record Construction Cost Index (ENRCCI). The updating factor was based on the ENRCCI at the midpoint of the physical construction period divided by the October 1981 ENRCCI (3672). The period of construction began in April 1968 with the acquisition of project lands. Construction was completed in July 1981. Thus, the midpoint was estimated as January 1975 (ENRCCI = 2103) and a factor of 1.746 (3672/2103) was applied to the reallocated cost share. Applying this factor results in an estimated reallocated storage cost of $11,466,000 for reallocating 5,000 acre-feet (water quality storage, reallocation plan) $20,179,000 for the 1475 reallocation plan; and $41,736,000 for the 1484 reallocation plan. The results of the cost allocation procedure are summarized in Table H-17.

In addition to the project share, the water supply purchaser would also be responsible for the cost of modifications to the projects. These modifications would include additional reservoir clearing, reconstruction of the boat launch ramps, as well as spillway and intake tower modifications. However, no significant water-supply related operation and maintenance costs would be associated with storage reallocation. As part of the reallocation investment costs, the storage purchaser would also be responsible for the associated interest cost during the construction of the modifications. The interest during construction costs for the project modifications were determined by separating the construction costs into the appropriate year within the installation period, and then bringing these costs forward to the beginning of the period by charging compound interest at 7 5/8 percent (the FY 1982 Federal discount rate) from the date the costs would be incurred. For this analysis, the total engineering, design, and construction period was assumed to cover three years.

Adding the modifications investment costs to the project storage costs yielded the total reallocation investment costs noted in Table H-18. For the water quality storage reallocation plan, the total investment cost was estimated as $11,466,000. The 1475 reallocation plan would cost approximately $22,279,000, while the 1484 plan would cost

TABLE H-16

POTENTIAL STORAGE ALLOCATIONS
IN BLOOMINGTON LAKE
(ACRE-FEET)

	Existing Conditions	Reallocation of Water Quality Storage	Reallocation of Flood Control Storage	
Purpose	1466 Pool	1466 Pool	1475 Pool	1484 Pool
Sediment Storage	2,700	2,700	2,700	2,700
Water Quality Storage	51,000	46,000	51,000	51,000
Water Supply Storage	41,000	46,000	49,800	59,200
Flood Control Storage	36,200	36,200	27,400	18,000
Total Storage	130,900	130,900	130,900	130,900
Unusable Storage (-)	2,700	2,700	2,700	2,700
Total Usable Storage	128,200	128,200	128,200	128,200
Reallocated Storage	0	5,000	8,800	18,800
Reallocated Storage Increment (%)*	0	3.900%	6.864%	14.197%

* Reallocated storage increment is based on the total usable storage.

TABLE H-17

SUMMARY OF COST ALLOCATION PROCEDURE
FOR ORIGINAL PROJECT SHARE

	Reallocation of Water Quality Storage	Reallocation of Flood Control Storage	
	1466 Pool	1475 Pool	1484 Pool
Total Construction Costs	$174,300,000	$174,300,000	$174,300,000
Less Recreation Costs	5,926,000	5,926,000	5,926,000
Construction Costs Subject to Allocation	$168,374,000	$168,374,000	$168,374,000
Reallocated Storage Increment	3.900%	6.864%	14.197%
Construction Costs Allocated to Reallocated Water Supply Storage	$ 6,567,000	$ 11,557,000	$ 23,904,000
ENRCCI Escalation Factor*	1.746	1.746	1.746
Escalated Cost Allocated to Reallocated Water Supply Storage	$ 11,466,000	$ 20,179,000	$ 41,736,000

* Engineering News-Record Construction Cost Index Escalation Factor is based on the Ratio of the October 1981 ENRCCI to the January 1975 ENRCCI.

TABLE H-18

SUMMARY OF COSTS FOR A
REFORMULATED BLOOMINGTON PROJECT

	Reallocation of Water Quality Storage 1466 Pool	Reallocation of Flood Control Storage 1475 Pool	Reallocation of Flood Control Storage 1484 Pool
INVESTMENT COSTS			
Project Modifications			
Reservoir Clearing	$0	$50,000	$60,000
Tower Modifications	0	744,000	1,435,000
Spillway Modifications	0	85,000	85,000
Boat Launch Modifications	0	405,000	459,000
Contingencies	0	256,000	408,000
Modifications Cost	0	$1,540,000	$2,447,000
Administrative Costs:			
Engineering and Design	0	308,000	489,000
Supervision and Administration	0	77,000	122,000
First Costs of Modifications	0	1,925,000	3,058,000
Interest During Construction*	0	175,000	279,000
Investment Costs for Modfications	0	2,100,000	3,337,000
Original Project Share:			
Cost of Reallocated Storage	11,466,000	20,179,000	41,736,000
Total Investment Costs	11,466,000	22,279,000	45,073,000
REALLOCATED WATER SUPPLY STORAGE IN MILLION GALLONS	1,630	2,900	5,900
COST PER MILLION GALLON OF ADDITIONAL SUPPLY	7,030	7,680	7,640

* Interest during construction was computed by separating construction costs into the appropriate year of a three-year design and construction phase, and then bringing these costs forward to the beginning of the period by charging compound interest at 7 5/8 percent (FY 1982 Federal discount rate).

$45,073,000. From a relative cost per supply point of view, the water quality storage reallocation plan was the least expensive, costing about $7,030 per million gallons of storage. The two flood control storage plans were estimated to be $7,680 per mg (1475 pool) and $7,640 per mg (1484 pool).

ASSESSMENT AND EVALUATION OF SIGNIFICANT EFFECTS

SEASONAL VS. YEAR-ROUND POOL

The issue of seasonal vs. year-round pool was addressed in several of the technical analyses. First, the flood hydrologic analysis determined that there were no signficant differences in flood flows between the two types of operations. It was estimated that less than 10 percent of the flood benefits would be affected by Bloomington Lake regulation with a year-round on permanent pool. From a water supply perspective, seasonal vs. year-round operation had no impact on Bloomington Lake's utility. In all of the fifty years of simulation, the Lake was able to refill from the lower winter pool in time for the water supply season. Additionally, the annual drawdown in the autumn months would not interfere with water supply operations.

On the other hand, a permanent year-round pool at any elevation would result in severe water quality impacts during the spring months, which could coincide with the fish spawning season. This impact would be caused by the lack of sufficient Savage River flow to dilute spring flood flows in the North Branch Potomac River. Given these findings, regulation for a permanent year-round pool at Bloomington Lake was not recommended.

FLOWBY SENSITIVITY

As part of the MWA Water Supply Study, the impacts of higher levels of flowby on the upstream system were examined as part of the Bloomington Lake Reformulation Study. These investigations concluded that impacts would result primarily in the low probability flow events. During most years, the upstream system would respond identically for estuary flowbys between 100 and 500 mgd. It would be only in the rare, extremely low flow events that major differences would occur.

For 2030 demands, the 100 mgd flowby condition would be easily satisfied according to the PRISM/COE simulations. For a 300 mgd flowby scenario, small deficits would be expected for a recurrence of the 1930-31 flows. However, the PRISM/COE model projected significant MWA deficits for the 1930-31 flow sequence, and some deficits in the 1966 flows, with a flowby target of 500 mgd. The higher flowbys (300 and 500 mgd) would deplete the entire Bloomington water supply storage even with maximum reallocation during the worst drought on record. Higher levels of flowby also would cause much larger drawdowns more frequently as noted earlier in Table H-13. Subsequently, the use of the lake's boat launch facility would be somewhat reduced. Additionally, the shoreline would be dewatered more frequently which would probably deter visitors from using the lake's recreational facilities.

Greater use of the Bloomington water supply storage would increase the risk of losing control of the North Branch Potomac River water quality (below Bloomington Lake) during extreme low flow years. During most years, higher flowbys would not cause any significant impacts on the lake or stream water quality; however, during extremely low flow events, major usage of the Bloomington water supply storage could result in depletion of the Savage storage volume. Should this occur and no dilution flow were available, there would be significant deterioration of the existing water quality and a detrimental shock to the river ecosystem. The risk of this happening would naturally increase with greater demands (i.e. flowby) on the upstream system. Greater use of the Bloomington storage would also have greater potential for releasing less desirable water (in terms of quality) from the reservoir to meet system needs.

Generally, the provision of higher flows into the Potomac Estuary would require some trade-offs with the upstream system quality and recreational use. These trade-offs would come into play in primarily during extremely low flow events since the hydrologic system can naturally provide a large base flow into the Potomac Estuary under normal flow conditions.

STORAGE REALLOCATION

Reallocation of Bloomington storage would be a feasible alternative for the MWA. The technical analyses undertaken in the course of this study indicated that storage reallocation of up to 18,200 acre-feet of storage would cause minor impacts. Consequently, these alternatives should be considered with the other available MWA alternatives. A summary of the impacts and project description for the three reallocation plans is presented in Table H-19. Discussions of each plan follow in the next paragraphs.

The water quality storage reallocation plan would transfer 5,000 acre-feet of water quality storage to the water supply purpose. This reallocation plan would not change the downstream flood protection capability provided by the existing project. Since the lake level would remain the same, no structural modifications would be required. The safe yield of the reallocated project would be increased by about 11 mgd. The use of the project would generally reflect the current use; similar drawdown patterns and water quality conditions would be expected. The project, however, would have slightly less dependable, acid-averaging capacity than the existing allocated project. There would be no impact on the area's cultural resources. The total investment cost of this plan would be approximately $11,466,000, or about $7,030 per million gallon of additional water supply storage.

Although the water quality analyses indicated that 5,000 acre-feet of Bloomington water quality storage would be available, it was also determined that the water quality storage in the Bloomington project could be used to meet downstream flowby needs, since estuary flowby of 100 mgd was also a water quality goal. Therefore, at this time, Bloomington water quality storage reallocation is not recommended for further consideration.

The 1475 reallocation plan would provide 8,800 acre-feet of additional water supply storage at a total investment cost of $22,279,000. This additional storage would increase the safe yield of the reallocated project by about 19 mgd over the existing condition. Raising Bloomington Lake to 1475 feet msl would require some structural modifications to the project, notably the extension of the Howell Run boat launch facility. The higher pool would result in $49,000 less annual flood benefits. This is about 3 percent of the existing project's flood control benefits. However, mainly rural areas and transportation facilities would be affected by the loss in flood protection.

TABLE H-19

STORAGE REALLOCATION ALTERNATIVES
DATA SUMMARY

	Existing Condition 1466 Pool	Reallocation of Water Quality Storage 1466 Pool	Reallocation of Flood Control Storage 1475 Pool	Reallocation of Flood Control Storage 1484 Pool
PROJECT DATA				
Pool Elevation (feet msl)	1466	1466	1475	1484
Top of Dam Elevation (feet msl)	1514	1514	1514	1514
Lake Surface Area (acres)	952	952	1009	1069
Maximum Depth (feet)	296	296	305	314
Reservoir Length (miles)	5.5	5.5	5.8	6.1
Total Storage (acre-feet) (Top of Dam)	148,200	148,200	148,200	148,200
FLOOD CONTROL				
Flood Control Storage (acre-feet)	36,200	36,200	27,400	18,000
Runoff Control (inches)	2.58	2.58	1.95	1.28
Foregone Benefits, $/year	0	0	$49,000	$108,000
Foregone Benefits, Percent	0	0	3	7
PMF Maximum Lake Elevation (feet msl)	1509.2	1509.2	1510.2	1510.8
August 1955 Flood Event				
Maximum Lake Elevation (feet msl)	1494.9	1494.9	1497.7	1499.3
Luke River Stage (feet)	10.5	10.5	10.5	11.6
Pinto River Stage (feet)	13.5	13.5	13.5	17.1
Cumberland River Stage (feet)	13.7	13.7	13.7	16.7
WATER SUPPLY				
Water Supply Storage (acre-feet)	41,000	46,000	49,800	59,200
100-mgd Flowby Scenario				
Drawdown 1 in 10-year event (feet)	10	10	10	10
MWA Regional Deficit (mg)	0	0	0	0
Drawdown in 1930-31 Event (feet)	25	25	25	25
MWA Regional Deficit (mg), 1930-31 Event	0	0	0	0
300 mgd Flowby Scenario				
Drawdown 1 in 10 year event (feet)	22	25	14	2
MWA Regional Deficit (mg)	0	0	0	0
Drawdown in 1930-31 Event (feet)	102	115	112	116
MWA Regional Deficit (mg), 1930-31 Event	2,089	773	0	0

TABLE H-19 (Continued)

STORAGE REALLOCATION ALTERNATIVES
DATA SUMMARY

	Existing Condition 1466 Pool	Reallocation of Water Quality Storage 1466 Pool	Reallocation of Flood Control Storage 1475 Pool	1484 Pool
500 mgd Flowby Scenario				
Drawdown 1 in 10-year Event (feet)	68	77	70	66
MWA Regional Deficit (mg)	0	0	0	0
Drawdown in 1930-31 Event (feet)	103	120	117	122
MWA Regional Deficit (mg), 1930-31 Event	31,952	30,033	27,947	24,650
Estimated 150-day Supply (mgd)	89	100	108	128
WATER QUALITY				
Water Quality Storage (acre-feet)	51,000	46,000	51,000	51,000
RECREATION				
Facilities Impacted				
High Timber Campground	No	No	No	No
Howell Run Picnic Area	No	No	No	No
Howell Run Boat Launch	No	No	Yes	Yes
Future Sites	No	No	No	No
COSTS				
Modifications	N.A.	0	$2,100,000	$3,337,000
Project Share	N.A.	$11,466,000	$20,179,000	$41,736,000
Total Investment Cost	N.A.	$11,466,000	$22,279,000	$45,073,000
Cost per mg of Additional Supply	N.A.	$7,030	$7,680	$7,640

The higher pool would have similar drawdown patterns as the 1466 pool, so there should be no resultant impact on the recreational use of the facilities. The 1475 pool would also have some potential for a boat-in campground due to the lake's configuration. The loss of terrestrial habitat associated with raising the pool would be minor, some 57 acres. There would be negligible differences in water quality between the 1466 and 1475 pools, although the higher pool would provide additional acid-averaging capacity, but have greater probability of uncontrolled flood flows.

Similarly, reallocation to the 1484 pool would provide 18,200 acre-feet of additional water supply storage, increasing the safe yield approximately 39 mgd. The total investment cost of this reallocation plan was estimated at $45,073,000, including the structural modifications and the reallocated storage's portion of the original project cost. The 1484 pool would have $108,000 fewer annual flood control benefits, amounting to about 7 percent of the existing project's flood control benefits. However, only rural areas and transportation would be affected by the loss in flood protection.

The 1484 pool should respond to reservoir releases like the 1466 pool; consequently, there should be no change in the use of the recreational facilities. As for the 1475 pool, the 1484 pool would have some potential for a boat-in campground. About 117 acres of terrestrial habitat would be inundated by the 1484 reallocation plan. This loss is not considered significant. The changes in water quality between the 1466 and 1484 pool would be negligible. The 1484 pool would provide some additional, acid-averaging capacity to the project, however, the higher pool would release uncontrolled, poor quality flood flows more frequently.

In summary, of the reallocation plans considered, the flood control storage reallocation plans for the 1475 and 1484 pools merited further consideration in the long-range planning phase of the MWA Water Supply Study. The relative advantages and disadvantages of these two plans with respect to the other supply alternatives are discussed in Appendix B, <u>Plan Formulation, Assessment, and Evaluation.</u>

ANNEX H-I

BACKGROUND INFORMATION

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-I - BACKGROUND INFORMATION

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-I

BACKGROUND INFORMATION

INTRODUCTION

The North Branch Potomac River has been the subject of many surveys, investigations, and studies since 1932 when House Document No. 101, 73rd. Congress (General Plan for Navigation, Water Power, Flood Control, and Irrigation, Potomac River and Tributaries, MD, VA, WV, and PA) was submitted. In 1937, a report on the Potomac River and tributaries recommended a survey of the Potomac River Basin for flood control. The North Branch remained under Congressional discussion and review during the 1950's when several resolutions were adopted by the House and Senate Public Works Committees for a comprehensive plan for the Potomac River Basin. Details of these resolutions are given in the Potomac River Review Report, North Branch Potomac River above Cumberland, Maryland, Volume I, U.S. Army Egineer District, Washington, April 1961. This Review Report recommended construction of the Bloomington Lake Project on the North Branch Potomac River for flood control and other purposes.

The Potomac River Basin Comprehensive Study was initiated in 1956. The purpose of this study, which was in response to a resolution of the Committee on Public Works, United States Senate, adopted 20 January 1950, was to produce a water resources development plan to provide the optimum contribution to the economic and social well-being of the people, industry, and business and social institutions of the basin. Such a plan would serve in the future as a guide to the orderly development of the basin's water resources. The study was completed in 1963 and recommended construction of 16 major reservoirs, 418 headwater tributary reservoirs, three small flood control projects, land management and conservation measures to reduce erosion, and treatment of all wastes. The Bloomington Lake Project was one of the 16 recommended for construction. The detailed background information of this study is given in Appendix A.

AUTHORITY FOR BLOOMINGTON LAKE PROJECT

The Bloomington Lake Project on the North Branch Potomac River in Garrett County, Maryland, and Mineral County, West Virginia, was recommended in the report of the Chief of Engineers, dated April 1961 entitled, "Potomac River Review Report, North Branch Potomac River above Cumberland, Maryland," published as House Document Number 469, 87th Congress, 2nd Session. The Chief of Engineers recommended construction of a dam on the North Branch Potomac River above its confluence with Savage River to provide for the purposes of flood control, municipal and industrial water supply, water quality control, and recreation. The project was authorized under the Flood Control Act of 23 October 1962, Public Law 874, 87th Congress, 2nd. Session, for these purposes. This authorization required a non-Federal interest to agree to repay all costs allocated to water supply amounting to 33.2 percent of the project construction costs.

STATUS OF BLOOMINGTON LAKE PROJECT

The construction of the Bloomington Lake Project was initiated in 1971 and the project was operationally completed in July 1981 when deliberate storage of water was initiated. The project was officially dedicated on 20 September 1981. The final completion of the project is expected in June 1983 when all of the recreation facilities will be available for public use. Total project construction cost is estimated to be $174,300,000.

AUTHORITY FOR THE REFORMULATION STUDY

On 13 April 1978, five MWA Congressional Representatives (Herbert E. Harris, Joseph L. Fisher, Gladys N. Spellman, Newton I. Steers, and Walter E. Fauntroy) requested, through the House Public Works and Transportation Committee, that a restudy of Bloomington Lake be undertaken. Other agencies, such as the Interstate Commission on the Potomac River Basin (ICPRB), also supported an investigation of the full water supply potential of the project.

The Office of the Chief of Engineers notified the House Public Works and Transportation Committee that the reformulation of Bloomington Lake could best be accomplished as an integral part of the on-going MWA Water Supply Study authorized by Section 85 of Public Law 93-251 - the Water Resources Development Act of 1974. This authorization directs the Secretary of the Army, acting through the Chief of Engineers, to: (1) make a full and complete investigation and study of the future water resource needs of the Washington Metropolitan Area, including but not limited to the adequacy of the present water supply, nature of present and future uses, the effect of water pricing policies and use restrictions may have on future demand, the feasibility of utilizing water from Potomac estuary, all possible water impoundment sites, natural and recharged groundwater supply, wastewater reclamation, and effects of such projects will have on fish, wildlife, and present beneficial uses, and shall provide recommendations based on such investigation and study for supplying such needs, and (2) report to the Congress on a course of action for meeting both short-range and long-range water supply needs of the MWA.

Consequently, the Corps of Engineers made a preliminary analysis of reallocating some flood control storage to water supply storage to determine if a detailed reformulation study of Bloomington Lake was warranted. Using available information, it was concluded that some flood control storage could be reallocated to water supply storage without substantial adverse impact on flood protection provided by the project as authorized. This additional water supply storage could be effectively used to meet growing MWA water supply needs. On the basis of these preliminary conclusions, the Corps of Engineers recommended that a detailed reformulation study be undertaken and the work on reformulation study was initiated in Fiscal Year 1979.

PURPOSE OF REFORMULATION STUDY

The Bloomington Lake Reformulation Study was designed to: (1) investigate the full water supply capability of the Bloomington Lake Project by identifying and devising optimum release rules for a specific set of hydrologic and demand conditions; and (2) determine the feasibility of reallocating some water quality and/or flood control storage to water supply storage to furnish additional water supply for MWA, without substantially impacting the water quality in the downstream reaches of the North Branch Potomac River.

It should be added that since the original authorization of the Bloomington Lake Project in 1962, water quality conditions have changed due to enforcement of mine regulations and upgrading or construction of new waste treatment facilities in the North Branch Potomac River basin. Because of these changes in water quality, the needs for water quality storage have changed as well.

OTHER REPORTS

In September 1977, the Johns Hopkins University, Baltimore, Maryland, Department of Geography and Environmental Engineering was awarded a grant from the Office of Water Research and Technology (U.S. Department of Interior) with matching grants from the Virginia State Water Control Board, Maryland Department of Natural Resources, and the Interstate Commission on the Potomac River Basin. The purposes of research project No. 14-31-0001-8089 were to analyze the operation of the reservoirs in the Potomac River Basin and to develop operating strategies that addressed the interests of the various major water users in the MWA. The research dealt with the combined regulation of the existing low flow augmentation storage in Bloomington Lake and Savage Reservoir plus storage in local reservoirs on Occoquan Creek and the Patuxent River. (See Figure H-I-1 for a schematic of the location of these projects and their relationship to the MWA). The product of the investigation was a computer simulation model titled "Potomac River Interactive Simulation Model (PRISM)." PRISM was developed as a site-specific storage and flow accounting model for the MWA which allowed the user to test different reservoir operating policies and then observe the effects on projected deficits and remaining reservoir storages. The important conclusion of the Johns Hopkins work was that combined or cooperative operation of the four reservoirs as an integrated system (Bloomington, Savage, Occoquan, and Patuxent) could furnish significantly more water during a drought than if each reservoir were operated independently.

In November 1980, a Progress Report was prepared which presented the progress made to date on the Reformulation Study. The report included preliminary efforts made for collection of data such as hydrologic, water quality, environmental, social, and cultural information. It presented development of the PRISM Model and results of preliminary runs made to determine the optimum downstream target factor. (Details of the PRISM Model are presented in Annex H-III.) The Progress Report contained analysis of preliminary runs and applications of the PRISM Model to the Bloomington Lake Reformulation Study. A hydrologic model developed to investigate and assess the effects of high flows or flood flows on project regulation was also given in the Progress Report. The conclusions made from the preliminary results provided in the Progress Report were useful in determining the study direction and data needs for Stage III analysis.

EXISTING PROJECT DESCRIPTION

LOCATION

The Bloomington Lake Project is located on the North Branch Potomac River on the state line between Western Maryland and northeastern West Virginia. It lies partly in Garrett County, Maryland, and Mineral County, West Virginia. The damsite is 7.9 miles upstream from the confluence with the Savage River at Bloomington, Maryland, and just upstream from Barnum, West Virginia. The location of the project is shown in Figure H-I-2.

FIGURE H-I-1
SCHEMATIC REPRESENTATION OF THE SYSTEM OF RESERVOIRS SERVING THE MWA

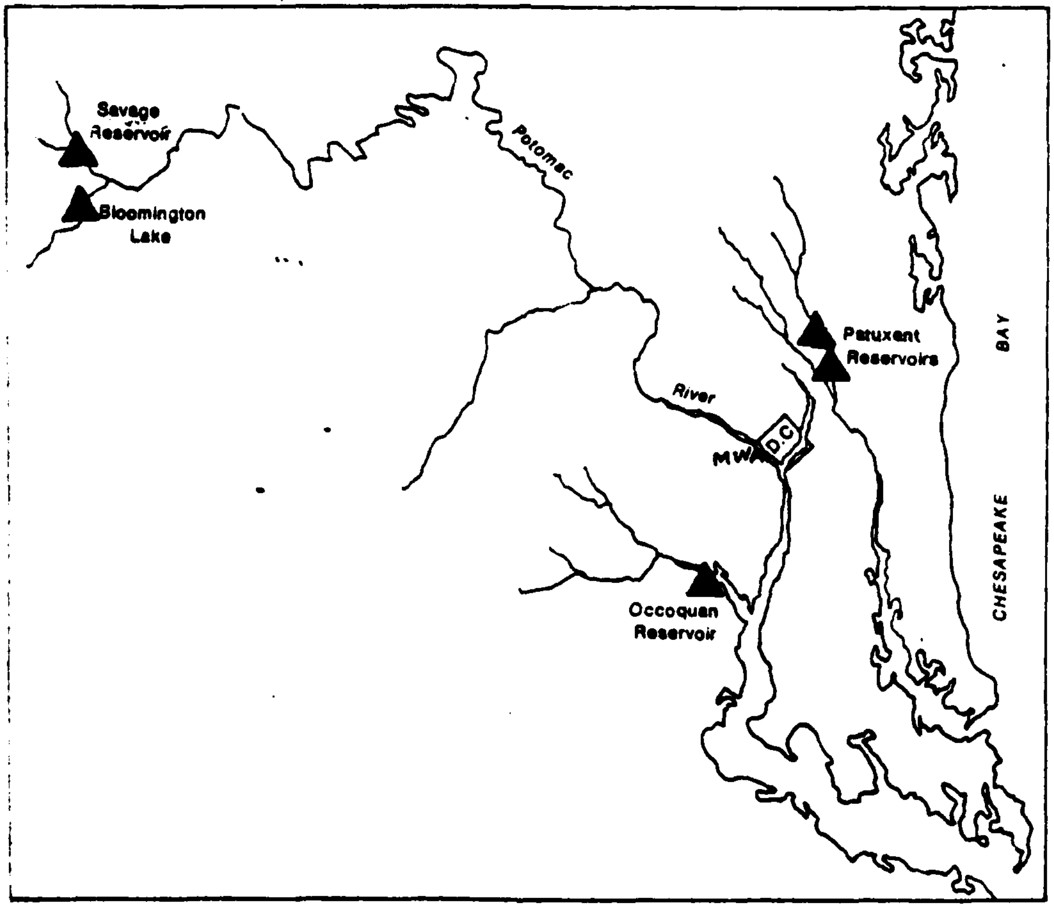
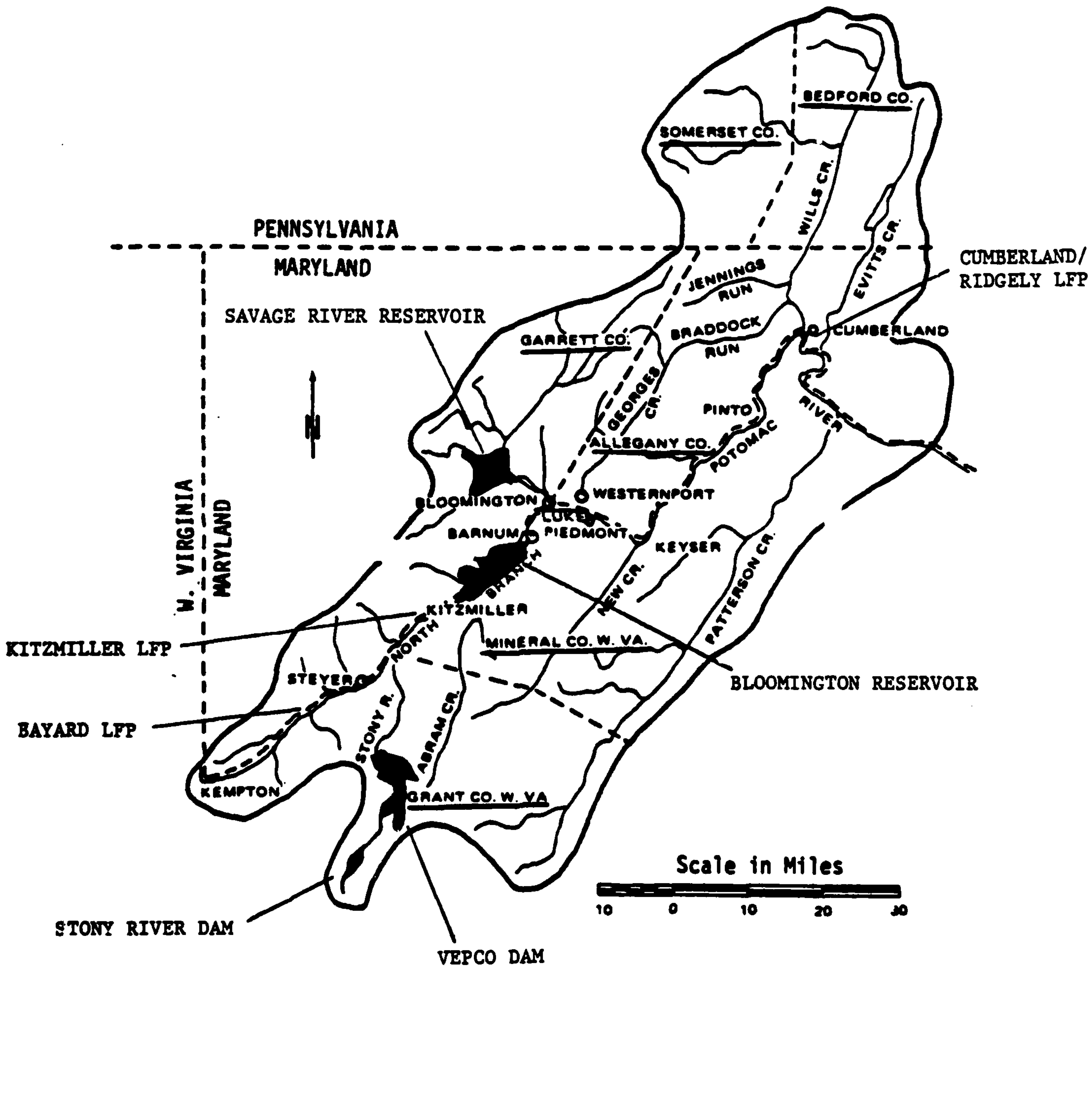


FIGURE H-I-2

LOCATION OF EXISTING PROJECTS IN
NORTH BRANCH POTOMAC RIVER BASIN



PROJECT AREA

The Bloomington Lake Project area is located in the Appalachian Highlands and is a part of the winding gorge of the North Branch Potomac River. From its source at about elevation 3150 feet above mean sea level (msl), the North Branch Potomac River descends to an elevation of about 1220 feet above msl at the damsite, a distance of approximately 36 miles. The watershed above the dam has a drainage area of 263 square miles; it is about 23 miles long, 12 miles wide, and is roughly rectangular in shape. The principal tributaries of the North Branch above the damsite are Stony River and Abrams Creek. The watershed contains no natural lakes and only a few small marshy areas. Since stream slopes are steep and the valleys are narrow, valley storage of floodwaters is small.

The hills bordering the river are heavily wooded and there is very little evidence of cultivation. The water of the North Branch Potomac River is clear, but the exposed rocks of the riverbed show the yellowish stains of sulphur pollution resulting mainly from mining operations upstream from the reservoir project. Much of the land around the project area has been stripped for coal. Generally, the water which drains the surrounding hillsides is heavily polluted with acid mine wastes, caused by both active and abandoned mines.

The mean annual precipitation for the watershed is abut 45 inches. Maximum and minimum amounts of annual precipitation of record at individual recording stations in the vicinity of the watershed are about 89 inches (Bayard in 1926) and 20 inches (Piedmont in 1930), respectively. The average annual snowfall is about 77 inches. The average annual temperatures at two stations in the vicinity of the project are between 47 and 53 degrees Fahrenheit.

There are two reservoirs upstream from the Bloomington Lake Project and both are on Stony River. One reservoir, owned by WESTVACO (West Virginia Pulp and Paper Company) was constructed in 1913 for downstream industrial water supply and has a drainage area of 12.6 square miles, a normal pool area of 435 acres, and a storage capacity of 5,520 acre-feet. The other, owned by the Virginia Electric Power Company (VEPCO), was completed in 1964 to provide cooling water for a stream-electric generating station and has a drainage area of 31.2 square miles, a normal pool area of 1,110 acres, and a storage capacity of 47,600 acre-feet. Their locations are shown in Figure H-I-2.

PROJECT FEATURES

The Bloomington Lake Project consists of a rolled earth and rockfill embankment approximately 296 feet high; a earth and random fill dike about 90 feet high in an adjacent saddle; a gated spillway in the left abutment with 5 tainter gates; a controlled outlet works consisting of an intake tower, service bridge, and concrete lined tunnel about 1,619 feet long under the right dam abutment; recreational facilities; relocation of the Western Maryland Railway, West Virginia Route 46, and utility lines; housing and shop facilities; and access roads. As authorized, the full conservation pool has a surface area of 952 acres, a shoreline of 13.6 miles, and extends upstream from the dam a distance of 5.5 miles. The flood control pool has a surface area of 1,184 acres and extends upstream from the dam about 6.6 miles. Pertinent data for the project are shown in Table H-I-1 and project features are shown in Figure H-I-3.

TABLE H-I-1
BLOOMINGTON LAKE PROJECT
PERTINENT DATA

DRAINAGE AREA (square miles)	
North Branch Potomac River at Bloomington Dam	263
North Branch Potomac River above confluence with Savage River	287
ELEVATIONS (feet above mean sea level)	
Top of dam	1,514
Spillway design flood (max pool)	1,508.9
Guide taking line for fee acquisition	1,508 *
Guide taking line for flowage easements for utility acquisition	1,500
Static full pool (top of closed crest gates)	1,500
Upper limit of clearing	1,469
Spillway crest	1,468
Conservation lake	1,466
Winter lake	1,410
Gate Sill	1,255
Streambed at centerline of dam	1,218
DAM	
Type	Rolled earth and rockfill
Length (ft)	2,130
Height above streambed (ft)	296
Top width (ft)	25
Maximum width at base (ft)	1,640
DIKE	
Type	Rolled earth and random fill
Length (ft)	900
Height (maximum ft)	90
Top width (ft)	25
Maximum width at base (ft)	845
SPILLWAY	
Type	Chute
Crest length (ft)	210
Number of tainter gates	5
Size of tainter gates (ft)	32 x 42

*Elevation 1508 (or a line measured 300 feet horizontally from the 1500 contour, whichever provides the greater area).

TABLE H-I-1 (Cont'd)

OUTLET WORKS

Type	Tunnel in rock
Length of tunnel	1,619
Inside diameter of tunnel	16'4"
Number of service gates	2
Size of gates	7'2" x 16'4"
Type of gates	Hydraulically opened
Number of emergency gates	2
Multilevel ports of water quality control	5

RESERVOIR

Length of conservation lake (airline, mi)	2.8
(along riverbed, mi)	5.5
Length of flood control pool (airline, mi)	3.5
(along riverbed, mi)	6.6
Shoreline of conservation pool (mi)	13.6

STORAGE	Acre-feet Net	Cumulative	Elevation ft above msl
Sediment reserve	2,700	2,700	
Conservation	92,000	94,700	1466
Flood control	36,200 *	130,900	1500
Design surcharge	10,800	141,700	1508.9
Top of dam	6,500	148,200	1514

POOL AREAS (ACRES)

Dead storage (below gate sill)	42
Conservation and recreation lake	952
Pool at spillway crest	965
Static full pool (top of closed crest gates)	1,184
Spillway design flood (maximum pool)	1,247

LANDS ACQUIRED (ACRES)

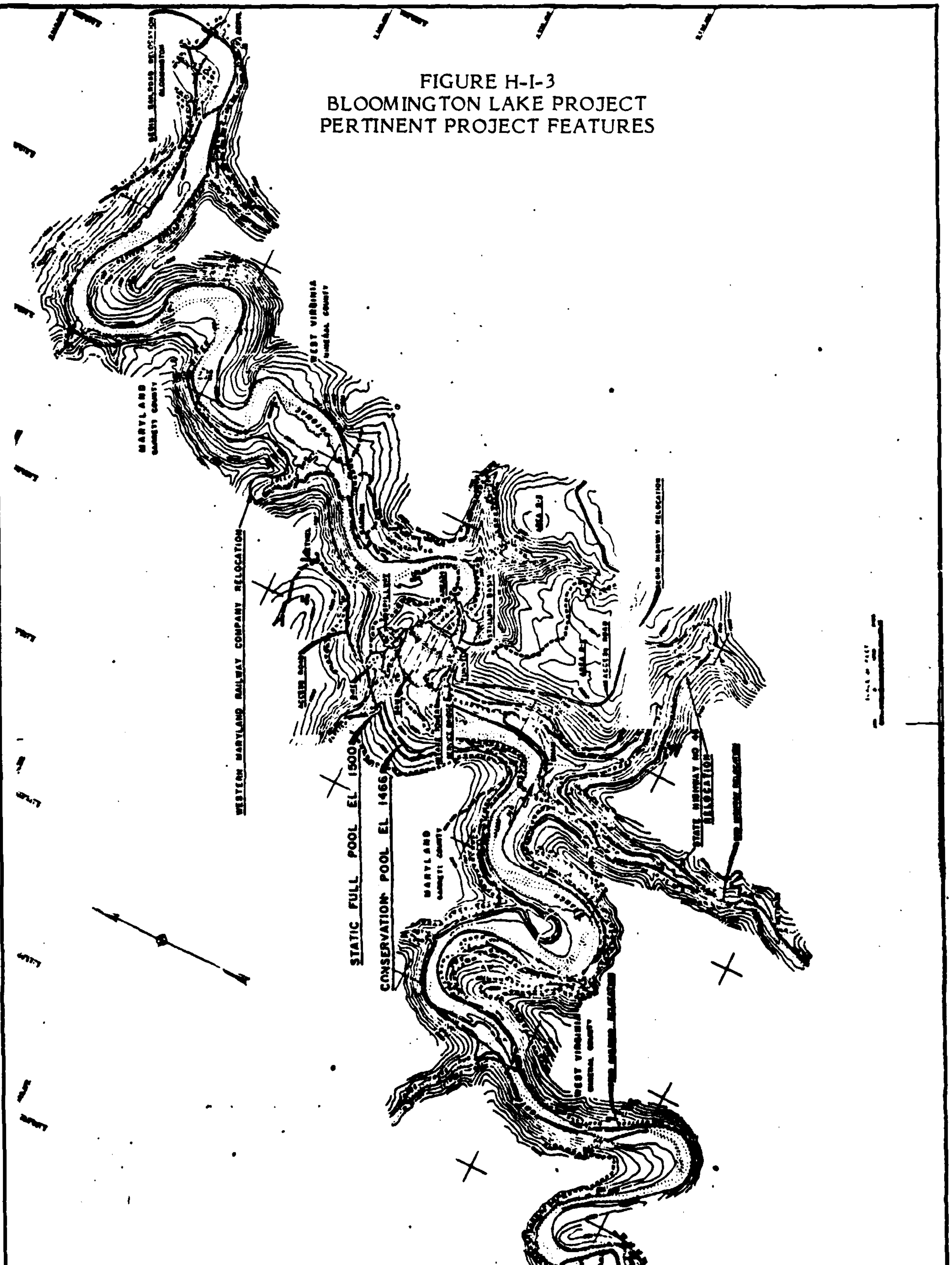
Dam and reservoir area	4,298
Public access area	146
Relocations	254
Total	4,698

RELOCATIONS

	Abandonment	Relocation
Western Maryland Railway (miles)	13.3	11.6
West Virginia Route 46 (miles)	2.5	3.3
Telephone lines (miles)	2.5	0
Powerlines (miles)	2.8	2.0
Pipelines (miles)	1.3	1.5
Cemeteries (42+ graves)	2	2

*In addition, a minimum of 44,400 acre-feet of conservation storage will be available seasonally for flood control.

FIGURE H-I-3
BLOOMINGTON LAKE PROJECT
PERTINENT PROJECT FEATURES



STORAGE

The project controls about 263 square miles of drainage area, or about 20 percent of the total drainage area in the North Branch Potomac River. The project's authorized storage is allocated as follows: 2,700 acre-feet for sediment; 92,000 acre-feet for low flow augmentation (water supply and water quality control) and recreation; 36,200 acre-feet for flood control; 10,800 acre-feet for design surcharge; and 6,500 acre-feet to the top of the dam for a total storage of 148,200 acre-feet (See Figure H-I-4). Overall, the project will store 10.37 inches of runoff from the drainage area above the dam. During the summer and fall months, the project provides 2.58 inches of flood runoff (36,200 acre-feet) between the top of conservation pool at elevation 1,466 feet msl and elevation 1,500 feet msl (top of flood control pool). During the winter and spring months, however, the project provides 5.74 inches of runoff (80,600 acre-feet) between elevations 1,410 feet msl and 1,500 feet msl when the conservation pool is purposely drawndown to accommodate larger flood runoffs.

In Table H-I-2, the authorized low flow augmentation (LFA) storage has been further suballocated into water quality and water supply storage according to the benefits attributed to these purposes in the authorization document. Column 2 of Table H-I-2 shows the percentage of the total average annual cost of the project suballocated among water supply and water quality purposes, as listed in Tables 27 and 28 of the authorization document for the Bloomington Lake Project (House Document No. 469). On this basis, 74.5 percent of the construction cost was allocated to LFA. Non-Federal interests were required to repay the 33.2 percent of the total construction cost allocated to water supply. The percentage of LFA storage for each of the purposes, water supply and water quality, is shown in Column 3 of Table H-I-2, with corresponding storages shown in Column 4. The water supply storage was further divided into initial water supply storage (7.78 percent of the total storage or 7,158 acre-feet) and future water supply storage (36.78 percent of the total storage or 33,837 acre-feet).

LOCAL COOPERATION

In accordance with the provisions of the Water Supply Act of 1958, as amended, costs allocated to water supply in any Federal project are to be repaid by non-Federal interests. For Bloomington Lake, the authorizing legislation required that certain actions be taken by non-Federal sponsors before construction could begin. These actions by the non-Federal sponsors included the following items:

(1) Agree to pay all costs allocated to water supply, amounting to 33.2 percent of the construction cost of the project, presently estimated at $57,867,600, to be paid either in a lump sum prior to commencement of construction or in installments prior to commencement of pertinent work items in accordance with construction schedules as required by the Chief of Engineers; or as an alternative:

(a) Contract with the United States to repay, within a period of 50 years, a portion of the costs allocated to water supply on the basis of initial requirements, amounting to 5.8 percent of the construction cost, presently estimated at $10,109,400 plus interest during construction; and

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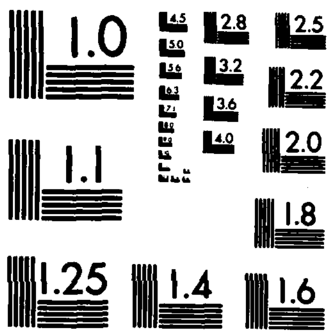

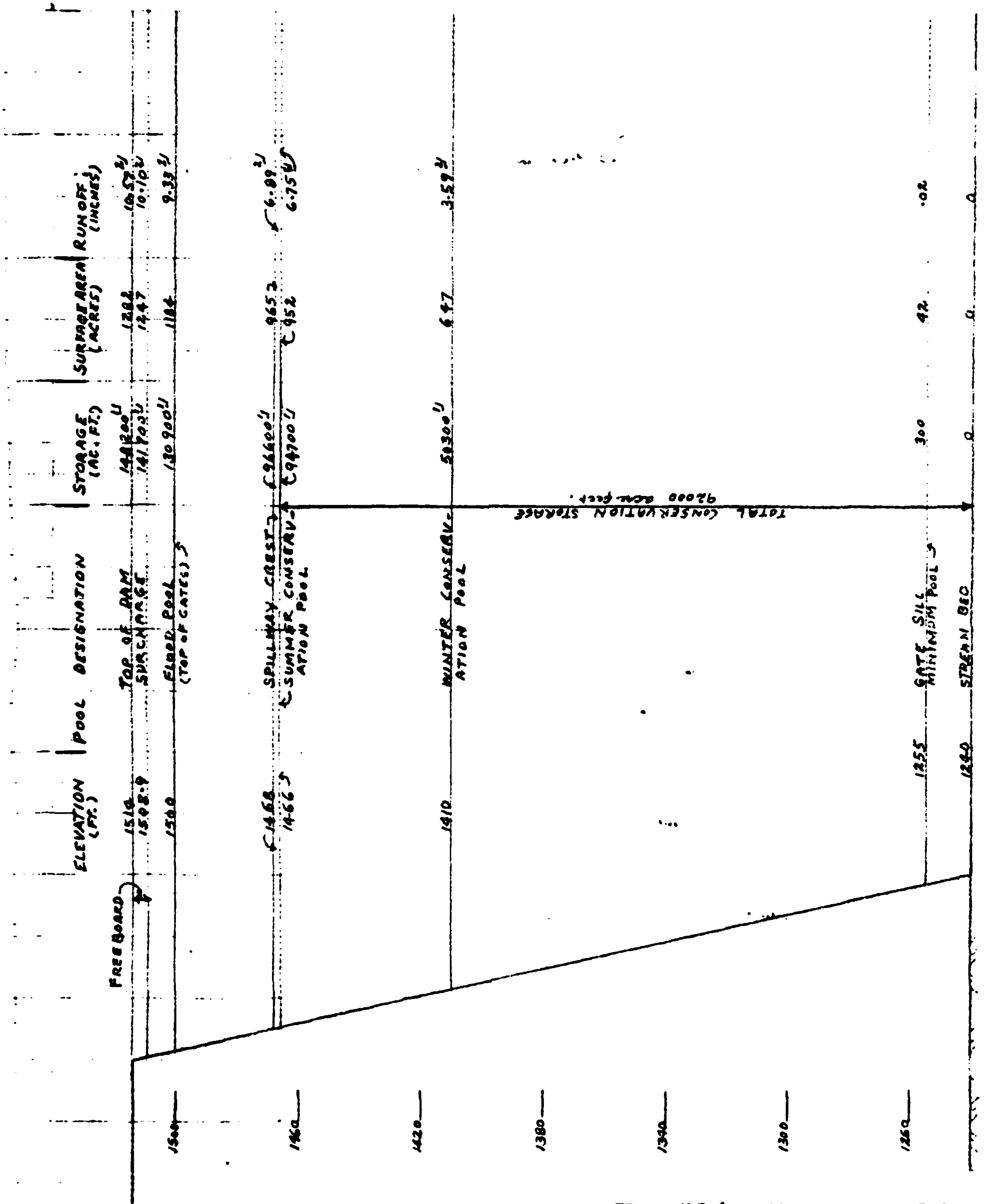

FIGURE H-I-4 BLOOMINGTON LAKE PROJECT ALLOCATION OF PROJECT STORAGE

TABLE H-I-2

SUBALLOCATION OF LOW FLOW AUGMENTATION (LFA) STORAGE*

Type & Location Project Construction Cost	Percentage of LFA Storage	Percent of (acre-feet)	Storage
(1)	(2)	(3)	(4)
A. Water Supply			
Initial (North Branch)	5.8	7.78	7,158
Future (North Branch)	20.6	27.65	25,438
Future (Downstream)	6.8	9.13	8,399
Subtotal (A)	33.2	44.56	40,995
B. Water Quality			
North Branch	32.8	44.03	40,508
Downstream	8.5	11.41	10,497
Subtotal (B)	41.3	55.44	51,005
Total LFA A+B	74.5	100.00	92,000

* Based on authorization document.

(b) Furnish assurances satisfactory to the Secretary of the Army that they would repay the remaining costs allocated to water supply on the basis of future requirements amounting to 27.4 percent of the construction costs, presently estimated at $47,758,200, plus interest during construction on this amount with interest on the unpaid balance, beginning 10 years after storage is first available for water supply and with final payment to be made 50 years thereafter, except that no interest would be charged thereon for the first 10 years after storage is first available for water supply.

(2) Contract with the United States to pay the operation and maintenance cost allocated to initial water supply, presently estimated at $9,860 annually, beginning when storage is first available for water supply, and furnish assurances satisfactory to the Secretary of the Army that they would pay the operaton and maintenance costs allocated to future water supply, presently estimated at $43,940, annually.

(3) Agree to pay the major replacement costs allocated to initial water supply as such costs are incurred, presently estimated to average $9,190 annually, and furnish assurances satisfactory to the Secretary to the Army that they would pay major replacement costs allocated to future water supply, presently estimated at $43,440, annually.

(4) Furnish assurances satisfactory to the Secretary of the Army of their intent to control pollution of the streams subject to low-flow augmentation by adequate treatment or other methods of controlling wastes at their source.

(5) Furnish assurances satisfactory to the Secretary of the Army that they would protect downstream channels from encroachments which would adversely affect operation of the project.

In 1969, the Maryland State Legislature created the Maryland Potomac Water Authority (MPWA) to contract for Bloomington's initial water supply storage and to furnish the assurances necessary to allow construction initiation. A water supply contract between the Federal Government and the MPWA for repayment of initial water supply costs was signed on 4 November 1970. Under terms of the contract, the initial water supply storage available to MPWA was 7.78 percent of the low flow augmentation storage (totalling 92,000 acre-feet), or 7,158 acre-feet. Repayment of the initial water supply storage was apportioned by the MPWA among Garrett, Allegany, Washington, Frederick, Montgomery, and Prince Georges Counties in Maryland, Fairfax County Water Authority in Virginia, and the District of Columbia. The District of Columbia was also authorized by Congress to participate in cost-sharing for Bloomington Lake water. Assurances covering repayment of costs allocated to future water supply were received from the Commonwealth of Virginia, the District of Columbia, the State of Maryland, and the State of West Virginia, which satisfied the requirements of the Water Supply Act of 1958, as amended, prior to the initiation of project construction.

Subsequently, the Potomac River water users, under the plan developed by the water suppliers in 1982 through the Metropolitan Washington Water Supply Task Force have agreed: (1) to purchase all the water supply storage in the Bloomington Lake Project from the Army Corps of Engineers and relieve the MPWA of any obligation for repayment of costs for the initial water supply storage it had already contracted for (the cost of all water supply storage including capital costs and operation, maintenance and major replacement costs will be shared by the three Potomac water users with WSSC paying 50 percent, FCWA 20 percent, and the Aqueduct 30 percent); and (2) the three Potomac water users will share the operation and maintenance costs of the Savage River Reservoir which was being paid by the Allegany County, because the Savage water is needed to neutralize the acidic water from the Bloomington Lake Project (these costs will be shared with WSSC paying 40 percent, FCWA 16 percent, District of Columbia (Aqueduct) 24 percent; and Allegany County 20 percent).

Formal contracts for the purchase of future water supply storage in Bloomington Lake and the transfer of responsibilities from the MPWA to the MWA users for the initial water supply storage were consumated in July 1982.

RESERVOIR OPERATION

The Bloomington Lake Project, as authorized, will operate to provide flood protection for communities along the North Branch Potomac River. The project will be operated to reduce flood flows at downstream damage centers. Key damage centers include Luke, Westernport, and Cumberland in Maryland and Piedmont, Keyser, and Ridgeley in West Virginia. Regulation of Bloomington Lake will be coordinated with the Savage River Reservoir. The Savage River Reservoir provides some incidental flood control storage, but most of its 20,000 acre-feet of storage capacity is used for low flow augmentation.

During low flow periods, Bloomington Lake will be used to supplement stream flows in the North Branch Potomac River for water supply and water quality control. Water will be stored in late winter and spring for release during the normally dry summer, fall, and early winter months. As presently authorized, the Bloomington Lake Project, in conjunction with the Savage River Reservoir, can provide a safe yield of 305 cubic feet per second (cfs) or 197 mgd at Luke, Maryland, during low flow periods. Of the total 305 cfs (197 mgd), Savage Reservoir and the natural North Branch Potomac River flow at Luke, Maryland, are expected to provide 93 cfs (60 mgd) with the remaining 212 cfs (137 mgd) to be provided by Bloomington Lake.

The Bloomington Lake Project was authorized in 1962 and one of the project purposes was to increase the North Branch Potomac River flow during the low flow periods at Luke, Maryland, from 93 cfs (60 mgd) to 305 cfs (197 mgd) for water quality control. Since the authorization of the project, many changes have taken place which have helped to improve water quality. New rules have been enforced to control mine discharges. Many communities have either upgraded or built new waste treatment facilities. With these changes in place, the water quality analysis conducted with the help of a water quality model have indicated that a flow of 120 cfs (78 mgd) at Luke, Maryland would be sufficient to maintain water quality standards in the downstream reaches of the North Branch Potomac River. Annex H-II - Water Quality Investigations contains more detailed information on the water quality analysis. It should be noted that the flow of 120 cfs (78 mgd) would be provided by operation of the Bloomington Lake Project in conjunction with the Savage River Reservoir (systems approach). For a discussion of systems operation, see Annex H-III - PRISM Development and Application.

RECREATIONAL RESOURCES

Because of the acid-polluted waters and low flows, the North Branch has limited recreation use at present, although some canoeing is done. There are presently no fishing or water-contact activities of any significance in the river, the later probably due to the social unacceptance of acid water for swimming rather than from a health standpoint. At the present time, hunting and hiking are the only activities of any significance.

The major attractions offered at Bloomington Lake will be sightseeing, picnicking, overnight camping, and boating. The initial plan of development will provide facilities to accommodate an initial visitation of 100,000. Additional development is planned to accommodate an ultimate visitation of 150,000 within 25 years after the project is constructed. Figure H-I-5 shows the locations of the areas planned for initial development and the areas proposed for further development.

The High Timber Camping area, which is located on the West Virginia shore on a high ridge overlooking the damsite, has approximately 100 campsites. Facilities include fresh water, showers, and comfort stations. Below the High Timber camping area, and between Route 46 and the shoreline, the Howell Run picnic area and the Howell Run boat launch are located. The picnic area will have approximately 100 tables, with several of the tables located under a pavilion. The boat launch has approximately 60 car-trailer spaces. In addition to the three formal recreation areas, there are several overlooks around the damsite that will have facilities for picnicking.

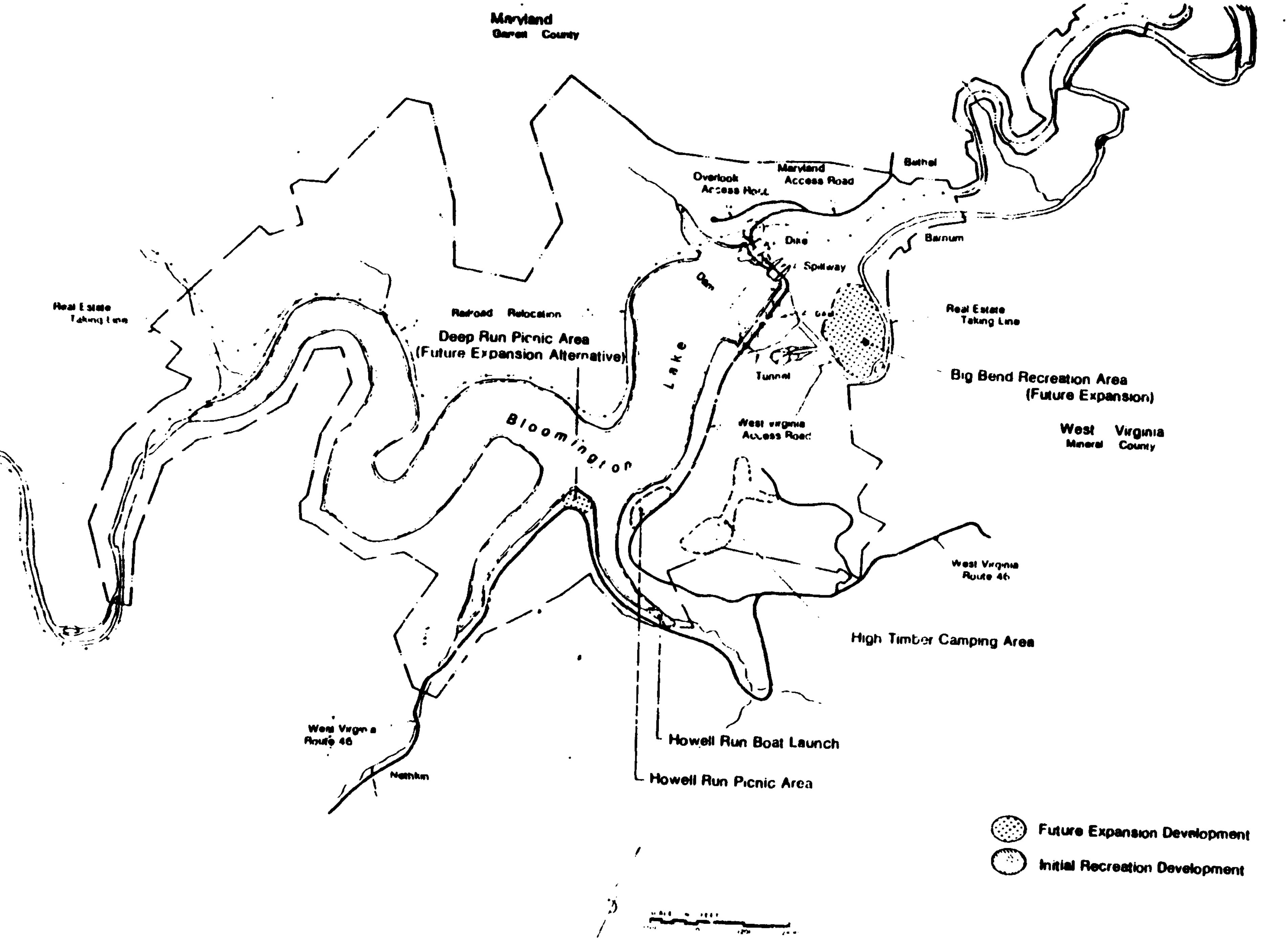

FIGURE H-I-5 RECREATION AREAS

OTHER PROJECTS

FEDERAL PROJECTS

SAVAGE RIVER RESERVOIR

The Savage River Reservoir was initiated in 1935 by the Upper Potomac River Commission (UPRC) for the purposes of increasing low flow for industrial use, and to relieve stream pollution conditions along the North Branch Potomac River from Luke to Cumberland, Maryland. The project is located on the Savage River in Garrett County, Maryland, approximately 5 miles upstream from the junction of Savage River and the North Branch and immediately downstream of the junction of Crabtree Creek and Savage River, approximately 5 miles northwest of Bloomington, Maryland (see Figure H-I-2). The construction of an earth and rockfill dam, with a maximum height of 184 feet above the streambed, was started in 1939 under the Works Progress Administration. With approximately 65 percent of the work completed, construction was suspended in December 1942 because of World War II. Construction was resumed in March 1949. The original design and final construction of the project was under the supervision of the U.S. Army Engineer District, Washington.

The project was first placed in operation in January 1952. The dam and reservoir were transferred to the UPRC for operation and maintenance under Federal regulations on 1 July 1953. The reservoir has a storage capacity of 20,000 acre-feet, which is primarily intended for regulation of stream flow for industrial purposes and pollution abatement with some incidental flood control protection provided by the storage capacity during scheduled periods of drawdown. The Savage River has good water quality, and releases from the Savage River Reservoir are used to dilute acidity in the North Branch Potomac River. Pertinent project data are given in Table H-I-3.

The primary purpose of the Savage River Reservoir was to maintain, during low flow periods in the North Branch Potomac River, a flow of 93 cfs (60 mgd) at Luke, Maryland. This 93 cfs (60 mgd) flow included natural flow in the North Branch Potomac River plus the Savage River Reservoir release. With the addition of the Bloomington Lake Project as authorized in 1962, it is estimated that a flow of 305 cfs (197 mgd) could be maintained at Luke, Maryland. During the Bloomington Lake Reformulation Study, the feasibility of combining the operation of both Bloomington Lake and Savage River projects as a system were investigated. This systems approach may improve water quality in the North Branch Potomac River and also help alleviate water supply deficits downstream.

At present, the UPRC operates and maintains the Savage River Project in accordance with Federal regulations. The cost of operation and maintenance of these facilities were paid by Allegany County through the UPRC. Recently, the Potomac River water users (WSSC, FCWA, and Aqueduct) have agreed to share with the Allegany County the operation and maintenance costs of the Savage River Reservoir, as the Savage River water would be needed to dilute the acidity in the North Branch Potomac River.

TABLE H-I-3

SAVAGE RIVER RESERVOIR
PERTINENT DATA

DRAINAGE AREA (square miles)	105
ELEVATION (feet above mean sea level)	
Top of Dam	1497.5
Spillway Crest	1468.5
DAM	
Type	earth and rockfill
Length (feet)	1050
Height of dam above streambed (feet)	184
Top width (feet)	20
RESERVOIR	
Area at spillway crest	360 acres
Storage at spillway crest	20,000 acre-feet
SPILLWAY	
Type of spillway	side channel
Length at crest elevation	320 feet
Discharge capacity - 24.3 feet depth on crest	97,200 cfs
OUTLET STRUCTURE	
a. Tunnel	
Type	Horseshoe-shaped
Diameter	10 feet
Length	1,170 feet
Discharge capacity (reservoir water surface at spillway crest)	4,850 cfs
b. Slide Gates	
Type	Hydraulically operated
Number	2 twin scts.
Size	4 ft. x 10 ft.

Before the Savage River Reservoir was constructed, the Town of Westernport, Maryland, had a small water supply dam at the site. This small dam was submerged under the new Savage River Reservoir, however, the Town of Westernport retained its rights to draw water directly from the Savage River Reservoir for its water supply needs. The maximum withdrawal is limited to one million gallons per day (mgd).

LOCAL FLOOD PROJECTS

The North Branch Potomac River watershed has three local flood protection projects which were constructed to protect several communities against floods. A small local flood protection project was constructed in Bayard, West Virginia, on Buffalo Creek, upstream of its confluence with the North Branch Potomac River. Completed in 1964, it consisted of channel improvements, a levee, and reconstruction of a highway bridge. Another local flood protection project was also completed in 1964 for Kitzmiller, Maryland, and Blaine, West Virginia. This project contained channel improvements, levees, and interior drainage controls. At Cumberland, Maryland, and Ridgeley, West Virginia, a local flood protection project was completed in 1959 consisting of channel improvements, floodwalls, levees, interior drainage facilities, construction of a new industrial dam, and alteration and reconstruction of highway and railroad bridges. Locations of all three local flood protection projects in relation to Bloomington Lake are shown on Figure H-I-2.

NON-FEDERAL PROJECTS

There are three non-Federal water supply reservoirs located within the MWA, (two in Maryland and one in Virginia), which were considered in the Bloomington Lake Reformulation Study. Figure H-I-1 shows the location of these reservoirs in relation to the Bloomington Lake Project.

The reservoirs in Maryland are Triadelphia and Rocky Gorge. These reservoirs control drainage areas of 78.4 square miles and 132 square miles, respectively. These reservoirs are owned by WSSC. Details of these reservoirs are presented in Appendix D - Supplies, Demands, and Deficits.

The Occoquan Reservoir is located on Occoquan Creek in Fairfax County, Virginia, and provides water to the Fairfax County Water Authority. Structural, hydrologic, and other details of this reservoir are also given in Appendix D - Supplies, Demands, and Deficits.

RELATED INVESTIGATIONS AND AGREEMENTS

LOW FLOW ALLOCATION AGREEMENT

The Potomac Low Flow Allocation Agreement (LFAA) provides a formula for allocating the Metropolitan Washington Area's available water supply from the Potomac River during periods of low flow so that no one user suffers disproportionate shortages. The Agreement insures that the water resource is equitably distributed, but it does not increase the available water supply and does not eliminate or reduce the water supply shortages in the MWA. The Agreement was signed on 11 January 1978 by the U.S. Government, the State of Maryland, Commonwealth of Virginia, the District of Columbia, the Washington Suburban Sanitary Commission, and the Fairfax County Water Authority; the Agreement was subsequently modified in July 1982.

The LFAA applies to water withdrawals in the reach of 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. Under the provisions of the Agreement (Article 2.C.2), water supply for the MWA will be allocated during Potomac River low flow periods based on a rolling average of winter demands (December, January, and February) for five consecutive winter periods immediately preceding the allocation period. In other words, each service area gets the same proportionate share of water supply during low flow conditions as it used, on the average, during the preceding five winter periods.

Because this agreement would have a direct, although variable, effect on future shortage conditions within the MWA and one of the purposes of the Bloomigton Lake Reformulation Study was to investigate means to alleviate MWA shortages through project operation and storage reallocation, the flow allocation formula in the Agreement was incorporated into the modified PRISM model. (See Annex III - PRISM Development and Application).

CO-OP PROGRAM OF INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

In November 1979, the Section for Cooperative Water Supply Operations on the Potomac (CO-OP) was established by the Interstate Commission on the Potomac River Basin (ICPRB), under its Section III charter authority. The CO-OP consists of the ICPRB Commissioners of the District of Columbia, Maryland, Virignia, and West Virginia; and is supported by a technical advisory committee comprised of representatives from the Fairfax County Water Authority (FCWA), Washington Suburban Sanitary Commission (WSSC), and the Washington Aqueduct (WAD) of the Corps of Engineers. The general purposes of the CO-OP are to assist in resolving issues relative to water supply for the Metropolitan Washington Area, assist in negotiating contracts and agreements for water supply, and to develop regulation procedures for reservoirs that provide water resources benefits within the Commission's boundaries.

In addition, the specific purposes of the CO-OP efforts are: (1) to establish a central cooperative technical center to receive and analyze all pertinent data on water availability in the Potomac, Patuxent, and Occoquan Basins; (2) to develop a long-range river flow forecasting technique suitable for scheduling reservoir releases; (3) to evaluate reservoir operating policies for all purposes at each reservoir; (4) to coordinate the purchase agreements for conservation storage in the Bloomington Lake; and (5) to develop techniques for annual drought risk assessments and emergency operation coordination.

The Bloomington Lake Reformulation Study focused on determining the maximum water supply potential of the Bloomington Lake Project, with and without storage reallocation, when operated in conjunction with the downstream reservoirs. The CO-OP program, however, is concentrating on river flow forecasting and establishing the actual mechanism by which multiple reservoir releases and river withdrawals can be efficiently managed on a day-to-day basis. For this purpose, the CO-OP Section has developed and is using a water supply simulation model developed specifically for this purpose. This model evaluates the effectiveness of various daily reservoir operating strategies for meeting the future water supply demands for the Potomac River users in the MWA. The water supply utilities have adopted this CO-OP Model as the tool for establishing the daily reservoir regulation policies for the joint operation of the reservoirs serving the MWA.

ENVIRONMENTAL FLOWBY

Environmental flowby is defined as the flow remaining in the Potomac River after water supply diversions have been made. A certain minimum volume of flowby is considered to be essential for maintaining the environmental integrity of the lower riverine and upper estuarine portions of the Potomac River.

Because of the physical possibility of being able to withdraw essentially all of the water from the Potomac River during low flow conditions, the establishment of a minimum flowby has received much attention. The flowby would maintain a minimum discharge downstream of Little Falls for fish and wildlife purposes, and could also serve to enhance the water quality of the Upper Potomac estuary. The issue of flowby is a direct outgrowth of the negotiations leading to the original signing of the Low Flow Allocation Agreement (LFAA) in January 1978. This Agreement requires that in calculating the water available for allocation, flow needed in the Potomac River for purposes of maintaining environmental flowby should be determined and balanced against essential human, industrial, and domestic requirements for water.

As part of their responsibility under the LFAA (Article 2.C), the State of Maryland, in coordination with the U.S. Fish and Wildlife, the Corps of Engineers, and others completed flowby investigations and published a final report in January 1982. The report recommended: (a) establishing a minimum daily environmental flowby of 100 million gallons per day below Little Falls Dam; (b) at a calculated flow of 500 mgd just above the Great Falls intake, shifting Aqueduct withdrawals to the Little Falls Dam intake to maintain at least 300 mgd between Great Falls Dam and Little Falls Dam; and (c) upon completion and operation of Bloomington Reservoir, establishing a monthly flow schedule, based on existing information regarding water management opportunities, that would optimize in-stream values while meeting water supply needs.

The signatories of the LFAA have adopted a resolution approving the recommended flowby (100 mgd) included in the State's report. Recommendation (b) was modified by adding a qualifying statement which permits reduction of the 300 mgd flow contingent upon the Aqueduct's ability to meet 200 mgd difference between 300 mgd in the reach above Little Falls and the 100 mgd flowby over Little Falls. The results, recommendations, and basis for the flowby recommendations are described in the report published by the State of Maryland entitled, "Potomac River Enviromental Flowby Study, Maryland Department of Natural Resources, Water Resource Administration, 1981." Further details of the flowby study are given in Appendix D - Supplies, Demands, and Deficits.

In the Bloomington Lake Reformulation Study, a flowby of 100 mgd over Little Falls was assumed. The sensitivity of water supply plans to higher levels of flowby (up to a maximum of 500 mgd) was also considered.

HYDROPOWER POTENTIAL

AUTHORIZATION REPORT

Hydropower was considered as a project purpose in the authorizaton report for the Bloomington Lake Project. The authorization report entitled, "Potomac River Review Report - North Branch Potomac River Above Cumberland," published as House Document No. 469-87-2, listed the Bloomington Project site as having potential as either a pumped storage or conventional peaking project. This recommendation was based on preliminary investigations made by the Federal Power Commission.

The pumped storage project would have an installed capacity of 600 megawatts (MW) under a head of 1,200 feet. Investigations for the conventional peaking alternative concluded that the optimum installed capacity would be 9 MW, with a dependable capacity of 2 MW and an average annual energy production of 58,000 MW-HR. Because of the significant potential of the conventional peaking alternative, it was proposed that a penstock with a bulkhead be included in the design of the Bloomington Dam for future hydropower development by Federal or Non-Federal interests.

1963 POTOMAC RIVER BASIN REPORT

In 1963 the Corps of Engineers, Baltimore District, published a comprehensive report on the Potomac River Basin. This report recommended construction of several reservoir projects to regulate the river flow for water supply and other purposes. Bloomington Lake Project was one of the several projects recommended.

The 1963 Potomac Report, published as House Document No. 91-343, June 1970, contained similar recommendations as were made for the authorization document concerning hydropower at the Bloomington Lake Project.

GENERAL DESIGN MEMORANDUM

During the preliminary design phase of the Bloomington Lake Project, the feasibility of including a hydroelectric plant was reevaluated by the Federal Power Commission. The Commission concluded that a pumped storage alternative could use the Bloomington Lake as the lower pool, and a reservoir site in nearby Piney Swamp as the upper pool. With this arrangement it was estimated that the optimum installed capacity would be 600 MW under an average head of 1,180 feet. The Commission also concluded that for a conventional peaking alternative to be economically feasible, Bloomington Lake would have to be maintained year-round at a summer conservation pool elevation of 1466 feet msl. If the reservoir was operated as planned for full drawdown of the conservation pool to elevation 1410 ft. m.s.l., a conventional peaking powerplant could not be economically justified.

If the reservoir was maintained at elevation 1466 m.s.l. year-round, the Commission concluded that the optimum installed capacity of a conventional peaking plant would be 30 MW under an average head of 210 ft. Average annual energy production was estimated to be 65,000 MW-HR. The powerplant would use the proposed tunnel as a conveyance system but it would have to be steel-lined. Additionally, a low reregulating dam would be necessary to minimize peaking discharges from the powerplant.

After a thorough evaluation of the optimum pumped storage and conventional peaking alternatives, the Commission concluded that they were both of marginal economic justification. Furthermore, it was decided that the project, as designed, was adaptable to the possible future installation of a hydropower facility without any specific provision in its initial construction.

Based on these conclusions, the Chief of Engineers decided that hydropower would not be included in the Bloomington Lake Project. Results of the Federal Power Commission's evaluations and the conclusions drawn from these analyses are described in the report entitled, "Bloomington Reservoir Supplement No. 1 to General Design Memorandum No. 3," - Baltimore District Corps of Engineers, June 1967."

NATIONAL HYDROELECTRIC POWER RESOURCES STUDY

Since the preliminary design studies, the hydopower economics have changed significantly with the massive oil price increases experienced in the 1970's. Because of the rise in energy prices due to imported oil and the Nation's desire to become energy self-sufficient, Congress authorized the National Hydroelectric Power Resources Study (NHS) in the Water Resources Development Act of 1976. The objective of the NHS was to investigate the most efficient method of using hydropower resources. As a result, the Corps of Engineers developed an inventory of potential hydropower sites. The Bloomington Lake Project was reevaluated as part of this effort, and based on a cursory review, showed the potential for a run-of-river powerplant with an installed capacity of 9.6 MW under an average head of 246 feet. Average annual energy production was estimated to be 37,400 MW-HR. Because of this potential, the Bloomington Lake Project was recommended for a more detailed hydropower evaluation.

RECONNAISSANCE REPORT

As a result of the NHS, the Chief of Engineers through a letter dated 15 December 1979, directed the Baltimore District to undertake a more detailed and site specific investigation of the power potential for the Bloomington Lake Project then under construction. These investigations were presented in the Bloomington Lake Hydropower Reconnaissance Report, which was completed in January 1981 using Operation and Maintenance appropriations under the authority of Section 216 of the Rivers and Harbors Flood Control Act of 1976, Public Law 91-6110. The scope of these investigations was limited to a run-of-river alternative because: (1) the other authorized project purposes such as water supply, water quality, flood control and recreation have precedence over hydropower; and (2) the limited study funding did not allow a detailed study including project storage reallocation for hydropower.

Stream flow duration procedures were used to develop the power potential under two different reservoir operation schemes: (a) conservation pool varying seasonally from elevation 1466 to 1410 feet msl; and (b) conservation pool maintained year-round at elevation 1466 msl. The powerplant alternatives were sized using the design flow at the 20, 30, and 40 percent exceedence levels on the flow duration curve. Multiple units were also investigated to ensure that the energy production was maximized. Different conveyance routes were considered including a new separate conveyance system and various methods of using the existing intake and tunnel. Evaluation of these alternatives indicated that the recommended plan was a 13.8 MW run-of-river powerplant with a new right abutment conveyance system, entirely separate from the existing tunnel. The estimated cost of this plan was $27,411,000 (November 1980 price levels) and the plan had a benefit-to-cost ratio of 1.04.

It was noted in the reconnaissance report that the recommended plan was not necessarily the optimum plan for hydropower addition to the Bloomington Project. Since the civil works features for the recommended plan were so costly, it was concluded that they should be analyzed in much greater detail in further studies to optimize the size and economic feasibility of the project, and to minimize the impacts to the existing project features and purposes. Additionally, it was noted that based on results of the results of the Bloomington Lake Reformulation Study, the possibility of using storage for some peaking capabilities should be considered. At a minimum, it was noted that the availability of pondage should be evaluated to maximize the value of the power produced by operating the power facilities on a daily or weekly cycle.

STATUS OF HYDROPOWER INVESTIGATIONS

Based on the findings, conclusions, and recommendations of the Bloomington Lake Hydropower Reconnaissance Report conducted by the Baltimore District, funds under the authority of Section 216 of the River and Harbor and Flood Control Act of 1976 have been requested for a detailed feasibility study.

It should be noted that the City of Westernport, Maryland, filed an application for a license with the Federal Energy Regulatory Commission (FERC) on 8 July 1982 for installing hydroelectric power generation facilities at the existing Bloomington Lake Project. Official notice of the application was issued on 29 November 1982, with final comments due by 7 February 1983. Westernport has entered into a contract with MITEX, Inc., for the design, construction, operation, maintenance and financing of the proposed hydroelectric power generation facilities.

ANNEX H - II

WATER QUALITY INVESTIGATIONS

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H - II - WATER QUALITY INVESTIGATIONS

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

TABLE OF CONTENTS (Continued)

List of Figures

BLOOMINGTON LAKE REFORMULATION STUDY

ANNEX H-II

WATER QUALITY INVESTIGATIONS

INTRODUCTION

PROJECT DESCRIPTION

The Bloomington Lake Project was authorized by the Flood Control Act of 1962 (PL 87-874) for the purposes of water supply, water quality control, flood control, and recreation. The project was completed by the Corps of Engineers in 1981. The present allocations for storage in the lake are 41,000 acre-feet for water supply and 51,000 acre-feet for water quality control of the available 92,000 acre-feet below lake elevation 1466 and 36,200 acre feet of flood control storage above elevation 1466 feet msl.

WATER QUALITY INVESTIGATIONS

As originally authorized, the project was formulated mainly to serve the needs in the North Branch Potomac River Basin. Water supply needs and water quality objectives have changed significantly, however, since the early 1960's when the Bloomington Lake Project was authorized. The population of Allegany County, which will benefit most from the project, has decreased by 0.1% during 1960-1970. The projected population of Allegany County by the Maryland Department of State Planning, is expected to show only slight growth (about 2%) by 1990 (Ref 10), whereas, the authorization document of the project estimated the population increase to be 35% by the year 1985 (Ref 3). Domestic and industrial water demands in the basin have also changed. Some industries have changed their operations so they need less water. The new industries expected in the 1960's did not materialize, and some industries closed since the project was authorized. Other areas such as the Metropolitan Washington Area (MWA) exhibited rapid growth during this period and can use additional water supply from Bloomington Lake.

The objectives of this portion of the Reformulation Study are: (1) to investigate the water quality in reservoir and downstream; (2) to determine storage needed to control the quality in reservoir and downstream; (3) to determine the feasibility of reallocating a portion of the presently authorized water quality storage to water supply storage; and (4) to investigate the effects on water quality by system regulation with Savage River Dam Reservoir. The effects of reallocating the storage in Bloomington on the water quality aspects of the project are described in this Annex. It should be noted that because of a large number of figures for this Annex, all figures are included at the end of the Annex.

WATER QUALITY CONDITIONS IN THE NORTH BRANCH POTOMAC RIVER (NBPR) WITHOUT BLOOMINGTON LAKE

SOURCES OF WATER POLLUTION

The NBPR has been polluted by acid mine drainage and industrial and municipal wastes. The characteristics of acid mine drainage water are low pH, high sulfate, high total dissolved solids, and significant amounts of aluminum, calcium, and magnesium.

The sources of the acid mine drainage (AMD) are the abandoned shaft and drift mines, and the active and abandoned surface mines scattered throughout the basin. In the early 1900's, coal miners adopted deep mining methods. Most of the deep mining methods utilized gravity drainage to avoid water accumulation in the mines. Pollution from abandoned deep mines, which employed this gravity drain method is exceedingly difficult to abate. The polluted water drains away from the mines and into the streams. After 1945, deep mining activity declined and most mines adopted surface mining methods. It increased the surface coal erosion and subsequent sedimentation of stream and the formation of AMD. The surface mines operated without any reclamation in the basin until 1955. A typical abandoned surface mine has highwalls, pits with AMD water, erosion, spoil piles, and landslide areas. Active surface mining operations discharge AMD effluent and create sediment from the mines and haul roads, spoil piles and pit areas.

The sources of the industrial and municipal wastes in the NBPR are from the cities, towns, and villages. The WESTVACO Pulp and Paper Company in Luke, Maryland, adds industrial pollutants to the river. The Upper Potomac River Basin Commission (UPRC) operates a secondary sewage treatment plant on the NBPR. The UPRC sewage treatment plant, located in Westernport, Maryland, discharges a relatively constant volume (33.5 cfs) throughout the year. Of the total influent to the treatment plant, 97% comes from the WESTVACO paper mill. The effluent from the sewage treatment plant has a neutral pH, moderate BOD_5, considerable total dissolved solids, high turbidity and high color.

AVAILABLE WATER QUALITY DATA AND RELATED STUDIES

WATER QUALITY, 1950 TO 1959

Water quality data at Luke, Maryland, have been collected by the WESTVACO Pulp and Paper Company since the early 1950's. The historical water quality data at Luke can be divided into two periods; water quality conditions prior to construction of Savage River Reservoir, and after construction of Savage River Reservoir. The Corps of Engineers completed the Savage River Reservoir in January 1952. With the completion of the Savage River Reservoir, better water quality has been maintained in the NBPR at Luke by augmenting acidic NBPR flows with the mildly alkalinic Savage River flows. Historical data showed that the minimum pH at Luke without and with Savage River Reservoir was 3.1 and 3.5, respectively (Ref. 14). The NBPR at Luke, Maryland was still not suitable for domestic and most industrial uses although the Savage River Reservoir operation improved the water quality of the NBPR downstream of Luke during low flow periods.

In 1956 the US Public Health Service (USPHS) collected water quality data to establish the needs for the NBPR. The purposes of the data collection were: (1) to determine the extent of the acid mine drainage problem; (2) to study the effects of low flow control by Savage River Reservoir; (3) to study the effects of changes in industrial operations on water quality; (4) to evaluate planned modifications to the Cumberland sewage treatment plant system; and (5) to study the possibility of a dam near Cumberland, Maryland. Twenty-three sampling stations on the North Branch and its tributaries were selected. Data for several biological and chemical water quality parameters were collected five times or more during a two-week reconnaissance in September and October. Stream water quality significantly changes with the streamflow volume. Therefore, flow is a major factor for evaluating water quality. Unfortunately, flows were quite low during the USPHS sampling effort.

At the time of the stream survey, the WESTVACO was discharging approximately 47,000 lb/day BOD_5 (5 day, 20°c, biological oxygen demand) and 106,000 lb/day suspended solids (Ref. 14). Sewers, such as those from Cumberland, Maryland were discharging directly into Wills Creek and into the Potomac River without any treatment. As a result of the municipal and industrial discharges, the NBPR experienced very high BOD loading and severe DO depletion. The survey showed the minimum pH of the NBPR just upstream of the confluence with the Savage River to be 4.0. The sampling station at Westernport, Maryland, which is just below the WESTVACO plant, showed 36.8 mg/l BOD_5 (highest BOD loading) and 2.10 mg/l DO concentration. The sampling station at Willey Ford, West Virginia, showed 0.62 mg/l DO concentration. This study pointed out that the NBPR had severe domestic and industrial waste loading problems coupled with the existing acid mine drainge pollution problem.

With the construction of the primary sewage treatment plant at Cumberland, Maryland (1957) and the UPRC activated sludge sewage treatment plant at Westernport, Maryland (1960), the NBPR experienced a significant reduction in BOD_5 and suspended solids. The DO concentration along the river increased in the late 1950's.

As part of the construction of Cumberland Local Flood Protection Project, the Corps of Engineers built an industrial pond for the water users in the Cumberland, Maryland area upstream of Wills Creek in 1959. This pond has about 430 acre-feet of storage capacity and is 15 feet deep. When the river experiences natural low flow during the summer and early fall, this industrial pond exhibits severe DO depletion and odor problems. When the water passes over the weir of the pond, the water is reaerated and the DO concentration is nearly saturated. Even though there are no available water quality data associated with the industrial pond for the 1950's, the DO downstream of the pond should not have been a problem after the construction of the Cumberland sewage treatment plant in late 1950's.

WATER QUALITY, 1960 TO 1969

Despite the municipal and industrial sewage treatment plants in Westernport and Cumberland, Maryland constructed in the 1950's, the municipal and industrial pollution problems of the NBPR still remained. In the 1960's, several governmental agencies and private industries were involved in studies aimed at solving the water quality problems in the basin related to acid mine drainage. The State of Maryland had collected water quality data in conjunction with the coal mining operations going on in the basin. The Federal Water Pollution Control Administration (now EPA) studied the mine drainage pollution of the NBPR and some industries became involved in a surveillance program for monitoring water quality in the basin.

In 1962, the Bloomington Lake Project was approved by Congress. The main water quality control aspects of the project were to be the "averaging" of acidity in reservoir, and the dilution of municipal and industrial wastes. The reservoir could also release lower temperature water in summer thus benefitting downstream users.

In the 1960's, the Maryland Department of Natural Resources (MDNR) conducted a surveillance program to monitor the water quality in streams affected by acid mine drainage. The MDNR compiled all the available information regarding the location of individual mines, and the water quality data from each contributing drainage (Ref. 16). The West Virginia Department of Natural Resources maintained a routine surveillance program in the West Virginia tributaries to the NBPR just as the MDNR had done in Maryland.

The WESTVACO Pulp and Paper Mill, the Celanese Fibers Company, and the Kelly-Springfield Company monitored water quality in the reaches of the NBPR from Luke to Cumberland, Maryland. This surveillance program consisted of 10 stations. Of the ten stations, five were sampled by WESTVACO; two by the Celanese Fibers Company; and three by the Kelly-Springfield Company. Data from the surveillance network were summarized annually by the Interstate Commission on the Potomac River Basin.

The Federal Water Pollution Control Administration (FWPCA) conducted a mine drainage study from 1966 to 1968 and also studied the effects of both mine drainage and industrial and municipal wastes on the NBPR. During that time, the WESTVACO mill discharged their wastes through the UPRC's activated sludge treatment plant. According to the WESTVACO data, the pH at Luke, Maryland, had deteriorated since 1965 (Ref. 17). A reduction in alkalinity of the waste material from the WESTVACO mill due to the improved UPRC sewage treatment facility and an increased acidity due to the increased coal mine activities occasionally caused a low pH in the vicinity of Cumberland, Maryland. At Pinto, Maryland, the pH dropped to between 4.5 and 6.0 quite frequently.

The water quality data collection and related studies in the 1960's were conducted to determine the basic problems and solutions related to the acid mine drainage problem and the industrial and municipal pollution in the basin.

WATER QUALITY, 1970 TO 1979

With the passage of the comprehensive federal water pollution legislation (Public Law 92-500) in 1972, the NBPR was studied more intensely for water pollution problems associated with acid mine drainage, and municipal and industrial discharges. The states and the EPA established new effluent standards for the municipal and industrial waste discharges and for the coal mine effluent to meet the requirements of PL 92-500. Some communities in the basin upgraded their existing treatment facilities (from primary treatment to secondary treatment), and some communities provided or planned new treatment facilities to meet the effluent standards. Active coal mining operations prepared treatment facilities such as lime treatment plants and waste collection ponds. There was some reclamation of old abandoned sites.

The State of Maryland and the State of West Virginia adopted abandoned mine drainage programs in the 1970's. The State of Maryland's "Mine Drainage Abatement Investigation" of 1973 recommended abatement plans for each acid discharge. According to this study, twenty percent of the acid mine waste discharged to the North Branch came from tributaries on the Maryland side of the river. Of this Maryland load, 75% came from Laurel Run, 19% from Three Forks Run, and 6% from Lostland and Elklick Runs.

Some abatement work was done in conjunction with active mine operations which also affected abandoned mine areas. In some cases, new operations had to fulfill the discharge and reclamation requirements needed to control the abandoned sites. In the other cases, an operator may have re-worked a portion of an old site, or an area adjacent to the site and in order to get a permit he would have to treat the abandoned site.

The Surface Mining Control and Reclamation Act of 1977 (PL 95-87), provided for an abandoned mine reclamation fund. Maryland used some of its share of the reclamation fund, but West Virginia has scheduled none of its allocation for abandoned mine drainage control in its portion of the North Branch Potomac Basin (Ref. 7).

The Corps of Engineers started the construction of Bloomington Lake Project in 1971 and initiated several intensive studies of the acid mine drainage problem in the basin. Several consulting companies participated in these studies. Water Resources Engineers, Inc., developed a mathematical model for the water quality and economic consequences of acid mine drainage abatement plans (Ref. 15). This study indicated that acid treatment plants at three locations (Dobbin Run, Elk Run, Buffalo Creek) would cause a fairly substantial change in acid concentration in the North Branch. However, the study concluded that the pH would not increase significantly because the stream would still contain sufficient acid to keep the pH low. MITRE studied three different water quality targets in Bloomington Lake and related them to the environmental impacts in the basin (Ref. 2). Skelly and Loy studied the water quality effect of pH based on several lime treatment abatement projects (Ref. 11). This study indicated need for treatment plants on Laurel Run, Stony River, Abram Creek, and Three Forks Run plus the plants on Dobbin Run, Elk Run and Buffalo Creek as recommended by Water Resources Engineers, Inc. This plan would decrease the acid concentration enough to raise the pH of Bloomington Lake to about 6.0. In addition, Skelly and Loy studied the possible solutions to the acid mine drainage problems concerning abatement and management, and analyzed various social and economical effects in the basin due to abatement.

The State of Maryland and the State of West Virginia have continuously monitored water quality in their tributaries as a routine surveillance program since the 1970's. The State of Maryland has filed all the available water quality data into a state computer system. The U.S. Geological Survey has also collected water quality data and filed the data in the WATSTORE computer system.

The Corps of Engineers in conjunction with the State of Maryland has collected monthly water quality data as a part of pre-impoundment survey for the Bloomington Lake project since 1977. Twenty-one sampling stations from Kitzmiller, Maryland, to Paw Paw, West Virginia, were sampled during this pre-impoundment survey.

The State of Maryland has started a water quality sampling program for sanitary wastes surveillance. Once a month, from April to November, samples are collected and analyzed for the following: total coliform, fecal coliform, turbidity, suspended solids, dissolved solids, pH, conductivity, DO, and sulfate. Moreover, the State of Maryland has developed a water quality management plan for the NBPR (Ref. 10). This plan concentrated on the control of existing and future pollutant loads from point sources. For instance, the UPRC sewage treatment plant added a new primary clarifier to reduce total suspended solids, and improved the aerator, the disinfection system, and the cooling system. Several sanitary districts were organized such as Braddock Road Sanitary District and Jennings Wills Creek Sanitary District. Each Sanitary District constructed a new municipal sewage treatment plant. Consequently, the point source controls along the NBPR basin significantly reduced BOD, coliform, and suspended solids concentration in the water.

WESTVACO monitored water quality in some regions of the NBPR in the 1970's. With the expanded UPRC sewage treatment plant facilities (1977), the BOD and suspended solids discharge loading from the paper mill was greatly reduced. Currently the UPRC sewage treatment plant discharges an average 3,200 lb/day BOD_5 (data: June 1981). When this BOD discharge loading is compared with the 1957 BOD discharge loading, the present facilities of the UPRC sewage treatment provide a reduction in BOD discharge of about 15 times. HydroQual, (Hydroscience) Inc., contracted by WESTVACO, developed a mathematical water quality model for DO in the reach from Luke to Pinto, Maryland

(Ref. 6). The report concluded that the current UPRC treatment plant can achieve the Maryland's dissolved oxygen standard of 5.0 mg/l by allowing the maximum 6020 lb/day, BOD_5 for the current minimum flow of 93 cfs.

WATER QUALITY 1980 TO PRESENT

EnviroPlan, Inc., under contract to the Corps of Engineers, did a biological survey at ten stations on the NBPR from Kitzmiller, Maryland to Paw Paw, West Virginia, in 1980 (Ref. 4). This study pointed out that the portion of the NBPR upstream of Pinto, Maryland, supports neither a variable fishery nor a healthy macroinvertebrate community but that conditions improve steadily as one goes downstream.

Data collected as part of the Bloomington pre-impoundment survey has been continued by the Corps of Engineers. The inflow water quality at the Bloomington Dam site has shown generally improving quality.

EXISTING WATER QUALITY IN THE NBPR

The NBPR has been polluted by acid mine drainage pollution and municipal and industrial wastes. The NBPR shows the characteristics of the acid mine drainage from its headwater to well downstream of Luke, Maryland (Figure H-II-1). In the reach of the NBPR upstream of Luke, pH ranges between 3.4 to 4.0 during low flow periods and 4.5 to 6.5 during high flow periods effectively eliminating biological activity in that reach.

Releases from Savage River Reservoir near Luke, Maryland help neutralize the acidic North Branch water. Savage River Reservoir's primary purpose is to provide a minimum flow of 93 cfs at Luke for pollution abatement in the NBPR.

Summer thunder showers cause acid slugs to occur in the NBPR. These acid slugs generally have a large volume of highly acidic water and can depress the pH for many miles downstream from the normal effects of the acid water. Consequently, these acid slugs cause fish kills where the stream is normally healthy.

The effluent from the UPRC plant is alkaline and tends to neutralize the acid pollution of the NBPR, but the effluent produces other adverse effects on water quality downstream. The NBPR exhibits high concentrations of turbidity, conductivity, and color as far downstream as Oldtown, Maryland, during low flow conditions. In late summer and fall, the water quality at Luke, Maryland usually improves because the flow generally contains a large portion of Savage water. This raises the pH in the range of 5.5 to 6.1.

The NBPR suffers some DO depletion downstream of the UPRC plant at Westernport, Maryland. Generally, the DO in NBPR is seldom below the state standards (5.0 mg/l DO) in the reach from Westernport to Cumberland, Maryland. The industrial pond near Cumberland, Maryland often has DO below the standard during the low flow season.

WATER QUALITY STANDARDS OF THE NBPR

The objective of stream water quality standards is to protect water uses and users as well as the environment. Natural water is polluted in many ways, with the main pollution source being man's activities. Quantities of materials, disposed of in the streams by man's activities, are altered by biological oxidation. By-products of this process often generate new forms of pollutants in the water system. Concentrations of certain materials cause major disruption of the biological equilibrium of the stream and result in deterioration of stream water quality. The States of Maryland and West Virginia have established stream water quality standards for the NBPR.

The water quality standards for the NBPR have been changed since the Bloomington Lake project was authorized in 1962. When the Bloomington project was authorized, the stream water quality standards for the NBPR were adopted by the Interstate Commission on the Potomac River Basin (ICPRB), as shown in Table H-II-1 (Ref. 14). Also at that time the Maryland Water Pollution Control Commission (MWPCC) set standards for the quality of waste effluent discharged into the North Branch (Ref. 14). The average monthly minimum DO concentration in the ICPRB standards was 4.0, and the DO concentration in the receiving water could not be depleted beyond 50 percent of normal saturation in the MWPCC standards. Biochemical oxygen demand for 5 day (BOD_5) in the ICPRB standards was a maximum of 5ppm. The BOD_5 in the MWPCC standards for effluents was not to exceed 100 ppm.

As a result of the Water Quality Control Act Amendment of 1972 (PL 92-500), the State of Maryland has established the current water quality standards for the North Branch Potomac River. Table H-II-2 (Ref. 10) shows the Maryland General Standards describing what substances all waters of the state must be free of. Table H-II-3 shows the detailed classification of the NBPR (Ref. 10). According to the classification of water uses by the State of Maryland, the main stem of the NBPR is classified as Class I water (water contact recreation and aquatic life). For protecting this class of water, special water quality standards have been set. The maximum or minimum allowable levels for each use in class I are shown in Table H-II-4 (Ref. 10). These stream water quality standards specify the limits for the following parameters: fecal coliform bacteria, DO, temperature, pH, and turbidity.

To maintain water quality standards, pollutant sources must be regulated stringently. There are two categories of pollutant sources, one is non-point sources, such as storm water runoff and land erosion, and the other is point source, such as sewage treatment plant and industrial treatment plant discharges. Presently non-point sources are essentially unregulated while point sources are regulated. For the point source control, the Water Pollution Control Act Amendments of 1972 (PL 92-500) specified the effluent and treatment facility discharge standards.

The effluent standards for point sources specify the allowable ranges for chemical, physical, and biological parameters of discharges necessary for the granting of a National Pollution Discharge Elimination System Permit (NPDES Permit) from the EPA. The parameters include BOD, suspended solids (SS), chlorine, coliform bacteria, pH, and dissolved oxygen (DO). Also, the parameters may include stream flow, nitrogen, phosphorous, temperature, and numerous industrial by-products. The Water Pollution Control Act also specifies the following treatment levels:

a. Secondary treatment for publicly-owned sewage treatment plant, and

b. Best practical control technology currently available (BPCTCA), for other point sources.

Table H-II-1

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

MINIMUM WATER QUALITY CRITERIA FOR STREAMS IN THE POTOMAC RIVER BASIN

Approved 8 August 1946

	CLASS A	CLASS B	CLASS C	CLASS D
	Drinking Water	Bathing, Fish	Domestic Water Supplies	General Sanitary
	(No treatment except cl.)	Life	(Before complete treatment). Industrial Process Water	Condition - to prevent nuisance
Coliform Bacteria	0 - 50	No. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowd which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	------			
Monthly av., ppm	------	1.5	2.0	3.0
Max. observation, ppm	------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av., ppm	7.5	6.5	6.5	4.0
Min. observation, ppm	6.5	5.0	5.0	Min. daily ave. 3.0 Absolute min. 2.0
Other Conditions	No toxic substances, oil tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor - producing substances.	Same as A	Same as A	No toxic substance, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the varous classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

Table H-II-2

GENERAL STANDARDS FOR WATER QUALITY
(Regulations 08.06.04.02, Maryland Water Resources Administration)

The Waters of the State shall at all times be free from:

(1) Substances attributable to sewage, industrial waste, or other waste that will settle to form sludge deposits that are unsightly, putrescent or odorous to such degree as to create a nuisance, or that interfere directly or indirectly with water uses;

(2) Floating debris, oil, grease, scum, and other floating materials attributable to sewage, industrial waste, or other waste in amounts sufficient to be unsightly to such a degree as to create a nuisance, or that interfere directly or indirectly with water uses;

(3) Materials attributable to sewage, industrial waste, or other waste which produce tests, odor, or change thte existing color or other physical and chemical conditions in the receiving waters to such a degree as to create a nuisance, or that interfere directly or indirectly with water uses; and

(4) High-temperature, toxic, corrosive or other deleterious substances attributable to sewage, industrial waste, or other waste in concentrations or combinations which interfere directly or indirectly with water uses, or which are harmful to human, animal, plant or aquatic life.

Approved September 1, 1974
April 30, 1979/rev

TABLE H-II-3

CLASSIFICATION OF THE WATERS OF THE
NORTH BRANCH POTOMAC RIVER BASIN

Class I Waters - Waters Contact Recreation and Aquatic Life

The North Branch and Georges Creek Mainstem are classified as Class I waters.

Class II Waters - Shellfish Harvesting

There are no waters thus classified in the North Branch Potomac River Basin.

Class III Waters - Natural Trout Waters

All tributaries to the North Branch Potomac River except those classified for recreational trout waters, below, and except for the minimum of Georges Creek

Class IV Waters - Recreational Trout Waters

Wills Creek Mainstem.

Evitts Creek Mainstem.

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TABLE H-II-4

CLASS I WATER QUALITY STANDARDS

Class I: Water Contact Recreation and Aquatic Life

Description: Waters which are suitable for water contact sports, play and leisure time activities where the human body may come in direct contact with the surface water, and the growth and propagation of fish (other than trout), other aquatic life, and wildlife.

Water Quality Standards:

Bacteriological:

There shall be no sources of pollution which constitute a public health hazard. If the fecal coliform density exceeds a log mean of 200 mpn/100 ml, the bacterial water quality shall be considered acceptable only if a detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters.

Dissolved Oxygen Standard

The dissolved oxygen concentration shall be not less than 4.0 mg/l at any time with a minimum daily average of not less than 5.0 mg/l, except where, and to the extent that, lower values occur naturally.

Temperature Standard

a. Thermal effects shall be limited and controlled so as to prevent:

(1) temperature changes that adversely affect aquatic life;

(2) temperature changes that adversely affect spawning success and recruitment; and

(3) thermal barriers to the passage of fish.

b. Temperature elevations above natural shall be limited to 5 degrees F., (2.8 degrees C.) and the temperature may not exceed 90 degrees F. (32 degrees C.) outside of designated mixing zones.

c. This limitation of temperature changes in Class I waters does not preclude the discharge of warmed water. Warming of a portion of a body of water is permissible if it will not produce substantial detrimental changes and if the volume of the new temperature is of such size and duration that the exposure of organisms or life stages thereof, is less than the time associated with deleterious biological effects at that particular temperature.

pH Standard

Normal pH values must not be less than 6.5 nor greater than 8.5, except where - and to the extent that - pH values outside this range occur naturally.

TABLE H-II-4 (Continued)

Turbidity Standard

a. Turbidity may not exceed levels detrimental to aquatic life; and

b. Within limits of Best Practicable Control Technology Currently Available, turbidity may not exceed for extended periods of time those levels normally prevailing during periods of base flow in the surface waters; and

c. Turbidity in the receiving water resulting from any discharge may not exceed 50 Jackson Turbidity Units (JTU) as a monthly average, nor exceed 150 JTU at any time.

Approved September 30, 1974
April 30, 1979/rev

Table H-II-5 shows the effluent standards for secondary treatment. These standards do not include color or total dissolved solids standards.

Since surface or strip mining activities result in non-point type discharges and due to the devastation effects of these discharges, special regulations for surface coal mining were passed. The states and EPA have enforced the regulations for prevention of water pollution. Table H-II-6 gives pertinent information for Maryland's coal mine effluent standards.

EXPECTED WATER QUALITY CONDITIONS IN BLOOMINGTON LAKE AND DOWNSTREAM

WATER QUALITY MODELLING

The Baltimore District Corps of Engineers developed a mathematical computer model to simulate the water quality in both the reservoir and downstream. The model consists of two parts: (1) the reservoir water quality model, and (2) stream water quality model. The reservoir model can simulate seven different physical and chemical water quality parameters on a daily basis. The stream model, using the output of the reservoir model, can simulate seven water quality parameters on a daily basis. Both the models operate according to the following operational constraints and assumptions.

RESERVOIR MODEL

Physical Constraints

1. Bloomington Lake and Savage Reservoir maintain a seasonal pool.

2. The filling of Bloomington Lake and Savage Reservoir to their respective conservation pool levels, i.e. 1466 and 1468.5 feet msl will commence between 1 February and 15 March.

3. The capacity of the Bloomington's low flow system is 1000 cfs for two wet wells.

4. The minimum outflows from Bloomington Lake and Savage Reservoir are 50 cfs and 20 cfs, respectively.

5. The combined flow should never be less than 93 cfs at Luke, Maryland.

The water quality storage of Bloomington Lake will be used to maintain the minimum flow at Luke, Maryland. Savage Reservoir water will be used to maintain uniform water quality downstream.

Reservoir Model Structure and Assumptions

The reservoir water quality model included water quality simulation in the reservoir, outflow, and the NBPR at Luke, Maryland, in conjunction with the Savage Reservoir operation.

The reservoir model used is applicable to impoundments that can be represented as a one dimensional system in which the isopliths are horizontal. When the lake is thermally stratified (April through October), the model uses a simplistic two layer system. It is assumed that the water within each layer is fully mixed. Each horizontal layer is

TABLE H-II-5

MARYLAND STATE STANDARDS FOR SECONDARY TREATMENT

Effluent from a sewage treatment plant can be considered to have undergone "secondary treatment": if it is within the following limits:

1. Five-day biochemical oxygen demand (BOD 5).

   a. no greater than 30 mg/l averaged over any 30 day period

   b. no greater than 45 mg/l averaged over any 7 day period

2. Total Suspended Solids

   a. no greater than 30 mg/l averaged over any 30 day period

   b. no greater than 45 mg/l averaged over any 7 day period

3. Bacteria

   a. no greater than the concentration allowed in the standards set for the water-use class of the receiving waters.

4. Total chlorine residual

   a. the instantaneous maximum must be no greater than .05 mg/l.

   b. lower values may be set to protect aquatic life according to the following formula:

   $$\text{Maximum Chlorine Residual} = \frac{E+S}{E} \times 0.01 - .02$$

   E = average flow of effluent
   S = 10 year, 7-day low flow of receiving stream

   c. in Natural Trout Waters, the maximum value is limited uniformly at .02 mg/l.

TABLE H-II-6

EFFLUENT LIMITS FOR SURFACE COAL MINING OPERATIONS

Parameter	Daily Minimum	Daily Maximum	Daily Average	Monitoring Sample Frequency	Requirements*** Sample Type
Turbidity	N/A	100 J.C.U.	N/A	2/Week	Grab
Total Suspended Solids	N/A	45 mg/1*	30 mgd/1	1/3 months	Grab
pH	6.0	9.0	N/A	Daily	Grab
Dissolved Oxygen	N/A	4.0 mg/1	2.0 mg/1	1/Week	Grab
Alkalinity**	20 mg/1	N/A	N/A	1/Week	Grab

* Except when runoff exceeds settling pond design (five inches of rainfall in a 24 hour period), and for four hours thereafter.

** Applies only when treating for iron removal.

*** These two columns are provided as examples only, a\ tual frequency and type vary.

NOTE: For the purposes of the permit, "daily minimum concentration" means the minimum determination of concentration for any 24 hour period.

assumed to be completely homogeneous with all isopliths parallel to the water surface both laterally and longitudinally. The model uses the results of the WESTEX Thermal Model to locate the thermocline and the mass transport across the thermocline. The model simplified the internal transport based on the thermal model and experience. Model results are most representative of conditions in the main body of the reservoir.

The movement of water within the reservoir is governed by the location of inflow to, and outflow from the reservoir. The computation of the layer volumes due to the location of inflows and outflows are of considerable significance in the operation of the model.

The allocation of inflows is based on the assumption that the inflow water will seek a level of like density within the lake. When the lake is stratified in spring and summer, the inflow enters a specific stratified layer, depending on the density, and is distributed throughout that layer. When the lake is not stratified, the inflow will be distributed throughout the entire lake.

At the start of thermal stratification in spring, the mixing zone (upper) will have better water quality until the inflow water worsens during the low inflow season (summer). The model utilizes a simple method to determine the withdrawal zones for the water quality releases. Initially a minimum flow from the epilimnion is set at: 1) 30% of total outflow if acidity in the upper zone is less than that of the lower zone, or 2) 15% of the total outflow if the acidity in the upper zone is greater than that of the lower zone. The remaining 70 or 85 percent of the total outflow is released from locations determined by the following procedure: the release from the upper zone is determined by the ratio of a projected volume above the thermocline, as determined by the WESTEX Thermal Model, and a calculated volume above the thermocline. The calculated volume is determined from the balance of inflow, outflow and interzonal flow. The ratio, not greater than 1.7 or less than 0.3, is then multiplied by 0.5 to give the final percentage of upper zone outflow. The remainder of the outflow is released from the lower zone.

The release obtained in the above scheme is made through the low flow gates. The maximum outflow from the mixing layer is 1000 cfs. Whenever the calculated outflow from the mixing zone is 1000 cfs or more, the volume over 1000 cfs will be released from the non-mixing zone (lower) to maintain summer pool or any desired pool elevation for a given day.

In a two-layered system, vertical advection, or mixing, will occur between the two layers. The vertical advection is defined as the inter-layer flow which result in a continuity of flow. To simplify the internal flow between the two layers, there are three assumptions used in this model:

1.15% of the inflow flows from the mixing zone (upper) to the non-mixing zone (lower) until Julian day 220 (8 August).

2.There is no internal zone flow between Julian day 220 and Julian day 250.

3.After the Julian day 250, the internal flow from the non-mixing zone to the mixing zone is defined by the followng equation: internal flow = non-mixing zone volume X 0.0015 X (Julian day - 249). This equation assumes that the lake would turn over in mid-November based on the WESTEX Thermal Model.

The model approach is based on the assumption that the dynamics of each chemical component can be expressed by the law of conservation of mass and the kinetic principals. There are two kinds of water quality parameters, conservative and non-conservative.

The conservative parameters do not decay, or otherwise change their quantity, and their mass can only be changed by dilution, internal inflow or mixing. Conservative materials have no sources other than local inflow. In addition, the conservative materials are not significantly affected by changes in temperature or any other biological, chemical or physical process. Alkalinity, acidity and conductivity are assumed to be conservative parameters because Bloomington Lake will have acidic water and exhibits little, if any, biological activity.

Non-conservative parameters can undergo a transformation into another form and their mass can be changed, or affected, by chemical, biological or physical processes. For example, non-conservative parameters include DO and BOD. This model cannot handle the non-conservative parameters.

The conservative parameters may be either dissolved or particulates. Dissolved parameters have the same transport pattern as the water itself. The particulates are carried by the turbulent drag forces and a resultant of gravity and buoyancy force. This model utilizes only dissolved parameters. The dissolved parameters are an integral part of water itself and move accordingly with the water. Therefore, when water containing the dissolved parameters flows in uniform density, in stratified flow, or density currents, the basic mass balance of each component can assume the equation:

$$\frac{dc}{dt} V = Q_i C_i + C_p V_p (1-k) - Q_o C_p + SV_p$$

Where:
- Q_i = inflow
- C_i = inflow concentration
- Q_o = outflow
- C_o = concentration of substance in the impoundment
- k = decay coefficient
- V = volume of the impoundment
- S = all sources and sink of non-conservatives

To integrate the above equations with respect to time, the expression becomes:

$$C = \frac{Q_{it} C_{it} + C_{pt} V_{pt} (1-k) - Q_{ot} C_p t + \Sigma SV_{pt}}{V}$$

Where:
- C_p = previous concentration of substance in the impoundment at the time
- V_p = previous impoundment volume at the time

Assuming that SV_{pt} and k approach zero, the relationship between the substance concentration in the impoundment at the time becomes:

$$C = \frac{Q_{it} C_{it} + C_{pt} V_{pt} - Q_{ot} C_{pt}}{V}$$

When the lake has two layers (mixing zone and non-mixing zone) in summer, the substance concentration in the impoundment becomes:

$$C_1 = \frac{Q_{it}\, C_{it} + C_{p1t}\, V_{p1t} - Q_{o1t}\, C_{p1t}}{V_1}$$

$$C_2 = \frac{C_{p2t}\, V_{p2t} + Q_u\, C_{p1t} - Qu\, C_{p2t} - Q_{o2}\, C_{p2}}{V_2}$$

Where C_{p1t}, C_1	the substance concentration in the mixing zone at the beginning and end of an intergration interval, respectively.
C_{p2t}, C_2	the substance concentration in the non-mixing zone at the begining and end of an intergration interval, respectively.
V_{p1t}, V_{p2t}	the mixing zone volume and non-mixing zone volume at the beginning, respectively.
V_1,V_2	The mixing zone and non-mixing zone volume at the end, respectively.
Qu	internal zone flow.
Q_{o1}, Q_{o2}	outflow from the mixing zone and non-mixing zone.

Likewise, the outflow substance concentration becomes:

$$C_3 = \frac{Q_{o1t}\, C_{p1t} + Q_{o2t}\, C_{p2t}}{Q_{o1} + Q_{o2}}$$

Where: C_3 = Outflow substance concentration

A simple water continuity storage for the reservoir becomes:

$$\frac{dv}{dt} = Q_i - Q_o + A\,(P-E_v)$$

Where: A = surface area
P = precipitation
Ev = evaporation rate

To integrate the above equation with respect to time, the expression becomes:

$$V = Q_{it} - Q_{ot} + A\,(P-Ev)\,t$$

The term of A (P-Ev) is conveniently fixed so that the lake loses a volume of 6 acre-feet/day.

System Operation of Two Reservoirs

System operation of the two reservoirs, Bloomington and Savage, can substantially improve water quality downstream. To maximize the benefits from the operation of Savage River Reservoir, three factors are considered: Bloomington outflow water quality, Bloomington outflow volume, and the storage of Savage River Reservoir. First, better water quality outflow from Bloomington would require less flow from Savage for buffering purposes. Based on titrations of the Savage River water with North Branch water, the effects of buffering North Branch water with Savage water are significant when the water quality of the North Branch water is bad, and minor when the quality of the North Branch is good. Second, the magnitude of the outflow from Bloomington Lake has to be based on the amount of the release from Savage River Reservoir. The UPRC sewage treatment plant (STP) discharges, for the most part, a constant volume and water quality into the river throughout the year. The buffering capacity of the effluent from the UPRC STP cannot always raise the pH enough to meet a target pH at Pinto. To consistantly meet a target pH at Pinto, Maryland, Savage River water is required. Lastly, Savage River Reservoir is used as a water supply for the town of Westernport's residents and for pollution abatement flow at Luke, Maryland. Consequently, the proper uses of the Savage water throughout the year is an important concept for the two reservoir operation.

The model established a discharge flow ratio for the two reservoir systems as follows: 1) In the spring, the discharge from Savage is 20% of the Bloomington outflow. Upon reaching summer pool, Savage River Reservoir will release on an inflow equal to outflow basis unless the Savage outflow falls below 15% of the Bloomington outflow. This scheme will continue until approximately late May (Julian day 150). 2) During the period of Julian day 150 to 180, the discharge flow ratio is maintained at 15% of the Bloomington outflow because Bloomington will exhibit fairly good water quality during that time. 3) After the Julian day 180, the discharge ratio of the two lakes will be as follows:

BLOOMINGTON - SAVAGE RELEASE RELATIONSHIP

Bloomington Release (cfs)	Savage Release (% of Bloomington release)
0 - 150	15.0
150 - 299	17.5
300 - 449	20.0
450 - 649	25.0
650 - 999	30.0
1000 - 1499	35.0
over 1500	40.0

When the storage ratio between Bloomington and Savage is over 6.5, the discharge ratio is fixed at 20% regardless of the outflow volume of Bloomington. This action is required to save the Savage water for future use.

If the required flow is 110 cfs at Luke, Maryland, it would consist of 90 cfs from Bloomington and 20 cfs from Savage. The flow ratio is 22.2% because the required minimum discharge of Savage River Dam is 20 cfs. A flow of 150 cfs at Luke would consist of 130 cfs from Bloomington and 20 cfs from Savage which is a release ratio of 15%. If Savage storage is depleted, then the Savage outflow is maintained at the Savage inflow and the rest of the minimum flow at Luke, Maryland, is made up from Bloomington releases. When Savage Lake storage is depleted, the minimum flow consists of only Bloomington releases. When the two reservoirs run out of storage the flow at Luke is the natural inflow from both the North Branch and Savage River. The model cannot simulate water quality loading when the flow is below 93 cfs because the quality loading equation developed has a flow boundary condition at that point. The flow at Luke and downstream has not dropped below 93 cfs since 1952. The simulated flow for 1930 is often below 93 cfs after Julian day 340. When the flow at Luke is below 93 cfs, the model calculates the unit quality loading for the fixed flow of 93 cfs and obtains the total loading by multiplying the unit loading by the simulated flow.

STREAM MODEL

A stream water quality model was developed to simulate the water quality at six stations on the NBPR from just upstream of New Creek to Paw Paw. The six stations were located on the NBPR near New Creek, Pinto, Wills Creek, Wiley Ford, Oldtown, and Paw Paw (see Figure H-II-1). The model was used to evaluate the water quality effects of the reservoir operation based on different water quality scenarios.

The stream system is represented conceptually as a linear network of segments. The NBPR is divided into seven segments from Bloomington Dam to Paw Paw, West Virginia. The method of hydraulic computation is adapted for stage-flow relationships.

This method assumes that all flows are to be routed without any time lag. The flow at any point is thus the accumulated flow from all upstream inflows and withdrawals. The other important assumption is that water within each segment is fully mixed vertically and laterally and that there are no losses.

Baseline Flow Computation

Uncontrolled stream flows of each segment with respect to time were calculated from the stream gage records of the US Geological Survey (USGS) in the NBPR Basin. The USGS has maintained four gage stations on the NBPR between Luke, Maryland, and Paw Paw, West Virginia. The baseline flows have been controlled by the Savage River Reservoir since 1953. To calculate the uncontrolled flow (natural flow) for a given year, the mass flow from the gage should be adjusted by the effects of the Savage River Reservoir with respect to time. Table H-II-7 shows the controlled and uncontrolled monthly daily average flow for 1962 at Luke and Table H-II-8 shows the monthly factors for determining flow at the four gage stations based on the uncontrolled flow at Luke, Maryland.

TABLE H-II-7

AVERAGE DAILY FLOW BY MONTHS FOR 1962 AT LUKE

	Savage Reservoir Effect Controlled	Natural Uncontrolled
Feb	1318	1369.9
March	2277	2324.6
April	1329	1500
May	545	564.5
June	642	653.7
July	298	296.0
Aug	115	78.46
Sept	132	62.2
Oct	188	118
Nov	711	692.9
Dec	346	353.7

TABLE H-II-8

FACTORS FOR DETERMINING BASELINE FLOW BASED ON UNCONTROLLED LUKE FLOW (1962 year)

	Luke	Pinto	Wiley Ford	Paw Paw
Feb	1	1.237	1.659	3.98
March	1	1.376	2.033	6.037
April	1	1.327	2.12	4.564
May	1	1.249	1.776	4.71
June	1	1.199	1.609	3.27
July	1	1.23	1.582	2.933
Aug	1	1.204	1.905	4.86
Sept	1	1.435	2.283	4.98
Oct	1	1.22	1.66	3.763
Nov	1	1.238	1.577	3.74
Dec	1	1.17	1.477	3.401

Mass Transport of the Stream

The transport of parameters in the river system will be similar to the transport of parameters in the reservoir. The basic mass balance becomes:

$$\frac{dc}{dt} Q_2 = Q_b C_b - Q_c C_c + Q_1 C_1 - K Q_1 C_1 + \Sigma S$$

Where $Q1$ = Stream flow with Bloomington at the previous segment
$Q_2 = Q_1 + Qr$
Q_2 = stream flow with Bloomington at the end of the segment
Qr = tributaries and runoff flow at the end of segment
Qb = flow controlled by Savage only at the end of segment (without Bloomington)

Qc = flow controlled by Savage *only* at the previous segment (without Bloomington)

Cb = substance concentration with the Savage River Dam at the end of the segment (without Bloomington)

Cc = substance concentration with the Savage River Dam at the end of previous segment (without Bloomington)

C_3 = substance concentration with Bloomington and Savage at the previous segment

C_4 = Substance concentration with Bloomington and Savage at the end of segment

Assuming that S and K approach zero, because K and S are compensated at the term of $Q_bC_b - Q_cC_c$ the substance concentrations with time will be:

$$C_4 = \frac{Q_b C_b - Q_c C_c + Q_1 C_3}{Q_2}$$

When there is a significant point source such as an industrial sewage treatment plant in the segment, the equation adds the substance concentration of the plant source as follows:

$$C_4 = \frac{Q_b C_b - Q_c C_c + Q_1 C_3 + Q_5 C_d}{Q_2}$$

Where Q_5 = effluent flow from a point source

C_d = effluent substance concentration from point source

LOADING FACTORS

Regression techniques are used to predict the parameter loading in the river with respect to flow. Most parameters exhibit an inverse response to river flow. The parameter loadings have changed with time due to stricter mining regulations, new or improved municipal and industrial sewage treatment plants, new industrial processes and the closing of some industries. Consequently, pollutant loading with respect to flow exhibits a dependency on time. This time factor makes it impossible to develop equations that predict water quality except for short time intervals. Historically, the water quality of the NBPR can be divided into three time periods:

1. A period of extensive industrial pollution coupled with increasing acid mine pollution from 1950 to 1960.

2. A period of severe acid mine drainage pollution coupled with moderate municipal and industrial pollution from 1961 to 1977.

3. A period of improving water quality, due to more stringent regulations applied to acid mine drainage, and moderate municipal and industrial pollution, from 1979 to present.

According to the historical water quality data for the NBPR the pH at Kitzmiller, Maryland, was 3.9 to 4.9 with an average acidity of 22.5 mg/l during the low flow season (September and October) of 1956. In the years following 1956 the water quality gradually deteriorated every year until the pH reached 2.4 to 3.5 during the low flow seasons of

1966-1972. During the period of 1966-1972, the acidity of the North Branch Potomac River at Kitzmiller, Maryland, was in the range of 50 to 200 mg/1. The pH has been improving gradually since the period of 1966-1972.

The water quality of the NBPR has improved in the last two or three years. Figure H-II-2 shows the historical pH data for September and October at Kitzmiller, Maryland for the last 30 years. The figure clearly indicates that the NBPR experienced the worst acid mine drainage pollution during 1968-1969. Presently, there is a trend toward easing discharge regulations. If the regulations are relaxed even slightly the water quality of the NBPR could revert back to what it was in the later sixties and early seventies.

Sulfate and conductivity are good indicators of acid mine drainage pollution. Sulfate is the most conservative water quality parameter. Current sulfate concentration of the inflow to the NBPR is higher than the sulfate concentration of data for the period of 1966-1972. The increased mine operations in the basin cause the increased sulfate concentration. Conductivity of AMD is generally high because mine wastes contains high concentrations of acidity, TDS, sulfate, metals, etc.

Reservoir Model

The reservoir model was applied to four different flow years: (1) a wet flow year (1967), (2) an average flow year (1962), (3) a dry flow year (1966), and (4) an extremely dry flow year (1930). A hypothetical water supply plan based on a 100 mgd flowby target at Little Falls was applied to the dry and extremely dry flow years. The volumes schedules for this hypothetical plan are shown on Table H-II-9.

The water quality in the reservoir was simulated using two scenarios: (1) best water quality scenario and (2) worst water quality scenario. The best water scenario represents the current water quality situation (1979-1980 data). The worst is based on data for the period of 1967 to 1972.

A series of linear and non-linear regression analysis were performed on the data for each scenario. The equation which best described the data was selected for each parameter. A general equation defining the various parameter loading is:

$$L=a+b\ \text{Log}_{10}\ Q + C\ (\text{Log}_{10}Q)^2 + D\ (\text{Log}_{10}Q)^3$$

Where	L	= loading (mg/1)
	a	= constant defining y intercept
	b,s,d	= constant defining the slope
	Q	= flow (CFS)

TABLE H-II-9

HYPOTHETICAL WATER SUPPLY RELEASE

Release Dates (Julian Day)	Bloomington Water Supply Release mgd (cfs) of 1930	Bloomington Water Supply Release mgd (cfs) of 1966
183-188	0	3.3 (5.1)
189-195	27.0 (41.8)	39.7 (61.2)
196-202	160.0 (249)	221.2 (342)
203-209	215.3 (333.1)	278.1 (430.3)
210-216	268.1 (414.9)	367.9 (569.3)
217-223	259.8 (402)	351.3 (543.6)
224-230	333.9 (516.7)	209.1 (323.57)
231-237	295.5 (457.1)	199.3 (308.41)
238-244	253.7 (392.6)	294.7 (456)
245-251	213.4 (330)	127.4 (197.2)
252-258	13.0 (20.1)	39.8 (61.6)
259-265	13.3 (20.6)	0
266-272	9.3 (14.4)	0
273-279	8.9 (13.8)	0
280-286	6.8 (10.5)	0
287-293	5.8 (9)	0
294-300	5.8 (9)	0
301-307	6.2 (9.6)	0
308-314	7.0 (10.8)	0
315-321	3.8 (5.9)	0
322-328	0	0
329-335	0	0
336-342	18.3 (28.3)	0
343-349	5.2 (8.0)	0

Figures H-II-3 thru H-II-7 are plots of the water quality parameters versus flow for the worst water quality scenario. All the parameters exhibit relatively good relationships for the loading versus flow. Figures H-II-7 thru H-II-11 are the plots for the best water quality scenario. Acidity, the most important parameter for determining pH, did not exhibit any clear relationship to flow. The reasons for the non-relationship between flow and acidity is not clear. An equation for acidity was generated, based on experience and judgment. The other parameters exhibited relatively good relationships with the flow.

The following equations are for the best water quality scenario:

Acidity
$$= 464.08232 - 254.2855 \times Q + 50.17211 \times Q^2 - 3.32834 \times Q^3$$

Conductivity
$$= 6061.323 - 2681.49 \times Q + 423.844 \times Q^2 - 22.67198 \times Q^3$$

Sulfate
$$= 5158.787 - 2360.034 \times Q + 368.116 \times Q^2 - 19.1022 \times Q^3$$

Manganese
$$= 5.13927 - 1.207 \times Q + 0.078 \times Q^2$$

Total Suspended Solids
$$= 31.435 + 0.636 \times C_0$$

Where Q is log (Flow) and C_o is conductivity

The following equations are for the worst water quality scenario:

Acidity
$$= 628.795 - 222.506 \times Q + 31.252 \times Q^2 - 1.515 \times Q^3$$

Conductivity

$$= 3442.916 - 1067.145 \times Q + 117.336 \times Q^2$$

Sulfate

$$= 2554.904 - 1193.299 Q + 197.8364 \times Q^2 - 11.1223 \times Q^3$$

Manganese

$$= 0.60 + 1.996 \times Q - 0.577 \times Q^2 + 0.041 \times Q^3$$

Total Suspended Solids

$$= 31.435 + 0.636 \times C_0$$

The model simulated the expected water quality from Julian day 32 through Julian day 361 (391 in 1930). Before Julian day 32, (February) the water quality of Bloomington Lake was assumed as follows:

	Best Scenario		Worst Scenario	
Acidity	18.6	mg/l	84.7	mg/l
pH	5.06		3.53	
Conductivity	315.92	micromhos/cm	235.5	micromhos/cm
Sulfate	125.10	mg/l	92.2	mg/l
Manganese	0.62	mg/l	0.515	mg/l
Total Dissolved Solids	232.5	mg/l	181.96	mg/l

There are generally two methods to determine pH. One is the regression analysis method, and the other is an ionic equilibrium method on a carbonate system. Natural waters are weak solutions of carbonic acid. The solubility of CO_2 in water is proportional to the molecular impacts of the CO_2, the water surface and inversely proportional to water temperature. CO_2 in water results in basic and acidic components co-existing to affect the pH. The major components determining pH are alkalinity and acidity. When water has little or no alkalinity, the pH is usually determined by the relationship of the acid concentration in water. When water has both alkalinity and acidity, the pH is determined by ionic equilibrium based on water temperature, alkalinity, acidity, and total dissolved solid concentration.

Water affected by acid mine drainage contains high acidity and almost no alkalinity. The river from Kitzmiller to the confluence of the Savage River is severely affected by acid mine drainage. When the Savage River enters the NBPR at Luke, the river contains a little alkalinity. The model determined the pH by the regression method for the NBPR upstream of Luke and by the ionic equilibrium below Luke using acidity, alkalinity, and total dissolve solids. Figure H-II-11 shows the relationship between pH and acid concentration at Barnum for the best water quality condition. The following equation represents the curve from Figure H-II-11.

$$pH = 7.025 - 0.17 \times C_{acid} + 0.00407\, C_{acid}^2 - 0.317 * 10^{-4} \times C_{acid}^3$$

Where C_{acid} is acidity concentration

The equation was applied to the reservoir and downstream to predict pH. Similarly, the following is for the worst water quality conditon.

$$pH = 5.713 - 0.04904 \times C_{acid} + 0.348 \times 10^{-3} \times C_{acid}^2 - 9\text{-}8.865 \times 10^{-7} \times C_{acid}$$

Stream Model

Water quality loading from Luke to Paw Paw is mainly affected by tributaries and municipal and industrial effluents. In order to determine the effects of the Bloomington project on the existing stream condition (without Bloomington) it was necessary to model the existing system. This also allowed the model to be calibrated to known data. The loading of the stream at each station is calculated by the same regression technique used in the reservoir model. The stream model analyzed 7 quality parameters. The parameters are temperature, pH, acidity, alkalinity, conductivity, sulfate, and TDS.

The existing water quality loading (without Bloomington) at Luke is the resultant loading from the Savage River and the North Branch Potomac River. The loadings equations for acidity, sulfate, conductivity, and TDS of the NBPR baseline are shown in Table H-II-10. These parameters showed a good relationship with flow. For water temperature

TABLE H-II-10

WATER QUALITY LOADING EQUATIONS (WITHOUT BLOOMINGTON)

Water Quality Loading Equations (Without Bloomington)

Station	Parameters	Equation
NBPR U/S Savage River	acidity	$\text{Exp}(5.88424 + 0.9115 \times \ln Q)/(Q \times 5.4)$
	sulfate	$\text{Exp}(8.72456 - 0.87499 \times \ln Q + 0.04092 \times \ln Q^2)/(Q \times 5.4)$
	conductivity	$\text{Exp}(8.20275 - 0.51677 \times \ln Q + 0.01873 \times \ln Q^2)/(Q \times 5.4)$
	TDS	$1709.3335 - 956.25 \times \log Q + 144.825 \times \log Q^2$
	Temp	$15.8 \times \text{SIN}(0.017214 \times I - 1.72) + 12.72$
Savage River at the mouth	alkalinity	10
	acidity	9
	conductivity	$388.889 - 201.1557 \times \log Q + 33.009 \times \log Q^2$
	sulfate	100
	TDS	$263.1236 - 140.398 \times \log Q + 23.821 \times \log Q^2$
NBPR U/S New Creek	alkalinity	$840.938.65 - 704.25483 \times \log Q + 198.25186 \times \log Q^2 - 18.645 \times \log Q^3$
	acidity	$-653.60294 + 584.90738 \times \log Q - 176.02 \times \log Q^2 + 17.7256 \times \log Q^3$
	conductivity	$-1326.12914 + 4081.90566 \times \log Q - 1936.01 \times \log Q^2 + 255.82607$
	sulfate	$10184.672 - 9946.1594 \times \log Q + 3288.81755 \times \log Q^2 - 362.63639 \times \log Q^3$
	TDS	$2599.74354 - 1291.28143 \times \log Q + 167.15959 \times \log Q^2$
NBPR at Pinto	alkalinity	$605.97891 - 464.10364 \times \log Q + 120.1308 \times \log Q^2 - 10.424 \times \log Q^3$
	acidity reduction	$5.5 - 8.92 \times 10^3 \times Q$
	conductivity	$4360.27571 - 2116.344 \times \log Q + 268.79483 \times \log Q^2$
	sulfate	$1904.5 - 1428.0246 \times \log Q + 391.6398 \times \log Q^2 - 37.319 \times \log Q^3$
	TDS	$4019.76273 - 2234.26542 \times \log Q + 324.08133 \times \log Q^3$
NBPR U/S Wills Creek	alkalinity	$533.564 - 377.84 \times \log Q + 86.764 \times \log Q^2 - 6.2049 \times \log Q^3$
	acidity reduction	$7.06 - 8.96 \times 10^{-3} \times Q$
	conductivity	$6678.66 - 4638.389 \times \log Q + 1129.544\ Q^2 - 93.647 \times \log Q^3$
	sulfate	$1136.2779 - 577.048 \times \log Q + 81.029 \times \log Q^2$
	TDS	$-43.48418 + 0.78344 * \text{Cond}$

Table H-II-10 (Continued)

NBPR at Wiley Ford	alkalinity	$777.56878 - 620.17112 \times \log Q + 168.76 \times \log Q^2 - 15.354 \times \log Q^3$
	acidity reduction	$5.97 - 0.7585 \times Q$
	conductivity	$7812.764 - 5803.2918 \times \log Q + 1488.305 \times \log Q^2 - 128.1575 \times \log Q^3$
	sulfate	$1890.0334 - 1249.979 \times \log Q + 277.5 \times \log Q^2 - 19.235 \times \log Q^3$
	TDS	$-43.48418 + 0.78344 \times Cond$
NBPR at Oldtown	alkalinity	$559.29 - 410.664 \times \log Q + 106.248 \times \log Q^2 - 9.26 \times \log Q^3$
	acidity reduction	2.1
	conductivity	$7527.04 - 5677.74 \times \log Q + 1508 \times \log Q^2 - 135.747 \times \log Q^3$
	sulfate	$307.726 - 51.92 \times \log Q$
	TDS	$-43.48418 + 0.78344 \times Cond$
NBPR at Paw Paw	alkalinity	$383.83 - 173.897 \times \log Q + 21.326 \times \log Q^2$
	reduction	1
	conductivity	$5035.345 - 3320.36 \times \log Q + 780.065 \times \log Q^2 - 62.75 \times \log Q^3$
	sulfate	$944.93281 - 489.22 \times \log Q + 69.416 \times \log Q^2$
	TDS	$-43.93281 + 0.78344 \times Cond$

Q = Flow (CFS)
Cond = Conductivity (micro mhos/am)
I - Julian Day

simulation at Luke, an equation of the natural NBPR stream water temperature vs. Julian day was generated. This equation, based on the measured data, is Temp = 15.8 X sim (0.017214 X I - 1.72) + 12.72 where I is Julian day. Since Savage Reservoir releases either over the spillway or through a bottom withdrawal, the following equations were developed for Savage River temperatures.

When the Savage pool attains the summer pool or before Julian day 90, the outflow temperature;

$$\text{Outflow temperature} = -21.17245 + 0.35987 \times I - 7.336\text{x}10^{-4} \times I^2$$

When the Savage pool is below summer pool or before Julian day 300;

$$\text{Outflow temperature} = -1.49424 - 3.79 \times 10^{-2} \times I + 8.81 \times 10^{-4} \times I^2 - 2.1539 \times 10^{-6} \times I^3$$

After Julian day 300;

$$\text{Outflow temperature} = 1349.1 + 12.274 \times I - 0.0367 \times I^2 = 3.6129 \times 10^{-5} \times I^3$$

Where I is Julian day.

The outflow quality loading of the Savage River at the mouth did not show any trends of acidity, alkalinity, or sulfate versus flow. The conductivity and TDS loads were related to flow (Table H-II-10). For this study the alkalinity, acidity, and sulfate loads of the Savage River at the mouth were fixed at 10 mg/1, 9 mg/1, and 100 mg/1, respectively.

For predicting stream pH for the station at Luke the following equation applies:

$$pH = pka - \log_{10} \frac{(acid)}{(alk)} - E$$

Where:

pka	=	minus inverse logarithm hydrogen concentration based on water temperature
(acid)	=	acidity concentration
(alk)	=	alkalinity concentration
E	=	correction factor

After the NBPR receives the effluent from the UPRC plant, the river water contains high alkalinity as well as phosphates and organic bases and high dissolved solids concentration. The equilibrium constant on water temperature decreases with increasing dissolved solids concentration. The model applies a correction factor (E) at each station to adjust for field pH data.

The water quality of the NBPR below Luke, Maryland, depends largely upon the WESTVACO Paper Mill operation. The WESTVACO Paper Mill at Luke, Maryland, withdraws water from the river for various purposes. The volume of water withdrawn can vary depending on the process method used. Currently, the plant uses around 60 cfs of water, of which 59.5 cfs is cooling and processing water and 0.5 cfs is drinking water. In 1968 the plant used about 108 cfs, of which 66 cfs was for cooling and 42 cfs for process water (Ref. 1). According to WESTVACO personnel, the plant will further reduce its water use to around 30 to 40 cfs. Of the present 60 cfs withdrawn from the NBPR, approximately 11 cfs of cooling water is discharged into the river without any treatment, approximately 10 cfs is pH adjusted and discharged from the ash lagoon, turbine condenser, and chlorine dioxide generator. The remaining approximately 33 cfs is processed water and is transported to the UPRC treatment plant. About 6 cfs is lost principally through evaporation. The discharge of the UPRC treatment plant (97% comes from the mill) into the NBPR reduces acidity and adds alkalinity to the river. The water quality of the NBPR, below Westernport, Maryland, depends upon the mill operation, mining regulations, and waste treatment policies and the operation of its Bloomington/Savage system. Table H-II-11 presents the characteristics of the influent and effluent of the UPRC plant in June 1981.

The present neutralizing capacity of the effluent from the WESTVACO plant and the UPRC plant is 7200 lb/day of net alkalinity. In 1968, its neutralizing capacity was 28,000 lb/day of net alkalinity (ref 13). The following are the equations that describe the water quality loadings from WESTVACO and the UPRC plant by the plant.

Alkalinity increase - $Alk = 152.16 + 0.886 \times Log_{10}Q - 43.33 \times (Log_{10}Q)^2 + 9.05 \times (Log_{10}Q)^3$

Acidity reduction - $Acid = 652.6 + 584.91 \times Log_{10}Q - 176 \times (Log_{10}Q)^2 + 17.725 \times (Log_{10}Q)^3$

Conductivity increase - $Cond = 8610.29 - 7878.12 \times Log_{10}Q + 2526.0 \times (Log_{10}Q^2 - 278.37 \times (Log_{10}Q)^3$

TDS increase-$TDS = 5358.06 - 5161.14 \times Log_{10}Q + 1725.98 \times (Log_{10}Q)^2 -197.44 \times (Log_{10}Q)^3$

where Q is flow (CFS) U/S of New Creek

The water quality loading upstream of New Creek is a resultant water from the NBPR water, Georges Creek water, and the effluents from the UPRC plant. Equations describing existing water quality loading (without Bloomington) were developed from data collected from 1977-1980. The equations are shown in Table H-II-10. To determine the effects on water quality loading by Georges Creek and other tributaries loading effects are calculated by taking the difference between the Luke data and data from upstream of New Creek, then subtracting the loading effects by the UPRC plant. Predicted loading upstream of New Creek is the sum of the loading at Luke modified by Bloomington, the effluent loading from the UPRC, and the loading from the tributaries. Stream temperature will be affected by WESTVACO and the UPRC plant. The water temperature increase caused by WESTVACO and the UPRC plant is reduced from the data. An equation was developed to establish the amount of change in temperature for flow and existing temperatures as follows:

$$\text{Temperature increment} = 9.22 - 0.0388 \times Q + 6.13 \times 10^{-5} \times Q^2 - 3.4 \times 10^{-8} \times Q^3$$

where Q is flow upstream of New Creek.

To compute the effects on water temperature by Georges Creek and other tributaries, the stream temperature of upstream of New Creek is determined by using the temperature equation for the NBPR upstream of the Savage River in the Table H-II-10. Water temperature upstream of New Creek is the resultant water temperature from the water temperature at Luke, water temperature increment by the WESTVACO and the UPRC plant, and water temperature of the tributaries.

TABLE H-II-10

INFLUENT AND EFFLUENT CHARACTERISTS UPRC PLANT JUNE 1982

UPPER POTOMAC RIVER COMMISSION, WASTE TREATMENT FACILITIES
WESTERNPORT MARYLAND

INDUSTRIAL WASTE INFLUENT

JUNE 1981

DATE	FLOW	SOLIDS			TURBID-ITY	OXYGEN		COLOR	pH	TEMP-	
		TOTAL	DISS.	SUSP.		D.O.	B.O.D.				
	MG	PPM	PPM	PPM	PPM	PPM	PPM	PPM		DEG. F	
1	20.59	3244	1436	1808	1000	-	360	998	7.0	-	
2	20.54	3168	1856	1312	900	-	454	857	9.4	-	
3	20.28	4032	1984	2048	1300	-	426	1026	8.8	-	
4	21.10	3740	2384	1356	950	-	394	955	6.9	-	
5	20.76	3160	2044	1116	850	-	227	607	9.5	-	
6	19.22	3840	2420	1420	1500	-	379	1012	8.5	-	
7	18.62	3980	2550	1430	1200	-	474	1433	8.2	-	
8	18.85	4020	2890	1130	1000	-	388	2107	6.6	-	
9	19.43	3760	2530	1230	850	-	348	1489	6.9	-	
10	19.38	2920	1780	1140	1000	-	468	1124	8.7	-	
11	20.15	3132	2224	908	900	-	408	2107	7.4	-	
12	19.31	2788	2052	736	850	-	344	1433	7.6	-	
13	19.30	2984	2052	932	1000	-	318	759	9.7	-	
14	19.40	2760	1840	920	1000	-	279	843	7.9	-	
15	19.93	3444	2432	1012	1000	-	253	624	11.2	-	
16	19.86	3396	2402	994	900	-	450	1405	8.2	-	
17	20.39	3628	2068	1560	1500	-	445	787	9.6	-	
18	18.05	2304	1298	1006	550	-	375	295	9.7	-	
19	20.05	2588	2054	534	700	-	314	511	8.2	-	
20	20.53	2860	2096	764	980	-	305	658	7.2	-	
21	19.17	3128	2264	864	720	-	343	1040	7.0	-	
22	19.48	3424	2158	1266	830	-	391	871	9.6	-	
23	19.35	3088	2040	1048	780	-	282	804	8.4	-	
24	19.94	4020	2840	1180	1100	-	346	970	7.6	-	
25	19.08	3332	2386	946	850	-	385	832	8.3	-	
26	20.05	3424	2388	1036	900	-	417	955	8.0	-	
27	19.85	2620	1742	878	850	-	402	927	8.0	-	
28	18.58	3052	2092	960	850	-	442	1040	7.7	-	
29	18.65	3032	2032	1000	1100	-	423	1053	6.8	-	
30	18.35	2912	2170	742	700	-	355	815	3.7	-	
31											
AVE.	19.61	3259	2150	1109	954	-	373	1011	7.8	-	

TABLE H-II-10 (Cont'd)

UPPER POTOMAC RIVER COMMISSION, WASTE TREATMENT FACILITIES
WESTERNPORT, MARYLAND

AVERAGE PLANT EFFLUENT — JUNE 1981

DATE	FLOW	SOLIDS			TURBID-ITY	OXYGEN		COLOR	pH	TEMP-
		TOTAL	DISS.	SUSP.		D.O.	B.O.D.			
	MG.	PPM	PPM	PPM	PPM	PPM	PPM	PPM		DEG. F
1	20.76	1564	1540	24	100	8.3	23	596	7.4	82
2	20.52	1860	1832	28	120	8.4	33	941	7.5	84
3	20.38	1876	1825	51	140	8.2	25	955	7.4	88
4	21.10	2104	2041	63	190	8.0	59	857	7.7	88
5	20.64	2352	2300	52	130	8.0	19	545	7.8	89
6	19.13	2120	2065	55	160	8.6	18	837	7.7	90
7	18.37	2400	2335	65	130	7.0	19	1152	7.7	88
8	18.59	2840	2780	60	150	8.3	25	1405	7.8	90
9	19.62	2260	2215	45	140	6.7	14	1096	7.4	88
10	19.55	1980	1896	84	100	8.4	11	984	7.8	76
11	20.11	1868	1826	42	230	8.2	24	1012	7.4	86
12	19.04	1996	1961	35	100	8.3	20	1124	7.5	86
13	19.52	1820	1794	26	110	8.4	15	787	7.4	92
14	19.83	1940	1882	58	130	8.5	7	703	7.6	82
15	19.96	2344	2275	69	240	8.0	21	815	7.8	92
16	19.79	1984	1937	47	170	7.9	11	843	7.7	96
17	20.10	1940	1855	85	250	7.2	27	821	7.7	86
18	17.60	1832	1779	53	130	7.7	14	585	7.8	86
19	19.94	1476	1451	25	100	7.1	7	503	7.7	92
20	20.76	2184	2153	31	110	6.5	9	568	7.5	90
21	19.24	2216	2143	73	100	8.6	14	927	7.5	89
22	19.46	2236	2127	109	100	6.5	18	837	7.4	90
23	18.95	2044	1937	107	120	7.1	22	798	7.3	91
24	19.66	2352	2230	122	140	7.0	15	815	7.5	93
25	19.25	2232	2151	81	100	7.1	21	776	7.5	93
26	19.72	2256	2164	92	110	7.5	22	826	7.4	90
27	19.66	2016	1983	33	130	8.8	19	1068	7.6	90
28	18.35	1960	1928	32	110	8.3	17	837	7.8	86
29	18.62	2188	2149	39	110	8.1	12	815	7.5	90
30	18.36	2080	2044	36	110	7.6	8	792	7.2	90
31										
AVE.	19.55	2077	2020	57	135	7.8	19	854	7.6	88

Existing water quality loading (without Bloomington) at Pinto is shown in Table H-II-10. The simulated water quality loading is calculated similar to water quality loading upstream of New Creek. The loading at Pinto is the total of the water quality loading from New Creek and other tributaries plus the loading of the NBPR upstream of New Creek. The acidity at Pinto is calculated by subtracting the average acidity reduction between Pinto and New Creek from the acidity upstream of New Creek. The average acidity reduction for each station was obtained from the pre-impoundment surveyed data. (Table H-II-11).

Water quality loading for stations below Pinto are obtained by the same method used to calculate water quality loading at Pinto with the following exceptions.

1) TDS data below Pinto were not available. The TDS concentration below Pinto was calculated from conductivity using the equation for the relationship between TDS and conductivity at Pinto.

2) Below the station U/S of Wills Creek, the following equation for the natural stream water temperature is used:

$$-11.877 \times \mathrm{SIN}\,(0.017214 \times I + 0.08715) + 12.94359$$

where I is Julian day

The equation is developed by using the temperature data collected at Wiley Ford during 1977-1980.

MODEL RESULTS

The water quality in Bloomington Lake was modeled for four different flow years, 1930, 1962, 1966, and 1967. Years 1962 and 1967 were average and wet years while 1930 and 1966 were dry years. Each year was modeled under a best case and worst case scenario. The best case uses equations developed from 1979 and 1980 water quality data. The worst case uses equations based on 1967 through 1972 water quality data. Each scenario was run with three different minimum release plans. These plans were for river flows of 110 cfs, 150 cfs, and 200 cfs at Luke, Maryland. The water quality at the outflow and the NBPR at Luke was modeled for the corresponding conditions. Thus a total of 24 reservoir model runs were prepared. As mentioned earlier in this text, temperature was not modeled but the output from a recent thermal model (WESTEX) for Bloomington was used as input to the quality model. It was felt that the thermal patterns in the lake would not change much due to the different quality scenarios and therefore the same thermal regime was applied to all reservoir model runs. There would be different thermal patterns in each flow year; however, changes in these patterns would not have significantly altered the model results.

PROJECTED WATER QUALITY CONDITIONS IN THE RESERVOIR

The impoundment of water in Bloomington will alter the water quality. As the water changes from a stream environment to a lake environment, the hydraulic character is changed from a free flowing river to a quiescent lake. There is a substantial increase in depth and a decrease in travel velocity and turbulance. Two considerations will affect water quality: (1) physical, chemical, and biological changes, and (2) volume. The sometimes pollutant-laden inflow water mixes with the lake water, and dilutes the water pollutants. By changing the stream to an impoundment, many particulates will settle to the bottom. Some parameters will react with other parameters and form totally different compounds. The dissolution and precipitation of these compounds will differ depending on pH and water temperature. For example, iron and aluminum ions from the inflow water will be hydrated or coagulated gradually with other ions at increased pH in the reservoir, and precipitate to the bottom. Overall water quality will not change appreciably within the lake.

Bloomington Lake is expected to stratify thermally and chemically. The lake will begin to stratify in mid-April and will turn over before mid-November. The pattern of the thermal stratification will vary depending upon inflow water temperature and discharge regime. The lake will exhibit chemical stratification in summer and winter. In summer, the inflow will enter above the thermocline and spread throughout the upper layer. Low inflow, containing high concentrations of AMD mixes with the upper layer of water. Thus the epilimnium accrues more and more AMD throughout the summer. The cold, bottom layer (hypolimnium) water will not mix with the warm inflow water. In winter when the lake is not strongly thermally stratified, inflow containing high dissolved solids will seek the bottom layer. Therefore, the lake will exhibit a low pH in the epilimnion and a higher pH in the hypolimnion in the summer, and opposite in the winter.

The lake water quality is dependent on two factors; inflow water quality and discharge regime. The inflow water quality will vary with the inflow volume. In the lake, the stream water quality is diluted by the lake's natural averaging effect. The regulation scheme of the project changes the water quality in the lake. Outflow quality can change significantly depending on the location of the withdrawal zone and the volume released from the selected zones. Whenever the lake makes releases greater than the inflow, the lake will have a decreased storage volume to average the inflows. The smaller the volume of the lake, the more it is affected by the quality of the inflow. Thus, the impact of a slug of acid water on the lake when the volume is low is much greater than when the lake is full.

The lake will often be used for water quality and/or water supply releases. The water quality and water supply release decreases the lake's volume and results in the weakening averaging capabilities of the lake on water quality. Every year the water quality release will be used to maintain the maximum water quality downstream. The effects of the water quality release in the lake will be minor. Water supply releases from the lake reduce its volume of water which is usually providing the averaging effect. After large water supply releases, the lake has only a small volume for the averaging and maintaining downstream flows. This study analyzed lake water quality under two scenarios: (1) lake water quality when water supply storage is not needed, (2) lake water quality when water supply storage is needed.

Water Quality Conditions When Water Supply Storage is Not Used

Temperature

The pattern of thermal stratification will vary depending upon inflow temperature, inflow volume, and the volume and location of discharge. Figures H-II-12 and H-II-13 are the thermal patterns developed by the WESTEX Thermal Model. The warm surface water (epilmnion) will be approximately 5-30 feet in depth with a temperature range of 22^{0}C to 26^{0}C. A zone of abrupt temperature change (thermocline) will be 10 to 50 feet below the surface. A cold zone (hypolimnion) will emcompass a large volume of water 170-200 feet in depth below the thermocline with a temperature range of 4^{0}C to 8^{0}C.

Most reservoirs are regulated to maintain a specific downstream temperature target. Bloomington Lake will be regulated to maintain the best long term overall quality downstream. Since the lake suffers from low pH as a result of mine drainage, pH will be the highest priority downstream quality objective. As a result, the downstream temperatures will fluctuate greatly from time-to-time and will not match the natural stream temperature. The hypolimnion volume will decrease by the amount of water released by the flood gates or lower selective withdrawal ports. Consequently, the hypolimnion temperature will be warmer in high flow years and colder in the low flow years when flood gate operation is less frequent. The effects on the hypolimnion temperature due to maintaining the different minimum outflows are minor but higher minimum outflow causes the model to decrease the volume of the hypolimnion to maintain downstream quality.

pH

The pH in the mixing zone will vary seasonally depending on the inflow pH. Maximum pH will accompany the high inflow of spring and the low inflow in late summer will contribute the lowest pH water. Figures H-II-14 and H-II-17 show the typical pH vs. time plots of the upper and lower zones. Table H-II-12 shows the pH values with various scenarios on typical days (Julian day 190, 240, 320). Julian day 190 is just before the water supply release, Julian day 240 is in the middle of the water supply release, and Julian day 320 is after the fall overturn. Without water supply releases, the different minimum flows do not affect the lake pH. The pH of the upper zone will be in the range of 4.8 to 6.1 under the best water quality scenario. For the worst water quality condition, the pH of the upper zone will be in the range of 3.4 to 3.7. The pH in the lower zone will be in the range of 5.5 to 5.8 for the best water quality condition and 3.4 to 3.7 for the worst water quality condition.

When the lake is thermally stratified, the water quality in the lower zone will remain relatively constant throughout the summer except during high inflow events in which the flood gates must be opened or the inflow becomes dense enough to sink through the thermocline. When the lake starts the fall overturn in early September, the pH of the upper zone will increase with time because the lower zone water, which has better pH, mixes with the upper zone and the resultant water will be of a higher pH. Different minimum outflows will have no effect on the upper zone pH.

Generally, water quality of the upper zone will be determined by the total inflow volume and thermal pattern in the lake. Water quality of the lower zone is determined by the inflow volume before the lake is thermally stratified.

Acidity

Acid concentration in the lake is related inversely to the pH. When the lake has a high acid concentration, the pH will be low and conversely when acid concentration is low, pH values are high. The acid concentration of the upper zone will be at its lowest point in the spring and at its highest point in late summer or fall. The mixing zone may often have very high acid concentration in the fall due to very low flow and the thickness of the mixing zone. Figures H-II-19 and H-II-21 show the simulated acid concentration of the upper and lower zones for the 1962 flow years for the best and worst scenarios. Table H-II-12 shows the acidity values with various scenarios on typical days. The acid

TABLE H-II-12

TYPICAL LAKE WATER QUALITY DATA FROM THE COMPUTER SIMULATION

BEST WATER QUALITY SCENARIO

Parameters	Zone	Julian Day	Water Supply Release 1930 110	1930 150	1930 200	Water Supply Release 1966 110	1966 150	1966 200	No Water Supply Release 1962 110	1962 150	1962 200	No Water Supply Release 1967 110	1967 150	1967 200
pH	upper zone	190	4.8	4.8	4.8	5.1	5.1	5.1	5.0	5.0	5.0	5.2	5.2	5.2
		240	4.7	4.7	4.7	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0
		320	4.9	4.8	4.7	5.1	5.0	5.0	5.2	5.2	5.2	5.1	5.1	5.1
	lower zone	240	4.7	4.7	4.7	4.9	4.9	4.9	4.9	4.9	4.9	5.0	5.0	5.0
acidity	upper zone	190	26.8	26.8	26.8	19.7	19.8	19.9	20.4	20.4	20.4	16.5	16.5	16.5
		240	30.6	30.9	31.2	22.8	23.4	23.9	23.8	23.8	23.9	19.7	19.7	19.8
		320	23.4	25.0	29.0	18.9	19.7	20.8	16.3	16.3	16.3	19.5	19.5	19.6
	lower zone	240	19.0	17.0	17.0	12.2	12.3	12.3	11.1	11.1	11.1	11.8	11.8	11.8
conductivity	upper zone	190	405	408	406	324	326	327	327	327	327	308	308	308
		240	502	509	517	395	402	410	366	367	368	333	333	333
		320	423	454	530	327	333	341	316	317	318	324	324	326
	lower zone	240	312	312	311	268	269	269	269	269	269	267	267	267
sulfate	upper zone	190	179	178	179	146	147	148	129	129	129	132	132	132
		240	256	261	268	192	196	201	154	154	155	138	138	138
		320	211	235	276	140	142	145	140	141	142	143	143	144
	lower zone	240	125	125	125	116	116	116	117	117	117	115	115	115
TDS	upper zone	190	289	290	290	235	234	240	239	239	239	227	228	228
		240	351	355	360	263	[illegible]	272	265	265	265	243	243	243
		320	301	300	361	239	244	249	233	233	233	238	238	239
	lower zone	240	230	230	230	202	202	202	203	203	203	201	201	201
day ended lower zone			310	302	291	317	306	[illegible]	[illegible]	315	316	318	318	320

WORST WATER QUALITY SCENARIO

Parameters	Zone	Julian Day	Water Supply Release 1930 110	1930 150	1930 200	Water Supply Release 1966 110	1966 150	1966 200	No Water Supply Release 1902 110	1902 150	1902 200	No Water Supply Release 1967 110	1967 150	1967 200
pH	upper zone	190	3.4	3.4	3.4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
		240	3.3	3.3	3.3	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.5
		320	3.4	3.4	3.3	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	lower zone	240	3.3	3.3	3.3	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.5
acidity	upper zone	190	104	104	104	91	91	91	91	91	91	89	89	89
		240	117	118	119	101	102	104	97	98	98	92	92	92
		320	103	107	119	91	92	94	90	90	90	90	90	90
	lower zone	240	87	87	86.9	82	82	82	82	82	82	80	80	80
conductivity	upper zone	190	435	436	437	326	322	330	306	306	306	300	300	301
		240	551	559	568	417	416	436	372	373	374	314	314	325
		320	400	436	519	318	[illegible]	339	299	300	301	316	316	318
	lower zone	240	263	263	263	234	[illegible]	234	229	229	229	236	236	236
sulfate	upper zone	190	139	140	140	121	121	121	112	112	112	114	114	114
		240	175	178	181	144	146	148	126	126	126	116	116	116
		320	145	157	186	118	119	121	115	116	116	118	118	118
	lower zone	240	103	103	103	101	101	102	101	101	101	102	102	102
TDS	upper zone	190	308	307	[illegible]	221	221	241	226	226	221	222	223	223
		240	382	384	[illegible]	[illegible]	[illegible]	309	266	269	270	237	238	238
		320	286	304	[illegible]	234	[illegible]	247	222	222	223	232	232	234
	lower zone	240	198	199	111	180	180	180	177	177	177	181	181	181
day ended lower zone			310	302	311	117	[illegible]	[illegible]	315	315	316	318	318	320

concentration of the upper zone varies with the inflow acid concentration and the discharge regime. The simulated acid concentration will be in the range of 8 to 33 mg/l for the best water quality condition and 70 to 100 mg/l for the worst water quality condition. The acid concentration of the non-mixing zone will be between 10 to 12 mg/l for the best water quality scenario and between 75 to 85 mg/l for the worst water quality scenario.

When the lake is thermally stratified, the acidity in the lower zone will remain relatively constant throughout the summer except during flood events. In early September the acidity of the upper zone will slowly decrease due to the mixing with the lower zone water due to the fall overturn and increasing inflows. The effects on acidity due to the various minimum flows are minor.

Conductivity

The inflow to Bloomington Lake contains high acid and sulfate concentrations and significant amounts of ions of such metals as aluminum, iron, manganese, magnesium, etc., due to the severe acid mine drainage problems. In the quiescient water of the lake some ions will react together and precipitate out. These reactions depend upon the water temperature, pH, and other governing factors. Some particulates will settle out because of the abrupt lowering of the velocity of the inflow. Some ferric iron present in the low pH inflow will react with hydroxide ion (OH) in the reservoir and precipitate out. The results will be a slight decrease in conductivity in the lake. The most important factor governing the lake conductivity is the inflow conductivity. The conductivity in the lake depends primarily on the inflow volume. High inflows have lower conductivity and low inflows have high conductivity. The conductivity in the upper zone varies with time much like the acid concentration. Conductivity will be the lowest in the upper zone in spring and gradually increase throughout the summer. Figures H-II-22 through H-II-25 show the simulated conductivity of the upper and lower zone for the best water quality and the worst water quality scenarios. Table H-II-12 presents conductivity values on typical days. The overall conductivity of the upper zone will be in the range 200 to 400 micromhos/cm for both the best and worst water quality scenarios.

The conductivity in the lower zone is relatively stable, except following high inflow events. The conductivity of the upper zone will slowly decrease as mixing with the lower zone water increases and as inflows begin to increase. The effects on conductivity in the lake of the different minimum flows are minimal.

The lake conductivity will change year to year because of the different total inflow volumes. For instance, in 1962, the lower inflow volume in late summer and fall caused high conductivity in the upper zone; in 1967, when flows were a bit higher, the conductivity in the upper zone was lower than that of 1962.

Sulfate

The sulfate concentration in the lake will follow the same trends as the other water quality parameters described previously. High flows contain low sulfate concentration while low flows will exhibit high sulfate concentration. Figures H-II-26 through H-II-29 are the simulated sulfate concentrations, and Table H-II-12 shows the sulfate on the typical days for the different water quality scenarios based on flow years 1962 and 1967. The sulfate concentration of the upper zone will be in the range of 95 to 170 mg/l for the best water quality condition and 90 to 140 mg/l for the worst water quality condition. Sulfate seems to be one of the most conservative parameters in the lake. A small amount of sulfate will precipitate out in the lake, however the major portion of the sulfate will remain in solution in the lake. The inflow sulfate concentration has been increasing proportionately with the increased mining operations in the basin. The sulfate concentration in the lower zone is expected to be in the range of 110 to 130 mg/l for the best water quality condition and 90 to 100 mg/l for the worst water quality condition. The effects on the sulfate concentration in the lake due to the different minimum flows and the flow year are minimal.

Total Dissolved Solids

The solubility of some materials depends upon the pH and temperature of the water. A major characteristic of AMD is high TDS. Therefore, it is expected that the lake will carry a high TDS concentration. TDS is closely related to conductivity, therefore TDS concentration in the lake will exhibit a similar trend to that of conductivity. The simulated TDS concentration of the upper zone will be in the range of 160 to 290 mg/l for the best water quality condition and 160 to 300 mg/l for the worst water quality condition. The expected TDS concentration of the lower zone will be in the range of 190 to 210 mg/l for the best water quality condition and 160 to 190 mg/l for the worst water quality condition. The effects on TDS due to previous minimum flows are minimal. Figure H-II-30 through H-II-31 exhibit the simulated TDS concentration in the upper and lower zones of the year 1962 for the best scenarios. Also, Table H-II-12 shows the TDS concentration on the typical days.

Manganese

Inflow to Bloomington Lake contains high manganese concentration, a characteristic of water polluted by AMD. Manganese is very soluble at low pH. Organic decomposition of sediment increases manganese concentration in most lakes. Bloomington Lake will not exhibit an increase in manganese concentration by the organic decomposition because low pH and cold water in the lake are major limiting factors of organic activity. It is expected that manganese concentration in the lake will be almost the same as the manganese concentration of the inflow. The manganese concentration of the upper zone will be in the range of 0.4 to 0.9 mg/l for the best water quality condition and 0.4 to 1.0 mg/l for the worst quality condition. The manganese concentration of the lower zone will be in the range of 0.45 to 0.55 mg/l for both water quality conditions.

The effects on the manganese concentration due to the minimum flows and flow year are minimal.

Dissolved Oxygen

It is expected that Bloomington Lake will experience minor dissolved oxygen (DO) depletion. The DO concentration in the lake varies with biological activity and chemical reactions. Biological activity in the lake will be limited due to the expected low pH. The only aquatic life present in the lake will be very persistent. DO in the lake is expected to be at or near saturation.

Fecal Coliform

The Maryland standard for fecal coliform is 200 colonies/100 ml based on the geometric mean of the live consecutive samples. The EPA recommended criteria for body contact recreation is 290 colonies/100 ml based on a logarithmic mean of a minimum of five samples in 30 days. According to the data collected by the State of Maryland, the inflow fecal coliform concentration at Kitzmiller had a median of 23 colonies/100 ml, with a maximum of 430 and a minimum of 2. Fecal coliforms in the lake will die due to high retention time in the acidic water. The lake will have very low fecal coliform concentration (much less than 200 colonies/100 ml).

Eutrophication Potential

The inflow has enough nutrient loading to develop eutrophication. (0.093 mg/l total phosphate). Some algae can survive the acidic water conditions so the lake may develop some eutrophication. The degree of the eutrophication is marginal under the current inflow water quality conditions. In summer, the europhication potential will disappear because the lake pH will be too low for blue-green algae to survive. Blue-green algae favors alkaline water.

Water Quality Conditions When Water Supply Storage is Used

In an average or wet year Bloomington Lake will be at full summer pool by late June or early July. However, in a dry year, Bloomington Lake will be drawn down a few feet from summer pool (1466 msl) because of releases for the minimum flow at Luke and any water quality releases. The extent of the draw-down depends upon the inflow volume and water quality conditions downstream. When water supply releases are made, the total outflow is the water supply flow requested plus a part of the minimum water quality flow at Luke. (The minimum water quality flow is the sum of the Bloomington and Savage outflow prior to the water supply release.) High minimum water quality flow has more Bloomington than Savage water. Therefore, high minimum water quality flows evacuate more water quality storage from Bloomington Lake. Figures H-II-32 and H-II-33 are the storage curves for Bloomington Lake vs. time for hypothetical water supply plans applied to the 1930 and 1966 low flow years. The hypothetical water supply plan is based on the water supply demand of the year 2030 and the flowby target of 100 mgd at Little Falls, Washington, D.C. (Table H-II-9). Bloomington Lake is drawn down 4.5 feet from the summer pool when the minimum water quality flow of 200 cfs is maintained, three feet with 150 cfs, and 1.5 feet with 100 cfs (prior to a water supply release beginning on 8 July 1966) (Figure H-II-33). In 1930, the pool is slightly drawn down on Julian day 150 and attains the full summer pool on Julian day 170. When water supply releases are started in early July, the lake is almost at full summer pool. After the water supply storage is completely evacuated, the storage difference due to the different water quality flows during the water scheme release is significant (Figure H-II-32 and H-II-33). In 1930, the lake had approximately 31,000 acre-feet of water quality storage remaining at the end of the water supply release (Julian day ?50) when the minimum water quality flow of 200 cfs was maintained. When the minimum water quality flow of 150 cfs is maintained the lake has 36,000 acre-feet of water quality storage. With the minimum water quality flow of 110 cfs, the lake has 43,000 acre-feet of water quality storage remaining on Julian day 250. The lake is completely depleted of available storage on Julian day 340 (mid-December) when the minimum water quality flow of 200 cfs is maintained. With the minimum water quality flows of 100 cfs and 150 cfs, the lake will have 30,000 acre-feet and 10,000 acre-feet respectively remaining at the end of January. In 1966, the lake has less storage remaining at the end of water supply release (Julian day 250) than in 1930. But as a result of high inflows in October and November, the lake attains a normal pool elevation at the end of the year. Bloomington Lake does not physically possess enough storage to maintain a mimimum water quality flow of 200 cfs at Luke when it is a dry low flow year.

The following sections will discuss the effects of water supply releases on lake water quality.

Temperature

The thermal stratification pattern for the 1930 and 1966 low flow years will resemble the pattern of the 1962 flow year before the lake releases for water supply: however, the temperature at depths in the different zones will differ. When water supply releases are made, the thermal pattern will not change but the depth of the epilimnion, thermocline, and hypolimnion will change depending on the zone of withdrawal. Generally the hypolimnion water (better water quality) will be heavily utilized to meet the objective quality downstream. The thickness of the hypolimnion layer decreases resulting from water supply releases due to increased demand. The temperature in the hypolimnion is colder in a dry year than that in an average and wet year because the cold inflow in the spring stays in the hypolimnion throughout the year. In a wet year, the cold spring time runoff in the hypolimnion is often released through the flood gates or lower selective withdrawal ports because of the high inflow in late spring. The expected lake temperature is 2°C to 3°C warmer in the epilimnion in a dry year and colder in the hypolimnion than its corresponding temperatures in an average and wet year.

pH

In 1930, low inflow in the spring caused depressed pH values in the upper zone. In 1962, high spring inflow caused high pH in the upper zone in spring, and extremely low inflow during late spring and summer dramatically decreased the pH in the upper zone. Figures H-II-34 through H-II-37 are the simulated pH values in the upper and lower zones for the worst scenario. The simulated pH of the upper zone will be in the range of 4.6 to 6.2 for the best water quality condition and 3.0 to 3.7 for the worst water quality condition. With water supply releases, the lower zone storage rapidly decreases by the time the lake experiences the fall overturn, the pH of the upper zone will exhibit only a slight improvement due to the low volume of good water available in the hypolimnion for mixing. After the lower zone storage runs out or fall overturn is complete, the upper zone pH continues to decrease unless the lake experiences high inflow for the rest of the year. The simulated pH of the lower zone will range between 5.0 to 5.5 for the best water quality scenario and 3.4 to 3.6 for the worst water quality scenario. Table H-II-12 shows the pH values on typical days for the various scenarios.

High (200 cfs) minimum water quality flows decrease the lake's averaging ability with time due to the losses of storage. Figure H-II-34 shows the change in pH for 1930 due to the different minimum water quality flows (worst water quality scenario). Around Julian day 240, the lake starts its fall overturn. The pH in the upper zone increases with time until the overturn is complete. As soon as the overturn is complete, the pH in the upper zone gradually decreases with time until the lake is completely empty on Julian day 340. After that, the lake represents inflow quality and has no quality control ability. When the minimum water quality flow is maintained at 150 cfs, the lake is able to perform its function of averaging water quality constituents to some degree. The minimum water quality flow of 110 cfs exhibits the best pH at the end of the year because the lake has a larger volume with which to average the water quality constituents. The effects of different minimum water quality flows on pH are apparent only for the worst water quality scenario.

Acidity

Figures H-II-38 through H-II-41 show the simulated acid concentration in the upper and lower zones for the best and worst water quality conditions of 1930 and 1966. It is expected that the acidity of the upper zone will be in the range of 30 to 55 mg/l for the best water quality scenario and 90 to 180 mg/l for the worst water quality scenario for the minimum water quality flow of 200 cfs for 1930. For the minimum water quality flow of 150 cfs, the acidity will range from 25 to 30 mg/l for the best water quality scenario and from 90 to 100 mg/l for the worst water quality scenario. The acidity for the minimum water quality flow of 100 cfs ranges around 20 to 25 mg/l for the best water quality scenario and 85 to 100 mg/l for the worst quality scenario. The expected acidity of the lower zone will be in the range of 10 to 18 mg/l for the best water quality scenario and 75 to 90 mg/l for the worst water quality scenario. Table H-II-12 shows the acidity on typical days for the various scenarios.

Again the effects of the different minimum water quality flows are significant only for the worst water quality scenario. When the total lake storage is less than 10,000 acre-feet, acidity in the lake will increase rapidly. Figure H-II-38 shows the increase in acidity for the minimum water quality flow of 200 cfs on Julian day 310.

Conductivity

The effects of water supply releases on conductivity follow the same trend as pH and acidity (see Table H-II-12). Figures H-II-42 through H-II-45 show the simulated conductance in the upper and lower zones for worst water quality case. The expected maximum conductivity of the upper zone will be in the range of 400 to 600 micromhos/cm, for both the best and worst water quality scenarios. The conductivity of the lower zone will be in the range of 270 to 310 micromhos/cm for the best water quality case, and 220 to 270 micromhos/cm for the worst water quality case. The conductivity of the upper zone ranges from 300 to 1000 micromhos/cm for both the best and worst water quality scenarios when the lake is completely empty. Again the lake will be in an inflow-outflow situation and will reflect the same quality parameters as the North Branch Potomac River upstream of the project.

Sulfate

The effects of water supply releases on sulfate concentration exhibit the same trends as conductivity (see Table H-II-12). Figures H-II-46 through H-II-49 show the simulated sulfate concentration of the upper and lower zones for the best and worst water quality cases. The sulfate concentration will generally be in the range of 100 to 310 mg/l for the best water quality scenario and 90 to 200 mg/l for the worst water quality scenario. When the lake is empty, the sulfate concentration is the same as the North Branch of the Potomac River, which ranges from 150 to 700 mg/l during the periods of the end of 1930.

Total Dissolved Solids

The expected TDS concentration is in the range of 150 to 350 mg/l for both the best and worst water quality scenarios. As with other parameters, the TDS concentration in the lake based on the minimum water quality flow of 200 cfs for 1930, exhibits severe fluctuation and ranges between 200 and 700 mg/l for the best water quality scenario and 250 to 700 mg/l for the worst water quality scenario. The TDS concentration of the lower zone ranges from 200 to 230 mg/l for the best water quality scenario and 175 to 200 mg/l for the worst water quality scenario. Table H-II-12 shows the TDS values at typical days for the various scenarios for comparison.

Manganese

The expected manganese concentration will be in the range of 0.4 to 1.25 mg/l for the best water quality scenario and 0.4 to 1.5 mg/l for the worst water quality scenario. When the lake is empty the manganese concentration will be the same as the stream manganese concentration in the North Branch Potomac River at the end of the year 1930 which ranges from 0.8 to 2.4 mg/l for the best water quality scenario and 0.9 to 2.4 mg/l for the worst water quality scenario. The manganese concentration of the lower zone ranges from 0.5 to 0.7 mg/l for both the best and worst water quality scenario. The Bloomington Lake project will have little manganese problems in the lake and downstream in the future, and is not discussed further in the text.

PROJECTED OUTFLOW WATER QUALITY CONDITIONS

Most outflow will be released through the selective withdrawal gates. Since the lake will be thermally and chemically stratified, the role of the selective withdrawal gates is very important to control downstream water quality. The outflow quality considerations include: 1) Bloomington Lake water quality and volume, 2) Savage Reservoir water quality and volume, and 3) the desired flow and quality at Luke. Therefore, the outflow water quality will change from time-to-time based on the withdrawal stategy of the outflow for the long term water quality downstream.

One of the main tools for operating Bloomington Lake for water quality control is the selective withdrawal capabilities of the intake tower. The outlet works consist of two service gates, two emergency gates and two low flow gates. The low flow gates are fed from any of a combination of 10 water quality ports located at five different elevations. It is through the low flow gate (water quality port system) that waters at different levels in the lake will be "blended" to achieve water quality objectives downstream. Figures H-II-50 through H-II-53 show the simulated outflow for the four flow years.

Temperature

Outflow temperature, a major operational concern of most lakes, is not the first priority at Bloomington Lake. Figures H-II-54 through H-II-57 show the simulated outflow temperature for the various water quality scenarios. Generally, Bloomington outflow temperature will be colder than the natural stream water temperature because the withdrawals will be taken from below the surface most of the time. Table H-II-13 shows the temperature values for four typical days for various scenarios. Julian day 150 is generally a day about the beginning of low inflow, Julian day 190 is a day just before the water supply release, Julian day 240 is a day of the middle of the water supply release periods, and Julian day 300 is a day during the fall overturn or a day after the fall overturn. The maximum expected outflow temperature is 15°C to 22°C, which occurs during the summer. This is approximately 5°C to 10°C lower than the natural stream temperatures during summer. When the lake does not make any water supply releases, (the years of 1962 and 1967) the outflow water temperature is not affected by the differing minimum water quality outflows. The outflow temperature of the high flow year of 1967 exhibits a slightly higher outflow temperature than that of 1962. This is because the lower zone temperature of the lake will be colder in dry years than in wet years. When the lake begins to release for water supply purposes, the outflow temperature will be slightly colder because the extra releases will incorporate more water from the colder lower zone. The expected outflow temperature during times of

TABLE H-II-13

TYPICAL DOWNSTREAM WATER TEMPERATURE FROM COMPUTER SIMULATION

Use / Flow year / Minimum flow / Julian day		Water supply release						No water supply release					
		1930			1966			1962			196[illegible]		
Location	Julian day	110	150	200	110	150	200	110	150	200	110	150	200
Barnum	150	8.7	8.6	8.6	13.3	13.3	13.3	10.8	10.8	10.8	13.5	13.[illegible]	13.5
	190	14.2	14.0	13.7	19.9	19.1	18.2	19.3	19.3	19.3	20.1	20.1	20.1
	240	9.8	9.6	9.4	11.1	10.8	10.4	14.7	14.5	14.2	15.9	15.8	15.6
	300	10.2	10.0	12.1	11.1	10.9	12.0	11.6	11.4	11.2	11.6	[illegible]	11.4
Luke	150	10.0	9.7	8.6	14.4	14.4	14.4	10.4	10.4	10.4	[illegible]	12.3	12.[illegible]
	190	13.8	13.6	13.2	18.6	17.9	17.2	18.2	18.2	18.1	18.5	18.9	15.8
	240	10.5	10.3	10.2	11.6	11.3	10.9	14.5	14.3	14.0	15.5	15.5	15.5
	300	10.4	10.2	12.0	11.1	10.9	11.9	11.5	11.4	11.2	11.6	11.5	11.4
u/s New Cr	150	17.2	15.5	13.2	17.3	17.3	17.3	12.6	12.6	12.6	13.7	13.7	13.7
	190	18.6	17.3	16.3	22.9	21.3	19.9	23.1	23.1	22.3	24.7	23.7	22.7
	240	11.1	10.9	10.6	12.1	11.6	11.1	20.5	19.2	17.8	16.9	20.9	19.5
	300	15.7	14.6	15.5	16.2	15.1	15.0	16.8	15.8	14.6	12.7	[illegible]	14.[illegible]
Pinto	150	18.[illegible]	16.4	14.0	18.3	18.3	18.3	13.8	13.8	13.8	14.8	14.8	14.8
	190	18.9	17.5	16.5	23.1	21.5	20.1	23.6	23.6	22.8	25.0	24.2	22.9
	240	11.2	10.9	10.6	12.1	11.6	11.2	20.6	19.4	17.9	11.4	21.3	20.0
	300	15.7	14.6	15.5	15.4	14.6	14.6	16.3	15.4	14.4	12.5	14.3	15.6
u/s Wills Cr	150	18.3	16.5	14.2	18.5	18.5	18.5	14.0	14.0	14.0	15.0	15.0	15.0
	190	18.9	17.6	16.5	23.1	21.5	20.1	23.7	23.7	22.9	25.0	24.2	23.[illegible]
	240	11.2	10.9	10.6	12.1	11.7	11.2	20.7	19.4	18.0	17.5	21.3	20.8
	300	15.7	14.6	15.5	15.3	14.5	14.6	16.2	15.4	14.3	12.4	14.2	13.5
Willey Ford	150	19.9	18.2	15.9	19.9	19.9	19.9	17.0	17.0	17.0	17.7	17.6	17.6
	190	19.4	18.0	16.9	24.1	22.5	21.2	24.7	24.7	23.9	25.6	[illegible]	23.6
	240	11.2	11.0	10.7	12.3	11.8	11.4	21.4	20.3	18.9	12.8	[illegible]	21.3
	300	15.6	14.5	15.4	13.7	13.3	13.7	14.8	14.4	13.7	10.4	[illegible]	10.4
		8.5	7.9	7.2	4.2	4.2	4.3	4.8	4.9	4.9	2.7	2.7	2.7
Oldtown	150	21.2	19.8	17.8	21.0	21.0	21.0	18.8	18.8	18.8	18.9	18.9	18.9
	190	20.2	18.7	17.5	24.6	23.1	21.8	25.2	25.2	24.5	26.0	25.[illegible]	24.1
	240	11.4	11.1	10.8	12.5	12.1	11.6	21.7	20.7	19.5	20.0	22.6	22.0
	300	10.5	14.4	15.3	11.8	11.8	12.3	13.8	13.6	13.1	9.5	9.3	9.3
Paw Paw	150	23.1	22.3	21.1	22.8	22.8	22.8	21.8	21.8	21.8	21.8	21.8	21.8
	190	22.3	20.8	19.6	26.0	24.8	23.7	26.4	26.4	25.9	27.0	26.4	25.4
	240	11.8	11.5	11.2	13.4	12.9	12.4	22.4	21.7	20.8	21.8	23.0	22.8
	300	14.8	14.0	14.9	9.6	9.7	10.1	11.6	11.8	11.7	8.6	8.4	8.5

water supply releases will range between 10^0C to 13^0C in 1930 and 13^0C to 16^0C in 1966. The outflow temperature will get progressively colder as the minimum water quality release is increased from 110 cfs to 150 cfs to 200 cfs. This is caused by drawing more water off of the bottom as the outflow increases.

pH

Outflow pH is the prime factor for determining the outflow water quality. Figures H-II-58 through H-II-65 show the simulated outflow pH for the various water quality scenarios. The outflow pH will be best in spring and gradually decrease with time. The outflow pH is significantly affected by the occurance of the fall overturn. It is expected that the overall pH in the lake will improve to a degree following the fall overturn. It is dependent on how much storge is depleted from the lower zone because of minimum water quality flows and water supply releases. The smaller the storage of the lower zone the less improvement to water quality from the overturn. When water supply releases are not required the lake has large volume of lower zone. As a result, the outflow pH is not affected by the fall overturn. However, when the lake utilized water supply releases, the outflow pH is significantly decreased after the fall overturn.

Table H-II-14 shows the pH values on typical days for various scenarios. The outflow pH is expected to be in the range of 5.0 to 6.0 for the best water quality scenario and 3.0 to 4.0 for the worst water quality scenario. The different minimum water quality flows will have only minor effects on the outflow pH except when releasing for water supply purposes, then the pH is affected significantly. Figure H-II-58 shows the effects of the different water quality flows on the outflow pH. The loss of storage from the lower zone because of the minimum water quality flow of 200 cfs causes the first drop of the outflow pH on around Julian day 290. The total loss of all the lake storage on Julian day 340 causes the second pH drop. Therefore, the pH is the same as the stream pH of the NBPR. The higher the minimum flow, the more the pH drop.

Acidity

Outflow acidity is dependent on the outflow pH. Figures H-II-66 through H-II-73 show the simulated acid concentration of the outflow for the various water quality scenarios. The outflow acidity will be lowest during spring, and highest during summer and fall. Table H-II-15 shows the acidity on typical days for the various scenarios. The expected outflow acidity for no water supply release will be in the range of 5 to 20 mg/l for the best water quality scenario and 70 to 95 mg/l for the worst water quality scenario. Although Figure H-II-66 shows definite differences in acidity for the different minimum water quality flows for the year 1962, the outflow acidity can be maintained at a fairly uniform concentration for all minimum water quality flows. When water supply releases are made, the outflow acidity at the end of the year increases due to the loss of storage thereby losing the "averaging" effect that the lake has when ample water storage is available. Acidity is related inversely to pH, therefore as the outflow acidity increases the pH decreases and vice versa.

For instance, when the minimum water quality flow is maintained at 200 cfs in 1930, the outflow acidity exhibits severe fluctuations after Julian day 340. The reasons for the fluctuations of acidity are the same as those discussed previously for pH.

Maintaining the low minimum water quality flows causes the low outflow acidity at the end of the year, and vice versa. When the minimum water quality flow of 200 cfs is maintained, the outflow acidity exhibits that of the North Branch of the Potomac River.

TABLE H-II-14

TYPICAL DOWNSTREAM PH DATA FROM THE COMPUTER SIMULATION

Scenario	Use	WATER SUPPLY RELEASE																		NO WATER SUPPLY RELEASE																	
	Flow Year	1930									1966									1962									1967								
	Minimum Flow (cfs)	110			150			200			110			150			200			110			150			200			110			150			200		
	Julian day / Location	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
BEST WATER QUALITY	Barnum	4.9	5.0	4.9	4.9	5.0	4.8	4.9	5.1	4.7	5.2	5.3	5.1	5.2	5.3	5.0	5.2	5.3	5.0	5.1	5.1	5.2	5.1	5.1	5.2	5.1	5.1	5.2	5.2	5.2	5.1	5.2	5.2	5.1	5.2	5.2	5.1
	Luke	5.2	5.5	5.4	5.3	5.5	5.2	5.3	5.5	5.0	5.3	5.6	5.5	5.3	5.6	5.3	5.4	5.5	5.2	5.2	5.4	5.5	5.2	5.3	5.5	5.3	5.4	5.5	5.5	5.4	5.4	5.3	5.3	5.4	5.4	5.4	5.4
	½ New Cr.	7.5	6.4	7.6	7.5	6.4	7.6	7.1	6.4	6.6	7.5	6.5	7.6	7.4	6.5	7.6	7.4	6.5	7.5	7.5	7.6	6.3	7.5	7.5	6.3	7.5	7.5	6.4	7.8	6.5	6.8	7.5	7.5	6.8	7.5	7.4	7.5
	Pinto	7.5	6.4	7.6	7.5	6.4	7.6	7.5	6.4	7.0	7.5	6.5	7.7	7.5	6.5	7.6	7.4	6.5	7.6	7.5	7.6	6.4	7.5	7.5	6.4	7.5	7.5	6.6	7.6	6.7	7.2	7.5	7.6	7.3	7.5	7.5	7.5
	½ Wills Cr.	7.5	6.4	7.6	7.5	6.4	7.6	7.5	6.4	7.0	7.5	6.5	7.7	7.5	6.5	7.6	7.4	6.5	7.6	7.5	7.6	6.4	7.5	7.5	6.4	7.5	7.5	6.6	7.6	6.7	7.2	7.5	7.6	7.2	7.5	7.5	7.6
	Wiley Ford	8.1	6.7	8.2	8.0	6.6	8.1	8.0	6.6	8.0	8.0	6.7	8.2	7.9	6.7	8.2	7.9	6.6	8.1	8.0	8.1	6.5	8.0	8.0	6.5	8.0	8.0	6.7	8.1	7.0	7.8	8.1	8.0	7.9	8.0	7.9	8.1
	Oldtown	8.1	6.7	8.2	8.0	6.6	8.1	8.0	6.6	8.0	8.0	6.8	8.3	8.0	6.7	8.2	7.9	6.7	8.1	8.0	8.1	6.8	8.0	8.1	6.8	8.0	8.0	7.1	8.1	7.5	8.0	8.1	8.0	8.0	8.0	8.0	8.1
	Paw Paw	8.0	6.9	8.4	8.2	6.9	8.3	8.1	6.7	8.2	8.1	7.0	8.3	8.1	6.9	8.2	8.1	6.9	8.0	8.2	8.2	7.1	8.2	8.2	7.1	8.1	8.1	7.3	8.2	8.0	8.2	8.2	8.0	8.2	8.1	8.0	8.3
WORST WATER QUALITY	Barnum	3.5	3.5	3.4	3.5	3.5	3.4	3.4	3.5	3.4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	Luke	4.6	4.8	4.7	4.7	4.9	4.6	4.7	4.9	4.4	4.6	4.9	4.8	4.7	4.9	4.7	4.7	4.8	4.6	4.6	4.8	4.8	4.6	4.6	4.8	4.6	4.7	4.8	4.8	4.7	4.7	4.6	4.6	4.7	4.7	4.7	4.7
	½ New Cr.	5.8	5.6	5.9	5.7	5.6	5.7	5.7	5.6	5.5	5.8	5.7	6.1	5.7	5.7	5.9	5.6	5.7	5.8	5.7	6.0	5.5	5.7	5.8	5.5	5.7	5.7	5.6	6.0	5.5	5.6	5.8	5.7	5.6	5.7	5.7	5.8
	Pinto	5.9	5.6	6.0	5.7	5.6	5.8	5.7	5.6	5.5	5.8	5.6	6.2	5.7	5.7	5.9	5.7	5.7	6.0	5.8	6.1	5.6	5.8	5.9	5.6	5.8	5.8	5.7	6.1	5.7	5.7	5.9	5.9	5.7	5.8	5.8	5.8
	½ Wills Cr.	5.8	5.6	6.0	5.7	5.6	5.8	5.7	5.6	5.5	5.8	5.7	6.2	5.7	5.7	6.0	5.7	5.7	5.8	[illegible]	6.1	5.6	5.8	5.9	5.6	5.8	5.8	5.8	6.1	5.7	5.7	5.9	5.9	6.7	5.8	5.8	5.6
	Wiley Ford	6.5	5.9	6.6	6.3	5.8	6.1	6.2	5.8	6.1	6.4	5.8	6.8	6.3	5.9	6.5	6.1	5.7	6.3	6.3	6.7	5.9	6.3	6.4	5.7	6.3	6.3	5.9	6.7	6.0	6.1	6.5	6.3	6.1	6.3	6.3	6.4
	Oldtown	6.5	5.9	6.7	6.3	5.9	6.4	6.2	5.8	6.1	6.4	5.8	7.1	6.3	5.8	6.8	6.2	5.9	6.4	6.4	6.3	6.2	6.4	6.7	6.0	6.4	6.4	6.1	6.8	6.2	6.2	6.5	6.6	6.2	6.4	6.5	6.5
	Paw Paw	6.6	6.0	6.4	6.5	6.0	6.6	6.1	5.7	6.3	6.6	6.0	7.1	6.5	6.0	6.7	6.9	6.0	6.7	6.6	7.0	6.2	6.6	6.7	6.7	6.5	6.6	6.5	7.0	6.3	6.5	6.7	6.7	6.5	6.5	6.6	6.7

TABLE B-II-15

TYPICAL DOWNSTREAM ACIDITY DATA FROM THE COMPUTER SIMULATION

Use		WATER SUPPLY RELEASE																		NO WATER SUPPLY RELEASE																	
Flow Year		1930									1966									1962									1967								
Minimum Flow (cfs)		110			150			200			110			150			200			110			150			200			110			150			200		
Scenario	Location / Julian day	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
BEST WATER QUALITY	Barnum	22	19	23	23	19	25	21	19	29	17	15	19	17	15	20	16	15	21	19	18	16	19	18	16	18	18	16	16	17	18	16	17	18	16	17	18
	Lake	20	17	21	20	17	23	20	17	29	16	14	17	16	14	18	15	14	19	17	16	15	17	17	15	17	16	15	15	16	16	15	16	16	15	16	16
	WV-New Cr.	1	11	1	1	12	1	2	12	7	1	9	1	1	9	1	1	9	1	1	1	12	1	1	12	1	1	11	1	8	4	1	1	4	1	1	1
	Pinto	1	11	1	1	12	1	1	12	3	1	9	1	1	9	1	1	9	1	1	1	12	1	1	12	1	1	11	1	7	2	1	1	2	1	1	1
	WV Wills Cr.	1	11	1	1	13	1	1	12	3	1	9	1	1	9	1	1	9	1	1	1	12	1	1	12	1	1	11	1	7	2	1	1	2	1	1	1
	Willey Ford	1	10	1	1	11	1	1	11	1	1	8	1	1	9	1	1	9	1	1	1	12	1	1	12	1	1	11	1	6	1	1	1	1	1	1	1
	Oldtown	1	9	1	1	10	1	1	11	1	1	7	1	1	8	1	1	9	1	1	1	9	1	1	9	1	1	7	1	3	1	1	1	1	1	1	1
	Paw Paw	1	9	1	1	10	1	1	11	1	1	7	1	1	8	1	1	8	1	1	1	8	1	1	8	1	1	5	1	1	1	1	1	1	1	1	1
WORST WATER QUALITY	Barnum	95	92	102	95	92	107	95	91	117	89	87	91	89	87	93	89	87	91	89	91	90	89	90	90	89	90	90	88	88	90	88	88	90	88	88	90
	Lake	84	75	87	82	75	94	81	75	115	77	72	76	77	71	81	77	74	84	79	76	77	79	79	77	77	77	77	74	75	78	77	77	78	76	76	78
	WV New Cr.	54	69	48	60	70	65	64	70	94	52	66	38	58	67	53	61	70	62	55	37	74	55	50	74	57	55	73	35	67	66	49	53	66	55	57	56
	Pinto	50	69	44	56	70	61	61	70	90	49	66	33	54	67	48	58	69	59	51	32	74	51	46	74	53	51	72	31	66	63	45	49	63	51	54	53
	WV Wills Cr.	50	69	44	56	70	61	61	70	90	49	66	33	54	67	48	58	69	59	51	32	74	51	46	74	53	51	72	31	66	63	45	49	63	51	54	53
	Willey Ford	45	68	39	52	69	57	57	69	85	44	66	29	50	66	41	55	69	55	47	28	74	47	42	74	50	48	72	26	66	61	40	42	61	[illegible]	[illegible]	47
	Oldtown	40	67	33	47	68	51	53	68	79	37	64	11	44	65	25	49	67	35	38	20	62	38	33	62	41	40	57	20	46	53	38	25	[illegible]	[illegible]	31	39
	Paw Paw	39	67	32	47	68	50	52	68	76	36	64	11	43	65	22	48	67	32	37	19	61	37	32	61	40	39	55	18	41	52	32	22	52	31	27	38

Conductivity

Outflow conductivity resembles the same pattern exhibited by outflow acidity. Figures H-II-74 through H-II-81 show the simulated outflow conductivity for the various water quality scenarios. The outflow conductivity is lowest in the spring and highest in summer and fall. The conductivity difference for the various scenarios is shown in Table H-II-16 for typical days.

The expected outflow conductivity for the years 1962 and 1967 will be in the range of 250 to 330 micromhos/cm for the best water quality scenario and 210 to 320 micromhos/cm for the worst water quality scenario. The expected outflow conductivity of the 1930 flow year is in the range of 300 to 500 micromhos/cm for the best water quality scenario and 250 to 500 microhos/cm for the worst water quality scenario for minimum water quality flows of 100 cfs and 150 cfs, and 250 to 1100 micromhos/cm for both the best and worst water quality scenarios for the minimum water quality flow of 200 cfs.

Sulfate

The sulfate concentration of the outflow resembles the same pattern as the outflow acidity. Figures H-II-82 through H-II-85 show the simulated sulfate concentration of the outflow for the best water quality scenario. The sulfate concentration of the outflow is lowest in spring, and gradually increases with time and reaches its highest point in late summer and fall. The trend of the sulfate concentration of the outflow resembles that of acidity. Table H-II-17 shows the sulfate concentration at the typical days for the various scenarios. The minimum flow affects the outflow sulfate concentration at the end of the year only when the lake is utilized for water supply release. Julian day 320 of the 1930 flow year shows different sulfate concentration due to the minimum flow (Table H-II-17). The expected sulfate concentration of the outflow during years is in the range of 105 to 150 mg/l for the best water quality scenario except the extreme dry 1930 year.

Total Dissolved Solids

Outflow TDS resembles the same patterns exhibited by outflow conductivity. Figures H-II-86 through H-II-89 show the simulated outflow TDS for the various water quality scenarios. Table H-II-18 shows the TDS at the typical days for the various years. The expected outflow TDS is in the range of 180 to 240 mg/l for the best water quality scenarios and 160 to 240 mg/l for the worst water quality scenarios. The difference due to the flow years and the minimum flow is the same as the conductivity as shown in Table H-II-18.

Dissolved Oxygen (DO)

Aeration of the discharge in the conduit and in the stilling basin will result in near saturation of DO under all operating scenarios.

Fecal Coliform

With the long hydraulic retention time and low pH, the inflow fecal coliform will die off in the reservoir. Thus, the outflow may not contain any fecal coliform or very few fecal coliform.

TABLE II-II-16

TYPICAL DOWNSTREAM CONDUCTIVITY DATA FROM THE COMPUTER SIMULATION

USE		WATER SUPPLY RELEASE																																			
FLOW YEAR		1950									1966																										
MINIMUM FLOW (cfs)		110			150			200			110			150			200																				
Users/day		190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320																		
SCENARIO	LOCATION																																				
BEST WATER QUALITY	Barnum	356	343	423	356	341	451	351	340	530	315	302	327	343	390	323	311	299	341																		
	Lake	334	297	382	327	295	418	324	293	525	293	267	301	290	262	313	288	268	322																		
	W/S New Cr.	827	534	939	724	573	885	641	54[illegible]	972	741	487	913	681	477	822	639	480	752																		
	Pinto	840	546	989	776	535	925	772	524	952	773	418	866	749	480	771	643	481	731																		
	W/S Wills Cr.	847	542	962	761	531	961	749	521	936	751	494	758	641	481	709	619	487	668																		
	Willey Ford	807	546	906	733	536	864	688	516	904	679	469	553	640	480	513	610	483	519																		
	Oldtown	776	534	860	714	529	832	675	514	876	651	468	482	621	429	470	596	482	995																		
	Paw Paw	661	519	729	634	510	712	663	501	708	550	477	357	539	469	367	529	471	373																		
WORST WATER QUALITY	Barnum	345	311	440	341	338	436	344	305	517	311	283	318	307	[illegible]	338	304	277	339																		
	Lake	324	271	363	317	269	402	313	266	515	290	248	273	285	245	308	281	249	321																		
	W/S New Cr.	812	500	920	781	497	820	691	496	912	737	471	907	676	461	817	633	462	750																		
	Pinto	839	520	972	767	508	929	714	496	741	769	403	860	703	472	786	657	478	729																		
	W/S Wills Cr.	932	516	945	751	501	891	719	493	926	717	478	751	676	468	704	618	469	666																		
	Willey Ford	798	514	889	721	498	890	710	499	891	675	474	518	636	461	550	605	466	517																		
	Oldtown	768	509	815	706	497	818	665	487	844	698	472	491	617	464	499	582	465	421																		
	Paw Paw	658	487	699	622	481	702	615	475	760	518	463	456	536	451	[illegible]	526	456	373																		

USE		NO WATER SUPPLY RELEASE																	
FLOW YEAR		1962									1967								
MINIMUM FLOW (cfs)		110			150			200			110			150			200		
Users/day		190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
SCENARIO	LOCATION																		
BEST WATER QUALITY	Barnum	315	322	316	315	320	317	315	318	318	301	308	324	301	308	324	301	307	326
	Lake	297	297	281	297	301	281	292	272	285	280	278	287	286	271	297	281	286	302
	W/S New Cr.	726	870	424	726	781	424	687	695	457	815	512	600	725	662	600	696	615	704
	Pinto	654	884	414	644	796	414	663	708	440	856	489	601	796	581	601	716	555	701
	W/S Wills Cr.	623	885	389	623	752	389	600	676	402	835	428	573	758	436	523	687	436	659
	Willey Ford	506	670	332	506	692	333	486	602	321	728	315	521	683	233	521	635	256	517
	Oldtown	508	614	355	502	584	353	496	625	346	626	352	515	651	319	515	617	327	544
	Paw Paw	441	504	301	441	507	305	410	500	294	555	287	458	550	264	418	536	269	461
WORST WATER QUALITY	Barnum	290	306	299	290	304	300	290	301	301	290	281	316	290	281	316	291	290	318
	Lake	276	284	266	276	288	267	271	272	270	270	264	290	276	276	290	272	271	295
	W/S New Cr.	707	958	416	707	768	411	668	681	445	856	499	553	765	670	513	687	602	647
	Pinto	677	873	401	677	733	402	645	695	429	878	476	594	787	571	594	702	574	695
	W/S Wills Cr.	605	814	376	605	739	376	583	662	371	827	415	566	749	426	566	629	426	695
	Willey Ford	472	662	322	472	632	322	465	514	312	742	306	511	675	227	515	637	278	554
	Oldtown	476	625	316	490	571	346	651	480	462	681	375	509	648	315	509	610	323	570
	Paw Paw	433	502	299	433	504	279	438	494	290	552	284	455	515	242	455	537	267	459

TABLE H-II-17

TYPICAL DOWNSTREAM SULFATE DATA FROM THE COMPUTER SIMULATION

Scenario	Use	Water Supply Release																	
	Flow Year	1930									1966								
	Minimum Flow (cfs)	110			150			200			110			150			200		
	[illegible] day / Location	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Best Water Quality	Barnum	150	147	211	150	145	225	149	141	296	142	136	140	141	135	143	140	134	145
	Lake	144	132	141	142	136	217	142	136	29[illegible]	135	129	133	139	128	137	134	128	146
	W/S New Cr.	217	156	313	158	154	308	157	152	366	145	145	281	162	193	247	172	148	223
	Pinto	197	151	286	183	149	287	175	149	349	177	141	247	168	139	193	162	139	183
	W/S Wills Cr.	191	150	277	178	148	280	171	146	358	172	140	206	141	138	192	159	139	182
	Walley Ford	214	157	301	197	151	299	167	152	350	187	146	192	128	141	141	171	144	178
	Old Town	134	131	141	135	133	213	135	132	280	133	127	146	133	126	146	132	126	117
	Paw Paw	144	140	189	143	139	206	140	138	260	125	131	88	125	130	90	126	130	93
Worst Water Quality	Barnum	120	115	145	120	111	157	119	113	187	118	113	118	117	112	113	116	111	121
	Luke	113	112	137	117	111	150	117	111	185	115	110	119	115	110	117	114	110	119
	W/S New Cr.	191	131	260	173	129	241	162	127	254	175	126	263	162	125	228	151	121	202
	Pinto	172	126	231	159	121	222	151	123	239	156	123	191	149	121	175	143	121	163
	W/S Wills Cr.	166	121	225	154	123	215	147	121	239	152	121	190	115	120	174	140	119	163
	Walley Ford	191	131	253	173	129	237	163	127	252	172	128	161	162	126	171	154	126	162
	Old Town	112	109	129	113	108	156	113	108	135	120	109	140	118	108	138	118	108	137
	Paw Paw	123	116	158	126	115	162	125	114	185	116	114	86	115	114	87	115	114	89

Scenario	Use	No Water Supply Release																	
	Flow Year	1962									1969								
	Minimum Flow (cfs)	110			150			200			110			150			200		
	[illegible] day / Location	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Best Water Quality	Barnum	126	137	140	126	136	141	126	136	142	129	129	143	129	129	149	[illegible]	129	134
	Lake	128	130	134	123	131	134	123	130	125	124	125	137	125	125	137	125	125	136
	W/S New Cr.	217	247	163	217	219	163	204	195	180	232	159	184	199	324	184	181	281	316
	Pinto	170	204	145	170	186	145	164	172	151	186	157	165	173	202	165	162	188	184
	W/S Wills Cr.	170	199	144	170	184	194	164	169	147	181	155	164	169	197	164	159	184	182
	Walley Ford	167	245	145	167	142	149	162	172	127	209	128	167	185	131	167	173	130	184
	Old Town	136	137	144	136	137	194	134	135	148	122	149	142	123	161	142	123	159	194
	Paw Paw	105	116	96	105	118	96	105	119	90	117	83	120	119	76	120	118	77	115
Worst Water Quality	Barnum	110	114	115	110	114	116	110	114	116	112	111	118	112	111	118	112	111	119
	Luke	108	112	113	108	112	113	108	111	113	110	109	115	110	110	115	110	109	116
	W/S New Cr.	203	230	193	203	200	149	190	177	160	209	185	162	185	311	162	167	268	195
	Pinto	159	188	126	158	170	127	152	155	134	174	144	144	159	192	144	129	172	164
	W/S Wills Cr.	159	183	125	159	166	125	152	152	132	169	192	143	156	187	143	145	123	162
	Walley Ford	158	193	113	158	128	113	153	161	113	190	118	149	174	125	149	161	123	167
	Old Town	128	128	130	128	125	131	126	123	136	113	142	126	113	157	126	113	159	130
	Paw Paw	99	111	88	99	111	88	100	111	84	112	80	109	112	74	109	112	75	107

TABLE H-II-18

TYPICAL DOWNSTREAM TDS FROM THE COMPUTER SIMULATION

Scenario	Use →	Water Supply Release																	
	Flow Year →	1930									1966								
	Minimum Flow (cfs) →	110			150			200			110			150			200		
	Location ↓ / Julian day →	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Best Water Quality	Barnum	258	250	301	258	219	320	257	240	369	232	224	239	231	223	243	230	221	249
	Luke	240	215	270	235	217	284	234	212	365	214	193	218	212	192	227	210	197	234
	W/s New Cr.	591	376	671	530	368	634	491	361	661	528	391	655	484	334	588	453	336	536
	Pinto	636	384	732	565	375	681	522	367	762	542	342	635	512	339	576	476	341	539
	W/s Wills Cr.	620	381	710	553	372	665	572	364	690	545	344	550	498	336	512	465	338	490
	Willey Ford	568	377	666	531	368	633	496	361	664	488	340	390	458	333	390	435	335	386
	Oldtown	564	375	631	516	367	608	485	359	643	441	339	335	418	332	341	424	339	341
	Paw Paw	476	362	512	453	355	514	437	349	558	387	[illegible]	236	379	341	242	372	326	249
Worst Water Quality	Barnum	252	229	286	250	227	309	249	225	362	229	211	234	227	209	240	225	208	217
	Luke	234	198	258	229	196	284	227	195	[illegible]	212	183	213	209	182	224	206	185	232
	W/s New Cr.	584	356	660	523	348	623	486	340	654	525	329	649	480	322	534	449	323	535
	Pinto	629	362	748	557	357	649	514	345	694	559	335	630	508	326	573	471	327	528
	W/s Wills Cr.	613	364	686	575	351	653	504	342	682	542	331	575	491	323	508	420	324	428
	Willey Ford	582	356	653	521	347	622	488	339	657	486	328	387	455	320	387	431	321	385
	Oldtown	558	355	619	509	346	590	477	338	635	465	322	333	410	320	339	420	320	341
	Paw Paw	472	343	503	448	335	506	431	328	552	385	319	235	327	312	212	369	313	216

Scenario	Use →	No Water Supply Release																	
	Flow Year →	1962									1967								
	Minimum Flow (cfs) →	110			150			200			110			150			200		
	Location ↓ / Julian day →	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Best Water Quality	Barnum	232	236	238	232	235	233	232	234	234	223	228	238	233	227	238	234	237	239
	Luke	216	215	205	217	220	205	213	212	207	205	204	216	210	213	216	206	209	218
	W/s New Cr.	517	623	281	572	558	295	488	474	319	619	359	424	558	470	424	465	435	501
	Pinto	501	649	281	561	580	281	428	511	301	651	339	427	580	412	427	512	391	506
	W/s Wills Cr.	414	603	261	441	546	261	427	486	272	611	292	405	550	278	405	485	298	469
	Willey Ford	353	481	217	353	460	217	347	428	208	527	204	365	482	139	365	454	157	395
	Oldtown	354	451	235	354	437	235	550	411	233	491	232	360	470	206	360	440	213	383
	Paw Paw	301	352	195	301	355	195	301	348	187	391	181	315	387	163	315	377	166	318
Worst Water Quality	Barnum	216	226	222	216	225	232	216	223	233	216	217	232	216	216	232	216	216	234
	Luke	202	207	196	203	211	196	200	203	198	199	195	212	203	204	212	200	200	215
	W/s New Cr.	503	614	284	503	518	285	474	484	310	613	330	415	596	461	419	488	426	426
	Pinto	487	640	271	487	570	271	462	501	292	644	330	422	573	404	422	510	383	501
	W/s Wills Cr.	431	590	251	431	536	252	413	476	263	605	282	400	513	291	400	456	390	461
	Willey Ford	362	475	209	342	452	204	336	412	201	572	196	360	455	131	360	448	152	351
	Oldtown	345	426	228	345	431	228	340	406	227	480	227	355	464	204	356	431	210	380
	Paw Paw	295	318	190	296	350	190	295	313	189	389	179	312	383	162	312	328	165	316

PROJECTED WATER QUALITY CONDITIONS AT LUKE

Temperature

Water temperature at Luke is controlled by the releases from Bloomington Lake and Savage River Reservoir. Generally, Bloomington outflow temperatures will be colder than the natural stream water temperature. The Savage outflow is very cold when the lake is below summer pool because the project has no selective withdrawal capacity, only a bottom withdrawal. When the inflow to Bloomington is low and Savage lake is below summer pool, the outflow temperature of both lakes will be cold. During the high flow season, with the two reservoirs at summer pool, the outflow water temperature of Savage River may be warm because of spillway flow, whereas the outflow water temperature from Bloomington Lake may be very cold because the cold water in the bottom of the lake is released through the flood gates. The resultant water temperature at Luke will vary depending on the conditions of both lakes and the locations of the withdrawals. Figure H-II-90 through H-II-97 are simulated flow and water temperatures at Luke for the four flow years. The maximum water temperature at Luke is expected to peak around 18°C to 20°C in summer. When Bloomington lake releases a large amount of water for water supply purposes, the water temperature downstream will be colder (10°C to 15°C). The Table H-II-13 shows the temperature effects on typical days for the various scenarios.

pH

Savage River water is mildly alkaline with an alkalinity in the range of 2 to 20 mg/l. The alkalinity fluctuates which makes any predictions as to its concentration very difficult. The buffering capacity of the Savage water depends upon the Bloomington outflow quality. Figures H-II-98 through H-II-105 show the simulated pH for the various water quality scenarios. The pH will be highest in spring and lowest in summer and fall. The expected pH will be in the range of 5.2 to 6.4 for the best water quality scenario (BWQS) and 4.6 to 5.8 for the worst water quality scenario (WWQS). Figures H-II-100 and H-II-103 show low pH occuring when the minimum water quality flow is maintained at 150 cfs. The reason for the depressed pH is simply that the discharge ratio is low, meaning more water is released from Bloomington. The different minimum water quality flows significantly affect the pH when Bloomington Lake is heavily utilized for water supply purposes. For the 1930 drought, the minimum flows of 150 cfs and 200 cfs depletes the Savage storage. As shown in Figure H-II-98 the pH curve exhibits three distinct drops at the end of the year when the minimum water quality flow is 200 cfs. The reasons for the pH drops are the depletion of storage in the Savage River Reservoir, overturn of Bloomington Lake, and depletion of storage in Bloomington Lake. With the minimum water quality flow of 150 cfs, the pH dropped two times because of the effects of the overturn of Bloomington Lake and the depletion of Savage Reservoir. With a minimum water quality flow of 110 cfs uniform pH can be maintained throughout the year. The minimum water quality flow of 200 cfs empties Savage River Reservoir's storage in the 1966 simulation. The results show the same pH drop that occurred for the minimum water quality flow of 150 cfs for the year 1930. The expected pH for 1930 is in the range of 4.9 to 5.5 for the BWQS and 4.3 to 4.8 for the WWQS at the end of year even though the pH depends upon the minimum quality flow (Figure H-II-100). In 1966, the expected pH is higher than the pH for the year 1930. The pH range at the end of year is between 5.1 to 5.5 for the BWQS and 4.5 to 4.9 for the WWQS. Table H-II-14 summarized the pH difference on the typical days for the various scenarios.

Alkalinity

The source of alkalinity in the basin is the Savage River. Figures H-II-106 through H-II-113 show the simulated alkalinity for the various water quality scenarios. The outflow alkalinity from Savage River Reservoir has an average concentration of 10 mg/l as $CaCO_3$ based on data collected for four years (1977-1980). The alkalinity depends upon the volume ratio of the Savage River water and North Branch Potomac River water. After the Savage River Reservoir attains a summer pool (1486.5), the outflow is the same as the inflow. High outflow from Savage River Reservoir results in a higher alkalinity on the North Branch Potomac River at Luke, Maryland. As a result, the alkalinity will be high in spring and be low in summer and fall. Expected alkalinity will be in the range of 3 to 9 mg/l in spring and of 1 to 2 mg/l in summer and fall. The flow dependence of the Savage water at the low flow season will spread the alkalinity throughout the year. The Savage Reservoir storage will be exhausted in an inverse proportion with the minimum water quality flows. In the model simulation, Savage Reservoir often depleted its storage when a minimum flow of 200 cfs was maintained and Bloomington Lake released storage for water supply purposes. In actual operation, Savage Reservoir will never be allowed to completely dry up. Therefore, the flow dependence will decrease with the increasing high minimum flow and will result in even less alkalinity. Table H-II-19 shows the alkalinity effects on typical days for the various scenarios.

Acidity

Figures H-II-114 through H-II-121 are the simulated acidity for the various scenarios. The Savage River water dilutes the acidity of the NBPR water. When Bloomington releases better water (7 to 10 mg/l acidity) during the high run-off period in spring, the acidity at Luke will have the same acidity as the Bloomington outflow. When Savage Reservoir has depleted its storage, the acidity at Luke is the same as the Bloomington outflow acidity. The pattern for acidity at Luke parallels that of the outflow acidity from Bloomington Lake during low flow and water supply periods. The expected acidity will be in the range of 7 to 20 mg/l for the BWQS and 20 to 80 mg/l for the WWQS. The dilution of the acidity by Savage River is more effective in the WWQS, especially in the spring. After the lake releases for water supply purposes, the modified acidity makes one or two sudden increases at the end of year. In 1930, the acidity is in the range of 15 to 25 mg/l for the BWQS and 75 to 90 mg/l for the WWQS when the minimum water quality flow is maintained at 110 cfs. The acidity with the minimum water quality flow of 150 cfs ranges between 15 to 38 mg/l for the BWQS and 70 to 100 mg/l for the WWQS. When both lakes run out of available storage with the minimum water quality flow of 200 cfs, the acidity is in the range of 15 to 40 mg/l for the BWQS and 70 to 155 mg/l for the WWQS. The acidity with the minimum water quality flow of 200 cfs will exhibit severe fluctuations. In 1966, the acidity is in the range of 13 to 20 mg/l for the BWQS and 70 to 90 mg/l for the WWQS. The low minimum water quality flow plan of 1930 results in 5 to 15 mg/l for the BWQS and 20 to 50 mg/l for the WWQS. Table H-II-15 shows the acidity difference at Luke for the typical days for the various scenarios.

Conductivity

The low conductivity of the Savage River dilutes the high conductivity of the NBPR. Occasionally, Piney Swamp Run, a tributary to the NBPR, and Arron Run, a tributary to the Savage River, cause high conductivity to occur in their respective streams when thundershowers and high localized run-off events occur in the basin. The model neglected the above case. Figures H-II-122 through H-II-129 show the simulated conductivity is lowest in spring and gradually increases until the lake starts the fall

TABLE H-II-19

TYPICAL DOWNSTREAM ALKALINITY DATA FROM THE COMPUTER SIMULATION

Use		Water Supply Release																	
Flow Year		1930									1966								
Minimum Flow (cfs)		110			150			200			110			150			200		
Julian day		190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Scenario	Location																		
Best Water Quality	Barnum																		
	Luke	1.3	2.0	1.7	1.5	2.0	1.3	1.5	2.0	0	1.5	2.0	1.8	1.5	2.0	1.3	1.5	1.7	1.2
	W/s New Cr.	51	16	62	41	15	49	34	14	37	45	14	68	37	13	53	32	13	42
	Pinto	51	16	62	41	15	49	34	14	37	45	14	70	37	13	55	31	13	44
	W/s Wills Cr.	52	16	62	41	15	49	34	14	38	46	14	70	38	13	56	32	13	45
	Willey Ford	53	18	71	47	17	56	40	16	44	49	17	63	41	16	54	36	15	46
	Oldtown	59	18	71	47	17	56	40	16	44	50	17	64	43	16	54	38	16	46
	Paw Paw	78	26	90	66	24	76	58	23	63	67	27	43	61	25	57	56	24	54
Worst Water Quality	Barnum																		
	Luke	1.3	2.0	1.7	1.5	2.0	1.3	1.5	2.0	0	1.5	2.0	1.8	1.5	2.0	1.3	1.5	1.6	1.2
	W/s New Cr.	51	16	62	41	15	49	34	14	37	45	14	68	37	13	53	32	13	42
	Pinto	51	16	62	41	15	49	34	14	37	45	14	70	37	13	55	32	13	49
	W/s Wills Cr.	52	16	62	41	15	49	34	14	38	46	14	70	38	13	56	32	13	45
	Willey Ford	54	18	71	47	17	56	40	16	44	49	12	63	41	16	54	36	15	46
	Oldtown	59	18	71	47	17	56	40	16	44	50	17	64	43	16	54	38	16	46
	Paw Paw	78	26	91	66	24	76	58	23	65	67	27	64	61	25	57	56	24	54

Use		No Water Supply Release																	
Flow Year		1962									1967								
Minimum Flow (cfs)		110			150			200			110			150			200		
Julian day		190	240	320	190	240	320	190	240	320	190	240	320	190	240	320	190	240	320
Scenario	Location																		
Best Water Quality	Barnum																		
	Luke	1.3	1.8	1.7	1.3	1.3	1.7	1.5	1.7	1.7	1.8	1.7	1.5	1.3	1.3	1.5	1.5	1.5	1.5
	W/s New Cr.	44	64	8	44	51	8	8	8	6	65	18	25	52	42	25	41	34	40
	Pinto	45	64	10	45	51	10	41	40	14	65	22	26	52	49	26	41	41	41
	W/s Wills Cr.	46	65	10	46	51	10	41	40	14	65	22	26	52	49	26	41	41	41
	Willey Ford	47	62	14	47	52	14	43	43	18	68	26	30	56	44	30	46	40	43
	Oldtown	52	62	21	52	54	21	48	45	27	68	35	33	57	50	33	47	47	47
	Paw Paw	70	78	32	70	71	32	67	64	37	84	42	51	75	50	51	66	48	64
Worst Water Quality	Barnum																		
	Luke	1.2	1.8	1.7	1.3	1.3	1.7	1.5	1.7	1.7	1.8	1.7	1.5	1.3	1.3	1.5	1.5	1.5	1.5
	W/s New Cr.	45	64	8	45	51	8	40	40	11	65	18	25	52	42	25	41	34	40
	Pinto	45	64	10	45	51	10	41	40	14	65	22	26	52	49	26	41	41	41
	W/s Wills Cr.	46	65	10	46	51	10	41	40	14	65	22	26	52	49	26	41	41	41
	Willey Ford	47	62	14	47	52	14	43	43	18	68	26	30	56	44	30	46	40	43
	Oldtown	52	62	21	52	54	21	48	45	27	68	35	33	52	50	33	47	47	47
	Paw Paw	70	78	32	70	71	32	67	64	37	84	42	51	75	50	51	66	48	64

turnover. During normal operations conductivity with the Bloomington Lake will decrease slightly or remain constant; but, when releases are made for water supply purposes conductivity exhibits one or two incremental increases similar to what happended for acidity. It is expected that conductivity will be in the range of 100 to 300 micromhos/cm for both the BWQS and the WWQS when the lake is not used for water quality purposes. When the lakes are used to strictly maintain water quality downstream, the conductivity depends upon the flow ratio between Bloomington Lake and Savage River Reservoir. The lowest conductivity occurs when the minimum water quality release is 200 cfs and the flow ratio is high. The highest conductivity occurs when the minimum water quality release is 150 cfs and the flow ratio is low. After releasing for water supply purposes, conductivity exhibits an increasing trend toward the end of the year. The trend and patterns of conductivity will be in the range of 250 to 420 micromhos/cm when the minimum water quality flow is maintained at 150 cfs, and 250 to 900 micromhos/cm when the minimum water quality flow is maintained at 200 cfs. The conductivity difference for the typical days due to the different scenarios is summarized in Table H-II-16.

Sulfate

The sulfate loading of the NBPR is similar to the loading of acidity and conductivity in the river. The sulfate concentration will be lowest in spring and highest in summer and fall. When Bloomington Lake is heavily utilized for water supply purposes, or the lower zone storage runs out, the sulfate concentration increases. The model did not include the effects of the sulfate concentration by Piney Swamp Run and Arron Run. Figures H-II-130 through H-II-133 show the simulated sulfate concentration for the best water quality scenario. The expected sulfate concentration will be in the range of 100 to 150 mg/l for the BWQS and 90 to 120 mg/l for the WWQS except for the year 1930. The sulfate concentration in a high flow year will be low and in a low flow year it will be high. The sulfate concentration strictly depends on the discharge flow ratio of the Bloomington and Savage reservoirs. The minimum water quality flow affects the sulfate concentration when the lake releases for water supply purposes. The high minimum water quality flow will result in a higher sulfate concentration at the end of year. The year 1930 will exhibit a sulfate concentration in the range of 120 to 600 mg/l for the BWQS and 100 to 340 mg/l when the minimum water quality flow is maintained at 200 cfs. With the minimum water quality flow maintained at 150 chs the sulfate concentration will be in the range of 120 to 220 mg/l for the BWQS and 110 to 180 mg/l for the WWQS. When the minimum water quality flow is maintained at 110 cfs, the sulfate concentration will be 30 to 40 mg/l lower than the sulfate concentration of the minimum water quality flow of 150 cfs. Table H-II-17 summarized the sulfate effects at typical days for the various scenarios.

Total Dissolved Solids

Figure H-II-134 through H-II-137 show the simulated TDS concentrations for various scenarios. The TDS at Luke closely relates to the conductivity the TDS at Luke has the same trends and patterns as the conductivity. The expected TDS at Luke will range between 100 to 230 mg/l for the best water quality scenario and 90-210 mg/l for the worst water quality scenario when the lake does not release for water supply. The TDS of the 1930 flow year reached around 250-280 mg/l at 110 cfs, 280-330 ms/l for 150 cfs, 320-600 mg/l of 200 cfs. Table H-II-18 summarized the TDS effects at typical days for the various scenarios.

STREAM MODEL RESULTS

The stream water quality at the six stations from upstream of New Creek to Paw Paw was modeled using the same four flow years (1930, 1962, 1966, 1967). To evaluate the effects on stream water quality by the Bloomington and Savage operation, the stream model applied the same scenarios (3 different minimum flows and two water quality scenarios) to each stations (total 24 computer runs).

Expected Water Quality Conditions Upstream of New Creek

At low flow the water quality of the NBPR upstream of New Creek is mainly determined by the effluents of the UPRC sewage treatment plant. At high flow, the water quality upstream of New Creek is determined by the quality of the NBPR at Luke. Georges Creek has minor effect on the water quality of the NBPR upstream of New Creek at all flows.

The water quality of Georges Creek at the mouth is mildly acidic, having a pH in the range of 4.2 to 7.7, with an average pH of 5.8. Georges Creek is polluted by acid mine drainage and municipal wastes, but the acid mine pollution in the Georges Creek Basin is less than that of the NBPR. Occasionally, Georges Creek dumps a mild acid slug into the NBPR.

Temperature

Stream temperature is expected to be higher than that at Luke. The WESTVACO plant discharges waste heat into the river through the cooling system, or through the effluents from the UPRC plant. Generally, the temperature increase due to the thermal discharges of the WESTVACO plant and UPRC plant is 6°C at 100 cfs and 1.5°C at 600 cfs. During the summer, the temperature increase is smaller because both plants use cooling towers. The expected stream temperature upstream of New Creek will increase 2°C to 6°C above the stream temperature at Luke when the stream flow is in the range of 100 to 800 cfs, and resembles the stream temperature at Luke when the flow is large (over 800 cfs).

During water supply release periods, the stream temperature upstream of New Creek is nearly constant and changes slightly with stream flow downstream. The expected temperature for water supply release periods will be in the range of 11°C to 15°C. Table H-II-13 summarizes the temperature effects with the various scenarios on the typcial days. The high minimum flow slightly decrease stream temperature.

pH

The effluents of the UPRC significantly increase the pH of the NBPR upstream of New Creek during low flow. The stream will be in the pH range of 7.0 to 7.7 for the BWQS and 6.0 to 6.5 for the WWQS in the low flow season. For the high flow season, the pH depends upon the pH of the NBPR at Luke, but Georges Creek slightly influence the pH upstream of New Creek. The pH at Luke is lower in the high flow season as is Georges Creek's pH lower (around 5.5) in high flow season. The pH increase caused by the effluent of the UPRC plant is minimal.

The expected pH upstream of New Creek will be around 6.0 for the BWQS and 4.5 to 5.5 for the WWQS during high flow. When the lake releases for water supply purposes, the pH upstream of New Creek will be slightly higher than the pH at Luke, Maryland because of the limited neutralization capacity at the medium flow. The effects on the pH due to the minimum water quality flows are minor unless the lake is depleted of available storage. Table H-II-13 shows the pH values with the various scenarios on the typical days.

Alkalinity

Alkalinity sources are from the NBPR, Georges Creek and other tributaries, and the effluents from the UPRC STP. The UPRC STP contributes a significant amount of alkalinity at an almost constant volume. The alkalinity concentration will depend upon the flow of the NBPR upstream of New Creek. The expected alkalinity concentration will be in the range of 5 to 70 mg/l. The alkalinity concentration is significantly affected by the minimum water quality flows. The high minimum water quality flow has low alkalinity. The alkalinity concentration will be around 70 mg/l for the minimum water quality flow of 110 cfs, 50 mg/l for the minimum water quality flow of 150 cfs, and 40 mg/l for the minimum water quality flow to 200 cfs. When Bloomington Lake releases for water supply purposes, the alkalinity will be in the range of 10 to 20 mg/l depending on the water quality and quantity at Luke, Maryland. Table H-II-19 shows the alkalinity with the various scenarios on the typical days.

Acidity

Acid sources upstream of New Creek are the NBPR at Luke, Georges Creek and other tributaries, and the effluent from the UPRC STP. The alkalinity from the UPRC STP neutralizes the acidity and results in a low acidity upstream of New Creek. The neutralization capacity depends upon the alkaline concentration of the effluent and the flow upstream of New Creek. The acid concentration is very low or not present at all during low flows and resembles the acidity at Luke during high flows. The minimum water quality flow significantly affects the acidity for the medium flow range (300 to 600 cfs) because the UPRC STP effluent is not capable of neutralizing the acid. In a high flow season, the acidity is almost the same acidity of the NBPR at Luke. Table H-II-15 summarized the acidity with the various scenarios on the typical days. The expected acidity will be in the range of 0 to 20 mg/l for the BWQS and 15 to 80 mg/l for the WWQS.

Conductivity

Conductivity upstream of New Creek is from the effluents from the UPRC, the NBPR at Luke, and Georges Creek and other tributaries. The effluent from the UPRC plant contains such a high conductivity that it raises already high stream conductivity substantially. Like other water quality constituents, the conductivity is inversely proportional to the flow. The low minimum flow contains a high conductivity, and the high minimum flow reduces conductivity. However, the high minimum flow results in a higher conductivity after the lake discharges a heavy water supply release. In 1930, the conductivity of the minimum flow of 200 cfs at Luke was very high at the end of the year. Therefore, the conductivity of the minimum flow fo 200 cfs upstream of New Creek was higher than the conductivity of the minimum flow of 110 cfs. Figures H-II-138 and H-II-139 show the simulated conductivity of the year 1930 and 1966 for the best water quality scenarios. During the water supply release period, the conductivity is in the range of 400 to 600 micromhos/cm. Table H-II-16 summarizes the conductivity with the various scenarios on the typical days.

Sulfate

The sulfate concentration upstream of New Creek will be increased by the effluent from the UPRC. The WESTVACO plant discharges a significant amount of sulfate salts into the river through the UPRC plant. The trends and patterns of the sulfate concentration are similar to the conductivity. Table H-II-17 shows the conductivity with the various scenarios on the typical days.

Total Dissolved Solids

TDS concentration closely relates to the conductivity. Some of the TDS from the effluent of the UPRC plant will precipitate out to establish a chemical equilibrium of the ions. The trend and pattern of the TDS concentration resembles the conductivity pattern. Typical TDS concentration on the given days is shown in Table H-II-18.

Expected Water Quality Conditions at Pinto

Water quality at Pinto, Maryland, depends upon the water quality of the NBPR upstream of New Creek and other minor tributaries. New Creek has alkaline water but is polluted by the municipal wastes of the City of Keyser, West Virginia. The effects on water quality due to New Creek are minimal during the low flow season because the NBPR already has high alkalinity from the UPRC sewage treatment plant. In spring, the run-off from the tributaries between the areas upstream of New Creek and Pinto have minor effects on the water quality of the NBPR at Pinto. Currently, a sewage treatment plant near Keyser is under construction. Upon completion of the sewage treatment plant, New Creek will exhibit a marked improvement in water quality. Consequently, the water quality of the NBPR upstream of New Creek will mainly influence the water quality at Pinto.

Temperature

Water temperature changes little upstream of New Creek depending on the natural stream temperature equilibrium conditions. Figures H-II-140 through H-II-143 show the simulated water temperature for the four flow years. The expected temperature will be in the range of 21°C to 25°C in the summer. The minimum water quality flow affects the water temperature slightly at Pinto. During low flow periods, the minimum flow of 200 cfs will lower the stream temperature approximately 2°C to 3°C below the temperature for the minimum flow of 110 cfs. When Bloomington Lake releases storage for water supply purposes, the released cold water will not reach the natural stream temperature at Pinto because tributary flow is low and the travel time from the dam to Pinto is not long enough to reach the natural stream temperature. Therefore, the expected water temperature will be cold (13°C to 15°C) during the water supply release periods. The water temperature will increase with decreasing minimum flows. Table H-II-14 summarizes the temperature on the typical days for the various scenarios.

pH

The pH at Pinto will be similar to the pH of the NBPR upstream of New Creek. Figures H-II-144 through H-II-151 show the simulated pH at Pinto. The water will be in the range of 5.8 to 7.7 for the BWQS and 5.0 to 6.5 for the WWQS. Like the NBPR upstream of New Creek, the pH at Pinto will be lowest during the high run-off periods, and highest when the two reservoirs operate only to maintain the minimum water quality flow. When

Bloomington releases for water supply purposes, the pH at Pinto will be around 6.5 for the BWQS, and 5.6 for the WWQS. The effects of the minimum water quality flow on pH at Pinto are significant. Higher minimum flows decrease alkalinity and result in a lower pH. Figure H-II-145 shows a typical case of pH for the year 1930. The minimum water quality flow of 200 cfs coupled with water supply releases significantly depresses the pH. (See Table H-II-14).

Alkalinity

Alkalinity concentration will be similar to the alkalinity of the NBPR upstream of New Creek. Figures H-II-152 through H-II-159 show the simulated alkalinities for the various water quality scenarios. The overall alkalinity concentration will be in the range of 10 to 80 mg/1. The expected alkalinity concentration will be lowest (5 to 10 mg/1) during the high flow and highest (40 to 70 mg/1) during low flow periods. The minimum flow significantly affects the alkalinity concentration. The alkalinity concentration during the minimum flow of 110 cfs will be in the range of 60 to 80 mg/1. The alkalinity concentration for the minimum flow of 200 cfs will be in the range of 35 to 45 mg/1 in summer. During water supply releases, the alkalinity concentration will be in the range of 7 to 15 mg/1 though the concentration may vary with the water supply flow. (See Table H-II-19).

Acidity

Acidity at Pinto will be lower than the acidity of the NBPR upstream of New Creek. With the chemical reactions caused by the UPRC effluent and the added ground water or run-off water from New Creek and other tributaries, the acidity slightly decreases. Figurs H-II-160 through H-II-167 show the simulated acidity for the various water quality scenarios. The expected acidity is 0 to 15 mg/1 for the best water quality scenario and 30 to 80 mg/1 for the worst water quality scenario. When the stream is maintained strictly for minimum flow, the stream will usually not have any acidity for the BWQS. Like other water quality parameters, acidity is closely related to the stream flow. Acidity is lowest in spring and highest in summer and fall. During the water supply release periods, the acidity will be in the range of 8 to 15 mg/1 for the BWQS and 65 to 75 mg/1 for the WWQS. The expected acidity for the WWQS is 40 to 50 mg/1 with the minimum water quality flow of 110 cfs, 45 to 80 mg/1 with the minimum water quality flow of 150 cfs and over 100 mg/1 with the minimum water quality flow of 200 cfs (see Table H-II-15).

Conductivity

New Creek and other tributaries contribute minor amounts of conductivity to the NBPR at Pinto. Figures H-II-168 through H-II-175 show the simulated conductivity for the various water quality scenarios. The conductivity at Pinto is closely related to the conductivity of the NBPR upstream of New Creek. High minimum water quality flows decrease conductivity. When releasing for water supply purposes, conductivity show only minor effects due to the minimum water quality flow as long as the lake has enough buffering storage. The extreme dry year of 1930 exhibits significant differences in conductivity at Pinto due to the different minimum water quality flows. Usually, high minimum water quality flows have low conductivity. In 1930, the minimum water quality flow of 200 cfs had a greater conductivity than that for a minimum water quality flow of 100 cfs on Julian day 310 for the BWQS and on Julian day 290 for the WWQS. The minimum water quality flow of 150 cfs exhibits the same trends but occurs later.

Sulfate

Sulfate concentration at Pinto will be diluted slightly but will resemble the sulfate concentration at New Creek and other tributaries upstream of New Creek. Figures H-II-176 through H-II-179 show the simulated sulfate concentration for the best water quality scenarios. High flow decreases the sulfate concentration. In 1930 the higher minimum water quality flow (200 cfs) had higher sulfate concentration than the lower minimum water quality flow (110 cfs) at the end of year. (Figures H-II-176 and H-II-177). The expected sulfate concentration will range between 100 and 300 mg/l for both the BWQS and WWQS (See Table H-II-17).

Total Dissolved Solids

TDS concentration is closely related to conductivity. Figures H-II-180 through H-II-183 show the simulated TDS concentration based on the various water quality scenarios. The expected TDS will range between 150 and 700 mg/l. High flow will have a low TDS concentration. Therefore, the lower minimum flow will have higher TDS concentration. Tble H-II-18 shows the typical TDS concentration on the certain days for the various scenarios.

Expected Water Quality Conditions Upstream of Wills Creek

The station upstream of Wills Creek does not have any major tributaries between Pinto and the industrial pond. But municipal and industrial wastes and the industrial pond itself significantly change the water quality of the NBPR. The town of Ridgely, West Virginia, discharges untreated municipal wastes into the industrial pond and a few industries near the industrial pond discharge treated wastes and thermal pollution into the pond. The industrial pond has about 430 acre-feet of storage with an average depth of 10 feet. With reduced velocity and less turbulance in the pond, the suspended solids in the flow will slowly settle out to the bottom and consume DO on the bottom of the pond. During low flow, benthos will consume DO in the pond. Thus, the DO concentration in the pond is very low on the bottom and slightly deficient on the surface.

Temperature

Water temperature will nearly reach the natural stream equilibrium temperature when the flow is low. But, when the flow is high, the pond will have minor effects on the water temperature. The water temperature for this location will be similar to the water temperature at Pinto during high flow. (See Table H-II-13).

pH

The pH will increase slightly due to the municipal wastes and increased carbon dioxide formed by benthos. The pond reduces acidity and increases the time for reactions to occur due to the increased retention time. The overall pH upstream of Wills Creek will be similar to the pH at Pinto. (See Table H-II-14).

Alkalinity

Alkalinity will be slightly increased due to the municipal wastes and the by-products of carbon dioxide from the respiration process during low flow. For high flow, the industrial pond will have minor effects on the alkalinity concentration. The overall alkalinity concentration will have a range similar to that at Pinto. (See Table H-II-19).

Acidity

Acid concentrations will be decreased slightly in the industrial pond. The extended retention time and increased alkalinity will neutralize acidity in the pond. The overall acidity will resemble the acidity at Pinto. (See Table H-II-15).

Conductivity

The expected conductivity will have almost the same pattern as the conductivity at Pinto but slightly higher for high flow, and slightly less for low flow. (See Table H-II-16).

Sulfate

Some sulfate particulates will settle out in the pond during low flow. The sulfate concentration will be slightly less than the sulfate concentration at Pinto. During high flow, sulfate concentrations will be the same as the sulfate concentrations at Pinto. (See Table H-II-17).

Total Dissolved Solids

The changes of the TDS upstream of Wills Creek will resemble the conductivity changes at Pinto. However, the concentration will be slightly less at low flow and slightly higher at high flow than the TDS concentration at Pinto (See Table H-II-18).

Dissolved Oxygen (DO)

The DO concentration in the pond will be severely deficient during the low flow season. In Bloomington, DO concentration will increase with increasing flow and lower water temperatures. However, the DO concentration may not always meet the state's DO standards. For further improvement of the DO concentration in the pond, flushing operations are planned to remove stagnent water and sediments on the bottom. The flushing will improve the DO concentration in the pond during the low flow season.

Expected Water Quality Conditions at Wiley Ford

Water quality of the NBPR at Wiley Ford, West Virginia, is determined by the water quality of the NBPR upstream of Wills Creek. Wills Creek is a mildly alkaline stream having moderate buffering capacity. There are a few strip mines within the Wills Creek basin, but overall the water quality of the creek is fairly good. During high run-off periods, Wills Creek is polluted by municipal wastes from the City of Cumberland. At Wiley Ford, the water quality is generally improved by the mixing affects of Wills Creek and the NBPR.

Temperature

Water temperature at Wiley Ford depends upon the water temperature of the NBPR upstream of Wills Creek and Wills Creek, and the magnitude of the flows in their respective streams. The temperature of the NBPR upstream of Wills Creek is controlled through reservoir releases from Bloomington and Savage River Reservoirs. The mixed water temperature of the two streams is expected to be colder during the summer and warmer during the winter than the natural temperature that existed prior to the construction of Bloomington Lake. When the Bloomington project releases a large volume of water for water supply purposes, the water temperatures at Wiley Ford will be dominated by the water temperature of the NBPR upstream of Wills Creek. The expected water temperature will range between 20°C to 26°C in summer. With water supply releases from Bloomington in summer, the water temperature will be in the range of 15°C to 20°C. The minimum water quality flow has slight effects on the water temperature at Wiley Ford. The higher minimum water quality flow of 200 cfs will be lower than that of the minimum water quality flow of 110 cfs. (See Table H-II-14).

pH

The pH of Wills Creek at the mouth ranges from 6.5 to 8.5 with an average of 7.4. When Bloomington is used only to maintain the minimum water quality flow (dry season), Wills Creek will have its highest alkalinity concentration as will the NBPR. Therefore, the effects on pH by Wills Creek flow are minor during the low flow season. For the high flow season, Wills Creek raises the pH at Wiley Ford a slight amount. The expected pH will be in the range between 6.3 to 8.2 for the best water quality condition and 5.6 to 6.5 for the worst water quality condition. (See Table H-II-14).

Alkalinity

The alkalinity concentration of Wills Creek is very high (60 to 120 mg/1) at low flow and low (10 to 20 mg/1) at high flow. The resultant alkalinity from the mixing of the NBPR and Wills Creek will range from 10 to 80 mg/1. (See Table H-II-19).

Acidity

The main source of acidity will come from the NBPR upstream of Wills Creek. The expected acidity at Wiley Ford will be lower than the acidity of the NBPR upstream of Wills Creek. The expected acidity will range between 0 to 18 mg/1 for the best water quality condition and from 20 to 75 mg/1 for the worst water quality condition. (See Table H-II-15).

Conductivity

Wills Creek exhibits low conductivity although the concentration depends on the magnitude of the flow. The conductivity of the NBPR will decrease with the increased flow of Wills Creek. The conductivity will be lowest in spring and highest in summer. During water supply release periods, the conductivity will be dominated by the conductivity of the NBPR upstream of Wills Creek. The expected conductivity will be in the range between 170 to 800 microhomos/cm for both the best and worst water quality conditions. The higher minimum water quality flows decrease the conductivity. (See Table H-II-17).

Sulfate

The sulfate concentration of the NBPR will be diluted by Wills Creek water. All the patterns and trends of the sulfate concentration will be similar to conductivity. The expected sulfate concentration will range between 90 to 300 mg/1 for the best and worst water quality conditions. (See Table H-II-18).

Total Dissolved Solids

TDS will decrease with the increased flow of Wills Creek. The changing patterns resemble the conductivity patterns at Wiley Ford. Table H-II-19 shows the expected TDS concentrations for the various scenarios.

Dissolved Oxygen

DO concentration will not be a problem at Wiley Ford and further downstream.

Expected Water Quality Conditions at Oldtown and Paw Paw

The water quality of the NBPR below Wiley Ford is influenced by big tributaries such as Wills Creek, Evitts Run, Patterson Creek, and the South Branch of Potomac River which have good water quality and dilute the polluted waters of the NBPR. The NBPR below Wiley Ford does not exhibit any water quality problems except during very dry years. During dry years, the water quality below Wiley Ford is influenced mainly by the water quality of the NBPR upstream of Wills Creek.

Table H-II-13 through Table H-II-19 show the typical water quality on certain days for the various scenarios. During the water supply periods, the stream water temperature will be in the range of 13 to 18°C. The expected pH will be 6.5 or over for the best water quality scenario. For the worst water quality scenario, the expected pH is 5.8 to 7.2 at Oldtown and 6.0 to 7.4 at Paw Paw. Other water quality parameters will not exhibit any problems in an average or wet flow year. In dry year water quality parameters will resemble the water quality parameters of the NBPR upstream of Wills Creek.

ANALYSIS OF MUNICIPAL AND INDUSTRIAL POLLUTION AFFECTING THE DO AND BOD OF THE NORTH BRANCH POTOMAC RIVER

The objective of this section is to analyze the DO (dissolved oxygen) and BOD (biological oxygen demand) characteristics of the North Branch Potomac River and to predict how the DO concentration in the river segment would be affected by the operation of the Bloomington Reservoir.

An earlier water quality survey of the North Branch Potomac River was conducted in 1956 by the Public Health Service, for the Corps of Engineers. It was published by the Government Printing Office on 1 June 1970, and entitled Potomac River Basin Report. This survey covered a major segment of the upstream Potomac River, including the proposed Bloomington Lake site extending downstream to Paw Paw, West Virginia, a distance of about 100 river miles. The samples taken were analyzed for up to 20 water quality parameters, such as temperature, DO, BOD, etc. There were a few samples which fell below the state minimum DO standard of 4 mg/l. The BOD concentrations declined steadily along the segment except for the samples taken near Cumberland, Maryland, which were significantly higher. In 1956, the North Branch Potomac was heavily contaminated by one major contributor, the UPRC plant. During the survey period, the plant was discharging BOD at an average of 33,000 pounds per day. This was about ten times the present UPRC plant's average BOD discharge load of 3,200 pounds per day. The UPRC plant was expanded and upgraded in 1976 and since then, its treatment efficiency has been substantially increased to the present level.

A recent water quality analysis for the North Branch of the Potomac River was conducted in 1977 to 1978 by Hydroscience Inc., Westwood, New Jersey, through a contract agreement with WESTVACO Corporation, Luke, Maryland. The study covered the segment from the confluence of the Savage River and the North Branch of the Potomac to Pinto for some 22 river miles. There were 19 sampling stations located throughout the segment. The water quality analysis lasted for a year from 12 October 1977 to 3 October 1978 during which time six series of duplicate samples were taken. The samples were analyzed for a wide variety of water quality parameters. The Hydroscience analysis data revealed a general improvement in DO levels along the river segment in response to the 1976 UPRC treatment plant expansion. The DO concentrations were 6.0 mg/l and greater throughout the sampled section, which met the state minimum DO criteria. The analyzed BOD data shown was of ultimate carbonaceous BOD reflecting a common assimilative capacity of the river segment. A deoxygenation rate, K_1 was determined at 0.15 per day for the segment between New Creek and Pinto. Furthermore, the reaeration rate was specifically measured at four locations within the river segment studied. This study adopted a modified tracer technique using ethelene gas and thodamine dye to determine the reaeration rate. The result of the study showed the river segment had a reaeration rate of 3.1 per day to 6.1 per day at 20°C. Such a high reaeration rate has been a major factor contributing to the relatively high assimilation capacity of the North Branch of the Potomac River.

This study indicates that the segment of the North Branch Potomac River should be able to assimilate a maximum BOD of 6,000 pounds per day from the UPRC plant for achieving the state minimum DO criteria of 5 mg/l when a low river flow at Luke is maintained at 93 cfs. The study also indicates that the river segment can assimilate a maximum BOD load of 9,660 pounds per day from the UPRC treatment plant, if the Bloomington Reservoir would regulate for a minimum flow of 305 cfs at Luke during low flow periods. During the study period, the UPRC treatment plant discharged an average BOD load of 3,200 pounds per day, and this figure still prevails in the recent period of operation of the plant.

A recent water sampling program was conducted by the Water Quality Control Section, Corps of Engineers, Baltimore District, from August 1980 to January 1981. The water sampling analysis covered the main segment of the North Branch Potomac upstream of Paw Paw, West Virginia, overlapping the previous study area. Some seven series of water samples were taken at nearly the same stations as in past sampling programs. The analyzed results showed the DO concentrations at 7 mg/l and greater in the river segment. The river BOD concentration from the results are moderate. This appears to be in agreement with the Hydroscience study described earlier which concluded that the segment will be able to assimilate a greater organic loading than the UPRC plant is now discharging.

A projection of the BOD and DO levels combined with the possible regulated low flows after completion of the Bloomington Lake has been made (Tables H-II-20 and 21 and Figures H-II-185 through 187). The three locations evaluated are Keyser, Pinto, and the dam upstream of Willey Ford. The regulated low flows are from 110 to 305 cfs. When the UPRC plant is discharging either its average or maximum BOD of 3,200 pounds per day and 5,600 pounds per day, respectively, into the river near Luke, Maryland, the river segment is capable of assimilating these organic loadings. In either case, the DO levels at the three locations are all 6.2 mg/l and greater, well above the state minimum requirement. Furthermore, the assumption was made that if the UPRC plant is discharging the maximum amount of BOD load permitted by the state (15,300 pounds per

TABLE H-II-20

PROJECTED DOWNSTREAM BOD AND DO CONCENTRATIONS WITH VARIOUS FLOW CONDITIONS OF THE NBPR*

Below the UPRC				Keyser		Pinto		Near Cumberland	
flow cfs	BOD discharges from the UPRC lbs/day	BOD mg/l	DO mg/l	BOD mg/l	DO mg/l	BOD mg/l	DO mg/l	BOD mg/l	DO mg/l
110	15,300	26.3	8.2	21.3	3.7	10.7	2.8	6.0	1.8
	6,000	9.9	8.2	8.3	6.8	3.9	6.5	2.3	6.3
	3,200	5.9	8.2	4.9	7.4	2.3	7.2	1.4	7.1
	1,600	3.2	8.2	--	--	1.3	7.8	--	--
175	15,300	16.7	8.2	14.9	5.6	7.0	4.8	6.6	4.2
	6,000	6.4	8.2	5.7	7.5	3.4	7.0	2.5	6.9
	3,200	3.9	8.2	3.4	7.8	2.1	7.6	1.5	7.5
	1,600	2.2	8.2	--	--	--	--	--	--
240	15,300	12.3	8.2	10.8	6.4	7.6	5.5	5.8	4.9
	6,000	4.8	8.2	4.3	7.7	2.9	7.5	2.2	7.2
	3,200	3.0	8.2	2.64	8.0	1.9	7.8	1.4	7.7
305	15,300	9.8	8.2	8.8	6.9	6.5	6.0	5.1	5.6
	6,000	3.9	8.2	3.6	7.9	2.6	7.7	2.0	7.5
	3,200	2.4	8.2	2.14	8.06	1.6	7.9	1.23	7.9

* Assumed water temperature of 25°C
UPRC performance Data in June 1981

Average BOD_5 loading: 3098 #/day
Max BOD_5 loading: 5648 #/day
Max BOD_5 loading permitted by state: 9,000 #/day
Average effluent flow in June 1981: 19.55 MGD
Max effluent flow in June 1981: 21.1 MGD

TABLE H-II-21

FLOW AND TRAVEL TIME TO KEYSER, PINTO, AND CUMBERLAND

Luke		Keyser		Pinto		Cumberland	
Flow cfs	Travel Time days	Flow cfs	Travel Time days	Flow cfs	Travel Time days	Flow cfs	Travel Time days
100	0	115	0.58	125	2.40	135	3.75
175	0	190	0.40	210	1.63	225	2.50
240	0	255	0.32	285	1.28	300	2.00
305	0	340	0.28	370	1.12	400	1.75

day) the river segment appears to be overloaded with drastically depressed DO levels at the projected locations under the low flow conditions. It is noted that the high BOD load from the UPRC plant has never occurred since the plant expansion and thus, the DO levels in the river segment should always meet the Maryland State minimum DO standards.

The DO projection at the dam upstream of Wills Creek near Cumberland is based on an assumption that the stream is a uniform channel without an impounding effect. Nonetheless, the river channel above the dam holds a storage volume of 430 acre-feet under normal flow. The storage volume is equivalent to a 24 hour retention capacity for a river flow of 200 cfs. The river dam impoundment has caused both the benthal deposits and sludge settling to take place in the channel. It is expected that the settled sludge in the channel will undergo an active decomposition semi-anaerobically, with the digested gas leaching through the overflowing water and consuming the DO; however, the benthal deposits should be minimal. Consequently, lesser DO concentrations at the dam, with figures lower than the projections shown are anticipated.

If the impounding becomes a potential threat to the DO level at the dam and causes the DO level to fall below the state minimum criteria, then corrective measures may have to be implemented. The first measure would be to periodically raise the river flow rate to create a turbulent condition at the impounding area. This would bring the settled sludge back into suspension and carry the sludge downstream with the flow. A series of field tests should be made to determine the effect of flushing and the optimum rate of flow.

If the corrective measures above do not prove practical, a second approach would be to construct a sludge by-passing vault located beside the impounding area. The vault should be equipped with sludge withdrawal pipes extending to the sludge accumulation area. This would allow sludge to pass downstream. This installation would utilize the available head difference of about 15 feet from the dam and drain the sludge without bringing it into suspension.

REALLOCATION OF WATER QUALITY STORAGE

THE 1466 POOL

The Bloomington project reduces AMD pollution downstream of the lake and dilutes the municipal and industrial wastes by increasing the baseline flow. The improved quality of effluent from the municipal and industrial treatment plants means less water is needed to dilute these wastes. The treatment of the effluents from the coal mines has dramatically reduced acidity; however, it is difficult to predict future water quality because of the uncertainty of environmental regulation policy. Currently, Bloomington lake water quality is marginal for any fishery. With the reduced pollution load, better pH in the lake and downstream is now the prime water quality objective with the lowest minimum water quality flow, the project can be operated to maintain a better pH in the lake and downstream. The minimum water quality flow also affects the DO, sulfate, color, and conductivity downstream. In addition, less drawdown of the lake can provide better recreational activity in the lake for those years when water supply is not needed. The higher minimum water quality flow decreases the sulfate, DO, TDS, etc. With the given water quality storages of 51,000 acre-feet for water quality control at Bloomington Lake, the Bloomington and Savage projects can provide a minimum flow between 93 and 150 cfs without a significant impact on the lake and downstream reaches.

To increase DO concentration in the industrial pond near Willey Ford, the required minimum water quality flow was calculated by a model developed by Hydroscience (Hydro Qual), Inc., (Ref. 6). Based on this study, the NBPR can assimulate 6020 pounds per day of five day carbonaceous BOD from the UPRC treatment plant with the 93 cfs at Luke, and 9600 pounds per day as a result of the minimum water quality flow increasing from 93 cfs to 305 cfs. The UPRC treatment plant discharged an average of 3200 pounds per day with the maximum 5500 pounds per day BOD_5 carbonaceous in June 1981. Other BOD_5 loadings from Georges Creek and the NBPR upstream of Georges Creek are estimated to be about 500 pounds per day. Total DO consumption by benthos in the industrial pond is estimated to be 500 pounds per day based on the $1.5 g/m^2$ per day. Total carbonaceous BOD_5 loading to be assimulated is approximately 6500 pounds per day. Figure H-II-187 shows the flow requirement to meet the state standard of DO for the NBPR. The required minimum flow is 120 cfs at Luke, Maryland. The water quality flow of 120 cfs has been found to be the absolute minimum flow. This flow will occur only in very dry years. Generally, the minimum yearly flow will be in the range of 200 cfs to 300 cfs. The actual optimum flow for the industrial pollution dilution would be in the range of 600 cfs which would be impossible to maintain with the present projects throughout the year.

To improve water quality downstream, the river will be flushed periodically during low flow periods to clear out the industrial sediments and low DO water. The flushing will be done once a week or as needed during the low flow season and will use about 4000 acre-feet of storage. The stream fluctuation will also increase fish production because of the movement of the benthic population. To further assure good downstream quality, frequent usage of the flood gates should be prevented. The pool will be allowed to drop about 3000 acre-feet below 1466 by mid to late June. That way minor flood events will be contained in the vacant storage and uniform quality can be maintained downstream to fulfill the objectives of water quality control. The Bloomington Lake project requires 46,000 acre-feet for water quality storage at the 1466 pool under the current water quality conditions. The following are the detailed water quality storages needed to operate the project for maximum water quality benefit: 1) 29,000 acre-feet to maintain the minimum flow of 120 cfs, 2) 3,000 acre-feet for vacant storage in the lake, 3) 4,000 acre-feet for flushing downstream, and 4) 10,000 acre-feet to maintain the averaging ability of the lake. The storage for averaging water quality parameters in the lake is obtained from the results of the modeled 1930 flow year. When the Bloomington storage is below 10,000 acre-feet during the 1930 flow year, the outflow rapidly increases in concentrations of such parameters as conductivity, acidity, and sulfate.

Based on the above analyses it is feasible to reallocate about 5000 acre feet of storage from the presently authorized water quality storage to a water supply storage. This storage can be used for either water supply storage or environmental flowby. The environmental flowby is the volume of fresh water allowed to flow over Little Falls into the Potomac estuary. According to the preliminary report of the flow loss and travel time by the U.S. Geological Survey, the flow loss is insignificant. For example, if the flow at Luke is 100 mgd then the flowby requirement at Little Falls of 100 MGD is met. There would be some events during the dry period when the flow at Luke of 120 cfs (78 mgd) would not be able to provide flow for 100 mgd flowby. The probability of these events might be rare but they would be a possibility. For those rare events, flow at Luke would be increased to 100 mgd using the unreallocated storage of 5000 acre feet to provide a flowby of 100 mgd.

THE 1475 AND 1484 POOLS

Higher pool elevations at Bloomington Lake that would result from a reallocation of a portion of flood control storage will affect the water quality in both the lake itself and the stream below the dam site. If Bloomington Lake is raised to the 1475 or 1484 pool, some of the physical characteristics of the lake are changed to include surface area and hydraulic retention time which directly affect the water quality in the lake. Table H-II-22 lists the physical charactertistics of the proposed 1475 and 1484 pool as compared to the presently authorized pool at elevation 1466.

TABLE H-II-22

PHYSICAL CHARACTERISTICS AT DIFFERENT LAKE ELEVATIONS

	Summer Pool				Winter Pool	
Pool Elevation	Water Supply** and Water Quality Storage (acre-feet)	Surface Area (acre	Mean Depth (ft)	Hydraulic* Retention Time (days)	Water Supply** and Water Quality Storage (acre-feet)	Surface Area (acre)
1466	92,000	952	99.4	102.5	47,500	645
1475	100,800	1009	102.6	112.4	56,200	1713
1484	110,200	1069	105.6	122.9	66,000	780

*Calculated the constant pool year-around using the annual mean flow 453 cfs.
**The storage included the sediment storage of 2700 acre-feet.

The storage increase due to the higher pools is 8800 acre-feet at the 1475 pool and 18,200 acre-feet at the 1484 pool. But the surface area increase is small compared to the storage increase for the higher pool levels (57 acres at the 1475 pool and 117 acres at the 1484 pool). The surface area and mean depth are important factors affecting the water quality in the lake. The small increase of the surface area at the higher pools will result in water quality pools similar to the upper zone of the 1466 pool. But the lower zone volume significantly increases with the increasing pool elevation.

To evaluate the effects on the water quality conditions at the higher pools, the model analyzed the lake, and downstream water quality. All three pools (1466, 1475, and 1484) were analyzed for the best water quality scenario assuming the minimum water quality flow of 120 cfs. Water supply demands for the year 2030 were used together with a flowby target 100 mgd at Little Falls, Washington, D.C. The operational strategy for the higher pools was the same as that used for the 1466 pool. The initial water quality conditions for the higher pools were also the same initial conditions as the 1466 pool. Actually, the initial water quality conditions due to the higher pools should be different from the 1466 pool because the winter pool storage increases with increasing higher pool levels. The flow dependence of the Savage River Reservoir decreases with increasing pool elevations of Bloomington Lake. Table H-II-23 gives the flow dependence ratio for the three different pools.

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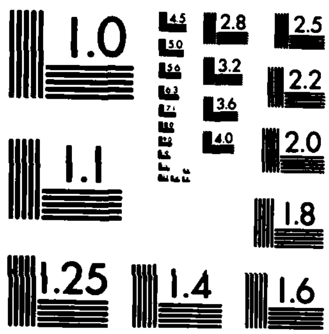

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE H-II-23

FLOW-DEPENDENT RATIOS OF SAVAGE RESERVOIR RELEASES

Bloomington Release (cfs)	Savage Release (% of Bloomington Release) 1466 Pool (%)	1475 Pool (%)	1484 Pool (%)
0-150 15.0	13.7	12.5	
150 - 299	17.5	15.6	14.6
300 - 449	20.0	18.2	16.7
450 - 649	25.0	22.8	20.9
650 - 999	30.0	27.3	25.0
1000 - 1459	35.0	31.9	29.2
over 1500	40.0	36.5	33.4

The lake water quality due to the higher pools will be slightly different with the increasing pool elevation. In the spring the lake water quality with the high pools will be worse than the water quality with the 1466 pool. The lake water quality in late winter is gradually diluted by the better water quality of the higher spring inflow. With the larger storages of the higher pools, the lake water quality of the higher pool will be better in late winter and worse in late spring when the lake begins the thermal stratification. After the stratification, the higher pool will have slightly worse water quality in the lower zone and similar water quality in the upper zone. But the difference in water quality between the 1466 pool and the higher pool will be minimal. The lower zone volume significantly increases with increasing pool elevation. The higher pool will have a larger volume of the lower zone storage (better water quality) during the summer.

If the lake is raised to the higher summer pool, the water quality needs more vacant storage (2,000 acre-feet) because the high pool will more frequently use the flood gate due to the reduced flood storages. Therefore, the water quality storages needed at the higher pool are 48,000 acre-feet at both the 1475 and 1484 pool. The 1475 pool and the 1484 pool can provide water supply storage of 52,800 acre-feet and 62,200 acre-feet, respectively.

WATER QUALITY CONDITIONS WITH STORAGE REALLOCATION

LAKE WATER QUALITY

The lake water quality of the 1466 pool (minimum water quality flow 120 cfs) will resemble the lake water quality of the 1466 pool with the minimum water quality flow 110 cfs. The effects on water quality due to the increased minimum water quality flow from 110 cfs to 120 cfs are small. The concentration of each parameter increases with time at a minimum water quality flow 120 cfs. However, the concentration of each of the water quality parameters are identical for the minimum water quality flow 110 cfs and 120 cfs.

The lake water quality at the higher pools is slightly different than at the 1466 pool. The concentration of the water quality parameters will increase slightly with increasing pool elevation in the lower zone when the early spring inflow is low. The overall quality effects due to the increased pool elevation are negligible. Figure H-II-188 through H-II-193 show the expected concentrations of acidity, pH, and conductivity in the lake for the year 1930.

OUTFLOW WATER QUALITY

With the increased winter pool and increased lower zone volume in summer in the higher pools, the outflow water quality will be better in early spring, and late summer and fall, than the outflow quality of the 1466 pool, and will be worse in spring. The outflow will have a larger mixed portion of the lower zone, and the resultant water will be better in the summer and fall. When the water supply storage increases with storage reallocation, the outflow quality will be slightly improved because the outflow has more lower zone water. Outflow temperature will decrease slightly with increased pool elevation because the outflow contains a larger volume of the lower zone water (cold water). However, when the flow years are average and/or high, the higher pools frequently discharge high flows through the flood gates because of the reduced flood storage. Figure H-II-194 and H-II-197 show the expected outflow temperature and outflow concentrations of acidity, pH, and conductivity of 1930. Consequently, the outflow improves water quality with the higher pools at a low flow year however outflow temperature or water quality during the high inflows in the summer will be worse.

WATER QUALITY AT LUKE

The flow dependence ratio relationship between Bloomington and Savage releases decreases with increasing pool elevation. The decreased volume of Savage River water at Luke decreases the buffering capacity and dilution effects. The resultant waters from the better quality of the higher pool and less volume from Savage water will be similar to the water quality of the 1466 pool. When Bloomington outflow discharges a high volume with worse water quality through the flood gates during an average and high flow year, Savage River Reservoir has to release a large volume of water for dilution. As a result, Savage River Reservoir often loses its storage, thereby making it difficult to maintain the desirable discharge flow ratio. The downstream water temperature will be slightly colder with the high pool. Figure H-II-198 through H-II-201 are the expected temperature, pH, acidity and conductivity of 1930 at Luke.

WATER QUALITY BELOW LUKE

The difference in downstream water quality due to the higher pool will be negligible because the water quality at Luke is similar to the water quality of the 1466 pool. The expected baseline water quality resembles the baseline water quality with the minimum water quality flow of 110 cfs, if the lake has enough vacant storage for high inflow during the summer. In the high flow season, water quality conditions downstream of Luke get progressively worse, since increasing the volume of the Bloomington causes the ratio of the volume of Savage Lake to Bloomington Lake to become progressively smaller.

DISCUSSION AND CONCLUSIONS

PROJECTED OPERATIONAL RANGE OF BASELINE WATER QUALITY CONDITIONS

The system operation of the two reservoirs will substantially improve water quality parameters downstream, especially pH. Based on the model results, the projected operational range of temperature, pH, and conductivity for baseline water quality conditions have been established for the Bloomington and Savage Projects. The minimum and maximum values of each parameter were obtained for each station depending upon the minimum water quality flows and the water quality scenario. The maximum and minimum values were obtained from four flow years, 1930, 1962, 1966, and 1967. The results were plotted as upstream water quality parameters versus river miles of the North Branch Potomac River. Also, the measured extreme values for the years 1977-1980 at each station are plotted to compare the water quality conditions prior to the Bloomington project operation. The estimated extreme values, which probably occurred in the period between 1950-1980, are also plotted.

TEMPERATURE

Figures H-II-202 and H-II-203 are the expected operational range of temperature for the minimum water quality flow 110 cfs and 150 cfs, respectively. The maximum temperature at Barnum will be in the range of 19 to 22°C (the primary target is not the temperature). The maximum natural stream temperature was 26-29°C at Barnum. For the different minimum water quailty flows, there will be negligible stream temperature effects.

pH

Projected operational range of pH is divided into two parts. The best water quality scenario and the worst water quality scenario. Each scenario has two minimum water quality flows of 110 cfs and 150 cfs. Figures H-II-204 and H-II-207 are the expected operational range of pH for the minimum water quality flows of 110 cfs and 150 cfs, respectively. The pH will range between 4.7 to 6.0 at Barnum and 5.3 to 6.5 at Luke for the best water quality scenario. In the reach from Barnum to Luke, the minimum pH will occur during the low flow season and the maximum pH will occur during the high flow season. The system operation of the two reservoirs can raise the pH at Luke approximately a half unit. A constant quality and quantity of effluent from the Upper Potomac River Commission STP varies the neutralization effects of the North Branch Potomac River. Depending upon the flow volume, the pH will be maximum at low flow and minimum at high flow below the station upstream of New Creek. Other downstream tributaries raise the pH further. The expected pH range will be 5.5 to 7.8 upstream of New Creek, 5.8 to 7.8 at Pinto, and 6.5 to 8.3 at Willey Ford. Below Willey Ford, the pH range will be above 6.5 at all times for the best water quality scenario. The different minimum water quality flows only change the pH between Barnum and Luke. Therefore, the higher minimum water quality flow decreases the pH. Below upstream of New Creek, the pH differences between the two minimum water quality flows are negligible because of the high amount of alkalinity discharge from the Upper Potomac River Commission STP which is located just above upstream of New Creek. The minimum water quality flow does not affect the maximum pH between Barnum and Luke, nor the minimum pH below upstream of New Creek because these happen during the high flow season.

For the worst water quality scenario, the pH will be in the range of 3.3 to 3.8 at Barnum and 4.2 to 6.2 at Luke when the minimum water quality flow is maintained at 110 c.f.s. Savage River water will substantially raise the pH downstream at Luke when the Bloomington project outflow is bad. The maximum pH will be around 6.5 between upstream of New Creek and upstream of Wills Creek and will usually occur during the low flow season. The minimum pH will be in the range of 4.5 to 5.5 between upstream New Creek and upstream Wills Creek, during the high flow season. The effects of the Upper Potomac River Commission STP on NBPR are its neutralization capacity of the acidity of the river. The STP cannot raise the pH of the river to 6.5 at the low flow periods but the other downstream tributaries will help to raise the pH of the river.

The occurence of the maximum and minimum pH downstream differs from each station depending on the flow. The NBPR in the reach between below the Dam and Luke will have the lowest pH at the low flow season and the highest pH at the high flow season. However, the NBPR in the reach between the UPRC STP and Paw Paw will have the maximum pH at the low flow season and the minimum pH at the high flow season. Consequently, the downstream pH of the Bloomington and Savage projects will be the most difficult to control at the high flow season.

CONDUCTIVITY

The Upper Potomac River Commission STP is a major contributor of conductivity in the North Branch Potomac River. Figures H-II-208 through H-II-211 provide the best and worst water quality scenario for the minimum water quality flows of 110 cfs and 150 cfs. The expected conductivity range will be between 200 to 450 micromhos/cm at Barnum and 100 to 400 micromhos/rm at Luke when the minimum water quality flow is maintained at 110 cfs. The minimum conductivity will occur during the high flow season, and the maximum conductivity will happen during the low flow season. Savage River water decreases the conductivity of the North Branch Potomac River.

The low minimum water quality flow produces high conductivity and the high minimum water quality flow produces low conductivity on the NBPR below the STP. The minimum water quality flow of 110 cfs is expected to have the highest conductivity in the range of 1,000 to 1,100 micromhos/cm below the UPRC STP. The conductivity gradually decreases further downstream. The conductivity for the minimum water quality flow of 150 cfs. resembles the conductivity for the minimum water quality flow of 110 cfs. The expected conductivity below the UPRC plant will be in the range of 450-600 micromhos/cm when the minimum flow of 200-300 cfs at Luke is maintained.

CONCLUSIONS

The NBPR was once heavily polluted by acid mine drainage and industrial and municipal wastes. Over the past few years, however, the water quality of the NBPR has improved significantly, especially pH and DO. The improvement has resulted from upgraded and/or new sewage treatment plants, improved treatment of the effluent from active coal mines, and reclamation of the abandoned strip mines in the basin.

The expected lake pH will be in the range of 4.8 to 6.1 for the current water quality condition. However a trend toward easing discharge regulations at the coal mining operations has been noted. If the discharge regulations from the coal mines are relaxed, the lake pH will decrease and be in the range of 3.5 to 3.7. On the other hand, if the coal mines overtreat their effluents, the lake pH will be far better than that of the best water quality scenario.

The outflow pH will be best in spring and gradually decrease over the life of the project. The outflow pH is expected to be in the range of 5.0 to 6.0. The maximum expected outflow temperature is $15^{o}C$ to $22^{o}C$. This is approximately $5^{o}C$ to 10^{o} lower than the natural stream temperature during summer.

The Bloomington Lake project can further improve pH and DO in the lake and downstream by buffering acid slugs and by increasing baseline flow. Based on the model study, the Bloomington and Savage projects can provide 93 to 150 cfs of minimum water quality flow at Luke without significant adverse water quality impacts in the lake and downstream. To achieve the state water quality criteria of DO (5 mg/l), in the NBPR, the minimum water quality flow needed is 120 cfs at Luke, Maryland. The optimum minimum water quality flow for meeting the state standards of DO and for maintaining better pH in the lake and downstream is 120 cfs. This flow, however, will be too low to dilute the industrial wastes from the UPRC STP. This is the water quality flow that can be maintained in a dry year. Generally, flows at Luke will be substantially higher than the minimum water quality flow.

The system regulation of the Bloomington Lake Project in conjunction with the Savage River Reservoir is very beneficial for water quality downstream. Savage water can reduce pH fluctuation downstream by increasing its outflow when the Bloomington Lake project releases for water supply or flood control. When the outflow quality is worse, the system regulation is more effective in raising pH downstream.

The minimum water quality storage needed for quality control regulation is 46,000 acre-feet at the 1466 pool. The remaining 5,000 acre-feet of the original 51,000 acre-feet water quality storage can be used for environmental flowby or water supply storage.

The high pools, 1475 and 1484, slightly improve water quality in the lake; however the higher pool decreases the flow dependence ratio of Savage River Reservoir. The resultant water quality at Luke resembles the water quality of the 1466 pool. With the higher pool the flood gates will be used more frequently because of the reduced flood storages. Therefore, the lake should provide more vacant storage for water quality control. The minimum water quality storage required at the 1475 and 1484 pools is estimated to be 48,000 acre-feet.

ADDITIONAL WATER QUALITY INVESTIGATIONS

Additional water quality investigations were conducted to evaluate the effects of providing flowby levels higher than 100 mgd on the water quality in the North Branch Potomac River. Several operational scenarios were assumed for the MWA water supply system with different levels of flowby.

To show the effects of various flowby targets, the water quality was modeled in the lake and downstream, from below the dam to Paw Paw, West Virginia, for three different flow years, 1930, 1962, and 1966. Year 1930 is an extreme dry year. Year 1962 is an average flow year. Year 1966 is a dry year. Each year was modeled for the best case scenario. The model analyzed three flowby targets 100 mgd, 300 mgd and 500 mgd for the 1466 seasonal pool (1410 winter pool), 100 mgd flow-by target for the 1466 year around pool, and 300 mgd and 500 mgd flowby targets for the 1475 seasonal pool (1423 winter pool). Each flowby target was based on a predetermined weekly water release plan depending upon the year of MWA water supply demand. The weekly water release plan established the flow for a hypothetical water supply demand and its flowby. The water quality of the three different flowby targets was analyzed at five stations below the dam, Luke, Pinto, Willey Ford, and Paw Paw.

THE 1466 SEASONAL POOL

TEMPERATURE

Below the Dam

The stream temperature below the dam varies with water supply and/or a flowby target and spring inflow volume. The highest flowby target, 500 mgd, releases a higher volume of cold water and results in the coldest outflow temperature among the three flowby targets. The 100 mgd flowby yields the warmest water temperature.

Figure H-II-212 through H-II-214 show the outflow temperatures for the 1930, 1962 and 1966 flow years. The outflow temperature differs with each flow year. The stream temperature of the 1930 flow year exhibited the coldest water temperature, $15^{\circ}C$ in summer. The reason for this was the low spring inflow of 1930 resulted in the coldest water temperature in the lower zone. During the average flow year of 1962, the outflow temperature of the 500 mgd flowby was 2 to $5^{\circ}C$ colder than the 100 mgd flowby.

Luke, Maryland

The temperature at Luke was about $1^{\circ}C$ lower than the temperature below the dam. At Luke, the Savage outflow decreases the stream temperature of the NBPR slightly. The temperature patterns due to the various flowby targets are essentially the same as the outflow temperatures below the dam. Figures H-II-215 through H-II-217 show the stream water temperatures for the flowby targets at Luke.

Pinto, Maryland

At Pinto, the thermal discharge by the WESTVACO plant and the UPRC STP increased the stream water temperature. The stream temperature exhibited a significant difference with each flowby target. Figures H-II-218 through H-II-220 show the stream temperature. The lower flowby target (100 mgd) at Pinto allowed a high temperature increase from WESTVACO while the stream temperature of the 300 mgd and 500 mgd flowby targets showed only a slight temperature increase. In 1962, the stream temperature of the 500 mgd flowby was 3 to $7^{\circ}C$ lower than the stream temperature for the 100 mgd and 300 mgd flowby target. In 1930, the stream temperature of the 500 mgd flow-by was the coldest, for a longer period. The 100 mgd flowby results in lower stream temperature at the end of the year because the 100 mgd flowby used less lake storage than the 300 or 500 mgd flowby. To evaluate this excess storage required higher discharges and resulted in lower stream temperature late in the summer and fall. In 1966, the stream temperature patterns were the same as those of the 1930 flow year. However, the 1966 100 mgd flowby showed a 4 to $5^{\circ}C$ higher temperature than the 1930 100 mgd flowby. The reason for the higher temperature in 1966 was that spring inflows were quite high and warmed the hypolimnion. The 1930 spring inflows were low and left the hypolimnion very cold into the late summer.

Wiley Ford, Maryland

At Wiley Ford, the stream temperature patterns and trends are identical to the stream water temperature patterns and trends at Pinto. The stream temperature at Wiley Ford is significantly influenced by the stream temperature at Pinto during the water supply or flowby release periods. Figures H-II-221 through H-II-223 exhibit the stream water temperatures for the 1930, 1962 and 1966 flow years. Typical water temperatures at Wiley Ford are about 2°C warmer than at Pinto. The temperatures at Pinto and Wiley Ford become more similar with a higher flow.

Paw Paw, West Virginia

By the time the Potomac River reaches Paw Paw, large tributaries such as the South Branch, Patterson Creek and Town Creek have diluted the river to a near natural stream temperature under the various flowby releases. The stream temperature at Paw Paw is influenced by the water supply/flowby release because the tributary flows are not high enough and the travel time is too short to raise the river temperature to its natural level. Figures H-II-224 through H-II-226 show the stream water temperatures for the different three flow years.

pH

Below the Dam

The low flowby target results in better pH in the lake and downstream than the high flowby target. In 1930, the outflow for the 100 mgd flowby target showed a significantly higher pH at the end of the year (Figure H-II-227). The differences in pH among the different flowby targets is within about 0.3 unit. Figures H-II-227 through H-II-229 exhibit the outflow pH below the dam.

Luke, Maryland

The system operation of Savage River Dam helps to increase the pH when the Bloomington Lake Project releases waters for the water supply/flowby purpose. Figures H-II-230 through H-II-232 show the pH at Luke for the flowby targets. Figure H-II-230 shows the typical pH influence by Savage River Reservoir at Luke. In 1930 and 1966, the NBPR for the 300 mgd and 500 mgd flowby target exhibited a 0.3 to 0.4 unit higher pH during the water supply/flowby release periods than the pH for the 100 mgd flowby target. The higher flowby target resulted in a greater flow dependence ratio that raised the pH. The pH difference between the flowby targets was greater at Luke than below the dam. The 100 mgd flowby target shows a higher pH at the end of the year. The pH of the 500 mgd flowby shows a sudden drop at the end of the year. The sudden pH drop was caused by the Savage Reservoir being completely depleted of storage.

Pinto, Maryland

The effluent from the UPRC STP neutralizes the NBPR water raising the pH. The stream pH for the higher flowby target suddenly drops from 7.6 to 6.5 at the beginning of the water supply/flowby release even though the pH at Luke for the high flowby target was 0.3 to 0.4 units higher thanthe pH for the 100 mgd flowby target. During the water supply/flowby release periods for the 500 mgd flowby target, the pH at Pinto ranged between 6.3 to 6.5 for all three flow years. The pH for the 300 mgd flowby also was in the range of 6.3 to 6.5 in 1930 and 1966. In 1962, the Bloomington Lake project did not release water for the 100 and 300 mgd flowby target. The 100 mgd flowby used less water. As a result, the lake had to release a lot of water at the end of the year. Therefore, a lower pH or a pH interruption occurred at the end of the year, because of a large release of water. Actual regulation will not allow this situation because the outflow volume will be controlled by the lake volume and the time of year. Therefore, the actual pH for the 100 mgd flowby target will gradually decrease with time at the end of the year for the 1966 and 1930 flow years. Whenever a large volume of water from the Bloomington and Savage projects is released for the water supply/flowby purpose, the pH will become lower during the release periods. Figures H-II-233 through H-II-235 exhibit the pH of the NBPR at Pinto for the flowby targets.

Wiley Ford, Maryland

Figures H-II-236 through H-II-238 show the pH at Wiley Ford for the three different flowby targets. The patterns and trends of the pH at Wiley Ford resemble those at Pinto. The pH at Wiley Ford showed a slight improvement over the pH at Pinto.

Paw Paw, West Virginia

Figures H-II-239 through H-II-241 show the pH at Paw Paw for the flowby target during the 1930, 1962 and 1966 flow years. In 1962, the pH at Paw Paw ranged between 7.0 and 8.3 even though the Bloomington Lake project released water for the 500 mgd flowby target. In 1930 and 1966, the pH at Paw Paw showed a sudden pH drop from 8.0 to 6.5 during the beginning of the water supply/flowby release and remained constant during the release periods. The minimum pH was always above 6.5 for all of the water supply/flowby release periods.

CONDUCTIVITY

Below the Dam

The outflow for the high flowby target has a low conductivity during the water supply/flowby release periods because the outflow for the higher flowby target has to withdraw from a low acidic water for better pH. The outflow for the 100 mgd flowby release periods showed the lowest conductivity at the end of the year. The opposite occurred during the high flowby targets at the end of the year in 1930. Figures H-II-242 through H-II-244 exhibit the outflow conductivity for the three different flow years. In 1962, the difference in the outflow conductivity due to the flowby targets is negligible.

Luke, Maryland

The conductivity of the outflow is reduced after mixing with the low conductivity water of Savage Reservoir. The reduction in conductivity of the NBPR from Savage River water depends upon the flow dependence ratio. In 1962 and 1966, the Savage River Reservoir had enough water for maintaining a predetermined flow ratio. In 1930, Savage ran out of water. The 100 mgd flowby target was associated with the higher flow dependence ratio because the Bloomington Lake storage was above the rule curve, therefore, a large volume of water had to be drawn down at the end of the year. The 500 mgd flowby target resulted ina lower flow discharge ratio because the Savage River Reservoir was depleted at the end of the year. Consequently, the conductivity at Luke showed a sudden drop for the 100 mgd flowby target and sudden increase for the 500 mgd flowby target at the end of the year. Figures H-II-245 through H-II-247 show the conductivity at Luke for the various flowby targets for the three flow years 1930, 1962 and 1966. The patterns and trends of the conductivity at Luke resemble those below the dam during the water supply/flowby release periods.

Pinto, Maryland

Conductivity at Pinto is inversely proportional to the stream flow because a constant high conductivity water enters from WESTVACO. In 1930 and 1966, the conductivity for the 100 mgd flowby target was in the range of 700 to 1,000 micromhos/cm during the water supply/flowby release periods and was interrupted at the end of the year because Bloomington Lake released a large volume of water. The higher flowby targets maintained the lower conductivities during the water supply/flowby release periods and vise versa. Figures H-II-248 through H-II-250 show the conductivity at Luke for the flowby target for the 1930, 1962 and 1966 flow years.

Wiley Ford, Maryland

The conductivity at Wiley Ford resembles the conductivity at Pinto. The conductivity is about 50 micromhos/cm lower than that at Pinto when the stream is maintained at the minimum flow. Figures H-II-251 through H-II-253 show the conductivity at Wiley Ford for the 1930, 1962 and 1966 flow years.

Paw Paw, West Virginia

The patterns and trends of the conductivity due to the flowby targets are the same for Paw Paw as Willey Ford. However, the conductivity at Paw Paw was 150 to 200 micromhos/cm lower than that at Wiley Ford when the stream is maintained at the minimum flow. Figures H-II-254 through H-II-256 show the conductivity at Paw Paw for the 1930, 1062 and 1966 flow years.

THE SEASONAL POOL 1475

300 MGD FLOWBY TARGET

Temperature

The stream temperature in the reach between Bloomington Lake and Luke had the same pattern of stream temperature as the 1466 seasonal pool. The temperature difference between the 1466 and 1475 pool was insignificant for all three years. The 1475 pool had the longer water supply/flowby release period. Therefore, the 1475 pool also kept colder stream temperatures longer with long release periods. The stream temperature pattern was the same as the 1466 pool except the extended water supply/flowby release periods extended the duration of the colder release.

pH

The major difference in water quality between the 1466 pool and 1475 pool is the pH in the reach between Bloomington Lake and Luke. The increased winter pool and increased lower zone volume in the lake resulted in a better water quality outflow than that of the 1466 pool. But the flow ratio with Savage decreased with the raised pool. As a result of the improved outflow quality and the reduced discharge flow ratio, the resultant water quality at Luke resembles the water quality of the 1466 seasonal pool. At Pinto, the pH difference between the 1466 pool and 1475 pool was negligible during the water supply/flowby release periods. The NBPR experienced a lower pH reading for a longer period of time due to the extended release periods from the 1475 pool. The pH at Wiley Ford and Paw Paw were not effected by the higher pool.

Conductivity

The conductivity of the 1475 pool resembled the conductivity of the 1466 pool.

500 MGD FLOWBY TARGET

Temperature

The stream temperature will be similar to the pattern of the 1466 pool. The stream temperature of the 1475 pool will be slightly lower than that of the 1466 pool because of the increased lower zone volume. The stream temperature along the river will be very similar to the temperature that occurred with the 1466 pool.

pH

The outflow pH will be slightly better than the 1466 pool. But the pH at Luke will be worse than the 1466 pool due to the lower discharge ratio with Savage. At Pinto, the pH will be similar to the pH of the 1466 pool except for the extended water supply/flowby release periods. The pH at Wiley Ford and Paw Paw resembles the pH of the 1466 pool except for the extended water supply/flowby release periods. The pH for the extended water supply/flowby release periods is the same as the pH during water supply/flowby release periods.

Conductivity

The conductivity of the 1475 pool is similar to the 1466 pool.

THE 1466 YEAR-ROUND POOL

During the high inflow season the 100 mgd flowby target for the 1466 year-round pool resulted in the worst outflow pH. If Bloomington Lake maintains a year-round pool, it will frequently release large volumes during spring runoff season. This runoff would normally be stored to refill the lake if it had a fall drawdown. Because Savage River Reservoir has a seasonal pool, it cannot maintain the flow dependence ratio needed to maintain a uniform downstream pH. As a result, the water quality will often be worse downstream. Therefore, it is not recommended that Bloomington Lake exist at a year-round constant pool.

The year-round pools present the very worst condition from a water quality standpoint especially in the area downstream of Luke. This condition became clearly evident after the 1466 year-round pool was modeled. The higher pools (1475 and 1484) were not modeled for a year-round pool condition. The conclusion drawn from the results of the 1466 year-round pool model can be extrapolated to the higher pools. The condition described in this Annex indicate that water quality conditions in Bloomington Lake vary only slightly between the 1466, 1475 and 1484 pools. But water quality conditions downstream of Luke become progressively worse in the high flow season (spring) as one increases the volume of Bloomington because the ratio of the volume of Savage River Reservoir to Bloomington Lake becomes progressively smaller.

Consequently, Savage is less able to counteract the larger, longer duration Bloomington releases. With a constant year-round pool at Bloomington and a seasonal pool at Savage this condition is magnified by two factors. First there is an extreme imbalance in the volume ratio of Bloomington to Savage Dam and, second, the fact that normal high inflows into Bloomington in the spring will be released while the high inflow in Savage must be stored in order to raise the pool to its summer level. This results in the flow at Luke being composed of almost 100% Bloomington water at mean high volumes.

For comparison purposes, the differences in the year-round pools of 1475 and 1484 are slightly more extreme than the differences between the 1466 year round pool and the 1466 seasonal pool.

OTHER FLOWBY PLANS

There were seven additional flowby plans investigated. The seven flowby plans and their effects on water quality downstream are as follows:

300 MGD FLOWBY TARGET WITH 1466 YEAR ROUND POOL

The water quality effects downstream are the same as those for the 100 mgd flowby target at the 1466 year-round pool described above.

500 MGD FLOWBY TARGET WITH 1466 YEAR ROUND POOL

The adverse water quality effects are the same as those for the 100 mgd 1466 year round pool during the high inflow season.

300 MGD FLOWBY TARGET WITH 1466 SEASONAL POOL AND 46,000 ACRE-FEET EACH FOR WATER QUALITY STORAGE AND WATER SUPPLY STORAGE

The water quality effects downstream will resemble the water quality effects with the 300 mgd flowby target on the 1466 seasonal pool described previously. The previous 1466 seasonal pool assumed water quality storage of 51,000 acre-feet and water supply storage of 41,000 acre-feet. The decrease in water quality storage reduces the averaging ability in the lake after water supply release and results in worse outflow quality. However, the difference of water quality between the water quality storage of 51,000 acre-feet and water quality storage of 41,000 acre-feet would be minor.

500 MGD FLOWBY TARGET WITH 1466 SEASONAL POOL AND 46,000 ACRE-FEET EACH FOR WATER QUALITY STORAGE AND WATER SUPPLY STORAGE

The water quality effects downstream will resemble the water quality effects with of the 500 mgd flowby target and the 1466 seasonal pool described previously.

300 MGD FLOWBY TARGET WITH 1484 SEASONAL POOL

The outflow quality will be slightly better than the outflow quality with the 300 mgd flowby target and the 1466 and 1475 seasonal pools. The extended water supply/flowby release periods result in the same water quality effects downstream during the release periods. However, the higher 1484 pool will discharge more frequently and have a larger volume during high inflow season. These will cause water quality problems.

500 MGD FLOWBY TARGET WITH 1484 SEASONAL POOL

The outflow quality will be slightly better than the outflow quality for the 500 mgd flowby target with the 1466 and 1475 seasonal pool. Other effects on water quality will be the same as the 300 mgd flowby target at the 1484 seasonal pool.

197 MGD FLOW AT LUKE WITH 1466 SEASONAL POOL

The purpose of this condition was to test the assumption made for the authorization document. The authorization document assumed a flow of 197 mgd at Luke for the low flow periods. Bloomington Lake will be used for water supply for the MWA. The water supply needs may be far greater than 197 mgd during certain drought periods. After water supply storage is depleted, Bloomington and Savage Reservoirs will not be able to maintain the 197 mgd flow at Luke and still maintain the required minimum storage of 10,000 acre-feet for water quality averaging in the lake. Therefore, outflow water quality will be worse at the end of the year. In an average or wet year, the water quality downstream will be best among the flowby targets.

CONCLUSIONS

With 100 mgd flowby target and a seasonal pool at elevation 1466 feet msl the highest pH, temperature and conductivity occurred along the river during the water supply release periods of any of the plans considered. The 100 mgd flowby target for the 1466 year-round pool had the worst pH along the basin during the high flow season. Based on the above findings, it is recommended that Bloomington Lake not be maintained at a year-round pool.

The 300 mgd flowby target for the 1466 pool had lower pH, temperature and conductivity at Pinto than those of the 100 mgd flowby target. During the release periods, the pH at Pinto was around 6.5. The NBPR from Wiley Ford had pH above 6.5 during the release periods.

The 300 mgd flowby target for the 1475 seasonal pool provided slightly worse pH at Luke than that of the 1466 seasonal pool, but resembled the pH of the 1466 seasonal pool at Pinto and further downstream.

The 500 mgd flowby target for the 1466 seasonal pool had the worst pH during the water supply release periods at Pinto and further downstream. At Luke, the flow discharge ratio should be reduced to balance the remaining storage of the two reservoirs. As a result, the pH will decrease.

The 500 mgd flowby target for the 1475 seasonal pool had the lowest discharge flow discharge ratio. At Pinto, the pH was the lowest among the scenario.

The high flowby target brings down the stream temperature during the release periods. The stream temperature for the 300 mgd and 500 mgd flowby targets was in the range of 13 to 15°C from Pinto to Paw Paw during the release periods in 1930. In 1966, the stream temperature was slightly higher than the stream temperature of 1930. The NBPR below Pinto does support some biological activities. The colder water temperature would prohibit fish production downstream and limit existing biological activities. Consequently, the 100 mgd flowby target provides best pH and temperature for the fishery in the NBPR.

The year-round pools present the very worst water quality condition in the area downstream of Luke in the high inflow season. Bloomington Lake can not maintain year-round pool throughout the year because of the minimum flow at Luke and downstream water quality problems. It is, therefore, recommended that Bloomington Lake not be maintained at a year-round pool.

The 197 mgd flow target at Luke with 1466 seasonal pool will maintain the best water quality downstream in an average or wet year. However, Bloomington Lake is not able to keep the minimum storage of 10,000 acre feet required for the water quality averaging in the lake at the end of the year when Bloomington Lake Project releases in a dry year.

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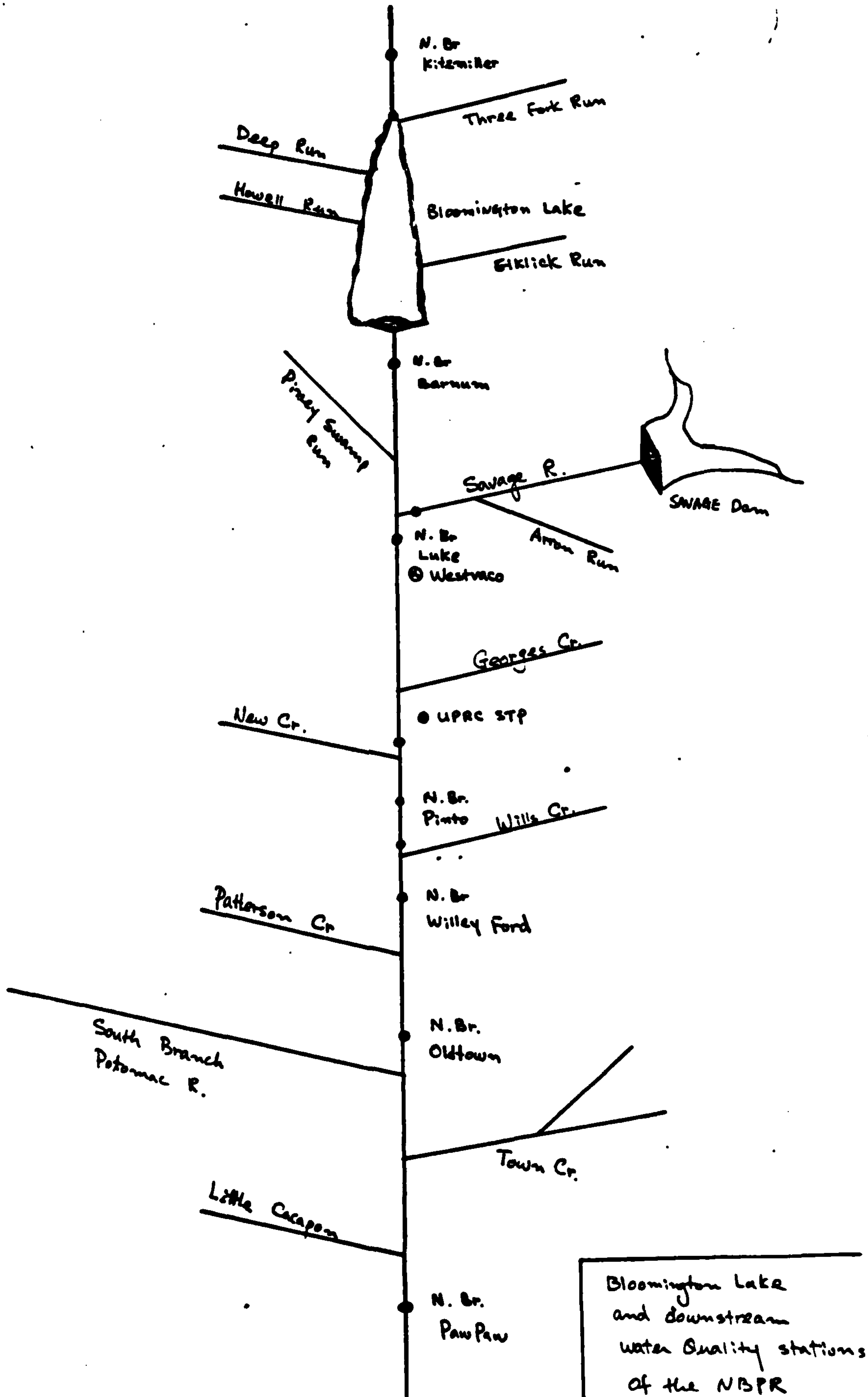

N. Br
Kitzmiller
Three Fork Run
Deep Run
Howell Run
Bloomington Lake
Elklick Run
N. Br
Barnum
Piney Swamp Run
Savage R.
SAVAGE Dam
N. Br
Luke
@ Westvaco
Aaron Run
Georges Cr.
UPRC STP
New Cr.
N. Br.
Pinto
Wills Cr.
N. Br
Willey Ford
Patterson Cr
N. Br.
Oldtown
South Branch
Potomac R.
Town Cr.
Little Cacapon
N. Br.
Paw Paw
Bloomington Lake
and downstream
water Quality stations
of the NBPR

FIGURE H-II- 1

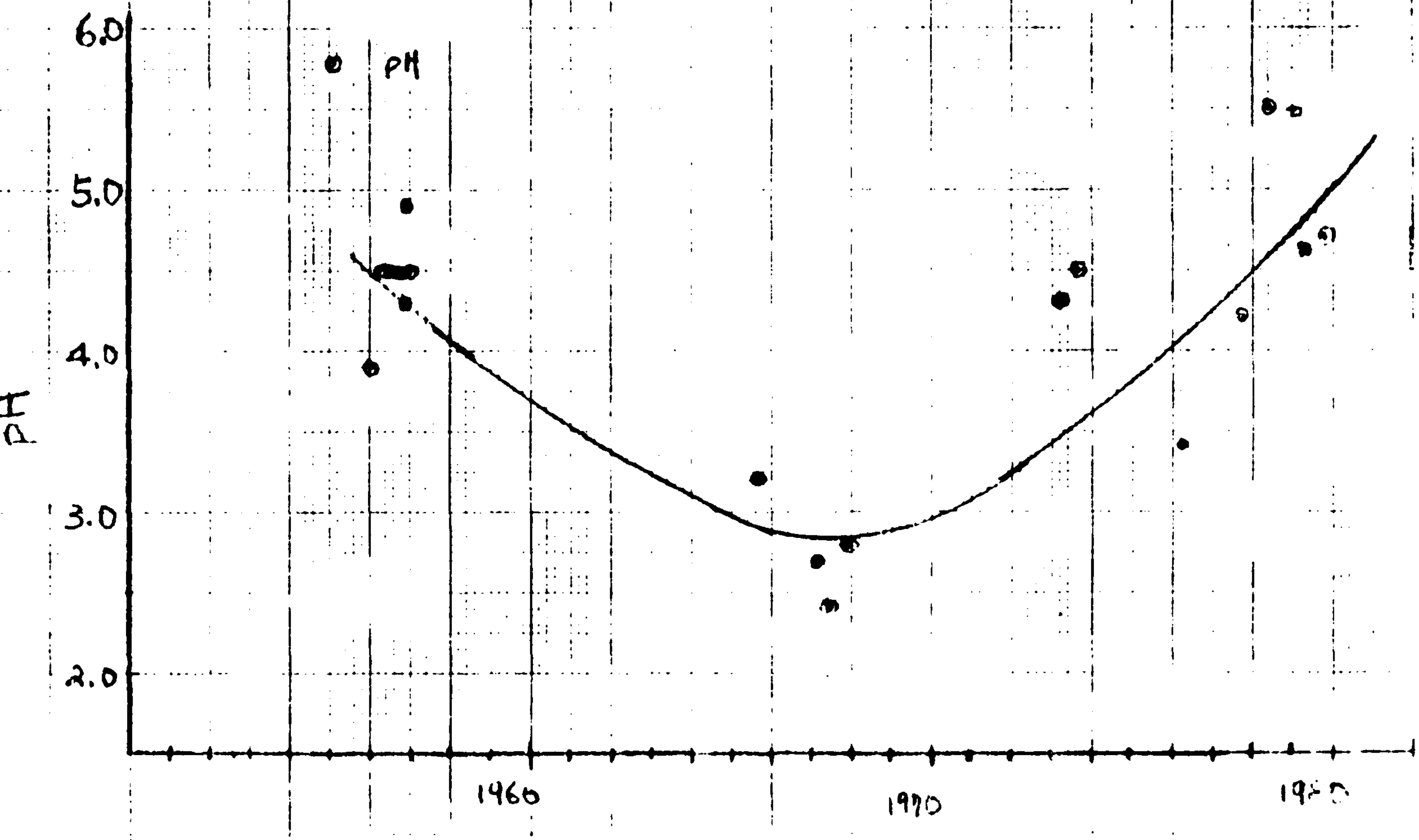


FIGURE H-II- 2 pH Variation with Time period [illegible]
[illegible] and October at [illegible] Maryland

WATER QUALITY (WORST CASE) AT KITZMILLER (1967-1972)

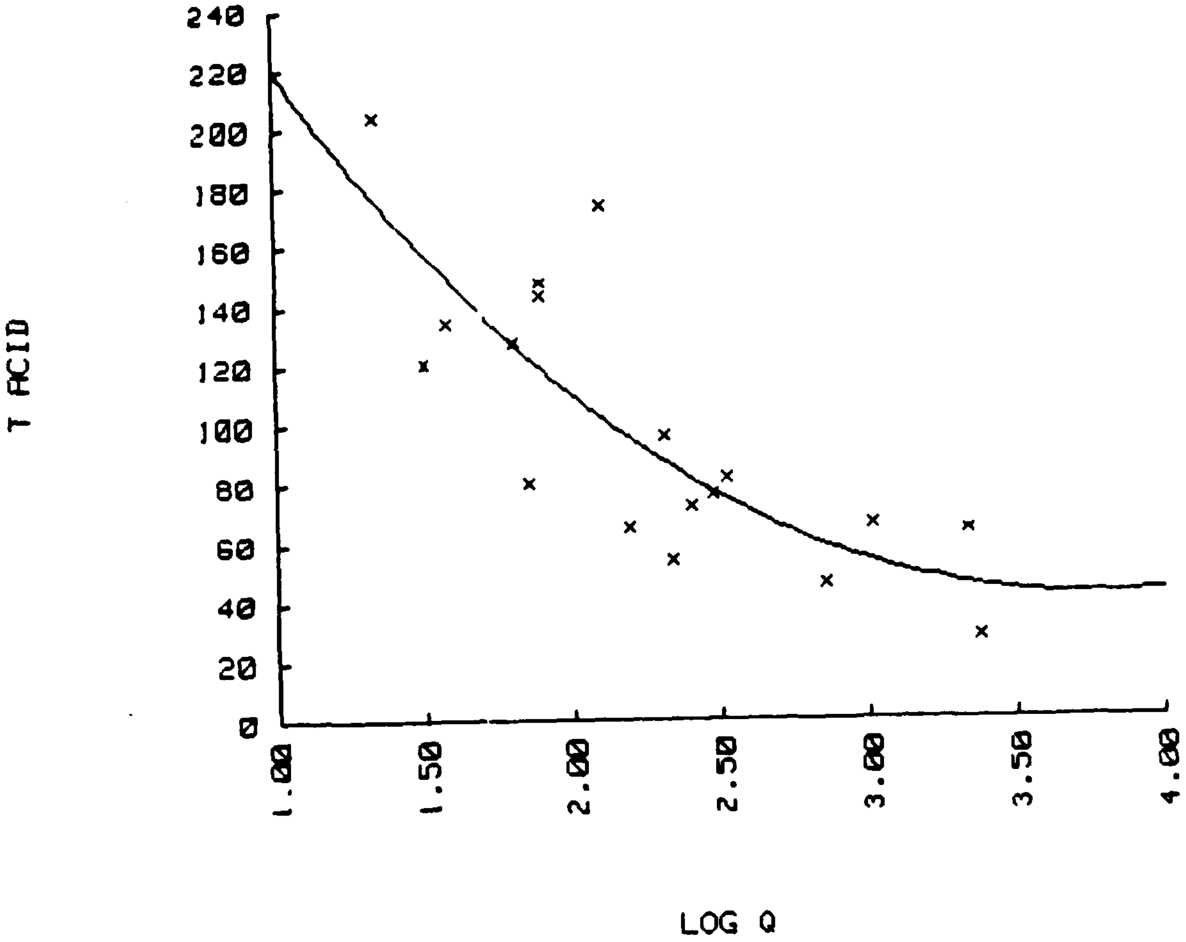


FIGURE H-II- 3

WATER QUALITY (WORST CASE) AT KITZMILLER (1967-1972)

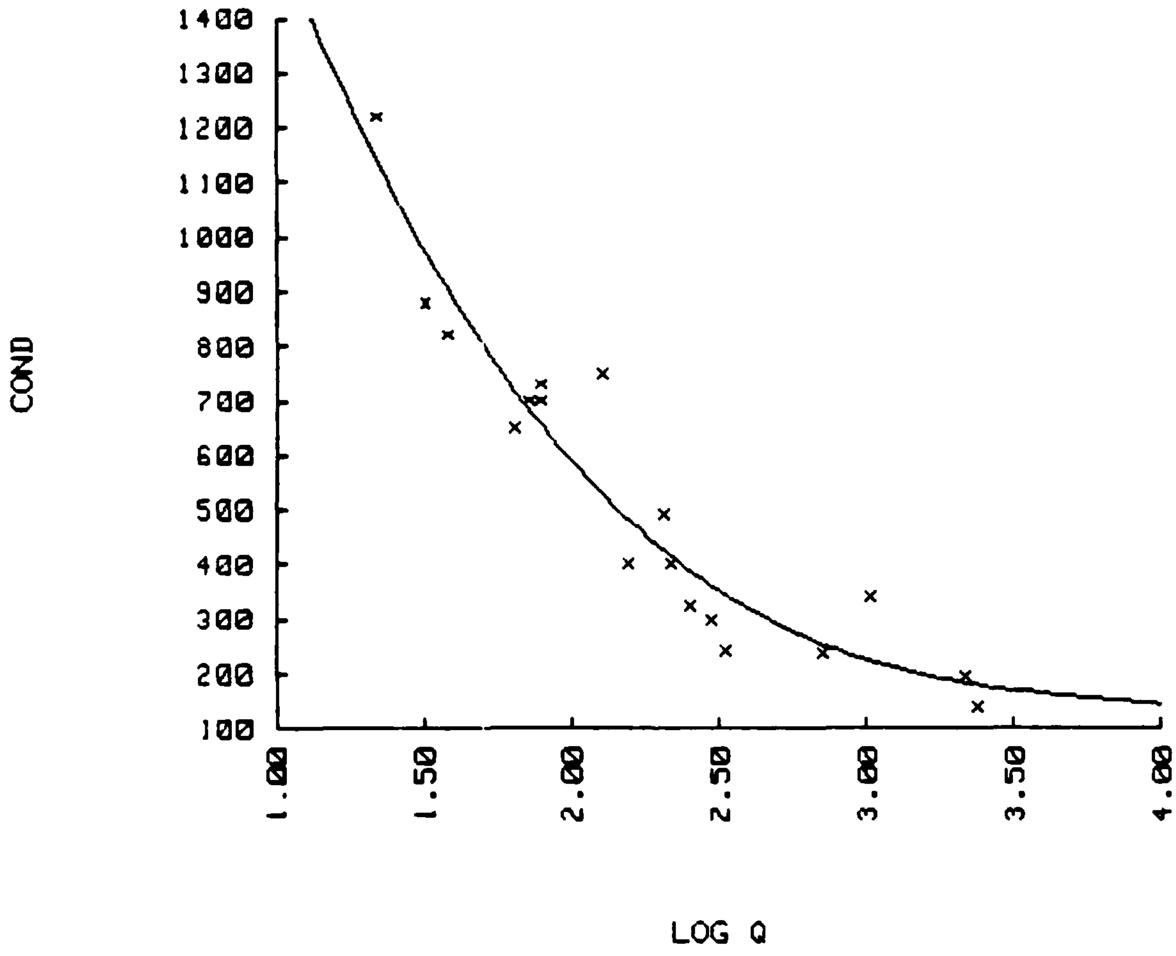


FIGURE H-II- 4

WATER QUALITY (WORST CASE) AT KITZMILLER (1967-1972)

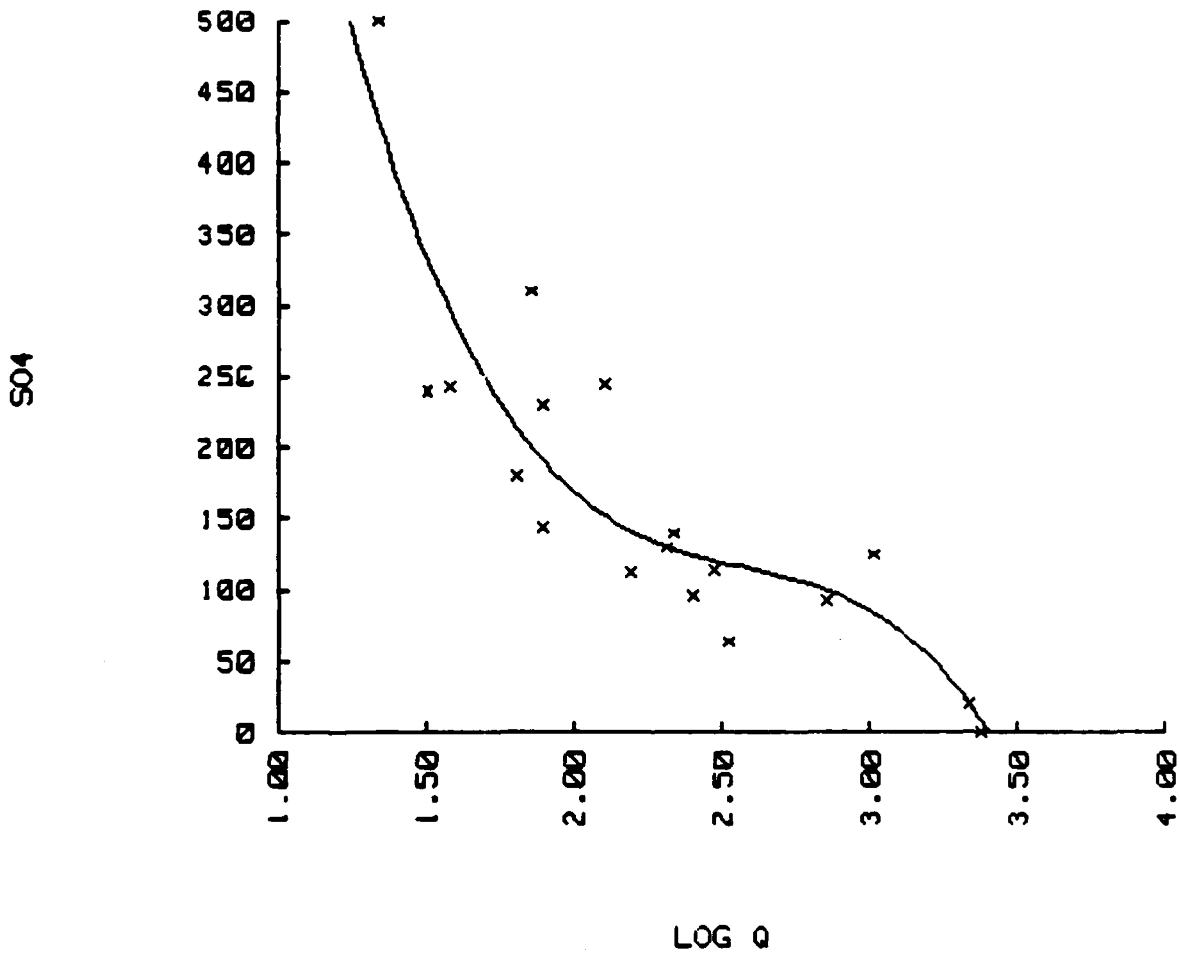


FIGURE H-II- 5

WATER QUALITY (WORST CASE) AT KITZMILLER (1967-1972)

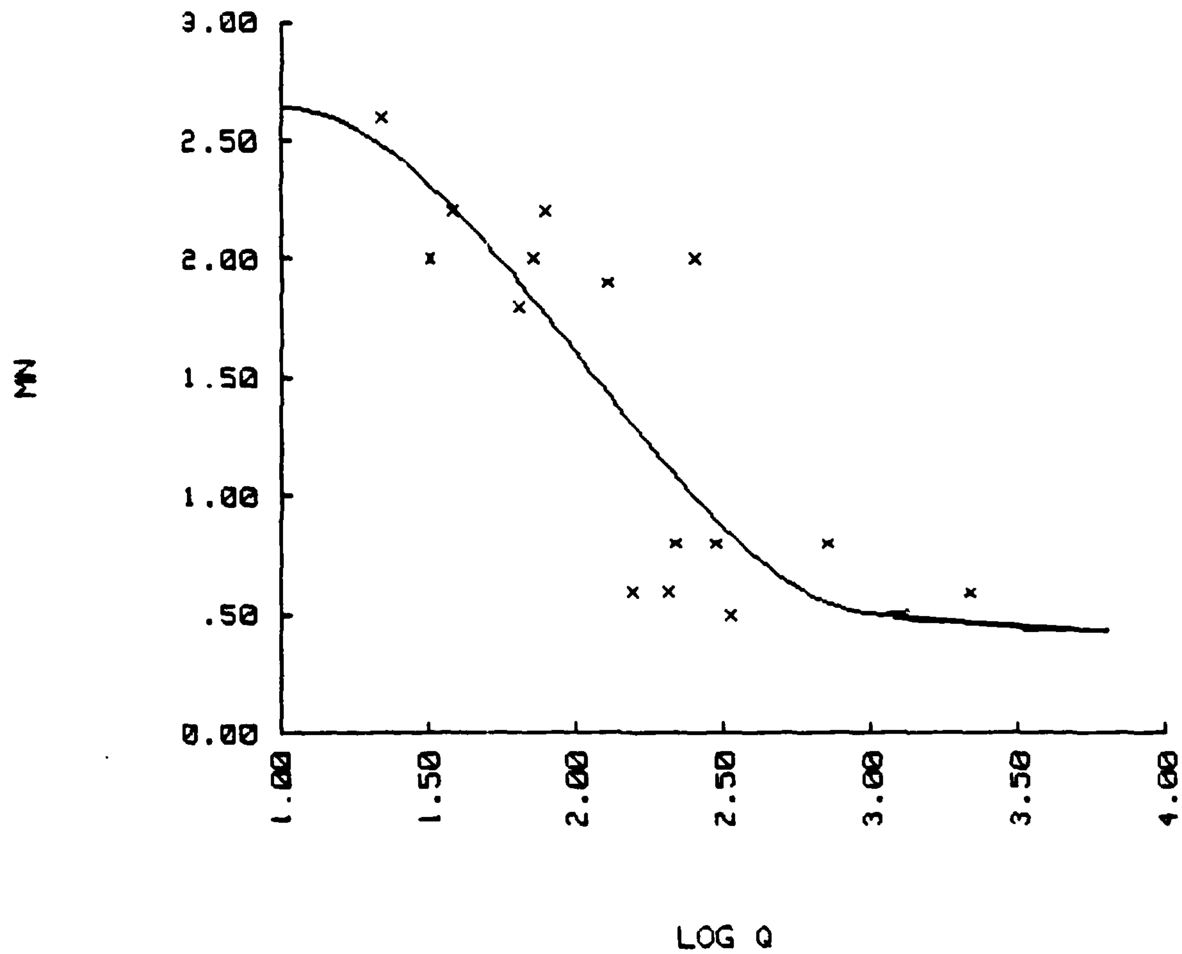


FIGURE H-II- 6

WATER QUALITY (WORST CASE) AT KITZMILLER (1967-1972)

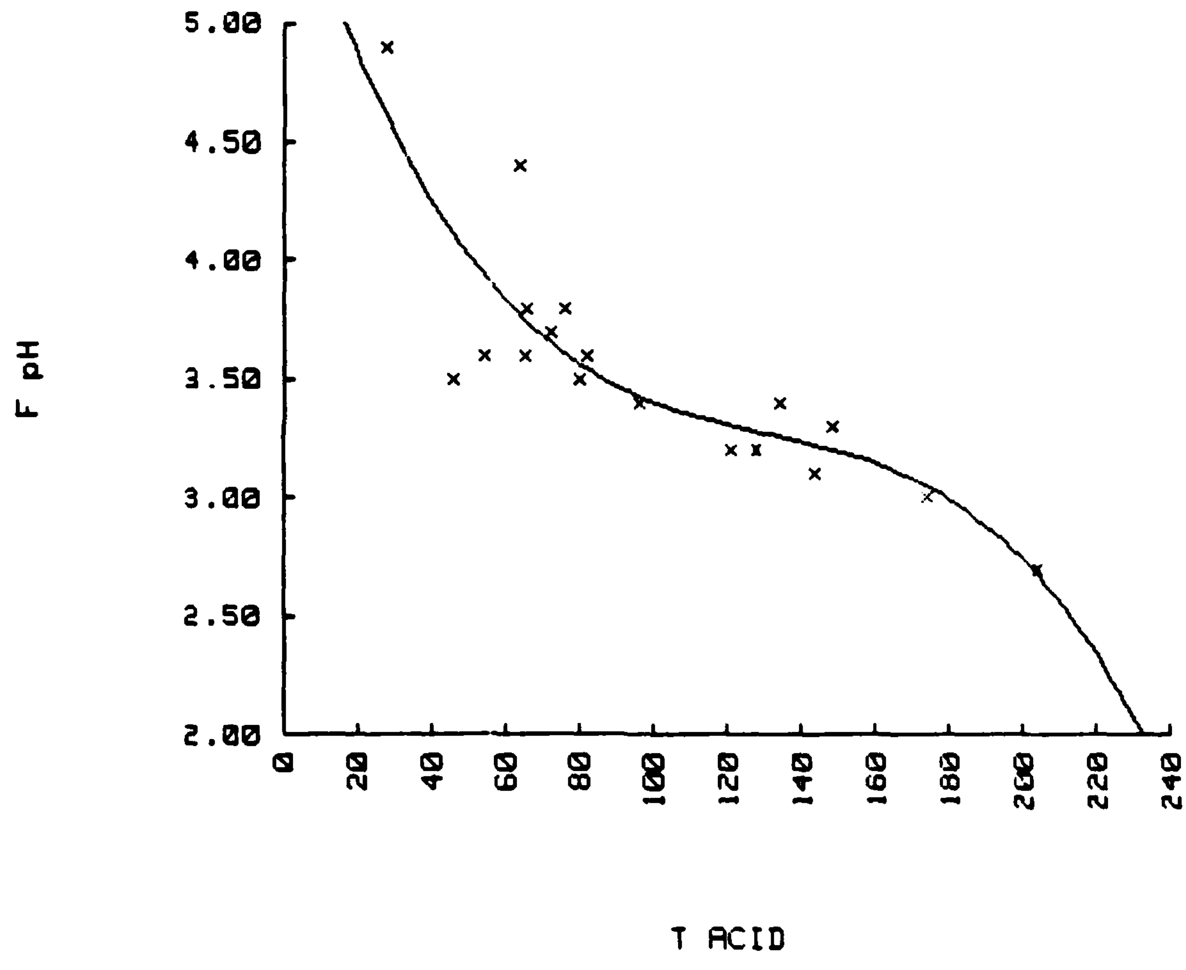
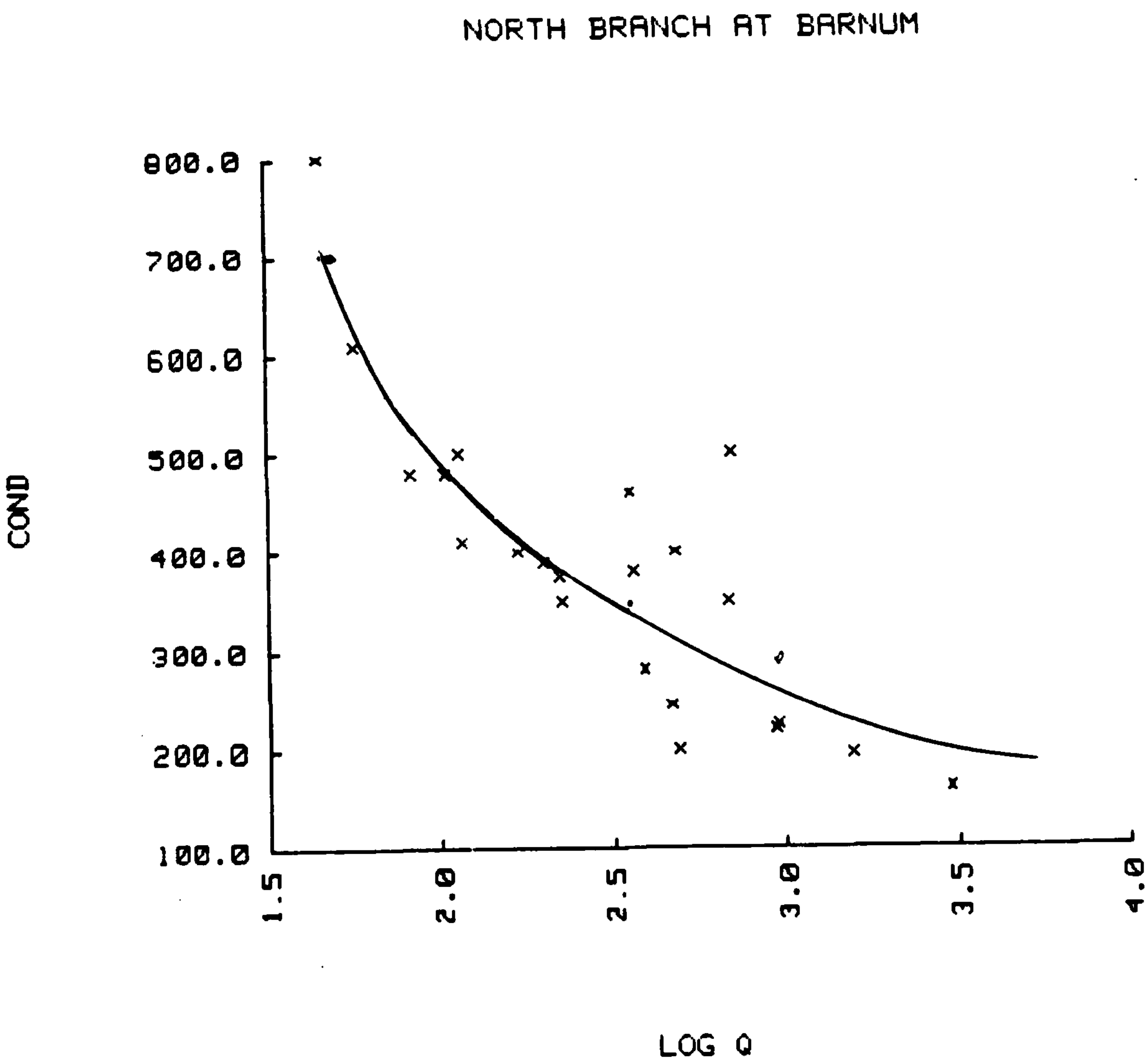


FIGURE H-II- 7



NORTH BRANCH AT BARNUM
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
COND
1.5
2.0
2.5
3.0
3.5
4.0
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FIGURE H-II- 8

NORTH BRANCH AT BARNUM

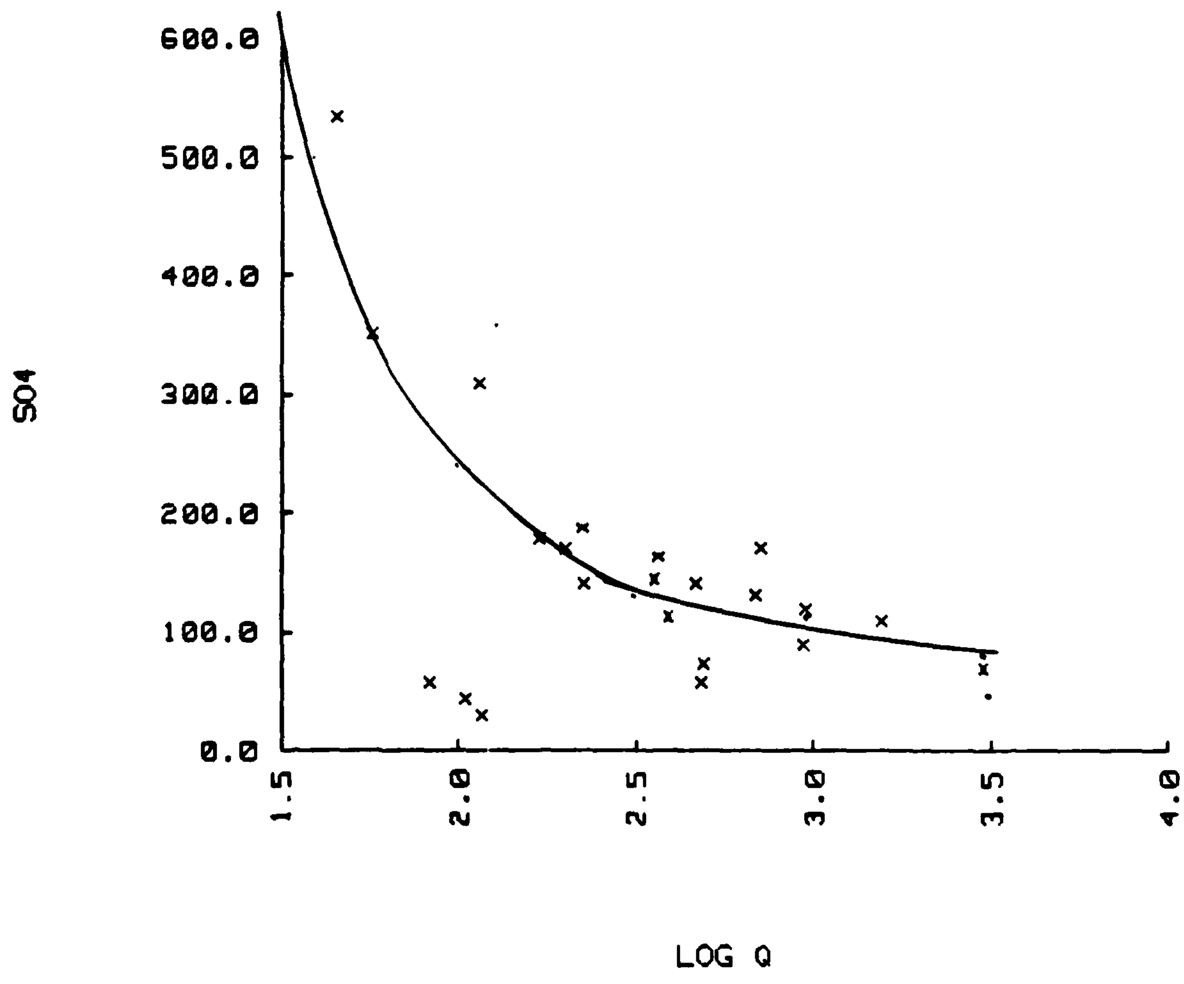


FIGURE H-II- 9

NORTH BRANCH AT BARNUM

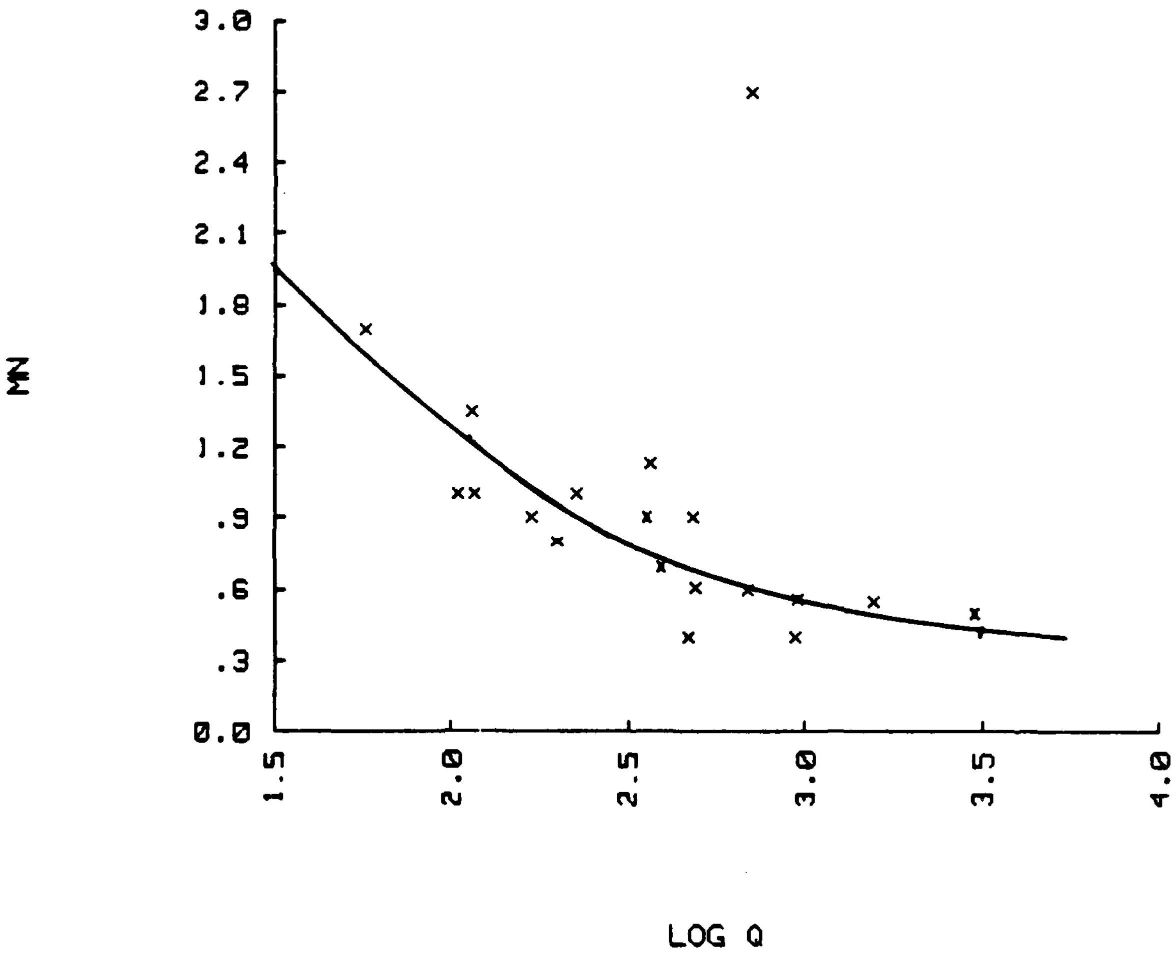


FIGURE H-II- 10

NORTH BRANCH AT BARNUM

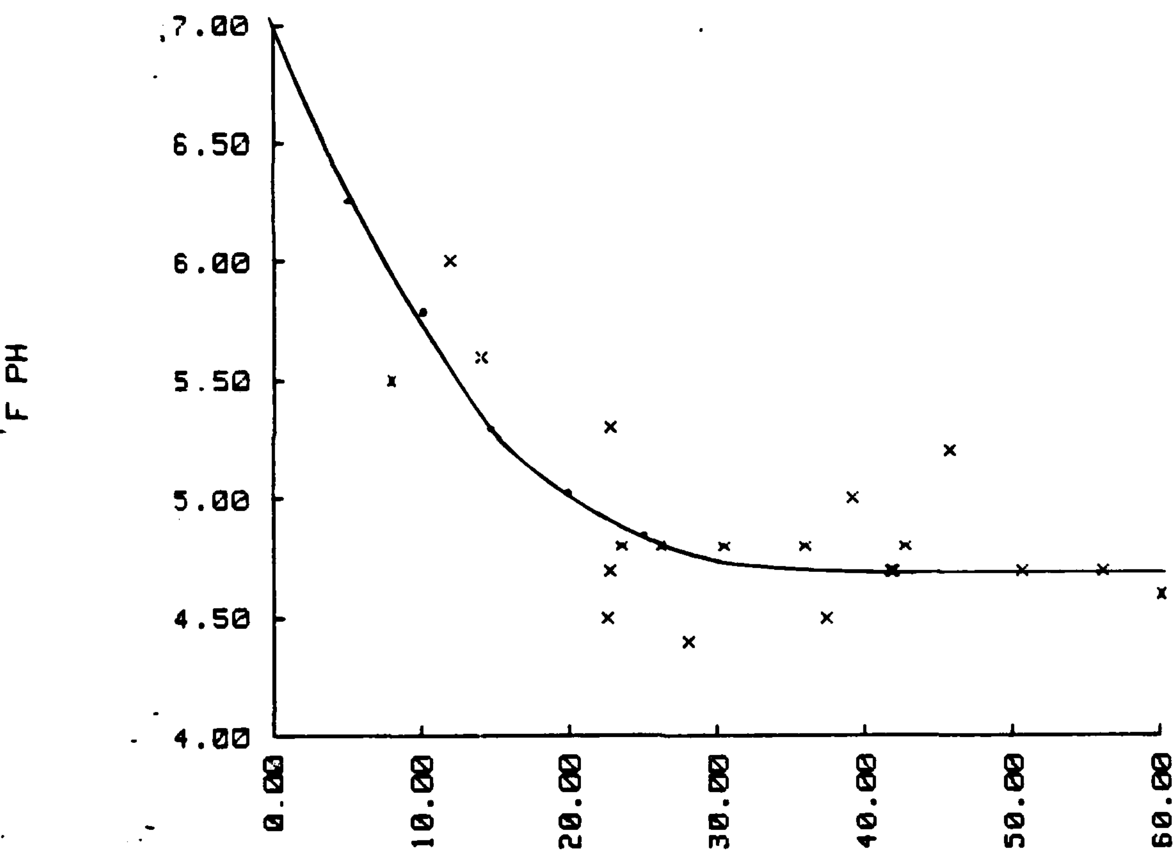


FIGURE H-II- 11

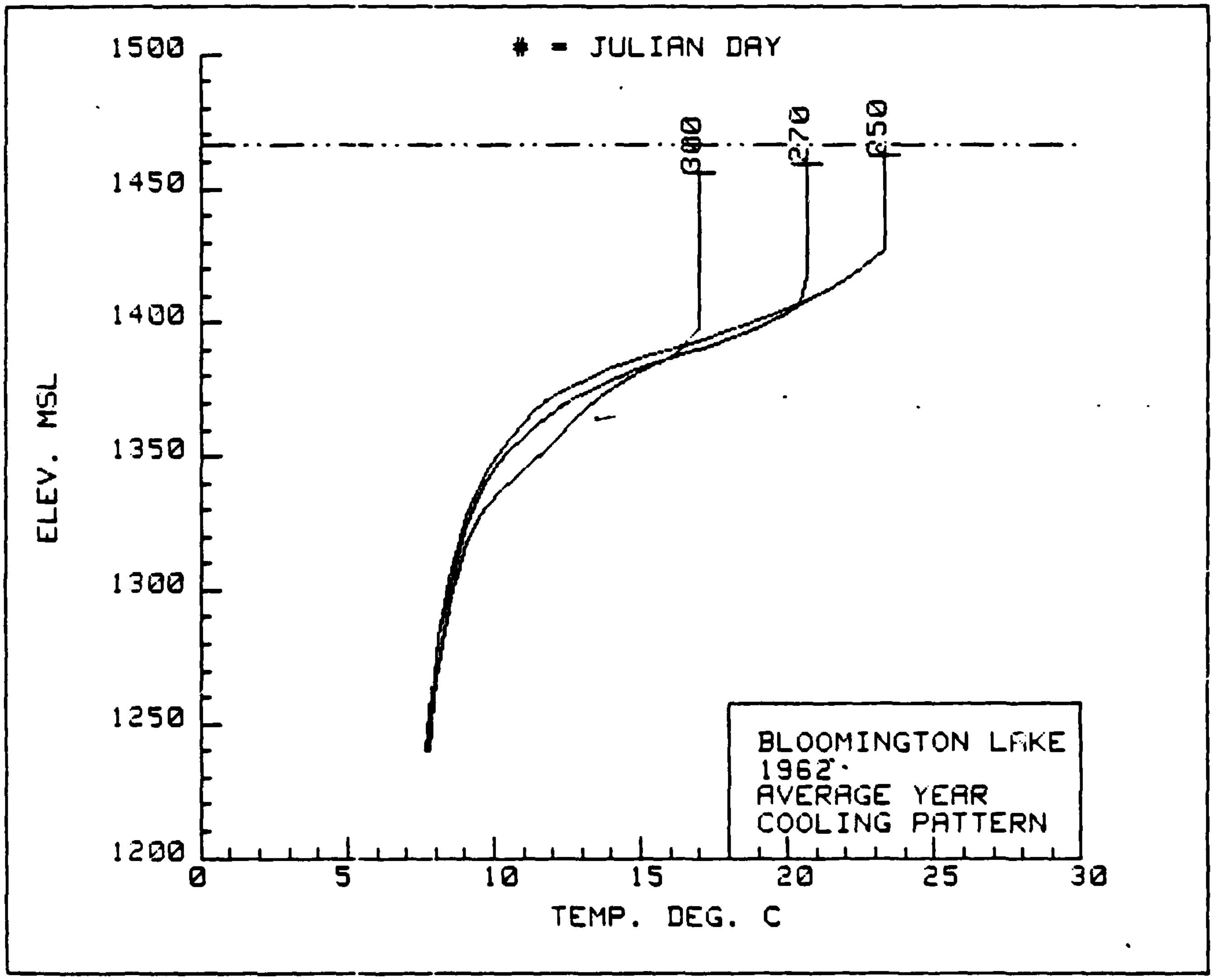


FIGURE H-II- 12

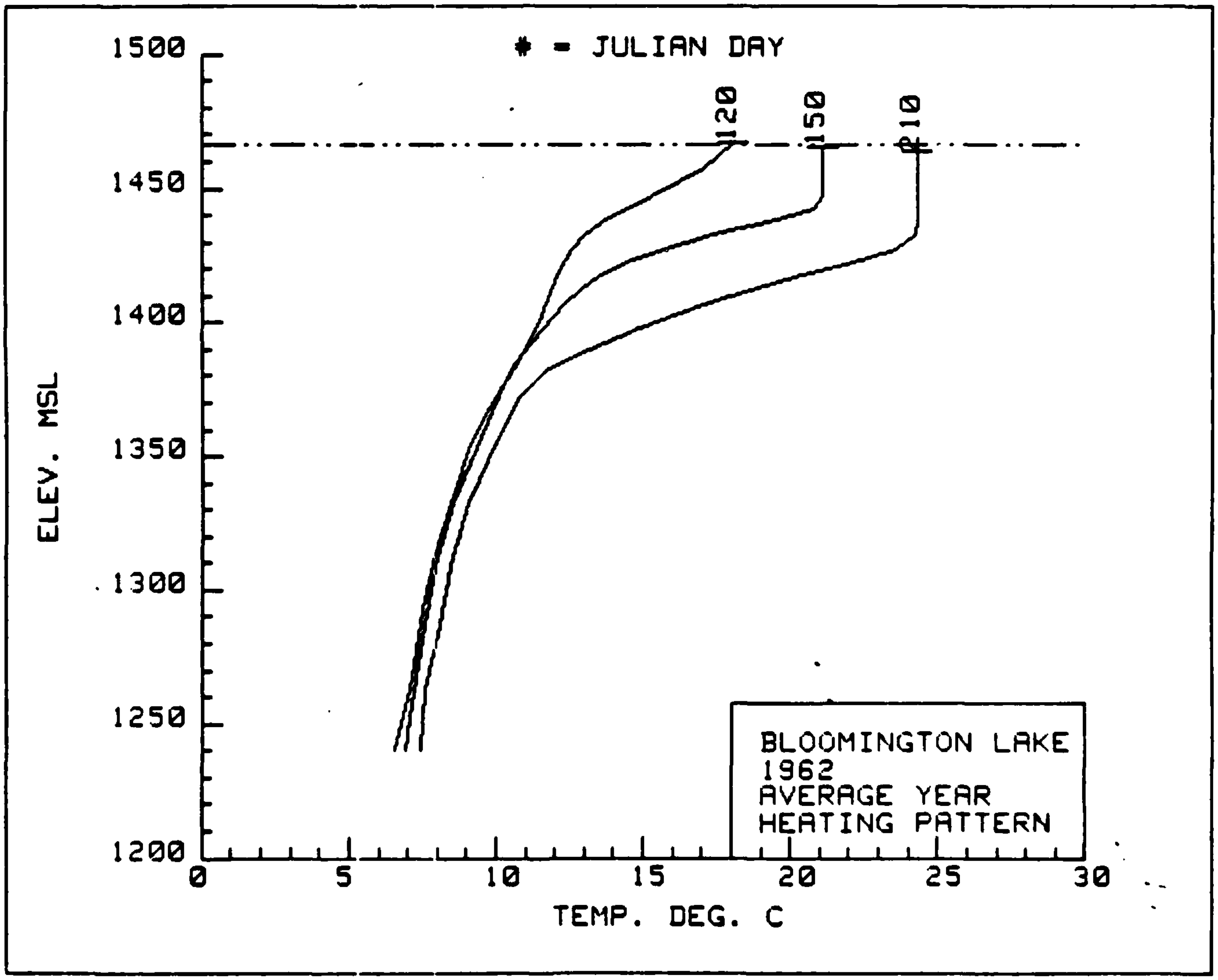


FIGURE H-II- 13

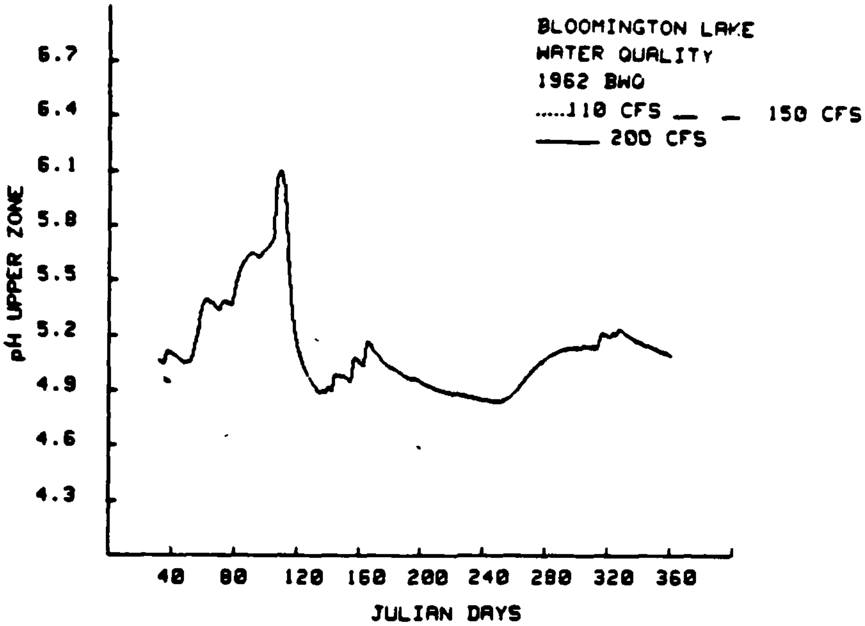


FIGURE H-II- 14

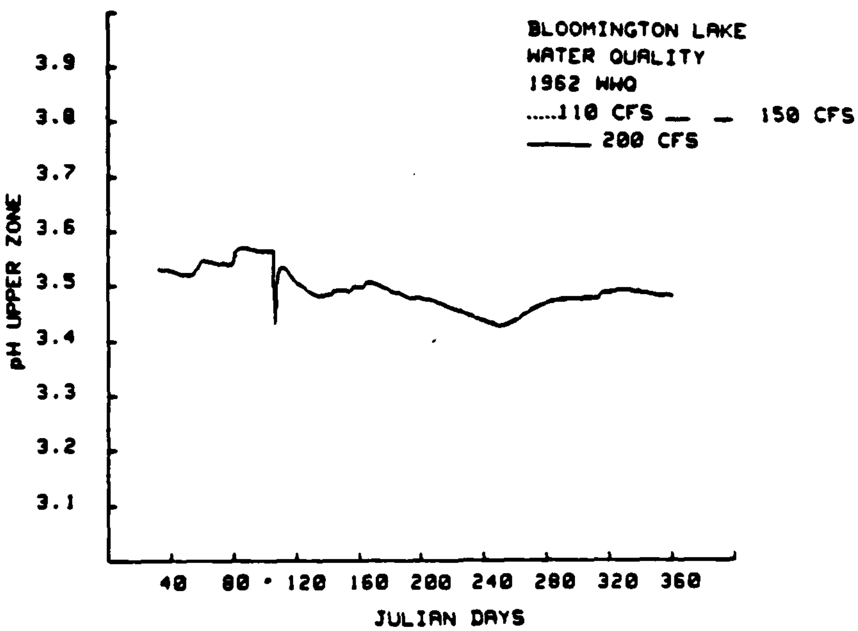


FIGURE H-II- 15

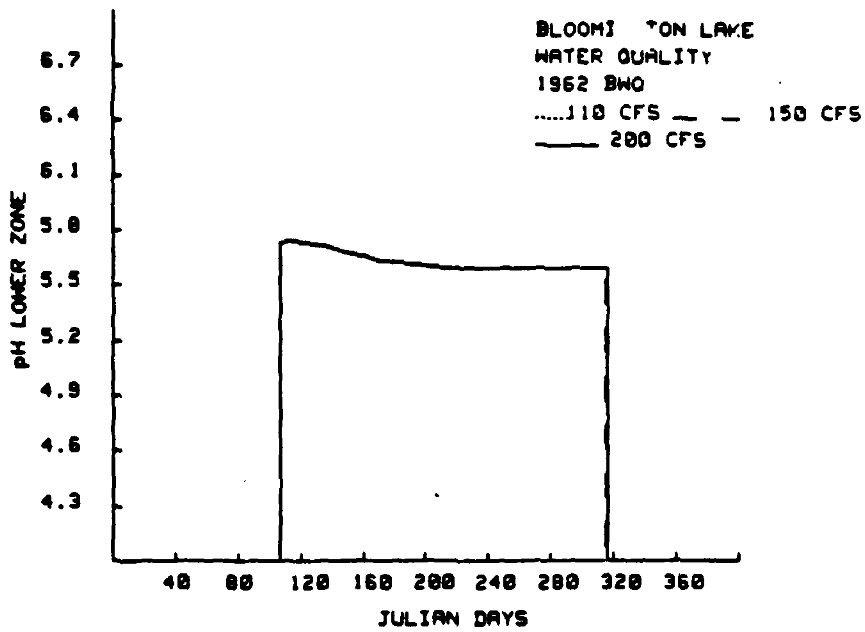


FIGURE H-II- 16

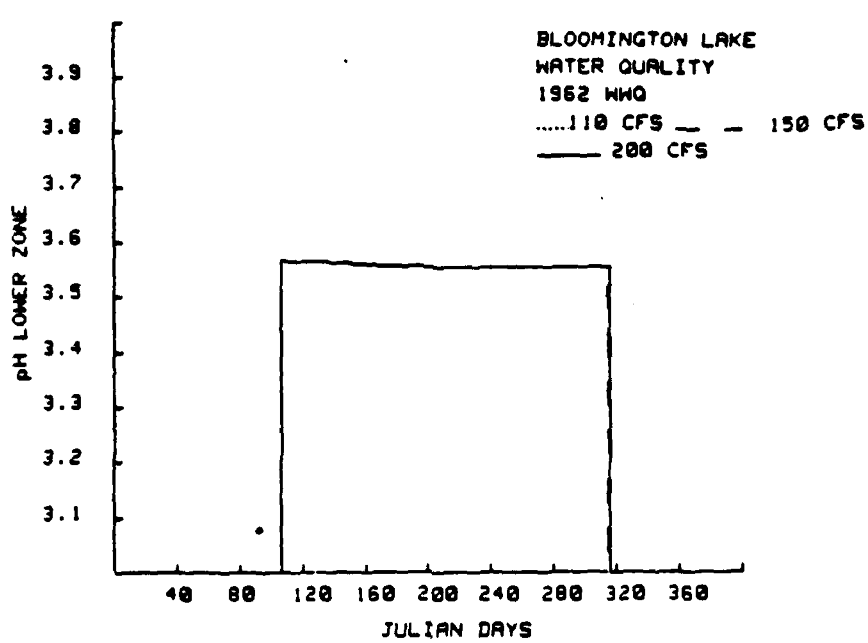


FIGURE H-II- 17

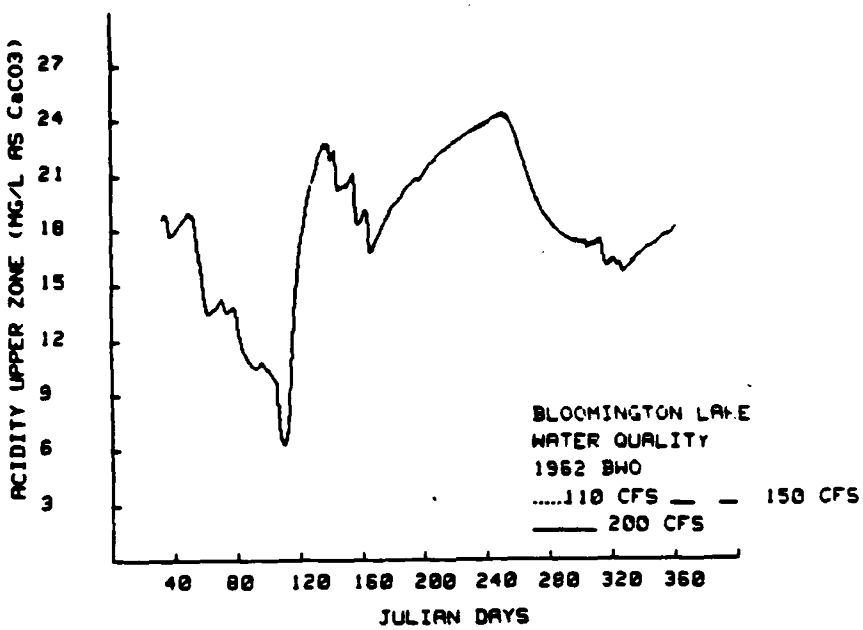


FIGURE H-II- 18

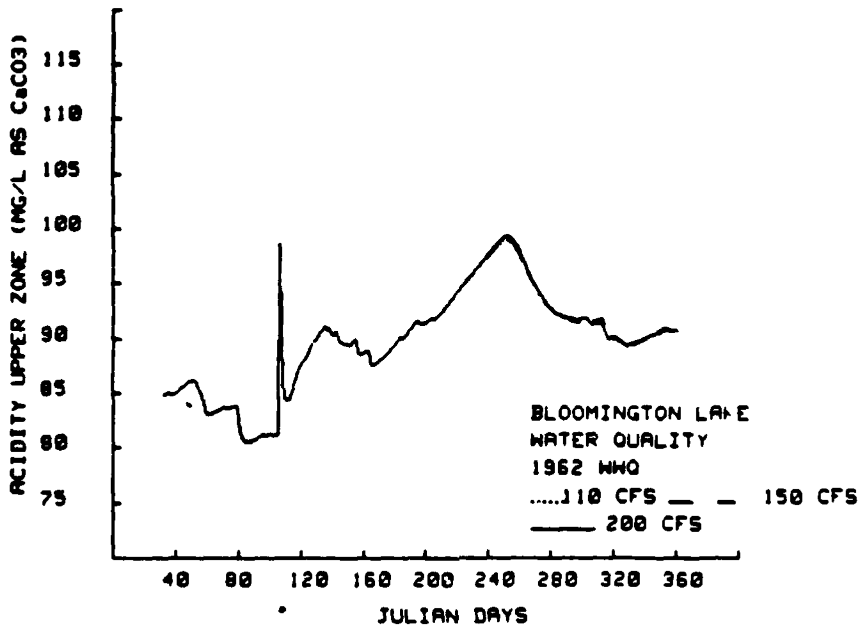


FIGURE H-II- 19

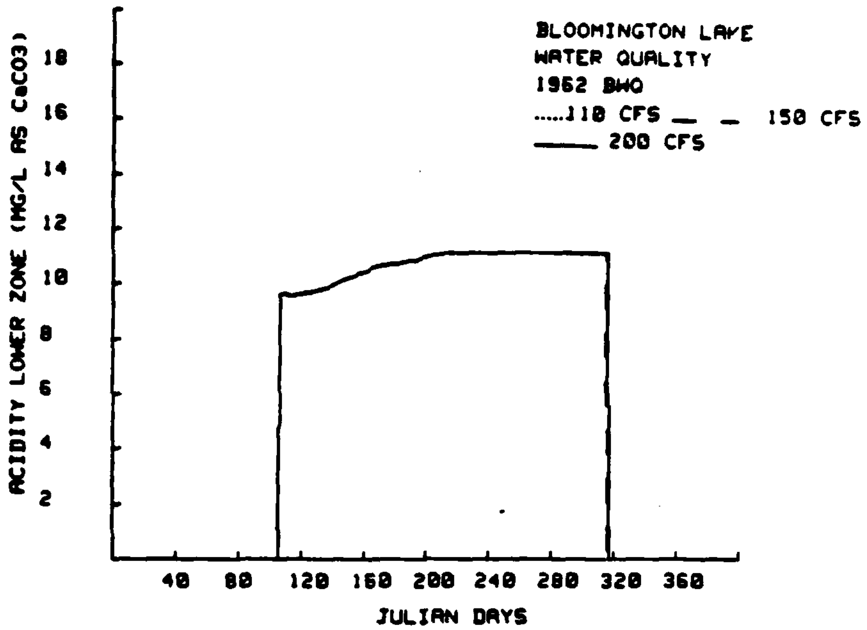


FIGURE H-II- 20

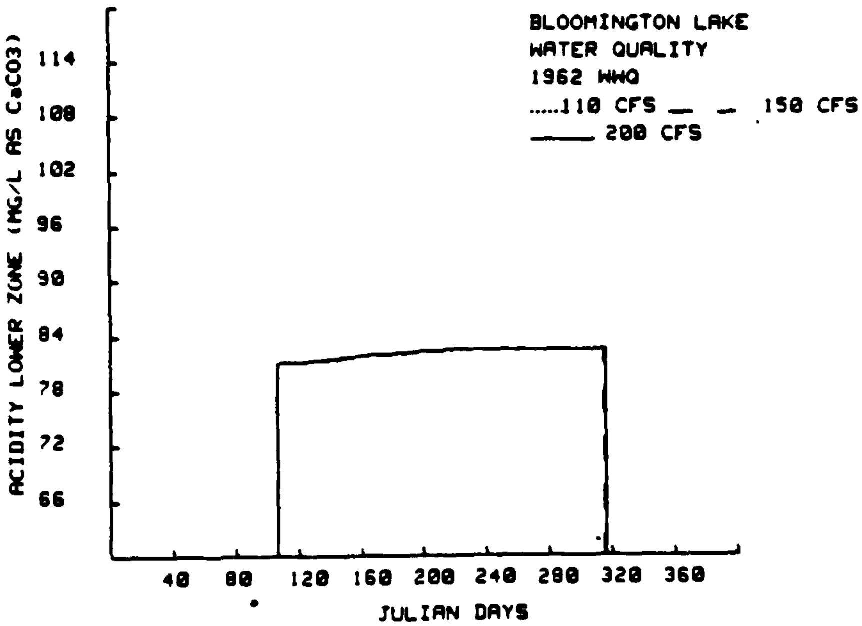


FIGURE H-II- 21

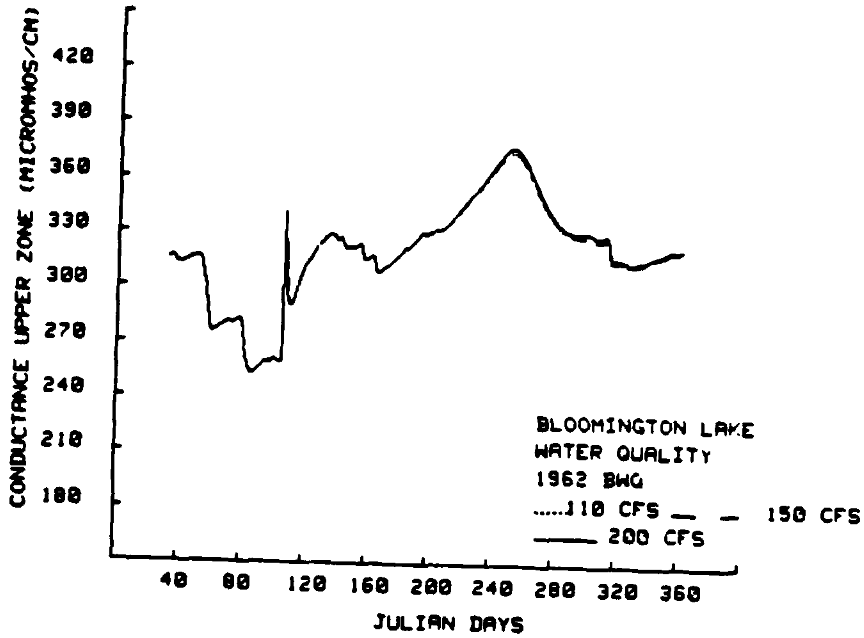


FIGURE H-II- 22

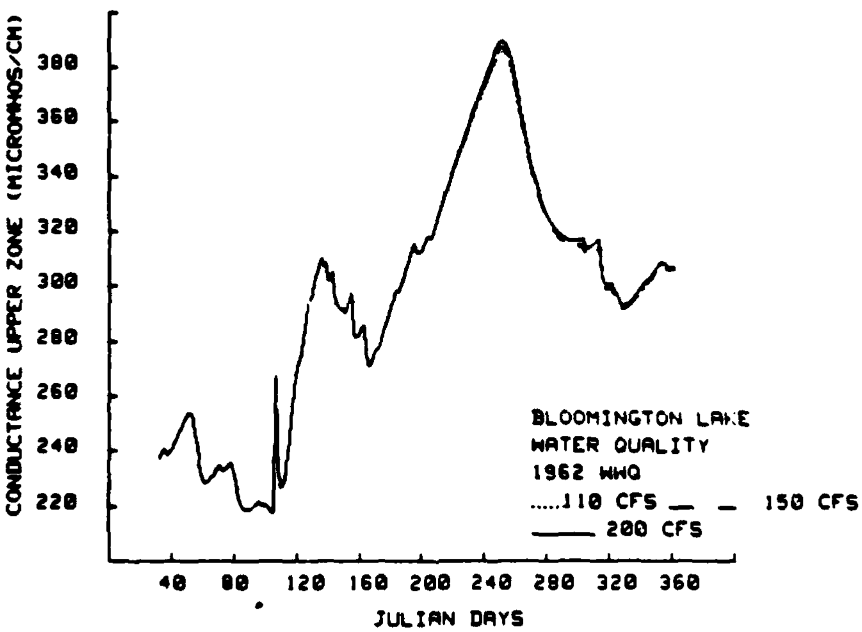


FIGURE H-II- 23

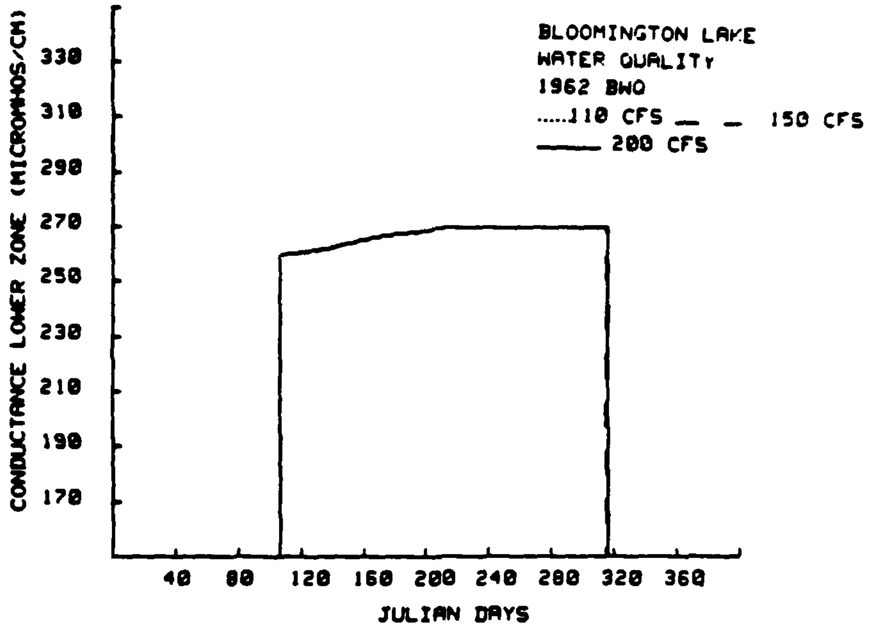


FIGURE H-II- 24

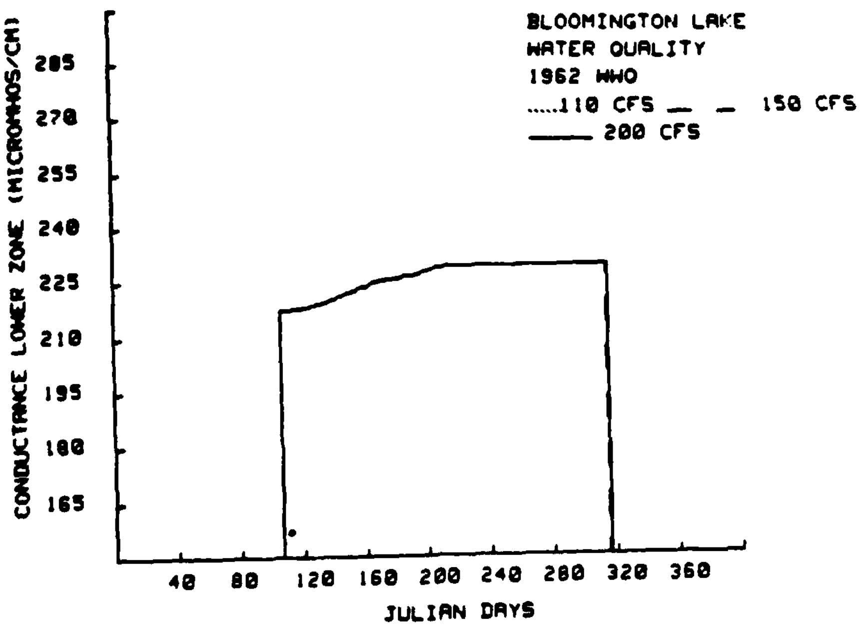


FIGURE H-II- 25

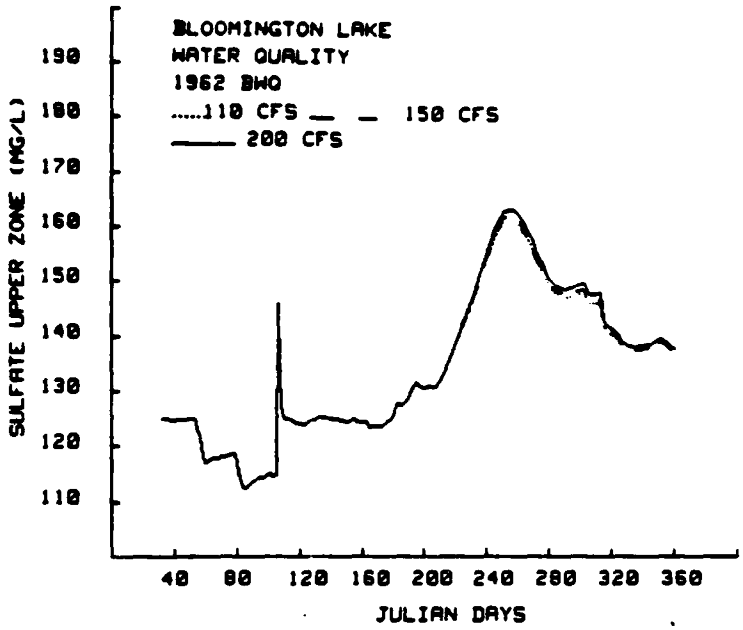


FIGURE H-II- 26

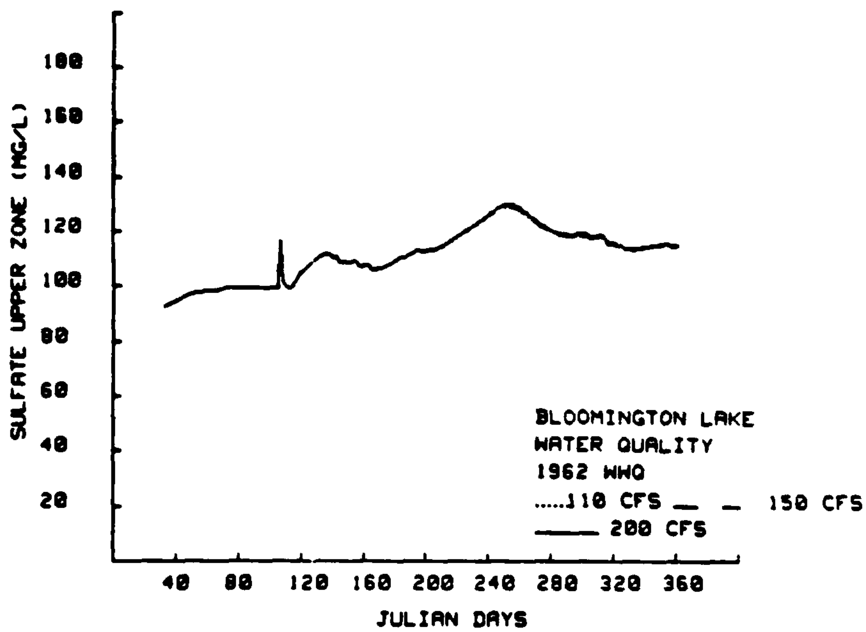


FIGURE H-II- 27

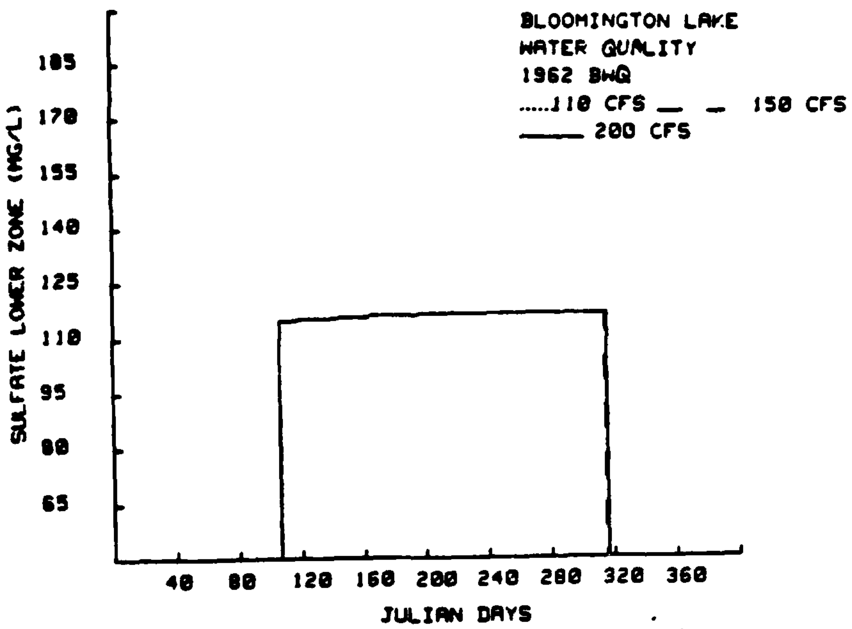


FIGURE H-II- 28

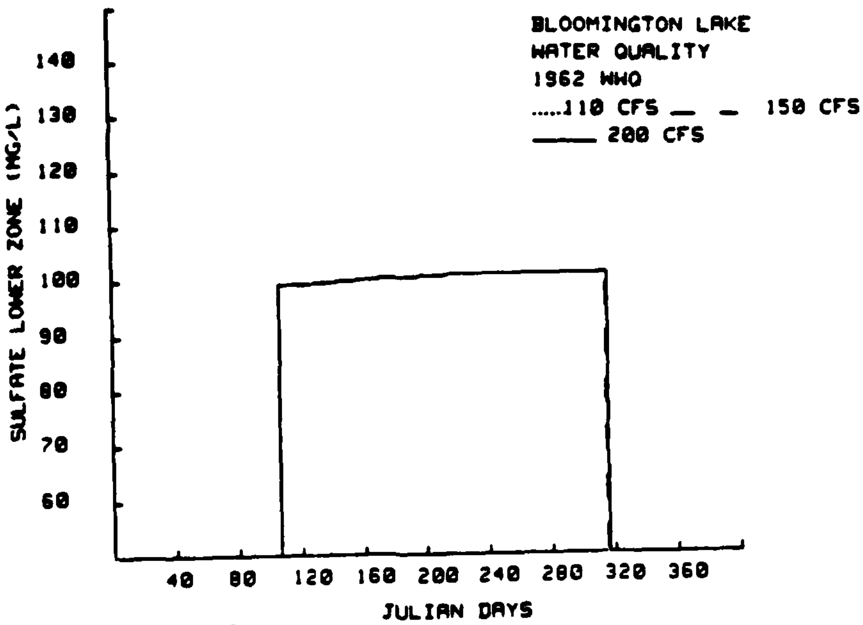


FIGURE H-II- 29

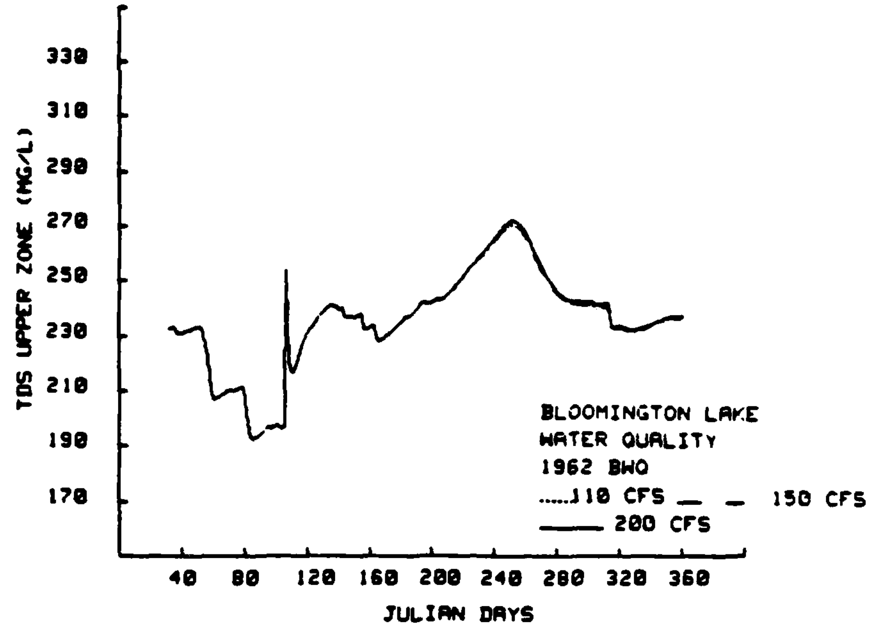


FIGURE H-II- 30

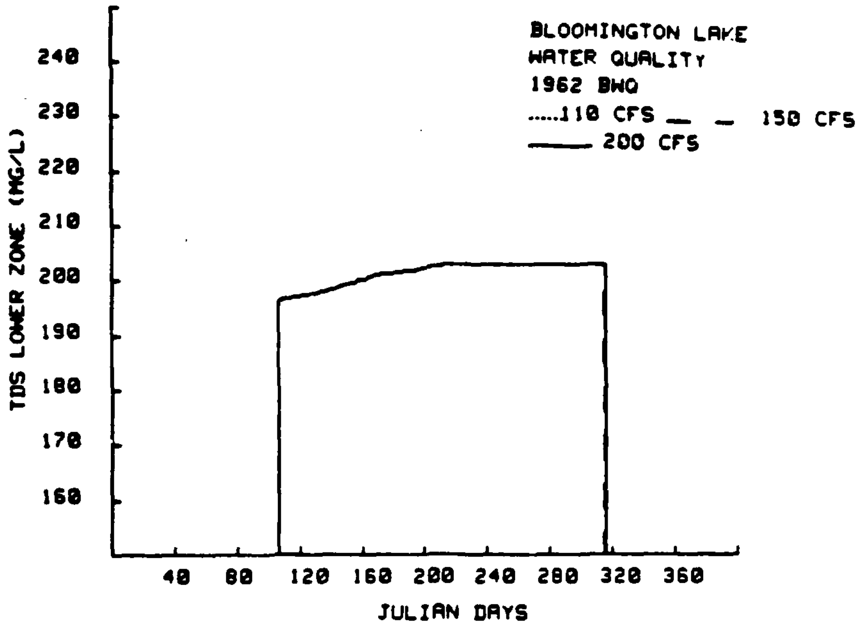


FIGURE H-II- 31

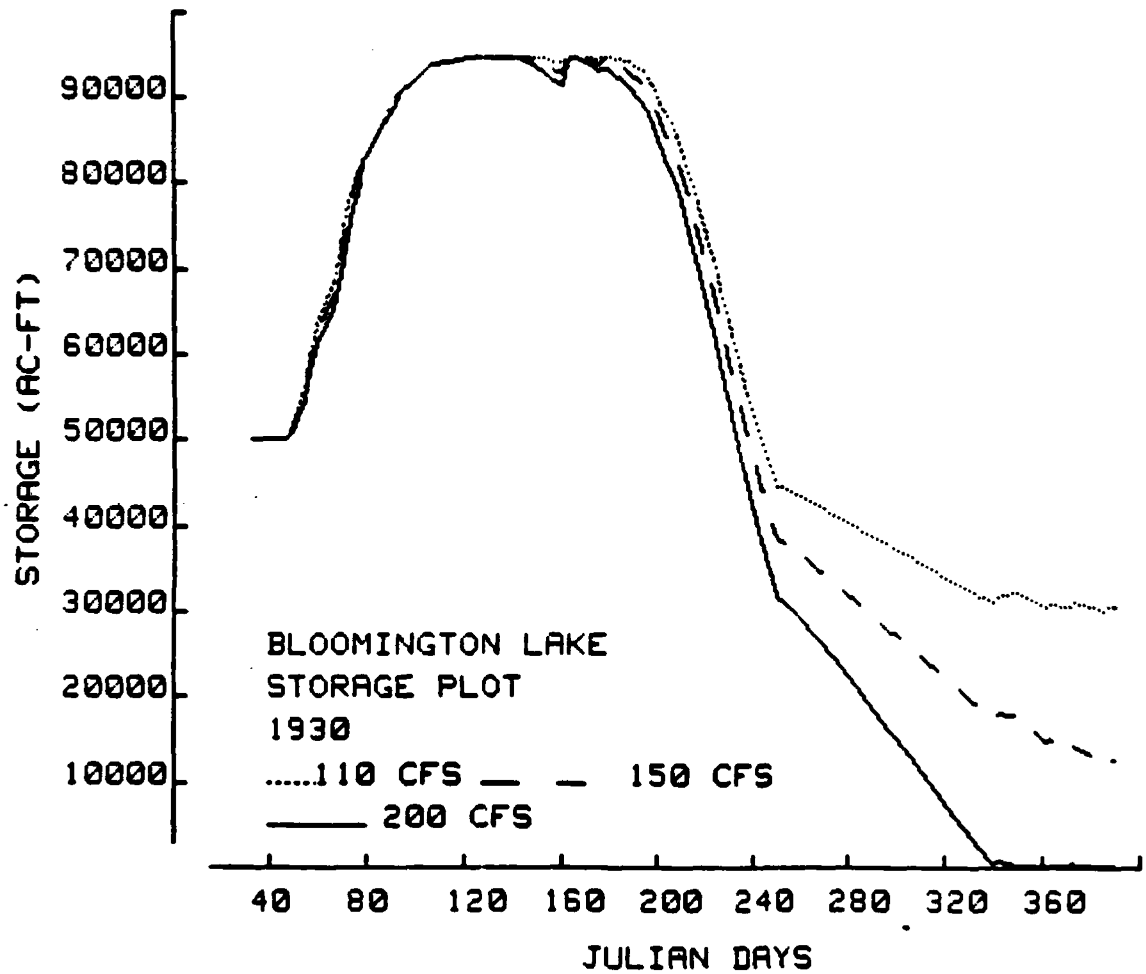


FIGURE H-II- 32

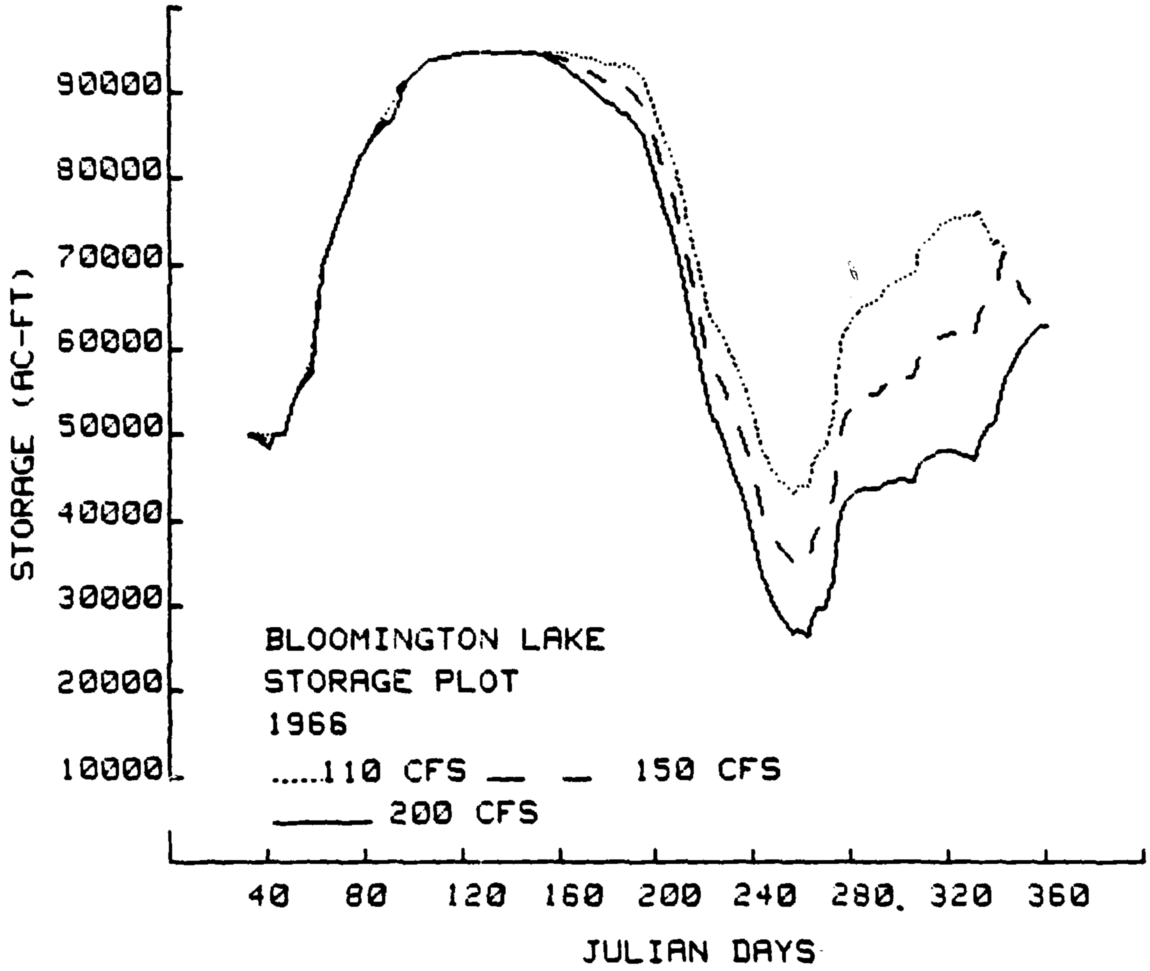


FIGURE H-II- 33

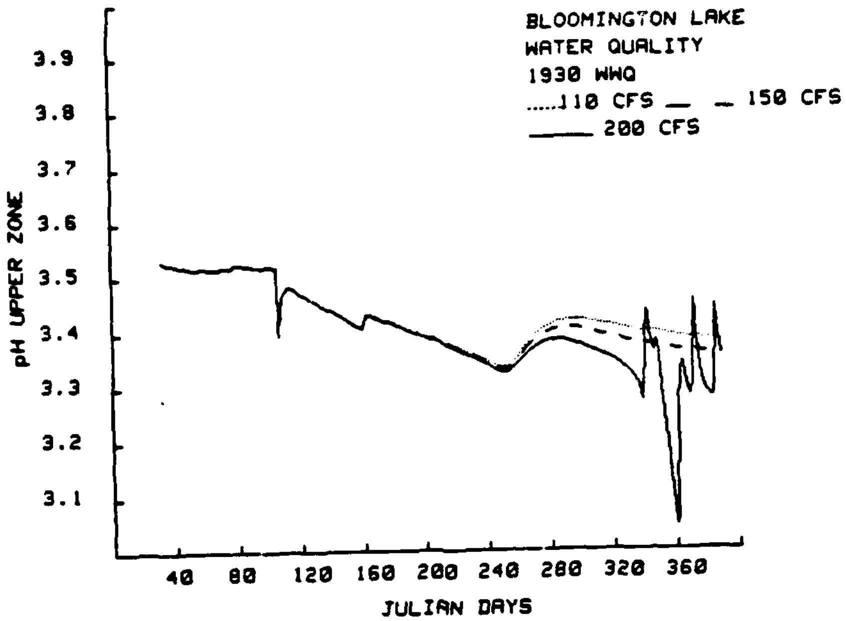


FIGURE H-II- 34

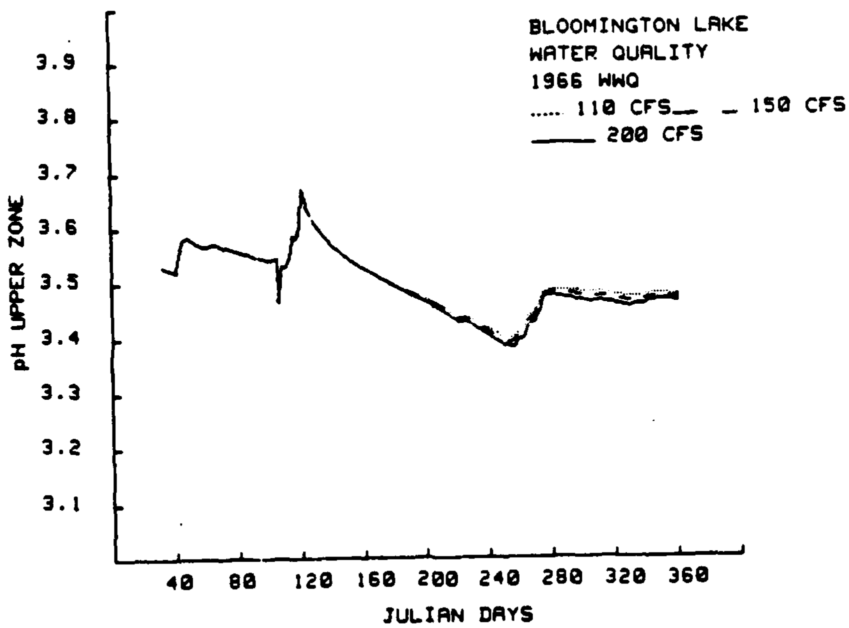


FIGURE H-II- 35

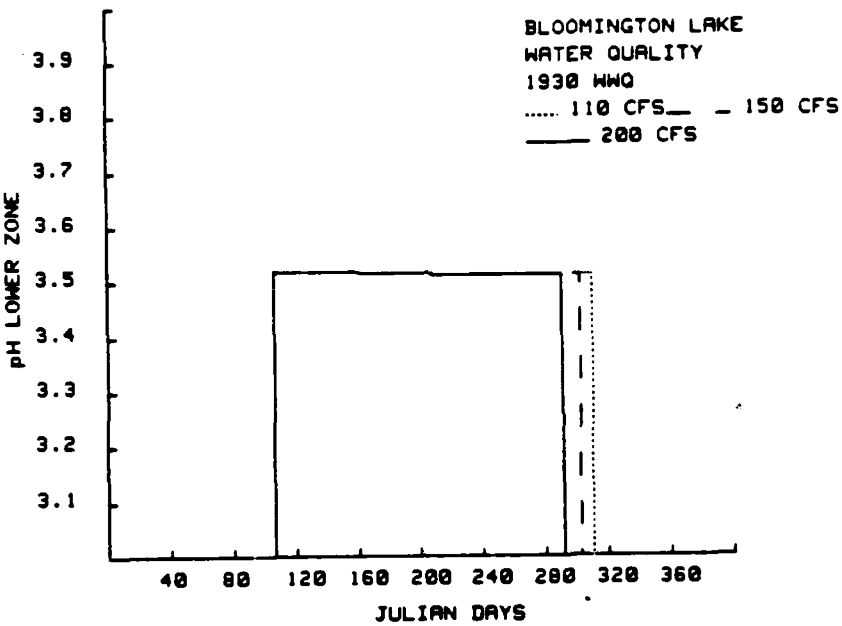


FIGURE H-II- 36

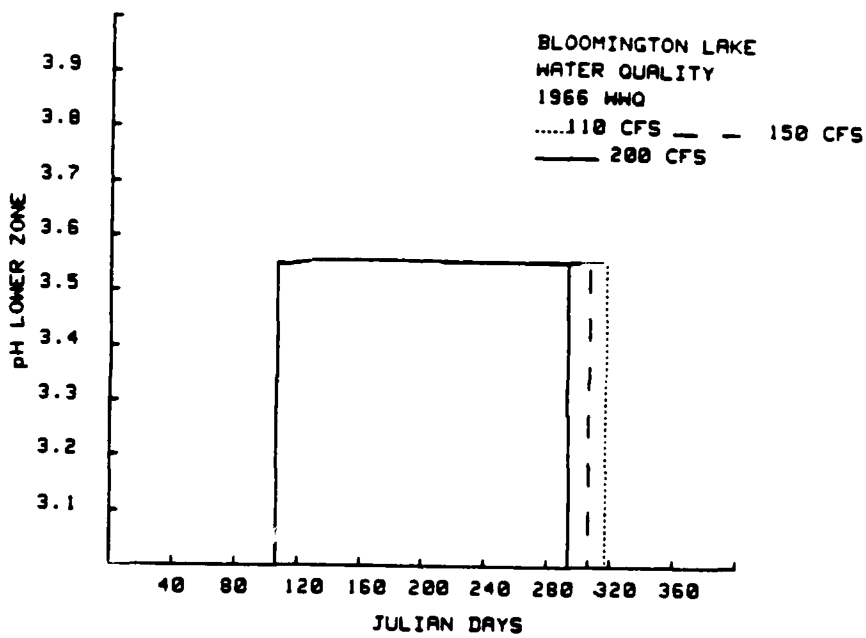
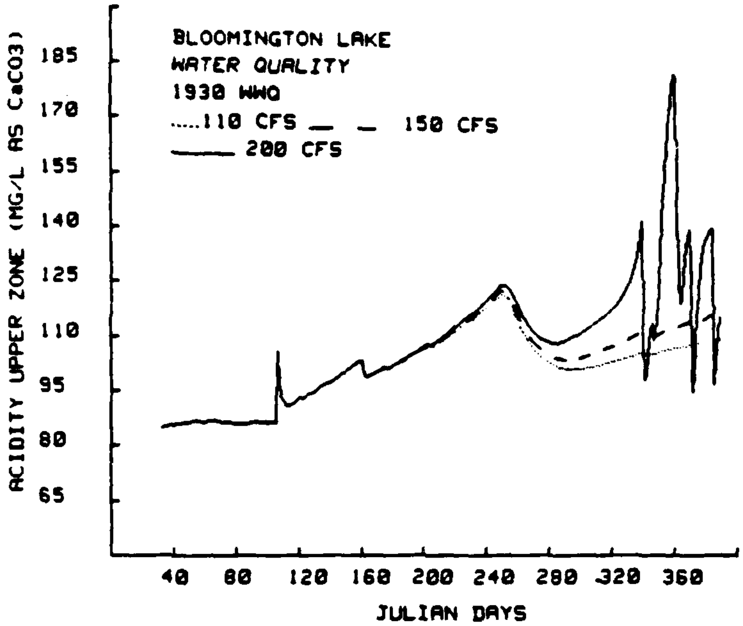


FIGURE H-II- 37



-3,¢ FIGURE H-II- 38

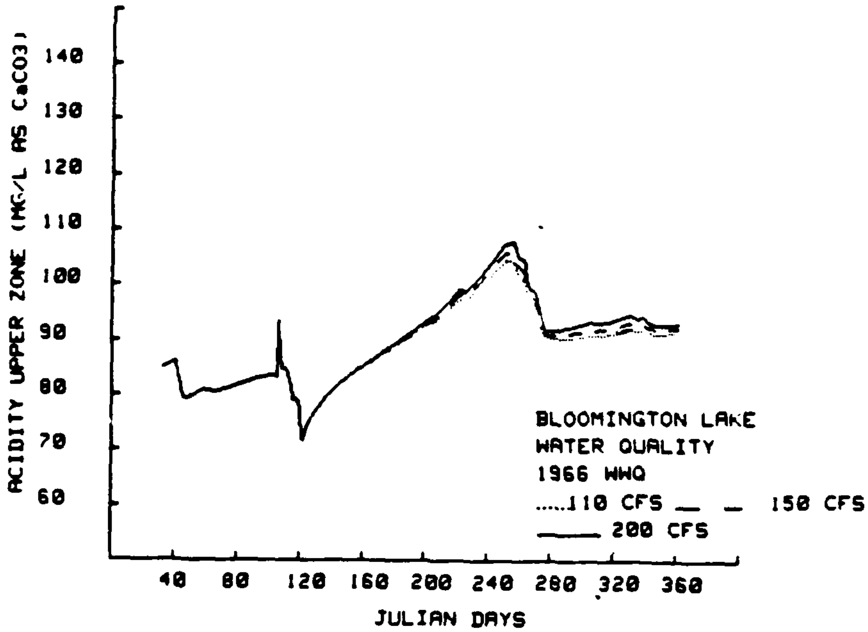


FIGURE H-II- 39

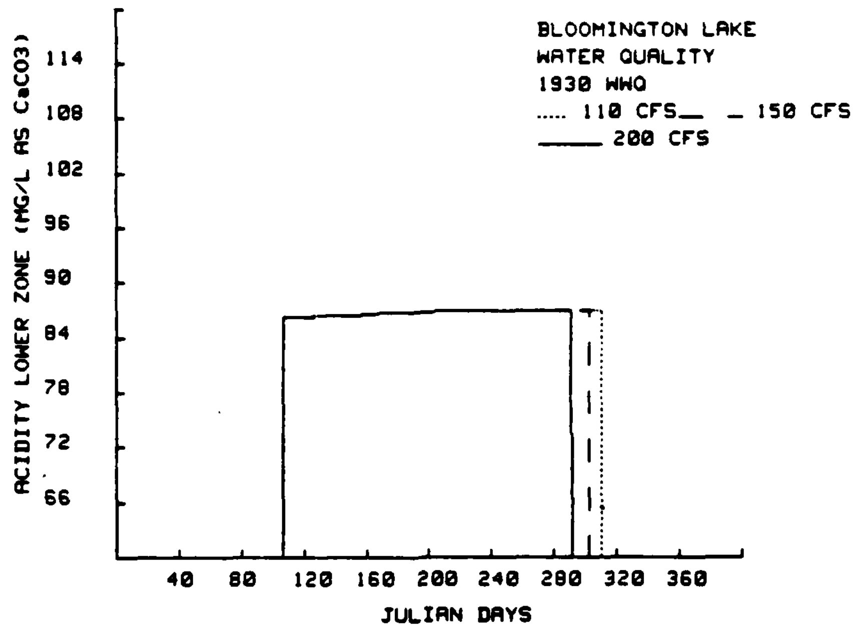


FIGURE H-II- 40

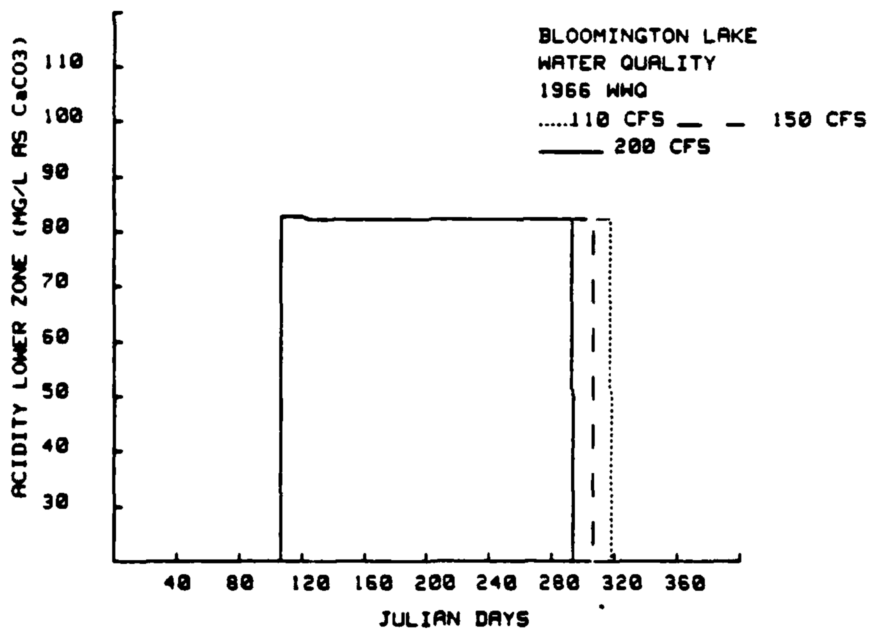


FIGURE H-II- 41

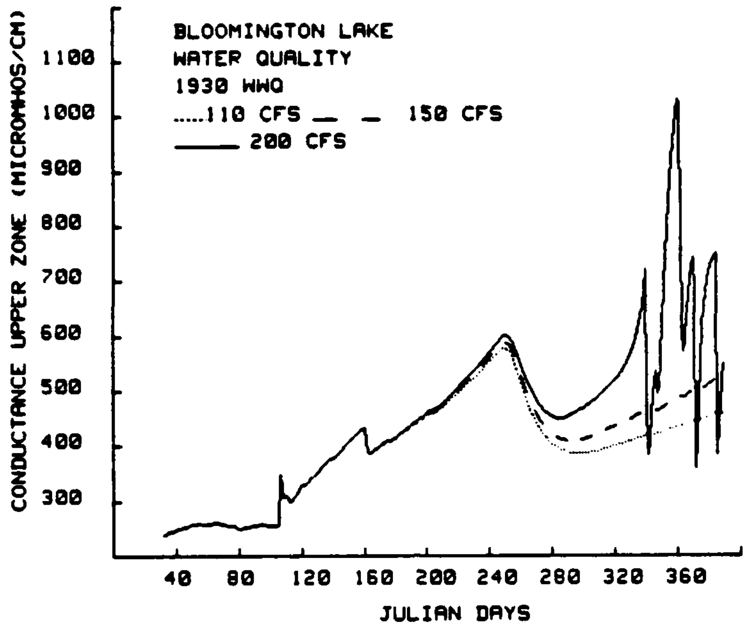


FIGURE H-II- 42

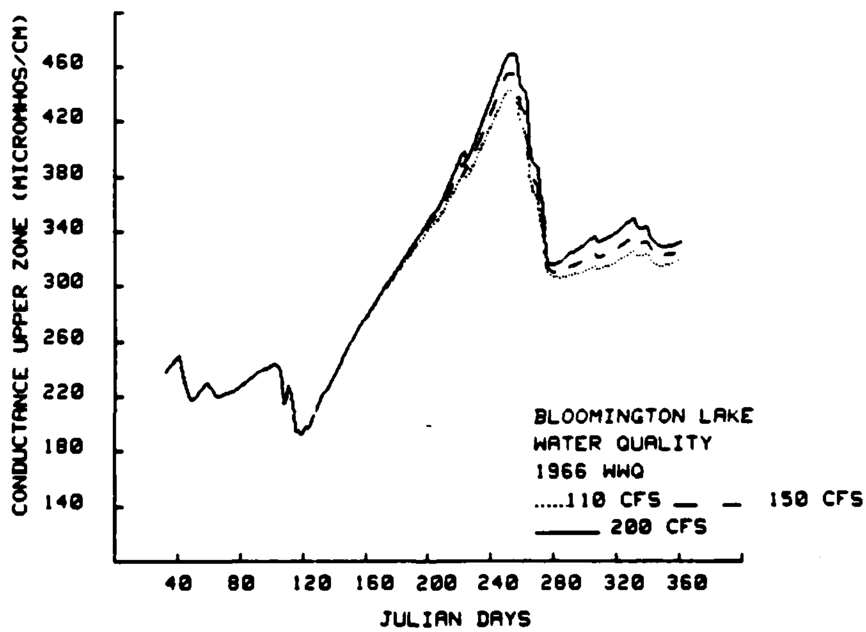


FIGURE H-II- 43

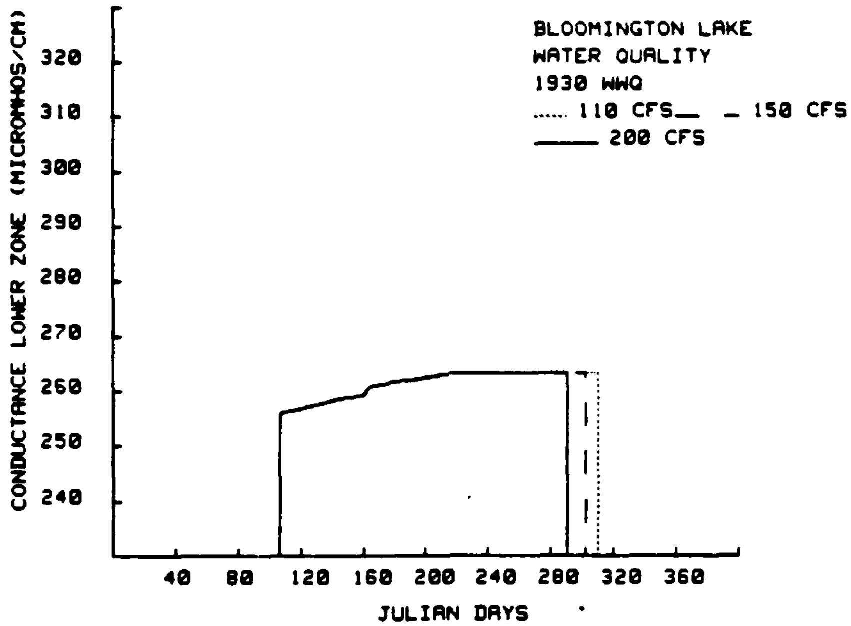


FIGURE H-II- 44

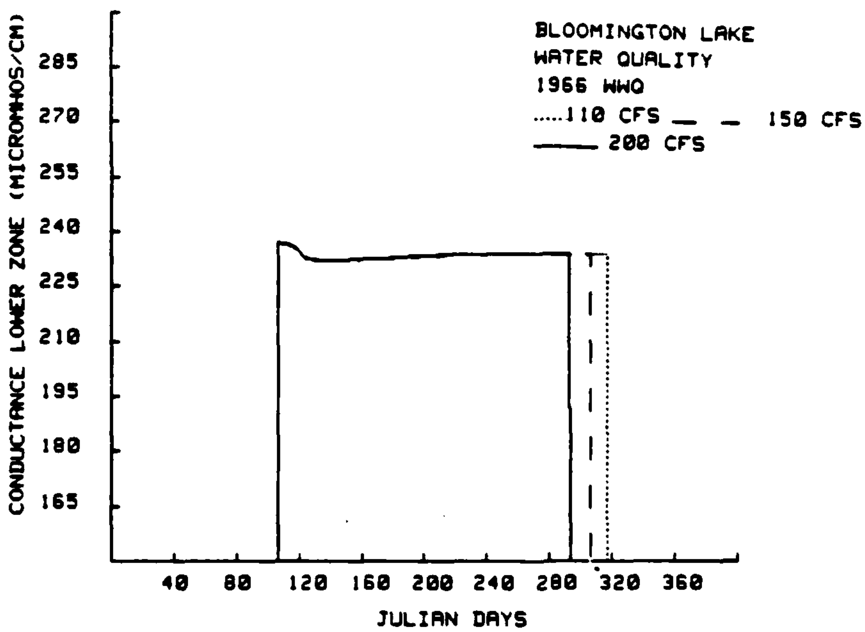


FIGURE H-II- 45

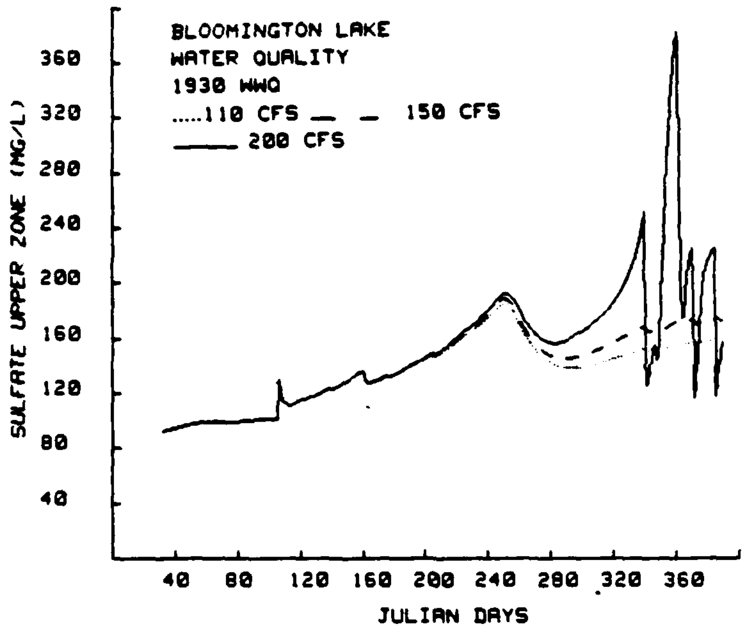


FIGURE H-II- 46

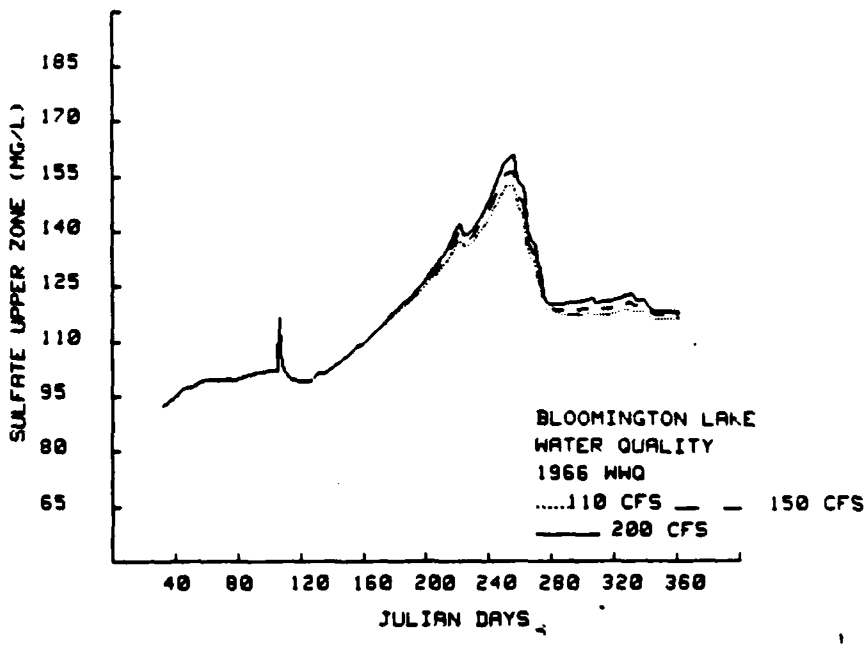


FIGURE H-II- 47

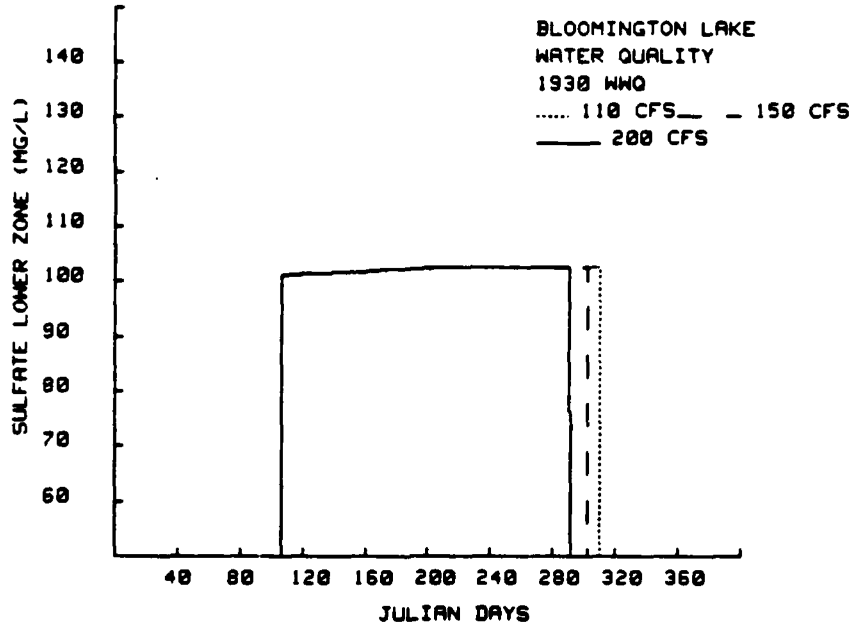


FIGURE H-II- 48

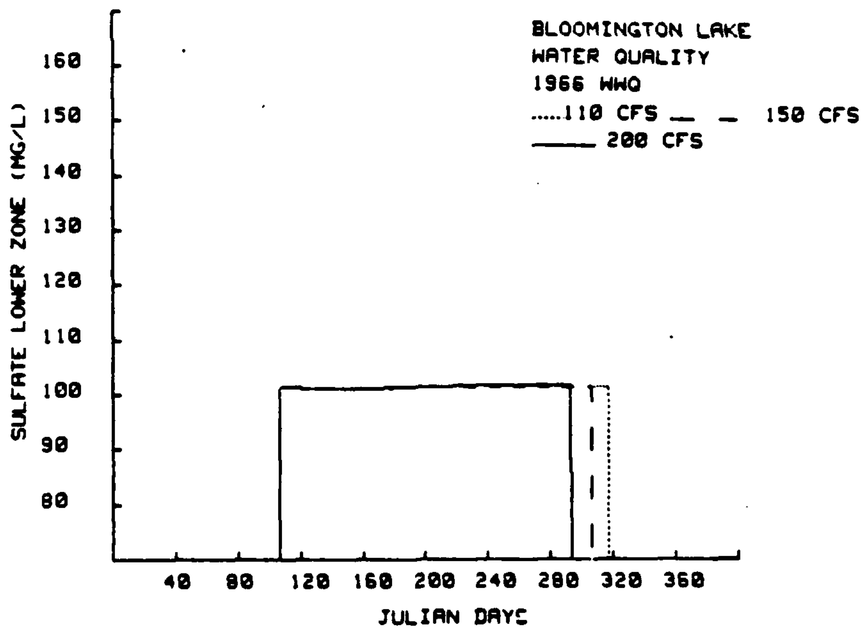
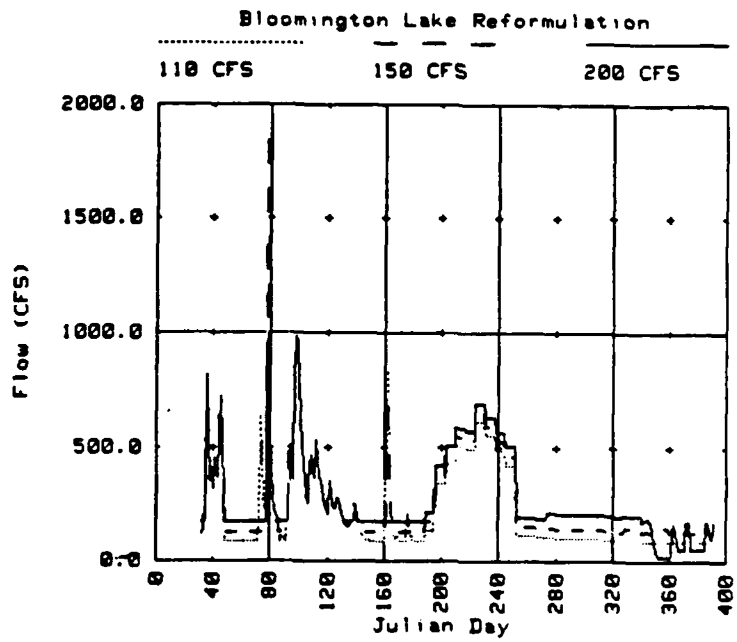


FIGURE H-II- 49



STATION: Barnum, MD
YEAR: 1938

FIGURE H-II- 50

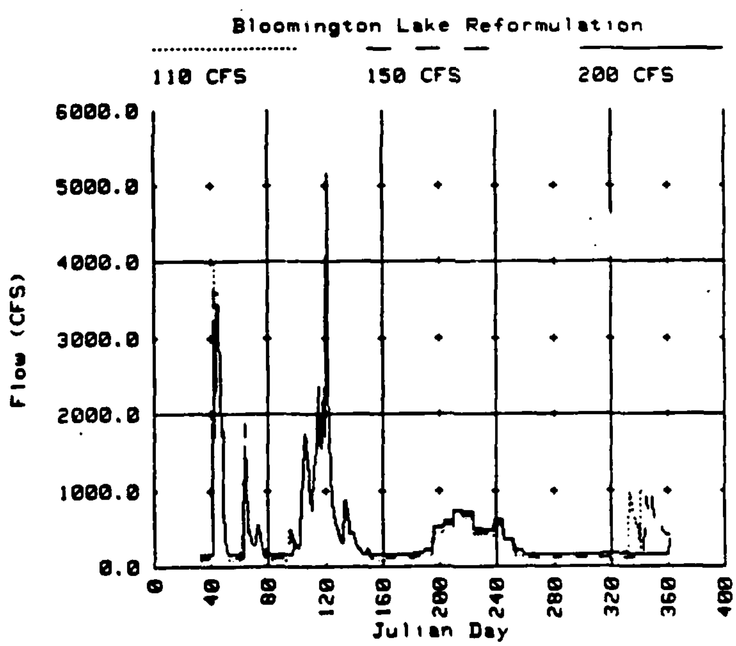
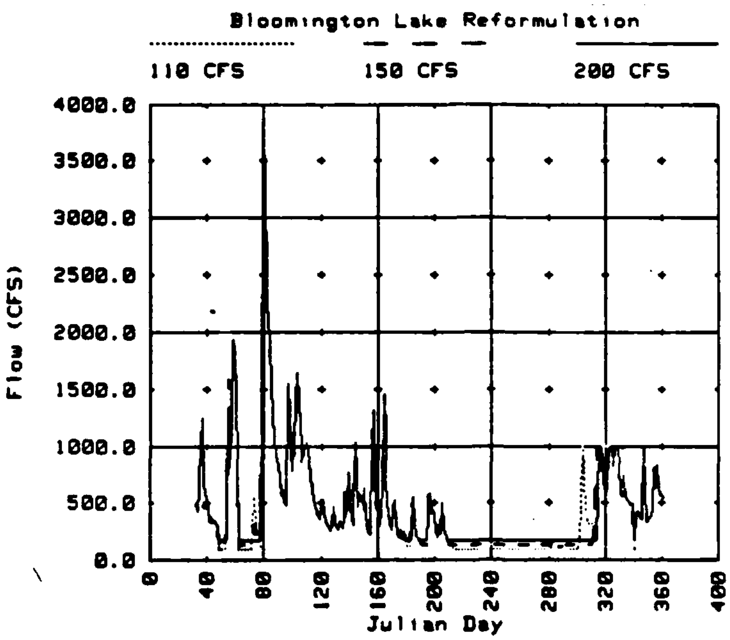


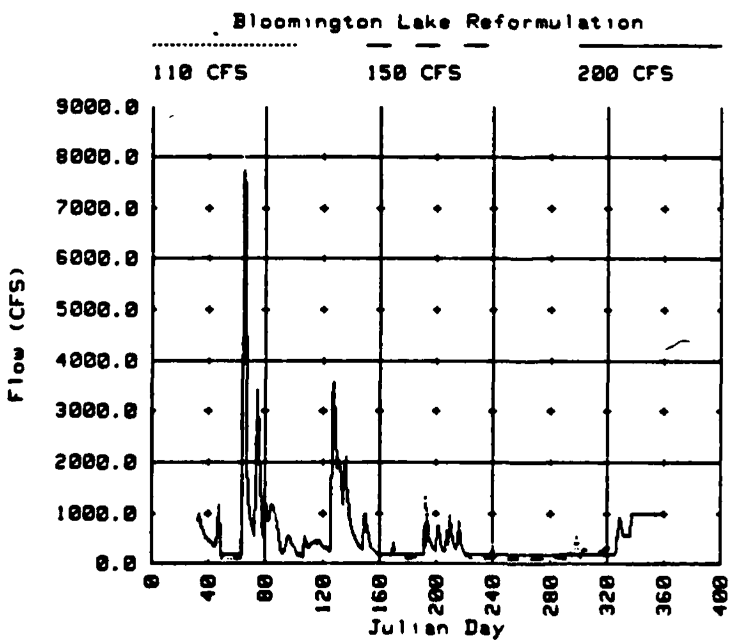
FIGURE H-II- 51

STATION: Barnum, MD
YEAR: 1966



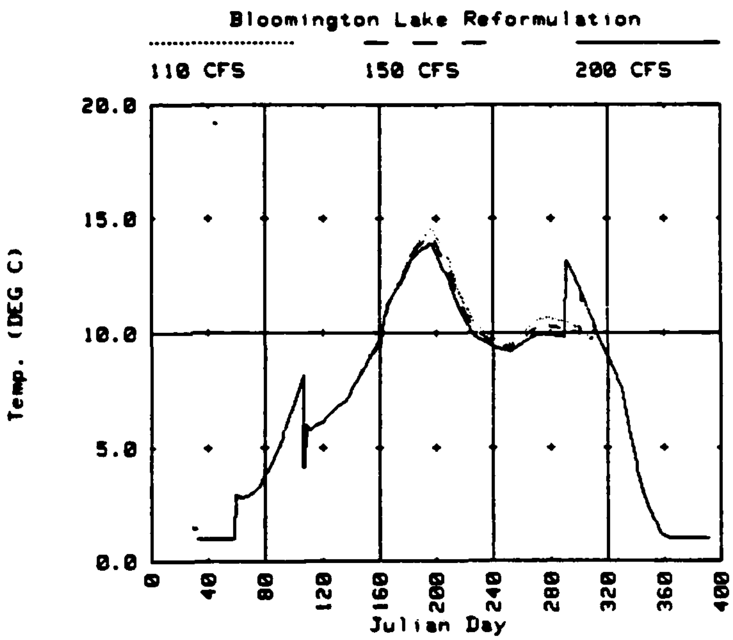
STATION: Barnum, MD
YEAR: 1962

FIGURE H-II- 52



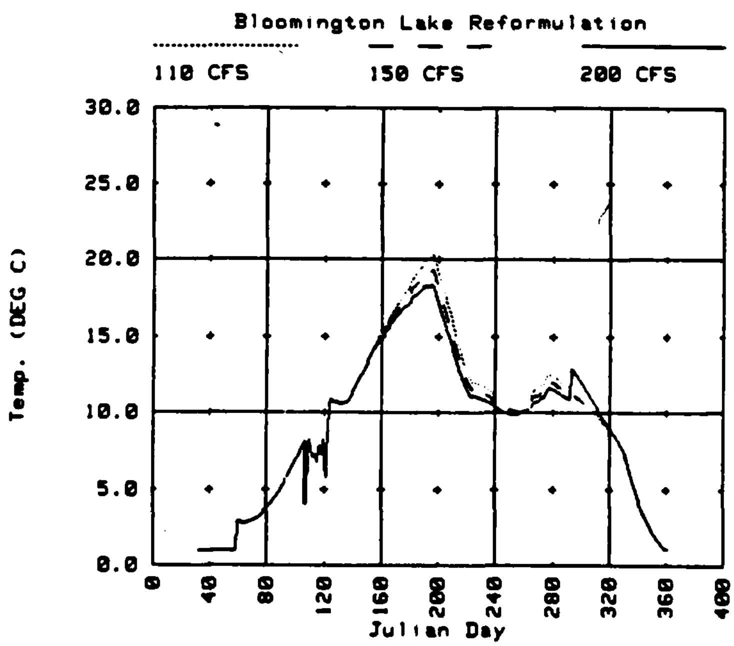
STATION: Barnum, MD
YEAR: 1967

FIGURE H-II- 53



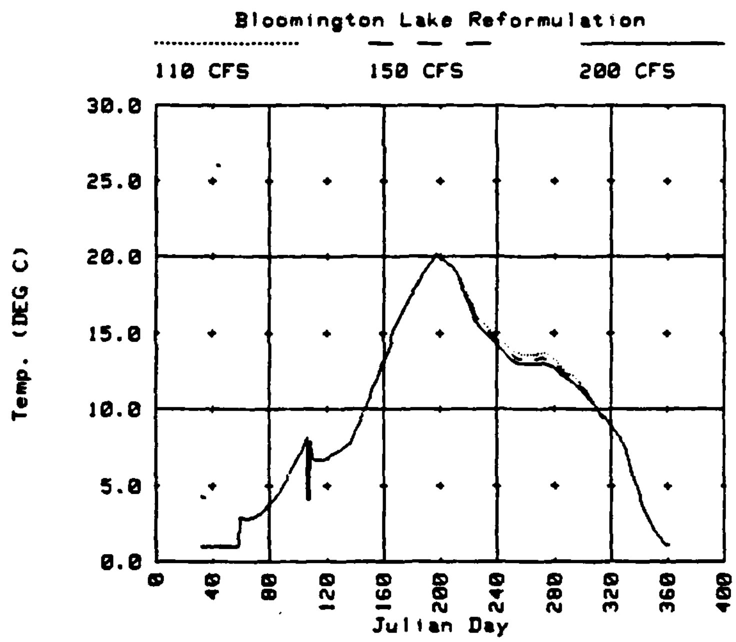
STATION: Barnum, MD
YEAR: 1930

FIGURE H-II- 54



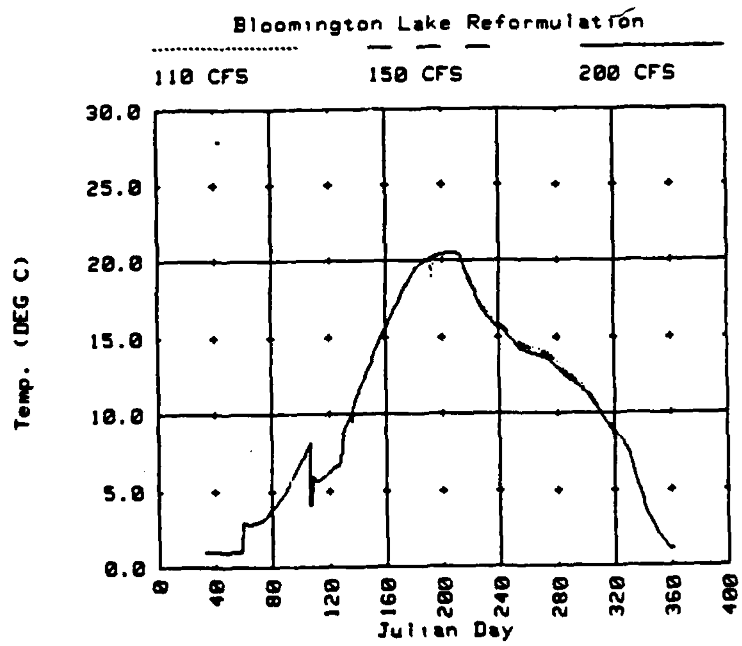
STATION: Barnum, MD
YEAR: 1966

FIGURE H-II- 55



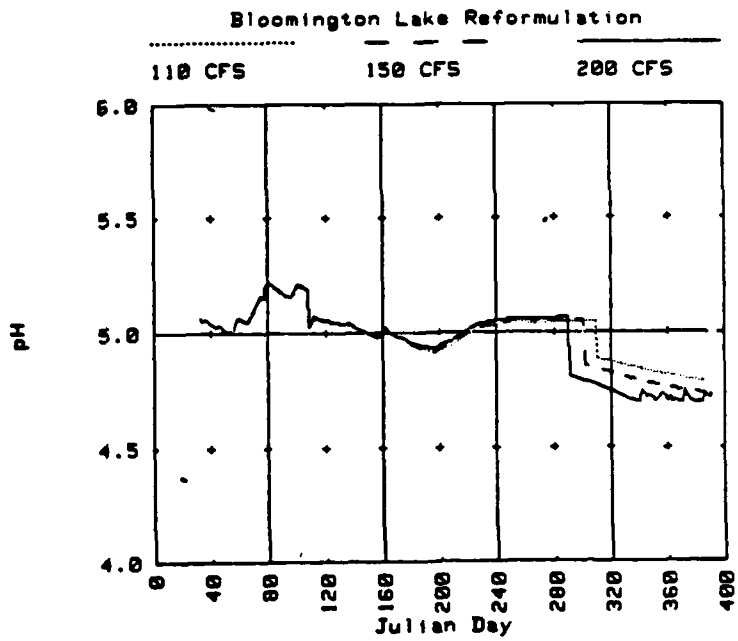
STATION: Barnum, MD
YEAR: 1962

FIGURE H-II- 56



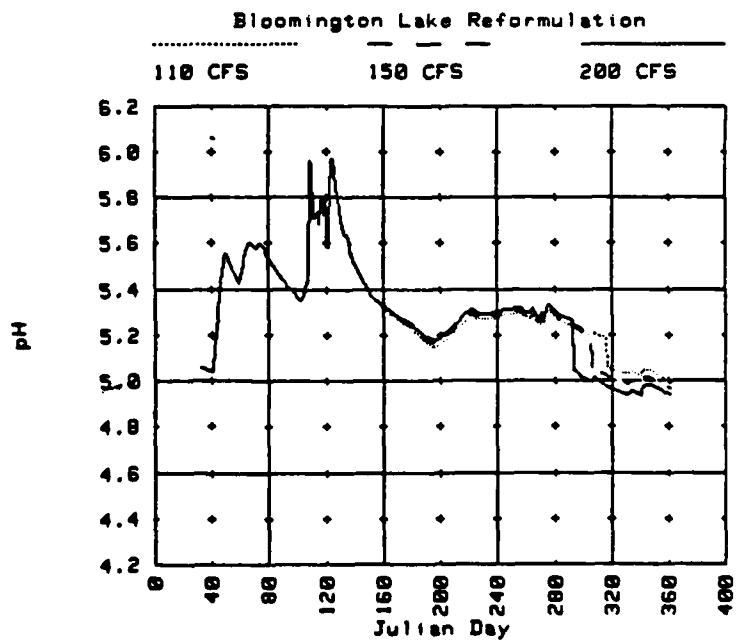
STATION: Barnum, MD
YEAR: 1967

FIGURE H-II- 57



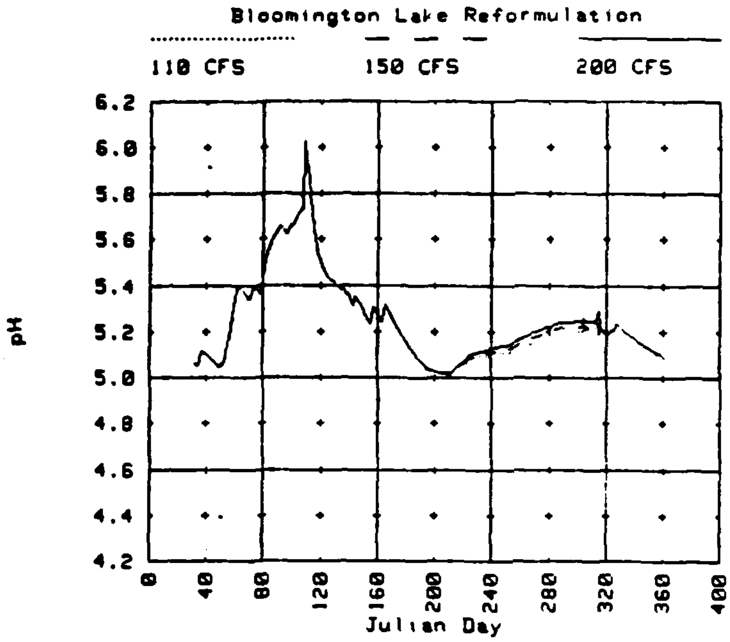
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 58



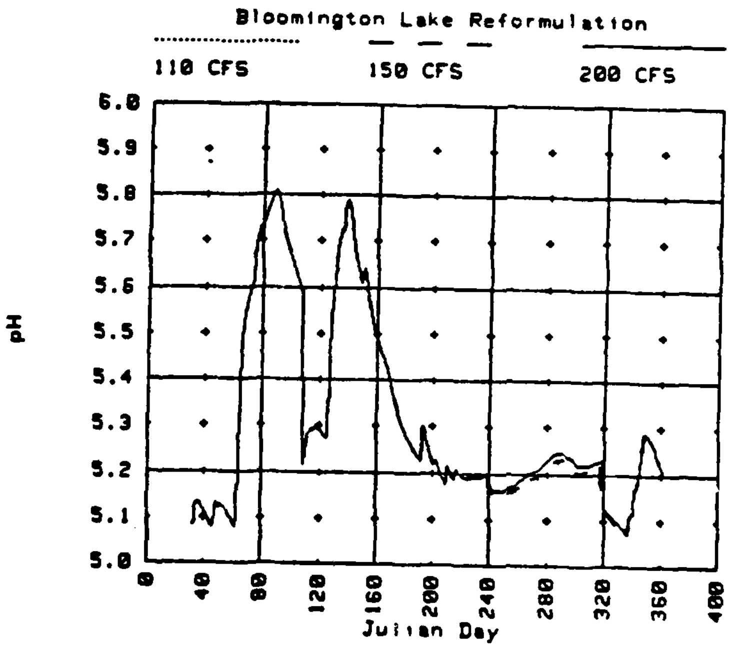
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 59



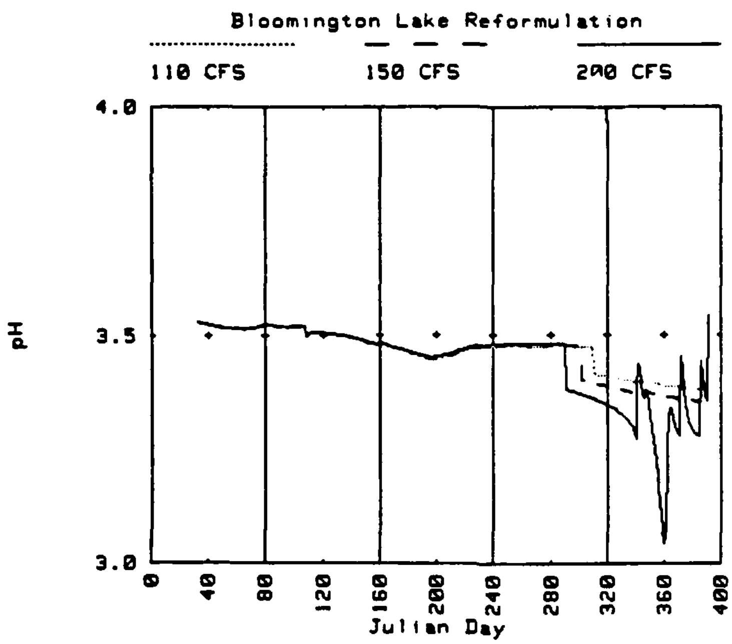
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 60



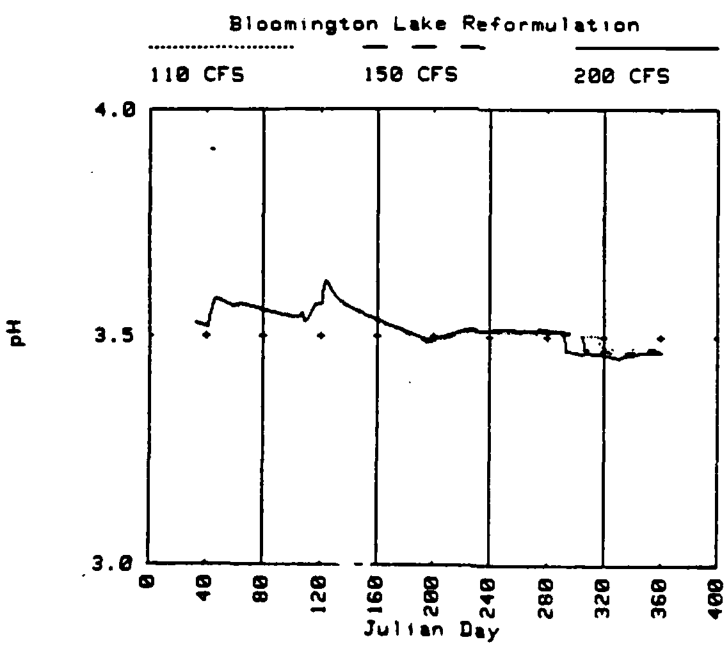
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 61



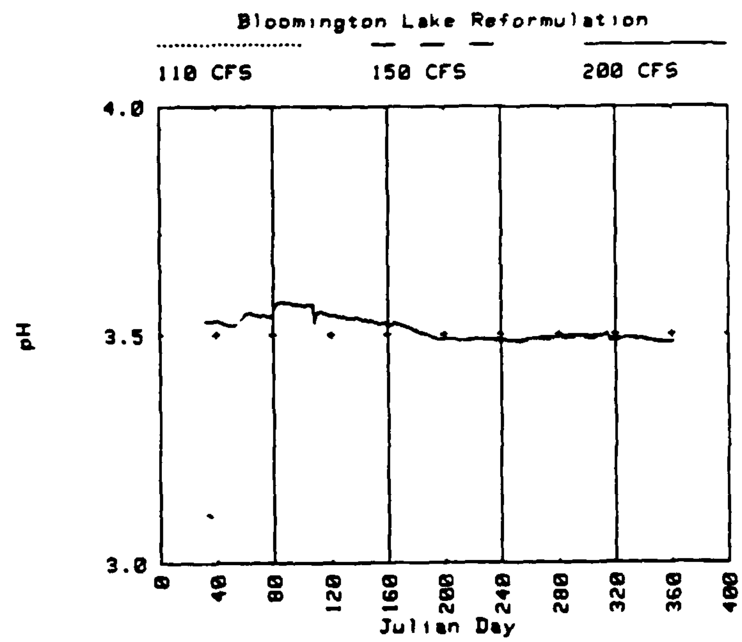
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 62



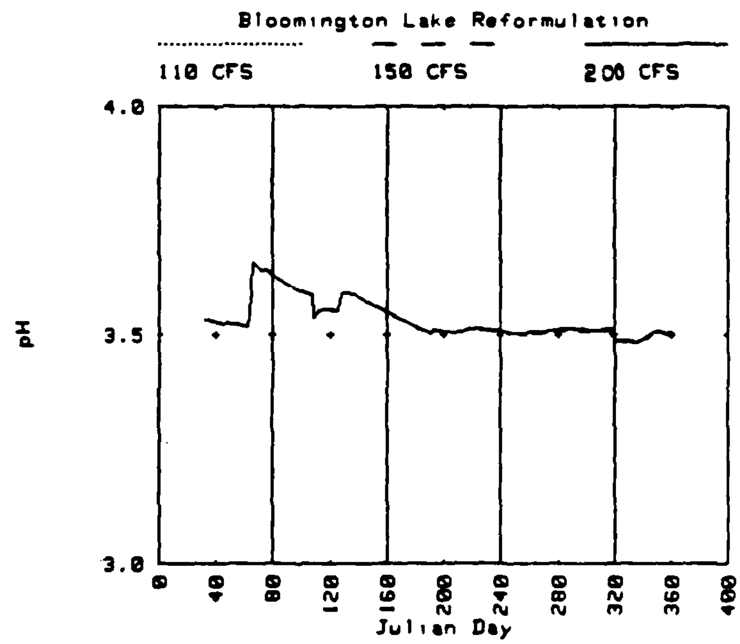
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 63



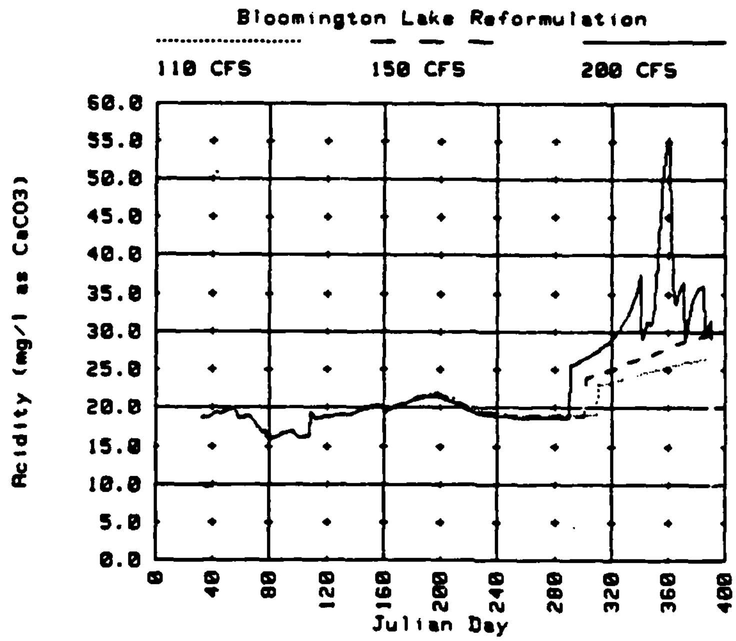
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 64



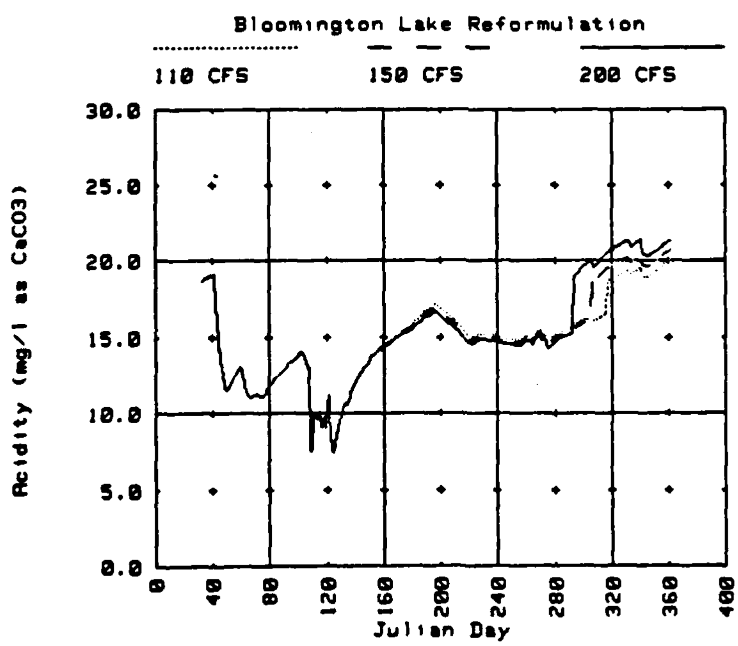
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 65



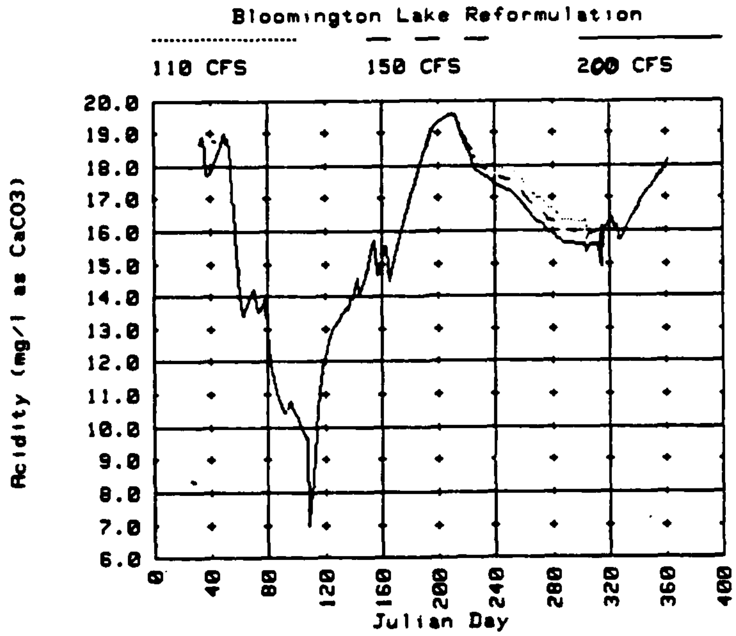
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 66



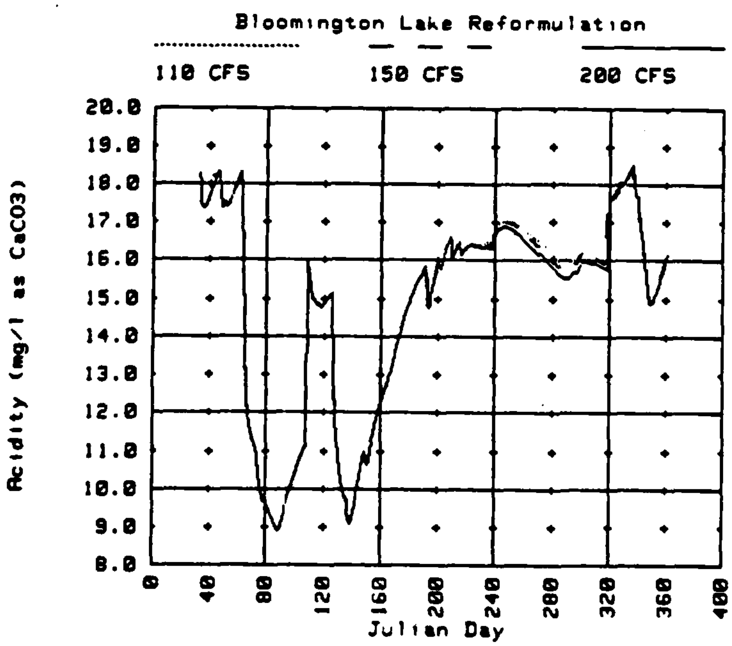
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 67



STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 68



STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 69

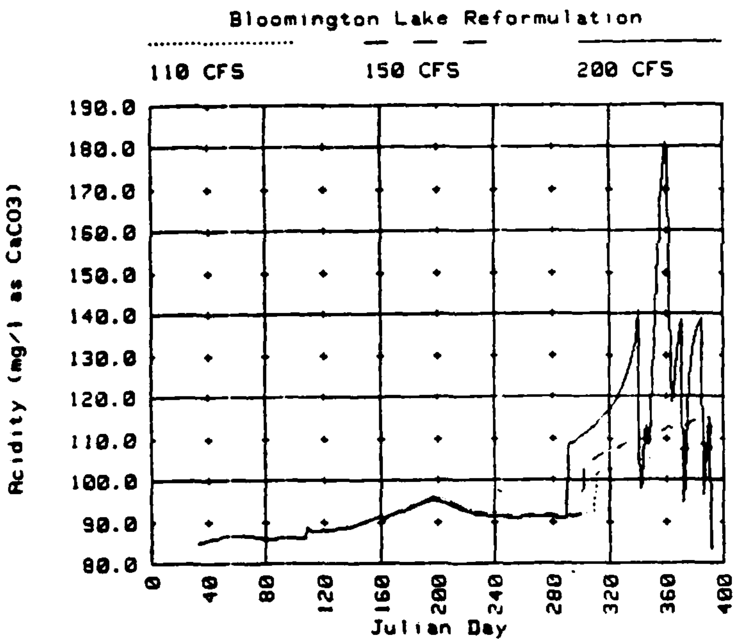


FIGURE H-II- 70

STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Worst Case

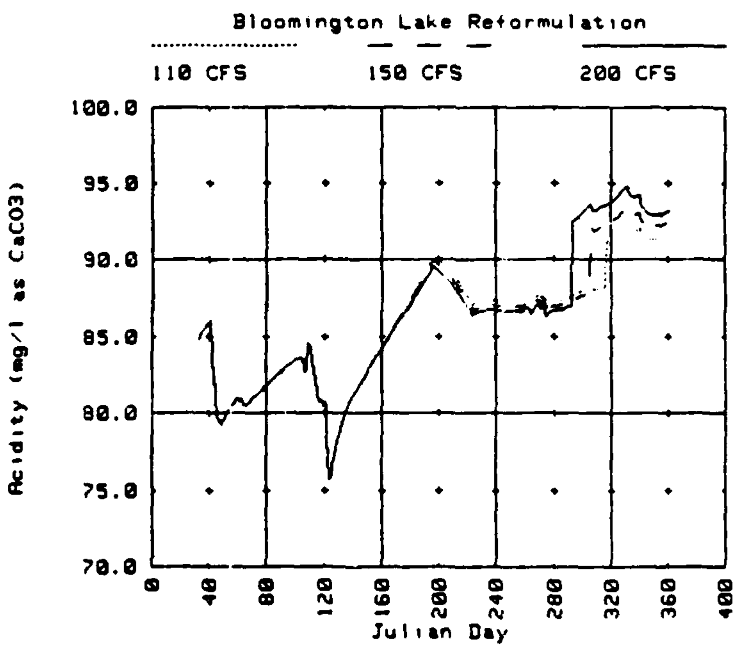
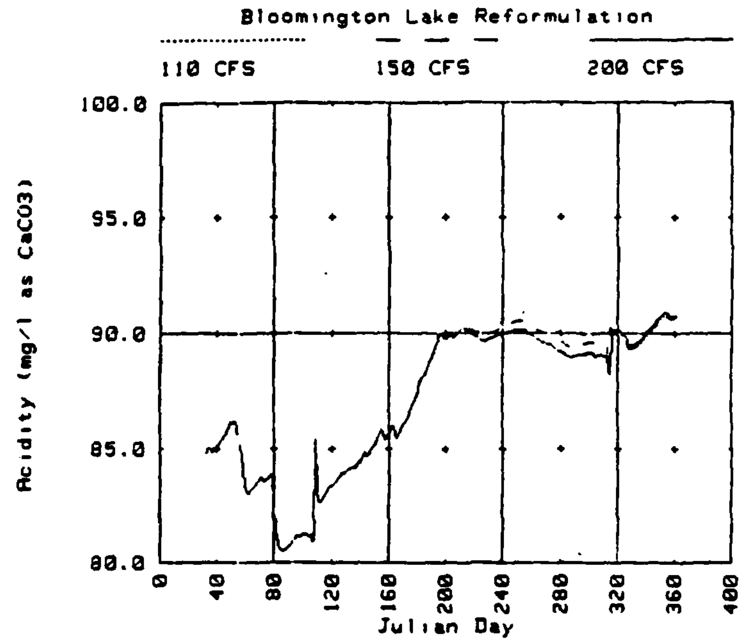


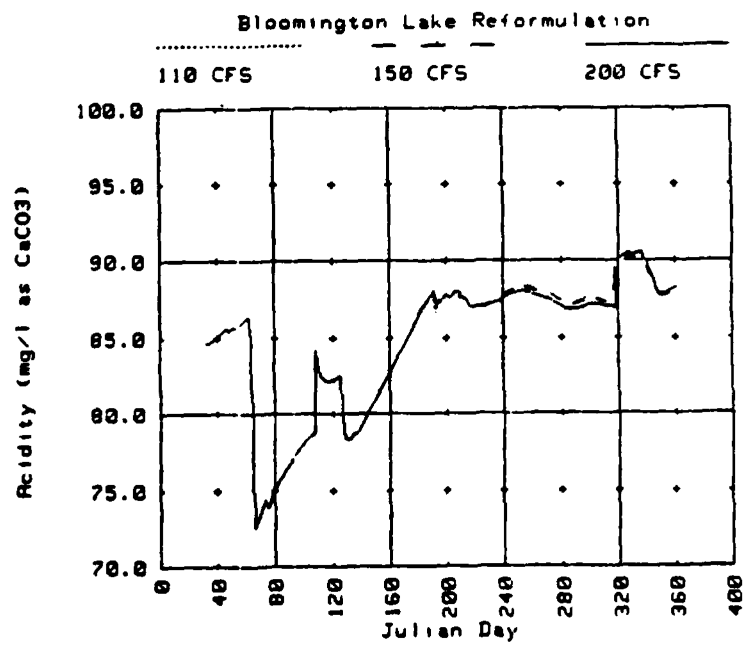
FIGURE H-II- 71

STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Worst Case



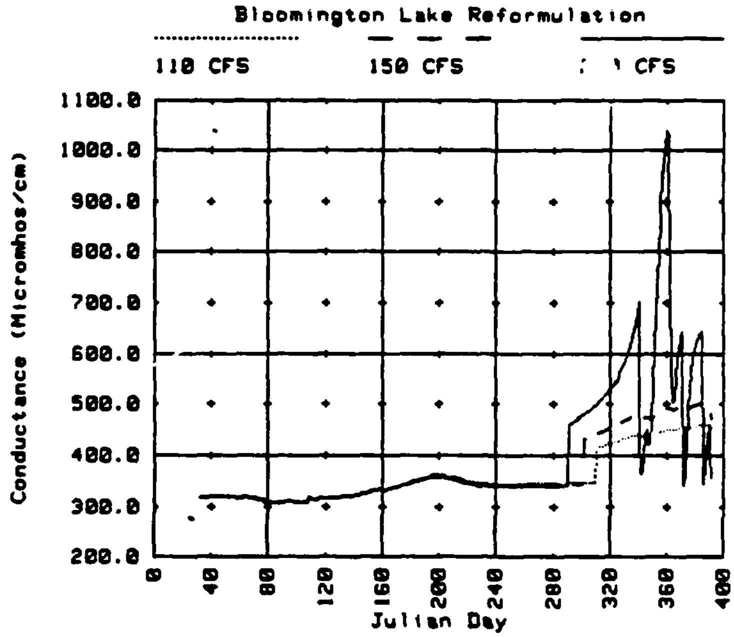
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 72



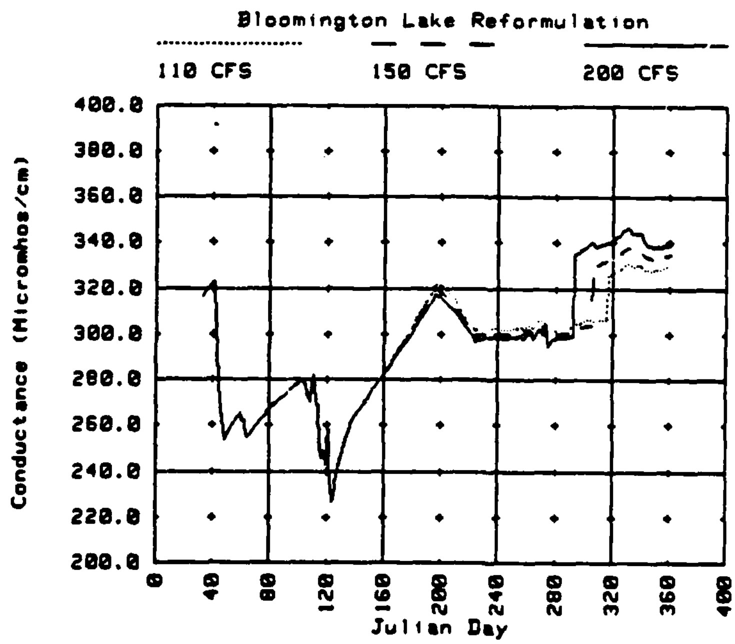
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 73



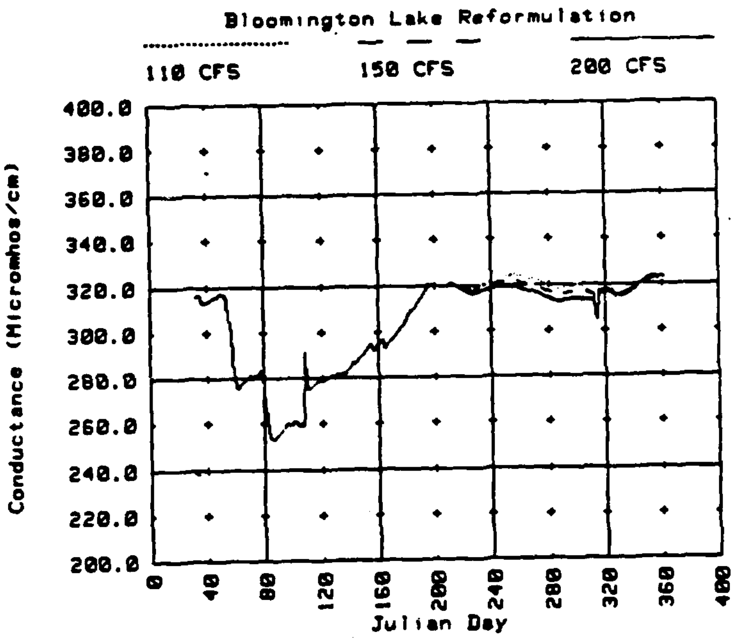
STATION: Barnum, MD
YEAR: 1938
WATER QUALITY: Best Case

FIGURE H-II- 74



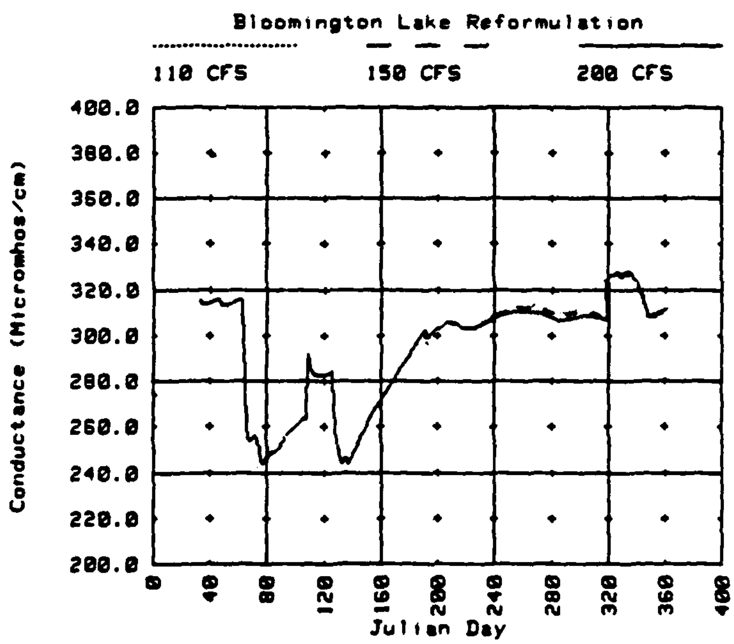
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 75



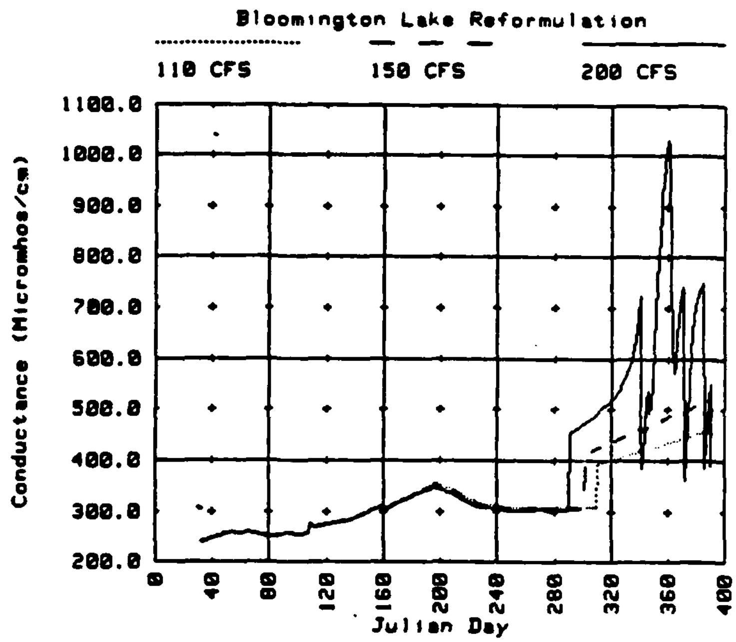
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 76



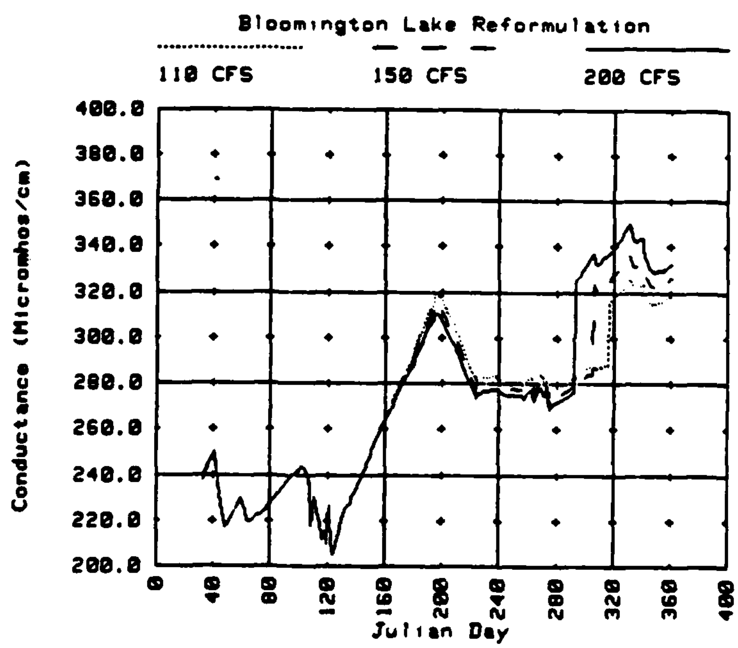
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 77



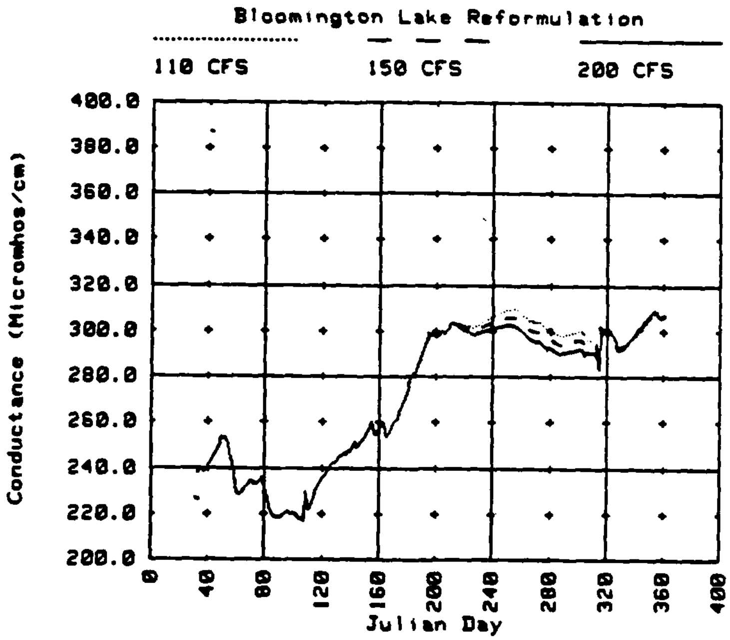
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 78



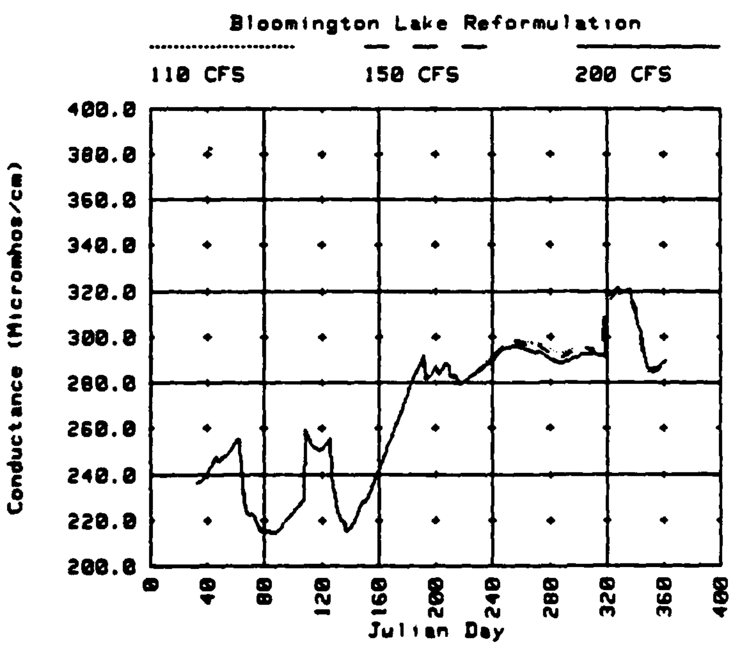
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 79



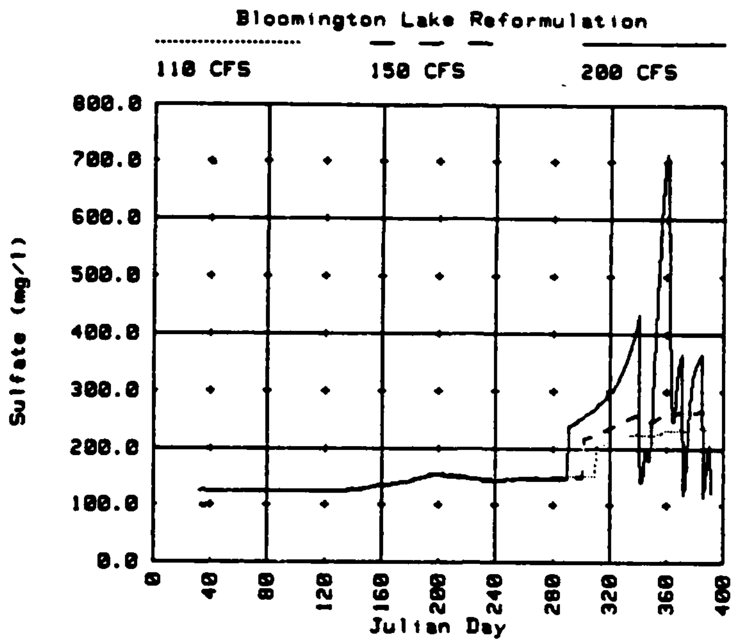
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 80



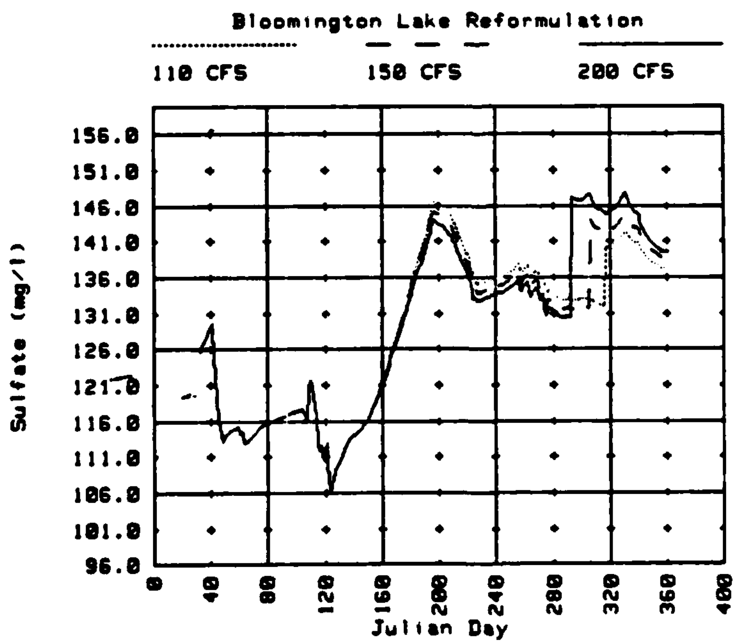
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 81



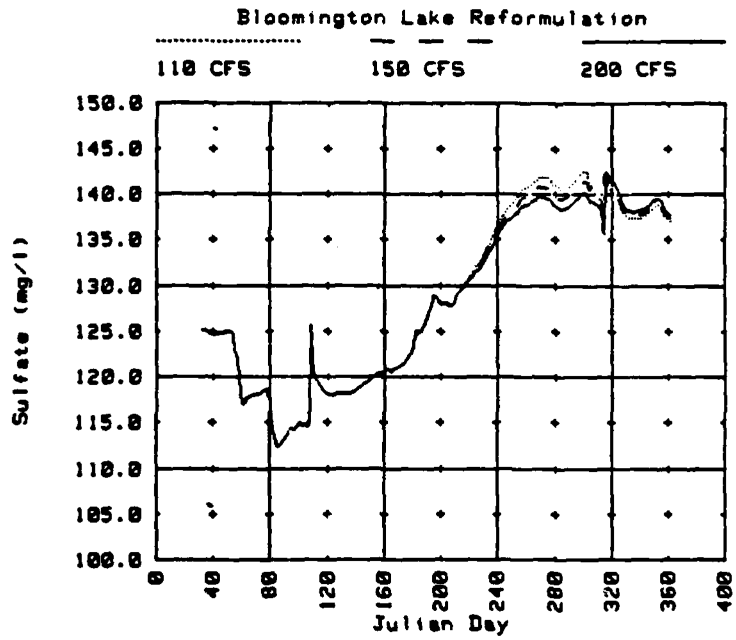
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 82



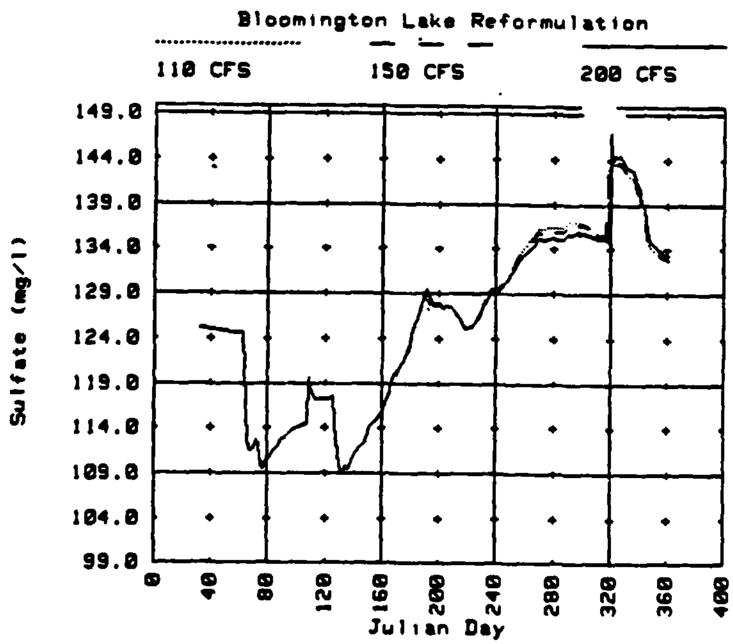
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 83



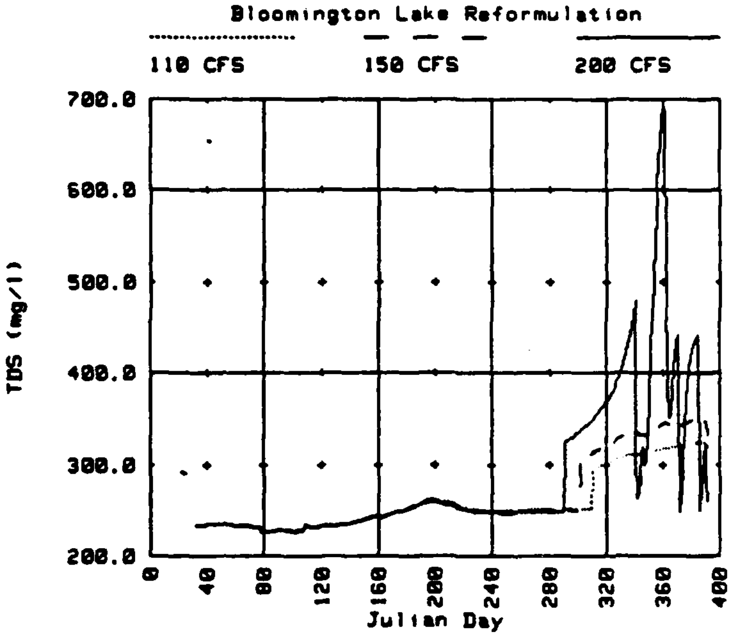
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 84



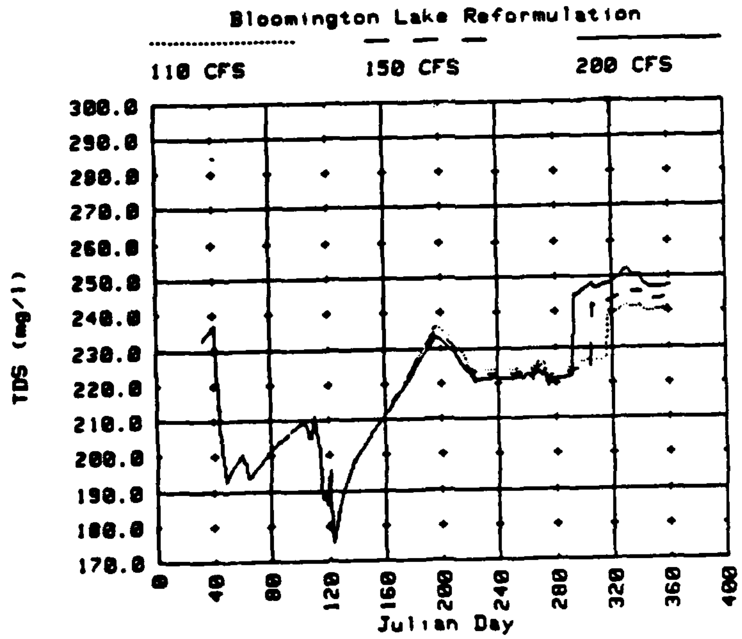
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 85



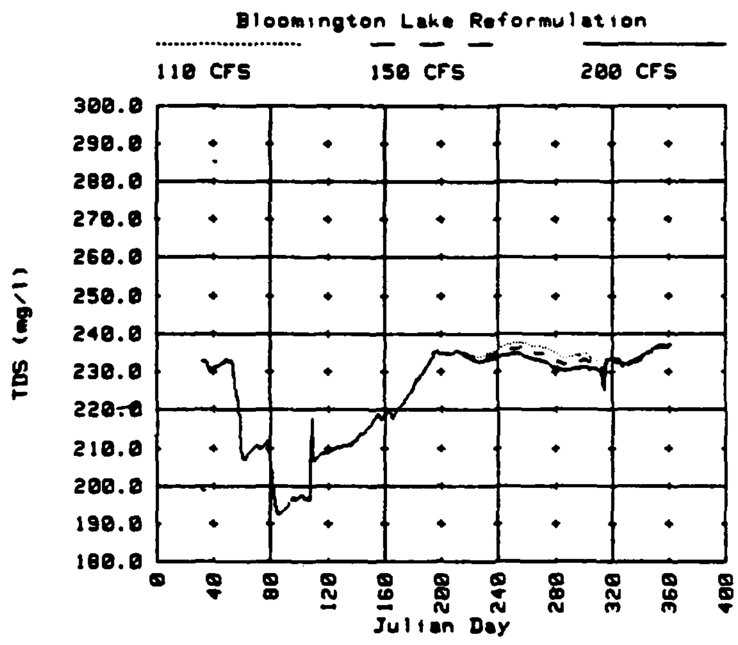
STATION: Barnum, MD
YEAR: 1938
WATER QUALITY: Best Case

FIGURE H-II- 86



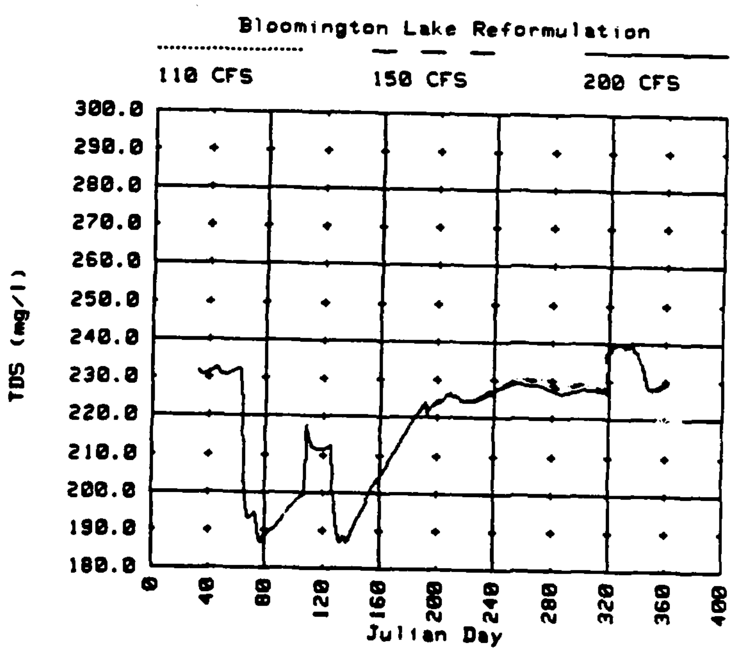
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 87



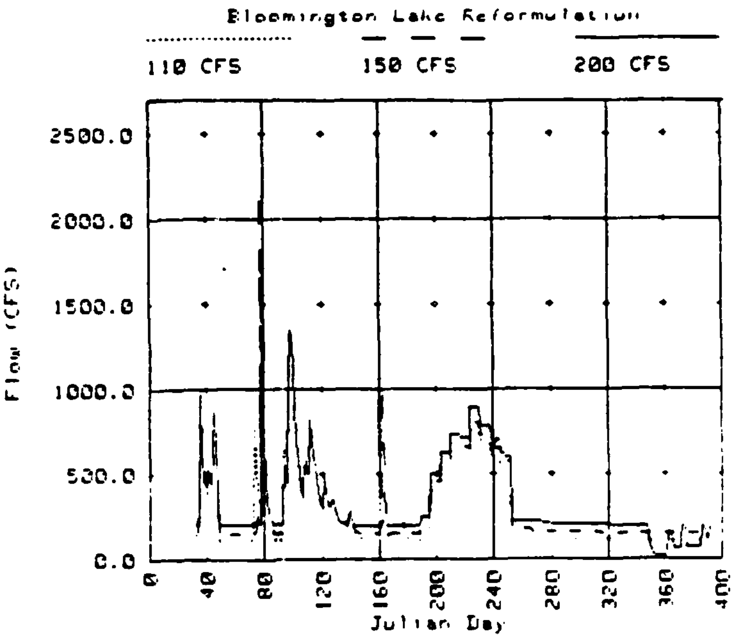
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 88



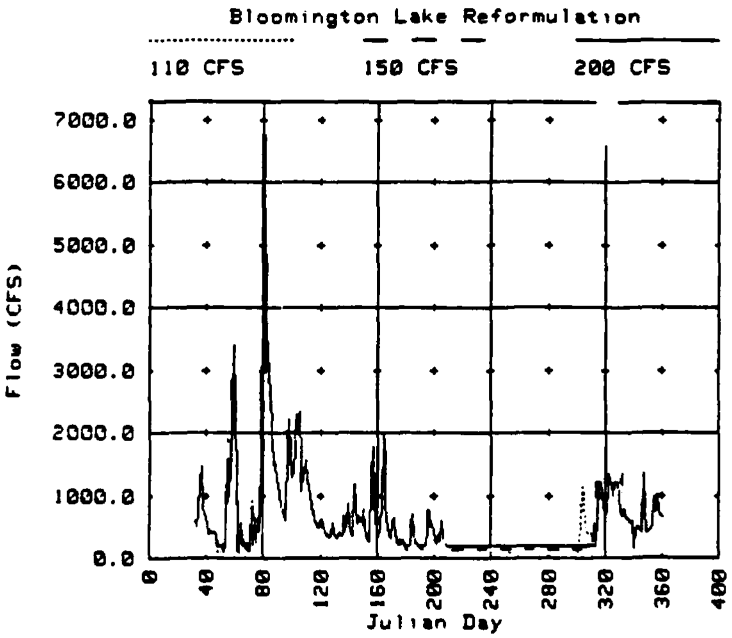
STATION: Barnum, MD
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 89



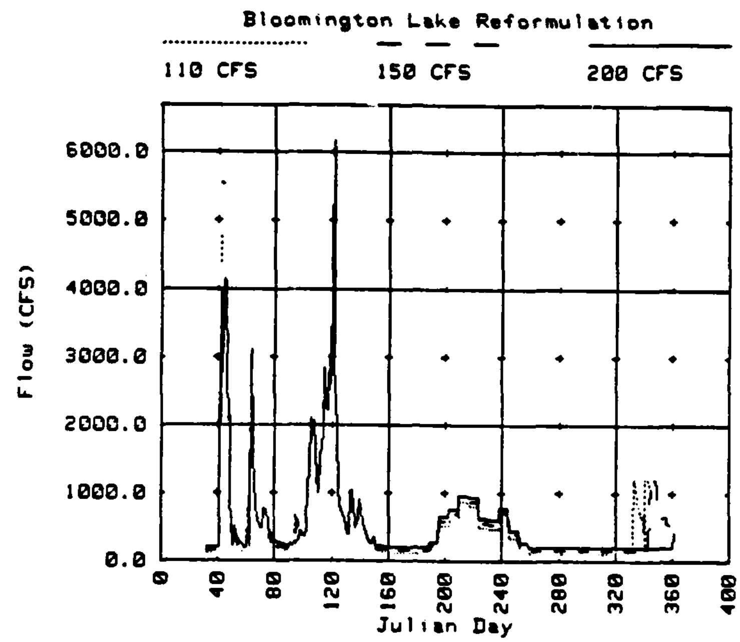
STATION: Luke, MD.
YEAR: 1930

FIGURE H-II- 90



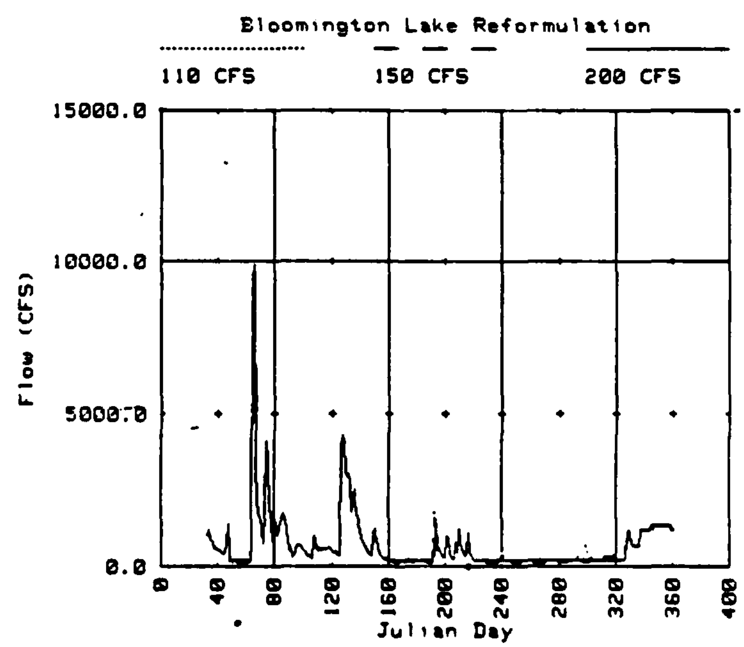
STATION: Luke, MD.
YEAR: 1962

FIGURE H-II- 91



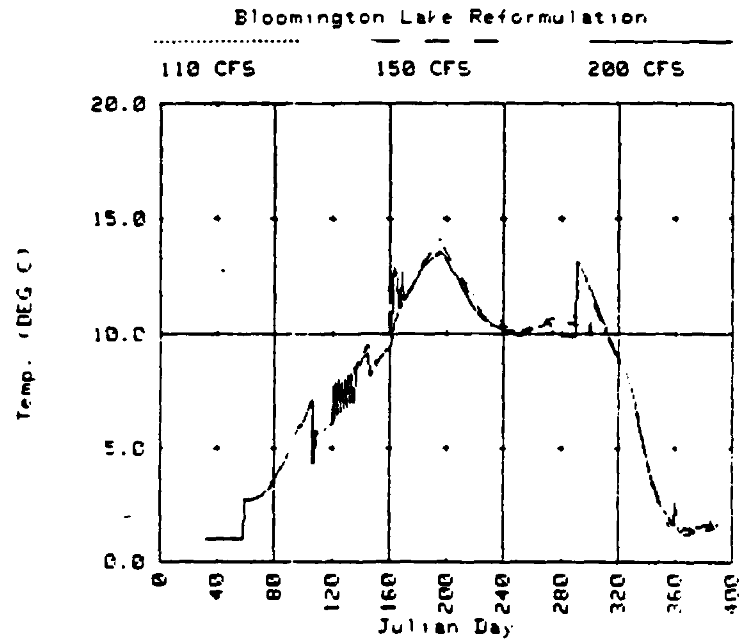
STATION: Luke, MD.
YEAR: 1966

FIGURE H-II- 92



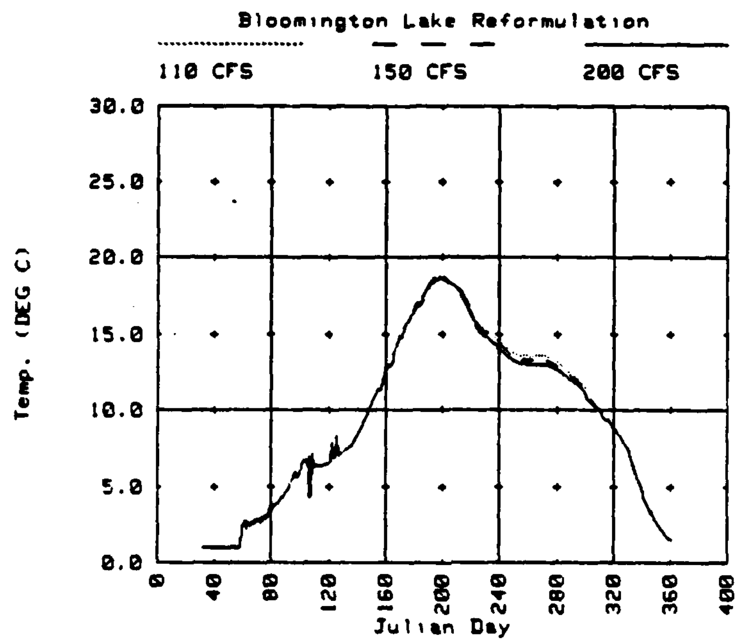
STATION: Luke, MD.
YEAR: 1967

FIGURE H-II- 93



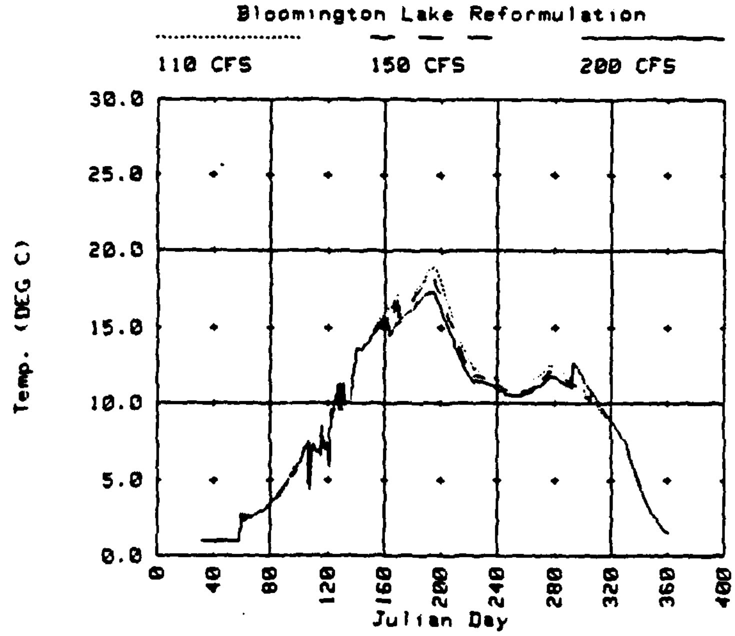
STATION: Luke, MD.
YEAR: 1930

FIGURE H-II- 94



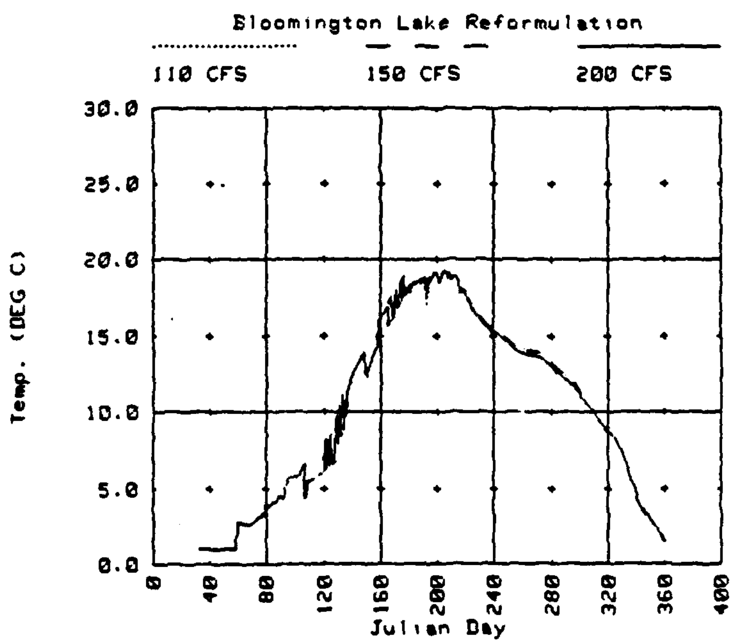
STATION: Luke, MD.
YEAR: 1962

FIGURE H-II- 95



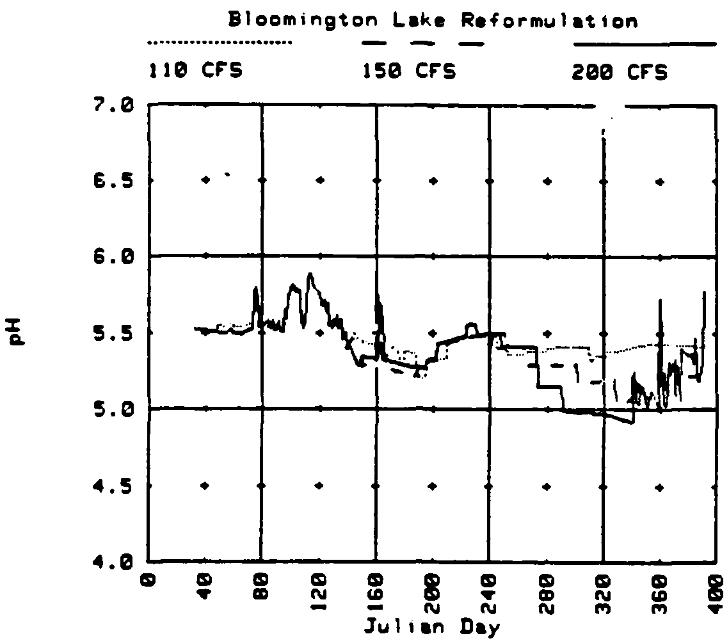
STATION: Luke, MD.
YEAR: 1966

FIGURE H-II- 96



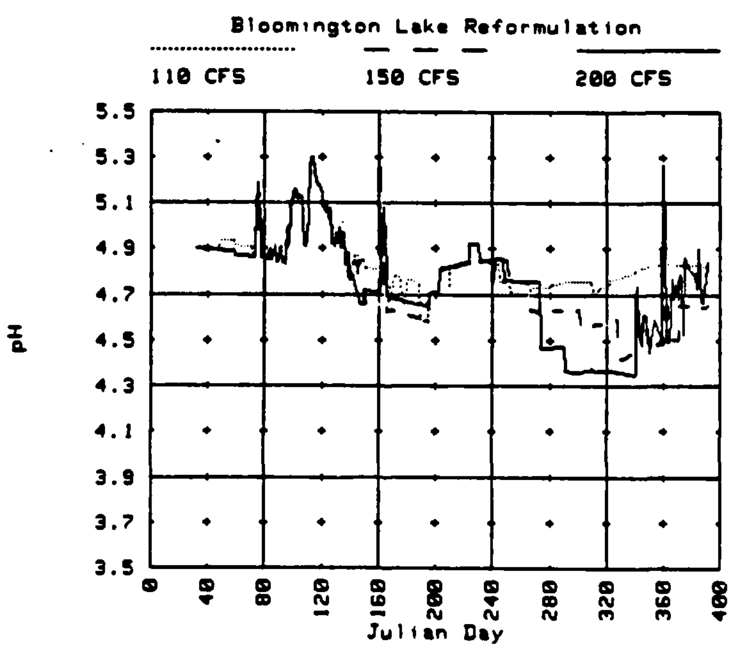
STATION: Luke, MD.
YEAR: 1967

FIGURE H-II- 97



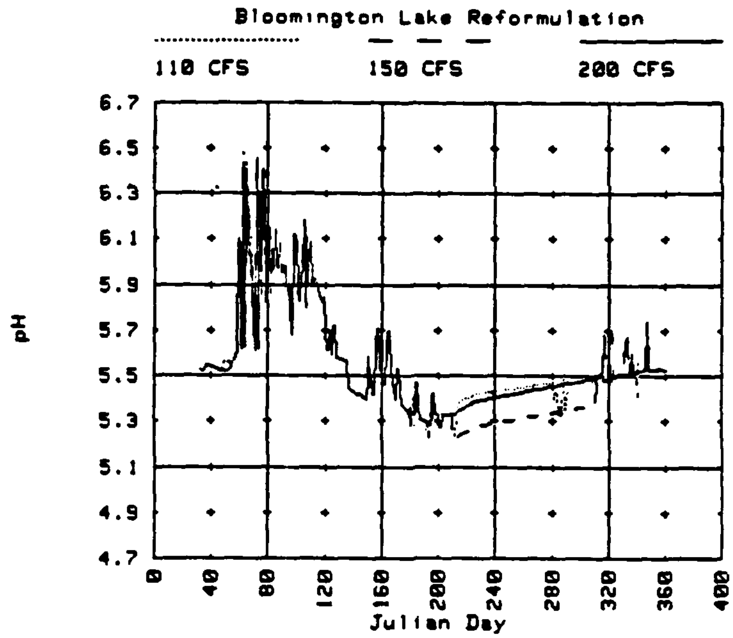
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 98



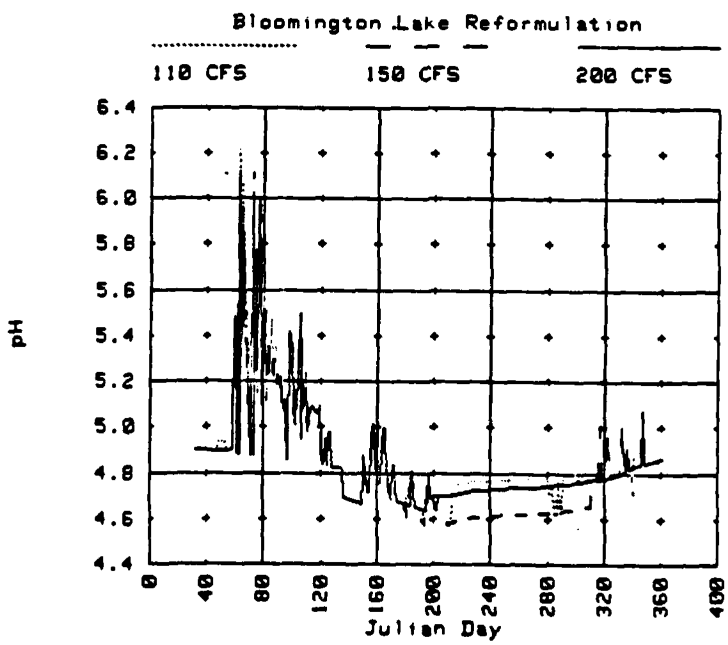
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 99



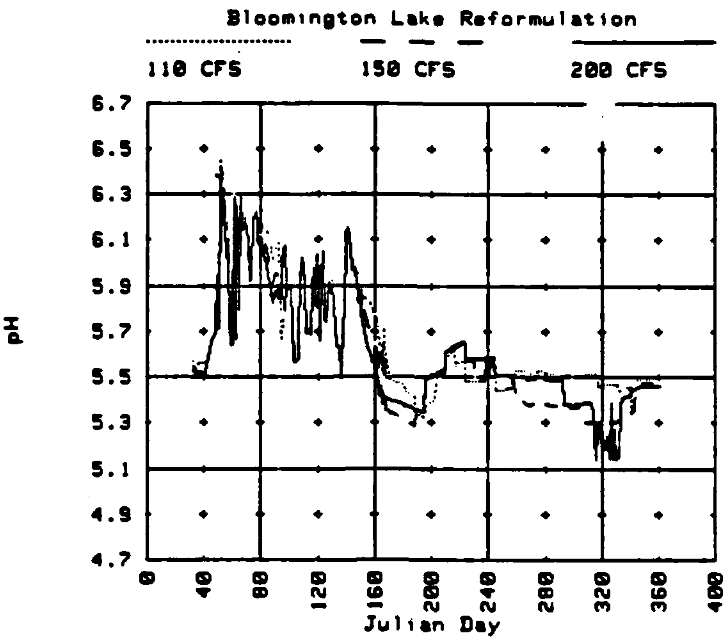
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 100



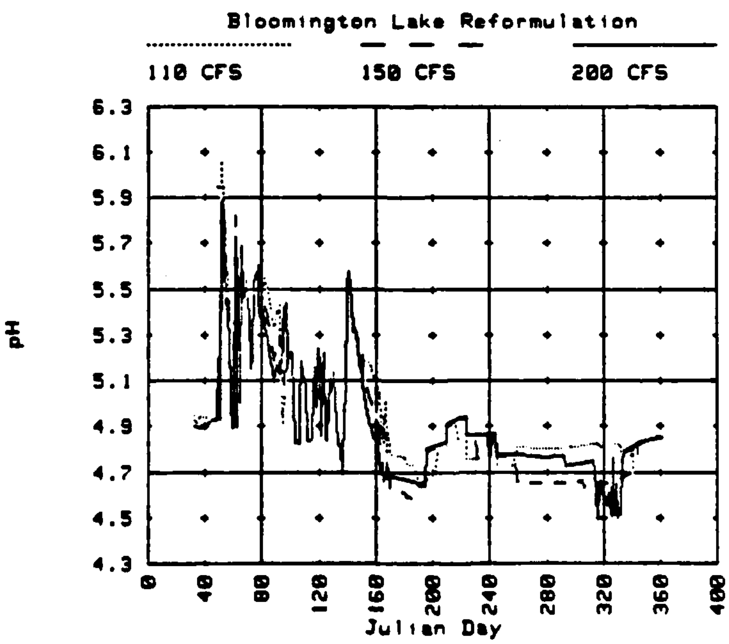
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 101



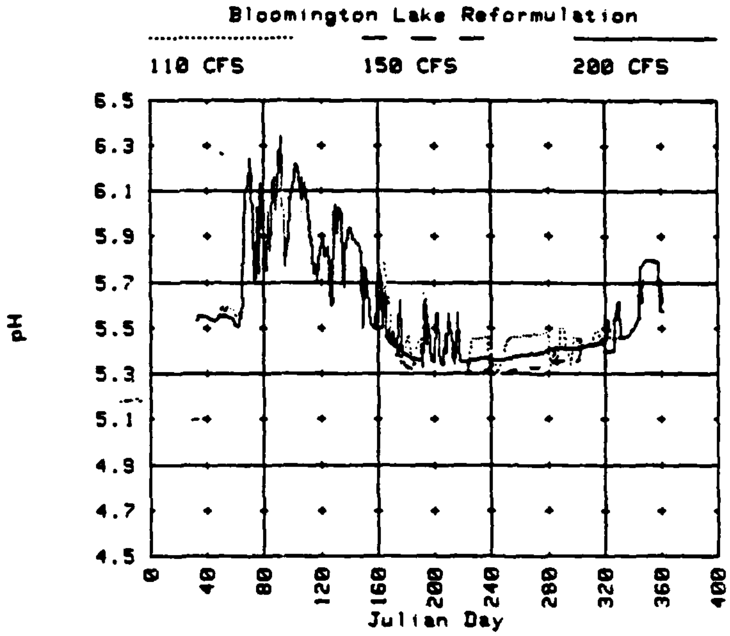
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 102



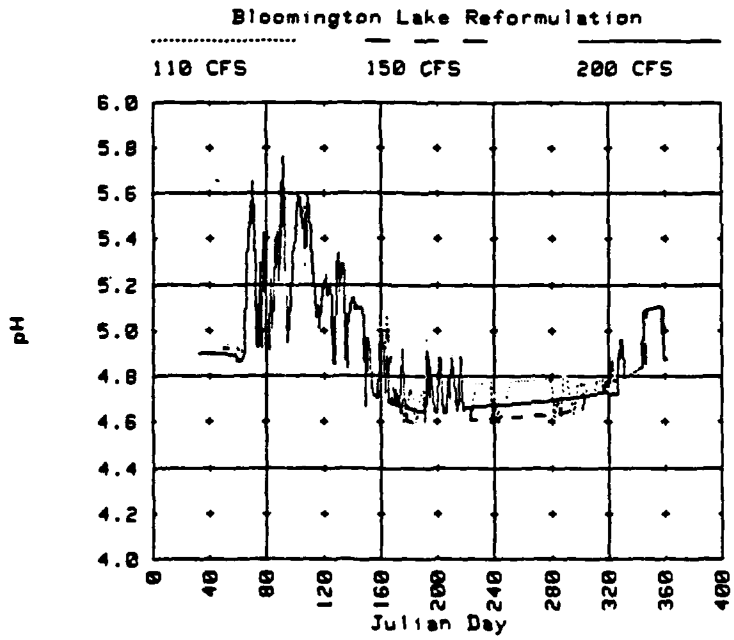
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 103



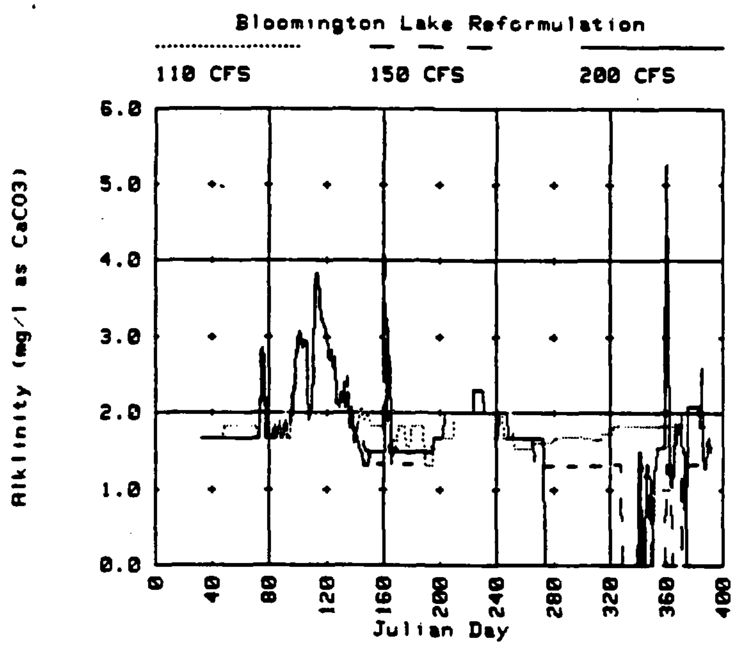
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 104



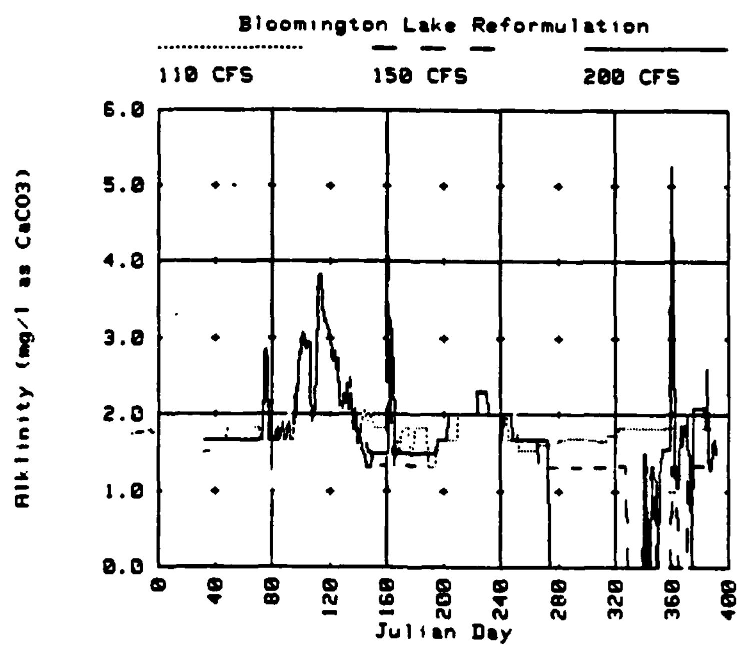
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 105



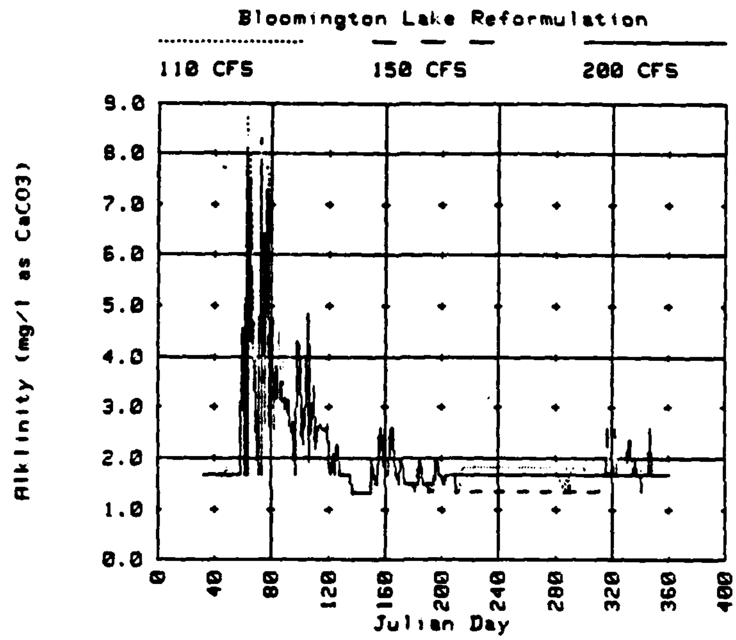
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 106



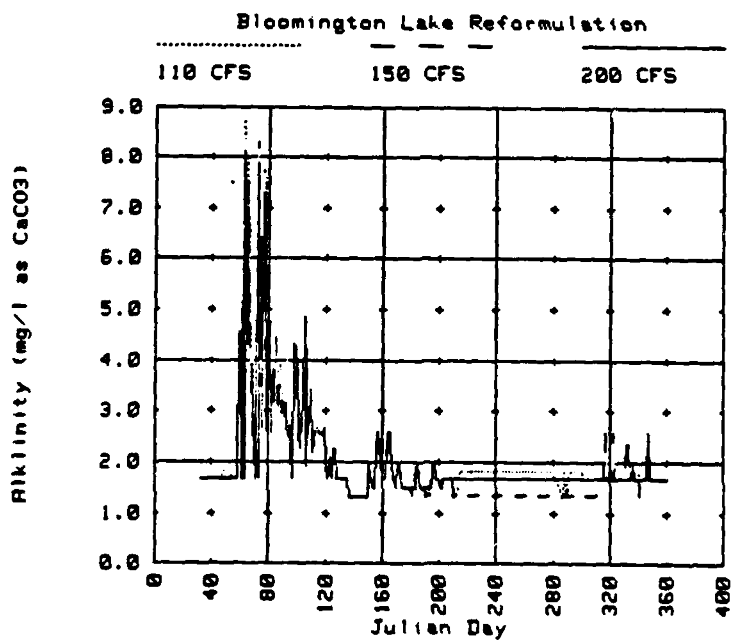
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 107



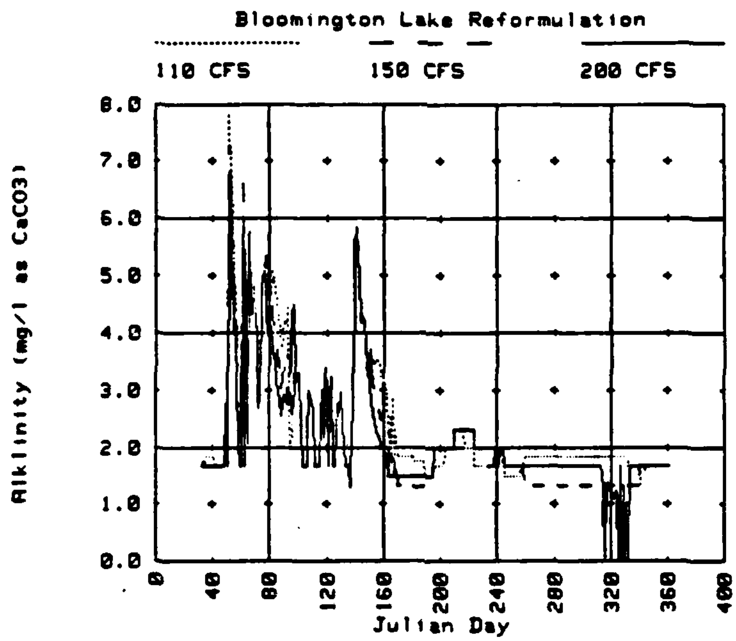
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 108



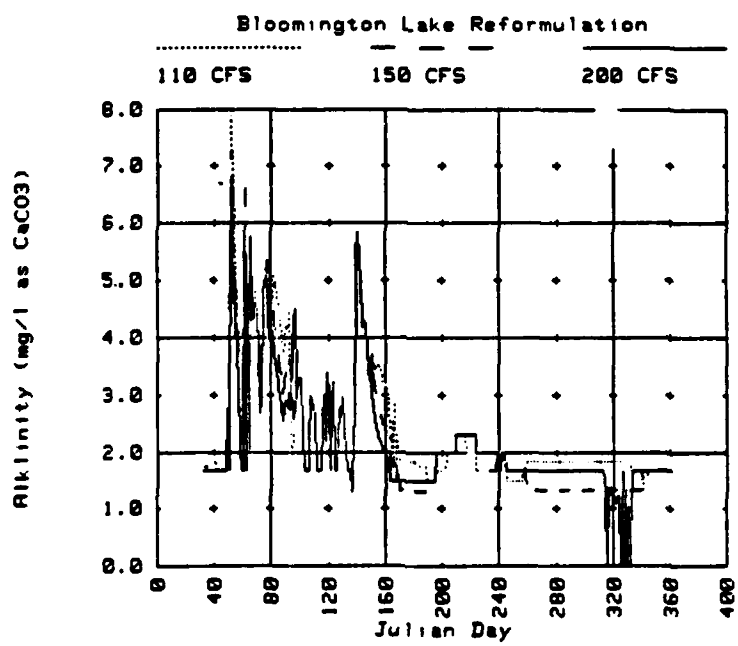
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 109



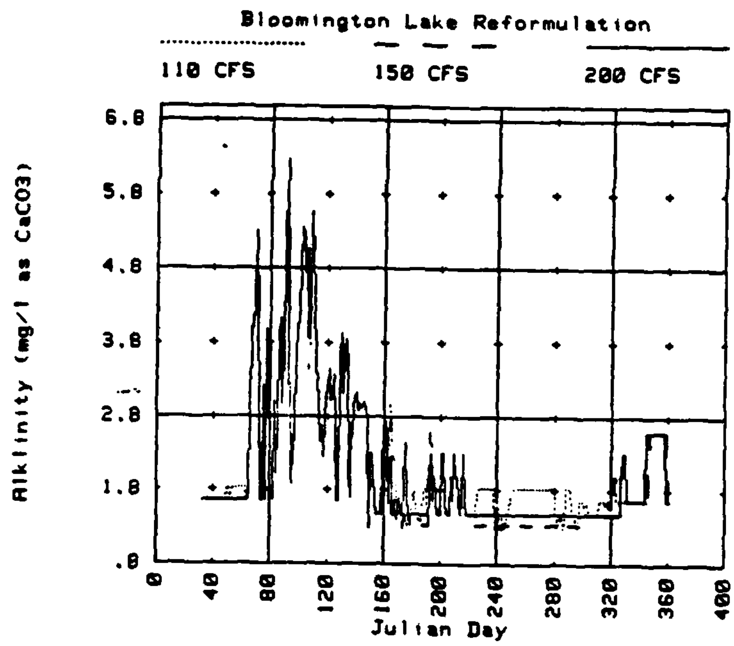
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 110



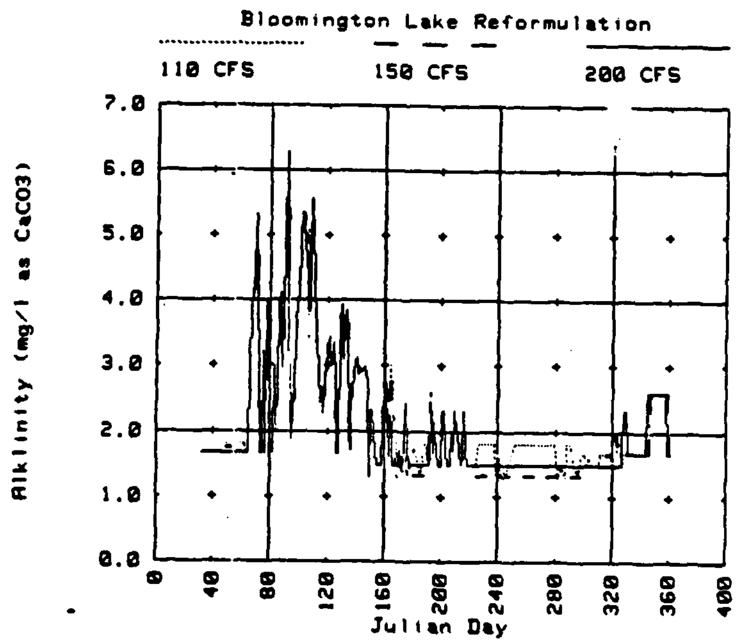
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 111



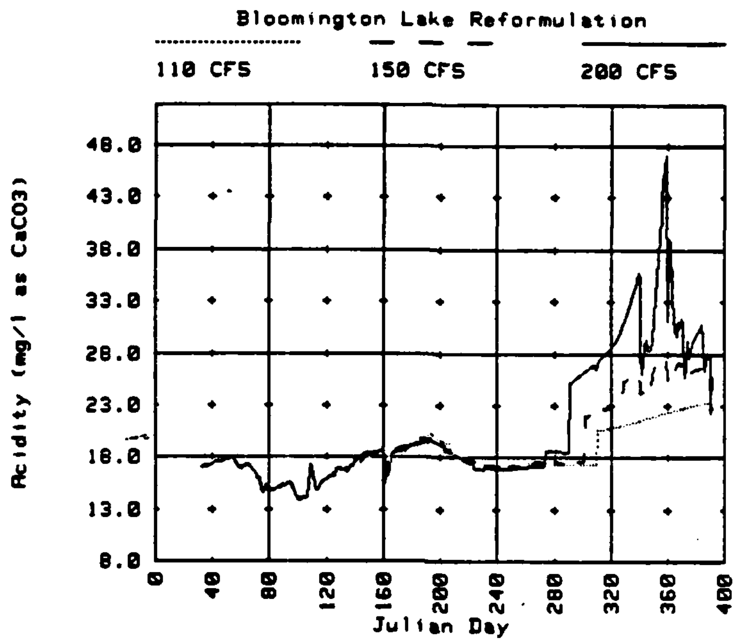
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 112



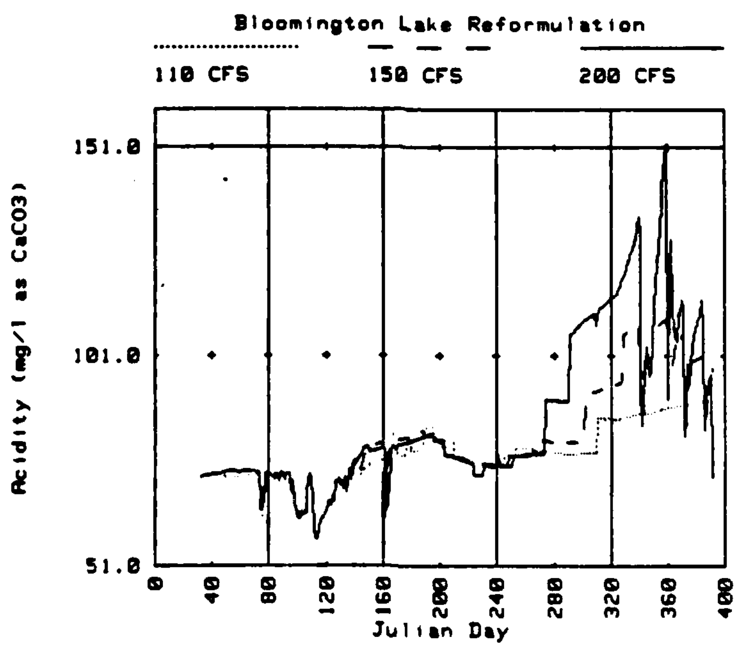
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 113



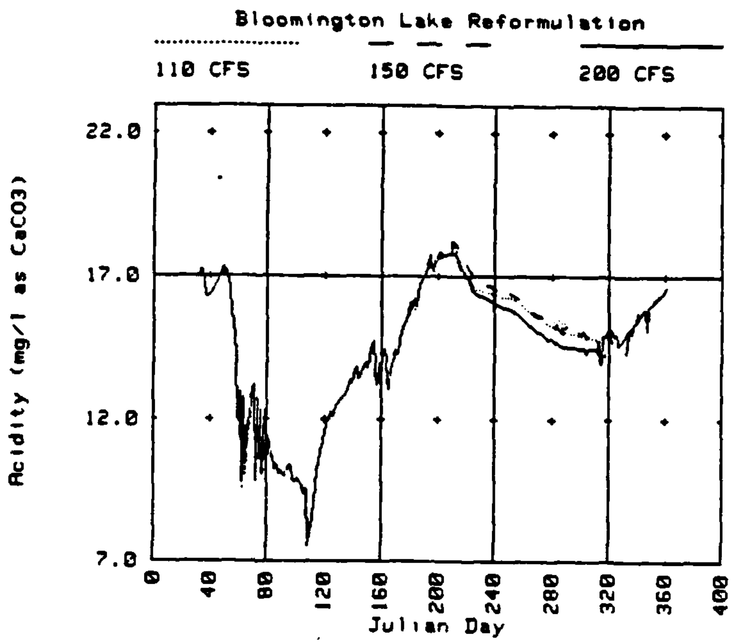
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 114



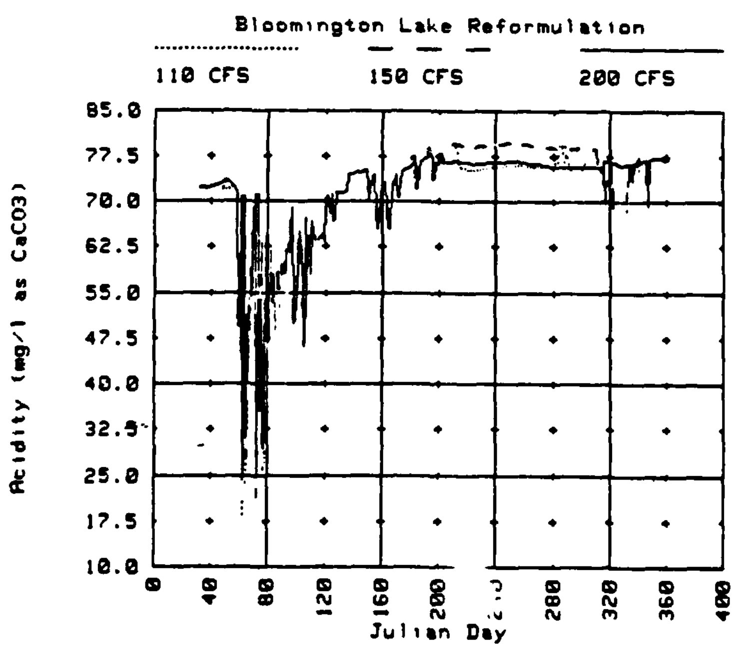
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 115



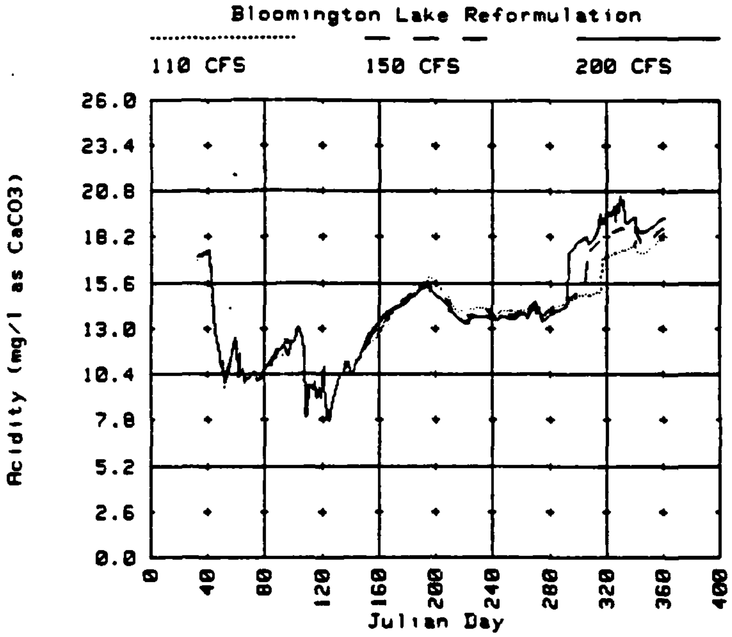
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 116



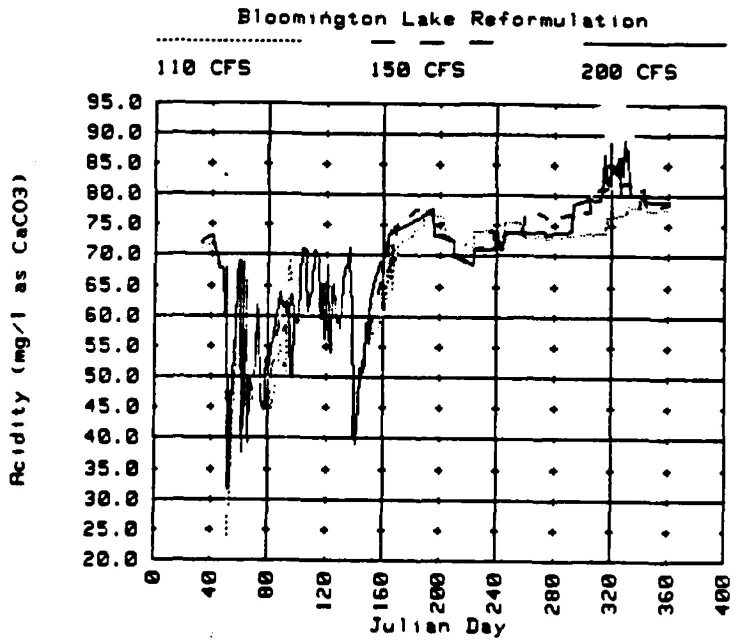
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 117



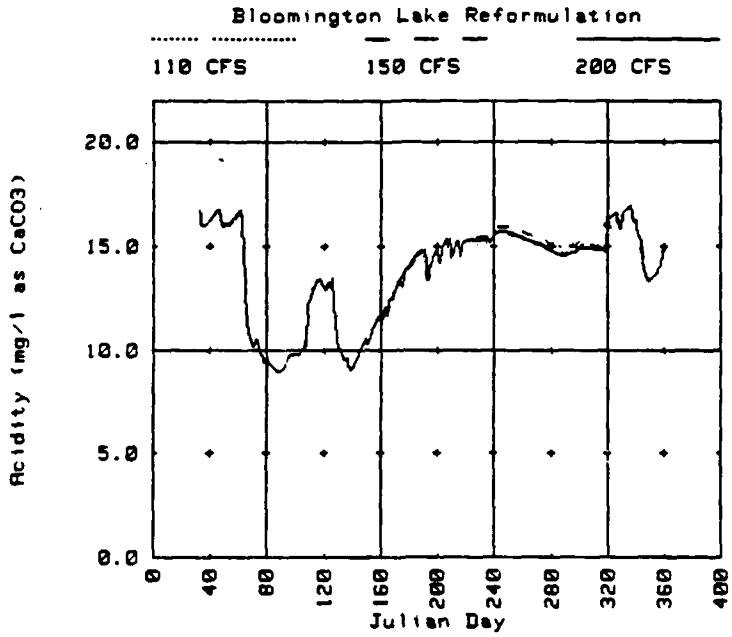
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 118



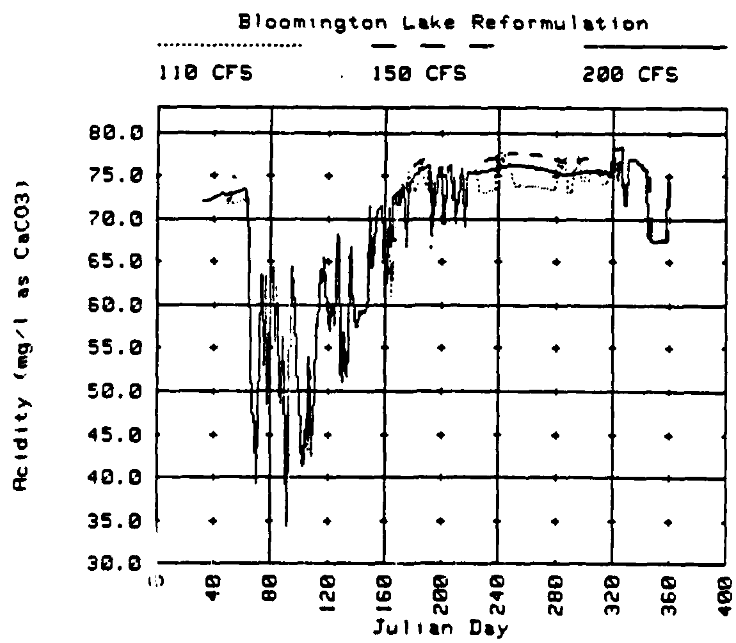
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 119



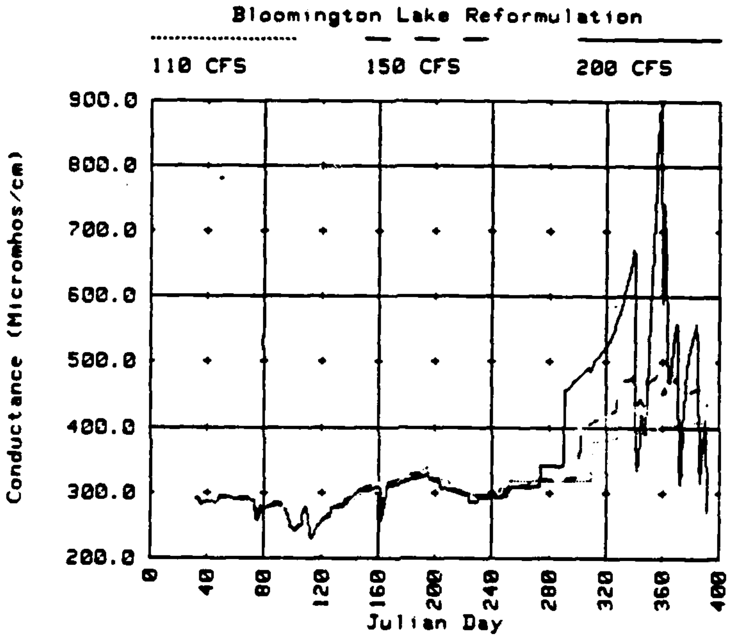
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 120



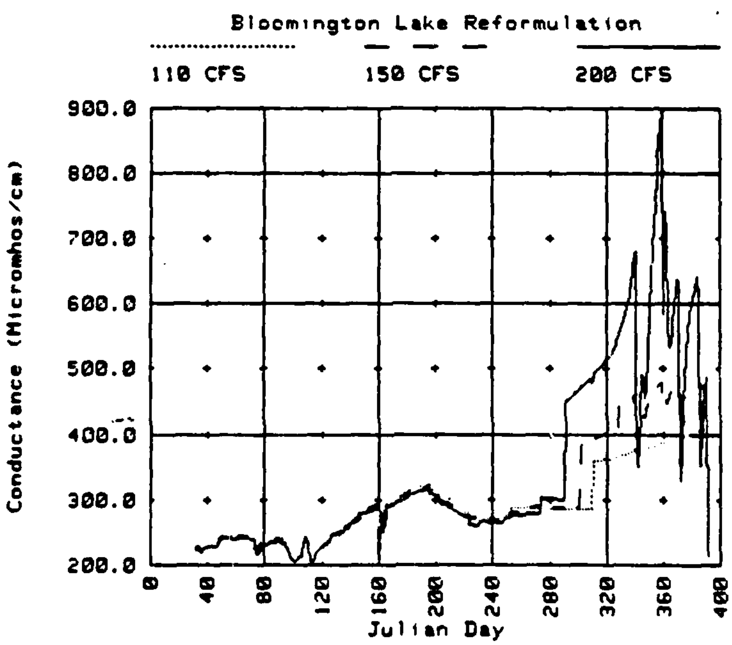
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 121



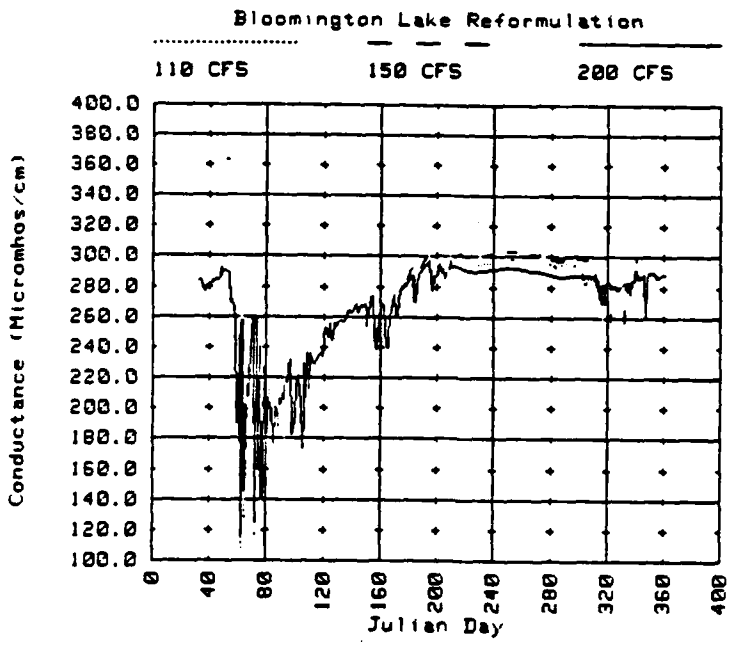
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 122



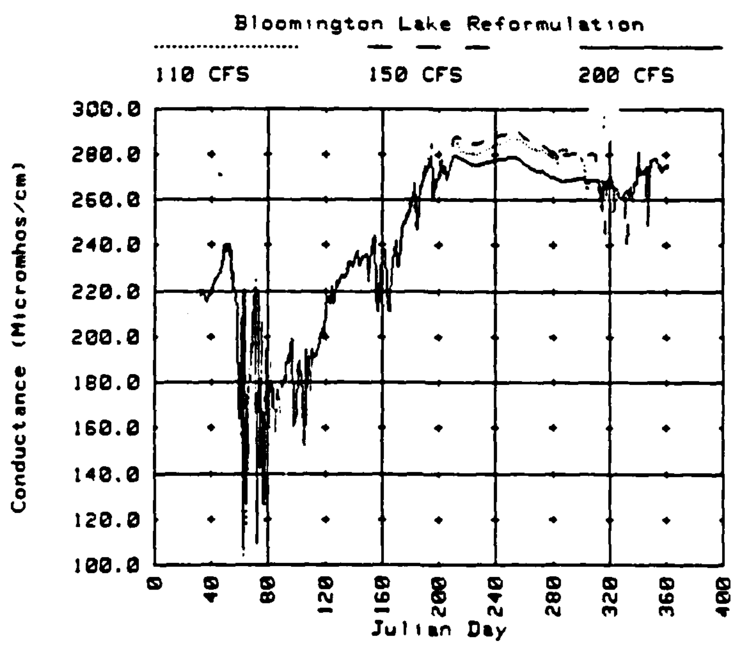
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Worst Case

FIGURE H-II- 123



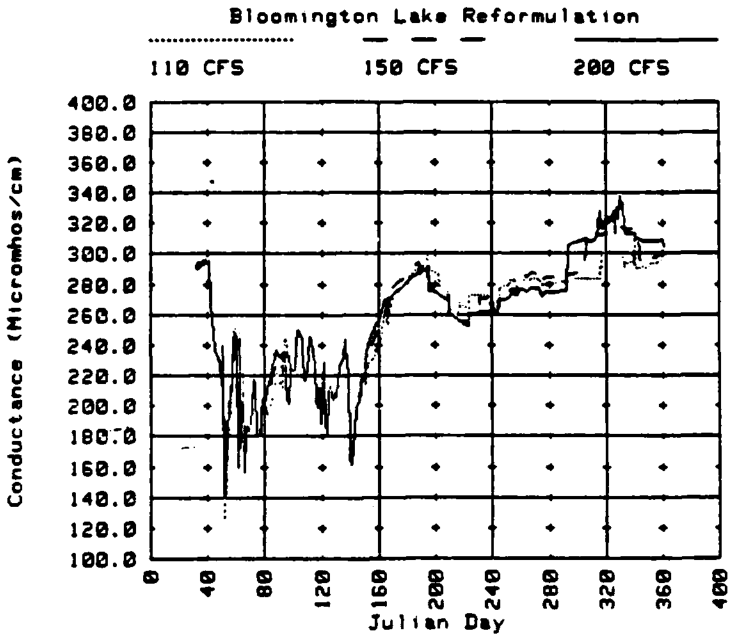
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 124



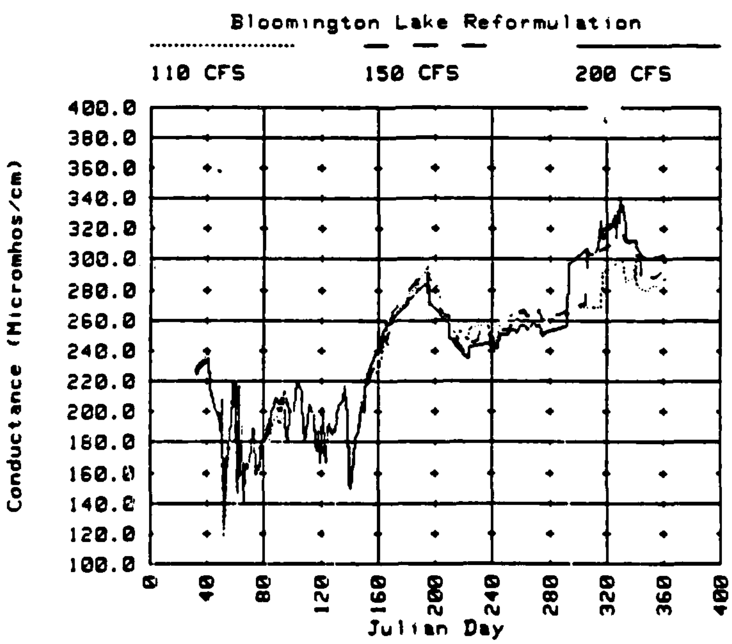
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Worst Case

FIGURE H-II- 125



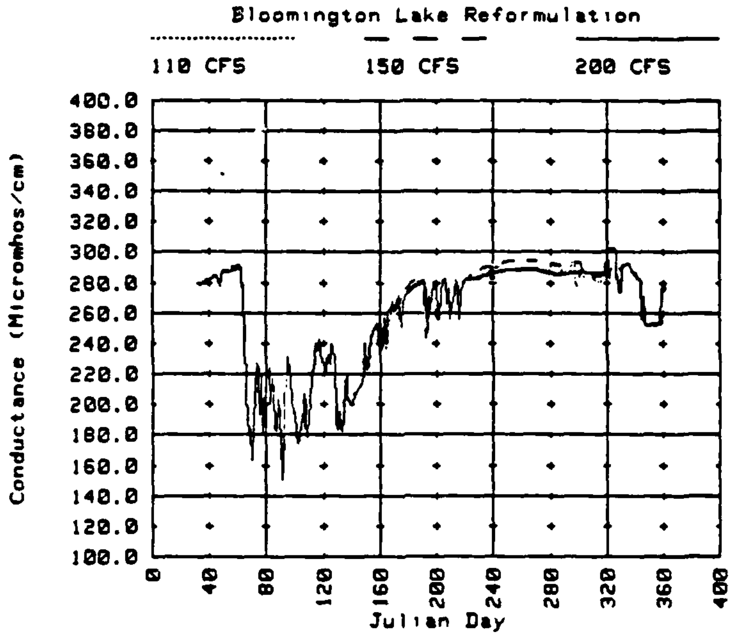
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 126



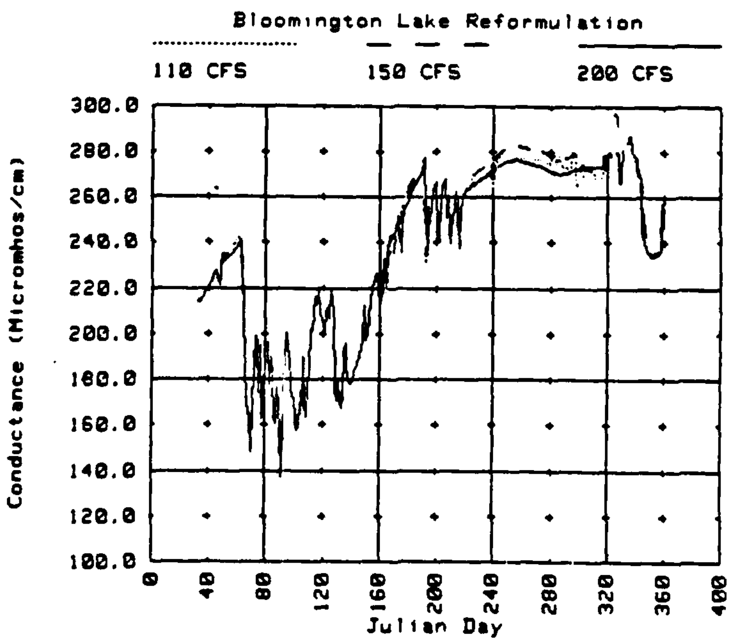
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Worst Case

FIGURE H-II- 127



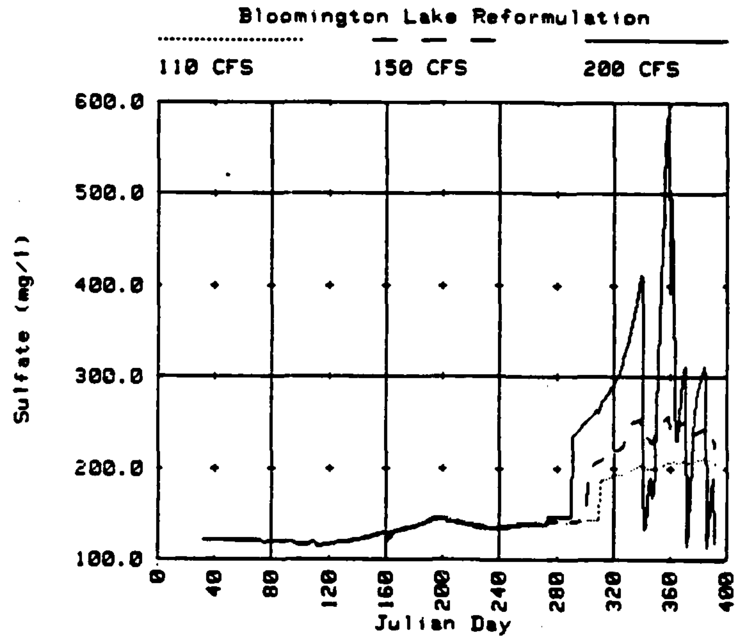
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 128



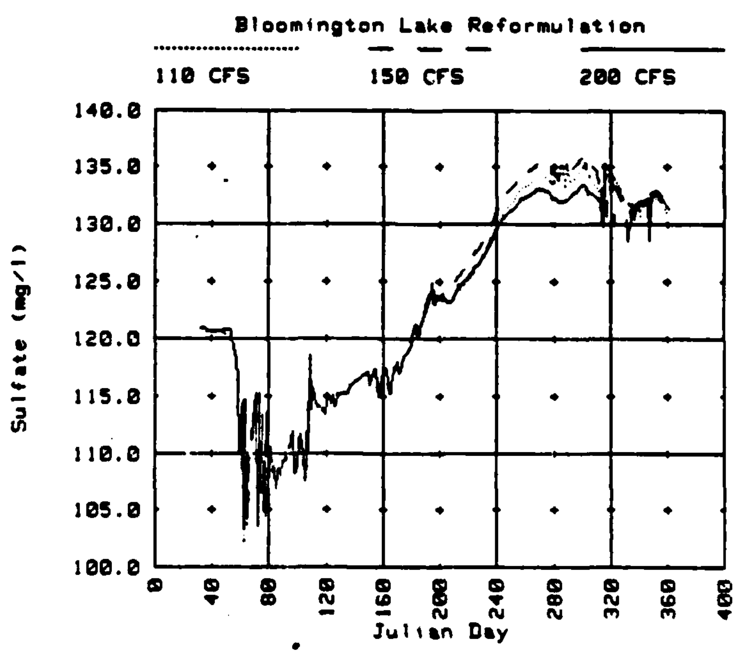
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Worst Case

FIGURE H-II- 129



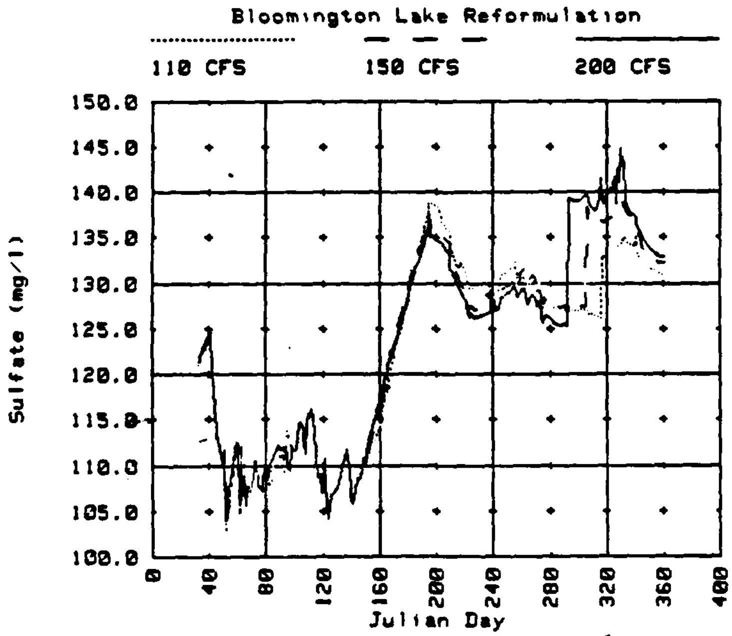
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 130



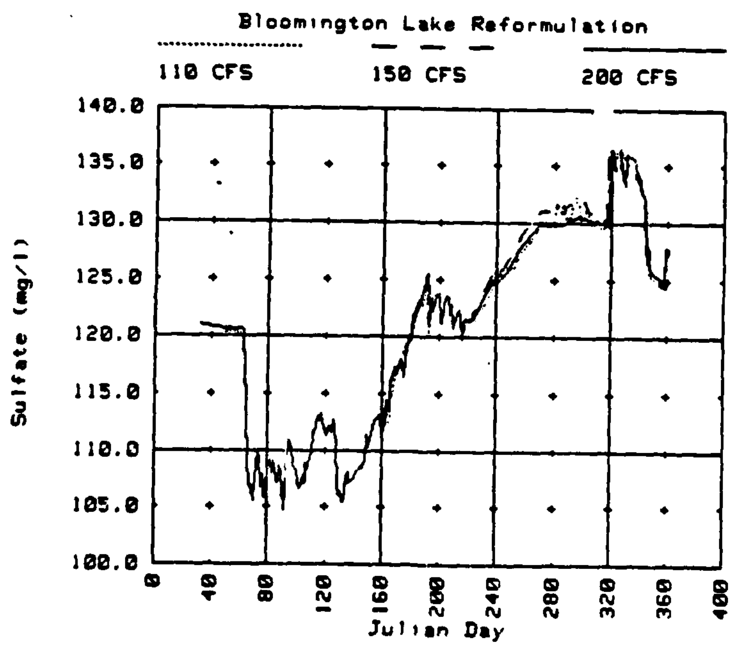
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 131



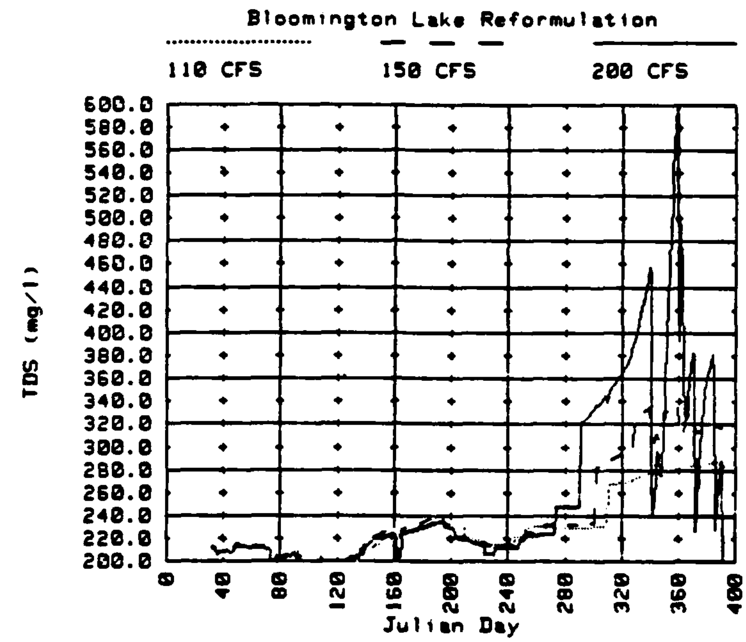
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 132



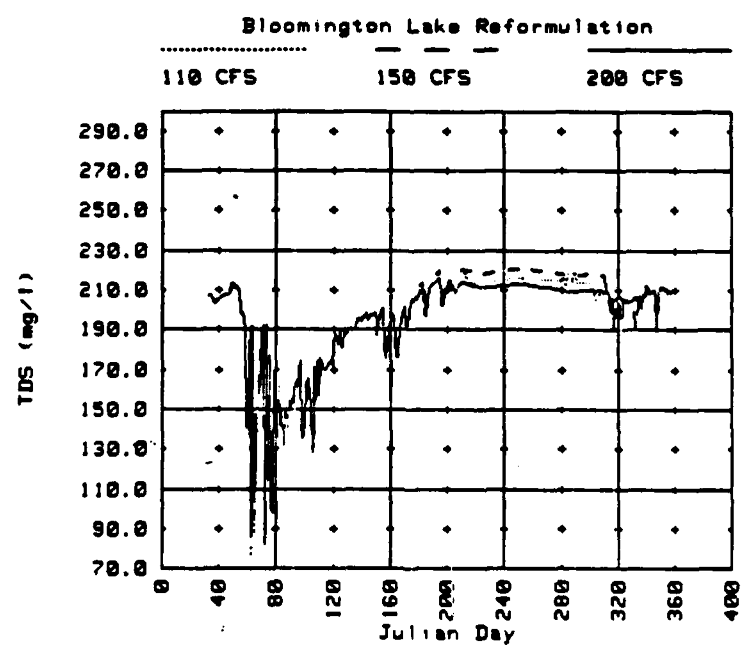
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 133



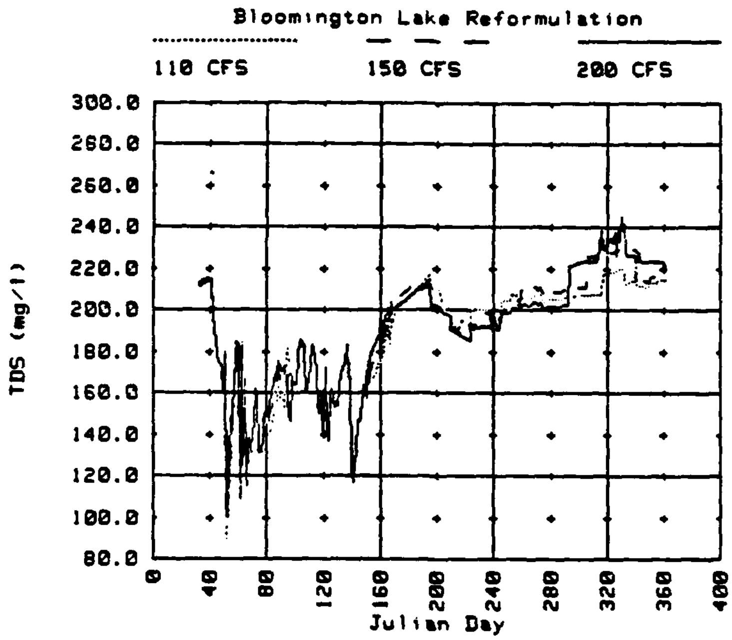
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 134



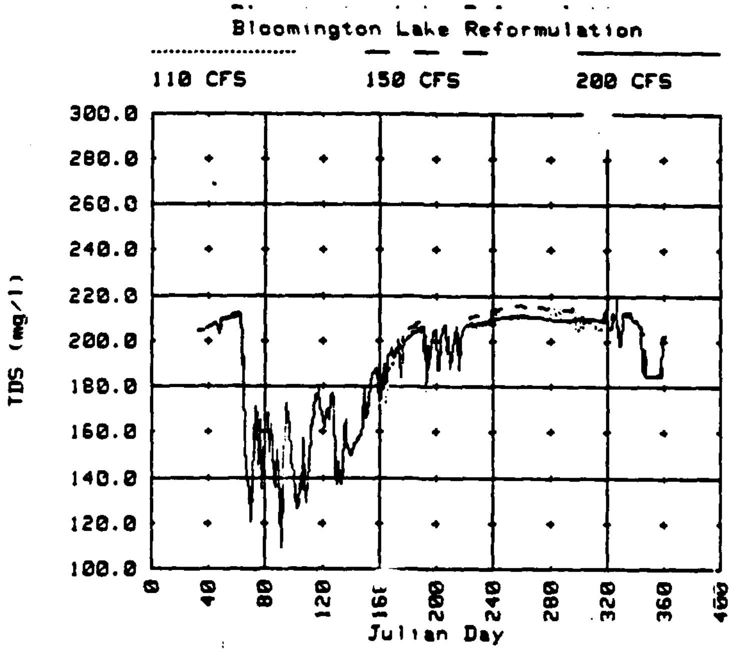
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 135



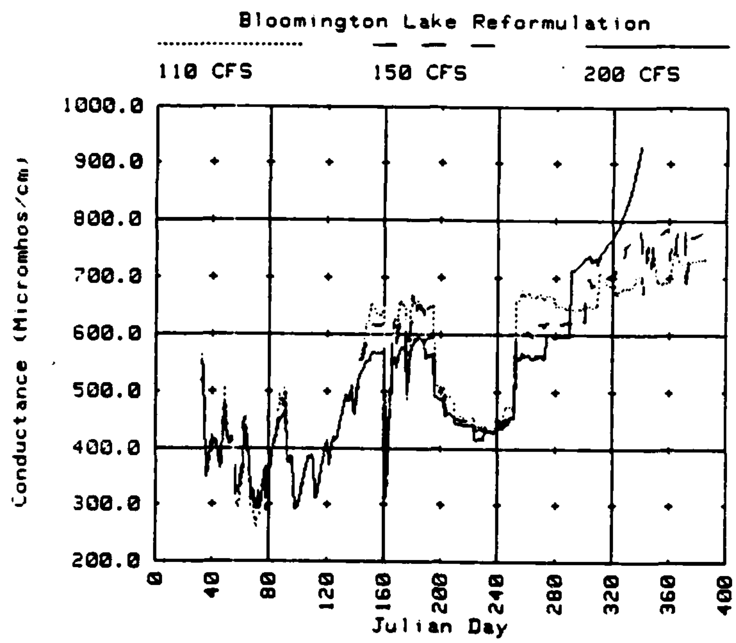
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 136



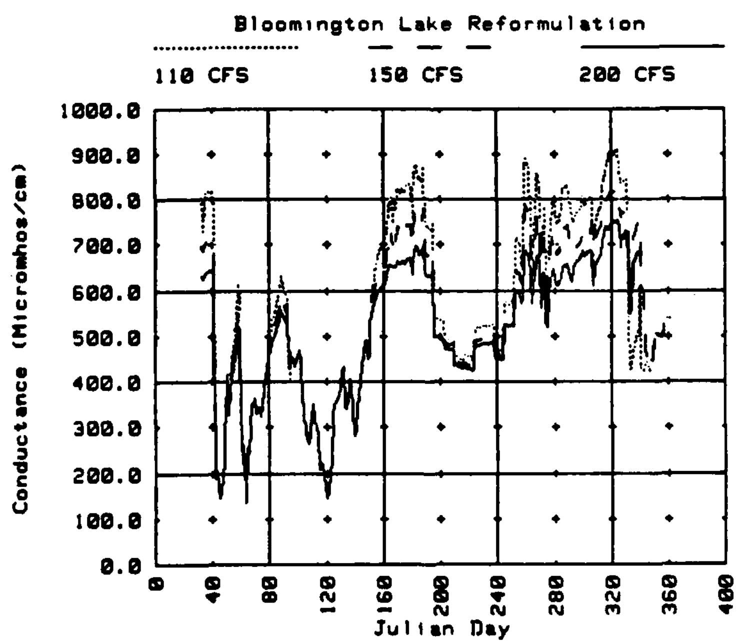
STATION: Luke, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 137



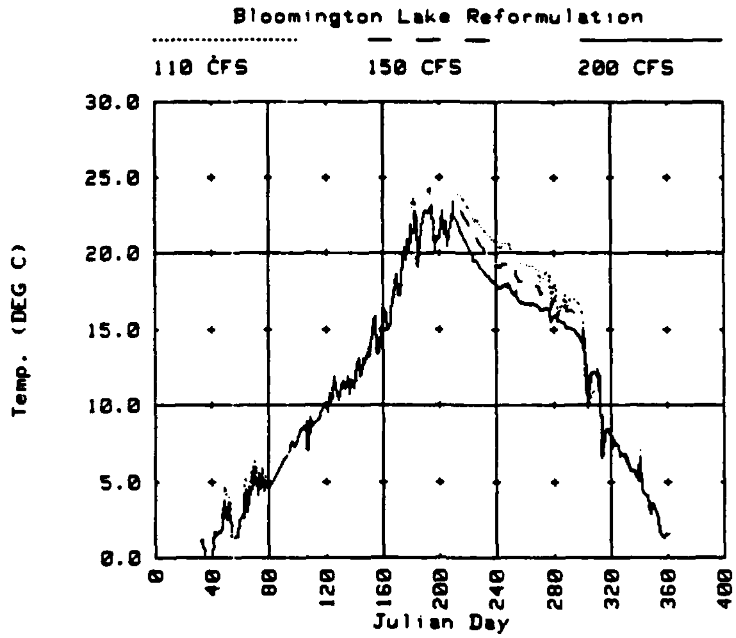
STATION: U/S of New Creek
YEAR: 1938
WATER QUALITY: Best Case
WESTVACO:ESTIMATED FUTURE PROCESS

FIGURE H-II- 138



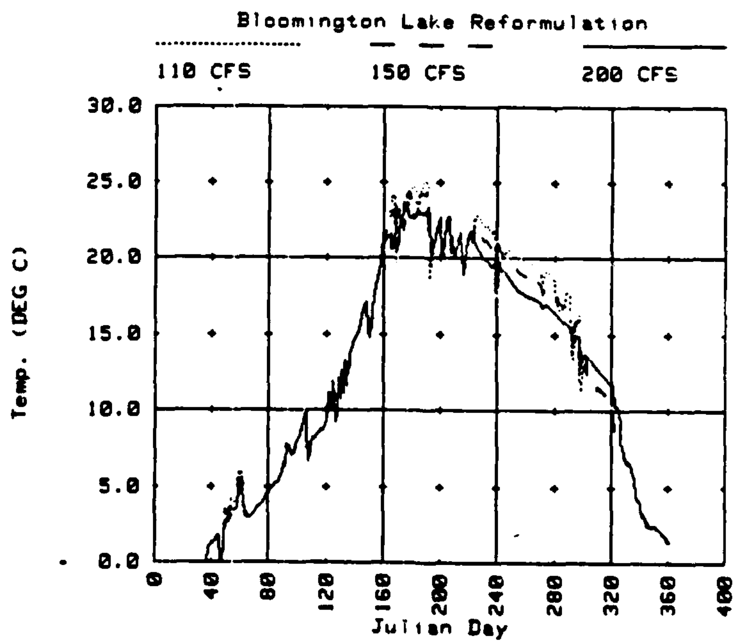
STATION: U/S of New Creek
YEAR: 1966
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 139



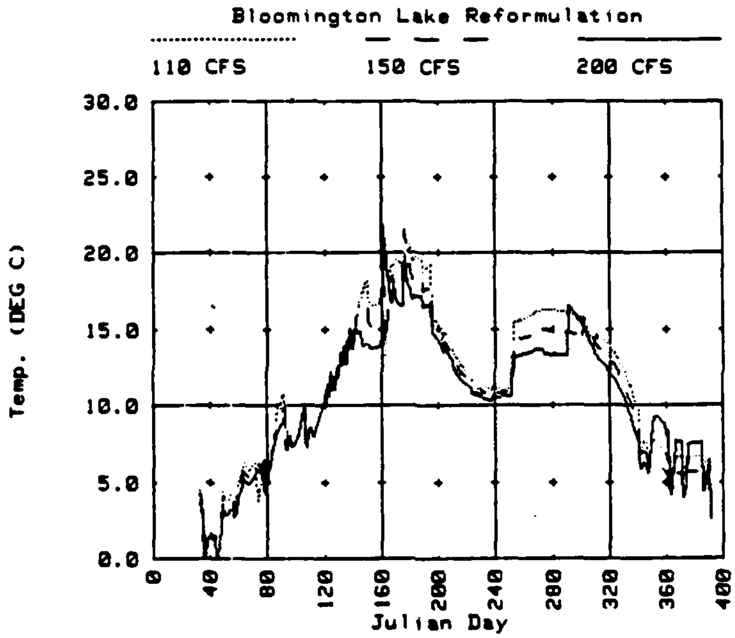
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case

FIGURE H-II- 140



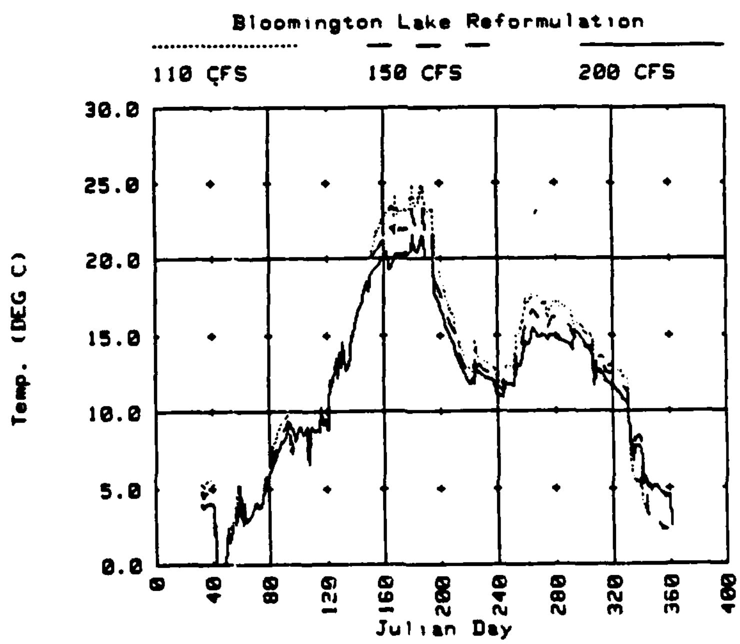
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case

FIGURE H-II- 141



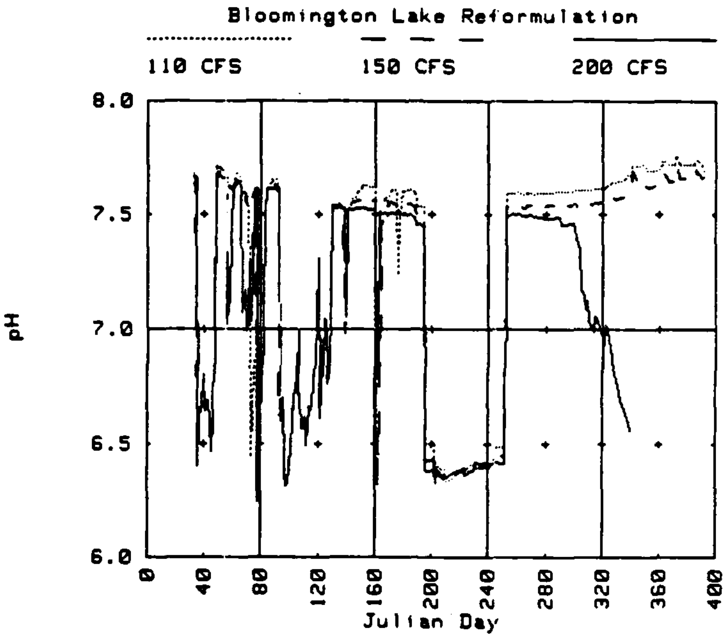
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case

FIGURE H-II- 142



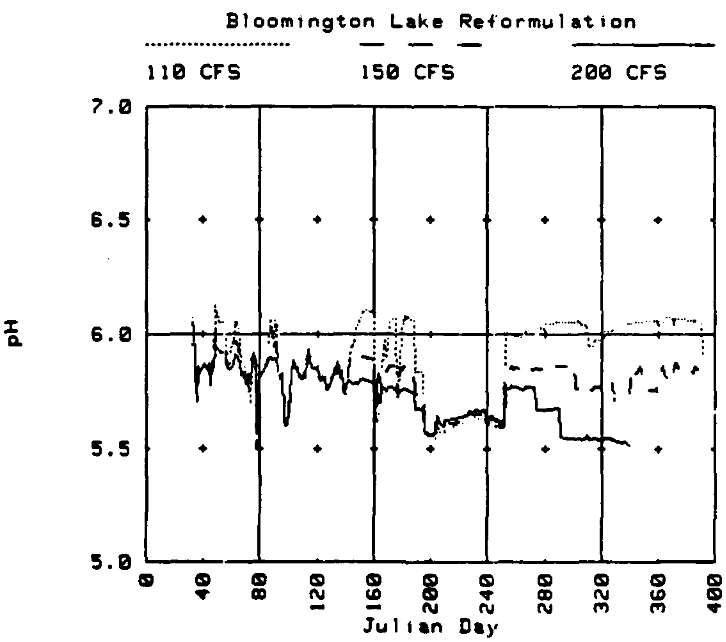
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case

FIGURE H-II- 143



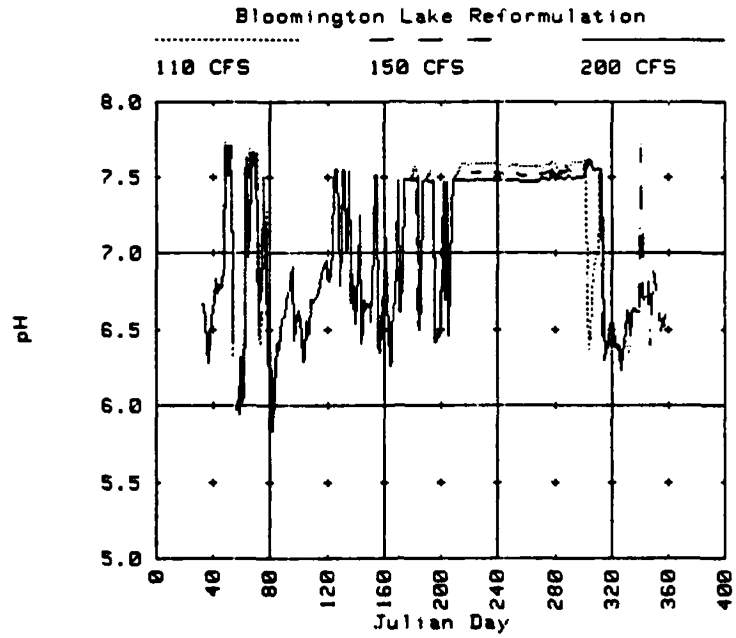
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 144



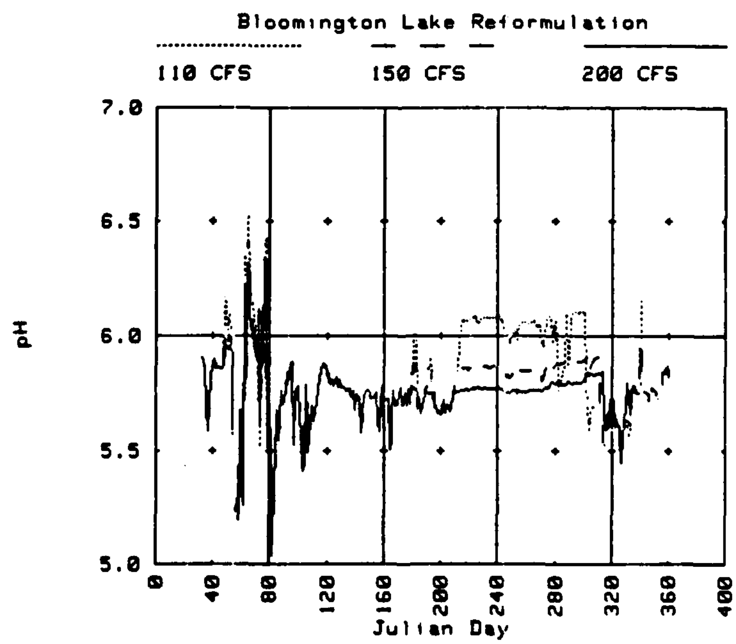
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 145



STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 146



STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 147

AD-A134 160 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY APPENDIX H BLOOMINGTON LA..(U) CORPS OF ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83

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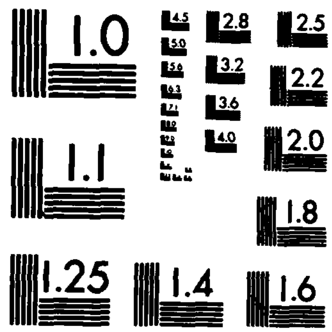
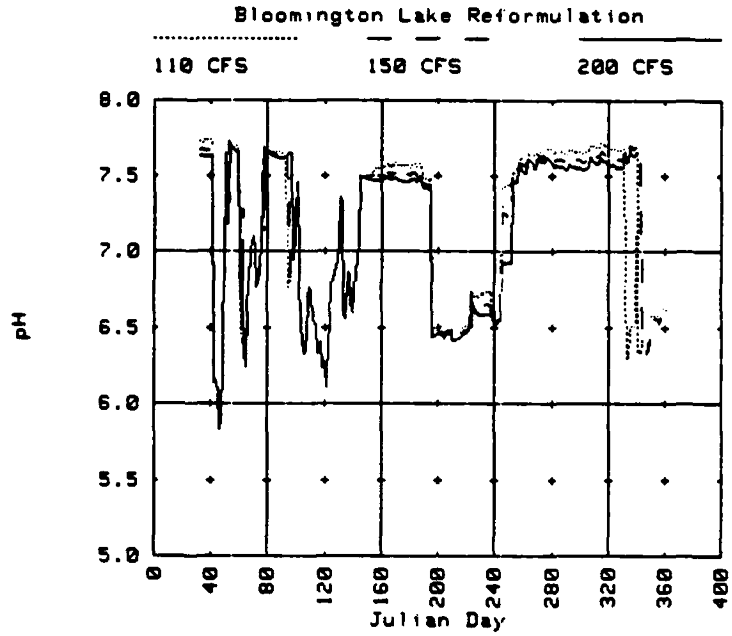
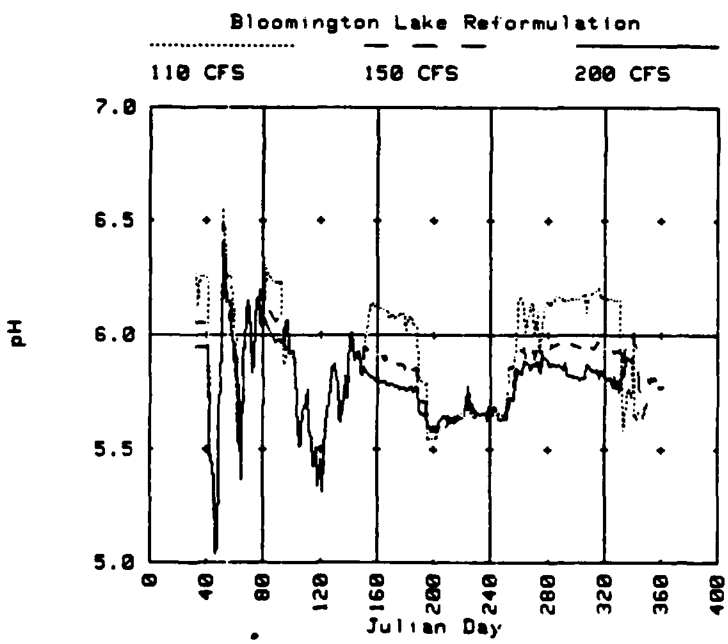


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



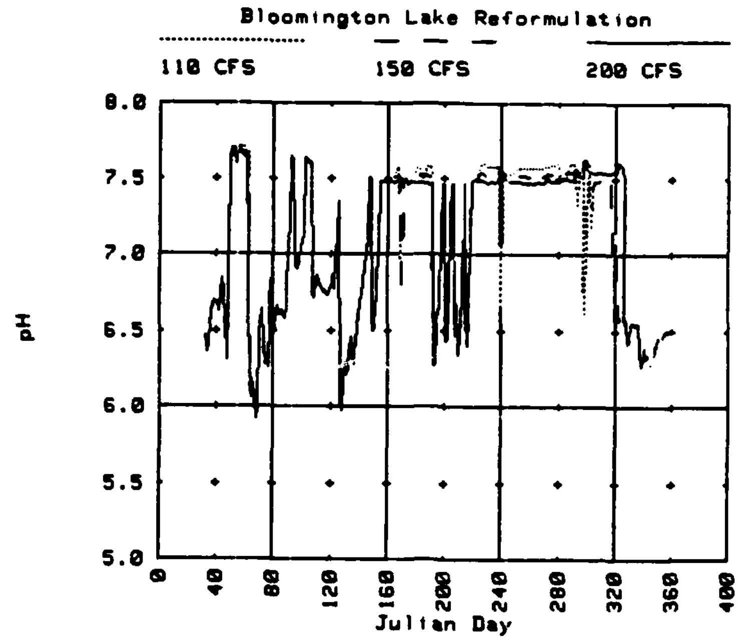
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 148



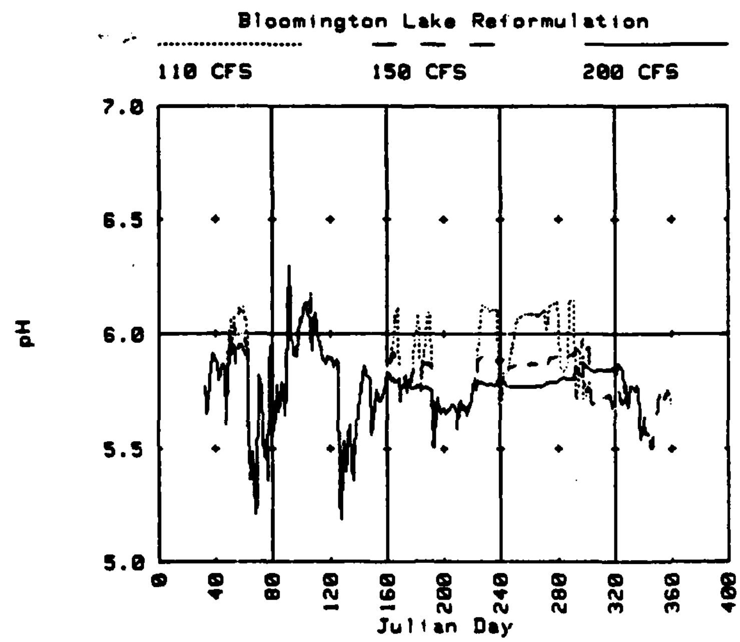
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 149



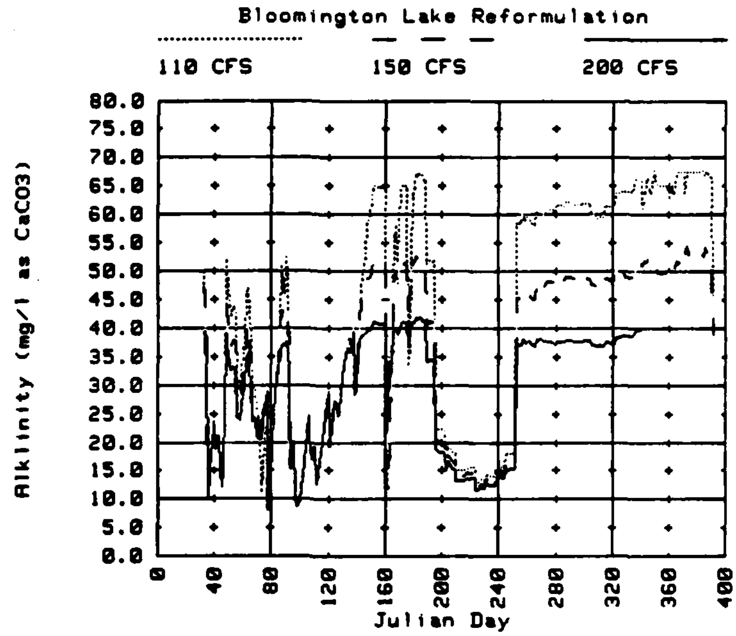
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 150



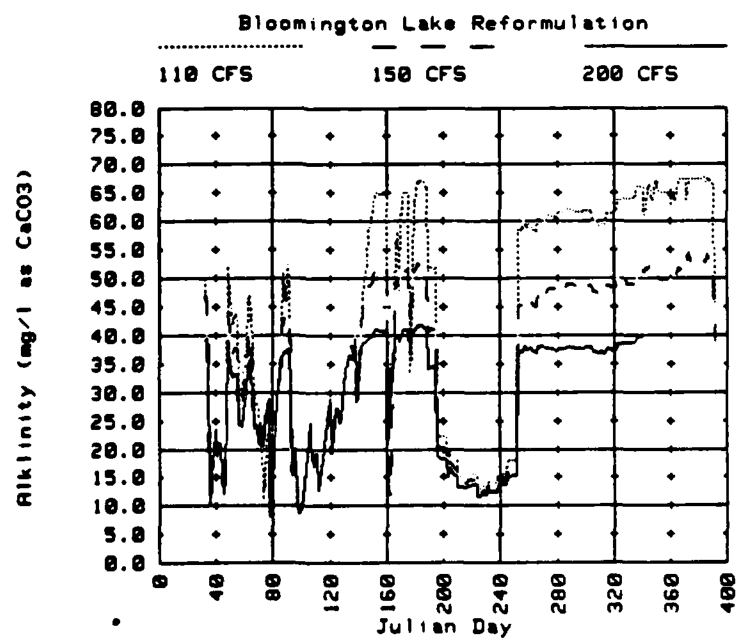
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 151



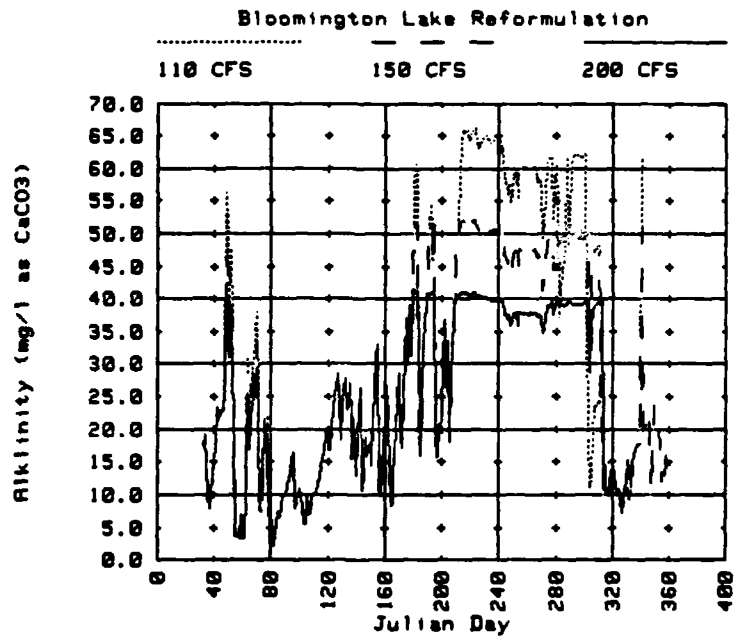
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 152



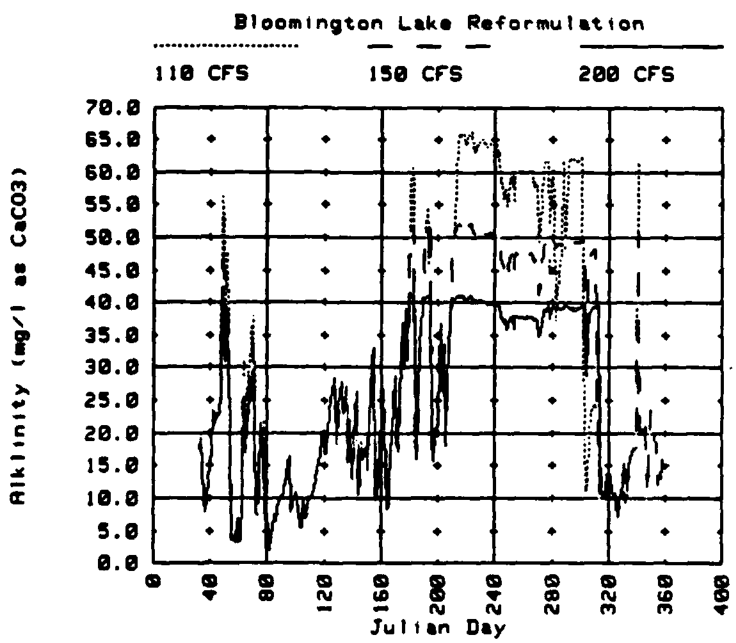
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 153



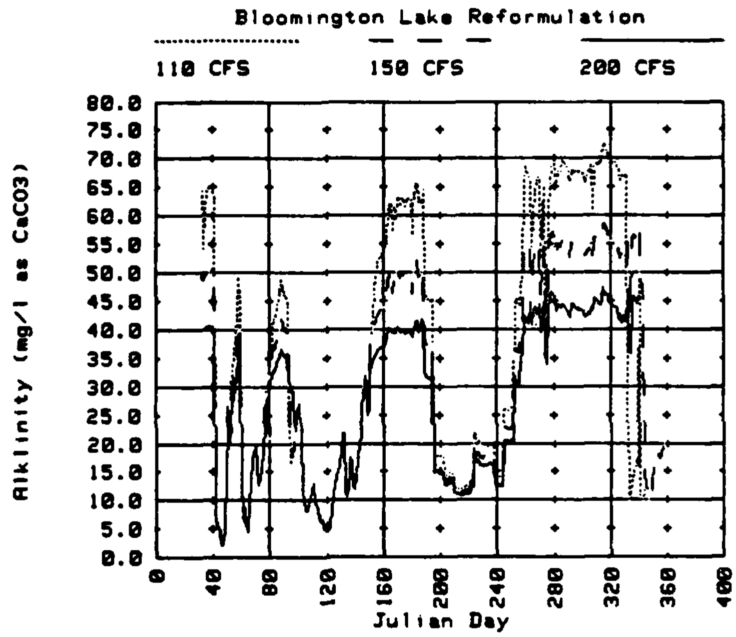
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 154



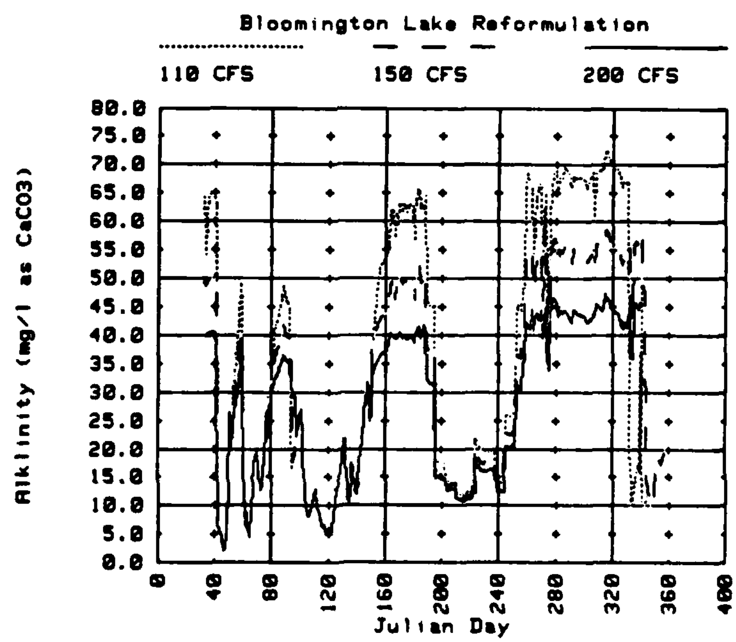
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 155



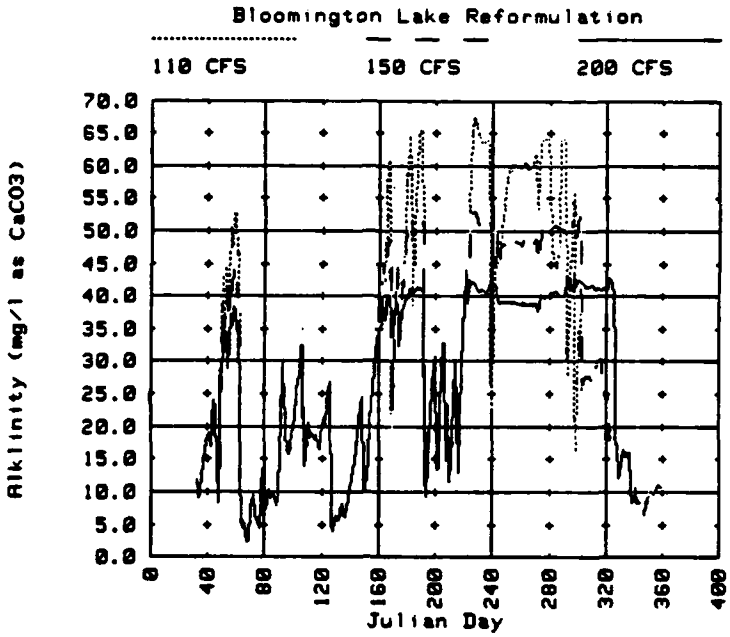
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 156



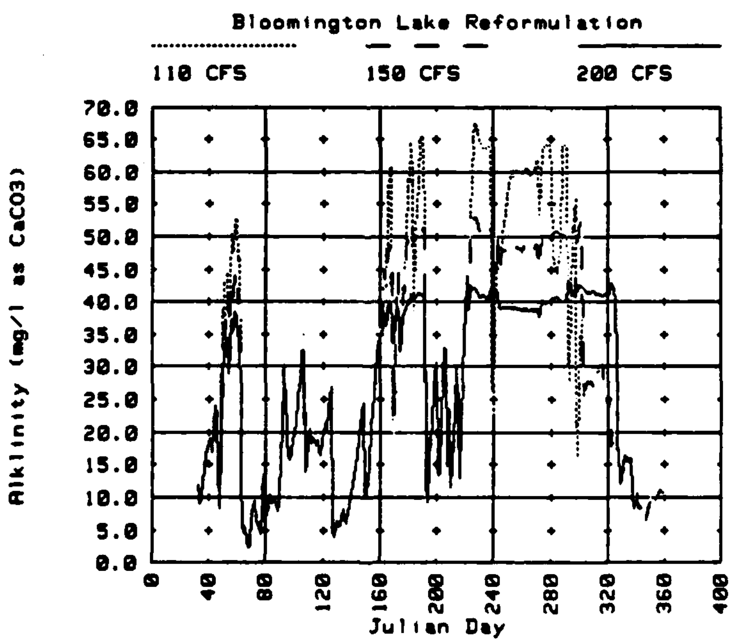
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 157



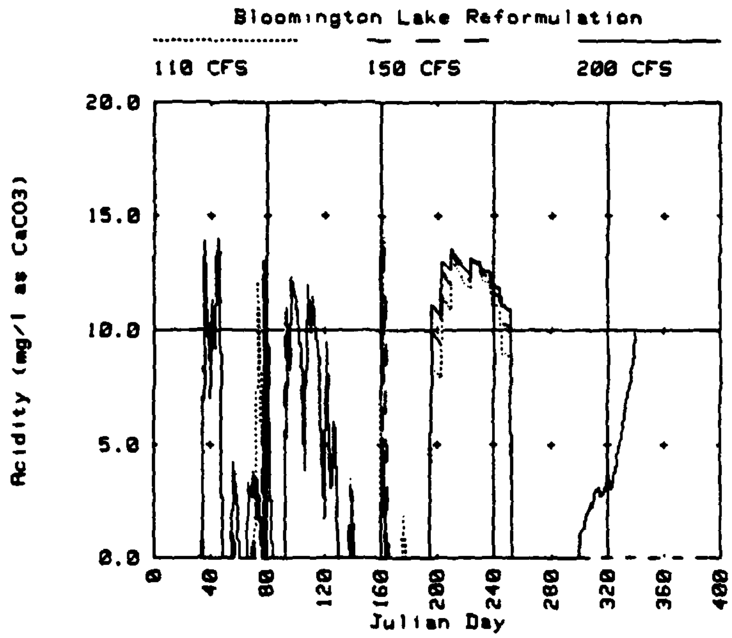
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 158



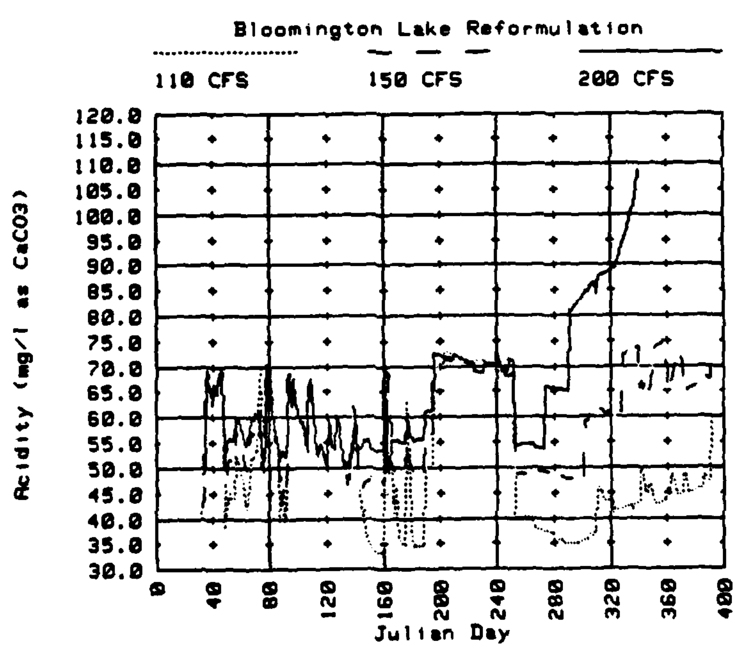
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 159



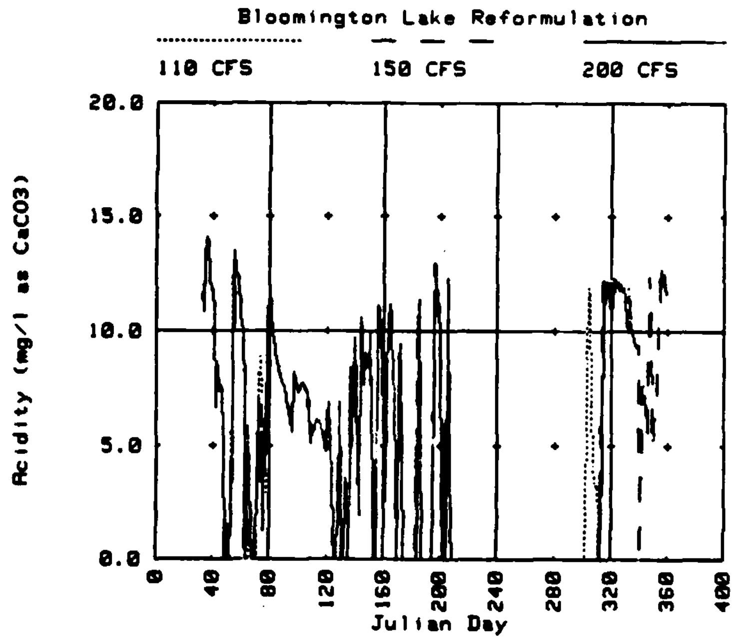
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 160



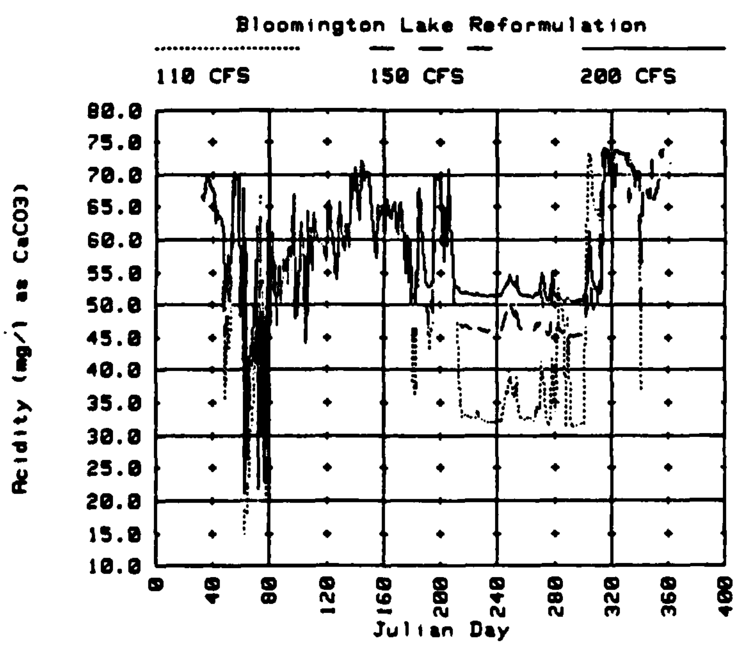
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 161



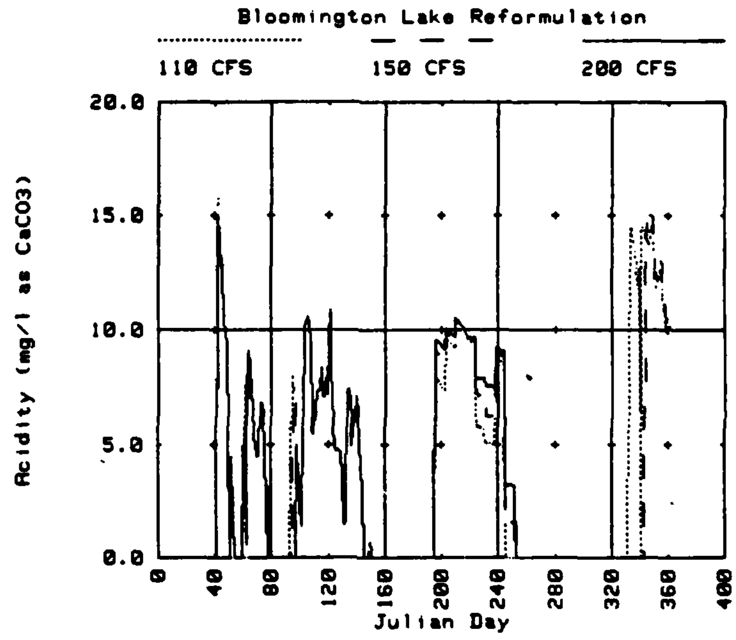
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 162



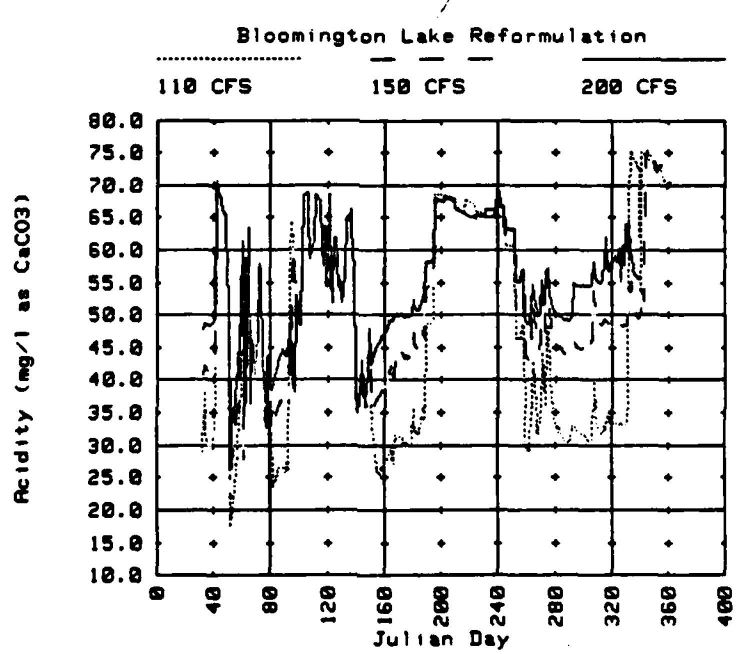
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 163



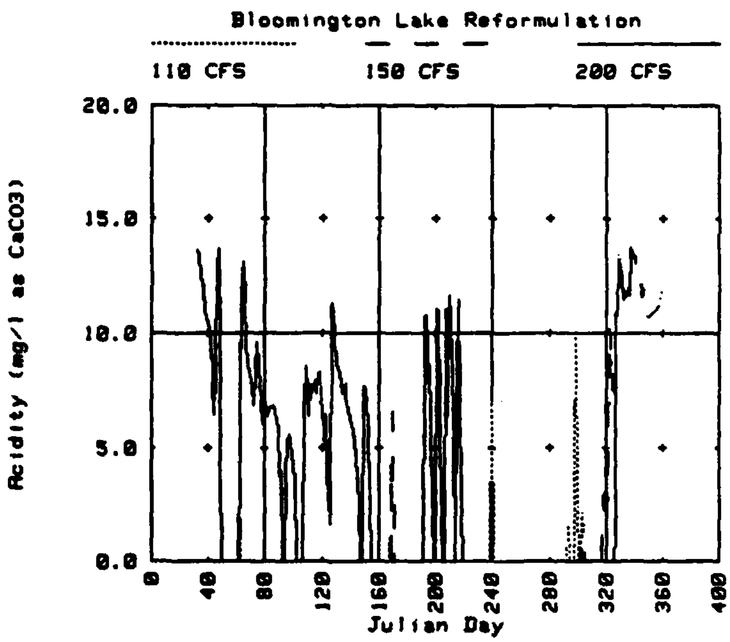
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 164



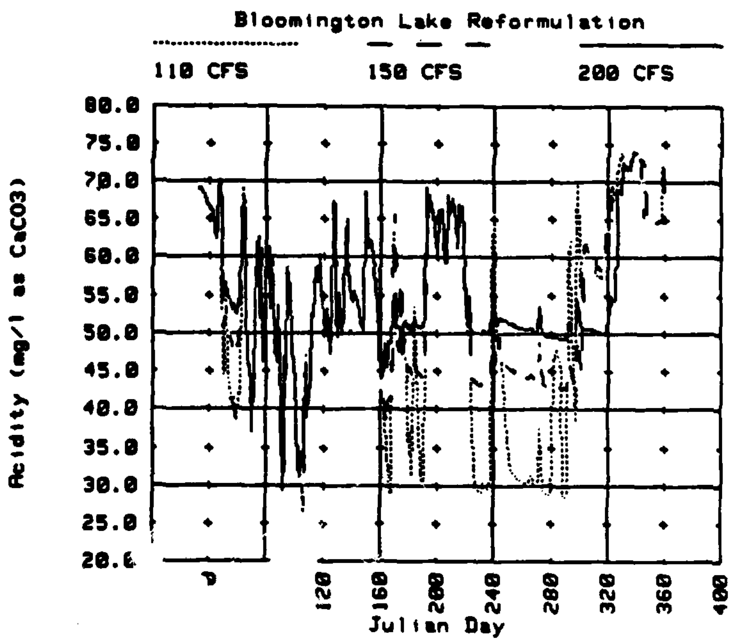
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 165



STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 166



STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 167

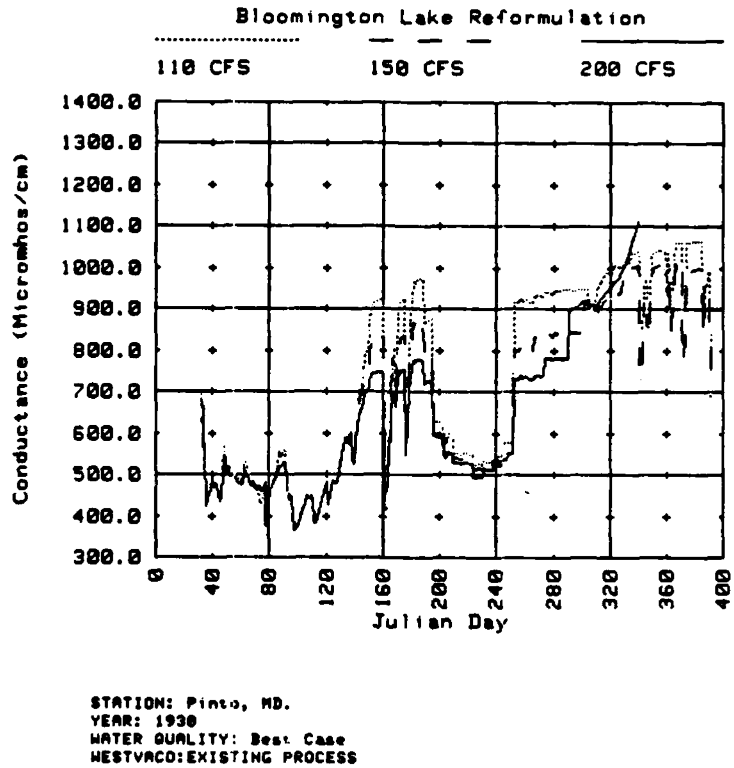


FIGURE H-II- 168

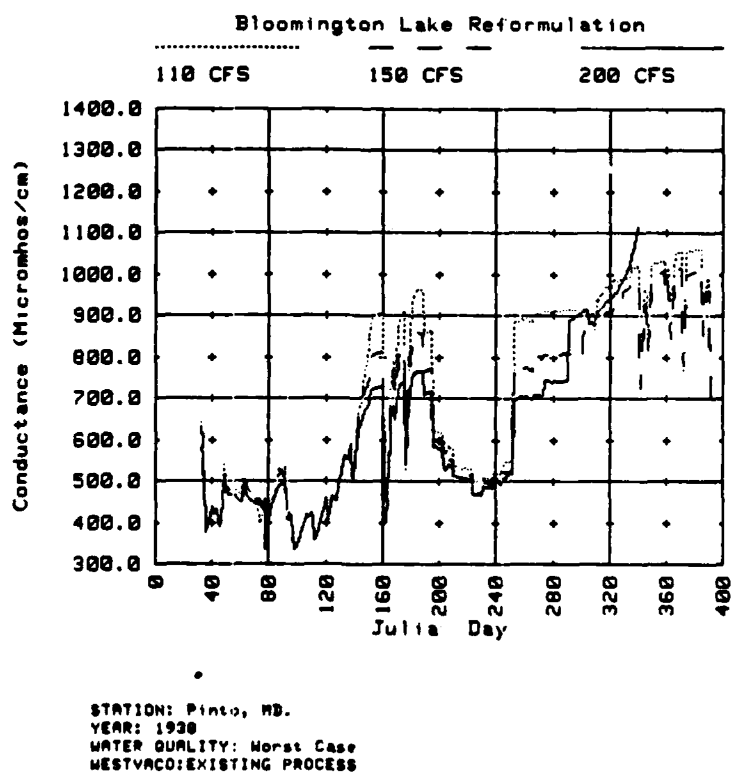
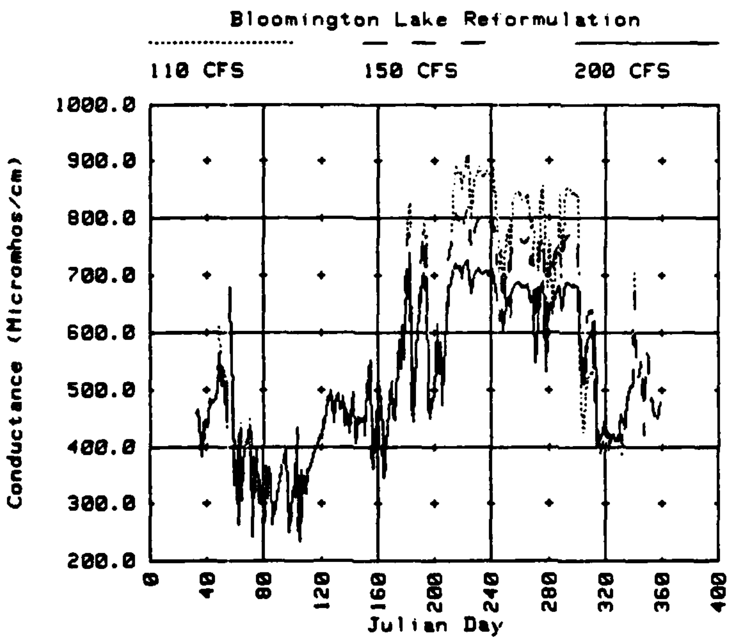
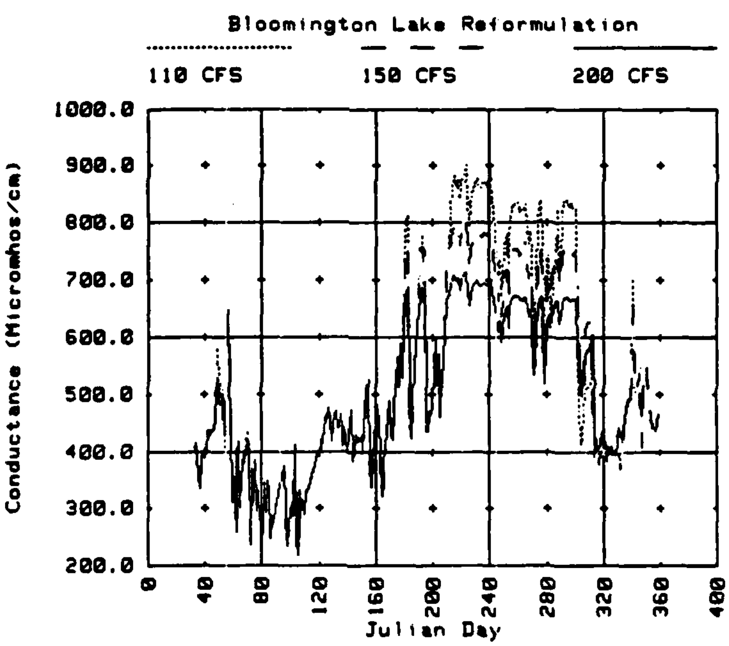


FIGURE H-II- 169



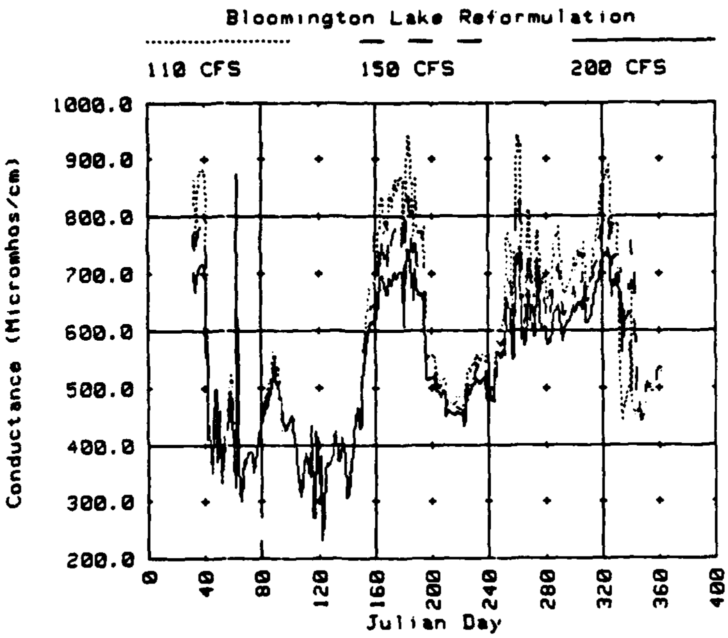
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 170



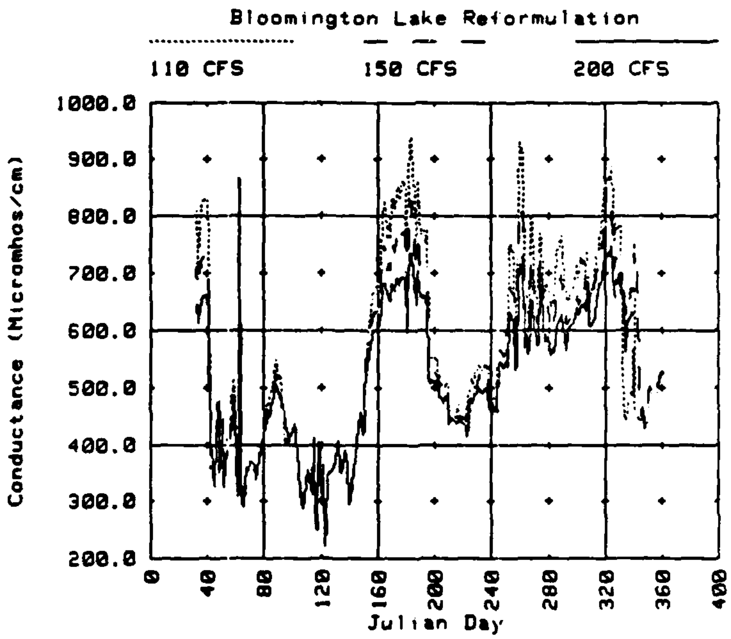
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 171



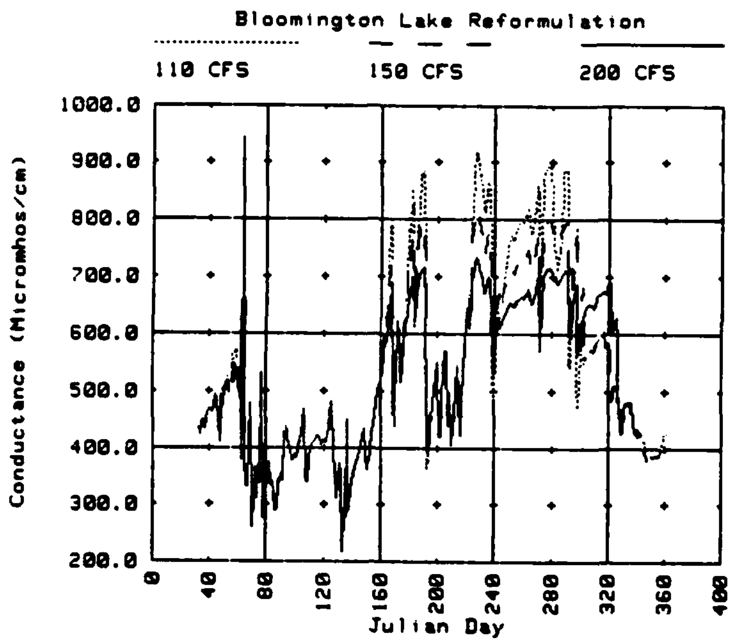
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 172



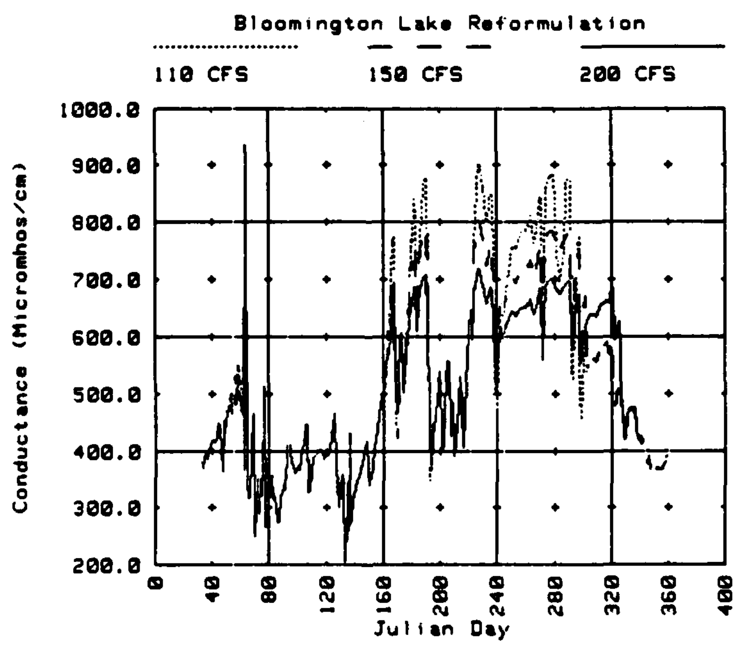
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 173



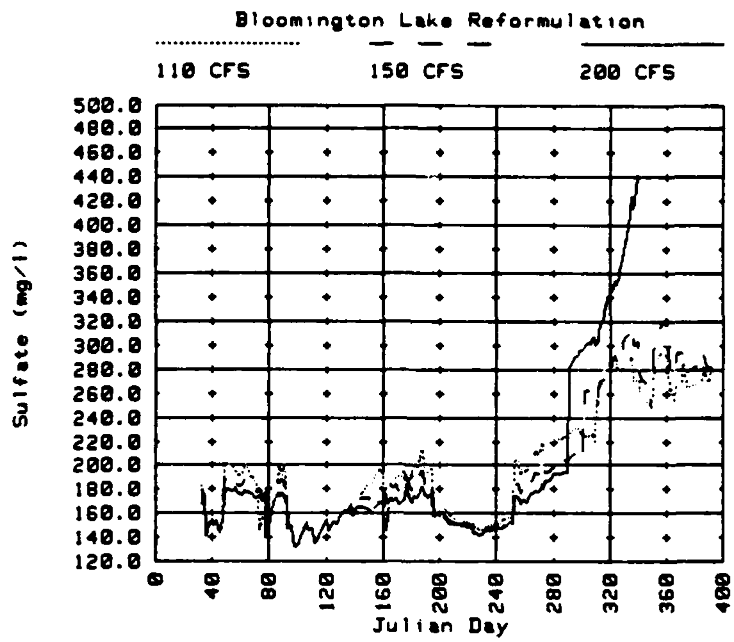
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 174



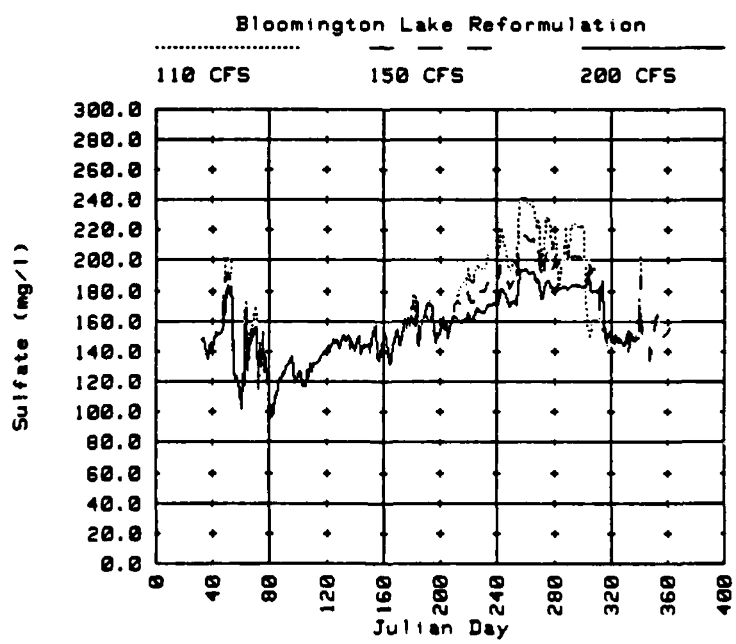
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Worst Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 175



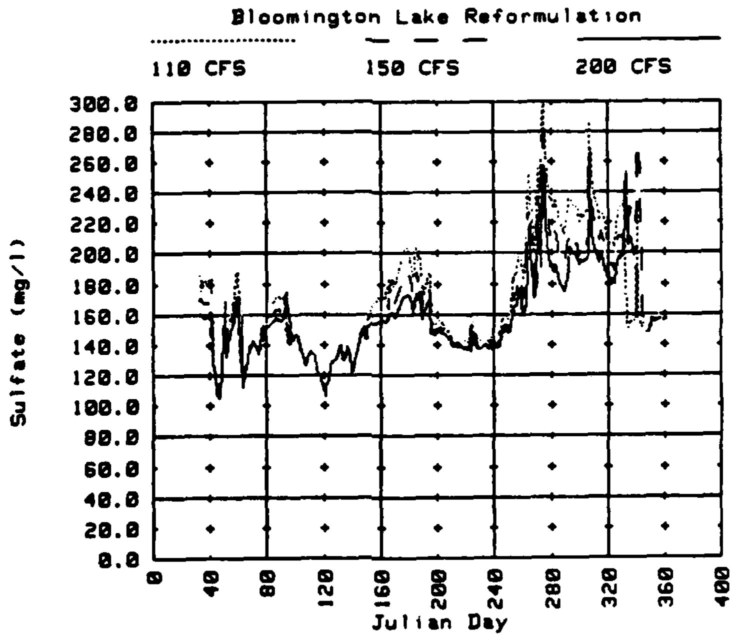
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 176



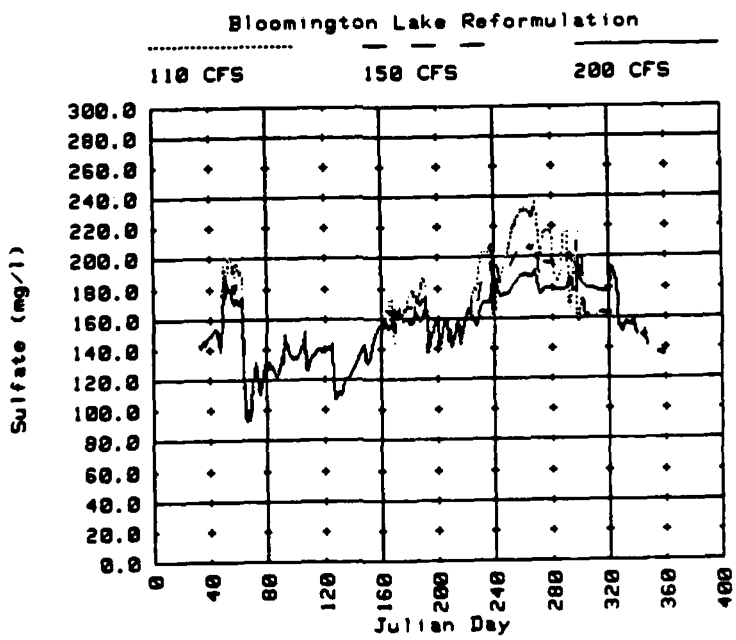
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 177



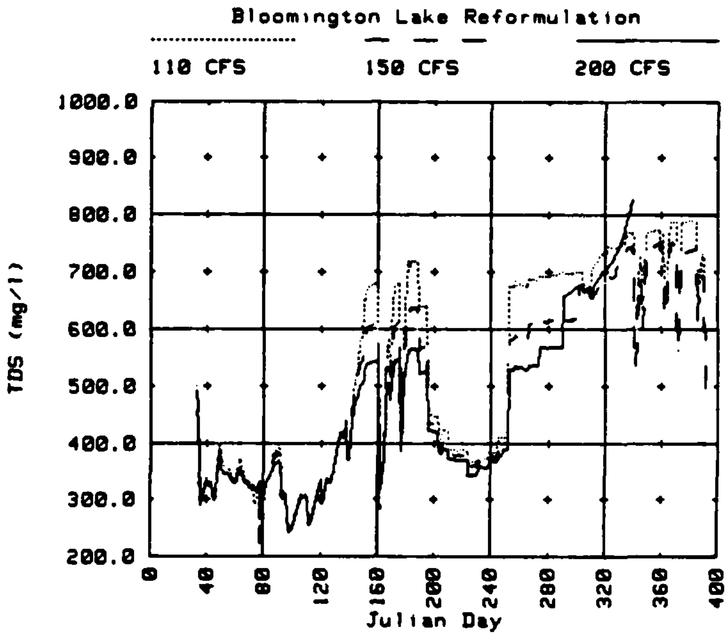
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 178



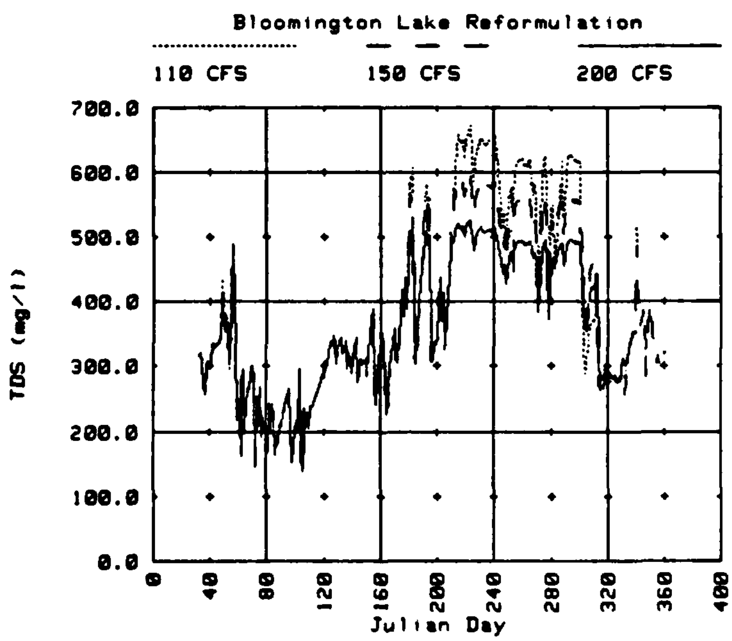
STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 179



STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

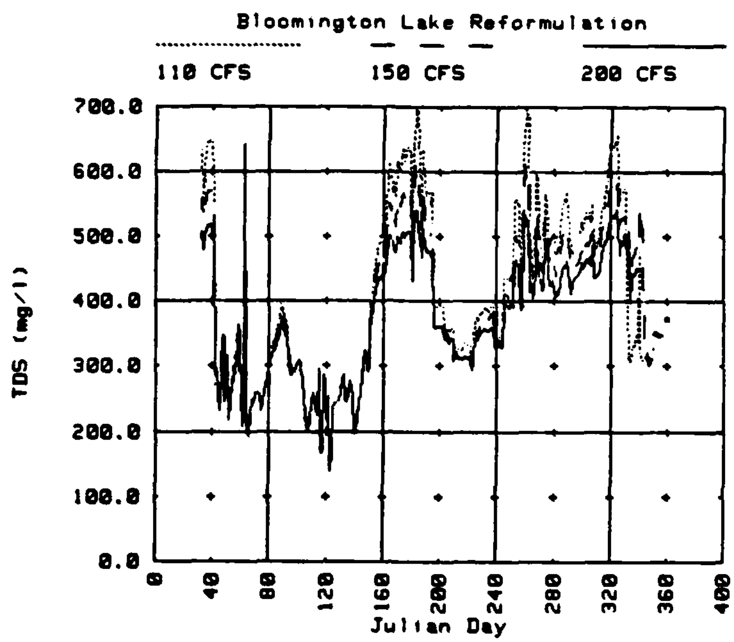
FIGURE H-II- 180



STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

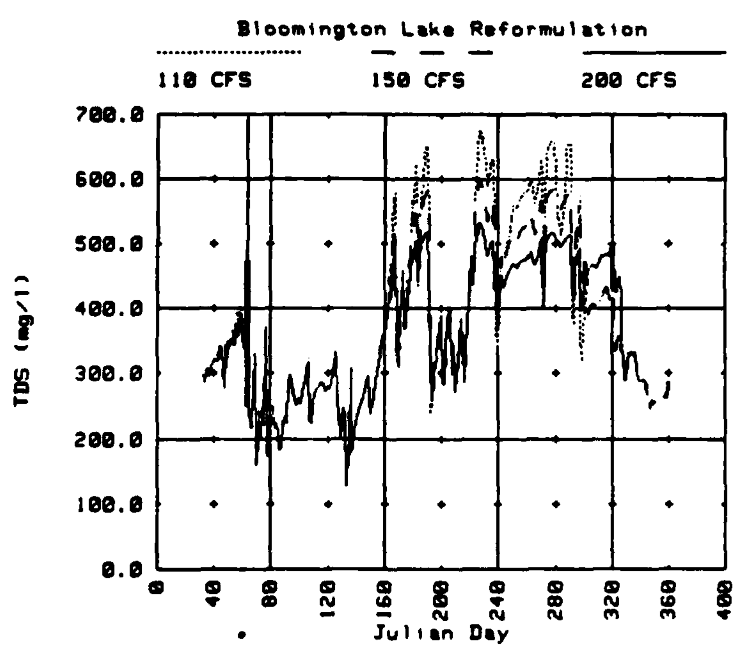
FIGURE H-II- 181

H-II-181



STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

FIGURE H-II- 182



STATION: Pinto, MD.
YEAR: 1967
WATER QUALITY: Best Case
WESTVACO:EXISTING PROCESS

H-II-150

FIGURE H-II- 183

FIGURE H-II- 184

BOD and DO projection of the NBPR from below the

UPRC STP to Cumberland, Maryland (Max. BOD loading)

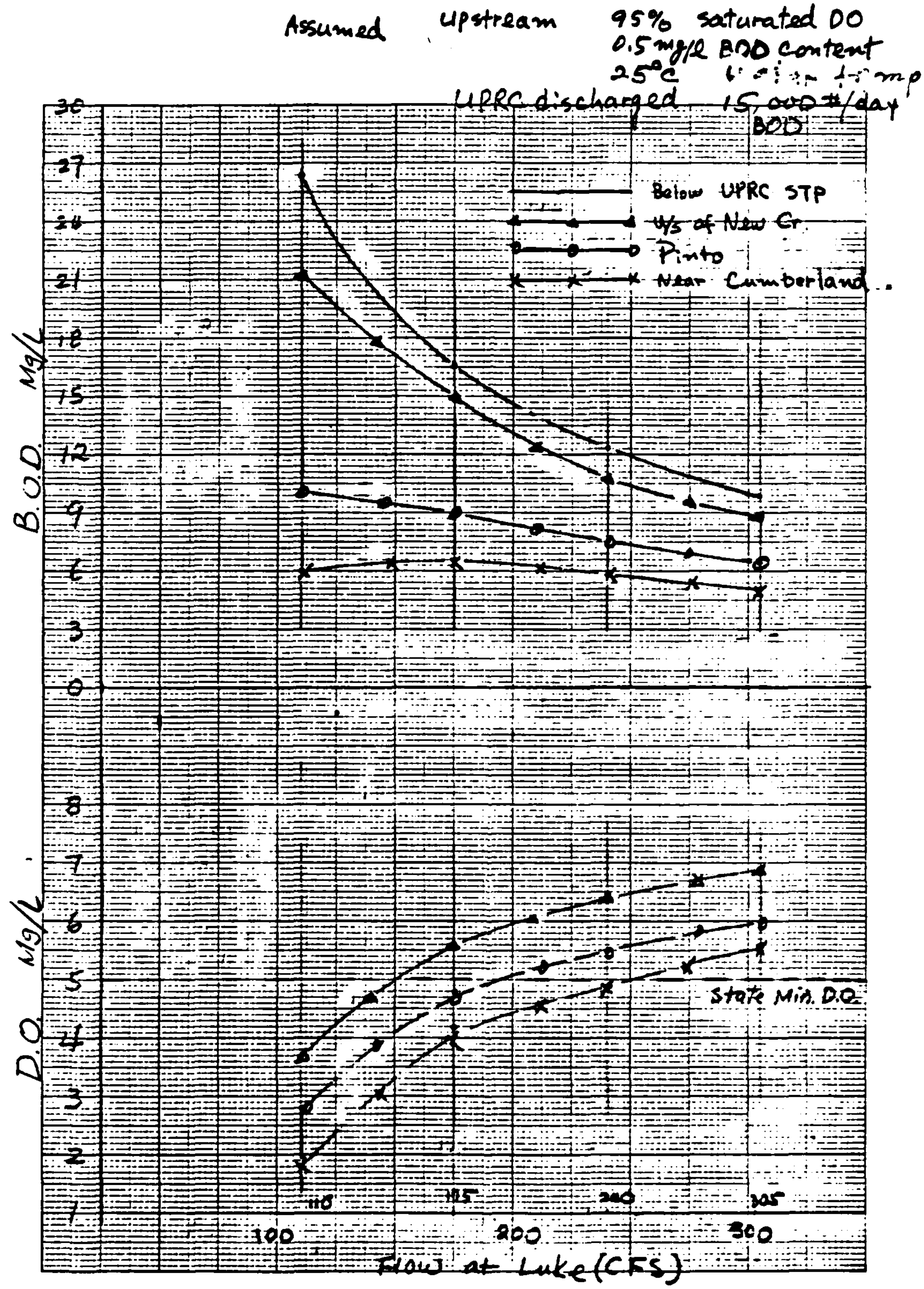


FIGURE H-II- 185

BOD and DO projection of the NBPR from below the UPRC STP to Cumberland, Maryland (average BOD loading)

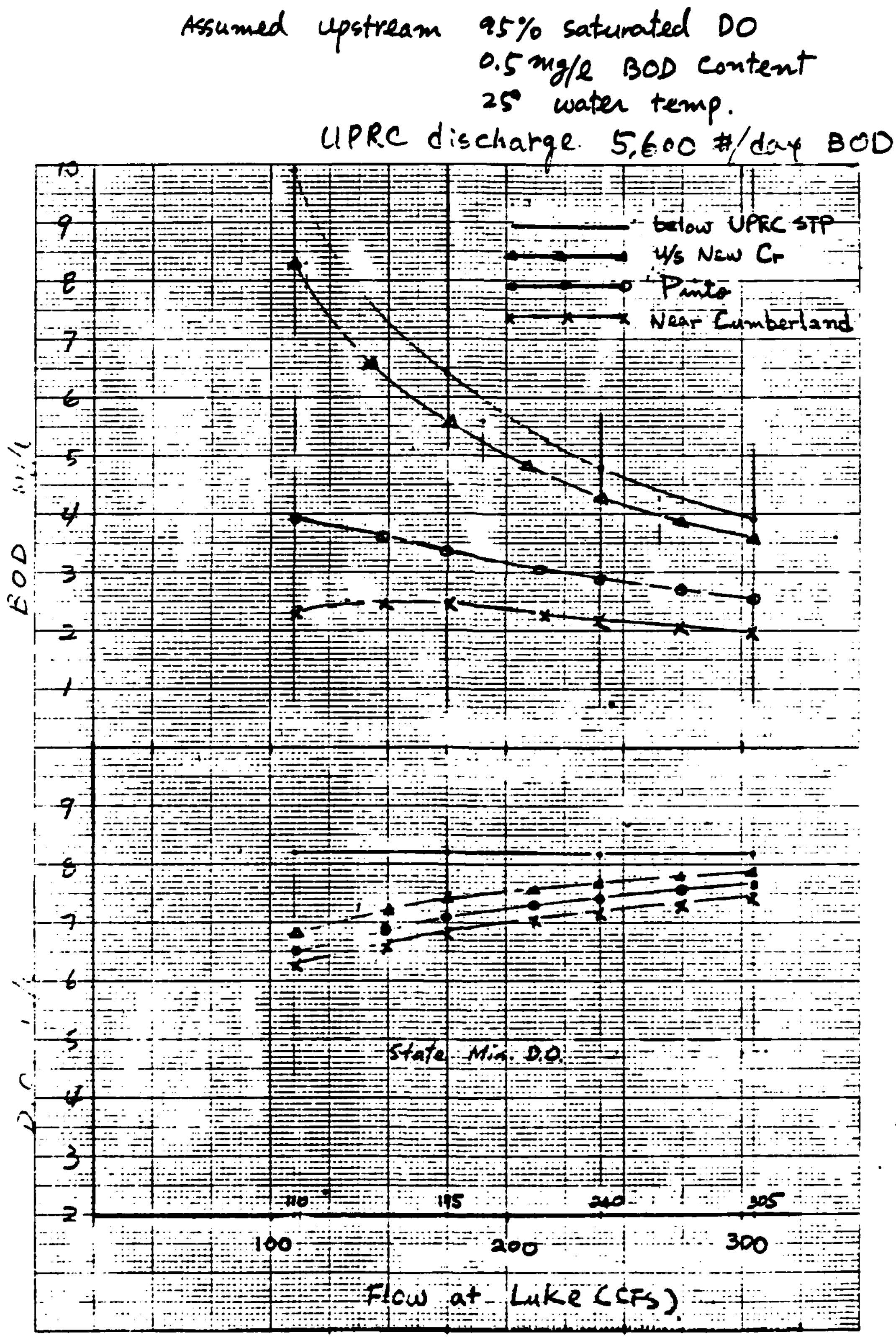
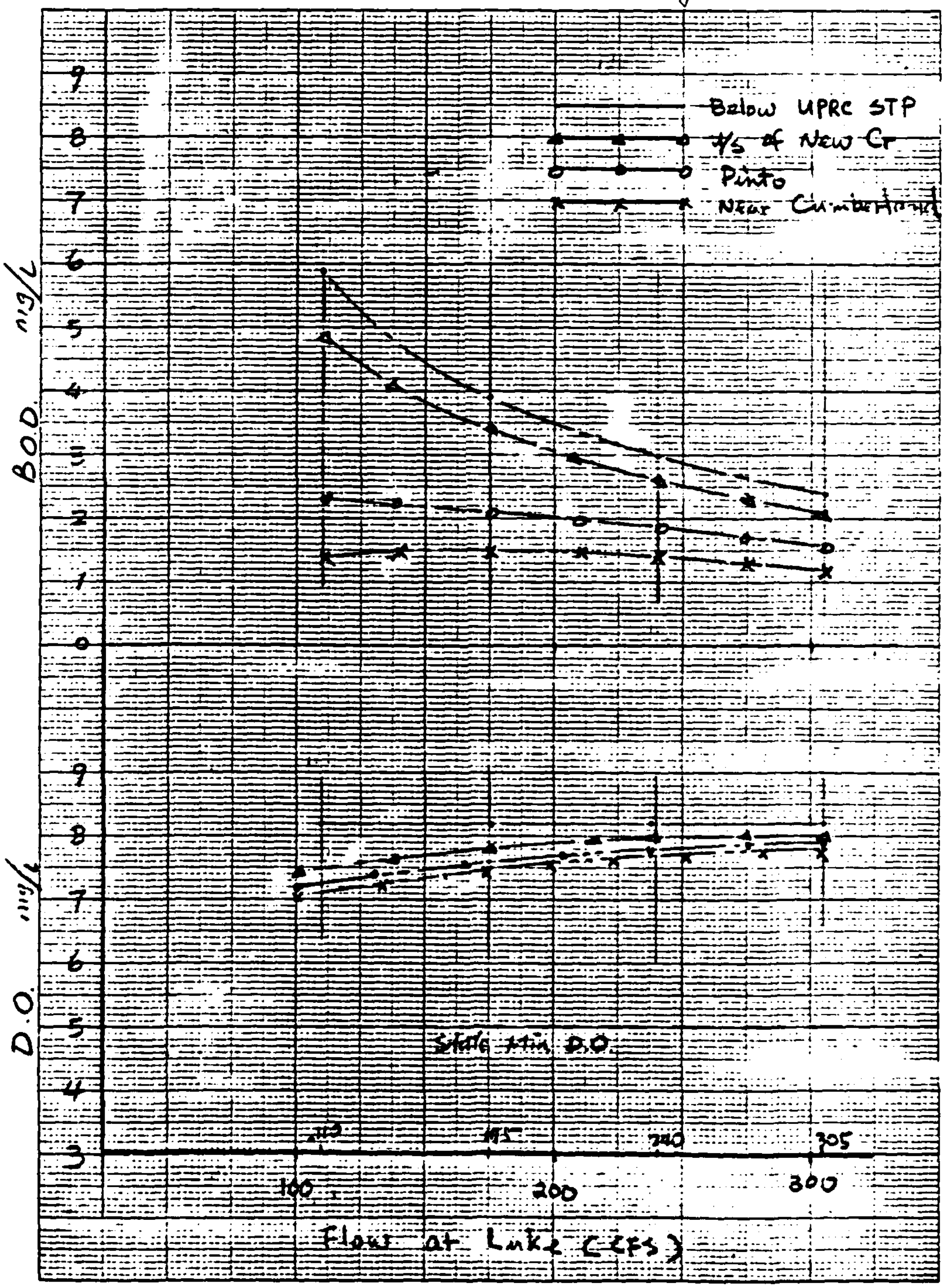


FIGURE H-II- 186

BOD and DO projection of the NBPR from below the UPRC STP to Cumberland, Maryland (Min. BOD loading)

Assumed upstream 95% saturated DO
0.5 mg/ℓ BOD content
25°C water temperature
UPRC discharge 3,200 #/day BOD



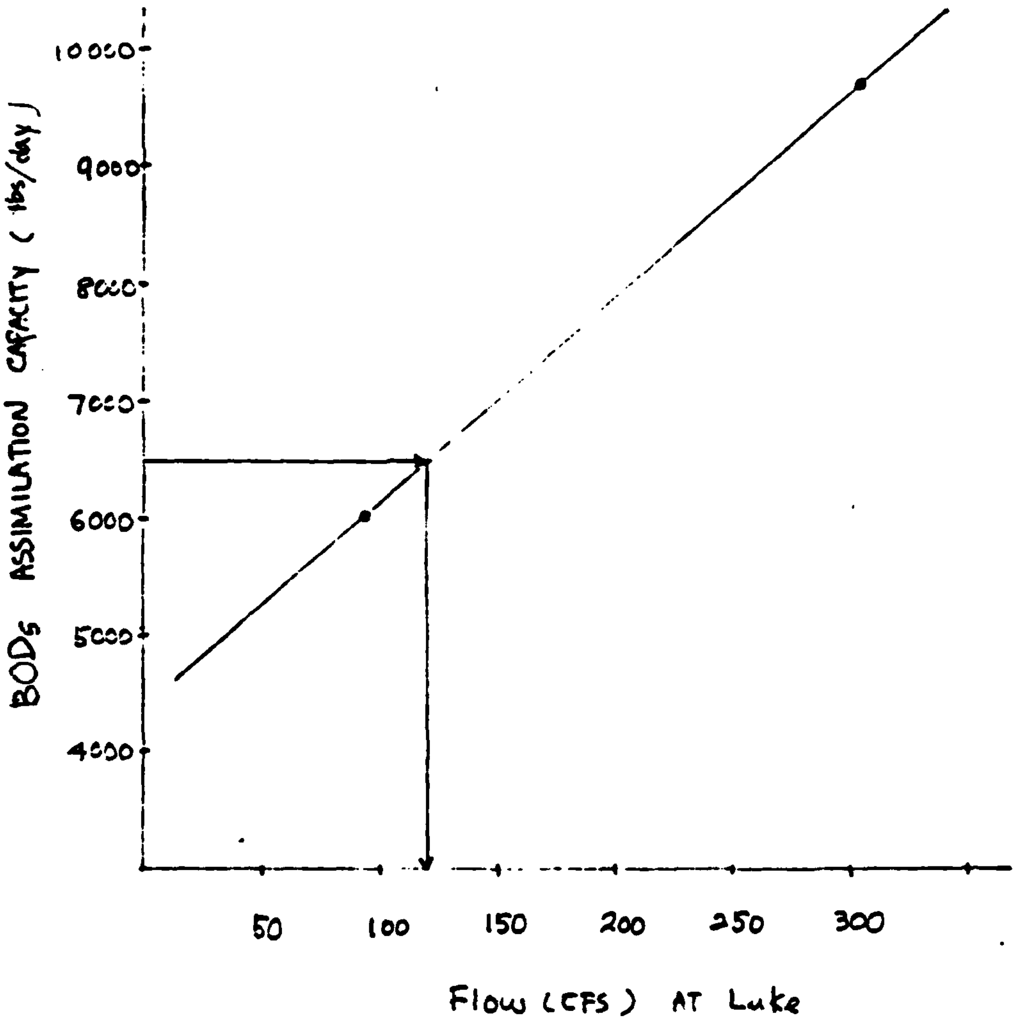


FIGURE H-II- 187 Projected Flow requirement to meet the state standard of DO (5 mg/l) for the NBPR

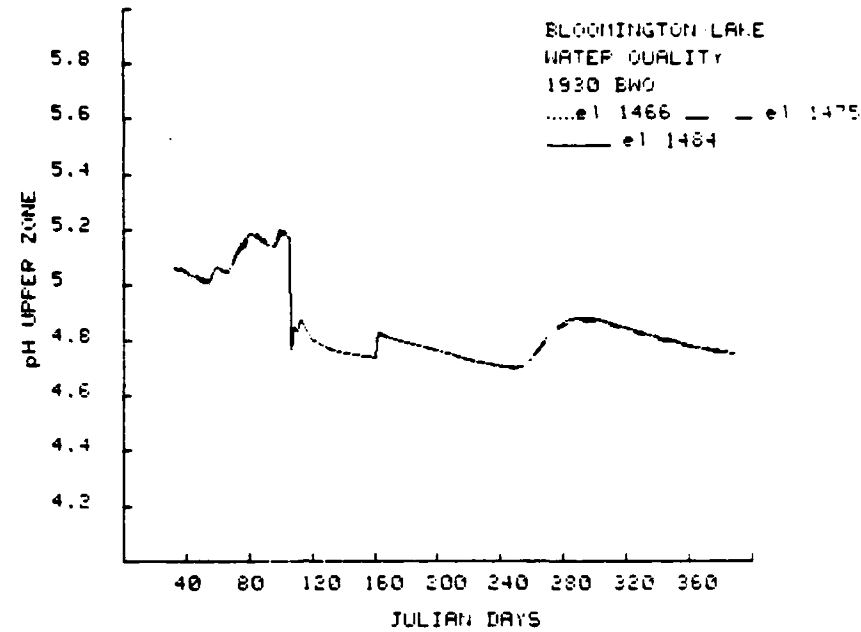


FIGURE H-II- 188

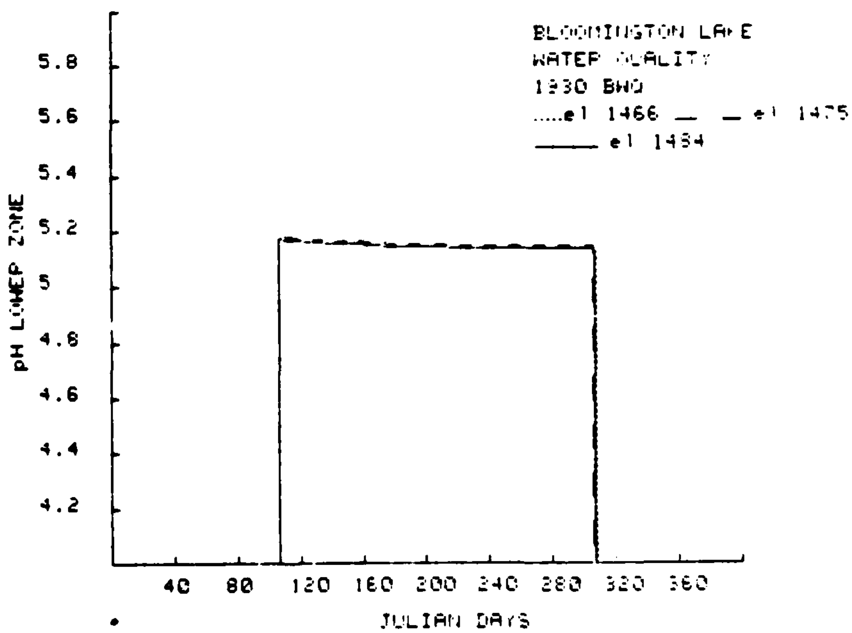


FIGURE H-II- 189

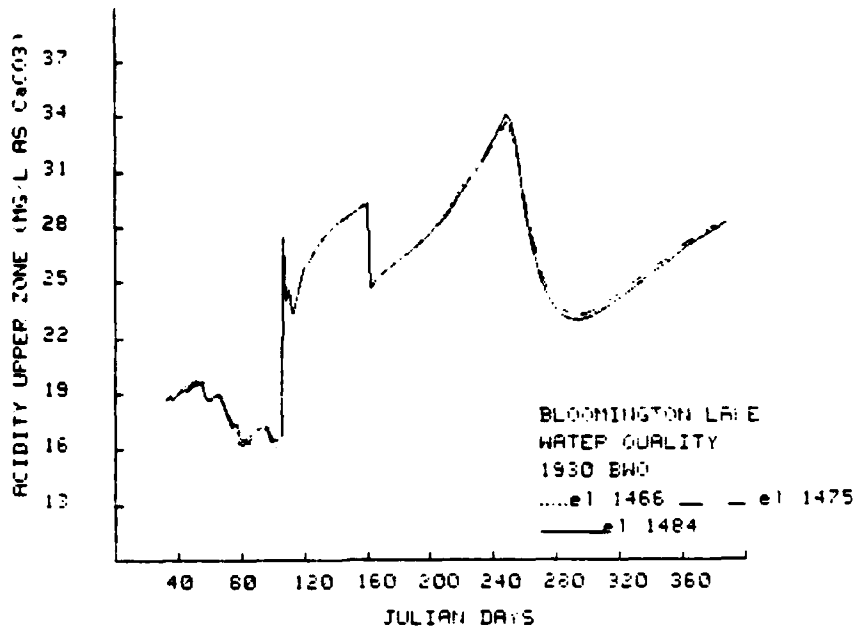


FIGURE H-II- 190

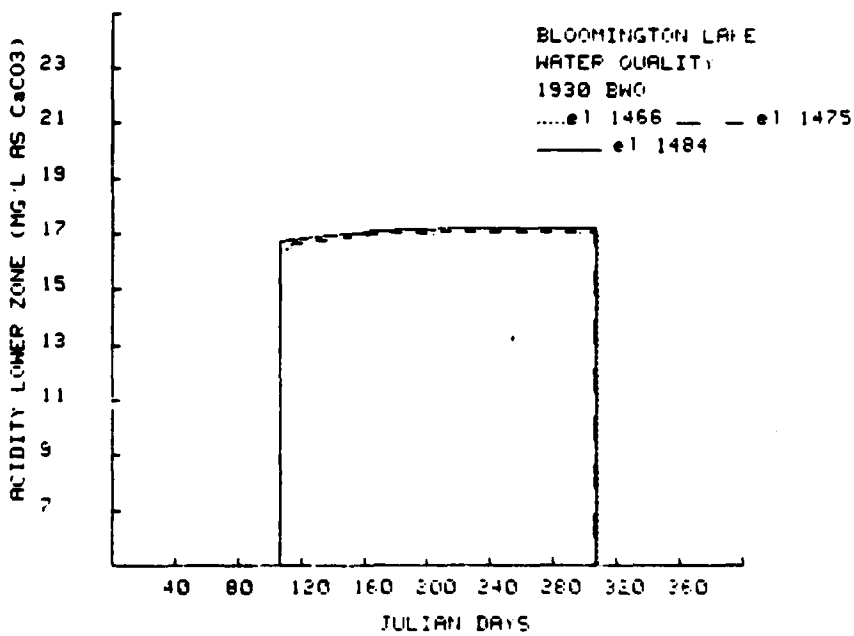


FIGURE H-II- 191

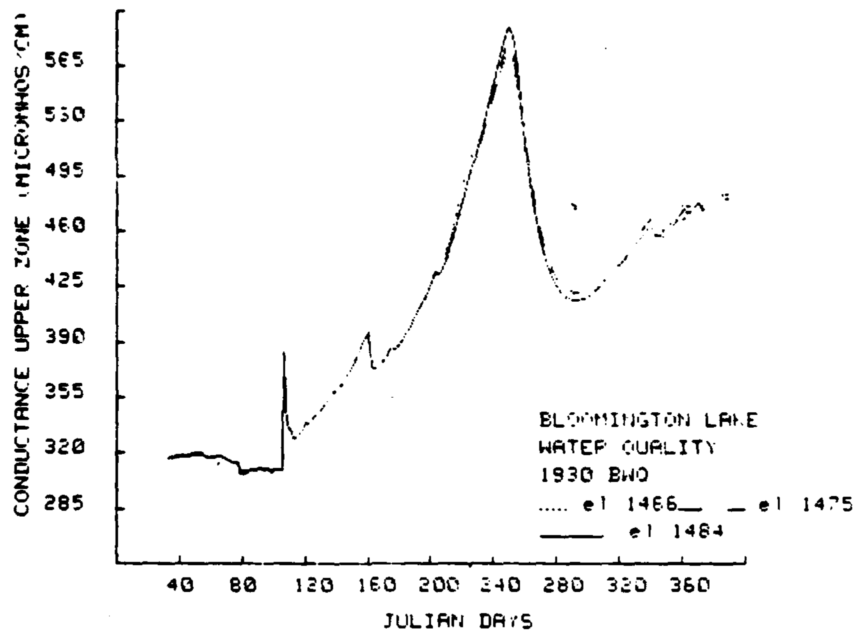


FIGURE H-II- 192

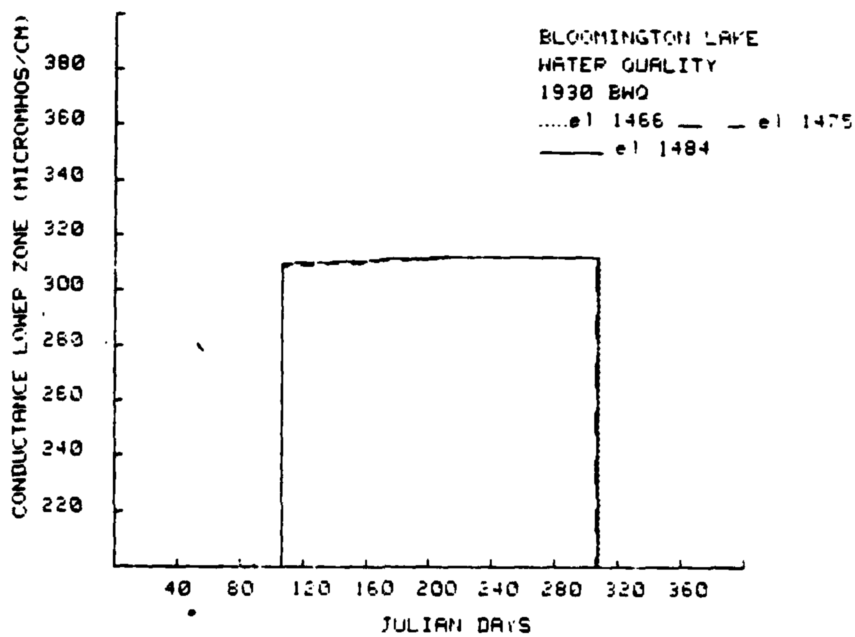
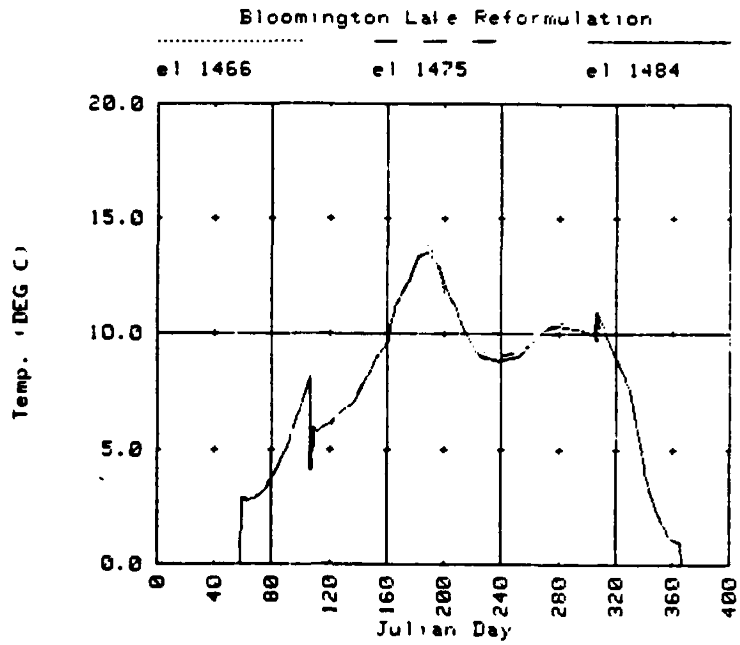
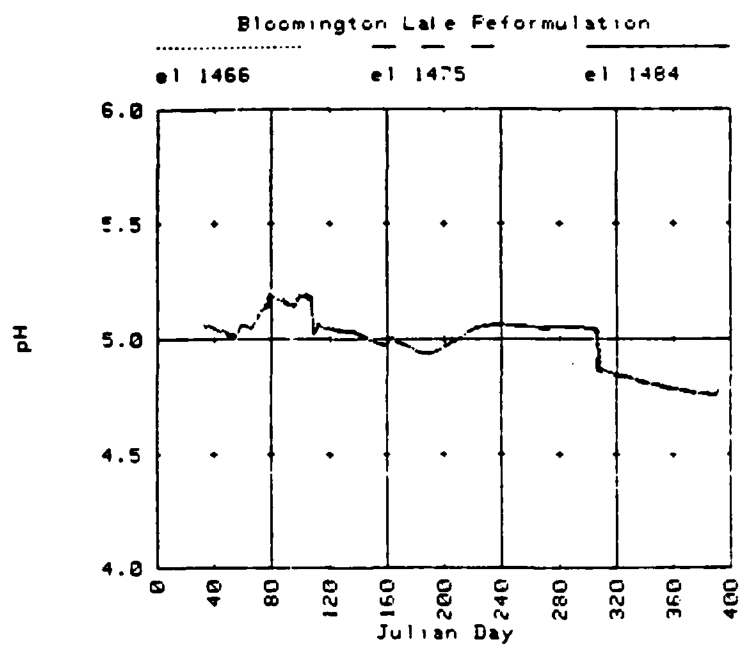


FIGURE H-II- 193



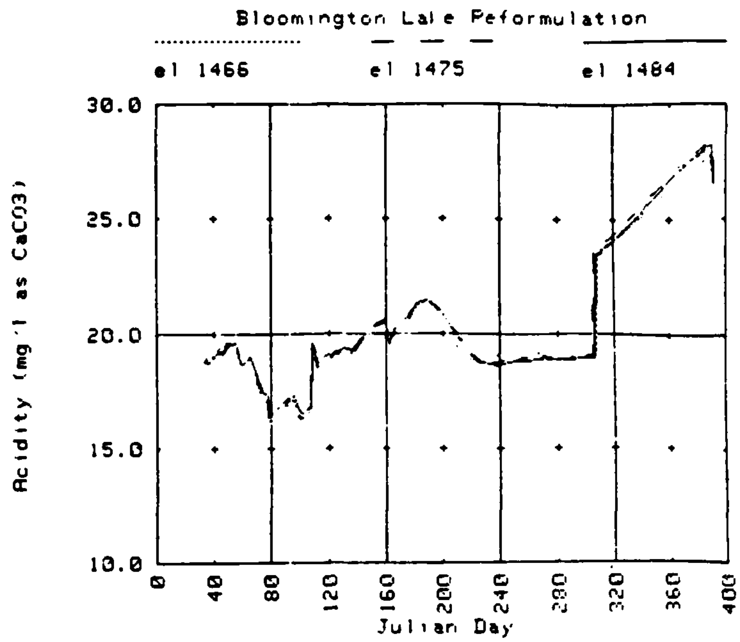
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 194



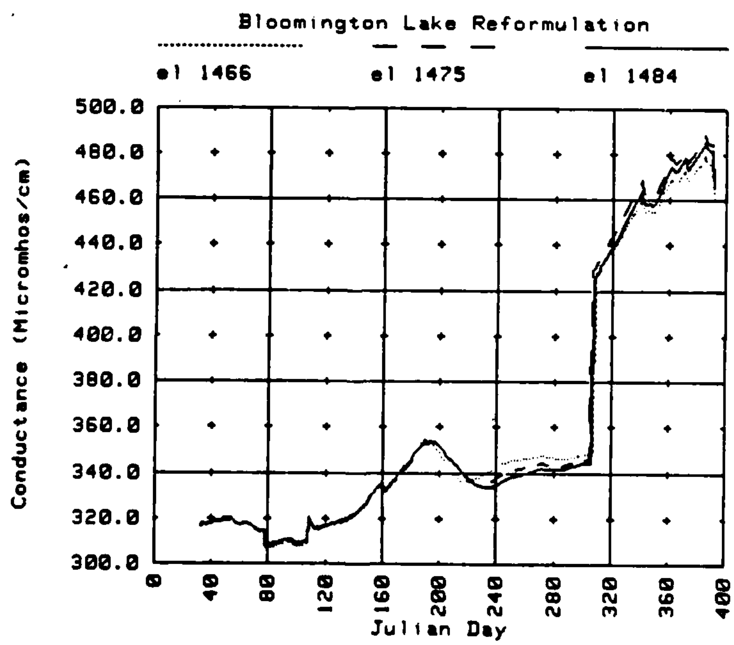
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 195



STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

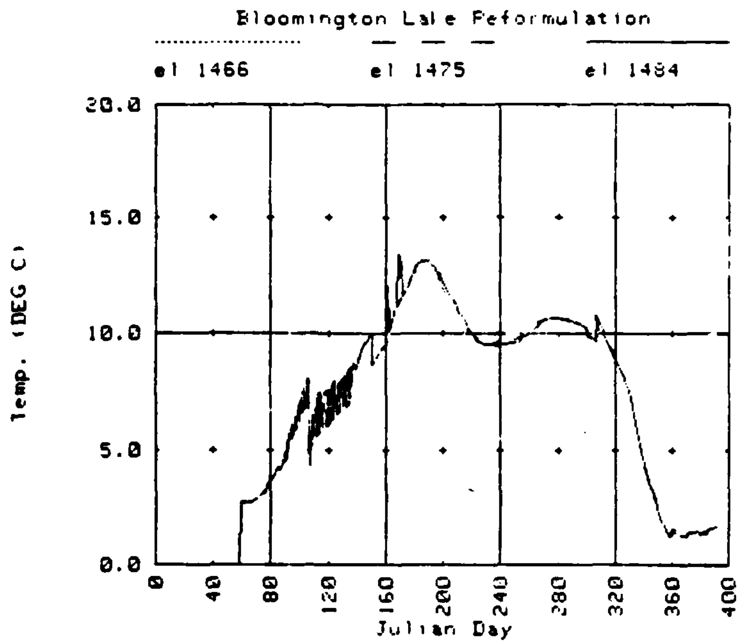
FIGURE H-II- 196



STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

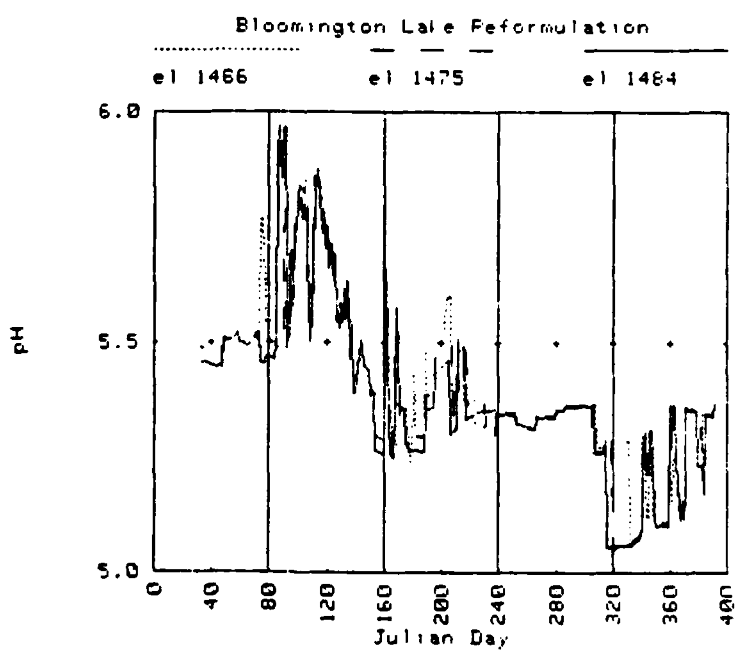
H-II 19?

FIGURE H-II- 197



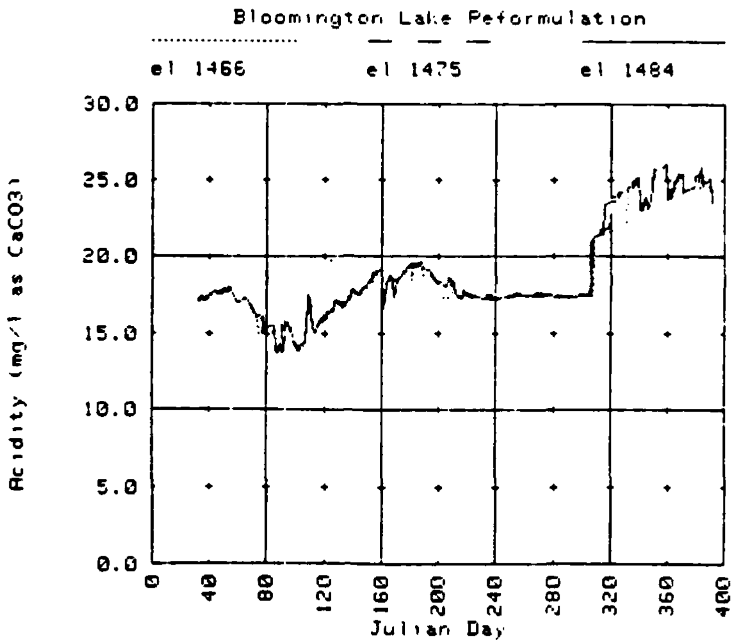
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 198



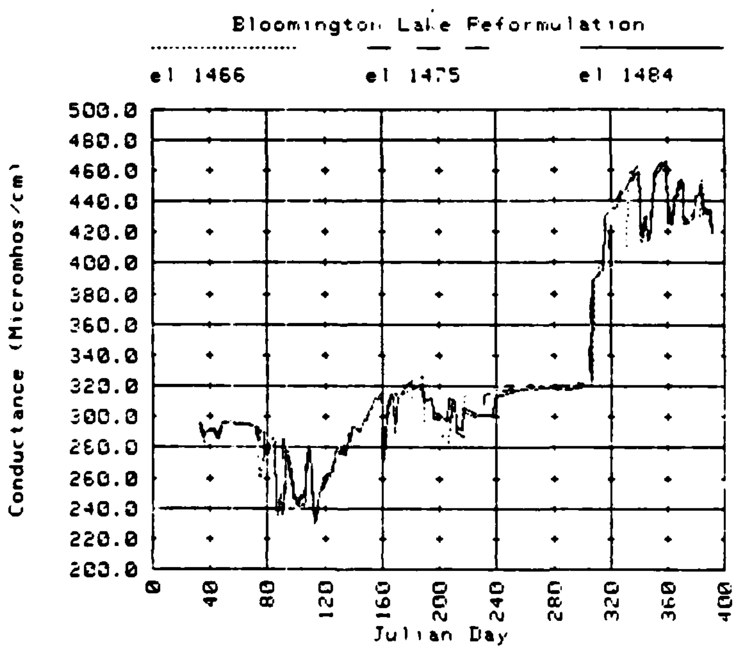
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 199



STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 200



STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
WESTVACO: EXISTING PROCESS

FIGURE H-II- 201

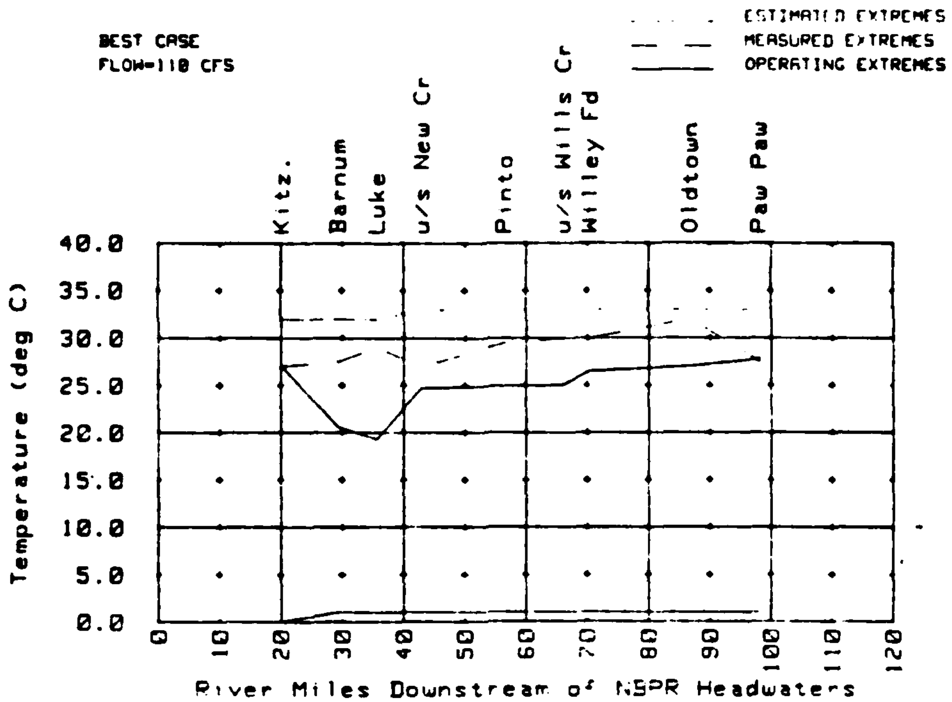


FIGURE H-II- 202

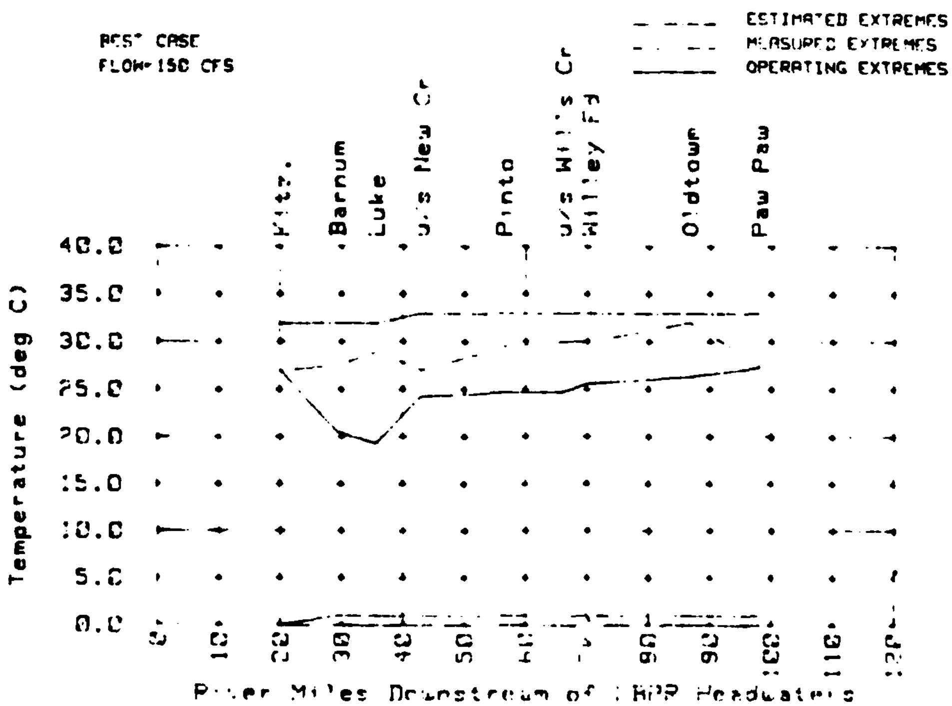


FIGURE H-II- 203

Bloomington Lake Reformulation

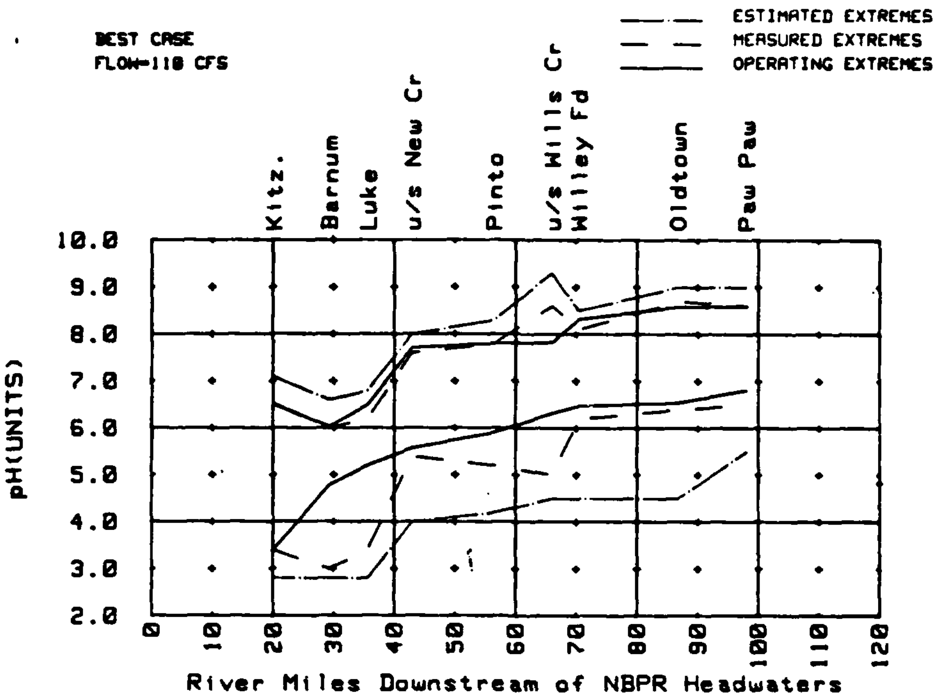


FIGURE H-II- 204

Bloomington Lake Reformulation

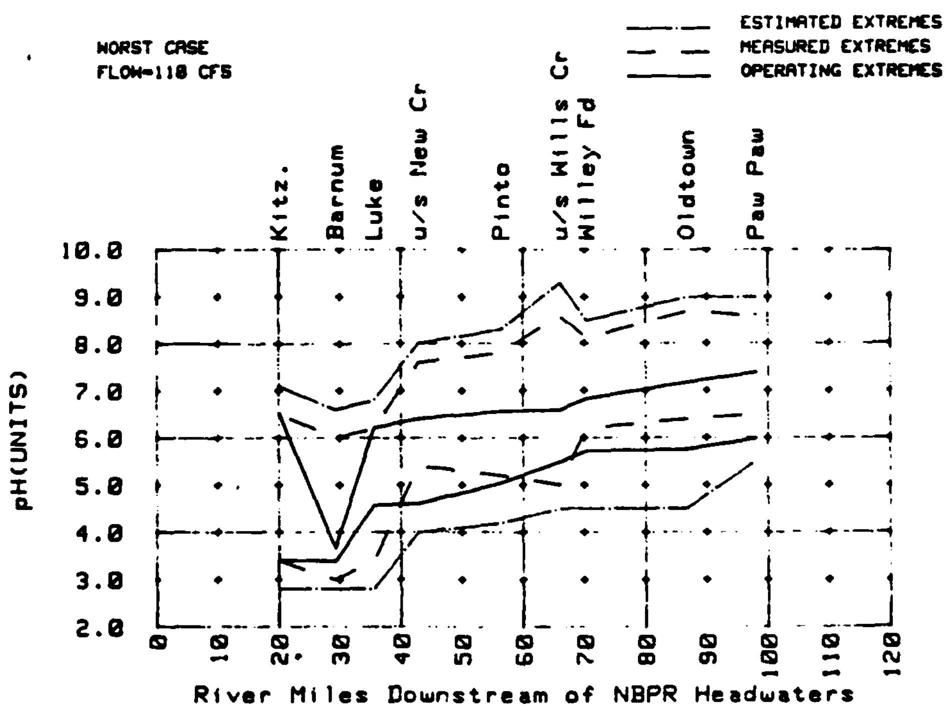


FIGURE H-II- 205

Bloomington Lake Reformulation

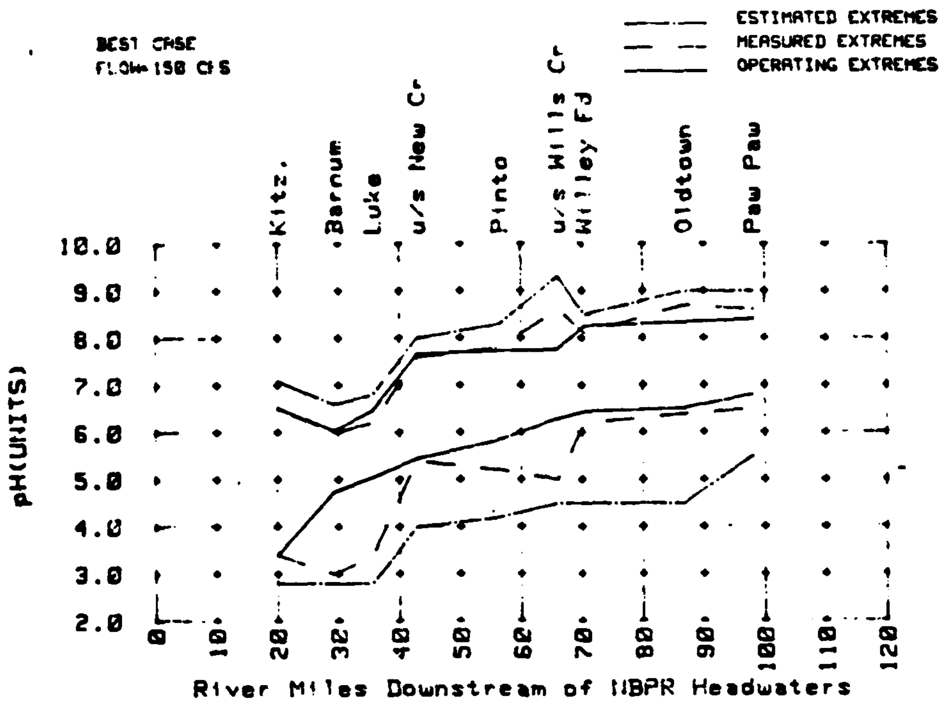


FIGURE H-II- 206

Bloomington Lake Reformulation

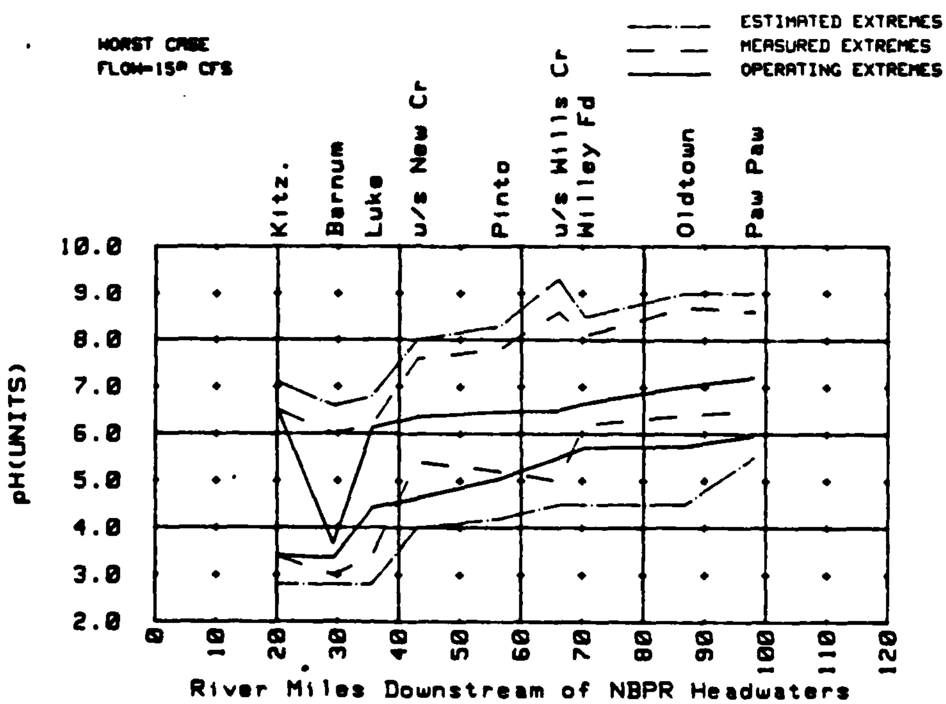


FIGURE H-II- 207

Bloomington Lake Reformulation

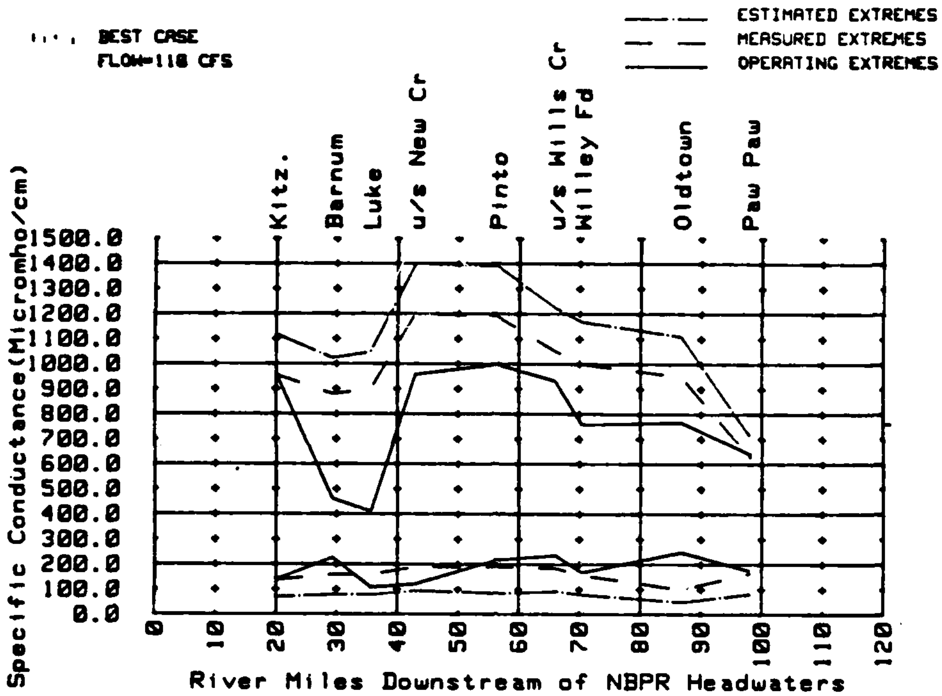


FIGURE H-II- 208

Bloomington Lake Reformulation

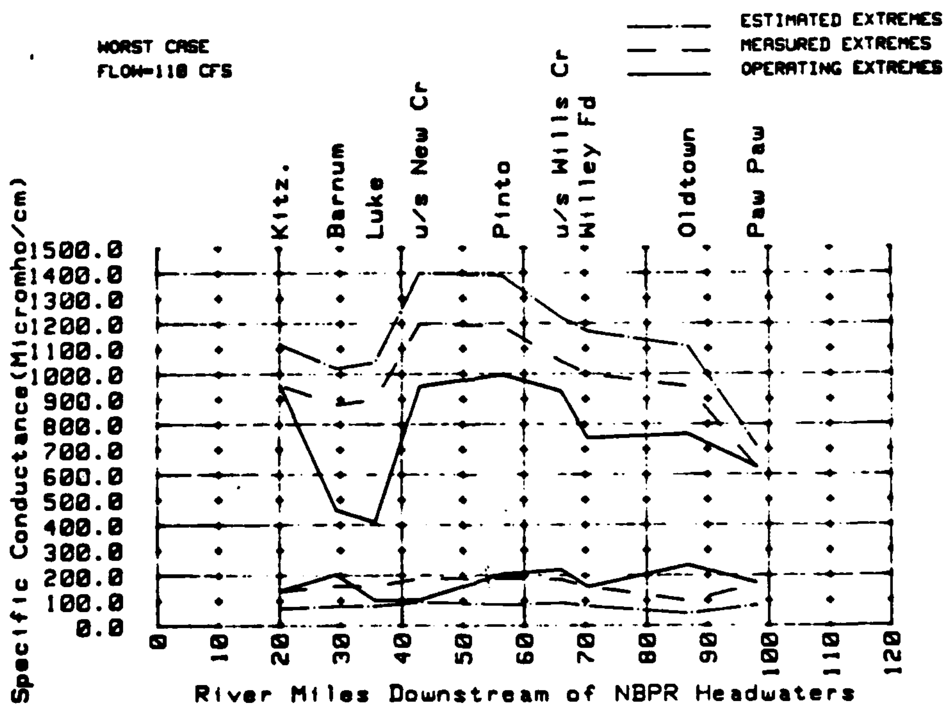


FIGURE H-II- 209

Bloomington Lake Reformulation

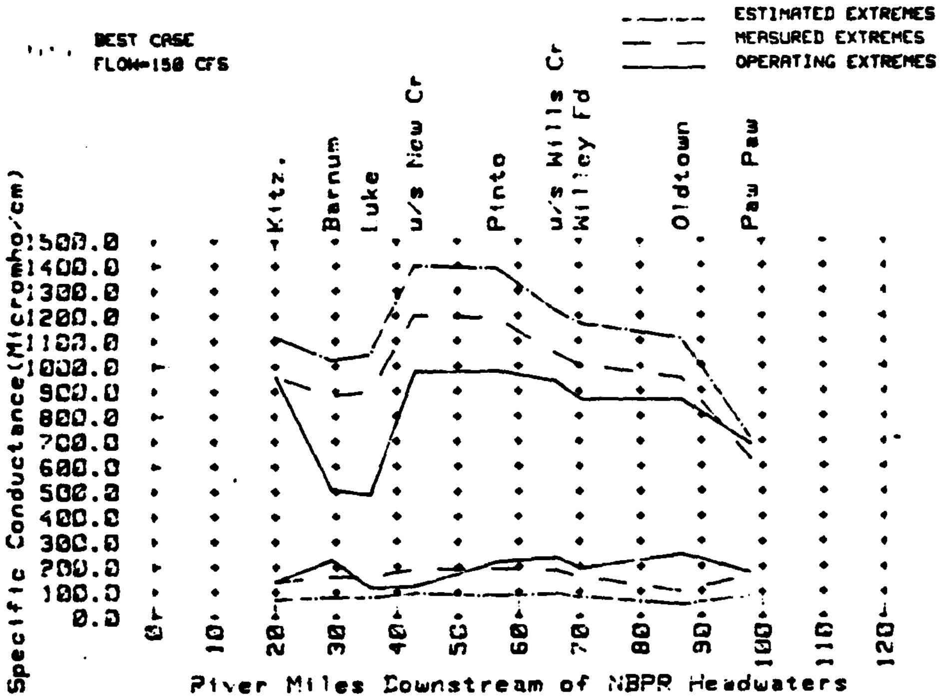


FIGURE H-II- 210

Bloomington Lake Reformulation

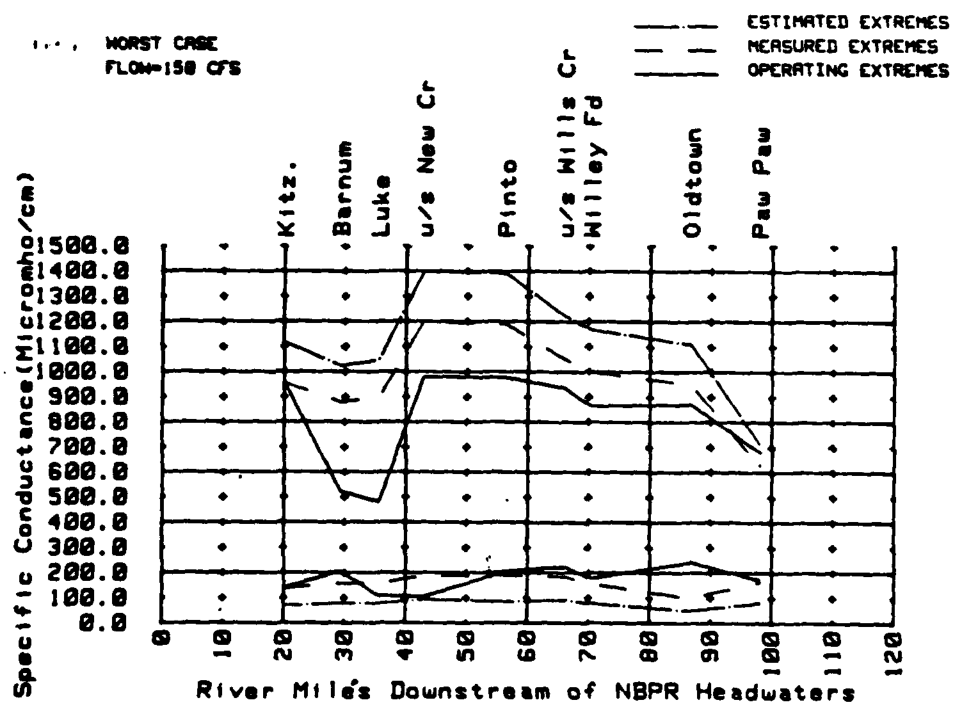
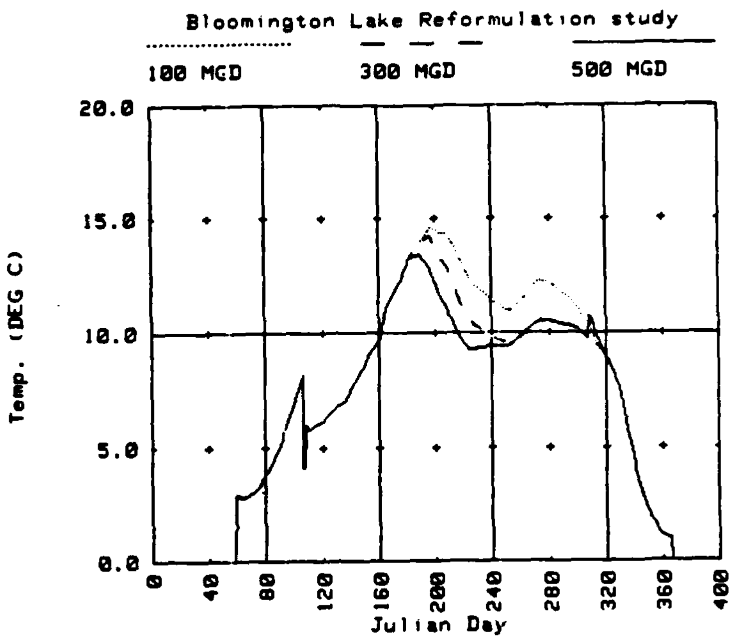
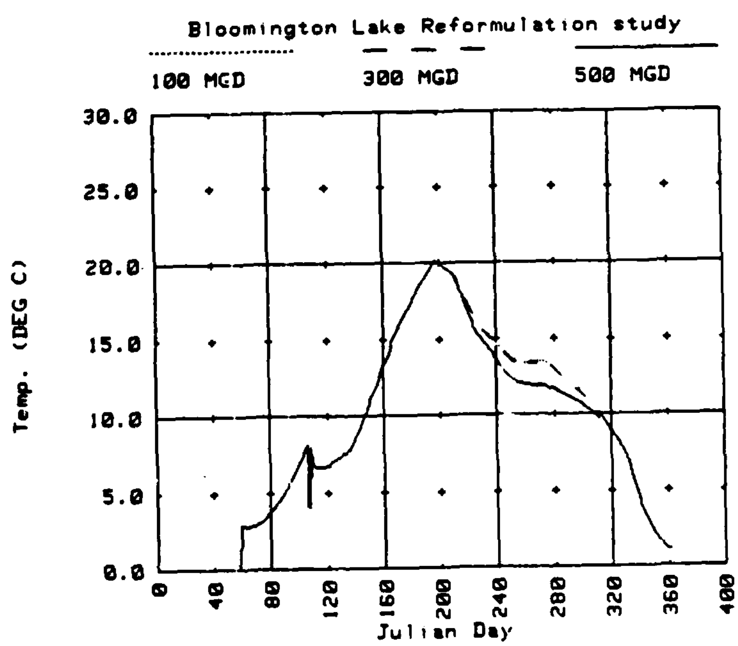


FIGURE H-II- 211



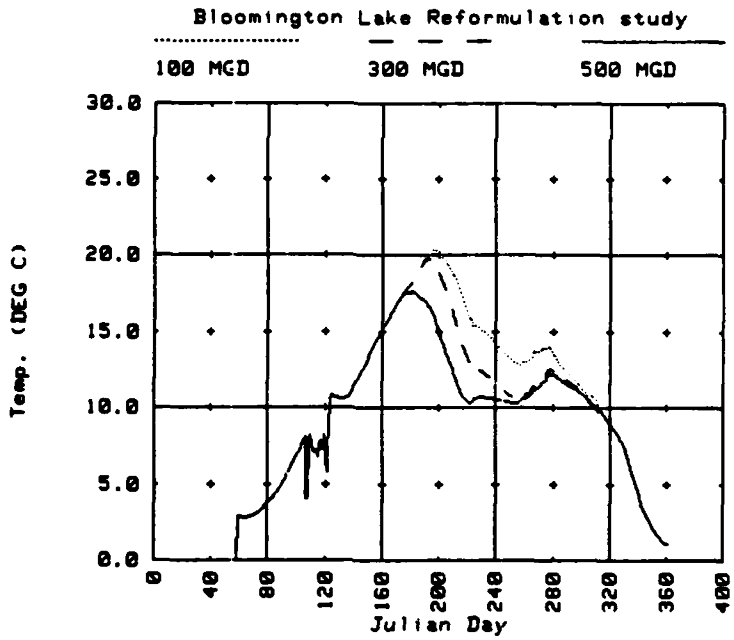
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 212



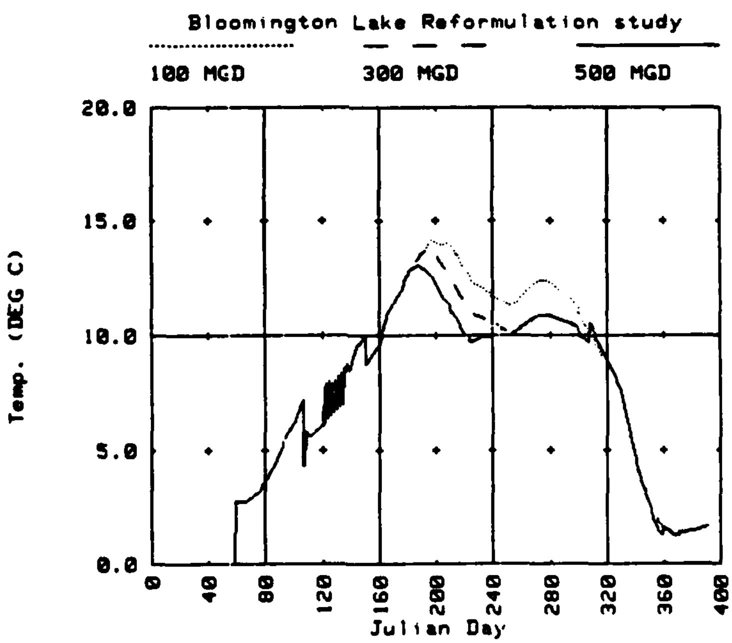
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 213



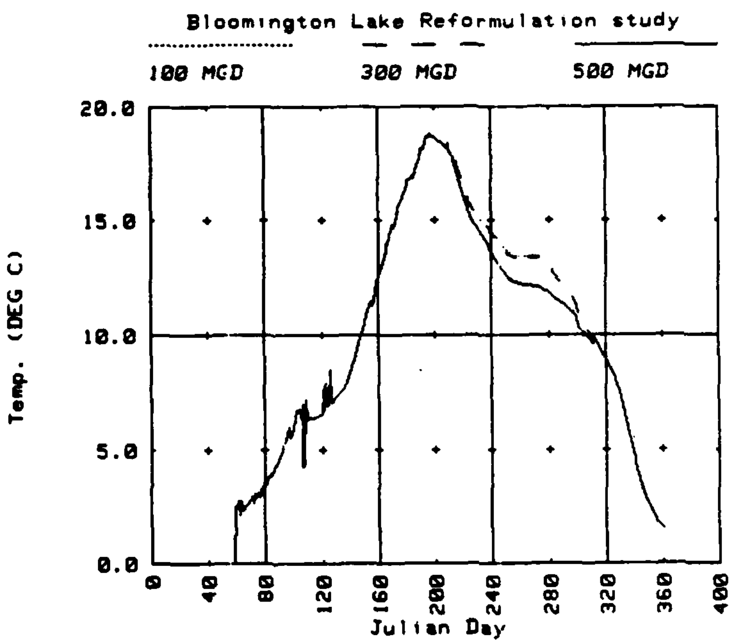
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 214



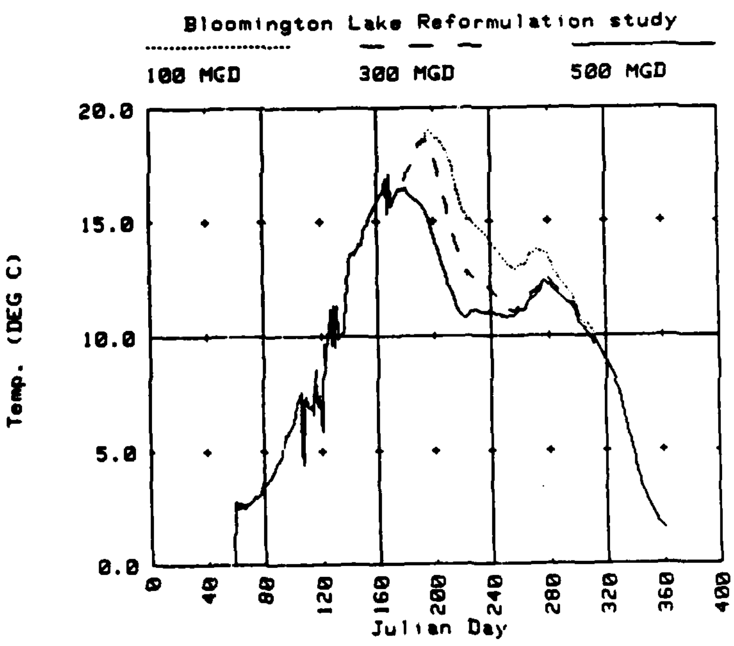
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 215



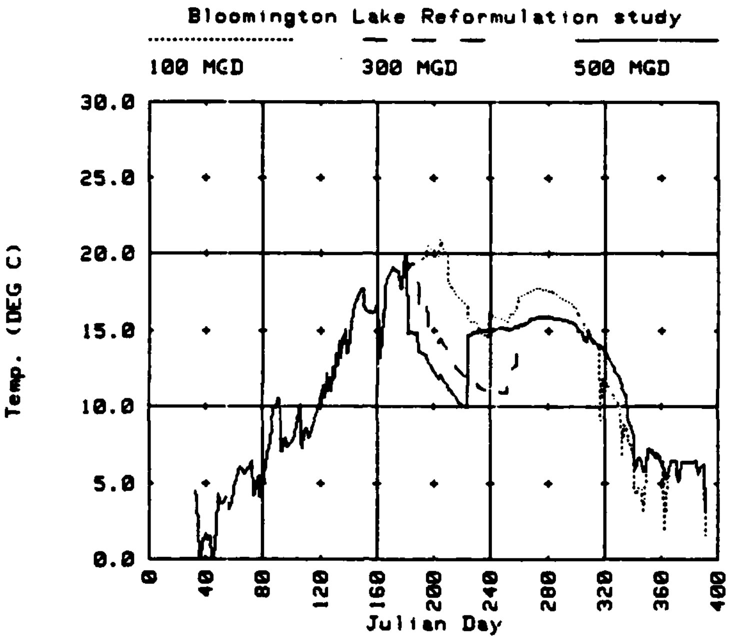
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 216



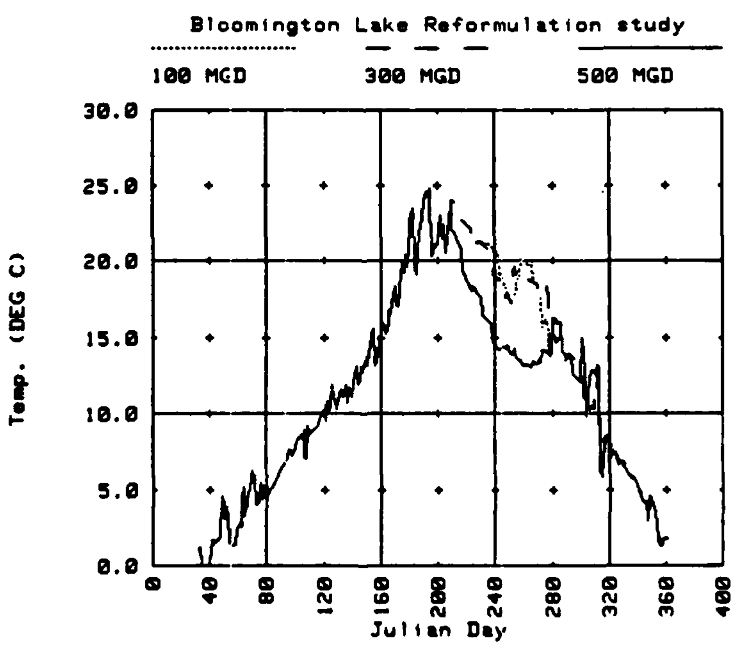
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 217



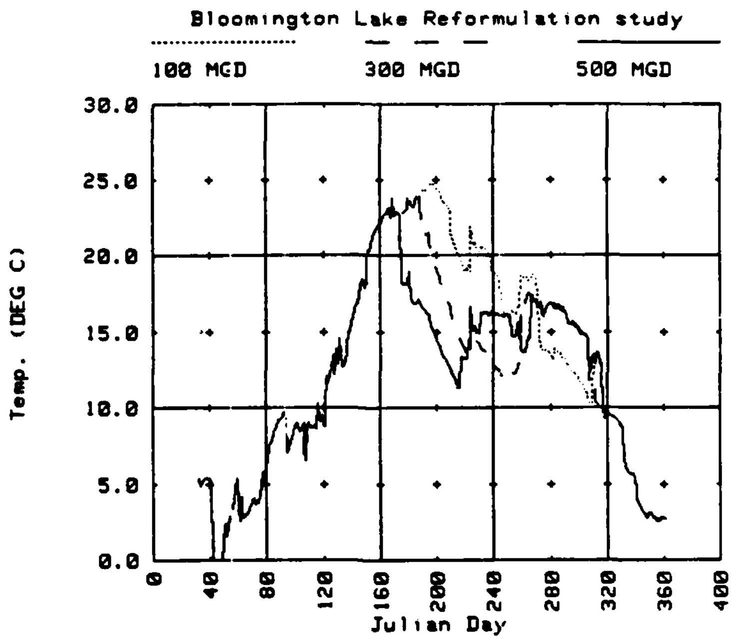
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 218



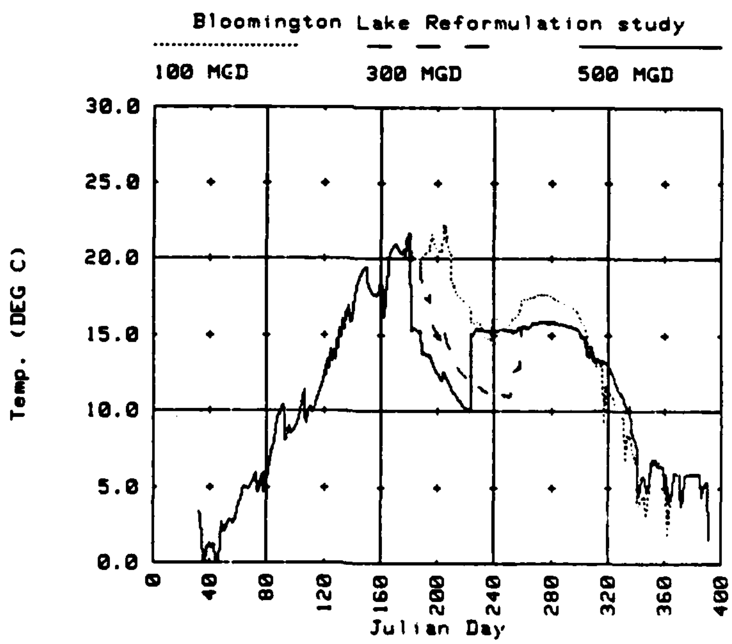
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 219



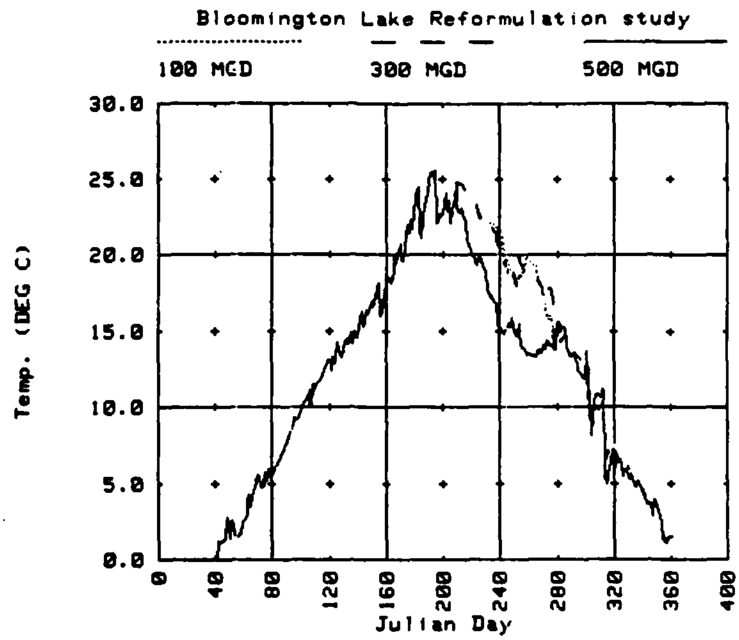
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 220



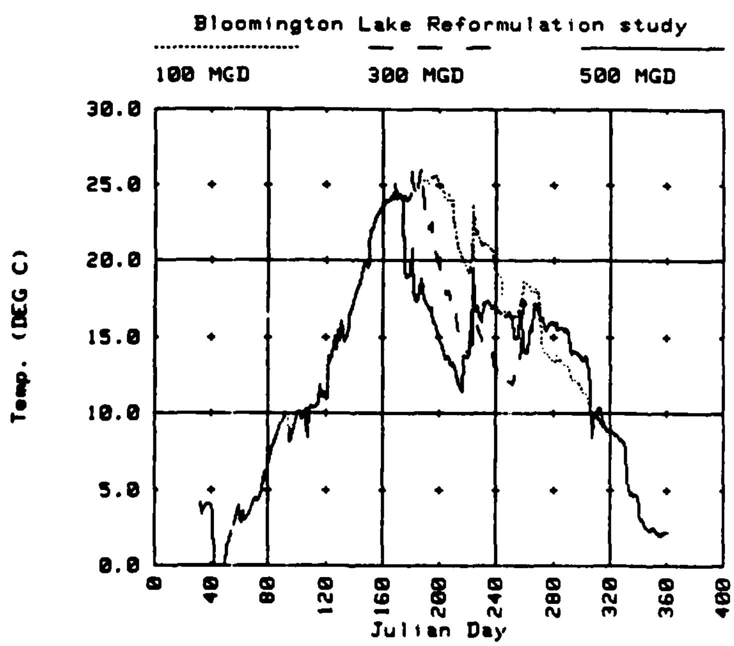
STATION: Kitzmiller Ford, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 221



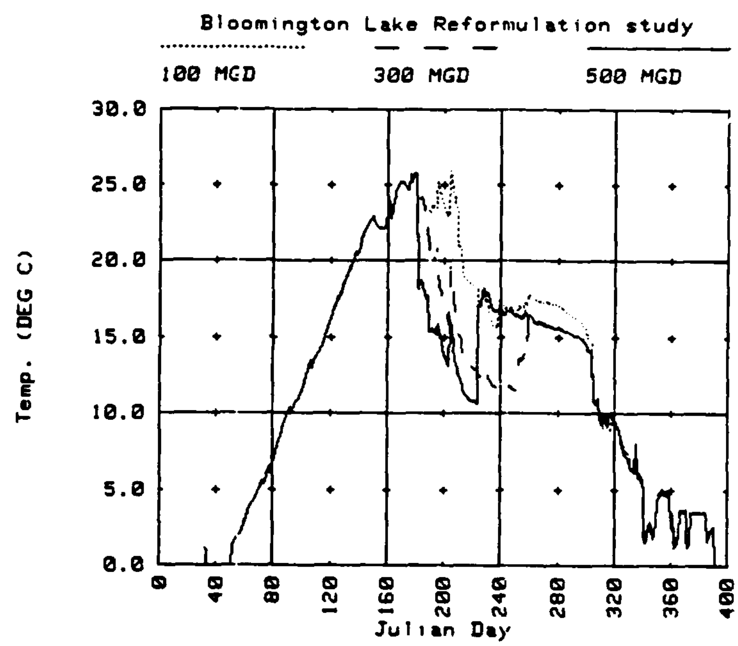
STATION: Willey Ford, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 222



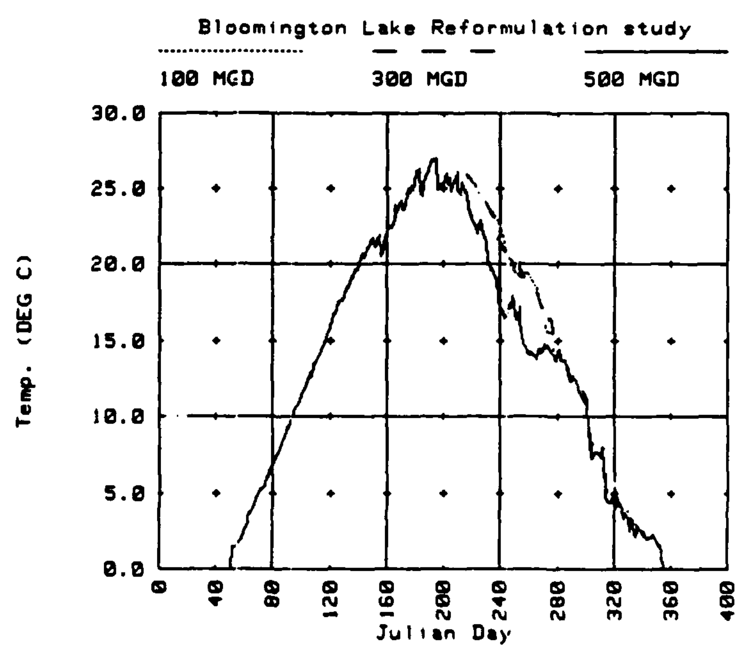
STATION: Willey Ford, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 223



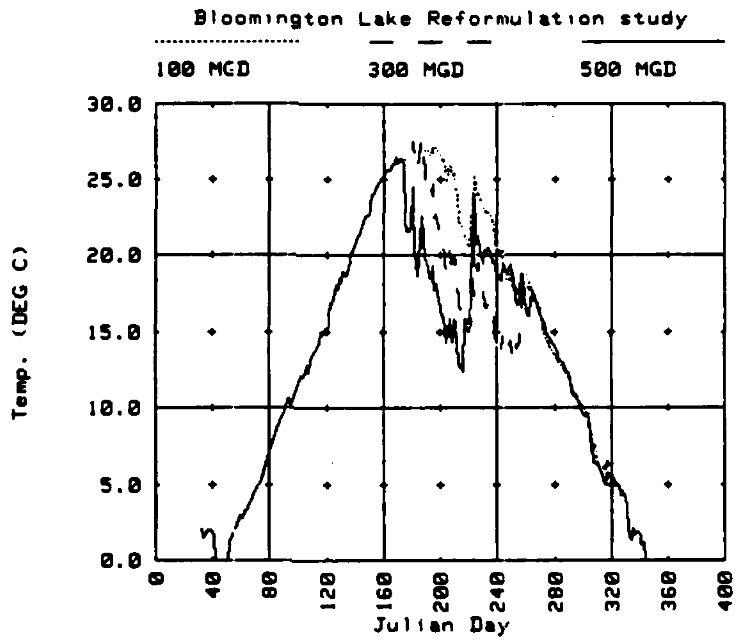
STATION: Paw Paw, W.Va.
YEAR: 1938
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 224



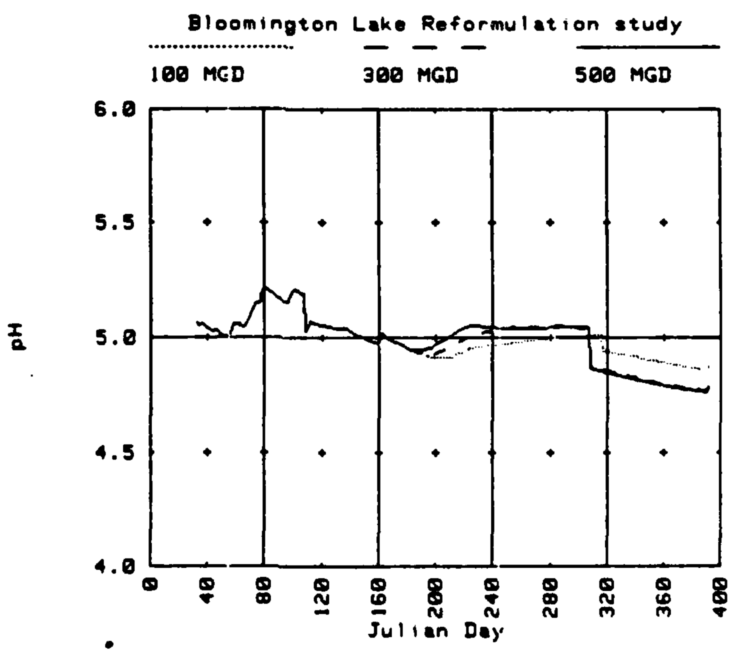
STATION: Paw Paw, W.Va.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 225



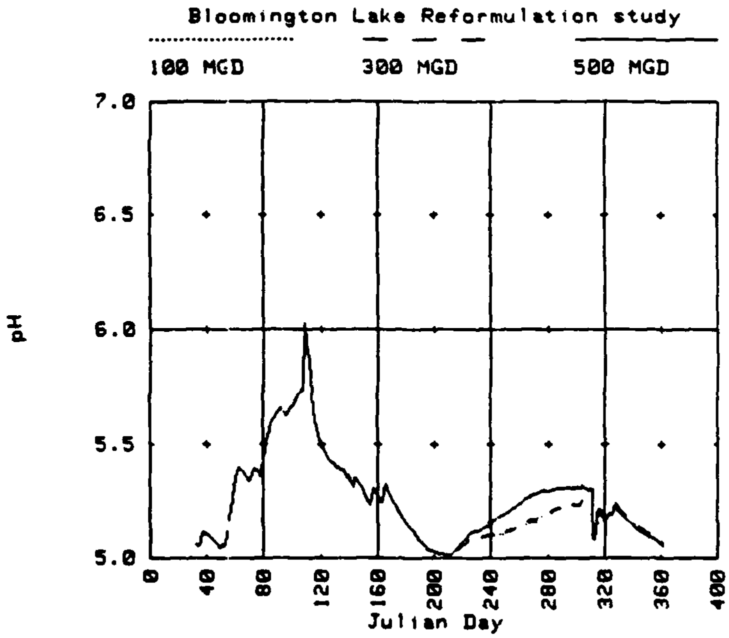
STATION: Paw Paw, W.Va.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 226



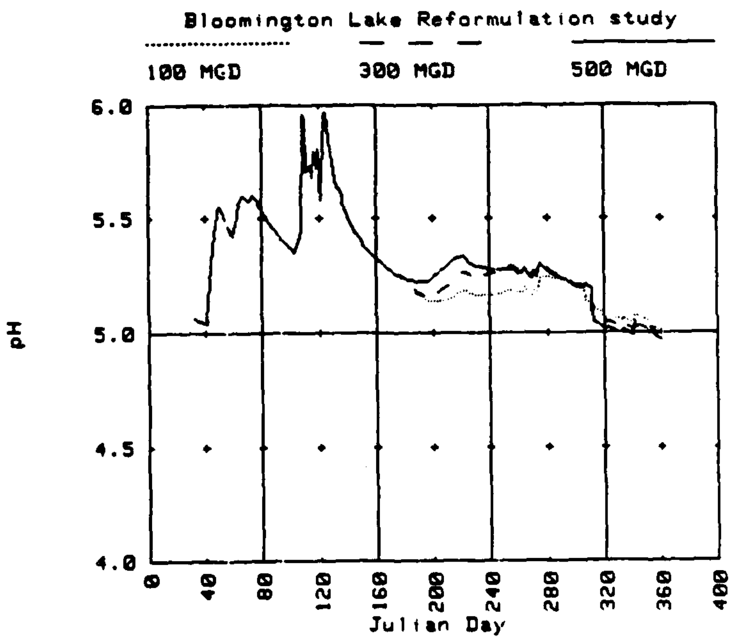
STATION: Barnum, MD
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 227



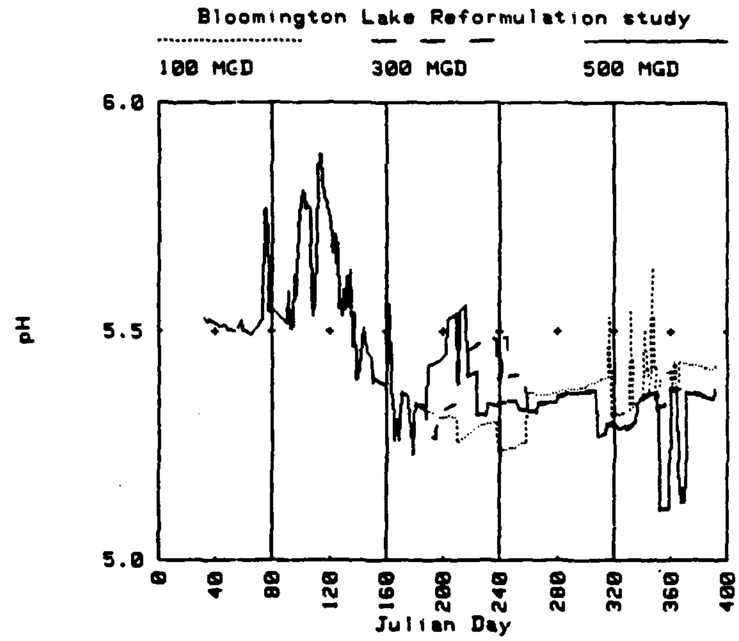
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 228



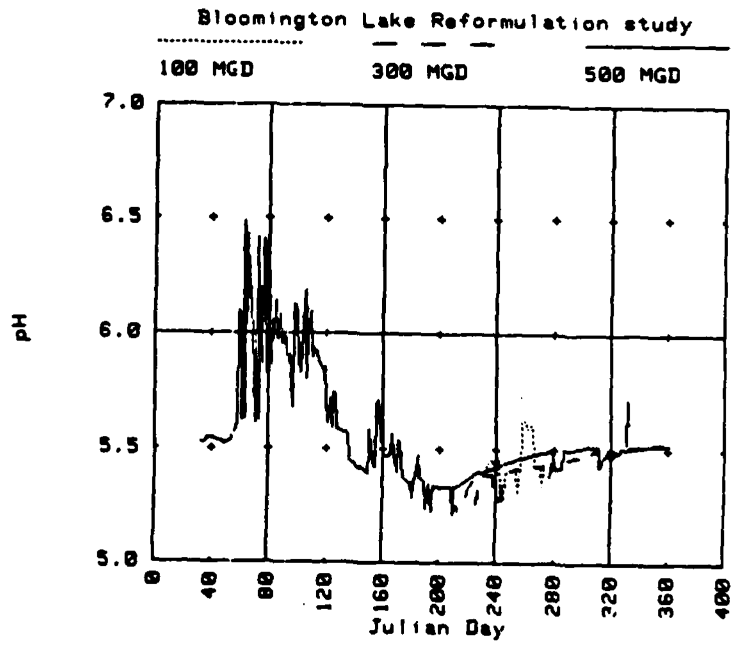
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 229



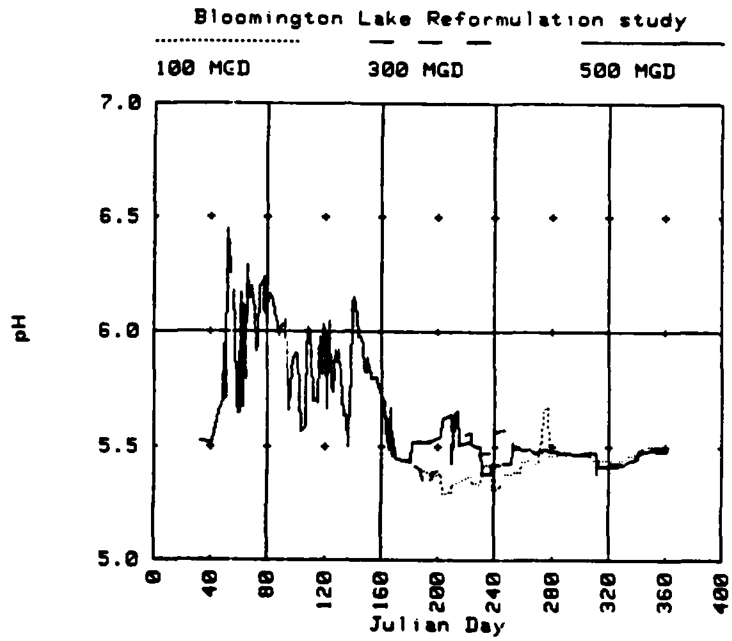
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 230



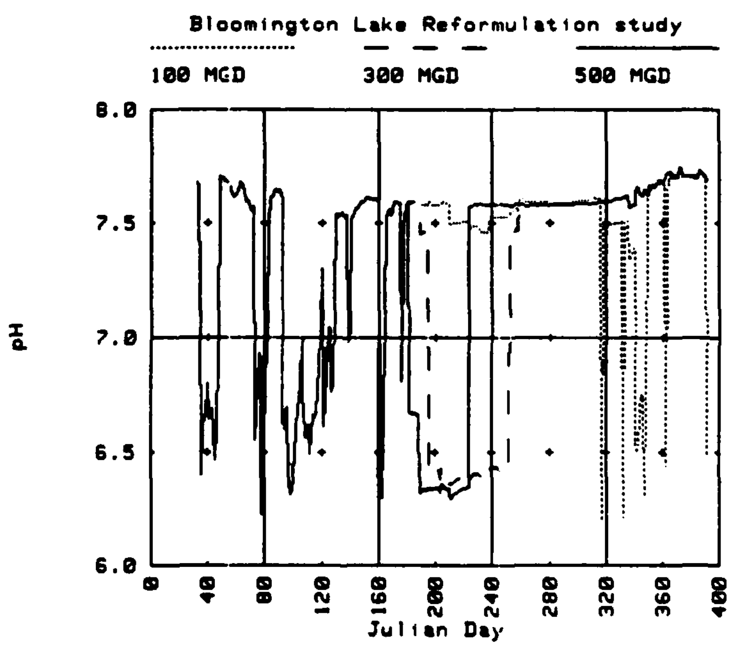
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 231



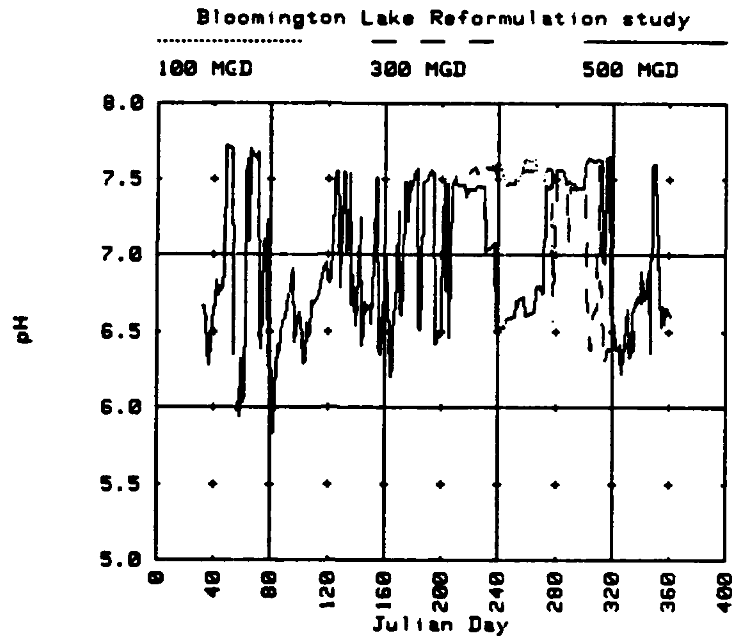
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 232



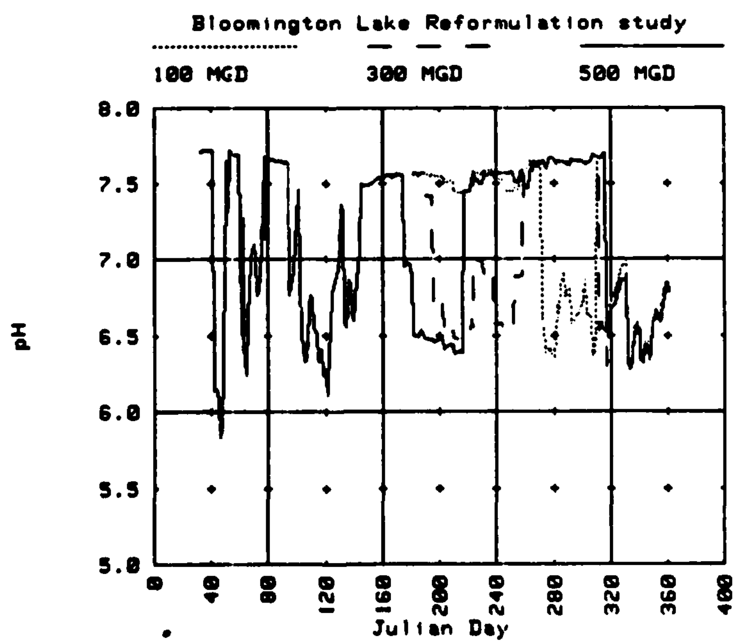
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 233



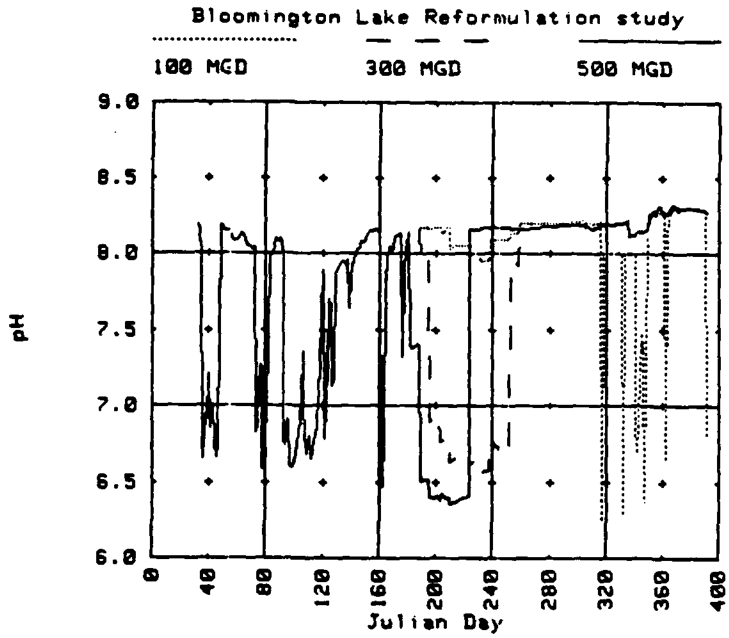
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 234



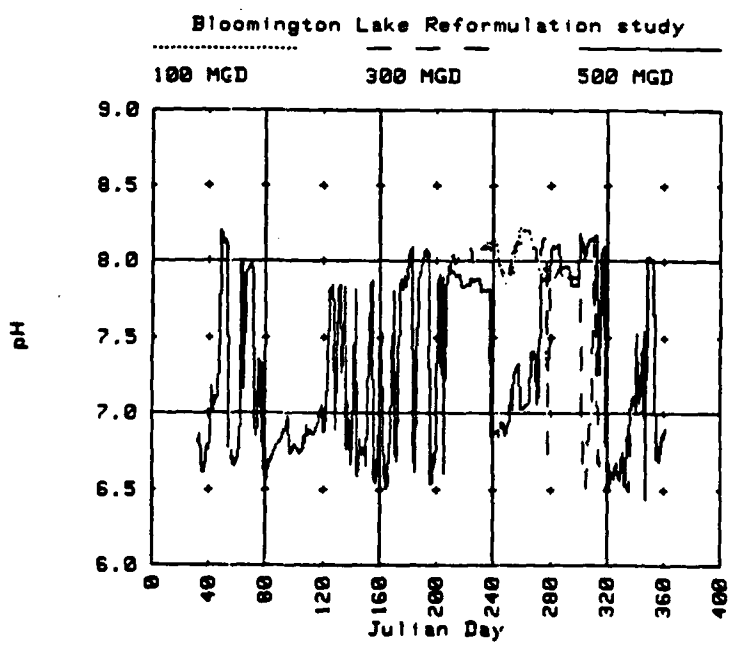
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 235



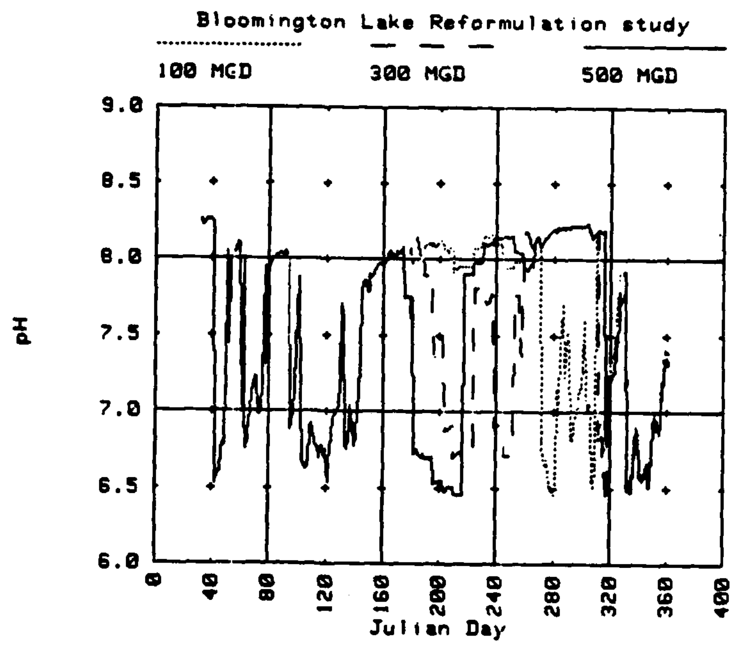
STATION: Willey Ford, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 236



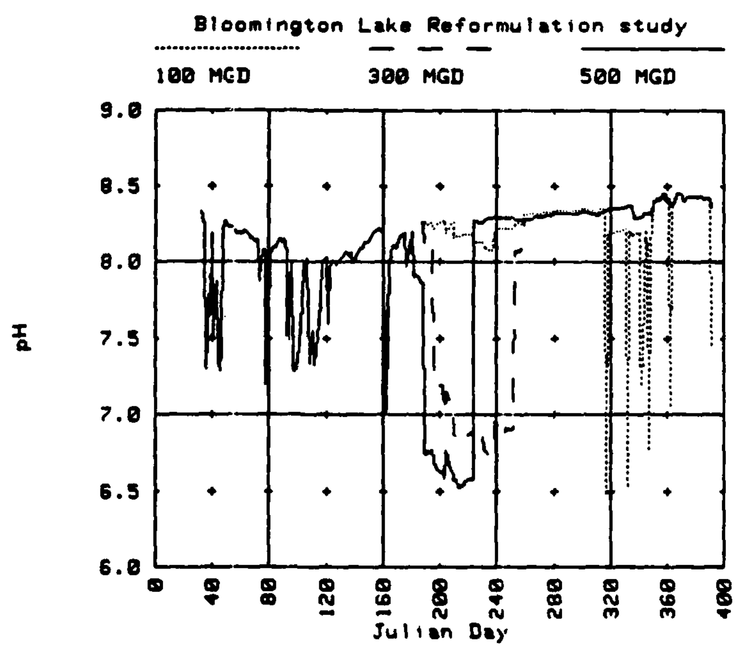
STATION: Willey Ford, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 237



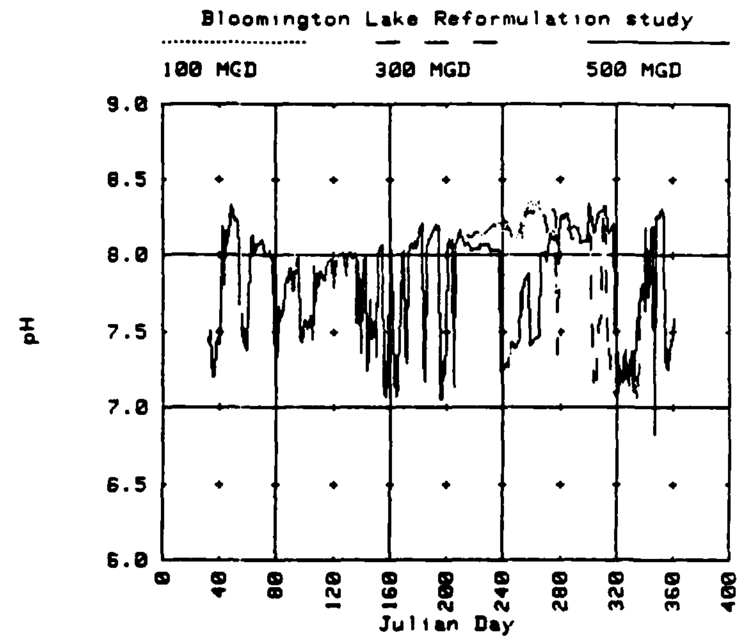
STATION: Willey Ford, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 238



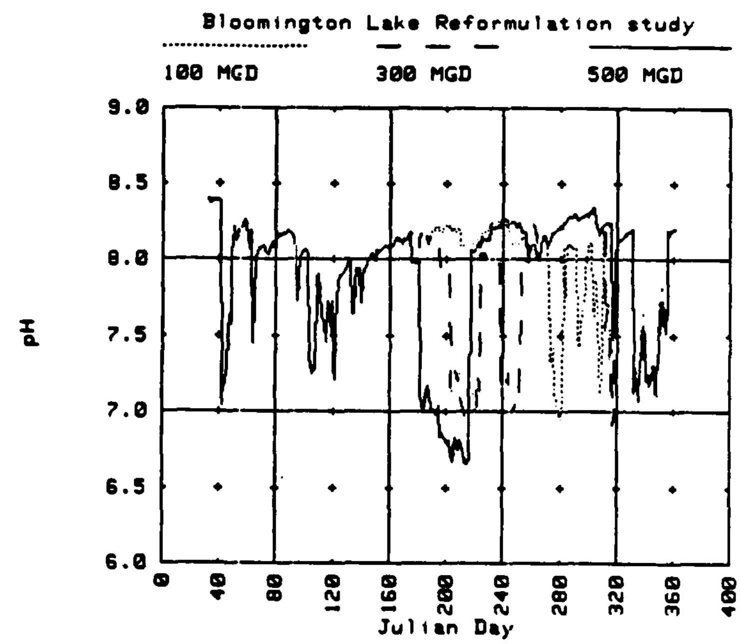
STATION: Paw Paw, W.Va.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 239



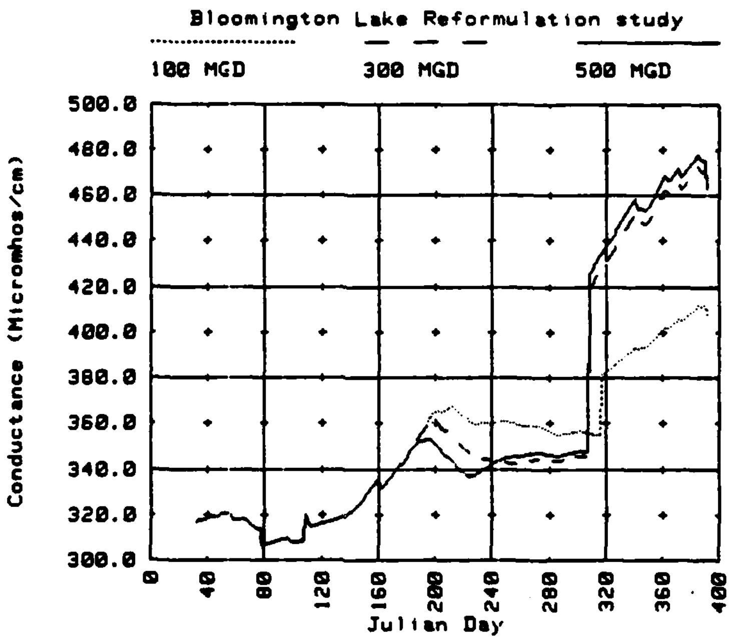
STATION: Paw Paw, W.Va.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 240



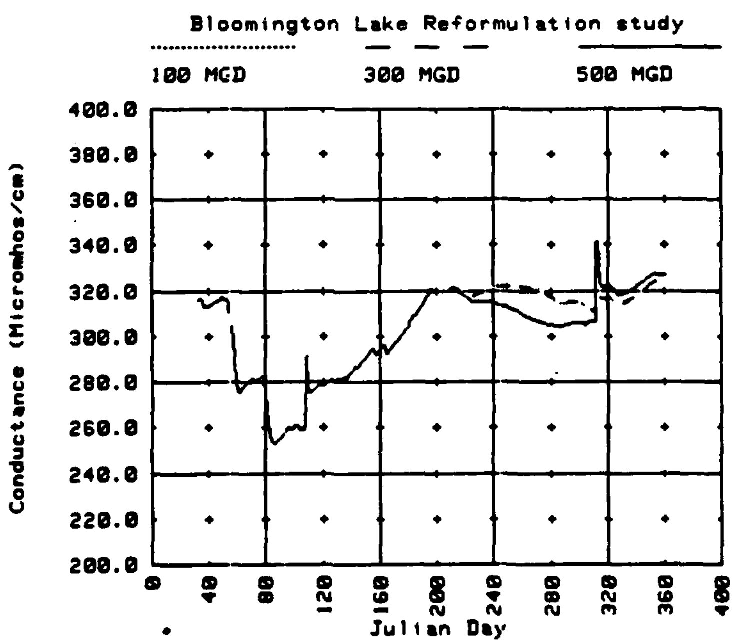
STATION: Paw Paw, W.Va.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 241



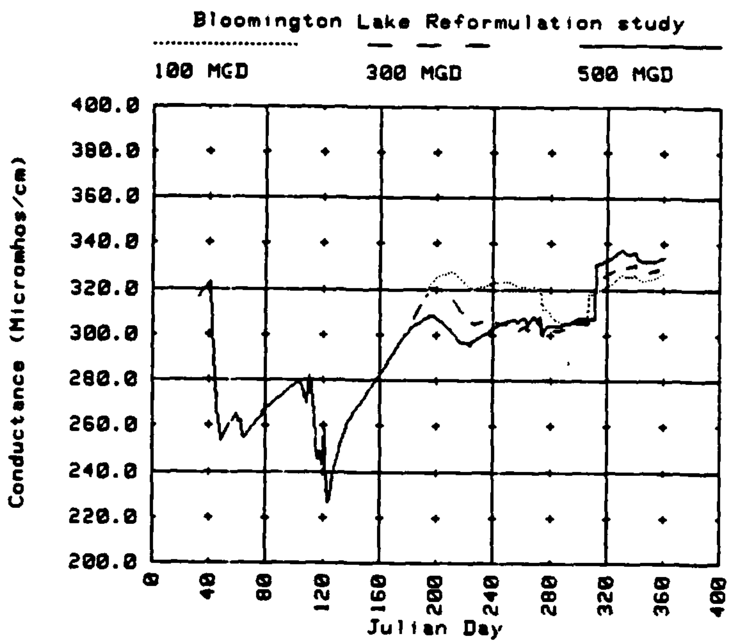
STATION: Barnum, MD
YEAR: 1938
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 242



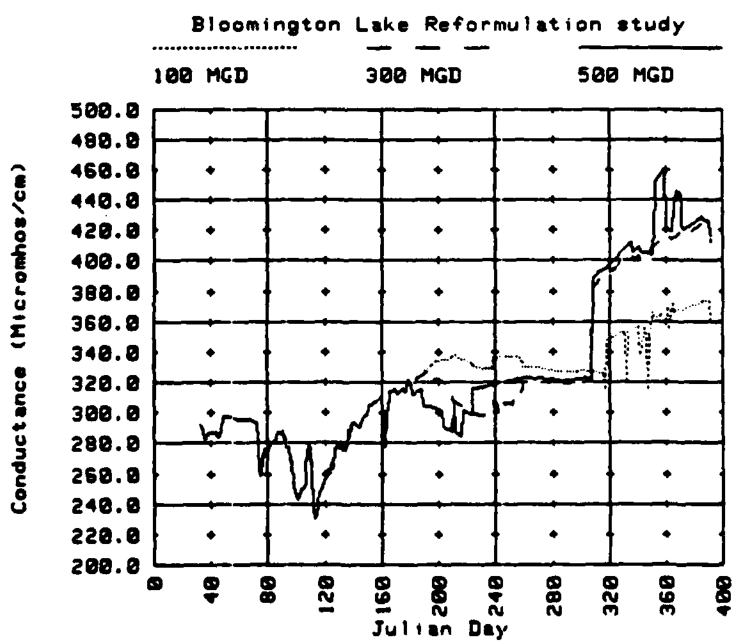
STATION: Barnum, MD
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 243



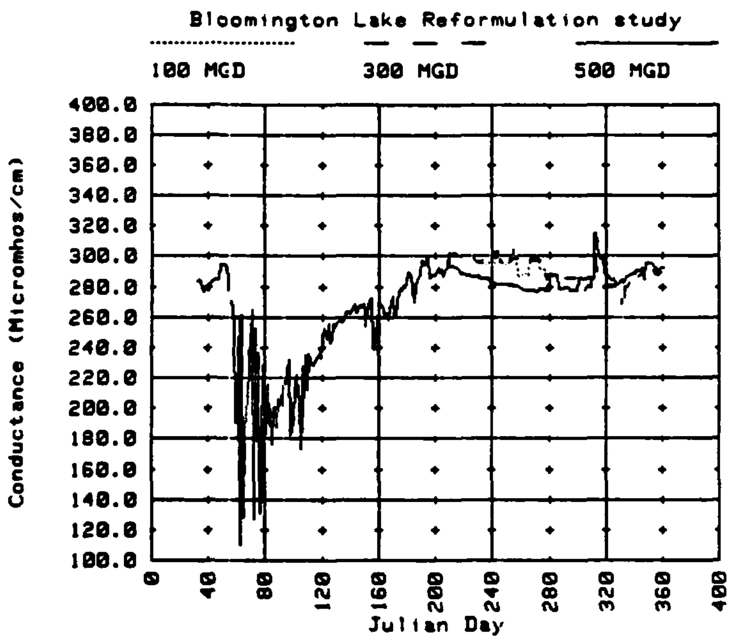
STATION: Barnum, MD
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 244



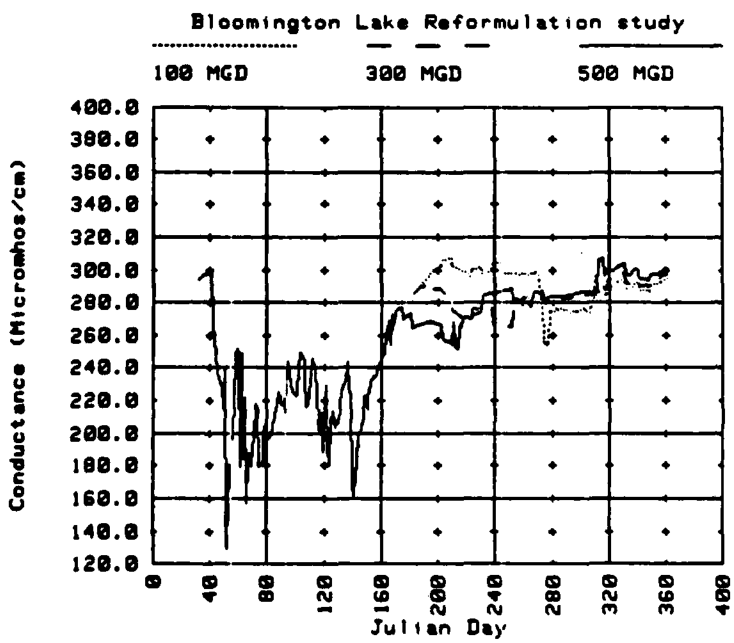
STATION: Luke, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 245



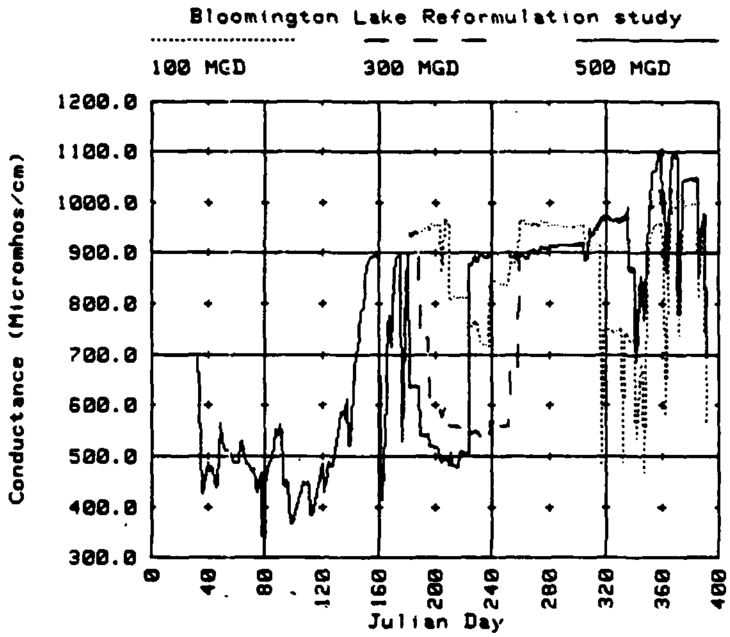
STATION: Luke, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 246



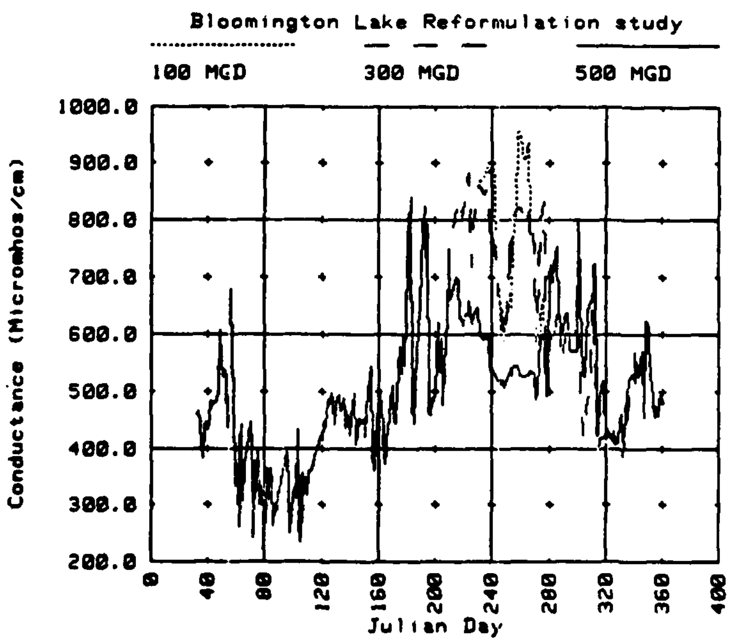
STATION: Luke, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 247



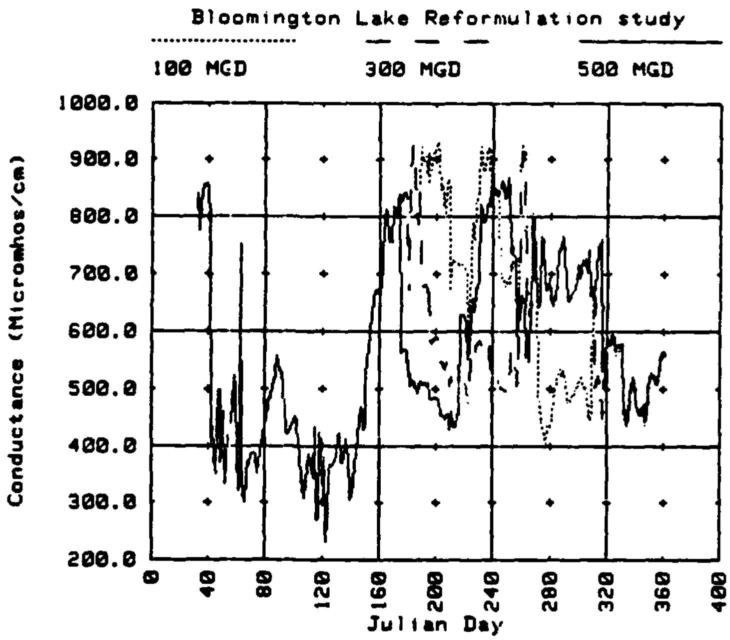
STATION: Pinto, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 248



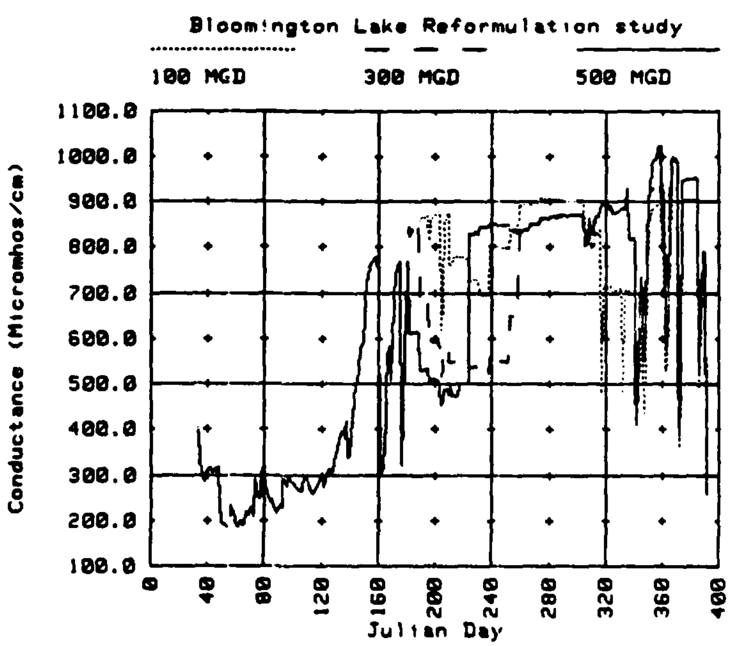
STATION: Pinto, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 249



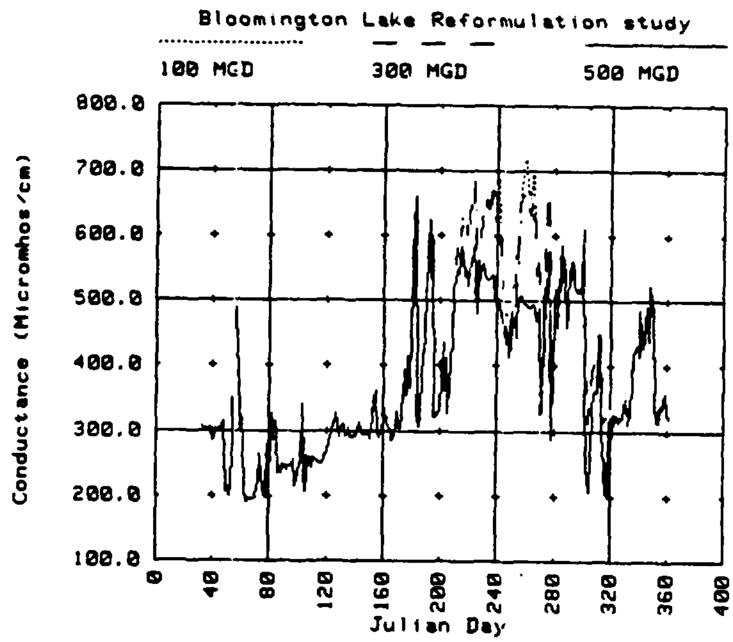
STATION: Pinto, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 250



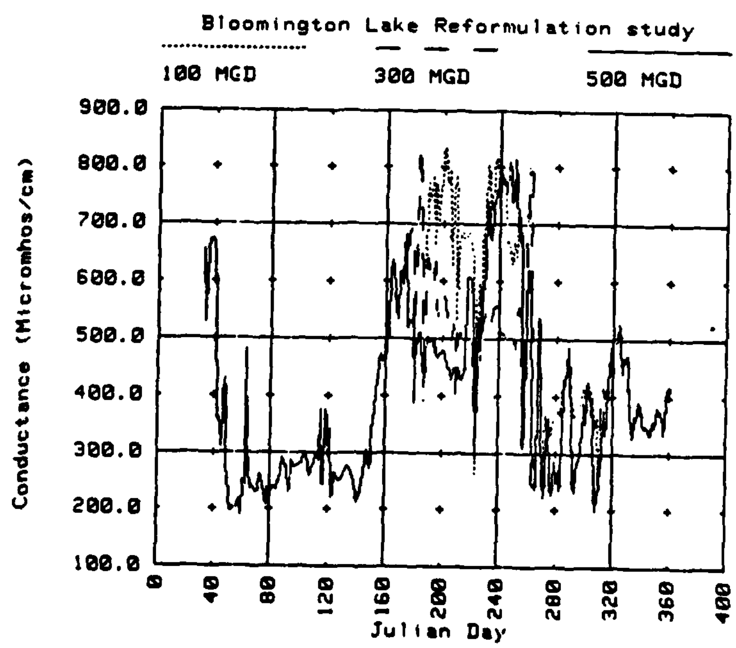
STATION: Willey Ford, MD.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 251



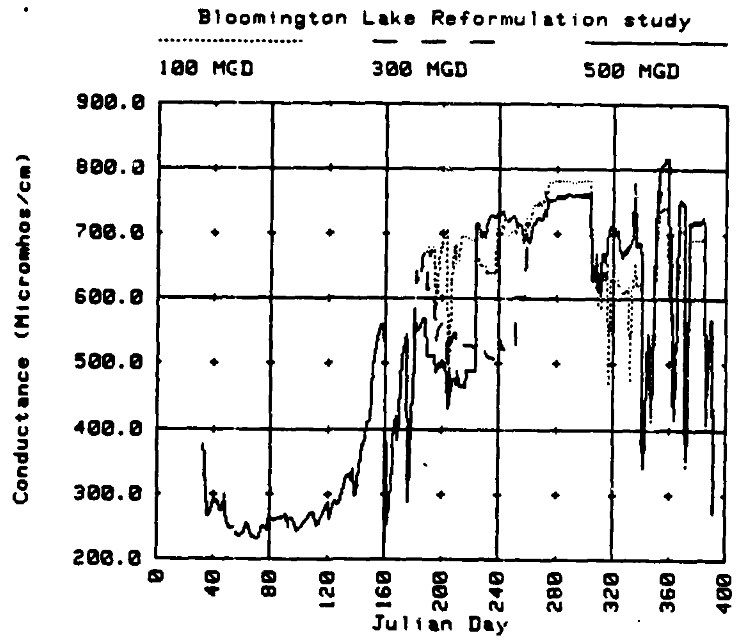
STATION: Willey Ford, MD.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 252



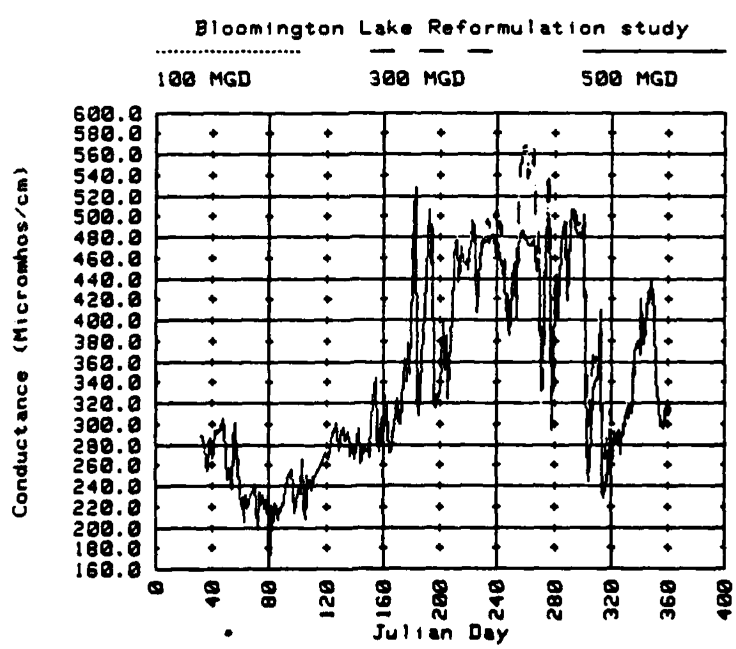
STATION: Willey Ford, MD.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 253



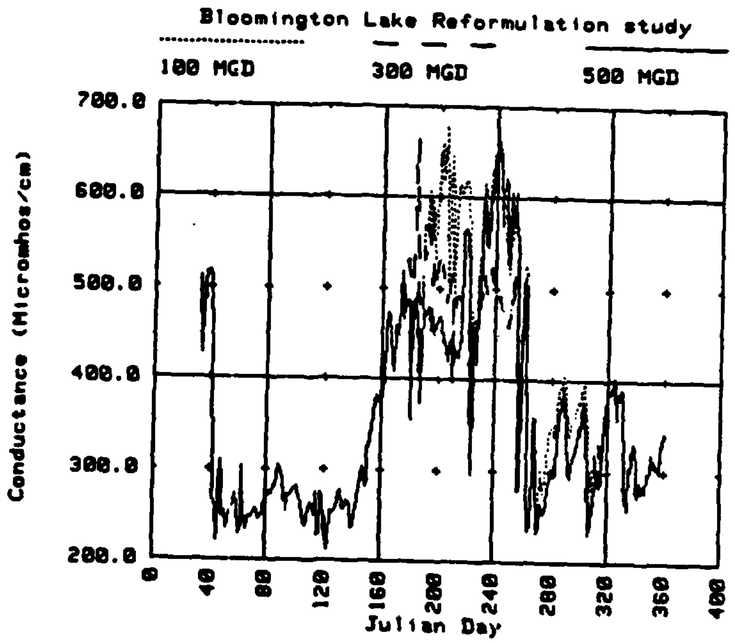
STATION: Paw Paw, W.Va.
YEAR: 1930
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 254



STATION: Paw Paw, W.Va.
YEAR: 1962
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 255



STATION: Paw Paw, W.Va.
YEAR: 1966
WATER QUALITY: Best Case
CONDITION: CONSERVATION 1466 POOL

FIGURE H-II- 256

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