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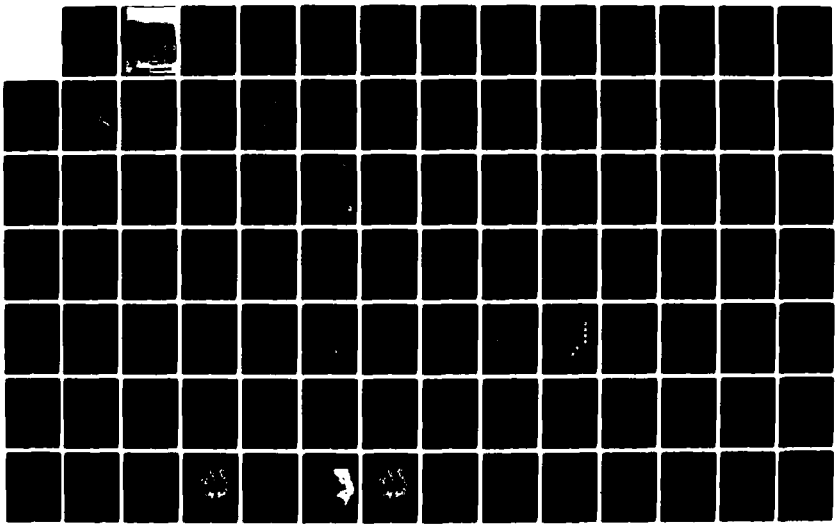

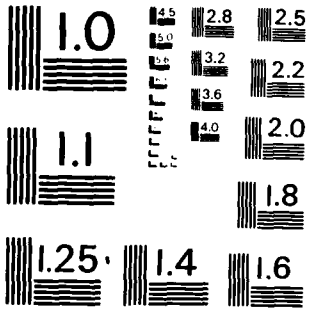

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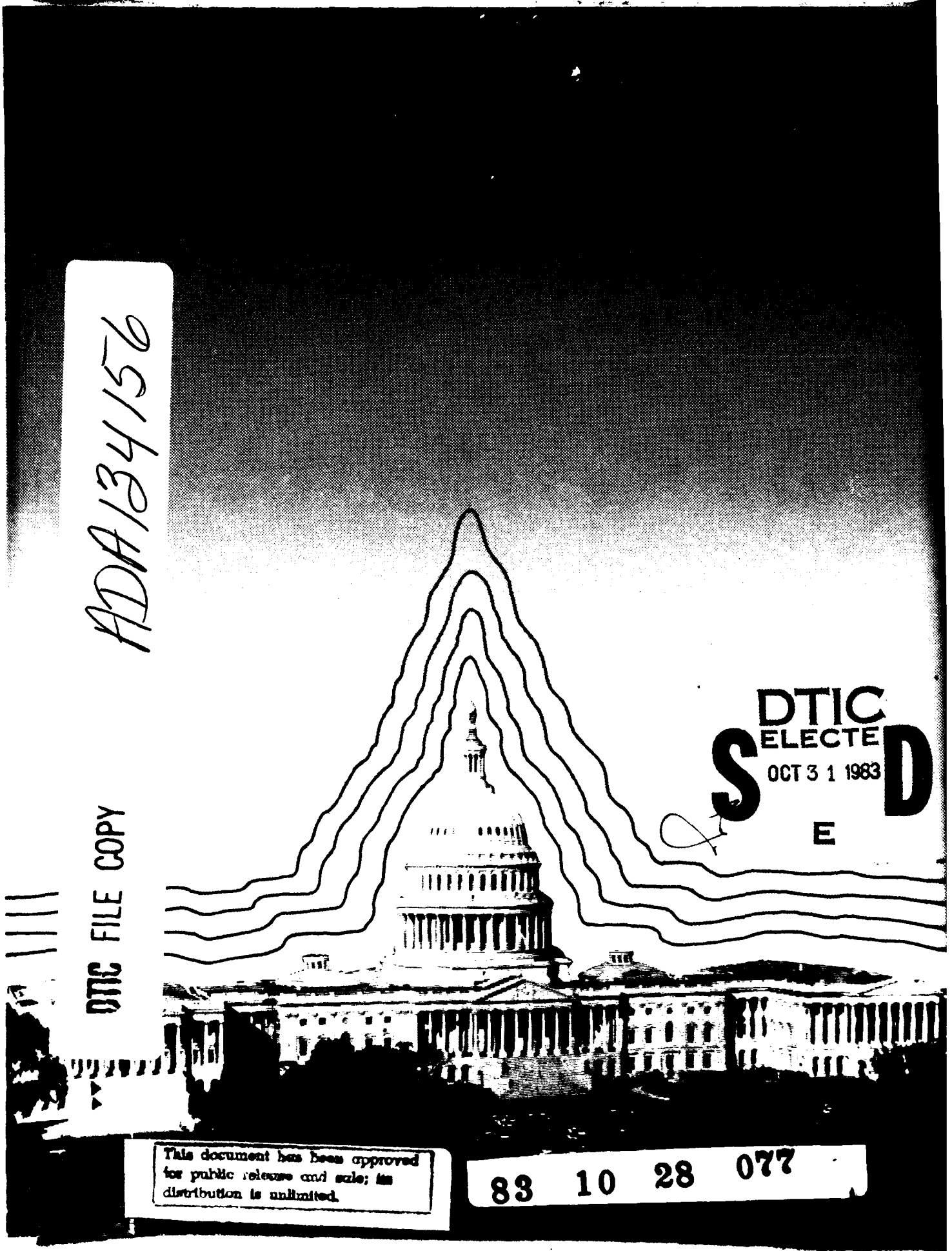

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water resources planning; water demand; water supply; Potomac River; groundwater; reservoir; raw water interconnection; Low Flow Allocation Agreement; Bloomington Lake; Little Seneca Lake; wastewater reuse; Potomac Estuary Experimental Water Treatment Plant; PRISM/COE; water pricing; water conservation; demand reduction; Cooperative Operations on the Potomac; flowby;

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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19. KEY WORDS (continued)

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

20. ABSTRACT (continued)

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 D
SUPPLIES, DEMANDS, AND DEFICITS

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Baltimore, Maryland

September 1983

METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY

APPENDIX D - SUPPLIES, DEMANDS, AND DEFICITS

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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
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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.

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Annex D-V	Potomac River Environmental Flowby, Executive Summary
Annex D-VI	PRISM/COE Output, Long-Range Phase

APPENDIX D

SUPPLIES, DEMANDS, & DEFICITS

The purpose of the Supplies, Demands, and Deficits Appendix is to present the basic information used to estimate supplies, calculate demands, and compute deficits for future years. The first section discusses the characteristics of the existing reservoirs furnishing water to the MWA while the second section describes the MWA's water supply intake, treatment and distribution facilities. The third section summarizes the water supply base used for the early-action phase of the study, including supplies computed by both a frequency analysis and a simulation analysis. The fourth section presents the methodology and results of the demand computations, followed in the fifth section by the calculation of deficits for the early-action study phase. The information in the first through fifth sections is summarized from the August 1979 Progress Report. Because of certain refinements, redefinitions, decisions, and actions following the August 1979 Progress Report, the sixth section addresses supplies, demands, and deficits as later projected for the long-range phase of study.

EXISTING RESERVOIR CHARACTERISTICS

This section presents information on characteristics of major reservoirs within the basins of the Occoquan Creek and the Potomac and Patuxent Rivers (Figure D-1). Most of the information is based on existing design conditions. In several instances, however, reservoir data were generated using the HEC-3 program, Reservoir System Analysis for Conservation which was developed by the Hydrologic Engineering Center (HEC) at Davis, California. This program is capable of accepting any configuration of reservoirs, power plants, diversions, and stream control points and simulates the operation of a reservoir system for conservation purposes. In existence for over 10 years, the program is well documented and verified. Computations are based on the principle of continuity as expressed by the following equation:

$$Si = S(i-1) + Ii - Qi - Ei$$

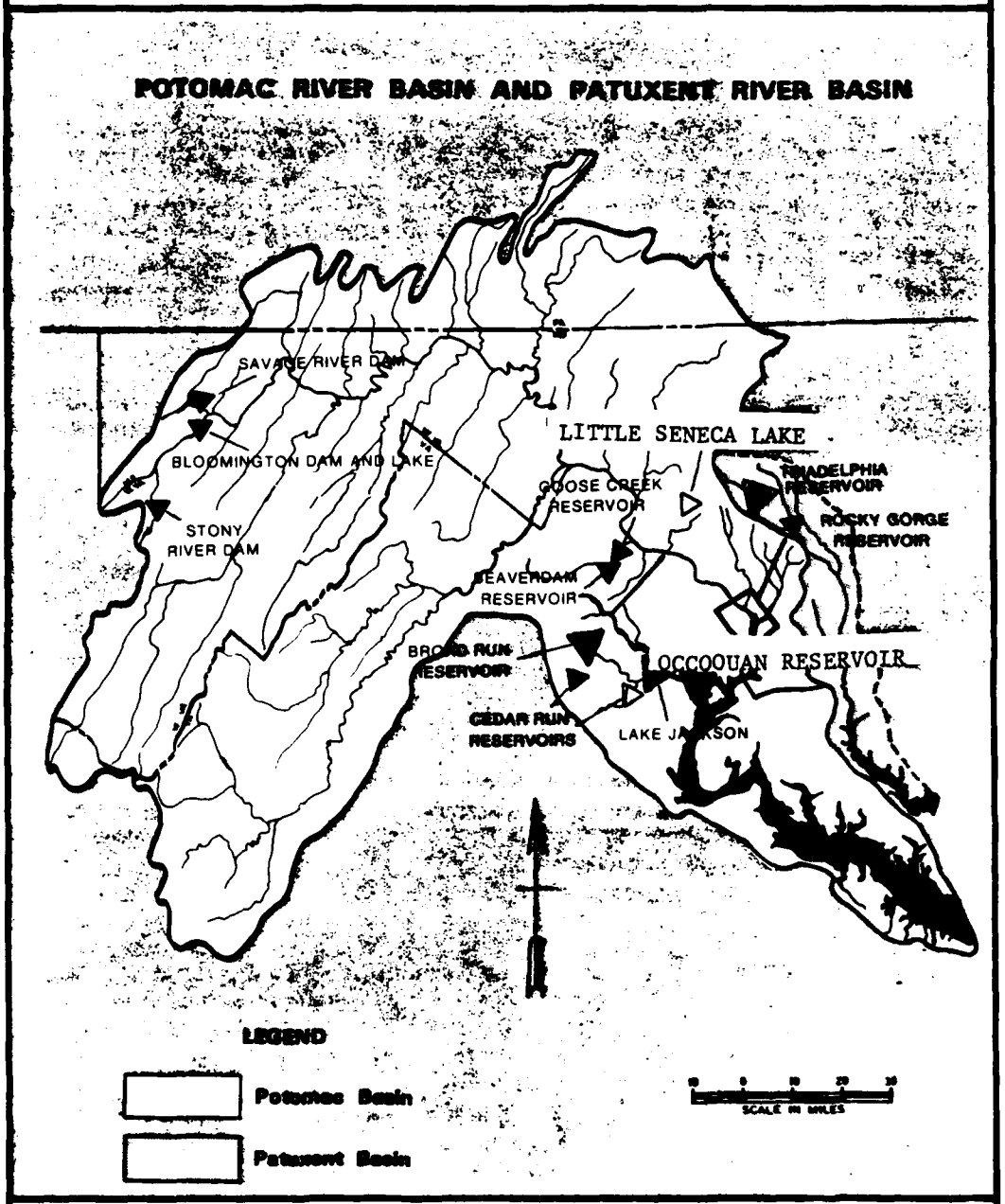
where

- Si = reservoir storage volume at the end of the current period, i.
- S (i-1) = reservoir storage volume at the end of the previous period, (i-1).
- Ii = inflow volume during period i.
- Qi = release volume during period i.
- Ei = net evaporation volume during period i.

Evaporation data are available for only a few points in the Potomac River Basin. Therefore, for the purposes of this report, reservoir evaporation was assumed to be uniform for the North Branch Potomac River Reservoirs and also for the reservoirs in and around the immediate MWA region. Tables D-1 and D-2 present the evaporation rates in inches per month for the respective areas.

Sedimentation and reservoir life were estimated from secondary data, except where specific studies had been performed. Based on values given in the Interstate Commission on the Potomac River Basin report, Non-Point Pollution in the Potomac River Basin, 1975, appropriate estimated average annual sediment yields can be summarized as follows for the following areas:

EXISTING AND PROPOSED RESERVOIRS
AFFECTING THE MWA



▲ EXISTING RESERVOIR

△ PROPOSED RESERVOIR

Figure D-1

TABLE D-1

MONTHLY DISTRIBUTION OF RESERVOIR EVAPORATION
FOR
NORTH BRANCH POTOMAC RIVER BASIN RESERVOIRS

MONTH	RESERVOIR EVAPORATION* (inches)
October	2.17
November	1.22
December	0.62
January	1.05
February	1.35
March	2.00
April	3.09
May	4.23
June	4.55
July	4.72
August	4.06
September	3.14

*Based on observations made by reservoir operation personnel. Pan evaporation values have been adjusted to reservoir evaporation values.

TABLE D-2
MONTHLY DISTRIBUTION OF RESERVOIR EVAPORATION IN THE MWA*

MONTH	CLASS A PAN EVAPORATION (inches)	RESERVOIR EVAPORATION** (inches)
October	3.1	2.3
November	1.5	1.1
December	0.3	0.2
January	1.6	1.1
February	2.2	1.6
March	3.7	2.7
April	4.5	3.3
May	5.6	4.1
June	6.6	4.8
July	7.8	5.7
August	6.2	4.5
September	4.8	3.5

*Adapted from Measurements made by National Weather Service, 29 years of record at Beltsville, Maryland.

**Applying a coefficient of 0.73 to Pan Evaporation, cf. Table 5-2, 169, Hydrology for Engineers, 2nd Edition, Linsley, Kohler and Paulhus, McGraw-Hill, 1975.

1. Upsteam of Point of Rocks: 113 tons/square mile
2. Below Point of Rocks but above Little Falls (including Seneca and Goose Creek drainage areas): 309 tons/square mile.
3. Below Little Falls (including all the Occoquan Creek drainage): 682 tons/square mile.

In general, sediment yields are highest in areas undergoing urbanization or subject to significant construction activities. Current development (construction or urbanization) activity would suggest sediment accumulation rates in active areas of development on the order of 5,000 to 10,000 tons per square mile of net drainage area per year. Where drainage areas have stabilized and are not subject to significant human activity, sediment accumulation rates on the order of 300 to 900 tons per square mile of net drainage area per year appear to be in order. For upland forested areas, sediment accumulation rates of 100 or less tons per square mile of net drainage area per year seem to be reasonable.

NORTH BRANCH POTOMAC RIVER RESERVOIRS

Figure D-2 shows the relative locations of the Bloomington, Stony River, Mount Storm and Savage River Reservoirs discussed in this section. The principal drainage patterns are shown, as are principal highways and major communities. Table D-3 presents summary characteristics of the North Branch Potomac Reservoirs.

NORTH BRANCH POTOMAC RIVER RESERVOIRS

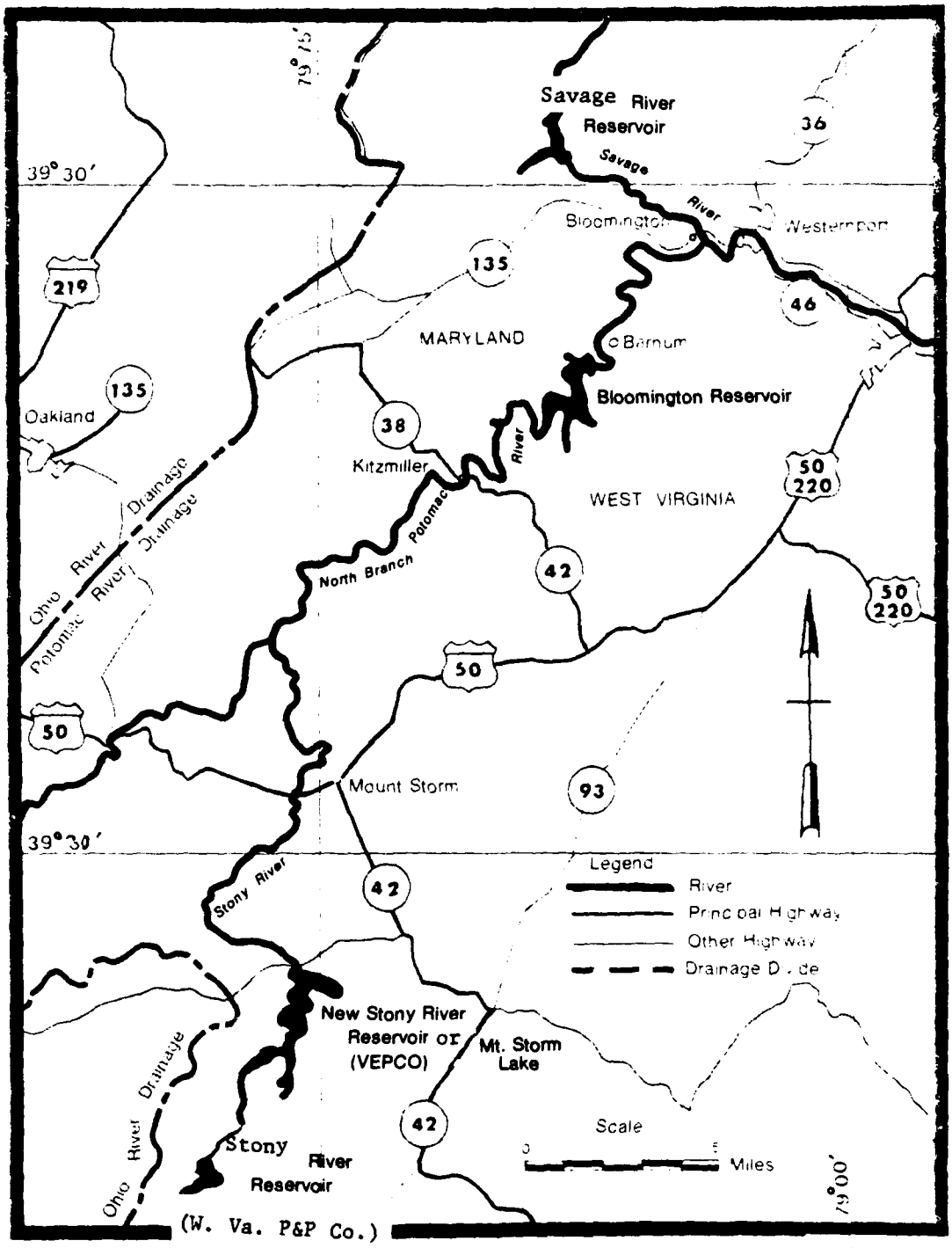


Figure D-2

TABLE D-3
NORTH BRANCH POTOMAC RIVER RESERVOIRS
SUMMARY CHARACTERISTICS

	STONY RIVER	BLOOMINGTON	SAVAGE	MT STORM
Normal Conservation Pool Elevation, feet msl	3,395	1,466	1,440	*-*
Flood Control Storage Above Normal Conservation Pool, acre-feet	1,320	47,000*	16,700	*-*
Total Storage at Normal Conservation Pool Level, acre-feet	4,200	94,700	12,000	47,600
Usable Storage at Normal Conservation Pool Level, acre-feet	3,250	92,000	11,000	*-*
Conservation Storage, acre-feet	3,250	34,400	11,000	*-*
Buffer and Inactive Storage, acre-feet	2,390	60,300	1,900	*-*
Principal USGS Stream Gage	01595500	01595500	01597500	
Drainage Area to Controlling Stream Gage, square miles	225	225	106	*-*
Drainage Area to Reservoir, square miles	12.5	263	105	*-*
Safe Yield, mgd	3.23	134.40	14.86	*-*

*includes 10,800 acre-feet Design Surcharge
*-*Data Unavailable

STONY RIVER DAM AND RESERVOIR

Stony River Dam is a concrete slab and buttress dam 52.5 feet high and 1103 feet long. The top of the dam is at elevation 3401.5 feet mean sea level (msl). The dam is owned and operated by the West Virginia Pulp and Paper Company, primarily for industrial water supply purposes. The dam is located on Stony River in Grant County, West Virginia, about 20 miles above the confluence with the North Branch Potomac River. The total drainage area above the dam is 12.5 square miles. In the past, the reservoir was operated in conjunction with the Savage River Reservoir with a common set of operating rules. These rules were devised to meet certain flow objectives below the confluence of the Savage River with the North Branch Potomac River.

The dam has two spillways which maintain normal pool elevation at 3395.0 feet msl. In addition, a broadcrested emergency spillway is in place four feet above the normal spillways (at elevation 3399.0 feet, msl). Provision is made to raise the pool level two feet above normal spillway crest by use of flashboards. An attempt is made to attain a full pool at flashboard level by June 1 of every year for low flow releases later in the summer. The dam outlet works consists of two 20-inch manually operated gate valves, one 48-inch manually operated gate valve, and one 8-inch manually operated gate valve.

Area-capacity curves for the Stony River Reservoir are shown in Figure D-3. Safe yield of the reservoir, given the operating rules where flashboards are used to attempt to maintain a reservoir level of 3,397 feet msl, was found to be 3.2 mgd. Safe yields were determined with use of the computer model, HEC-3, and the filled-in-gage record for the North Branch Potomac River at Kitzmiller, Maryland, (U.S.G.S. gage 01595500) adjusted to the Stony River Dam drainage area.

The reservoir was operated jointly with the Savage Reservoir based on a common set of operating rules devised by the U.S. Army Corps of Engineers, Baltimore District. The goal of the operating rules was to maintain a minimum flow of 60 mgd at Luke, Maryland on the North Branch Potomac River. The primary burden for low flow augmentation centered around releases from the Savage River Reservoir with supplemental flows from the Stony River Reservoir of the West Virginia Pulp and Paper Company. These latter low flow releases usually occurred from mid to late summer and ranged from 3 cfs up to 20 cfs (12.9 mgd). With the addition of Bloomington Lake to the system of reservoirs in the North Branch Potomac River, the operating rules for the Stony River Reservoir are being modified.

MOUNT STORM LAKE

Mount Storm Lake (also known as New Stony River Reservoir) is an impoundment on the Stony River, approximately 10.4 miles upstream from the confluence of the Stony River with the North Branch Potomac River. The reservoir is owned by the Virginia Electric and Power Company (VEPCO), and was placed in service in 1963.

The impoundment is formed by an earthfill embankment approximately 1,125 feet long and 125 feet high, and has a surface area of about 1,110 acres. The drainage area is 31.2 square miles, including the 12.5 square mile drainage to the West Virgnia Pulp and Paper Company Stony River Reservoir. The impoundment serves as a source of cooling water for a steam power plant located adjacent to the reservoir. The reservoir is operated in a

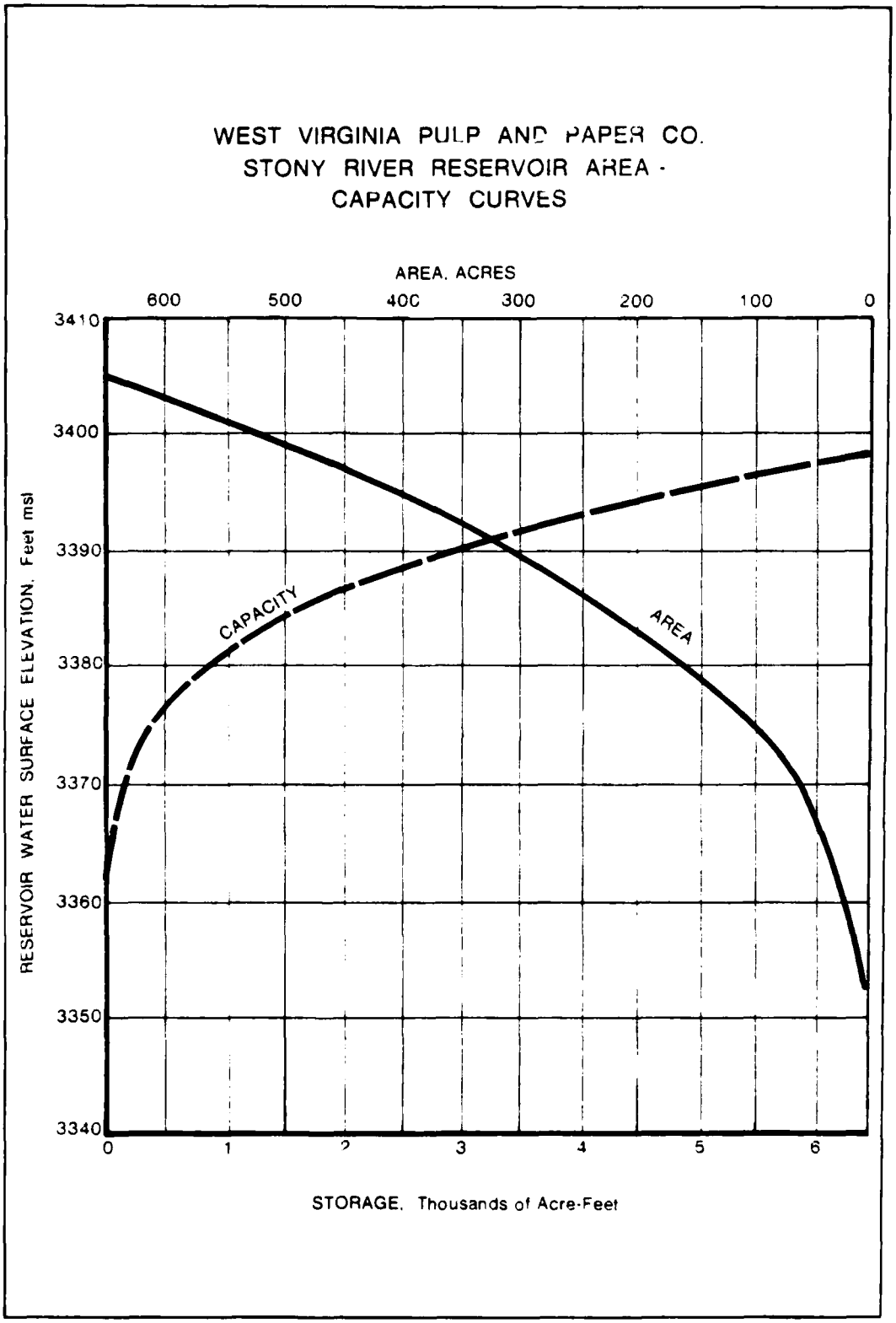

WEST VIRGINIA PULP AND PAPER CO.
STONY RIVER RESERVOIR AREA -
CAPACITY CURVES
AREA, ACRES
600
500
400
300
200
100
0
3410
3400
3390
3380
3370
3360
3350
3340
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
1
2
3
4
5
6
STORAGE, Thousands of Acre-Feet

Figure D-3

run-of-the-river manner, and offers very little regulation to Stony River. Overflow discharge is accomplished by weir overflow into a chute spillway which empties into Stony River below the dam. Spillway crest elevation is at elevation 3,244 feet mean sea level. The storage capacity at normal pool is 47,600 acre-feet. Little provision is made for recreation.

BLOOMINGTON DAM AND LAKE

The Bloomington Reservoir project was authorized by the Flood Control Act of 1962 (Public Law 874, 87th Congress, Second Session) for the purposes of water quality control, reduction of flood damages, water supply, and recreation. The project is located in Garrett County, Maryland, and Mineral County, West Virginia, on the North Branch Potomac River. The project was constructed by the U.S. Army Corps of Engineers; construction began in 1971 and was completed in 1981. The Maryland Potomac Water Authority originally contracted with the Federal government for the purpose of acquiring the initial water supply storage in the Bloomington Reservoir. Arrangements have recently been negotiated with non-Federal sponsors for repayment of the cost allocated to future water supply storage to be used primarily to provide supplemental flow to the MWA during drought periods. These arrangements were also structured so that the non-Federal sponsors for the future water supply storage costs would assume the Maryland Potomac Water Authority's repayment responsibilities for the initial costs as well.

Bloomington Lake has a drainage area of 263 square miles. The completed dam consists of an earth and rockfill structure with a top elevation of 1,514 feet mean sea level. The principal embankment is approximately 2,130 feet long and stands 294 feet above the stream bed. The spillway structure passes through a ridge to the north of the main earth embankment on the North Branch Potomac River.

The spillway crest is at elevation 1,468 feet msl (the maximum conservation pool will be at elevation 1,466 feet msl). Tainter gates will normally rest in closed position near the crest of the spillway. Tainter gates are of the radial type and each measures approximately 42 feet wide and 32 feet high. The maximum design discharge is 193,000 cfs.

The dam outlet works consist of an intake tower with inlets centered at elevations 1,447; 1,417; 1,382; 1,328 feet msl, respectively, and a gated inlet channel with invert elevation 1,225 feet msl. The intake tower rests on a gate chamber which connects to a 16 foot diameter tunnel passing through the right abutment. The tunnel empties into a stilling basin downstream from the toe of the dam and from thence the flow is channeled back into the river. Maximum rated discharge at maximum flood pool is 17,650 cfs.

Area-capacity curves for the reservoir are shown in Figure D-4. Principal elevation, area, and capacity data are presented in Table D-4. Safe yield for the Bloomington Reservoir, given normal pool at elevation 1,466 feet msl, was found to be 135 mgd. Safe yield was determined with the use of the computer model, HEC-3, and the filled-in gage record for the North Branch Potomac River at Kitzmiller, Maryland (U.S.G.S. gage 01595500) adjusted to the Bloomington Dam drainage area. (This so-called "safe yield" was the subject of considerable analysis in the long-range phase of the study to determine if the project could be regulated more efficiently. For the purpose of the study's early-action phase, though, Bloomington Lake was assumed to provide 135 mgd to the MWA).

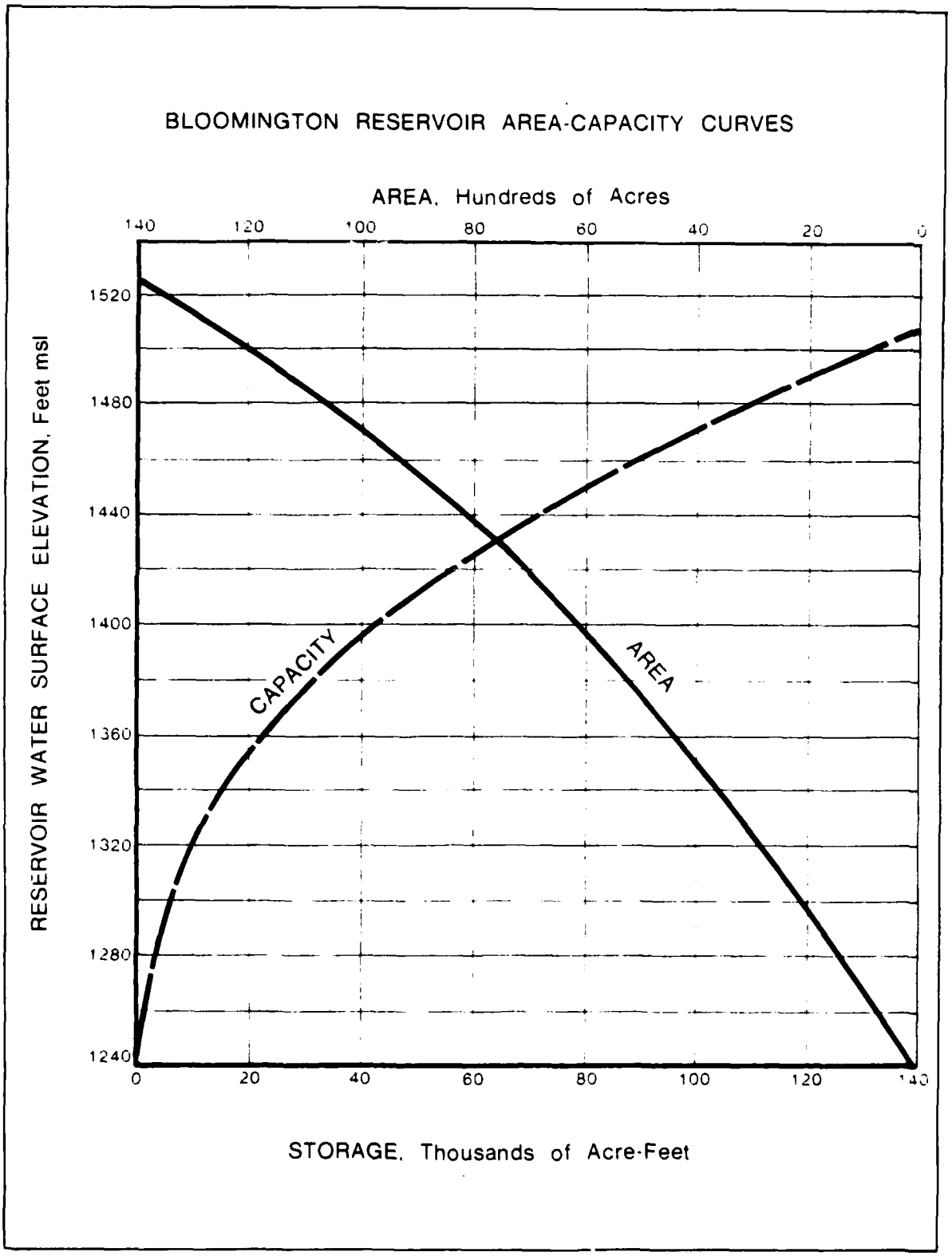

BLOOMINGTON RESERVOIR AREA-CAPACITY CURVES
AREA, Hundreds of Acres
140
120
100
80
60
40
20
0
RESERVOIR WATER SURFACE ELEVATION, Feet msl
1520
1480
1440
1400
1360
1320
1280
1240
CAPACITY
AREA
0
20
40
60
80
100
120
140
STORAGE, Thousands of Acre-Feet

Figure D-4

TABLE D-4
BLOOMINGTON DESIGN CHARACTERISTICS

	Elevation (feet msl)	Area (acres)	Capacity (acre-feet)
Top of Dam	1,514.0	1,282	148,200
Max. Flood Pool	1,508.9	1,247	141,700
Static Full Pool (normal pool)	1,500.0	1,184	130,900
Spillway Crest	1,468.0	965	96,500
Max. Conservation Pool	1,466.0	952	94,700
Gate Still	1,255.0	42	2,700
Streambed at Dam Centerline	1,220.0	0	0

Recreation facilities provide for boating, fishing, camping, hiking, and picnicing. Development of recreation is confined to the West Virginia side of the reservoir because of the lack of suitable areas on the Maryland side. A picnic and camping area, with necessary amenities, is provided. It is expected that the initial annual visitation will be approximately 110,000 visitor days per year.

The Bloomington Lake project is regulated in conjunction with the Savage River Reservoir and Stony River Reservoir to provide a dependable low flow quantity and quality at Luke, Maryland, on the North Branch Potomac River downstream from the reservoirs (see Figure D-2). The project is also regulated to provide flood damage protection along the North Branch Potomac River and to provide water supply storage for downstream communities, including the MWA, during droughts. As part of the Metropolitan Washington Area Water Supply Study, the Bloomington Lake project was the subject of a reformulation examination to determine: (1) the best regulation scheme for the existing project to satisfy current conditions and criteria, and (2) whether any reallocation of storage among project purposes might be necessary to satisfy future needs. Appendix H, Bloomington Lake Reformulation Study contains the details of this investigation.

SAVAGE RIVER DAM AND RESERVOIR

Savage River Dam is an earth and rock fill structure 184 feet high and 1,050 feet long. The top of the embankment is at elevation 1,497.5 feet mean sea level. The dam was designed by the U.S. Army Corps of Engineers and construction was started by the Work Progress Administration prior to World War II. Following World War II, construction was completed by a private construction company under Corps of Engineers supervision. The dam and reservoir are now owned and operated by the Upper Potomac River Basin Commission.

Drainage to the reservoir is approximately 105 square miles. The spillway is a side channel spillway. The elevation of the crest of the overflow weir is at elevation 1,468.5 feet msl. Discharge capacity is given at 97,200 cfs with flow at 24.3 feet depth on the crest.

An outlet structure consisting of a 10-foot diameter horseshoe-shaped tunnel passes under the right abutment of the dam. The tunnel has an overall length of 1,170 feet beginning with an intake structure, passing through an operations house containing appropriate control valves, and discharging into a tunnel outlet channel below the toe of the dam and emptying into the Savage River. With the reservoir at normal pool elevation of 1,468.5 feet msl, the tunnel discharge capacity is 4,850 cfs.

Principal control of outflow is attained through the operation of two 4-foot by 10-foot hydraulically operated slide gates. To meet conservation bypass requirements for flow in the Savage River of 10 cfs immediately below the dam, two 8-inch manually operated gate valves are used. Water supply requirements of up to 3 cfs (2 mgd) can be delivered to Westernport, Maryland, through use of a direct connection controlled by two 16-inch manually operated gate valves.

Area-capacity curves for the reservoir are shown in Figure D-5. Safe yield for the Savage River Reservoir, given the current operating rules and normal pool elevation of 1,468.5 msl, was found to be 14.8 mgd. Safe yields were determined with the use of the computer program HEC-3, and the filled-in-gage record for the Savage River below Savage River Dam near Bloomington, Maryland (U.S.G.S. gage 01597500) adjusted to the Savage River Reservoir drainage area.

The Savage River Reservoir was operated jointly with the Stony River Reservoir of the West Virginia Pulp and Paper Company to assure Luke, Maryland, of a dependable flow in the North Branch Potomac River of 93 cfs (60 mgd). For fish and wildlife purposes, a minimum flow of 10 cfs is required in the Savage River below the dam. With the completion of the Bloomington Reservoir, the three reservoirs are to be operated as a system. A problem arises because of the natural acidity of water captured in Bloomington Reservoir. Average pH values of 4.5 are expected. Consequently, releases from Bloomington need to be carefully coordinated with the releases from the alkaline pool in Savage Reservoir to satisfy downstream water quality targets at Luke.

Recreational access to the impoundment is possible. A light duty road skirts the western edge of the reservoir from the dam embankment to the point where the Savage River enters the reservoir. Boating and fishing are possible activities, but no park area has specifically been set aside.

EXISTING MWA RESERVOIRS IN MARYLAND

Figure D-6 shows the relative locations of the principle storage reservoirs in the Maryland portion of the MWA as well as the proposed Little Seneca Lake project discussed in Appendix F. The principal drainage patterns are shown, as are the principal highways and some of the major communities. Table D-5 presents in summary form characteristics of these reservoirs.

TRIADELPHIA RESERVOIR AND BRIGHTON DAM

Brighton Dam is an earthfill structure 62.4 feet high and 995 feet long. The dam is constructed in three distinct sections consisting of two earth fill embankments extending from a central concrete spillway structure to natural valley walls. The total drainage area above the dam is 78.4 square miles.

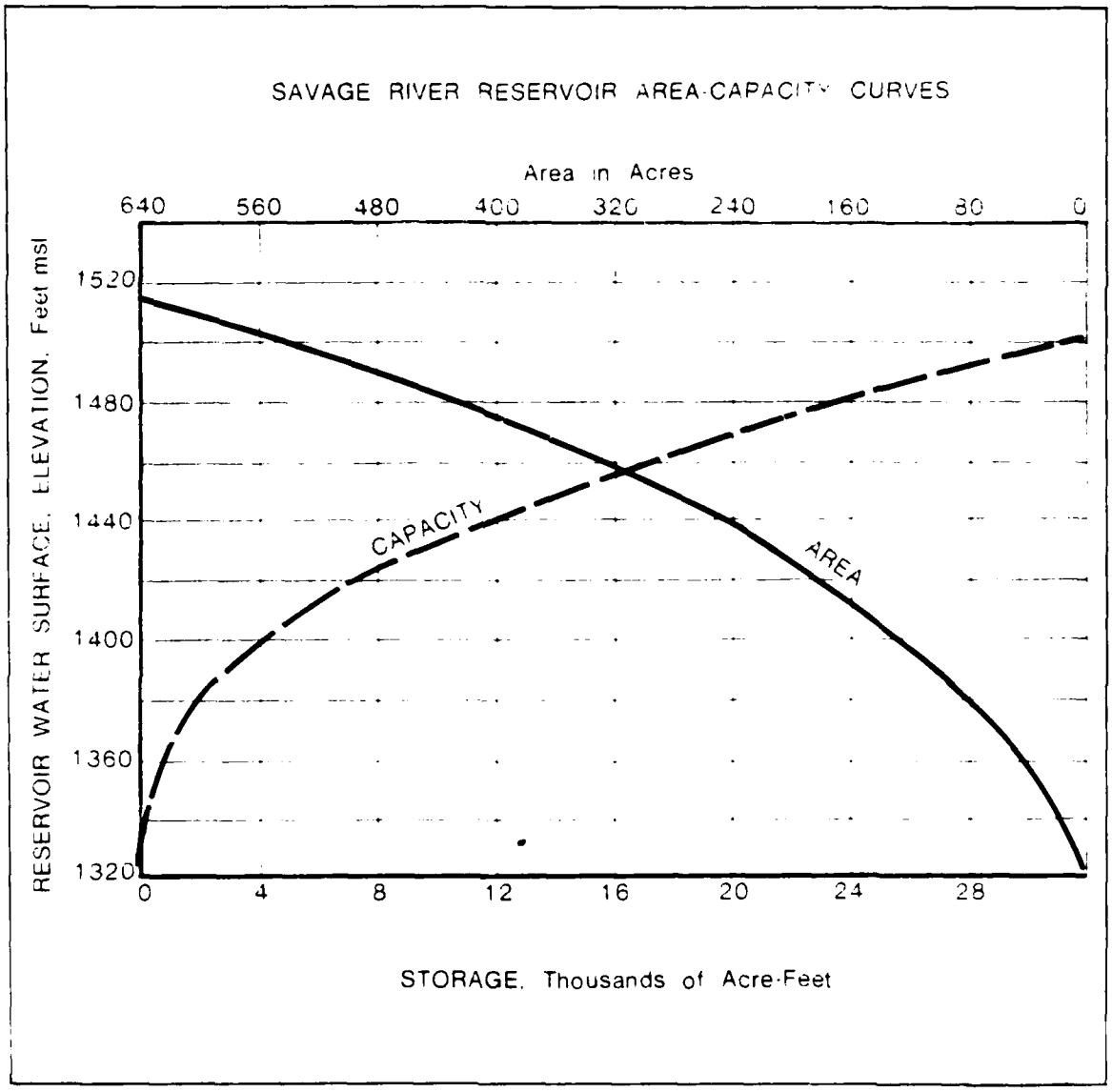

SAVAGE RIVER RESERVOIR AREA-CAPACITY CURVES
Area in Acres
640
560
480
400
320
240
160
80
0
RESERVOIR WATER SURFACE, ELEVATION, Feet msl
1520
1480
1440
1400
1360
1320
CAPACITY
AREA
0
4
8
12
16
20
24
28
STORAGE, Thousands of Acre-Feet

Figure D-5

PRINCIPAL MWA RAW WATER STORAGE RESERVOIRS IN MARYLAND

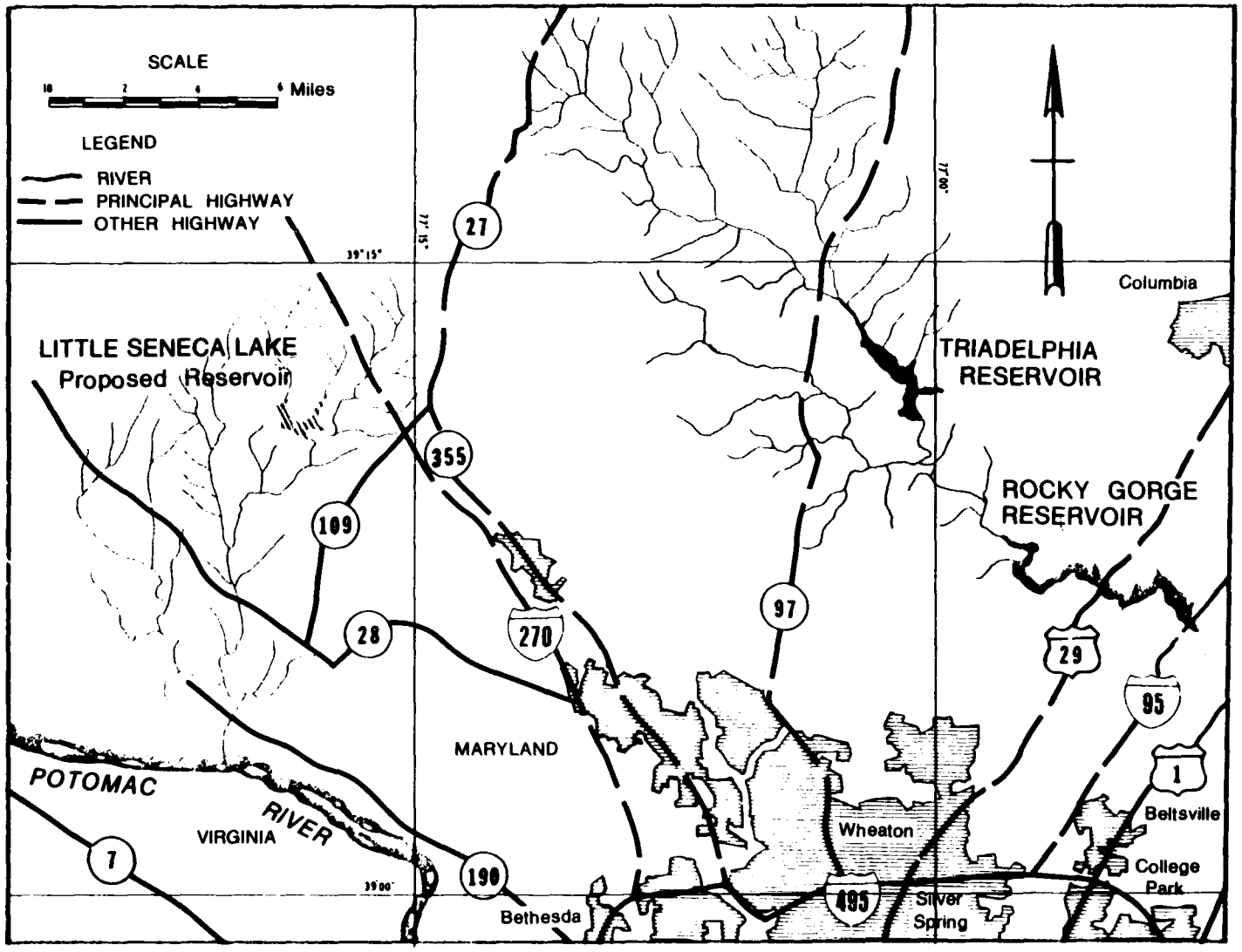


Figure D-6

TABLE D-5

PRINCIPAL MWA RAW WATER STORAGE RESERVOIRS IN MARYLAND
SUMMARY CHARACTERISTICS

	TRIADELPHIA		ROCKY	PROPOSED SCS SITE 3	
	EXISTING	RAISED 5'	GORGE	SCS VERSION	WSSC VERSION
Normal Conservation Pool Elevation, feet msl	363.4	368.4	283.4	380.0	385.0
Flood Control Storage Above Normal Conservation Pool, acre-feet	3,450	4,600	5,200	6,575	3,920
Total Storage at Normal Conservation Pool Level, acre-feet	18,950	22,400	16,800	10,850	13,050
Usable Storage at Normal Conservation Pool Level, acre-feet	17,415	20,865	13,731	8,640	12,350
Conservation Storage, acre-feet	17,415	20,865	13,731	8,640	12,350
Buffer and Inactive Storage, acre-feet	1,535	1,535	3,069	2,210	700
Inactive Storage, acre-feet	1,535	1,535	3,069	2,210	700
Principal USGS Stream Gage	01591000	01591000	01591000	01645000	01645000
Drainage Area to Controlling Stream Gage, square miles	34.8	34.8	132.0	101	101
Drainage Area to Reservoir, square miles	78.4	78.4	132.0	20.8	20.8
Safe Yield, mgd	29.0	35.5	21.3	8.2	9.1

The spillway crest is at elevation 350.0 feet mean sea level. Tainter gates normally rest in closed position on top of the spillway crest. Tainter gates each measure 18 feet wide by 15 feet high and are topped by 17 inch flashboards. Spillway discharge capacity is controlled by the reservoir water surface elevation and the amount of gate opening.

The outlet works consist of five silt valves and two needle valves. Total rated discharge capacity is approximately 1,000 cubic feet per second. The area-capacity curves shown in Figure D-7 were obtained from the Washington Suburban Sanitary Commission. Safe yield for the Triadelphia Reservoir, given the current operating rules where reservoir level is maintained at 363.4 feet msl, was found to be 29 mgd. Assuming a five foot addition to the dam with an operating level of 368.4 feet msl, the safe yield was found to be 32.9 mgd. Safe yields were determined with use of the computer model, HEC-3, Reservoir-System Analysis for Conservation, and the filled-in-gage record for the Patuxent River at Unity, Maryland (U.S.G.S. gage 01591000) adjusted to the Brighton Dam drainage area.

An increase of five feet in the operational height of the normal reservoir pool has been suggested. The increase in storage capacity that would result is illustrated in Figure D-7. Residents of Howard County, adjacent to the reservoir, have objected to expansion of the reservoir. The expansion could be accomlished by modification of the spillway structure and tainter gate system and by strengthening the earthen embankments on each side of the spillway structure. Formal plans and specifications for such an expansion have not been developed.

The reservoir is owned by the Washington Suburban Sanitary Commission (WSSC) to include the area directly surrounding the reservoir which is maintained under strict conservation management to prevent unnecessary silt loads on the reservoir. The bulk of the watershed is rural and agricultural, except for urbanizing areas along the fringes of the watershed.

Rights to the water tributary to the reservoir are typical as reserved for riparian property owners. The major downstream water user is the WSSC, which owns and operates the Rocky Gorge Reservoir 11 miles downstream. Triadelphia Reservoir is operated primarily to assure adequate water releases to Rocky Gorge Reservoir where WSSC has a withdrawl point for its Patuxent Water Treatment Plant. (Triadelphia is operated at three feet less than full pool elevation, 363.4 feet msl as opposed to elevation 366.4 feet msl, to provide some flood storage.

There are no provisions for recreation at the reservoir, since it is operated primarily for water supply purposes.

ROCKY GORGE RESERVOIR AND T. HOWARD DUCKETT DAM

T. Howard Duckett Dam, located just upstream of Laurel, Maryland, is a buttress type, concrete gravity dam 125.4 feet high and 840 feet long. The dam is constructed in three sections consisting of two buttress supported concrete bulkheads extending from a central concrete spillway structure to the natural valley walls on each side. The total drainage area tributary to the dam is 132 square miles. The 132 square miles of drainage area include 78.4 square miles controlled by the Triadelphia Reservoir, drainage from 39.2 square miles of the Hawlings River and the Patuxent River between Brighton Dam and the Rocky Gorge Reservoir and 14.4 square miles draining directly into the Rocky Gorge Reservoir.

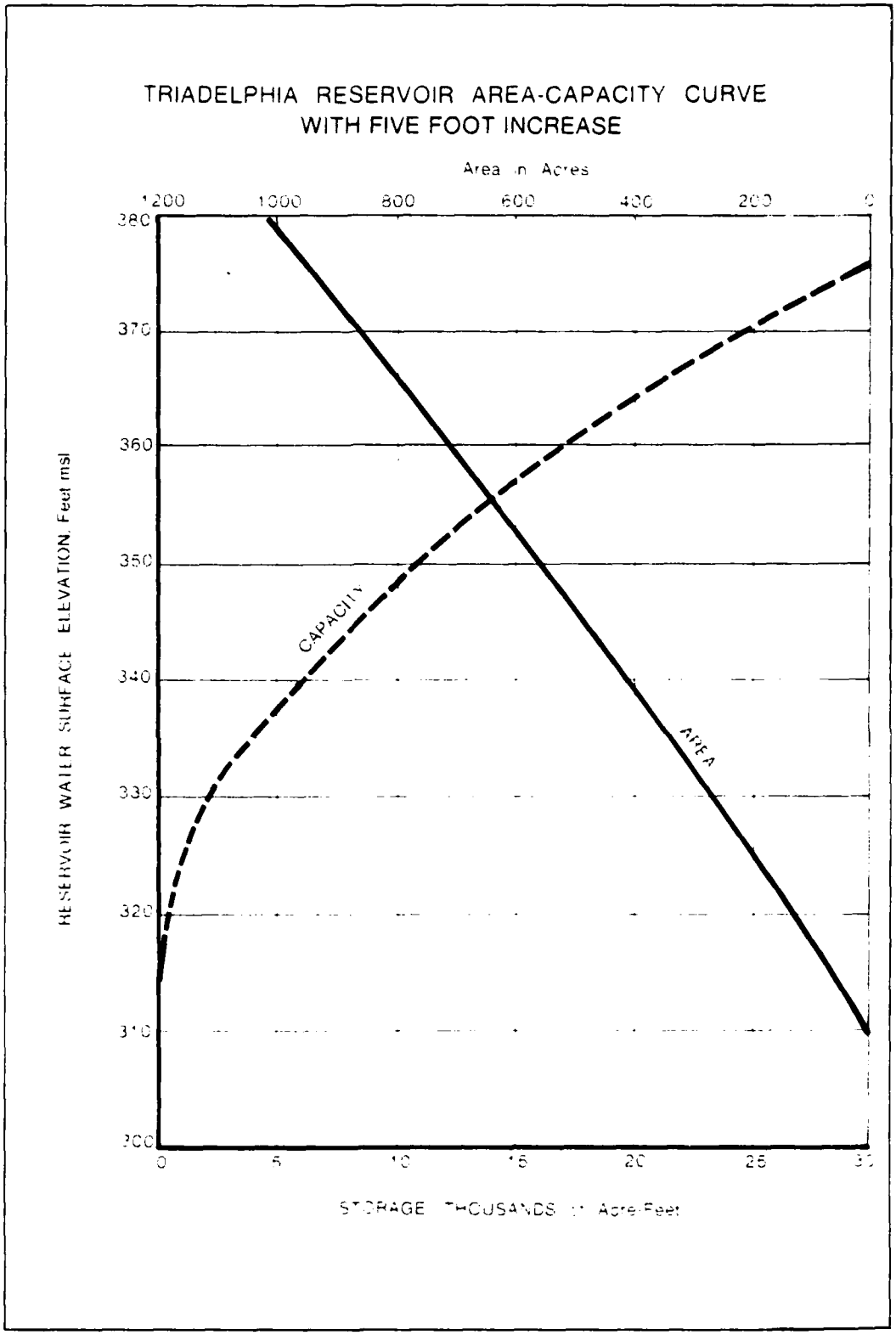

TRIADELPHIA RESERVOIR AREA-CAPACITY CURVE
WITH FIVE FOOT INCREASE
Area in Acres
1200
1000
800
600
400
200
0
380
370
360
350
340
330
320
310
300
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
5
10
15
20
25
30
STORAGE THOUSANDS of Acre-Feet

Figure D-7

The spillway crest is at elevation 270.0 feet mean sea level. Tainter gates usually rest in closed position on top of the spillway crest. Tainter gates are of the radial type. Each gate is structural steel and measures 27 feet wide by 15 feet high, and is topped by 17 inch flashboards. Spillway discharge capacity is controlled by the reservoir water surface elevation and the amount of gate opening.

The outlet works consists of a 30-inch undersluice valve rated at approximately 800 cfs when fully open. In addition, there are three turbines rated at 50 cfs each. Area-capacity curves for the reservoir are shown in Figure D-8. The curves were obtained from the Washington Suburban Sanitary Commission. Safe yield for the Rocky Gorge Reservoir, given the current operating rules where the reservoir level is maintained at 283.4 feet msl was found to be 21.3 mgd. This valve represents the safe yield of the Rocky Gorge Reservoir acting independently of Triadelphia Reservoir. Safe yields were determined with use of the computer model, HEC-3, and the filled-in-gage record for the Patuxent River at Unity, Maryland, (U.S.G.S. gage 01591000) adjusted to the Duckett Dam drainage area. Additional analyses performed by the Corps of Engineers indicated that the safe yield of the combined Triadelphia and Rocky Gorge Reservoirs was 32 mgd. This number was determined by simulating the 1930-1932 drought conditions for the Patuxent River, using inflow data and downstream release data furnished by the WSSC.

The reservoir and the area directly surrounding the reservoir, are owned by the Washington Suburban Sanitary Commission, which it keeps under strict conservation management to prevent unnecessary silt loads to the reservoir. The bulk of the watershed is rural and agricultural, except for urbanizing areas along the fringes of the watershed. Rights to the water tributary to the reservoir are those rights typically reserved to riparian owners. The Triadelphia and the Rock Gorge Reservoirs are both owned and operated by the WSSC as an interdependent system.

The WSSC is required to maintain a minimum flow downstream of the reservoirs at Laurel, Maryland. To do this, reservoir releases must satisfy one of two conditions: either the downstream flow must equal 10.5 mgd (16.5 cfs) or the flow must equal the natural flow as if no diversions existed, whichever is less. The natural flow at Laurel is taken to be 3.8 times the flow at the Unity, Maryland, gage (USGS gage number 01591000).

Although the reservoir is accessible to fishermen, recreation is not a primary consideration for Rocky Gorge Reservoir.

EXISTING MWA RESERVOIRS IN VIRGINIA

Figure D-9, shows the relative locations of existing MWA storage reservoirs within the Occoquan and Goose Creek drainage basins. The principle drainage patterns are shown, as are principal highways and some of the major communities. Summary data for these reservoirs are presented in Table D-6.

BROAD RUN DAM AND RESERVOIR

The Broad Run Reservoir, commonly referred to as Lake Manassas, was first filled in 1972. Lake Manassas is a water supply impoundment that has replaced the Manassas, Virginia, well system as the principal water supply source for that municipality. A drainage area of 60 square miles contributes to the reservoir.

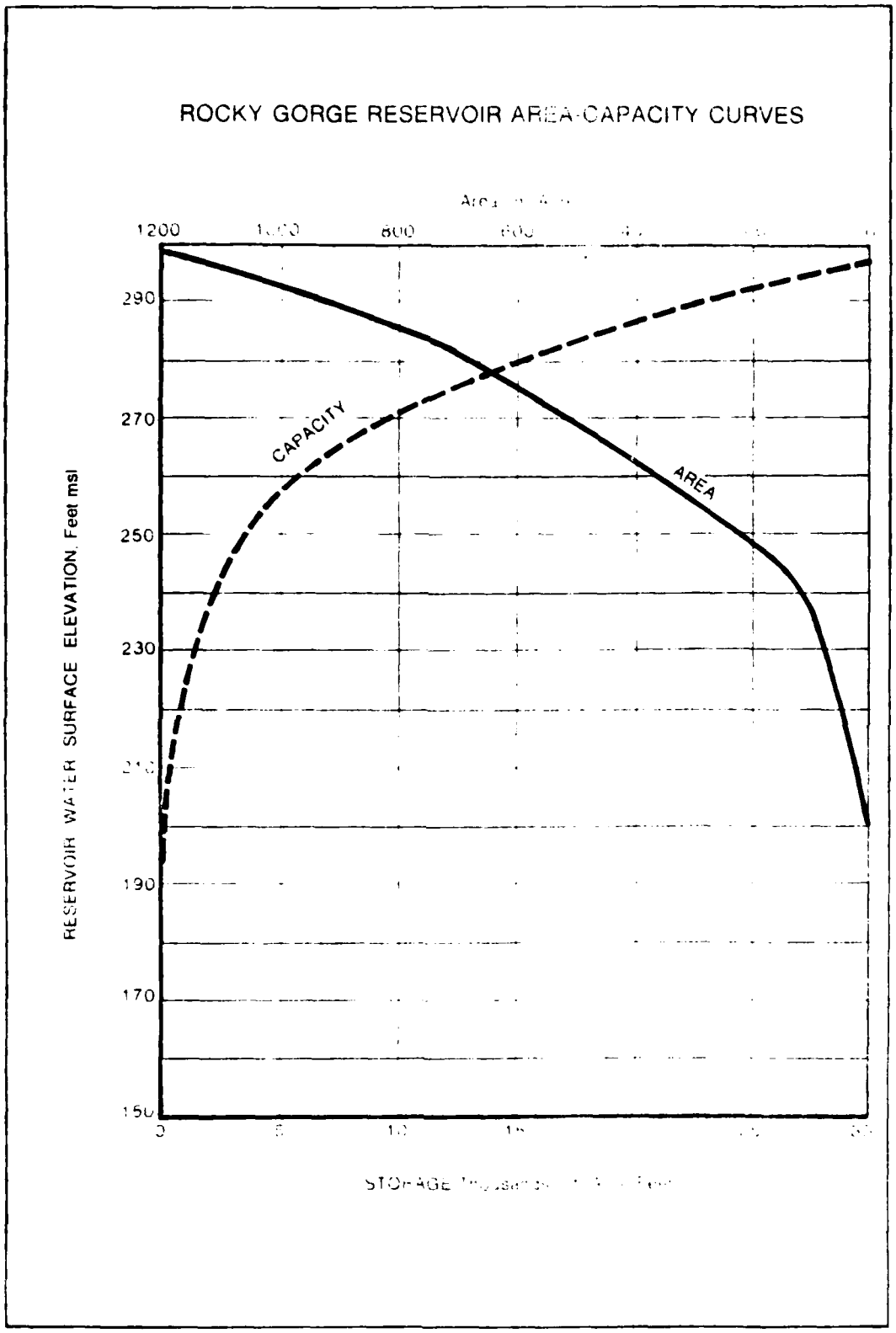

ROCKY GORGE RESERVOIR AREA-CAPACITY CURVES
1200
800
290
270
250
230
190
170
150
0
CAPACITY
AREA
RESERVOIR WATER SURFACE ELEVATION, Feet msl

Figure D-8

PRINCIPAL MWA RAW WATER RESERVOIRS IN VIRGINIA

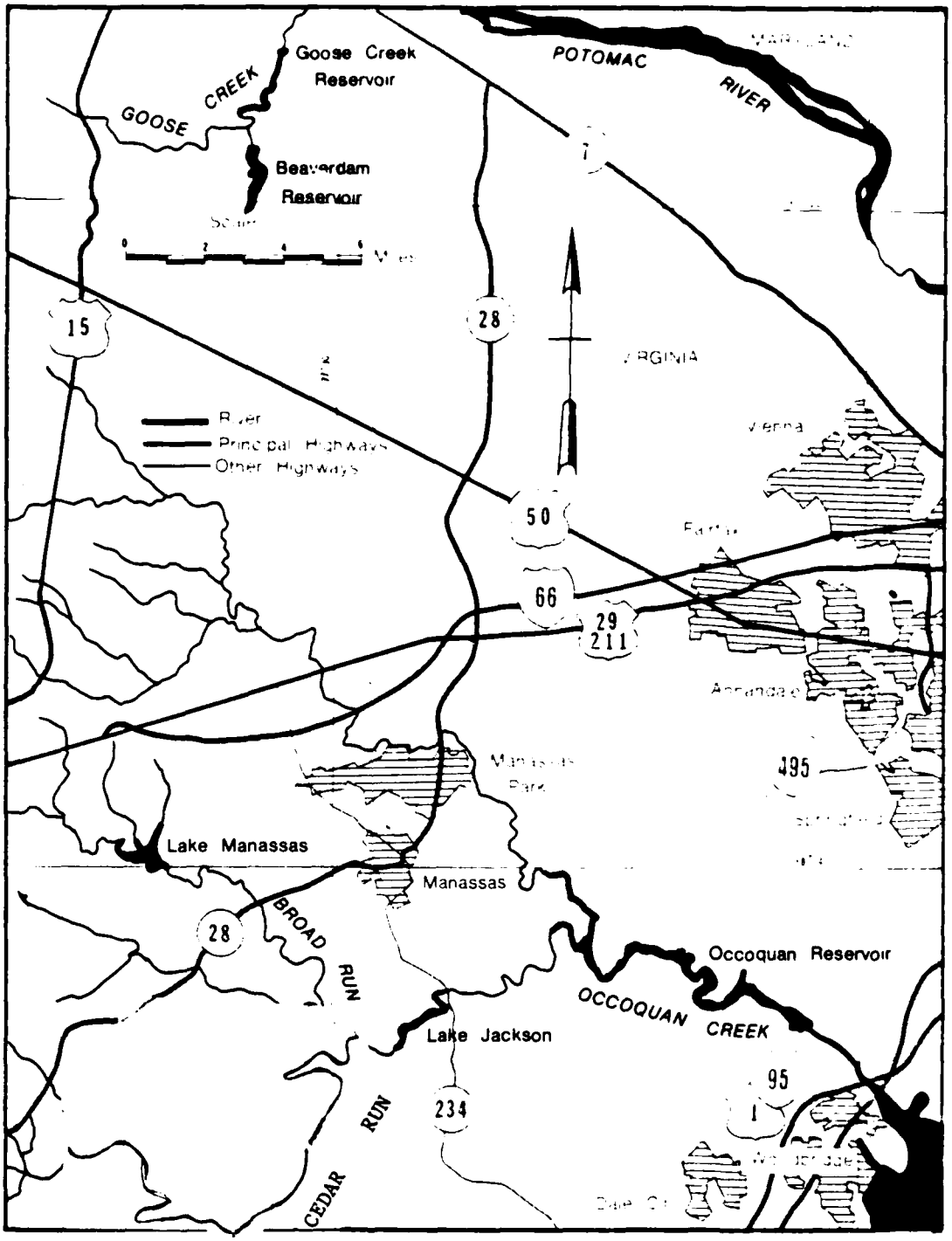


Figure D-9

TABLE D-6

PRINCIPAL MWA RAW WATER STORAGE RESERVOIRS IN VIRGINIA
SUMMARY CHARACTERISTICS

	GOOSE CREEK	BEAVERDAM	BROAD RUN (LAKE MANNASSAS)	LAKE JACKSON	OCCOQUAN (RAISED 2')*	OCCOQUAN (RAISED 5')**
Normal Conservation Pool Elevation, ft msl	240	290	285	148	122	125
Flood Control Storage Above Normal Conservation Pool Level, acre-feet	583	2,673	15,100	760	0	0
Total Storage at Normal Conservation Pool Level, acre-feet	767	4,155	17,500	1,640	30,991	40,520
Useable Storage at Normal Conservation Pool Elevation, acre-feet	767	4,094	12,666	840	26,387	38,372
Conservation Storage, acre-feet	767	4,094	12,666	840	26,387	38,372

TABLE D-6 (continued)
PRINCIPAL MWA RAW WATER STORAGE RESERVOIRS IN VIRGINIA
SUMMARY CHARACTERISTICS

	GOOSE CREEK	BEAVERDAM	BROAD RUN (LAKE MANASSAS)	LAKE JACKSON	OCCOQUAN (RAISED 2')*	OCCOQUAN (RAISED 5')**
Buffer and Inactive Storage, acre-feet	276	61	4,834	800	4,604	4,604
Inactive Storage, acre-feet	0	61	4,834	800	4,604	4,604
Principal USGS Stream Gage	01644000	01656700	01656700	01656700	01657500	01656100
Drainage Area to Controlling Stream Gage, square miles	332	332	343	343	570	570
Drainage Area to Reservoir, square miles	358	6	60	343	570	570
Safe Yield, mgd	2.58	2.26	17.4	6.45	67.5	80

* Occoquan Dam modified in 1980 to include 2 feet of additional storage

** Earlier studies considered the possibility of raising the Occoquan Dam by as much as five feet. More recent studies by FCWA have concluded that such an increase is not feasible for various technologic and economic reasons.

The dam itself is a combination concrete gravity dam and earthfill dam. The dam consists of a concrete gravity section with an ogee spillway and an intake and trashrack built integrally with the concrete portion of the dam. The top of the concrete dam is at elevation 302 feet msl, and the concrete portion of the dam has an overall length of 636 feet, beginning at the left abutment facing downstream. From the concrete section of the dam to the right abutment, nearly 440 feet of earth embankment exists. This embankment is at the 320 feet msl elevation for the most part. The spillway, with a width of 220 feet, is centered over the stream bed and has a crest elevation of 285 feet msl. The height of the top of the dam is some 60 feet above the stream bed.

Intakes are built integrally into the dam. Intake ports are provided at elevation 275, 265, 255, 245, and 240 feet msl. Flow is controlled through a 48-inch gate valve and a cone valve at the water treatment plant below the dam.

Area capacity curves for the reservoir are shown in Figure D-10. These curves are based on those provided the Town of Manassas by the engineers for the dam. Safe yield for Lake Manassas, given the current spillway crest of 285 feet msl, was found to be 17.4 mgd. Safe yields were determined with use of the computer model, HEC-3, and the filled-in gage record for Broad Run at Buckland, Virginia (U.S.G.S. gage 01656500) adjusted to the Broad Run Dam drainage area.

Raising the normal pool level of Lake Manassas to elevation 290.0 feet msl, 295.0 feet msl, and 300.0 feet msl by the addition of bascule gates or tainter gates has been discussed. No firm plans have been initiated to raise the normal pool; however, Manassas does presently own the shoreline up to elevation 300.0 feet msl.

Downstream flow requirements contained in Title 62 of the Code of Virginia require the release of water as follows:

- At least the average flow when the flow immediately above the impoundment is greater than the average flow.

- At least the flow immediately above the impounding structure when that flow is equal to or less than the average flow.

There is some question concerning the applicability of Title 62 of the Code of Virginia to municipal impoundment of water. Upstream water rights are those typically reserved to riparian owners and are in keeping with Title 62 of the Code of Virginia.

Although Lake Manassas was developed for water supply purposes, it provides good recreational potential for boating, fishing, and picnicking. Any recreational benefit that accrues to the public however, is strictly incidental to the the reservoir's main purpose.

LAKE JACKSON DAM AND RESERVOIR

Lake Jackson Dam was placed in service in 1930. The impoundment was created to provide a hydroelectric power source for the Virginia Electric and Power Company (VEPCO). The dam is a concrete gravity type structure, standing about 25 feet above the streambed and measuring about 260 feet long. The present top of the dam is at elevation 148 feet msl. Provision was made in the past for flashboards on top of the structure to raise the normal pool to 153 feet msl. The present normal pool is at 148 feet msl, and

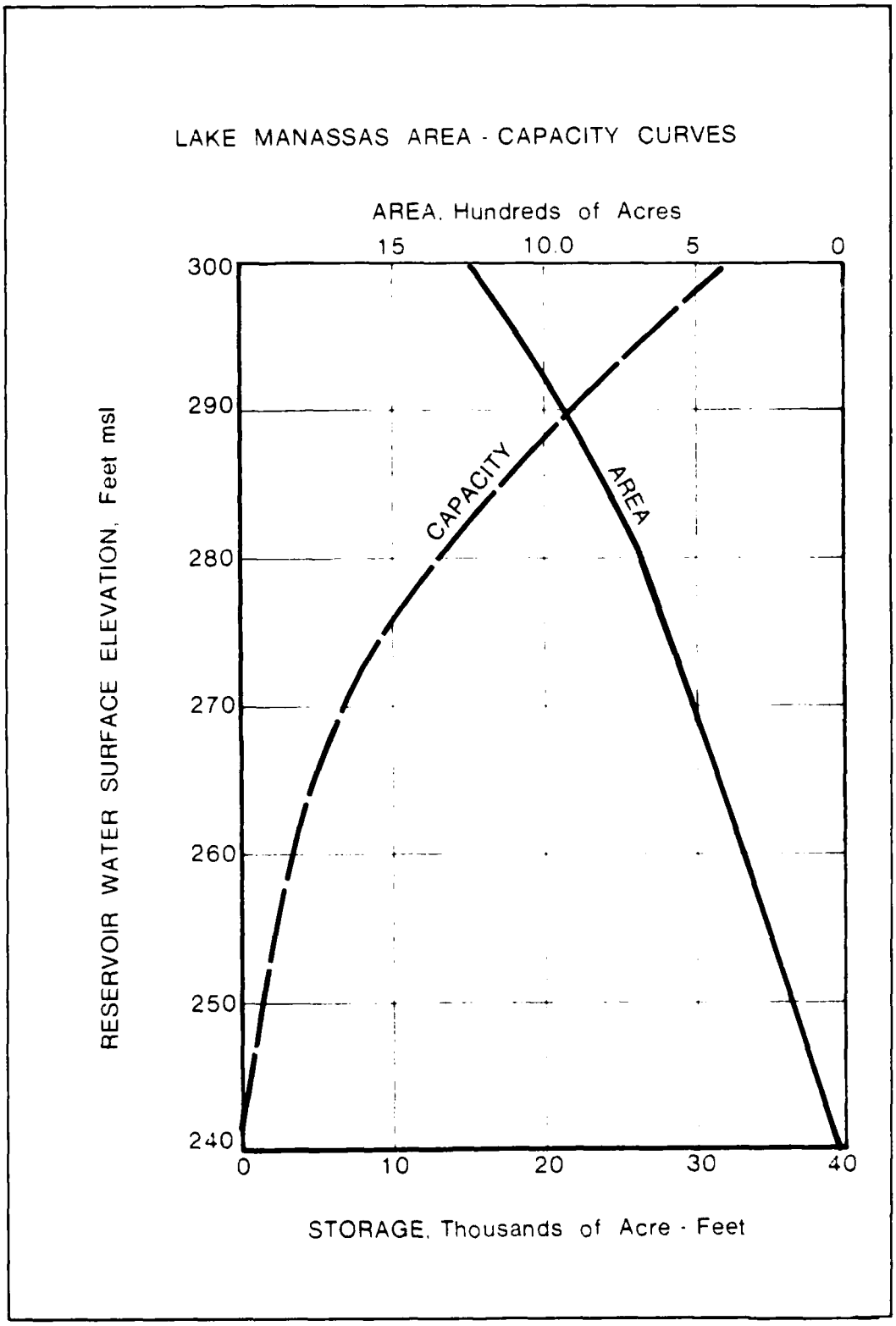

LAKE MANASSAS AREA - CAPACITY CURVES
AREA, Hundreds of Acres
15
10.0
5
0
300
290
280
270
260
250
240
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
10
20
30
40
STORAGE, Thousands of Acre - Feet

Figure D-10

corresponds to the top of the dam. Drainage area to the dam is nearly 343 square miles. The generating facility was abandoned by VEPCO and the project was sold to Prince William County. Since its purchase, Lake Jackson has served as a recreational area.

The spillway is an integral part of the dam and has an ogee-shape with a crest at elevation 138 feet msl. A single tainter gate measuring 20 feet wide by 15 feet high rests in a closed position on the crest of the spillway. (The 15-foot height matches the elevation of the flashboards, which are no longer on the dam.) Some consideration has been given to replacing the flashboards on Lake Jackson and re-establishing the normal pool at 153.0 feet msl, since Prince William County owns the land to that elevation.

Other outlet works pertaining to hydroelectric power generation are no longer in operating condition. Area-capacity curves for the reservoir are shown in Figure D-11. These curves are approximate and are based on the limited amount of data available from reports developed for the proposed Cedar Run Reservoir. Safe yield for Lake Jackson, given the current operating level of 148 feet msl, was found to be 6.45 mgd. Lake Jackson currently operates as a run of the river impoundment. Safe yields were determined with the use of the computer model, HEC-3, and the filled-in gage record for Cedar Run near Occoquan, Virginia (U.S.G.S. gage 01656700) which has essentially the same drainage area as the Lake Jackson Dam.

Water rights in the Occoquan Creek system are a cause of concern. Demand for water from the Occoquan Reservoir, located immediately downstream from Lake Jackson and discussed in the next section, is already high, and withdrawals from the Occoquan Reservoir often exceed the safe yield of the reservoir. Any project that might tend to reduce the safe yield of the Occoquan Reservoir would not be looked upon with favor by those jurisdictions concerned. Lake Jackson is actively used for recreational purposes, including fishing, rowboating, motor boating, and swimming.

OCCOQUAN DAM AND RESERVOIR

The Occoquan Reservoir system, composed of a lower and upper dam, has served as the principal source of water for the Fairfax County Water Authority for a number of years. The lower dam was built in 1950 by the Alexandria Water Company and is located approximately one-half mile downstream from the upper dam. It is a concrete gravity dam 30 feet high and 436 feet wide with an ogee-shaped spillway with a width of 387 feet and a crest elevation of 52 feet msl. This dam impounds 55 million gallons of water. A 350 kilowatt hydroelectric generator is also in use below the dam.

The Occoquan upper dam, also built by the Alexandria Water Company, was placed in service in 1957. The dam, reservoir, treatment works, and associated facilities were obtained and are presently owned by the FCWA. Ownership includes the shoreline to elevation 120 feet msl with easements to 130 feet msl.

These faciltites were acquired through condemnation proceedings begun 3 February 1962 and concluded 10 October 1967. The Alexandria Water Company, reorganized as the Virginia American Water Company, retained ownership of water distribution systems in Alexandria, Virginia, and Dale City, Virginia, and remains a wholesale customer of the FCWA.

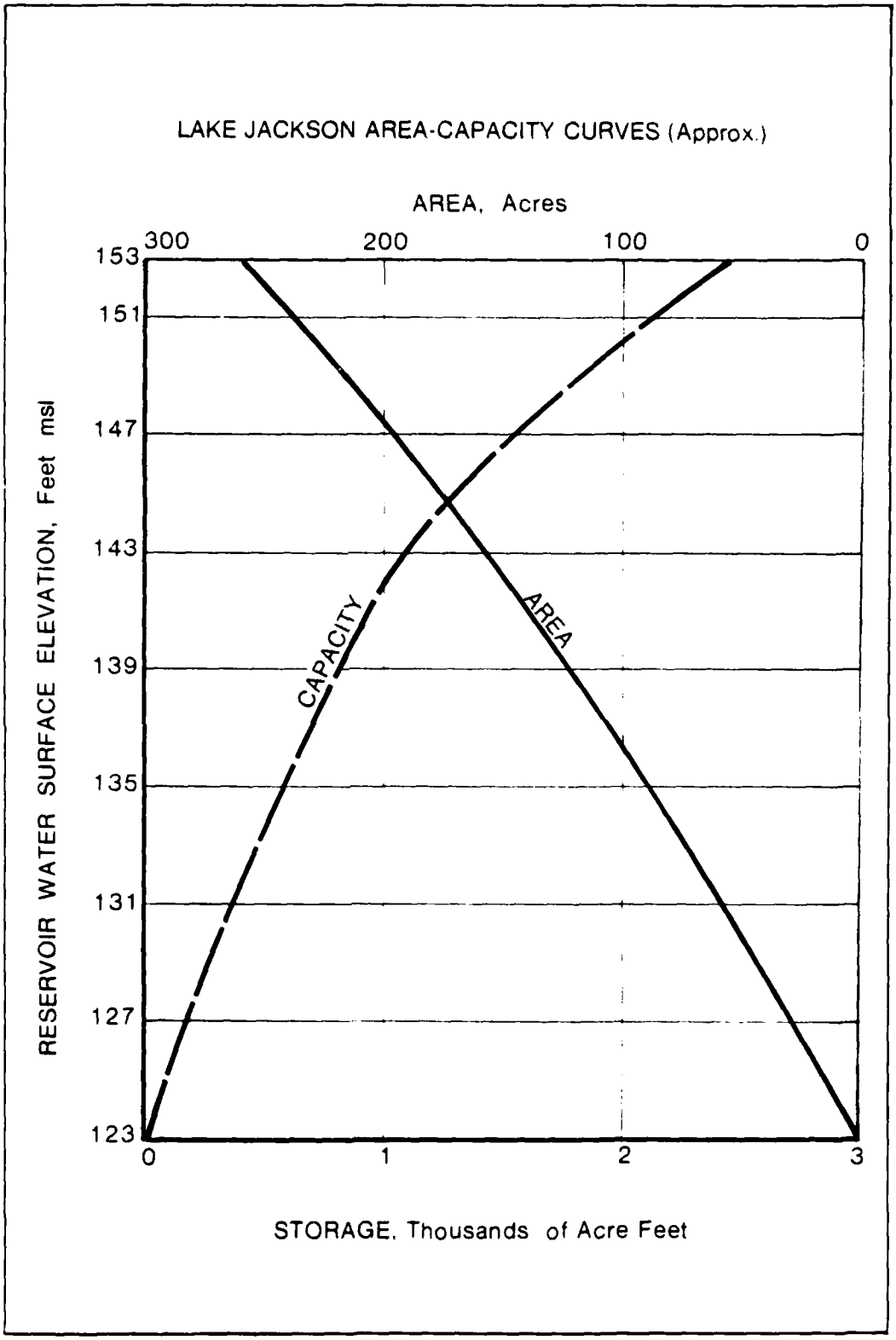

LAKE JACKSON AREA-CAPACITY CURVES (Approx.)
AREA, Acres
300
200
100
0
153
151
147
143
139
135
131
127
123
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
1
2
3
STORAGE, Thousands of Acre Feet

Figure D-11

The upper dam is a concrete gravity type dam with an overall length of approximately 730 feet. Most of this length consists of a free overflow ogee-shaped weir measuring 523 feet in length. The dam has a maximum height of 70 feet above the foundation, except for the intake structure, which is at elevation 130 feet msl or 80 feet above the foundation. Drainage area tributary to the Upper Dam is generally reported as 570 square miles.

The intake structure, on the north end of the dam, serves the pipelines leading to the water treatment plant located less than a mile downstream. Three additional intakes were installed in 1966 in the south end of the dam in a non-overflow portion of the dam. A small powerhouse with two 500-kw generating units adjoins the intake structure on the downstream side. This hydroelectric unit is reported capable of generating 17,500 KW-HR per day. Power generation is only attempted when an excess of water is available and the dam is overflowing or is imminently awaiting overflow. Such a condition usually occurs between the months of November and May.

Area-capacity curves for the reservoir are shown in Figure D-12. The curves are based on those developed by the Fairfax County Water Authority. Safe yield for the Occoquan Reservoir, given the original normal pool elevation of 120 feet msl, was found to be 65 mgd. The safe yield was determined with the use of the HEC-3 computer model and the filled-in gage record for the Occoquan River at Occoquan, Virginia (U.S.G.S. gage 01657500) adjusted to the drainage area of the Occoquan High Dam.

At one time, the FCWA had investigated the feasibility of increasing the existing reservoir storage level by 5 feet, but from an engineering viewpoint the structural integrity of the existing dam could not be maintained without major modifications. Furthermore, additional flood easements would probably need to be acquired. A second alternative, which investigated raising the pool level by 2 feet, proved to be both structurally and economically feasible. The dam was subsequently modified in 1980 by placing a 2-foot high poured in place concrete cap along the length of the existing spillway, increasing the storage capacity of the reservoir to 10.1 billion gallons. (See Table D-6).

Additional analyses by the Corps of Engineers showed that the safe yield of the reservoir if operated under the 1930-1932 drought conditions was 69 mgd, given the two foot raising. This value was determined using inflow and sewage treatment plant return flow valves obtained from the FCWA.

The Occoquan Reservoir releases flow downstream to the extent necessary to cause water to pass over the spillway of the Occoquan Low Dam, approximately one-half mile downstream from the High Dam. The Occoquan Reservoir is actively used for recreational activities including fishing, rowboating, motor boating, camping, and picnicking.

GOOSE CREEK DAM AND RESERVOIR

The existing Goose Creek Dam was put into service in 1960. The dam and reservoir, located in Loudoun County, Virginia, are owned by the City of Fairfax, Virginia, and are used for water supply. The dam is a concrete weir serving to impound sufficient water to provide a pool from which water can be pumped to the City of Fairfax Water Filtration Plant, also located in Loudoun County. At its highest point the dam stands only 27 feet

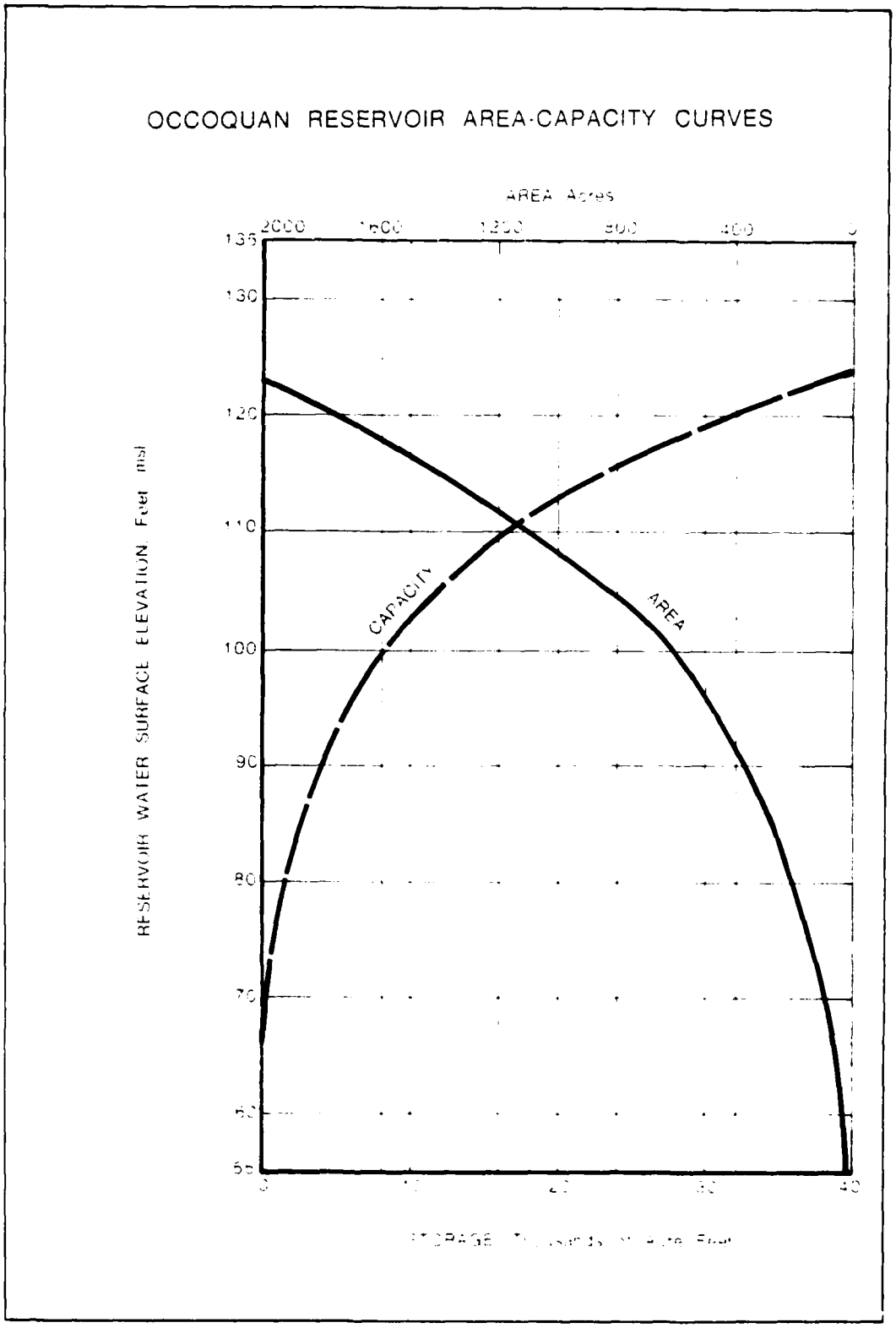

OCCOQUAN RESERVOIR AREA-CAPACITY CURVES
AREA Acres
2000
1600
1200
800
400
0
135
130
120
110
100
90
80
70
60
55
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
40

Figure D-12

above the streambed and has a crest elevation of 240 feet msl. The dam is a concrete gravity dam 715 feet wide, including left and right abutments. Drainage area to the dam is 358 square miles.

The dam forms an ogee-shaped spillway for 500 feet of its 715 foot width. The dam operates as a run-of-the-river structure and serves only to impound water for pumped withdrawal. Sediment storage also is accomplished. A discharge of 80,000 cfs can be attained with a depth over crest of 12 feet.

A fish ladder is provided up the right abutment. In addition to normal dam overflow, an additional 2.5 to 5 cfs flow may be lost through the fish ladder. Other than pumped withdrawal, no other outlet works are provided. Limited data are available for the reservoir. Based on reported data for the dam and planimeter measurements of topographic map contours, an area-capacity curve has been estimated and is presented in Figure D-13. Safe yield for the existing Goose Creek impoundment, given discharge only over the top of the dam, was found to be 2.58 mgd. Safe yield was determined with use of the computer model, HEC-3, with the filled-in-gage record for Goose Creek near Leesburg, Virginia, (U.S.G.S. gage 01644000) adjusted to the existing Goose Creek drainage area.

Safe yield is in part a function of the usable storage capacity of a reservoir and the drainage area contributing to it, as well as a function of the precipitation falling in the drainage area. The existing Goose Creek Reservoir has a usable storage of under 250 million gallons, but a drainage area of 358 square miles. In contrast, Beaverdam Reservoir has a usable storage of approximately 1,335 million gallons, but a drainage area of only six square miles. Consequently, Beaverdam acts as an immense, naturally-filling raw water storage tank. Fully drawn down, the Beaverdam Reservoir could be expected to fill within four to six months given average precipitation.

The average flow in Goose Creek at the Leesburg gage (U.S.G.S. gage 01644000) is over 195 mgd. However, during three late summer months in 1930, average streamflow was less than 1.5 mgd. Safe yields of up to 18.5 mgd for the Goose Creek-Beaverdam Reservoir system have been promulgated. Given the 1930 historic low flows, this yield could be sustained for three months, but at the expense of almost total drawdown of the Beaverdam Reservoir and virtual depletion of all reserve storage in the system. As noted above, the Beaverdam Reservoir could be expected to refill from the six square mile drainage area in a period of four to six months.

Some past discussion has centered around constructing a new dam and reservoir approximately one mile upstream from the existing Goose Dam. Such a dam would have vastly increased storage capacity over the existing Beaverdam Reservoir, owned by Fairfax City, as well as most of the present Goose Creek impoundment. Such a development is not likely, however, unless the Virginia General Assembly changes the current status of Goose Creek from a "Scenic River" to a less restrictive status.

Goose Creek Dam passes all overflows downstream. In addition, a constant discharge of approximately 2.5 cfs usually flows down the fish ladder into Goose Creek below the dam. By court order, Fairfax City has been given rights to 15 mgd of flow from Goose Creek at all times.

Limited recreation is available on the Goose Creek Reservoir. Fishing and rowboating are the principal forms of recreation.

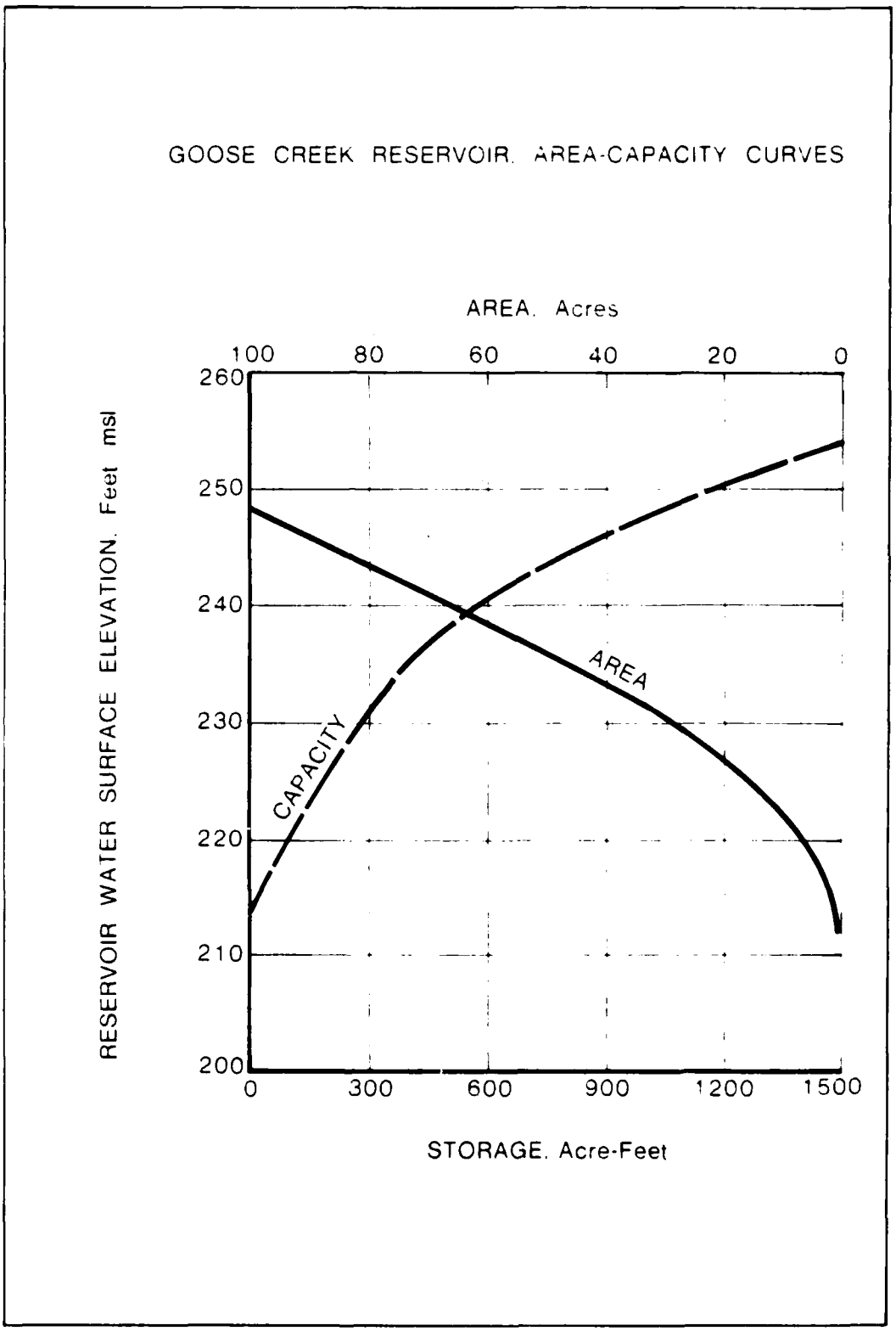

GOOSE CREEK RESERVOIR. AREA-CAPACITY CURVES
AREA. Acres
100
80
60
40
20
0
260
250
240
230
220
210
200
RESERVOIR WATER SURFACE ELEVATION. Feet msl
AREA
CAPACITY
0
300
600
900
1200
1500
STORAGE. Acre-Feet

Figure D-13

BEAVERDAM DAM AND RESERVOIR

Because of extremely low flows available from Goose Creek during the drought of 1966, Fairfax County acquired land and built a reservoir approximately 3.7 miles upstream from the existing Goose Creek Dam. The project is intended to be used for emergency conditions only. The dam is located on a small tributary to Goose Creek called Beaverdam Creek. The drainage area to the dam is approximately 6 square miles. The dam is an earthfill dam measuring approximately 50 feet high and 1,600 feet long. The top of the embankment is at elevation 298 feet msl.

The spillway is a weir approximately 175 feet long adjacent to the right abutment. Overflow spills into a chute which carries the flow down to Beaverdam Creek at the toe of the embankment. The spillway has a crest elevation of 290 feet msl.

An intake riser connects to a 36-inch diameter drain conduit with an invert elevation of 245 feet msl which passes under the dam near its left abutment, facing downstream. The top intake is at 277 feet msl and has a 20-inch manually operated gate valve. The middle intake is at elevation 266 feet msl and has a 20-inch manually operated gate valve. The bottom intake is at 246 feet msl and has a 24-inch gate valve. Area-capacity curves for the reservoir are shown in Figure D-14. These curves are based on those provided to Fairfax City by the engineers for the dam. Normal reservoir operation is to keep the reservoir full from the natural drainage until such time as demands on the existing Goose Creek impoundment exceed natural supply. At that time, releases are to be made to the extent necessary to keep the existing Goose Creek impoundment full. Drawdown is limited to 6 inches per day to maintain the structural integrity of the embankment. Since the reservoir was filled in 1975, no releases have been made for water supply or other purposes. Normal overflow has occurred, however.

An analysis made of Beaverdam Reservoir operating seperately from Goose Creek and assuming the full working storage was accessible determined that a safe yield of 2.26 mgd could be maintained. Safe yield was determined with use of the computer model, HEC-3, with the filled-in gage record for Goose Creek near Leesburg, Virginia (U.S.G.S. gage 01644000) adjusted to the Beaverdam Reservoir drainage area. Recreation is discouraged on Beaverdam Reservoir.

EXISTING WATER SUPPLY FACILITIES

The water supply users in the MWA are served from a number of sources, through a multitude of supply agencies and from an even greater number of finished water distributors. Figures D-15 through D-17 are schematics of the MWA regional water supply system. These schematics include: (a) sources of raw water (solid box); (b) supply agencies (shaded box) which produce finished water; (c) a delineation of service areas (broken box); and (d) a definition of major jurisdictions served (ellipse) where service area geographical coverage is not obvious. For the purpose of this report, a source is defined as a surface or groundwater component of the hydrologic system from which a raw water supply is withdrawn. A supply agency or a public agency is defined as the agency whose purpose is to withdraw that raw water from a source and supply finished water either to a set of retail users, wholesale users, or a combination thereof.

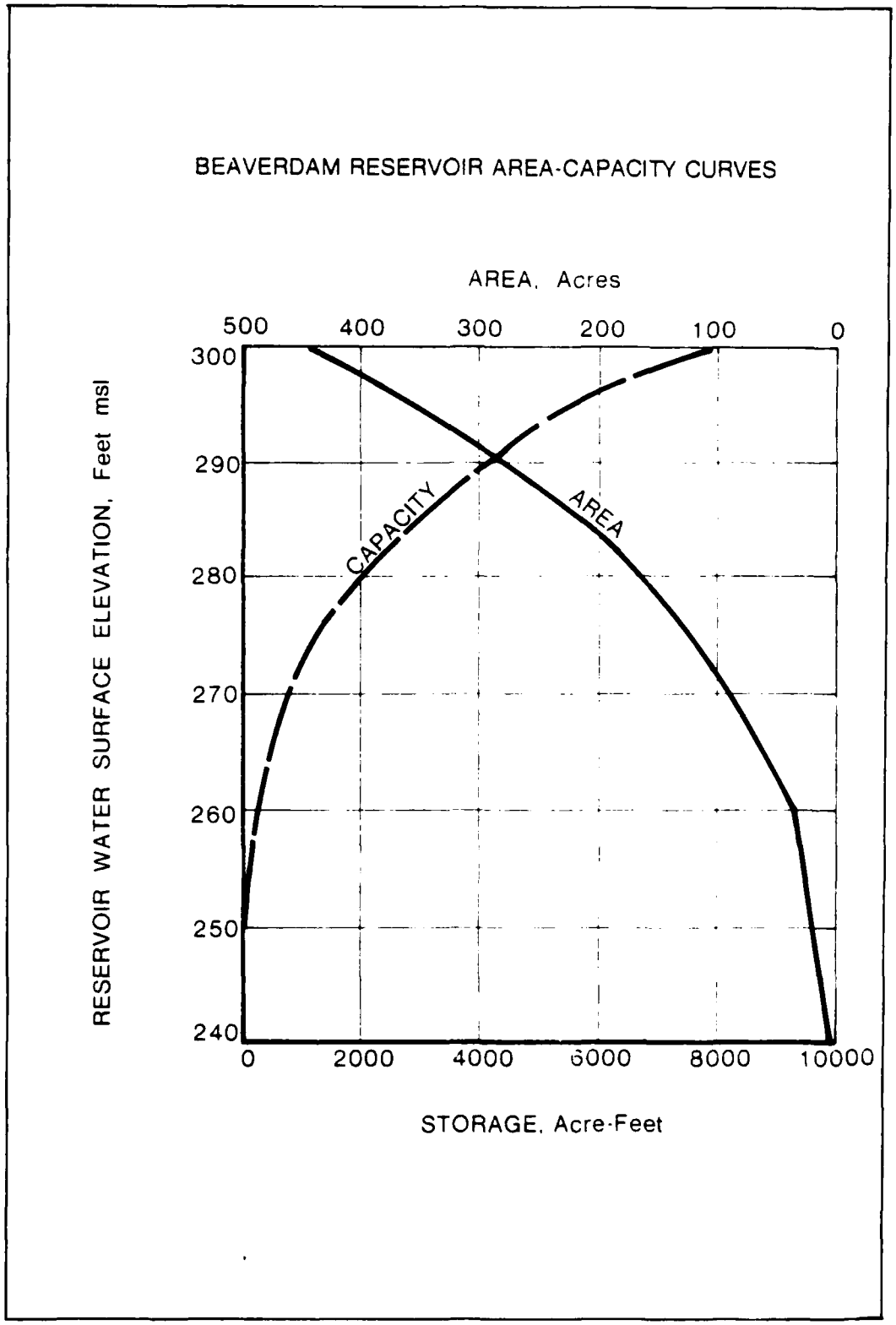

BEAVERDAM RESERVOIR AREA-CAPACITY CURVES
AREA, Acres
500
400
300
200
100
0
300
290
280
270
260
250
240
RESERVOIR WATER SURFACE ELEVATION, Feet msl
CAPACITY
AREA
0
2000
4000
6000
8000
10000
STORAGE, Acre-Feet

Figure D-14

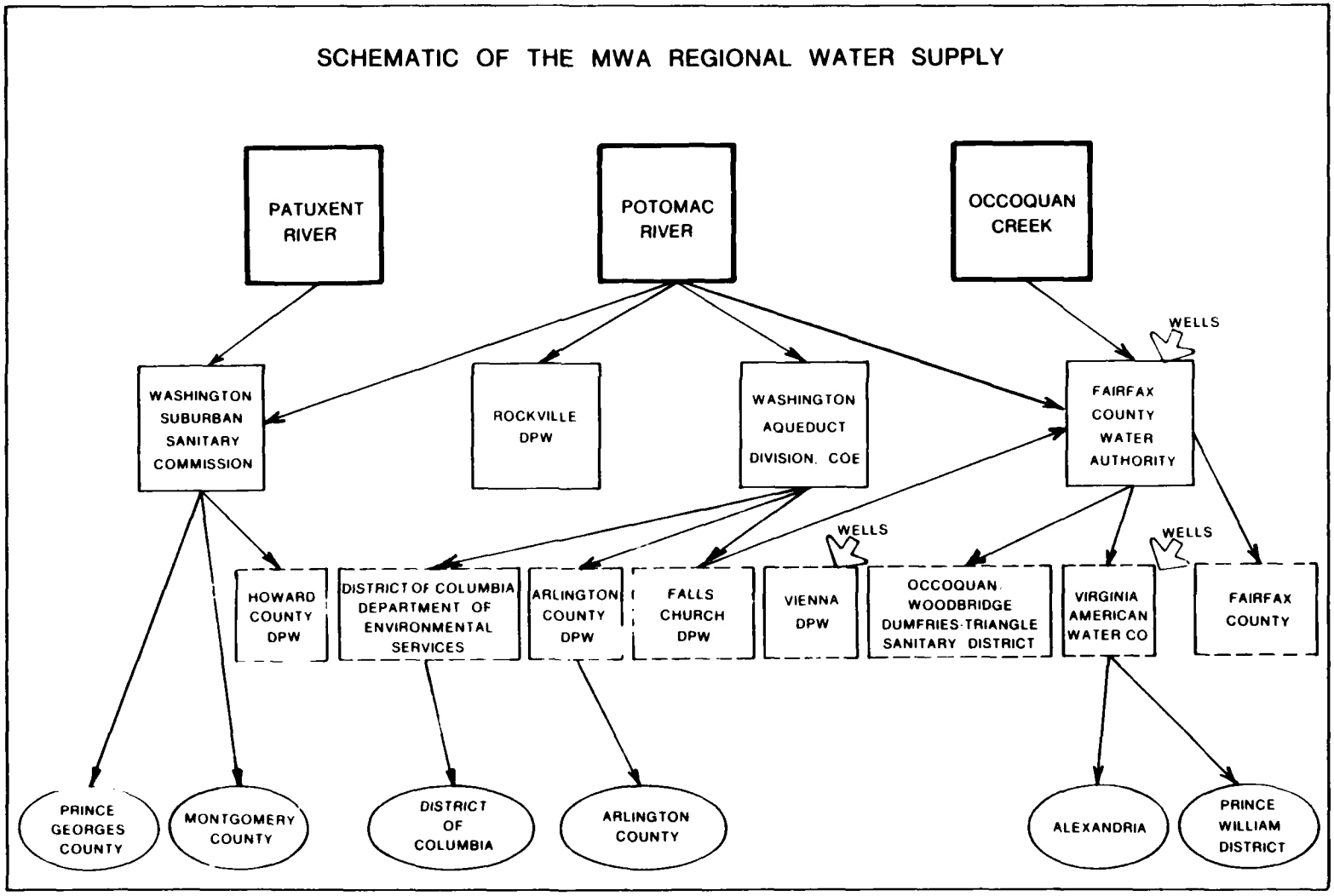

SCHEMATIC OF THE MWA REGIONAL WATER SUPPLY
PATUXENT RIVER
POTOMAC RIVER
OCCOQUAN CREEK
WELLS
WASHINGTON SUBURBAN SANITARY COMMISSION
ROCKVILLE DPW
WASHINGTON AQUEDUCT DIVISION, COE
FAIRFAX COUNTY WATER AUTHORITY
WELLS
WELLS
HOWARD COUNTY DPW
DISTRICT OF COLUMBIA DEPARTMENT OF ENVIRONMENTAL SERVICES
ARLINGTON COUNTY DPW
FALLS CHURCH DPW
VIENNA DPW
OCCOQUAN WOODBRIDGE DUMFRIES-TRIANGLE SANITARY DISTRICT
VIRGINIA AMERICAN WATER CO
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
MONTGOMERY COUNTY
DISTRICT OF COLUMBIA
ARLINGTON COUNTY
ALEXANDRIA
PRINCE WILLIAM DISTRICT

Figure D-15

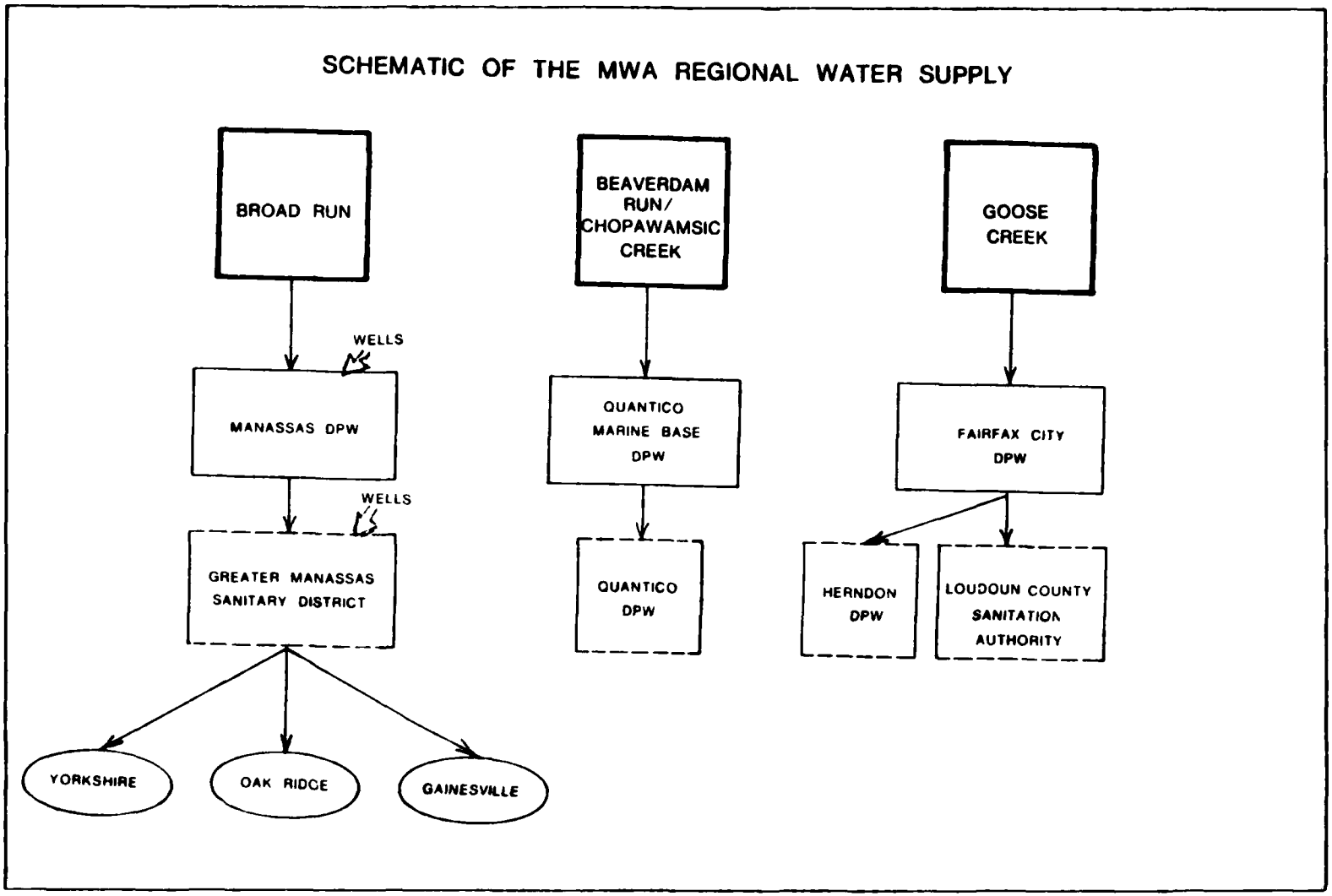

SCHEMATIC OF THE MWA REGIONAL WATER SUPPLY
BROAD RUN
BEAVERDAM RUN/ CHOPAWAMSIC CREEK
GOOSE CREEK
WELLS
MANASSAS DPW
QUANTICO MARINE BASE DPW
FAIRFAX CITY DPW
WELLS
GREATER MANASSAS SANITARY DISTRICT
QUANTICO DPW
HERNDON DPW
LOUDOUN COUNTY SANITATION AUTHORITY
YORKSHIRE
OAK RIDGE
GAINESVILLE

Figure D-16

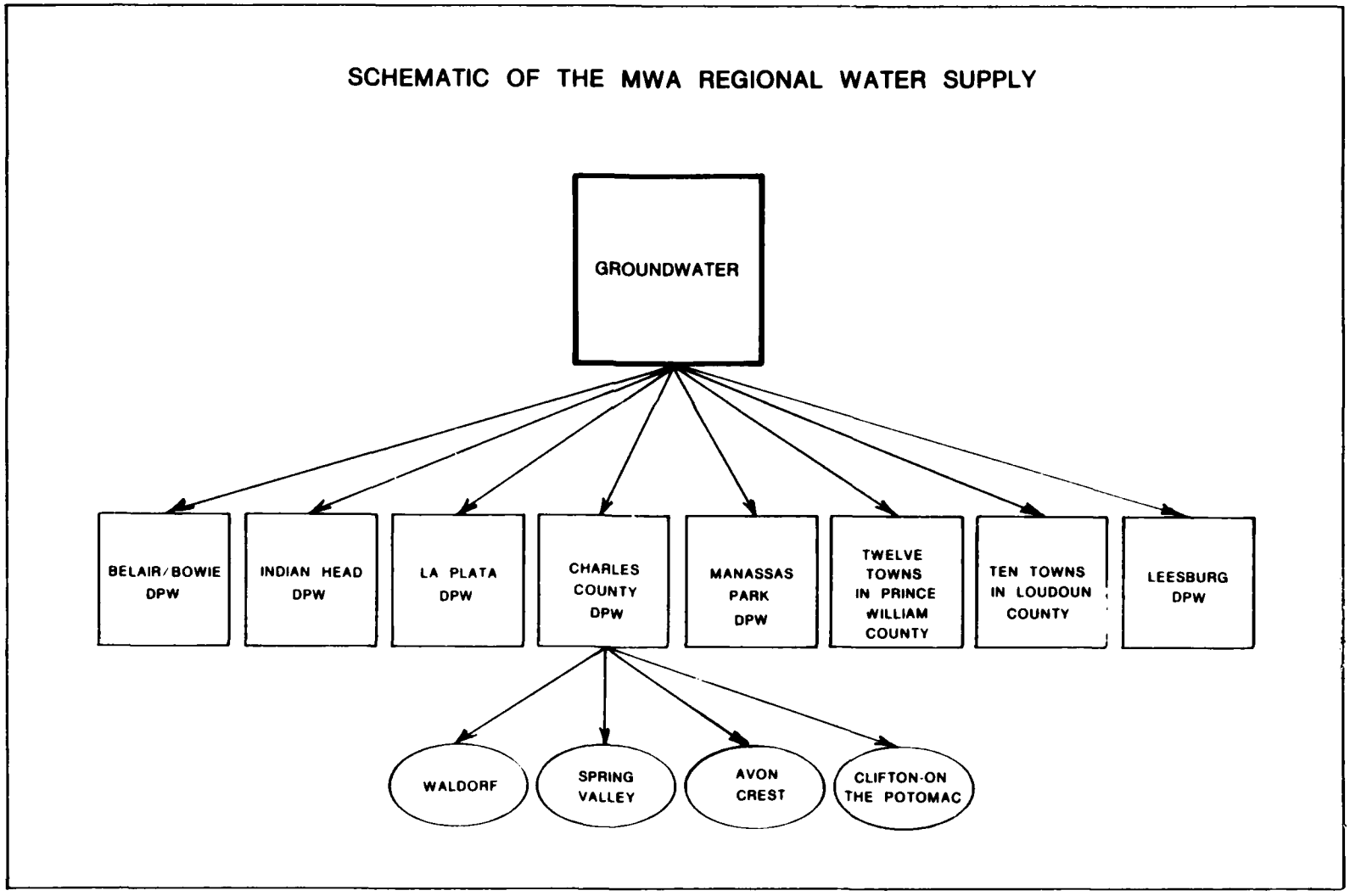

SCHEMATIC OF THE MWA REGIONAL WATER SUPPLY
GROUNDWATER
BELAIR/BOWIE DPW
INDIAN HEAD DPW
LA PLATA DPW
CHARLES COUNTY DPW
MANASSAS PARK DPW
TWELVE TOWNS IN PRINCE WILLIAM COUNTY
TEN TOWNS IN LOUDOUN COUNTY
LEESBURG DPW
WALDORF
SPRING VALLEY
AVON CREST
CLIFTON-ON THE POTOMAC

Figure D-17

The primary sources of surface water supply within the MWA are the Potomac River, Patuxent River, Occoquan Creek, Goose Creek, Broad Run, and Beaverdam Run. The relative percent of raw water extracted from each of these sources is estimated as follows:

Potomac River	70 percent
Patuxent River	12 percent
Occoquan Creek	14 percent
Goose Creek	2 percent
Broad Run	1 percent
Beaverdam Run	1 percent

As can be seen from the above listing, surface water supplies more than 99 percent of the available water within the MWA. Groundwater is used in the outlying areas for domestic and commercial/industrial uses, but its contribution to the overall supply is less than one percent.

The three largest supplier/distributors in the MWA are the Washington Aqueduct Division (WAD) of the Baltimore District, U.S. Army Corps of Engineers; the Washington Suburban Sanitary Commission (WSSC); and the Fairfax County Water Authority (FCWA). Together, these agencies provide approximately 95 percent of the total water treatment capacity in the MWA. Figure D-18 shows the location of these agencies' service area boundaries and treatment plants. Table D-7 presents a summary of the existing major water treatment facilities, sources of water supply, types of treatment, and plant capacities.

The following sections discuss the existing facilities (raw and finished water capacities) of the three major supplier/distributors in the MWA. Discussions of the smaller water supply systems in the surrounding counties of Charles, Prince William, and Loudoun are contained in Appendix I - Outlying Service Areas.

WASHINGTON AQUEDUCT DIVISION

The Aqueduct, under the supervision of the Baltimore District Engineer, is responsible for the withdrawal, treatment, and transmission of water to the District of Columbia, Arlington County, and the City of Falls Church. Distribution of water within these areas is then the responsibility of local jurisdictions. The major facilities of the Aqueduct consist of two water treatment plants: Dalecarlia and McMillan; and three raw water storage reservoirs: Dalecarlia, Georgetown, and McMillan. Figure D-19 is a schematic of the existing water system.

The sole source of raw water supply for the Aqueduct is the Potomac River. The Aqueduct withdraws water from the Potomac River through intake structures located at Great Falls and Little Falls, Maryland. Flow from the Potomac at Great Falls is conveyed to Dalecarlia Reservoir, a distance of nine miles, by gravity flow through two conduits with a combined capacity of 200 mgd. Withdrawals at Little Falls are also conveyed to Dalecarlia Reservoir via the Little Falls pumping station (working capacity 350 mgd, installed capacity 450 mgd) and a one mile long tunnel. The combined total capacity of the raw water transmission system is 650 mgd.

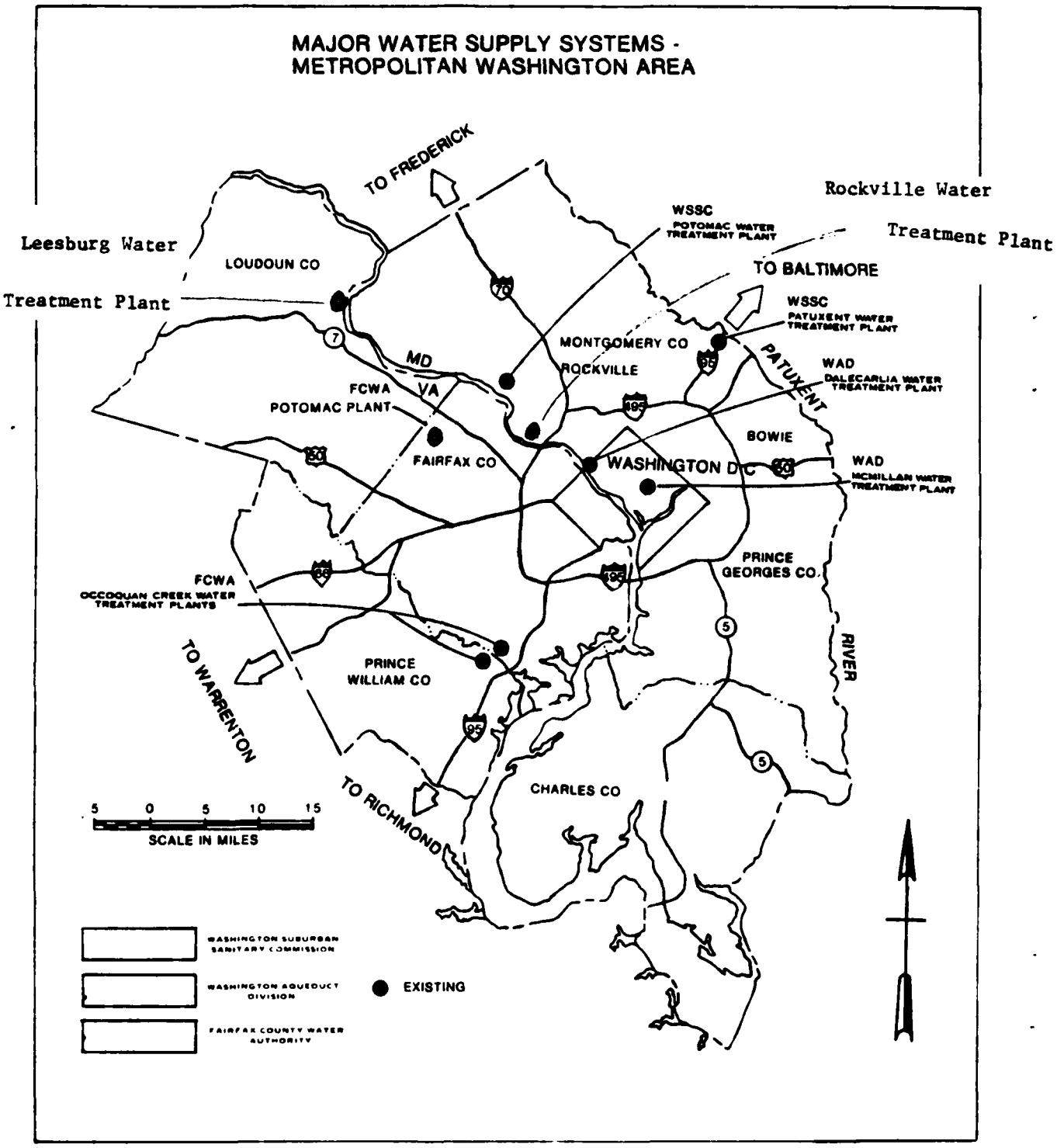

MAJOR WATER SUPPLY SYSTEMS -
METROPOLITAN WASHINGTON AREA
TO FREDERICK
Leesburg Water
Treatment Plant
LOUDOUN CO
Rockville Water
Treatment Plant
WSSC
POTOMAC WATER TREATMENT PLANT
TO BALTIMORE
WSSC
PATUXENT WATER TREATMENT PLANT
MONTGOMERY CO
ROCKVILLE
MD
VA
FCWA
POTOMAC PLANT
PATUXENT
WAD
DALECARLIA WATER TREATMENT PLANT
BOWIE
FAIRFAX CO
WASHINGTON D.C.
WAD
MCMILLAN WATER TREATMENT PLANT
PRINCE GEORGES CO.
FCWA
OCCOQUAN CREEK WATER TREATMENT PLANTS
TO WARRENTON
PRINCE WILLIAM CO
RIVER
CHARLES CO
TO RICHMOND
5 0 5 10 15
SCALE IN MILES
WASHINGTON SUBURBAN SANITARY COMMISSION
WASHINGTON AQUEDUCT DIVISION
FAIRFAX COUNTY WATER AUTHORITY
EXISTING

Figure D-18

TABLE D-7
MAJOR EXISTING WATER TREATMENT FACILITIES

WATER SOURCE	WATER SYSTEM	INTAKE CAPACITY (mgd)	TREATMENT PLANTS	TYPE OF TREATMENT	NOMINAL CAPACITY (mgd)	MAXIMUM CAPACITY (mgd)
Potomac River	Washington Aqueduct	650	Dalecarlia	Conventional*	164	246
			McMillan	Conventional	100	125
	Washington Suburban Sanitary Commission	400	Potomac	Conventional	180	240
	Fairfax County Water Authority	200	Potomac	Conventional	32	50
	Rockville	8	Rockville	Conventional	8	8
Occoquan Creek	Fairfax County Water Authority	112	Occoquan	Conventional	62	112
Patuxent River	Washington Suburban Sanitary Commission	65	Patuxent	Conventional	50	65

*Conventional Treatment (coagulation, sedimentation, filtration, and disinfection)

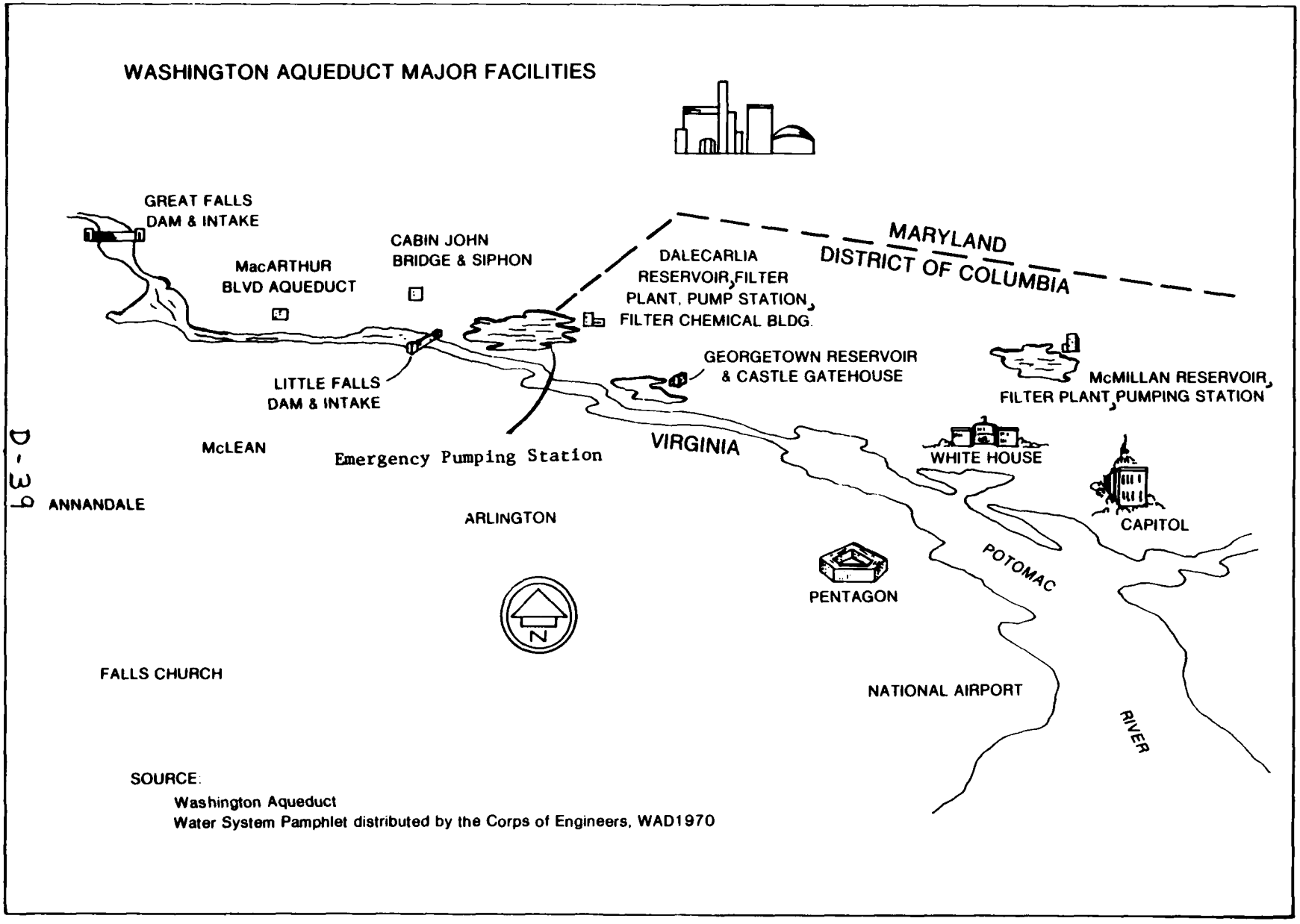

WASHINGTON AQUEDUCT MAJOR FACILITIES
GREAT FALLS DAM & INTAKE
MacARTHUR BLVD AQUEDUCT
CABIN JOHN BRIDGE & SIPHON
DALECARLIA RESERVOIR, FILTER PLANT, PUMP STATION, FILTER CHEMICAL BLDG.
MARYLAND
DISTRICT OF COLUMBIA
GEORGETOWN RESERVOIR & CASTLE GATEHOUSE
McMILLAN RESERVOIR, FILTER PLANT, PUMPING STATION
LITTLE FALLS DAM & INTAKE
McLEAN
Emergency Pumping Station
VIRGINIA
WHITE HOUSE
CAPITOL
ANNANDALE
ARLINGTON
POTOMAC
PENTAGON
N
FALLS CHURCH
NATIONAL AIRPORT
RIVER
SOURCE:
Washington Aqueduct
Water System Pamphlet distributed by the Corps of Engineers, WAD1970

Figure D-19

Treatment of water is provided by two plants: Dalecarlia and McMillan. Dalecarlia, the larger of the two plants, was completed in 1928. It is a rapid sand filtration plant and uses conventional water treatment methods (coagulation, sedimentation, filtration, disinfection and Ph adjustment) and fluoridation. The plant has undergone continued improvement and expansion since its completion in 1928, and presently has a nominal capacity of 164 mgd and a maximum capacity of 246 mgd (based on 150 percent of design capacity). Finished water from the plant is pumped to four service areas within the District of Columbia and to Arlington County and Falls Church, Virginia.

The McMillan Water Treatment Plant, built in 1905, provides the balance of the WAD water treatment capacity. The plant receives its water via gravity from Dalecarlia Reservoir (coagulation, fluoridation, and prechlorination are applied at the Dalecarlia Plant) through Georgetown Reservoir, the City Tunnel, and East Shaft water pump to McMillan Reservoir. At McMillan the water is treated using slow-sand filtration chlorination, lime, and conventional treatment methods. The plant has a nominal capacity of 100 mgd and a maximum capacity of 125 mgd. Finished water from this plant can be pumped to any area within the District of Columbia. The McMillan plant is presently being upgraded to provide rapid sand filters, but the treatment capacities will remain about the same.

The three open raw water reservoirs provide a combined usable storage of 200 million gallons at full capacity. A listing of the storage capacities of each reservoir is given below:

a. Dalecarlia is used as a receiving and settling reservoir. It covers an area of 50 acres and has a usable storage capacity of 50 million gallons.

b. Georgetown Reservoir, located between Dalecarlia and McMillan, is used for sedimentation and storage of raw water transmitted from Dalecarlia. It covers an area of 42 acres and has a usable storage capacity of 50 million gallons.

c. McMillan Reservoir is used for storage and sedimentation of raw water transmitted from Dalecarlia. It covers an area of 42 ares and has a usable storage capacity of 100 million gallons.

Figure D-20 is a flow diagram depicting the treatment process of raw water withdrawal from the Potomac River to the distribution of finished water.

In addition to the two intakes at Great Falls and Little Falls on the free-flowing Potomac River, the Aqueduct's system also includes an emergency pumping station located at the upper end of the Potomac Estuary just upstream of Chain Bridge. The Emergency Estuary Water Pumping Station provides for a maximum withdrawal of 100 mgd from the upper Potomac Estuary for use during critical water supply emergencies, but only after it is determined that the water will meet existing health standards. The estuary water would be pumped to the Dalecarlia Reservoir for subsequent purification at the Dalecarlia and McMillan Water Treatment Plants. To date, it has not been necessary to use the Emergency Estuary Water Pumping Station.

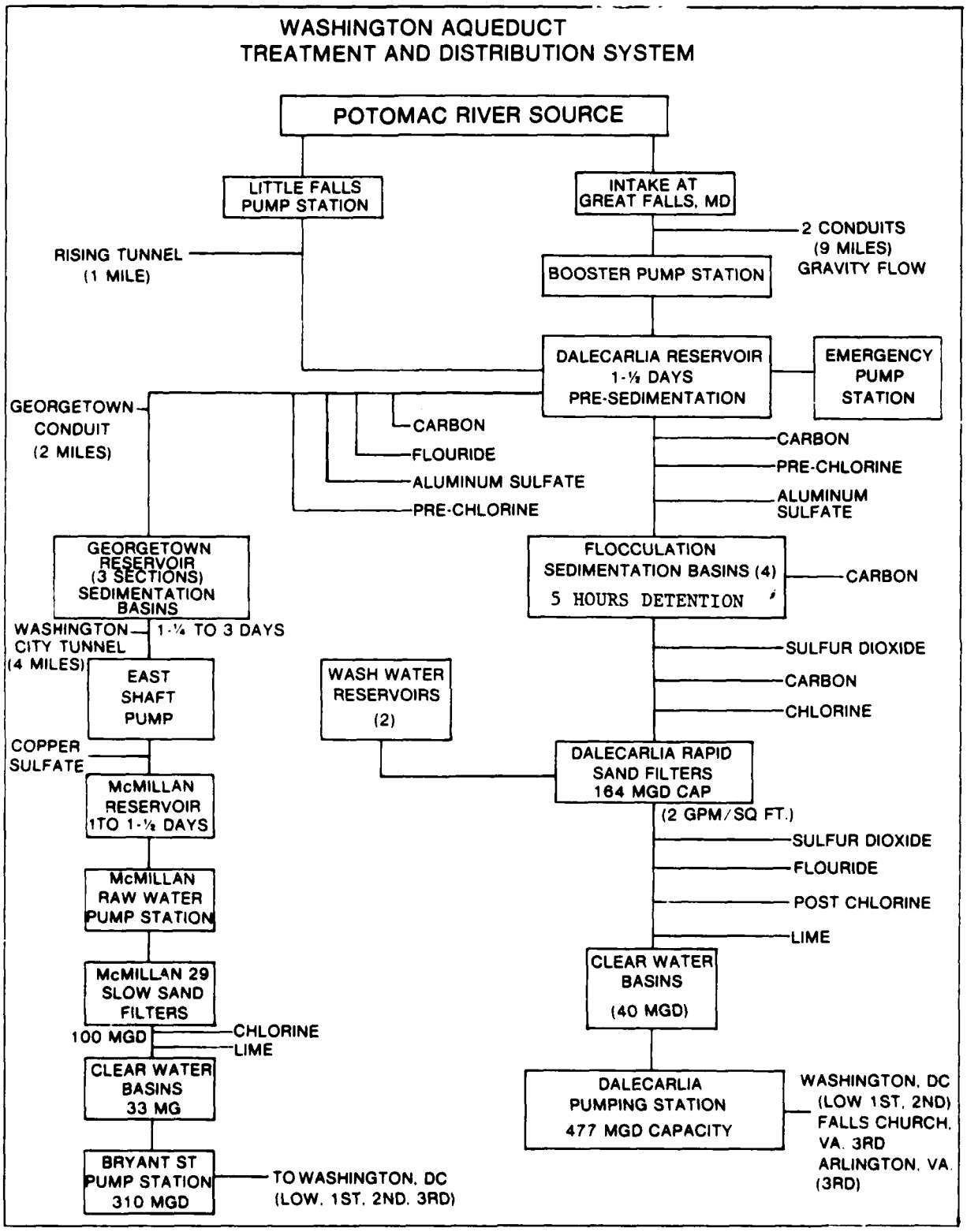

WASHINGTON AQUEDUCT
TREATMENT AND DISTRIBUTION SYSTEM
POTOMAC RIVER SOURCE
LITTLE FALLS PUMP STATION
INTAKE AT GREAT FALLS, MD
2 CONDUITS (9 MILES) GRAVITY FLOW
RISING TUNNEL (1 MILE)
BOOSTER PUMP STATION
DALECARLIA RESERVOIR 1-½ DAYS PRE-SEDIMENTATION
EMERGENCY PUMP STATION
GEORGETOWN CONDUIT (2 MILES)
CARBON
FLOURIDE
ALUMINUM SULFATE
PRE-CHLORINE
CARBON
PRE-CHLORINE
ALUMINUM SULFATE
GEORGETOWN RESERVOIR (3 SECTIONS) SEDIMENTATION BASINS
FLOCCULATION SEDIMENTATION BASINS (4)
5 HOURS DETENTION
CARBON
WASHINGTON CITY TUNNEL (4 MILES)
1-¼ TO 3 DAYS
SULFUR DIOXIDE
CARBON
CHLORINE
EAST SHAFT PUMP
WASH WATER RESERVOIRS (2)
COPPER SULFATE
DALECARLIA RAPID SAND FILTERS 164 MGD CAP
(2 GPM/SQ FT.)
McMILLAN RESERVOIR 1TO 1-½ DAYS
SULFUR DIOXIDE
FLOURIDE
POST CHLORINE
LIME
McMILLAN RAW WATER PUMP STATION
McMILLAN 29 SLOW SAND FILTERS
CLEAR WATER BASINS (40 MGD)
100 MGD
CHLORINE
LIME
CLEAR WATER BASINS 33 MG
DALECARLIA PUMPING STATION 477 MGD CAPACITY
WASHINGTON, DC (LOW 1ST, 2ND) FALLS CHURCH, VA. 3RD ARLINGTON, VA. (3RD)
BRYANT ST PUMP STATION 310 MGD
TO WASHINGTON, DC (LOW, 1ST, 2ND, 3RD)

Figure D-20

WASHINGTON SUBURBAN SANITARY COMMISSION

The WSSC, a public agency established by the Maryland General Assembly in 1918, is responsible for the withdrawal, treatment, and transmission of (Potomac and Patuxent River) water to the suburban areas of Montgomery and Prince Georges Counties, and a small portion of Howard County, Maryland. The major facilities of WSSC's water system consist of two water treatment plants (Potomac and Patuxent) and a tandem natural fill raw water reservoir system located on the Patuxent River (Triadelphia and Rocky Gorge Reservoirs). Figure D-21 is a plan schematic of the existing water system.

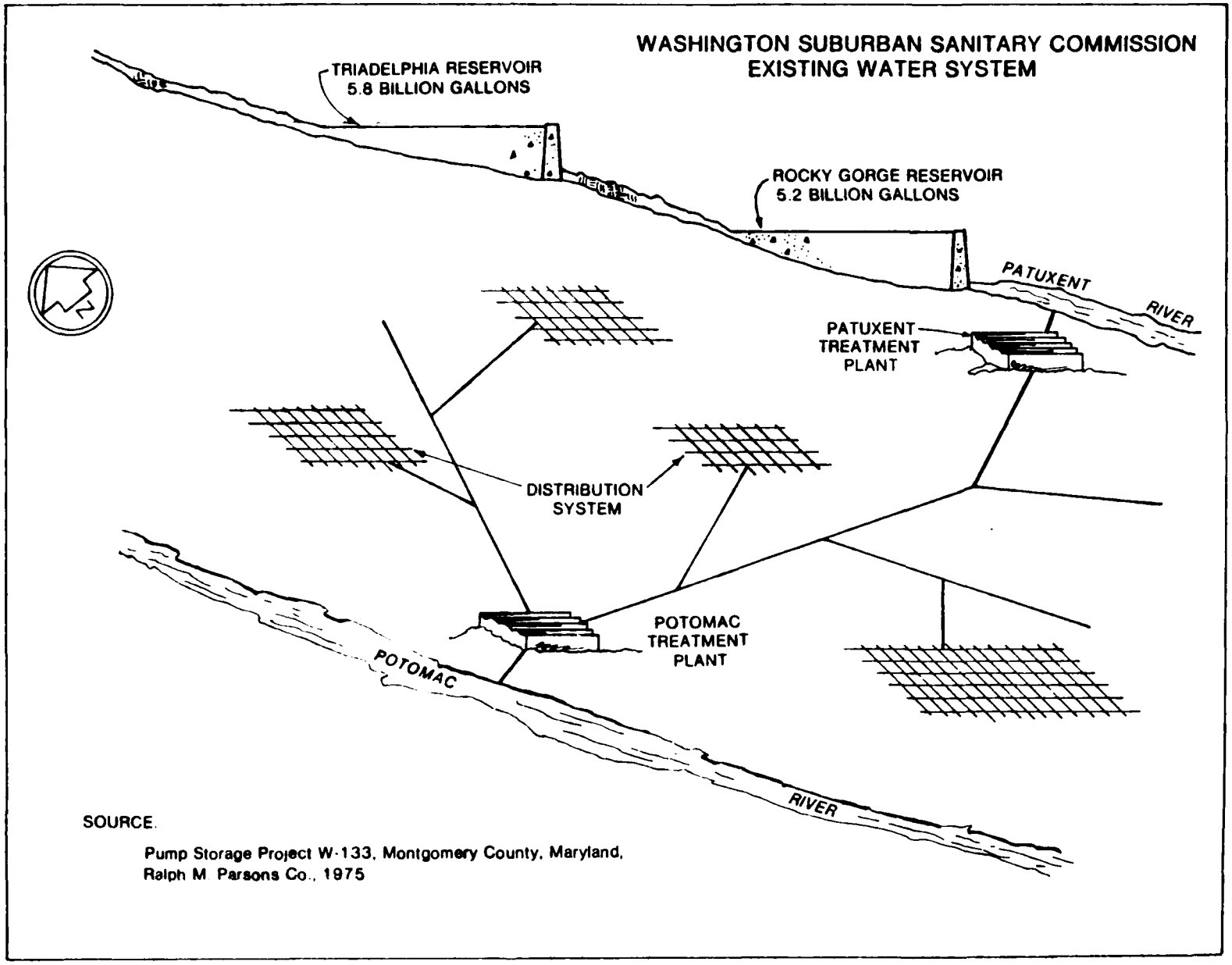
The non-Potomac source of water supply for the WSSC is the Patuxent River forming the northeast boundary of WSSC's service area. Two water supply reservoirs are located on the Patuxent: at Brighton in Montgomery County, 14 miles north of the northernmost boundary of Washington, D.C., and at Rocky Gorge, about two miles northwest of Laurel, in Prince Georges County. These reservoirs are designated primarily for water supply purposes.

The Patuxent River Water Filtration Plant, constructed in three stages in 1944, 1951, and 1955 is located about two miles from the Patuxent River, near Laurel, Maryland. Raw water is supplied from Rocky Gorge Reservoir to the plant via Rocky Gorge Pumping Station and three parallel pipelines. It is a rapid sand filtration plant and uses conventional water treatment and fluoridation. The maximum one-day treatment capacity of the plant is 65 mgd. Finished water is delivered through pipelines from storage to Montgomery and Prince Georges Counties with a small amount going to Howard County.

The second major source of raw water supply for WSSC is the free-flowing Potomac River. The Potomac is the larger of the two raw water supplies and provides approximately 70 percent of WSSC's needs.

The Potomac River Filtration Plant, placed in operation in 1961, is located near Watts Branch, Montgomery County, two miles upstream from Great Falls, Maryland. The plant treats Potomac River water, which is supplied via a raw water pumping station, located 140 feet below the plant. Raw water is treated using conventional treatment and fluoridation together with rapid sand filtration. The Potomac River Filtration Plant distributes finished water to both Montgomery and Prince Georges Counties. Figure D-22 is an elevation schematic of the WSSC's Potomac Plant.

The Potomac River Filtration Plant has undergone continued expansion since 1961 and presently has a maximum one-day treatment capacity of 240 mgd. In July 1978, the Corps of Engineers granted WSSC a permit to construct a 400 mgd intake adjacent to the site of its existing Potomac River intake structure. This new intake was completed in 1981 and enables WSSC to increase its Potomac withdrawals from a maximum of 184 mgd to 400 mgd. To complement this increased intake capacity, WSSC was also planning to expand its Potomac River Filtration Plant to provide a maximum daily treatment capacity of 400 mgd. The treatment plant expansion plans have been delayed indefinitely until such time as sufficient needs are exhibited to warrant the expansion. Figure D-23 shows a plan view of the new intake, existing treatment plant, and proposed expansion at WSSC's Potomac River Filtration Plant. With the existing Potomac River Filtration Plant and the Patuxent River Filtration Plant, WSSC's maximum water treatment capacity is about 305 mgd.

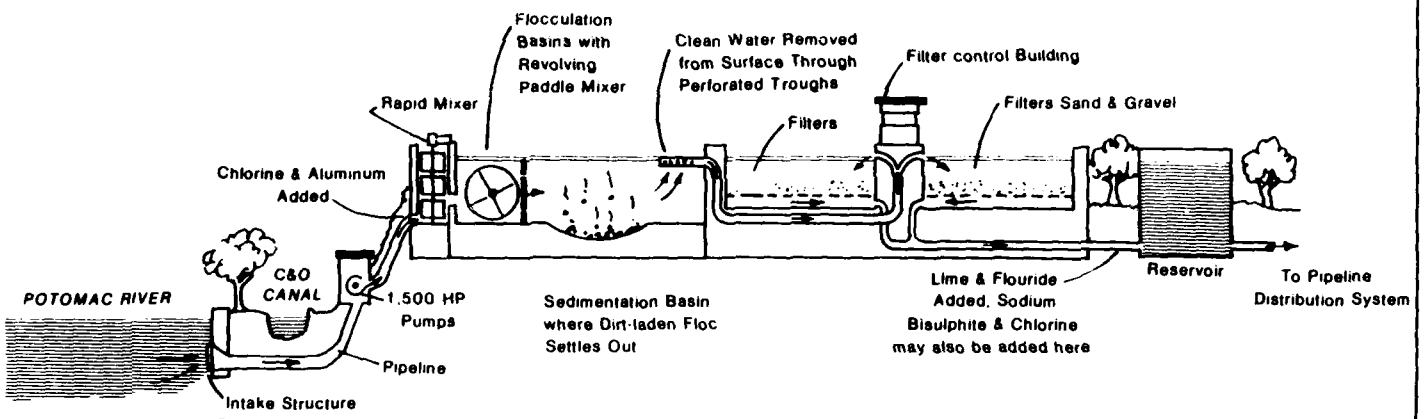


SOURCE:

Pump Storage Project W-133, Montgomery County, Maryland,
Ralph M. Parsons Co., 1975

Figure D-21

WSSC POTOMAC RIVER FILTRATION PLANT



SOURCE: YOUR WATER, A pamphlet distributed by the Washington Suburban Sanitary Commission, 1976

Figure D-22

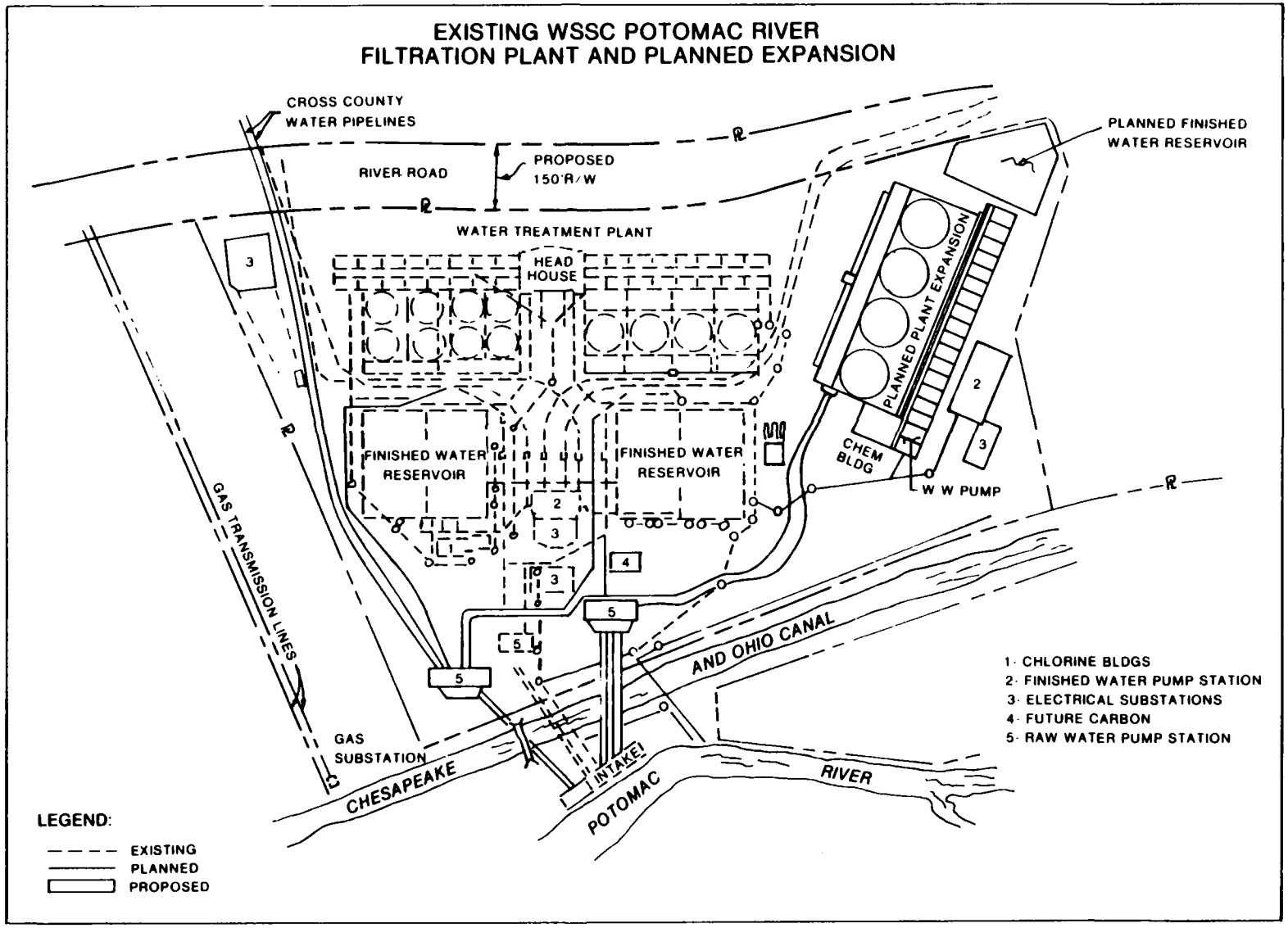

EXISTING WSSC POTOMAC RIVER
FILTRATION PLANT AND PLANNED EXPANSION
CROSS COUNTY
WATER PIPELINES
RIVER ROAD
PROPOSED
150'R/W
WATER TREATMENT PLANT
HEAD
HOUSE
PLANNED FINISHED
WATER RESERVOIR
PLANNED PLANT EXPANSION
FINISHED WATER
RESERVOIR
FINISHED WATER
RESERVOIR
CHEM
BLDG
W W PUMP
GAS TRANSMISSION LINES
GAS
SUBSTATION
CHESAPEAKE
AND OHIO CANAL
INTAKE
POTOMAC
RIVER
1- CHLORINE BLDGS
2- FINISHED WATER PUMP STATION
3- ELECTRICAL SUBSTATIONS
4- FUTURE CARBON
5- RAW WATER PUMP STATION
LEGEND:
EXISTING
PLANNED
PROPOSED

Figure D-23

FAIRFAX COUNTY WATER AUTHORITY

The FCWA is the second largest supplier of water in the Commonwealth of Virginia. The FCWA provides water to both retail and wholesale customers in the City of Alexandria, Fairfax County, and a portion of Prince William County. The major facilities of the FCWA consist of the tandem reservoir system located on Occoquan Creek furnishing water to two interconnected water treatment plants at Occoquan and Lorton, and a Potomac River intake and treatment plant near Lowes Island.

Until just recently, the Occoquan system of reservoirs and treatment plants provided nearly all of the water to the FCWA system. The FCWA's Occoquan treatment facilities were constructed in stages, during the period 1950-1973. Conventional treatment and fluoridation are used in processing the raw water. The maximum one-day combined treatment capacity of the plant is 112 mgd. Figure D-24 is a schematic of the Occoquan and Lorton treatment facilities.

Twenty-two booster pumping stations, with installed capacities ranging from 0.12 to 42.0 mgd, maintain operating pressures throughout the service areas. These stations are non-attended; the larger stations being operated by remote control from the Occoquan Creek production and treatment facilities, and the smaller ones being automatically controlled installations. A total of 19 million gallons of finished water is stored in 43 distribution system reservoirs at various locations in the service areas.

In July, 1978, the Corps of Engineers granted FCWA a permit to construct a 200 mgd intake structure in the Potomac River at Lowes Island, Loudoun County, Virginia. This intake structure was completed in 1981. In connection with this intake, FCWA also constructed a Potomac River Treatment plant to treat and distribute water to the northern portion of the FCWA service area. The treatment plant was completed in 1982 and has a maximum capacity of 50 mgd. Additional treatment capacity will be added in 50 mgd increments on an as-needed basis with an ultimate maximum one-day capacity of 200 mgd.

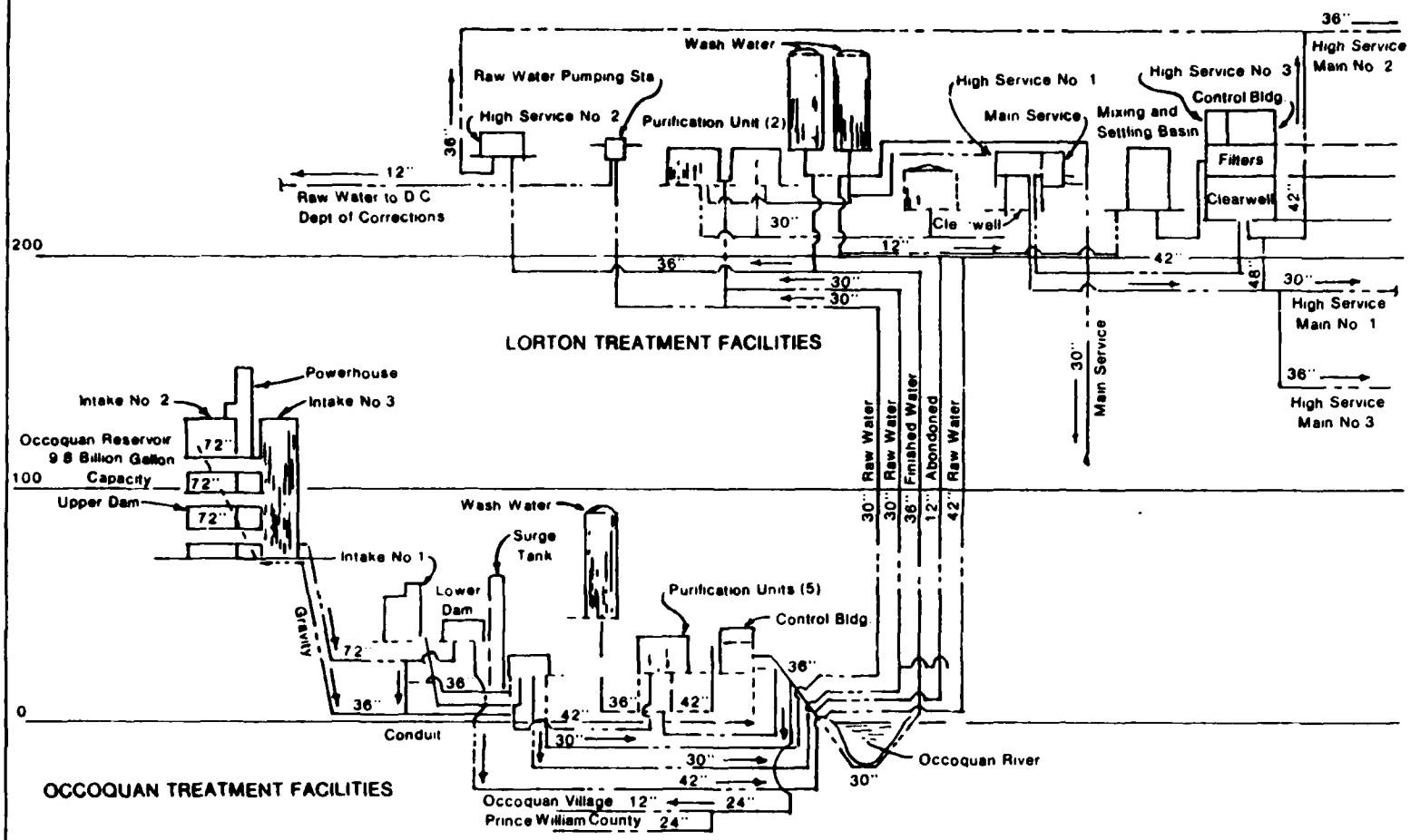
The treatment plant site is located in northwestern Fairfax County on the westerly side of Stuart Road and south of Sugarland Road (refer to Figure D-25). The Atlantic Seaboard Pipeline forms the southern boundary of the site. The treatment facilities utilize standard water treatment processes including screening, flocculation, sedimentation, and filtration including application of chemical disinfectants and fluoridation. Solids collected from sludge dewatering are removed from the site to an approved landfill site. Approximately 111 acres of clear and wooded farmland are utilized for the site. Twenty acres will be devoted to structures and access facilities, while the remaining 91 acres will be used as a lawn-type buffer area.

OTHER WATER SUPPLY FACILITIES

In addition to the three major water supplier/distributors just discussed, there are several other smaller systems in the MWA. Most of these systems are in the less urbanized fringes surrounding the central urban core served by the Aqueduct, WSSC, and FCWA. These smaller water supply systems are discussed in Appendix I - Outlying Service Areas.

Two of these smaller systems deserve mention in this appendix, however, because they withdraw water from the Potomac River along with the Aqueduct, WSSC, and FCWA.

FAIRFAX COUNTY WATER AUTHORITY TREATMENT FACILITIES AT OCCOQUAN



SOURCE: Fairfax County Water Authority

Figure D-24

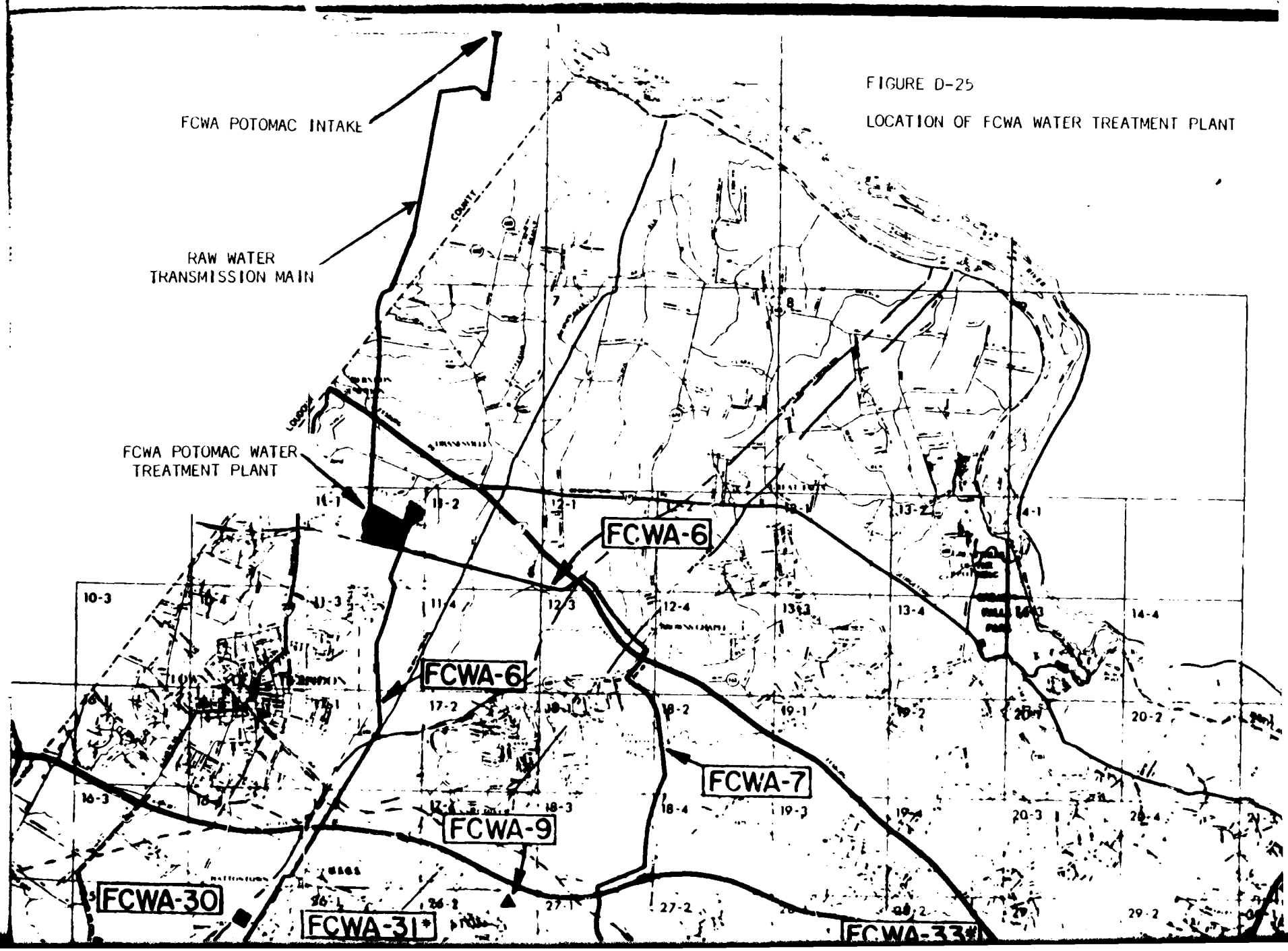


FIGURE D-25

LOCATION OF FCWA WATER TREATMENT PLANT

The City of Rockville in Montgomery County, Maryland, has an 8 mgd intake in the Potomac River about 1.5 miles upstream from Great Falls. The water is conveyed about one-half mile to a water treatment plant, treated, and then delivered to Rockville about six miles away. The treatment plant was placed in operation in 1958 and has had additional units added since then; its present nominal capacity is about 8 mgd.

The other utility which will soon withdraw water supply from the Potomac River is the Town of Leesburg in Loudoun County, Virginia. The Town of Leesburg is presently constructing a 2.5 mgd intake in the Potomac River across from Harrison Island (ultimate capacity of 10 mgd). The facility is expected to be completed in 1982 and will replace the well system which the town presently uses.

There also exists one other large water intake in the Potomac River within the MWA. This intake serves the Dickerson coal-fired electric generating plant (Potomac Edison) and furnishes water for once-through cooling. Average withdrawal and return flow approximate 400 mgd.

WATER SUPPLY BASE - EARLY-ACTION PHASE

This section presents the derivation of the water supply base which was used during the early action phase of the Metropolitan Washington Area Water Supply Study. As explained in a later section, the water supply base was redefined for the long-range phase because of certain actions taken by non-Federal interests as a result of the August 1979 Progress Report.

The water supply sources considered in the early action phase of the study included the unregulated Potomac River and its tributaries, Bloomington Lake, Occoquan Reservoir, Patuxent Reservoir, Lake Manassas, Goose Creek Reservoir, and groundwater resources. Information used in developing the MWA water supply base was obtained primarily through the United States Geological Survey (USGS) streamflow records, local water supply representatives, and recent water supply reports and publications.

Two major types of supply base data were computed and tabulated: frequency data and sequential or simulation data. Comparison of supply base frequency data to projected demands allowed shortage curves to be computed for the study period, 1980 through 2030. From these shortage curves, water supply components were staged to develop alternative water supply plans for satisfying future water needs. Once plans were developed for various shortage curves, costs were derived and applied allowing a comparison of the plans to be made. On the other hand, simulation supply base data were used to "test" the alternative plans against known droughts to determine the adequacy of the plans designed on a frequency basis. The alternative plans developed for the early action phase of the study are described in Appendix B - Plan Formulation, Assessment, and Evaluation.

PRINCIPAL STREAM GAGES IN THE MWA

There are six principal stream gages in the MWA which were used during the MWA Water Supply Study. These gages are USGS gaging stations and were chosen because of their proximity to the MWA's major water supply sources. These MWA major water supply sources and their corresponding USGS gaging stations are depicted in Table D-8 and Figure D-26.

TABLE D-8

MAJOR WATER SUPPLY SOURCES AND THEIR RESPECTIVE GAGING STATIONS

Source	USGS Gaging Station
Potomac River	#(01646500) Potomac River near Washington, DC (adjusted) includes water supply diversions)
Shenandoah River	#(01631000) South Fort Shenandoah River at Front Royal, Virginia
Goose Creek	#(01644000) Goose Creek near Leesburg, Virginia
Seneca Creek	#(01645000) Seneca Creek at Dawsonville, Maryland
Occoquan Creek	#(01657500) Occoquan Creek near Occoquan, Virginia
Patuxent River	Patuxent River near Burtonsville, Maryland

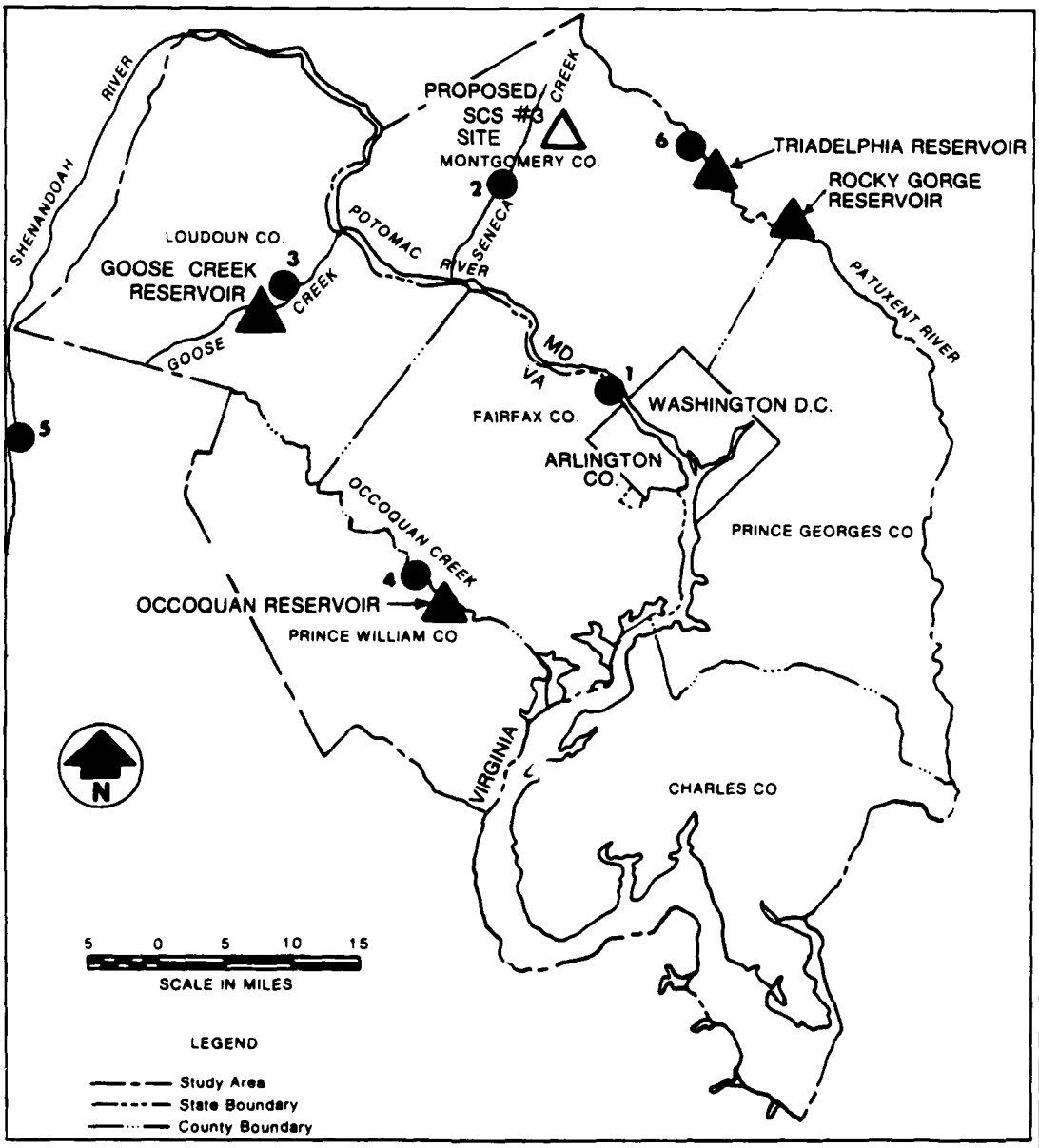
Each of these gaging stations is reliable and has a fairly long recording period. Figure D-27 shows graphically the availability of the records at each of the six USGS gaging stations.

For the calculation of reservoir inflows, additional or filled-in data were required. The technique used in this study to generate filled-in streamflow data was based on the "Multivariate Data Fill-in Program" developed in 1970 for the Office of Water Resources Research, U.S. Department of the Interior. The program was used to generate monthly streamflow data only. The source for the supply data base for the Potomac River was the daily streamflow records of the USGS Potomac River near Washington D.C. (adjusted) gaging station (#01646500). It was the key gage used to derive frequency and simulation data. This gage was chosen because: (1) it is considered by the major water suppliers to be the most representative gage; (2) it has continuous records since before the 1930's drought, the critical drought period in the region; (3) it is a very dependable and stable gage, giving accurate measurements at all water stages; and (4) it is located just upstream of the Potomac Estuary and downstream from the major water supply intakes. The main disadvantage of the use of this Washington, D.C. gage, as opposed to the Potomac River Point of Rocks gage in Frederick County, is that it is located downstream from the MWA Potomac River intakes. For this reason, an adjustment must be made to the actual recorded data to account for that amount of water diverted for water supply or recreation (Chesapeake and Ohio Canal) purposes.

FREQUENCY SUPPLY BASE

Generation of supply base data by frequency was performed with use of the Potomac River adjusted gaging station near Washington, D.C. This USGS gage supplied the data

STREAM GAGE LOCATIONS



KEY: USGS GAGING STATIONS

1. POTOMAC RIVER NEAR WASHINGTON D.C. (No.01646500)
2. SENECA CREEK AT DAWSONVILLE, MD. (No.01645000)
3. GOOSE CREEK NEAR LEESBURG, Va. (No. 01644000)
4. OCCOQUAN CREEK NEAR OCCOQUAN, Va. (No. 01657500)
5. S. FORK SHENANDOAH RIVER AT FRONT ROYAL (No. 01631000)
6. FORMER PATUXENT RIVER BURTONSVILLE GAGE

Figure D-26

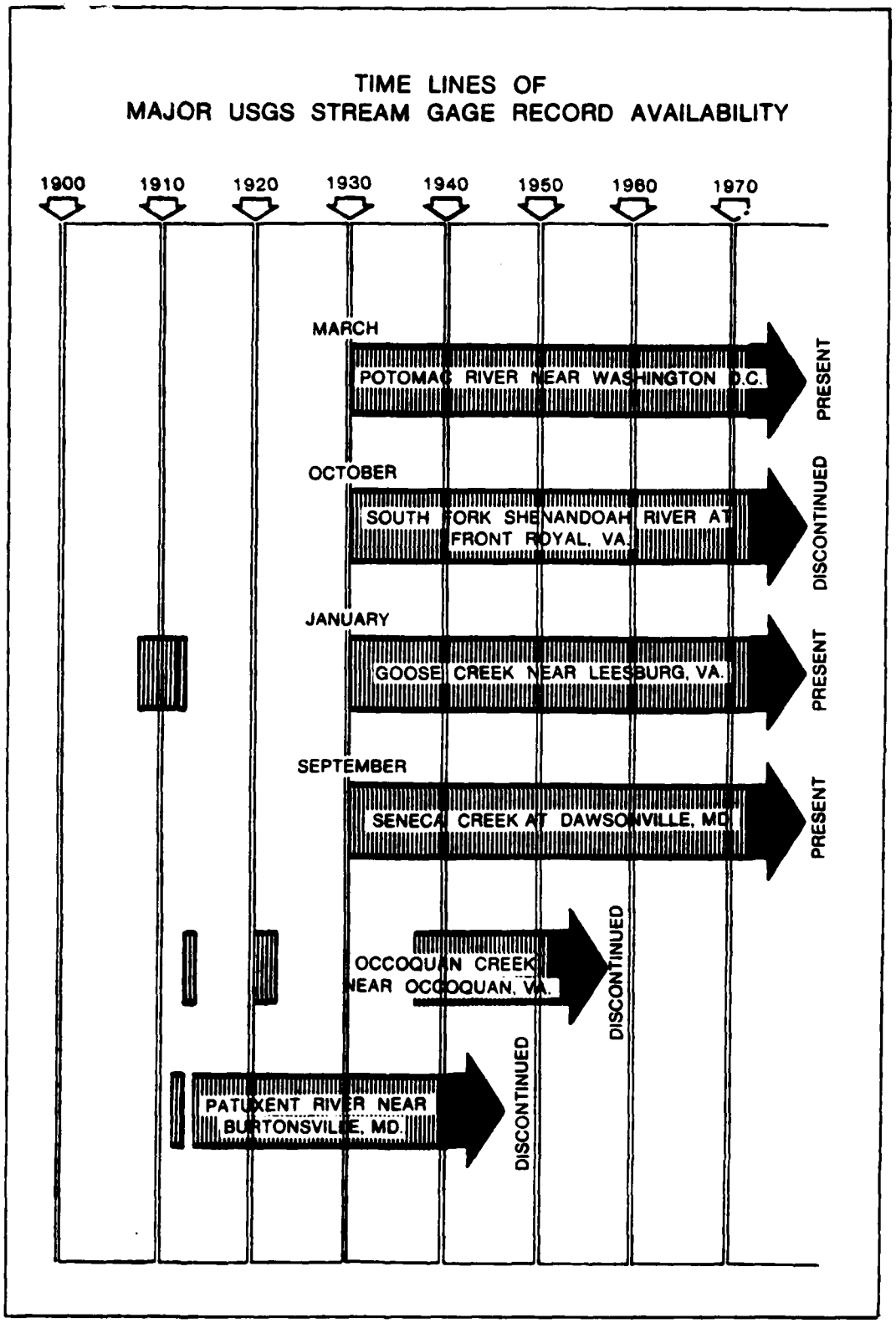

TIME LINES OF
MAJOR USGS STREAM GAGE RECORD AVAILABILITY
1900
1910
1920
1930
1940
1950
1960
1970
MARCH
POTOMAC RIVER NEAR WASHINGTON D.C.
PRESENT
OCTOBER
SOUTH FORK SHENANDOAH RIVER AT FRONT ROYAL, VA.
DISCONTINUED
JANUARY
GOOSE CREEK NEAR LEESBURG, VA.
PRESENT
SEPTEMBER
SENECA CREEK AT DAWSONVILLE, MD.
PRESENT
OCCOQUAN CREEK NEAR OCCOQUAN, VA.
DISCONTINUED
PATUXENT RIVER NEAR BURTONSVILLE, MD.
DISCONTINUED

Figure D-27

necessary to generate an annual series of frequency curves (refer to Figure D-28). These frequency curves were derived by USGS by use of the Logarithmic Pearson Type III distribution method. This method requires three parameters for a complete mathematical specification; the mean, the variance, and the skew of the sample data. Since the distribution is logarithmic, all the parameters are estimated from logarithms of the flow values rather than from the actual flow values. The Log Pearson Type III distribution is useful in hydrologic investigations because the third parameter, the skew, permits the filling of non-normal samples of the distribution. If the skew is zero, the Log Pearson Type III distribution becomes a two parameter distribution that is identical to the logarithmic normal distribution.

Table D-9 summarizes the data presented in Figure D-28 and shows Potomac River frequency data in mgd for 30, 7 and 1-day durations and recurrence intervals for once in 100 years, once in 50 years, once in 20 years and once in 10 years.

SIMULATION SUPPLY BASE

Simulation supply data were derived for both monthly average flows and weekly average flows. The determination of the time frame for the monthly average analysis was based on the lowest flow period on record having the longest duration. The time frame chosen for the weekly average analysis spanned a thirteen week period from 29 June 1966 to 27 September 1966. Although the 1966 drought was not as prolonged as the early 1930's drought, the 1966 drought did exhibit the lowest observed flow on record.

To define the data used for the simulation supply base, this section has been divided into two subsections. The first subsection identifies the data sources and assumptions used to derive streamflow and reservoir inflow data. Subsection two presents data on the important reservoir characteristics used in the simulation analysis.

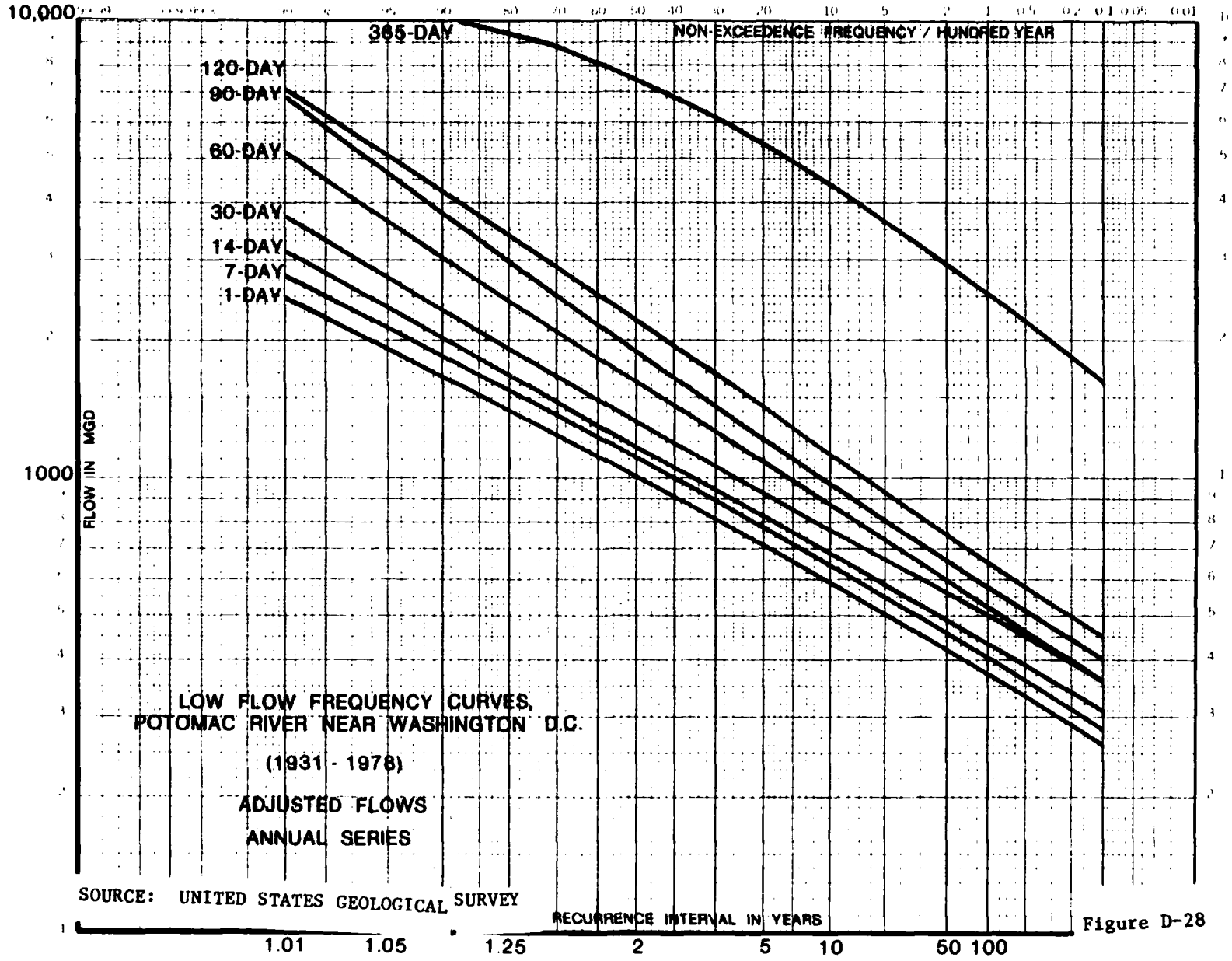
MWA STREAMFLOW AND RESERVOIR INFLOW DATA

As previously mentioned, the principal gaging station used was the Potomac River near Washington, D.C. (adjusted) gage. Daily streamflow records were used to compute the monthly average and weekly average Potomac River supply values for the 1930 and 1966 droughts, respectively.

The major tributary entering the Potomac River at Harpers Ferry, West Virginia, is the Shenandoah River. For purposes of this study, the supply values used were taken from the USGS South Fork Shenandoah River at Front Royal, Virginia, (#01631000) gaging station. This gage was used because of its close location to one of the study's proposed raw water interconnection alternative route alignments.

In addition to the Potomac and Shenandoah Rivers, there are also several smaller tributaries affecting the water supply of the MWA. These tributaries consist of the Occoquan Creek, Goose Creek, Beaverdam Creek, and Seneca Creek. For each of these tributaries, streamflow data were either collected or generated in order to obtain monthly inflows for the reservoirs located on them.

On the Occoquan Creek there are two factors which must be considered in determining supply inflow data. The first consideration is that a regional sewage treatment plant has recently been constructed on Occoquan Creek. This regional Upper Occoquan Sewage Authority (UOSA) plant is expected to affect significantly the Occoquan Reservoir



SOURCE: UNITED STATES GEOLOGICAL SURVEY

Figure D-28

TABLE D-9

POTOMAC RIVER LOW FLOWS FOR VARIOUS DURATIONS AND FREQUENCIES

	FLOW IN MGD		
	30-Day	7-Day	1-Day
FREQUENCY			
1/100	493	401	369
1/50	552	454	419
1/20	654	546	505
1/10	762	642	593

SOURCE: Potomac River (adjusted) near Washington, D.C. 1931-1978 Annual Series (See Figure D-28)

inflows by the year 2000. In order to account for this projected inflow, data were obtained from FCWA and used in computing the total expected Occoquan inflow. FCWA computed its Occoquan Reservoir inflow data based upon previous work done by the consulting engineering firm of Harza Engineering. The inflow data used covered the simulation period April 1930 - December 1931. The 1932 data were taken from the Occoquan USGS gaging station (#01657500). Total Occoquan Reservoir inflow data were computed as the sum of the sewage treatment inflows and the stream data.

For the Patuxent River, which has both the Rocky Gorge and the Triadelphia Reservoirs located on it, actual inflow data were available from the discontinued USGS Patuxent River gaging station near Burtonsville . These data were obtained from the WSSC.

The Goose Creek Reservoir lies west of the District of Columbia, in Loudoun County, Virginia. The data used for inflows to this reservoir were taken from the USGS Goose Creek near Leesburg gaging station (#01644000). No fill-in data were required for this gage, since the gage dates back to the early 1930's.

Seneca Creek is the tributary of the Potomac River where WSSC intends to construct its Little Seneca Lake project. Inflow values for Little Seneca Lake were derived from the USGS Dawsonville, Maryland, gaging station (#01645000). Since this gage was not in operation until late 1930, some fill-in data were required.

The final MWA reservoir which required inflow data was the Beaverdam Reservoir, located on Beaverdown Creek, a tributary to Goose Creek, upstream from the Goose Creek Reservoir. Unlike the other reservoirs, there is no USGS gaging station located on this creek. For this reason, inflow values were estimated for Beaverdam Creek by applying a drainage area ratio (6/358 = 0.017) of the areas tributary to the two reservoirs, Beaverdam and Goose Creek, to the Goose Creek Reservoir Inflows.

Table D-10 summarizes the monthly average flows during the 1930 to 1932 drought for the different streams affecting the MWA. Table D-11 lists the weekly average flows for the Potomac River during the severe drought in the summer of 1966.

RESERVOIR DATA

The major water supply reservoirs for the MWA are located on the Patuxent River, Occoquan Creek, and Goose Creek. On the Patuxent River there are two reservoirs, Rocky Gorge and Triadelphia, which serve the WSSC water service area. As previously mentioned, these reservoirs are served by the Patuxent River Water Filtration Plant located near Laurel, Maryland.

The Occoquan Creek contains one water supply reservoir which serves the FCWA water service area. Downstream there are two interconnected filtration plants serving the Occoquan Reservoir.

There are also two reservoirs located on Goose Creek. These impoundments are the Goose Creek Reservoir and the Beaverdam Reservoir. These reservoirs serve the Fairfax City water service area and rely on one water treatment facility.

Table D-12 summarizes the combined safe yields for the reservoir systems and also indentifies the maximum 1-day and 7-day capacities for their associated water treatment facilities. The combined safe yields were computed using the HEC-3 computer program, Reservoir System Analysis for Conservation. The 1 day maximum treatment plant capacities correspond to those presented in an earlier section. The 7 and 30-day treatment plant capacities were computed as 85 percent and 75 percent, respectively, of the maximum 1-day treatment plant capacity. These percentage values allow for filter backwashing and normal maintenance.

GROUNDWATER

Presently, groundwater sources account for only a small percentage of the MWA's total water supply. Studies have shown that there exists a wide range of available groundwater resources throughout the Potomac River Basin. At present, these resources provide adequate domestic and agricultural water supplies and locally provide large supplies for industrial and municipal use.

Table D-13 shows 1976 pumping records, in million gallons per day, for the eight MWA water service areas. Also shown in this table is the percentage used by each water service area. It should be noted that only about one half of the water service areas either record or pump enough groundwater to be counted.

The role of groundwater in the future is uncertain. Several studies are being conducted throughout the region. One such groundwater study was conducted by the USGS for the Corps of Engineers to determine the potential yield of Coastal Plain aquifers in southern Maryland. Detailed discussion of the USGS study is contained in Appendix F.

TABLE D-10
MONTHLY AVERAGE FLOWS (MGD)
1930 - 1932

TRIBUTARY	DATA SOURCE	1930 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Potomac River	Potomac River near Washington, DC, (adjusted) USGS Gage (#01646500)	6,153	2,760	2,052	1,018	570	641	553	654	1,319
Occoquan River	Upper Occoquan Sewage Authority (UOSA) Sewage Inflow	10	11	12	13	12	12	11	10	10
	(HARZA Eng.) Occoquan Inflow	323	127	59	21	3	3	3	6	39
	Total Occoquan Inflow	333	138	71	34	15	15	14	16	49
Goose Creek	Goose Creek near Leesburg, VA. USGS Gage (#01644000)	203	73	31	10	1	1	1	3	19
Patuxent River	Patuxent River at the Burtonsville USGS Gage	105	48	30	14	7	6	7	13	25
Beaverdam Creek		3	1	1	0	0	0	0	0	0
Seneca Creek	Seneca Creek at Dawsonville, MD USGS Gage (#01645000)	126	57	12	15	1	11	11	10	19
Shenadoah River	South Fort, Shenandoah River at Front Royal, Virginia, USGS Gage (#01631000)	548	221	94	134	142	41	148	157	174

TABLE D-10 (Cont'd)
MONTHLY AVERAGE FLOWS (MGD)
1930 - 1932

TRIBUTARY	DATA SOURCE	1931											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Potomac River	Potomac River near Washington, DC, (adjusted) USGS Gage (#01646500)	2,154	2,592	4,385	10,503	9,477	4,415	4,136	3,059	1,826	1,079	803	1,937
Occoquan River	Upper Occoquan Sewage Authority (UOSA) Sewage Inflow	9	9	9	10	11	12	13	12	12	11	10	10
	(HARZA Eng.) Occoquan Inflow	61	34	97	179	131	76	60	60	31	9	13	31
	Total Occoquan Inflow	70	43	106	189	142	88	73	72	43	20	23	41
Goose Creek	Goose Creek near Leesburg, VA. USGS Gage (#01644000)	32	17	54	106	75	41	32	32	15	4	6	15
Patuxent River	Patuxent River at the Burtonsville USGS Gage	34	25	43	49	42	41	68	54	14	11	14	24
Beaverdam Creek		1	0	1	2	1	1	1	1	0	0	0	0
Seneca Creek	Seneca Creek at Dawsonville, MD USGS Gage (#01645000)	23	17	28	37	19	28	36	23	6	6	8	14
Shenadoah River	South Fort, Shenandoah River at Front Royal, Virginia, USGS Gage (#01631000)	287	225	474	1,241	1,035	659	583	678	357	203	203	181

TABLE D-10 (Cont'd)
MONTHLY AVERAGE FLOWS (MGD)
1930 - 1932

TRIBUTARY	DATA SOURCE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				1932									
Potomac River	Potomac River near Washington, DC, (adjusted) USGS Gage (#01646500)	4,564	7,903	11,032	11,568	18,097	2,788	2,192	962	848	5,020	13,768	5,619
Occoquan River	Upper Occoquan Sewage Authority (UOSA) Sewage Inflow	9	9	9	10	11	12	13	12	12	11	10	10
	(HARZA Eng.) Occoquan Inflow	172	203	568	310	325	188	85	14	25	95	435	193
	Total Occoquan Inflow	181	212	577	320	336	200	98	26	37	106	445	203
Goose Creek	Goose Creek near Leesburg, VA. USGS Gage (#01644000)	101	154	310	314	535	80	46	8	18	130	782	269
Patuxent River	Patuxent River at the Burtonsville USGS Gage	61	59	83	78	90	59	22	18	12	70	131	79
Beaverdam Creek		2	3	5	5	9	1	1	0	0	2	13	5
Seneca Creek	Seneca Creek at Dawsonville, MD USGS Gage (#01645000)	38	40	70	65	63	26	14	5	8	61	102	62
Shenadoah River	South Fort, Shenandoah River at Front Royal, Virginia, USGS Gage (#01631000)	445	761	1,539	1,053	1,786	428	341	181	205	991	1,844	963

TABLE D-11

POTOMAC RIVER WEELY AVERAGE FLOWS*
SUMMER 1966

7-DAY PERIOD	AVERAGE WEEKLY FLOW (MGD)
29 June - 5 July	946
6 July - 12 July	933
13 July - 19 July	795
20 July - 26 July	620
27 July - 2 August	547
3 August - 9 August	532
10 August - 16 August	738
17 August - 23 August	800
24 August - 30 August	590
31 August - 6 September	481
7 September - 13 September	404
14 September - 20 September	7,246
21 September - 27 September	7,149

*Data Source: Potomac River gage near Washington, D.C., adjusted; USGS Gage Number 01646500.

OTHER SUPPLY CONSIDERATIONS

In addition to the streamflow, reservoir, and groundwater data just presented, several other criteria were defined for the purpose of the early-action phase of the Metropolitan Washington Area Water Supply Study.

Flowby is defined as the minimum amount of water allowed to remain in a stream after all withdrawals. The flowby value should consider water quality, navigation, and recreation needs as well as water supply needs. At the time the early-action phase was underway, the State of Maryland was conducting a study of the lower portion of the freshwater Potomac River to establish an acceptable flowby level. Because the flowby study had not progressed to a point where recommendations could be made, the Corps of Engineers assumed a Potomac flowby value of 100 mgd for its calculations of supplies,

TABLE D-12

SUMMARY OF RESERVOIR AND TREATMENT PLANT SUPPLY DATA
(VALUES IN MGD)

River System	Reservoir	Combined Safe Yield	Water Treatment Plant	Maximum 1 Day Capacity	Maximum 7 Day Capacity	Maximum 30 Day Capacity
Patuxent River	Rocky Gorge Triadelphia	32	Patuxent WTP	65	55	49
Occoquan River	Occoquan	69 *	Combined Occoquan WTP's	112	95	84
			Broad Run	6	5	5
Goose Creek	Goose Creek Beaverdam	5	Goose Creek WTP	18	15	14

* Assumes 2-foot addition.

TABLE D-13

MWA GROUNDWATER SUPPLIES

JURISDICTION	DAILY AVERAGE SUPPLY* (estimated in million gallons per day)	PERCENTAGE (%)
WAD	0	0
WSSC	0	0
FCWA	1	0
Rockville	0	0
Prince William County	5	41
Loudoun County	2	18
Fairfax City	0	0
Charles County	5	41
TOTAL	12 mgd	100%

*Based on 1976 pumpage records

demands, and deficits in the August 1979 Progress Report. This assumption was consistent with the one used in the Northeastern United States Water Supply Study. For the Shenandoah River, a 15 mgd flowby level was assumed. This value was derived by drainage area ratios applied to the assumed Potomac River flowby.

A final and very important water supply source was Bloomington Lake which was nearing completion when the August 1979 Progress Report was published. Because project regulation rules had not been finalized, it was necessary to make certain assumptions about the Bloomington release schedule for the purposes of the early action phase. The schedule assumed monthly average releases of 60 mgd in July, 135 mgd in August, 135 mgd in September, 135 mgd in October, and 75 mgd in November to supplement existing flow in the Potomac River. This release schedule was defined in the NEWS Study, and was derived from the 1930's drought.

It should be noted that the assumptions regarding flowby and Bloomington releases for the early action phase of study were the subject of considerable refinement in the long-range phase as better information became available. A later section in this Appendix, as well as the Main Report and Appendix B, discusses the refinements and modifications to the supply base which was defined for the early-action phase as documented in the August 1979 Progress Report.

WATER DEMAND PROJECTIONS - EARLY-ACTION PHASE

In reading this section, the reader should recognize that the data presented herein is fundamentally the same information as was presented in the demand projection chapter of the August 1979 Progress Report for the early-action phase. As such, the base year for much of the data is 1976 - the most recent year for which information was available when the demand investigation was started. Most of the data manipulations and computations were performed in 1977 and 1978 prior to the publication of the Progress Report. The basic demand information developed in the early-action phase was used throughout the study, with proper adjustments for the long-range phase. Some of these adjustments are discussed in a later section of this appendix concerning the redefinition of supply and demand for the long-range portion of the study. Appendix G - Non-Structural Studies also contains a section which discusses water conservation and demand reduction measures as applied to the baseline demands which are projected in the following section.

Traditionally, water demands have been computed based on two types of projections, population and per capita water use. However, with current technology and the increased use of sophisticated computers in water resources planning, this demand methodology has become outdated. To make use of the increased capability resulting from the advancing technology, the firm of Water Resources Engineers (WRE, Incorporated, a unit of Camp, Dresser, and McKee) developed a computer program for the MWA Water Supply Study which projected water demands based on population, employment, water use, and household data. The output resulting from this computer model was average monthly water service area demands projected from 1980 to 2030.

The population projections were developed by the Corps of Engineers based on the 1976 Metropolitan Washington Council of Governments (MWCOG) population forecasts which were extended to the year 2030 through the use of logarithmic regression. The employment and households data used by WRE in the water demand model were also based on the MWCOG forecasts as well as on input from local planning agencies.

To aid the reader in following the methodology used to compute the MWA demands, this section has been divided into five main parts. These parts are as follows: Population Projections, Employment and Households Projections, 1976 Base Water Use, the MWA Water Demand Projection Model, and Development of Simulation Demands.

Sections one through four describe in detail the methodology used to develop the major input parameters to the water demand model and present results in terms of MWA population, employment and households, and water use, respectively. The fourth section describes the computer demand model and how monthly demands were computed. Finally, Section five presents, in tabular form, the resulting projected average monthly, 7 and 1-day demands by benchmark year and service area.

POPULATION PROJECTIONS

PREVIOUS PROJECTIONS

Since the early 1960's, there have been several widely varying projections of population for the MWA. Using the large growth experienced in the MWA during the 1960's as a base, some projections have estimated equally large population increases for the future. Recent population data, however, suggest that these forecasts may be far from

accurate. To illustrate the progression of the various population projections, Figure D-29 provides a graphic comparison of seven different population estimates developed for the MWA since 1963.

In 1963, population projections were prepared by the Corps of Engineers for the Potomac River Basin Report. The Counties of Prince William, Loudoun, and Charles were not included in the projections. The report projected a population of 3.5 million in 1985 and 5.2 million in 2010 for the MWA. A regional Development Guide was published by the Metropolitan Washington Council of Governments (MWCOG) in 1965 for the MWA (excluding Charles County). The Regional Development Guide projected a population of 3.7 million for 1980 which was expected to increase to 5.3 million by the year 2000. Hammer, Greene, Siler, and Associates in 1969 developed the highest population projections for the MWA (excluding Charles County). They projected a population of 6.1 million in 1990 and 7.7 million by the year 2000. These projections were used by the MWCOG for many of their planning activities in the late 1960's and early 1970's.

The 1972 projections by the Bureau of Economic Analysis (formerly the Office of Business Economic and the Economic Research Service, otherwise known as OBERS Projections) estimated a population of 4.4 million in 1990, 5.2 million in 2000, and 6.9 million in 2020 for the MWA (excluding Charles County). In 1976, the Bureau of Economic Analysis revised the 1972 projections for the MWA. This revised set of projections is also presented on Figure D-29. The EMPIRIC Activity Allocation Model (6.2 modified) was run in 1973 and the results were used in the Northeastern United States Water Supply (NEWS) Study. The EMPIRIC Model projected a population of 3.7 million in 1980, 5.2 million in 2000, and 6.8 million in 2020 for the MWA (including Charles County).

At the time the early-action phase was being conducted, the most recent estimates of population had been developed in 1976 as part of the MWCOG Cooperative Forecasting Program. An estimated population of 4,238,000 was projected for the MWA in 1995 (excluding Charles County). Data received from the Maryland Department of State Planning indicated that Charles County was estimated to have a population of 82,000 in 1995. (Information from the Maryland Department of State Planning was used because MWCOG did not develop data for Charles County.) The MWA total population estimate of 4,321,000 in 1995 represents a 48 percent increase over the 1970 population of 2,910,000. The planning estimates through 1995 for the Washington D.C. SMSA, presented in Table D-14, are based on the Cooperative Forecasting Program and the Maryland Department of State Planning estimates.

REGIONAL PROJECTIONS

Planning studies for water resource projects require projections for a period of several decades. For the MWA Water Supply Study, the planning period is based on a 50-year time horizon, 1980 through 2030. As previously mentioned, the population projections developed by the MWCOG Cooperative Forecasting Program and the Maryland Department of State Planning were used through the year 1995. For this reason, the Baltimore District, Corps of Engineer· developed regional and service area populations for the remainder of the planning period. The basic methodology used to develop the projections beyond 1995 is presented below:

COMPARISON OF PREVIOUS MWA POPULATION PROJECTIONS

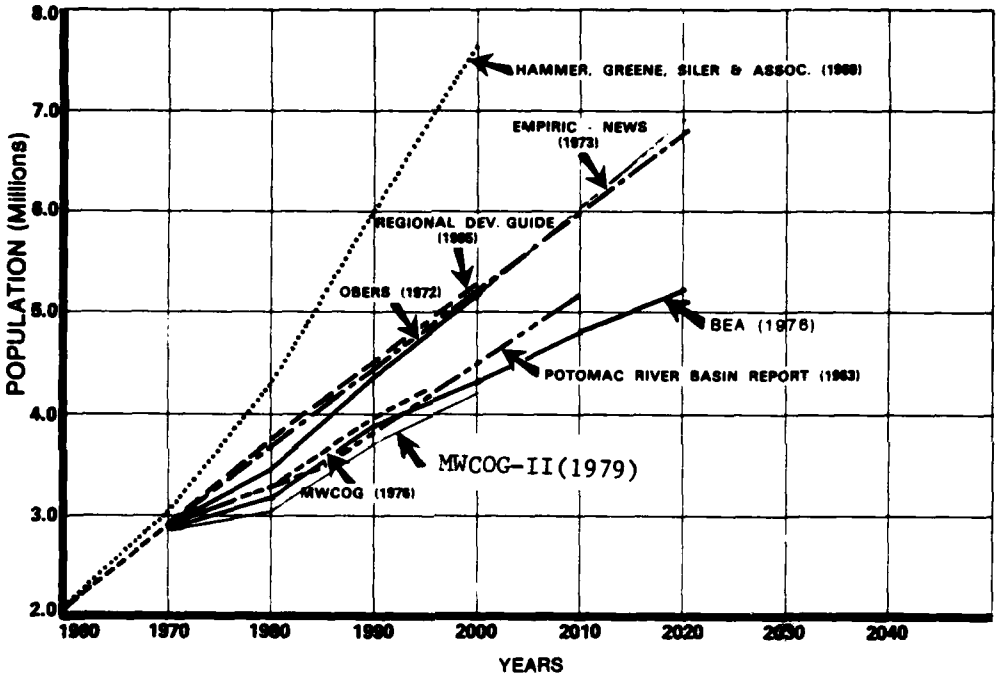


Figure D-29

TABLE D-14

POPULATION ESTIMATES FOR THE
METROPOLITAN WASHINGTON AREA
1970-1995
(1,000's)

	1970	1980*	1985	1990	1995
District of Columbia	757	730	750	772	793
Charles County	48	62	71	76	82
Montgomery County	523	609	678	717	758
Prince Georges County	661	718	812	934	1,028
Arlington County	174	148	166	183	192
Alexandria	111	125	137	148	160
Fairfax County	455	651	752	852	933
Fairfax City	22	22	22	22	22
Falls Church	11	13	14	14	15
Loudoun County	37	61	74	89	102
Prince William County	111	179	198	218	236
TOTAL	2,910	3,318	3,674	4,025	4,321

*Value given in Table for 1980 was an estimate based on population data available in 1976 and 1977. Actual 1980 census data indicated a total population of 3,060,000.

SOURCE: Metropolitan Washington Council of Governments Cooperative Forecasting Summary Report, December 1976.
Maryland Department of State Planning, 1977.

a. Determine growth rates to 2020 based on 1976 Bureau of Economic Analysis (BEA) population estimates.

b. Apply growth rates to population projections beyond 1995.

c. Develop regression equation to estimate 2025 and 2030 population.

The MWCOG is recognized as the official area-wide planning agency and as such maintains coordination with the state and local governments in the area. This was evident in the development of population projections by the MWCOG. An essential element in the iterative process of projection development was initial approval by the member agencies of the methodology used. Additionally, input was required of the agencies at various stages of the process along with approval of the results.

About the time the MWCOG projections were released, the Bureau of Economic Analysis revised its earlier estimates. These 1976 revisions of the 1972 OBERS Projections, Regional Economic Activity in the U.S. included Charles County as part of the Washington D.C. SMSA and were tentatively considered as a most probable population estimate. (The MWA is identical to the Washington, D.C. SMSA and the terms are used interchangeably.) Though both the revised BEA projections and the MWCOG projections compared favorably, the MWCOG projections were selected as the most probable projections because of the comprehensiveness of the planning effort and the assumption that these projections better represented the area's concerns.

While the 1976 BEA population estimates were slightly lower than the MWCOG projections, rates of growth for the two projections were similar. Therefore, growth rates based on the BEA estimates were determined for the year 1995 to the year 2020. The BEA population estimates and growth rates for the MWA are shown in Table D-15. These growth rates were then used to obtain SMSA population estimates to the year 2020. The growth rate estimated for the 1995-2000 period was applied to the 1995 population estimate of 4,321,000 to obtain an estimate of population in the year 2000. To obtain a 2005 estimate, the procedure was repeated by applying the 2000-2005 growth rate to the 2000 population arrived at previously. This method was continued until a 2020 population estimate was obtained. At this point, a regression was used to estimate population for 2025 and 2030 because BEA data did not extend beyond 2020.

The regression equation was of the following form:

$$\log Y = A + B \log X$$

where Y = estimated SMSA growth rate

and X = time (years)

A and B represent numerical values derived from MWCOG data (1970-1995) and BEA data (2000-2020).

The log Y-values were converted to percentages and these were applied to the population estimates in the manner previously described to arrive at estimates for 2025 and 2030. The MWA tabulations are presented in Table D-16.

TABLE D-15

BEA POPULATION ESTIMATES
1990-2020

	POPULATION	FIVE-YEAR GROWTH RATES*
1990	3,892,900	5.8234%
1995	4,119,600	5.5029%
2000	4,346,300	4.9513%
2005	4,561,500	4.7199%
2010	4,776,800	4.7199%
2015	5,006,300	4.8044%
2020	5,235,800	4.5842%

*Five year intervals were interpolated.

BREAKDOWN OF REGIONAL PROJECTIONS

The intent of the following discussion is to explain the breakdown of regional population projections to Transportation Planning Board (TPB) Zones and the subsequent aggregation of the TPB zones into larger, more workable areas of analysis called "sections." The "section" became the principal tool of analysis and led to an additional aggregation of sections into eight water service areas.

Development of Sections

After developing regional population projections, the MWCOG disaggregated these into smaller areas known as Transportation Planning Board (TPB) Zones. These zones were developed by the MWCOG Transportation Planning Board from information based on an origin-destination survey. The formulation of the approximately 1,180 zones resulted from analysis of existing arterials, homogeneity of land use, and jurisdictional boundaries. The population projections associated with the TPB zones were an indication of present and expected development and density patterns on a small area basis. For these reasons, the TPB zones were used as the basis for developing larger areas of analysis. Because Charles County was not included in the Transportation Planning Board's analysis, Charles County election districts were used as the analysis tool in the MWA Water Supply Study.

The transition from TPB zones to the larger areas of analysis, sections, was based upon several interrelated factors. The types of land use among zones and tendencies toward comparable degrees of growth were considered in aggregating the zones to sections. The aggregation of over 1,100 TPB zones to 71 sections was undertaken because these sections would not only be a larger, more appropriate analytical tool, but would also result in a relatively efficient data management device in terms of actual computer input. Figure D-30 is an illustration of the general procedure used to aggregate the TPB zones into 71 sections and, ultimately, eight water service areas.

TABLE D-16

POPULATION PROJECTIONS FOR THE
METROPOLITAN WASHINGTON AREA, 1980-2030*
(1,000's)

	1970	1980[1]	1985	1990[1]	1995	2000[1]	2005	2010[1]	2015	2020[1]	2025	2030[1]
District of Columbia	757	730	750	772	793	798	802	806	810	810	810	810
Charles County	48	62	71	76	82	88	94	99	105	111	117	122
Montgomery County	523	609	678	717	758	792	822	851	881	909	932	952
Prince Georges Co.	661	718	812	934	1,028	1,101	1,189	1,262	1,331	1,397	1,456	1,506
Alexandria	111	125	137	148	160	167	173	178	184	190	195	198
Arlington County	174	148	166	183	192	193	192	191	191	190	189	187
Fairfax County	455	651	752	852	933	1,001	1,052	1,116	1,193	1,277	1,350	1,430
Fairfax City	22	22	22	22	22	23	23	24	24	25	25	25
Falls Church	11	13	14	14	15	15	15	15	15	15	15	15
Loudoun County	37	61	74	89	102	118	135	154	174	196	219	242
Prince William Co.	111	179	198	218	236	262	287	314	342	371	398	426
TOTAL	2,910	3,318	3,674	4,025	4,321	4,558	4,784	5,010	5,250	5,491	5,706	5,913

*Projections to 1995 are based on data obtained from the MWCOG and the Maryland Department of State Planning

[1]-Benchmark years for the MWA Water Supply Study

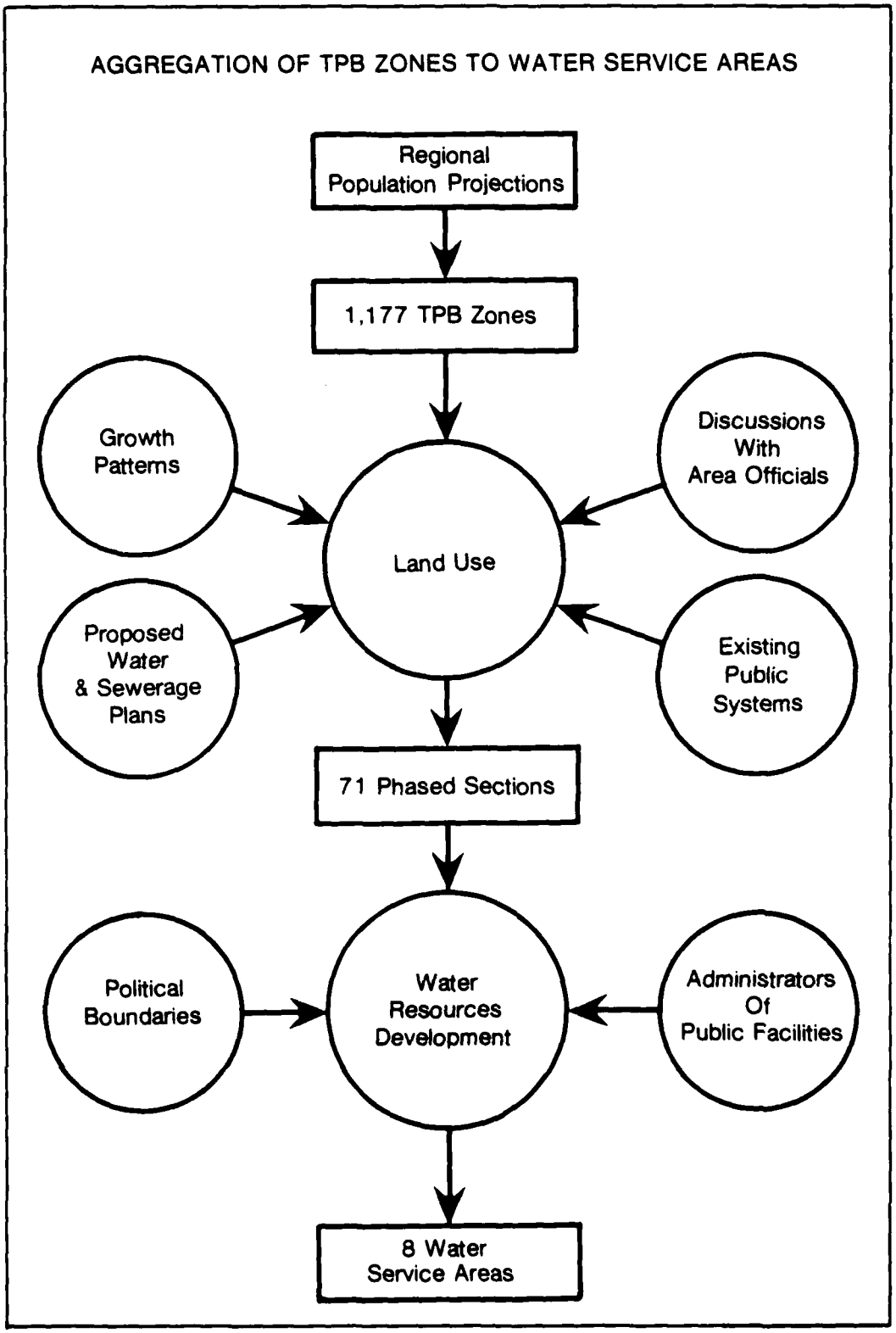

AGGREGATION OF TPB ZONES TO WATER SERVICE AREAS
Regional Population Projections
1,177 TPB Zones
Growth Patterns
Discussions With Area Officials
Land Use
Proposed Water & Sewerage Plans
Existing Public Systems
71 Phased Sections
Political Boundaries
Water Resources Development
Administrators Of Public Facilities
8 Water Service Areas

Figure D-30

As indicated in Figure D-30, land use was the primary consideration in aggregating the TPB zones into sections. Land use information was obtained from discussions with various local planning officials as well as from general growth plans. The discussions were especially beneficial in that they served as a stimulus to each planning official to examine past and present socio-economic trends, housing permits, zoning laws and anticipated changes to these laws, local environmental concerns, and patterns of development. Factors pertaining to water and sewerage systems were also considered in the aggregation of TPB zones into sections but were examined in greater detail in the "phasing" of sections, which is discussed next. These factors and the local planners' expertise and knowledge of specific situations helped identify 71 sections in terms of immediate and long-term development. Figure D-31 illustrates the concept of sections as applied to the study area.

Phasing of Sections

Having established the 71 sections in the MWA based upon factors such as highway development, land use, urban and rural characteristics of the area, and expertise of local planning representatives, the sections were then examined to determine present and anticipated water demands on public water facilities. This aspect also required discussions and meetings with representatives of the various water facilities in the MWA to determine the extent of service by public water systems. This information was used to determine regions in the MWA currently served by public systems, regions expected to be served by these systems in the immediate future, and regions projected to be served within the duration of the 50-year planning period (1980-2030). This process resulted in a "phasing" of the 71 sections. Various sections within each county were "phased" into the existing public systems each benchmark year based upon the information obtained from the various sources. It was determined that certain sections within the MWA would remain on individual or private systems through the year 2030. As a result, as many as seven phases of public water system development were derived. Figure D-32 indicates when the transition from private to public systems was projected to occur for each section, and Figure D-33 locates the phased sections relative to the MWA.

Water Service Areas

The development of the water service areas was the last step in aggregating the smaller TPB zones into more manageable units. Based on previously-held conversations with local planning representatives and information received concerning growth patterns, degree of development, and existing public water systems, the 71 sections were aggregated into eight water service areas (see Table D-17 and Figure D-34). This aggregation process also took into consideration the political boundaries of the jurisdictions within the MWA and the service areas of existing water suppliers. These eight service areas are presented in Figure D-35. An assumption basic to the development of these water service areas is that any future public water supply and/or distribution system formed in the MWA will lie within one of the eight water service areas.

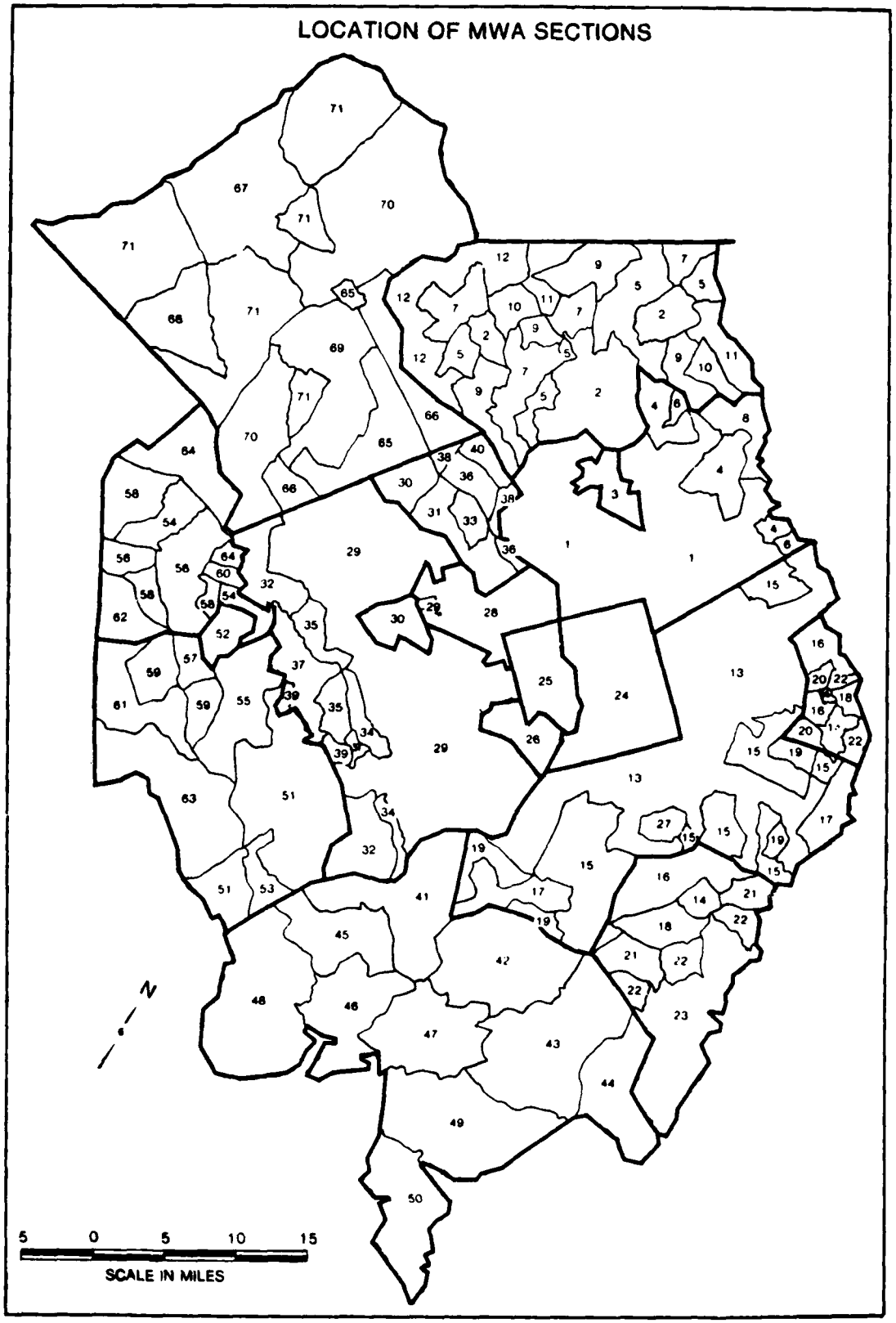
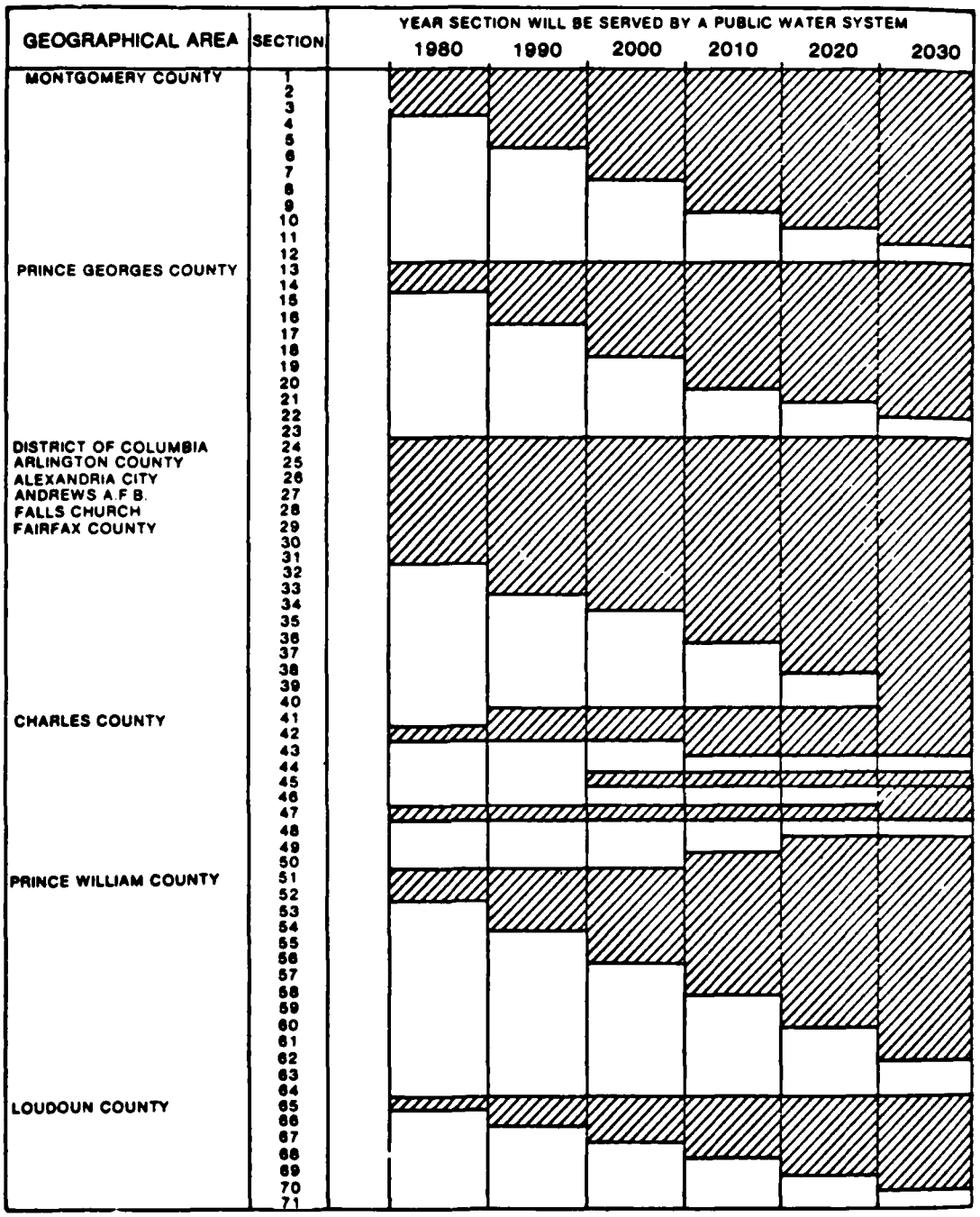


Figure D-31

TIME **PHASING OF MWA SECTIONS**



LEGEND: Section Publicly Served

Figure D-32

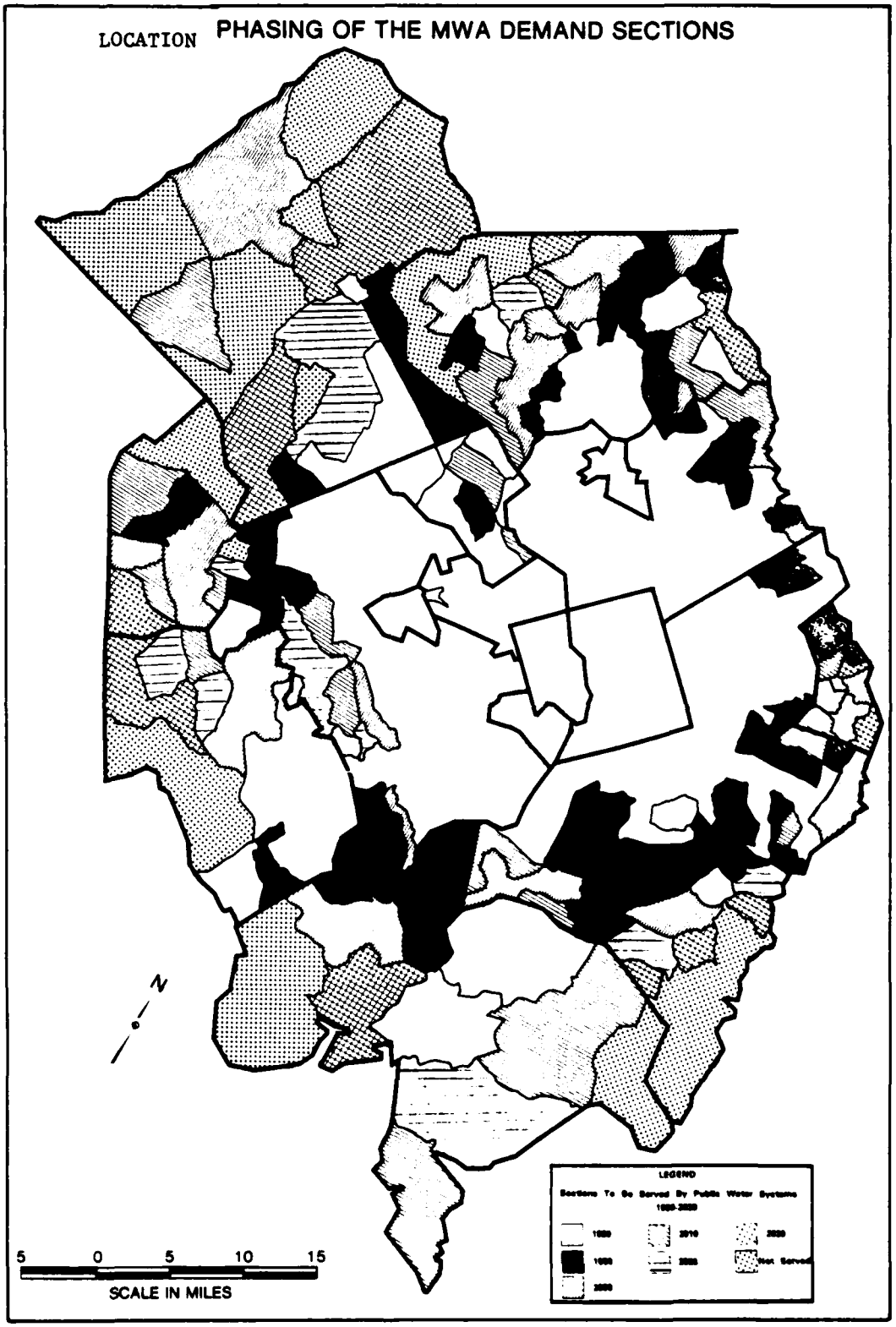

LOCATION
PHASING OF THE MWA DEMAND SECTIONS
N
5 0 5 10 15
SCALE IN MILES
LEGEND

Figure D-33

TABLE D-17

WATER SERVICE AREAS

1. Washington Suburban Sanitary Commission (WSSC)

   Montgomery County
   Prince Georges County

2. Washington Aqueduct Division (WAD)

   District of Columbia
   Arlington County
   City of Falls Church

3. Fairfax County Water Authority (FCWA)

   Fairfax County
   City of Alexandria
   Prince William County (portion)

4. Loudoun County Service Area

   Loudoun County

5. Prince William County Service Area

   Prince William County

6. Charles County Service Area

   Charles County

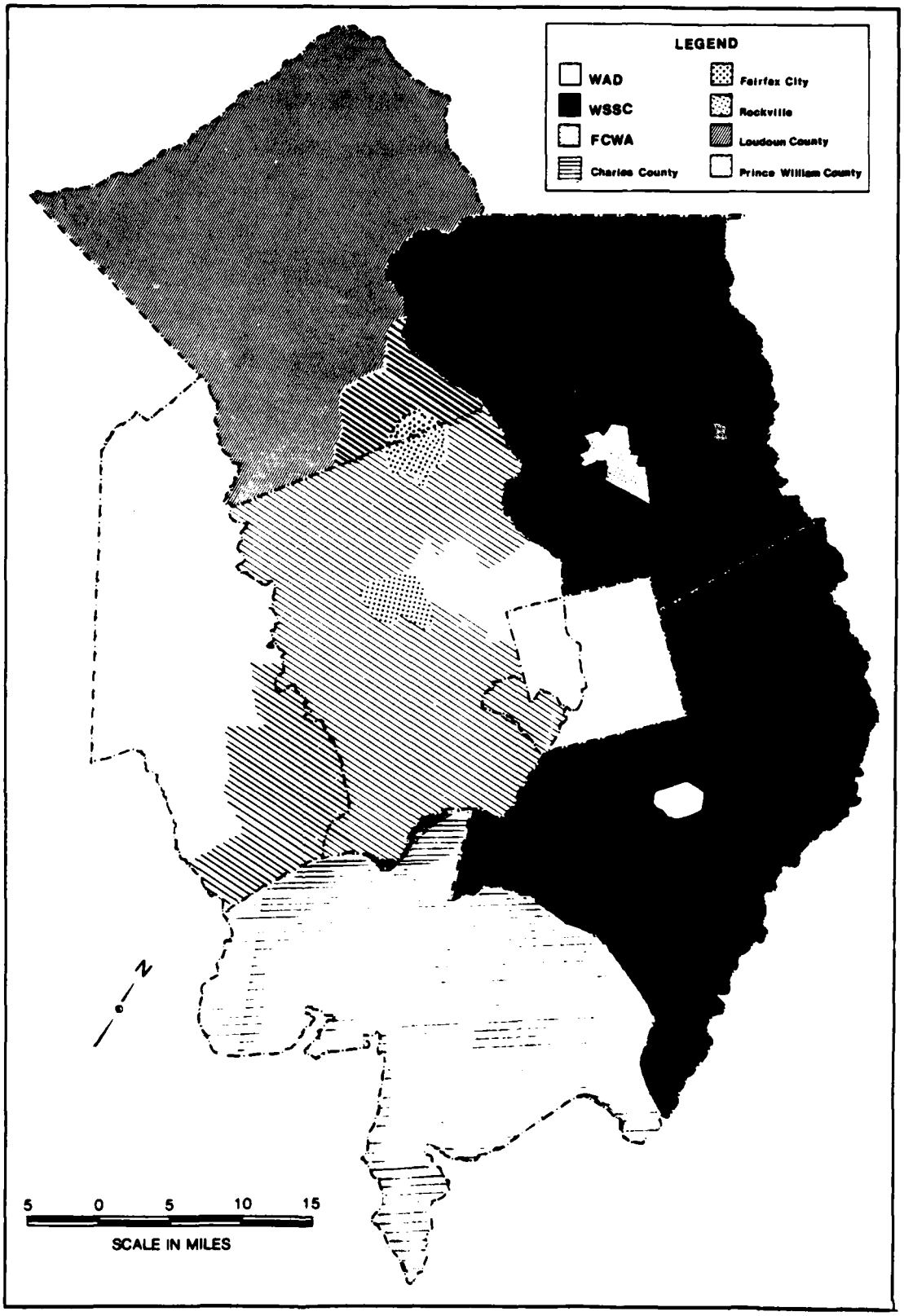
7. Fairfax City Service Area

   City of Fairfax
   Town of Herndon
   Loudoun County Sanitation Authority

8. Rockville City Service Area

   City of Rockville

MWA WATER SERVICE AREAS



D-76

Figure D-34

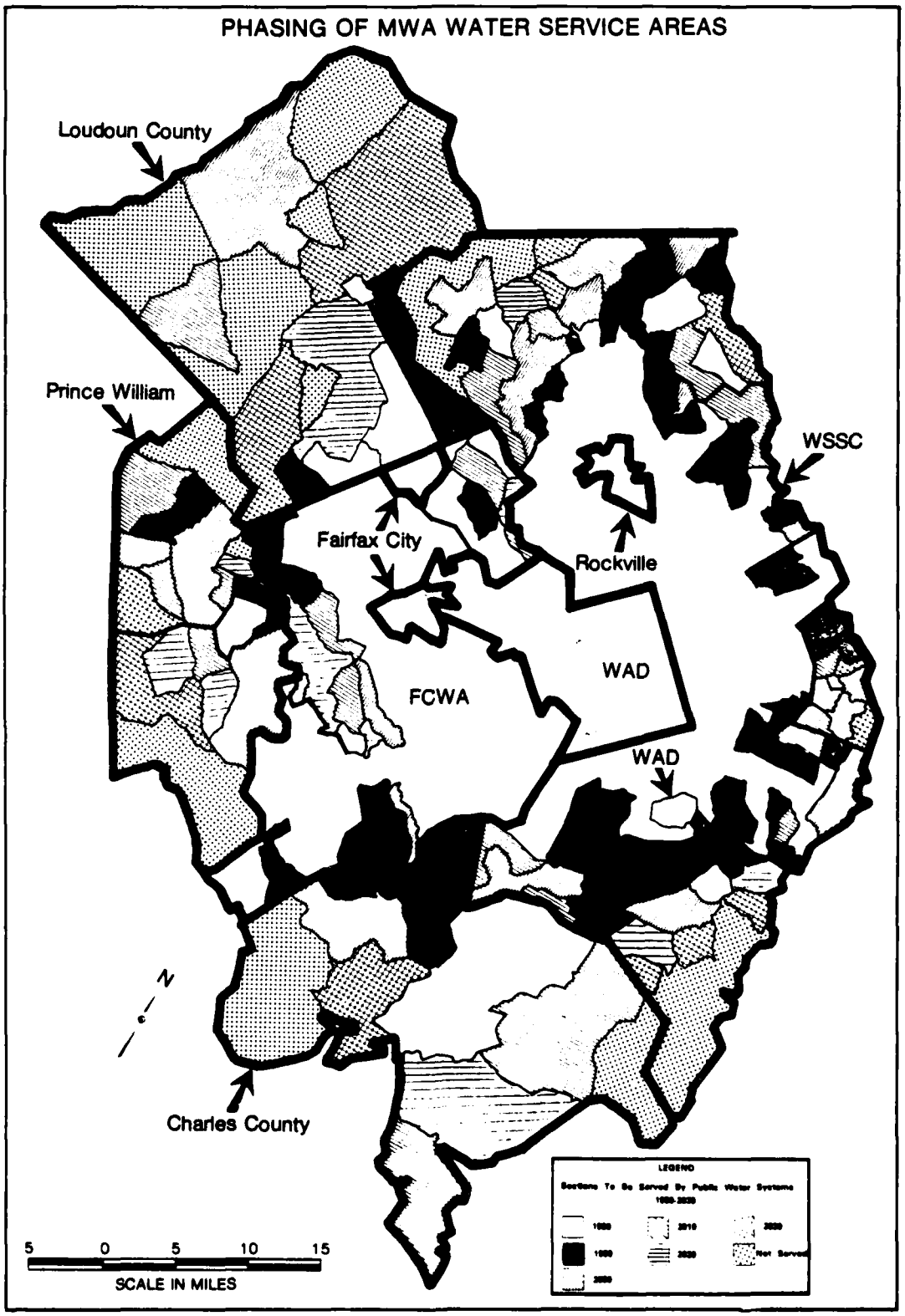

PHASING OF MWA WATER SERVICE AREAS
Loudoun County
Prince William
WSSC
Fairfax City
Rockville
WAD
FCWA
WAD
Charles County
N
5 0 5 10 15
SCALE IN MILES
LEGEND

Figure D-35

The concept of "phasing" sections into the various public water supply systems was an integral part of the overall process of developing water demands, because as each section was added to a public system for each benchmark year, so also was each section's projected population. The "phasing" of the sections resulted, then, in a "phasing" of additional population to be served each benchmark year by the various public systems. This is shown in Table D-18 by an "S" which represents population served or an "NS" indicating that this projected number of persons will not be served by a public system in that particular benchmark year.

EMPLOYMENT AND HOUSEHOLDS PROJECTIONS

Realizing that projections of MWA population are a necessary but insufficient parameter for development of water demand projections, additional socio-economic factors of employment and number of households were also projected to the benchmark year 2030. This task was facilitated, in part, by the availability of these data from the MWCOG for the benchmark years of 1980 and 1990. Beyond 1990, the information used to project these growth indicators was obtained through coordination with the following agencies:

Metropolitan Washington Council of Governments
Maryland Department of State Planning
Maryland-National Capital Park and Planning Commission
District of Columbia Municipal Planning Office
Fairfax County Office of Comprehensive Planning
Fairfax City Planning Department
Falls Church Planning Department
Arlington County Planning Commission
Alexandria City Office of Planning and Community Development
Prince William County Planning Commission
Charles County Planning Commission
Loudoun County Department of Comprehensive Planning
Rockville Planning Department
Manassas Planning Department
Manassas Park Planning Department

Generally speaking, the MWCOG data were used through 1990. The local planning agencies and water utilities were instrumental in providing information to establish the 1976 condition as well as indicating anticipated trends within the context of the planning period. Based on the information received from these many planning agencies, projections of the following factors were made for each of the service areas:

- occupants per single-family dwelling unit
- occupants per multi-family dwelling unit
- single-family to multi-family total dwelling unit ratio
- single-family to multi-family total population ratio
- commercial and industrial combined employment to total employment ratio
- State and local government combined employment to total employment ratio
- Federal Government employment to total employment ratio
- unaccounted for volumes of water

TABLE D-18

MWA SERVICE AREA POPULATION PROJECTIONS

WATER SERVICE AREA	(1)	1980	1990	2000	2010	2020	2030
WASHINGTON SUBURBAN SANITARY COMMISSION	S	1,112,000	1,499,700	1,759,400	2,002,800	2,218,500	2,380,500
	NS	163,000	93,600	75,250	50,500	27,150	15,200
WASHINGTON AQUEDUCT DIVISION	S	1,016,200	1,115,900	1,173,700	1,192,400	1,215,300	1,231,800
FAIRFAX COUNTY WATER AUTHORITY	S	673,800	880,300	1,033,900	1,168,200	1,338,000	1,489,900
	NS	28,200	21,700	22,200	12,700	3,800	0000000
LOUDOUN COUNTY	S	13,600	23,000	38,400	59,700	88,300	125,100
	NS	28,900	31,700	35,400	36,700	34,500	27,600
PRINCE WILLIAM COUNTY	S	55,000	74,600	118,300	151,000	189,400	231,400
	NS	38,300	40,400	22,400	20,600	17,200	9,800
CHARLES COUNTY	S	23,800	44,200	56,000	84,900	100,400	113,200
	NS	38,300	31,800	32,100	14,100	10,500	8,600
FAIRFAX CITY	S	77,500	112,500	136,500	160,800	191,500	221,600
ROCKVILLE CITY	S	48,800	53,300	54,250	55,200	56,150	57,100
TOTAL MWA POPULATION	S	3,020,700	3,803,500	4,370,450	4,875,000	5,397,500	5,850,600
	NS	296,600	219,200	187,350	134,600	93,150	61,200
	(2)	3,318,000	4,025,000	4,558,000	5,010,000	5,491,000	5,913,000

(1) S indicates served by a public system and NS represents population not served by a public system
(2) Total population estimates may not agree due to rounding

Existing data were available on the number of persons per single-family and multi-family dwelling unit. Based on the MWCOG data, a trend existed in almost every service area that indicated the total population to total household ratio was decreasing over time. With this information, and given the total population served in each area, total households served and occupants per single-family and multi-family dwelling unit were projected.

Employment projections were then calculated using the same types of data. Overall employment was projected based upon extrapolation of the given trend and the employment-to-population ratios. In some service areas, employment was projected to grow at a faster rate than population, as determined from the MWCOG data. However, employment was limited by a given employment-to-population ratio. The primary service area where this constraint existed, according to the MWCOG data, was the Washington Aqueduct Division Service Area. In other areas, current employment was projected to grow at a slower rate than population, yet the rate was projected to increase later. This was the case in the outlying counties, and is similar to the prior growth patterns of the inlying areas which were previously sparsely populated but are now developed.

Regional employment breakdown trends were presented by the MWCOG in a report entitled Cooperative Forecasting Summary Report - 1976. In Figure D-36, the trend of the percent share of employment for each employment sector is given. As can be seen, the Federal employment proportion was forecast to drop, and state and local employment proportions were expected to rise. Since the change in the breakdown of employment for each service area was not available, the rate change in sector employment for each water service area was assumed to equal the rate of change associated with regional sector employment. In addition, it was assumed that the ultimate regional Federal share of total employment was 18 percent, and it reached and maintained that level in the year 2000. For the same period, the ultimate regional state and local government employment was assumed to reach and remain at 16 percent. Therefore, the percent change in each sector's employment was calculated for 1980, 1990, and 2000. The percent changes were then applied to the 1976 employment breakdowns, and the results were broken down by sector employment for every benchmark year.

There was, however, one exception to the above methodology. In the case of the WAD Service Area (primarily D.C.) this method forced a decrease in the Federal sector employment. Therefore, the initial percentage breakdown assigned to 2000 was re-assigned to the year 2030, and the values for the years between 1976 and 2030 were calculated as a linear interpolation of the extremes. The resulting employment and housing-related growth factors for each of the eight service areas are given in Annex D-I at the end of Appendix D.

1976 BASE WATER USE

UNIT WATER USE

One additional major parameter was examined prior to the development of water demands. An extensive survey of existing public system water use was undertaken to determine both service area and regional demands. This effort indicated that water use could be disaggregated to six major user categories: single-family residential,

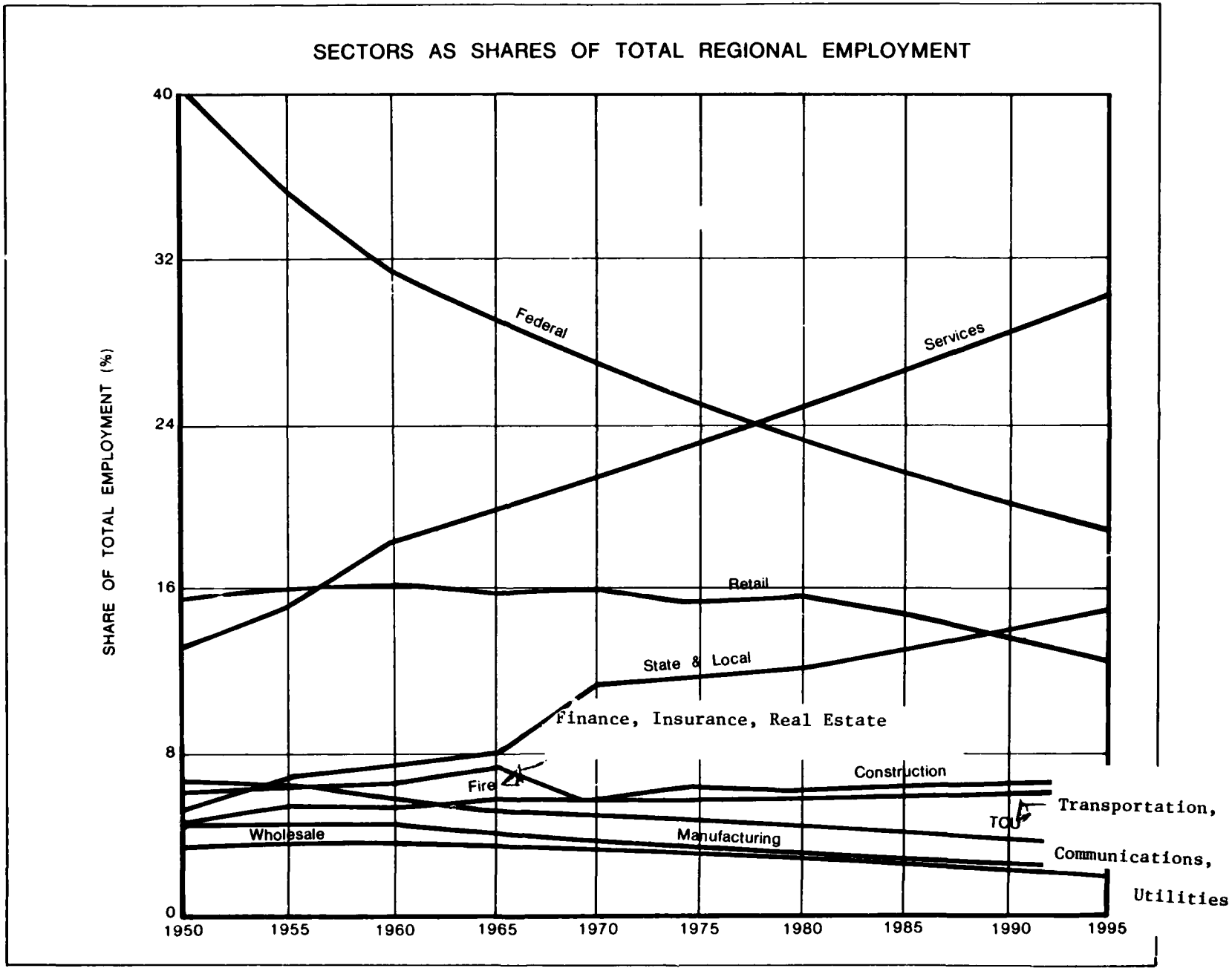

SECTORS AS SHARES OF TOTAL REGIONAL EMPLOYMENT
SHARE OF TOTAL EMPLOYMENT (%)
40
32
24
16
8
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Federal
Services
Retail
State & Local
Finance, Insurance, Real Estate
Construction
Fire
Transportation,
TCU
Communications,
Utilities
Wholesale
Manufacturing

Figure D-36

multi-family residential, commercial/industrial, governmental/ institutional, Federal Government and unaccounted for water use. For each of the first five categories, a unit water use was developed based on the growth factors previously discussed. The user categories and the accounted units or growth factors are presented below:

Category	Units
Single-family Residential	Dwelling Units
Multi-family Residential	Dwelling Units
Commercial/Industrial	Employment
Government/Institutional	Employment
Federal Government	Employment

The year 1976 was selected as the base year for investigating unit water use because it was a fairly typical year (no extreme floods or droughts) and because it was the latest year for which data were available when the examination was initiated.

Using 1976 total water use determined for each category, together with 1976 housing and employment data obtained from local planning agencies and aggregated to the eight service areas, the base year unit water use for each category was computed for all eight service areas. The total number of units (dwelling units and employees), the average annual use, and the resulting unit use for each category are given for each service area in Annex D-II - Service Area Water Demand and Unit Use by Category. A summary of the estimated 1976 water use by category and service area is provided in Table D-19.

As observed in the tables in Annex D-II, water use per dwelling unit in the single-family category is seen to vary from a high of 395.8 gpd in the Loudoun County Water Service Area to a low of 189.8 gpd in the Rockville Water Service Area. In the multi-family category, the Fairfax City Water Service Area has the highest use per dwelling unit, 314.2 gpd, compared to the lowest use, 155.9 gpd, which again is in the Rockville Water Service Area. However, in comparing the water use per dwelling unit, one must also consider the average number of occupants per dwelling unit. For example, in the Rockville Water Service Area there are 1.760 occupants per dwelling unit in multi-family housing compared to 2.316 occupants per multi-family dwelling unit in the Fairfax City Water Service Area. Thus, the multi-family use per person in the Fairfax City Water Service Area is 135.7 gpcpd compared to 88.6 gpcpd in the Rockville Water Service Area. A comparison of residential water use in the MWA is given in Table D-20. It is significant to note that the water use per person in the multi-family housing is consistently higher than in single-family housing. The lack of individual water meters in most multi-family units very likely contributes to a less conscious effort to use water conservatively by residents living in multi-family dwellings. Also, the average occupancy per dwelling unit is generally less in multi-family residences and the household-related water use, therefore, assumes a larger percentage of the total use.

TABLE D-19

METROPOLITAN WASHINGTON AREA WATER USE - 1976

Water Service Area	Water Use by Category (mgd)					Unaccounted For	Bulk Sales	Total
	Single Family	Multi-Family	Comm/ Ind*	Gov/ Inst*	Federal			
WAD	42.5	63.4	16.6	10.9	27.6	34.2	0.0	195.2
WSSC	61.6	38.0	17.9	3.6	5.0	13.0	0.0	139.1
FCWA	28.7	15.3	7.3	3.7	3.8	5.0	0.9 **	64.7
Rockville	1.9	0.6	1.1	0.3	0.0	0.2	0.0	4.1
Fairfax City	3.5	1.2	0.9	0.2	0.0	1.9	0.0	7.7
Pr. William Co.	2.2	0.5	0.8	0.1	2.5	0.8	0.0	6.9
Loudoun Co.	1.1	0.1	0.2	0.0	0.0	0.2	0.0	1.6
Charles Co.	1.0	0.2	0.2	0.1	0.0	0.2	0.0	1.7
TOTAL	142.5	119.3	45.0	18.9	38.9	55.5	0.9	421.0

*Without Federal use component
**Miscellaneous bulk sales within the Service Area.

TABLE D-20

COMPARISON OF RESIDENTIAL UNIT WATER USE IN THE EIGHT MWA WATER SERVICE AREAS

	SINGLE-FAMILY			MULTI-FAMILY		
Demand Area	Total (mgd)	Per Dwelling Unit (gpd)	Per Person (gpcpd)	Total (mgd)	Per Dwelling Unit (gpd)	Per Person (gpcpd)
WAD	42.50	270	88	63.41	263	119
WSSC	61.58	281	81	38.00	281	131
FCWA	28.65	198	58	15.27	207	98
Rockville	1.92	190	52	0.56	156	89
Fairfax City	3.47	279	83	1.20	314	136
Pr. Wm. County	2.22	194	54	0.48	166	76
Loudoun County	1.05	396	108	0.12	262	103
Charles County	0.98	290	83	0.19	241	96

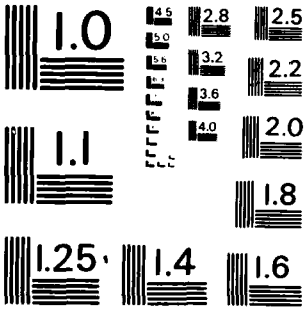
MONTHLY DEMAND DISTRIBUTION FACTORS AND FRACTIONAL SEASONAL WATER USE

To allocate average annual demands to seasonal bases, historical monthly distribution factors and fractional seasonal water use factors for each user category were applied to the water demands. The following paragraphs present the methodology used to compute these values.

Average monthly demand distribution factors were developed to determine average monthly water use patterns for each MWA water service area based on average annual demand values. These factors were calculated individually for FCWA, WAD, and WSSC using daily pumpage and/or plant production records for the period 1968 through 1976. This time frame was chosen because it was the most representative of the MWA's water use trends. Due to the lack of sufficient daily water use records for Charles County, Fairfax City, Loudoun County, Prince William County, and the City of Rockville, separate sets of factors could not be developed.

In order to assign average monthly demand distribution factors to these water service areas, patterns of socio-economic growth, land use, and employment were examined and compared to the three major water service areas. Subsequently, water service areas exhibiting similar development patterns were grouped together for the purpose of assigning average monthly demand distribution factors as shown in Table D-21. It was assumed that all factors would remain relatively constant throughout the planning period.

AD-A134 156 METROPOLITAN WASHINGTON AREA WATER SUPPLY STUDY 2/4
APPENDIX D SUPPLIES DEMANDS AND DEFICITS(U) CORPS OF
ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83
UNCLASSIFIED MWA-83-P-APP-D F/G 5/1 NL



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

The average monthly demand distribution factor is defined as the ratio of the average monthly demand for a particular month to the average annual demand. The number produced by this ratio indicates how the average monthly demand compares to the average annual demand (i.e., whether the average demand for that month is above, below, or equal to the average annual demand). The procedure used to arrive at average monthly demand distribution factors was as follows:

a. The average monthly demand for each month (January-December) for the period 1968 through 1976, was summed and divided by the number of years of record, producing an average monthly value for the period.

b. The average annual demand for each year was then summed over the same period (1968 through 1976) and then divided by the number of years to produce an average annual demand value, representative of the entire period.

c. A ratio of each composite monthly average value to the overall average annual value was then computed, producing 12 ratios called monthly demand distribution factors. A set of monthly distribution factors was generated for each of the three major service areas and assigned to the other service areas shown previously in Table D-21. The factors resulting from this analysis are presented in Table D-22.

TABLE D-21

GROUPING OF WATER SERVICE AREAS FOR
AVERAGE MONTHLY DEMAND DISTRIBUTION FACTORS

1. WSSC

   City of Rockville
   Charles County

2. FCWA

   City of Fairfax
   Loudoun County
   Prince William County

3. WAD

The fractional seasonal water use in a number of user categories is given in Table D-23. Based upon information included in that table, the unadjusted fractional seasonal factors were the following for each of the study's five user categories:

Category	Unadjusted Fractional/Seasonal
Single-family Residential	0.14
Multi-family Residential	0.14*
Commercial/Industrial	0.23
Government/Institutional	0.20
Federal Government	0.20

*Factor developed by weighting all multi-family factors by the number of observations in each class (Ecological Analysts, Inc., 1977).

TABLE D-22

AVERAGE MONTHLY DEMAND DISTRIBUTION FACTORS

	FACTORS BY SERVICE AREA		
MONTH	WSSC Charles Co. Rockville	WAD	FCWA Pr. William Co. Loudoun Co. Fairfax City
Jan	0.907	0.918	0.888
Feb	0.908	0.913	0.888
Mar	0.909	0.891	0.892
Apr	0.954	0.932	0.967
May	1.023	0.974	1.026
Jun	1.109	1.079	1.099
Jul	1.154	1.167	1.176
Aug	1.108	1.154	1.122
Sep	1.108	1.084	1.076
Oct	0.983	0.998	0.982
Nov	0.943	0.949	0.948
Dec	0.925	0.925	0.936

TABLE D-23

SEASONALITY OF WATER USE IN WSSC SERVICE AREA (SEPTEMBER 1973 THROUGH AUGUST 1974)

Customer Classification	Number of Observations	Mean Use (gdc)*	Fraction Seasonal**
All customers, all density zones	424,697	523	0.20
All customers, high density***	133,392	503	0.23
All customers, medium density***	232,121	538	0.19
All customers, low density***	59,184	500	0.15
Single-family residential, all density zones	406,180	274	0.14
Garden apartment residential, all density zones	3,645	11,904	0.15
High-rise apartment residential, all density zones	639	25,124	0.11
Commercial, industrial, all density zones	13,307	2,146	0.23
Government, institutional, all density zones	976	23,203	0.20
Single-family residential, high density	125,933	255	0.12
Single-family residential, medium density	222,568	273	0.15
Single-family residential, low density	57,629	322	0.18

*gdc=gallons per day per connection.
**Fraction seasonal is the excess of average annual use over average winter use, divided by average annual use.
***High density zone: more than 1,900 persons per square mile
Medium density zone: less than 1,900 persons per square mile, but more than 550 persons per square mile
Low density zone: less than 550 persons per square mile.

Source: Ecological Analysts, Inc., Table 3-10, October, 1977.

These unadjusted fractional seasonal factors had to be adjusted in each service area to allow the total water use in any service area to follow its recorded monthly use pattern. The fractional seasonal factors for each user category were adjusted by maintaining the overall fractional seasonal factor as calculated from the monthly average demand distribution factors. This allowed the total water use to follow the determined monthly patterns while spreading the seasonality as it was reported by the Bi-County Water Supply Study among the user categories. For all months, the percent of unaccounted for water use was assumed constant.

One task remained; separating the indoor and outdoor use of water in each category to determine the effect of alternative water conservation plans on total water use. This was done by calculating the average winter use in each category, assuming that it was all indoor use. The winter months, as defined for the purpose of this study, were November, December, January, February, March, and April. The average flow for these months in each user category was subtracted from all the other months by user category to obtain an indoor and outdoor component of use. The assumption that the average winter use represented the indoor use was based on the knowledge that little outdoor water use occurs during the winter. Thus, the above procedure determined the total indoor and outdoor water use by month, user category, and service area for 1976.

MWA WATER DEMAND PROJECTION MODEL

Having the water demand growth indicators, the water use by category for 1976, and the monthly distribution factors, a methodology was developed to project the water demand for the future time horizon. The methodology allowed the imposition of various water conservation scenarios and predicted their effect on future water use (refer to the Water Conservation and Demand Reduction section in Appendix G for a complete description). Because of the tremendous number of calculations that had to be performed, the projection methodology made use of a computer program.

The computer program was used to project water use in each user category at ten-year intervals (herein called time horizons) for each water service area. The program used 1976 water use information and the growth indicators as the basis for its calculations.

The following data were required as input to the program:

- Total use per category by month for both indoor and outdoor use in 1976,
- The water demand growth indicators including 1976 values and those projected until 2030, and
- The effects of any conservation measures (i.e., reduction factors) that were to be evaluated.

The program determined the existing employment or dwelling units in each of the user categories, developed a per unit water use in each user category by dividing the water use by the existing appropriate growth indicator value, calculated the change of the per unit water use within the residential categories due to a change in the number of persons per dwelling unit, and assessed the sum effects of conservation measures in each user category over time.

The main equation used in the methodology is the following:

$$WAT = UNT(I,IT) * (((1. - FACI(I,IT)) * FIND(I,M)) + ((1. - FACO(I,IT)) * OUT(I,M)))$$

Where,

WAT	=	Water use in gallons/day for a particular category, month, time period (i.e., 1980-1990, 1990-2000, etc.), and time horizon,
UNIT (I,IT)	=	units of category 1, brought on line in time period IT,
FACI (I,IT)	=	sum effects of the indoor conservation measures in Category I, on the units brought on line in time period IT,
FACO (I,IT)	=	sum effect of the outdoor conservation measures in Category I, on the units brought on line in time period IT,
FIND (I,M)	=	indoor water use per unit in gallons/day for a particular category, month, and time horizon, and
OUT (I,M)	=	outdoor water use per unit in gallons per day for a particular category, month, and time horizon.

Prior to using the above equation, which determined the use based upon units and unit use, the number of units (i.e., employees or dwelling units) in each category was determined for every time period within a given time horizon. Given the total households, total population, and any two of the following:

- persons per single-family unit,
- persons per multi-family unit
- single-family to multi-family dwelling unit ratio, or
- single-family to multi-family population ratio,

the number of total single-family and multi-family units were calculated for each time horizon. The difference between the new time horizon total and the prior time horizon total was the number brought on line during the intervening time period. The total employment for each employment sector was calculated as the employment fraction for that sector times the total employment.

The program also made an adjustment to unit use which was done in all cases. After the indoor residential unit use (FIND (I,M)) was entered into the model for the first time horizon, it was adjusted over time to reflect the change in the number of persons per single-family unit and multi-family unit at each interval. The adjustment to the indoor water use was based on information obtained from the literature. For example, one study showed that for the 355 households in the sample, the indoor water use varied exponentially with the persons per household (E. K. Gibbs, "Price Variable in Residential Water Demand Models," W.R.R. Vol. 14, No. 1, February 1978). This exponential coefficient for the Metropolitan Washington Area was calculated to be 0.290. Therefore, the adjusted residential indoor water use over time was considered a function of the persons per household in the following manner:

$$FIND\ (I,M)_1 = FIND\ (I,M)_2 * EXP\ ((PERSF - PERSFO) * B1)$$

where,

$FIND\ (I,M)_1$ = indoor unit household use given for a single-family category for a particular month and time horizon,

$FIND\ (I,M)_2$ = input indoor unit household use given for a particular category, month, and time horizon,

PERSF = present number of persons per single-family unit,

PERSFO = prior number of persons per single-family unit,

B1 = regional exponent of variability of water use with the persons per single-family unit, and

EXP = common nomenclature for exponent.

This same program was included for the multi-family dwelling units.

SUMMARY OF MODEL OUTPUT

The results obtained by the demand model are contained in 16 tables for each water service area. These 16 tables contain information on water use for the period 1976 through 2030. Included as Annex D-III to this appendix is a complete set of tables generated for the baseline condition for WAD, WSSC, FCWA, and the Rockville water service areas. The baseline condition represents projected water demands assuming that water reduction is acheived through the implementation of existing plumbing codes. The plumbing codes require low water use fixtures (i.e. toilets at 3.5 gallons/flush, showers at 3.0 gallons per minute (gpm) and faucets at 4.0 gpm) in 100 percent of the new residential and non-residential construction from 1980 through 2030.

The WAD service area tables (Tables D-III-1 through 16) presented in Annex D-III are referred to in the following discussion as examples of the type of data generated by the demand projection model.

The data in Table D-III-1, Water Demand Growth Indicators, is a presentation of the growth indicators by year for each user category and, thus, represents a partial echo of the input data. In this table, the explicit factors used to define growth in each category are given along with the percent of unaccounted for water use, for every time horizon. This table includes the total population served, total households served, total employment served, occupants per single-family dwelling unit, occupants per multi-family dwelling unit, single-family to multi-family dwelling unit ratio, single-family to multi-family population ratio, commercial plus industrial employment ratio, state and local employment to total employment ratio, Federal Government employment to total employment ratio, and the unaccounted for water use in percent.

In Tables D-III-2 through 6, Resulting Water Use for Each Time Horizon by Time Period and User Category, the number of units served, type of unit, and total use are given for every benchmark period. Each table presents the projected growth and water

requirements for one of the five user categories. These results are useful for determining the effectiveness of conservation measures on each user category.

In Tables D-III-7 through 13, Resulting Water Use and Unit Use for Each Time Horizon, the category name, number of units, type of unit, unit use, and total use are printed out. Each table is a separate time horizon and includes all five user types, the unaccounted-for water use, and the total water use. At a glance, one can observe the water use and unit use within each of the categories.

In Table D-III-14, Summary of Water Use in Each Category for Each Time Horizon, the water use is presented for every time horizon for each category, and the unaccounted water use is shown along with the total water use. The results are presented in mgd with the categories displayed horizontally and the time horizons vertically. These results allow one to easily trace the change in the use in each category over time.

In Table D-III-15, Monthly Demands (mgd) by Time Horizon, the monthly demands in mgd are shown for every time horizon. These results enable one to determine the variation of water use within a year for each ten-year interval. In Table D-III-16, Summary of the Overall Water Use by Time Horizon, the total water use, total population, and average daily use divided by the population are given. These results show how the total water use and aggregated use per person changes over time. The results are in mgd on an average annual basis. The remaining tables in Annex D-III provide similar information for WSSC, FCWA, and Rockville.

PEAKING FACTORS

In addition to average monthly service demands, one and seven-day demands were computed as well. This was accomplished by development of one and seven-day peaking factors. The following paragraphs briefly define and describe the development of the one and seven-day peaking factors.

A one-day peaking factor is defined as being the ratio of the maximum one-day demand occurring in a particular month to its monthly average demand. The number produced by this ratio indicates how the maximum one-day demand compares to its monthly average. The procedure used to develop a one-day peaking factor was analogous to the previously outlined procedure for the monthly distribution factors.

a. The maximum one-day demand occuring in each month of the calendar year was summed over the period 1968 through 1976 and divided by the number of years of record to produce a composite maximum one-day average value for each month.

b. A ratio of each composite maximum one-day average value to its corresponding composite monthly average value (developed previously) was then computed.

c. The number generated by this ratio represented the maximum one-day peaking factor associated with each month for a specific water service area.

Similarly, a seven-day peaking factor is defined as being the ratio of the maximum consecutive seven-day demand occurring in a particular month to its monthly average demand. The number produced by this ratio indicates how the maximum consecutive seven-day average demand compares to its monthly average.

The procedure used to develop a seven-day peaking factor was exactly the same as that used in developing a one-day peaking factor. The important difference, however, was that a seven-day moving average analysis was first performed on each set of monthly data to determine the maximum consecutive seven-day average demand.

Table D-24 lists the one and seven-day peaking factors and the water service areas to which they were applied. Also listed are the monthly demand distribution factors as developed in Table D-22.

As indicated previously, these one and seven-day peaking factors were used to compute monthly, one and seven-day service area demands. This was done by multiplying the monthly demand by its peaking factor. For example; to obtain a 7-day monthly (April) demand for WSSC, multiply the April monthly WSSC demand times the WSSC April 7-day peaking factor.

PROJECTED MWA WATER DEMANDS

Tables D-25 through D-30 summarize the projected demands by the benchmark years of 1980, 1990, 2000, 2010, 2020, and 2030, respectively, for each water service area and for the entire region. These demands are based on the projected average annual and monthly values generated by the MWA demand model (see Annex D-III). Seven and one-day demands were computed using the peaking factors listed in Table D-24.

DEVELOPMENT OF SIMULATION DEMANDS

In order to evaluate the water supply alternatives or plans by simulation, as explained elsewhere in the report, it was necessary to identify continuous seven-day duration demands for a given drought period. The summer months of July, August and September 1966 were selected because this period corresponded to a very low period in all of the MWA's streams.

By examination of Tables D-25 through D-30, it can be seen that demands were generated by use of the demand model on a continuous average monthly basis; however, the seven-day demands were not continuous, rather they were maximum seven-day average values for a given month. For this reason it was necessary to generate a continuous seven-day demand simulation schedule. The seven-day simulation analysis period chosen for this study was 13 weeks, beginning June 29, 1966 and continuing through September 27, 1966.

The base data used were 1966 pumping records supplied by the water service authorities. This information was used to determine seven-day peaking factors for each of the 13 weekly intervals. However, 1966 pumping station record data were only available from the WAD and WSSC water service authorities. The WSSC peaking factor was used for the FCWA water service area. This assumption was made since the previous peaking factors for both water service areas were nearly identical for the period 1968 through 1976.

The procedure used to determine these peaking factors was simply to average the daily pumping record data for each interval and divide this value by the average annual 1966 pumping value. Table D-31 indicates the time frame used for each of the 13 time intervals and shows the computed seven day continuous peaking factors.

TABLE D-24

ONE AND SEVEN DAY PEAKING FACTORS*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WSSC (applied to ROCK and CHAR also)												
1-DAY	1.15	1.06	1.08	1.17	1.19	1.24	1.22	1.18	1.16	1.11	1.07	1.08
7-DAY	1.03	1.02	1.02	1.09	1.08	1.15	1.13	1.10	1.10	1.06	1.02	1.03
MONTHLY	0.907	0.908	0.909	0.954	1.023	1.109	1.154	1.108	1.108	0.983	0.943	0.925
FCWA (applied to LOUD, FXCT, and PRWI also)												
1-DAY	1.09	1.07	1.08	1.19	1.15	1.23	1.24	1.20	1.18	1.12	1.09	1.10
7-DAY	1.03	1.02	1.04	1.10	1.07	1.17	1.14	1.12	1.09	1.06	1.04	1.04
MONTHLY	0.888	0.888	0.892	0.967	1.026	1.099	1.176	1.122	1.076	0.982	0.948	0.936
WAD												
1-DAY	1.06	1.06	1.07	1.11	1.11	1.15	1.12	1.12	1.11	1.09	1.07	1.07
7-DAY	1.02	1.03	1.02	1.05	1.05	1.09	1.06	1.05	1.06	1.04	1.03	1.03
MONTHLY	0.918	0.913	0.891	0.932	0.974	1.079	1.167	1.154	1.084	0.998	0.949	0.925

*Abbreviations
- WSSC - Washington Suburban Sanitary Commission
- WAD - Washington Aqueduct Division (Corps of Engineers)
- FCWA - Fairfax County Water Authority
- CHAR - Charles County
- PRWI - Prince William County
- LOUD - Loudoun County
- ROCK - Rockville City
- FXCT - Fairfax City

TABLE D-25

MWA WATER DEMANDS

YEAR 1980. SERVICE AREA AND REGIONAL

(IN MGD)

Duration	WAD	WSSC	FCWA	ROCK	FRNT	FXCT	CHAR	LOUD	REG
"JAN 1-DAY"	191.0	150.0	66.0	4.8	7.3	9.5	2.7	1.9	433.0
"JAN 7-DAY"	184.0	134.0	65.0	4.9	6.8	9.4	2.4	1.8	407.0
"JAN 30-DAY"	180.0	130.0	63.0	4.2	6.6	9.0	2.4	1.7	397.0
"FEB 1-DAY"	190.0	138.0	67.0	4.4	7.1	9.6	2.5	1.8	421.0
"FEB 7-DAY"	185.0	133.0	65.0	4.3	6.7	9.5	2.4	1.8	406.0
"MAR 1-DAY"	187.0	141.0	68.0	4.5	7.1	9.8	2.6	1.9	422.0
"MAR 7-DAY"	179.0	133.0	66.0	4.3	6.9	9.4	2.4	1.8	402.0
"MAR 30-DAY"	175.0	130.0	63.0	4.2	6.6	9.1	2.4	1.7	392.0
"APR 1-DAY"	203.0	160.0	81.0	5.1	8.5	11.7	2.9	2.2	475.0
"APR 7-DAY"	192.0	149.0	75.0	4.8	7.9	10.8	2.7	2.1	445.0
"APR 30-DAY"	183.0	137.0	68.0	4.4	7.2	9.8	2.5	1.9	414.0
"MAY 1-DAY"	212.0	177.0	84.0	5.7	8.8	12.1	3.2	2.3	505.0
"MAY 7-DAY"	201.0	161.0	78.0	5.1	8.2	11.6	2.9	2.2	469.0
"MAY 30-DAY"	191.0	149.0	72.0	4.8	7.6	10.5	2.7	2.0	441.0
"JUN 1-DAY"	243.0	201.0	96.0	6.4	10.1	13.9	3.7	2.7	577.0
"JUN 7-DAY"	230.0	186.0	92.0	6.0	9.6	13.4	3.4	2.5	543.0
"JUN 30-DAY"	211.0	166.0	78.0	5.2	8.4	11.3	3.1	2.2	482.0
"JUL 1-DAY"	256.0	206.0	104.0	6.6	10.9	15.1	3.8	2.9	605.0
"JUL 7-DAY"	242.0	191.0	96.0	6.1	10.0	13.8	3.5	2.7	565.0
"JUL 30-DAY"	228.0	169.0	84.0	5.4	8.8	12.1	3.1	2.3	513.0
"AUG 1-DAY"	243.0	191.0	96.0	6.1	10.0	13.7	3.5	2.7	576.0
"AUG 7-DAY"	237.0	178.0	90.0	5.7	9.4	12.7	3.2	2.5	539.0
"AUG 30-DAY"	226.0	162.0	80.0	5.2	8.4	11.5	2.9	2.2	493.0
"SEP 1-DAY"	256.0	188.0	90.0	6.0	9.4	13.0	3.4	2.5	548.0
"SEP 7-DAY"	225.0	178.0	84.0	5.7	8.7	12.0	3.2	2.3	519.0
"SEP 30-DAY"	212.0	162.0	77.0	5.2	8.0	11.0	3.0	2.1	490.0
"OCT 1-DAY"	213.0	159.0	78.0	5.0	8.2	11.2	2.9	2.2	480.0
"OCT 7-DAY"	204.0	151.0	74.0	4.8	7.7	10.6	2.7	2.0	457.0
"OCT 30-DAY"	196.0	143.0	70.0	4.5	7.3	10.0	2.6	1.9	435.0
"NOV 1-DAY"	199.0	145.0	73.0	4.6	7.7	10.5	2.6	2.0	445.0
"NOV 7-DAY"	192.0	138.0	70.0	4.4	7.3	10.0	2.5	1.9	426.0
"NOV 30-DAY"	186.0	135.0	67.0	4.3	7.0	9.6	2.5	1.8	414.0
"DEC 1-DAY"	194.0	143.0	73.0	4.6	7.6	10.5	2.6	2.0	438.0
"DEC 7-DAY"	187.0	137.0	69.0	4.4	7.2	9.9	2.5	1.9	418.0
"DEC 30-DAY"	182.0	133.0	66.0	4.3	7.0	9.5	2.4	1.8	405.0
" 30-DAY"	237.0	172.0	88.0	5.7	9.2	12.7	3.2	2.4	537.0
" 60-DAY"	231.0	170.0	83.0	5.4	8.8	12.1	3.1	2.3	517.0
" 90-DAY"	225.0	166.0	82.0	5.3	8.6	11.9	3.0	2.3	504.0
" 120-DAY"	221.0	163.0	80.0	5.2	8.4	11.5	3.0	2.2	495.0
" 183-DAY"	212.0	157.0	77.0	5.0	8.1	11.1	2.8	2.1	475.0
" 365-DAY"	196.0	145.0	71.0	4.6	7.4	10.2	2.6	2.0	439.0

NOTES
1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
WAD - WASHINGTON AQUEDUCT DIVISION (CORPS OF ENGINEERS)
FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

FRNT-FREDERICK WINCHESTER COUNTY
LOUD LOUDOUN COUNTY
ROCK-ROCKVILLE CITY
FXCT-FAIRFAX CITY
REG - REGIONAL

TABLE D-26

MWA WATER DEMANDS

YEAR 1990

SERVICE AREA AND REGIONAL

(IN MGD)

Duration	WAD	WSSC	FCWA	ROCK	PRWT	FXCT	CHAR	LOUD	REG.
"JAN 1-DAY"	211.0	181.0	95.0	5.3	8.5	13.1	4.6	2.9	523.0
"JAN 7-DAY"	204.0	171.0	81.0	4.7	8.1	12.4	4.1	2.7	488.0
"JAN 30-DAY"	200.0	166.0	78.0	4.6	7.8	12.0	4.0	2.7	475.0
"FEB 1-DAY"	210.0	177.0	84.0	4.9	8.4	12.9	4.3	2.8	504.0
"FEB 7-DAY"	204.0	170.0	81.0	4.7	8.1	12.3	4.1	2.7	487.0
"MAR 1-DAY"	207.0	180.0	85.0	5.0	8.5	13.0	4.4	2.9	506.0
"MAR 7-DAY"	198.0	170.0	82.0	4.7	8.2	12.5	4.1	2.8	482.0
"MAR 30-DAY"	194.0	167.0	79.0	4.6	7.9	12.1	4.0	2.7	470.0
"APR 1-DAY"	225.0	205.0	101.0	5.7	10.2	15.6	5.0	3.4	571.0
"APR 7-DAY"	213.0	191.0	94.0	5.3	9.4	14.5	4.6	3.2	534.0
"APR 30-DAY"	203.0	175.0	85.0	4.8	8.5	13.1	4.2	2.9	496.0
"MAY 1-DAY"	236.0	229.0	106.0	6.3	10.5	16.6	5.5	3.7	612.0
"MAY 7-DAY"	223.0	207.0	98.0	5.7	9.8	15.1	5.0	3.4	568.0
"MAY 30-DAY"	213.0	192.0	92.0	5.3	9.1	14.1	4.6	3.2	533.0
"JUN 1-DAY"	272.0	260.0	122.0	7.2	12.1	18.8	6.4	4.3	703.0
"JUN 7-DAY"	258.0	242.0	116.0	6.6	11.5	17.8	5.9	4.1	661.0
"JUN 30-DAY"	236.0	210.0	99.0	5.8	9.8	15.2	5.1	3.5	585.0
"JUL 1-DAY"	287.0	268.0	132.0	7.4	13.1	20.5	6.6	4.7	739.0
"JUL 7-DAY"	272.0	248.0	122.0	6.8	12.0	18.8	6.1	4.3	690.0
"JUL 30-DAY"	257.0	219.0	107.0	6.0	10.6	16.5	5.4	3.8	625.0
"AUG 1-DAY"	284.0	248.0	122.0	6.8	12.1	18.7	6.0	4.3	701.0
"AUG 7-DAY"	266.0	231.0	114.0	6.3	11.2	17.5	5.6	4.0	655.0
"AUG 30-DAY"	254.0	210.0	101.0	5.8	10.0	15.6	5.1	3.6	605.0
"SEP 1-DAY"	284.0	243.0	114.0	6.7	11.3	17.6	5.9	4.0	667.0
"SEP 7-DAY"	252.0	231.0	106.0	6.2	10.5	16.2	5.6	3.7	630.0
"SEP 30-DAY"	238.0	210.0	97.0	5.8	9.6	14.9	5.1	3.4	583.0
"OCT 1-DAY"	238.0	204.0	98.0	5.6	9.7	15.0	4.9	3.4	578.0
"OCT 7-DAY"	227.0	195.0	93.0	5.3	9.2	14.2	4.7	3.2	551.0
"OCT 30-DAY"	218.0	184.0	88.0	5.0	8.7	13.4	4.4	3.0	524.0
"NOV 1-DAY"	221.0	185.0	91.0	5.1	9.1	14.0	4.5	3.1	533.0
"NOV 7-DAY"	212.0	176.0	87.0	4.9	8.7	13.3	4.3	3.0	510.0
"NOV 30-DAY"	206.0	173.0	84.0	4.8	8.4	12.8	4.2	2.8	494.0
"DEC 1-DAY"	215.0	183.0	91.0	5.1	9.1	13.9	4.4	3.1	525.0
"DEC 7-DAY"	207.0	175.0	86.0	4.8	8.6	13.2	4.2	2.9	501.0
"DEC 30-DAY"	201.0	170.0	82.0	4.7	8.3	12.7	4.1	2.8	485.0
" 30-DAY"	264.0	230.0	111.0	6.3	11.0	17.0	5.6	3.8	648.0
" 60-DAY"	257.0	219.0	104.0	6.0	10.5	16.2	5.3	3.6	623.0
" 90-DAY"	251.0	213.0	102.0	5.9	10.3	15.9	5.2	3.6	608.0
" 120-DAY"	246.0	209.0	101.0	5.8	10.0	15.5	5.1	3.5	597.0
" 183-DAY"	236.0	202.0	97.0	5.5	9.7	14.9	4.9	3.4	574.0
" 365-DAY"	218.0	187.0	89.0	5.2	8.9	13.7	4.5	3.1	530.0

NOTES

1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
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FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

PRWT-PRINCE WILLIAM COUNTY
LOUD LOUDOUN COUNTY
ROCK-ROCKVILLE CITY
FXCT-FAIRFAX CITY
REG - REGIONAL

TABLE D-27

MWA WATER DEMANDS

YEAR 2000

SERVICE AREA AND REGIONAL

(IN MGD)

Duration	WAD	WSSC	FCWA	ROCK	PRWT	FXCT	CHAR	LOUD	REG
"JAN 1-DAY"	222.0	219.0	97.0	5.0	11.0	15.0	5.7	5.1	[illegible]
"JAN 7-DAY"	214.0	196.0	93.0	5.0	10.9	14.6	5.1	4.4	543.0
"JAN 30-DAY"	210.0	191.0	91.0	4.8	10.2	14.2	5.0	4.3	529.0
"FEB 1-DAY"	221.0	202.0	97.0	5.1	11.0	15.2	5.3	4.6	563.0
"FEB 7-DAY"	215.0	195.0	93.0	4.9	10.9	14.5	5.1	4.4	543.0
"MAR 1-DAY"	218.0	207.0	99.0	5.2	11.1	15.2	5.4	4.6	564.0
"MAR 7-DAY"	208.0	195.0	95.0	4.9	10.7	14.8	5.1	4.5	537.0
"MAR 30-DAY"	204.0	191.0	91.0	4.8	10.3	14.2	5.0	4.2	525.0
"APR 1-DAY"	226.0	225.0	116.0	5.9	13.3	18.9	6.1	5.5	633.0
"APR 7-DAY"	224.0	219.0	109.0	5.5	12.3	17.0	5.7	5.1	596.0
"APR 30-DAY"	213.0	201.0	99.0	5.1	11.6	15.[illegible]	5.2	4.7	554.0
"MAY 1-DAY"	248.0	263.0	123.0	6.6	13.7	19.2	6.9	6.0	697.0
"MAY 7-DAY"	235.0	239.0	115.0	6.0	12.9	17.7	6.2	5.5	637.0
"MAY 30-DAY"	224.0	221.0	107.0	5.6	12.0	16.7	5.9	5.2	597.0
"JUN 1-DAY"	287.0	301.0	142.0	7.5	15.9	22.3	7.9	6.2	791.0
"JUN 7-DAY"	272.0	279.0	135.0	7.0	15.1	21.2	7.3	6.6	744.0
"JUN 30-DAY"	249.0	243.0	116.0	6.0	12.9	18.1	6.4	5.6	657.0
"JUL 1-DAY"	303.0	310.0	155.0	7.7	17.3	24.4	8.2	7.6	823.0
"JUL 7-DAY"	287.0	287.0	143.0	7.1	15.9	22.4	7.6	7.0	776.0
"JUL 30-DAY"	271.0	254.0	125.0	6.3	14.0	19.[illegible]	6.7	6.1	702.0
"AUG 1-DAY"	300.0	286.0	142.0	7.1	15.9	22.[illegible]	7.5	7.0	788.0
"AUG 7-DAY"	281.0	267.0	133.0	6.6	14.6	20.6	7.0	6.5	736.0
"AUG 30-DAY"	267.0	243.0	119.0	6.0	13.3	18.6	6.4	5.8	679.0
"SEP 1-DAY"	278.0	281.0	133.0	7.0	14.9	20.9	7.4	6.5	748.0
"SEP 7-DAY"	265.0	267.0	123.0	6.6	13.8	19.[illegible]	7.0	6.0	708.0
"SEP 30-DAY"	250.0	242.0	113.0	6.0	12.6	17.7	6.4	5.5	654.0
"OCT 1-DAY"	250.0	235.0	114.0	5.9	12.7	17.7	6.1	5.5	647.0
"OCT 7-DAY"	232.0	224.0	108.0	5.6	12.0	16.6	5.8	5.2	616.0
"OCT 30-DAY"	230.0	211.0	102.0	5.3	11.4	15.6	5.5	4.9	586.0
"NOV 1-DAY"	232.0	212.0	106.0	5.4	11.9	16.5	5.5	5.0	594.0
"NOV 7-DAY"	223.0	202.0	101.0	5.1	11.4	15.6	5.3	4.7	569.0
"NOV 30-DAY"	217.0	196.0	97.0	5.0	10.9	15.2	5.2	4.6	553.0
"DEC 1-DAY"	226.0	210.0	105.0	5.3	11.9	16.5	5.5	5.0	585.0
"DEC 7-DAY"	218.0	200.0	99.0	5.1	11.2	15.6	5.2	4.7	559.0
"DEC 30-DAY"	211.0	195.0	96.0	5.0	10.8	15.0	5.1	4.5	542.0
" 30-DAY"	278.0	265.0	129.0	6.6	14.4	20.1	6.9	6.2	726.0
" 60-DAY"	271.0	252.0	121.0	6.3	13.8	19.2	6.6	5.9	697.0
" 90-DAY"	264.0	245.0	120.0	6.1	13.5	18.8	6.4	5.8	681.0
" 120-DAY"	259.0	241.0	117.0	6.0	13.2	18.4	6.3	5.6	667.0
" 183-DAY"	248.0	232.0	113.0	5.8	12.7	17.7	6.1	5.4	641.0
" 365-DAY"	230.0	215.0	104.0	5.4	11.7	16.2	5.6	5.0	593.0

NOTES
1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
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FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

PRWT-PRINCE WILLIAM COUNTY
LOUD LOUDOUN COUNTY
ROCK-ROCKVILLE CITY
FXCT-FAIRFAX CITY
REG - REGIONAL

TABLE D-28

MWA WATER DEMANDS

YEAR 2010

SERVICE AREA AND REGIONAL

(IN MGD)

DURATION	WAD	WSSC	FCWA	ROCK	PRWI	FXCT	CHAR	LOUD	REG.
"JAN 1-DAY"	227.1	246.0	111.0	5.7	13.5	18.1	8.5	7.1	633.0
"JAN 7-DAY"	219.1	220.0	105.0	5.1	12.7	17.1	7.5	6.7	594.0
"JAN 30-DAY"	214.1	214.0	102.0	5.0	12.3	16.6	7.3	6.5	573.0
"FEB 1-DAY"	226.1	227.0	109.0	5.3	13.2	17.7	7.8	7.1	613.0
"FEB 7-DAY"	220.1	219.1	105.0	5.1	12.6	16.9	7.5	6.7	593.0
"MAR 1-DAY"	222.1	232.0	111.0	5.4	13.4	18.0	7.9	7.1	617.0
"MAR 7-DAY"	213.1	219.1	107.0	5.1	12.5	17.3	7.5	6.8	588.0
"MAR 30-DAY"	208.1	215.0	103.0	5.0	12.4	16.6	7.3	6.5	573.0
"APR 1-DAY"	242.1	263.1	132.0	6.1	16.0	21.5	9.0	8.5	693.0
"APR 7-DAY"	229.1	245.1	123.0	5.7	14.8	19.8	8.4	7.8	653.0
"APR 30-DAY"	218.1	225.0	111.0	5.6	13.4	18.0	7.7	7.1	605.0
"MAY 1-DAY"	254.1	287.0	133.0	6.8	16.6	22.5	10.1	9.6	755.0
"MAY 7-DAY"	240.1	269.0	130.0	6.3	15.9	21.0	9.2	8.5	700.0
"MAY 30-DAY"	229.1	250.0	121.0	5.7	14.5	19.5	8.5	[illegible]	656.0
"JUN 1-DAY"	294.1	340.0	161.0	7.9	19.3	26.2	11.7	10.7	871.0
"JUN 7-DAY"	273.0	316.0	153.0	7.2	18.4	24.9	10.9	10.1	820.0
"JUN 30-DAY"	255.1	275.0	131.0	6.3	15.7	21.3	9.3	8.7	722.0
"JUL 1-DAY"	311.0	351.0	175.0	8.0	21.1	28.7	12.1	11.6	913.0
"JUL 7-DAY"	294.1	325.0	162.0	7.4	19.5	26.4	11.2	10.6	855.0
"JUL 30-DAY"	277.1	287.0	142.0	6.9	17.1	23.1	9.9	9.3	773.0
"AUG 1-DAY"	307.1	324.0	161.0	7.4	19.6	26.2	11.1	10.7	867.0
"AUG 7-DAY"	288.1	303.0	150.0	6.9	18.1	24.5	10.4	10.1	810.0
"AUG 30-DAY"	274.1	274.0	134.0	6.3	16.1	21.6	9.4	8.9	745.0
"SEP 1-DAY"	325.0	318.0	151.0	7.2	18.1	24.5	11.0	10.6	833.0
"SEP 7-DAY"	272.1	301.0	140.0	6.5	16.7	22.6	10.4	9.1	773.0
"SEP 30-DAY"	257.1	274.0	133.0	6.2	15.3	20.7	9.4	8.5	713.0
"OCT 1-DAY"	256.1	264.0	129.0	6.1	15.3	20.7	9.0	8.5	702.0
"OCT 7-DAY"	244.1	252.0	122.0	5.6	14.5	19.6	8.6	8.1	675.0
"OCT 30-DAY"	235.0	238.0	115.0	5.5	13.7	18.5	8.1	7.5	641.0
"NOV 1-DAY"	237.0	238.0	119.0	5.5	14.4	19.3	8.2	7.6	649.0
"NOV 7-DAY"	235.0	237.0	113.0	5.3	13.7	18.4	7.8	7.3	631.0
"NOV 30-DAY"	232.1	233.0	109.0	5.2	13.2	17.7	7.6	7.0	614.0
"DEC 1-DAY"	231.0	236.0	118.0	5.5	14.3	19.2	8.1	7.6	640.0
"DEC 7-DAY"	232.0	225.0	112.0	5.2	13.5	18.2	7.7	7.2	611.0
"DEC 30-DAY"	216.0	218.0	108.0	5.1	13.0	17.5	7.5	6.9	592.0
" 30-DAY"	284.0	298.1	145.1	6.9	17.5	23.6	10.2	9.5	794.0
" 60-DAY"	277.0	288.0	137.0	6.5	16.5	22.4	9.7	9.0	764.0
" 90-DAY"	270.0	276.0	136.0	6.4	16.3	22.0	9.5	8.9	746.0
" 180-DAY"	266.0	271.0	133.0	6.3	15.9	21.5	9.3	8.6	731.0
" 183-DAY"	254.0	262.0	128.0	6.0	15.4	20.7	9.0	8.3	702.0
" 365-DAY"	235.0	242.0	117.0	5.6	14.1	19.0	8.3	7.7	649.0

NOTES
1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
WAD - WASHINGTON AQUEDUCT DIVISION (CORPS OF ENGINEERS)
FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

PRWI-PRINCE WILLIAM COUNTY
LOUD LOUDOUN COUNTY
ROCK-ROCKVILLE CITY
FXCT-FAIRFAX CITY
REG- REGIONAL

TABLE D-29

MWA WATER DEMANDS

YEAR 2020 SERVICE AREA AND REGIONAL

(IN MGD)

DURATION	WAD	WSSC	FCWA	[illegible]	PRWI	FXCT	CHAR	LOUD	REG.
"JAN 1-DAY"	233.0	271.0	122.0	5.2	16.4	21.3	9.3	[illegible]	653.0
"JAN 7-DAY"	225.0	262.0	121.0	5.2	15.4	20.1	8.8	9.7	647.0
"JAN 30-DAY"	220.0	255.0	117.0	5.1	14.4	19.6	8.6	9.6	629.0
"FEB 1-DAY"	232.0	250.0	125.0	5.4	16.0	21.0	9.1	10.3	669.0
"FEB 7-DAY"	226.0	249.0	121.0	5.2	15.2	19.9	8.7	9.9	645.0
"MAR 1-DAY"	229.0	255.0	127.0	5.5	16.2	21.2	9.3	10.5	673.0
"MAR 7-DAY"	218.0	241.0	122.0	5.2	15.2	20.4	8.7	10.1	641.0
"MAR 30-DAY"	214.0	236.0	118.0	5.1	15.0	19.6	8.6	9.7	625.0
"APR 1-DAY"	248.0	290.0	152.0	6.3	16.3	25.3	10.5	12.5	763.0
"APR 7-DAY"	235.0	270.0	140.0	5.8	17.9	23.4	9.8	11.5	713.0
"APR 30-DAY"	224.0	247.0	127.0	5.4	15.2	21.3	9.0	10.7	661.0
"MAY 1-DAY"	261.0	323.0	160.0	7.0	20.2	26.7	11.9	13.6	828.0
"MAY 7-DAY"	247.0	297.0	149.0	6.2	18.5	24.3	10.8	12.6	767.0
"MAY 30-DAY"	235.0	275.0	139.0	5.9	17.5	23.2	10.0	11.8	719.0
"JUN 1-DAY"	302.0	377.0	186.0	8.0	22.9	31.1	13.8	15.9	957.0
"JUN 7-DAY"	286.0	349.0	177.0	7.4	22.4	29.6	12.8	15.1	900.0
"JUN 30-DAY"	263.0	304.0	151.0	6.4	19.1	25.3	11.1	12.9	792.0
"JUL 1-DAY"	320.0	388.0	203.0	8.2	25.2	34.2	14.3	17.5	1011.0
"JUL 7-DAY"	303.0	[illegible]	187.0	7.6	23.7	[illegible]	13.2	16.1	941.0
"JUL 30-DAY"	286.0	318.0	164.0	6.7	20.8	27.5	11.7	14.1	849.0
"AUG 1-DAY"	316.0	358.0	186.0	7.6	23.5	[illegible]	13.1	15.8	951.0
"AUG 7-DAY"	296.0	334.0	173.0	7.0	22.1	29.1	12.2	14.9	889.0
"AUG 30-DAY"	268.0	303.0	155.0	6.3	19.6	25.0	11.1	13.2	818.0
"SEP 1-DAY"	293.0	358.0	174.0	7.3	23.0	28.1	12.5	14.3	905.0
"SEP 7-DAY"	280.0	336.0	161.0	7.0	20.3	26.4	12.2	13.7	854.0
"SEP 30-DAY"	264.0	303.0	147.0	6.5	18.6	24.6	11.1	12.6	793.0
"OCT 1-DAY"	268.0	291.0	146.0	6.2	18.6	25.5	10.5	12.5	775.0
"OCT 7-DAY"	251.0	278.0	140.0	5.9	17.6	23.2	10.0	11.8	733.0
"OCT 30-DAY"	242.0	263.0	133.0	5.6	16.6	21.4	9.5	11.1	701.0
"NOV 1-DAY"	244.0	263.0	136.0	5.7	17.4	22.3	9.5	[illegible]	703.0
"NOV 7-DAY"	234.0	250.0	130.0	5.4	16.6	21.7	9.1	10.7	678.0
"NOV 30-DAY"	223.0	245.0	127.0	5.3	15.9	20.9	8.9	10.3	659.0
"DEC 1-DAY"	232.0	259.0	136.0	5.6	17.3	22.7	9.4	11.2	693.0
"DEC 7-DAY"	229.0	247.0	129.0	5.3	16.3	21.4	9.0	10.6	667.0
"DEC 30-DAY"	223.0	240.0	123.0	5.2	15.7	20.6	8.7	10.2	646.0
" 30-DAY"	292.0	329.0	157.0	7.0	21.2	27.9	12.0	14.0	820.0
" 60-DAY"	285.0	313.0	158.0	6.7	20.1	26.6	11.4	13.4	836.0
" 90-DAY"	278.0	305.0	156.0	6.3	19.8	25.1	11.1	13.1	816.0
" 120-DAY"	273.0	299.0	152.0	6.4	19.3	25.2	10.9	12.8	800.0
" 183-DAY"	261.0	282.0	147.0	6.2	18.6	24.6	10.5	12.3	769.0
" 365-DAY"	242.0	267.0	135.0	5.7	17.1	22.5	9.7	11.3	710.0

NOTES:
1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
WAD - WASHINGTON AQUEDUCT DIVISION (CORPS OF ENGINEERS)
FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

PRWI-PRINCE WILLIAM COUNTY
LOUD LOUDOUN COUNTY
FXCT-FAIRFAX CITY
REG-REGIONAL

TABLE D-30

MWA WATER DEMANDS

YEAR 2030

SERVICE AREA AND REGIONAL

(IN MGD)

DURATION	WAD	WSSC	FCWA	ROCK	PRWI	FXCT	CHAR	LOUD	REG.
"JAN 1-DAY"	239.0	291.0	142.0	5.0	18.0	24.0	11.0	15.	745.0
"JAN 7-DAY"	230.0	280.0	135.0	5.2	18.0	23.2	9.5	14.	696.0
"JAN 30-DAY"	225.0	253.0	131.0	5.2	17.8	22.7	9.5	13.7	678.0
"FEB 1-DAY"	237.0	288.0	140.0	5.5	18.1	24.2	10.2	15.	719.0
"FEB 7-DAY"	231.0	258.0	133.0	5.3	18.2	23.1	9.8	14.	694.0
"MAR 1-DAY"	234.0	274.0	142.0	5.6	19.3	24.6	10.7	14.	724.0
"MAR 7-DAY"	223.0	258.0	136.0	5.3	18.6	23.7	9.8	14.	690.0
"MAR 30-DAY"	219.0	253.0	131.0	5.2	17.8	22.8	9.8	13.	673.0
"APR 1-DAY"	254.0	311.0	159.0	6.4	23.1	29.4	11.8	17.8	822.0
"APR 7-DAY"	240.0	290.0	156.0	6.0	21.3	27.1	11.0	16.	766.0
"APR 30-DAY"	229.0	266.0	152.0	5.5	19.4	24.7	10.1	14.	711.0
"MAY 1-DAY"	267.0	353.0	179.0	7.1	24.2	31.1	12.2	19.	835.0
"MAY 7-DAY"	253.0	320.0	167.0	6.4	22.4	28.8	12.1	16.	788.0
"MAY 30-DAY"	241.0	297.0	155.0	6.0	21.0	27.1	11.6	15.	775.0
"JUN 1-DAY"	303.0	406.0	209.0	8.1	28.3	36.1	15.5	22.	1039.0
"JUN 7-DAY"	293.0	377.0	193.0	7.5	26.2	34.7	14.3	21.	977.0
"JUN 30-DAY"	269.0	328.0	170.0	6.5	23.0	29.5	12.5	19.	856.0
"JUL 1-DAY"	326.0	419.0	222.0	8.3	31.1	38.8	16.0	23.	1054.0
"JUL 7-DAY"	310.0	388.0	210.0	7.7	28.5	37.5	14.4	23.	1019.0
"JUL 30-DAY"	289.0	344.0	184.0	6.9	25.1	32.3	13.1	20.	913.0
"AUG 1-DAY"	324.0	365.0	222.0	7.7	28.3	38.3	14.7	22.	1039.0
"AUG 7-DAY"	302.0	360.0	195.0	7.2	26.4	33.9	13.7	21.	951.0
"AUG 30-DAY"	289.0	337.0	174.0	6.9	23.6	30.3	12.8	19.	833.0
"SEP 1-DAY"	300.0	379.0	195.0	7.6	26.4	37.6	14.4	21.	872.0
"SEP 7-DAY"	287.0	360.0	190.0	7.2	24.4	31.8	13.7	19.	833.0
"SEP 30-DAY"	270.0	327.0	165.0	6.5	22.4	29.7	12.9	18.	751.0
"OCT 1-DAY"	270.0	314.0	165.0	6.3	22.3	28.5	11.8	17.	735.0
"OCT 7-DAY"	257.0	299.0	157.0	6.0	21.0	27.0	11.6	16.	735.0
"OCT 30-DAY"	247.0	282.0	148.0	5.7	19.6	25.4	10.8	15.	755.0
"NOV 1-DAY"	249.0	261.0	153.0	5.8	20.1	26.4	10.7	16.	762.0
"NOV 7-DAY"	241.0	268.0	145.0	5.5	19.0	25.0	10.5	15.	739.0
"NOV 30-DAY"	233.0	253.0	140.0	5.4	18.1	23.6	10.0	14.	703.0
"DEC 1-DAY"	243.0	273.0	151.0	5.7	20.7	26.2	10.6	15.	753.0
"DEC 7-DAY"	234.0	256.0	143.0	5.5	19.5	24.0	10.1	15.	717.0
"DEC 30-DAY"	227.0	238.0	138.0	5.3	18.2	23.3	9.8	14.	695.0
" 30-DAY"	299.0	354.0	187.0	7.2	25.4	32.4	13.4	20.	939.0
" 60-DAY"	272.0	337.0	178.0	6.8	24.6	30.2	12.8	19.	900.0
" 90-DAY"	264.0	328.0	175.0	6.5	23.3	30.4	12.4	19.	879.0
" 120-DAY"	279.0	322.0	170.0	6.5	23.2	29.6	12.2	18.	862.0
" 183-DAY"	267.0	311.0	164.0	6.3	22.3	28.5	11.8	17.	829.0
" 365-DAY"	247.0	288.0	151.0	5.8	20.5	26.2	10.9	16.	765.0

NOTES

1.) WSSC- WASHINGTON SUBURBAN SANITARY COMMISSION
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FCWA- FAIRFAX COUNTY WATER AUTHORITY
CHAR- CHARLES COUNTY

PRWI-PRINCE WILLIAM COUNTY
LOUD LOUDOUN COUNTY
ROCK-ROCKVILLE CITY
FXCT-FAIRFAX CITY
REG - REGIONAL

TABLE D-31

TIME FRAME AND PEAKING
FOR 7-DAY CONTINUOUS DEMANDS

Time Schedule	7 Day Peaking Factor	
	WAD	WSSC & FCWA & ROCKVILLE
June 29-5	1.31	1.49
July 6-12	1.28	1.31
July 13-19	1.32	1.37
July 20-26	1.36	1.55
July 27-2	1.31	1.32
August 3-9	1.23	1.30
August 10-16	1.16	1.08
August 17-23	1.27	1.24
August 24-30	1.30	1.39
August 31-6	1.29	1.44
September 7-13	1.17	1.27
September 14-20	0.96	0.98
September 21-27	0.93	0.93

Next, these peaking factors were applied to the water service area average annual (365-day duration) demands for the benchmark year 2030. Table D-32 shows the resulting projected continuous seven-day simulation demands together with the 30 day duration simulation data for the WAD, WSSC, FCWA, and Rockville water service areas.

It should be noted here that Table D-32 was computed based on Conservation Scenario 3 demands and not baseline demands. The decision to evaluate plans assuming Conservation Scenario 3 was a direct result of feedback received from all interested parties at a Federal - Interstate - State - Regional Advisory Committee (FISRAC) meeting. (For more information on this decision, refer to Appendix B - Plan Formulation, Assessment, and Evaluation.) As previously stated, effects of conservation legislation was incorporated in the baseline demands, however, Water Conservation Scenario 3 was designed to further reduce water use in the residential sectors. A detailed presentation of Conservation Scenario 3 demands is contained in Appendix G - Non-Structural Studies. The demands generated by this "simulation" method were combined with the supply data for the same "simulation" period (see earlier section on Simulation Supply Base) to test alternative plans for performance during an historical drought. This procedure is more fully explained in Appendix B.

TABLE D-32

SIMULATION SCENARIO 3 DEMANDS - YEAR 2030

7-Day
(all values in mgd)

Time Schedule	WAD	Rockville	WSSC	FCWA
June 29-5	287	8	381	200
July 6-12	280	7	335	175
July 13-19	289	7	351	184
July 20-26	298	8	397	208
July 27-2	287	7	338	177
August 3-9	269	7	333	174
August 10-16	254	6	276	145
August 17-23	278	6	317	166
August 24-30	285	7	356	186
August 31-6	283	7	369	193
September 7-13	256	7	325	170
September 14-20	210	5	251	131
September 21-27	204	5	238	125

30-Day
(all values in mgd)

Month				
January	199	5	226	116
February	198	5	226	116
March	194	5	226	117
April	203	5	237	127
May	213	5	264	138
June	238	6	290	150
July	259	6	304	163
August	256	6	290	154
September	239	6	290	148
October	219	5	292	131
November	206	5	235	124
December	201	5	230	123

DEVELOPMENT OF DEFICITS - EARLY-ACTION PHASE

The purpose of this section is to present the MWA's water deficits which were computed using the supply and demand data developed in the two previous sections. The development of these deficits played a critical role in the study because these deficits provided the basis for the formulation and design of water supply plans formulated during the early-action phase of the study. The deficits, as redefined for the long-range phase, are discussed in a later section.

In developing these deficits for the early-action phase, certain basic assumptions were made to isolate or target the level of deficit according to duration and frequency as well as to certain geographic areas. With respect to duration, both 30 and 7-day averages for supply and demand were used in the development of deficits. These durations represented an acceptable level for the design of plans from a technical viewpoint as well as from the inputs received from the public. For these same reasons, a once-in-one hundred year frequency for supply was also chosen. Furthermore, shortages were calculated for two levels of demand: one level was the Baseline demand projection presented in a previous section and also a second level called the Conservation Scenario 3 demand projection fully described in Appendix G - Non-Structural Studies. Conservation Scenario 3 was selected from a series of five water conservation programs developed during the early-action phase. It represented a consensus of the MWA's water purveyors as to a reasonable assumption regarding the long-term effects of water conservation. In the tables and figures which follow in this section, calculations show the effects of using either the Baseline or Conservation Scenario 3 demands.

For the purposes of analysis, water supply deficits were also calculated at both the regional level and at the individual service area level for FCWA, WSSC, WAD, and Rockville. These service areas rely heavily (in the case of WAD and Rockville, entirely) on flows in the Potomac River and account for the largest users of water in the MWA. Examination of the smaller water utilities is documented in Appendix I - Outlying Service Areas.

POTOMAC LOW FLOW ALLOCATION AGREEMENT

One factor which merits a detailed discussion at this point regarding deficit calculations is the use of the Potomac Low Flow Allocation Agreement (LFAA) in allocating the available sources of water supply to the four Potomac-dependent water service areas during periods of low flow in the Potomac River.

The purpose of the Potomac LFAA is to provide a means to equitably allocate Potomac River water among its users during low flow situations so that no one area suffers disproportionate shortages. The Potomac LFAA was signed on 11 January 1978 by the following parties: the Secretary of the Army through the Chief of Engineers; the State of Maryland; the Commonwealth of Virginia; the Washington Suburban Sanitary Commission; the Fairfax County Water Authority; and the District of Columbia. A copy of the Potomac LFAA is provided as Annex D-IV. (As discussed elsewhere in the report, the signatories are presently negotiating certain modifications to the basic Potomac LFAA. For the purposes of this section on deficit calculation for the early-action phase, however, the original version of the agreement was the operable document in effect at

the time deficits were being calculated. Hence, the remainder of this section discusses the deficits as computed by applying the terms of the 11 January 1978 Potomac LFAA.)

The allocation procedure is based upon a rolling average of winter demands (December, January and February) for five consecutive winter periods immediately preceding a supply allocation period. The allocation of supply is described in the Agreement as follows:

> "The amounts pumped during the 5 most recent winter periods which have elasped as of the time of allocation, or less than 5 if fewer have so elapsed, shall be combined for the purpose of computing each user's average daily winter use, except that, in the case of a user becoming subject to this Agreement subsequent to its initial execution, the average daily winter use of such user shall be the average of the amounts of water pumped during all of the winter periods, commencing December 1 of the year immediately prior to its first withdrawal from the subject portion of the river, which have elapsed as of the time of allocation, but not exceeding the 5 most recent winter periods. The ratio which the average daily winter use of each user bears to the average daily winter use of all users will be applied to the daily amount of water available at the time of allocation from the subject portion of the Potomac River (after deduction for environmental flow-by) and all other sources as specified in Paragraph 5 below (calculated at maximum capacity practicable). The resulting amount, less the amount then available to said user by use of the maximum capacity practicable from all such other sources, will be such user's allocated fair share of the flow of the Potomac River."

In other words, each service area gets the same proportionate share of water during low flow conditions as it used, on the average, during the preceding five winter base periods. As an example, assume WSSC's five-winter average demand is 120 mgd, the regional five-winter average demand is 300 mgd, WSSC's non-Potomac sources account for 60 mgd, FCWA's non-Potomac sources account for 90 mgd, the flowby requirement is 100 mgd, and the Potomac supply at the time of allocation is 350 mgd. Then, WSSC's allocated share of Potomac flow is calculated as follows:

$$\text{Allocated Potomac Share} = \frac{120}{300} \times (350 + 60 + 90 - 100) - 60 = 100$$

To incorporate the use of the LFAA formula into the water supply analysis required the calculation of demands for future benchmark years. The five-year "rolling average" was based on interpolation of benchmark demands (1980-1990, 1990-2000) presented in the previous section to obtain a mid-benchmark (1985, 1995) demand. This process resulted in the development of ratios of service area demands to total regional demands.

Consequently, a ratio developed for the year 1990 is actually based on the water demands between 1985 and 1990. The allocation could vary from year to year as growing suburban water service areas, FCWA and WSSC, exert increasing demands on the Potomac River.

The original Agreement further stipulates that the formula can be "frozen" at the 1988 allocations or anytime thereafter if a new negotiated agreement is desired by any signatory. The allocation ratio in effect at that time would continue until a subsequent agreement is reached. Thus, for the purposes of the early-action phase of the study documented in the August 1979 Progress Report and in this section, two sets of allocation ratios were used to calculate deficits. One set of allocation ratios was based on the continuous rolling average formula (without a "freeze") and one set was based on the "frozen" 1988 ratios. These two sets of allocation ratios are listed in Table D-33 as calculated using the Baseline demands. If Conservation Scenario 3 demands are used, the allocation ratios change slightly as shown in Table D-34. (It should be noted that the July 1982 modification to the original version of the Potomac LFAA eliminates the "freeze" provision after the proposed Little Seneca Lake is completed and the regional agreements are in full effect. This modification is discussed elsewhere in the report.)

USE OF SUPPLY AND DEMAND DATA

Table D-35 and D-36 contain the supply data and Table D-37 contains the demand data used to calculate the 30 and 7-day deficits, assuming Baseline demands. Tables D-38 and D-39 contain the supply data and Table D-40 contains the demand data used to calculate the 30 and 7-day shortages assuming Conservation Scenario 3 demands. The data presented in these tables are based on average August values because the difference between supply and demand is normally the greatest during August in severe drought years. Values are shown for each benchmark year for the period 1980-2030. Regional as well as individual service area totals are shown. As discussed earlier, seven-day service demands were developed through the use of peaking factors. The seven-day peaking factor was defined as the ratio of the maximum consecutive seven-day demand occurring in a particular month to its monthly demand (in this case, August). Thus, the seven-day demands represented a reasonable extension of 30-day information. The seven-day peaking factors used for each service area for the month of August follow:

WSSC and Rockville	1.10
FCWA	1.12
WAD	1.05

DEFICIT CALCULATIONS

Using the supply and demand data previously discussed, 30 and seven-day deficits were calculated by benchmark year for each Potomac-dependent water service area. These shortages were calculated for Baseline demands and for Conservation Scenario 3 demands, assuming both with and without the 1988 freeze provision. The shortages were computed by first deriving available Potomac River supply from low flow frequency data, adding 135 mgd to those flows based on August Bloomington Reservoir average monthly releases, and subtracting 100 mgd flowby to the Potomac Estuary. To determine each service area's deficits, each area's demands were satisfied first to the maximum extent possible from offstream storage areas (limited by 7 and 30-day reservoir water treatment capacities). The difference between their remaining demand and their share of the available Potomac River flows (allocated by the terms of the Potomac LFAA) represented their potential surplus or deficit.

TABLE D-33

COMPARISON OF ALLOCATION RATIOS FOR 1988 AND 2030 CONDITIONS*
(BASELINE DEMANDS)

Benchmark Year	WAD 1988 Freeze	WAD Rolling Average	WSSC 1988 Freeze	WSSC Rolling Average	FCWA 1988 Freeze	FCWA Rolling Average	Rockville 1988 Freeze	Rockville Rolling Average
1980	57.14	57.14	41.59	41.59	-	-	1.27	1.27
1988	45.48	45.48	35.95	35.95	17.38	17.38	1.19	1.19
1990	45.48	44.93	35.95	36.41	17.38	17.51	1.19	1.15
2000	45.48	42.53	35.95	38.04	17.38	18.40	1.19	1.03
2010	45.48	40.19	35.95	39.62	17.38	19.25	1.19	0.94
2020	45.48	38.29	35.95	40.56	17.38	20.28	1.19	0.87
2030	45.48	36.72	35.95	41.15	17.38	21.31	1.19	0.82

*Based on Application of Potomac Low Flow Allocation Agreement to Baseline Demands. FCWA assumed to start withdrawing Potomac water in 1982.

TABLE D-34

COMPARISON OF ALLOCATION RATIOS FOR 1988 AND 2030 CONDITIONS*
(CONSERVATION SCENARIO 3 DEMANDS)

Benchmark Year	WAD 1988 Freeze	WAD Rolling Average	WSSC 1988 Freeze	WSSC Rolling Average	FCWA 1988 Freeze	FCWA Rolling Average	Rockville 1988 Freeze	Rockville Rolling Average
1980	56.79	56.79	41.78	41.78	-	-	1.43	1.43
1988	45.21	45.21	36.38	36.38	17.29	17.29	1.12	1.12
1990	45.21	44.52	36.38	36.93	17.29	17.45	1.12	1.10
2000	45.21	42.15	36.38	38.52	17.29	18.31	1.12	1.02
2010	45.21	39.88	36.38	40.03	17.29	19.15	1.12	0.94
2020	45.21	37.86	36.38	41.00	17.29	20.27	1.12	0.87
2030	45.21	36.25	36.38	41.58	17.29	21.35	1.12	0.82

* Based on application of Potomac Low Flow Allocation Ratios to Conservation Scenario 3 Demands. FCWA assumed to start withdrawing Potomac water in 1982.

TABLE D-35
30-DAY SUPPLY FOR POTOMAC RIVER-DEPENDENT WATER SERVICE AREAS
(BASELINE DEMANDS)

Data: 1/100 yr recurrence August	1980		1990		2000		2010		2020		2030	
	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
Potomac River Natural Flow	493	493	493	493	493	493	493	493	493	493	493	493
Bloomington Add (August)	135	135	135	135	135	135	135	135	135	135	135	135
Minus Flowby	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Available Potomac Flow	528	528	528	528	528	528	528	528	528	528	528	528
WSSC												
(1) Reservoir Supply	49	49	49	49	49	49	49	49	49	49	49	49
(2) Potomac Share	191	191	192	189	202	189	213	189	219	189	223	189
Total Service Area Supply	240	240	241	238	251	238	262	238	268	238	272	238
FCWA												
(3) Reservoir Supply	84	84	84	84	84	84	84	84	84	84	84	84
(2) Potomac Share	-	-	32	31	38	31	43	31	50	31	57	31
Total Service Area Supply	84	84	116	115	122	115	127	115	134	115	141	115
WAD												
(2) Potomac Share	330	330	297	301	281	301	266	301	253	301	243	301
Total Service Area Supply	330	330	297	301	281	301	266	301	253	301	243	301
Rockville												
(2) Potomac Share	7	7	7	7	7	7	6	7	6	7	5	7
Total Service Area Supply	7	7	7	7	7	7	6	7	6	7	5	7

(1) Patuxent Reservoir Supply based on maximum 30-day reservoir treatment plant capacity
(2) Flows divided according to Potomac Low Flow Allocation Agreement (assuming Baseline demands)
(3) Occoquan Reservoir Supply based on maximum 30-day reservoir treatment plant capacity

TABLE D-36
7-DAY SUPPLY FOR POTOMAC RIVER-DEPENDENT WATER SERVICE AREAS
(BASELINE DEMANDS)

Data: 1/100 yr Recurrence August	1980		1990		2000		2010		2020		2030	
	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
Potomac River Natural Flow	401	401	401	401	401	401	401	401	401	401	401	401
Bloomington Add (August)	135	135	135	135	135	135	135	135	135	135	135	135
Minus Flowby	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Available Potomac Flow	436	436	436	436	436	436	436	436	436	436	436	436
WSSC												
(1) Reservoir Supply	55	55	55	55	55	55	55	55	55	55	55	55
(2) Potomac Share	149	149	158	155	168	155	177	155	183	155	186	155
Total Service Area Supply	204	204	213	210	223	210	232	210	238	210	241	210
FCWA												
(3) Reservoir Supply	95	95	95	95	95	95	95	95	95	95	95	95
(2) Potomac Share	-	-	8	7	13	7	17	7	24	7	30	7
Total Service Area Supply	95	95	103	102	108	102	112	102	119	102	125	102
WAD												
(2) Potomac Share	281	281	263	267	249	267	236	267	224	267	215	267
Total Service Area Supply	281	281	263	267	249	267	236	267	224	267	215	267
Rockville												
(2) Potomac Share	6	6	7	7	6	7	6	7	5	7	5	7
Total Service Area Supply	6	6	7	7	6	7	6	7	5	7	5	7

(1) Patuxent Reservoir supply based on maximum 7-day reservoir treatment plant capacity
(2) Flows divided according to Potomac Low Flow Allocation Agreement (assuming Baseline demands)
(3) Occoquan Reservoir supply based on maximum 7-day reservoir treatment plant capacity

TABLE D-37
REGIONAL AND WATER SERVICE AREA BASELINE DEMANDS
(AUGUST)

BENCHMARK YEAR	WATER SERVICE AREA	AUGUST BASELINE DEMANDS (MGD) 7-Day	30-Day
1980	WAD	237	226
	WSSC	178	162
	FCWA	90	80
	Rockville	5	5
	Regional Total	510	473
1990	WAD	265	253
	WSSC	231	210
	FCWA	113	101
	Rockville	7	6
	Regional Total	616	570
2000	WAD	280	267
	WSSC	267	243
	FCWA	132	118
	Rockville	7	6
	Regional Total	686	634
2010	WAD	287	274
	WSSC	301	274
	FCWA	150	134
	Rockville	7	6
	Regional Total	745	688
2020	WAD	295	282
	WSSC	333	303
	FCWA	174	155
	Rockville	7	6
	Regional total	809	746
2030	WAD	303	289
	WSSC	360	327
	FCWA	195	174
	Rockville	7	6
	Regional Total	865	796

TABLE D-38
30-DAY SUPPLY FOR POTOMAC RIVER-DEPENDENT WATER SERVICE AREAS
(CONSERVATION SCENARIO 3 DEMANDS)

Data: 1/100 yr. recurrence August	1980		1990		2000		2010		2020		2030	
	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
Potomac River Natural Flow	493	493	493	493	493	493	493	493	493	493	493	493
Bloomington Add. (August)	135	135	135	135	135	135	135	135	135	135	135	135
Minus Flowby	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Available Potomac Flow	528	528	528	528	528	528	528	528	528	528	528	528
WSSC												
(1) Reservoir Supply	49	49	49	49	49	49	49	49	49	49	49	49
(2) Potomac Share	192	192	195	192	205	192	215	192	222	192	226	192
Total Service Area Supply	241	241	244	241	254	241	264	241	271	241	275	241
FCWA												
(3) Reservoir Supply	84	84	84	84	84	84	84	84	84	84	84	84
(2) Potomac Share	-	-	31	30	37	30	43	30	50	30	57	30
Total Service Area Supply	84	84	115	114	121	114	127	114	134	114	141	114
WAD												
(2) Potomac Share	328	328	295	299	279	299	264	299	250	299	240	299
Total Service Area Supply	328	328	295	299	279	299	264	299	250	299	240	299
Rockville												
(2) Potomac Share	8	8	7	7	7	7	6	7	6	7	5	7
Total Service Area Supply	8	8	7	7	7	7	6	7	6	7	5	7

(1) Patuxent Reservoir Supply based on maximum 30-day reservoir treatment plant capacity
(2) Flows divided according to Potomac Low Flow Allocation Agreement (assuming Conservation Scenario 3 demands)
(3) Occoquan Reservoir Supply based on maximum 30-day reservoir treatment plant capacity

TABLE D-39
7-DAY SUPPLY FOR POTOMAC RIVER-DEPENDENT WATER SERVICE AREAS
(CONSERVATION SCENARIO 3 DEMANDS)

Data: 1/100 yr. recurrence August	1980		1990		2000		2010		2020		2030	
	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
Potomac River Natural Flow	401	401	401	401	401	401	401	401	401	401	401	401
Bloomington Add. (August)	135	135	135	135	135	135	135	135	135	135	135	135
Minus Flowby	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Available Potomac Flow	436	436	436	436	436	436	436	436	436	436	436	436
WSSC												
(1) Reservoir Supply	55	55	55	55	55	55	55	55	55	55	55	55
(2) Potomac Share	150	150	161	158	171	158	179	158	185	158	189	158
Total Service Area Supply	205	205	216	213	226	213	234	213	240	213	244	213
FCWA												
(3) Reservoir Supply	95	95	95	95	95	95	95	95	95	95	95	95
(2) Potomac Share	-	-	7	6	12	6	17	6	24	6	30	6
Total Service Area Supply	95	95	102	101	107	101	112	101	119	101	125	101
WAD												
(2) Potomac Share	279	279	261	265	247	265	234	265	222	265	212	265
Total Service Area Supply	279	279	261	265	247	265	234	265	222	265	212	265
Rockville												
(2) Potomac Share	7	7	7	7	6	7	6	7	5	7	5	7
Total Service Area Supply	7	7	7	7	6	7	6	7	5	7	5	7

(1) Patuxent Reservoir Supply based on maximum 30-day reservoir treatment plant capacity
(2) Flows divided according to Potomac Low Flow Allocation Agreement (assuming Conservation Scenario 3 demands)
(3) Occoquan Reservoir Supply based on maximum 30-day reservoir treatment plant capacity

TABLE D-40
REGIONAL AND WATER SERVICE AREA CONSERVATION SCENARIO 3 DEMANDS
(AUGUST)

BENCHMARK YEAR	WATER SERVICE AREA	AUGUST SCENARIO 3 DEMANDS (mgd) 7-DAY	30-DAY
1980	WAD	224	213
	WSSC	168	153
	FCWA	84	75
	Rockville	5	5
	Regional Total	481	446
1990	WAD	243	232
	WSSC	211	192
	FCWA	104	92
	Rockville	6	5
	Regional Total	564	521
2000	WAD	251	239
	WSSC	239	212
	FCWA	118	106
	Rockville	6	6
	Regional Total	614	568
2010	WAD	256	244
	WSSC	269	244
	FCWA	134	119
	Rockville	6	6
	Regional Total	665	613
2020	WAD	263	250
	WSSC	296	269
	FCWA	154	137
	Rockville	6	6
	Regional Total	719	662
2030	WAD	269	256
	WSSC	319	290
	FCWA	172	154
	Rockville	6	6
	Regional Total	766	706

Tables D-41 and D-42 list the regional and service area shortages for the 30 and 7-day flow durations, respectively, using Baseline demands. Figure D-37 displays the same information graphically showing a projected 30-day regional shortage of 135 mgd in year 2030 and a projected 7-day regional shortage of 279 mgd in year 2030, again assuming Baseline demands.

Tables D-43 and D-44 likewise list the regional and service area shortages for the 30 and 7-day low flow durations, respectively, but now assuming Conservation Scenario 3 demands. Figure D-38 displays the regional shortages graphically, showing a projected 30-day shortage of 45 mgd in year 2030 and a projected 7-day shortage of 180 mgd in year 2030, assuming Conservation Scenario 3 demands.

Comparison of Tables D-41 versus D-43 and Tables D-42 versus D-44 demonstrates the potential reduction in shortages by implementing Conservaton Scenario 3. For the 30-day duration, the projected 2030 shortage would drop from 135 mgd to 45 mgd, or a 90 mgd reduction. Similarly, for the 7-day duration, the projected 2030 shortage would drop from 279 mgd to 180 mgd, or a 99 mgd reduction. As noted elsewhere in the report, the design condition ultimately selected for the early-action phase was the once-in-100 year, 7-day shortage with implementation of Conservation Scenario 3. Thus, the early-action plans were designed to satisfy a projected 180 mgd regional shortage which reflected the 99 mgd reduction due to Conservation Scenario 3 by the year 2030.

An additional item of interest in the early-action phase was the effect of freezing the allocation ratios at the 1988 level. Both sets of allocation ratios (with freeze and without freeze) necessarily produce the same regional shortage for any given year, but the division of the surplus or shortage among the four users depends on which set of allocation ratios is used, as is demonstrated in Tables D-41 through D-44. Under the continuous rolling average (without freeze), the deficits for the WAD and Rockville service areas would be greater than those for the freeze condition. On the other hand, in the WSSC and FCWA service areas, shortages would be less without the freeze than with the freeze. This is because the continuous rolling average would gradually allocate more water later in the period to the growing service areas of the FCWA and the WSSC at the expense of the relatively stable WAD service area.

LONG-RANGE PLANNING: REDEFINITION OF THE WATER SUPPLY PROBLEM

The supply and demand analysis in the early-action phase of the MWA Water Supply Study reflected the planning knowledge and expected future conditions as of August 1979. Since that time, several developments have transpired which have significantly changed the MWA water supply situation. Some of these developments were a direct result of actions taken in response to the findings documented in the August 1979 Progress Report.

During the past three years, the MWA water utilities have joined together and taken several steps toward solving the region's water supply problems. These steps are indicative of the spirit of regional cooperation which has evolved since the publication of the Progress Report. As a result of these steps taken by local initiative, the water supply base condition (the "without" condition) has changed significantly, creating a need to redefine the water supply problem for the long-range portion of the study. The next few sections detail these recent developments and the subsequent modifications to the water demands and supplies which were used in the long-range planning phase of

TABLE D-41
PROJECED 30-DAY DEFICITS [4]
(MGD)
BASELINE DEMANDS

	1980		1990		2000		2010		2020		2030	
SERVICE AREA	WO[1] Freeze	W[2] Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
WSSC	+78	+78	+31	+28	+8	0	-12	-17	-35	-53	-55	-81
FCWA	+4[3]	+4[3]	+15	+14	+4	0	-7	-10	-21	-32	-33	-54
WAD	+104	+104	+44	+48	+14	+26	-8	0	-29	0	-46	0
ROCKVILLE	+2	+2	+1	+1	+1	+1	0	0	0	0	-1	0
REGIONAL	+188	+188	+91	+91	+27	+27	-27	-27	-85	-85	-135	-135

(1) W/O Freeze: Based on application of Potomac Low Flow Allocation Agreement to Baseline demands (Rolling Average).
(2) W Freeze: Application of 1988 Allocation percentage for 1980 - 2030, Baseline demands.
(3) FCWA: Does not withdraw from Potomac prior to 1982; surplus is difference between demand and Occoquan supply.
(4) Deficits based on 30-day August supplies, 1/100 year frequency (see Table D-35) and 30-day August Baseline demands (see Table D-37).

TABLE D-42
PROJECTED 7-DAY DEFICITS [4]
(MGD)
BASELINE DEMANDS

	1980		1990		2000		2010		2020		2030	
SERVICE AREA	WO[1] Freeze	W[2] Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
WSSC	+26	+26	-17	-20	-44	-57	-69	-91	-95	-123	-119	-150
FCWA	+5[3]	+5[3]	-10	-10	-24	-30	-38	-48	-55	-72	-70	-93
WAD	+44	+44	-3	0	-31	-13	-51	-20	-71	-28	-88	-36
ROCKVILLE	+1	+1	0	0	-1	0	-1	0	-2	0	-2	0
REGIONAL	+76	+76	-30	-30	-100	-100	-159	-159	-223	-223	-279	-279

(1) W/O Freeze: Based on application of Potomac Low Flow Allocation Agreement to Baseline demands (Rolling Average).
(2) W Freeze: Application of 1988 Allocation percentage for 1980 - 2030, Baseline demands.
(3) FCWA: Does not withdraw from Potomac prior to 1982; surplus is difference between demand and Occoquan supply.
(4) Deficits based on 7-day August supplies, 1/100 year frequency (see Table D-36) and 7-day August Baseline demands (see Table D-37).

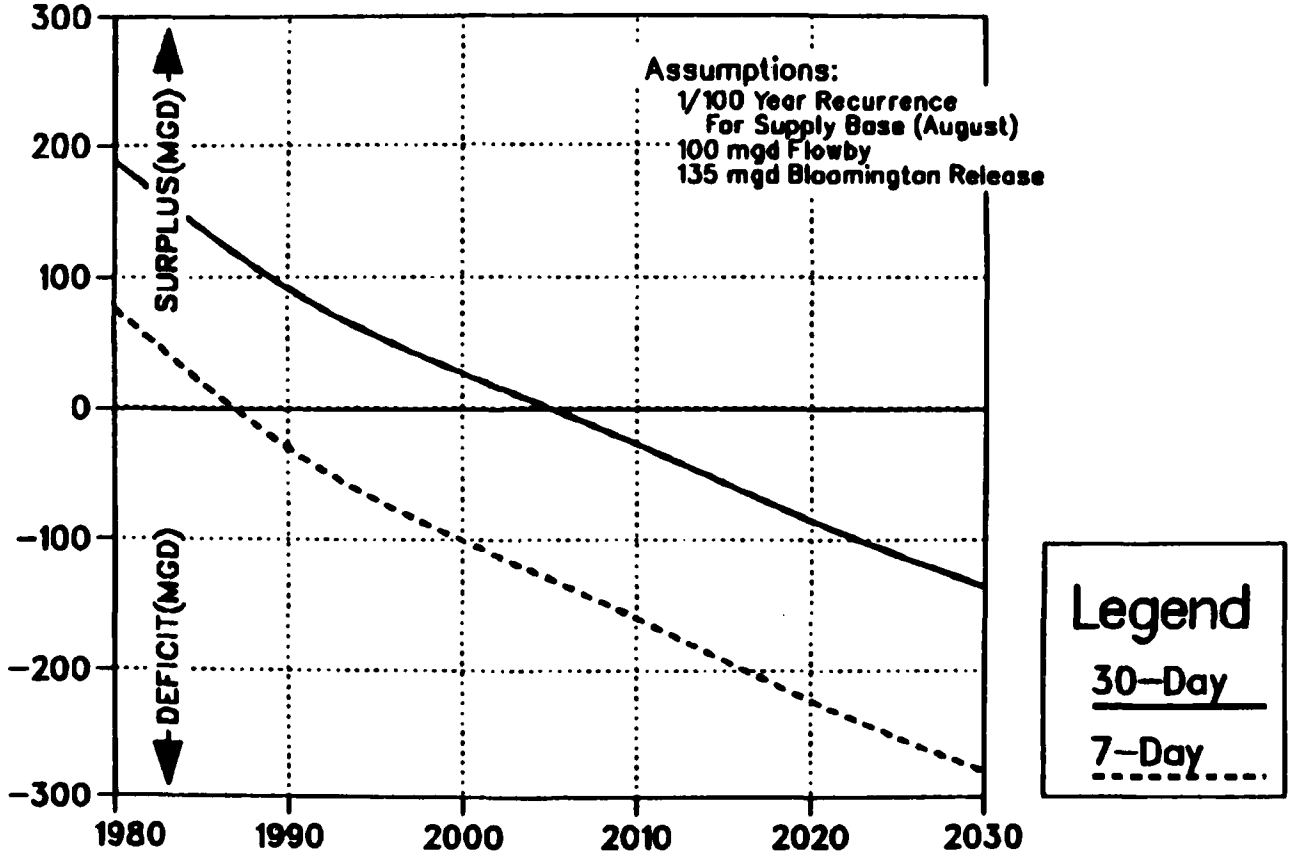

30 AND 7-DAY SHORTAGES FOR THE REGION
WSSC, WAD, FCWA, AND ROCKVILLE
BASELINE DEMANDS
300
200
100
0
-100
-200
-300
SURPLUS(MGD)
DEFICIT(MGD)
1980
1990
2000
2010
2020
2030
Assumptions:
1/100 Year Recurrence
For Supply Base (August)
100 mgd Flowby
135 mgd Bloomington Release
Legend
30-Day
7-Day

FIGURE D-37

TABLE D-43
PROJECTED 30-DAY DEFICITS [4]
(MGD)
CONSERVATION SCENARIO 3 DEMANDS

	1980		1990		2000		2010		2020		2030	
SERVICE AREA	WO[1] Freeze	W[2] Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
WSSC	+88	+88	+52	+49	+37	+24	+20	0	0	0	-15	-20
FCWA	+9[3]	+9[3]	+23	+22	+15	+8	+8	0	-1	-1	-13	-25
WAD	+115	+115	+63	+67	+40	+60	+20	+47	0	0	-16	0
ROCKVILLE	+3	+3	+2	+2	+1	+1	0	+1	0	0	-1	0
REGIONAL	+215	+215	+140	+140	+93	+93	+48	+48	-1	-1	-45	-45

(1) W/O Freeze: Based on application of Potomac Low Flow Allocation Agreement to Conservation Scenario 3 demands (Rolling Average).
(2) W Freeze: Application of 1988 Allocation percentage for 1980 - 2030, Conservaton Scenario 3 demands.
(3) FCWA: Does not withdraw from Potomac prior to 1982; surplus is difference between demand and Occoquan Supply.
(4) Deficits based on 30-day August supplies, 1/100 year frequency (see Table D-38) and 30-day August Conservaton Scenario 3 demands (see Table D-40).

TABLE D-44
PROJECTED 7-DAY DEFICITS [4]
(MGD)
CONSERVATION SCENARIO 3 DEMANDS

	1980		1990		2000		2010		2020		2030	
SERVICE AREA	WO[1] Freeze	W[2] Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze	WO Freeze	W Freeze
WSSC	+37	+37	+5	+2	-13	-15	-35	-49	-56	-81	-75	-105
FCWA	+11[3]	+11[3]	0	0	-12	-13	-22	-30	-35	-52	-47	-71
WAD	+55	+55	+16	+19	-3	0	-22	0	-41	0	-57	-4
ROCKVILLE	+2	+2	+1	+1	0	0	0	0	-1	0	-1	0
REGIONAL	+105	+105	+22	+22	-28	-28	-79	-79	-133	-133	-180	-180

(1) W/O Freeze: Based on application of Potomac Low Flow Allocation Agreement to Conservaton Scenario 3 demands (Rolling Average).
(2) W Freeze: Application of 1988 Allocation percentage for 1980 - 2030, Conservaton Scenario 3 demands.
(3) FCWA: Does not withdraw from Potomac prior to 1982; surplus is difference between demand and Occoquan Supply.
(4) Deficits based on 7-day August supplies, 1/100 year frequency (see Table D-39) and 7-day August Conservaton Scenario 3 demands (see Table D-40).

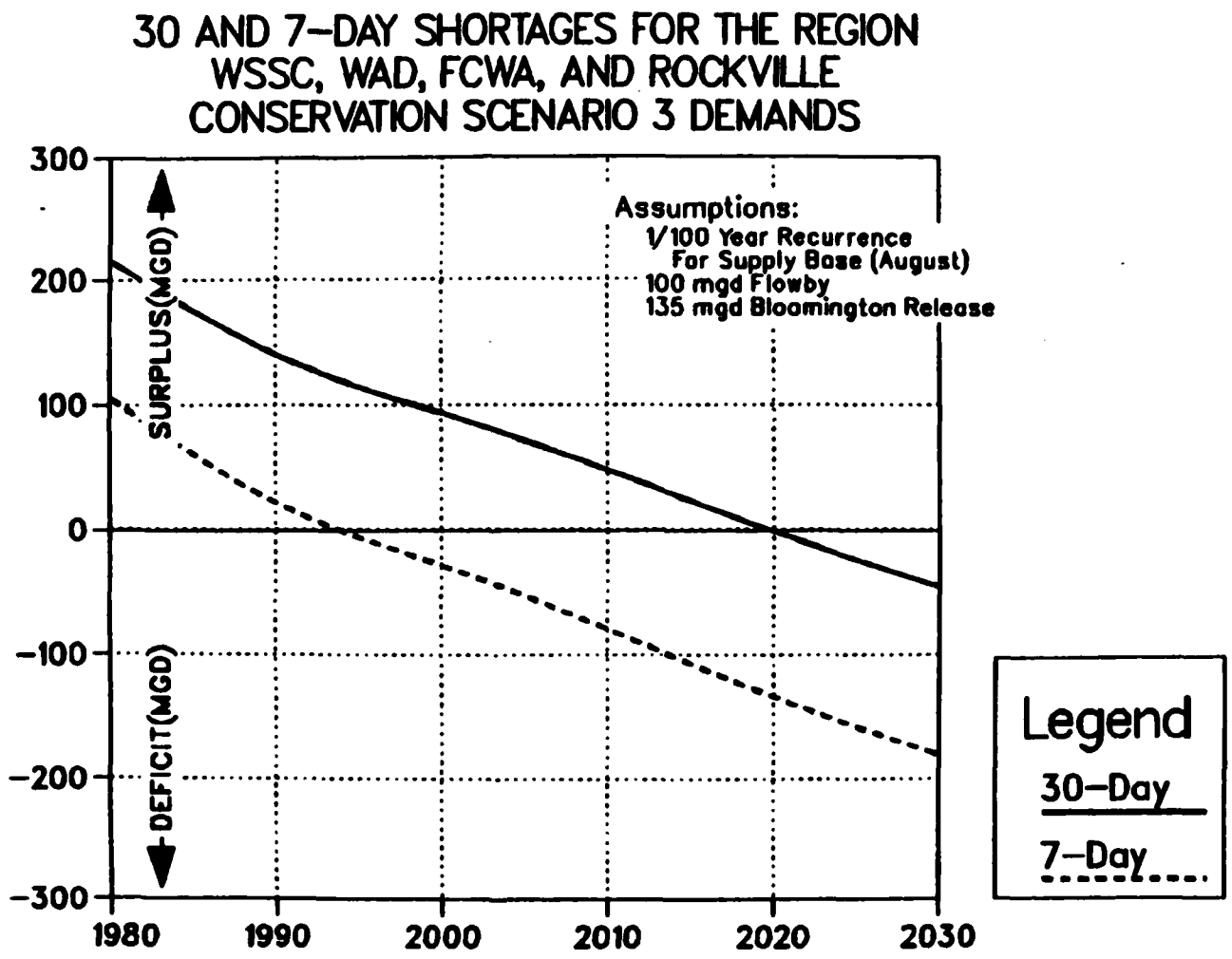

30 AND 7-DAY SHORTAGES FOR THE REGION
WSSC, WAD, FCWA, AND ROCKVILLE
CONSERVATION SCENARIO 3 DEMANDS
300
200
100
0
-100
-200
-300
SURPLUS(MGD)
DEFICIT(MGD)
1980
1990
2000
2010
2020
2030
Assumptions:
1/100 Year Recurrence
For Supply Base (August)
100 mgd Flowby
135 mgd Bloomington Release
Legend
30-Day
7-Day

FIGURE D-38

this study. The last section of this appendix presents the water supply deficit calculations which formed the basis of the long-range plan formulation activities.

RECENT WATER SUPPLY ACTIVITIES

Since the publication of the August 1979 Progress Report, the MWA water utilities and local governments have pursued several activities to accomplish their water supply goals. One of these activities is the ongoing program for water conservation within the region. Both FCWA and WSSC have adopted water rate structures which encourage water conservation, particularly during the summer months. In addition, the water utilities have continued to support an active consumer-education program.

The major accomplishment of the past three years has been the degree of regional cooperation which has been achieved. The importance of regional cooperation was first outlined in the early-action "Plans for Choice" which were described in the August 1979 Progress Report (a summary of the early-action plan formulation can be found in Appendix B, Formulation, Assessment, and Evaluation). It was demonstrated that a regional water supply solution could provide significant cost-savings relative to independently pursued plans. The Progress Report also suggested that the solution to the MWA's problems could be implemented by the local users without assistance from the Federal government.

Given these findings, the local governments and water utilities realized that actions to solve future MWA water supply problems could be taken immediately. At the December 1979 meeting of the Federal-Interstate-State-Regional Advisory Committee (FISRAC), the members of that group initiated the formation of a regional task force to develop a regional water supply management strategy. This task force, the Washington Metropolitan Regional Water Supply Task Force, then set out to develop a plan of action for the region. As a result of its leadership, many of the benefits of regional cooperation have been attained. (More details about the Regional Task Force activities are presented in the Main Report and Appendix B.) The plan of action which the Regional Task Force developed, and which is currently being implemented through the local jurisdictions and utilities, includes the construction of Little Seneca Lake, the purchase of the Bloomington Lake future water supply storage, modifications to the Potomac Low Flow Allocation Agreement (LFAA), a regional water supply operation agreement, and a cost-sharing formula for any future water supply projects. The foundation of this plan of action is the utilities' intent to operate their systems and facilities from a regional supply and demand perspective. The regional water supply operation will be accomplished through the CO-OP (Cooperative Operations on the Potomac River) section of the Interstate Commission on the Potomac River Basin (ICPRB). The CO-OP section will be responsible for monitoring all of the water needs of the region, and then scheduling releases from Bloomington Lake water supply storage and Little Seneca Lake to supplement natural Potomac flow and withdrawals from the Patuxent and Occoquan Reservoirs. In order to provide this service, the CO-OP group will rely on their computer model which predicts the statistical risks of various operational decisions.

The Regional Task Force plan of action is well on its way to fulfillment. The Little Seneca Lake project has received all of the necessary permits and approvals, a repayment mechanism has been negotiated, and construction was initiated in September 1982. Its 4,020 million gallons (12,350 acre-feet) of water supply storage should be available by the water supply season of 1985. A contract for the purchase of the future water supply storage in Bloomington Lake (11,026 million gallons, 33,837 acre-feet) has

been negotiated among the MWA utilities and local governments, as well as a contract to share the operation and maintenance costs of Savage River Reservoir with Allegany County. Additionally, the LFAA signatories have approved a modification which eliminates the freeze provision once Little Seneca Lake is completed and operational, and the CO-OP program is functioning.

In addition to the Regional Task Force activities, two related studies which affected the MWA supply and demand calculations were also undertaken in the three years since the early-action analysis. These studies were the Potomac River Environmental Flowby Study which was completed by the State of Maryland in 1981, and the Bloomington Lake Reformulation Study which is part of the overall MWA Water Supply Study and is included as part of this report (Appendix H).

The Potomac River Environmental Flowby Study was an outgrowth of LFAA negotiations in the mid-1970's. Under the terms of the allocation agreement, the State of Maryland was charged with assessing the effects of low flows on the Potomac River ecosystem and setting forth a recommended level of flow into the Potomac Estuary. The results of Maryland's investigations are published in their report, The Potomac River Environmental Flowby Study. Two of the recommendations resulting from the flowby study were: (1) a minimum daily flow of 100 mgd should be maintained below Little Falls intake , and (2) a portion of the Aqueduct's withdrawals should be shifted from the Great Falls intake to the Little Falls intake when the flow at Great Falls approaches 500 mgd or less. These two recommendations, especially the recommendation for a minimum of 100 mgd of environmental flowby below Little Falls, were important elements in the redefinition of supply availability for the long-range study. The executive summary of the State of Maryland's flowby study is contained in Annex D-V.

The Bloomington Lake Reformulation Study was initiated in January 1980. Its intent was to take a closer, more detailed look at the use of Bloomington Lake for water supply. The investigation had two purposes: (1) to examine the full water supply capability of the project and its most efficient use under existing Congressional authorization, and (2) to determine the feasibility of reallocating some water quality and/or flood control storage to water supply for downstream needs. The initial results of this study demonstrated that the water supply provided to the MWA from Bloomington Lake could be significantly increased by coordinated management of the area's reservoirs as a regional system. This preliminary finding, along with the jurisdictional movements toward a regional water supply approach, reinforced the need to reexamine the supply and demand assumptions used in the early-action planning effort to establish the base or "without" condition for the long-range phase.

EFFECTS OF REDEFINITION ON EARLY-ACTION WATER DEMANDS

In the early action phase of the MWA Water Supply Study, the deficit analysis for the Potomac service areas used the Conservation Scenario 3 demands, based on MWCOG Round I population forecasts. For the long-range planning phase, these demands were reevaluated in the context of the current available information. The results of this reevaluation are presented below. The demands for the outlying counties were also examined, and a discussion of the demand calculations for these areas can be found under the individual jurisdiction in Appendix I - Outlying Service Areas.

In 1980, MWCOG published its Round II forecasts for population in the MWA. These projections were not significantly different from the Round I forecasts. The Round II

intermediate projections showed a total population in the Washington, D.C. SMSA about 8 percent less than the Round I forecasts. However, most of the differences between Round I and Round II were reflected in the outlying service areas, with only minor decreases in the Potomac River users' jurisdictions. Furthermore, the Round I population projections and subsequent water demands had been accepted by several local groups, including CO-OP and the Regional Task Force, as the basis for their water supply planning efforts. For these reasons, the Round II population projections were not pursued further in the demand analysis for the Potomac users. The Round II projections, however, were used for the outlying areas as described in Appendix I.

In the past few years, the water supply utilities in the MWA have continued their efforts in water conservation. Reconfirming their decision in the early-action phase, the Potomac users still feel that the 10 to 11 percent demand reduction by 2030, represented by the conservation measures contained in Scenario 3 demands, is reasonable and attainable. Therefore, the Scenario 3 conservation level was continued in the long-range planning phase.

Based on the existing planning conditions and the early-action demand assumptions, the Conservation Scenario 3 and Round I population forecasts were considered appropriate for the long-range planning. As in the earlier analysis, monthly demand variations were recognized. However, the weekly demand peaks of the early-action phase were not used in the long-range deficit analysis for several reasons. First, the simulation model which was used in the long-range deficit analysis showed that weekly demand peaks had little or no impact on the overall supply availability in a long-term drought. Second, emergency conservation measures, such as those required by the Metropolitan Washington Water Supply Emergency Agreement, would be capable of controlling large fluctuations in demand. Additionally, the Round II population forecasts indicated less future growth in the Potomac dependent service areas which was not reflected in the Round I monthly average demands. As a result, the Round I demands were considered conservative from a deficit point of view. The set of 2030 demands for WSSC, WAD, and FCWA services areas, which were used in the long-range phase formulation, are tabulated in Table D-45. These monthly demands are identical to those used in the early-action phase.

REDEFINED WATER SUPPLY BASE

The early action water supply base was significantly revised and modified for the long-range phase of the study, both to reflect changed conditions in the intervening three years and to overcome previous shortcomings. The early-action supply was based strictly on the 7-day and 30-day system capacities and statistical flow duration data. It did not address low flow periods of longer duration or the flexibility of a regional system which can trade-off between upstream and local impoundments. (A regionally managed system also has the advantage of allowing the water utilities to choose between reservoir and river withdrawals, to best meet their water demands. However, the early-action supply analysis did not examine the benefits to be derived from this type of system operation.) In particular, the early-action analysis, which assumed a continuous release of 135 mgd from Bloomington Lake, did not consider variable Bloomington water supply releases to satisfy fluctuating regional needs. Consequently, the operation of the Bloomington project assumed in the early-action analysis was inefficient and not representative of regional cooperation which the region endorsed subsequent to the publication of the August 1979 Progress Report. Although some test simulations were performed for the 1930's and 1960's droughts, the early-action analysis did not thoroughly examine the effects of the low flow periods on the system's reservoirs. In particular, the analysis did

TABLE D-45

LONG-RANGE MWA WATER SUPPLY DEMANDS
2030, CONSERVATION SCENARIO 3

Demand (mgd)

Month	WSSC	WAD	FCWA	TOTAL
January	224	199	115	538
February	224	198	115	537
March	225	193	116	534
April	235	202	126	563
May	263	212	138	613
June	291	238	150	679
July	304	259	163	726
August	290	256	154	700
September	290	239	146	675
October	251	219	130	600
November	233	206	123	562
December	229	201	121	551

not evaluate the effects of long-term droughts on the capability of reservoirs to deliver adequate quantities of water throughout the drought. In a long-term drought, the availability of storage would most likely be the limiting constraint of the supply system.

In addition to these two shortcomings, the early-action supply base did not include regional management of the Savage River Reservoir. Also, the analysis did not account for travel time and flow losses between Bloomington Lake and the MWA's Potomac intakes which could be significant during low flow periods.

Because of the need for improvement in some of the technical analyses, the early-action supply base methodology was critically reviewed for potential changes to be incorporated in the long-range planning phase. This review process culminated in the establishment of several analytical goals for the long-range planning supply base. These goals were:

(1) to examine Bloomington Lake and Savage River Reservoirs, in detail, as well as the other local reservoirs,

(2) to analyze the effects of several months of low flow as well as shorter periods, such as seven days,

(3) to incorporate the LFAA provisions and the reregulation plans for the Occoquan and Patuxent distribution facilities,

(4) to include the effects of transit losses and time between Bloomington and the MWA intakes,

(5) to evaluate the trade-offs between upstream and downstream (local) storage and between reservoir and river withdrawals,

(6) to examine the utility of regional cooperation by simulating the system's reservoirs for maximum, efficient use on a regional level,

(7) to investigate more effective release strategies for Bloomington, and

(8) to include flexibility in the supply parameters for additional analyses.

To accomplish these goals, standard mathematical hydrologic models were investigated. However, they were unable to incorporate some important system constraints, such as the LFAA and reregulation. They were also limited in time scale, using time intervals of one month or longer. As such, these models would mask more frequent fluctuations in streamflow which are critical in the Potomac River Basin. Consequently, the study turned to site-specific simulation modelling as a tool to analyze the interaction of reservoir storage, streamflow, and water demands.

Additionally, the recent developments in the MWA water supply situation changed the character of the supply vs. demand problem. In the early-action analysis, the emphasis was on a rate of supply (Potomac flow and reservoir withdrawals) vs. demand. The realization of reregulation plans, Little Seneca Lake, Bloomington water supply storage, and regional cooperation, effectively reduced the short-term water supply flow problems. The remaining constraint in the supply situation was then the volume of storage available in a long-term drought. This volumetric supply and demand relationship became the major problem to be solved in the long-range planning phase. This type of problem lent itself easily to a simulation type of analysis.

Simulation modelling describes the changes in the system caused by user actions/decisions. By their nature, simulation models can incorporate many site-specific elements when they are properly designed. For the MWA system, such a model was originally developed by a research team at Johns Hopkins University, and later modified by the Corps of Engineers for use in the MWA Water Supply Study. The Corps' modified model, named the Potomac River Interactive Simulation Model (PRISM/COE), is capable of simulating the operation and management of the MWA multi-reservoir and river system on a weekly basis for up to 50 years of flow record. Records between October 1929 and September 1979 were used. The model incorporates the major supply elements of the MWA system: Bloomington Lake, Savage River Reservoir, Triadelphia and Rocky Gorge Reservoirs, Occoquan Reservoir, and the Potomac River. (At the time of the PRISM/COE development in the late 1970's, the construction of Little Seneca Lake did not appear imminent; therefore, the reservoir was not included in the model. However, calculations were later made to account for Little Seneca Lake as explained later in the text).

The PRISM/COE simulation model is able to monitor the storage levels and releases of all of the reservoirs as well as flows in the major streams. The model also accounts for

the effects of reregulation throughout a drought. Important system constraints such as Bloomington flood control and water quality operations and the LFAA are defined in the model programming. The model also provides a detailed accounting of Bloomington storage and releases, characteristic of the probable regulation of that project. Full details of the PRISM/COE simulation model are described in Annex H-III - PRISM Development and Application.

As a result of its unique capabilities, the PRISM/COE model was used to simulate the without condition for the Potomac users in the long-range planning phase. The model also formed the basis for the supply analysis in the Bloomington Lake Reformulation Study since its structure was designed to evaluate the Bloomington storage in detail. The supply and demand baseline analysis for the outlying areas in the MWA was conducted separately from the Potomac users and is discussed in Appendix I, Outlying Service Areas. The important modelling assumptions and operations for the without condition for the Potomac users are outlined in the following paragraphs.

In the long-range planning supply base, the regulation of the upstream reservoirs, Bloomington Lake and Savage River Reservoir, considered the multiple purposes of those impoundments. For the without condition analysis, Bloomington Lake's authorized conservation volume was 92,000 acre-feet, of which 41,000 acre-feet were dedicated to water supply storage for non-Federal users, and 51,000 acre-feet to water quality storage controlled by the Federal government. The available Savage conservation storage was set at 18,000 acre-feet since about 2,000 acre-feet of Savage's 20,000 acre-feet capacity is set aside for water supply for the Town of Westernport.

In the PRISM/COE model, the reservoir simulation included the specific rule curves for both upstream reservoirs, drawing down the pools in winter for flood control and bringing them back up in the late spring. Water quality releases were made from each reservoir based on meeting a flow target of 78 mgd (120 cfs) at Luke and maintaining adequate water quality in the North Branch Potomac River. Further studies indicated that the 100 mgd of Potomac estuary flowby could be provided by water quality storage in Bloomington, if needed. For water quality reasons, the proportion of releases from Savage vs. Bloomington varied depending on the time of the year and total flow at Luke. A description of the water quality investigations for the Luke flow target and a detailed explanation of the reservoir release ratios is given in Annexes H-II and H-III.

Water supply storage in Bloomington was released to meet downstream needs when the Potomac River flow declined to low levels; at the same time, a proportional Savage release was also made to dilute the additional acidic Bloomington flow. The volume of upstream water supply release was a variable controlled by the model user. As the user desired, the regional strategy could be to depend more heavily on the downstream reservoirs (Occoquan, Triadelphia, and Rocky Gorge) for supply instead of Bloomington Lake, or vice versa. This balance between upstream reservoir usage and downstream reservoir usage was quite important to the overall MWA supply base. Releasing large volumes of upstream (Bloomington) storage allowed large Potomac withdrawals, thereby preserving the downstream reservoir storage. However, this strategy quickly depleted the Bloomington water supply storage and proved to be a great risk in a long-term drought. A large degree of reliance on the Occoquan and Patuxent reservoirs drained their storages rapidly, but maintained a large supply in Bloomington. This policy could backfire if the Potomac flows dropped off quickly and upstream releases were not made in time.

The balance between the two sets of reservoirs essentially became a fine tuning of the system supply network. During the long-range planning analysis, this balance was studied intensively and a proper balance was selected, taking into account environmental, water quality, and water supply concerns. The particulars of this investigation can be found in Appendix H.

The PRISM/COE simulations assumed the upstream releases reached the MWA intakes without loss within two weeks. About 47 percent of the release arrived within the actual week of release, and the remaining 53 percent arrived in the following week. These travel times and volumes were the results of low flow modelling by the USGS in their travel time study which is discussed in Annex H-V - USGS Flow Lows and Travel Time Studies. According to the PRISM/COE model, the flow in the Potomac River which was available to the MWA water supply users consisted of the natural flow in the Potomac River plus the augmented flow from the upstream reservoirs. This flow was then allocated to the three major Potomac users (FCWA, WSSC, and WAD) according to the allocation formula set forth in the LFAA and described in the early-action portion of this appendix. For the long-range analysis, the potential freeze option of the LFAA was not invoked because the LFAA signatories were considering the modification to the LFAA that eliminated the freeze provision. The final Potomac withdrawal of each utility was limited by this allocation, the demand that could be supplied by its Potomac facility, and the capacity of its intake facility. For FCWA, WSSC, and WAD, the Potomac intake capacities were set at 200, 400, and 650 mgd, respectively. These values are identical to those assumed in the early-action supply evaluation.

The downstream reservoir modelling assumed a conservation capacity of 10,300 mg for the Occoquan Reservoir, and a total conservation capacity of 10,100 mg for both WSSC reservoirs on the Patuxent. The Occoquan storage capacity included the two-foot extension to the dam by the addition of bascule gates. The water supply withdrawals from these offstream reservoirs were limited by the maximum treatment capacities of their systems. For the Occoquan (FCWA), this value was 95 mgd, while WSSC could only treat a maximum of 55 mgd on a weekly basis. Additionally, the pumping facilities at the reservoirs require a constant minimum flow for operational reasons, so minimum reservoir withdrawals of 30 mgd (Occoquan) and 20 mgd (Patuxent) were assumed.

The PRISM/COE model does not include a provision for Little Seneca Lake within its model programming. During the development of the PRISM/COE model, the Little Seneca Lake project was still in the permit approval process, and its eventual construction was not guaranteed. Therefore, the project was not included in the PRISM/COE computer model. However, it was recognized at the time that the water supply benefits of Little Seneca Lake could be evaluated by other techniques for the long-range analysis if the project became a reality.

With the signing of the cost-sharing agreement by the FCWA, WSSC, and the District of Columbia and the granting of the Section 404 permit in March 1982, as well as the initial construction contracting, the realization of the Little Seneca project was evident. Therefore, it was decided that the Little Seneca Lake storage should be considered as part of the without condition for the long-range planning phase.

For the supply base, then, the storage in Little Seneca Lake was monitored separately from the computer modelling for the critical drought periods. The conservation storage capacity was defined as 12,350 acre-feet (4,020 million gallons). Natural inflows and net reservoir evaporation losses were taken into account. For the period October 1929 to

September 1930, daily flow records from the Northwest Branch Anacostia River USGS gage at Colesville, Maryland (drainage area = 21.1 square miles), were adjusted by a factor of 0.851 to represent the Little Seneca Lake drainage area of 20.8 square miles. A direct linear relationship was not assumed because flow records from October 1930 through December 1932 indicated larger flows per unit area from the Northwest Branch than in the Seneca Creek basin. Inflows for October 1930 and later were linear transformations from the USGS Seneca Creek gage records at Dawsonville, based on a drainage area relationship. The net reservoir evaporation losses were derived from the monthly precipitation and evaporation values in the Project Development Report on Little Seneca Lake for the Washington Suburban Sanitary Commission (Black and Veatch, Consulting Engineers, 1980). For the simulation, a minimum release rate of 1.12 mgd (1.73 cfs) or the reservoir inflow, whichever was less, was maintained in accordance with Maryland environmental regulations. Water supply releases were assumed to flow without loss to the MWA intakes within the weekly release period. The timing and magnitude of the releases were based on deficit conditions in the MWA. If a deficit was projected for a particular week without a Little Seneca Lake release, then a reservoir release was made to avoid that deficit, up to the maximum outlet capacity of 275 mgd. If there was no projected deficit, then no release was made. This release policy is not necessarily the optimal strategy for regional management; however, model limitations prevented further analysis. With eventual regional management of the supply system, a day-to-day operational model will be able through CO-OP to better maximize the use of the system elements, including Little Seneca Lake.

A comparison of the analytical elements for the supply and demand analyses of the early-action phase and the long-range phase is presented in Table D-46. This table demonstrates that the long-range phase devoted considerably more analysis to reservoir storage and regional management of the MWA system than did the early-action phase.

ESTIMATED DEFICITS

With this redefined supply base and modified "without condition," a set of simulations was performed for 50 years of historical flow data between 1929 and 1979 using PRISM/COE. These simulations provided the base for the deficit analysis of the redefined "without condition" in the long-range planning phase. The data for this analysis are summarized in Table D-47. As noted in the data table, an estuary flowby level of 100 mgd was assumed in the without condition simulations. This value corresponds to the flow designated by the State of Maryland in its study as the minimum desired level of freshwater flow to the estuary. A summary of the simulation results for 1930-31 and 1966 flows are presented in Table D-48. An actual PRISM/COE simulation output is attached as Annex D-VI to this appendix.

The "without condition" simulation for the long-range phase showed that the MWA supply system, as it currently exists, could satisfy 2030 demands (Conservation Scenario 3) without difficulty. For the longest historical drought (1930-31) as well as the severest low flow occurrence (1966), the system would experience no deficits. A key to the system's operation without deficits is the availability of Little Seneca Lake releases on short notice. On some occasions, unpredicted sudden drops in Potomac River flow may cause deficits had not releases from Little Seneca Lake been immediately available.

For the 1930-31 drought, the simulated system operated for 13 weeks at the minimum flowby level as depicted in the Potomac River hydrograph in Figure D-39. For the

TABLE D-46

COMPARISON OF WATER SUPPLY BASE
AND DEMAND ASSUMPTIONS
EARLY-ACTION VS. LONG-RANGE

Description	Early-Action Planning	Long-Range Planning
MWA Demands	Round I forecast Conservation Scenario 3 Weekly peaks	Round I forecast Conservation Scenario 3 Monthly Average
Potomac Withdrawal Capacity		
FCWA	200 mgd	200 mgd
WSSC	400 mgd	400 mgd
WAD	650 mgd	650 mgd
Occoquan Max. Withdrawal	95 mgd	95 mgd
Patuxent Max. Withdrawal	55 mgd	55 mgd
Occoquan Storage	Not Addressed*	31,600 acre-feet
Patuxent Storage	Not Addressed*	31,000 acre-feet
Bloomington Storage, Total	Not Addressed*	92,000 acre-feet
Water Quality	Not Addressed	51,000 acre-feet
Water Supply	Not Addressed	41,000 acre-feet
Bloomington Release	135 mgd	Regional Need-Dependent
Travel Time of U/S Release	Not Addressed	47% 1st Week, 53% 2nd Week
Little Seneca Lake Storage	Not Addressed **	12,350 acre-feet
Little Seneca Lake Release	Not Addressed**	Offset Potential Deficits
Regional Managment	Not Addressed	Systems Approach
Flow Data	Frequency-Duration	Recorded Drought Simulation

* The storages in these reservoirs were not analyzed in detail in the early action analysis; however, their storage was considered as a supply source via their release capacity.

** Little Seneca Lake was considered in the plan formulation aspect, rather than the supply base.

remaining simulated periods in the 50 years of flow record, the minimum flowby of 100 mgd was reached in a total of 11 weeks of system operation; 7 weeks during 1966, 2 weeks during 1964, and 2 weeks during 1932. Otherwise, the system passed higher flows into the Potomac estuary.

Noting that the PRISM/COE simulations indicated the system could easily handle historical droughts with the 100 mgd flowby target, a sensitivity analysis using higher estuary flowby levels was performed. Additional flowby targets of 300 mgd and 500 mgd were selected for the sensitivity analysis. While the PRISM/COE simulations modelled the higher targets as an estuary need, the higher flowbys could also be viewed as additional system demands on the Potomac River source or as lower Potomac base flows. The additional Potomac demands could be the result of (1) larger population growth than anticipated in the Round I forecast, (2) higher unit water use than that indicated by Conservation Scenario 3, or (3) reduction in the water supply capability of an offstream source, such as the Occoquan or Patuxent Reservoir. In addition, the higher Potomac demand could conceptually represent a lower base river flow than recorded in

TABLE D-47
SUPPLY AND DEMAND
WITHOUT CONDITION 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
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
Seasonal Drawdown for Flood Control	yes
Flow Target at Luke, Maryland	78 mgd
Bloomington: Savage Release Ratios	time-dependent, flow-dependent
Water Supply Target Factor	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	400 mgd
FCWA	200 gmd
Potomac Estuary Flowby	100 mgd
LFAA provisions	No Freeze
Demand Year	2030
Level of Conservation	Scenario 3

TABLE D-48

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.

the past 50 years. Therefore, the higher flowby analysis was designed to evaluate how sensitive the MWA system was to greater demands or lower supply conditions than those in the "without condition" analysis which formed the basis for the long-range phase.

The simulation results for the flowby targets of 100, 300, and 500 mgd are tabulated in Tables D-49 through D-53 for the 5 major historical low flow periods. In the other 45 years of simulation, Little Seneca Lake releases were not needed even with a flowby target of 500 mgd. In the 50 years of simulated flow, Little Seneca Lake storage was released only in 2 years out of 50 with 100 mgd flowby, in 2 years with 300 mgd flowby, and in 5 years with 500 mgd flowby (in the other years, any reservoir drawdowns were due to net evaporation losses). With the 300 mgd estuary flowby target, system deficits occurred only for the 1930-31 flow simulation. The 500 mgd flowby target resulted in a severe MWA deficit in 1930-31, a moderate deficit in 1966, and an insignificant deficit in 1963. The extent of the deficits and flow conditions during the 1930-31 drought is clearly depicted by the simulated Potomac River hydrographs in Figures D-40 and D-41.

FIGURE D-39

SIMULATED POTOMAC RIVER HYDROGRAPH
WITHOUT CONDITION
100 MGD FLOWBY

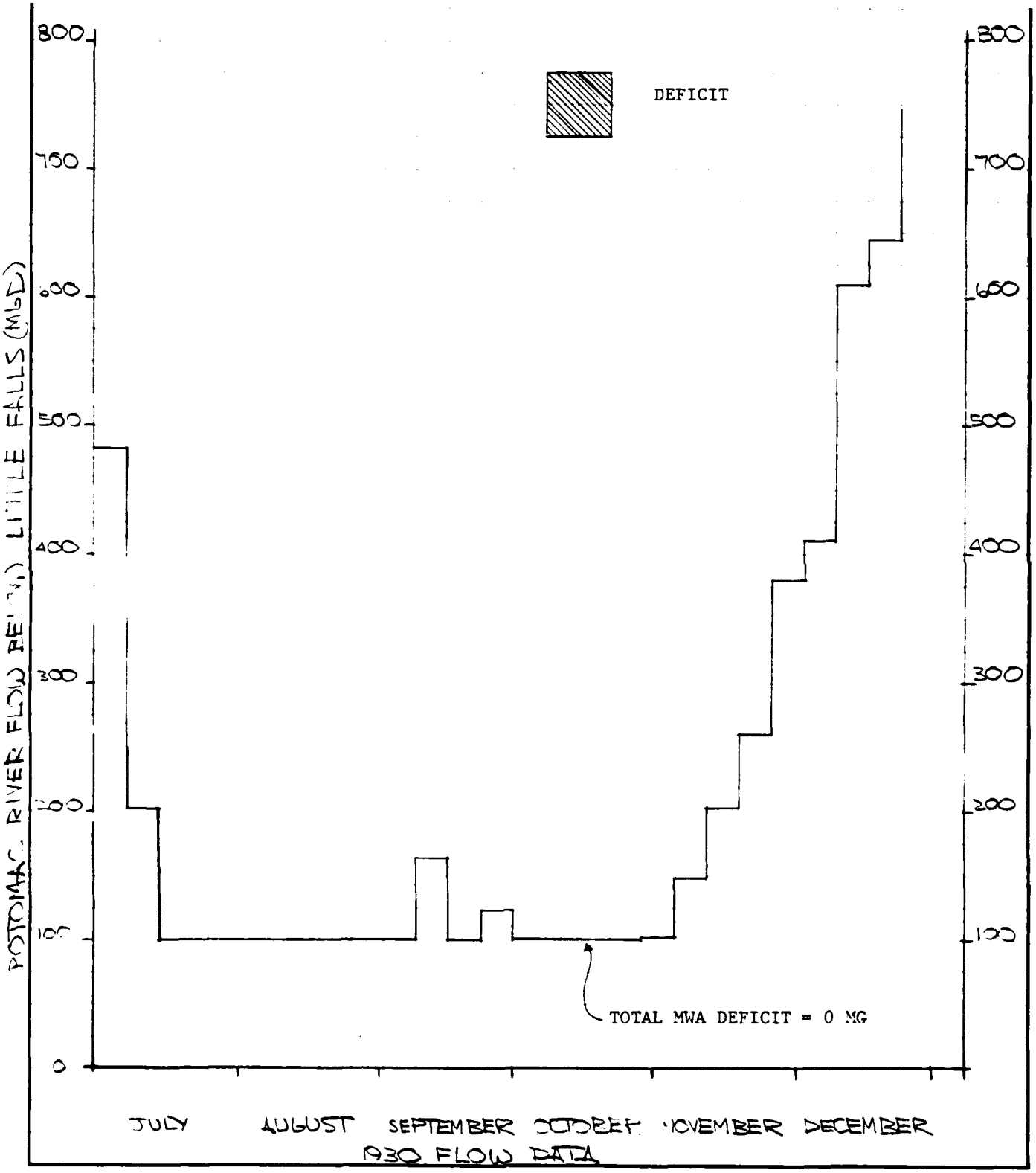


TABLE D-49
SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE
WITHOUT CONDITION
1930-31 FLOWS

	Flowby Level, mgd		
	100	300	500
Maximum Deficit, mgd			
WSSC	0	38	173
FCWA	0	23	63
WAD	0	38	150
Region	0	99	362
Cumulative Deficit, mg			
WSSC	0	835	14,503
FCWA	0	607	4,928
WAD	0	942	12,604
Total	0	2,384	32,035
Available Storage Remaining, mg			
Water Supply			
Bloomington	11,822	0	0
Occoqan	1,780	0	0
Patuxent	4,758	2,707	1,379
Little Seneca	3,797	0	0
Total	22,157	2,707	1,379
% of Capacity (37,790 mg)	58.6%	7.2%	3.6%
Non-Water supply			
Bloomington	13,275	6,852	6,778
Savage	4,801	543	0
Total	18,076	7,395	6,778
% of Capacity (22,530 mg)	80.2%	32.8%	30.1%
Total Storage Remaining	40,233	10,102	8,157
% of Total Capacity (60,320 mg)	66.7%	16.7%	13.5%
Weeks at Minimum Flowby level	13	18	21

TABLE D-50

SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE
WITHOUT CONDITION
1932 FLOWS

	Flowby Level, mgd		
	100	300	500
Maximum Deficit, mgd			
WSSC	0	0	0
FCWA	0	0	0
WAD	0	0	0
Region	0	0	0
Cumulative Deficit, mg			
WSSC	0	0	0
FCWA	0	0	0
WAD	0	0	0
Total	0	0	0
Available Storage Remaining, mg			
Water Supply			
Bloomington	13,370	7,527	0
Occoquan	8,559	7,636	7,871
Patuxent	8,259	7,934	7,745
Little Seneca	3,931	2,673*	356*
Total	34,119	25,770	15,972
% ofCapacity (37,790 mg)	90.3%	68.2%	42.3%
Non-Water Supply			
Bloomington	16,040	13,855	13,890
Savage	5,619	3,881	1,748
Total	21,659	17,736	15,638
% of Capacity (22,530 mg)	96.1%	78.7%	69.4%
Total Storage Remaining	55,778	43,506	31,610
% of Total Capacity (60,320 mg)	92.5%	72.1%	52.4%
Weeks at Minimum Flowby Level	2	4	3

*This 1932 simulation started with the Little Seneca pool partially drawn down, due to 1930-31 releases.

TABLE D-51

SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE
WITHOUT CONDITION
1963 FLOWS

	Flowby Level, mgd		
	100	300	500
Maximum Deficit, mgd			
WSSC	0	0	5
FCWA	0	0	6
WAD	0	0	10
Region	0	0	21
Cumulative Deficit, mg			
WSSC	0	0	34
FCWA	0	0	43
WAD	0	0	67
Total	0	0	144
Available Storage Remaining, mg			
Water Supply			
Bloomington	13,370	9,901	0
Occoquan	7,710	7,152	4,896
Patuxent	7,758	7,692	6,375
Little Seneca	4,018	3,998	0
Total	32,856	28,743	11,271
% of Capacity (37,790 mg)	86.9%	76.1%	29.8%
Non-Water Supply			
Bloomington	16,630	12,764	14,458
Savage	5,445	5,154	744
Total	22,075	17,918	15,202
% of Capacity (22,530 mg)	98.0%	79.5%	67.5%
Total Storage Remaining	54,931	46,661	26,473
% of Total Capacity (60,320 mg)	91.1%	77.4%	43.9%
Weeks at Minimum Flowby Level	0	3	7

TABLE D-52

SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE
WITHOUT CONDITION
1965 FLOWS

	Flowby Level, mgd		
	100	300	500
Maximum Deficit, mgd			
WSSC	0	0	0
FCWA	0	0	0
WAD	0	0	0
Region	0	0	0
Cumulative Deficit, mg			
WSSC	0	0	0
FCWA	0	0	0
WAD	0	0	0
Total	0	0	0
Available Storage Remaining, mg			
Water Supply			
Bloomington	13,370	8,341	0
Occoquan	8,676	7,662	5,040
Patuxent	7,169	6,986	5,840
Little Seneca	4,010	3,974	945
Total	33,225	27,073	11,699
% of Capacity (37,790 mg)	87.9%	71.6%	31.0%
Non-Water Supply			
Bloomington	13,820	13,034	10,305
Savage	5,069	4,218	1,003
Total	18,889	17,252	11,308
% of Capacity (22,530 mg)	83.8%	76.6%	50.2%
Total Storage Remaining	52,114	44,325	23,007
% of Total Capacity (60,320 mg)	86.4%	73.5%	38.1%
Weeks at Minimum Flowby Level	0	4	13

TABLE D-53

SUMMARY OF SIMULATION RESULTS FOR LONG-RANGE PHASE
WITHOUT CONDITION
1966 FLOWS

	Flowby Level, mgd		
	100	300	500
Maximum Deficit, mgd			
WSSC	0	0	235
FCWA	0	0	51
WAD	0	0	203
Region	0	0	487
Cumulative Deficit, mg			
WSSC	0	0	2,802
FCWA	0	0	713
WAD	0	0	2,343
Total	0	0	5,858
Available Storage Remaining, mg			
Water Supply			
Bloomington	12,225	862	0
Occoquan	6,181	6,163	5,764
Patuxent	7,033	7,171	6,789
Little Seneca	3,082	3,942	0*
Total	28,551	18,138	12,553
% of Capacity (37,790 mg)	75.6%	48.0%	33.2%
Non-Water Supply			
Bloomington	13,645	13,344	13,234
Savage	4,731	1,797	1,194
Total	18,376	15,141	14,428
% of Capacity (22,530 mg)	81.6%	67.2%	64.0%
Total Storage Remaining	46,927	33,279	26,981
% of Total Capacity (60,320)	77.8%	55.2%	44.7%
Weeks at Minimum Flowby Level	7	6	8

* This 1966 simulation started with the Little Seneca pool partially drawn down, due to 1965 releases.

FIGURE D-40

SIMULATED POTOMAC RIVER HYDROGRAPH
WITHOUT CONDITION
300 MGD FLOWBY

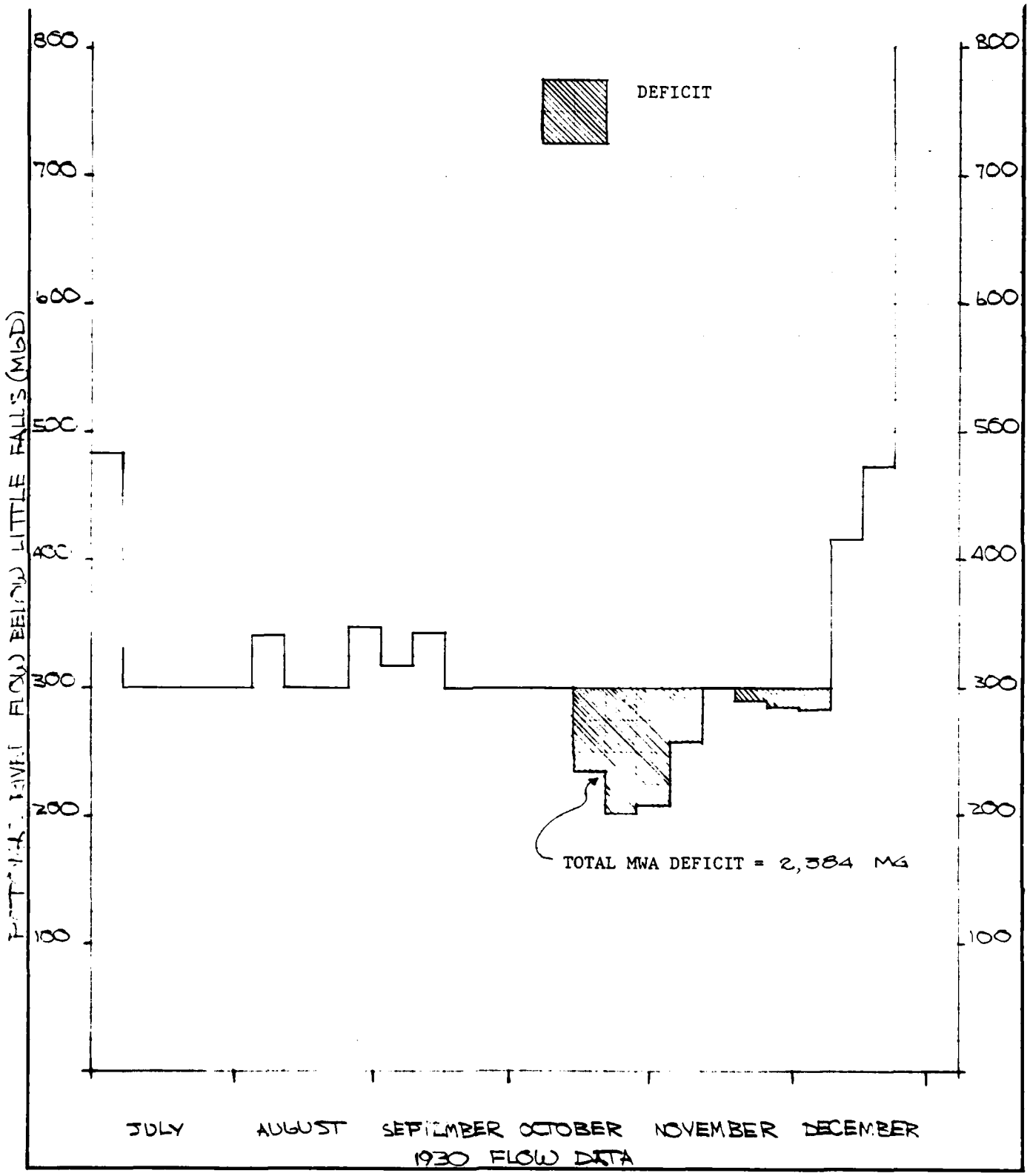
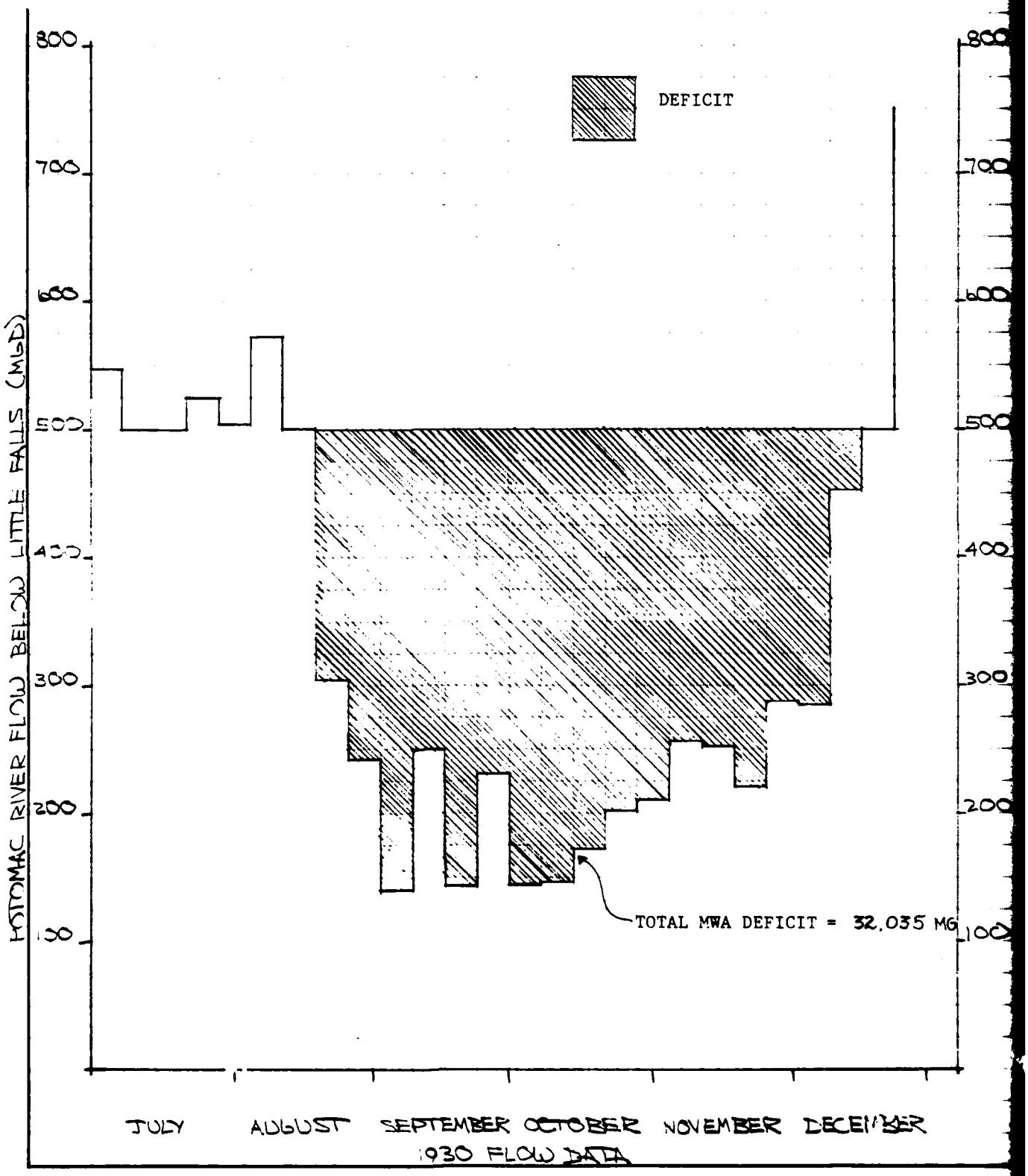


FIGURE D-41

SIMULATED POTOMAC RIVER HYDROGRAPH
WITHOUT CONDITION
500 MGD FLOWBY



ANNEX D-I

MWA WATER DEMAND GROWTH INDICATORS BY SERVICE AREA

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON AQUEDUCT DIVISION DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	1013342.	1016200.	1115900.	1173700.	1192400.	1215300.	1231000.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	394806.	389300.	456400.	484600.	497400.	512000.	524600.
TOTAL EMPLOYMENT SERVED	865250.	873500.	135[illegible].	1152900.	1213000.	1283300.	1350000.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.050	3.164	3.005	3.004	3.003	3.002	3.001
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.214	2.262	2.114	2.086	2.057	2.029	2.000
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	.652	.629	.591	.577	.562	.548	.533
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	.914	.880	.840	.831	.828	.811	.800
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.616	.621	.633	.644	.656	.668	.680
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.068	.070	.074	.078	.082	.087	.091
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.316	.309	.293	.278	.262	.245	.229
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	17.521	17.521	17.521	17.521	17.521	17.521	17.521

TABLE D-I-1

WASHINGTON AQUEDUCT DIVISION WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	1054873.	1112000.	1499700.	1759400.	2002800.	2210500.	2300500.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	354302.	390300.	526000.	629300.	730700.	826000.	904650.
TOTAL EMPLOYMENT SERVED	610000.	640700.	825600.	952500.	978600.	999000.	1101064.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.480	3.340	3.350	3.284	3.210	3.152	3.086
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.151	2.060	2.066	2.025	1.984	1.944	1.930
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	1.630	1.609	1.576	1.580	1.587	1.592	1.543
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	2.624	2.609	2.556	2.562	2.574	2.581	2.467
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.709	.710	.711	.713	.713	.713	.713
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.129	.124	.150	.167	.167	.167	.167
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.166	.166	.139	.121	.121	.121	.121
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	9.340	9.340	9.340	9.340	9.340	9.340	9.340

TABLE D-I-2

WASHINGTON SUBURBAN SANITARY COMMISSION WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX COUNTY WATER AUTHORITY DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	651000.	673800.	880300.	1033900.	1168200.	1338000.	1489900.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	218300.	228000.	312000.	373600.	430600.	502800.	570800.
TOTAL EMPLOYMENT SERVED	151000.	208100.	279300.	341600.	401900.	479200.	555700.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.425	3.399	3.253	3.203	3.133	3.106	3.080
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.114	2.098	2.088	1.977	1.968	1.918	1.824
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	1.960	1.930	1.887	1.815	1.774	1.672	1.672
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	3.176	3.127	3.057	2.941	2.824	2.708	2.824
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.667	.662	.652	.642	.642	.642	.642
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.191	.265	.229	.255	.255	.255	.255
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.142	.133	.119	.103	.103	.103	.103
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	9.161	9.161	9.161	9.161	9.161	9.161	9.161

TABLE D-I-3

FAIRFAX COUNTY WATER AUTHORITY WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS DEPARTMENT OF THE ARMY BALTIMORE DISTRICT	**** METROPOLITAN WASHINGTON AREA **** **** WATER SUPPLY STUDY **** **** WATER DEMAND PROJECTION MODEL ****	WATER RESOURCES ENGINEERS A DIVISION OF CAMP DRESSER AND MCKEE SPRINGFIELD, VIRGINIA

ROCKVILLE DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	43527.	48000.	51300.	54250.	55200.	56150.	57100.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	13733.	16700.	18600.	19100.	19600.	20100.	20600.
TOTAL EMPLOYMENT SERVED	26899.	34300.	41200.	45400.	48130.	49770.	50800.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.670	3.291	3.195	3.199	3.201	3.203	3.205
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	1.760	1.757	1.753	1.750	1.750	1.750	1.750
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	2.836	3.159	3.374	3.040	2.772	2.549	2.359
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	5.873	5.917	6.156	5.557	5.070	4.665	4.320
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.696	.679	.649	.616	.616	.616	.616
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.271	.291	.325	.361	.361	.361	.361
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.032	.030	.027	.023	.023	.023	.023
UNACCOUNTED WATER USE (PERCENT OF TOTAL)	4.695	4.695	4.695	4.695	4.695	4.695	4.695

TABLE D-I-4

ROCKVILLE WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS DEPARTMENT OF THE ARMY BALTIMORE DISTRICT	**** METROPOLITAN WASHINGTON AREA **** **** WATER SUPPLY STUDY **** **** WATER DEMAND PROJECTION MODEL ****	WATER RESOURCES ENGINEERS A DIVISION OF CAMP DRESSER AND MCKEE SPRINGFIELD, VIRGINIA

FAIRFAX CITY DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	58572.	77500.	112500.	136500.	160800.	191500.	221600.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	16218.	24900.	37500.	45900.	55200.	67100.	79300.
TOTAL EMPLOYMENT SERVED	26580.	30300.	37600.	46650.	57900.	71850.	89200.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.364	3.363	3.234	3.218	3.156	3.096	3.036
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.316	2.299	2.256	2.213	2.170	2.127	2.084
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	3.265	3.241	3.191	3.121	3.060	3.000	2.940
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	4.742	4.742	4.360	4.538	4.450	4.367	4.283
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.617	.609	.544	.496	.496	.496	.496
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.372	.381	.446	.496	.496	.496	.496
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.011	.010	.009	.008	.008	.008	.008
UNACCOUNTED WATER USE (PERCENT OF TOTAL)	24.938	24.938	24.938	24.938	24.938	24.938	24.938

TABLE D-I-5

FAIRFAX CITY WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

PRINCE WILLIAM COUNTY DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	47254.	55000.	74600.	110300.	151000.	189400.	231400.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	14350.	17000.	23700.	30800.	51200.	66500.	84200.
TOTAL EMPLOYMENT SERVED	24264.	25600.	31000.	37000.	46200.	57400.	70400.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.569	3.524	3.429	3.329	3.230	3.130	3.030
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.190	2.164	2.195	2.044	1.983	1.923	1.862
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	3.963	3.704	3.706	3.509	3.441	3.282	3.145
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	6.450	6.026	6.019	5.845	5.605	5.342	5.110
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.288	.310	.346	.452	.514	.549	.583
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.123	.126	.144	.164	.183	.199	.212
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.597	.564	.465	.344	.313	.252	.205
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	12.186	12.186	12.186	12.186	12.186	12.186	12.186

TABLE D-I-6

PRINCE WILLIAM COUNTY WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

LOUDOUN COUNTY DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1970	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	10890.	13600.	23030.	38400.	59700.	88300.	125100.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	3180.	3970.	7100.	12000.	18800.	28200.	40500.
TOTAL EMPLOYMENT SERVED	2280.	2920.	5080.	8900.	14800.	23400.	35400.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.674	3.586	3.402	3.372	3.359	3.328	3.300
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.540	2.479	2.346	2.320	2.305	2.277	2.250
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	6.054	5.899	5.511	5.122	4.734	4.346	3.974
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	8.756	8.537	7.991	7.445	6.899	6.352	5.828
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.636	.654	.650	.656	.656	.656	.656
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.132	.135	.159	.176	.176	.176	.176
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.232	.211	.196	.168	.168	.168	.168
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	14.000	14.000	14.000	14.000	14.000	14.000	14.000

TABLE D-I-7

LOUDOUN COUNTY WATER SERVICE AREA GROWTH INDICATORS

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

CHARLES COUNTY DEMAND AREA

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	13720.	23400.	44200.	56000.	84900.	100400.	113200.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	4161.	7280.	13800.	17900.	27700.	33400.	38560.
TOTAL EMPLOYMENT SERVED	7950.	13640.	24700.	30400.	45000.	51600.	56600.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.479	3.453	3.389	3.324	3.260	3.195	3.131
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.568	2.481	2.435	2.389	2.343	2.296	2.250
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	4.388	4.289	4.126	3.782	3.702	3.756	3.511
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	6.186	5.970	5.743	5.263	5.151	5.227	4.845
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.698	.715	.754	.754	.798	.798	.798
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.158	.154	.125	.126	.105	.105	.105
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.144	.131	.120	.120	.105	.105	.105
UNACCOUNTED WATER USE (PERCENT OF TOTAL)	13.763	13.763	13.763	13.763	13.763	13.763	13.763

TABLE D-I-8

CHARLES COUNTY WATER SERVICE AREA GROWTH INDICATORS

ANNEX D-II

SERVICE AREA WATER DEMAND AND UNIT USE BY CATEGORY (1976)

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON AQUEDUCT DIVISION DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	157362.	DWELLINGS	270.1	42.500
MULTI-FAMILY	241438.	DWELLINGS	262.6	63.410
COMMERCIAL/ INDUSTRIAL	532994.	EMPLOYEES	31.2	16.640
GOVERNMENTAL/ INSTITUTIONAL	50837.	EMPLOYEES	185.8	10.930
FEDERAL GOVERNMENT	273419.	EMPLOYEES	100.8	27.560
UNNACCOUNTED	N/A	N/A	N/A	34.210
TOTAL POP	1013342.	PERSONS	192.7	195.250

TABLE D-II-1

WASHINGTON AQUEDUCT DIVISION WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	218975.	DWELLINGS	281.2	61.580
MULTI-FAMILY	135327.	DWELLINGS	280.8	38.000
COMMERCIAL/ INDUSTRIAL	291257.	EMPLOYEES	61.5	17.910
GOVERNMENTAL/ INSTITUTIONAL	51359.	EMPLOYEES	70.5	3.620
FEDERAL GOVERNMENT	68193.	EMPLOYEES	73.0	4.980
UNACCOUNTED	N/A	N/A	N/A	12.990
TOTAL Pop	1054873.	PERSONS	131.8	139.080

TABLE D-II-2
WSSC WATER SERVICE AREA BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX COUNTY WATER AUTHORITY DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	144557.	DWELLINGS	198.2	28.652
MULTI-FAMILY	73743.	DWELLINGS	207.8	15.266
COMMERCIAL/ INDUSTRIAL	100717.	EMPLOYEES	72.2	7.273
GOVERNMENTAL/ INSTITUTIONAL	28841.	EMPLOYEES	128.1	3.694
FEDERAL GOVERNMENT	21442.	EMPLOYEES	175.8	3.770
UNACCOUNTED	N/A	N/A	N/A	5.915
TOTAL PoF	651988.	PERSONS	99.2	64.570

TABLE D-II-3

FCWA WATER SERVICE AREA BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

ROCKVILLE DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	10135.	DWELLINGS	189.8	1.924
MULTI-FAMILY	3598.	DWELLINGS	155.9	.561
COMMERCIAL/ INDUSTRIAL	18727.	EMPLOYEES	57.0	1.068
GOVERNMENTAL/ INSTITUTIONAL	7298.	EMPLOYEES	43.5	.317
FEDERAL GOVERNMENT	861.	EMPLOYEES	55.6	.048
UNMACCOUNTED	N/A	N/A	N/A	.193
TOTAL	43527.	PERSONS	94.4	4.111

TABLE D-II-4

ROCKVILLE WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX CITY DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	12415.	DWELLINGS	279.1	3.465
MULTI-FAMILY	3803.	DWELLINGS	314.2	1.195
COMMERCIAL/ INDUSTRIAL	16400.	EMPLOYEES	51.8	.849
GOVERNMENTAL/ INSTITUTIONAL	9888.	EMPLOYEES	19.2	.190
FEDERAL GOVERNMENT	292.	EMPLOYEES	17.1	.005
UNMACCOUNTED	N/A	N/A	N/A	1.895
TOTAL POP.	56972.	PERSONS	150.3	7.599

TABLE D-II-5

FAIRFAX CITY WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

PRINCE WILLIAM COUNTY DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	11465.	DWELLINGS	194.8	2.224
MULTI-FAMILY	2891.	DWELLINGS	166.3	.481
COMMERCIAL/ INDUSTRIAL	6777.	EMPLOYEES	114.0	.772
GOVERNMENTAL/ INSTITUTIONAL	2977.	EMPLOYEES	45.3	.135
FEDERAL GOVERNMENT	14458.	EMPLOYEES	170.5	2.464
UNACCOUNTED	N/A	N/A	N/A	.844
TOTAL POP.	47254.	PERSONS	146.6	6.926

TABLE D-II-6

PRINCE WILLIAM COUNTY WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

LOUDOUN COUNTY DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	2661.	DWELLINGS	395.8	1.053
MULTI-FAMILY	439.	DWELLINGS	261.7	.115
COMMERCIAL/ INDUSTRIAL	1450.	EMPLOYEES	150.3	.218
GOVERNMENTAL/ INSTITUTIONAL	301.	EMPLOYEES	86.4	.026
FEDERAL GOVERNMENT	529.	EMPLOYEES	11.3	.006
UNACCOUNTED	N/A	N/A	N/A	.231
TOTAL POP	10490.	PERSONS	151.4	1.649

TABLE D-II-7

LOUDOUN COUNTY WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
WATER SUPPLY STUDY ****
WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

CHARLES COUNTY DEMAND AREA

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	3389.	DWELLINGS	289.8	.982
MULTI-FAMILY	772.	DWELLINGS	240.8	.186
COMMERCIAL/ INDUSTRIAL	5549.	EMPLOYEES	36.8	.204
GOVERNMENTAL/ INSTITUTIONAL	1256.	EMPLOYEES	36.6	.046
FEDERAL GOVERNMENT	1145.	EMPLOYEES	36.7	.042
UNACCOUNTED	N/A	N/A	N/A	.233
TOTAL	13720.	PERSONS	123.4	1.693

TABLE D-II-8

CHARLES COUNTY WATER SERVICE AREA
BASE YEAR (1976) UNIT WATER USE

ANNEX D-III

PROJECTED BASELINE WATER DEMANDS
(1980-2030)

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON AQUEDUCT DIVISION DEMAND AREA
BASELINE

TABLE D-III-1

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	1013342.	1016200.	1115900.	1173700.	1192400.	1215300.	1231000.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	398000.	389300.	456400.	484600.	497400.	512000.	524600.
TOTAL EMPLOYMENT SERVED	865250.	873500.	1059600.	1152900.	1213000.	1203300.	1350000.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.058	3.164	3.005	3.004	3.003	3.002	3.001
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.264	2.262	2.114	2.086	2.057	2.029	2.000
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	.652	.629	.591	.577	.562	.548	.533
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	.904	.880	.848	.831	.828	.811	.808
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.616	.621	.633	.644	.656	.668	.680
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.068	.070	.074	.078	.082	.087	.091
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.316	.309	.293	.278	.262	.245	.229
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	17.521	17.521	17.521	17.521	17.521	17.521	17.521

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**** WATER DEMAND PROJECTION MODEL ****

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A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON AQUEDUCT DIVISION DEMAND AREA
BASELINE

TABLE D-III-2

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
SINGLE FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	157362.	DWELLINGS	270.1	42.500
1976 TOTAL	157362.	DWELLINGS	270.1	42.500
PRE-1976	157362.	DWELLINGS	278.0	43.743
1976-1980	-7043.	DWELLINGS	206.5	-1.454
1980 TOTAL	150319.	DWELLINGS	281.3	42.289
PRE-1976	157362.	DWELLINGS	266.2	41.895
1976-1980	-7043.	DWELLINGS	198.0	-1.394
1980-1990	19232.	DWELLINGS	198.0	3.807
1990 TOTAL	169552.	DWELLINGS	261.3	44.308
PRE-1976	157362.	DWELLINGS	266.2	41.884
1976-1980	-7043.	DWELLINGS	197.9	-1.394
1980-1990	19232.	DWELLINGS	197.9	3.806
1990-2000	7817.	DWELLINGS	197.9	1.547
2000 TOTAL	177369.	DWELLINGS	258.5	45.843
PRE-1976	157362.	DWELLINGS	266.1	41.872
1976-1980	-7043.	DWELLINGS	197.9	-1.393
1980-1990	19232.	DWELLINGS	197.9	3.805
1990-2000	7817.	DWELLINGS	197.9	1.547
2000-2010	1541.	DWELLINGS	197.9	.305
2010 TOTAL	178909.	DWELLINGS	257.9	46.136
PRE-1976	157362.	DWELLINGS	266.0	41.861
1976-1980	-7043.	DWELLINGS	197.8	-1.393
1980-1990	19232.	DWELLINGS	197.8	3.804
1990-2000	7817.	DWELLINGS	197.8	1.546
2000-2010	1541.	DWELLINGS	197.8	.305
2010-2020	2439.	DWELLINGS	197.8	.482
2020 TOTAL	181348.	DWELLINGS	257.8	46.686
PRE-1976	157362.	DWELLINGS	265.9	41.850
1976-1980	-7043.	DWELLINGS	197.8	-1.393
1980-1990	19232.	DWELLINGS	197.8	3.803
1990-2000	7817.	DWELLINGS	197.8	1.546
2000-2010	1541.	DWELLINGS	197.8	.305
2010-2020	2439.	DWELLINGS	197.8	.482
2020-2030	1069.	DWELLINGS	197.8	.211
2030 TOTAL	182418.	DWELLINGS	256.6	46.884

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TABLE D-III-3

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
MULTI-FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	241438.	DWELLINGS	262.6	63.410
1976 TOTAL	241438.	DWELLINGS	262.6	63.410
PRE-1976	241438.	DWELLINGS	266.0	64.411
1976-1980	-2457.	DWELLINGS	198.2	-.487
1980 TOTAL	238981.	DWELLINGS	267.5	63.924
PRE-1976	241438.	DWELLINGS	256.3	61.885
1976-1980	-2457.	DWELLINGS	190.6	-.468
1980-1990	47868.	DWELLINGS	190.6	9.125
1990 TOTAL	286848.	DWELLINGS	245.9	70.542
PRE-1976	241439.	DWELLINGS	254.4	61.419
1976-1980	-2457.	DWELLINGS	189.2	-.465
1980-1990	47868.	DWELLINGS	189.2	9.058
1990-2000	20383.	DWELLINGS	189.2	3.857
2000 TOTAL	307231.	DWELLINGS	240.4	73.869
PRE-1976	241438.	DWELLINGS	252.4	60.940
1976-1980	-2457.	DWELLINGS	187.8	-.461
1980-1990	47868.	DWELLINGS	187.8	8.989
1990-2000	20383.	DWELLINGS	187.8	3.828
2000-2010	11259.	DWELLINGS	187.8	2.114
2010 TOTAL	318491.	DWELLINGS	236.8	75.410
PRE-1976	241438.	DWELLINGS	250.5	60.481
1976-1980	-2457.	DWELLINGS	186.4	-.458
1980-1990	47868.	DWELLINGS	186.4	8.923
1990-2000	20383.	DWELLINGS	186.4	3.800
2000-2010	11259.	DWELLINGS	186.4	2.099
2010-2020	12161.	DWELLINGS	186.4	2.267
2020 TOTAL	330652.	DWELLINGS	233.2	77.112
PRE-1976	241438.	DWELLINGS	248.6	60.010
1976-1980	-2457.	DWELLINGS	185.0	-.455
1980-1990	47868.	DWELLINGS	185.0	8.856
1990-2000	20383.	DWELLINGS	185.0	3.771
2000-2010	11259.	DWELLINGS	185.0	2.083
2010-2020	12161.	DWELLINGS	185.0	2.250
2020-2030	11531.	DWELLINGS	185.0	2.133
2030 TOTAL	342182.	DWELLINGS	229.0	78.648

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TABLE D-III-4

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
COMMERICAL-INDUSTRIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976 TOTAL	532994.	EMPLOYEES	31.2	16.640
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980 TOTAL	542444.	EMPLOYEES	31.1	16.885
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980-1990	128283.	EMPLOYEES	25.9	3.327
1990 TOTAL	670727.	EMPLOYEES	30.1	20.212
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980-1990	128283.	EMPLOYEES	25.9	3.327
1990-2000	71741.	EMPLOYEES	25.9	1.861
2000 TOTAL	742460.	EMPLOYEES	29.7	22.073
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980-1990	128283.	EMPLOYEES	25.9	3.327
1990-2000	71741.	EMPLOYEES	25.9	1.861
2000-2010	53260.	EMPLOYEES	25.9	1.381
2010 TOTAL	795728.	EMPLOYEES	29.5	23.455
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980-1990	128283.	EMPLOYEES	25.9	3.327
1990-2000	71741.	EMPLOYEES	25.9	1.861
2000-2010	53260.	EMPLOYEES	25.9	1.381
2010-2020	61516.	EMPLOYEES	25.9	1.596
2020 TOTAL	857244.	EMPLOYEES	29.2	25.050
PRE-1976	532994.	EMPLOYEES	31.2	16.640
1976-1980	9449.	EMPLOYEES	25.9	.245
1980-1990	128283.	EMPLOYEES	25.9	3.327
1990-2000	71741.	EMPLOYEES	25.9	1.861
2000-2010	53260.	EMPLOYEES	25.9	1.381
2010-2020	61516.	EMPLOYEES	25.9	1.596
2020-2030	60756.	EMPLOYEES	25.9	1.576
2030 TOTAL	918000.	EMPLOYEES	29.0	26.626

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TABLE D-III-5

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
GOVERNMENTAL-INSTITUTIONAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976 TOTAL	58837.	EMPLOYEES	185.8	10.930
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980 TOTAL	61145.	EMPLOYEES	184.8	11.301
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980-1990	17265.	EMPLOYEES	160.6	2.772
1990 TOTAL	78410.	EMPLOYEES	179.5	14.073
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980-1990	17265.	EMPLOYEES	160.6	2.772
1990-2000	11516.	EMPLOYEES	160.6	1.849
2000 TOTAL	89926.	EMPLOYEES	177.1	15.922
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980-1990	17265.	EMPLOYEES	160.6	2.772
1990-2000	11516.	EMPLOYEES	160.6	1.849
2000-2010	9540.	EMPLOYEES	160.6	1.532
2010 TOTAL	99466.	EMPLOYEES	175.5	17.453
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980-1990	17265.	EMPLOYEES	160.6	2.772
1990-2000	11516.	EMPLOYEES	160.6	1.849
2000-2010	9540.	EMPLOYEES	160.6	1.532
2010-2020	12181.	EMPLOYEES	160.6	1.956
2020 TOTAL	111647.	EMPLOYEES	173.8	19.409
PRE-1976	58837.	EMPLOYEES	185.8	10.930
1976-1980	2308.	EMPLOYEES	160.6	.371
1980-1990	17265.	EMPLOYEES	160.6	2.772
1990-2000	11516.	EMPLOYEES	160.6	1.849
2000-2010	9540.	EMPLOYEES	160.6	1.532
2010-2020	12181.	EMPLOYEES	160.6	1.956
2020-2030	11203.	EMPLOYEES	160.6	1.799
2030 TOTAL	122850.	EMPLOYEES	172.6	21.208

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BASELINE

D-III-6

TABLE

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
FEDERAL GOVERNMENT

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976 TOTAL	273419.	EMPLOYEES	100.8	27.560
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1980 TOTAL	269912.	EMPLOYEES	101.0	27.254
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1980-1990	40551.	EMPLOYEES	87.1	3.533
1990 TOTAL	310463.	EMPLOYEES	99.2	30.787
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1990-1996	40551.	EMPLOYEES	87.1	3.533
1990-2000	10043.	EMPLOYEES	87.1	.875
2000 TOTAL	320586.	EMPLOYEES	98.8	31.662
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1990-1990	40551.	EMPLOYEES	87.1	3.533
1990-2000	10043.	EMPLOYEES	87.1	.875
2000-2010	-2749.	EMPLOYEES	87.1	-.235
2010 TOTAL	317806.	EMPLOYEES	98.9	31.427
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1990-1990	40551.	EMPLOYEES	87.1	3.533
1990-2000	10043.	EMPLOYEES	87.1	.875
2000-2010	-2700.	EMPLOYEES	87.1	-.235
2010-2020	-3398.	EMPLOYEES	87.1	-.296
2020 TOTAL	314409.	EMPLOYEES	99.0	31.131
PRE-1976	273419.	EMPLOYEES	100.8	27.560
1976-1980	-3508.	EMPLOYEES	87.1	-.306
1990-1990	40551.	EMPLOYEES	87.1	3.533
1990-2000	10043.	EMPLOYEES	87.1	.875
2000-2010	-2700.	EMPLOYEES	87.1	-.235
2010-2020	-3399.	EMPLOYEES	87.1	-.296
2020-2030	-5259.	EMPLOYEES	87.1	-.458
2030 TOTAL	309150.	EMPLOYEES	99.2	30.673

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TABLE D-III-7

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	157362.	DWELLINGS	270.1	42.500
MULTI-FAMILY	241438.	DWELLINGS	262.6	63.410
COMMERCIAL/ INDUSTRIAL	532994.	EMPLOYEES	31.2	16.640
GOVERNMENTAL/ INSTITUTIONAL	58837.	EMPLOYEES	185.8	10.930
FEDERAL GOVERNMENT	273419.	EMPLOYEES	100.8	27.560
UNNACCOUNTED	N/A	N/A	N/A	34.210
TOTAL	1613342.	PERSONS	192.7	195.250

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TABLE D-III-8

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1980

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	150319.	DWELLINGS	281.3	42.289
MULTI-FAMILY	238981.	DWELLINGS	267.5	63.924
COMMERCIAL/ INDUSTRIAL	542444.	EMPLOYEES	31.1	16.885
GOVERNMENTAL/ INSTITUTIONAL	61145.	EMPLOYEES	184.8	11.301
FEDERAL GOVERNMENT	269912.	EMPLOYEES	101.0	27.254
UNNACCOUNTED	N/A	N/A	N/A	34.340
TOTAL	1016230.	PERSONS	192.9	195.993

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TABLE D-III-9

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1990

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	169552.	DWELLINGS	261.3	44.308
MULTI-FAMILY	286848.	DWELLINGS	245.9	70.542
COMMERCIAL/ INDUSTRIAL	670727.	EMPLOYEES	30.1	20.212
GOVERNMENTAL/ INSTITUTIONAL	78410.	EMPLOYEES	179.5	14.073
FEDERAL GOVERNMENT	310463.	EMPLOYEES	99.2	30.787
UNNACCOUNTED	N/A	N/A	N/A	38.221
TOTAL	1115908.	PERSONS	195.5	218.143

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TABLE

RESULTING WATER DEMAND AN D-III-10 H TIME HORIZON
2000

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	177369.	DWELLINGS	258.5	45.843
MULTI-FAMILY	387231.	DWELLINGS	248.4	73.869
COMMERCIAL/ INDUSTRIAL	742468.	EMPLOYEES	29.7	22.073
GOVERNMENTAL/ INSTITUTIONAL	89926.	EMPLOYEES	177.1	15.922
FEDERAL GOVERNMENT	326506.	EMPLOYEES	98.8	31.662
UNNACCOUNTED	N/A	N/A	N/A	40.228
TOTAL	1173700.	PERSONS	195.6	229.597

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TABLE D-III-11

RESULTING WATER DEMAND AT EACH TIME HORIZON

2010

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	178909.	DWELLINGS	257.9	46.136
MULTI-FAMILY	318491.	DWELLINGS	236.8	75.410
COMMERCIAL/ INDUSTRIAL	795728.	EMPLOYEES	29.5	23.455
GOVERNMENTAL/ INSTITUTIONAL	99466.	EMPLOYEES	175.5	17.453
FEDERAL GOVERNMENT	317886.	EMPLOYEES	98.9	31.427
UNNACCOUNTED	N/A	N/A	N/A	41.186
TOTAL	1192480.	PERSONS	197.1	235.066

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TABLE D-III-12

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
2020

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	181348.	DWELLINGS	257.8	46.686
MULTI-FAMILY	330652.	DWELLINGS	233.2	77.112
COMMERCIAL/ INDUSTRIAL	857244.	EMPLOYEES	29.2	25.858
GOVERNMENTAL/ INSTITUTIONAL	111647.	EMPLOYEES	173.8	19.489
FEDERAL GOVERNMENT	314489.	EMPLOYEES	99.8	31.131
UNNACCOUNTED	N/A	N/A	N/A	42.339
TOTAL	1215308.	PERSONS	198.8	241.646

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TABLE D-III-13

RESULTING WATER DEMAND AND U... USE FOR EACH TIME HORIZON
2030

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	182418.	DWELLINGS	256.6	46.804
MULTI-FAMILY	342182.	DWELLINGS	229.8	78.648
COMMERCIAL/ INDUSTRIAL	918868.	EMPLOYEES	29.0	26.626
GOVERNMENTAL/ INSTITUTIONAL	122858.	EMPLOYEES	172.6	21.208
FEDERAL GOVERNMENT	309158.	EMPLOYEES	99.2	30.673
UNNACCOUNTED	N/A	N/A	N/A	43.327
TOTAL	1231608.	PERSONS	200.8	247.286

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TABLE D-III-14

SUMMARY OF WATER DEMAND IN EACH CATEGORY FOR EACH TIME HORIZON

TIME HORIZON	SINGLE FAMILY (MGD)	MULTI-FAMILY (MGD)	COMMERICAL/ INDUSTRIAL (MGD)	GOVERNMENTAL/ INSTITUTIONAL (MGD)	FEDERAL GOVERNMENT (MGD)	UNNACCOUNTED FOR USE (MGD)	TOTAL USE (MGD)
1976	42.508	63.410	16.640	18.938	27.568	34.218	195.250
1980	42.289	63.924	16.885	11.381	27.254	34.340	195.993
1990	44.308	70.542	20.212	14.873	30.787	38.221	218.143
2000	45.843	73.869	22.873	15.922	31.662	40.228	229.597
2010	46.136	75.418	23.455	17.453	31.427	41.186	235.066
2020	46.606	77.112	25.050	19.489	31.131	42.339	241.646
2030	46.804	78.648	26.626	21.268	30.673	43.327	247.286

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TABLE D-III-15

MONTHLY DEMANDS (MGD) BY TIME HORIZON

TIME HORIZON	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1976	179.347	178.378	174.150	182.182	198.367	218.625	228.838	225.479	211.841	195.676	185.404	183.657
1988	180.245	179.263	175.821	183.813	191.220	211.405	228.398	225.865	212.408	195.866	186.332	181.560
1998	199.512	198.425	193.738	202.577	212.542	236.425	256.522	253.534	237.612	218.839	206.258	200.960
2008	209.662	208.528	203.587	212.883	223.649	249.171	278.646	267.453	250.438	229.524	216.743	211.193
2018	214.447	213.279	208.233	217.741	228.963	255.328	277.498	274.288	256.629	235.038	221.698	216.812
2028	220.217	219.018	213.836	223.608	235.364	262.704	285.709	282.289	264.062	241.658	227.655	221.825
2038	225.139	223.912	218.614	228.597	240.851	269.056	292.789	289.268	270.457	247.343	232.742	226.782

CORPS OF ENGINEERS DEPARTMENT OF THE ARMY BALTIMORE DISTRICT	**** METROPOLITAN WASHINGTON AREA **** **** WATER SUPPLY STUDY **** **** WATER DEMAND PROJECTION MODEL ****	WATER RESOURCES ENGINEERS A DIVISION OF CAMP DRESSER AND MCKEE SPRINGFIELD, VIRGINIA

WASHINGTON AQUEDUCT DIVISION DEMAND AREA
BASELINE

TABLE D-III-16

SUMMARY TABLE OF OVERALL WATER DEMAND BY TIME HORIZON

TIME HORIZON	TOTAL USE (MGD)	TOTAL POPULATION (PERSONS)	AVERAGE DAILY USE/ TOTAL POPULATION (GPD/PERSON)
1976	195.258	1013342.	192.7
1980	195.993	1016200.	192.9
1990	218.143	1115900.	195.5
2000	229.597	1173700.	195.6
2010	235.066	1192400.	197.1
2020	241.646	1215300.	198.8
2030	247.286	1231800.	200.8

CORPS OF ENGINEERS
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BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
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WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-17

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	1054873.	1112000.	1499700.	1759400.	2002800.	2218500.	2305500.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	354302.	390300.	526000.	629300.	730700.	826000.	904650.
TOTAL EMPLOYMENT SERVED	410000.	440700.	625600.	752500.	878600.	999000.	1101064.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.408	3.340	3.350	3.284	3.218	3.152	3.086
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.151	2.060	2.066	2.025	1.984	1.944	1.930
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	1.618	1.609	1.576	1.580	1.587	1.592	1.543
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	2.624	2.609	2.556	2.562	2.574	2.581	2.467
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.709	.710	.711	.713	.713	.713	.713
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.125	.124	.150	.167	.167	.167	.167
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.166	.166	.139	.121	.121	.121	.121
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	9.340	9.340	9.340	9.340	9.340	9.340	9.340

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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
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TABLE D-III-18

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
SINGLE FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	218975.	DWELLINGS	281.2	61.580
1976 TOTAL	218975.	DWELLINGS	281.2	61.580
PRE-1976	218975.	DWELLINGS	270.2	59.173
1976-1980	21739.	DWELLINGS	281.4	4.379
1980 TOTAL	240714.	DWELLINGS	264.0	63.552
PRE-1976	218975.	DWELLINGS	270.9	59.330
1976-1980	21739.	DWELLINGS	202.0	4.391
1980-1990	81088.	DWELLINGS	202.0	16.377
1990 TOTAL	321802.	DWELLINGS	248.9	80.098
PRE-1976	218975.	DWELLINGS	266.2	58.291
1976-1980	21739.	DWELLINGS	198.5	4.316
1980-1990	81088.	DWELLINGS	198.5	16.098
1990-2000	63569.	DWELLINGS	198.5	12.620
2000 TOTAL	385372.	DWELLINGS	237.0	91.324
PRE-1976	218975.	DWELLINGS	261.5	57.270
1976-1980	21739.	DWELLINGS	195.1	4.242
1980-1990	81088.	DWELLINGS	195.1	15.824
1990-2000	63569.	DWELLINGS	195.1	12.405
2000-2010	62911.	DWELLINGS	195.1	12.277
2010 TOTAL	448283.	DWELLINGS	227.6	102.018
PRE-1976	218975.	DWELLINGS	257.0	56.270
1976-1980	21739.	DWELLINGS	191.0	4.170
1980-1990	81088.	DWELLINGS	191.0	15.555
1990-2000	63569.	DWELLINGS	191.0	12.194
2000-2010	62911.	DWELLINGS	191.0	12.068
2010-2020	59088.	DWELLINGS	191.0	11.319
2020 TOTAL	507295.	DWELLINGS	219.9	111.577
PRE-1976	218975.	DWELLINGS	252.5	55.288
1976-1980	21739.	DWELLINGS	188.6	4.100
1980-1990	81088.	DWELLINGS	188.6	15.291
1990-2000	63569.	DWELLINGS	188.6	11.988
2000-2010	62911.	DWELLINGS	188.6	11.864
2010-2020	59088.	DWELLINGS	188.6	11.120
2020-2030	41594.	DWELLINGS	188.6	7.844
2030 TOTAL	548884.	DWELLINGS	214.1	117.501

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A DIVISION OF CAMP DRESSER AND MCKEE
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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-19

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
MULTI-FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	135327.	DWELLINGS	280.8	38.000
1976 TOTAL	135327.	DWELLINGS	280.8	38.000
PRE-1976	135327.	DWELLINGS	274.0	37.077
1976-1980	14259.	DWELLINGS	204.2	2.911
1980 TOTAL	149586.	DWELLINGS	267.3	39.988
PRE-1976	135327.	DWELLINGS	274.4	37.137
1976-1980	14259.	DWELLINGS	204.5	2.916
1980-1990	54612.	DWELLINGS	204.5	11.167
1990 TOTAL	204198.	DWELLINGS	250.8	51.219
PRE-1976	135327.	DWELLINGS	271.4	36.734
1976-1980	14259.	DWELLINGS	202.3	2.885
1980-1990	54612.	DWELLINGS	202.3	11.049
1990-2000	39731.	DWELLINGS	202.3	8.038
2000 TOTAL	243928.	DWELLINGS	240.7	58.706
PRE-1976	135327.	DWELLINGS	268.5	36.332
1976-1980	14259.	DWELLINGS	200.2	2.854
1980-1990	54612.	DWELLINGS	200.2	10.931
1990-2000	39731.	DWELLINGS	200.2	7.953
2000-2010	38489.	DWELLINGS	200.2	7.704
2010 TOTAL	282417.	DWELLINGS	232.9	65.774
PRE-1976	135327.	DWELLINGS	265.6	35.944
1976-1980	14259.	DWELLINGS	198.1	2.824
1980-1990	54612.	DWELLINGS	198.1	10.818
1990-2000	39731.	DWELLINGS	198.1	7.870
2000-2010	38489.	DWELLINGS	198.1	7.624
2010-2020	36292.	DWELLINGS	198.1	7.189
2020 TOTAL	318718.	DWELLINGS	226.8	72.269
PRE-1976	135327.	DWELLINGS	264.6	35.809
1976-1980	14259.	DWELLINGS	197.4	2.814
1980-1990	54612.	DWELLINGS	197.4	10.778
1990-2000	39731.	DWELLINGS	197.4	7.841
2000-2010	38489.	DWELLINGS	197.4	7.596
2010-2020	36292.	DWELLINGS	197.4	7.163
2020-2030	37064.	DWELLINGS	197.4	7.315
2030 TOTAL	355774.	DWELLINGS	222.9	79.318

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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-20

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
COMMERICAL-INDUSTRIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976 TOTAL	291257.	EMPLOYEES	61.5	17.910
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980 TOTAL	312765.	EMPLOYEES	60.8	19.019
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980-1990	132037.	EMPLOYEES	51.6	6.808
1990 TOTAL	444802.	EMPLOYEES	58.1	25.827
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980-1990	132037.	EMPLOYEES	51.6	6.808
1990-2000	91656.	EMPLOYEES	51.6	4.726
2000 TOTAL	536457.	EMPLOYEES	57.0	30.553
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980-1990	132037.	EMPLOYEES	51.6	6.808
1990-2000	91656.	EMPLOYEES	51.6	4.726
2000-2010	89897.	EMPLOYEES	51.6	4.635
2010 TOTAL	626354.	EMPLOYEES	56.2	35.188
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980-1990	132037.	EMPLOYEES	51.6	6.808
1990-2000	91656.	EMPLOYEES	51.6	4.726
2000-2010	89897.	EMPLOYEES	51.6	4.635
2010-2020	85833.	EMPLOYEES	51.6	4.426
2020 TOTAL	712187.	EMPLOYEES	55.6	39.613
PRE-1976	291257.	EMPLOYEES	61.5	17.910
1976-1980	21508.	EMPLOYEES	51.6	1.109
1980-1990	132037.	EMPLOYEES	51.6	6.808
1990-2000	91656.	EMPLOYEES	51.6	4.726
2000-2010	89897.	EMPLOYEES	51.6	4.635
2010-2020	85833.	EMPLOYEES	51.6	4.426
2020-2030	72761.	EMPLOYEES	51.6	3.752
2030 TOTAL	784949.	EMPLOYEES	55.2	43.365

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A DIVISION OF CAMP DRESSER AND MCKEE
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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-21

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
GOVERNMENTAL-INSTITUTIONAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976 TOTAL	51350.	EMPLOYEES	70.5	3.620
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980 TOTAL	54647.	EMPLOYEES	69.9	3.821
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980-1990	39193.	EMPLOYEES	61.0	2.391
1990 TOTAL	93840.	EMPLOYEES	66.2	6.212
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980-1990	39193.	EMPLOYEES	61.0	2.391
1990-2000	31527.	EMPLOYEES	61.0	1.923
2000 TOTAL	125367.	EMPLOYEES	64.9	8.135
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980-1990	39193.	EMPLOYEES	61.0	2.391
1990-2000	31527.	EMPLOYEES	61.0	1.923
2000-2010	21000.	EMPLOYEES	61.0	1.281
2010 TOTAL	146375.	EMPLOYEES	64.3	9.416
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980-1990	39193.	EMPLOYEES	61.0	2.391
1990-2000	31527.	EMPLOYEES	61.0	1.923
2000-2010	21000.	EMPLOYEES	61.0	1.281
2010-2020	20059.	EMPLOYEES	61.0	1.223
2020 TOTAL	166433.	EMPLOYEES	63.9	10.639
PRE-1976	51350.	EMPLOYEES	70.5	3.620
1976-1980	3297.	EMPLOYEES	61.0	.201
1980-1990	39193.	EMPLOYEES	61.0	2.391
1990-2000	31527.	EMPLOYEES	61.0	1.923
2000-2010	21000.	EMPLOYEES	61.0	1.281
2010-2020	20059.	EMPLOYEES	61.0	1.223
2020-2030	17004.	EMPLOYEES	61.0	1.037
2030 TOTAL	183437.	EMPLOYEES	63.7	11.677

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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-22

RESULTING DEMAND FOR EACH [illegible] BY TIME PERIOD
FEDERAL GOVERNMENT

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976 TOTAL	68193.	EMPLOYEES	73.0	4.980
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980 TOTAL	73156.	EMPLOYEES	72.4	5.294
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980-1990	13802.	EMPLOYEES	63.2	.872
1990 TOTAL	86958.	EMPLOYEES	70.9	6.166
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980-1990	13802.	EMPLOYEES	63.2	.872
1990-2000	3718.	EMPLOYEES	63.2	.235
2000 TOTAL	90676.	EMPLOYEES	70.6	6.401
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980-1990	13802.	EMPLOYEES	63.2	.872
1990-2000	3718.	EMPLOYEES	63.2	.235
2000-2010	15195.	EMPLOYEES	63.2	.960
2010 TOTAL	105871.	EMPLOYEES	69.5	7.361
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980-1990	13802.	EMPLOYEES	63.2	.872
1990-2000	3718.	EMPLOYEES	63.2	.235
2000-2010	15195.	EMPLOYEES	63.2	.960
2010-2020	14508.	EMPLOYEES	63.2	.917
2020 TOTAL	120380.	EMPLOYEES	68.8	8.277
PRE-1976	68193.	EMPLOYEES	73.0	4.980
1976-1980	4963.	EMPLOYEES	63.2	.314
1980-1990	13802.	EMPLOYEES	63.2	.872
1990-2000	3718.	EMPLOYEES	63.2	.235
2000-2010	15195.	EMPLOYEES	63.2	.960
2010-2020	14508.	EMPLOYEES	63.2	.917
2020-2030	12299.	EMPLOYEES	63.2	.777
2030 TOTAL	132678.	EMPLOYEES	68.2	9.035

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WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
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TABLE D-III-23

RESULTING WATER DEMAND AND [illegible] EACH TIME HORIZON
1976

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	218975.	DWELLINGS	281.2	61.500
MULTI-FAMILY	135327.	DWELLINGS	280.0	38.000
COMMERCIAL/ INDUSTRIAL	291257.	EMPLOYEES	61.5	17.910
GOVERNMENTAL/ INSTITUTIONAL	51358.	EMPLOYEES	70.5	3.620
FEDERAL GOVERNMENT	68193.	EMPLOYEES	73.0	4.980
UNNACCOUNTED	N/A	N/A	N/A	12.990
TOTAL	1054873.	PERSONS	131.0	139.000

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APPENDIX D SUPPLIES DEMANDS AND DEFICITS(U) CORPS OF
ENGINEERS BALTIMORE MD BALTIMORE DISTRICT SEP 83
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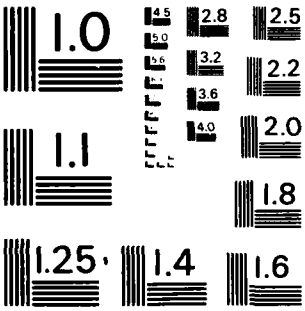

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CORPS OF ENGINEERS
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TABLE D-III-24

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1980

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	240714.	DWELLINGS	264.0	63.552
MULTI-FAMILY	149586.	DWELLINGS	267.3	39.980
COMMERCIAL/ INDUSTRIAL	312765.	EMPLOYEES	60.6	19.019
GOVERNMENTAL/ INSTITUTIONAL	54647.	EMPLOYEES	69.9	3.821
FEDERAL GOVERNMENT	73156.	EMPLOYEES	72.4	5.294
UNNACCOUNTED	N/A	N/A	N/A	13.569
TOTAL	1112888.	PERSONS	130.6	145.239

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TABLE D-III-25

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1990

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	321002.	DWELLINGS	248.9	80.098
MULTI-FAMILY	284198.	DWELLINGS	250.8	51.219
COMMERCIAL/ INDUSTRIAL	444882.	EMPLOYEES	58.1	25.827
GOVERNMENTAL/ INSTITUTIONAL	93848.	EMPLOYEES	66.2	6.212
FEDERAL GOVERNMENT	86958.	EMPLOYEES	70.9	6.166
UNNACCOUNTED	N/A	N/A	N/A	17.464
TOTAL	1499788.	PERSONS	124.7	186.585

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TABLE D-III-26

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
2000

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	385372.	DWELLINGS	237.0	91.324
MULTI-FAMILY	243928.	DWELLINGS	248.7	58.786
COMMERCIAL/ INDUSTRIAL	536457.	EMPLOYEES	57.0	30.553
GOVERNMENTAL/ INSTITUTIONAL	125367.	EMPLOYEES	64.9	8.135
FEDERAL GOVERNMENT	90676.	EMPLOYEES	70.6	6.401
UNNACCOUNTED	N/A	N/A	N/A	28.181
TOTAL	1751408.	PERSONS	122.3	215.210

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TABLE D-III-27

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
2010

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	448283.	DWELLINGS	227.6	102.010
MULTI-FAMILY	282417.	DWELLINGS	232.9	65.774
COMMERCIAL/ INDUSTRIAL	626354.	EMPLOYEES	56.2	35.188
GOVERNMENTAL/ INSTITUTIONAL	146375.	EMPLOYEES	64.3	9.416
FEDERAL GOVERNMENT	105871.	EMPLOYEES	69.5	7.361
UNNACCOUNTED	N/A	N/A	N/A	22.640
TOTAL	2002888.	PERSONS	121.0	242.396

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
WATER SUPPLY STUDY
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-28

RESULTING WATER DEMAND AND 2020 TIME HORIZON

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	507298.	DWELLINGS	219.9	111.577
MULTI-FAMILY	318718.	DWELLINGS	226.8	72.269
COMMERCIAL/ INDUSTRIAL	712187.	EMPLOYEES	55.6	39.613
GOVERNMENTAL/ INSTITUTIONAL	166433.	EMPLOYEES	63.9	10.639
FEDERAL GOVERNMENT	120388.	EMPLOYEES	68.8	8.277
UNNACCOUNTED	N/A	N/A	N/A	24.978
TOTAL	2218568.	PERSONS	120.5	267.346

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-29

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
2030

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	548884.	DWELLINGS	214.1	117.501
MULTI-FAMILY	355774.	DWELLINGS	222.9	79.318
COMMERCIAL/ INDUSTRIAL	784949.	EMPLOYEES	55.2	43.365
GOVERNMENTAL/ INSTITUTIONAL	183437.	EMPLOYEES	63.7	11.677
FEDERAL GOVERNMENT	132678.	EMPLOYEES	68.2	9.055
UNNACCOUNTED	N/A	N/A	N/A	26.000
TOTAL	2300500.	PERSONS	120.9	287.795

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**** METROPOLITAN WASHINGTON AREA ****
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WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-30

SUMMARY OF WATER DEMAND IN EACH CATEGORY FOR EACH TIME HORIZON

TIME HORIZON	SINGLE FAMILY (MGD)	MULTI-FAMILY (MGD)	COMMERICAL/ INDUSTRIAL (MGD)	GOVERNMENTAL/ INSTITUTIONAL (MGD)	FEDERAL GOVERNMENT (MGD)	UNNACCOUNTED FOR USE (MGD)	TOTAL USE (MGD)
1970	61.580	38.880	17.910	3.620	4.980	12.990	139.080
1980	63.552	39.980	19.819	3.421	5.294	13.569	145.239
1990	80.890	51.219	25.827	6.212	6.166	17.464	186.985
2000	91.324	58.786	30.553	8.135	6.401	20.181	215.210
2010	102.010	65.774	35.188	9.416	7.361	22.640	242.396
2020	111.977	72.269	39.613	10.639	8.277	24.970	267.346
2030	117.501	79.310	43.365	11.677	9.855	26.080	287.795

CORPS OF ENGINEERS DEPARTMENT OF THE ARMY BALTIMORE DISTRICT	**** METROPOLITAN WASHINGTON AREA **** **** WATER SUPPLY STUDY **** **** WATER DEMAND PROJECTION MODEL ****	WATER RESOURCES ENGINEERS A DIVISION OF CAMP DRESSER AND MCKEE SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-31

MONTHLY DEMANDS (MGD) BY TIME HORIZON

TIME HORIZON	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1976	125.117	125.241	125.420	131.545	142.427	154.473	160.684	154.348	154.236	136.912	130.855	127.613
1980	131.186	130.235	130.421	136.790	148.877	162.078	168.873	161.933	161.831	142.838	135.241	132.702
1990	166.445	166.610	166.849	174.997	192.864	210.845	219.316	209.858	209.692	183.833	173.815	169.767
2000	190.793	190.942	191.216	200.554	221.331	242.864	253.967	242.648	242.441	211.473	198.282	194.568
2010	214.872	214.284	214.591	225.871	249.529	274.563	287.471	274.383	274.071	238.068	222.522	218.344
2020	235.389	235.622	235.968	247.482	275.449	303.786	318.397	303.491	303.229	262.477	244.688	240.886
2030	252.815	253.066	253.428	265.804	296.712	327.792	343.817	327.469	327.181	282.484	262.794	257.868

CORPS OF ENGINEERS DEPARTMENT OF THE ARMY BALTIMORE DISTRICT	**** METROPOLITAN WASHINGTON AREA **** **** WATER SUPPLY STUDY **** **** WATER DEMAND PROJECTION MODEL ****	WATER RESOURCES ENGINEERS A DIVISION OF CAMP DRESSER AND MCKEE SPRINGFIELD, VIRGINIA

WASHINGTON SUBURBAN SANITARY COMMISSION DEMAND AREA
BASELINE

TABLE D-III-32

SUMMARY TABLE OF OVERALL WATER DEMAND BY TIME HORIZON

TIME HORIZON	TOTAL USE (MGD)	TOTAL POPULATION (PERSONS)	AVERAGE DAILY USE/ TOTAL POPULATION (GPD/PERSON)
1976	139.888	1064873.	131.0
1980	145.239	1112000.	130.6
1990	186.985	1499700.	124.7
2000	215.210	1759400.	122.3
2010	242.396	2002600.	121.0
2020	267.346	2218500.	120.5
2030	287.795	2380500.	120.9

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX COUNTY WATER AUTHORITY DEMAND AREA
BASELINE

TABLE D-III-33

WATER DEMAND GROWTH INDICATORS

INDICATOR / YEAR	1976	1980	1990	2000	2010	2020	2030
TOTAL POPULATION SERVED	651000.	673000.	880300.	1033900.	1160200.	1338000.	1489900.
TOTAL HOUSEHOLDS SERVED (DWELLING UNIT)	218300.	228000.	312000.	373600.	430600.	502800.	570800.
TOTAL EMPLOYMENT SERVED	151000.	208100.	279300.	341600.	401900.	479200.	555700.
OCCUPANTS/DWELLING UNIT (SINGLE FAMILY)	3.425	3.399	3.253	3.203	3.133	3.106	3.380
OCCUPANTS/DWELLING UNIT (MULTI-FAMILY)	2.114	2.098	2.008	1.977	1.948	1.918	1.824
SINGLE FAMILY/MULTI-FAMILY DWELLING UNIT RATIO	1.968	1.930	1.887	1.815	1.774	1.672	1.672
SINGLE FAMILY/MULTI-FAMILY POPULATION RATIO	3.176	3.127	3.057	2.941	2.824	2.708	2.824
COMMERCIAL + INDUSTRIAL/ TOTAL EMPLOYMENT RATIO	.667	.662	.652	.642	.642	.642	.642
STATE + LOCAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.191	.205	.229	.255	.255	.255	.255
FEDERAL GOVERNMENT/ TOTAL EMPLOYMENT RATIO	.142	.133	.119	.103	.103	.103	.103
UNNACCOUNTED WATER USE (PERCENT OF TOTAL)	9.161	9.161	9.161	9.161	9.161	9.161	9.161

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
WATER SUPPLY STUDY
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX COUNTY WATER AUTHORITY DEMAND AREA
BASELINE

TABLE D-III-34

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
SINGLE FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	144557.	DWELLINGS	198.2	28.652
1976 TOTAL	144557.	DWELLINGS	198.2	28.652
PRE-1976	144557.	DWELLINGS	196.9	28.455
1976-1980	5628.	DWELLINGS	146.6	.825
1980 TOTAL	150184.	DWELLINGS	195.0	29.280
PRE-1976	144557.	DWELLINGS	189.2	27.355
1976-1980	5628.	DWELLINGS	141.1	.794
1980-1990	53745.	DWELLINGS	141.1	7.583
1990 TOTAL	203929.	DWELLINGS	175.2	35.732
PRE-1976	144557.	DWELLINGS	186.7	26.993
1976-1980	5628.	DWELLINGS	139.3	.784
1980-1990	53745.	DWELLINGS	139.3	7.485
1990-2000	36953.	DWELLINGS	139.3	5.146
2000 TOTAL	240882.	DWELLINGS	167.8	40.408
PRE-1976	144557.	DWELLINGS	183.3	26.491
1976-1980	5628.	DWELLINGS	136.7	.770
1980-1990	53745.	DWELLINGS	136.7	7.350
1990-2000	36953.	DWELLINGS	136.7	5.053
2000-2010	34490.	DWELLINGS	136.7	4.717
2010 TOTAL	275373.	DWELLINGS	161.2	44.386
PRE-1976	144557.	DWELLINGS	181.9	26.299
1976-1980	5628.	DWELLINGS	135.8	.764
1980-1990	53745.	DWELLINGS	135.8	7.298
1990-2000	36953.	DWELLINGS	135.8	5.018
2000-2010	34490.	DWELLINGS	135.8	4.683
2010-2020	39253.	DWELLINGS	135.8	5.330
2020 TOTAL	314626.	DWELLINGS	157.0	49.393
PRE-1976	144557.	DWELLINGS	180.7	26.122
1976-1980	5628.	DWELLINGS	134.9	.759
1980-1990	53745.	DWELLINGS	134.9	7.250
1990-2000	36953.	DWELLINGS	134.9	4.985
2000-2010	34490.	DWELLINGS	134.9	4.653
2010-2020	39253.	DWELLINGS	134.9	5.295
2020-2030	42591.	DWELLINGS	134.9	5.748
2030 TOTAL	357177.	DWELLINGS	153.4	54.805

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
WATER SUPPLY STUDY
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

FAIRFAX COUNTY WATER AUTHORITY DEMAND AREA
BASELINE

TABLE D-III-35

RESULTING DEMAND FOR EACH TIME HORIZON BY TIME PERIOD
MULTI-FAMILY RESIDENTIAL

TIME PERIOD	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
PRE-1976	73743.	DWELLINGS	207.0	15.266
1976 TOTAL	73743.	DWELLINGS	207.0	15.266
PRE-1976	73743.	DWELLINGS	206.1	15.201
1976-1980	4072.	DWELLINGS	153.5	.625
1980 TOTAL	77816.	DWELLINGS	203.4	15.826
PRE-1976	73743.	DWELLINGS	201.2	14.836
1976-1980	4072.	DWELLINGS	149.9	.611
1980-1990	30255.	DWELLINGS	149.9	4.536
1990 TOTAL	108071.	DWELLINGS	184.9	19.982
PRE-1976	73743.	DWELLINGS	199.5	14.713
1976-1980	4072.	DWELLINGS	148.7	.606
1980-1990	30255.	DWELLINGS	148.7	4.499
1990-2000	24647.	DWELLINGS	148.7	3.665
2000 TOTAL	132718.	DWELLINGS	176.9	23.483
PRE-1976	73743.	DWELLINGS	199.0	14.678
1976-1980	4072.	DWELLINGS	148.4	.604
1980-1990	30255.	DWELLINGS	148.4	4.489
1990-2000	24647.	DWELLINGS	148.4	3.657
2000-2010	22510.	DWELLINGS	148.4	3.340
2010 TOTAL	155227.	DWELLINGS	172.4	26.768
PRE-1976	73743.	DWELLINGS	196.4	14.481
1976-1980	4072.	DWELLINGS	146.4	.596
1980-1990	30255.	DWELLINGS	146.4	4.430
1990-2000	24647.	DWELLINGS	146.4	3.609
2000-2010	22510.	DWELLINGS	146.4	3.296
2010-2020	32947.	DWELLINGS	146.4	4.824
2020 TOTAL	188174.	DWELLINGS	166.0	31.237
PRE-1976	73743.	DWELLINGS	191.5	14.122
1976-1980	4072.	DWELLINGS	142.9	.582
1980-1990	30255.	DWELLINGS	142.9	4.323
1990-2000	24647.	DWELLINGS	142.9	3.522
2000-2010	22510.	DWELLINGS	142.9	3.217
2010-2020	32947.	DWELLINGS	142.9	4.708
2020-2030	25449.	DWELLINGS	142.9	3.637
2030 TOTAL	213623.	DWELLINGS	159.7	34.111

CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

ROCKVILLE DEMAND AREA
BASELINE

TABLE D-III-57

RESULTING WATER DEMAND AND UNIT USE FOR EACH TIME HORIZON
1990

CATEGORY	NUMBER OF UNITS	UNITS	UNIT USE (GPD)	AVERAGE ANNUAL USE (MGD)
SINGLE FAMILY	14351.	DWELLINGS	154.5	2.218
MULTI-FAMILY	4249.	DWELLINGS	149.5	.635
COMMERCIAL/ INDUSTRIAL	26698.	EMPLOYEES	54.2	1.446
GOVERNMENTAL/ INSTITUTIONAL	13398.	EMPLOYEES	40.8	.546
FEDERAL GOVERNMENT	1112.	EMPLOYEES	54.8	.060
UNNACCOUNTED	N/A	N/A	N/A	.242
TOTAL	53308.	PERSONS	96.6	5.147

CORPS OF ENGINEERS
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BALTIMORE DISTRICT

**** METROPOLITAN WASHINGTON AREA ****
**** WATER SUPPLY STUDY ****
**** WATER DEMAND PROJECTION MODEL ****

WATER RESOURCES ENGINEERS
A DIVISION OF CAMP DRESSER AND MCKEE
SPRINGFIELD, VIRGINIA

ROCKVILLE DEMAND AREA
BASELINE

TABLE D-III-62

SUMMARY OF WATER DEMAND IN EACH CATEGORY FOR EACH TIME HORIZON

TIME HORIZON	SINGLE FAMILY (MGD)	MULTI-FAMILY (MGD)	COMMERICAL/ INDUSTRIAL (MGD)	GOVERNMENTAL/ INSTITUTIONAL (MGD)	FEDERAL GOVERNMENT (MGD)	UNNACCOUNTED FOR USE (MGD)	TOTAL USE (MGD)
1976	1.924	.561	1.068	.317	.048	.193	4.111
1980	2.063	.609	1.284	.418	.056	.218	4.648
1990	2.218	.635	1.446	.546	.060	.242	5.147
2000	2.223	.690	1.508	.668	.057	.253	5.391
2010	2.229	.744	1.586	.696	.060	.262	5.575
2020	2.233	.798	1.633	.718	.062	.268	5.713
2030	2.238	.852	1.664	.732	.063	.273	5.823

providing a public water supply for the inhabitants of the District of Columbia; and

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

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

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

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

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

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

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

ARTICLE 1. Enforcement.

A. Certain Definitions:

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

ARTICLE 7. Severability.

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

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

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

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

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

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

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

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

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

ANNEX D-VI

PRISM/COE OUTPUT, LONG-RANGE PHASE

WATER SUPPLY RELEASE FROM BLOOMINGTON RESERVOIR, MGD

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	38.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	38.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	60.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	78.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	90.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	91.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	90.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

D-VI-7

DEMAND OF WSSC, MGD

	1	2	3	4	5	6	7	8	9	10
1	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50
2	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50
3	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50	250.50
4	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86
5	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86
6	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86
7	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86	232.86
8	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61
9	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61
10	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61
11	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61
12	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61	228.61
13	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05
14	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05
15	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05
16	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05
17	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05	224.05
18	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35
19	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35
20	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35
21	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35
22	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35	224.35
23	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66
24	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66
25	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66
26	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66
27	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66	224.66
28	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99
29	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99
30	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99	234.99
31	234.99	234.99	234.99	[illegible]	234.99	234.99	234.99	234.99	234.99	234.99
32	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96
33	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96
34	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96
35	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96	262.96
36	290.62	290.62	290.62	290.62	290.62	290.62	[illegible]	[illegible]	290.62	290.62
37	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62
38	290.62	290.62	290.62	290.62	290.62	290.62	290.62	[illegible]	[illegible]	290.62
39	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62	290.62
40	304.00	304.00	304.00	[illegible]	[illegible]	304.00	[illegible]	[illegible]	[illegible]	[illegible]
41	304.00	[illegible]	304.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	304.00	304.00	[illegible]	[illegible]	304.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	304.00	304.00	304.00	[illegible]	304.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44	290.32	290.32	290.32	290.32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	290.32	290.32	290.32	290.32	[illegible]	290.32	[illegible]	[illegible]	[illegible]	[illegible]
46	290.32	290.32	290.32	[illegible]	[illegible]	[illegible]	[illegible]	290.32	[illegible]	[illegible]
47	290.32	290.32	290.32	290.32	290.32	[illegible]	[illegible]	290.32	[illegible]	[illegible]
48	290.02	290.02	290.02	[illegible]	290.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49	290.02	290.02	290.02	290.02	290.02	290.02	[illegible]	290.02	[illegible]	[illegible]

DEMAND OF FCWA, MGD

	1	2	3	4	5	6	7	8	9	10
1	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49
2	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49
3	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49	130.49
4	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18
5	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18
6	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18
7	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18	123.18
8	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55
9	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55
10	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55
11	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55
12	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55	121.55
13	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
14	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
15	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
16	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
17	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
18	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
19	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
20	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
21	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
22	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38	115.38
23	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86
24	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86
25	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86
26	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86
27	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86	115.86
28	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61
29	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61
30	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61
31	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61	125.61
32	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80
33	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80
34	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80
35	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80	137.80
36	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83
37	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83
38	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83
39	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83	149.83
40	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50
41	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50
42	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50
43	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50
44	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56
45	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56
46	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56
47	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56	153.56
48	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93
49	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93
50	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93
51	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93	145.93

DEMAND OF WAD, MSD

	1	2	3	4	5	6	7	8	9	10
1	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02
2	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02
3	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02	219.02
4	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06
5	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06
6	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06
7	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06	206.06
8	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88
9	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88
10	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88
11	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88
12	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88	200.88
13	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
14	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
15	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
16	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
17	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
18	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32	199.32
19	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29
20	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29
21	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29
22	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29	198.29
23	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62
24	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62
25	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62
26	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62
27	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62	193.62
28	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44
29	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44
30	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44
31	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44	202.44
32	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54
33	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54
34	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54
35	212.54	212.54	212.54	212.54	212.54	212.54	212.54	212.54	[illegible]	212.54
36	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	[illegible]	238.20
37	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20
38	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20
39	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20	238.20
40	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20
41	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20
42	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20
43	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20	259.20
44	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09
45	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09
46	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09
47	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09	256.09
48	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50
49	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50
50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50	239.50
51	239.50	239.50	239.50	239.50	239.50	239.50	239.50	[illegible]	[illegible]	[illegible]

D-VI-20

FLOW IN POTOMAC AFTER WITHDRAWALS INCLUDING ENVIRONMENTAL FLOWS, MGD

	1	2	3	4	5	6	7	8	9	10
1	15666.03	100.00	825.48	665.47	2458.47	[illegible]542.42	1009.49	852.97	2571.53	664.58
2	3262.11	100.00	474.51	764.70	1531.88	2839.18	929.00	558.83	4838.44	590.34
3	1469.01	100.00	455.64	8950.06	1731.89	1528.34	850.69	8630.76	6977.05	577.20
4	26524.65	100.00	378.42	4214.93	1504.73	1071.04	846.55	2937.30	22720.47	774.31
5	5432.68	101.17	425.47	4221.97	1197.29	1017.62	2017.83	1485.36	51229.19	778.84
6	8759.30	148.37	365.98	13978.83	1354.52	1663.15	1262.42	2046.79	7818.09	1240.10
7	4560.40	202.85	373.09	13064.78	1386.59	1291.90	6752.78	1642.34	11798.34	994.12
8	19959.95	260.28	404.45	16151.96	1471.08	1223.02	6196.86	1210.13	6359.92	1225.92
9	5254.85	379.05	439.93	5505.70	1448.32	19837.12	3654.41	1018.08	5893.92	1389.59
10	4071.86	411.31	556.34	3542.55	1301.61	22510.81	3234.74	3608.15	5240.12	3950.14
11	4875.71	607.48	2763.22	2642.85	1184.75	4579.80	5652.51	9443.90	3432.68	13437.99
12	5753.98	641.15	1828.83	2364.15	4293.70	3657.16	9609.27	9256.25	7443.87	3715.76
13	5874.05	1535.50	1165.87	9135.40	2760.91	5502.95	3213.01	8374.53	4531.30	2676.15
14	9503.18	1265.54	2924.60	9663.55	5017.23	5153.34	12896.81	16100.33	4589.14	2825.98
15	5664.05	2103.41	5971.44	5200.27	14076.39	5579.37	23237.01	19457.58	4355.32	4200.57
16	3950.13	1135.77	2995.82	3969.32	3500.96	5099.64	15336.48	14521.46	3276.51	2876.62
17	2880.08	960.73	2264.62	11079.95	2524.25	24410.58	10303.86	45683.64	5115.14	4481.62
18	2613.63	1491.86	4175.53	16989.17	1927.68	8289.14	4839.44	15599.18	7622.46	21427.86
19	10241.86	654.72	20099.37	8657.67	1714.76	8847.23	5073.86	12898.93	4161.16	39318.41
20	5874.94	1890.69	4219.11	6705.05	1255.26	22315.45	6894.99	15218.39	5631.83	20639.65
21	4443.77	1883.53	2467.54	8432.35	1312.34	20863.89	16399.10	22697.81	5831.71	12225.74
22	5057.37	1463.68	1746.32	7883.06	1524.67	11175.32	43722.04	15453.73	5055.37	19504.05
23	9166.81	3033.86	5389.60	5601.12	10366.13	8785.04	23243.18	7552.67	4494.53	16536.58
24	10649.21	2235.78	5512.83	17603.17	5451.11	15995.49	30045.27	5432.04	7258.70	13718.12
25	6649.84	2090.53	11531.90	30645.97	4281.32	10814.28	123928.10	11363.52	12028.86	8587.96
26	4605.69	7346.24	18935.63	13138.42	9286.45	9220.98	28687.88	5415.21	5759.18	5430.19
27	4045.22	16717.90	25691.29	9250.23	11406.65	11468.24	14777.38	4796.62	6465.38	6807.00
28	7793.57	12133.40	11064.67	17899.69	8251.41	31897.00	28473.21	6116.47	5840.73	6663.80
29	4483.56	4122.18	8592.52	38534.80	7271.14	17798.28	13252.30	4838.11	4998.09	24295.75
30	4462.88	8094.42	4210.44	32713.30	5038.36	7544.68	6927.35	67037.71	4827.83	11155.48
31	3044.10	5123.96	8162.92	9340.66	3283.56	6335.46	5123.20	32890.99	3164.84	8642.42
32	2188.72	7919.95	9372.90	21456.32	3234.59	14228.41	4410.02	11369.47	2709.55	5252.54
33	1675.34	13850.03	52285.53	22406.60	2540.38	7725.93	3790.02	7033.59	3262.25	3777.90
34	1562.96	15116.86	8229.43	9950.22	2762.07	5286.92	3268.37	5535.05	13375.55	4144.57
35	937.53	7220.96	4208.59	7306.60	2176.39	3911.78	2316.35	5148.37	8204.27	3294.02
36	433.90	4741.70	2125.56	4706.10	1478.00	2551.49	1591.49	3557.13	4159.16	3948.04
37	1623.43	2344.31	1434.20	3531.93	971.11	3246.69	3325.25	4376.64	2356.67	1758.38
38	1221.34	4195.53	2428.87	2256.22	2670.93	2642.70	2733.25	4113.06	2704.5[illegible]	3111.18
39	629.69	2179.53	1631.55	1601.37	1454.24	2059.36	1546.95	3392.05	3729.90	4038.22
40	482.74	1771.01	1519.97	3996.10	518.01	2448.29	1415.24	2478.28	1819.08	4769.94
41	[illegible]	4636.96	[illegible]	[illegible]	537.[illegible]	2609.34	1028.59	[illegible]	[illegible]	2722.68
42	100.00	4201.10	1047.[illegible]	1150.09	356.15	2001.73	14[illegible]	3357.02	1022.00	1203.05
43	100.00	4126.87	566.5[illegible]	1534.42	314.25	1739.03	1046.07	1767.24	3139.32	7[illegible].97
44	100.00	1455.94	602.19	[illegible]	1011.[illegible]	1597.[illegible]	[illegible]	11[illegible].48	4451.55	10455.54
45	100.00	[illegible]	333.79	[illegible]	4[illegible]	2[illegible]	782.[illegible]	1002.60	4[illegible]	3165.51
46	100.00	597.51	[illegible]	1732.4	[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	[illegible].59
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2[illegible].5	[illegible]	[illegible]	[illegible]	[illegible]
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49	[illegible]	[illegible]	511.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2[illegible].47	[illegible]	[illegible]	10[illegible]	465.[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1460.63	[illegible]	[illegible]	[illegible]	[illegible]

D-VI-27

TOTAL FLOW AT LINE, MARYLAND, MGD

	1	2	3	4	5	6	7	8	9	10
1	954.13	78.00	214.63	89.63	179.45	317.30	171.74	79.36	404.11	138.00
2	515.98	78.00	231.09	205.97	211.04	265.27	235.45	162.67	495.61	195.95
3	516.99	78.00	268.92	530.51	252.81	247.30	234.38	702.22	524.95	210.09
4	650.13	78.00	216.42	297.39	263.96	236.84	251.23	350.44	2873.11	199.78
5	674.90	78.00	243.22	330.21	240.70	294.57	300.99	262.53	1975.49	217.31
6	593.26	78.00	235.66	600.21	341.20	378.75	281.62	564.84	536.60	233.39
7	823.58	93.78	263.49	443.63	403.26	317.71	559.53	321.70	506.40	227.87
8	959.82	184.67	225.33	774.66	480.43	498.58	437.08	274.62	351.46	313.50
9	421.96	200.49	284.60	351.41	373.26	841.35	365.83	259.20	472.69	269.94
10	553.25	291.48	310.71	308.74	420.95	621.67	433.99	779.34	391.23	486.04
11	1039.69	283.49	1371.52	305.42	387.45	397.44	878.11	680.65	400.22	542.43
12	685.96	215.60	545.53	344.80	1337.93	394.61	704.73	481.91	1474.76	330.08
13	644.45	272.56	485.10	842.20	538.16	897.93	415.02	962.19	650.55	331.79
14	721.01	172.00	545.63	517.89	1176.24	502.71	663.06	1118.00	529.92	386.98
15	410.97	102.58	777.53	334.04	1721.37	784.35	1275.48	1738.78	258.40	277.10
16	234.67	78.00	275.23	265.41	358.92	700.73	946.87	1242.80	146.91	162.92
17	116.95	358.90	464.43	509.50	408.31	1835.83	522.91	3124.48	465.62	431.27
18	78.00	305.02	632.65	531.94	269.66	272.43	161.67	675.03	251.70	1291.11
19	157.12	123.14	1603.93	316.28	78.00	114.44	78.00	836.87	109.53	1572.06
20	131.19	179.98	131.09	256.99	78.00	720.12	107.51	354.39	346.74	1400.29
21	129.22	127.09	91.89	268.92	78.00	364.00	137.66	397.70	189.67	481.11
22	195.12	186.11	78.00	546.32	78.00	492.44	2017.96	179.88	104.11	991.55
23	375.63	129.90	134.19	276.18	394.77	437.46	1222.01	303.03	472.50	766.22
24	628.54	100.45	106.60	2113.37	345.05	1052.75	2034.42	193.77	838.14	822.77
25	546.09	206.81	1194.41	2042.03	245.13	343.15	4519.53	1281.19	497.21	263.63
26	188.80	922.66	972.46	572.63	583.92	316.47	2906.00	581.33	275.64	192.50
27	341.58	1135.94	1895.58	745.06	754.60	394.17	945.16	232.43	418.80	362.14
28	518.14	926.53	401.14	842.93	516.94	1376.97	1327.75	227.06	401.58	408.45
29	295.70	307.46	355.84	1886.24	464.99	874.50	545.19	253.21	359.68	1997.06
30	278.75	861.29	214.22	1103.65	273.28	349.47	305.95	2633.47	386.15	541.95
31	208.06	539.11	306.44	479.02	173.79	654.38	213.58	809.08	219.63	486.99
32	164.49	766.42	781.16	1757.79	114.28	1330.80	140.13	426.93	181.25	240.65
33	128.63	1180.98	2439.30	1559.09	142.13	530.69	221.06	384.69	1101.04	220.08
34	112.65	1543.13	342.91	435.48	124.59	519.82	159.20	279.85	1851.93	145.60
35	78.00	568.35	141.48	289.77	103.03	219.59	82.16	724.17	477.25	91.28
36	78.00	385.83	83.89	246.59	78.00	236.96	78.00	209.09	296.12	284.21
37	249.05	240.28	128.07	118.45	78.00	211.40	140.00	248.06	204.18	129.28
38	78.00	117.63	144.70	78.00	191.90	415.84	78.00	270.30	401.40	476.67
39	91.89	78.00	233.13	78.00	78.00	224.24	78.00	160.08	150.36	701.88
40	78.00	78.00	191.48	101.44	78.00	163.54	78.00	89.62	78.00	618.40
41	78.00	184.69	442.67	78.00	78.00	264.16	78.00	78.00	78.00	237.96
42	78.00	78.00	78.19	78.00	78.00	91.61	78.00	78.00	108.82	157.03
43	78.00	78.00	78.00	78.00	78.00	116.49	78.00	78.00	778.52	549.79
44	121.58	78.00	78.00	78.00	78.00	290.51	78.00	78.00	258.70	401.00
45	121.58	78.00	78.00	122.77	78.00	420.38	78.96	78.00	175.41	141.98
46	147.99	78.00	78.00	141.26	223.75	135.95	78.00	78.00	88.95	167.93
47	168.81	78.00	78.00	711.94	129.90	96.75	78.00	78.00	78.00	115.74
48	111.85	86.90	78.00	251.77	78.00	98.91	78.00	629.13	78.00	78.00
49	110.51	116.30	78.00	508.52	78.00	1187.59	60.74	290.66	79.75	105.16
50	93.06	78.00	78.00	211.53	79.52	305.73	78.00	146.12	86.96	102.29
51	78.00	146.91	78.00	575.17	294.07	173.23	78.00	93.38	98.41	81.28
52	89.36	411.87	88.47	143.00	183.65	121.23	[illegible]	[illegible]	[illegible]	[illegible]

D-VI-28

Little Seneca Lake Simulation

1930-31 Flow Data

100 mgd flowby

Year = 1930-31 100 mgd * already in Potomac account

Week	Storage MG	Inflow MGD	Precip-Evap IN	Precip-Evap MGD	Min. Release* MGD	MWA Need MGD	WS Release MGD	Remaining Deficit MGD	Cumulative Deficit MG	
40	4020	2.50	3.59	1.57	1.12	0				
	4018.67	2.08		[illegible]	1.12					
42	4014.40	1.40		[illegible]	1.40					* Potomac [illegible] 100
	4003.41	1.05		1.57	1.05					*
44	3992.42	0.46	0	[illegible]	0.46	4.34	4.34	0		*
	3951.05	0.32	4.29	[illegible]	0.32	0				*
46	3937.89	0.41		1.88	0.41	0				*
	3924.73	0.39		1.88	0.39	6.88	6.88	0		*
48	[illegible]	0.42	0	1.88	0.42	0				*
	[illegible]	0.36	2.88	1.31	0.36					*
50	3841.08	1.84		1.31	1.12					
	3844.79	0.47		1.31	0.47					*
52	3835.62	0.49	0	[illegible]	0.49					
	[illegible].45	0.36	2.32	1.02	0.36					*
54	3819.3	0.69		[illegible]	0.69					*
	3812.17	1.00		[illegible]	1.00					*
	3805.0[illegible]	1.29	0	[illegible]	[illegible]					*
	[illegible]97.89	1.53	[illegible]	0.47	1.12					[illegible]
56	3797.47	2.13		0.47	[illegible]					
	3801.25	2.15	0	[illegible]	[illegible]					
58	3805.[illegible]	2.30	0	0.47	[illegible]					
	[illegible]	2.05	[illegible]	[illegible]	[illegible]					
60	3817.25	2.94		0.10	[illegible]					
	3830.79	2.22		[illegible]	1.12					
62	3839.19	1.33		0.10	[illegible]					
	3841.36	10.50	0	[illegible]	[illegible]					
64	[illegible].72	3.65	1.03	0.47	[illegible]					
	[illegible].72	5.59		0.47	[illegible]					
66	3963.30	5.38		0.47	[illegible]					
	3990.41	4.03	0	0.47	[illegible]					
68	4020	[illegible]				0				