Water for the Future of the Nation's Capital Area, 1984: A Review of the U.S. Army Corps of Engineers Metropolitan Washington Area Water Supply Study (1984)

Pages
93

Size
5 x 9

ISBN
0309323789

Committee to Review the Metropolitan Washington Area Water Supply Study; Water Science and Technology Board; National Research Council

Water for the Future of the Nation's Capital Area 1984

A Review of the U.S. Army Corps of Engineers Metropolitan Washington Area Water Supply Study

NATIONAL ACADEMY PRESS
Washington, D.C. 1984

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PREFACE

With this report the Committee to Review the Metropolitan Washington Area Water Supply Study of the National Research Council (NRC) fulfills its responsibilities to review and comment upon the scientific and technical aspects of the Corps of Engineers' Washington Area Water Supply Study. When the committee was initially formed in 1977, it was noted that for an NRC committee this was a relatively long-term assignment.

In 1980 the committee was partially reorganized after completing its review of the "early action report." Professor Daniel A. Okun, the committee's first chairman, set the tone for its work. He resigned the chair in 1981 so that he might carry out a larger role in the review process. Other members of the committee were rotated depending upon the review assignments as given by the Corps. Members of the committee, past and present, were unstinting in contributing their time, energy, and intellect. Their only compensation was the satisfaction derived from performing a professional service for society. Committee members accepted their responsibilities with alacrity and good humor in spite of occasionally intense debates among themselves and the representatives of the Corps. After seven years of working together we have come to know and respect each other even more than when we began this review.

In the course of this project the committee had the opportunity to work with three successive Chief Engineers of the Baltimore District--Colonels Withers, Peck, and Brown. We have been reassured that the comings and goings of these distinguished engineers results from the Corps' tri-annual rotation policy rather than from their interactions with the committee.

The several reports prepared by this committee could not have materialized without the dedication, resourcefulness, and good will of the staff of the Water Science and Technology Board. We are especially indebted to Sheila David, who performed all kinds of staffly duties in support of our efforts. Without her organizing and editing skills the committee's labors would not have been productive or coherent. Dr. Charles R. Malone (who left Washington for the cleaner air and heads of the west) was instrumental in organizing this project and helped to guide it through its early years. Stephen Parker, Jeanne Aquilino, and Carole Carstater performed countless (and ofttimes thankless) tasks which made it possible to fulfill our responsibilities.

In the final analysis, this was truly a cooperative activity between the members of the committee and the staff.

Walter R. Lynn, Chairman
March 1984

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ABBREVIATIONS

bgd	billion gallons per day
CO-OP	Cooperative Water Supply Operations on the Potomac
COE	Corps of Engineers
COG	Council of Governments
CTF	Citizens' Task Force
EEWTP	Experimental Estuary Water Treatment Plant
EPA	U.S. Environmental Protection Agency
FCWA	Fairfax County Water Authority
FISRAC	Federal Interstate - State Regional Advisory Council
ICPRB	Interstate Commission on the Potomac River Basin
LFAA	Low-Flow Allocation Agreement
MCL	Maximum Contaminant Level
mgd	million gallons per day
MWA	Metropolitan Washington Area
NAS/NAE	National Academy of Sciences/National Academy of Engineering

1

BACKGROUND

This report is the culmination of a continuing review by the National Research Council (NRC) of the U.S. Army Corps of Engineers (COE) Metropolitan Washington Area Water Supply Study, which was initiated in 1977 and completed in 1983.

The review was undertaken by the NRC at the request of the Secretary of the Army in 1977. On March 4, 1974, Congress mandated that the Secretary of the Army, acting through the Chief of Engineers,

> make a full and complete investigation and study of the future water resources needs of the Washington metropolitan area, including but not limited to the adequacy of present water supply, nature of present and future uses, the effect water pricing policies and use restrictions may have on future demand, the feasibility of utilizing water from the Potomac estuary, all possible water impoundment sites, natural and recharged groundwater supply, wastewater reclamation, and the effect such projects will have on fish, wildlife and present beneficial uses, and shall provide recommendations based on such investigations for supplying such needs.

Congress also directed the Secretary of the Army to "request the National Academy of Sciences-National Academy of Engineering to review and by written report comment upon the scientific basis for the conclusions reached by the investigation and study of the future water resources needs of the Washington metropolitan

area and the pilot project for the treatment of water from the Potomac estuary" (P.L. 93-251, 1974).

In 1976 the NRC was engaged to review the Corps study of the Potomac Estuary Experimental Water Treatment Plant to be built on two acres adjoining the Blue Plains Sewage Treatment Plant in the District of Columbia. This project was conceived as one alternative for providing water for the metropolitan Washington area. In 1977 the Corps requested that the NRC review and comment upon the scientific basis for the conclusions reached by their investigation of the future water resources needs of the metropolitan Washington area.

Thus, two committees were established with overlapping memberships to ensure that both could be informed of the progress of the Corps' overall effort. This report is concerned with the review of the Corps' overall water supply study; a separate report concerning the review of the pilot plant study has been written by that committee.[1]

By contractual agreement with the Corps of Engineers, the NRC was to deliver a written review one year after completion of their seven-and-one-half year study. At the first meeting of the Committee to Review the Metropolitan Washington Area Water Supply Study, it was agreed that the committee would provide the Corps of Engineers with an ongoing review for each stage of the Corps' study in addition to a final report. The committee believed that the Corps and the nation's capital area could be better served by maintaining frequent and open discussions with the representatives of the Corps of Engineers responsible for the study, the water utilities, and the many public interest groups involved and interested in future water supplies for the Washington area.

In 1981 the committee was reorganized, retaining an overlapping membership with the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project. The committee was led initially by Daniel A. Okun, Kenan Professor of Environmental Engineering at the University of North Carolina and member of the National Academy of Engineering and the Institute of Medicine, and subsequently by Walter R. Lynn, Professor of Civil and Environmental Engineering and Director of the Program of Science, Technology and Society at Cornell University. Dr. Lynn is also chairman of the NRC's Water Science and Technology Board.

The committee was composed of individuals with special expertise in civil, environmental, and sanitary engineering; political science; economics; groundwater geology; biophysics; limnology; ecology; geography; and water resource management. The committee received many useful comments and suggestions from various organizations, including the Interstate Commission on the Potomac River Basin (ICPRB), the Washington Suburban Sanitary Commission (WSSC), the Federal Interstate-State Regional Advisory Council (FISRAC), the Metropolitan Washington Council of Governments (COG), the Citizens' Task Force (CTF), the Maryland Department of Environmental Resources, the Fairfax County Water Authority (FCWA), and the League of Women Voters.

Since 1977 the committee has met two to three times each year. Five letter reports have been transmitted to the Baltimore District, Corps of Engineers, including an interim report released in 1980. Synopses of the contents of these reports follow.

NRC REPORTS 1977-1981

August 3, 1977, Letter Report

The first letter report reviewed the Washington Metropolitan Area (WMA) section of the Northeastern U.S. Water Supply Study (NEWS) published by the Corps in 1975. The Corps planned to use the information contained in the NEWS study as a starting point for the current study. The committee commented that several major issues were not adequately treated in the NEWS report, including (1) inadequate population and demand forecasting, (2) public health significance of using Potomac estuary water, (3) institutional arrangements needed to optimize use of regional resources, (4) ecological impacts, (5) interconnections, (6) availability of groundwater supplies, and (7) water quality and public health.

August 21, 1978, Letter Report

In its second letter report the committee evaluated the Corps' March 1978 final Plan of Study for the Metropolitan Washington Area Water Supply Study. The committee noted that much of the contents of this plan

was similar to the Corps' 1975 NEWS study reviewed in the first letter report in 1977. Attention was again called to the several weaknesses in the 1975 study in the Corps' 1978 study plan, such as inadequate forecasting or projections of water supply deficits, public health and ecological consequences for various water supply alternatives, insufficient emphasis on good water quality in planning, and the need for an independent and timely analysis of institutional aspects of the metropolitan Washington area.

April 13, 1979, Letter Report

This letter commented on the February 26, 1979, briefing given by the Corps representatives to the committee's Panel on Institutional Arrangements. It referred to the committee's letter report dated August 21, 1978, noting the fact that the concerns expressed by the committee in its 1978 report remained unresolved. The committee also recommended that the Corps study include an assessment of the potential consequences raw or finished water interconnections and alternative actions might have on regional institutional and governmental arrangements.

December 11, 1979, Letter Report

The committee conveyed its preliminary views of the Corps' August 1979 Draft Progress Report. The letter discussed the Corps analysis of the costs of alternative water supply schemes, benefit-cost analysis, omission of water quality considerations (including potential consequences of highly acidic water released from Bloomington Reservoir), institutional arrangements, and regional cooperation.

1980 Report: Water for the Future of the Nation's Capital Area

This interim report reviewed the U.S. Army Corps of Engineers' Draft Progress Report on the Metropolitan Washington Area Water Supply Study for the Potomac Water Users, published August 1979. The committee commended the Corps for improvements in water use forecasting,

emphasis on non-structural options, recognizing the importance of regional cooperation, and its exemplary efforts toward public participation. It reminded the Corps that in the time remaining for the overall study greater attention should be paid to detailed analysis of future water supply demand, benefit-cost analyses for each proposed plan, equitable distribution of benefits, environmental issues, and the importance of drinking water quality.

July 24, 1981, Letter Report

This letter report discussed committee concerns raised at a meeting held March 25-26, 1981, where representatives from the Corps of Engineers presented the status of the water supply study and the work remaining. The committee asked for clarification and an explanation of the method the Corps planned to use in deciding the final flowby volume and the Corps statements regarding implications of the environmental flowby study then being carried out by Maryland's Department of Natural Resources. This report also discussed the Bloomington Lake Reformulation Study and the Experimental Estuary Water Treatment Plant and their potential effects on the outcome of the Corps study, especially as they pertained to water quality.

Note: The preceding reports are reproduced in full in the Corps of Engineers' 1983 final report, Metropolitan Washington Area Water Supply Study, Appendix C. Copies are also available from the Water Science and Technology Board of the NRC.

SUMMARY OF THE CORPS OF ENGINEERS FINDINGS

In its final report the Corps concluded that regional cooperation is the key to meeting the future water supply needs for the Washington area.

A progress report issued in 1979 endorsed the concept of regional cooperation. Local entities in the metropolitan Washington area formed a task force and worked toward implementing a management plan to share water in the event of a shortage. Major elements of this plan include the cooperative management of the region's existing water supply resources, construction of a new

reservoir by local interests, and the purchase of water supply storage in the Corps' Bloomington Lake.

A series of agreements were signed by representatives of the District of Columbia and the states of Virginia and Maryland. These included a Low-Flow Allocation Agreement (LFAA) signed in 1978 (modified in 1982), the Water Supply Emergency Agreement (WSEA) signed in 1979, and the Water Supply Coordination Agreement signed in 1982. Detailed descriptions of these plans are included in the Corps' final report, and a brief description can be found in the Corps' Water Forum Notes, No. 9, April 1983.

Figure 1 gives a visual overview of how the regional water supply system will operate by showing the onset of a typical summer drought and the sequence of actions that can be taken to avoid shortages:

- Large Potomac flow, minimize reservoir releases.
- Declining Potomac flow, begin increasing releases from Bloomington and Savage.
- More water needed soon, increase withdrawals from Patuxent and Occoquan.
- Deficits imminent, release water from Little Seneca Lake.
- Critical period over, stop releases from Little Seneca Lake.
- Begin reducing releases from other reservoirs.

Figure 2 shows the location of structural elements of the regional plan.

The results of the entire MWA Water Supply Study are presented in the Corps' final report issued September 1983. This document consists of a Main Report and nine technical appendixes. The Main Report provides a summary of the investigations, the planning process, and the significant findings and recommendations by the district engineer. The nine appendixes contain detailed information to support the findings listed in the Main Report. These compose the documents that the NRC committee reviewed and the ones on which the following comments are made.

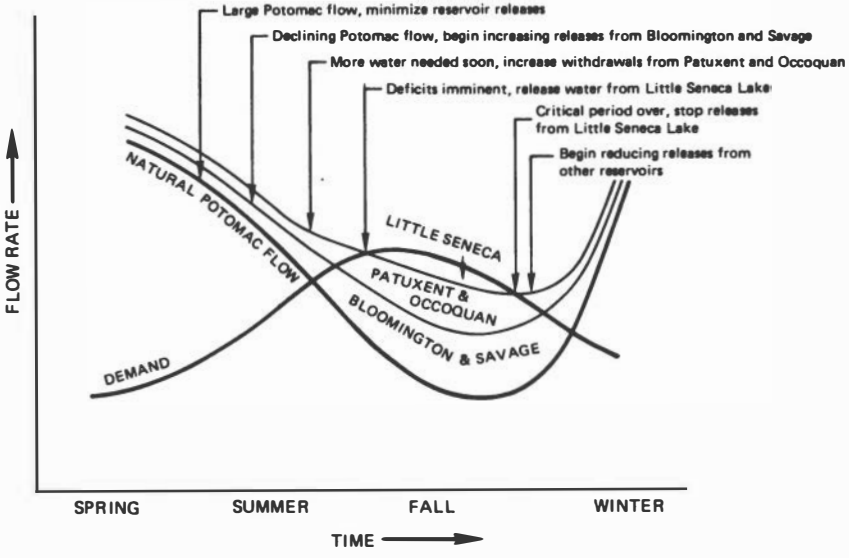
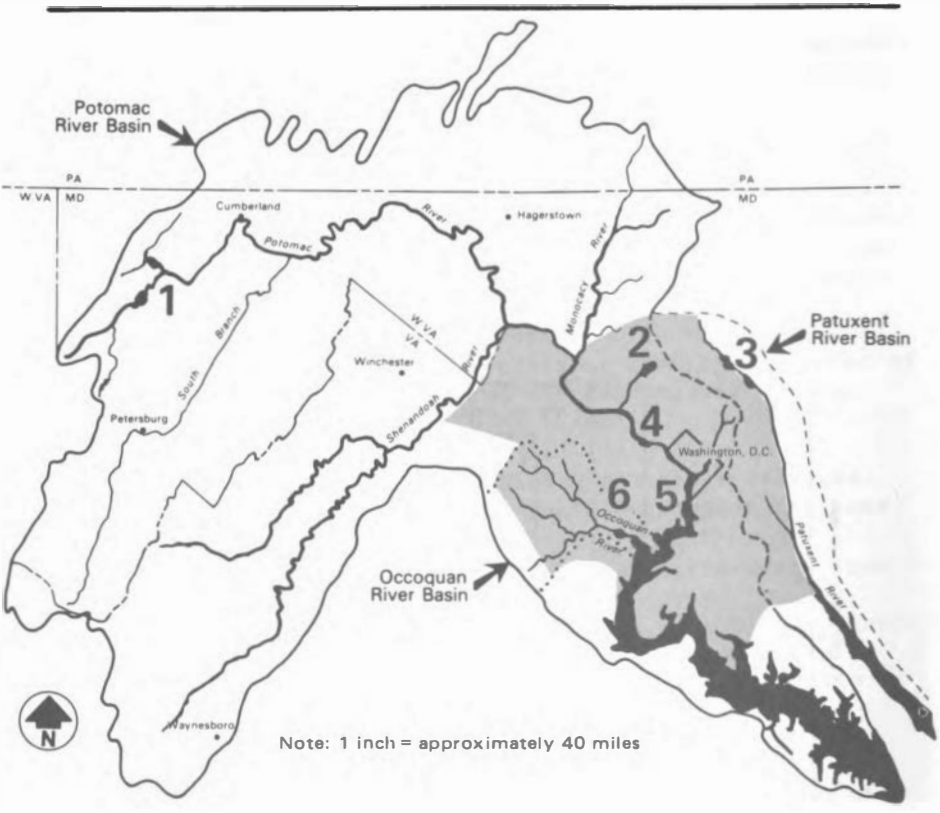


FIGURE 1 Schematic of System Operation.

SOURCE: Corps of Engineers, Baltimore District, Water Forum Notes, No. 9, April 1983.



Metroploitan Washington Area (includes the following: Washington, DC; Montgomery, Prince Georges and Charles counties in MD; and Arlington, Fairfax, Prince William and Loudoun counties in VA).

1 UPSTREAM RESERVOIRS

Approximate 7-Day Travel Time to MWA Intakes
Releases Blended to Improve Water Quality

SAVAGE RESERVOIR
Total Available Storage - 5900 Million Gallons
Maximum Release - 3130 MGD

BLOOMINGTON LAKE
Total Available Storage - 30,000 Million Gallons
Maximum Release - 10,710 MGD

2 LITTLE SENECA LAKE

Total Available Storage - 4020 Million Gallons
Maximum Release - 275 MGD
Approximate 1-Day Travel Time to MWA Intakes

3 PATUXENT RESERVOIRS

ROCKY GORGE & TRIADELPHIA
Total Available Storage - 10,100 Million Gallons
Max. Water Supply Withdrawal - 65 MGD

4 MWA INTAKES

	Maximum Withdrawal (MGD)	Treatment Capacity (MGD)
FCWA	200	50
WSSC	400	240
Rockville	8	8
Aqueduct	650	371

5 ENVIRONMENTAL FLOWBY

Environmental Flowby to the Estuary with a Minimum Value of 100 MGD

6 OCCOQUAN RESERVOIR

Total Available Storage - 10,300 Million Gallons
Max Water Supply Withdrawal - 112 MGD

FIGURE 2 Location of Key Elements of the Regional Plan.

SOURCE: Corps of Engineers, Metropolitan Washington Area Water Supply Study, Main Report, September 1983.

SUMMARY OF COMMITTEE FINDINGS

Congress directed the Secretary of the Army to request the NAS/NAE to review and by written report comment upon the scientific basis for the conclusions reached in the Corps' investigation of the future water resource needs of the Washington metropolitan area.

The determination of future water resource needs and the means for satisfying these needs are only in part "scientific" questions. Plans for any engineering work are based upon scientifically derived facts and assumptions. At the same time, proposed solutions to any engineering problem require judgment in order to balance technical and economic factors and issues of political feasibility and acceptability. The major questions that the Corps of Engineers addressed required not only careful development of the facts of the Metropolitan Washington Area (MWA), but also extrapolations of this information to a time some 50 years in the future. The time periods selected for planning such works may vary, as will the physical, chemical, biological, political, economic, social, and demographic environments of any study that strives to determine future water resource needs. Thus, the planning of water resource systems requires identifying, collecting, collating, and synthesizing all relevant knowledge and information and the exercise of judgment in developing recommendations for various courses of action.

This committee review focused upon

1. the methods employed by the Corps to obtain the information and data used to identify and analyze the future water resource problems of the MWA; and

2. the compatibility of the Corps of Engineers' findings and recommendations with the future water resource problems so identified and analyzed.

The Corps of Engineers was charged with responsibility for developing a plan for future water resource needs of the MWA, not with responsibility for implementing this plan. The ability to supply the MWA with adequate water of good quality has been a matter of long-standing concern and, needless to say, there have been many studies and reports dealing with these resource issues over the past decades. Because of this history and the critical importance of an adequate future water supply in the nation's capital region, the Corps' assignment presented a unique set of challenges and opportunities. Not the least of these was the opportunity to perform a water resource planning study that was methodologically up to date, complete, and scientifically accurate so that it could serve as a model for similar studies in other U.S. metropolitan areas. While the Corps explicitly declined to accept this obligation (i.e., of performing a paradigm study), the committee believes that the Corps did in fact conduct the study in an imaginative, creative, and scientifically sound manner and that the study serves the national interest in that the experience gained can be applied elsewhere, subject to adjustment for local conditions. However, the Corps report fell below the committee's expectations in several important areas, which are briefly presented on pages 11-13 and discussed in Chapter 3.

Among the most outstanding features of the study were these:

1. The development of systems management (non-structural) solutions to problems relative to the future water supply needs of the MWA.[2] To use these nonstructural recommendations as the principal means of resolving the MWA water supply problem, the Corps encouraged and aided the efforts of the parties responsible for collection, treatment, and distribution of water within the region. (The Low-Flow Allocation Agreement, the Potomac River Interactive Simulation Model (PRISM) for managing drought situations, and the reassessment of the role of Bloomington Reservoir were important elements in achieving this goal.)

2. The determination and assessment of future water demands through the use of improved modeling

techniques.[3] These methods provided more information and greater insights than were possible using only traditional engineering design methods for assessing water requirements.

3. The development of a wide range of alternative methods of meeting future water resource needs of the MWA. These alternatives were developed in a serious and purposeful manner, and each was considered before arriving at a set of final recommendations.[2,4,5,6]

4. The excellent procedures followed by the Corps to involve and utilize the citizens of the MWA in developing design criteria and recommendations for future actions.[7] The Corps' long-standing commitment to citizen involvement in planning and program decision making was carried out in a responsible and effective manner through the use of public meetings and publication of a newsletter, Water Forum Notes.

5. The collection and collation of current and historical data used in the analyses of the MWA study. This information will continue to be used in managing the water resources of this region.[8]

The committee acknowledges and commends the Corps for these achievements.

Regretfully, however, the committee believes that the Corps study contains several flaws that detract from the many truly innovative contributions that characterize the study. These flaws lie in three areas: Reliability of Institutional Arrangements, Preservation of Reservoir Sites, and Drinking Water Quality. The next several pages present these areas briefly. More detailed discussion of each topic can be found in Chapter 3.

RELIABILITY OF INSTITUTIONAL ARRANGEMENTS

A central element in the plan adopted in the Corps report is the change in water resource management arrangements for the MWA that resulted from the strong leadership of key individuals from the MWA's water utilities and other interested groups. The inter-local compacts constitute a voluntary system for operating the region's water supply, and this is a step forward. It provides for decisions by "their best efforts," with final recourse to the courts when an impasse is reached. The local governments and other agencies are to be congratulated for gaining consensus on these matters.

However, the long-term significance of what has been accomplished has perhaps been overstated.

The set of cooperative arrangements still leaves many serious questions unresolved. For example, this committee has raised the possibility of a need for more reservoirs (see pages 12, 41-43); the Corps report identifies the need for watershed protection and monitoring programs; and at some future time, the 100 million gallons per day (mgd) flowby minimum may need revision. Such difficult questions will have to be dealt with by the institutional structure, which the Corps has accepted as capable of successfully managing water supply for the MWA even though no final decision-making device has been recommended by the Corps to handle these types of issues. Moreover, no such device is perceived to be necessary by the Corps.

The committee believes that the Corps' institutional analysis is incomplete and does not adequately assess the strengths and weaknesses or the comprehensiveness of the cooperative agreements.

PRESERVATION OF RESERVOIR SITES

Considering the Corps' charge to create long-term plans for water supply for the MWA, it was inappropriate to have eliminated from consideration potential reservoir sites for future use, particularly as the Corps states that "the greatest supply of high quality water for the MWA at the lowest unit cost" rests with upstream reservoirs. The committee finds no evidence for the Corps conclusion that the MWA will not need additional water supply reservoirs. Considering that in time the Potomac River water may present increasing public health risks, one important option that would help ensure safe drinking water quality for the area would be to use water from upstream reservoirs. Also, demands beyond the time frame of this study may well be met by upstream reservoirs. Once deauthorized, the reservoir sites originally identified by the Corps may be claimed for other incompatible uses and thus would no longer be available for water supply purposes.

DRINKING WATER QUALITY

Although the Congress charged the Corps with developing a plan that addresses the region's water resource needs, it was clearly understood by the committee that the primary focus was on public water supplies for the MWA, the quality of which is determined by that needed for drinking water. In its first letter report[9] (August 1977) to the Corps, the committee reviewed the Corps' Northeastern U.S. Water Supply Study (NEWS). This letter report stated that inadequate consideration had been given to water quality and public health. This criticism was repeated in the committee review of the Corps' early action progress report.[10] The committee strongly stated that inadequate attention had been given to water quality considerations in the development of sources of water supply. In the "long-range planning report"[11] only perfunctory attention is given to drinking water quality issues; clearly such vital matters do not receive the attention they deserve. The final report and the study have not included the following vital aspects of drinking water quality.

1. Data based on state-of-the-art assessment of contaminants and pollutants, particularly with regard to maximum contaminant levels for trihalomethanes, are not analyzed. Also, the extensive data on existing water supplies gathered in the preparation of the companion Estuarine Treatment Study are not considered.
2. Projected water quality standards based on the current status of research and investigations, particularly with regard to organics and heavy metals, are not considered.
3. The significance of secondary drinking water standards, particularly with regard to taste and odor, as well as consumer acceptability, was not considered. Nevertheless, water quality consideration would not likely have had much impact on the Corps' final recommendations.

More detailed comments concerning water quality are in Chapter 3 under several headings--Water Quality, Potomac Estuary, Raw Water Interconnections, Bloomington Lake Reformulation Study, and Wastewater Reuse.

STATEMENT OF SIGNIFICANT FINDINGS BY THE CORPS OF ENGINEERS AND NRC COMMITTEE EVALUATION

In this chapter the committee restates the Corps' significant findings and then evaluates each according to the same order used in the Corps' Main Report, Chapter VIII.[11]

SUPPLIES

Corps of Engineers Finding

The Potomac River is the MWA's major source of supply, furnishing about 70 percent of the area's water supply needs. With the recent completion of Bloomington Lake in 1981 and the expected completion of Little Seneca Lake in the mid-1980's, supplemental releases will be available during naturally low flow periods in the Potomac River. Other major sources of supply are the Occoquan Reservoir in Virginia and the Patuxent Reservoirs in Maryland furnishing about 12 percent and 14 percent, respectively, of the MWA needs. Together these three sources furnish 96 percent of the water used in the MWA. Studies indicate that water from these sources can be treated to satisfy drinking water standards; likewise no problems are expected in the foreseeable future in producing potable water from these sources. Because of the extreme variability of natural flow in the Potomac River and because it is the MWA's primary source of water supply, prudent use must be made of existing reservoir storage capacity available to the MWA.

NRC Committee Evaluation

A review of the characteristics and safe yield of the existing reservoirs and surface water sources in the area and a description of the responsibilities and capabilities of each of the area's water supply organizations, presented initially in the August 1979 progress report,[10] is contained in Appendix D, March 1983.[3] Conventional methods of analysis, extended by use of an analytical simulation model of the Potomac River system, were employed to determine safe yields and water system capabilities. The Bloomington Lake Project was estimated to provide a safe yield of 135 million gallons per day (mgd), and a minimum Potomac River flowby of 100 mgd was assumed. The analysis accorded little attention to groundwater sources, presumably because of their minor role in supplying MWA needs (12 mgd estimated use in 1976) and the relatively high cost of developing, treating, and transporting groundwater to the MWA. The U.S. Geological Survey (USGS) has reported that substantial groundwater supplies exist in the Atlantic Coastal Plain of southern Maryland, within 30 miles of Washington, D.C.[3] However, the Corps of Engineers ruled out the use of this groundwater supply because of opposition from the public residing in the regions where these waters could be extracted and because it was one of the most costly alternatives available to the MWA (see Groundwater, pages 45-46).

Since the 1979 report, several changes have occurred that affected the potential sources of water. These include

- Local commitment to the Little Seneca Lake project.
- Completion of the Bloomington Lake Reformulation Study,[6] including consideration of coordinated operation of Bloomington and Savage reservoirs.
- Completion of the Potomac River Environmental Flowby Study,[12] supporting the 100-mgd flowby assumption.
- Modifications to the Potomac River Low-Flow Allocation Agreement, recognizing the terms of the cooperative agreements.
- Implementation of a set of agreements among the various water supply agencies providing for coordinated development and management of water sources.

These recent developments were considered in determining the long-range water supply base in addition to the findings of the early action analysis.

As noted, the committee found that the methods used in estimating safe yields and system capabilities are conventional except for one major innovation: development and use of the Potomac River Interactive Simulation Model/Corps of Engineers (PRISM/COE) to assess the effects of water supply management schemes on possible stream flows and water storage.[6] The model was used to determine the effects on water supply of multiple flood control/water supply storage reallocation possibilities in Bloomington Lake as well as the water supply potential of coordinated operation of Bloomington Lake and Savage Reservoir. We conclude that the Corps of Engineers' findings on supplies are sound and acceptable.

DEMANDS

Corps of Engineers Finding

Average annual water demands within the MWA, after accounting for a realistic conservation factor of approximately 11 percent, are expected to increase from around 440 mgd in 1980 to about 680 mgd in 2030. Seasonal summer peak use will be well in excess of the average annual values and are projected to range as high as 970 mgd by 2030. Categorical breakdowns of water use show that single and multifamily residential units are estimated to account for about 62 percent of existing total water use. Percentages in other use categories are: unaccounted - 13 percent; commercial/industrial - 11 percent; Federal government - 9 percent; and non-Federal government/institutional - 5 percent.

Within the MWA, there are 25 independent water service areas. Four of the more highly developed areas are served by the Washington Suburban Sanitary Commission (WSSC), Fairfax County Water Authority (FCWA), Washington Aqueduct Division (WAD), and Rockville City which meet about 96 percent of the MWA's total demand. These four service areas are either partially or wholly dependent upon the Potomac

River, and were the primary focus of the report. The remaining service areas were defined as the outlying communities and were analyzed to a lesser degree of detail.

NRC Committee Evaluation

In its review of the water demand forecast in the early action plan,[10] the committee's 1980 report[13] noted that the forecast could have been improved by: (1) the use of economic demand models for the residential sectors; (2) explicitly considering the relationship between weather and seasonal water use; and (3) probable impacts of present or prospective rate-making policies in the region. The method chosen by the Corps of Engineers to forecast water demands led to some apparent anomalies in the results, such as relatively high household water use in multifamily structures when compared to single-family units. The treatment of water conservation was also faulted because the Corps used a scenario approach that precluded any assessment of the sensitivity of future water use to different conservation schemes. A revised demand forecast prepared for the long-range phase of the study produced similar results and is subject to the same criticism.

Water service agencies using the Potomac River concurred in the Corps' assumption that existing and planned water conservation programs will reduce year 2030 water use 10 to 11 percent below base forecast levels (Conservation Scenario 3).[2] This reduction is reflected in the long-range demand forecasts. The final water demand is forecast on a monthly basis, omitting the daily and weekly peaks that had previously been considered. The Corps has concluded that conservation and local storage measures are adequate to control day-to-day and week-to-week fluctuations in water use under drought conditions.

The committee's earlier concerns regarding the effect of price and of rate-making policy on future water use levels were addressed in a separate study.[2] Except for the expanded analysis of outlying areas (i.e., those not dependent on the Potomac River) no changes were made in the water use forecasts.

Although use of standard econometric methods might have permitted added consideration of possible changes in future water demands as well as greater insight into

demand levels under drought conditions, the methods actually used were an improvement over methods previously used by the Corps. The committee concludes that the study resulted in adequate demand forecasts.

SHORTAGES

Corps of Engineers Finding

Large water supply deficits for the MWA had been forecast when the study was being initiated. As the nature of the supplies, demands, and capabilities of the existing resource base were better defined, the magnitude of the problem was found to be less severe than originally estimated. Certain actions by non-Federal entities during the course of the study further reduced the deficits which were first projected.

With the series of regional agreements recently signed in July 1982, the availability of Bloomington Lake and Little Seneca Lake, and the implementation of certain conservation measures, no shortages are now projected for the four major Potomac users within the planning horizon (year 2030). This statement is predicated upon the assumption of a minimum 100 mgd flowby target during severe drought, coordinated regional management by the major utilities to make the most efficient possible use of the river and reservoir sources, and the occurrence of a drought no worse than the most severe on record (1930-31).

NRC Committee Evaluation

Water shortages (i.e., deficits) were determined in the Corps' early action plan on the basis of the ability of the available water supply to meet the 7-day and 30-day peak water demands that would be expected to occur once every 100 years. The analysis showed that the existing system would fail to meet peak demands of the late 1980s for the 7-day peaks and at about 2005 for the 30-day peaks. These deficits could be deferred until about

1994 and 2020, respectively, if the conservation methods proposed were employed.

The Corps' long-range deficit predictions are based on forecasts of 30-day water use (unchanged from the early action phase), 100-mgd flowby at Little Falls, and the proposed measures. The predictions also assume fully coordinated use of all reservoirs, upstream and local, including the Little Seneca reservoir (now under construction). The analysis relies on the use of the PRISM/COE model as a basis for operating and managing the overall metropolitan Washington area as a multireservoir and river system. Assuming a 30-day drought expected to recur once in 100 years and a 100-mgd flowby and conservation, no deficits would be expected during the planning period (to 2030). Furthermore, no deficits would be expected to occur with respect to monthly demands if droughts of the magnitude experienced in 1930-1931 or of the mid 1960's were to recur.

The Corps analyzed the effect of increased Potomac River flowby requirements (300 mgd and 500 mgd) on deficits during selected sequences of the historic 1930-1931 drought. If at some future time it is determined that the minimum flowby, 100 mgd, must be increased significantly, the Corps plan would have to be reevaluated in light of these requirements. The committee concludes that the methods used to estimate the performance of the system are acceptable.

The above analysis and findings do not apply to the outlying service areas (portions of the Counties of Fairfax, Loudon, Charles and Prince William), which do not depend on the Potomac River system. The Corps of Engineers predicts that the population of these areas will increase fourfold between 1980 and 2030 and that water demand will rise from 21 mgd to 107 mgd. The methods of population and demand forecast used here are essentially the same as those used for those portions of the MWA depending on the Potomac River, except for omission of water conservation.[14] The long-range plan does not present specific recommendations for meeting these expanded water demands. Instead, it reviews nine alternative steps, structural and non-structural, and five planning approaches for analyzing these alternatives. These alternatives and approaches are offered as general considerations.

FLOWBY

Corps of Engineers Finding

As part of its responsibilities under the LFAA, the State of Maryland in cooperation with others conducted an investigation of environmental flowby into the Potomac Estuary and recommended that a minimum target of 100 mgd be established. The LFAA signatories later adopted this value, and it was subsequently used for planning purposes throughout the MWA Water Supply Study. Analyses were performed, however, to determine the sensitivity of the projected surpluses and shortages in the year 2030 to other flowby levels. Two values, 300 and 500 mgd, were selected for examination. Results of the examination simulating a recurrence of the 1930-31 drought indicated that a 300 mgd flowby target would cause only small shortages throughout the water supply system in year 2030; however, nearly all of the system's water supply storage would be exhausted (Bloomington, Savage, Occoquan, Patuxent, and Little Seneca). For a 500 mgd flowby target and simulation of the 1930-31 drought, large shortages would occur throughout the system in year 2030 and all water supply reservoirs would be emptied. The volumes of shortages associated with 300 and 500 mgd flowby targets in the year 2030 would approach 2.0 bg and 32.0 bg, respectively.

NRC Committee Evaluation

Environmental flowby is that minimum river flow needed to maintain desired environmental and ecologic conditions in the Potomac River below Great Falls.

The major investigation and sensitivity analysis for various flowby levels for the Potomac River and the upper estuary was completed by the State of Maryland[12] as part of its responsibilities under the Low-Flow Allocation Agreement (LFAA). These investigations focused primarily on the area between Great Falls and Little Falls Dam because water quality in this area

appeared to be the most sensitive to the minimum flowby levels considered.

The recommended target of 100 mgd for flow into the estuary coincides with the historical experience of the 1966 drought when approximately 119 mgd was the minimum instream flow into the estuary. In addition, simulation studies and other work demonstrated that the 100 mgd flowby could be maintained without creating serious stress or shortages in the proposed system.

The committee finds that the flowby level of 100 mgd is supported by the data and analysis conducted by the Corps of Engineers and the State of Maryland and resulted in an acceptable solution that was adopted in the Low-Flow Allocation Agreement.

WATER QUALITY

Corps of Engineers Finding

The water quality of existing and proposed water supply sources was of particular concern to the NAS-NAE Review Committee and the Citizens Task Force throughout the study process. Investigations were undertaken by EPA to determine the potability of existing sources. Based on limited available data, the EPA study concluded that the existing water treatment plants are capable of producing water from their respective sources which satisfies current drinking water standards. Additionally, the existing water treatment plants are capable of responding to moderate changes in raw water source quality, should such changes occur, without large scale modifications to the treatment processes.

Nevertheless, strong watershed protection programs should be enacted for those areas upstream of the MWA's water supply reservoirs in order to maintain or improve the water quality of reservoir inflows. These watershed protection programs should be accompanied by an intensive and continuing water quality monitoring network to detect changes in the raw water sources that are used for potable purposes.

NRC Committee Evaluation

The Corps statement that water quality was of particular concern to the NAS/NAE Review Committee regarding proposed water supply sources is correct. In its report, Water for the Future of the Nation's Capital Area,[13] the committee affirmed the concerns expressed in previous verbal and written communications[9,15,16] that little attention was being given to these issues in the Corps study. In particular, the committee's report raised the following questions: "Is water quality in the Potomac River adequate for a safe supply, and will it be so during the coming half century?" The report went on to say,

> In planning water supplies to serve millions of people during the next 50 years, a careful assessment of quality is required. The Potomac River, especially in the vicinity of metropolitan Washington, has a questionable reputation for its quality, and questions such as these need to be addressed in view of the growing public awareness of and insistence on the safest possible drinking water.

Only late in the study (1982) did the Corps contract with the U.S. Environmental Protection Agency (EPA) for an investigation to determine the potability of existing sources. The Corps' findings are conditioned by the "limited available data." However, data collections for the Experimental Estuary Water Treatment Plant (EEWTP) study were not utilized by the EPA investigation, and such data included information on trihalomethanes and other organics. In addition there was ample time and strong insistence by the committee since 1977 that decisions concerning the MWA water supply should be based upon a thorough examination of the quality issues and that such a study should be at the level of the state of the art. Accordingly, the statement in the findings that "the EPA study concluded that the existing water treatment plants are capable of producing water from their respective sources which satisfies current drinking water standards" may, in fact, be correct, but it does not recognize that abundant scientific evidence exists that EPA's National Interim Primary Drinking Water Regulations (NIPDWRs) do not reflect current knowledge in the field.

The following comments highlight those areas concerning water quality in which the committee feels the Corps report is deficient:

Drinking Water Standards/Potability Study The EPA report, Appendix G, Annex G-III, "Examination of Water Quality and Potability for the Metropolitan Washington Area Water Supply Study"[2] does not demonstrate that the water treatment plants are capable of producing water that satisfies current drinking water standards. While Table 7 in Appendix G refers to the National Interim Primary Drinking Water Regulations, it entirely omits consideration of the quality parameters in section 141.12, "Maximum Contaminant Levels for Organic Chemicals." Neither are considerations of radioactivity and maximum microbiological contaminants included in the assessment.

A serious fault is the failure to investigate the problem of trihalomethanes (THMs). This group of organic chemicals, originating as it does in water treatment itself as a reaction of chlorine with precursor organics, has been a matter of considerable scientific concern. That should have indicated to the Corps and the EPA that an evaluation of THMs at the various water resources for the metropolitan Washington area was required. It has been well known that run-of-river supplies have generally had difficulty in reducing THMs to acceptable levels. The use of the word "current" in the findings is inappropriate, not only because THMs were added to the regulations in 1982 but because for many years earlier it was generally recognized that such an addition to the standards was imminent.

Therefore, the committee concludes that it was inappropriate for the Corps of Engineers to limit the scope of its charge to EPA to assess the capacity of the treatment plants to meeting only the current water quality standards. The Corps is responsible for presenting options for at least 50 years into the future, and facilities that are built following any such plan will in all likelihood serve many years into the future. The findings that the treatment plants are capable of responding to moderate changes in raw water source quality may be true, but there is no indication that they can be responsive to changes in the drinking water standards themselves. To say that the water meets present drinking water standards is itself less

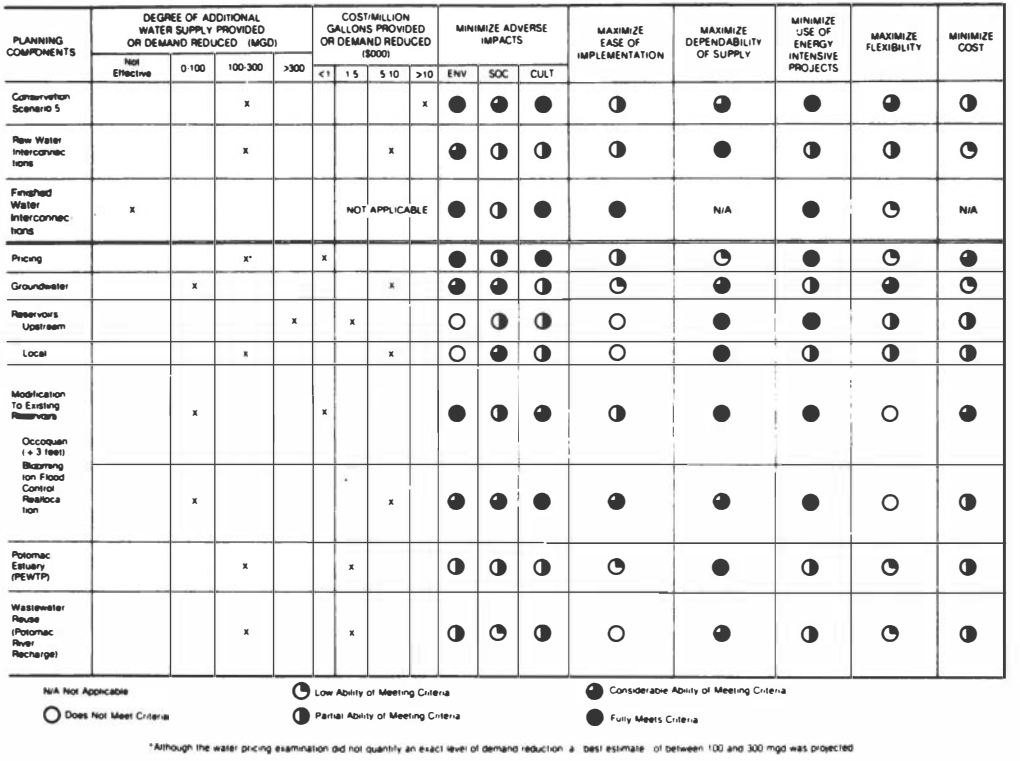
meaningful than it purports to be. What is being said is that the water meets the maximum contaminant levels (MCLs) in the regulations. The National Interim Primary Drinking Water Regulations[17] state that "priority should be given to selection of the purest source. Polluted sources should not be used unless other sources are economically unavailable. . . ." Accordingly, the MCLs are based upon drawing water from a high-quality source, and the standards might be substantially different if a source is contaminated. More importantly, even for high-quality sources, it can be expected that future drinking water standards, which will need to be met by the works being planned in this study, will list many more contaminants. Thus, the standards represent a moving target, and while they may be useful for regulation, they cannot be considered adequate for long-range planning.

The EPA study compares the various existing sources of water in the MWA, but only for metals, minerals, and aesthetic parameters. Synthetic organic chemicals and microbiological assessments are not included. Yet, as interconnections begin to be developed and reregulation becomes a part of the water supply infrastructure, the relatively poor quality of the Occoquan River water may have a significant impact on the quality of the overall supply.

Failure to consider water quality in evaluating the several options is made clear in Figure 3 from page 52 of the Corps' Main Report,[11] which is an evaluation matrix for long-range planning measures. Many factors are considered, including adequacy of meeting demand, cost, adverse impacts, ease of implementation, dependability of supply, use of energy, and flexibility. Water quality is not included in the matrix, yet the study is designed to provide water for drinking.

The responsibility for the investigation rested with the Corps and not with EPA, although EPA might properly have circumscribed its report to the Corps with appropriate caveats, including not only that there were limited available data but that the financial resources made available to EPA for so important an investigation were entirely inadequate.

Accordingly, the committee has no reason to question that the quality of the existing drinking water supplied to the MWA meets the EPA Primary Drinking Water Regulations. However, the Corps has not assembled



PLANNING COMPONENTS	DEGREE OF ADDITIONAL WATER SUPPLY PROVIDED OR DEMAND REDUCED (MGD)				COST/MILLION GALLONS PROVIDED OR DEMAND REDUCED ($000)				MINIMIZE ADVERSE IMPACTS			MAXIMIZE EASE OF IMPLEMENTATION	MAXIMIZE DEPENDABILITY OF SUPPLY	MINIMIZE USE OF ENERGY INTENSIVE PROJECTS	MAXIMIZE FLEXIBILITY	MINIMIZE COST
	Not Effective	0-100	100-300	>300	<1	1-5	5-10	>10	ENV	SOC	CULT					
Conservation Scenario 5			x					x	●	◕	●	◑	◕	●	◕	◑
Raw Water Interconnections			x				x		◕	◑	◑	◑	●	◑	◑	◔
Finished Water Interconnections	x					NOT APPLICABLE			●	◑	●	●	N/A	●	◔	N/A
Pricing			x*		x				●	◑	●	◑	◔	●	◔	◕
Groundwater		x					x		◕	◕	◑	◔	◕	◑	◕	◔
Reservoirs Upstream				x		x			○	◑	◑	○	●	●	◑	◑
Local			x				x		○	◕	◑	○	●	◑	◑	◑
Modification To Existing Reservoirs Occoquan (+3 feet)		x			x				●	◑	◕	◑	●	●	○	◕
Blazzeng ion Flood Control Reallocation		x					x		◕	◕	●	◕	◕	●	○	◑
Potomac Estuary (PEWTP)			x			x			◑	◑	◑	◔	●	◑	◔	◑
Wastewater Reuse (Potomac River Recharge)			x			x			◑	◔	◑	○	◕	◑	◔	◑

N/A Not Applicable
○ Does Not Meet Criteria
◔ Low Ability of Meeting Criteria
◑ Partial Ability of Meeting Criteria
◕ Considerable Ability of Meeting Criteria
● Fully Meets Criteria

*Although the water pricing examination did not quantify an exact level of demand reduction a best estimate of between 100 and 300 mgd was projected

FIGURE 3 Long-Range Planning Measures, Evaluation Matrix.

SOURCE: U.S. Army Corps of Engineers, Baltimore District, 1983, Main Report, Metropolitan Washington Area Water Supply Study.

adequate scientific data to support their finding that existing water treatment facilities are necessarily capable of producing water that meets water quality requirements for potability in the future.

Watershed Protection Programs The findings include a statement that strong watershed protection programs be enacted for areas upstream of MWA water supply reservoirs to maintain or improve the water quality of reservoir inflows. Inasmuch as most of the water used in the MWA is drawn directly from the Potomac River, the Corps should be concerned not only with inflows to existing reservoirs, which after all may have capacity for improving quality as the water flows through them, but also for discharges directly into the Potomac and its tributaries where reservoirs do not exist. No mention is made in the report of the pollution of the Shenandoah River by industrial wastes,[18] including the impact of mercury incorporated into the sediments of this important tributary of the Potomac.

The Corps report finds that these watershed protection programs should be accompanied by an intensive and continuing monitoring program to detect changes in the raw water sources used for potable purposes. However, the Corps neglects to mention the very difficult institutional problems inherent in mounting watershed protection programs and monitoring programs, a problem with which it is fully familiar. The Corps now recognizes the institutional arrangements developed by the local governments and utilities as the best solution to the management of the MWA water resources. However, in its 1979 Draft Progress Report,[10] the Corps virtually abandoned any prospects for regional cooperation in effecting a program for optimum management of the water resources in the area. Water planning for the metropolitan Washington area has been plagued by considerable political difficulty in obtaining acquiescence to reservoir development in upstream reaches of the watershed and by resistance to watershed management, which almost always exacts a considerable cost to the local authorities involved. Watershed management may involve restricting or regulating development or imposing water quality measures such as silt control and is not likely to be easy to achieve. Watershed management is a function of each of the local authorities, but the report

implies that implementing these measures is straightforward.

Future Reservoir Sites The committee is concerned with the basis upon which the conclusion is drawn that there is no need for additional water supply reservoirs for the MWA. If in time it is recognized that run-of-river supply in a drainage area as large as the Potomac presents inherent public health risks, one option that could ensure improved quality for the area is the use of water supplies drawn directly from upstream reservoirs on smaller and more controlled watersheds. It would seem to be incumbent upon the Corps that for any long-term plan for the area, future water supply needs both from the standpoint of quantity and quality should be recognized and addressed by measures involving land use plans that do not entirely eliminate potential reservoir sites (i.e., as recommended in the Corps' Conclusion #3, see Appendix A) from possible use for water supply purposes.

The committee agrees with parts of the Corps' conclusion number 9 (see Appendix A) that ". . . these studies [potability] were admittedly of a limited nature. Any future study of water supply needs in the MWA should consider a more thorough examination of the quality and/or potability of different water sources. Additionally, strong watershed protection programs and water quality monitoring systems should be undertaken now to prevent the degradation of existing raw water supplies and to collect data regarding water quality trends throughout the MWA, respectively." However, implementation of such actions is not nearly so simple as is implied.

OUTLYING SERVICE AREAS

Corps of Engineers Finding

Although the outlying communities make up only a small percentage of the MWA's overall water supply needs, they nevertheless face potential shortages well before the major utilities. The nature of these shortages and the alternatives available to overcome them are peculiar to each outlying community. The report contains some

general planning guidelines which could be adopted to any specific area. Some of the same alternatives formulated for the major utilities would also apply to the outlying communities, but developed to a smaller scale. The most likely future sources for the outlying communities appear to be groundwater development and small reservoirs.

NRC Committee Evaluation

In Charles County, Maryland, strong aquifers assure ample groundwater supplies. In the Virginia service areas the aquifers are less productive and the potential supply is questionable. With good reservoir sites in short supply the Corps should have indicated that the land necessary should be acquired before it is purchased for other purposes (see Upstream Reservoirs, pages 41-43).

The Corps summary and conclusions statement would be much enhanced by highlighting some of the controlling and critical features, such as: population increasing from 294,000 in 1980 to 561,000 in 1995; a parallel growth in water demands from 21 mgd to 45 mgd, and to 107 mgd in 2030; periodic water shortages in some parts of the service areas, past and present overpumping of well fields, and occasional substitution of surface ponds or reservoirs; more specifically, the recently constructed Leesburg Potomac River intake and water treatment plant (10 mgd), and the proposal to connect five Prince William communities to the FCWA for total supply.

The NRC committee agrees with the Corps decision not to investigate in detail the many existing water systems in Outlying Service Areas. These facilities will be planned and constructed locally with little or no federal participation. The extent and complexity of the task is shown by the mass of data and information assembled in the Corps' final report, Appendix I. Springs, wells, and local surface water systems may suffice in some places for several years. Ultimately connections to the Fairfax County Water Authority system or other substantial source seems certain. However, further consideration should have been given in the Corps report to how the future water demands of these

outlying areas might impact on the sources assumed to be available to the MWA.

SYSTEM OPERATION

Corps of Engineers Finding

The basic cornerstone to satisfying water supply needs through the year 2030 for the major Potomac users is cooperative regional management of the entire water supply system. With operation of the system as a regional unit, it is possible to obtain certain synergistic effects which improve the system's water supply capability. A systems model (PRISM/COE) was developed and applied to identify and evaluate the regional management strategies which offered the most promise. Selection of an appropriate release balance between upstream reservoirs (Bloomington and Savage) and downstream reservoirs (Patuxent and Occoquan), for instance, can reduce the storage "wasted" early in the water supply season and conserve water for later use, during a more critical period. With conjunctive operation of all reservoirs, drawdowns could also be kept to a minimum throughout the reservoir system. Regulation of the system in such a manner would furnish an adequate base supply for most situations; however, Little Seneca Lake would be available as an emergency supplemental source should Potomac flows be lower than projected or demands greater than anticipated. Regulation of the entire water supply system as a regional unit also offers added flexibility in responding to seasonal and daily variations in supply and demand, and would have generally positive effects on the associated environmental resources.

NRC Committee Evaluation

Cooperative regional management of the Potomac River water supply system rests on a series of agreements and

contracts executed by the three major water utilities and other agencies on July 22, 1982. These are

- A contract obligating the three utilities to purchase all water supply storage in Bloomington Lake (reproduced in the Corps final report as Appendix H/Annex IX). The previous contract with the Maryland Potomac Water Authority was simultaneously terminated (see Appendix H/Annex X).
- An agreement among the water utilities providing for sharing the construction and operating costs of Little Seneca Lake (Appendix B/Annex II).
- An agreement among the water utilities and Allegany County, Maryland, providing for sharing the operating and maintenance costs of the existing Savage River Reservoir (Appendix B/Annex III).
- A Water Supply Coordination Agreement, including a Drought Operations Manual, signed by the utilities and the Interstate Commission on the Potomac River Basin (ICPRB), setting forth the agreed operating procedures and providing cost-sharing criteria for any future supply augmentation (Appendix B/Annex I).
- A modification to the Low-Flow Allocation Agreement (LFAA), incorporating Little Seneca Lake and removing a provision that could have frozen allocations after 1988 (Appendix D/Annex IV).

Within this framework of contracts and agreements, successful regional operation is contingent upon the initiative of the individual utilities (including the Corps) in operating their distribution systems, implementing conservation measures, and participating in regional drought management programs. It also depends on the ability of the ICPRB's Cooperative Water Supply Operations on the Potomac (CO-OP) to coordinate water allocation and drought management programs.

The evidence suggests that these operating arrangements will be effective, and the agreements appear to be carefully drawn. Individual utilities are basically free to operate their own systems consistent with their obligations under the agreement. CO-OP appears to be well prepared to discharge its responsibilities efficiently. The PRISM/COE systems model has been extensively tested and provides a comprehensive and credible basis for allocation decisions.

In defining the scope of the Corps study, the authorizing legislation (P.L. 93-251) makes no direct

reference to institutions. The Corps is, however, directed to "make a full and complete investigation of the future water resources needs of the Washington metropolitan area. . . ." In carrying out that study, the Corps inventoried water-related institutions in the study area, but initially consideration of intergovernmental cooperation was considered to be infeasible. The initiative for institutional innovations featured in the Corps report was provided by the Regional Task Force and CO-OP and endorsed by the Corps.

The inter-local compact is not greatly different from a voluntary system for operating the region's water supply. One of the reasons for the successful cooperation in the MWA should be explained. Several individuals in leadership roles at the time the agreements were signed were dedicated to resolving the management problems in the area and persisted in spite of technical, legal, and political obstacles. This leadership of key individuals and their dedication are important factors without which the agreements might never have been signed. The local governments and other agencies are to be congratulated for gaining consensus on this matter. It must be noted, however, that while the agreements provide an operating plan for existing water supply, they scarcely fulfill the promise of comprehensiveness asserted by the Corps.

The Main Report recommends "no further action" by the Corps. Leaving the matter at that point leaves important questions unsettled. For example, article 11 of the Water Supply Coordination Agreement (see page 69) requires unanimous agreement for resolution of any further disputes and speaks of the local agencies resolving such matters through use of "their best efforts" and "by in- formal negotiation." Short of unanimity, the parties agree they may go to court to litigate a question. This could have been done in the absence of an agreement.

Finally, the Corps report lacks comprehensive institutional considerations and leaves unanswered such questions as who is to be responsible for

- wastewater protection,
- water quality monitoring,
- changes in the requirement for flowby, flood control, or drinking water demand, and
- providing the highest-quality drinking water from the several suppliers to the MWA.

In effect the metropolitan Washington area water agencies have decided to cooperate for the time being but not to be bound by an institutional change that would force future cooperation. While these changes in water management in the Washington region now seem important and effective, the long-term significance of what has been accomplished should not be overstated. The Corps has decided to depend upon inter-local arrangements to make future decisions that may be of high importance. No water quantity problems are anticipated for the region through the year 2030, assuming that voluntary regional cooperation continues. The Corps' conclusions are supported by the facts with an important limitation (quantity only) and an important assumption (continued cooperation) in mind. The Corps' final conclusion (no federal action) should have been based on a fuller examination of the strengths and weaknesses of the institutional changes relied upon. Without that examination, the Corps recommendation rests on an incomplete analysis.

BLOOMINGTON LAKE REFORMULATION STUDY

Corps of Engineers Findings

Bloomington Lake represents a major new source of water for the MWA, and its use directly affects water supply management decisions in the MWA. The Bloomington Lake Reformulation Study was undertaken to answer two questions: (1) Could the existing project be regulated in a more efficient manner than the method suggested in the project's 1962 authorization document?, and (2) Could more water supply storage be made available within the project by reallocating either flood control or water quality storage?

Regulation of Existing Project

The Bloomington Lake Reformulation Study revealed that regulating the project to maintain a continuous flow target of 197 mgd (305 cfs) at Luke, as suggested in the 1962 authorization document, would be very

inefficient from a water supply viewpoint, and detrimental to the water quality in the North Branch as well. Present studies indicate that the minimum flow target at Luke should be approximately 78 mgd (120 cfs) to be met by releases from nearby Savage River Reservoir and Bloomington Lake's water quality storage. Given the flow target at Luke, supplemental releases for the MWA can then be made from Bloomington Lake's water supply storage, buffered as necessary by joint releases from Savage River Reservoir. Concurrent analysis resulted in the development of a series of seasonally-dependent and flow-dependent ratios to be used in balancing the potentially acidic releases from Bloomington with the normally alkaline releases from Savage. Projections by the USGS estimated the transit loss between Bloomington Lake and the MWA to be insignificant even at low flows. Furthermore, the USGS estimated that 47 percent of any release would arrive at the MWA within the first seven days, with the remaining 53 percent arriving during the subsequent seven days. In another related investigation, it was determined that the Bloomington Lake project should continue to be regulated to provide a winter drawdown for flood control and water quality purposes.

Storage Reallocation

Two storage reallocation possibilities were considered for Bloomington Lake--water quality storage to water supply and flood control storage to water supply. Studies indicated that all of Bloomington Lake's existing water quality storage (16.6 bg) should be reserved for satisfying flowby targets at both Luke, Maryland, and downstream in the MWA during low flow periods. On the other hand, up to 50 percent (5.9 bg) of the project's existing flood control storage could conceivably be reallocated to water supply storage with only a seven percent reduction in the project's average annual benefits. The perceived loss of

flood damage protection, however, may be objectionable to communities immediately downstream of the project without some form of mitigation. To accommodate the increase in water supply storage, certain physical modifications would have to be made to the intake tower, spillway, and boat launching areas. The costs for these items, as well as an allocated share of the project's original cost, would have to be repaid by a non-Federal sponsor. Environmental impacts of creating a larger lake would be minor, representing a loss of about 117 acres of terrestrial habitat which is of marginal value due to its steep nature. Water quality in the lake would be only slightly improved with a larger and deeper lake; however, downstream water quality, pH, and temperature may often show a sudden drop because flood releases through the gated spillway would occur more often.

NRC Committee Evaluation

Bloomington Lake was designed as a multipurpose reservoir with storage available for flood control, water supply, and maintenance of downstream river water quality. Savage River Reservoir was planned to provide flood control and maintain river water quality. The joint operation of these two reservoirs was originally envisioned as increasing the base flow in the Potomac by delivering a combined reservoir yield of 197 mgd to the North Branch of the Potomac River. This flow was established as the minimum continuous target downstream at Luke, Maryland. Authorization of Bloomington Lake in 1962 did not anticipate or consider that the Bloomington/Savage reservoir system would provide for short-term fluctuations in demand from the MWA.

Analysis made possible by the PRISM/COE simulation model suggested that the Bloomington/Savage Reservoir could be regulated in ways that would improve river water quality and simultaneously provide additional flow for water supply during drought conditions. A minimum flow target at Luke of 78 mgd was shown to provide adequate downstream water quality, and a balancing of the flows from the two reservoirs could be used to adjust the normally acid flows from Bloomington with the normally alkaline flows from Savage. With the revised flow

target at Luke, supplemental releases for the MWA can be made from storage, provided that releases from the two reservoirs are properly balanced to buffer the acidity of one with the alkalinity of the other. An important factor in the analysis of the operation of the Bloomington/Savage reservoir system was the estimate by the USGS that transit losses are insignificant and that these flow releases would reach the MWA intakes in a shorter time than originally believed.

The Corps study therefore proposes that more efficient use of the Bloomington/Savage Reservoir system can be made by providing a combined discharge to reduce the minimum flow at Luke from 197 mgd to 78 mgd and utilizing the difference as supplemental water supply storage for use during droughts in the MWA. Inasmuch as the entire capacity of Bloomington Lake had been previously allocated to flood control, water quality, and water supply, it was necessary to determine to what extent the additional storage for water supply would reduce the capacity for flood control or water quality, and the consequence of such reallocation.

The study suggests that all of the capacity for additional water supply be deducted from flood control storage, and it evaluated 10 alternative plans to determine the best reallocation arrangement. The effect of storage reallocation on peak flows at Luke, Pinto, and Cumberland, Maryland, was determined as follows:

1. The frequency curves of maximum annual flows were developed for the above locations without storage reallocation. The curves were developed in accordance with procedures described in Water Resources Council Bulletin 17, Guidelines for Determining Flood Flow Frequency[19] and used the COE Hydrologic Engineering Center's Computer program HECWRC.
2. Similar frequency curves were then developed for each proposed storage reallocation plan and were compared to the curves developed in step 1.

Average flood control benefits are calculated to be reduced only 7 percent with a 50 percent decrease in flood control storage (the study does not address the original reasons for the low economic benefit from 50 percent of the flood control storage capacity).

The Corps' Bloomington Lake Reformulation Study focuses on the following question: Is it feasible to reallocate to water supply storage a portion of the

storage now reserved for flood control in Bloomington Lake. More specifically, the study's purpose is to determine the effects of different reallocation plans on the primary flood control purpose and to assess the physical and economic damages that could be produced by these plans. The committee concludes that

- Bloomington Lake is a regional water resource of great value; efficient management of this resource is an essential element of the area's future water supply strategy;
- The Corps' study methodology is appropriate and acceptable. The approach involves an examination of 10 alternative combinations of flood control storage and water supply storage that encompass a broad spectrum of possible arrangements, including the present reservoir management plan. The procedures employed in the study reflect general standard practice. The use of PRISM/COE significantly aided in the complex analyses of the many alternatives;
- The Corps' analyses and investigations were conducted in proper scientific and engineering manner; and
- The conclusions reached are appropriate and reasonable.

RAW WATER INTERCONNECTIONS

Corps of Engineers Finding

Two raw water interconnections were identified as having potential to serve MWA water supply needs - a Potomac to Rocky Gorge interconnection for WSSC and a Potomac to Occoquan interconnection for FCWA. Sizes could vary, but studies indicated that the most appropriate capacity for each interconnection would be between 60 and 70 mgd. Reversible capability in both interconnections would add significant flexibility to the water supply systems by taking full advantage of the water treatment plant capacities at either end of the interconnections. Raw water interconnections would be expensive projects, and would cause some social and environmental disruption during

construction. The most significant impact during the operation phase would be the possibility of accelerated reservoir drawdowns. Water quality in both the Rocky Gorge or Occoquan Reservoirs would be slightly degraded and treatment costs at the reservoir treatment plants would be slightly increased if Potomac River water was discharged directly into the reservoirs. The water quality effects of pumping reservoir water to the Potomac River would be minimal.

NRC Committee Evaluation

The Corps' engineering analysis and evaluation of raw water interconnections covered many alternatives.

By using Potomac River water to meet demands and to fill the reservoirs ahead of the dry season through interconnections, the system could meet larger water demands during periods of drought. The procedures and methods used to analyze various ways of physically interconnecting these systems meet standards of engineering practice. However, adverse effects (such as heavy algae growth, other organisms, and chemicals) on drinking water quality were dismissed without the benefit of substantial analysis.

FINISHED WATER INTERCONNECTIONS

Corps of Engineers Finding

While finished water interconnections would not provide any "new" water to the MWA, they would improve the capability of the overall system to respond to localized emergencies in any one area. Furthermore, appropriate finished water interconnections could make use of treatment capacity at the Washington Aqueduct, thus deferring the need for construction of additional treatment facilities by other utilities. Five finished water interconnections were considered with capacities ranging from 4 to 60 mgd.

Cost-savings would be possible if the pipeline construction costs and the associated

plant modifications were less costly than treatment plant expansion. Environmental impacts related to construction activities would be negligible; however, some social disruption could occur as most of the finished water interconnections would be constructed in highly urbanized areas. Operational impacts would be minimal except that environmental quality of the Potomac River upstream of the Aqueduct intakes could be slightly improved because of reduced FCWA and WSSC withdrawals. The blending of water from different sources within a single distribution would not be expected to produce any significant adverse effects on water potability in the MWA as the raw water sources and treatment plant processes are relatively similar in character.

NRC Committee Evaluation

The Corps' investigation of finished water interconnections is important for security of supply. The rapid expansion of three large water supply systems in the MWA without substantial interconnections ignores the lessons of past failures in water supply facilities in many cities. Sudden contamination of raw water supplies, failure of or damage to water treatment and pumping facilities, and major breaks in transmission mains and distribution systems could leave densely populated areas without water supply. Past investigations and reports on MWA water supply have urged the installation of large-capacity interconnections for emergencies.

The finished water interconnections identified by the Corps as serving a large part of the MWA could be constructed in stages over a few years. As has been suggested, the WSSC and the FCWA might utilize the excess capacity in the Aqueduct plant and avoid the cost of additional treatment facilities.

These analyses do not play a central role in the Corps recommendations; however, they provide useful information that the local utilities can use to strengthen the MWA's water supply system. The committee concludes that the engineering and evaluation of finished water interconnections in the Corps study meets the standard of engineering practice.

REREGULATION

Corps of Engineers Finding

With the recent completion of the FCWA Potomac treatment plant, both WSSC and FCWA can now take advantage of reregulation and are proceeding to do so. Reregulation allows for the efficient and flexible use of reservoir storage capacity in both systems. Withdrawals from the reservoirs can be reduced during periods of adequate flow in the Potomac River, thereby saving stored water in the reservoirs for later use during critical low flow periods. By nature, reregulation saves small amounts of water over an extended period, and must be consciously implemented well in advance of the probable low flow season to be fully effective. Reregulation is a very low cost alternative as maximum use is made of existing facilities and no structural modifications are required. Environmental impacts of reregulation would be negligible, with the possible exception of accelerated reservoir drawdowns during low flow periods in the Potomac River. Water potability would not be adversely affected due to reregulation in either the WSSC or FCWA system, and EPA's drinking water standards would not be violated.

NRC Committee Evaluation

The term "reregulation" is used by the COE to describe the joint operation of the water supply extraction, treatment, and distribution systems of the MWA during periods of drought. In particular, boundaries between pumping zones are to be temporarily changed so that a portion of the distribution system can be shifted from one source to another. Reregulation is the vital element of the COE's proposed solution. Clearly the success of reregulation depends on the availability of additional supplies from Bloomington and Savage reservoirs and the cooperation of the water utilities. The analytical procedures (models) utilized in these studies are innovative and technically valid applications of systems analysis techniques. The findings of

this section are previously discussed under System Operation (pages 29-32).

WATER CONSERVATION

Corps of Engineers Finding

Permanent water conservation and demand reduction measures have the potential to substantially decrease projected MWA baseline demands throughout the planning period. A distinction was made between permanent conservation measures which were addressed in this study and temporary emergency measures which had already been addressed as part of the Metropolitan Washington Council of Government's Water Supply Emergency Agreement. Five water conservation scenarios were developed which proposed permanent measures capable of reducing the year 2030 demands from 7 to 27 percent. For planning purposes, the MWA water utilities adopted Conservation Scenario 3 which assumed an approximate 11 percent water use reduction. Any of these conservation scenarios would be extremely flexible in that they could be independently applied in any service area and could be implemented in combination with other water supply measures. Although non-structural in nature, successful water conservation programs would probably require some direct expenditures by consumers and, depending on the level of reduction desired, could be costly. Water conservation could also result in some significant cost savings to the water and wastewater utilities by delaying or negating the need to enlarge treatment plants and pipelines.

NRC Committee Evaluation

As reported by the Corps, the water conservation study uses questionable data and incorporates several errors. The results, in general, are not supported by the analysis performed. The single result used in the Corps conclusions (Conservation Scenario 3), attributes an

overall water use reduction of 11 percent to the implementation of conservation measures, including pressure-reducing valves, pipe insulation, water-saving plumbing fixtures, and water use education campaigns. This result is consistent with the experience of many other communities that have implemented similar measures and is an adequate planning assumption. It could not, however, be justified on the basis of the Corps analysis. Results for Scenarios 4 and 5, used in the long-range study but not related to any study conclusions or recommendations, do not appear credible.

Data collected by the Council of Governments, WSSC, and the Corps' Institute for Water Resources which became available after 1978 were not used in the Corps study[20,21,22] (WSSC and COG data referred to are unpublished). Estimates of specific water use reductions are presented uncritically and without attention to their reliability or applicability. Some statements imply misunderstanding of the topics under discussion. For example, the report incorrectly discusses metering and pricing as separate and presumably additive conservation measures. Further, statements on the effectiveness of pricing misinterpret the research results cited. The total effectiveness of conservation is overestimated as a result of consistent double counting. Every water use reduction is assumed independent of any other water conservation measure taken. The screening process used to select the best scenario is difficult to follow.

In spite of these problems, the water conservation program chosen (Scenario 3), while not necessarily optimal and not supported by the analysis reported, is a reasonable planning assumption. Further, the Corps should be commended for demonstrating a positive attitude toward conservation as an element of water supply planning.

UPSTREAM RESERVOIRS

Corps of Engineers Finding

Seven upstream reservoir sites were examined, ranging in storage capacity from 8.8 bg to 33.9 bg and in yield potential from 32 mgd to 110 mgd. The upstream reservoirs could be developed as multiple-purpose sites to include,

as a minimum, recreation and flood control. As a component group, the upstream reservoirs would provide the greatest water supply potential for the MWA at the lowest unit cost. However, they could create significant adverse environmental and social impacts, depending on the characteristics of a specific project area. In the past, residents in the upper Potomac River Basin have objected strongly to major storage projects that primarily serve downstream municipalities.

NRC Committee Evaluation

The study identifies seven upstream reservoir sites and indicates that "as a component group, the upstream reservoirs would provide the greatest water supply potential for the MWA at the lowest unit cost." However, the study abandons interest in the upstream reservoirs because, "they would likely create significant adverse environmental impacts as well as adverse social impacts, depending on the degree of development within the specific project area."

Clearly, the study does not fully address the upstream reservoir issue because of its environmental/political overtones. "Likely . . . significant adverse environmental impacts" should have been quantified for each site and the sites should have been ranked according to such issues as cost, impact on the MWA water supply problem, and environmental impacts. Potential minimization or mitigation of adverse environmental impacts should have been considered in the ranking. More importantly, water quality for potability and protection from possible sources of contamination should have been evaluated. Then, upstream reservoirs should have been compared with other alternatives presented in the Corps report. Water quality, protection from contamination, treatability, and potential health effects should have been among the key points of comparison (see Water Quality, pages 21-27).

In its efforts to find alternatives to new reservoirs, the Corps study does not address the inherent benefits of well-protected reservoirs in providing the most secure method of minimizing public health risks.

From a drinking water quality viewpoint, upstream storage is desirable. The downstream contamination of

the main stem of the Potomac by urban and industrial polluters is a potential threat and one that is of increasing concern to the public. The Corps should have sought the best reservoir sites that can be obtained, using an appropriate ranking system. Consideration should have been given to protecting the best sites, thereby maintaining options for future development so that the MWA may have access to high-quality water in the future. Construction need not be contemplated unless it is absolutely necessary. Sites and watersheds that are not protected may be preempted for non-compatible purposes and irretrievably lost as sources of water supply. While the Corps study has shown how much can be done with a little storage, its lack of attention to long-term needs and drinking water quality concerns has resulted in a finding that ignores consideration and identification of upstream reservoir sites for protection and possible future use.

LOCAL RESERVOIRS

Corps of Engineers Finding

In addition to Little Seneca Lake, six new local reservoirs were examined which would have capabilities for providing water supply to the MWA. These local sites could also offer multi-purpose potential, such as recreation or flood control. The sites ranged in storage capacity from 3.3 bg to 39.1 bg, and in yield potential from 12 mgd to 125 mgd. Such local reservoirs would generally represent relatively costly approaches to satisfying needs, primarily because they would have to be constructed as high-flow skimming projects with accompanying pipelines to the Potomac River. The environmental impacts of the various local reservoirs would obviously vary according to the specific dam site, reservoir size, and pipeline length, but the stream valleys in question are generally very sensitive environmental areas. Water quality at most of the sites is good. In the past, development of such local reservoir sites has generally faced strong public opposition.

One other local reservoir possibility within the MWA would be to raise the Occoquan Reservoir level by three feet to provide 2.2 bg of additional storage and an increase in yield of about 12 mgd. This project modification would increase the flexibility of the regional system, but could create significant social and institutional impacts as additional land would have to be acquired.

NRC Committee Evaluation

The new Little Seneca Lake project has proved critical to meeting the short-term demands of the MWA. In addition, six offstream storage sites were identified to divert a portion of high flows from the Potomac. Environmental impacts are identified as matters of great concern, as is the issue of "undoubtedly strong public opposition."

The Corps is remiss in not considering the security to water supply for the MWA that would be provided by local reservoirs. The committee's concerns relative to local reservoirs are similar to those for upstream reservoirs. However, the water quality of a local pumped storage project is not likely to be as good as that of a well-selected upstream reservoir. Nevertheless, a quantitative ranking of sites in comparison with other alternatives is a more reasonable procedure to evaluate local reservoirs than a simple out-of-hand dismissal, and such issues as water quality, cost, and environmental factors should be tabulated. Local reservoirs have the special advantage of being able to meet short-term peaking demands within the MWA and can provide a significant source of acceptable-quality water should the Potomac become contaminated for a short period by a spill or other sudden source of contamination.

In addition, such reservoirs can also provide a means of protecting river water quality while simultaneously increasing green space in the metropolitan Washington area.

GROUNDWATER

Corps of Engineers Finding

Initially, two sites were identified as having potential for groundwater development - one in Maryland's Hagerstown Valley and a second in Maryland's Atlantic Coastal Plain. The Hagerstown Valley examination was terminated soon after study initiation due to strong local and state opposition; thus, no statement can be made regarding the yield, feasibility, costs, or impacts of developing this source.

The analysis of groundwater development in the Atlantic Coastal Plain was carried to completion, and it was determined that the maximum yield from the deep-aquifers would be about 100 mgd. Groundwater represents one of the most costly alternatives available to the MWA. Wells, pumping stations, pipelines, and water treatment plants would be required, with accompanying environmental and social impacts during construction. Water quality in the deep aquifers, based on a limited comparison with other deep wells in the area, is projected to be acceptable for potable use after chlorination. Before actual development of large-scale groundwater projects in the Atlantic Coastal Plain, pumping tests should be conducted in the deep aquifers to confirm estimated drawdown rates, yields, and zones of influence. A significant institutional constraint at this time is the State of Maryland's policy prohibiting the export of groundwater from the Atlantic Coastal Plain because its shallow aquifers provide nearly all of the area's domestic water supply.

NRC Committee Evaluation

The groundwater portion of the MWA report focuses on the investigation of the characteristics of four aquifers in the coastal plain of southern Maryland. This area appears to be the only nearby area where high-capacity well fields could be developed as a potential water supply source for the MWA.

Groundwater development in the Atlantic Coastal Plain aquifers for MWA was investigated by the U.S. Geological Survey under contract to the Corps as part of the overall water supply study. The objective of the investigation was to evaluate the availability of groundwater and the impact of large-scale pumping from coastal plain aquifers. The evaluation itself was based on a simulation model using a finite difference method and existing data for the study area. Hydrologic and geologic conditions related to aquifer depths, thicknesses, hydrologic conductivities, storage coefficients, and groundwater usage were simulated in the model.

The most important aspect of the modeling is the calibration. The accuracy of calibration depends on the accuracy of the estimated prepumping head distributions (the natural water levels in the aquifer at various locations). However, the report recognizes that head distributions were based on an extremely sparse number of water levels, especially when one considers the size of the grid for the model. Consequently, the model was not fully calibrated and the results should be applied with caution.

However, the essential link in the investigation is the use of a groundwater flow model. The idea of modeling is appropriate, and the model methodology appears to have been well executed.

Since the model results would influence the well-field scheme to be selected, additional field data are required to provide a more accurate simulation of the natural flow system during the model calibration. The costs for the groundwater alternatives were estimated using the Methodology for Areawide Planning Studies (MAPS) computer programs. The results of these economic analyses compare favorably with current groundwater development experience.

Although the potential supply (100 mgd) appears to exist, it is doubtful that groundwater will ever be available as a regional source of supply for the MWA. It continues to be a closely guarded local resource, and opposition on all levels of government to long-distance transport may rule out future consideration of this resource. On the other hand, the Corps decision to rely on local groundwater and streams for outlying areas is well-founded.

Preliminary analysis of the layout of wells, collection mains, treatment, and pumping from aquifers in southeastern Maryland is relatively expensive for reserve supplies that are used infrequently.

POTOMAC ESTUARY

Corps of Engineers Finding

From an examination of the first year's findings from the pilot EEWTP testing program, it appears technologically feasible to treat Potomac Estuary water to provide a potable water supply source. There may be some undetermined health risks, however, in using a source such as the Potomac Estuary which is subject to discharges from large wastewater treatment plants and from untreated non-point sources. Preliminary results from the Chesapeake Bay Model testing program also indicate that the salinity concentration at an estuary treatment plant intake may rise to unacceptable levels during prolonged use in a severe drought. The aquatic resources of the upper Potomac Estuary may also be adversely affected by the increase in salinity levels associated with use of the Estuary. Due to the many uncertainties with regard to estuary use, public acceptability remains as a major unresolved issue. Preliminary cost data suggest that a full scale Estuary water treatment plant, when considering the transmission, land, and pumping requirements along with the actual treatment costs, may be a very expensive alternative. The EEWTP test results, however, may also have far-ranging applicability for water supply in other cities located at the head of a sizable estuary. Documentation of the entire testing program is contained in a special report being submitted directly to the U.S. Congress.

NRC Committee Evaluation

The Corps report indicates that Potomac Estuary water would not be needed to augment the water supply in the near future, and thus the potability question may appear moot. However, the pilot plant study represents an important milestone in determining the feasibility of reclaiming contaminated water, and as such has significant implications for other water-short areas of the

country. Thus, it is important that the limitations to the conclusions reached be clearly stated. It must be emphasized that the Corps study did not provide sufficient scientific evidence to conclude that estuary water of the quality anticipated during a drought and treated by the processes studied is of potable quality.

A separate committee of the National Research Council (see Background, pages 1-8) has been charged with reviewing the Corps' special report resulting from the Potomac Estuary Experimental Water Treatment Plant (EEWTP) study, and this committee will deliver a separate detailed report to the Corps of Engineers.[1] The information contained in Appendix F, Structural Alternatives,[4] represents only a brief summary of this study. The reader should refer to the separate report[23] submitted by the Corps to Congress in order to place the conclusions reached in a proper context.

In general, the questions outlined with respect to treatment of Potomac Estuary water for use as a potable water supply are logical and clear. Within the limitations of the resources available, the study was conducted in a sound scientific and engineering manner.

The results of modeling studies of estuary quality during drought conditions appear to have been carried out well and provide useful background information for the treatment plant study. The mixture of treated effluent and estuary water used for this study admittedly cannot simulate exactly the quality of estuary water expected under a future drought. The modeling results do suggest that under certain drought conditions, the estuary water at Chain Bridge (a possible withdrawal location) could contain as much as or more than 50 percent treated wastewater effluent. The simulated water represents a reasonable compromise considering all of the uncertainties for the future, and should provide a water quality sufficiently similar for demonstration purposes to that expected.

Currently, there is no general consensus in the scientific and engineering community about criteria for judging the potability of treated water obtained from a highly contaminated source. For this reason, the Corps developed a set of water quality goals to guide plant operations and to serve as a basis for process selection. In Appendix F,[4] the proper and cautionary statement was made that "the goals presented are not intended to imply that a water meeting these goals is potable." Unfortunately, this caveat is not

sufficiently represented in the conclusion listed in the Corps' Main Report[11] that "it appears technologically feasible to treat Potomac Estuary water to provide a potable water supply source." While the study did not uncover any additional health risks associated with the treated water in comparison with three existing local supplies, the evidence provided was not sufficiently complete to be conclusive.

This study did provide a more comprehensive set of information to address the potability question than is currently available and provides an excellent framework for future studies. However, there are significant questions still unanswered that must be addressed before a sound conclusion on the potability question is reached.

A Panel on Quality Criteria for Water Reuse was established by the NRC Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project to develop a testing protocol that might help answer the potability question. The Corps study conducted through its contractor was in accord with several of the NRC panel suggestions made.[24] These included a detailed comparative study with the quality of existing supplies, detailed chemical and biological characterization of treated water, and some toxicological testing. These studies were conducted in a highly professional manner and resulted in no information to suggest that health risks through use of treated estuary water would be any greater than those posed by existing supplies. However, because of the nature of the water treated, these results alone are insufficient to reach an adequate conclusion on the potability question. The NRC panel report on Quality Criteria for Water Reuse[24,25] also made recommendations for other toxicological studies that would be needed as a minimum to judge health risks imposed by use of such a polluted source. The Corps indicated that it did not have the time available nor the financial resources for the additional testing. However, without the additional evidence, a conclusive answer to the potability question cannot be made. Further, the development of alternative water sources with better quality may be more desirable to use of estuary water, should the need develop in the future.

PRICING

Corps of Engineers Finding

Adjustment in the price of water charged to consumers was investigated as a possibility for reducing the overall demand for water. Marginal cost peak period pricing was determined to be the most applicable method within the MWA as it would assure efficiency in resource use and equity in cost distribution among resource users. However, investigation of this pricing policy revealed that prices high enough to depress demand could not be justified on the basis of marginal costs at this time. This finding reflected the recent progress by the non-Federal entities in implementing new increments of capacity at relatively inexpensive costs. It also reflected the high proportion of fixed costs to total costs in the major Potomac utilities which had the effect of keeping marginal cost peak period rates below present rates. Moreover, the recent cost-sharing formula for future projects, incorporated into the Water Supply Coordination Agreement, provides strong incentives for participating utilities to reduce peak demands. In the future, marginal cost peak period pricing may be considerably more effective when the benefits from existing supply management have been maximized and the cost for new supplies has increased.

NRC Committee Evaluation

The Corps report[2] argues, properly, that the use of marginal cost pricing principles would both increase economic efficiency within the water supply sector and provide equitable allocation of the costs of supply. Marginal cost pricing principles require that the price of water be set equal to the expected incremental (marginal) cost of supply. Fixed costs are recovered through fixed charges. The Corps study included determination of marginal costs for each utility in the MWA, and a comparison of these costs to current prices. If it had been found that prices were generally below

marginal costs, the Corps was evidently prepared to recommend the introduction of marginal cost pricing, which would reduce overall water use as well as promoting efficiency and equity. On completing the study, however, the Corps found that MWA water prices are generally higher than the measured marginal costs. If true, these results indicate that a change to marginal cost pricing would increase not decrease overall water use. Noting this, the report includes references to an "apparent conflict between empirical and theoretical conclusions" and concludes that "better pricing policies based on marginal cost concepts [are] found to be inapplicable, over the near-term" (Volume I, p. I-4).

On the assumption that the empirical component of the study was properly done, there is no conflict between empirical and theoretical findings, then the conclusion that better pricing policies are "inapplicable" is not supported. The Corps appears to have implicitly accepted the notion that reductions in water use are beneficial and that desirable water pricing policies are those which produce water use reductions. In fact the data, if correct, show that certain pricing policies (based on marginal cost principles) that increase water use would be beneficial in the MWA, since they would improve economic efficiency and cost distribution. The only conclusion supported by the study is that marginal cost pricing should be encouraged, that commodity prices should be lower (and fixed charges higher to maintain revenue), and that future planning should provide for greater, not less, water use as a consequence of this policy. The Corps does not draw this conclusion; pricing policy is simply dismissed as a factor in water supply planning.

WASTEWATER REUSE

Corps of Engineers Finding

Several forms of wastewater reuse for water supply were considered, including land application with subsequent reclamation, agricultural and industrial use of partially treated wastewater, groundwater recharge, and surface water recharge. Most of these options were found to have limited application in the

MWA because of the large acreage requirements for land application, minimal use of water by industry and agriculture, and insignificant reliance by the major utilities on groundwater sources. The remaining option was surface water recharge which was investigated through a scheme to pump Blue Plains treated wastewater effluent to a discharge point immediately downstream of the Washington Aqueduct's Little Falls intake. This scheme, in effect, would furnish flowby while allowing the water utilities to withdraw most of the Potomac River's natural flow. The transfer pipeline would involve costly urban construction (with associated high levels of social and cultural impacts) adjacent to streets, parks, buildings, and historic sites of national significance.

NRC Committee Evaluation

The Corps examined wastewater reclamation (including land application with subsequent reclamation) as a potential water supply source and as a source of supply for agriculture, industry, recreation, navigation, power generation, groundwater recharge, surface water recharge, and dual water systems. This investigation also considered the possibility of using effluent from the Blue Plains wastewater treatment plant for maintaining minimum low flows in the Potomac estuary below Washington's Little Falls intake.

The Corps concluded that wastewater reuse is not a significant source of supply for the MWA because of the "large acreage requirements for land application, minimal use of water by industry and agriculture, and insignificant reliance by the major utilities on groundwater sources." These conclusions are based on their engineering studies of land application potential, municipal demand, future industrial demand forecasts, etc. Wastewater reuse and reclamation have been, and can be expected to be, economically efficient and environmentally desirable solutions for specific water supply and wastewater problems in local areas or for satisfying certain kinds of demand (e.g., industrial). The major deficiency in the analysis, conclusions, and recommendations concerning wastewater reuse and reclamation is that the Corps only addressed these as

regional issues and largely ignored the potential for local implementation of wastewater reuse or wastewater reclamation.

The alternative of wastewater reuse by discharging Blue Plains effluent to a point just downstream of Great Falls and above the Washington Aqueduct's water supply intakes is not discussed from a drinking water quality standpoint. The Corps indicates that there would be public resistance to the discharge of treated wastewater effluent above the water supply intakes; however, the same comment can be made even more forcefully in respect to the second option, discharge below Great Falls.

In summary, the committee believes that the Corps' methodology and study approach are acceptable, although the study was not detailed. Rough analysis indicated that large-scale projects are not economically feasible. Smaller-scale projects are eliminated in the study presumably because they alone could not solve water supply problems; however, collectively such projects could represent a significant and cost-effective means of augmenting water supplies.

The committee believes that the study conclusions in regard to surface recharge are acceptable. Recharge of the Potomac River was selected as the best reuse alternative. This project would not be used directly for drinking water supply augmentation but rather as an "environmental flowby" substitute, permitting larger upstream water supply withdrawals.

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25. National Research Council. 1982. Quality Criteria for Water Reuse. Panel on Quality Criteria for Water Reuse, Board on Toxicology and Environmental Health Hazards. National Academy Press, Washington, D.C. 20418.

APPENDIX A

CORPS OF ENGINEERS
CONCLUSIONS AND RECOMMENDATIONS
As Taken from COE Main Report, pages 68-71

CONCLUSIONS

Several noteworthy conclusions and observations were made at the completion of the study which deserve explicit statement. They pertain to the overall study and are provided below.

1. The proposed programs embodied by the series of agreements signed on 22 July 1982 are projected to satisfy water supply needs of the Potomac water utilities until at least the year 2030 under the revised assumptions of supply and demand used as the base condition during the long-range phase of study. These programs resulted, in part, from the information and decisions generated as part of the Corps' early-action study phase.

2. There is no need for additional water supply projects or programs by the Corps of Engineers, such as those studied in the long-range phase, at this time. Institutional arrangements, either existing or newly created by the July 1982 agreements, are capable of implementing the proposed programs and are proceeding smoothly.

3. Given that there is no need for additional water supply projects, further work on the Verona Lake project (authorized for Phase I Advanced Engineering and Design by Section 85(a) of P.L. 93-251) near Staunton, Virginia is not required. The Commonwealth of Virginia concurs in this decision (see Annex C-VIII - Background Correspondence) as there are no local needs in the Staunton area for a Federal water supply project. Thus, the Metropolitan Washington Area Water Supply Study and Final Report are considered to be responsive to Section 85(a) of the Water Resources Development Act of 1974. The Sixes Bridge project, also authorized for Phase I

Advanced Engineering and Design by Section 85(a), was deauthorized in December 1981.

4. The Interstate Commission on the Potomac River Basin's CO-OP (Cooperative Water Supply Operations on the Potomac) Program is the appropriate mechanism to promote and sustain the necessary level of regional cooperation endorsed in the recent series of agreements and contracts. The Water Supply Coordination Agreement formalizes the region's commitment to cooperative management from an overall perspective. Without such regional management, it is likely that the separate water supply systems would not be managed for the maximum benefit of all users throughout the MWA and shortages could result.

5. PRISM/COE is an effective planning tool for investigating how the water supply systems of the major utilities will respond to different drought scenarios and for examining alternative system regulation schemes on a weekly basis. Improvements, refinements, and additions to PRISM/COE, such as those undertaken by CO-OP, have also made the model applicable for day-to-day operational decisions. PRISM/COE and its derivatives are extremely valuable assets to any water supply manager in the MWA and should be updated periodically to reflect changes to the water supply system.

6. Modification Number 1 to the Potomac Low Flow Allocation Agreement provides for a review every five years to determine the fairness and reasonableness of the allocation formula. This periodic review also requires a forecast of the MWA supplies and demands for coming years. Should further action be needed in the future to balance supplies and demands, the provisions of the LFAA furnish the logical means by which such needs can be identified sufficiently in advance of a shortage situation to undertake appropriate management actions. This periodic review of the water supply situation will also allow the LFAA signatories to assess the effectiveness of the various agreements and contracts in satisfying water supply needs.

7. Conjunctive regulation of Bloomington Lake and Savage River Reservoir to (a) satisfy a minimum flow target at Luke of 78 mgd (120 cfs), (b) maximize the amount of water available for downstream users, and (c) improve water quality in the North Branch Potomac River, is within the authority of the District Engineer. There is no need, at the present time, to reallocate either

flood control or water quality storage to provide more water supply storage in Bloomington Lake.

8. The alternatives investigated during the long-range phase appear to have limited application in the immediate future because: (a) they are not cost-effective, (b) they create potentially significant adverse environmental impacts, (c) they represent options which have been generally opposed by the public in recent years, (d) they are not engineeringly feasible given the current technology, or (e) they contain a combination of the drawbacks listed in (a) through (d). Furthermore, there is no pressing desire for implementation of any of these alternatives at the present time as the needs are projected to be satisfied with the implementation of some of the early-action programs. Should additional water supply programs be needed in the future, the work accomplished as part of the long-range phase would be an appropriate starting point for more detailed investigations.

9. Although water potability studies were performed which indicated that the current drinking water standards could be met now and in the foreseeable future, these studies were admittedly of a limited nature. Any future study of water supply needs in the MWA should consider a more thorough examination of the quality and/or potability of different water sources. Additionally, strong watershed protection programs and water quality monitoring systems should be undertaken now to prevent the degradation of existing raw water supplies and to collect data regarding water quality trends throughout the MWA, respectively.

RECOMMENDATIONS

1. The Corps of Engineers take no further action at this time to satisfy Metropolitan Washington Area water supply needs:

2. The Final Report for the Metropolitan Washington Area Water Supply Study be transmitted to Congress as an information document, in accordance with the directives of the study's authorizing legislation - Section 85 of the Water Resources Development Act of 1974 (Public Law 93-251).

Due to of the concerns regarding the future quality of raw water sources in the Metropolitan Washington Area, I

(Colonel Gerald C. Brown, District Engineer) further recommend that appropriate Federal, state, and local agencies undertake the necessary programs to protect and enhance the quality of both present and potential raw water sources. These programs, as a minimum, should include watershed protection programs and water quality monitoring programs.

APPENDIX B

REPOSITORIES FOR CORPS OF ENGINEERS REPORTS FOR PUBLIC REVIEW

A complete set of the Main Report and the appendixes is available for public review at the following repositories:

DISTRICT OF COLUMBIA

Council of Governments
1225 Connecticut Ave., N.W.
Washington, DC

Martin Luther King
Memorial Library
901 G St., N.W.
Washington, DC

Washington Aqueduct
5900 MacArthur Blvd., N.W.
Washington, DC

Water Science and
Technology Board
National Research Council
2100 Pennsylvania Ave, N.W.
Washington, DC

MARYLAND

Prince George's Co.
Memorial Library
6532 Adelphi Road
Hyattsville, MD

Montgomery Village
Jr. High Library
19300 Watkins Mill Road
Gaithersburg, MD

Montgomery Co. Library
8901 Colesville Road
Silver Spring, MD

Frederick Co. Public Library
116 Record Street
Frederick, MD

Interstate Commission on
the Potomac River Basin
1055 First Street
Rockville, MD

Charles Co. Library
La Plata, MD

Washington Co. Free Library
100 S. Potomac Street
Hagerstown, MD

St. Mary's County Library
Leonardtown, MD

VIRGINIA

Fairfax Co. Central Library
3915 Chain Bridge Road
Fairfax, VA

Fairfax Co. Library
6400 Cumberland
Springfield, VA

Prince William Co.
Central Library
8601 Mathis Ave.
Manassas, VA

Fairfax Co. Library
6614 Ft. Hunt Road
Alexandria, VA

Thomas Balch Library
52 West Market Street
Leesburg, VA

Potomac River Fisheries
Commission
222 Taylor Street
Colonia Beach, VA

APPENDIX C

WATER SUPPLY COORDINATION AGREEMENT

THIS AGREEMENT, dated for convenience of reference as the _____ day of _____, 1982, made and entered into by and among the UNITED STATES OF AMERICA acting through the Baltimore District, Corps of Engineers, U.S. Army, functioning through the Washington Aqueduct Division (hereinafter called the "Aqueduct"); the FAIRFAX COUNTY WATER AUTHORITY (hereinafter called the "Authority"); the WASHINGTON SUBURBAN SANITARY COMMISSION (hereinafter called the "Commission"); the DISTRICT OF COLUMBIA (hereinafter called the "District"); and the INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN SECTION FOR COOPERATIVE WATER SUPPLY OPERATIONS ON THE POTOMAC (hereinafter called the "CO-OP").

WITNESSETH

WHEREAS, the Chief of Engineers is charged with the operation and maintenance of the Washington Aqueduct for the purpose of providing an adequate supply of potable water for distribution to and consumption by the agencies and instrumentalities of the Federal Government situated in the District and its environs, and of providing a public water supply for the inhabitants of the District, and certain communities in northern Virginia; and

WHEREAS, the Authority is an authority established pursuant to the laws of the Commonwealth of Virginia charged with responsibility for providing a safe and adequate public water supply within certain geographic areas of northern Virginia, and is also authorized to enter into agreements to purchase and provide water, and

for that purpose is operating and maintaining water treatment facilities and a water distribution system; and

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

WHEREAS, the District is authorized and empowered to contract to provide a safe and adequate water supply to the inhabitants and entities within its jurisdiction and accomplishes this purpose through cooperation with the Washington Aqueduct Division, Corps of Engineers, United States Army, and is also authorized to contract for the purpose described herein; and

WHEREAS, the Interstate Commission on the Potomac River Basin (ICPRB) has created CO-OP devoted to forecasting demand and supply in the Washington Metropolitan Area; and

WHEREAS, CO-OP has developed a program for optimal utilization of all available water supply facilities in the Washington Metropolitan Area, particularly during drought periods; and

WHEREAS, the Aqueduct, the Authority, and the Commission (hereinafter called the "suppliers") now have in place, on the Potomac River, water intakes installed in accordance with appropriate Federal and state laws; and

WHEREAS, the suppliers are governed by the provisions of the Potomac River Low Flow Allocation Agreement, dated January 11, 1978, which is hereby incorporated by reference into this agreement and made part thereof; and

WHEREAS, it is in the mutual benefit of the suppliers to manage Potomac River flows, reservoir releases, and water supply withdrawals so as to reduce or eliminate the possibility that the Emergency Stage of the Low Flow Allocation Agreement will ever be reached or that the allocation formula set forth therein becomes operative.

NOW, THEREFORE, in consideration of the mutual covenants herein contained the parties hereto do hereby agree as follows:

ARTICLE 1. - The suppliers agree to operate their respective water supply systems in a coordinated manner so as to provide the optimal utilization of all

available water supply facilities for the benefit of the inhabitants of the Washington Metropolitan Area.

ARTICLE 2. - The Authority and the Commission agree to operate their non-Potomac water supplies (Occoquan River and Patuxent River) so as to maximize the availability of reservoir storage associated therewith for use during periods of low flows in the Potomac River.

ARTICLE 3. - The District, the Authority, and the Commission agree that, notwithstanding the extent to which they each may participate in the cost of construction, operation and maintenance of Bloomington Lake, and the proposed Little Seneca Lake and in the operation and maintenance costs of the Savage Reservoir, releases of water from Bloomington Lake water supply storage and Little Seneca Lake shall be made as provided by this agreement.

ARTICLE 4. - The suppliers agree that all available water supply facilities shall be managed and operated as provided in the attached Drought-Related Operations Manual for the Washington Metropolitan Area Water Suppliers (hereinafter called the "Operations Manual"), which manual is hereby made part of this agreement.

ARTICLE 5a. - CO-OP agrees to provide the administrative, technical, supervisory and managerial services set forth in the attached Operations Manual and the District, the Authority, and the Commission agree to pay the costs thereof in the following proportions: District-30%, Authority-20% and Commission-50%.

ARTICLE 5b. - The District shall take all necessary actions to procure the required appropriations to meet its cost sharing obligations hereunder; provided, however, that no payments shall be made by the District until appropriations for such purposes have been made pursuant to the requirements of the Budget and Accounting (Anti-Deficiency) Act of 1921 (31 U.S.C. 665) as amended.

ARTICLE 6. - The parties agree that the services to be provided by CO-OP may be terminated at any time either by the unanimous agreement of the District, the Authority and the Commission or by CO-OP, in which event CO-OP shall deliver to the suppliers all computer hardware and software, equipment, supplies, records, etc., which may have been acquired or developed at the expense of the District, the Authority, and the Commission and thereupon the suppliers shall make appropriate arrangements for continuing the functions, duties and responsibilities theretofore performed by

CO-OP. The District, the Authority, and the Commission agree to pay necessary termination expenses incurred by CO-OP.

ARTICLE 7. - The suppliers do hereby establish an Operations Committee which shall comprise a representative of each supplier. The Committee shall be responsible for overseeing implementation of this agreement and the Operations Manual and shall be empowered, upon unanimous agreement, to revise the Operations Manual as circumstances may require. The Operations Committee shall:

(a) as necessary, review decisions of the Director of CO-OP and by unaminous agreement, change such decisions and so inform the Director of CO-OP,

(b) monitor compliance with the terms of this agreement and the Operations Manual,

(c) provide executive support to the Director of CO-OP within their agencies,

(d) approve expenditures of CO-OP relevant to the terms of this agreement,

(e) establish joint and coordinated operating procedures for use by the suppliers to monitor supply (including rainfall forecasts) and demand during emergencies and droughts, and

(f) establish CO-OP as the agency responsible for executing the procedures in 7(e) above and for the establishment and maintenance of a system for monitoring supply and demand and performing drought management analysis.

ARTICLE 8. - The consideration for this agreement is the promises herein exchanged based upon the premises above mentioned and the public and governmental interests deemed necessary and desirable by the parties to this agreement.

ARTICLE 9. - It is agreed that the waters released from Bloomington Lake water supply storage and Little Seneca Lake are to be utilized to achieve the objectives of this agreement without regard to any cost-sharing by the District, the Authority, and the Commission in Bloomington Reservoir and Little Seneca Lake.

ARTICLE 10. - In April 1990 and in April of each fifth year thereafter during such time as this agreement is in effect and the proposed Little Seneca Lake has been constructed and is operational, the Aqueduct, the Authority, the Commission and the District shall review

and evaluate the adequacy of the then available water supplies to meet the water demands in the Washington Metropolitan Area which may then be expected to occur during the succeeding twenty year period. If as a result of any such review and evaluation it is determined that additional water supplies will be required to meet the expected demands, the Aqueduct, the Authority, the Commission and the District shall undertake negotiations to provide the required additional water supplies and, when provided, water from such additional water supplies shall be included as water subject to the allocation formula under the terms of the Potomac River Low Flow Allocation Agreement. Such facilities shall be operated under the terms of this agreement. The District, the Authority, and the Commission agree that the costs of construction, operation and maintenance of such additional water supplies shall be shared among these parties in accordance with the following formulae:

$$\text{District's Share } -\% = \frac{(A-B)}{(A-B) + (C-D) + (E-F)} \times 100$$

$$\text{Authority's Share } -\% = \frac{(C-D)}{(A-B) + (C-D) + (E-F)} \times 100$$

$$\text{Commission's Share } -\% = \frac{(E-F)}{(A-B) + (C-D) + (E-F)} \times 100$$

Where:

A = The average number of gallons of processed water pumped daily by the Aqueduct to all its customers from all sources (expressed in million gallons per day) during the month of July in each of the five (5) years immediately preceding the award of a contract(s) for the construction of the additional water supply facilities.

B = The average number of gallons of processed water pumped daily by the Aqueduct to all its customers from all sources (expressed in million gallons per day) during the month of July in each of the years 1981 through 1985.

C = Same as A, except substitute the number of gallons of processed water pumped daily by the Authority.

D = Same as B, except substitute the number of gallons of processed water pumped daily by the Authority.

E = Same as A, except substitute the number of gallons of processed water pumped daily by the Commission.

F = Same as B, except substitute the number of gallons of processed water pumped daily by the Commission.

Whenever application of the above formulae results in a negative amount for any one of these parties, such party's share of the costs shall be zero. Thereupon, the formulae applicable to the other two parties shall be revised by eliminating therefrom the term which relates to the party with zero cost share (e.g., if the District's share is zero, the term (A-B) shall be eliminated; if the Authority's share is zero, the term (C-D) shall be eliminated; and if the Commission's share is zero, the term (E-F) shall be eliminated) and the revised formulae shall be applied to determine the respective shares of costs to be borne by the other two parties. Whenever application of the above formulae results in negative amounts for any two of these parties, their respective shares of the costs shall be zero and the entire costs shall be borne by the third party.

ARTICLE 11. - The suppliers, the District and CO-OP agree to utilize their best efforts to resolve any disputes which arise under this agreement or the Operations Manual by informal negotiation, the resolution of which shall require unanimous agreement of the suppliers, and the District. However, any party may initiate litigation, the purpose of which is to construe a provision of or resolve a dispute that arises under this agreement or the Operations Manual. The parties to this agreement hereby agree the issues to be litigated may be litigated in any court of competent jurisdiction sitting in Maryland, Virginia, or the District of Columbia and consent to venue in any such court and to the service of all papers and pleadings related thereto. Pending final resolution of any dispute, the provisions of this agreement and the Operations Manual shall continue in effect.

ARTICLE 12. - The effective date of this agreement shall be the date on which the last party executes the same.

ARTICLE 13. - Unless sooner terminated by unanimous agreement of the suppliers, and the District, this agreement shall continue in effect for as long as the water systems of the suppliers remain in existence and operation.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed as of the date which appears with their respective signatures.

Approved in form and in legal sufficiency:

Date: 22 July 1982

UNITED STATES OF AMERICA

By: District Engineer, Baltimore District, Corps of Engineers, U.S. Army

Date: 22 July 1982

Date: July 22, 1982

FAIRFAX COUNTY WATER AUTHORITY

By: Chairman

Date: July 22, 1982

Date: July 22 '82

William A. Lanham

Date: July 22, 1982

WASHINGTON SUBURBAN SANITARY COMMISSION

By: General Manager

Date: 22 Jul 82

Date: July 22, 1982

THE DISTRICT OF COLUMBIA

By: Mayor

Date: 7-22-82

Date: July 22, 1982

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN SECTION FOR COOPERATIVE WATER SUPPLY OPERATIONS ON THE POTOMAC

By:

Date: July 22, 1982

APPENDIX D

BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS AND NRC PROJECT DIRECTORS

WALTER R. LYNN

Dr. Lynn received his Ph.D. in civil engineering from Northwestern University in 1963. He has been at Cornell University since 1961 and has served as professor of environmental engineering, director of the Center for Environmental Quality Management, director of the School of Civil and Environmental Engineering, and professor of Public Health at Cornell's Medical College. At present he is director of the Program of Science, Technology and Society.

Dr. Lynn has served on this NRC committee since 1977 and has been its chairman since 1981. He is also chairman of the NRC's Water Science and Technology Board, created in 1982.

WILLIAM W. AULTMAN

Mr. Aultman obtained a B.S. degree in engineering and economics from the California Institute of Technology. He has over 50 years of experience in the fields of water resources planning and wastewater collection and treatment. Mr. Aultman worked for 21 years with the Metropolitan Water District of Southern California on the Colorado River Aqueduct Project. From 1955 to 1959 he served as executive vice president of James M. Montgomery Consulting Engineers, Inc., and is presently chairman emeritus of the board of directors. Mr. Aultman's work with this firm has included all facets of domestic water system planning and population and water demand forecasting, with particular emphasis on water treatment studies and plant design. He served on this NRC committee from 1977 to 1980.

DUANE D. BAUMANN

Dr. Baumann received his Ph.D. in geography from Clark University in 1968. He has been with Southern Illinois University since then. Dr. Baumann's expertise is in studies of social acceptance of alternative solutions to water resources management problems and wastewater reuse and the evaluation of water conservation in municipal and industrial water supply. He served as a member of this committee from 1977 to 1980 and is currently professor of geography at Southern Illinois University.

BERNARD B. BERGER

Mr. Berger received his M.S. in sanitary engineering from Harvard University in 1948. From 1966 to 1978 he was director of Water Resources Research Center and professor of civil engineering, University of Massachusetts. He was water resources specialist, Office of Science and Technology, Executive Office of the President, and chairman, Federal Commission on Water Resources Research, 1968 to 1969. Since 1979 he has served as professor emeritus of civil engineering. He is a member of the National Academy of Engineering and has served on this NRC committee since 1981.

GUTHRIE S. BIRKHEAD

Dr. Birkhead received his Ph.D. in political science from Princeton University in 1951. He has been at Syracuse University since 1951 and has served at the university as instructor in political science, assistant professor, associate professor, professor, and chairman of the Department of Political Science. He is currently dean of the Maxwell School of Citizenship and Public Affairs. Dr. Birkhead has served as a consultant to the New York State Department of Audit and Control, and to Resources for the Future. He has published extensively on jurisdictional, legal, and political aspects of water resources planning and resource allocations. He has participated in several large river basin studies and on other NRC committees, such as the Committee on Water Quality Policy. Dr. Birkhead has been a member of this committee since 1977.

JOHN J. BOLAND

Dr. Boland received his Ph.D. from Johns Hopkins University in 1973. He is an engineer and an economist with an extensive teaching, research and environmental engineering background, including experience in the

management and operation of water and wastewater utilities. Dr. Boland is a consultant to federal and state water and energy agencies and to a number of water and wastewater utilities, and is a registered Professional Engineer. He is currently a professor in the Department of Geography and Environmental Engineering, Johns Hopkins University, where he teaches courses such as Economics of Public Works and Water Resources Planning, Economic Foundations for Public Decision-Making, Environmental Policy Analysis, and Public Utility Economics. Dr. Boland has served on both this committee and the Committee to Review the Metropolitan Washington Area Water Supply Study since 1976. He is also a member of the NRC's Water Science and Technology Board.

PAUL BUSCH

Dr. Busch received his Ph.D. in civil engineering from Harvard University. Since 1963 he has held various positions at Malcolm Pirnie, Inc., consulting environmental engineers and scientists, in White Plains, New York where he is currently Vice President of Engineering and Technical Services. His experience is primarily in areas related to water quality and water and wastewater treatment issues. He is a trustee of the American Academy of Environmental Engineers. Dr. Busch has served on this committee since 1981.

JOHN CAIRNS, JR.

Dr. Cairns received his Ph.D. in aquatic biology (limnology) from the University of Pennsylvania in 1953. He was assistant curator of limnology at the Academy of Natural Sciences in Philadelphia and became curator in 1961. Dr. Cairns was also professor of zoology at the University of Kansas from 1967 to 1968. His expertise lies in water quality criteria and environmental impacts for rivers and estuaries, water management, and ecology of polluted waters. Since 1968 he has held the position of University Distinguished Professor of Biology and Director, Center for Environmental Studies, Virginia Polytechnic Institute and State University. He was a member of this committee from 1977 to 1980.

KENNETH P. CANTOR

Dr. Cantor received his Ph.D. in biophysics from the University of California at Berkeley in 1969 and an M.P.H. from the Harvard School of Public Health in

1973. He is an environmental health research specialist with extensive experience in epidemiologic assessments of drinking water contaminants. Dr. Cantor served on this NRC committee from 1978 to 1980. He is presently with The National Cancer Institute, Environmental Epidemiology Branch.

LEO M. EISEL

Dr. Eisel received his Ph.D. in engineering from Harvard University in 1970. He has been a member of this NRC committee since its inception, except for a brief absence (two years) when he was appointed director of the Water Resources Council. From 1971 to 1973 he was a staff scientist with the Environmental Defense Fund in New York. In 1973 he became director of the Illinois Division of Water Resources, which involved responsibility for development and management of water resources for flood control, navigation, recreation, and fish and wildlife conservation. Presently Dr. Eisel is with the Wright Water Engineering firm in Denver, Colorado.

JEROME B. GILBERT

Mr. Gilbert has an M.S. in civil engineering administration from Stanford and is general manager of the East Bay Municipal Utility District, Oakland, California. He has 30 years' experience in environmental engineering, with particular expertise in planning, and financial, institutional, and regulatory aspects of water management. He has been executive officer for the California State Water Resources Control Board and chief engineer and general manager for the North Marin County Water District. His public offices have included terms as chairman of the California Health Effects Advisory Committee (current), chairman of the San Francisco Bay Regional Water Quality Control Board, and vice chairman of the California Advisory Committee on Western States Water Planning. He was president of the AWWA for the year 1980. Mr. Gilbert has served on this NRC committee since 1977. He is a member of the NRC Water Science and Technology Board and has also served on the NRC Steering Committee on Cooperation in Urban Water Management. He is a member of the American Society of Civil Engineers and a Diplomate of the American Academy of Environmental Engineers.

ROBERT H. HAVEMAN

Dr. Haveman received his Ph.D. in economics from Vanderbilt University in 1963. Prior to joining the faculty at the University of Wisconsin in 1970, he was with the Brookings Institution and Grinnell College. His expertise is in the use of benefit-cost and other public expenditure criteria, especially as applied in the natural resources area. He has published several critiques of economic and policy analyses performed by the Corps of Engineers and other institutions responsible for water resources development. Dr. Haveman served on this committee from 1977 to 1980.

RICHARD HAZEN

Mr. Hazen received an M.S. in sanitary engineering from Harvard in 1937. He has served on the committee since its inception in 1977 except for a brief absence in 1981. His engineering experience includes 2 years with West Virginia Pulp and Paper Co. (now West Vaco Corporation) and 10 years as engineer and partner with the consulting firm of Malcolm Pirnie Inc. Mr. Hazen has served on consulting boards dealing with water supply problems in New York, Detroit, and the Washington, D.C. area. He is now retired from his engineering consulting firm of Hazen and Sawyer. Mr. Hazen is also a member of the National Academy of Engineering.

PERRY L. McCARTY

Dr. McCarty received his Sc.D. in sanitary engineering from Massachusetts Institute of Technology in 1959. He has been at Stanford University since 1962. From 1962 to 1967 he was associate professor of civil engineering, and since 1967 he has served as professor of civil engineering. He is a member of the National Academy of Engineering and has served on this NRC committee since 1977. Dr. McCarty was also chairman of the NRC Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project.

DAVID W. MILLER

Mr. Miller received an M.S. in geology from Columbia University in 1951. From 1951 to 1953 he worked with the U.S. Geological Survey, and since then has been a private consultant with several firms. He currently is a partner in the groundwater consulting firm of Geraghty & Miller, Inc. Mr. Miller has served on this NRC

committee since 1977. His expertise is in groundwater hydrology and the evaluation of groundwater in resources planning.

JEROME W. MILLIMAN

Dr. Milliman received his Ph.D. in economics from UCLA in 1956. Since then he has held several academic appointments and has consulted for such organizations as the National Planning Association, the Rand Corporation, and Resources for the Future. Dr. Milliman's expertise is in groundwater hydrology and evaluation of groundwater in resources planning. He was a member of this committee from 1977 to 1980 and presently is director of the Bureau of Economics and Business Research at the University of Florida. He is also a member of the NRC's Water Science and Technology Board.

DANIEL A. OKUN

Dr. Okun received an Sc.D. in sanitary engineering from Harvard University in 1948. He served as chairman of this committee from 1977 to 1981 and also as a member of the NRC's Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project from 1976 to 1981. He was assistant sanitary engineer for the U.S. Public Health Service for Washington, D.C.; Ohio; New Jersey; and New York from 1940 to 1942. Dr. Okun was an associate to Malcolm-Pirnie Engineers and went from associate professor of environmental engineering at the University of North Carolina in 1952 to head, Department of Environmental Sciences and Engineering in 1955. He has been a consultant to the World Health Organization, the Environmental Protection Agency, and the Agency for International Development. Dr. Okun's expertise is in water quality management and wastewater treatment. He is a member of other NRC committees, the National Academy of Engineering, and the Institute of Medicine.

LEONARD ORTOLANO

Dr. Ortolano received his Ph.D. in water resources planning from Harvard University in 1969. His professional experience includes: Sanitary engineer, U.S. Public Health Service in Denver; research scientist, Center for the Environment and Man in Connecticut; and visiting professor at the Italian Institute for Water Research in Rome. He has been a professor of civil engineering at Stanford University since 1969 and served on this NRC committee from 1981 to 1983.

GERARD A. ROHLICH

Dr. Rohlich received his Ph.D. in sanitary engineering from the University of Wisconsin in 1940. He was an instructor in civil engineering at the Carnegie Institute of Technology from 1937 to 1941. He served as professor of sanitary engineering at the University of Wisconsin from 1946 to 1972. Dr. Rohlich served on several NRC committees such as The Safe Drinking Water Committee and the NAS-NAE Committee for Water Quality Criteria. His expertise lies in environmental impacts associated with resource development and with quality requirements of potable water. He was the first chairman of the NRC's Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project from 1976 to 1979. He was professor of civil engineering at the University of Texas at Austin and a member of the National Academy of Engineering. (Deceased 1983).

W.R. DERRICK SEWELL

Dr. Sewell received his Ph.D. degree in geography from the University of Washington in 1964 and since then has been on the faculties of the Universities of Chicago and Victoria, British Columbia, where he is presently Chairman of the Department of Geography. The author and editor of some 25 books and monographs, and author of more than 150 articles in scholarly journals, his research interests have focused principally upon water resources, energy, and environmental policy matters. He has been an advisor to governments of several countries, as well as to the United Nations and the World Bank. Dr. Sewell served on this committee from 1978 to 1981.

NRC Project Directors

CHARLES R. MALONE

Dr. Malone received a Ph.D in ecology in 1967 from Rutgers University. His professional experience includes research programs at Oak Ridge National Laboratory on the fate and effects of chemicals on ecosystems and use of microcosms to predict environmental impacts. He was a principal staff officer with the NRC's Environmental Studies Board from 1970 to 1976 and became Executive Secretary of the Committees on Water Supply Reviews in 1976. He served as study director of both the NRC water supply study review and

the treatment plant review from 1976-1982. Presently, he is with EG&G Idaho, Inc.

SHEILA D. DAVID

Ms. David has been study director for the NRC's reviews of the Metropolitan Washington Area Water Supply Study and the Treatment Plant Project since 1982 and assisted in the management of these studies since 1976. She has been a staff officer with the Water Science and Technology Board since 1979 and has organized and managed other NRC committees and conferences on such topics as Coal Mining and Ground Water Resources in the U.S.; Safety of Existing Dams; and Cooperation in Urban Water Management. Prior to her work with the NRC she worked as conference coordinator and assistant editor for Forum for the Advancement of Students in Science and Technology (FASST) in Washington, D.C.