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The Potomac Estuary Experimental Water Treatment Plant

A Review of the U.S. Army Corps of Engineers, Evaluation of the Operation, Maintenance and Performance of the Experimental Estuary Water Treatment Plant

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PREFACE

With this report the Committee to Review the Potomac Estuary Experimental Water Treatment Plant fulfills its obligation to review and comment upon the operation, maintenance and performance of the Corps of Engineers Potomac Estuary Experimental Water Treatment Plant.

The National Research Council (NRC) review was undertaken in response to a 1974 Congressional directive to the Secretary of the Army for a review of the Corps feasibility study concerning use of the Potomac estuary as a source of water supply.

At the time of this directive relatively little was known about the chemical, biological, and radiochemical constituents that might be present in treated domestic wastewaters and urban runoff. In addition, federal and/or state drinking water regulations were not and still are not available for judging the health risks that might result from using such highly contaminated waters. Thus, major knowledge barriers were present that made the feasibility evaluation difficult. With population and industrial growth, contamination of water supplies throughout the country is likely to increase. This will further raise the need for answers to the questions addressed in this particular study. The estuary feasibility study provided an excellent opportunity to increase knowledge in this important area.

While great advances have recently been made in analytical methods to identify contaminants in water, they are only capable of identifying a small fraction of the contaminants present. This has frustrated attempts to develop acceptable quality criteria for drinking water from highly contaminated sources. Because of the need for such criteria for this study, the committee established a Panel on Quality Criteria for Water

Reuse. This panel, chaired by Russell F. Christman, established criteria that were recommended for use by the Corps for the Potomac estuary study. Unfortunately, the Corps felt it did not have the financial resources nor the time available to follow the complete protocol as recommended by the panel, however they did carry out certain portions of it. From the detailed but still limited studies conducted, no evidence was uncovered to suggest that drinking estuary water after advanced treatment would pose any greater health risks than from consumption of conventional supplies now being used in the Washington metropolitan area. However, this committee does not believe that such a conclusion on health risks can be made until the entire protocol recommended by the panel for evaluation has been followed.

To assist in our recommendations during the formative period, the committee organized several panels of experts including one on microbiology and virology headed by former committee member Rita R. Colwell; a second on experimental design chaired by David H. Marks; a third on toxicology chaired by former committee member Frank Lyman; a fourth on analytical chemistry chaired by former committee member Thurston E. Larson; and a fifth on processes that was chaired by the current committee chairman. The contributions made by the members of these panels, including the panel on quality criteria for water reuse, were most beneficial to carrying out the committee's task.

During the earlier period of this study, the committee was chaired by the late Gerard A. Rohlich, an individual who made many significant contributions to the environmental engineering profession. Dr. Rohlich chaired or was a member of several other NRC committees and panels and was the first chairman of the NRC's Safe Drinking Water Committee which has provided such useful guidelines to the evaluation of water quality. His presence will be sorely missed by the water works profession. Also one who will be missed is the late Samuel S. Baxter, one of the original members of the committee and a giant in the water works field.

This review was conducted for the Corps of Engineers, and the committee would like to extend its appreciation to their representatives, particularly Perry Costas, Deputy Chief of the Washington Aqueduct Division, and Harry C. Ways, Chief of the Washington Aqueduct Division, who were so open in their interactions with

the committee. While differences will inevitably arise between two groups such as ours, a great deal of cooperation was established in setting goals for this study and carrying them out.

The Corps was assisted in their studies by two most capable engineering firms. Malcolm Pirnie, Inc. received the contract for the design of the experimental water treatment facilities and for the development of the initial experimental protocol. The firm of James M. Montgomery Consulting Engineers, Inc. was retained to operate the facility, to develop in more detail the experimental design to be followed, and to develop and analyze the results of this study. The Montgomery activities were directed by Michael Kavanaugh, an individual who was most cooperative in working with our committee. The committee members felt unanimously that the high standards and dedication to this study exhibited by Mr. Kavanaugh and his staff, and by the members of the Montgomery analytical team, headquartered in Pasadena, California, were largely responsible for the significant progress made on this project. While the studies were not as complete as the committee had hoped they would be (due to financial limitations), we wish to commend this group in particular for providing a solid base of scientific and engineering information upon which future efforts in water reclamation for potable purposes can be built.

Finally, this report reflects to a large degree the devotion and support provided by the staff of the Water Science and Technology Board of the National Research Council. We especially wish to thank Sheila David, who over the long course of this study kept the committee together and headed in the right direction. We appreciate her special contributions in the preparation of this report and her cheerful disposition and unstinting professional assistance to the committee. Special appreciation is also extended to Charles R. Malone, former executive secretary in charge of this study who so effectively helped organize this committee and carried it through its early years when significant input to the direction of the study was made. Steve Parker and Jeanne Aquilino were instrumental in helping us to meet our commitments with the completion of this report, and Robert J. Golden and Robert G. Tardiff, former staff with the NRC's Board on Toxicology and Environmental Health Hazards, most effectively assisted our Panel on Quality Criteria for Water Reuse. To all these individuals the committee owes a good deal of thanks.

Finally, I wish to extend my appreciation to each of the committee and panel members who so willingly participated over the years in this study. Their outstanding professional competence, patience, and cooperation in keeping with this study deserves special recognition.

Perry L. McCarty,
Chairman

CONTENTS

TABLES

ABBREVIATIONS

BOD	biochemical oxygen demand
COE	Corps of Engineers
DEM	Dynamic Estuary Model
EEWTP	Estuary Experimental Water Treatment Plant
EPA	Environmental Protection Agency
ft^3/s	cubic feet per second
GAC	granular activated carbon
GCMS	gas chromatographic mass spectrometer
LLE	liquid-liquid extraction
MBAS	methylene blue active substances
MCL	maximum contaminant level(s)
mgd	million gallons per day
mg/L	milligrams per liter
ml	milliliter
MPN	most probable number
MWA	Metropolitan Washington Area

EXECUTIVE SUMMARY

Section 85 of the Water Resource Development Act of 1974 (P.L. 93-251) authorized the U.S. Army Corps of Engineers to determine the feasibility of using the Potomac estuary waters as a source of water supply. In this connection, a two-year pilot plant project was authorized involving the construction, operation, and evaluation of a small water treatment plant. The act also directed the Corps to request the National Academy of Sciences/National Academy of Engineering (NAS/NAE) to provide a review and written report commenting upon the scientific basis for the conclusions reached by the Corps from this study. The National Research Council (NRC) Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project was established in response to this request made by the Corps in 1976.

The committee maintained an ongoing review through the several design, operational, and testing phases of the pilot plant study. Four letter reports from the NRC committee were issued to the Baltimore District, Corps of Engineers, to recommend modifications in its overall testing program. The Corps accepted many but not all of the recommendations. Most significant of those accepted were modifications made to the program in response to the committee's comments concerning the preliminary design analysis and specifications for the pilot plant as recommended by the Corps' initial contractor, Malcolm Pirnie, Inc., and in the operation and data collection program as carried out by the Corps' second contractor, James M. Montgomery Consulting Engineers, Inc. The Corps, however, acted only partially upon the committee's recommendations for detailed toxicological testing.

In reviewing the Corps' final report, the NAS/NAE was specifically requested to comment on the "scientific basis" for the conclusions reached. The committee recognized at the outset that it would be most difficult to obtain a scientifically defensible conclusion regarding the safety for human consumption of treated estuary water. The Corps study indicated that water taken even from the farthest upstream points in the estuary would be contaminated during drought conditions with as much as 50 percent treated wastewater. Currently, there are no accepted standards or criteria upon which to judge the safety of such water for human consumption even when treated within the framework of existing technology. Accepted good practice is to obtain water for human consumption from the least contaminated sources available in order to avoid the undefined risks associated with use of a highly contaminated supply.

There are many water-short areas within the United States where the best available supplies tend to be highly contaminated. For such areas the alternatives are quite limited for obtaining a supply with little or no known health risk. Even in areas with plentiful supply, contamination from treated sewage from upstream cities continues to increase with the rise in population. These pressures make it highly desirable to develop procedures for evaluating health risks and treatment technologies that can remove contaminants reliably. Thus, the Potomac Estuary Experimental Water Treatment Plant (EEWTP) study provided an excellent opportunity to address these needs, and the NRC committee felt that the pilot plant study undertaken by the Corps would have important national significance.

The quality of Potomac estuary water varies considerably with distance from point of its beginning, with time of year, with river discharges into it, and with the quantity of sewage and street runoff that it receives. If a full-scale plant were to be built to treat Potomac estuary water, then processes suitable for achieving acceptable water quality regardless of estuary quality would need to be included. The simulated estuary quality used in the pilot-scale study by the Corps represented a worst case, one that would occur only during time of drought when minimal amounts of Potomac River water would be available for diluting the local sewage discharges. The study protocol and conclusions reached were based upon an implicit assumption that the quality of treated water under these conditions should meet the same criteria as a normal water supply used continuously over a lifetime of exposure. That is, no increase in health risk or reduction in wholesome quality of the water was assumed even for a short-term emergency condition. This may be an unnecessarily conservative approach, and thus far its consequences have not been evaluated.

The pilot plant study, in general, was conducted in a highly professional manner and provided information on treatment plant reliability and treated water quality that was previously not available. Within the limits of the information obtained, no evidence was uncovered that would indicate that the treated estuary water would pose greater health risks to the public than those from consumption of conventional supplies now being used. However, the number of organic contaminants actually identified and measured in the treated estuary water, while much larger than most previous studies, was very small compared with the total number present. In addition, the toxicological testing conducted on treated water was very limited, in fact too limited to permit adequate judgment of the health hazards that may be present. Thus, the Corps study did not provide sufficient scientific evidence to support its conclusion that estuary water of the quality anticipated during a drought and treated by the processes studied would be of potable quality.

The above statement is not meant to negate the value of the information that was generated by this study. It is meant to add a stronger cautionary note to the conclusions than was provided in the Corps' final report. However, there were several commendable features of the study that should be recognized in addition to its limitations. Both are discussed in detail within the body of this report, and are briefly summarized as follows.

Among the most outstanding features of the Corps study were:

1. The detailed comparative evaluation of the quality of treated estuary water with that of three major treated water supplies for the Washington metropolitan area. This evaluation indicated for a broad range of physical, chemical, and biological contaminants that advanced treatment processes can improve a highly contaminated source so that its quality is similar to that of traditional water supplies. While more detailed

toxicological testing is yet required to confirm the safety of the renovated water, the outlook provided is quite promising.

2. The development of a detailed inorganic and organic chemical characterization of treated estuary water and of local water supplies. This evaluation provided a broad data base on the types and concentration levels for contaminants beyond the limited range provided by general listings such as the U.S. Environmental Protection Agency's (EPA's) designated priority pollutants. While much yet remains to be done in this area, the study provided an excellent background of information and procedures for further work in this area.

3. The development of a data base on microbiological contaminants and toxicological indicators. As with the chemical constituents, the analyses here went far beyond evaluations normally made of potentially hazardous materials in drinking water supplies, and thus provided information of general value for all water supplies.

4. The demonstrated reliability of advanced treatment processes to provide treated water with relatively consistent quality. The study served to demonstrate that well designed and properly constructed advanced processes, when operated by highly trained and dedicated individuals, are capable of treating a contaminated supply to produce water with relatively consistent quality.

The committee commends the Corps for these outstanding achievements. However, there are important limitations to this study and to the conclusions reached. They are as follows:

1. Insufficient scientific evidence was provided to adequately evaluate the safety to humans from consumption of treated estuary water. While the evaluation made of the quality of treated water was much broader than that presently available elsewhere, insufficient toxicological testing was conducted to reach an acceptable conclusion on the potability question. Since its formation in 1976, the committee has brought this limitation to the attention of the Corps repeatedly. In addition, the National Research Council formed a separate panel (Panel on Quality Criteria for Water Reuse, see page 11) whose major purpose was to outline in detail a program of

toxicological testing that would address this issue. It is regrettable that only a very limited aspect of the proposed program was implemented. Had the broader program been undertaken, the results would have been much more conclusive and would have been of much greater value to other areas of the country facing the use of highly contaminated drinking water sources. The inadequacy of the toxicological testing is not addressed within the Corps conclusions. The Corps conclusion on potability might lead the reader to believe that the program conducted was adequate to demonstrate that the treated water would be suitable for human consumption. This is not the case.

2. The potential changes in the quality of estuary water that might result from biological growth during drought conditions were not adequately addressed. Under low-flow conditions, the nutrient contributions from wastewater discharges, the higher summer temperatures, and the absence of flushing flows in the estuary are likely to lead to excessive growth of algae. Such conditions can lead to major difficulties in treatment and to excessive problems with water taste and odor. Further attention should be given to this issue if treatment of estuary water is considered in the future.

3. Failure to detect viruses in EEWTP finished waters cannot be accepted as an indication that they are absent. The data do indicate that a reduction through treatment did occur in the numbers of viruses that can be detected. However, the state-of-the-art methods used are not sufficiently sensitive for detection of even routinely cultivable enteric viruses, let alone pathogens such as hepatitis A and certain gastroenteritis viruses for which analytical procedures are not yet available. Thus, although the health-hazard risk from pathogenic viruses in treated Potomac-estuary-simulated water is estimated to be low, the degree of freedom from virus-associated health hazards cannot be stated accurately.

4. The economic evaluation of a Potomac estuary water treatment plant was inadequate as it did not provide a comparative cost with other alternatives. The cost of highly contaminated estuary water treated by the advanced processes considered was found to be high in comparison with current costs for water in the metropolitan area. Indeed, the costs would have been even higher if land value, transmission, and solids handling costs associated with an estuary water system

had been included. Nevertheless, high costs would be associated with any new treatment plant built to satisfy a growing water demand. Granular activated carbon treatment is the only nonconventional process used in the estuary treatment plant. With a full-scale estuary treatment plant this process might need to be operated only during drought conditions, thus reducing average treatment costs considerably. Because a sufficient supply of relatively uncontaminated water now appears to be available at acceptable cost, the decision not to consider estuary water further as a source for drinking water is reasonable. Nevertheless, the economic feasibility of an estuary supply could become an issue in some future decision. For this reason, the committee believes it is important to note that the economic feasibility question was not adequately discussed.

Recommendation

The committee believes that the information on treatment plant reliability and treated water quality obtained from the two year testing of the Corps' pilot plant would be helpful and of great interest to state health agencies across the country where water reuse is being considered or being carried on at present. Therefore, we recommend that the Corps of Engineers disseminate this information to all state health agencies and other local agencies interested in potable water reuse in the U.S., along with copies of the NRC committee review reports and the NRC's panel report on "Quality Criteria for Water Reuse."

The Corps report taken in context with the cautionary notes and review given by the NRC committee/panel should be of great help to those persons responsible for delivering safe drinking water to consumers, especially where potable reuse is concerned.

1

BACKGROUND

This report is the culmination of an eight-year review by the National Research Council (NRC) of the U.S. Army Corps of Engineers' design, operation and maintenance, and performance evaluation of the Potomac Estuary Experimental Water Treatment Plant (EEWTP).

Section 85 of the Water Resource Development Act of 1974 (P.L. 93-251) authorizes the Corps of Engineers to undertake the phase 1 design memorandum for the Sixes Bridge Dam and Lake in Maryland. The act also required the Corps to undertake two studies related to the future water supply needs of the Washington metropolitan area, the second of which is a study to determine the feasibility of using the Potomac estuary waters as a source of water supply. In this connection, a $6 million pilot project was authorized involving the construction, operation, and evaluation of a small treatment plant. Further, the Corps was required to submit to the Congress a report of its studies, including the results of two years' testing at the treatment plant.

Finally, the act directs the Corps of Engineers to request the National Academy of Sciences/National Academy of Engineering (NAS/NAE) to provide a review and written report commenting upon the scientific basis for the conclusions reached by the Corps.

This request was received from the Corps in 1976 and thus the NRC Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project was established. Approximately one year later the Corps also requested the Academy to review their overall Washington Metropolitan Area Water Supply Study in the same manner as mandated by Congress. Thus, two NRC committees were designed with an overlapping membership so that several committee members were assigned to both studies for the duration of the projects. This enabled the committee members to be kept apprised of the progress of the Corps' overall effort and the specific effort concerning the pilot plant. A separate NRC report entitled 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) will be issued to the Corps of Engineers concurrently with this report.

It was decided that the committee would maintain an ongoing review process through the several design, operational, and testing phases of the pilot plant and would report to the Corps of Engineers throughout this eight-year period, with a final report to be issued one year after the committee received the Corps' final report.

The membership of the committee was reorganized in 1979, and has been guided by two chairmen since 1976, Gerard A. Rohlich, professor of civil engineering at the University of Texas at Austin (deceased 1983), and Perry L. McCarty, present chairman and professor of environmental engineering at Stanford University. Both chairmen are also members of the National Academy of Engineering.

Expertise of the committee and panel membership has included environmental, civil, and sanitary engineers; chemists; epidemiologists; virologists; microbiologists; biochemists; public health officials; water chemists; and medical doctors including oncologists and pediatricians.

Since 1976 the committee has held two to three meetings per year as required and has issued four letter reports to the Baltimore District, Corps of Engineers. The letter reports are reproduced in their entirety in Appendix A. Following is a brief synopsis of the contents of each report.

NRC REPORTS 1977-1981

March 2, 1977, Letter Report

The first letter report contains the committee's review of the preliminary design analysis and specifications, prepared by Malcolm Pirnie, Inc., for the experimental water treatment plant under development by the Corps of

Engineers. It also includes a report from the committee's Panel on Processes. The committee and panel reviewed the Corps' Design Memorandum - Experimental Estuary Water Treatment Plant, 1976[1] and the preliminary submission, September 1976, of the proposed Design Analysis and Specifications[2] for the plant. Comments were made on the proposed treatment processes, including the filtration and chlorination steps, elimination of the alum coagulation modification, breakpoint chlorination, adding of a deep bed filtration system, two-stage recarbonation, and air injection for activated carbon backwashing.

August 4, 1977, Letter Report

The second letter report reviews the proposed testing and evaluation program for the experimental water treatment plant. Several of the committee's comments that merit special attention involve the need for a clearly defined objective of the overall project; necessity of using effluent from Blue Plains Wastewater Treatment Plant of the same quality as that released into the Potomac estuary; merits of restricting the treatment process configurations to be tested; comparing quality of output water from the plant with quality of drinking water presently supplied to the metropolitan Washington area; evaluation of output water in terms of consumer palatability; and necessity of toxicological tests on the plant's output water.

March 22, 1979, Letter Report

The third report reviews the Corps' final draft report titled Development of a Testing and Evaluation Program for the Experimental Estuary Water Treatment Plant, Washington, D.C.,[3,4] dated October 1978. The committee expressed concern that the Corps had not devoted sufficient attention to understanding the quality of the input water that will require treatment. A basic question that the committee considered not adequately answered was: What percentage of wastewater effluent would be in the estuary during operation of a full-scale estuary water treatment plant and how would this vary over time? Topics covered are specification of input waters and process effectiveness and output water quality.

November 6, 1981, Letter Report

This letter report to the Corps was prepared by the committee's Panel on Quality Criteria for Water Reuse. It conveyed the committee's views on the pilot plant's testing and evaluation program being carried out for the Corps by James M. Montgomery Consulting Engineers, Inc. The committee endorsed the panel's conclusion that the Corps' experimental plants for the pilot plant were in need of improvement in two important areas: (1) predictive testing for adverse health effects and (2) more comprehensive organic analysis. A final recommendation was that the Corps should make prompt efforts to secure additional funds in order to incorporate the recommended additional tests to their program.

POTOMAC ESTUARY EXPERIMENTAL WATER TREATMENT PLANT

The plant was designed by Malcolm Pirnie, Inc., of White Plains, New York, and construction of the plant was completed in January 1980 at a total cost of $9,470,000. An additional $11,930,000 was required to support the operation, testing, and evaluation program. It was located on 2 acres adjoining the District of Columbia Blue Plains Advanced Waste Treatment Plant and was rated at 0.5 million gallons per day (mgd) with a maximum of 1.0 mgd, and incorporated state-of-the-art water treatment processes and techniques.

The two-year testing program was conducted by the Washington Aqueduct Division of the Baltimore District, Corps of Engineers, using the firm of James M. Montgomery Consulting Engineers, Inc., to operate the plant and conduct all water quality analyses and tests. In order to simulate the water quality expected in the estuary during periods of extended drought, the influent to the plant was a blend of estuary water and nitrified secondary effluent from the Blue Plains Advanced Waste Treatment Plant. The blended water was subjected to aeration, coagulation, flocculation, sedimentation, predisinfection, filtration, carbon adsorption, postdisinfection in succession, with sampling points before and after each process. The treated water was discharged to the Blue Plains Advanced Wastewater Treatment Plant. Chemical and biological tests were performed on samples taken from several points located throughout the treatment process. Comparisons were made with the drinking water presently supplied by three of the major utilities serving the metropolitan Washington area, with the EPA Drinking Water Standards, and with water quality goals developed by the Corps or their contractor. Together, these tests and comparisons were used as the basis for evaluating the efficiency of the treatment process and the quality of the water produced at the pilot plant.

QUALITY CRITERIA FOR WATER REUSE

In 1979 the committee appointed the Panel on Quality Criteria for Water Reuse and charged it with advising the committee on the criteria needed for determining the suitability of water supplies produced from unacceptable or polluted sources, such as wastewater. The committee took this step because of the lack of standards for defining potability of a drinking water source that has been subjected to high levels of contamination. Moreover, current drinking water standards in general do not address water quality issues of this nature.

In its 1982 report (Quality Criteria for Water Reuse),[5] the panel attempts to offer the best practical scientific statement concerning health effects criteria for the evaluation of reused water intended for human consumption. It was not possible to evaluate the health effects of the many compounds detected in the aquatic environment; thus, the panel recommended that the quality of the reused water be compared with that of conventional drinking water supplies, which are assumed to be safe. In assessing water being considered for potable reuse, comparison should be made with the highest-quality water locally available. In the Corps study the quality of water from three major level water treatment systems was compared with that from the EEWTP. Whether any or all of the three would be representative of the "highest quality water locally available" is difficult to evaluate since the Corps was not charged in their study with identifying what other water supplies might be available for use. Under the circumstances, the comparisons appear reasonable for this preliminary evaluation. The panel recommended that whole-animal toxicological tests be done to evaluate the effects of exposure to concentrates of the mixtures of organic chemicals present in water. This approach consisting of three phases would more closely represent actual human exposure (see Table 1 below).

TABLE 1
TOXICOLOGICAL TESTS

PHASE 1

Conventional Water and Reused Water

In Vitro:

Mutagenicity

In vitro transformation

In Vivo:

Acute toxicity

Teratogenicity

Short-term, repeated dose studies - 14 day (includes cytogenetics assay)

PHASE 2

Subchronic 90-day study in at least one rodent species, preferably in two species

Reproductive toxicity

PHASE 3

Chronic lifetime feeding study in one species of rodent

SOURCE: National Research Council (1982) Quality Criteria for Water Reuse.

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

In this chapter each of the Corps of Engineers' Significant Findings is restated, with the NRC committee's evaluation following. Each finding is listed in the same order as presented in the Corps' final, 1983 report, Executive Summary.[6]

SELECTION OF INFLUENT WATER QUALITY

Conclusions by Corps of Engineers

1. An equal blend (1:1) of treated wastewater and Potomac River estuary water was selected to simulate the expected water quality conditions in the Potomac River estuary at Chain Bridge, (a possible location of an estuary water treatment plant) under 1930 drought conditions with projected water supply demands for the year 2030.

2. The 1:1 blend was found to be a conservative simulation of expected water quality in the estuary at Chain Bridge, based on a comparison of water quality projections developed by the Dynamic Estuary Model (DEM), and the water quality observed in the blended influent.

NRC Committee Evaluation

Raw Water Sources for Estuary Experimental Water Treatment Plant

The "1:1 blend" of treated wastewater and Potomac estuary water signifies a mixture of 50 percent treated effluent from the Blue Plains regional sewage treatment facility and 50 percent Potomac estuary water.

The Blue Plains plant processes wastewater originating in the District of Columbia and surrounding counties in Maryland and Virginia. The tributary sewerage systems include both separate and combined sewers. The wastewater received at the Blue Plains plant is principally domestic sewage occasionally mixed with some surface-water runoff. Industrial waste is not currently a significant problem, but could become so if not carefully monitored and controlled. The basic treatment system includes primary treatment by sedimentation and secondary treatment by the activated sludge process. A third stage of treatment includes phosphorus removal by chemical precipitation and nitrification for ammonia reduction. The final treatment stage consists of filtration and disinfection with chlorine.

The Experimental Estuary Water Treatment Plant (EEWTP) is located adjacent to the Blue Plains plant. One of the sources of raw water for the EEWTP was the effluent from the nitrification stage of treatment at the Blue Plains sewage treatment plant. At this point in the Blue Plains sewage treatment process, the sewage has been clarified and biochemically stabilized, but has not been filtered or disinfected with chlorine. Consequently, that fraction of the sewage diverted to the EEWTP received less treatment than that which was (or will be) provided for the bulk flow of wastewater. This introduces possible elements of uncertainty into the water quality simulation process. The quality of the partially treated sewage pumped to the EEWTP will in many, but not all, respects be inferior to that discharged to the estuary following the final stages of treatment at the Blue Plains plant. Filtration treatment will remove a substantial proportion of residual nonsettleable solids (organic and inorganic) from the nitrified wastewater, as well as large numbers of bacteria. Chlorine disinfection of the wastewater prior to its discharge should, in some respects, provide better effluent quality than that available following the prior nitrification stage. A disadvantage is that while improving the microbiological quality, the chlorination process may somewhat degrade chemical quality as a result of interaction of the chlorine with residual organics in the treated wastewater. The result may be the formation of small amounts of chlorinated organic compounds that are difficult to remove by water treatment processes and are of possible health significance.

It is doubtful that the elements of quality uncertainty introduced by the above-cited selection of nitrified effluent as part of the raw water source for the EEWTP are of major significance as far as the overall water treatment investigation is concerned. Nevertheless, it is the committee's view that at least a brief explanation of this matter should have been included in the Corps report of this investigation.

The source of the other 50 percent of the EEWTP raw water supply was the Potomac River estuary. Up to 1.0 million gallons per day (mgd) of water could be delivered to the plant, but the amount actually pumped during normal operation of the EEWTP was usually much less, about one-fourth of a million gallons per day. This portion of the estuary is a "tidal fresh zone," and under normal hydrologic conditions the total dissolved mineral solids do not exceed the background concentrations of TDS in the flowing river.

The EEWTP was designed for a maximum hydraulic capacity of 1 mgd, but normal operating capacity was established at approximately 0.5 mgd. For a 1:1 blend and operation at normal capacity, this corresponds to about 0.25 mgd of Blue Plains nitrified wastewater and a like amount of Potomac River estuary water.

Projected Water Quality for Future Estuary Treatment Plant

Water Quality Models

Various water quality modeling efforts were undertaken for the purpose of predicting future estuary water quality at or near the site of the intake for a possible full-scale estuary water treatment plant. A major limitation of initial modeling efforts was identified as the use of monthly average inflows to the estuary. These monthly average values apparently produce a "smoothing" effect that restricts the ability of the model to respond to water quality changes produced by short periods of unusually low flow. Revised modeling was undertaken, employing the U.S. Environmental Protection Agency's Dynamic Estuary Model (DEM). This two-component model can be used to predict water movement and water quality in the estuary. Ready application of the DEM requires that the quality parameters investigated behave in a conservative (stable) fashion; i.e., they are not subject to biochemical degradation, precipitation, volatilization, etc. Inorganic parameters such as total dissolved solids, chloride, sulfate, calcium, magnesium, and certain trace metals are examples of parameters that are or may be considered conservative. Nonconservative parameters include coliform organisms, algae, organic, radiological substances, etc. Ammonia and nitrate are usually considered nonconservative, but their rate of degradation is low, and rough estimates of their concentration perhaps can be projected, on the basis of assumed conservative behavior, within the time frame of the modeling period.

Accurate characterization of most nonconservative quality parameters is virtually impossible considering the multiplicity of complex, natural processes and factors controlling their degradation and transformation. The precise nature and kinetics of these reactions in the estuary are currently unknown.

Base Conditions for Employment of Dynamic Estuary Model (DEM)

The following summarizes base conditions that were established for the prediction of future water quality during an extreme drought.[7]

- Potomac River inflow to the estuary at Chain Bridge was based on observed flows corrected for removals by the Washington Aqueduct's Dalecarlia plant. The 183-day simulation covered the period July through December 1930.
- For the year 2030, corrected 1930 flows were further adjusted by deducting an additional 450 cubic feet per second (ft^3/s) in consideration of further upstream withdrawals by various water authorities.
- During the simulation period, flowby was 0 on one day, but greater than 100 mgd (155 ft^3/s) during most

of the remainder of the 183-day drought period. Anacostia River inflow was held constant at about 13 mgd (20 ft^3/s).

- Municipal demand, including that furnished by the full-scale estuary plant, was held constant at 1,000 mgd (1,550 ft^3/s) during the simulation period.
- The intake for the full-scale estuary water treatment plant was located near Chain Bridge and the plant was operated at full capacity, 200 mgd from 14 August through 15 December.
- "Consumptive" use of water withdrawn was estimated at 10 percent; e.g., for each 100 million gallons withdrawn from the river and estuary, 10 million gallons would be evaporated or otherwise diverted from the flow eventually returned in the form of treated wastewater.
- Domestic, commercial, and industrial use of the water withdrawn resulted in a total dissolved solids (TDS) increase (use increment) of 400 milligrams per liter (mg/L) in the return flow. (This use increment was subsequently revised.)
- Potomac River water and all other source water was assumed to have a background TDS level of 180 mg/L.
- Over 75 percent of wastewater flow from the metropolitan area originated at the Blue Plains plant.

Intake Location at Potomac Park

The DEM was also utilized for water quality predictions under identical drought conditions with the full-scale (200 mgd) water treatment plant intake located near Potomac Park rather than near Chain Bridge. Potomac Park, a possible full-scale plant site, is located approximately 6 miles downstream from Chain Bridge. This location was considered the lowest point on the estuary suitable for a plant site. From a public water supply standpoint, the disadvantage of this intake site is that it places the estuary water treatment plant intake much closer to the Blue Plains outfall sewer, and therefore reduces the time available for the forces of estuary self-purification to act upon any residual pollutants present in the Blue Plains effluent. This could result in the fairly rapid development of serious water quality problems at the estuary water treatment plant in the event of a major process breakdown at the Blue Plains wastewater treatment works. Water supply withdrawal through an intake at Potomac Park would, in effect, approximate a 100 percent wastewater reuse system. The beneficial influence of inflow to the estuary would be considerably reduced and there would be a greater buildup in the maximum concentration of TDS and other conservative quality parameters at the Potomac Park intake location than at the Chain Bridge location, used in the base model. This increase, shown by the model run, was approximately 20 percent. With a water supply intake at Potomac Park and no flowby at Chain Bridge, the model can simulate a condition of overuse of the Potomac River or other situation that restricts the flow at Chain Bridge for a substantial time period. Under these adverse conditions, there is a maximum buildup of the TDS concentration, in a 3-month drought period, to a value of about 750 mg/L. Based on these extreme conditions, predicted maximum concentrations of conservative parameters are about 70 percent greater than those predicted under the base modeling conditions, which assumed an intake location at Chain Bridge.

Breakdown of Nitrification Facilities at Blue Plains

This investigation was designed to study the possible quality effects of wastewater treatment plant breakdown. Ammonia is a significant parameter in both water and wastewater treatment and was the principal parameter of interest in this modeling study.[8]

Ammonia (usually expressed in terms of nitrogen, i.e., NH_3-N) is a key substance in water disinfection with chlorine. Consequently, its concentration in a raw water supply is a matter of concern. Ammonia in raw water can be destroyed (converted to elemental nitrogen) by chlorine, but objectionable side reactions (formation of trihalomethanes) occur and the chlorine requirement is quite large (usual range: 7 to 15 times the NH_3-N concentration, but possibly greater[9]). For normal Blue Plains operations, the effluent concentration was estimated at 1.0 mg/L of NH_3-N. Background concentration in the estuary was fixed at 1.0 mg/L and the use increment at 10.0 mg/L.

The possible effects of short- and long-term failure of the Blue Plains nitrification process were modeled under the previously given drought conditions. An additional important assumption was that the ammonia discharged would behave as a conservative parameter. This is approximately true under winter conditions, but during the summer the ammonia concentrations in the estuary could be reduced substantially through biochemical conversion to nitrite and nitrate. Nevertheless, this was a worthwhile investigation because it provided an estimate of the highest possible concentration of NH_3-N that could be encountered as a result of nitrification breakdown at Blue Plains. For an intake location at Chain Bridge, the estuary provides a breakdown time delay of about 40 days as compared to very little time at a location near Potomac Park. After 40 days, the NH_3-N buildup proceeds at about the same rate at both intake locations. This delay, provided by the estuary, plus the likelihood of significant summer ammonia reduction by estuary biochemical action, emphasizes the probable advantages of a Chain Bridge intake location. Similar comments probably apply, more or less, to other contaminants released to the estuary because of wastewater treatment plant breakdown; e.g., coliform organisms, biochemical oxygen demand (BOD), and suspended solids.

Revision of Maximum Projected Concentrations

"Use Increments" designated "1981 Original" are presented in Table 2. For example, the "1981 Original" TDS gain as a result of water use in the metropolitan area is given as 400 mg/L. "Background Concentration" of TDS, listed in the same table, is 180 mg/L. The "1983 Revised Use Increments," also listed in this table, were obtained by subtracting the "Background Concentration," as listed, from the arithmetic mean concentration of Blue Plains effluent, as measured over the two-year period of operation of the EEWTP. This table lists 24 parameters: major cations, anions, and nutrients, plus trace metals, such as cadmium, chromium, lead, mercury, nickel, and zinc.

The revised use increments were in many cases considerably lower than those originally modeled, and employment of the revised use increments in model runs resulted in lower maximum projected concentrations for most parameters. On the other hand, the revisions led to higher use increments for nitrate (11.4 mg/L N versus 6.7 mg/L N), total phosphorus (0.33 mg/L P versus 0.31 mg/L P), and sulfate (54.2 mg/L versus 43 mg/L sulfate ion). Revised use increments for trace metals were generally lower. Several use increments, including

TABLE 2
MAXIMUM PROJECTED WATER QUALITY PARAMETER CONCENTRATIONS AT CHAIN BRIDGE INTAKE (2030 WATER DEMANDS, JULY - DECEMBER 1930 HYDROLOGIC CONDITIONS)

Parameter	Background Concentration (mg/L)	Use Increments 1981 Original (mg/L)	Use Increments 1983 Revised[a] (mg/L)	Maximum Projected Concentrations 1981 Original (mg/L)	Maximum Projected Concentrations 1983 Revised (mg/L)
Major Cations, Anions, and Nutrients					
Total Dissolved Solids	180	400	195	447	310
Calcium	26.9	30	29.2	47	46.4
Hardness (as $CaCO_3$)	91	100	83.1	158	146.5
Magnesium	5.9	6.0	2.4	9.9	7.5
Potassium	2.3	7.0	6.4	7.0	6.6
Sodium	8.0	85	35.9	65	32.0
Alkalinity (as $CaCO_3$)	63	100	---[b]	130	63[c]
Chloride	9.4	107	61.2	81	50.3
Nitrogen-NO_3-N	1.27	6.7	11.4[d]	5.7	8.9[d]
Nitrogen-NH_3-N	0.06	1.9	0.5	1.3	0.4
Total Phosphorus-P	0.09	0.31	0.33[e]	0.30	0.31[e]
Sulfate	27.2	43	54.2	56	62.2
Trace Metals					
Aluminum	0.83	0.2	---[b]	0.96	0.83[c]
Cadmium	0	0.1	0.0017[f]	0.07	0.0001[f]
Chromium	0.012	0.17	---[b]	0.13	0.012[c]
Copper	0.006	0.10	0.0087[f]	0.07	0.0087[f]
Iron	1.36	0.1	0.2553	1.4	1.53
Lead	0.002	0.1	0.0002	0.07	0.002
Manganese	0.096	0.2	0.147	0.23	0.194
Mercury	0	0.0014	0.0003	0.001	0.0002
Nickel	0.010	0.05	---[b]	0.04	0.01[c]
Silver	0	0.02	0.0011	0.01	0.0007
Strontium	0.22	0.2	NM[g]	0.35	0.22[c]
Zinc	0.026	0.04	0.0024	0.05	0.028

a. Calculated using reported background concentrations and Blue Plains Nitrified Effluent arithmetic mean values measured during EEWTP operation.

b. Background concentration greater than Blue Plains Nitrified Effluent arithmetic mean; thus, these parameters could not be calculated.
c. Background concentration listed as "worst case" estimate.
d. Nitrogen-Nitrate+ Nitrite concentrations used.
e. Orthophosphate concentration used.
f. Concentrations as measured by AAS, as opposed to ICAP, used.
g. Not measured in this study.

SOURCE: U.S. Army Corps of Engineers (1983), Main Volume.

those for alkalinity, aluminum, chromium, and nickel, could not be calculated because estuary background levels exceeded the concentrations found in the Blue Plains nitrified effluent.

Revised use increments, generally lower in value than those originally employed in the model, led to considerably reduced concentrations projected for most parameters. For example, the original projected maximum TDS was 447 mg/L, but the revised 1983 value was only 310 mg/L. There were increases in the projected concentrations for nitrate N (5.7 to 8.9 mg/L), total phosphorus as P (0.30 to 0.31 mg/L), and sulfate as SO_4 ion (56 to 62.2. mg/L).

Parameters Not Modeled

Important nonconservative parameters difficult or impossible to model were physical/aesthetic parameters (e.g., turbidity, temperature, color); microbiological parameters (e.g., total coliform organisms, fecal coliform organisms, standard plate count); organic parameters (e.g., total organic carbon, total organic halide, total trihalomethanes); and radiological parameters (e.g., gross alpha, gross beta).

The following tabulation summarizes the arithmetic mean concentration of various unmodeled parameters as measured in the EEWTP blend tank.

	Arithmetic Mean (Rounded) EEWTP Blend Tank
Temperature	18.6°C
pH	7.0
Dissolved oxygen	8.4 mg/L
Turbidity (grab sample)	14 NTU
Total suspended solids	16 mg/L
Apparent color	37 color units
MBAS	0.068 mg/L
Gross alpha	0.52 pCi/L
Gross beta	6.46 pCi/L
Total coliform	33,000 MPN/100 ml
Fecal coliform	6,300 MPN/100 ml
Standard plate count	17,000 colonies/ml
Salmonella	<1. MPN/100 ml
Endotoxin	62 ng/ml

Total organic carbon (TOC)	
Composite samples	4.6 mg/L as C
Grab samples	4.6 mg/L as C
Total organic halide (TOX)	9.5 μg/L
Total THM (by LLE)	2.4 μg/L*
Tetrachlorethene (by LLE)	0.97 μg/L
Trichlorethene (by LLE)	0.13 μg/L

*THM concentrations exhibited considerable seasonal variations, but never approached EPA's maximum contaminant level of 100 μg/L.

Note: Only limited information (single samples) reported on algae and asbestos.

The above values are listed merely to provide a rough, general idea of the magnitude of the various parameters listed. It is emphasized that the concentrations listed are arithmetic mean values as measured at the EEWTP. They give no indication of the dispersion of individual measurements above and below the arithmetic mean values.

Projected Drought Quality Versus Quality of EEWTP Blended Influent

Table 3 presents 1983 Revised Maximum Projected Concentrations (RMPC) of 23 inorganic parameters, including eleven trace metals. The 1983 revised maximum projected TDS concentration is 310 mg/L as compared with the original estimate of 447 mg/L (See Table 2).

It also includes arithmetic mean and 90 percentile concentration values for the EEWTP blended influent. The mean value of the TDS concentration in the blended influent is 273 mg/L; the 90 percentile, 329 mg/L. Thus, the 90 percentile TDS value for the blended influent is greater than the 1983 Revised Maximum Projected Concentration. The same is true of the 90 percentile values of all other blended influent parameters. For over half of the parameters listed, the mean value of the blended influent is greater than the 1983 RMPC.

Microbiological parameters were not modeled and are not included in Table 3, but it is probable that bacterial numbers in the EEWTP blended influent will exceed those that would be encountered in the Potomac

TABLE 3

COMPARISON OF MAXIMUM PROJECTED WATER QUALITY PARAMETER CONCENTRATIONS TO OBSERVED EEWTP INFLUENT CONCENTRATIONS

Parameter	1983 Revised Maximum Projected Concentration (RMPC)(mg/L)[a]	EEWTP Blended Influent: Arithmetic Mean (mg/L)	EEWTP Blended Influent: 90 Percentile (mg/L)	Comparison of EEWTP Simulation to Projected Concentrations Using the DEM
Major Cations, Anions, and Nutrients				
Total Dissolved Solids	310	273	329	RMPC < EEWTP 90%ile
Ca	46.4	46.8	58.0	RMPC < EEWTP mean
Hardness (as $CaCO_3$)	146.5	150.8	185.0	RMPC < EEWTP mean
Mg	7.5	8.2	10.5	RMPC < EEWTP mean
K	6.6	6.0	7.1	RMPC < EEWTP 90%ile
Na	32.0	29.5	36.9	RMPC < EEWTP 90%ile
Alkalinity (as $CaCO_3$)	---[b]			
Cl	50.3	45.8	58.0	RMPC < EEWTP 90%ile
NO_3-N	8.9	7.3	9.1	RMPC < EEWTP 90%ile
NH_3-N	0.4	0.26[c]	0.7[c]	RMPC < EEWTP 90%ile
Total P	0.31	0.38[d]	0.63[d]	RMPC < EEWTP mean
SO_4	62.2	63.5	85.0	RMPC < EEWTP mean
Trace Metals[e]				
Al	---[b]			
Cd	0.0001	0.0002	0.0004	RMPC < EEWTP mean
Cr	---[b]			
Cu	0.0087	0.0450	0.0140	RMPC < EEWTP mean
Fe	1.53	1.37	2.38	RMRC < EEWTP 90%ile

(Continued)

TABLE 3 (Continued)

COMPARISON OF MAXIMUM PROJECTED WATER QUALITY PARAMETER CONCENTRATIONS TO OBSERVED EEWTP INFLUENT CONCENTRATIONS

Parameter	1983 Revised Maximum Projected Concentration (RMPC)(mg/L)	EEWTP Blended Influent Arithmetic Mean (mg/L)	EEWTP Blended Influent 90 Percentile (mg/L)	Comparison of EEWTP Simulation to Projected Concentrations Using the DEM
Pb	0.002	0.003	0.006	RMPC < EEWTP mean
Mn	0.194	0.197	0.340	RMPC < EEWTP mean
Hg	0.0002	0.0005	0.0004	RMPC < EEWTP Mean
Ni	---[b]			
Ag	0.0007	0.0006	0.0014	RMPC < EEWTP 90%ile
Zn	0.028	0.026	0.047	RMPC < EEWTP 90%ile

a. Assuming July - December 1930 stream flow, 2030 water demands, and intake at Chain Bridge.
b. Revised use increments could not be calculated because concentrations in Blue Plains effluent was less than the assumed background concentrations.
c. Blue Plains Nitrate+Nitrite concentration used.
d. Blue Plains orthophosphate concentration used.
e. Blue Plains concentration as measured by AAS, as opposed to ICAP, used.

SOURCE: U.S. Army Corps of Engineers (1983). Main Volume

River estuary in the future, especially at the Chain Bridge intake site. The major fraction (90 percent plus) of coliform bacteria, etc., in the EEWTP raw water was derived from the Blue Plains plant effluent that was pumped directly to the EEWTP blend tank. Under full-scale operating conditions, with an intake at Chain Bridge, there would be a substantial reduction in coliform numbers due to disinfection of Blue Plains effluent and to normal die-away in the estuary. The blend employed at the EEWTP, therefore, probably contains considerably larger numbers of coliform bacteria than would confront a full-scale plant, especially one having an intake at Chain Bridge.

Organic parameters in the EEWTP blended water were contributed principally (approximately 60 to 70 percent) by the nitrified effluent from Blue Plains. The 1:1 blend of estuary and Blue Plains nitrified effluent provided sufficient organics to challenge the plant removal processes. Total organic carbon (TOC) in the EEWTP blended influent generally ranged from 4.0 to 10.0 mg/L over the 1981-1983 sampling period. Other organic parameters for the same period exhibit the following approximate ranges: total organic halide (TOX) 50 to 200 (μg/L); total trihalomethane (TTHM) 1 to 10 μg/L; tetrachlorethene, <1 to 8 μg/L. These parameters are unstable (nonconservative) and, therefore, could not be modeled. The organic levels that the estuary experimental plant "saw" during the 1981-1983 period were probably higher than those that would be encountered at a full-scale plant, especially one whose intake is located at Chain Bridge, well upstream from the Blue Plains effluent. In the estuarine environment, the concentration of organics would be reduced by chemical, physical, and biological forces of self-purification. This is in sharp contrast to conditions at the EEWTP, where the Blue Plains nitrified effluent, the principal source of these organics, was pumped directly and quickly to the EEWTP blend tank.

Radiological parameters were monitored, but not modeled, to include gross alpha, gross beta, tritium, and strontium-90. Arithmetic mean EEWTP blend-tank concentrations (March 1981-March 1983) were as follows: gross alpha, 0.52 piocurie per liter (pCi/L); gross beta, 6.46 pCi/L. The Blue Plains effluent was the source of about half of the gross alpha activity and about two-thirds of the gross beta activity.

Few data were reported on asbestos and algae concentrations. Table 4 indicates asbestos fiber levels of 4.9 and 36.9 million fibers per liter in the Blue Plains effluent and the Potomac estuary, respectively. Algae numbers in the estuary are also reported in this table, as 1,500 per milliliter (ml).

Quality Variations Among the Three Phases of Operation

Table 5 presents a comparison of geometric means of 10 parameters for the three phases of operation of the EEWTP. These parameters include key quality components, such as turbidity, color, nitrate N, ammonia N, coliforms, TOC, and TOX. While there were differences during the three phases, they were probably not of sufficient magnitude to affect the performance of the EEWTP in the three operational phases. The various phases were of different duration, and operations were conducted during different seasons. The greatest numerical difference was in blended influent coliform numbers between Phases IA (alum coagulation + two-stage chlorination) and IB (alum coagulation + ozonation/ chlorination). This difference probably reflects certain effluent variations at the Blue Plains plant, the source of about 90 percent of the total coliforms in the EEWTP blended influent. Another possible explanation is combined sewer overflows into the estuary, which could contribute to sudden, large excursions in coliform numbers.

After reviewing the section of the Corps report on Selection of Influent Water Quality and its significant findings, the committee believes that

- The conclusion that an influent blend ratio of 1:1 will simulate expected water quality conditions in the Potomac River estuary at Chain Bridge under 1930 drought conditions with projected water supply demands for the year 2030 is essentially correct and is supported by the information presented and the data obtained.
- The conclusion that the 1:1 blend was a conservative simulation of expected water quality conditions is also essentially correct and is supported by the information presented and the data obtained. However, this conclusion assumes no significant industrial discharges in the future.

TABLE 4

SUMMARY OF AVAILABLE MONITORING DATA IN EEWTP SOURCE WATERS FOR PARAMETERS NOT MODELED (AS OF MARCH 1981)

Parameter	Units	Blue Plains Nitrified Effluent	Potomac Estuary
Turbidity[1]	NTU	—	18±14
TSS[2]	mg/L	17±17	—
TOC[3]	mg/L - C	10	7
TOX[4]	μg/L - Cl	250	160
Sum of Purgeable Organic Compounds[5]	μg/L	25 - 32	0.9 - 4.0
Asbestos[6]	MFL	4.9	36.9
Radiological			
Gross Alpha[6]	pCi/L	0±3.8	0.5±4.2
Gross Beta[6]	pCi/L	11.5±30.1	17.8±30.3
Algae[1]	(no./ml)	—	1,500

1. U.S. Army Corps of Engineers Potomac River estuary baseline study, 1975 - 1979.
2. From Blue Plains monitoring data, August 1980 - February 1981 (daily composite samples and influent monitoring).
3. Influent monitoring, December 1980 - February 1981.
4. Average of three samples, February 1981.
5. Range of two samples (13 compounds quantified, 3 detected but below quantification limit of 0.1 μg/L).
6. Single sample, MFL = million fibers per liter

SOURCE: U.S. Army Corps of Engineers (1983). Main Volume.

TABLE 5

COMPARISON OF EEWTP BLENDED INFLUENT WATER QUALITY FOR THREE PHASES OF OPERATION

Parameter	Units	Geometric Mean Concentration		
		Phase IA	Phase IB	Phase IIA
Turbidity	NTU	11.07	15.32	8.72
Color	color units	33.7	44.9	47.3
Sodium	mg/L	29.1	22.5	30.8
Nitrogen, NO_3+NO_2	mg/L-N	6.90	6.66	7.72
Nitrogen, NH_3	mg/L-N	0.13	0.13	0.18
Lead	mg/L	0.0016	0.0021	0.0021
Manganese	mg/L	0.1646	0.2366	0.1104
Total Coliforms	MPN/100 ml	63553	21624	28990
TOC	mg/L-C	4.50	4.63	4.46
TOX	mg/L-Cl	85.0	76.7	115.8

SOURCE: U.S. Army Corps of Engineers (1983), Main Volume.

- An explanation of the reason for the choice of Blue Plains nitrified effluent, rather than filtered-disinfected effluent, as one of the raw water sources for the EEWTP should have been included. As previously indicated, the choice of the nitrified effluent could introduce certain elements of uncertainty into the quality of the experimental plant's raw water source, a 1:1 blend of Blue Plains effluent and Potomac River estuary water.
- The rather difficult and elusive matter of the possible eutrophication of the upper Potomac River estuary by Blue Plains effluent is not addressed in the Corps of Engineers' final report. Admittedly, the projection of the impact of eutrophication on future water quality is exceedingly difficult, but the report should have included a discussion of such impact. If the full-scale estuary plant's intake is located at Chain Bridge and is expected to perform at design rate (200 mgd) under extreme drought conditions, with a flowby of 100 mgd, then there will be a slow movement of Blue Plains effluent up the estuary. This effluent could contain 10 mg/L or more of nitrogen (from nitrite and nitrate) and possibly as much as 0.5 mg/L of phosphorus (as P). This condition would probably occur in the late summer or early fall when the estuary water is clear, its temperature fairly high, and solar radiation plentiful. The combination of fertilization by nitrogen and phosphorus, plus the other factors, produces almost ideal conditions for sudden heavy algal blooms, which could produce estuary water quality problems and consequent serious operating problems at the water treatment plant; e.g., obnoxious taste and odor, increased color, coagulation difficulties, high chlorine demand, obnoxious sludge, short filter runs, and toxicity problems. The situation briefly described is the worst possible one and may occur infrequently. Nevertheless, the committee believes that the Corps report should have included an assessment of the problems that might result from estuary eutrophication.

[It should be noted that during the summer of 1983, a significant problem with blue-green algae took place in the Potomac River. This resulted even though the Washington, D.C., region presently has some of the most stringent effluent standards anywhere in the U.S. The Metropolitan Council of Governments along with the U.S. Environmental Protection Agency were beginning to look into the cause and possible corrective action needed to manage an unexpected severe blue-green algae bloom when this report went to Press.]

EVALUATION OF FINISHED WATER QUALITY

Monitoring Program and Data Analysis

Conclusions by Corps of Engineers

In the Corps of Engineers report on the EEWTP pilot study, no specific findings or recommendations were made about the monitoring program or the data analysis. However it is clear that the way the monitoring was performed (choice of parameters, frequency, technique, methods of analysis) and the way the resulting data were statistically analyzed is vitally important in the final evaluation of the plant's performance. Therefore, the committee has evaluated the monitoring program and data analysis as follows.

NRC Committee Evaluation

The committee found that both the monitoring program and methods of data analysis were well done and well communicated. There was extensive interaction with the NRC committee on the monitoring program both before its inception and during the midcourse corrections. Since some of the justifications for modifications in pilot plant operation were based on the data analysis, it would have been informative for the Corps to state what aspects of this analysis led to these decisions. An appendix on the details of the midcourse data analysis and how it impacted on the modifications suggested would have been helpful.

The choice of a data distribution model for statistical analysis, the procedure for dealing with missing or undetected data, the procedures used for hypothesis testing for comparisons with water quality goals, and with data from other facilities, and the procedures for evaluating data frequency and serial correlation all seem appropriate.

Monitoring Program

A monitoring program was conducted at the EEWTP site and also at other local water treatment sites to gain comparisons of the EEWTP output water with other locally available public water supply. At meetings with the NRC committee well before the establishment of the monitoring program, both the types of data to be collected, the location for collection, and the collection frequency were examined in great depth. Suggestions before the fact were incorporated in the Corps plan that resulted in the first-year monitoring program. More than 200 different individual parameters were monitored during the entire monitoring program. These are listed in Tables 6 and 7. The sample frequency definitions for these parameters are listed in Table 7-A.

After several months of operation, the sampling program was revised based on the monitoring results. Changes were based on sampling logistics, the need for increased sampling at selected sites, and engineering judgment on the cost-benefit of specific analyses. However, no details on the underlying factors that led to these decisions were presented. The major highlights of the revised program were the following:

- Sampling was increased at the Blue Plains and estuary raw water intakes to permit quantification of the source of contaminants to the EEWTP.
- Increased sampling was instituted within the EEWTP process train to permit determination of individual process performance.
- Sampling was increased at the three local water treatment plants such that all plants were monitored with the same frequency and for the same parameters.
- Fecal coliform and taste analyses were discontinued. Endotoxin sampling was reduced to quarterly.
- Additional toxicological tests using the Ames assay were instituted within the EEWTP process sequence.

While these steps seem logical, the Corps report does not explain how the results of this first operational period provided the motivation for the later changes in procedures.

Data Analysis Techniques

In the monitoring program more than 400,000 data points were generated. For each constituent there was a need

TABLE 6

SUMMARY OF WATER QUALITY PARAMETERS IN MONITORING PROGRAM

Physical/Aesthetic

Asbestos
Chlorine residual
Color
Dissolved oxygen
Methylene Blue Active Substances (MBAS)
Odor
Ozone residual
Particle size
pH
Taste
Temperature
Total suspended solids
Turbidity

Major Cations, Anions, and Nutrients

Alkalinity
Bromide
Calcium
Chloride
Cyanide
Electroconductivity
Fluoride
Hardness
Iodide
Magnesium
Nitrate + Nitrite
Nitrogen, Ammonia
Nitrogen, Total Kjehldahl
Phosphate (ortho-)
Potassium
Silica
Sodium
Sulfate
Total dissolved solids

Trace Metals

Aluminum
Antimony
Arsenic
Barium

(Continued)

TABLE 6 (Continued)

SUMMARY OF WATER QUALITY PARAMETERS IN MONITORING PROGRAM

Beryllium
Boron
Cadmium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Manganese
Mercury
Molybdenum
Nickel
Selenium
Silver
Thallium
Tin
Titanium
Vanadium
Zinc

Radiological

Gross alpha
Gross beta
Radium
Strontium-90
Tritium

Trace Organics (by analytical technique)

Acid extraction, GC/MS
Base-neutral extraction, GC/MS
Closed-loop stripping
Purge and Trap, GC/MS
Liquid/liquid extraction (Pentane), GC (Trihalomethanes)
Liquid/liquid extraction (methylene chloride), GC (herbicides/pesticides/PCBs)
Total organic carbon (TOC)
Total organic halide (TOX)

SOURCE: U.S. Army Corps of Engineers (1983), Executive Summary.

TABLE 7
PLANT MONITORING PROGRAM
16 March 1981 to 31 November 1981

	Blue Plains Nitrified Effluent	Potomac River Estuary	Blend-ed Inf.	Recarb-onation Tank Eff.	Dual Media Filtra-tion Eff.	Lead Carbon Column Eff.	Final Carbon Column Eff.	EEWTP Finish. Water	WTP1 Finish. Water	WTP2 Finish. Water	WTP3 Finish Water	Sludge
PHYSICAL/AESTHETIC												
Temperature	H2	H2	H2					H2	DR	DR	DR	
pH	H4	H4	H4	H4			H4	H4	DR	DR	DR	
Dissolved Oxygen	DG	DG	DG	DG	H12	H12	H12	DG				
Particulate Parameters												
Turbidity	H4	H4	H2	H2	H4		H4	H2				
Total Suspended Solids	DC	DC	DC	DC	DC		DC					FG
Asbestos	WC	WC	WC		WC			WC	WC	WC	WC	WC
Color			DC		DC			DC	DC			
MBAS	DC	DC	DC					DC	DC			
Odor								DC	DC			
Taste								DC	DC			
Chlorine Residual (Free & Total)					H4			H4	DR	DR	DR	
INORGANIC												
Major Cations and Trace Metals[1]			DC		DC			DC	DC	DC	DC	FG
Anions												
Total Dissolved Solids	DC	DC	DC					DC	DC			
Electroconductivity			H2									
Alkalinity		DC	DC				DC	DC	DC			
Bromide			DC					DC	DC			
Chloride	DC	DC	DC					DC	DC			
Cyanide	DC	DC	DC					DC	DC			
Fluoride			DC					DC	DC			
Iodide	DC	DC	DC					DC	DC			
Silica	DC	DC	DC					DC	DC			
Sulfate	DC	DC	DC					DC	DC			
Nutrients												
Nitrogen, Ammonia		DC	DC				DC	DC	DC			
Nitrogen, Nitrate/Nitrite			DC				DC	DC	DC			
Nitrogen, Total Kjehldahl			DC									
Phosphorus, Ortho-Phosphate			DC				DC	DC	DC			
Radiological[2]			WC		WC			WC	WC	WC	WC	

(Continued)

TABLE 7 (Continued)
PLANT MONITORING PROGRAM
16 March 1981 to 31 November 1981

	Blue Plains Nitrified Effluent	Potomac River Estuary	Blended Inf.	Recarbonation Tank Eff.	Dual Media Filtration Eff.	Lead Carbon Column Eff.	Final Carbon Column Eff.	EEWTP Finish. Water	WTP1 Finish. Water	WTP2 Finish. Water	WTP3 Finish Water	Sludge
MICROBIOLOGICAL												
Total Coliform	FG	FG					FG	FG	FG	WG	WG	
Fecal Coliform	FG	FG					FG	FG	FG	WG	WG	
Standard Plate Count	FG	FG					FG	FG	FG	WG	WG	
Endotoxin	MG	MG					MG	MG	MG			
Salmonella	MG	MG					MG	MG	MG	MG	MG	
Viruses	MX	MX			MX		MX	MX	MX	MX	MX	
Parasites	MX	MX			MX		MX	MX	MX	MX	MX	
ORGANIC												
Total Organic Carbon												
(Off-site)	DC		DC				DC	DC	DC	DC	DC	
(On-site)			H8	H8	H8	H8	H8	H8				
Total Organic Halide	DC		DC				DC	DC	DC	DC	DC	
Synthetic Organics												
Liquid/Liquid Extraction												
(Off-site)			SC				SC	SC[3]	SC[3]	SC	SC	
(On-site)			SG	SG	SG	SG	SG	SG				
Base/Neutral and Acid Extractions			R3				R3	R3	R3	R3	R3	
Volatile Organics Analysis			RC				RC	RC	RC	RC	RC	
Herbicides			R3				R3	R3	R3	R3	R3	
Pesticides and PCBs			R3				R3	R3	R3	R3	R3	
TOXICOLOGICAL												
Ames								WX	WX	WX	WX	
Mammalian Cell Transformation								MX	MX	MX	MX	

1. Major cations and trace metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, tin, titanium, vanadium and zinc; also hardness at the following sites: Potomac River Estuary, EEWTP Blended Influent, Final Carbon Column Effluent, EEWTP Finished Water and WTP1 Finished Water.
2. Radiological parameters: gross alpha, gross beta, and tritium
Radium is analyzed in all samples for which gross alpha (plus 2-sigma) exceeds 5 pCi/L.
Strontium-90 is analyzed in all samples for which gross beta (plus 2-sigma) exceeds 8 pCi/L.
3. At these sites, weekly grabs were scheduled for seven day terminal THM analysis.

SOURCE: U.S. Army Corps of Engineers (1983), Main Volume.

TABLE 7-A

SAMPLE FREQUENCY DEFINITIONS

Hourly
- H4 Grab every 4 hrs
- H2 Grab every 2 hrs
- H8 Grab every eight hours
- H12 Grab every 12 hrs

Daily
- DC Daily 24 hr Composite (7 samples/week)
- DG Daily Grab (7 samples/week)
- DR Reading/Measurement every 24 hours obtained from off-site

Five Days per Week (Daily except weekends)
- FC Daily 24 hr Composite (5 samples/week)
- FG Daily Grab (5 samples/week)

Alternate Days
- AC Every Other Day 24-hour Composite (4 samples/week)

Semiweekly
- SC Semiweekly 24 hr Composite
- SG Semiweekly Grab

Weekly
- WC Weekly 24 hr Composite
- WG Weekly Grab
- WX Weekly Concentration

Biweekly
- BC Biweekly 24 hr Composite
- BX Biweekly Concentration

Triweekly
- RC Triweekly 24 hr Composite
- R3 Triweekly 72 hr Composite

Monthly
- MC Monthly 24 hr Composite
- MG Monthly Grab
- MX Monthly Concentration

Quarterly
- QG Quarterly grab (one sample every four months)

SOURCE: U.S. Army Corps of Engineers (1983), Main Volume.

for an appropriate distribution model. Also needed were sufficient data for hypothesis testing. In general these procedures were well conceived and applied. There were some problems in the written description, but not in the performance of these tests. On page 5-3-2 in the Corps Main Volume,[8] the example chosen to demonstrate tests of hypothesis regarding differences between two means is inconsistent with the detailed description given in Appendix B (page B-1-17 and B-1-18). The main report deals with a one-tail test, while the appendix deals with a two-tail test. In Volume 1, Appendix B on pages B-1-16 and B-1-17, a section on a comparison of EEWTP results with a set goal begins with a statement of the null hypothesis that the mean is less than the goal. However, in the example given two paragraphs later the null hypothesis is redefined to be where the mean is equal to the goal. The calculations provided as examples, however, indicate that these tests were carried out correctly even though the description was contradictory.

Physical-Aesthetic Parameters

Conclusions by Corps of Engineers

The key physical-aesthetic water quality parameters include turbidity, color, odor, and pH. These parameters are included in either the primary or secondary drinking water regulations.

1. The three treatment process combinations monitored (Phases IA, IB and IIA) produced a finished water quality that rarely exceeded the Maximum Contaminant Levels (MCLs) for turbidity, and color, but frequently exceeded the MCL for odor. Although levels of pH were lower than the standard of pH 6.5 during the first few months of Phase IA operation adjustments in plant operation maintained finished water pH between the desired limits of 6.5 to 8.5.

2. Geometric mean values of turbidity in the finished waters during all phases of operation were less than the highest geometric mean turbidity value in one of the local water *treatment plants, as demonstrated by appropriate statistical comparisons.**

3. Odor levels during Phase IA operation exceeded the secondary MCL threshold odor number of 3 TON in more than 95 percent of the samples. However, the odor testing panel was judged to be especially sensitive, and comparison with other panel results or standards is not valid. Thus, for this parameter, comparison of EEWTP values with values from the local WTPs was selected as the best basis for judging acceptability of the finished water quality with respect to odor. Such comparisons indicated that EEWTP odor levels were generally comparable to levels observed in local water treatment plants, although the geometric the mean value exceeded the highest geometric mean odor level in one local plant during this phase of operation.

4. The Phase IIA process reduced the odor levels considerably, with the geometric mean value during this phase of operation being significantly less than the highest value observed in a local plant. More than eighty percent of the odor samples during this phase had levels lower than the levels observed in one local plant.

**Hypothesis testing was used to determine if the geometric mean values of water quality parameters in the EEWTP finished waters were significantly different compared to geometric mean values of the same parameters observed in the monitored local water treatment plants. The difference was considered to be statistically significant based on a five percent level of significance using the standard Student's t-test. This meant that there was a five percent chance that a false conclusion may have been inferred from the results of the hypothesis testing.*

NRC Committee Evaluation

In reviewing the conclusions of any pilot study, one must review the assumptions and the objectives of the project. In the case of the EEWTP project, the objective was to review the technical feasibility of using the Potomac River estuary as a supplemental raw water supply source for the metropolitan Washington area to meet potential water shortages that might occur during severe drought.

The assumption made for the study was that at the time of severe drought, the quality of the Potomac River estuary at Chain Bridge would be an equivalent blend of Blue Plains nitrified effluent and Potomac River water. Through use of the Dynamic Estuary Model (DEM), a 1:1 blend was anticipated to be a conservative simulation of expected water quality.

Turbidity, color, odor, and, to a lesser degree, pH are important aesthetic water quality parameters because they can be readily noted by the consuming public. The committee found the conclusions reached in the Corps report supported by the information presented. The data for Phase IIA cover only 28 weeks, but the committee is of the opinion that the use of granular activated carbon (GAC) with a 30-minute empty-bed contact time followed by ozonation and chlorine disinfection would have yielded the same conclusions if the plant had been operated for one full year. The water supply industry has satisfactorily treated surface waters for which physical-aesthetic parameters were of lesser quality than the 1:1 blend. The possibility of odor problems resulting from algal blooms on the Potomac estuary were not evaluated as a part of the Corps study (see section above on Selection of Influent Water Quality).

The quality of the Blue Plains effluent and the Potomac River water are not the same as found in many other river basins, so care must be taken when applying these conclusions to other locations.

Major Cations, Anions, and Nutrients

Conclusions by Corps of Engineers

This parameter group includes eighteen inorganic parameters, three of which are included in the primary drinking water regulations (nitrate, sodium, and fluoride), and three of which are included in the secondary regulations (chloride, sulfate, total dissolved solids). Cyanide is also included in *this group, as it is currently being considered for inclusion in the regulations because of potential adverse health effects.*

1. In general, the finished water quality from the EEWTP during all phases of operation exhibited higher levels than the local plants for the parameters included in this group, a consequence of increased levels of dissolved salts in the treated wastewater portion of the blended influent, and the inability of the process combinations tested to remove these dissolved salts.

2. The levels of nitrate in three percent of the EEWTP finished water samples exceeded the primary MCL of 10 mg/L-N, during Phase IA. In all cases, this occurred when the blended influent consisted of nitrified effluent only.

3. Nitrate levels in the EEWTP finished waters were significantly higher than values observed in the local water treatment plants. The 90th percentile values of nitrate observed during the three phases of operation reached 9 mg/L-N, compared to the primary MCL of 10 mg/L-N. The 90th percentile values observed also match the maximum projected value of nitrate expected in the estuary during drought conditions. Because the high nitrate levels would provide almost no safety factor for this parameter compared to the MCL, the levels of nitrate represent a potential health issue should an estuary plant be constructed.

4. In addition to nitrate, the arithmetic mean values of those parameters of health or aesthetic significance in this parameter group were significantly greater than the highest arithmetic mean value observed in the local water treatment plants. These parameters include total dissolved solids, sulfate, chloride and sodium. Cyanide levels in the EEWTP were low (<0.003 mg/L) and not significantly different from the local water treatment plants. The levels of sodium exceeded the suggested EPA optimum level of 20 mg/L, but the observed levels were similar to median values observed in water systems in the U.S. None of the observed levels of these *parameters are expected to pose significant adverse health risks to consumers, however.*

NRC Committee Evaluation

Generally speaking, one would anticipate higher levels of cations, anions, and nutrients in the EEWTP effluent than found in the three metropolitan Washington area (MWA) plants, based upon the treatment processes and the influent quality to the EEWTP. However, many potable water supplies exceed the total dissolved solids (TDS) found in the EEWTP effluent. Most of the time the blended EEWTP effluent contained between 200 and 300 mg/L TDS and seldom exceeded the secondary maximum contaminant levels (SMCL) of 500 mg/L. TDS levels found in the EEWTP effluent would not present a health concern in a future raw water supply.

Considering the concern over occasionally high nitrate and nitrogen levels in the EEWTP effluent, nitrogen in the form of nitrate can be removed to acceptable values of nitrate by several cost-effective treatment processes. Nitrate nitrogen should not be a limiting MCL or a "potential health issue" if proper treatment is provided.

Higher levels of sodium appeared to occur during the winter months. This would lead one to believe that the sodium was originating from street-salting programs and could possibly be reduced if it were really a health issue. It should be pointed out that our average daily intake of sodium exceeds 2,000 mg/day. It is difficult to relate to short-term exposures of 10 to 15 mg/L, i.e., 30 to 40 mg/day additional sodium, as being a serious or even a significant health issue, for any future supply.

The committee feels that the conclusions are supportable and that the concerns outlined here may be overstated as they relate to the major cations, anions, and nutrients. For the Potomac estuary under the conditions contemplated and for the time period tested, the conclusions are proper.

Trace Metals

Conclusions by Corps of Engineers

Twenty-four individual metals were included in this parameter group, eight of which are included in the primary drinking water regulations (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) and four in the secondary regulations (copper, iron, manganese, and zinc.)

1. For those metals of health or aesthetic significance, the geometric mean values in the EEWTP finished waters during one or more of the operational phases exceeded the highest geometric mean value observed in the local plants only for the following metals: mercury, manganese, nickel, and zinc. The observed arithmetic and geometric mean values for mercury were below the MCL, however, and not considered to pose increased health risks. The geometric mean mercury levels during Phase IIA operation were reduced below the highest geometric mean observed in one local water treatment plant.

2. With the exception of mercury and manganese, concentrations of metals in the EEWTP finished waters never exceeded the specified maximum contaminant levels. Only during Phase IA of operation did the mercury levels exceed the MCL (three samples or about one percent of the total samples taken). The 90th percentile value for mercury was 0.0007 mg/L, less than one-half of the MCL of 0.002 mg/L.

3. During Phase IA operation, the secondary MCL for manganese was exceeded in 34 percent of the samples. Oxidant addition (permanganate in Phase IA and ozone in Phase IB) combined with adjustments to pH were successful in reducing manganese to levels consistently below the MCL.

NRC Committee Evaluation

The comparison made and conclusions derived for the 24 trace metals found in the EEWTP and the local metropolitan water plants are valid. For these materials the levels found in the effluent from the EEWTP might also be compared to levels of trace metals found in potable waters throughout the United States. This information has been summarized in Chapter 5 of Drinking Water and Health,[10] published by the National Research Council.

Concentrations of lead exceeded the MCL of 0.05 mg/L only once in the blended influent. While many of the values that have been reported for lead nationally are for water taken from distribution systems and tend to be a little higher than for plant effluents, the mean value of lead found in sampling 1,577 raw water supplies was 0.023 mg/L. Therefore, EEWTP effluent water is comparable.

Manganese levels found in the survey of 1,577 raw waters[10] varied from a minimum of 0.0003 mg/L, a maximum 323 mg/L, and a mean of 0.058 g/L. The mean value of manganese found in 380 finished waters was 0.026 g/L. Influent manganese levels for the EEWTP did exceed the SMCL of 0.05 mg/L most of the time, but could be reduced to acceptable levels by proper treatment. High concentrations of manganese are only of concern because of undesirable taste and discoloration. With respect to human health, the NRC report states that "the potential for harm from manganese at 0.05 mg/L is virtually nonexistent."[10] Therefore, high manganese concentrations need not be a major concern with use of Potomac estuary water.

It would be of interest to know whether the mercury found in the EEWTP effluent was methylmercury or inorganic mercury. Methylmercury is the form that has major health significance to man. The values found for mercury exceeded the MCL of 0.002 mg/L only three times in two years, and should present little health concern with either short- or long-term exposure. The Corps' conclusion is supportable on the basis of the information supplied. The committee would have preferred that the study address the source of the mercury and analytically differentiate if the mercury found was organic mercury or inorganic mercury.

Nickel is not included in the National Interim Primary Drinking Water Regulations (NIPDWR) or in the National

Secondary Drinking Water Regulations (NSDWR). A recent study completed by the National Academy of Sciences[11] on the medical and biological effects of nickel supports the recommendation of the U.S. Environmental Protection Agency that no standard be set for nickel in drinking water. It was interesting to note that increased values were noted in summer and autumn. This could possibly be correlated to lower river flows. These conclusions are supportable by the information supplied.

The arithmetic mean level of selenium from the blend tank from March 1981 to March 1983 was 0.0010 mg/L well below the 0.01 mg/L MCL. The time series plots of selenium in September 1981 and June 1982 suggest an industrial discharge. It would be interesting to correlate the values found to historic water quality values in the estuary and the river basin.

Source Contributions of Trace Metals, Table 8, indicates that the trace metals present were not originating in a single-source water. For a raw water source and from the standpoint of trace metals, the two sources were good. Metals present in Potomac estuary water need not be of concern if used as a drinking water source.

Radiological Parameters

Conclusions by Corps of Engineers

The monitored radiological parameters included gross alpha, gross beta, tritium and strontium-90, all of which are included in the NIPDWR.

1. Levels of these parameters in the finished waters from the EEWTP never exceeded the MCLs.

2. Gross beta radionuclides in the EEWTP finished waters were greater than the levels observed in the local water treatment plants during all of the EEWTP operational phases. Levels of strontium-90 and tritium were well below the MCLs and were not at levels expected to cause any measurable increase in adverse health risks.

TABLE 8

SOURCE CONTRIBUTIONS OF TRACE METALS

Parameter	Arithmetic Mean Blend Tank (mg/L)	Source Contribution (Percent) Blue Plains WWTP	Potomac Estuary
Aluminum	0.469	18	82
Antimony	0.0006	50	50
Arsenic	0.0012	35	65
Barium	0.033	32	68
Beryllium	ND[2]	NA[3]	NA[3]
Boron	0.0513	77	23
Cadmium[1]	0.0002	30	70
Chromium[1]	0.0067	65	35
Cobalt[1]	0.0052	73	27
Copper[1]	0.0089	65	35
Iron	1.370	56	44
Lead	0.0030	12	88
Lithium[1]	0.0059	62	38
Manganese	0.1971	63	37
Mercury	0.00048	62	38
Molybdenum	0.001	44	56
Nickel	0.0049	54	46
Selenium	0.0010	43	57
Silver	0.0006	78	22
Thallium	0.0005	NA[3]	NA[3]
Titanium	0.012	75	25
Vanadium	0.0048	66	34
Zinc	0.0256	63	37

1. Caiculated using data as measured by AAS.
2. ND = Not detected in blended influent.
3. NA = Not Applicable, values ND in source waters.

SOURCE: U.S. Army Corps of Engineers (1983), Main Volume.

NRC Committee Evaluation

The values for gross alpha, gross beta, and strontium-90 did not exceed the NIPDWR values at any time. While gross alpha levels did not exceed the criterion for radium, it would have been interesting to know the radium values at peak periods of radioactivity. However, the radiological parameters appear within recommended limits and do not present an undue health concern. The conclusions reached are supportable. However, there remains the question of what removal efficiency and effluent quality can be obtained if at some time high concentrations of radioactivity were to occur in the plant influent.

Microbiological Parameters

Conclusions by Corps of Engineers

This parameter group consisted of seven parameters; viruses, parasites, Salmonella bacteria, endotoxin, standard plate count, fecal and total coliforms. Only total coliforms are included in the primary drinking water regulations. These parameters have known or potential acute health effects when present in drinking water.

1. Although detected in the blended influent, no viruses, parasites or Salmonella bacteria were detected in the finished waters produced by the EEWTP.

2. Standard plate count levels were generally low in the EEWTP finished waters (median value less than 1 colony/ml), during all phases of operation. Levels were significantly lower than the highest geometric mean values observed in two of the three local water plants, and well below the National Research Council recommended level of less than 100 colonies/ml for treated waters obtained from heavily contaminated sources.

3. During Phase IA operation, fecal and total coliform levels in the EEWTP finished waters exceeded the levels observed in the local water treatment plants. Although total *coliform levels never exceeded the primary MCL of 1 MPN/100 ml, positive coliform counts were observed in over seventy percent of the samples. The high volume coliform technique used permitted detection of coliforms to a level of 0.02 MPN/100 ml. These results were due primarily to the presence of high ammonia concentrations and insufficient levels of free chlorine during the first four months of the Phase IA operation. Improved process performance after the first four months of operation reduced the coliform levels below 0.1 MPN/100 ml in ninety percent of the samples.*

4. The Phase IIA process reduced the EEWTP fecal and total coliform levels below that observed during Phase IA. The percent positive samples were only slightly above that observed in the local water treatment plants. Over ninety percent of the samples were less than the detection limit of 0.02 MPN/100 ml.

NRC Committee Evaluation

The conclusion that the EEWTP produced hazard-free water acceptable for human consumption was based upon demonstration of finished waters with microbiological parameters considered to be of acceptable levels. Process Phases IA and IIA were considered capable of providing acceptable modes of treatment if careful control of final disinfection was maintained.

The validity of the conclusions depends upon whether the microbiologic parameters determined represent a valid assessment of acceptable finished waters. The report accepts the parameters as reasonable criteria of water quality and, with one exception, offers data to substantiate the conclusions presented. The exception is endotoxin, for which insufficient information was presented to support a conclusion. The remaining microbiologic parameters purportedly show grossly polluted waters to have been treated effectively, with production of finished waters with a health-hazard risk presumed to be low or negligible.

It must be emphasized that the degree of freedom from a health hazard can only be presumed to be low. The acceptability of using bacterial indices per se to evaluate water quality has been questioned where protozoa and virus pathogens are concerned. Quantification of reduction of bacterial indices as an indication of the degree of removal of these pathogens continues to be the subject of debate. The analytic methods described for detection of protozoan parasites are of sufficient sensitivity and reliability to justify acceptance of the results of direct tests as evidence of their absence in finished waters. The analytical methods described for viruses are less satisfactory. The methods used represent state of the art, but their sensitivity and reliability for detection of even the routinely cultivable enteric viruses are subject to variation, and pathogens such as hepatitis A and gastroenteritis viruses were not looked for (because of lack of satisfactory routine procedures).

Failure to detect viruses in EEWTP finished waters, therefore, is neither an acceptable direct measurement of virus pathogen absence nor confirmation of their bacterially indicated absence. Detection of viruses in influent water and failure of detection in finished water show that a reduction in numbers of at least some detectable viruses occurred. A presumed reduction equivalent to that obtained for coliform reduction cannot be accepted per se because differential removal of bacteria and viruses during treatment procedures occurs, and a differing sensitivity to disinfectant inactivation is known to result in a differing survival capability.

The superiority of the Phase IIA process over the Phase IA process is supported by data showing a greater reduction of fecal and total coliform levels by the former. Careful control of final disinfection necessary with Phase IA processes places undue dependence upon disinfection to provide health-hazard-free water and ignores the importance of earlier coagulation, sedimentation, and filtration procedures.

Although the health-hazard risk is estimated to be low, the degree of freedom from virus-associated health hazards cannot be stated accurately.

Organic Parameters

Conclusions by Corps of Engineers

Of the 151 primary (targeted) compounds specifically monitored in this parameter group, only seven compounds (four pesticides, two herbicides and total trihalomethanes) are included in the primary drinking water regulations. Another six volatile organic chemicals are currently under consideration for inclusion in the regulations. Organic parameters monitored during this project include three categories; surrogate parameters (total organic carbon (TOC) and total organic halides (TOX)); primary or targeted organic compounds (compounds targeted for analysis using standards for confirmed identification and quantification), and secondary or non-targeted compounds (tentative identification, approximate quantification). The latter category included an additional 300 organic compounds detected in influent waters and the finished waters.

1. The MCLs for pesticides and herbicides were never exceeded in any of the finished waters. The regulated pesticides and herbicides were not detected in the EEWTP finished waters.

2. Total trihalomethanes (TTHM) in the EEWTP finished waters never exceeded the values observed in the local water treatment plants, with geometric and arithmetic mean values significantly less than at all three local water treatment plants.

3. For all other targeted organic compounds, only thirteen compounds were quantified frequently enough to permit quantitative estimates of sample population statistics. With the exception of the trihalomethanes, the estimated geometric means of the other quantified compounds were less than 1 μg/L (one part per billion).

4. The observed levels of all but three monitored organic compounds in the EEWTP finished waters were lower than values observed in the finished waters from the local water treatment plants.

5. For those synthetic organic chemicals (SOCs) for which an EEWTP finished water had higher estimated geometric mean concentrations (PCE, napthalene, and 1,3/1,4-Xylene), the

EEWTP values were 0.05 μg/L or less. The chronic health risks associated with these levels can be assumed to be negligible. For example, the 10^{-6} risk level for PCE is 4.5 μg/L, approximately 100 times greater than the estimated geometric mean in EEWTP finished waters.

6. The numbers of targeted and non-targeted (secondary) organic compounds detected at least once in the finished waters were observed to be lower in the EEWTP finished waters than in the local water treatment plants.

7. Total organic halide, a measure of the total quantity of halogenated organic compounds in the finished waters, was lower in the EEWTP finished waters than in the local finished waters by a factor of three to ten. Lowest values were observed during the Phase IIA process, due to the elimination of free chlorine from the process.

8. Based on observed concentration levels of the targeted compounds and other tentatively identified SOCs in the finished waters from the EEWTP, it is concluded that the water quality produced by all three process combinations would be of equal or better quality than that of the local plants for compounds which could be detected and identified by the techniques used on this project.

9. Because only a small fraction of the organic compounds included in the total organic carbon and total organic halide measurements can be detected by currently available analytical techniques, it is not currently possible to evaluate the absolute risks associated with ingestion of the finished waters produced by the EEWTP, or by other water treatment plants.

NRC Committee Evaluation

A reasonably extensive effort was made in the two-year monitoring program to evaluate the presence of organic contaminants in the blended influent and effluent of the EEWTP. Analytical and monitoring programs were designed to evaluate the effectiveness of the treatment options to compare the measured organic water quality of the EEWTP effluent with the effluents of three water treatment plants in the metropolitan Washington area.

However, the results of even good aquatic organic monitoring programs can be overinterpreted. The analytical methodology applicable to trace organic analysis of complex aquatic samples is currently in a rapid state of development. Many methods that might be called state of the art have been verified* (proven to detect a known deliberately induced compound) but not validated (proven to produce measurements of concentration at consistently reasonable levels of accuracy between laboratories). Progress is slow for known reasons; i.e., there are a vast number of organic compounds in water and waste samples, usually in extremely dilute concentration; no single method isolates all compounds and not all detection devices are compound-specific. In comprehensive assessments of the kind undertaken in the EEWTP study it is necessary, therefore, to use many procedures, each of which must be verified for compounds of interest. It is also helpful to use validated methods that other workers are using where possible, although additional methods must sometimes be developed to analyze compounds unique to the study in question. The sum of all identified organic species must also be related to the values obtained for total surrogate parameters (TOC, TOX). Given the complexity of even state-of-the-art methodology, it is important that scientific conclusions regarding organic water quality do not go beyond those actually supported by verified measurements.

The EEWTP organic monitoring program resulted in two years of data on total organic product surrogates (TOC and TOX), and 151 synthetic organic compounds (SOC) using several different isolation/ identification techniques based upon priority pollutant analytical protocols (EPA Methods 624, 625, and 608). Other EPA methods were employed for special categories (TOC, trihalomethanes, and trihalomethane formation potential), and several additional specialized methods were applied (polynuclear aromatic hydrocarbons, herbicides, dihaloacetonitriles, and other polar

*No consistent definition of the terms verification and validation is in popular use. The definition above applies only to the usage herein.

organics). All methods were verified for compounds targeted, and appropriate quality assurance programs were conducted. Sampling frequency for the second year was appropriately adjusted based upon the results of the first-year monitoring results.

In general, the method selection reflects an awareness of the analytical complexities referred to above, and the program collectively constitutes a thoughtful approach to a comprehensive organic parameter survey of this kind. Extra effort was made during the Corps study to identify organic components appearing on the chromatograms that were not due to targeted compounds. This effort consisted primarily of tentative identifications at the contractor's off-site lab (low-resolution quadrupole), although some tentative identifications were strengthened with accurate mass measurements using different mass spectrometers at other experienced laboratories (Harvey Labs and University of North Carolina [UNC] at Chapel Hill). Tentative identification of more than 300 additional compounds (100 in finished water sites) resulted from this effort. Finally, a few samples of carbon from the GAC treatment unit were sent to the UNC laboratory for analysis of adsorbed compounds, which resulted in identification of 26 compounds, 10 of which had not been identified by the other procedures.

One weakness in this otherwise enlightened approach is that only the original 151 targeted compounds were quantified. Although the sampling frequency was modified (second year) on the basis of initial results, the verification and quantification of at least some of the more than 300 additional compounds tentatively identified was not pursued. It constitutes an important weakness in the data since only 13 (4 THMs and 9 SOCs) of the 151 targeted compounds were found more than 15 percent of the time (frequency required to calculate a geometric mean), whereas 27 of the additional compounds were detected at least this frequently.

Although the conclusion that only 9 of the SOCs were detectable more than 15 percent of the time is supported by the two-year data base, this outcome was not unexpected. In its recommendation to the Corps of Engineers in November 1981 (See Appendix A), the NRC Review Committee and its Panel on Quality Criteria for Reuse stated:

> The panel's concern is that most of the organic composition will probably not be priority pollutants, but may be other chromatographable organic constituents appearing on the reconstructed gas chromatograms (RGC) of the priority pollutant fractions. . . .
>
> In addition, the fractions of purgeable and nonpurgeable organic chemicals identified and quantified by the GC and GC-MS analyses should be estimated. A useful approach would be to compare the purgeable and nonpurgeable organic carbon measured in the unconcentrated samples to the values calculated from the summation of individually quantified organics in the concentrated volatile and nonvolatile fractions, respectively.

Although the Corps final report makes no reference to these recommendations, it is obvious that the study design was affected by them. The extra effort put into nontargeted qualitative identifications, and the limited use of outside laboratories are both consistent with these recommendations. No effort was made, however, to estimate the fraction of total organic matter (TOC or TOX) that was accounted for by quantified measurements, although the final conclusion in the Organic Parameters section of the Main Volume states that this fraction is small.*

These omissions, i.e., the failure to iterate the quantitative monitoring program on the basis of initial results, and the lack of emphasis given to total carbon accounting make the data less useful than they might have been in terms of the principal purposes of the study, one of which was to determine whether the EEWTP finished water was of acceptable quality for human consumption. It must be pointed out that the likelihood of identifying even a significant fraction of the TOC

*Indeed, it is small. The geometric mean value for Phase IIA finished water TOC is 670 g C/L to which the largest measured contributors were the four THMs at 1.0 g/L (total). Assuming 7 volatile organic compounds (VOCs), 9 targeted SOCs and 19 other SOCs present over 15 percent of the time average 0.1 g/L (high according to reported values) and all molecules contain 50 percent C, the TOC accounted for is approximately 0.3 percent. A similar estimate for TOX accounted for could be made.

(or TOX) was recognized as slight from the outset of the study, and this was a principal reason that the comparative strategy (other water treatment plants) was adopted and extensive toxicological testing was recommended (see committee letter report of November 1981, Appendix A).

The report's conclusions regarding compound identification, concentration levels, treatment effects at the EEWTP, and all of the data-based comparisons with the three area water treatment plants (WTP) are probably valid and are supported by the two-year organic parameter monitoring data. Furthermore, this data base will be a useful addition to the scientific literature on this subject. The inherent weaknesses in the data, however, are that most of the organic content was not identified and that most of those compounds that were identified were not validated and quantified. This condition does not permit adequate judgments to be made about the degree of safety for human consumption.

The facts that EEWTP effluent (especially Phase II) contained lower total organic parameter values and generally fewer identified components than the comparison water treatment plants' do not of themselves support the speculation that these waters are of equivalent risk. There are no scientific data to show that the unidentified materials (the vast majority) are the same. The latter assumption must be made to support the conclusions offered in the Corps report.

The conclusions listed under "Organic Parameters" in the Corps' Executive Summary[6] appear focused on existing MCLs and the relationship of measured EEWTP organic characteristics to those of the comparison water treatment plants. These are fine as simple observations, but there is the definite implication that the finished water from the EEWTP is just as safe as or safer for human consumption than is water from the comparison WTPs.

The limitations are alluded to in the Corps' conclusions concerning organic parameters but not reflected significantly in the tone and order of the other statements.

Principal conclusions scientifically supportable by the data include the following. First, the two-year organic parameter data base resulted in identification of only a small fraction of the total organic carbon known to be present for either the EEWTP or the comparison WTP finished waters. Secondly, in terms of compounds that were identified and quantified, the EEWTP effluent was of comparable or superior quality to the comparison water treatment plants. Third, since only a small fraction (less than 1 percent) of the organic carbon present in the EEWTP and the comparison plants' finished waters could be measured, it is not possible with these data alone to evaluate the absolute risks associated with human ingestion of any of these finished waters. Fourth, with current technology it is most difficult to measure the majority of components, and indeed if one could, their health significance would still be unknown. It is thus necessary to make use of other techniques for evaluating health risks such as toxicological evaluations in whole animal systems.[5]

Toxicological Parameters

Conclusions by Corps of Engineers

The two in vitro toxicological parameters monitored in the EEWTP were the Ames Salmonella microsome test and a mammalian cell transformation test using a special mouse cell line (C3H/10T1/2). These tests represent two of the tests recommended by the National Research Council (NRC) Committee on Water Quality Criteria for Reuse, for determination of the relative acceptability of a drinking water for human consumption, regardless of the source water quality. Neither of these parameters is currently regulated. In addition, the absolute values of the test results cannot currently be used to estimate potential health risks. Finally, it is difficult to compare results observed on this project with values reported in other finished drinking waters because of non-standardized sampling and analytical protocols. Thus, results can only be discussed based on comparisons between sampling sites specific to this project.

1. Positive Ames assay results, as measured by either the specific activity or the mutagenic ratio (two measures of mutagenic activity), were observed in the finished waters *from both the EEWTP and the local water treatment plants. The number of positive assays in both Salmonella tester strains (TA 98 and TA 100) was lower in all of the EEWTP finished waters than in the local water plants. This was based on more than twenty-five assays conducted during the Phase IA process and more than twenty assays during the Phase IIA process.*

2. Although positive assay results were observed in the EEWTP finished waters, the health implications of these results are unknown. However, because the frequency of positive mutagenic assays was lower in the treatment plants, it is concluded that EEWTP finished waters would not increase potential chronic health risks identified by the Ames assay. With respect to this toxicological parameter, the EEWTP finished waters are judged acceptable for human consumption.

3. Median values for the specific activities (revertants/L) in the EEWTP finished water during all phases of operation were slightly lower than values observed in the local plants for both Salmonella tester strains. These results again indicate the relative acceptability of the finished waters for human consumption.

4. Of the 23 to 25 mammalian cell transformation assays completed at each finished water site, three samples in the EEWTP finished waters and one to three samples in each of the local water plants (a total of six positives in the local plants) were positive for transformation activity. Where positive samples were observed, the number of plates with transformed cells was low, and generally similar to results observed in the local water treatment plants.

5. Based on the comparative results of the mammalian assays, it is concluded that the EEWTP finished waters did not indicate any increase in potential chronic health effects which may be detected by transformation assays compared to the three local water treatment plants.

NRC Committee Evaluation

The two in vitro tests conducted by the Corps, the Ames salmonella reversion assay using strains TA 98 and TA 100 and an in vitro cell transformation assay using the C3H/10T1/2 mouse cell line, appear to have been well conducted, considering the nature of the test material examined and conditions surrounding the preparation and delivery of test samples. It must be noted that acetone eluates from XAD resins (a Rohm and Haas product) were stored for periods up to two weeks and that such eluates were too toxic to be applied directly to test systems. This condition necessitated dilution of such eluates with dimethyl sulfoxide (DMSO) that resulted in test concentrations representing 4.0 to 8.0 liters of water per test plate. It must also be noted that tests conducted during the course of this project indicated that the XAD columns used adsorbed 15 to 30 percent of the column influent total organic carbon and 10 to 54 percent of the total organic halide.

The two test systems employed were a portion of the test systems recommended by the NRC Panel on Quality Criteria for Water Reuse for a Phase I evaluation of water concentrates (Letter Report to Corps of Engineers, November 1981, see Appendix A). Phase I tests identified by the committee that were not performed due to time and money constraints included:

1. mammalian cell gene mutation assay
2. acute toxicity
3. teratogenicity evaluation
4. short-term repeated dose study in rodents--14 days (includes in vivo cytogenetic assay)

The elimination of the whole-animal tests severely restricts the evaluation of EEWTP finished water potability. Although the Ames assay results indicated that, on a comparative basis, EEWTP water quality was equivalent to or better than the three local water treatment plant products examined, this is not sufficient evidence on which to judge EEWTP water acceptable for human consumption. It is not possible from the analysis performed to ascertain whether positive results from the EEWTP concentrates were due to the same or different compounds that gave positive results in the three water treatment plant concentrates. These results do indicate that mutagenic substances can occur over time in both EEWTP or the other WTP finished waters. Indeed they occur in water supplies throughout the country. The possible human health hazards associated with this activity at the concentrations experienced by human beings remain to be assessed by more extensive toxicological evaluations of such water concentrates. Evaluating mixtures of substances in water concentrates by more extensive animal testing has considerable merit due to a number of factors, including these: (1) It is the condition of exposure for human beings, and (2) It is almost impossible considering time and resource factors, to identify every chemical component and perform extensive toxicological evaluations on each. However, it must be recognized that such testing has limitations due to the loss of organic carbon in the concentration processes used and problems in interpreting results from mixtures.

The data from in vitro transformation studies also indicated that EEWTP water was comparable in quality to WTP water. However, the extent of such testing was not adequate for forming firm conclusions. These data do indicate that substances producing cell transformation occur in both EEWTP and WTP finished waters. Evaluation of possible health hazards would also be contingent on factors previously mentioned.

The concept of toxicological assessment of mixtures of chemicals in water supplies is a relatively new development in evaluating the potability of water. It is regrettable that the Corps was unable, due to constraints identified in the report, to conduct more of the NRC committee recommendations for toxicological testing of water concentrates. If the remainder of the tests suggested for even a Phase I assessment had been conducted, a better appreciation of potential health effects would have been possible. It is only through such an appreciation that a more critical reappraisal of the adequacy of current drinking water standards can be achieved.

PROCESS PERFORMANCE

Conclusions by Corps of Engineers

During the two-year operation of the EEWTP, three treatment process combinations were evaluated as to their technical feasibility for producing a water *acceptable for human consumption. Each process combination was monitored extensively to determine the capabilities of individual processes for controlling water quality parameters with known or suspected health effects. The process combinations have been summarized in Table E.3-1.*

Phase IA

1. The finished water from the Phase IA process combination exhibited three water quality problems, compared to the finished water quality in the local water treatment plants; high odor levels, high manganese levels, and high and fecal total coliform levels.

2. The process combination tested during Phase IA was demonstrated to be a technically feasible combination for producing a finished water with acceptable quality, provided that appropriate levels of process chemicals are added to maintain target pH levels following sedimentation and target free chlorine residual levels following final disinfection.

3. To reduce total coliforms to acceptable levels, a free chlorine residual greater than 2.5 mg/L following sixty minute contact with a pH of 7.4 to 7.7 was required.

4. To control soluble manganese levels below the secondary MCL of 0.05 mg/L, control of pH between 7.5 and 8 combined with an oxidant (potassium permanganate) added ahead to coagulation was required.

5. High odor levels in Phase IA were reduced by maintaining the finished water pH above 7, and the final free chlorine residual above 2.5 mg/L.

6. During the winter months (December through March), ammonia levels in the EEWTP influent reached values of 1 to 2 mg/L-N, due primarily to disruption in the nitrification facilities at Blue Plains. Breakpoint chlorination prior to gravity filtration was required to permit free chlorine disinfection following GAC adsorption. Fluctuations in ammonia levels during these months and the required high chlorine doses caused several water quality problems including low pH values, the need for increased amounts of NaOH, an increase in potential corrosivity of the finished water, several high odor *samples in the finished water (TON > 50), and high levels of TOX in the GAC influent, leading to more rapid exhaustion of the GAC for TOX removal.*

7. The Phase IA process combination exhibited satisfactory process reliability in meeting all the MCLs in the primary drinking water regulations. The 90th percentile values for all parameters included in the regulations were generally a factor of two or more lower than the MCL with the exception of nitrate.

8. The Phase IA process combination exhibited lower process reliability compared to Phases IB and IIA in meeting the secondary MCLs for odor and manganese. Both of these water quality problems can be controlled by appropriate process operating strategies, however.

Phase IB

1. In the second process combination tested, Phase IB, improved process reliability was obtained for control of manganese by the addition of ozone ahead of the gravity filters. Maintenance of the target free chlorine residual (> 2.5 mg/L with a pH of 7.5) also significantly improved the process reliability for reduction of total coliforms.

2. The process combination tested during Phase IB was demonstrated to be a technically feasible process when treating an influent water of the quality observed. Under conditions of high influent ammonia levels, however, this process combination would likely experience difficult process control problems in achieving breakpoint chlorination. It is likely that under these conditions, finished water quality might exhibit unacceptable levels of total coliforms in the finished water. Thus, this process was not considered to be sufficiently reliable for producing a water quality acceptable for human consumption under influent water quality conditions similar to that observed during the full year of monitoring.

Phase IIA

1. The Phase IIA combination was demonstrated to be a technically feasible process for producing a *finished water with acceptable quality, under all observed influent water quality conditions, and all operating conditions tested.*

2. Process reliability for Phase IIA was superior to that demonstrated for Phases IA and IB with respect to total coliforms and manganese. Odor levels in Phase IIA were also lower than observed in the alum processes, but levels still exceeded the secondary MCL threshold odor number of 3 TON. The high odor levels were attributed to the conditions of the analytical test, especially with respect to the sensitivity of the odor panel as discussed. The geometric mean odor levels in the finished water from Phase IIA were lower than the highest geometric mean levels in the local water treatment plants.

NRC Committee Evaluation

The conclusions are based on thorough testing of the processes and are supportable based on the data obtained. The findings give an excellent basis for selecting the sequence of processes most likely to produce the best quality of water in nearly every respect.

The problems of using the breakpoint chlorination process to control ammonia were clearly established in Phase IA when unexpectedly high ammonia concentrations were found in the sewage treatment plant effluent. For example, a much higher concentration of total organic halide (TOX) was observed in the product water. The chemical composition and health effects of this material are poorly defined, and because of this its concentration should be minimized as much as possible. The mutagenicity and toxicity testing that was included in this study was not sufficient to fully establish either safe or hazardous levels of TOX.

Unfortunately, the high ammonia concentrations in the influent did not recur after Phase IA, so one can only speculate about how the processes used in Phase IB and IIA would respond. The authors of the Corps report discuss possible difficulty in achieving suitable bacteriological quality if high concentrations were experienced for the processes used in Phase IB; but in addition, in Phase IIA, possible adverse effects include extensive biological growth on the dual media and GAC filters that could cause anaerobic conditions, severe odors, and other problems. These effects may be aggravated if ozone, such as was used in Phase IB, was applied before dual media and GAC filtration.

It must also be noted that because of the raw water source certain water quality conditions may occur in the future which did not occur during the time of operation of the pilot plant. For example, certain organic chemicals may necessitate more frequent regeneration of the GAC, or may require the addition of a more efficient stripping process to the treatment sequence. The ability of the plant to remove organometallic compounds such as methylmercury was not tested, and the algal blooms that may develop if nitrified effluent is discharged to the estuary under drought conditions may cause severe operating problems. The occurrence of nitrate in excess of its MCL would also require that another process be added to the treatment plant to remove it. The design of a full-scale plant should take into account the periodic, adverse water quality conditions that might occur as well as the quality that was experienced during the time of operation of the pilot plant.

The testing program showed that the water produced by the treatment plant was of good quality, but more attention should have been given to quality changes that might take place in the distribution system. The high free residual chlorine used in the latter part of Phase IA, for example, is likely to accelerate corrosion. Some reduction by dechlorination would likely prove necessary. Further, although ozone and monochloramine, as used in Phase IIA, produced water of satisfactory microbiological quality, this water may result in significant problems with biofilms in distribution systems. The ozone will increase the amount of biodegradable organic matter, and monochloramine may not be sufficiently strong to prevent the growth of microorganisms in the form of slimes on pipe walls. These slimes can cause odors, promote corrosion, increase the amount of energy required to distribute the water, as well as other effects. A more severe problem with biological slimes is expected if a high ammonia concentration is in the water to be treated and if it is not removed during treatment.

Inclusion in the treatment scheme of a process that is designed to remove biodegradable organic matter and any ammonia that might appear is desirable in order to produce a water that is biologically stable and to provide better operation of the rapid filters and GAC filters. If such a process was one of the first used, and if ozone was applied for disinfection and oxidation before filtration, the GAC would remove any remaining biodegradable compounds in addition to its adsorption function. Lower levels of final disinfectant could then be applied to protect the quality in the distribution system.

COSTS OF PROCESSES MONITORED

Conclusions by the Corps of Engineers

Capital and annual costs have been estimated for a hypothetical 200 MGD estuary water treatment plant using the processes monitored in the Phase IA and Phase IIA treatment combinations. Because of uncertainties in the location and operating characteristics of any estuary water treatment plant, costs are summarized for the treatment plant only, excluding influent and finished water treatment plant components that would be needed for an actual estuary plant. Costs are based on continuous operation at the full 200 MGD design capacity.

1. Capital Costs for the Phase IA and Phase IIA processes are approximately $122 and $174 million, respectively (April 1983 dollars).

2. Annual unit costs, based on the operating strategies used at the EEWTP (e.g., actual carbon usage rate) and including amortization (eight percent, twenty years), are $0.34/1,000 gallons and $0.48/1,000 gallons, for the Phase IA and Phase IIA processes, respectively. Operation and maintenance costs account for approximately fifty percent of the unit costs.

3. Annual unit costs for the Phase IA process are approximately twice the costs of a conventional water treatment plant treating a river water source without the use of granular activated carbon.

4. Some cost reductions in the GAC process could be achieved in the actual operation of a full-scale estuary water treatment plant by *selection of less conservative regeneration criteria for the GAC. It has been shown that operation of GAC contactors in parallel, with a target finished water TOC level of 2 mg/L-C (the regeneration criteria used during Phase IA) could reduce the carbon usage rates used in the above cost estimates up to sixty percent.*

5. If GAC regeneration is based on TOC criteria for the blended effluent of many columns operated in parallel, a TOC goal of 1 mg/L may be more prudently compared to the goal of 2 mg/L. Under this more conservative regeneration criterion, unit operating costs are estimated to be $0.32/1,000 gallons and $0.41/1,000 gallons for the process combinations from Phases IA and IIA, respectively.

6. If air stripping in a packed tower is included in the Phase IA process combination as an additional treatment barrier for control of volatile organic chemicals, the unit costs would increase by about ten percent to $0.37/1,000 gallons.

7. Should it be necessary to remove several dissolved inorganic parameters of potential health or aesthetic concern (nitrate, sodium, hardness, TDS), a reverse osmosis process would be added to treat half of the 200 MGD plant capacity. The unit costs for Phase IA combination with RO replacing GAC would be $0.69/1,000 gallons.

NRC Committee Evaluation

Costs were determined and summarized in the Corps final report for a full-scale water treatment plant, designed specifically to use the Potomac estuary as a raw water source. The treatment processes proposed for use in the full-scale plant are based on those evaluated at the EEWTP. Because of uncertainties regarding location, date of construction and mode of operation of the full-scale plant, costs associated with intake and intake pumping, finished water pumping, land purchase, and other items were omitted from the cost estimates. Therefore, the costs considered are those of the treatment processes themselves, together with necessary structures, sitework, and administrative, laboratory, and maintenance facilities.

Two alternative treatment plants were considered: (1) alum/GAC/chlorine (similar to the Phase IA process evaluated for the EEWTP) and (2) lime/GAC/ozone/chloramine (similar to the Phase IIA process for the EEWTP). Both plants were assumed to operate at full capacity (200 mgd) year-round, without interruption. In addition, selected process modifications were reviewed, including possible GAC cost savings, the use of air stripping, and the addition of reverse osmosis.

Treatment costs, based on full-time operation, were estimated to be 34 cents per 1,000 gallons (gal) for the alum/GAC/chlorine process, and 48 cents/1,000 gal for the lime/GAC/ozone/chloramine process. These costs are compared to an estimate of 19 cents/1,000 gal for conventional water treatment. All costs are stated in April 1983 dollars. Modifications in the GAC unit process are estimated to reduce overall cost by up to 4.4 cents/1,000 gal for the alum/GAC/chlorine process, and up to 9.3 cents/1,000 gal for the lime/GAC/ozone/chloramine process. Packed tower air stripping would add 2.9 cents/1,000 gal to total costs, while reverse osmosis in place of GAC would increase costs by 35.1 cents/1,000 gal (see Table E.11-3, Corps' Executive Summary).

The cost data were developed in a conventional way, and the assumptions and data used are discussed fully in the report. Independent estimates by the committee confirm the reasonableness of the construction cost estimate for the conventional treatment plant (used as a point of reference for the other estimates), and the construction and capital costs of other unit processes seem within the range of present experience. Subject to the assumptions used, the cost estimates appear to be reliable and fully supported by available data. However, several of the underlying assumptions bear some examination, as they may lead to future misuse of the results of this study.

- Site-related costs are omitted. These costs, which include the costs of raw water pumping and intake, finished water pumping, transmission mains to the existing water system, land costs, solids handling and disposal, etc., may be considerable, perhaps as much as an additional $100 million in construction cost (1983 price levels). Solids handling and disposal costs, alone, may be surprisingly high. While the report is quite explicit as to its scope, the results may be used in the future long after the caveats are forgotten.

- Capital costs are based on an 8 percent interest rate. The costs, as now stated, appear to rely on debt financing through tax-exempt municipal bonds. The interest rate used, 8 percent per year, is typical of this market some months ago, and somewhat lower than the 10 percent levels current at the end of 1983. The actual plant, should it be built, will not necessarily use this method of financing. Long-term Treasury bonds, for example, now yield nearly 12 percent. The sensitivity of the stated costs (expressed in cents/1,000 gal) to the interest rate assumption should have been discussed, reducing the possibility for future misunderstandings.

- Cost estimates assume full-time operation. Water supply conditions would make full-time operation of such a complex and costly system seem unlikely. At the same time, the report argues convincingly against intermittent or fluctuating flows. If such a plant is built, it might be used on a seasonal basis, with operations beginning when low river flows are first forecast, and ending after water use levels drop (in the fall). Operation may begin with a period of discharge to waste, until proper process operation can be established and verified. The operating season may end with a period of "mothballing" designed to minimize corrosion and deterioration during the inactive season. Such an operating mode would imply costs very different from those estimated. Capital costs would be spread over many fewer units of output, and operating costs would be incurred when water was not being produced (during startup and, to some degree, when the plant was not in use). Under this assumption, actual cost/1,000 gal may be as much as 3 times the stated amounts, even though such operation may be consistent with minimizing the total cost of regional water supply.

- Existing MWA water treatment plants do not include GAC capability. The economic comparison of the estuary plant to conventional water treatment facilities would be radically changed if both of two events occur in the future: (1) additional water treatment capacity is required to meet maximum-day demands; and (2) future water quality conditions in the Potomac or the Occoquan rivers require the installation of GAC facilities at any new or expanded treatment plants. At present, it seems unlikely that both conditions would occur in the short- or medium-term future (the region presently has excess treatment capacity). However, if or when these events do occur, the cost of an estuary plant similar to that discussed here, especially if lower-cost GAC operating modes prove feasible, could be very similar to incremental costs of new treatment facilities elsewhere.

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BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS AND NRC PROJECT DIRECTORS

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, and since 1979 has been chairman, Department of Civil Engineering. 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 as chairman of this committee since 1980. Dr. McCarty was also a member of the NRC Committee to Review the Metropolitan Washington Area Water Supply Study and the Panel on Quality Criteria for Water Reuse.

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 was in environmental impacts associated with resource development and with quality requirements of potable water. He was the first chairman of this committee from 1976 to 1979 and also a member of the Committee to Review the Metropolitan Washington Area Water Supply Study during that time period. He was a professor of civil engineering at the University of Texas at Austin and a member of the National Academy of Engineering (Deceased 1983).

SAMUEL S. BAXTER

Dr. Baxter received an honorary degree of doctor of engineering from Drexel Institute in 1967. His experience ranged from employment at the Philadelphia Department of Public Works from 1923 to 1951 to being a member of the National Water Commission in 1968. He was a registered Professional Engineer in Pennsylvania and also a diplomate in American Academy of Engineers. Dr. Baxter was a member of this committee from 1976 to 1979 and was elected to the National Academy of Engineering in 1970 (Deceased 1982).

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.

RUSSELL F. CHRISTMAN

Dr. Christman received his Ph.D. in chemistry from the University of Florida in 1962. His professional experience has been as research assistant at the University of Washington, assistant professor civil engineering, associate professor applied sciences, and assistant to provost on environmental affairs. He is now professor of environmental science and engineering at the University of North Carolina at Chapel Hill. Dr. Christman has served on this committee since 1979 and was also a member of the Panel on Quality Criteria for Water Reuse.

RITA R. COLWELL

Dr. Colwell received her Ph.D. in marine microbiology from the University of Washington in 1961. Since that time she has been an assistant professor of microbiology at Georgetown University; associate professor in 1964. Since 1974, she has been a professor of biology at the University of Maryland and is currently Vice-President for Academic Affairs, University of Maryland (System). She is also President-Elect of the American Society for Microbiology. Dr. Colwell has served on several NRC committees and was a member of this committee from 1976 to 1979 and also chairman of the Panel on Microbiology.

EARNEST F. GLOYNA

Dr. Gloyna received his doctorate in sanitary engineering and water resources from Johns Hopkins University in 1953. From 1952 to 1970 he was professor of engineering and Director of the Center for Research in Water Resources at the University of Texas at Austin. Presently, he is Dean of the College of Engineering and holder of the Bettie Margaret Smith Chair in Environmental Health Engineering at The University of Texas at Austin. Dr. Gloyna is a member of the National Academy of Engineering and has served on various NRC committees and was a member of this committee from 1976 to 1979.

PAUL D. HANEY

Mr. Haney received a B.S. in chemical engineering from the University of Kansas and an M.S. in sanitary engineering from Harvard University. His association with Black and Veatch Engineers-Architects began in 1954 and has continued to the present time. Before joining Black and Veatch, Mr. Haney was associated with the Kansas State Board of Health and was appointed State Sanitary Engineer in 1942. Later he served as associate professor in the Graduate School of Public Health of the University of North Carolina and as a commissioned engineer officer in the Regular Corps of the U.S. Public Health Service. Mr. Haney was elected to the National Academy of Engineering in 1974 and has served on several NRC committees. He has been a member of this committee since its inception in 1976.

ROBERT H. HARRIS

Dr. Harris received his Ph.D. in environmental sciences and engineering from Harvard University in

1971. He has worked with Ralph Nader's Corporate Accountability Research Group on studies concerning drinking water and water pollution. From 1971 to 1973, he was assistant professor of civil engineering at the University of Maryland and taught courses in microbiology, ecology, and polluted waters and introduction to environmental engineering. Dr. Harris also worked for the Environmental Defense Fund as Associate Director of the Toxic chemicals program in Washington, D.C.

In 1980, Dr. Harris was appointed to the President's Council on Environmental Quality. He is now at Princeton University. Dr. Harris served on this committee from 1976 to 1980.

THURSTON E. LARSON

Dr. Larson received his Ph.D. from the University of Illinois. Since 1932, he has been employed by the Illinois State Water Survey. Dr. Larson is the author of 80 publications on corrosion, water chemistry, analytical methods, and water treatment. He is a member of the National Academy of Engineering and has served as a member of this committee from 1976 to 1979.

FRANK L. LYMAN

Dr. Lyman received his B.A. degree in biology from Swarthmore College in 1943 and his M.D. from Hahnemann Medical College in 1946. He was employed as a physician, coach, and instructor of biology at William Penn College from 1947 to 1948. He was in private practice in Iowa until 1955 when he was commissioned an officer in the Navy serving actively until 1957. He recently retired from the reserves as a captain. From 1960 to 1976 he was Director of Industrial Medicine for the CIBA-GEIGY Corp. He is now a consultant in toxicology and an adjunct associate professor at Temple University School of Medicine. He served on this committee from 1976 to 1979, was a member of the Experimental Design Panel and chairman of the Panel on Toxicology.

DAVID H. MARKS

Dr. Marks received his Ph.D. in environmental engineering from Johns Hopkins University in 1969. Since then he has been a professor of civil engineering at the Massachusetts Institute of Technology. His area of special interest is the application of operations research and systems analysis to environmental problems. Dr. Marks served as chairman of an NRC Conference on Cooperation in Urban Water Management in 1982. He has been a member of this committee since 1976, and also served as chairman of the committee's Panel on Experimental Design.

JOSEPH L. MELNICK

Dr. Melnick received a Ph.D. in biochemistry from Yale in 1939. He has been a professor of virology and epidemiology at the Baylor College of Medicine in Houston, Texas, since 1957. Dr. Melnick has served as a member of various expert panels on virus diseases, cancer, allergy, and infectious diseases. He has been a member of this committee since 1979.

KENNETH J. MILLER

Mr. Miller received a B.A. in chemistry from the University of Colorado. He is Director of Water Engineering at CH_2M-Hill in Denver and is responsible for maintaining firmwide technical excellence, quality control, technological development, and cost-effective project execution. Prior to this be served as director of Planning and Water Resources for the Denver Water Department where he stayed for 17 years. Mr. Miller has served the NRC as a member of this committee since 1976.

DANIEL A. OKUN

Dr. Okun received an Sc.D. in sanitary engineering from Harvard University in 1948. He served on this committee from 1976 to 1981, while also serving as Chairman of the Committee to Review the Metropolitan Washington Area Water Supply Study. 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, 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.

VERNE RAY

Dr. Ray received his Ph.D. in microbiology from the University of Texas in 1959. His professional experience includes microbial genetic studies in fermentation, chemotherapy of infectious diseases, water microbiology and toxicological evaluation of drugs and other chemicals. Since 1970, he has directed the Genetic Toxicology Unit at Pfizer, Inc. and is currently Assistant Director of Drug Safety Evaluation. Dr. Ray is a past President of the Environmental Mutagen Society and has been a member of several boards and commissions both in the U.S. and overseas. He has served on several NRC committees and was a member of the Panel on Quality Criteria for Water Reuse.

VERNON L. SNOEYINK

Dr. Snoeyink received a Ph.D. in water resources engineering from the University of Michigan. He joined the faculty at the University of Illinois in 1969 and prior to that was with Metcalf and Eddy Engineers for one year. His expertise is in process engineering and the design of water treatment plants to meet variable drinking water criteria. He has been a consultant to the World Health Organization and the Environmental Protection Agency. Dr. Snoeyink has been a member of this committee since 1979.

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 Committee 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.

APPENDIX A

LETTER REPORTS

NRC COMMITTEE LETTER REPORTS

LETTER REPORT OF MARCH 2, 1977

March 2, 1977

Mr. Daniel J. Mahoney
U.S. District Corps of Engineers
Department of the Army
Baltimore District
P.O. Box 1715
Baltimore, MD 21203

Dear Mr. Mahoney:

I am writing to report on a significant aspect of the second meeting of the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project, held in Washington, DC, November 17 and 18, 1976. This committee was established by the National Research Council to perform the work specified in Contract Number DACW31-76-C-0069 between the National Academy of Sciences and the Department of the Army, Baltimore District, Corps of Engineers. The primary task of the committee is to review and report on the Experimental Water Treatment Plant Project following completion of the project by the Baltimore District. Additionally, the contract calls for comments on various aspects and phases of the project during the planning and construction, such as the proposed Design Analysis and Specifications for the plant.

To assist in these tasks, the committee established several panels, and each was assigned a specific subject area. Accordingly, the Panel on Processes was composed to study and comment on the treatment processes proposed for the experimental plant and the effectiveness of the processes in producing a safe and potable finished water supply. At the request of the committee, the panel met on November 9, 1976 to discuss the treatment processes as presented in the Design Memorandum--Experimental Estuary Water Treatment Plant, 1976 and the preliminary submission, September 1976, of the proposed Design Analysis and Specifications for the plant.

On November 18, 1976, the Chairman of the Panel on Processes, Perry L. McCarty, reported the panel's deliberations to the committee. As result of the presentation and ensuing discussion, the committee wants to make several suggestions and comments that your office might find helpful. These comments are briefly noted below and elaborated upon more fully in the panel's "Rationale" statement which was prepared for the committee and attached to this letter. Please note that the rationale from which the comments were derived are based upon a number of assumptions made by the panel pertaining to the characteristics of the influent water to be treated by the experimental plant and the desired quality of the finished product water. The assumptions are outlined on pages 86-88 of the attached statement.

The committee's comments on the proposed treatment processes for the Experimental Estuary Water Treatment Plant are as follows:

1. Consideration should be given to obtaining blend water from the Blue Plains Treatment Plant after, rather than before, the filtration and chlorination steps (see pages 86-88 of the "Rationale").

2. Consideration should be given to elimination of the alum modification of chemical treatment (see pages 88-90 of the "Rationale").

3. The desirability of regeneration of lime sludges should be further evaluated (see pages 88-90 of the "Rationale").

4. The desirability of moving the predisinfection step to a point between a first stage and second stage of activated carbon adsorption should be considered. Provision of sufficient capacity for breakpoint chlorination also should be considered (see pages 90-92 of the "Rationale").

5. The desirability of adding a deep bed filtration system after activated carbon adsorption should be reviewed. The need for filtration prior to activated carbon adsorption should be evaluated during the proposed study (see pages 90-92 of the "Rationale").

6. The desirability of two-stage recarbonation and a more optimal softening system for chemical treatment with lime and provision for recycle of clarifier underflow to the inflow to the chemical treatment clarifier should be considered (see pages 92-93 of the "Rationale").

7. Provision of air injection for activated carbon backwashing should be considered (see pages 92-93 of the "Rationale").

8. Provision for addition of alum or other coagulant aid prior to filtration should be considered (see page 90-92 of the "Rationale").

9. Special attention should be given in the treatment plant design and in the design of the sampling system to

using materials that will not contaminate samples or water with organics (see pages 93-94 of the "Rationale").

The committee would like to say a few words about the methodology of the panel review. The panel was confronted with reviewing a document on Design Analysis and Specifications that ran to about 1,500 pages. To do this within the period required by the Corps for completing this phase, the panel adopted a strategy of reviewing as a body the major issues in detail; the balance of the document was divided among the members according to their special fields of expertise and spot checked by them.

It is the committee's observation that some of the conclusions and suggestions made here for the Corps' consideration, if adopted, could be incorporated in any modifications of the pilot plant at some future time.

If the Corps' project engineers require more elaboration of the concerns and conclusions of the panel and committee, I will be pleased to ask the members to provide additional analysis and detailed comments. The committee would welcome the Corps' reaction to this report, and would find it especially helpful to be informed of any changes made in the design of the treatment processes as a result.

I express the appreciation of the committee for the continued cooperation of the Corps' staff associated with the experimental treatment plant project, in particular for their discussions with the committee during the November 17-18 meeting.

Sincerely yours,

Gerard A. Rohlich, Chairman
Committee to Review the
Potomac Estuary
Experimental Water
Treatment Plant Project

Attachment

March 2, 1977
Attachment of letter to Mahoney from Rohlich

RATIONALE FOR COMMENTS ON THE PROPOSED DESIGN OF THE EXPERIMENTAL ESTUARY WATER TREATMENT PLANT

INTRODUCTION

Section 85 of the Water Resources Development Act of 1974 authorized by the U.S. Army Corps of Engineers to construct and test an experimental water treatment plant on the Potomac River estuary as part of a study on the feasibility of using the estuary as a source of potable water for the Washington, DC metropolitan area. The legislation further directed the Corps to request that the National Academies of Sciences and Engineering (acting through the National Research Council) review the Corps' work and comment on the scientific bases of its findings. In response to the Congressional directive the Corps' Baltimore District initiated the Experimental Estuary Water Treatment Plant Project and contracted with the National Academy of Sciences for a review of the study.

The National Research Council appointed a Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project as the unit responsible for conducting the review, and the committee in turn established several panels to advise it on various aspects of the study. A Panel on Processes was assigned the task of critiquing the treatment processes proposed by the Corps' designing engineers for the experimental plant. As a result of this assignment, the panel met on November 9, 1976 to discuss the proposed processes as presented in the Design Memorandum, the preliminary Design Analysis and the Specifications, all prepared by Malcolm Pirnie, Inc. for the experimental water treatment plant.

On November 18, 1976 the Chairman of the Panel on Processes, Perry L. McCarty, presented the panel's views to the committee. The committee concluded that several of the panel's comments were sufficiently important to merit being called to the Corps' attention. Because the rationale behind the comments made by the panel and discussed by the committee are lengthy, the committee requested the panel to report on the Rationale. Accordingly, this "Rationale" statement, based upon its discussion of November 9, 1976, was prepared by the panel.

RATIONALE

A major objective of the experimental plant operation will be to determine the capability and reliability of state-of-the-art technology for removing viruses, heavy metals, and most important, trace organic chemicals. This objective is central to considerations of plant design and operation.

Before discussing the preliminary design, and in determining the capabilities required of the treatment plant, it was necessary for the panel to make various assumptions about the characteristics of the water to be treated by the experimental plant and about the desired characteristics of the finished product water. Alternative process flow schemes for treatment systems which might have these capabilities were discussed, with the conclusion that the processes proposed by the designing engineers included those with the greatest promise for meeting the overall objectives of the project. The design factors used for each proposed process and the proposed sequencing of the process units within the overall system also were discussed. On the basis of the information available, the panel determined that some aspects of the design factors and the sequencing deserved further evaluation by the Corps' designing engineers. These points and the reasoning supporting them are discussed below.

Assumptions Regarding Influent and Effluent Water Characteristics

The future quality of the Potomac River estuary water that would be treated by a full-scale plant is not yet well defined, nor is the quality of the various blends of water to be treated in the experimental plant. In making the following comments, it was necessary for the panel to assume certain characteristics for the water to be treated. For example, it was assumed that the water would contain more than 20 percent nitrified and biologically treated municipal wastewater. The total dissolved solids on occasion could range from 600 to 900 mg/l, largely as a result of some sea water intrusion into the upper estuary. The total nitrogen content of the blended influent was assumed to be below 10 mg/l so that excess nitrate nitrogen concentration would not exceed drinking water standards proposed by the U.S. Environmental Protection Agency. The ammonia nitrogen concentration was assumed to be 1 mg/l or less.

Determining the capability for organic removal is a primary objective of the experimental plant, and for this reason the experimental plant should treat water containing as close as possible the blend of organics expected in the future estuary waters. The proposed plan is to use nitrified, but not filtered and chlorinated, secondary effluent from the Blue Plains wastewater treatment plant as part of the blend water to simulate future Potomac estuary water. It is suggested by the panel that the filtered and chlorinated effluent be considered for use in order to better simulate the estuary water. For additional more realistic simulation, consideration should be given to storing the blended water for some "aging" because chlorination and storage can result in significant transformations in some organic materials.

The desired characteristics of the finished product water also have not yet been specified. For the panel's critique, some generally desired characteristics for the treated waters were assumed. These assumed characteristics have not been adequately evaluated by the panel and should not be considered for any use other than this preliminary evaluation. It was assumed first that the water should be at least as good in quality as the present water supply for the District of Columbia. Further, it was assumed to be of prime importance that the finished product water be as free as practicable of trace organic chemicals, heavy metals, and pathogens. Multiple treatment processes which can assure this are essential. As a general measure of organic content, the concentration of total organic carbon (TOC) should not exceed 2 to 3 mg/l, which is near the average concentration of surface water supplies in the United States. Preferably the concentration should be lower than this as TOC is only a general parameter and not truly indicative of the organic materials significant to health. It was also assumed that the treated estuary water must at least meet the limits of currently proposed EPA drinking water standards as well as the 1962 PHS drinking water standards. In addition, it was assumed that economic and aesthetic parameters such as total dissolved solids and hardness should not exceed concentrations in the present water supply for the District of Columbia which were estimated to be about 250 mg/l and 120 mg/l, respectively.

Treatment Capabilities and Process Flow Schemes

Treated estuary water could in the future be injected directly into the water distribution system, or it could be discharged into the Potomac River above water supply intakes and thus be used for flow augmentation. The quality needs for these two alternatives would differ. The panel observed that the proposed treatment scheme for the experimental plant should be capable of meeting the more stringent needs of the former alternative. The treatment scheme also should be capable of providing information which would be needed to evaluate the feasibility for the second alternative. In addition, the panel concluded that, with river flow augmentation, the total dissolved solids concentration would be less critical because of the dilution afforded by Potomac River water.

The panel agreed that the treatment scheme proposed by the designing engineers contained the processes which would be the most likely choices for meeting the quality requirements for either alternative. For upstream discharge, chemical coagulation, activated carbon adsorption, and disinfection probably would be required. For direct injection into a distribution system, filtration and demineralization probably would be required in addition.

Process Alternatives

The proposed design for the treatment plant includes more than one alternative for some of the individual processes. The panel expressed concern about the ability of the Corps to adequately evaluate the performance of each alternative within the time constraints of the experimental project. Therefore, consideration was given to the elimination of some alternatives in order to ease this problem.

The need for an aeration step as one initial process was questioned. In general, the panel considered that little of value would result from aeration, but opinions were not strong enough to suggest that this process be considered for elimination.

Alternatives for chemical treatment in the proposed design include alum treatment and lime treatment. The value of studying the alum alternative was questioned because lime treatment has several additional advantages with little or no added cost. Removal of hardness and a reduction in total dissolved solids is possible with lime treatment, thus reducing subsequent demineralization costs. Alum treatment on the other hand, achieves no reduction in dissolved salts and can significantly add to the sulfate concentration. Other benefits of lime are: the pH associated with its use results in good disinfection; it is superior to alum for heavy metal removal; problems with sludge handling are less than with alum; regeneration of lime has less potential for recycling of organics than regeneration of alum.

Regarding sludges, there was concern that the regeneration of either lime or alum sludges as proposed may lead to complications which would significantly detract from the overall objectives of the experimental plant. Despite the fact that contaminants may be present in recycled coagulants and that their potential effect on finished water quality ultimately should be evaluated, the increased cost and operator time required for regeneration in an experimental plant may be excessive in comparison with the information which may be obtained. The opinion that regeneration should be eliminated was not unanimous within the panel, but there was concern that the experimental design needs to give more recognition to this problem and possibly less emphasis to evaluating the sludge reclamation variables.

Three alternatives for demineralization have been proposed for the experimental plant design: reverse osmosis, ion exchange, and electrodialysis. Some panel members questioned whether electrodialysis would be competitive in advantage or cost with the other two, but there appeared to be no compelling reason for evaluating the elimination of this alternative.

The experimental plant has provision for evaluating both a dual media and multimedia filtration, and for evaluating upflow and downflow activated carbon adsorption. These different modifications are worthy of evaluation, although differences in performance are not expected to be great.

Process Location

There was considerable discussion on the location within the overall treatment system of two processes: predisinfection and filtration. In the design plans reviewed, predisinfection is proposed after chemical treatment and before filtration and activated carbon adsorption. Either chlorination or ozonation can be provided. It is suggested that (1) predisinfection with chlorine, providing for chlorination to a free residual (breakpoint chlorination), be considered so that more effective disinfection can be obtained, and (2) the disinfection be carried out between two stages of activated carbon adsorption rather than at the location presently proposed by the designing engineers.

Recent laboratory and field scale studies indicate that breakpoint chlorination after chemical treatment of wastewater, as proposed, results in the formation of relatively high concentrations of chlorinated organics, many of which are not readily removed by activated carbon adsorption. Included in this class are chloroform and other trihalomethane compounds. Breakpoint chlorination after activated carbon adsorption results in the formation of much lower concentrations of chlorinated organics. However, some less polar chlorinated organics which might otherwise be removed by activated carbon are also no doubt formed by post-carbon chlorination. Chlorination after one stage of activated carbon treatment would result in minimal formation of chlorinated organics, and subsequent passage through a second stage of activated carbon should result in removal of at least the relatively nonpolar and hence readily adsorbable compounds that may be formed. The adverse effects from chlorination should be minimized by this procedure.

Ozonation also results in significant alternation of organic molecules. With our current limited understanding of the organic material present in treated wastewaters, it appears best to remove the majority of organics before applying oxidizing disinfectants, and then to pass the disinfected wastewater again through activated carbon for removal of newly formed organic materials. This alternative, together with post-disinfection by a variety of alternatives, should provide maximum disinfection with formation of a minimum of potentially harmful organic materials.

In the proposed design, filtration is provided prior to activated carbon adsorption. Whether filtration might better be placed after activated carbon adsorption or, perhaps, be provided in both places was discussed by the panel. In the proposed location, filtration would protect the activated carbon columns from additional suspended solids loading and perhaps from scale formation. The panel questioned whether these problems would be significant, especially if two-stage carbonation were practiced. Concern was expressed over whether the effluent from activated carbon adsorption might exceed the recommended EPA standard of one turbidity unit because of possible fermentation and release of biological growth from the activated carbon and because of the release of activated carbon fines. This may not be a problem if subsequent demineralization is practiced, but could be otherwise. The panel noted that filtration after activated carbon adsorption would be desirable to ensure against the possibility of high effluent turbidities. But because of the added cost of additional filters and the uncertainty of the degree of need, no suggestion was made to consider additional filters.

In the present experimental design, effluent from the activated carbon columns will be passed through cartridge filters prior to demineralization. Cartridge filters are usually not realistic for a full-scale treatment plant, and if indeed such filtration is necessary prior to demineralization, then perhaps a more realistic filtration system should be considered.

Because of the questions about filtration, consideration should be given to including a study of the effect of no filtration before activated carbon adsorption. With the present plant design, the filters cannot be used after carbon adsorption. The panel was informed that provision of this alternative would be somewhat difficult. The panel did not take a strong position on this issue to recommend changing the filter location, but it suggested that if post-filtration is required it probably could be better evaluated with short-term studies using pilot-scale filters.

Finally, provision for addition of alum or coagulant aids prior to filtration is very much worth considering.

Process Design

Time did not permit the panel to consider in detail the design of individual processes. Certain factors were thought to deserve further consideration by the designing engineers and these are briefly discussed in this section.

As proposed, the major components of the experimental plant are designed with a normal capacity of 0.5 mgd, and a maximum capacity of 1.0 mgd. In general, the design factors appear reasonable for a flow of 0.5 mgd, but the plant may be stressed at a flow rate of 1.0 mgd. It will be important to consider this aspect in the overall experimental design for the operation of the plant. Additional consideration should be given to the desirability of the proposed extensive operation near 1.0 mgd since this may not effect the treated water quality desired.

In order to achieve reliable and adequate disinfection, it was believed that chlorination to provide a free residual is desirable. The quantity of chlorine which must be added for this purpose will be determined to a major extent by the concentration of ammonia present. Approximately 8 mg of chlorine are required for each mg of ammonia nitrogen to achieve a free residual. It is not known what concentration of ammonia nitrogen to expect in the water to be treated, and the currently planned dosage of 10 mg/l for chlorine may be inadequate. It was suggested that this be given additional consideration.

The currently proposed chemical treatment with lime provides only single-stage recarbonation. Additional consideration should be given to the inclusion of two stages of recarbonation with the benefits of additional softening and demineralization which would result. An evaluation here would require better information on the expected mineral quality of the influent water. It could be that operation as a softening plant may result in sufficient hardness and TDS removal so that during many times of the year demineralization of estuary water may not be required.

Providing for recycle of lime sludge from the clarifier underflow for mixing with the influent stream should provide more effective and economical lime treatment. Consideration might also be given to two-stage lime treatment as well as to two-stage recarbonation. If lime were first added to effect $CaCO_3$ precipitation only, the resulting sludge might be more suitable for regeneration and recycle because it would not contain magnesium and as much of the heavy metals. A second stage of lime treatment at elevated Ph would then effect magnesium and heavy metal removal, and the resulting sludge could be disposed separately.

Half of the activated carbon columns are designed for upflow and half for downflow. This will allow an evaluation of the two different systems to be made. Some discussion concerned the desirability of having each column provide both upflow and downflow so that more flexibility would be available. However, it was argued that currently available equipment was generally designed for either alternative, but not for both, and that the best upflow and downflow systems available should be sought in order to successfully evaluate the two alternatives. It was suggested that lower backflow rates than currently proposed, together with air injection, may give better backwashing efficiency. Attention should be given to obtaining activated carbon with minimal tendency for attrition so that the potential problem of fines in the effluent can be minimized.

As a general comment, specific characteristics of chemicals, activated carbon, and individual pieces of equipment can have significant effect on water quality. It is suggested that this be given extensive consideration before selections of materials and equipment are made. The lists of materials and equipment contained in the Design Memorandum and the preliminary Design Analysis and Specifications thus should be considered as preliminary and not final.

Sampling Needs

One of the main factors to be evaluated by the experimental plant is organic materials remaining in the finished product water. Many of the plastics used in piping, organics used in lubricants, and pipe and tank protective coatings contain organics which slowly leach into waters with which they come into contact. Experience at some advanced wastewater treatment systems near the size of the proposed experimental plant indicates that this often can be a serious problem and could negate efforts to demonstrate the efficiency of advanced wastewater systems for removal of many organics. Three major problems can result. First, the apparent efficiency of the treatment system for organic removal as determined with contaminated samples will be lower than the real efficiency; second, the leached organics frequently mask the presence of other organics which may have greater health significance; and third, plastic sampling tubes may adsorb and thus remove organic materials in the water which are of health interest. Thus, the use of plastic tubing pipes for sampling in the treatment system, such as those made of PVC or tygon, and organic coatings on pipes and tanks may add organics, remove organics, or mask the presence of organics in samples for analysis, thus leading to inconclusive results. This is a problem of which we are just becoming aware. Because of the special importance of organic analyses in the proposed experimental study, this problem needs much greater attention in the system design.

LETTER REPORT OF AUGUST 4, 1977

August 4, 1977

Mr. Daniel J. Mahoney, Project Director
Department of the Army
Baltimore District, Corps of Engineers
P.O. Box 1715
Baltimore, Maryland 21203

Re: Contract No. DACW31-76-C0069

Dear Mr. Mahoney:

The Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project has reviewed the proposed testing and evaluating program for the experimental water treatment plant. The report attached to this letter describes the basis of the review and discusses in detail the comments of the committee. A list of the committee members also is attached to the report.

There are several of the committee's comments that merit special consideration because of their important bearing on the success of the experimental project. As you read the report, I hope you will bear in mind the following points:

1. The need to clearly define the objective of the overall project and to design the experimental testing program accordingly (discussed on pages 99-100);
2. The necessity of utilizing effluent from the Blue Plains Wastewater Treatment Plant that is of the same quality as that released into the estuary of the Potomac River (discussed on pages 99-102);
3. The merits of restricting the treatment process configurations to be tested. (See pages 104-105);
4. The desirability of comparing the quality of the output water from the plant to the quality of drinking water presently supplied to the metropolitan Washington area. (See pages 104-105);
5. The need to evaluate the output water for consumer acceptance in terms of palatability. (See pages 104-105).
6. The necessity of conducting toxicological tests on the plant's output water and of carefully designing such experiments in the context of the overall testing program. (See pages 106-108).

The committee hopes that these comments will be helpful in considering modifications of the proposed testing program for the experimental plant. Should the program be revised, we would be glad to assist further with additional comments. If this or other assistance will be helpful to the Corps, please inform me.

Sincerely yours,

Gerard A. Rohlich, Chairman

August 4, 1977
ATTACHMENT: Letter Report to Mahoney from Rohlich

COMMENTS ON THE PROPOSED TESTING AND EVALUATION PROGRAM for the EXPERIMENTAL ESTUARY WATER TREATMENT PLANT PROJECT by the

Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project

INTRODUCTION

Section 85 of the Water Resources Development Act of 1974 authorized the U.S. Army Corps of Engineers to construct and test an experimental, or pilot, water treatment plant on the Potomac River estuary as part of a study on the feasibility of using the estuary as a source of potable water for the Washington, D.C. metropolitan area. The legislation further directed the Corps to request that the National Academies of Sciences and Engineering (acting through the National Research Council) review and comment on the scientific basis of the Corps' work. In response to the Congressional directive the Corps' Baltimore District initiated the Experimental Estuary Water Treatment Plant Project and asked the National Academy of Sciences to review the study.

Accordingly, this committee was established and directed by the National Research Council to review and report on the Experimental Water Treatment Plant Project by the Baltimore District. Additionally, the committee is to comment on various aspects and phases of the project during planning and construction.

To assist in reviewing specific aspects of the project, the committee established a panel for each of the following subject areas: Processes, Analytical Chemistry, Toxicology, Microbiology, and Experimental Design. The first task undertaken was to comment upon the proposed design analysis and specifications for the treatment processes to be incorporated into the experimental plant. The committee asked its Panel on Processes to perform that review, and a letter reporting on the panel's comments was transmitted by the chairman of the committee to the Corps on March 2, 1977.

The second task undertaken by the committee and reported upon herein was a review of the proposed testing and evaluation program for the experimental plant. This aspect of the Corps' pilot plant project is crucial because the experiments conducted upon the plant must demonstrate conclusively whether water from the Potomac River estuary can be rendered potable. As with most experimental projects, there are limited resources of time, personnel, and finances for testing the pilot plant. Therefore, the testing and evaluation program must be carefully designed to accommodate these constraints and meet the aims of the program. It is to this end that the committee offers the comments in this report.

The following review was based on Chapter XXXIV, "Testing Program and Program Evaluation" of the Corps' Design Memorandum - Experimental Estuary Water Treatment Plant. The committee asked each panel to review and report to the committee upon the appropriate aspects of Chapter XXXIV, and the comments from the panels then were used as the basis for this report. The majority of the comments below concern the experimental design aspects of the Corps' proposed testing program, but other aspects such as microbiology and toxicology also are incorporated.

COMMENTS

Experimental Design

Objectives of the Testing Program

The experimental water treatment plant project is being undertaken to determine the feasibility of producing potable water from the estuary of the Potomac River. As noted above, the burden of that determination rests upon the design of the experiments and the testing program.

The committee believes that a basic deficiency exists in the approach proposed for the testing program. In a typical advanced treatment process there are several important components, and in the proposed plant the final configuration of these is not fixed. Rather, the designers have allowed experimentation with different configurations and with side stream experiments for simultaneous comparison of processes. These procedures would be of interest if there were no doubts that potable water could be obtained, because such experimental tests could help optimize the cost effectiveness of the advanced water treatment system by identifying good combinations of subcomponents. However, there are many additional problems in this particular experiment that concern the inputs to and outputs from the system.

The input estuary water quality varies throughout the year. Thus, fairly long-time streams through one pilot plant configuration are necessary to identify which output variations are due strictly to input variability. Also, the water source quality for the future full scale plant is expected by the Corps to be poorer than at present. Present plans to synthesize the influent by mixing estuary water with effluent from the Blue Plains Wastewater Treatment Plant, when little is known about the quality time series of either, could confound the experimental results.

In terms of outputs, questions remain as to what characteristics should be measured, and to what standards they should be compared. This results from rapidly evolving knowledge and public and political attitudes that cause consequent changes in the definition of safe drinking water.

In summary, the Corps plans to build a pilot plant and collect data, but towards what objective? There are several classes of questions which such an experiment might answer (i.e., process selection, operating information, overall evaluation, input source evaluation). It appears to the committee that the stated purpose of determining the feasibility of producing a public water supply from the estuary has small likelihood of being accomplished by the existing experimental program.

A specific hypothesis relating to an important new concept, such as using estuary water, must gain or lose both technical and general public acceptance. This depends upon clear, well defined experimental results, to which end the committee suggests that: (1) the Corps revise its experimental design to encompass fewer experiments in greater depth, (2) give more attention to synthesis of the inputs, and (3) rethink evaluation of the outputs. More detailed comments on inputs, process system, and outputs from the pilot plant are given below.

Inputs

Background

Two important problems relate to the inputs to the pilot water treatment plant. First, an eventual full scale plant would take estuary water at a different location from the present site of the pilot plant. Estuary water in the future is hypothesized by the Corps to be of poorer quality than the present water quality of the estuary. The problem is to simulate more realistically the type of future input water to the full scale plant. Estuary water in the future is hypothesized by the Corps to be of poorer quality than the present water quality of the estuary. The problem is to simulate more realistically the type of future input water to the full scale plant. Second, the estuary water quality, present or future, varies over time. There are short term seasonal and long term trends, some of which may be non-stationary (i.e., the mean quality may be getting better or worse over time). Quality may be better or worse in winter than in the summer, on the outgoing tide rather than the incoming tide, and during dry periods rather than after storms. In conducting experiments, such variables lead to difficulties in identifying effects caused by the apparatus from those caused by the input. To further complicate matters, it has been suggested that treated sewage either from the secondary or tertiary effluent from the nearby Blue Plains Wastewater Treatment Plant be mixed with the estuary water and also that it be used directly as the sole input water source.

Specifics

Chapter XXXIV of the Design Memorandum proposes testing the system with actual estuary water in the first winter, a mixture of Blue Plains effluent and estuary water for a year and a half, and then totally Blue Plains effluent for 3 months. The specifications for the mixed water have been set mainly by looking at data from the 1965-66 drought. Such a procedure presents a problem because some of the stochastic processes occurring in the estuary are non-stationary. Long-term variations in input water would probably be lost. In addition, two very different water streams are being mixed. The Blue Plains effluent will have much less temperature variation during the year than estuary water, but is much more likely to show sudden changes in other parameters caused, for example, by malfunction of treatment equipment. A relatively good understanding of the effluent's variability can be gained by sampling over the life of the experiment to augment existing data. It is more difficult, however, to capture the long term variability of the estuary by sampling in a relatively short time period prior to trial operation of the pilot plant, as proposed by the Corps.

The basic experimental design questions are:

(a) How is the representative input water chosen?

(b) As the input water will have variability in quality, how do we insure that this variability does not confuse the comparisons we wish to make in the experiments?

(c) What parameters should be chosen and how often should they be measured? (This must be carefully coordinated with output tests.)

At a minimum, it is suggested that the Corps begin analyzing (1) water quality in the estuary at points near the proposed input to the pilot plant and (2) the final treated effluent from the Blue Plains plant that represents the quality of wastewater that will be released into the estuary. This latter point is important because during prolonged drought when the flow of the Potomac River is minimal, the flow from the Blue Plains could account for the majority of the water in the estuary. Thus, the treatment plant should be capable of processing only Blue Plains effluent in the event that the quality of the estuary closely approaches that of the effluent. These programs would aid in understanding of the time series nature of water quality in each of these flows in terms of the parameters upon which the outputs will be evaluated. An effort of such magnitude may require an upgrading of the present analytical capabilities of the Corps' laboratory and technicians conducting the analyses. In addition, the Corps could use a qualified consultant in statistics to help establish a procedure for producing an acceptable input to the pilot plant during the experiment.

The Process System

Background

The proposed experimental design calls for testing different input waters ranging from estuary water to Blue Plains effluent, different flow volumes ranging from full capacity to twice full capacity, and different unit processes. Later in this report, the committee suggests expanding the testing program for treated water. At this point, however, it should be emphasized that care must be taken not to lose sight of the two important objectives of determining whether or not a potable water can be produced is best met by operating the experiment with a single previously designated "best" configuration as long as possible. The second and minor objective is to minimize operating and maintenance costs of the treatment facility. The Corps experimental design appears to stress the second objective rather than the first. Given the limited testing period, even if the experiments were to focus on the second objective, the data would be so confounded with changes in input conditions (particularly temperature) that progress towards either objective would be severely limited.

Specifics

The crucial consideration regarding process is deciding which configurations should be tested and for how long. A first look at the constraints of the testing period (6 months start-up plus 2 years of experimental runs) suggests that the time available is too short to test all of the factors of interest. The amount of experimental time available apparently cannot be increased due to the nature of the decision time scale for other aspects of the Corps' Washington Metropolitan Water Supply Study, of which the pilot plant is a component. Therefore, the committee feels that the number of experiments should be drastically decreased. We also feel, based on experience in other plants, that a very limited number (possibly only one of two) of clearly dominant alternative configurations should be tested. For example, in its study and review of treatment processes steps and various alternatives included in the pilot plant, the committee suggested elimination of the alum alternative and consideration of eliminating the aeration step and sludge regeneration process. (Reference is made to the March 2, 1977 letter report on processes to the Corps from the chairman of the committee.) Using such an approach each experiment could be conducted until sufficient data were gathered to satisfy the primary objective of the program. Numerous data from other existing full scale and pilot plants can be used to evaluate the economic aspects of subprocess choices. Specifically, the committee suggests that the Corps contract with a consultant on experimental design who can help suggest:

(1) where data should be collected in a given process, with what frequency and which parameters; and,
(2) how to decide when enough data have been collected to test the primary hypothesis for the best configuration so that a new experiment may be started.

Outputs

Background

To a large extent, the project will not be considered successful unless the outputs from the treatment plant satisfy some standards. These standards, in the form of tolerable levels of various water quality parameters, are fundamental to whether or not potable water can be produced from the Potomac estuary. Unfortunately, there is a limited theoretical understanding of how water quality affects public health. The Corps is attempting to meet a moving target, because the concept of safe public water supply has in the past and will continue to change over the lifetime of the Potomac Estuary Experimental Water Treatment Plant Project.

The problem of measuring and meeting output targets are as follows:

(1) What should be measured?
(2) What frequency of measurement is required?
(3) What are the target levels each of the parameters is to achieve?
(4) Should the targets be deterministic or stochastic (i.e., is there an allowable percentage of time when a successful experiment does not meet a target?)

(5) What if the output meets most but not all of the targets?

Specifics

In order to confront the critical question of success or failure of the experiment, it is suggested that the Corps take measurements of the pilot plant outputs that can be compared with the following:

(1) Drinking water standards developed by the U.S. Environmental Protection Agency (EPA) and in effect when the pilot plant is operational.
(2) Drinking water quality monitored by EPA for other municipal water supplies.
(3) The quality of drinking water supplied to the metropolitan Washington area from existing sources and in particular from the freshwater portion of the Potomac River.

It is also desirable that the outputs provide a basis for future researchers in water quality to make *ex post* assessment of the success of pilot plant operation.

To accomplish these comparisons, analytical measurements of water quality must provide the data compatible with the national drinking water regulations developed by EPA. In addition, measurements must be taken in both existing supplies and for the treatment plant output. The measurements in these cases should probably be more extensive than those currently taken by EPA. These measurements should provide a basis for analyzing not only the average quality in each case, but the variability in quality. This is important if the effects of input variability are to be identified. Also there is concern that the required analytical testing may be beyond what the Corps can accomplish either presently or with its anticipated upgrading of facilities. It is difficult to gear up quickly in relatively state-of-the-art measurements of water quality beyond those routinely tested. Therefore, it is suggested that the Corps consider some arrangements with EPA or outside firms to relieve the burden of trying to achieve a major short term increment in the Corps' own in-house analytical capabilities.

COMMENTS ON SPECIFIC ASPECTS OF THE TESTING PROGRAM

The program should provide adequate testing for taste and palatability of the output from the pilot plant. The committee suggests that the Corps consider including such tests in the program to provide insight into the issue of consumer acceptance of the estuary as a source of drinking water.

Possible adverse health effects resulting from contaminants in public water supplies have been receiving greatly increased national attention in recent years. EPA and water supply agencies are increasing efforts to determine the existence of carcinogenic and toxic substances in present public drinking water supplies, to evaluate their potential harmful effects, and to develop more stringent water quality requirements. Thus, a major concern of the committee is that the testing program demonstrate adequate removal of viruses, organic substances (especially halogenated compounds) and heavy metals. To this end, the following suggestions are made:

Microbiology Aspects:

1. The input and output water must be adequately monitored for micro-organisms. The analytical laboratory staff therefore must include a qualified microbiologist and parasitologist.
2. Sampling for viruses and bacteria should be coordinated and should include effluent from the Blue Plains Wastewater Treatment Plant. The most current and best scientific methodologies should be utilized in testing for a broad spectrum of viruses. The need to include adeno viruses should be evaluated.
3. Water samples analyzed for viruses, especially those taken from the estuary, should include data on water turbidity and temperature.
4. Consideration should be given to testing ultrafiltration treatment processes for removing micro-organisms.

Analytical Chemistry and Toxicological Aspects:

1. Because some parameters listed in Table 34-3 of the <u>Design Memorandum</u> are not useful in delineating the health aspects of water quality, consideration should be given to eliminating the following from the proposed

monitoring program: biochemical oxygen demand, chemical oxygen demand, carbon chloroform extract, and surfectants.

2. New methodologic developments now make it possible to measure purgeable as well as nonpurgeable total organic carbon. It is suggested that both fractions of the total organic carbon be analyzed frequently to obtain a comprehensive index of fluctuations in organic carbon loading in the output waters.

3. It would be desirable to conduct routine monitoring of total organic chlorine, because as a general class the chlorinated compounds are often more toxic than the non-chlorinated ones. A cautionary note is that this parameter sometimes cannot be measured because of interfering substances within the water sample.

4. The following individual organic compounds probably will be included in future drinking water criteria or standards and should be included in the monitoring program: benzene, benzidene, benzo (a) pyrene, chloroform, carbon tetrachloride, diphenylhydrazine, ethylene dibromide, paradichlorobenzene, 1, 1-dichloroethylene (vinylidene chloride) nitrosamines, hexachlorobenzene, hexachlorobutadiene, nitrobenzene, nitrochlorobenzene, pentachlorophenol, polybrominated biphenyls, polynuclear aromatic hydrocarbons (those covered in the World Health organization standards), tetrachlorodibenzopara-dioxin, 1, 2, 4-trichlorobenzene, 1, 2-trichloroethylene, tricresylphosphate, vinyl chloride, and styrene. It is suggested that a survey of industries upstream from the pilot plant be conducted to determine the types of raw materials used and the products manufactured and potential principal waste byproducts that would be discharged into the water. The results of such a survey may lead to a modification or reduction of the list of individual compounds to be monitored in the output water.

5. Consideration should be given to increasing the number of inorganic elements assayed and to conducting the analyses simultaneously on the samples. Simultaneous multi-elemental analysis can presently be conducted by a number of different techniques including proton-induced X-ray emission, inductively coupled plasma emission, and neutron activation analysis.

6. Water at various stages of treatment and the final output water will require toxicological testing to assure the absence of harmful substances that might not

be detected by chemical analyses. For testing water at various stages of the treatment process, consideration should be given to using rapid in-vitro screening tests such as Ames bacterial systems and mammalian cell cultures. More time consuming and expensive whole animal studies can be reserved for testing the final output water. The design of such a testing program will require detailed planning by competent toxicologists working in conjunction with the designers of the overall experimental and evaluation program.

7. In all aspects of toxicological testing, it is desirable that work undertaken for the pilot plant project not duplicate work being done elsewhere. This general guideline could help prevent expenditures of limited resources for the overall testing and evaluation program.

LETTER REPORT OF MARCH 22, 1979

March 22, 1979

Colonel G. K. Withers
District Engineer
Baltimore District, Corps of
Engineers
P.O. Box 1715
Baltimore, Maryland 21203

Dear Colonel Withers:

This letter is written on behalf of the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project and conveys the committee's review of the final draft report entitled "Development of a Testing and Evaluation Program for the Experimental Estuary Water Treatment Plant, Washington, D.C." dated October 1978. The following review is based on a meeting of the committee on November 16-17, 1978, during which the final draft report was discussed with representatives of the Army Corps of Engineers and the consultants that prepared the report. A list of our committee members is attached.

In our second letter report dated August 4, 1977, the committee commented upon a proposed testing and evaluation program that was described in Chapter XXXIV in the Corps' "Design Memorandum" for the Experimental Water Treatment Plant (EEWTP). Our present comments will make frequent reference to the previous letter because in large part they reiterate our earlier concerns. The August 4, 1977 letter also provides background information about our committee's role in the EEWTP project.

The following comments are under headings that correspond either to headings in our earlier letter report or to the principal sections in the final draft report on the testing and evaluation program.

SPECIFICATION OF INPUT WATERS

During discussions with representatives of the Corps on November 16, 1978, we learned that the plan to blend nitrified wastewater effluent with estuary water to make up the input waters for the EEWTP has been altered. This significant change in the final draft report was made necessary because nitrified effluent is not available from the Blue Plains wastewater treatment plant in suburban Maryland. We learned further that the Corps plans to compensate for this unanticipated development by pre-treating the available secondary effluent by an ion exchange process in order to reduce ammonia. This appears to us a possible but regrettable solution to an unfortunate situation. However, we are encouraged to find at the top of page 32 of the final draft report that "Should any of these treatment facilities (at the Blue Plains plant) not be in operation as scheduled, the make-up of the input and its impact on the experimental program will require re-evaluation in order to maintain the integrity of the testing and evaluation program as presented in this report."

Thus, when the re-evaluation is performed, the committee urges the Corps to also determine the impact of the decision not to use wastewater effluent that has been filtered and disinfected. This advice is based upon the belief that the effluent might cause such problems as the fouling of the ion exchange resins and the screens in the EEWTP. Moreover, the chosen effluent quality will not be representative of the wastewater that will be discharged into the estuary at some time in the future, when a full-scale estuary water treatment plant might be constructed. Cognizance of that situation and its implications to the testing and evaluation program is of fundamental importance to the success of the project. As suggested at the bottom of page 31 of the Corps' final draft report, the situation can be remedied, if necessary, during the second year of the testing program.

In addition to the problems noted above, we find that the Corps has not devoted sufficient overall attention and effort to understanding the quality of the input water that will require treatment. In this connection, inadequate data have been obtained on the quality of the Blue Plains effluent, the Estuary Baseline Study is not providing all the data that was once envisioned, especially regarding organics, and the potential usefulness of data from other agencies and studies has not been fully explored (e.g., the U.S. Geological Survey Potomac Estuary Study). The committee persists in its view, as expressed in its report of August 4, 1977, that an early start should be taken to collect analytical data in order to characterize the estuary water to be blended for the raw water input to the EEWTP. Significant lead time is needed to evaluate the accuracy and precision of the analyses used for detecting organic compounds.

With regard to composition of the input water, we find that the proposed input blending ratio of one part wastewater effluent to two parts estuary water needs further study. Such study would provide maximum assurance that the blend will achieve a reasonable simulation of the raw water quality that a full-scale regional estuary water treatment plant is most likely to encounter in the future. It is not clear to the committee whether the ratio chosen was based on objective, thorough, and rigorous analyses of adequate data or on subjective judgment similar to that presented in the last paragraph on page 32 of the final draft report.

The basic questions that the committee considers inadequately answered about the input water composition is: What percentage of wastewater effluent will be in the estuary during operation of a full-scale estuary water treatment plant, and how will this vary over a significant period of time? In answering these questions, it would be helpful to have a duration curve showing the probability of freshwater flows past a full-scale plant. The preparation of such a curve would require consideration of both freshwater flows and water supply withdrawals upstream of the plant. This, in turn, will require an analysis of hydrologic data and the establishment of (a) projections of upstream withdrawals for water supply, (b) estimates of the capacity of a full-scale plant, and (c) calculations of the freshwater input to the estuary, especially in relation to drought frequency and duration.

If the Corps considers it unlikely that the future water quality conditions of the estuary can be satisfactorily simulated regardless of the blending ratio, consideration should be given during the second year of testing to the use of input water that characterizes the extreme conditions likely to be encountered by a full-scale plant. This might be done, for example, by using Blue Plains effluent alone and by using estuary water during a storm occurring while the river is at or near low-flow as types of input water for the EEWTP.

EVALUATION OF RESULTS: PROCESS EFFECTIVENESS AND OUTPUT WATER QUALITY

Evaluation of the EEWTP will depend upon adequate samplings of treatment process streams, thorough analyses of the samples for all important water quality parameters, and comparisons of the test results with a suitable set of standards. The testing and evaluation program relies heavily upon time-series analysis for determining much of the sampling program and the frequency of many of the parameter analyses. While time-series models are good in theory, they should receive continued study and necessary adjustment, as test data become available. Awareness of this is expressed on pages 35, 38, and 43 of the final draft report, and we believe that the proposed integration of models with real data needs to be rigorously pursued throughout the testing and evaluation period.

What we have just stated is especially true of the sampling scheme chosen for organic compounds. The committee considers organic compounds to be particularly important for judging the EEWTP. The final draft report gives insufficient attention to the basis for the selection of the sampling frequency for the detailed analyses of organic compounds presented in Table 3.1 of the Report. This aspect of the testing program needs to be more carefully reviewed.

In regard to sampling and analysis of parameters to determine process effectiveness, we conclude that:

- Water quality data on both the raw water input to the plant and the finished output water should be correlated with weather and other significant events such as chemical spills, which could alter the effectiveness of treatment processes.
- Consideration should be given to using manual chemical oxygen demand (COD) analysis on a routine basis for back-up in case the automated instrumentation fails.
- Toxicological tests should be made on samples that have been completely characterized analytically. Analysis for synthetic organics and <u>in vitro</u> tests using the same test sample should be coordinated.
- For a critique of the anticipated toxicological testing, more details than are presented in the final draft report would be required on the Ames tests and mammalian cell culture tests that are now proposed. For example, how will the water samples to be tested be

taken and prepared, how will volatile compounds be handled, and what specific test protocols will be used?

- Sampling and testing for viruses in raw and finished water should employ state-of-the-art techniques--a matter the committee considers important because of the rapid developments being made in virus detection.

A crucial aspect of the evaluation of the test results is the choice of standards against which to make comparisons. The Corps has chosen to apply national drinking water regulations and standards as well as the quality of the water provided by its Washington Aqueduct Division. We agree with this decision, insofar as quality criteria for municipal water supplies taken from polluted sources do not exist, but as we stated in our August 4, 1977 letter report we suggest that the comparison should also be made with the other major water supply sources in the metropolitan Washington area. This position is based on our understanding that a full-scale estuary water treatment plant could serve the entire metropolitan area through a series of finished water interconnections. In our earlier report, we suggested that the quality of the treated estuary water be compared to the finished water supplies of other cities where reasonably comparable data exist. The committee hopes that analytic comparisons with water elsewhere remains a practical consideration within the Corps' EEWTP project. The U.S. Environmental Protection Agency has studied the drinking water of some 80 cities, and therefore, data comparable to that required for the EEWTP are at hand.

On page 7 of the final draft report, under the heading Evaluation of Water Quality, there is a statement that evaluation of the EEWTP is hampered because, among other things, there is "no basis for assurance that the public will accept any quality of water produced from the estuary source." We trust that insight into the uncertainties of public acceptance will come from the Corps' ongoing Metropolitan Washington Area Water Supply Study. Without this information, the estuary cannot be fully evaluated as an alternative water supply source.

Our final comment concerns the parameters of water quality to be studied and the sampling locations and frequencies presented in Tables 1 and 3 in the final draft report. We encourage the Corps to remain flexible about such matters so as to allow adjustments to new trends in technical information and to data that become available during the EEWTP project. As more scientific information or guidelines become available on using polluted sources of water for municipal supplies, it may be prudent to modify the sampling and parameter analysis program to include either more or fewer process points and quality criteria. We recognize that an awareness of this is evident on pages 55-57 of the final draft report. We add one cautionary note: Expert advice should be sought in deciding the final parameters of water quality that will be used for evaluating the EEWTP. The Corps may find itself subject to criticism and controversy if, as stated on page 57 of the final draft report, certain evaluations are "based on guidelines determined to be acceptable to the Corps of Engineers."

In closing, the committee is pleased to commend the Corps on the overall progress made in developing the testing and evaluation program. Although we find that several aspects of the program ought to be strengthened, as we have noted above, our general view is that the program is a reasonably adequate one. Its success will depend in large part on the knowledge, experience, and skills of those who operate, test, and evaluate the EEWTP, whether they are members of the Corps' staff or contractors. We encourage the Corps to continue to be intimately involved in and informed of the status of the project, even though non-Corps personnel may have the day-to-day working responsibility for the EEWTP.

The committee appreciates the assistance that the Corps' staff and consultants have given us in conducting this review, and we look forward to receiving any comment or questions that this letter report may elicit.

Sincerely yours,

Gerard A. Rohlich
Chairman, Committee to
Review the Potomac Estuary
Experimental Water
Treatment Plant Project

cc: Daniel J. Mahoney
Micah H. Naftalin
Charles R. Malone

LETTER REPORT OF NOVEMBER 6, 1981

November 6, 1981

Colonel James W. Peck
District Engineer
Baltimore District, Corps of Engineers
P.O. Box 1715
Baltimore, Maryland 21203

Dear Colonel Peck:

On March 18, 1981 the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project met with members of your staff to discuss the testing and evaluation program underway in the Corps' Experimental Estuary Water Treatment Plant (EEWTP) study. This letter conveys our views on the program and therefore constitutes a continuation of the National Research Council's review of the EEWTP as specified in Contract Number DACW31 76 C 0069 between the Department of the Army, Corps of Engineers, Baltimore District, and the National Academy of Sciences.

The letter report has been reviewed on behalf of the National Research Council by an independent group of experts, other than members of the committee, according to the customary procedures approved by the Report Review Committee of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

BACKGROUND

Section 85 of the Water Resources Development Act of 1974 (Public Law 93-251) authorizes the Corps of Engineers to construct, operate, and evaluate a pilot project on the estuary of the Potomac River to determine the feasibility of using the estuary as a water supply source for the metropolitan Washington, DC area. The legislation specifies that the water treatment project will be operated and tested for a period of two years and that results of the study will be reviewed by the National Academy of Sciences and National Academy of Engineering.

When the Corps of Engineers began its Experimental Estuary Water Treatment Plant (EEWTP) study in 1976, the Academies through the National Research Council, established the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project. The committee's task has been to observe and comment on the study at appropriate stages, and also to review and report on the Corps' final report to Congress.

Since 1976, the committee has met seven times to review the EEWTP study, and has prepared three letter reports, subsequently transmitted to the Corps of Engineers by the National Research Council. The first report, dated March 2, 1977, commented upon the design analysis and specifications for the EEWTP. Subsequent reports, dated August 4, 1977 and March 22, 1979, commented respectively on proposed and final plans for a testing and evaluation program for the EEWTP. The committee's 1979 letter report addressed itself to the October 1978 final report on the testing and evaluation program, titled "Development of a Testing and Evaluation Program for the Experimental Estuary Water Treatment Plant, Washington, DC" (prepared for the Corps by Malcolm Pirnie, Inc.).

At its sixth meeting, on November 20, 1980, the committee learned that the two-year testing and evaluation program for the EEWTP would begin on March 16, 1981 and that the program would be based on the 1978 report by Malcolm Pirnie, Inc. Because the outcome of the study depends so critically on the testing and evaluation program, the committee took two steps to ensure that it was familiar with the program. First, the committee asked its Panel on Quality Criteria for Water Reuse to review plans for the program as of January 1981. Second, the committee requested a Corps of Engineers briefing on the program as actually implemented on March 16. Such a briefing was arranged for March 18, two days after the EEWTP testing program began.

The panel, whose ultimate task is developing criteria for the acceptability of reused wastewater, met on January 19 to discuss the human health aspects of the testing and evaluation program. In February it transmitted its report commenting on the program to the committee.

Thus, on March 18, at its seventh meeting, the committee had available to it the panel report and information from the Corps on the testing and evaluation program as actually implemented. After considering all the materials available, the committee decided that the panel's comments were significant to warrant this letter report.

THE EEWTP TESTING AND EVALUATION PROGRAM

James M. Montgomery, Consulting Engineers, Inc., is operating and testing the EEWTP for the Corps of Engineers. An explicit description of the program, in Montgomery File No. 1040.0160, was made available to the committee. Because the existing program builds on the one initially developed by Malcolm Pirnie, Inc., understanding the testing now underway requires a familiarity with Pirnie's October 1978 report.

To help those familiar with Pirnie's report, we are appending two documents from the Montgomery material that reflect alterations in the complex testing and evaluation program finally implemented. Attachment A provides the critical information on the types and frequencies of tests being conducted on the EEWTP. This information is keyed by numbers to specific locations and treatment processes in the plant as shown on Attachment B. To provide more information than this would render our report needlessly complex for the purpose of conveying our comments to the Corps.

COMMENTS

The EEWTP testing and evaluation program, as presented to the committee and reflected in Attachments A and B, appears reasonable. It embodies flexibility that will permit future alterations based on analyses of continuing tests. For example, if data on concentrations of inorganic compounds indicated that less frequent analyses would suffice, those tests could be reduced in number and frequency. This would conserve the program's scarce resources, allowing them to be concentrated elsewhere, such as on the health aspects of the program.

The committee believes it is important to conduct the program in the most cost-effective manner possible, so that resources may be made available for additional health-related testing. Accordingly, the committee endorses the changes in the testing program recommended by the Panel on Quality Criteria for Water Reuse (Attachment C).

The importance of sufficient tests on potential health effects cannot be overemphasized. When the EEWTP study was conceived during 1974-76, the potential risks of organic chemicals in drinking water was not well understood as it is today. This aspect of water quality science has developed rapidly in more recent years, so that it now dominates the success of the EEWTP. Public acceptance of the concept of water reuse embodied in the EEWTP study will depend upon the Corps' ability to demonstrate that the water is safe to drink. Such a judgment, in terms of water quality science as now perceived, will rest heavily on the consequences of such tests as suggested by the panel.

We recognize that these concerns were not apparent when the study was conceived and that to take them into account now will require modification of the testing and evaluation program. A complete reevaluation of the program is unnecessary, since the plan embodies enough flexibility to accommodate most of these concerns. However, incorporating additional health effects tests will be costly, and our final recommendation is that prompt efforts be made to secure additional funds. The attached panel report (Attachment C) includes guidance as to the additional tests required and their costs.

FUTURE PLANS

The committee hopes to have the opportunity, at an appropriate stage, to study results of the EEWTP testing and evaluation program that began on March 16. Our understanding of the program's schedule suggests that substantial and significant data will be available after six months of testing. With this in mind, we will schedule a one-day meeting late in 1981, in hopes that the Corps can provide material for our study and subsequent discussion.

The cooperation of the Corps and its consultants with the committee has been exemplary. We look forward to continued appraisals of the EEWTP testing and evaluation program and to future phases of the study.

On behalf of the Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project and its Panel on Quality Criteria for Water Reuse, I remain respectfully yours,

Perry L. McCarty,
Chairman of the Committee

ATTACHMENTS

A. "Frequency of Sampling" (attachment C from Montgomery)

B. "EEWTP-Automatic Composite Sampling" (attachment F from Montgomery)

C. "Review of the Sampling and Analytical Programs of the Potomac Estuary Experimental Water Treatment Plant" by the Panel on Quality Criteria for Water Reuse.

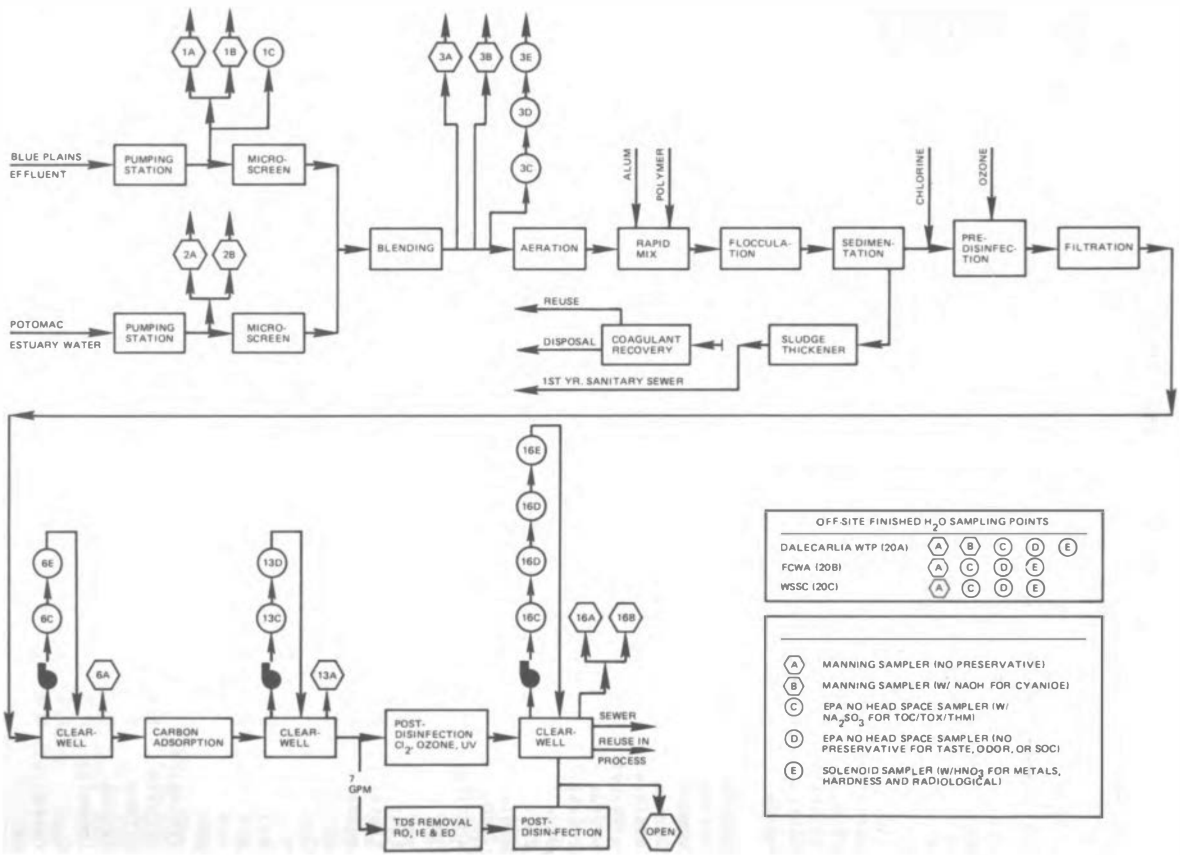
ATTACHMENT A

Size Needed for Analysis	Preservation and Handling	Analytical Method	Reference	Analysis Location
50 cc	4°C	chloroplatinate	EPA 110.2	EEWTP
200 cc	4°C--glass, no head space	threshold	EPA 140.1	Pas
100 cc	4°C	evaporation	EPA 160.1	EEWTP
100 cc	4°C analysis in 24 hrs.	filtration	EPA 160.2	EEWTP
--	in situ	conductivity	EPA 120.1	EEWTP
200 cc	4°C--glass, no head space	comparison	APHA 221A	Pas
--	in situ	thermometer	EPA 1170.1	EEWTP
100 cc	4°C--24 hrs.	turbidimeter	EPA 180.1	EEWTP
10 cc	4°C	automated methyl orange	EPA 310.2	Pas
1000 cc	4°C--$HgCl_2$	electron microscope	EPA interim	Pas
25 cc	4°C	ion chromatography	IC Anal of Env Pollutants (1978)	Pas
10 cc	4°C	automated $Hg(SCN)_2$	EPA 325.2	Pas
2000 cc	immediate	measure residual	ASTM 1237	EEWTP
200	immediate	amperometric	APHA 409C	EEWTP
300	immediate BOD bottle	electrode	EPA 360.1	EEWTP
10 cc	4°C--plastic	automated complexone	EPA 340.3	Pas
50 cc	4°C HNO_3pH2	ICP for Ca + Mg	Fed Register 12/79	Pas
25 cc	4°C	ion-chromatography	DIONEX Document	Pas
200 cc	4°C HNO_3pH2	ICP	Fed Register 12/79	Pas
10 cc	4°C H_2SO_4pH2	automated phenate	EPA 350.1	Pas
10 cc	4°C H_2SO_4pH2	automated Cd reduction	EPA 353.2	Pas
10 cc	4°C H_2SO_4	automated ascorbic acid	EPA 365.1	Pas
1000 cc	immediate	iodometric	APHA 423A	EEWTP
--	in situ	electrode	EPA 150.1	EEWTP
10 cc	4°C plastic	ICP	Fed Register 12/79	Pas
10 cc	4°C	automated methylthymol blue	EPA 375.2	Pas
10 cc	4°C pH 12	automated colorimetric	EPA 335.3	Pas
100 cc	4°C	colorimetric	EPA 425.1	Pas
4000 cc	4°C extract in 7 days	GC/GC-MS	Fed Register 12/79	Pas
60 cc	4°C-$NaSO_3$, no head space	GC	EPA 501.2	Pas
25 cc	4°C-$NaSO_3$, no head space	TOC analyser	EPA 415.1	Pas
200 cc	4°C-$NaSO_3$, no head space	TOX analyser	TOX Joint Task Group Report	Pas
25 cc	H_2SO_4	automated phenate	EPA 351.2	Pas
2000 cc	HNO_3	proportional counter	APHA 703	Pas
100 cc	Sterile	Umukua assay	DIFCO	Pas
100 cc	Sterile	membrane counting	APHA 909	EEWTP
Up to 500 gal	Sterile	counting filter	EPA-600/9-79-001	Pas
6 1	Sterile	MPN	Modified APHA 912A	EEWTP
10 cc	Sterile	20°C incubation	APHA 907	EEWTP
Up to 500 gal	Sterile	concentrate and count	Modified APHA 913	Pas
100 1	resin 4°C	elute from resin - test	Mutation Research 31:347-64 (1975)	Pas
100 1	resin 4°C	elute from resin - test	Cancer Research 33, 3239-69 (1973)	Pas

FREQUENCY OF SAMPLING AT SITE #

Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20a	20b	20c	Type of Sample
Color			D			D										D				D			Composite
Odor																D							Composite
TDS	D	D	D													D				D			Composite
TSS		D	D			D							D										Composite
E.C.		C		C																			Continuous
Taste																D				D			Composite
Temperature	C	C	C										C			C				C			Continuous
Turbidity	D	D	C		C	D			D			D	D			C				C			Composite
Alkalinity		D	D													D				D			Composite
Asbestos	W	W	W			W										W			W	W	W	W	Composite
Bromide			D													D				D			Composite
Chloride	D	D	D													D				D			Composite
Chlorine Demand													G										Grab
Chlorine Residual																G				G			Grab
Dis Oxygen	G	C				G							G			G							Grab
Fluoride			D													D				D			Composite
Hardness		D	D										D			D				D			Composite
Iodide	D	D	D													D				D			Composite
Metals			D			D										D			D	D	D	D	Composite
Ammonia		D	D										D			D				D			Composite
NO_3-NO_2			D										D			D				D			Composite
Ortho-PO_4			D										D			D				D			Composite
Ozone						G								G									Grab
pH	C	C	C		C								C			C			C	C			Continuous
Silica	D	D	D													D				D			Composite
Sulfate	D	D	D													D				D			Composite
Cyanide	D	D	D													D				D			Composite
MBAS	D	D	D													D				D			Composite
SOC			T										M			T				T	T	T	Composite
THM			S										S			S**				S**	S	S	Composite
TOC	D		D	C		C	C	C	C	C	C	C	D			D				D	D	D	Composite
TOX	D		D										D			D				D	D	D	Composite
TON			D																				Composite
Radiological			SW			W										W				W	W	W	Composite
Endotoxin	M	M											M			M				M			Grab
Coliform	G	G											G			G				G			Grab
Parautes	M	M				M							M			M				M	M	M	Grab
Salmonella	M	M											M			M				M			Grab
SPC	G	G											G			G				G			Grab
Viruses	M	M				M							M			M				M	M	M	Grab
Ames																W				W	W	W	Grab
Mat = aban																M				M	M	M	Grab

ATTACHMENT B



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EEWP-AUTOMATIC COMPOSITE SAMPLING

ATTACHMENT C

REVIEW OF THE SAMPLING AND ANALYTICAL PROGRAMS OF THE POTOMAC ESTUARY EXPERIMENTAL WATER TREATMENT PLANT

by the

Panel on Quality Criteria for Water Reuse

for the

Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project

The Panel on Quality Criteria for Water Reuse is assembling a report on the assessment of health effects criteria for water reuse. In the process of developing this report the panel was asked to review the sampling and analytical programs of the Estuary Experimental Water Treatment Plant (EEWTP) Study. In the panel's opinion, changes in the testing program would yield data better suited to addressing the issue of human health effects due to chemical constituents. The primary issue in evaluating the success of the EEWTP is the usefulness of the test programs results in judging the potential health effects of reused water. Unless the program enables such judgments, it is questionable whether the goal of determining potability can be achieved.

The experimental plans reviewed by the panel are in need of improvement in two important areas:

- Predictive testing for adverse health effects
- More comprehensive organic analyses.

Each of these areas is treated briefly in the sections that follow.

PREDICTIVE TESTING FOR ADVERSE HEALTH EFFECTS

The panel is of the opinion that the most practical way to make health effects judgments of the water from the Potomac Estuary is to compare the potential adverse health effects of currently used, conventional potable water supplies and water prepared from treated wastewater effluent blended with Potomac estuary water.

(We note however, that such a comparison does not indicate the absolute hazard of either source.)

Risk evaluation rests on a series of toxicological procedures that rely eventually on responses in whole animals. Traditionally, individual chemicals are evaluated in such tests. However, reused water contains mixtures of many chemicals, and evaluations of the treatment process must take this reality into account. The health effects testing recommended here involves evaluating the effects of exposure to mixtures in whole animals. This approach departs from traditional toxicological procedures, but it more closely represents actual human exposure. Further, the panel recognizes that generally, in the testing of health effects of real environmental samples, regardless of environmental medium, such mixtures should be used.

It would be virtually impossible to evaluate thoroughly and compare the health effects differences of reused and "conventional" water based on analysis of individual compounds alone. Data of this type are not only time-consuming to obtain, but are also incapable of predicting the health effects of combinations of chemicals. The number of compounds already identified in drinking water supplies, although large, represents only 10-15 percent of the total organic carbon known to be present. It is impossible to prepare accurate synthetic mixtures for use in whole animal studies, and concentrates of organic constituents from actual water samples must be used.

The testing of mixtures in animals does create problems in the interpretation of results for risk evaluation purposes, besides the usual problems of extrapolating the high concentrations (doses) needed for testing to the levels to which humans would be exposed to in drinking water. The following factors assume experimental importance, owing to the complex and undefined compositions of the mixtures involved:

- The variability of sample composition with time
- Additive, synergistic or antagonistic effects of mixture components
- The influence of concentration procedures on the chemical and physical compositions of test materials
- The chemical and physical stability of concentrates with time.

Animal studies will require large quantities of water concentrates. A concentrate can be obtained and used throughout the study, or it can be prepared on a continuing basis over the course of the study. The latter is preferable, because it more accurately simulates actual human exposure. Any effects observed in animal studies would be compared to results obtained with conventional water supplies using similar concentrations.

Considerations of concentration factors are central to the testing sequence. The aim is to obtain high enough concentrations to get measurable toxic effects while minimizing the formation of artifacts (effects due to the concentration procedure). The potential for such effects should be evaluated toxicologically before dose-response testing. This can be accomplished in short-term tests, such as the Ames test, at a constant dose but varied concentration factors. Dose-response testing can then be carried out at a concentration factor that displays no such concentration effects.

Because of the uncertainty in this area it would also be wise to prepare concentrates by at least two complementary procedures. Although macroreticular resins are useful for concentrating aqueous samples, especially for nonpolar constituents and aquatic humic material, recovery of polar constituents from these resins is variable. Although it may not be necessary for analytical purposes, it is recommended that reverse osmosis (RO) be employed as a complementary concentration method, since this process is already available as a unit operation of the EEWTP. The buildup of salt during the RO concentration process must be considered; it may be necessary to desalt as well, perhaps by electrodialysis.

In selecting the actual health effects studies to be performed, the panel recommends emphasizing those types of toxicity termed irreversible effects (including carcinogenicity, teratogenicity, and genetic effects). Some of these tests require chronic exposure to samples of water concentrates. However, since chronic studies take long periods of time compared with the time course of this project, short-term tests (e.g., mutagenicity, teratogenicity and in vitro transformation assays) could be used to determine the emphasis given to later chronic exposure tests.

Positive results in the short-term tests could form the basis for alterations in the treatment process.

Such changes, which reduce the short-term toxicity of water concentrates, should precede the selection of samples for in vivo testing. Also, seasonal variations in the composition of reused water mixtures that affect the final product from the treatment process should be evaluated.

The panel envisions toxicological evaluation of water concentrates as consisting of three separate phases. Phase I includes short-term in vitro, tests and an in vivo, mouse or rat study. Data from Phase I can be obtained relatively quickly and inexpensively, and are indicative of mutagenic, carcinogenic, and teratogenic potential as well as target organ toxicity. Phase II and Phase III testing are required to evaluate the initial toxicological test results for relevance to human health effects. Phase II tests involve a subchronic 90-day feeding study in rodents or dogs, and a reproductive study in rodents. Phase III tests involve chronic studies of carcinogenicity and other special evaluations. The panel recognizes that reversible toxic effects may be as important as irreversible effects, however the panel did not specifically address this issue. This was due in part to the overall concerns with irreversible effects and also because it was thought that careful implementation of Phases II and III would be able to detect reversible as well as irreversible effects.

Phase I tests, including in vitro and in vivo components, are recommended for immediate implementation in the EEWTP analytical program. The full panel report will address all phases of toxicological evaluation.

PROPOSED PHASE I TESTING

In Vitro Tests

Short-term tests including mutagenicity and in vitro transformation models, have been used to predict the mutagenic and carcinogenic potentials of chemicals from a variety of environmental sources. The degree of correlation between the results of these tests and those of whole animal studies has been high enough to make these tests valuable in screening large numbers of chemicals to establish the need for further toxicological evaluations. The preliminary evaluation of reused water for possible health effects requires testing large numbers of water concentrates from experimental purification plants; short-term tests will be needed as a part of the initial biological testing scheme.

Short-term tests may be grouped according to the specific information required. The Toxic Substances Control Act Interagency Testing Committee workshop held in San Antonio, Texas, in February 1979, recommended one such grouping for detecting carcinogenic potential:

a. Point mutation in *Salmonella typhimurium* (Ames Assay)
b. Gene mutation in mammalian cells such as mouse lymphoma or Chinese hamster ovary models
c. *In vitro* transformation.

These three types of assays, used as a battery, were recommended based on their degree of correlation with rodent bioassays and the value of a negative result.

In Vivo Tests

It is customary to conduct acute toxicity tests for general and teratological toxicity in rats or mice. In this case the test material is administered once or several times over a relatively short period of time, and the animals or their offspring are observed for toxic and lethal effects. This panel recommends a 14-day oral study in mice. An LD_{50} (lethal dose to 50 percent of the population) should be determined if possible. The study should include *in vivo* cytogenetic analysis (metaphase) of bone marrow cells, histopathological analysis of target organs and clinical pathology. The panel recommends also an 18 to 20-day oral study in mice or rats, to indicate teratological effects.

ESTIMATED TESTING COSTS

Table 1 summarizes the estimated costs of the recommended tests, including an artifact formation test and toxicity dose range finding. Costs were obtained by averaging estimates given by two private toxicological testing laboratories. The values are given as approximations and may change when detailed testing protocols are prepared.

TABLE 1 RECOMMENDED ADDITIONAL TESTS AND APPROXIMATE COSTS

Test	Cost per Sample ($)	Number of Samples	Total Cost ($)
Point mutation	--	--	--
Gene mutation	--	--	--
In vitro transformation	4,800	6	28,800
Artifact formation test	6,000	2	12,000
Toxicity range finding	6,000	1	6,000
In vivo cytogenetics		6	18,000-87,000
Mice	13,500		
Rats	14,500		
General toxicity and LD_{50} (14-day)	18,000	6	108,000
Teratology (Rats)	30,000	6	180,000

In Vitro Tests

No costs are given for the gene and point mutation tests, since they are parts of the current testing protocol. Cost for the *in vitro* transformation tests are $4,800 per sample.

In Vivo Tests

The costs for an *in vivo* (14-day) dosing schedule (LD_{50}) using 15 mice of each sex in control and treatment groups and including only gross necropsy, ranges from $3,000-$6,400 per sample. The addition of bone marrow cytogenetic analysis would add approximately $13,500 (mice) or $14,500 (rats) per sample. Additional costs for teratological testing in rats would be $30,000 per sample.

The chances of discovering any significant target organ toxicity by light microscopy after only 14 days of dosing is remote, and complete histopathological examination is therefore thought to be unnecessary. By using only gross pathology as a guide and examining only a few tissues (e.g., liver and kidney) the total price (Table 1) would be kept at approximately $18,000 per sample.

COMPREHENSIVE ORGANIC ANALYSIS

Arrangements should also be made to obtain organic analyses other than those represented by the priority pollutants. The panel's concern is that most of the organic composition will probably not be priority pollutants, but may be other chromatographable organic constituents appearing on the reconstructed gas chromatograms (RGC) of the priority pollutant fractions.

It would be prudent therefore for Montgomery Engineers to estimate the resources required to identify all peaks appearing in the RGC's. This may require a gas chromatography-mass spectrometry (GC-MS) facility capable of electron impact, chemical ionization, and mass measurement accuracy in the order of 10 ppm (-0.001 mass units). This accuracy would give the best chance of evaluating the elemental compositions of previously unidentified peaks on the RGC's, and would therefore enable a more extensive qualitative estimate of the effluent's organic composition.

At the risk of repetition it should be emphasized that the priority pollutant procedures are designed to identify only a limited number of specified compounds (the priority pollutants). In fact, without this qualitative evaluation there could be a serious false economy in the application of relatively sophisticated GC/MS techniques to the effluent samples.

In addition, the fractions of purgeable and nonpurgeable organic chemicals identifed and quantified by the GC and GC-MS analyses should be estimated. A useful approach would be to compare the purgeable and nonpurgeable organic carbon measured in the unconcentrated samples to the values calculated from the summation of individually quantified organics in the concentrated volatile and nonvolatile fractions, respectively.

Finally, this comprehensive organic analysis will be vitally important for characterizing the composition of the concentrates prepared for toxicological testing. Comparison of this data with similar data on unconcentrated effluent will permit some judgment on the possible artifacts introduced in the concentration process.

APPENDIX B

GLOSSARY

Definitions reprinted from: Water and Wastewater Control Engineering Glossary Third Edition, by permission. Copyright 1981, The American Water Works Association.

ACTIVATED SLUDGE PROCESS--A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is then separated from the treated wastewater by sedimentation and wasted or returned to the process as needed.

AIR STRIPPING--Technique for removal of volatile substances from a solution. The process is designed so that the solution containing the volatile pollutant contacts large volumes of air.

ALGAL BLOOM--Large masses of microscopic and macroscopic plant life, such as green algae, occurring in bodies of water.

ANAEROBIC--(1) A condition in which no free oxygen is available. (2) Requiring, or not destroyed by, the absence of air or free oxygen.

ANION--A negatively charged ion, attracted to the anode under the influence of electric potential.

BIOCHEMICAL OXYGEN DEMAND (BOD)--The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

CATION--A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in potential.

COLIFORM-GROUP BACTERIA--A group of bacteria predominantly inhabiting the intestines of man or animal, but occasionally found elsewhere.

CONSERVATIVE PARAMETERS--Water quality parameters that are not subject to biochemical degradation, precipitation, volatization, etc.

EFFLUENT--Wastewater or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial plant.

ESTUARY--A passage in which the tide meets a river current; especially an arm of the sea at the lower end of a river.

EUTROPHICATION--Nutrient enrichment of a lake or other water body, typically characterized by increased growth of planktonic algae and rooted plants. It can be accelerated by wastewater discharges and polluted runoff.

FILTRATION--The process of contacting a dilute liquid suspension with filter media for the removal of suspended or colloidal matter, or for the dewatering of concentrated sludge.

GAS CHROMATOGRAPHIC MASS SPECTROMETER (GC-MS)--An analytical technique involving the use of both gas chromatography and mass spectrometry, the former to separate a complex mixture into its components and the latter to deduce the atomic and molecular weights of those components. It is particularly useful in identifying organic compounds.

INFLUENT--Water, wastewater, or other liquid flowing into a reservoir, basin or treatment plant, or treatment process.

INORGANIC MATTER--Mineral-type compounds that are generally non-volatile, not combustible, and not biodegradable. Most inorganic-type compounds, or reactions, are ionic in nature, and therefore, rapid reactions are characteristic.

MAXIMUM CONTAMINANT LEVEL (MCL)--The maximum permissible level of a contaminant in water at the free-flowing outlet of the ultimate user of a public water system, except in the case of turbidity, where the maximum permissible level is measured at the point of entry to the distribution system. Generally expressed in mg/L.

NITRIFICATION--The oxidation of ammonia nitrogen to nitrate nitrogen in wastewater by biological or chemical reactions.

NONCONSERVATIVE PARAMETERS--Water quality parameters subject to change by biological decomposition, or chemical or physical change.

NUTRIENT--Any substance that is assimilated by organisms and promotes growth.

ORGANIC--Refers to volatile, combustible and sometimes biodegradable chemical compounds containing carbon atoms bonded together with other elements. The principal group of organic substances found in wastewater are proteins, carbohydrates, and fats and oils.

POTABLE WATER--Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.

PRIMARY TREATMENT--The first major treatment in a wastewater treatment facility, usually sedimentation but not biological oxidation.

RAW WATER--Untreated water, usually the water entering the first treatment unit of a water treatment plant.

REVERSE OSMOSIS--An advanced method used in water and wastewater treatment which relies on a semipermeable membrane to separate the water from its impurities. An external force is used to reverse the normal osmotic flow, resulting in movement of the water from a solution of higher solute concentration to one of lower concentration.

SECONDARY TREATMENT--Used interchangeably with concept of biological wastewater treatment particularly the activated sludge process.

SEDIMENTATION--The process of subsidence and decomposition of suspended matter carried by water, wastewater, or other liquids, by gravity.

THRESHOLD ODOR NUMBER (TON)--The greatest dilution of a sample with odor-free water that yields a definitely perceptible odor.

TOTAL DISSOLVED SOLIDS (TDS)--The sum of all dissolved solids (volatile and non-volatile) in a water or wastewater.

TOTAL ORGANIC CARBON (TOC)--The amount of carbon bound in organic compounds in a sample. Because all organic compounds have carbon as the element, TOC measurements provide a fundamental means of accessing the degree of organic pollution.

TOTAL SUSPENDED SOLIDS (TSS)--The sum of insoluble solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids. Solid organic or inorganic particles held in suspension by agitation or flow.

TOXICOLOGY--The study of quantitative effects of chemicals on biologic tissue particularly in defining harmful actions and degree of safety.

WASTEWATER--The spent or used water of a community or industry which contains dissolved and suspended matter.

WASTEWATER REUSE--The direct or indirect use of treatment plant effluent for municipal, industrial, agricultural, recreational or water recharge applications.

WATER QUALITY CRITERIA--Scientific standards on which a decision or judgment may be based concerning the suitability of water of a specific quality to support a designated use.