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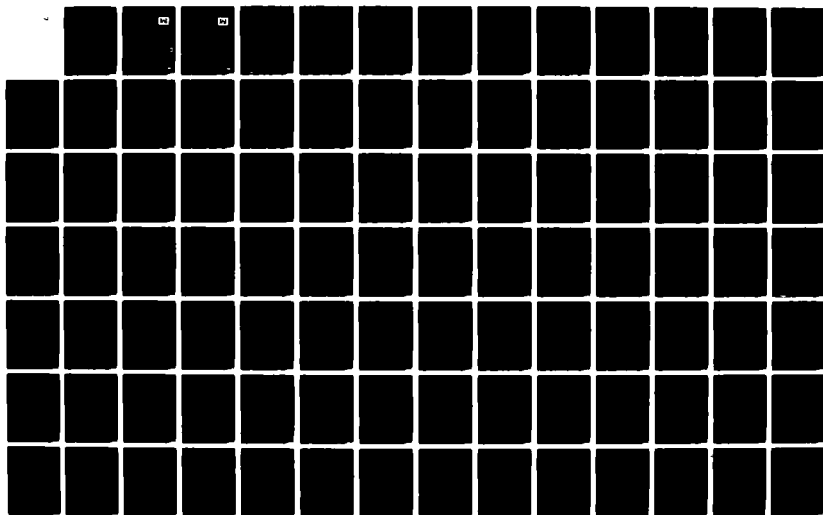
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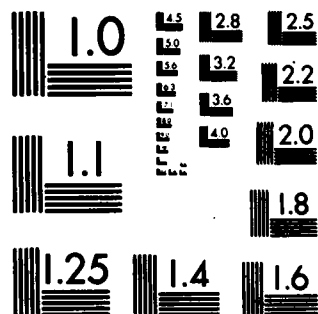
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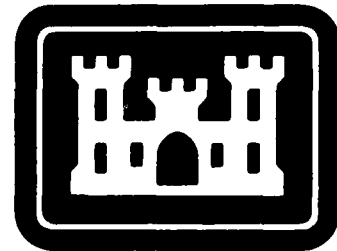




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OPERATION, MAINTENANCE
AND PERFORMANCE EVALUATION

of the

POTOMAC ESTUARY EXPERIMENTAL
WATER TREATMENT PLANT

EXECUTIVE SUMMARY

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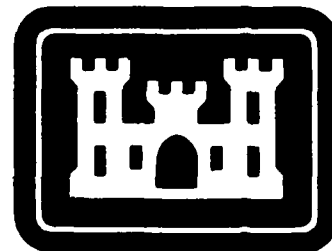
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BALTIMORE DISTRICT**



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AND PERFORMANCE EVALUATION
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POTOMAC ESTUARY EXPERIMENTAL
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EXECUTIVE SUMMARY

SEPTEMBER 1980 - SEPTEMBER 1983

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Water Resources Act of 1974 authorized the Baltimore District of the U.S. Army Corps of Engineers to investigate the use of the Potomac River Estuary as a possible supplemental water supply source for the Metropolitan Washington Area (MWA). Use of the Estuary, a source expected to be contaminated with substantial amounts of treated wastewater during a severe drought, was one of several structural and non-structural alternatives to meet the long term water supply needs of the MWA, which were evaluated in the U.S. Army Corps of Engineers' MWA Water		

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19. KEY WORDS (continued)

Estuary Model.

20. ABSTRACT (continued)

Supply Study.

The investigation evaluated the water quality produced by a 1.0 MGD demonstration water treatment plant (EEWTP), which was located adjacent to the Estuary at the Blue Plains WPCP, Washington, D. C.

Based on certain hydrologic conditions and the results of the EPA Dynamic Estuary Model, a raw water mix of 50 percent estuary water and 50 percent nitrified Blue Plains sewage effluent was selected for treatment.

Three water treatment process combinations were investigated. The first process combination included alum coagulation, sedimentation, intermediate chlorination, gravity filtration, granular activated carbon (GAC) adsorption and free chlorine disinfection. The second process substituted ozone as the intermediate oxidant. The final combination consisted of lime coagulation, sedimentation, recarbonation, gravity filtration, GAC adsorption at twice the contact time, ozone and chloramine for final disinfection.

An extensive water quality analysis program was conducted to determine the acceptability of the water for human consumption. The sampling frequency rates exceeded recommended standards. The analytical program parameters included physical and aesthetical (13); major cations, anions and nutrients (19); trace metals (24); radiological (5); microbiological (6) including enteric viruses (41 identifiable types), parasites (7), and four bacterial groups; organic (151); and toxicological (2). Finished water samples were collected from three MWA water treatment plants to compare their water quality against the project's finished water quality.

Within the limits of the analytical techniques used and the influent water quality conditions observed it was concluded that the three process combinations monitored were technically feasible of producing a water acceptable for human consumption.

Estimated treatment cost for a 200 MGD estuary water treatment plant, using design and operating criteria similar to that used in the EEWTP, are approximately 34.3¢/1000 gallons for the first alum mode and 47.6¢/1000 gallons for the lime mode of operations. Due to uncertainties over the plant's location, intake and certain finished water structures and related costs were excluded from the cost estimates.

ERRATA SHEET

EXECUTIVE SUMMARY

1. Synopsis, Page 4, Paragraph 2; first sentence should read, "EEWTP influent total coliform levels had a median value of 24,000/100 ml with a 90th percentile value of 160,000/100 ml."
2. Chapter E-2, Figure E.2-1; location arrow for Little Falls should be above end of free flowing river.
3. Chapter E-9, Page E-9-15, Table E.9-9; MCL for mercury should be 0.002 mg/L
4. Chapter E-9, Page E-9-18, Paragraph 4, "unknown heath effects" should be "unknown health effects"
5. Chapter E-9, Page E-9-22; page missing, attached page to be inserted in Chapter E-9.

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SYNOPSIS OF REPORT

BACKGROUND AND APPROACH

In 1974, the U.S. Congress passed the Water Resources Development Act, Public Law 93-251, which directed the Secretary of the Army, acting through the U.S. Army Corps of Engineers, to undertake an investigation of the use of the Potomac River estuary as a possible supplemental water supply source for the Metropolitan Washington Area (MWA). Use of the estuary, a source expected to be contaminated with substantial amounts of treated wastewater during a severe drought, is one of several structural and non-structural alternatives to meet the long-term water supply needs of the MWA, which were evaluated in the U.S. Army Corps of Engineers' MWA Water Supply Study.

Determination of the technical feasibility of using the estuary as a water supply source required the design, construction, operation and performance evaluation of a one million gallon per day (MGD) demonstration water treatment plant.

This Final Report presents the results of a two year testing program at the 1 MGD demonstration plant, designated the Potomac Estuary Experimental Water Treatment Plant (EEWTP). The EEWTP contained water treatment processes representing conventional and advanced water treatment technology expected to be capable of producing a finished water of quality acceptable for human consumption from a water source heavily contaminated with treated wastewater. The influent to the EEWTP was selected to simulate a water of quality similar to that expected in the estuary during a drought in the year 2030 equal to the worst recorded drought in the Potomac River basin.

The acceptability of the EEWTP finished water for human consumption (the most significant factor affecting the technical feasibility of an estuary water treatment plant) was based on comparison of EEWTP finished water quality to: (1) the current primary and secondary drinking water regulations; (2) the finished water quality observed during the testing program at three existing water treatment plants (WTPs) in the MWA; and, (3) proposed regulations, available health risk information, or water quality observed in other drinking waters outside the MWA.

Three water treatment process combinations were operated during the two year testing program. The first process combination, designated Phase IA, was operated for twelve months and included alum coagulation, sedimentation, intermediate chlorination, and gravity filtration followed by adsorption on granular activated carbon (GAC), and free chlorine disinfection. The second combination, designated Phase IB, was operated for four months with ozone replacing chlorine as the intermediate oxidant. Finally, the third combination, designated Phase II, was operated for eight months and consisted of lime

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coagulation, sedimentation, recarbonation, gravity filtration, GAC adsorption at twice the contact time as Phase IA, ozone as the final disinfectant, and chloramine as the residual disinfectant.

Sampling was conducted at key sites within the EEWTP, and in the finished waters at three local WTPs. Over 220 water quality parameters were monitored using analytical techniques meeting the requirements of the Environmental Protection Agency (EPA). The parameters have been organized into seven major groups for ease of presentation and discussion as follows: physical/aesthetic parameters (13); major cations, anions, and nutrient parameters (19); trace metal parameters (24); radiological parameters (5); microbiological parameters (6) including enteric viruses (41 identifiable types), parasites (7), and four bacterial groups; organic parameters (2 surrogate parameters, 149 primary organic compounds (confirmed identification and quantification); and two toxicological parameters (Ames mutagenicity assay, and a mammalian cell transformation assay). In addition, over 300 additional organic compounds were tentatively identified. Over 400,000 points of analytical information were generated from the monitoring programs.

In order to assess the economic feasibility of an estuary water treatment plant in comparison to other alternatives being considered to meet the long-term water supply needs of the MWA, cost estimates were prepared for a 200 MGD estuary water treatment plant. Because of uncertainties regarding the site of such a plant, costs were developed for the water treatment plant only, operating at 100 percent hydraulic capacity. Costs have been developed for EEWTP process combinations which demonstrated their capability to produce a finished water of quality acceptable for human consumption.

RESULTS AND CONCLUSIONS

SELECTION OF INFLUENT QUALITY

Based on a simulation of the Potomac River estuary in the year 2030 during a 1930-equivalent drought, using EPA's Dynamic Estuary Model (DEM), an equal blend of the Blue Plains Wastewater Treatment Plant nitrified effluent and estuary water, was selected for treatment at the EEWTP. For all water quality parameters modeled (major cations, anions, nutrients and selected trace metals), the observed levels in the 1:1 mixture exceeded the values projected by the DEM, indicating the simulated influent mix was conservative.

PHYSICAL/AESTHETIC PARAMETERS

The three process combinations tested were effective in reducing the physical/aesthetic parameters to acceptable levels. All particulate contaminants (turbidity, asbestos fibers) in the EEWTP finished waters were below the EPA Maximum Contaminant Levels (MCLs) or below levels of potential health concern. Color and odor, two important parameters affecting the aesthetic appeal of the EEWTP finished waters were comparable to or lower than levels observed in the local water treatment plants.

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MAJOR CATIONS, ANIONS AND NUTRIENT PARAMETERS

Of the nineteen water quality parameters in this group, ten are considered to be of health or aesthetic concern. Generally, the levels of these parameters in EEWTP finished waters exceeded levels in the local plants during all three phases of operation because of the increase in dissolved salts in the influent water. Parameters of potential concern include hardness, total dissolved solids, chloride, sulfate, sodium, and nitrate. EEWTP sodium levels exceeded the EPA recommended optimum level of 20 mg/L, but the arithmetic mean value of approximately 30 mg/L is unlikely to pose serious health risks. EEWTP nitrate levels did not exceed the primary standard of 10 mg/L-N, except when the influent was treated wastewater only, an event of zero probability in the estuary. Levels of the other parameters were either below secondary MCLs, or at levels comparable to levels observed in many finished waters in the U.S.

TRACE METAL PARAMETERS

Of the 24 metals in this group, only 12 were detected frequently enough in the finished waters to permit statistical comparisons. The three treatment process combinations effectively reduced all metals to levels below the MCLs, with the lime process (Phase IIA) providing the greatest degree of reliability. EEWTP metal levels were less than or not significantly different than levels in at least one local WTP, with the exception of manganese (Phase IA), arsenic (Phase IB), mercury (Phases IA and IB), nickel (Phase IA), selenium (Phase IB), and zinc (all phases). In those cases where EEWTP levels were higher, the observed values were still many times lower than specified MCLs or other criteria and are not of health concern. High manganese levels during Phase IA could be eliminated in a future estuary water treatment plant with appropriate pH control following sedimentation and the use of permanganate addition.

RADIOLOGICAL PARAMETERS

The concentration of radiological parameters in the EEWTP influent never exceeded the primary MCLs. The geometric mean value of gross beta activity in the EEWTP finished water during Phase IA exceeded the geometric mean value observed in one local plant, but the observed geometric mean (5.9 picocuries/Liter (pCi/L)) was well below the 50 pCi/L standard.

MICROBIOLOGICAL PARAMETERS

The parameters in this group are of potential health concern either as direct acting human pathogens or as indicators of potential acute health risks. Enteric viruses, from the coxsackie virus, polio virus, and echo virus groups, were detected in nearly half of the EEWTP influent water samples during Phases IA and IIA. No enteric viruses were detected in the 56 EEWTP finished water samples nor in the 68 finished water samples from the local water treatment plants. In addition, none of the seven monitored protozoan and helminth parasites were detected in the EEWTP finished waters.

All process combinations reliably removed *Salmonella* species from the influent sources, as none were detected in the EEWTP finished waters (detection limit, 0.02/100 ml). These process combinations also reduced the number of bacteria

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detected by the standard plate count (SPC) technique to levels significantly less than at one local WTP. Geometric mean SPC values for the three combinations were less than 0.5 colony/ml.

EEWTP influent total coliform levels ranged from a geometric mean of 20,000/100 ml to a 90th percentile value of 350,000/100 ml. The levels of total coliforms in the EEWTP finished waters never exceeded the primary MCL of 1 most probable number (MPN)/100 ml during all three phases of plant operations. During Phase IA, however, the EEWTP finished water had larger numbers of positive coliform samples than in the local WTPs. This was due to an insufficient chlorine dose as the final disinfectant during the first four months of Phase IA operation. Subsequent operating periods showed lower numbers of positive coliforms, with the finished water in Phase IIA containing comparable levels of total coliforms as the local WTPs. A high volume coliform analysis technique permitted quantitative analyses of total coliforms at levels below 1 MPN/100 ml, levels not usually seen during monitoring of most water treatment plants in the U.S.

Although the EEWTP coliform levels were higher than the local WTPs during Phases IA and IB, these process combinations nonetheless were able to meet the National Research Council (NRC) reliability criterion of less than or equal to 0.1 MPN/100 ml in at least 90 percent of the samples for acceptability of a finished water obtained from a contaminated source. However, the Phase IB process combination was not expected to demonstrate acceptable process reliability for control of total coliforms when influent ammonia levels exceed 0.5 mg/L-N. Thus, the EEWTP finished waters were presumed acceptable for human consumption with respect to microbiological parameters for two of the three process combinations, provided that careful control of the final disinfectant process is maintained.

ORGANIC PARAMETERS

Organic chemicals in any finished water are of particular concern for evaluating the acceptability of the water for human consumption because of potential long-term chronic health effects. Assessment of the health risks to humans caused by consumption of water containing trace quantities (less than 100 µg/L (parts per billion) of organic chemicals is still in an early stage of scientific development. For this project, considerable effort was invested in quantitative analysis of 149 primary or targeted synthetic organic chemicals (SOCs). In addition, over 300 additional secondary or non-targeted SOC's, were observed, either of industrial origin or produced by the treatment processes, notably by chlorination. In addition, two surrogate organic parameters were routinely and frequently monitored, total organic carbon (TOC) and total organic halide (TOX), the latter a measure of the total concentration of halogenated organics (including some chemicals identified as animal carcinogens).

TOC and TOX levels in the EEWTP finished waters were significantly lower than levels in all local WTPs during the three phases of EEWTP operation. This was a consequence primarily of the GAC process, which was not used in the local WTPs.

Of the 149 primary organic compounds monitored, only three (chloroform, bromodichloromethane, and dibromochloromethane) were consistently observed at levels above 1 µg/L (one part per billion) in the finished waters. The EEWTP finished waters had significantly lower levels of total trihalomethanes

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(TTHMs) compared to levels in the local WTPs, all of which are meeting the EPA MCL for TTHMs of 0.10 mg/L. In addition, none of the six pesticides in the primary standards were detected in the EEWTP finished waters.

Of the six volatile organic chemicals currently being considered for regulation by EPA with possible MCLs as low as 5 µg/L, none were detected in the EEWTP finished waters above this level, with estimated geometric mean values generally below method detection limits of 0.2 µg/L.

For all other primary and secondary organic compounds, the EEWTP finished waters generally exhibited lower concentrations, and fewer detected compounds than observed in the local WTPs. Where compounds were detected frequently enough to estimate geometric mean values, the levels in EEWTP finished waters and in the local WTPs were below 0.1 µg/L, and thus not considered to pose any health hazards to consumers.

TOXICOLOGICAL PARAMETERS

The two in vitro toxicological parameters monitored were the Ames Salmonella microsome test, capable of detecting chemical mutagenesis caused by chemicals or chemical mixtures, and a mammalian cell transformation assay, shown to detect the potential for carcinogenesis by individual chemicals.

The Ames test was conducted weekly on finished waters. The level of mutagenic activity was low in all finished water from the EEWTP and the local WTPs. The observation of some positive mutagenic assays in the finished waters was not unexpected, as this appears to be characteristic of all water treatment plants using free chlorine for final disinfection.

The mammalian cell transformation assay was conducted monthly on all finished waters. Of the nearly 25 assays performed, only a few positive assay plates were observed, and in all cases, the frequency of cell transformation was very low. Typically, for positive assay plates, a maximum of 2 plates of the 10 to 15 phases tested would show transformation activity. The extent of transformation activity in the EEWTP finished waters was similar to that observed in the local WTPs during all phases of operation. The results of the mammalian cell transformation assays were consistent with results using analogous transformation assays reported on finished waters, from other water treatment plants.

SUMMARY

The water produced by two of the three process combinations monitored at the EEWTP was of acceptable quality for human consumption when compared to the primary and secondary drinking water regulations. For those parameters not regulated as well as other parameters of health concern, the EEWTP finished waters were observed to be of comparable quality to that in the local WTPs. In those cases where the finished water quality in the EEWTP exceeded values in the local WTPs, an evaluation of the health significance of the results indicated that the water was still of acceptable quality for human consumption. Within the limits of the analytical techniques used, it is concluded that the three process combinations monitored were technically feasible for producing a water

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acceptable for human consumption under the influent water quality conditions observed.

COSTS

For two of the three process combinations monitored, costs were prepared based on a 200 MGD estuary water treatment plant operated continuously at 100 percent of hydraulic capacity. The costs included only the operation, maintenance and amortization for the treatment plant, excluding various intake and finished water structures, due to uncertainties regarding the eventual location and operations strategy of an estuary water treatment plant.

Capital costs for the Phase IA and Phase IIA process combinations, using design and operating criteria similar to that used in the EEWTP, are \$122 and 174 million dollars (April, 1983), respectively. Unit costs (which include amortization at 8 percent, 20 year loan) for these combinations are 34.3¢/1,000 gallons and 47.6¢/1,000 gallons, respectively.

For a conventional treatment plant similar to Phase IA not using GAC adsorption, the unit costs were estimated to be 19¢/1,000 gallons. Thus, inclusion of GAC adsorption approximately doubles the cost of water treatment.

Additional treatment barriers for control of VOCs (air stripping in a packed tower prior to GAC adsorption), or for removal of undesirable inorganic parameters (reverse osmosis) would increase unit costs, but would improve treatment plant process reliability. Inclusion of the reverse osmosis process, for reduction of total dissolved solids, nitrate, and sodium would increase unit costs to nearly 70¢/1,000 gallons.

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EXECUTIVE SUMMARY

CHAPTER E-1

INTRODUCTION

In March 1974, the U.S Congress passed the Water Resources Development Act Public Law 93-251, which directed the Secretary of the Army to undertake an investigation of the use of the Potomac River estuary as a possible supplemental water supply source for the Metropolitan Washington Area (MWA). Public Law 93-251 authorized the construction of a demonstration plant to be located on the Potomac River estuary for the purposes of conducting the investigation. This Executive Summary presents the main findings and conclusions of a three-year study to operate, maintain, and conduct a performance evaluation of the demonstration plant.

The principal project objective was to determine the technical feasibility of using the tidal fresh water portion of the Potomac River estuary as a supplemental source of water supply for the MWA, during water quality conditions comparable to those expected during severe droughts and regional water supply demands based on projections in the year 2030. In addition, the estimated costs of applicable treatment alternatives would be prepared to be used as the basis for cost comparisons between this alternative for meeting long-term water supply needs and other alternatives being investigated by the U.S. Army Corps of Engineers in the MWA Water Supply Study.

The Potomac Estuary Experimental Water Treatment Plant (EEWTP), was a one million gallon per day advanced water treatment facility presumed to be capable of producing a water quality suitable for human consumption treating a raw water source highly contaminated with treated wastewater.

The Final Report consists of the Executive Summary, a main volume, and Appendices. The Executive Summary presents highlights of the major findings and conclusions and is organized into the following chapters:

- Chapter E-2 - Project Description
- Chapter E-3 - Conclusions
- Chapter E-4 - Monitoring Programs
- Chapter E-5 - Analytical Methods and Sampling
- Chapter E-6 - Data Analysis Techniques
- Chapter E-7 - Influent Water Quality
- Chapter E-8 - Process Performance
- Chapter E-9 - Evaluation of Finished Water Quality
- Chapter E-10 - Special Testing and Evaluation
- Chapter E-11 - Costs

CHAPTER E-2

PROJECT DESCRIPTION

The Potomac Estuary Experimental Water Treatment Plant (EEWTP) project was authorized by Section 85.b(2) of Public Law 93-251, which states that:

"The Secretary of the Army, acting through the Chief of Engineers, shall undertake an investigation and study of the use of estuary waters to determine the feasibility of using such waters as a source of water supply and is authorized to construct, operate, and evaluate a pilot project on the Potomac estuary for the treatment of such waters at an estimated cost of \$6,000,000. The Secretary of the Army, acting through the Chief of Engineers, shall report to the Congress on the results of such project within three years after commencement of operation of such project and such report shall include the results of two years testing at the pilot project for the treatment of water from the Potomac estuary."

Concurrent with the submittal of the report to Congress, the U.S. Army Corps of Engineers was directed to submit the report to a committee formed by the National Academy of Sciences-National Academy of Engineering (NAS-NAE) which would report to Congress within one year on the scientific and technical merit of the project findings. Furthermore, the NAS-NAE Committee was requested to provide project review on a regular basis throughout the duration of the project beginning with the conceptual stage and continuing through the performance evaluation of the EEWTP. The Committee met approximately every six to eight months for review of conceptual design of the treatment processes, development of the testing program for monitoring of the EEWTP, and finally for review of progress reports submitted as part of the operation, maintenance, and performance evaluation of the EEWTP.

Use of the Potomac River estuary as a supplemental water supply source is one of several alternatives being considered by the U.S. Army Corps of Engineers for meeting the long term water supply needs of the MWA. The background and history of efforts by the U.S. Army Corps of Engineers in dealing with water supply problems of the region are presented in the Metropolitan Washington Area Water Supply Study.

Use of the estuary was proposed as an alternative for augmenting existing water sources in the region during drought conditions. Two scenarios for a possible estuary water treatment plant were suggested, 1) treatment of up to 200 million gallons per day (MGD) to a level of quality suitable for drinking purposes, and pumping and releasing of the finished water several miles above the current water intakes on the Potomac River, and 2) treatment followed by direct distribution of the finished water into existing water distribution systems in the MWA.

Project Description

In either case, a demonstration was needed to verify that existing water treatment technology was capable of producing a water of an acceptable quality for human consumption.

PROJECT OBJECTIVES

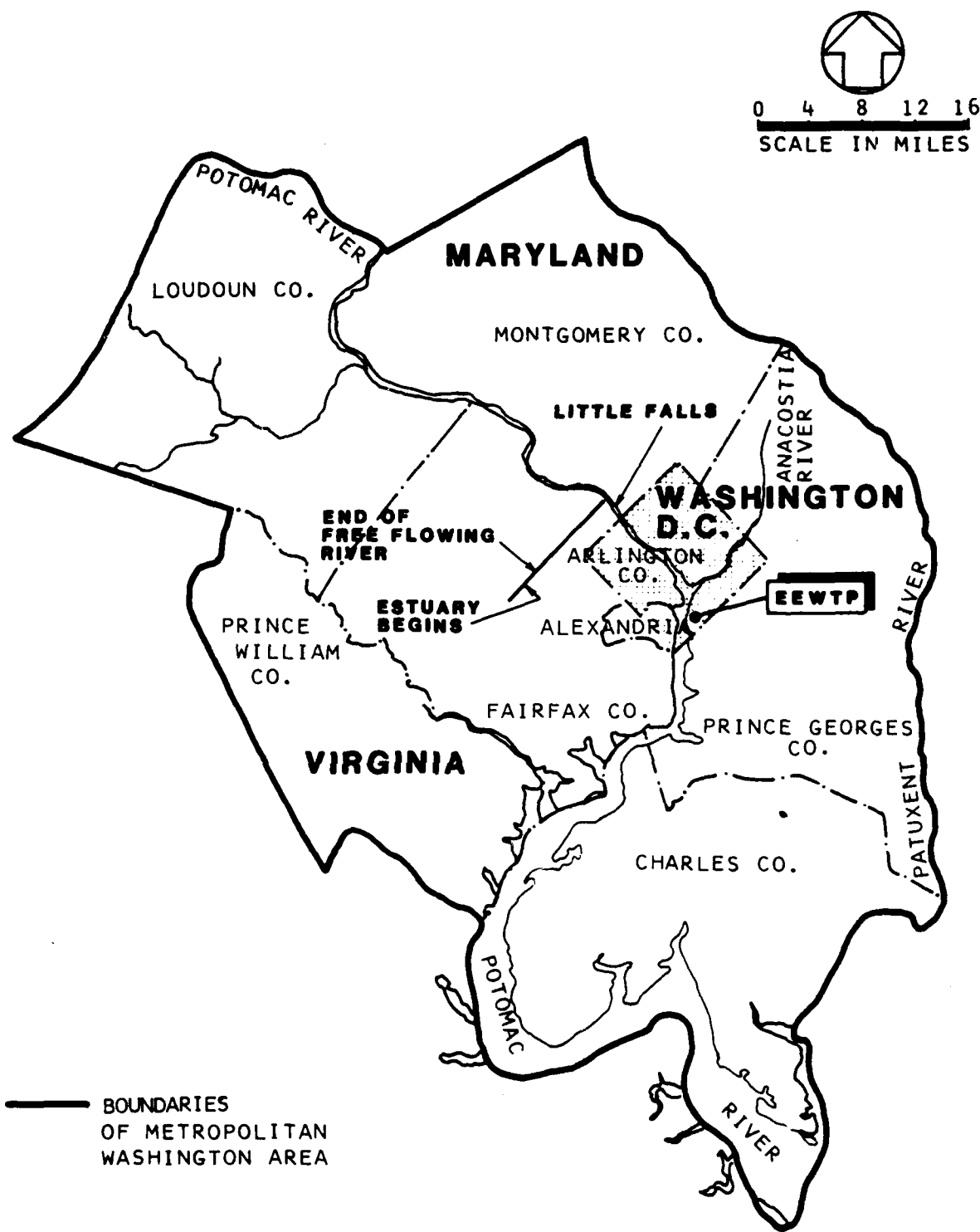
The project objective was to determine the technical feasibility of using the Potomac River estuary as a supplemental water supply source for the Metropolitan Washington Area under water quality conditions similar to those expected to be encountered in the year 2030 assuming drought conditions similar to the worst drought on record which occurred in 1930. In order to achieve the stated project objective, a number of specific questions had to be addressed as presented below:

1. What influent water quality to the EEWTP best simulates projected conditions in the Potomac River estuary during drought conditions?
2. What quality of water can be produced by commonly used water treatment processes?
3. What are the process combinations which will ensure production of a water of acceptable quality?
4. Is the EEWTP finished water quality acceptable for human consumption?
5. What is an acceptable level of reliability for the selected process combination?
6. What are the estimated costs of the selected process combinations for treating the water to a defined level of quality?

The design of the EEWTP was completed in 1976 by Malcolm Pirnie, Inc. Construction was completed in 1980. The specified three-year testing program for the operation, maintenance and performance evaluation of the EEWTP was conducted by James M. Montgomery, Consulting Engineers, Inc., under the technical direction of the U.S. Army Corps of Engineers, Washington Aqueduct Division. The testing program consisted of a six months start-up phase, two years of plant operation, and monitoring, and a final six-month period for plant deactivation, and preparation of the final report.

SITE DESCRIPTION

The EEWTP was located in the southern section of Washington, D.C., on the site of the Blue Plains Wastewater Treatment Plant along the Potomac River estuary, as shown in Figure E.2-1. The EEWTP obtained water from the estuary and from the Blue Plains Wastewater Treatment Plant, which is operated by the Department of Environmental Services of the District of Columbia. This plant is the major wastewater discharger in the MWA and is currently capable of treating approximately 309 MGD prior to discharge to the River estuary.



PROJECT LOCATION MAP
FIGURE E. 2-1

Project Description

The water source for the EEWTP from the Blue Plains Wastewater Treatment Plant was selected to be water following secondary treatment with nitrification, but prior to filtration and chlorine disinfection. This source was considered to be a conservative choice for simulating potential water quality conditions that might occur in the estuary under the assumed hydrologic boundary conditions.

The EEWTP provided a variety of unit processes and operations thought to be capable of removing a wide spectrum of potential contaminants and, thus, expected to be capable of producing a finished water of acceptable quality for human consumption. A plant operating capacity of one million gallons a day was considered sufficient to demonstrate the technical feasibility of using the estuary under conditions comparable to a full scale estuary water treatment plant.

The liquid processing facilities were selected to represent currently available treatment technology in the water treatment field. These facilities included microscreens for removal of large particulate material; surface aeration for oxidation of iron and manganese and removal of some volatile organic chemicals; chemical coagulation and sedimentation for removal of organic and inorganic contaminants; gravity filtration for removal of particulate materials; granular activated carbon for control of naturally occurring and synthetic organic chemicals found in water sources, and intermediate oxidation/disinfection and final disinfection for removing microbiological contaminants.

The treatment plant also contained sidestream demineralization facilities for evaluation of dissolved salts removal which was considered to be a potential problem in the estuary during drought conditions. Facilities for solids processing and disposal were also provided at the EEWTP.

Auxiliary facilities essential for operation and performance evaluation of the treatment plant included an on-site laboratory for physical, chemical and microbiological analyses needed for process control and performance evaluation, as well as facilities for handling and storage of samples to be analyzed in an off-site laboratory. Samples were shipped to the off-site laboratory of James M. Montgomery, Consulting Engineers, Inc. in Pasadena, California where most analyses were performed. In addition, the EEWTP was equipped with computer hardware required for the storage, retrieval, and analysis of the more than 400,000 data records obtained during the monitoring of the demonstration plant. The on-site computer facilities included a mini-computer (for data storage and transfer to the host computer in Pasadena, California), auxiliary terminals, a printer, plotter, and communications equipment.

CHARACTERIZATION AND EVALUATION OF WATER QUALITY

Perhaps the most difficult and controversial task in conducting this project was the determination of acceptable finished water quality for human consumption. The simulated drinking water source consisted of a blend of nitrified effluent and Potomac River estuary water. In the current regulatory framework used in the United States, water produced by community water systems is considered acceptable for human consumption if it meets the National Interim Primary

Project Description

Drinking Water Regulations (NIPDWR). The NIPDWR specify the acceptable levels in drinking water of those parameters believed to have either chronic or acute adverse impacts on health. Twenty-three parameters are currently included in the NIPDWR. In addition, National Secondary Drinking Water Regulations address eleven parameters considered to impact the aesthetic quality of the treated water and therefore consumer acceptance. At the levels specified, these parameters are not considered to be of health significance. If a finished water from community water systems meets the primary and secondary regulations, it can be considered acceptable for human consumption.

In addition to those parameters currently included in the primary and secondary regulations, other parameters are being considered for inclusion in the regulations. These include six volatile organic chemicals found frequently in groundwater sources. Other parameters are currently being evaluated by the EPA and could be included or removed from the standards in the future. Thus, standards are constantly evolving, dependent on new developments in analytical chemistry, engineering, toxicology, and microbiology.

The regulations, however, were based on the assumption that the water system would utilize a water source with the highest water quality economically available. The Safe Drinking Water Act explicitly states that "polluted sources should not be used unless other sources are economically unavailable and then only when personnel, equipment, and operating procedures can be depended on to purify and otherwise continuously protect the drinking water supply."

The NIPDWR alone, therefore, may not be suitable for evaluation of acceptable water quality under conditions of treating a highly contaminated source. Unfortunately, the definition of a "contaminated source" has not been developed in quantitative terms. In this project, however, the influent to the EEWTP (selected to simulate water quality conditions during a drought event) would contain a high percentage of treated wastewater. Under these conditions, it was concluded that the criteria for determining the acceptability of water for human consumption would have to be expanded.

The approach taken was three-fold.

1. Increase the number of parameters monitored beyond the 34 parameters currently included in the primary and secondary regulations.
2. Increase the frequency of sampling beyond that required by the primary and secondary regulations.
3. Include monitoring of finished water quality provided by conventional supplies in the MWA for purposes of comparison with the EEWTP finished water quality.

Over two hundred individual parameters were included in the plant monitoring program and organized into seven principle parameter groups for ease of analysis and discussion. The number of parameters in each group is as follows:

Project Description

physical/aesthetic parameters - 13
major cations, anions, and nutrient parameters - 19
trace metals - 24
radiological parameters - 5
microbiological parameters - 6
organic parameters - 151 (plus over 300 additional organic compounds
which were tentatively identified)
toxicological parameters - 2

For those water quality parameters which can be quantified with current analytical techniques, the definition of an acceptable water quality can be based on several comparisons:

1. Comparison of the level of each parameter to existing Federal or state drinking water regulations.
2. Comparison of EEWTP finished water quality to the quality of MWA conventional supplies.
3. Comparison of water quality levels to potential Federal or state regulations, to standards proposed for treating waters to drinking water quality regardless of the source, or to specific concentration levels for known animal carcinogens estimated to pose specified levels of increased health risks.
4. Comparison of EEWTP finished water quality to levels of particular parameters found in community water systems in the U.S. or elsewhere treating unprotected sources, that is, those systems treating a source substantially influenced by treated wastewater discharges.

Each of these comparisons was used to determine whether the EEWTP finished waters produced by the tested treatment process combinations were of acceptable quality for human consumption.

Acceptability was based on demonstrating that levels of water quality parameters of health or aesthetic concern in the EEWTP finished waters met the current drinking water regulations, or were not significantly different from levels of water quality parameters observed in the local water treatment plants. In those instances where the health or aesthetic parameters in the EEWTP exceeded values in the local plants, the water was considered to be acceptable only if it could be shown that the observed levels posed little or no additional adverse health risk to consumers.

CHAPTER E-3

CONCLUSIONS

The objective of the EEWTP project was to evaluate the technical feasibility of using the Potomac River estuary as a supplemental water supply source for the Metropolitan Washington Area to meet potential water shortages that might occur during severe droughts.

This chapter presents the conclusions of this evaluation, based on the results of two years of water quality monitoring. Three treatment process combinations were investigated during the two-year monitoring program as summarized in Table E.3-1.

TABLE E.3-1
SUMMARY OF TREATMENT PROCESS COMBINATIONS MONITORED
DURING THE TWO-YEAR OPERATION OF THE EEWTP

Phase	Processes	Duration
Phase IA	Surface aeration, alum coagulation, flocculation, sedimentation, intermediate disinfection with chlorine, dual-media gravity filtration, granular activated carbon (lignite based with fifteen minute empty-bed contact time), free chlorine disinfection.	16 March 1981 to 16 March 1982 52 weeks
Phase IB	As above with ozone in place of chlorine as intermediate oxidant/disinfectant.	17 March 1982 to 7 July 1982 15 weeks
Phase IIA	Lime coagulation, flocculation, sedimentation, recarbonation, dual-media gravity filtration, granular activated carbon (bituminous based carbon, thirty minute empty-bed contact time), ozone disinfection, chloramine disinfection.	17 July 1982 to 1 February 1983 28 weeks
Phase IIB	Same process as IIA. Decreased monitoring of influent to permit data evaluation in final report.	1 February 1983 to 15 March 1983 6 weeks

Conclusions

The key issues addressed by the EEWTP project were as follows:

1. Selection of the appropriate blend of treated wastewater and Potomac River estuary water for the EEWTP influent to simulate the estuary water quality expected under drought conditions.
2. Acceptability for human consumption of the finished water produced by the EEWTP treatment combinations.
3. Process performance and reliability of the selected treatment combinations monitored during the two-year program with respect to control of those water quality parameters known to affect the aesthetic quality of the finished water and known or suspected to pose potential health risks to consumers.
4. Estimated costs of a full-scale estuary water treatment plant using those treatment combinations demonstrated to be technically feasible for producing a water of quality acceptable for human consumption.

The conclusions summarized below address each of these issues.

SELECTION OF INFLUENT WATER QUALITY

Selection of the appropriate mixture of Blue Plains nitrified effluent and Potomac River estuary water was based on simulating water quality in the upper reaches of the estuary during drought conditions. The Dynamic Estuary Model (DEM), developed by EPA and calibrated for the Potomac River estuary was used for water quality simulation. Only those water quality parameters that do not undergo transformations in the water body (i.e., are conservative) were modeled because of uncertainties in the rates of transformation of most water quality parameters of potential health concern. These parameters included total dissolved solids (TDS), and many of the dissolved inorganic ions. This approach resulted in the following:

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.

EVALUATION OF FINISHED WATER QUALITY

Within the limits of analytical techniques used on this project, the process combinations tested in the EEWTP (see Table E.3-1) were shown to be capable of producing a finished water of quality suitable for human consumption.

Conclusions

The finished waters from the three process combinations monitored were of acceptable quality for human consumption when compared to the primary and secondary drinking water regulations. For those parameters not regulated as well as other parameters of health or aesthetic concern, the EEWTP finished waters were observed to be of comparable or superior quality to those in the local WTPs.

For several water quality parameters, EEWTP levels exceeded the highest levels observed in the finished waters of three major MWA water treatment plants. For most of these parameters, however, the potential increase in health risks was judged to be negligible. Conclusions regarding the acceptability for human consumption based on levels of the key water quality parameters in the EEWTP finished waters are presented below by parameter group.

PHYSICAL-AESTHETIC PARAMETERS

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.¹
 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 mean value exceeded the highest geometric mean odor level in one local plant during this phase of operation.
-
1. 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.

Conclusions

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.

MAJOR CATIONS, ANIONS, AND NUTRIENT PARAMETERS

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.

Conclusions

TRACE METAL PARAMETERS

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.

RADIOLOGICAL PARAMETERS

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.

MICROBIOLOGICAL PARAMETERS

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.

Conclusions

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.

ORGANIC PARAMETERS

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 quantitation), 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.

Conclusions

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, naphthalene, 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.

TOXICOLOGICAL PARAMETERS

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

Conclusions

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 EEWTP finished waters than in the finished waters of the local water 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.

PROCESS PERFORMANCE

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

Conclusions

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 of 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.

Conclusions

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.

COSTS

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

Conclusions

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.

CHAPTER E-4

MONITORING PROGRAM

During the two years of operation, a comprehensive monitoring program was carried out at selected sites in the EEWTP and in the local WTPs. This program was designed to characterize EEWTP finished water quality, EEWTP process performance, and the finished water quality produced at three local water treatment plants in the Metropolitan Washington Area. Development of the sampling program required specification of the parameters to be measured, the sampling sites, the types of samples and the sampling frequency. Initial selection of these program elements was based on analytical capabilities as of 1979. The number of sample sites and the sampling frequency were selected based primarily on the perceived importance of the given water quality parameter with respect to health effects, and the constraints of the project budget.

PARAMETER GROUPS

The parameter groups and the water quality parameters monitored in the project are summarized in Table E.4-1. Over 200 individual parameters were monitored during the two years of the program.

PHYSICAL/AESTHETIC PARAMETERS

The physical/aesthetic parameter group includes water quality parameters which characterize the aesthetic appeal (e.g., color, taste, odor), and particulate content (i.e., turbidity, suspended solids, asbestos) of the water. This group also includes certain parameters which do not conveniently fit in other parameter groups including dissolved oxygen, chlorine residual, pH and temperature.

MAJOR CATIONS, ANIONS, AND NUTRIENTS PARAMETERS

This group includes all the major cations and anions used in computing the ion balance for data quality control purposes. It also includes the major nutrient parameters, phosphorus and nitrogen species, and those parameters which characterize the concentration of dissolved salts in the water, total dissolved solids and electroconductivity.

TRACE METAL PARAMETERS

Trace metal parameters include twenty-four metals usually present in concentrations less than 1 mg/L. Excluded are the major cations, calcium, magnesium, sodium, and potassium.

Analytical Methods and Sampling

TABLE E.4-1
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 Kjeldahl
Phosphate (ortho-)
Potassium
Silica
Sodium
Sulfate
Total dissolved solids

Trace Metals

Aluminum
Antimony
Arsenic
Barium

Analytical Methods and Sampling

TABLE E.4-1 (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)

Analytical Methods and Sampling

RADIOLOGICAL PARAMETERS

Five individual parameters constitute the radiological parameter group. These parameters include only those regulated by the National Interim Primary Drinking Water Regulations (NIPDWR).

MICROBIOLOGICAL PARAMETERS

The microbiological parameter group includes traditional total and fecal coliforms and the standard plate count (a measure of the total bacterial level in the water). The other bacterial parameter monitored was Salmonella species, a known human pathogen.

Six different parasites were monitored regularly in the parasite group including Giardia cysts, Entamoeba histolytica, Acanthamoeba, Naegleria Gruberi cysts, Ascaris eggs, Hookworm eggs, and Trichuris Trichiura eggs. Viruses were determined by quantification on three separate cell lines capable of detecting the presence of over forty waterborne viruses.

ORGANIC PARAMETERS

The monitored organic parameters can be classified into two groups, surrogate organic parameters, (total organic carbon (TOC) and total organic halide (TOX)) and the synthetic organic chemicals (SOC) of either industrial origin or produced by chemical oxidation in the treatment process. As many as 149 SOCs were routinely monitored using various analytical techniques. In addition to these 149 targeted (or primary), compounds approximately 300 additional SOCs were tentatively identified, with approximate quantification based on peak size on the chromatographs. Shown in Table E.4-1 are the analytical techniques used and the surrogate parameters.

TOXICOLOGICAL PARAMETERS

The two in vitro toxicological tests were the Ames Salmonella microsome test, and a mammalian cell transformation assay. The Ames test is a bacterial bio-assay using a strain of Salmonella bacteria, which measures mutagenicity of single chemicals or chemical mixture by the expression of an observable mutation of a specific gene. The mammalian cellular transformation assay uses a mouse cell line to test for cell transformations which may indicate carcinogenic potential of chemicals or chemical mixtures. Organic concentrates were obtained on XAD resins.

Analytical Methods and Sampling

FIRST YEAR MONITORING PROGRAM

The first-year monitoring program, instituted between 16 March 1981 to 31 November 1981, is summarized in Table E.4-2. The principal sites monitored include:

- Blue Plains nitrified effluent
- Potomac River estuary
- Blended influent
- Sedimentation or recarbonation tank effluent
- Dual media filtration effluent
- GAC column effluents
- EEWTP finished water

Additionally, sampling was conducted in three local water treatment plants in the MWA at approximately the same frequency as in the EEWTP finished water. Both grab and composite type samples were taken, depending upon the nature of the analysis and the feasibility of sample preservation. In addition, some concentrates were taken for specialized analysis including organic concentrates for the toxicological tests and particulate concentrates for the virus and parasite analyses. Sampling frequency ranged from two hour grab samples for turbidity to a monthly 24-hour composite sample for the mammalian cell transformation assay.

REVISED SAMPLING PROGRAM

Following approximately seven months of operation at the EEWTP, an analysis was made of the monitoring results from key sites at the EEWTP and the local water treatment plants. Changes were made on the basis of sampling logistics, the need for increased sampling at selected process sites and engineering judgment on the cost/benefit of specific analyses. The major highlights of the revised program were as follows:

1. Sampling was increased at the Blue Plains and estuary raw water intake sites to permit quantification of the source of contaminants to the EEWTP.
2. Increased sampling was instituted within the EEWTP process train to permit determination of individual process performance.
3. 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.
4. Fecal coliform and taste analyses were dropped. Endotoxin sampling was reduced to quarterly.
5. Additional toxicological tests using the Ames assay were instituted within the EEWTP process sequence.

Analytical Methods and Sampling

TABLE E.4-2
PLANT MONITORING PROGRAM
16 March 1981 to 31 November 1981

	Blue Plains Nitrified Effluent	Potomac River	Blend- ed Inf.	Recarb- Media on Tank 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	DG				
Particulate Constituents											
Turbidity	H4	H4	H2	H2		H4	H2				
Total Suspended Solids	DC	DC	DC	DC		DC					
Asbestos	WC	WC	WC	WC	WC		WC	WC	WC	WC	FG
Color	DC	DC	DC	DC	DC		DC	DC			WC
MBAS											
Odor											
Taste											
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	DC			
Electroconductivity		DC	H2	DC			DC				
Alkalinity		DC	DC	DC		DC	DC	DC	DC	DC	
Bromide			DC	DC			DC	DC	DC	DC	
Chloride	DC	DC	DC	DC			DC	DC	DC	DC	
Fluoride			DC	DC			DC	DC	DC	DC	
Iodide	DC	DC	DC	DC			DC	DC	DC	DC	
Silica	DC	DC	DC	DC			DC	DC	DC	DC	
Sulfate	DC	DC	DC	DC			DC	DC	DC	DC	
Cyanide	DC	DC	DC	DC			DC	DC	DC	DC	
Nutrients											
Nitrogen, Ammonia		DC	DC	DC		DC	DC	DC	DC	DC	
Nitrogen, Nitrate/Nitrite			DC	DC		DC	DC	DC	DC	DC	
Nitrogen, Total Kjeldahl			DC	DC							
Phosphorus, Ortho-Phosphate			DC	DC		DC	DC	DC	DC	DC	
Radiological (2)				WC					WC	WC	

Analytical Methods and Sampling

TABLE E.4-2 (Continued)
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 Filtration Eff.	Lead Carbon Column Eff.	Final Carbon Column Eff.	EETP 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	MG	MG	
Salmonella	MX	MX					MX	MX	MX	MX	MX	
Viruses	MX	MX					MX	MX	MX	MX	MX	
Parasites	MX	MX					MX	MX	MX	MX	MX	
ORGANIC												
Total Organic Carbon												
(Off-site)	DC		DC		H8	H8	DC	DC	DC	DC	DC	
(On-site)			H8				H8	H8	DC	DC	DC	
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)												
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												
Anes												
Amalian Cell Transformation												
							WX	WX	WX	WX	WX	
							MX	MX	MX	MX	MX	

I. 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 WTPI 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. gross beta exceeds 10,000 pCi/L, and tritium exceeds 10,000 pCi/L. Radium is analyzed in all samples for which gross alpha (plus 2-sigma) exceeds 5 pCi/L. gross beta exceeds 10,000 pCi/L, and tritium exceeds 10,000 pCi/L.

3. At these sites, weekly grabs were scheduled for seven day terminal THM analysis.

Analytical Methods and Sampling

TABLE E.4-2 (Continued)
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)

SECOND YEAR MONITORING PROGRAM

During the second year of plant monitoring a final revised program shown in Table E.4-3 was instituted. This program was designed to improve the level of confidence in the statistical characterization of water quality at the EEWTP. Major changes included the following:

1. Virus monitoring frequency was dropped within the process and increased to weekly at the blend tank and EEWTP finished water.
2. Sampling frequency for acid extractibles, base neutral extractibles, herbicides, pesticides, and PCBs was decreased from biweekly to monthly 24-hour composites.
3. Liquid/liquid extraction sampling was increased from weekly to every other day.
4. Influent monitoring of viruses and parasites was confined to the blend tank for cost saving purposes.
5. Gross alpha and beta monitoring were reduced from weekly to biweekly composites.
6. Fecal coliform was reinstated.
7. Ames sampling frequency was reduced from weekly to biweekly because of low levels of mutagenic activity observed.
8. Six metals were dropped because of few positive observations: antimony, beryllium, cobalt, molybdenum, thallium and tin.

The basis for sample frequency selection in the final sampling program was principally a statistical evaluation of results obtained during the first eight months of the project. Several statistical techniques were utilized to determine appropriate sample frequency for the last year of operation. These included:

1. Characterization of the geometric mean of the sample population within some desired confidence interval.
2. Acceptable confidence that the sample population was below a desired goal such as a maximum contaminant level.
3. Acceptable confidence that the water quality level in the EEWTP was less than the value observed in the local water treatment plant, with the sample size corrected for serial correlation.
4. Economics and engineering judgment.

First year data analysis and economic considerations were used to specify a sampling frequency expected to give an adequate characterization of the parameter at a reasonable cost.

Analytical Methods and Sampling

TABLE E.4-3
PLANT MONITORING PROGRAM
16 March 1982 to 16 March 1983

	Blue Plains Nitrified Effluent	Potomac River Estuary	Blended Inf.	Recarb- onation 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
PHYSICAL												
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 Constituents												
Turbidity	H4	H4	H2	H2	H4		H4	H2	DR	DR	DR	WG
Total Suspended Solids	WC	WC	WC	WC	WC		WC	WC	MC	MC	MC	
Asbestos	WC	WC	WC	WC	WC			WC	WC	WC	WC	
Color	WC	WC	WC	WC	WC			WC	WC	WC	WC	
MBAS												
Odor							WC	FG	DR	DR	DR	
Chlorine Residual (Free and Total)								FG(5)				
Ozone Residual (liquid)												
INORGANIC												
Major Cations and Trace Metals (1)	SC	SC	SC	SC	SC		SC	SC	SC	SC	SC	SG
Cyanide	SC	SC	SC	SC	SC			SC	SC	SC	SC	
Anions (2)	SC	SC	SC	SC	SC			SC	SC	SC	SC	
Nutrients (3)	SC	SC	SC	SC	SC		SC	SC	SC	SC	SC	
Radiological (4)												
Gross Alpha	BC	BC	BC	BC				BC	BC	BC	BC	
Gross Beta	BC	BC	BC	BC				BC	BC	BC	BC	
Tritium								MC	MC	MC	MC	
MICROBIOLOGICAL												
Total Coliform	WG	WG	WG	WG	WG		FG	FG	FG	FG	FG	
Fecal Coliform	WG	WG	WG	WG	WG		FG	FG	FG	FG	FG	
Standard Plate Count	WG	WG	WG	WG	WG		FG	FG	FG	FG	FG	
Endotoxin								QG	QG	QG	QG	
Salmonella	MG	MG	MG	MG	MG		MG	MG	MG	MG	MG	
Virus Identification								WX	MX	MX	MX	
Parasites								MX	MX	MX	MX	

Analytical Methods and Sampling

TABLE E.4-3 (Continued)
PLANT MONITORING PROGRAM
16 March 1982 to 16 March 1983

	Blue Plains Nitrified Effluent	Potomac River Estuary	Recarb- onation Tank Eff.	Dual Media Filtration Eff.	Lead Carbon Column Eff.	Final Carbon Column Eff.	EWTP Finish. Water	WTP1 Finish. Water	WTP2 Finish. Water	WTP3 Finish. Water	Sludge
ORGANIC											
Total Organic Carbon											
(Off-site)	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	
(On-site)			H8								
Total Organic Halide	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	
Synthetic Organics											
Liquid/Liquid Extraction											
(Off-site)	AC	AC	AC	AC	AC	AC	AC	AC	AC	AC	
(On-site)											
Acid Extraction	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	
Base/Neutral Extraction	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	
Volatile Organics Analysis	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	
Closed Loop Stripping	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	
Herbicides	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	
Pesticides and PCBs	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	
TOXICOLOGICAL											
Ames	BX	BX	BX	BX	BX	BX	BX	BX	BX	BX	
Mammalian Cell Transformation											

1. Same constituents as in Table E.4-2 except antimony, beryllium, cobalt, molybdenum, thallium and tin were dropped.
2. Anions: Same constituents as in Table E.4-2.
3. Nutrients: Same constituents as in Table E.4-2.
4. Radiological parameters: Same constituents as in Table E.4-2.
5. Sample taken at post-ozonation site (prior to ammonia and chlorine addition points).

CHAPTER E-5

ANALYTICAL METHODS AND SAMPLING

ANALYTICAL METHODS

Samples were analyzed either in EEWTP laboratory facilities or at the off-site laboratory in Pasadena, California. Samples were collected and stored on-site at 4°C for shipment to Pasadena. Most of the analytical methods followed the recommended EPA procedures or those procedures in Standard Methods, 15th Edition. For some analyses, specialized protocols were developed as summarized in Table E.5-1.

DETECTION LIMITS OF ANALYTICAL METHODS

Because levels of parameters were expected to be quite low, analytical techniques were chosen to provide the lowest detection limits obtainable with current instrumentation within economic constraints. Two types of detection limits were calculated: instrument detection limits (IDL) as applied to organic parameters and method detection limits (MDL) utilized for both organic and inorganic parameters. The IDL is a minimum concentration above which an analyst can detect and identify a parameter. The MDL has been defined as the concentration determined by computing three times the standard deviation of seven replicates of a parameter at a concentration no more than five to ten times greater than the instrumentation detection limit.

MDLs and IDLs for inorganic parameters are summarized in Table E.5-2. IDLs for organic parameters are summarized in Table E.5-3. For organic compounds in the liquid/liquid extraction fraction, the volatile fraction, and the base/neutral fraction, the MDL was approximately two to five times greater than the IDLs. For parameters in the closed-loop stripping fraction, MDLs ranged from five to one hundred times higher than the IDL.

QUALITY CONTROL AND QUALITY ASSURANCE

A quality assurance/quality control (QA/QC) program was used in this project, encompassing analytical performance tests, blind spikes, sampling handling checks, field quality control checks, travel blanks, and laboratory certification. Generally, EPA approved QA/QC procedures were utilized. The key elements of the quality assurance program included field QC checks, and standard laboratory QC. The field QC included regular checking of the sampling lines between the sample location and the automatic composite samplers, routine checks on preservatives added to the samples, the use of travel blanks for the organics analysis and spiked samples for a check of the accuracy of the on-site and off-site laboratories. The spiked samples were usually incorporated into the program without the knowledge of the analyst.

Analytical Methods and Sampling

Standard laboratory QC procedures included regular checks of instrument performance, replicates, spikes, and the use of appropriate standards. The replicate analyses were used as the basis for development of Shewart control charts which were used to determine the acceptability of any given data point. The off-site laboratory is certified by EPA. The EEWTP laboratory was certified for total coliform and given interim approval for THM analysis by EPA.

Analytical Methods and Sampling

TABLE E.5-1
SUMMARY OF ANALYSES REQUIRING
SPECIALIZED PROTOCOLS - NON-STANDARD METHODS

Parameter Group/Parameter	Synopsis of Method
Physical/Aesthetic Asbestos Fibers	Sample filtration, counting with Transmission Electron Microscope, identification with electron diffraction.
Major Cations, Anions, Nutrients Bromide	Ion chromatography.
Trace Organics Total Organic Halide (TOX)	Adsorption of organics on activated carbon, pyrolysis of carbon, quantification by microcoloumetric titration.
Closed-Loop Stripping (CLS)	Purging, adsorption on activated carbon, elution with carbon disulfide, identification and quantitation by GC/MS.
Microbiological Enteric Viruses	Adsorption on Filterite filters (pH 3.5) elution with beef extract (pH 9.0), reconcentration by organic flocculation, assay on two cell lines, BGM and MA104.
Coliform	Modified high-volume MPN method, using 1,000 ml or 100 ml portions.
Parasites	Concentration by filtration on fiber filter, centrifugation, separation by flotation, staining, and microscopic counting.
Toxicological Ames Assay	Organic concentration on macroreticular resins (XAD-2 and XAD-7), elution with acetone, reduction of extract to 1 ml by evaporation, assay on two tester strains of <u>Salmonella typhimurium</u> to determine dose response.
Mammalian Assay	Organic concentrations as in Ames Assay, addition of extract to monolayers of actively growing mouse embryo cells, cell staining and scoring of transformed cells by microscopic evaluation.

Analytical Methods and Sampling

TABLE E.5-2
INORGANICS DETECTION LIMITS

	Method Detection Limit
PHYSICAL/AESTHETIC	
Dissolved Oxygen	0.15 mg/L
Temperature	-15°C (IDL)
pH	0.1 units
Turbidity	0.05 NTU
Total Suspended Solids	3.6 mg/L
Color	3.0 color units
MBAS	0.03 mg/L
Taste	2.0 taste units
Odor	1.0 TON
Free/Total Chlorine	0.1 mg/L-Cl
Ozone Residual	0.1 mg/L
MAJOR CATIONS, ANIONS AND NUTRIENTS	
TDS by drying	10.0 mg/L
TDS by addition	1.0 mg/L
Electroconductivity	0.1 umho/cm
Calcium	0.2 mg/L
Hardness (Ca + Mg)	1.0 mg/L-CaCO ₃
Hardness (titration)	2.0 mg/L-CaCO ₃
Magnesium	0.1 mg/L
Potassium	0.3 mg/L
Sodium	0.1 mg/L
Alkalinity	2.7 mg/L-CaCO ₃
Bromide	0.003 mg/L
Chloride	0.1 mg/L
Cyanide, Total	0.005 mg/L
Fluoride	0.1 mg/L
Iodide	0.002 mg/L
Nitrogen, Nitrate + Nitrite	0.02 mg/L
Nitrogen, Ammonia	0.02 mg/L
Nitrogen, Total Kjeldahl	0.2 mg/L
Ortho Phosphate	0.01 mg/L
Silica	0.2 mg/L
Sulfate	0.6 mg/L
METALS (All values in mg/L)	
Aluminum, Inductively Coupled Argon Plasma (ICAP)	0.003
Antimony furnace AAS	0.0003
Arsenic furnace AAS	0.0002

Analytical Methods and Sampling

TABLE E.5-2 (Continued)

INORGANICS DETECTION LIMITS

	Method Detection Limit
METALS (Continued; all values in mg/L)	
Barium ICAP	0.002
Beryllium ICAP	0.0008
Boron ICAP	0.004
Cadmium ICAP	0.0008
Cadmium furnace AAS	0.0002
Chromium ICAP	0.003
Chromium furnace AAS	0.0002
Cobalt ICAP	0.003
Cobalt furnace AAS	0.0001
Copper ICAP	0.0008
Copper flame AAS	0.0012
Iron ICAP	0.003
Lead furnace AAS	0.0003
Lithium ICAP	0.001
Lithium flame AAS	0.0004
Manganese ICAP	0.001
Mercury cold vapor	0.0003
Molybdenum ICAP	0.002
Nickel ICAP	0.001
Selenium furnace AAS	0.0002
Silver flame AAS	0.0008
Silver furnace AAS	0.0002
Thallium furnace AAS	0.0009
Tin ICAP	0.004
Titanium ICAP	0.002
Vanadium ICAP	0.002
Zinc ICAP	0.002
Zinc flame AAS	0.0012
RADIATION (All values in pCi/L)	
Gross Alpha	0.1
Gross Beta	0.1
Radium	0.1
Strontium-90	0.2
Tritium	1,000

Analytical Methods and Sampling

TABLE E.5-3

ORGANIC PARAMETERS INSTRUMENT DETECTION LIMITS

Analysis	Range ($\mu\text{g/L}$)	Exceptions
Liquid-liquid extraction	0.1	Dichloriodomethane (0.5 $\mu\text{g/L}$)
Pesticides	0.01	
PCBs	0.1-0.2	
Herbicides	0.1	
Volatile Organics Analysis (VOA)	0.1-0.5	
Base/neutral extractables	0.1-5.0	Benzidine (50 $\mu\text{g/L}$) Tricresol phosphate (50 $\mu\text{g/L}$) Dioxin (10 $\mu\text{g/L}$)
Acid extractables	1.0-5.0	2-Methyl-4,6-dinitrophenol (10 $\mu\text{g/L}$)
Closed-loop Stripping (CLS)	0.0005-0.01	Toluene (0.02 $\mu\text{g/L}$)

CHAPTER E-6

DATA ANALYSIS TECHNIQUES

Nearly 400,000 individual data points were generated in the course of the two year EEWTP monitoring program. Consequently, one of the key factors in evaluating project results was the use of appropriate data analysis techniques to characterize the results. Data from each of the parameter groups may in some cases require special data handling techniques because of the presence of a large number of non-detected or non-quantified results. This chapter presents a brief overview of the data analysis techniques employed for statistical characterization and interpretation of the results. Principal statistical issues which had to be resolved included the following:

1. Selection of the appropriate statistical characterization of the sample population for each water quality parameter as specified by the central tendency of the population and the variance about the central tendency.
2. Selection of the appropriate frequency distribution model for purposes of estimating the central tendency and variance for sample populations containing results not detected (ND) or not quantified (NQ).
3. Appropriate statistical techniques for analysis of populations with a majority of the data points either ND or NQ.

SELECTION OF APPROPRIATE STATISTICS

Several statistics can be used to characterize the central tendency of a population of data points. Because of the diversity of data generated in this project, four separate statistics have been utilized for statistical characterization. These include the arithmetic mean, the geometric mean, the median or 50th percentile value and the 90th percentile value. Each of these is discussed below.

ARITHMETIC MEAN

The arithmetic mean defines the central tendency of a normally distributed sample population. It is the sum of the values of all samples divided by the number of samples. The variance about the central tendency of the arithmetic mean is called the standard deviation and is computed by the standard statistical formula. The arithmetic mean is a well known statistic and is used to determine the average amount of a parameter consumed for those parameters known to cause chronic adverse health effects. Computation of the arithmetic mean is thus the appropriate statistic for determining the average dose of a parameter which would be ingested by a consumer over a lifetime.

Data Analysis Techniques

For all water quality parameters the arithmetic mean has been determined and summarized in appropriate tables. Samples with values not detected were assumed to have values of one-half the instrument detection limit, as summarized in Table E.6-1.

GEOMETRIC MEAN

The geometric mean is a statistic characterizing the central tendency of a sample population which is distributed log-normally. The geometric mean is determined by taking the average of the logarithmic value of each data point and determining the anti-log of the arithmetic mean of these values. The measure of variance of the geometric mean is called the spread factor. The spread factor is computed by a standard statistical formula and is the anti-log of the standard deviation. The geometric mean has the characteristic of reducing the influence of extreme values on the computation of the central tendency. Where the underlying sample population is best described by a log-normal frequency distribution, the geometric mean and spread factor are the appropriate statistics for characterizing that population. As discussed below, the log-normal frequency distribution appeared to be more appropriate for characterizing the observed results. Computation of the geometric mean with values not detected utilized techniques more rigorous than those utilized for arithmetic means, as summarized below. Consequently, the geometric mean has been utilized as the statistic for determining individual process performance and for the comparison of finished water quality between the EEWTP and the local water treatment plants.

OTHER DATA CHARACTERIZATION

Two additional numbers used for characterizing large sample populations are the median and the 90th percentile values. The median value is that value representing the mid-point of all the sample results (also called the 50 percentile). The 90th percentile value is the sample value that is ranked at the 90th percent in the sample population. The median value represents an actual data point observed in the monitoring program and is a measure of central tendency useful for comparing different sample populations. The 90th percentile value provides an indication of the spread of observed values of the population and can be compared to certain goals or standards. The 90th percentile value is useful for quantifying process reliability of selected process combinations. These parameters have been utilized where deemed appropriate in the interpretation of the results from the monitoring study.

SELECTION OF AN APPROPRIATE FREQUENCY DISTRIBUTION

Numerous frequency distributions can be utilized to model the value distribution of a variable based on values observed in a sample population. The two most common are the normal or Gaussian distribution and the log-normal distribution. In this project, both the normal and log-normal frequency distributions were used to characterize the sample statistics. Both distributions adequately modeled some of the sample distributions. In general, however, the log-normal frequency distribution provided a better fit for the majority of water quality parameters monitored. Consequently, the log-normal

Data Analysis Techniques

frequency distribution was selected for data presentation as well as for purposes of data extrapolation in sample populations containing less than 85 percent not detected or not quantified values.

STATISTICAL ANALYSIS OF SAMPLE POPULATION CONTAINING ND OR NQ RESULTS

The strategy used for calculating the arithmetic and geometric means, in those cases where data populations contained any results which were not detected or not quantified, is summarized in Table E.6-1. The geometric mean was estimated only when the number of quantified values exceeded fifteen percent, using a maximum likelihood statistical algorithm. This algorithm is an iterative technique used to estimate the parameters (geometric mean, spread factor) of the total sample population. The fifteen percent criteria for the use of this algorithm was based on the excessive computational requirements and time required when fewer than fifteen percent of the samples were above the MDL.

Data Analysis Techniques

TABLE E.6-1
PROJECT APPROACH FOR ESTIMATING STATISTICAL PARAMETERS
WITH DATA BELOW DETECTION LIMITS

Situation	Arithmetic Mean and Standard Deviation	Geometric Mean and Standard Deviation
All data either ND ^a or NQ ^b	Mean = ND or NQ Standard Deviation not reported	Geometric Mean not reported Spread Factor not reported
Some data above MDL, ^c but less than 15% of data quantified	Mean and standard deviation calculated and reported using standard algorithms and following conventions: $ND = 1/2(IDL)^d$ $NQ^e = IDL + 1/2(MDL-IDL)$	Geometric Mean not reported Spread Factor not reported
15% or more of data quantified	Mean and standard deviation calculated using standard algorithms and following conventions: $ND = 1/2(IDL)$ $NQ = IDL + 1/2(MDL-IDL)$	Geometric Mean and Spread Factor calculated by maximum likelihood procedure

a. ND = Not Detected.

b. NQ = Not Quantifiable

c. MDL = Method Detection Limit.

d. For inorganic and microbiological parameters, IDL=MDL = detection limit.

e. Organic chemical compounds only.

CHAPTER E-7

INFLUENT WATER QUALITY

A key issue for the EEWTP project was the selection of the appropriate mix of Blue Plains nitrified effluent and Potomac River estuary water to simulate the expected water quality conditions in the Potomac River estuary during drought conditions and the year 2030 water supply demands.

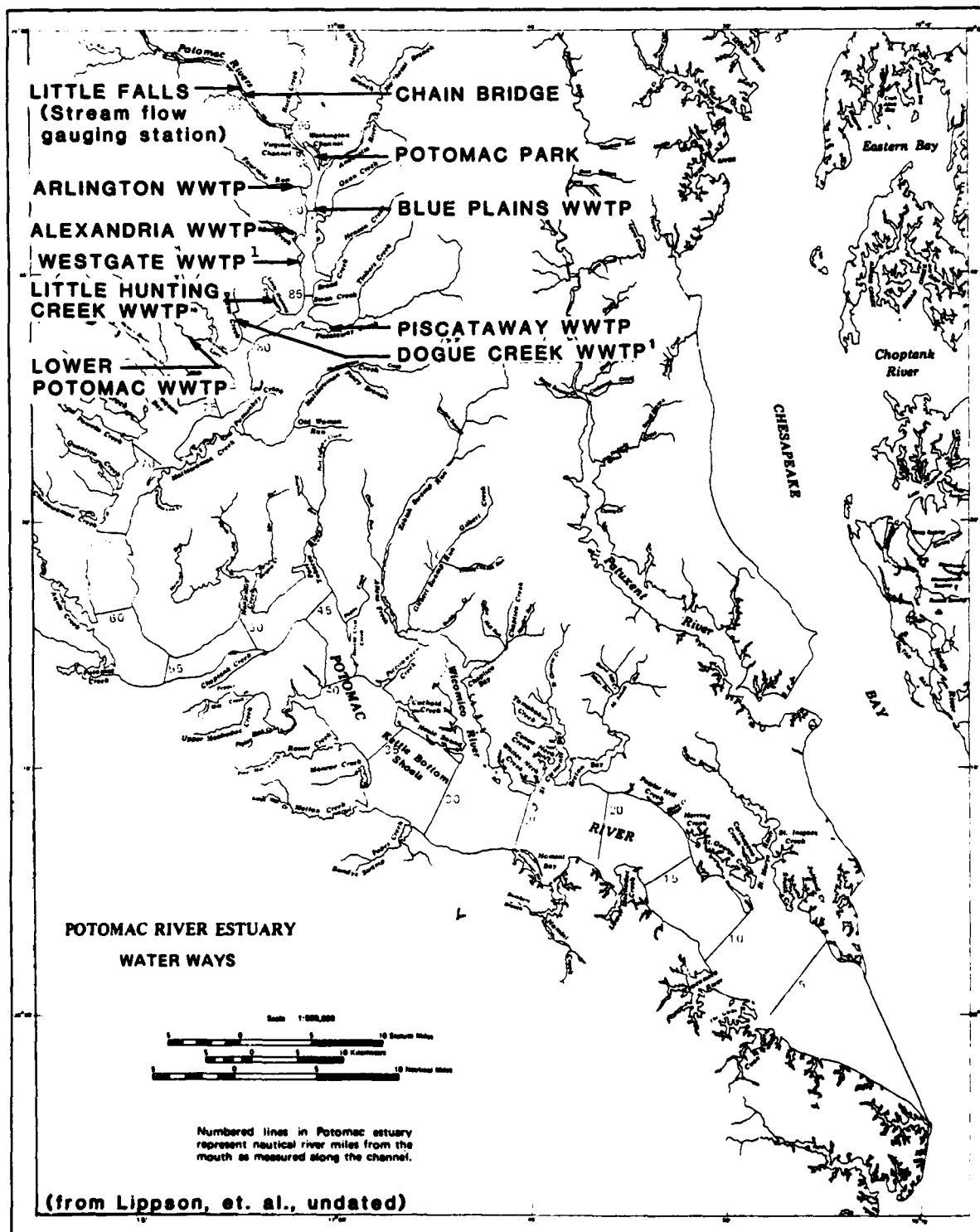
Modeling was performed to evaluate the sensitivity of model conditions to varying use increments. A use increment is defined as that portion of any given contaminant contributed to the treated wastewater due to domestic or municipal water use. Modeling was also performed to evaluate the potential impact of extreme events on water quality conditions in the estuar Events modeled included the possibility of:

1. River flows entering the estuary decreasing to zero.
2. Extended breakdown of the nitrification facilities at the Blue Plains Wastewater Treatment Plant.
3. Alternative sites for the estuary water treatment plant, other than Chain Bridge, the originally selected site for the plant.

The model used to predict water quality conditions in the estuary was the Dynamic Estuary Model (DEM) developed by EPA. The model provides an accurate hydrologic analysis of the Potomac River estuarine system. It is a one dimensional model utilizing finite difference equations to simulate the hydrologic conditions in the river estuary system. The hydrologic model is combined with a water quality model to predict the impact of hydrologic phenomena on the levels of selected water quality parameters in the estuary. For the project, the model was used only to simulate conservative parameters (those which do not undergo transformations). The geographical setting for the modeling work and the potential sites of the future estuary water treatment plant are shown in Figure E.7-1. Also shown are the wastewater treatment plant discharge locations as utilized in the model.

PROJECTED WATER QUALITY IN THE POTOMAC RIVER ESTUARY

The base conditions for prediction of expected water quality levels in the estuary included hydrologic conditions comparable to the 1930 drought, year 2030 water supply demands, a 100 MGD flowby entering the estuary and a drought duration of ninety days. Modeling was then based on 200 MGD withdrawal to an estuary water treatment plant with subsequent discharge through the existing wasteater plants. A ten percent consumptive loss was assumed.



1. These wastewater treatment plants no longer discharge to the Potomac estuary. Their contribution to total wastewater discharges is small and results were unaffected by their inclusion.

**LOCATION MAP OF
POTOMAC RIVER ESTUARY
FIGURE E. 7-1**

Influent Water Quality

The projected TDS levels in the Potomac River estuary at Chain Bridge are shown in Figure E.7-2. The TDS use increment from municipal and industrial use was assumed to be 400 mg/L. An analysis of the TDS levels in the estuary indicated that the TDS increases were due entirely to the treated wastewater discharges and that the contribution from tidal action from the seaward boundary into the upper reaches of the estuary was negligible.

Using these predictions for TDS with appropriate background levels and use increments for a number of inorganic parameters, computations were made of the maximum projected concentrations of these parameters in the estuary at Chain Bridge. These maximum projected values are summarized in Table E.7-1 for major cations, anions and nutrients and trace metal parameters.

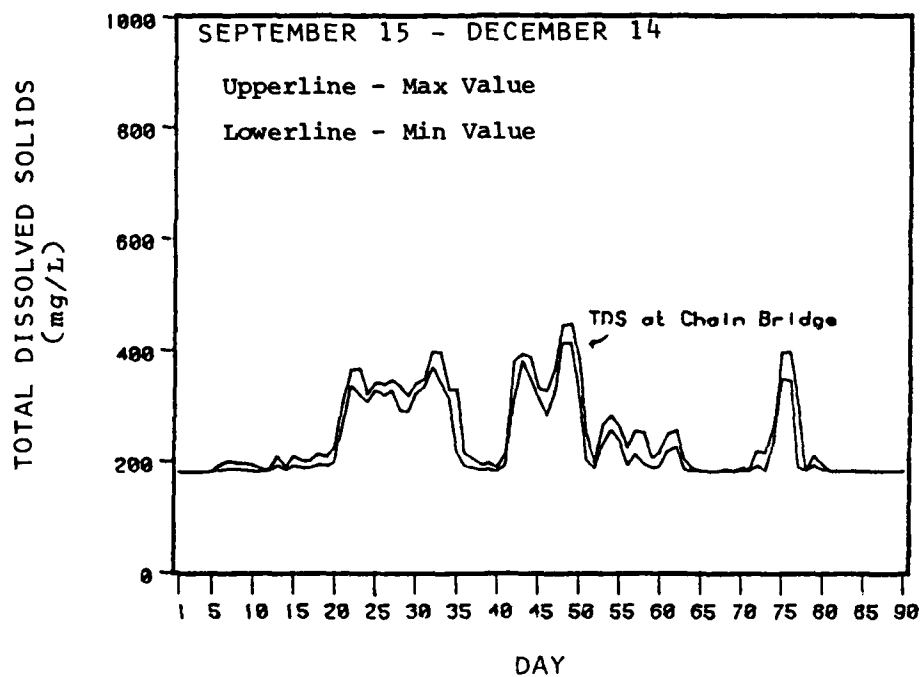
For an alternate estuary plant site, located at Potomac Park, the levels of these inorganic parameters would be expected to increase by approximately twenty percent. Should the treatment plant be located at Potomac Park under a scenario of zero flowby, the TDS levels would increase by a factor of 1.7 times the maximum values shown in Figures E.7-2 and Table E.7-1.

Estimates were made of the impact of failure of the nitrification facilities at the Blue Plains Plant on the levels of ammonia in the estuary. This scenario was important because of high levels of ammonia (up to 2 mg/L-N) observed in the estuary at Chain Bridge. These ammonia levels were observed prior to the start up of nitrification at the Blue Plains Wastewater Treatment Plant.

As shown in Figure E.7-3, breakdowns of nitrification are projected to increase the ammonia levels in the estuary. These estimates are based on the assumption that ammonia is a conservative parameter. However, this is unlikely in the summer because microbial nitrification in the estuary would occur. The projected values thus represent the maximum possible values of ammonia which could be expected in the estuary during drought conditions and low temperatures.

SELECTION OF MIX

Table E.7-2 shows the comparison between the maximum projected values in the estuary at Chain Bridge with the expected levels of several parameters based on an equal mix of Blue Plains nitrified effluent and estuary water. The expected levels were based on water quality monitoring data obtained from an estuary baseline study conducted by the U.S. Army Corps of Engineers and from data obtained from the District of Columbia, Department of Environmental Services. These were the data available at the time of the selection of the influent mix ratio.

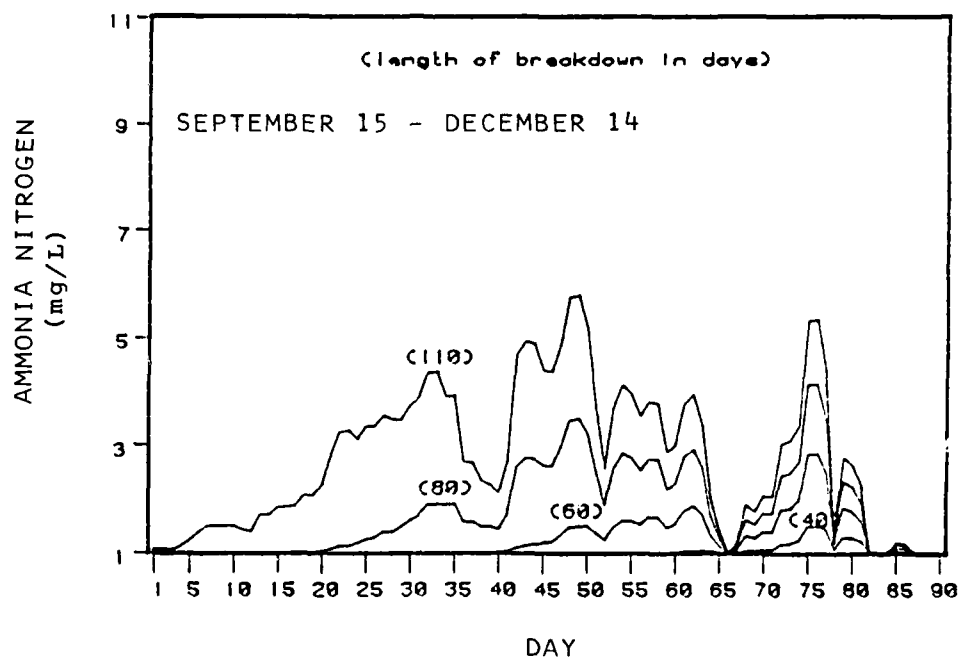


**DEM PROJECTIONS
TDS LEVELS AT CHAIN BRIDGE
400mg/L TDS USE INCREMENTS
FIGURE E. 7-2**

Influent Water Quality

TABLE E.7-1
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 (mg/L)	Maximum Projected Concentrations 1981 (mg/L)
<u>Major Cations, Anions and Nutrients</u>			
Total Dissolved Solids	180	400	447
Calcium	26.9	30	47
Hardness (as CaCO ₃)	91	100	158
Magnesium	5.9	6.0	9.9
Potassium	2.3	7.0	7.0
Sodium	8.0	85	65
Alkalinity (as CaCO ₃)	63	100	130
Chloride	9.4	107	81
Nitrogen-NO ₃	1.27	6.7	5.7
Nitrogen-NH ₃	0.06	1.9	1.3
Total Phosphorus	0.09	0.31	0.30
Sulfate	27.2	43	56
<u>Trace Metals</u>			
Aluminum	0.83	0.2	0.96
Cadmium	0	0.1	0.07
Chromium	0.012	0.17	0.13
Copper	0.006	0.10	0.07
Iron	1.36	0.1	1.4
Lead	0.002	0.1	0.07
Manganese	0.096	0.2	0.23
Mercury	0	0.0014	0.001
Nickel	0.010	0.05	0.04
Silver	0	0.02	0.01
Strontium	0.22	0.2	0.35
Zinc	0.026	0.04	0.05



**MAXIMUM DAILY AMMONIA LEVELS AT
CHAIN BRIDGE ASSUMING BREAKDOWN OF
NITRIFICATION FACILITIES AT
BLUE PLAINS WWTP
FIGURE E. 7-3**

Influent Water Quality

TABLE E.7-2

COMPARISON OF PROJECTED WATER QUALITY AT CHAIN BRIDGE WITH ESTIMATED EEWTP INFLUENT USING EQUAL MIX RATIO (AS OF MARCH 1981)

Parameter	Maximum Projected Concentration ¹ 1981	Estimated Value ² Equal Blend Ratio	
		Statistic Used ³	Concentration ¹
Total Coliform	NM ⁴	Mean	2x10 ⁵ MPN/100 ml
TDS	447	90%	366
Cl	81	Mean	69
Total-P	0.3	Mean	0.6
NH ₃ -N	1.3	90%	4.2
NO ₃ -N	5.7	90%	6.4
Cd	0.07	Mean	0.008
Total-Cr	0.13	Mean	0.004
Ni	0.04	Mean	0.005
Pb	0.09	Mean	0.003
Zn	0.05	Mean	0.04
TOC	NM	Mean	8.5
TOX (µg Cl/L)	NM	Mean	200
Purgeable Organics (µg/L)	NM	Range	12-20
Turbidity (NTU)	NM	Mean	15
Asbestos (M FL)	NM	Single Value	22
Algae (no./ml)	NM	Max	750

1. Units in mg/L except where noted.
2. Values obtained from Tables 6.2-1 and 6.2-2.
3. When available, 90 percentile statistic used for comparison with maximum projected value.
4. NM = not modeled.

Influent Water Quality

As can be seen in Table E.7-2, the 1:1 blend was expected to provide parameter levels both greater (i.e., NO_3) and less than (i.e., TDS) projected values. Parameters of potential health concern include nitrate, which was expected to exceed the projected value. For all metals and TDS, the values in the equal blend were expected to be lower than projected maximum values.

As is apparent from this analysis, the selection process had severe limitations. First, many parameters of health significance including bacterial contaminants, viruses, asbestos fibers, and organic chemicals could not be modeled by the DEM. No one blend mix could be expected to match the model projections. An equal blend was, therefore, selected for the influent to the EEWTP for the two-year monitoring period. This mixture was expected to be conservative, providing higher levels of parameters with potential health concern compared to a blend containing a higher portion of estuary water as recommended in prior studies. However, an equal blend was considered to be the maximum level permissible because of the high levels of nitrate expected.

COMPARISON OF MONITORED RESULTS TO PREDICTED VALUES

Following completion of the two-year monitoring program, the actual monitoring results obtained from the blend of the two influents were compared to the original projected levels of water quality expected under the assumed hydrologic conditions. Use increments were revised based on monitoring program results and revised maximum projected concentrations were determined. These revised projections are summarized in Table E.7-3 along with the arithmetic mean and 90th percentile values observed in the EEWTP blended influent based on the 23 months of monitoring.

For all parameters modeled, the actual maximum EEWTP levels were greater than the revised maximum projected concentrations (RMPC). Geometric mean levels measured in the EEWTP blended influent were often greater than the RMPC, and 90th percentile values were greater in all cases. Thus, the selected blend mixture was conservative.

It was expected that the levels of some parameters would likely be lower under actual estuary conditions because of natural decay processes in the estuary. The modeling efforts, however, were limited by the inability of the DEM to model most water quality parameters of significant health concern.

TABLE E.7-3
COMPARISON OF MAXIMUM PROJECTED WATER QUALITY PARAMETER CONCENTRATIONS
TO OBSERVED EEWTP INFLUENT CONCENTRATIONS

Parameter	1983 Revised Maximum Projected Concentration (RMPC)(mg/L) ^a	EEWTP Blend Tank		EEWTP Performance
		Arithmetic Mean (mg/L)	90 Percentile (mg/L)	
<u>Major Cations, Anions, and Nutrients</u>				
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)	---			
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
<u>Trace Metals</u>				
Al	---			
Cd	0.0001	0.0002	0.0004	RMPC < EEWTP mean
Cr	---			
Cu	0.0087	0.0450	0.0140	RMPC < EEWTP mean
Fe	1.53	1.37	2.38	RMRC < EEWTP 90%ile

Influent Water Quality

TABLE E.7-3 (Continued)

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

Parameter	1983 Revised Maximum Projected Concentration (RMPC)(mg/L) ^a	EEWTP Blend Tank		EEWTP Performance
		Arithmetic Mean (mg/L)	90 Percentile (mg/L)	
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, year 2030 water demands, and intake at Chain Bridge.
b. Revised use increments could not be calculated.
c. Blue Plains Nitrate+Nitrite concentration used.
d. Blue Plains orthophosphate concentration used.

CHAPTER E-8

PROCESS PERFORMANCE

During the two years of operation, three process combinations were monitored and the results used to evaluate EEWTP finished water quality. This chapter summarizes the characteristics of those individual processes, the particular operational parameters, and the performance of the overall and individual processes with respect to key water quality parameters.

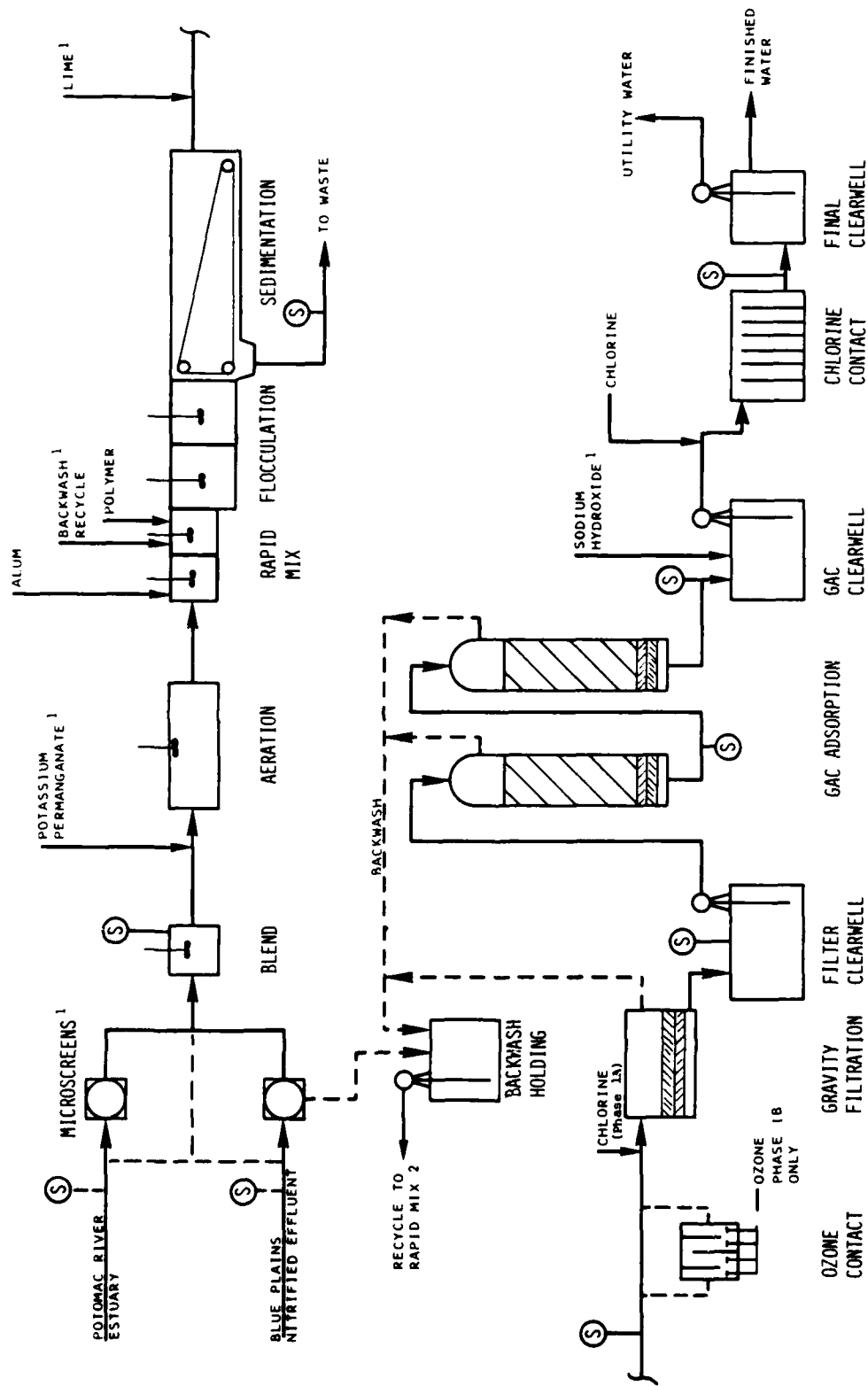
PROCESS SELECTION

The first process monitored consisted of a conventional water treatment plant sequence with the use of granular activated carbon (lignite-based GAC) adsorption following gravity dual-media filtration, as shown in Figure E.8-1. The processes were selected to match the local water treatment processes which are used extensively in the water treatment industry with the exception of granular activated carbon adsorption. Alum is a widely used coagulant known to be effective in removal of organic matter as measured by total organic carbon. Chlorine was used as an intermediate disinfectant because of the high levels of total coliforms in the EEWTP influent and anticipated algae growths in the sedimentation basin. Free chlorine was used as the final disinfectant.

The principal operating criteria for the processes are summarized in Table E.8-1. This process combination, designated as Phase IA, was operated for a one-year period between 16 March 1981 and 15 March 1982 to assess the impact of seasonality on process performance, plant reliability and finished water quality.

The second process monitored was an extension of the alum GAC process except that chlorine was replaced by ozone as the intermediate oxidant. Ozone was selected to improve removal of manganese and because of reported potential improvements in TOC removal on GAC. The operational levels for the ozone addition are also summarized in Table E.8-1. Generally, operating parameters for this period of operation, designated as Phase IB, were similar to Phase IA with the exception of ozone. Phase IB was operated between 16 March 1982 and 7 July 1982.

The principal water quality problems observed during Phases IA and IB were formation of chlorinated organics in the finished water, high odor levels in the finished water and some difficulties in achieving satisfactory microbiological removals as measured by the total coliform parameter. As a consequence, an alternative process was selected to reduce or eliminate the water quality problems observed during these phases. This process is shown in Figure E.8-2.



S SAMPLE LOCATION
 1. SEE TABLE 7. 1-1
 FOR OPERATING PERIODS

EEWTP PROCESS FLOW SCHEMATIC
(PHASES I A AND B)
FIGURE E. 8-1

Process Performance

TABLE E-8-1
OPERATIONS SUMMARY FOR PHASES IA AND IB
(16 MARCH 1981 TO 7 JULY 1982)

Process	Major Design Criteria	Operating Criteria
Microscreens	Number: 2 Screen Panels Material: polyester cloth Mesh size: 35 μm (0.0014 in) Drum Diameter: 1.6 m (5.2 ft) Area: 6.7 m² (71.7 ft²) Speed Range: 0.3 to 9 rpm	Operating period: 3/16/81 to 10/15/81 Avg. hyd. loading rate: 5 L/m²-S (7.5 gpm/ft²) Avg. drum speed: 5 rpm Avg. headloss across panel: 23 mm (0.9 in)
Preoxidation Surface Aeration	Type: mechanical-pitched blade vertical turbine Motor power: 1.5 kw (2 hp) Mixing energy, G=180 sec⁻¹ Detention time @ avg. flow: 22 min.	Operating period: IA & IB
Preoxidation Potassium Permanganate	Manual batching 1 to 4% solution, fed to process with small metering pump	Operating period: 6/1/81 to 1/24/82 Addition points: 6/1/81 to 6/15/81 - Rapid Mix (RM) No. 1 6/16/81 to 10/1/81 - Aeration tank 10/2/81 to 1/24/82 - Blend tank eff. Dose: 1 mg/L for entire period
Rapid Mix	Number: 2 in series Detention time @ avg. flow: 1 min each Mixing energy, G = 400 sec⁻¹	Operating period: Phases IA & IB Addition of alum in RM No. 1 Addition of coagulant aid in RM No. 2

TABLE E-8-1 (Continued)
OPERATIONS SUMMARY FOR PHASES IA AND IB
(16 MARCH 1981 TO 7 JULY 1982)

Process	Major Design Criteria	Operating Criteria
Coagulation Chemical Addition	Primary coagulant: liquid alum 8.3% Al ₂ O ₃ Coagulant aid polymers: Hercofloc 1018 (anionic) Calgon 233 (nonionic) Betz 1160 (cationic)	Alum Operating period: Phases IA & IB Avg. alum dose 54 mg/L Polymer Operating periods: See text Avg. polymer dose 0.1 to 0.2 mg/L
Flocculation	Number of stages: 2 Det. time @ avg flow ea: 20 min Mixers Number per stage: 2 Type: variable speed, pitched blade turbine Speed range: 30 to 100 rpm Mixing energy, G=20 to 100 sec ⁻¹	Operating period: Phase IA & IB Tapered operation Stage 1 avg. rpm: 60 Stage 2 avg. rpm: 30
Sedimentation	Detention time @ avg flows: 4.5 hours Surface loading rate: 19.2 m ³ / m ² -d (470 gpd/sq ft) Weir loading rate: 78 m ³ /m-d (6,250 gpd/ft)	Operating Phases IA & IB Sludge withdrawal daily - collector mechanism on 2 hours prior to pumping to waste
Intermediate pH Control	Hydrated bagged lime, manually batched and fed with chemical metering pump	Operating period: 9/18/81 to 7/6/82
Intermediate Disinfection/ Oxidation	See final disinfection for de- tails of feed equipment	Operating period: Phase IA Avg residual target: 1 mg/L total Cl ₂ Also used for ammonia removal during February and March 1982
Chlorine (Phase IA)	Cl ₂ solution injected into process water in-line prior to gravity filtration	

Process Performance

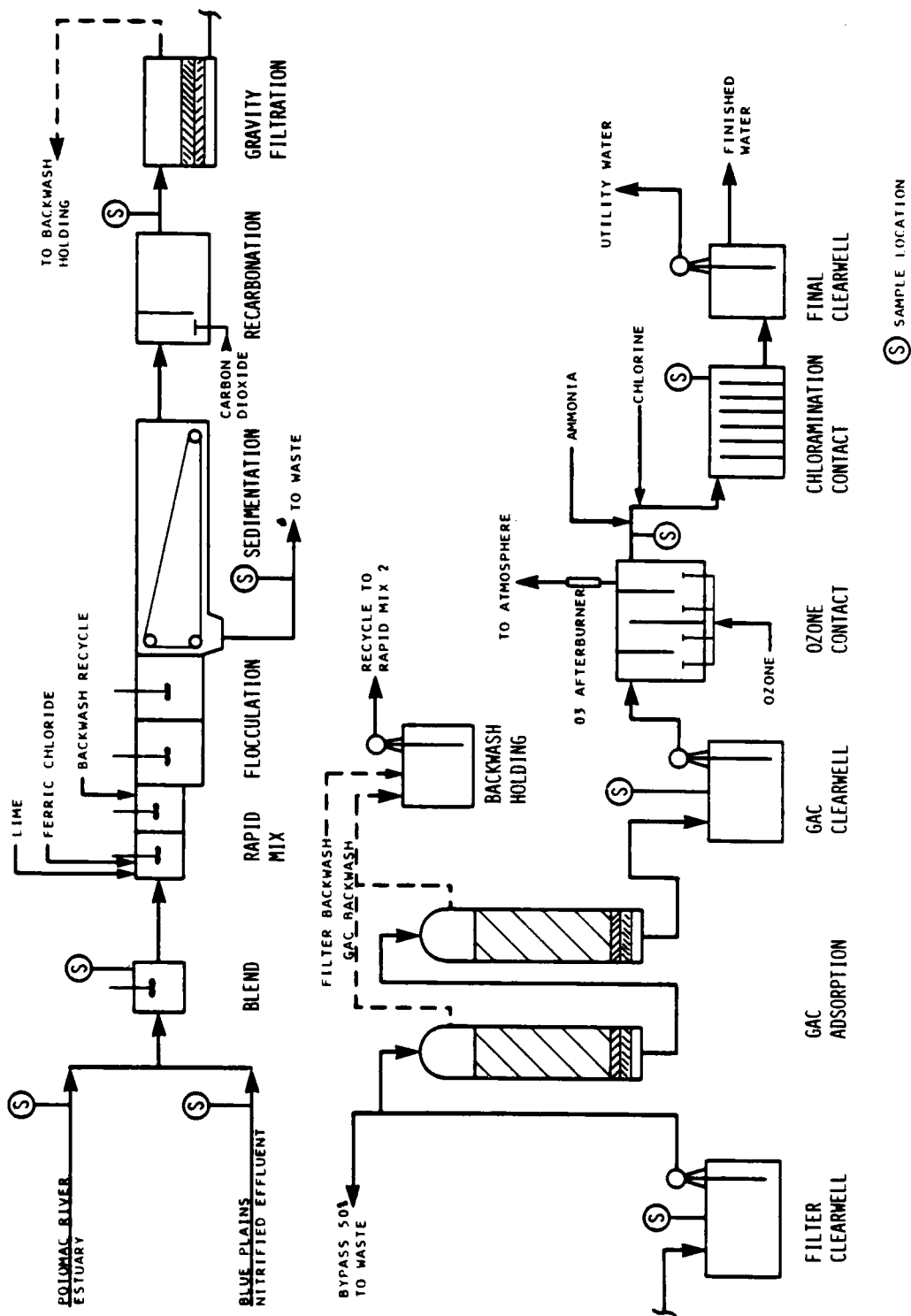
TABLE E.8-1 (Continued)
OPERATIONS SUMMARY FOR PHASES IA AND IB
(16 MARCH 1981 TO 7 JULY 1982)

Process	Major Design Criteria	Operating Criteria
Intermediate Disinfection/ Oxidation	Ozone Generator Type: horizontal tube, corona discharge Capacity: 36 kg/day (80 lbs/day)	Operating period: Phase IB
Ozone (Phase IB)	Contactors Type: 4 pass serpentine Diffusers: ceramic Detention time (total): 10.6 min	Ozone applied in countercurrent passes 1 and 3 Avg. Applied Dose: 3/18 to 4/20/81: 0 to 2.0 mg/L 4/21 to 7/7/81: 4.0 mg/L O ₃ conc. in feed gas = 1% by weight
Dual Media Gravity Filtration	Number: 2 Filter area ea: 5.6 m ² (60 sq ft) Filtration rate: avg: 2 L/m ² -s (3 gpm/sq ft) max: 4 L/m ² -s (6 gpm/sq ft) Media Anthracite Depth: 0.5 m (20 in) Eff. size: 1.4 mm Uniformity coefficient: 1.4 Sand Depth: 0.25 m (10 in) Eff. size: 0.5 mm Uniformity coefficient: 1.4	Operating periods: IA & IB Control mode: constant rate with automatic effluent valve control Backwash Rates Low: 6.8 L/m ² -min (10 gpm/sq ft) High: 11.5 L/m ² -min (17 gpm/sq ft) Backwash water recycled to rapid mix
Granular Activated Carbon Adsorption	Configuration: 2 pressure contactors in series EBCT ea: 7.5 min Surface loading rate: 6 L/m ² -s (9 gpm/sq ft) GAC type: lignite based - ICI 816 Hydroarco 8x16 mesh	Operating period: Phase IA & IB See text for details of carbon in service (virgin or regen- erated), column sequence, service times, backwash criteria and procedures and exhaustion criteria

Process Performance

TABLE E-8-1 (Continued)
OPERATIONS SUMMARY FOR PHASE IA AND IB
16 MARCH 1981 to 7 JULY 1982

Process	Major Design Criteria	Operating Criteria
Final pH Adjustment	Liquid sodium hydroxide (50% solution)	Operating period: 2/18/82 to 7/6/82 Target pH: 7.5
Final Disinfection	Chlorine Feed System Type: Standard gas Chlorinator feed from 150 lb cylinders with remote vacuum control Contact Tank Configuration: serpentine Total contact time @ avg. flow: 55 min	Operating period: Phase IA & IB



EEWTP PROCESS FLOW SCHEMATIC
(PHASE II)
FIGURE E. 8-2

Process Performance

The process consists of lime coagulation with recarbonation, gravity filtration, granular activated carbon adsorption (bituminous based carbon) with a longer empty bed contact time than used in the alum phases, and final disinfection with ozone, with chloramine added as the residual disinfectant. The principal operating levels of the various processes during the lime phase, designated as Phase IIA, are summarized in Table E.8-2. Phase IIA covers the period from 16 July 1982 to 1 February 1983.

The final operating period, designated as Phase IIB, was an extension of Phase IIA in most respects, and covers the period from 1 February 1983 to 15 March 1983. Fewer influent samples were collected during this operating period in order to permit completion of data analysis for the final report. The data from this period are included in Appendix G.

PROCESS PERFORMANCE - ALUM PHASES

PHYSICAL/AESTHETIC PARAMETERS

A summary of EEWTP process performance for the parameters included in the physical/aesthetic parameter group is shown in Table E.8-3 for both Phase IA and IB operational periods. The performance of the process sequences with respect to removal of apparent color and turbidity are similar with greater than ninety percent removal observed. The levels of these two parameters in the blended influent exceeded the maximum contaminant levels specified in the primary and secondary drinking water regulations. MBAS, a parameter included in the secondary standards, did not exceed the maximum contaminant level in the blended influent and removal was not a concern. Figure E.8-3 shows the frequency distributions for turbidity at four sites within the EEWTP during Phases IA and IB indicating the efficiency of the various processes for reducing particulate matter causing turbidity. No differences were noted for turbidity removal between Phases IA and IB. Generally, the turbidity levels in the effluent from granular media filtration were well below the primary MCL of 1 NTU. The process combination easily achieved greater than ninety percent removal of chrysotile asbestos fibers. Chrysotile asbestos fibers are not currently a regulated parameter although they are of potential health concern. It is apparent that the alum phase treatment processes are capable of removing particulate contaminants to acceptable levels.

MAJOR CATIONS, ANIONS, AND NUTRIENT PARAMETERS

Overall process performance for Phase IA is shown in Table E.8-4. Generally, the process combinations employed were not expected to reduce the levels of most dissolved minerals, with the exception of orthophosphate, bromide cyanide, and nitrogen species. Orthophosphate is removed by chemical precipitation, with the latter compounds removed by oxidation with chlorine or ozone.

Increases in sulfate, and slight increases in TDS were also expected due to the use of alum (aluminum sulfate) as the chemical coagulant. Generally, similar results were observed for Phase IB.

Process Performance

TABLE E.8-2
OPERATIONS SUMMARY FOR PHASES IIA AND IIB
(16 JULY 1982 TO 16 MARCH 1983)

Process	Major Design Criteria	Operating Criteria
Rapid Mix	Number: 2 in series Detention time: 1 min each Mixing energy, $G = 400 \text{ sec}^{-1}$	Operating period: Phase IIA & IIB Addition of lime in rapid mix 1 Addition of FeCl_3 in rapid mix 1
Coagulation Chemical Addition	Primary coagulant: lime (slaked quicklime, fed to process in slurry form) Coagulant aid: ferric chloride 30% solution - FeCl_3	Operation Period: Phase IIA & IIB Average lime dose: 80 mg/L CaO Average ferric chloride dose: 2 mg/L Process controlled by pH maintenance in floc tank no. 1 pH ranges used: 10.2 to 11.4
Flocculation	Number of stages: 2 Det. time @ avg flows ea: 20 min <u>Mixers</u> Number per stage: 2 Type: variable speed, pitched blade turbine Speed range: 30 to 100 rpm	Operating period: Phase IIA & IIB Tapered operation Stage 1 avg rpm: 70 Stage 2 avg rpm: 35
Sedimentation	Detention time: 4.5 hours Surface loading rate: 19.2 $\text{m}^3/\text{m}^2\text{-d}$ (470 gpd/ft^2) Weir loading rate: 18 $\text{m}^3/\text{m-d}$ (6,250 gpd/ft)	Operating period: Phase IIA & IIB Collector mechanism on continuously Sludge withdrawal daily - 1 hour Sludge flow sampled and sent to waste

Process Performance

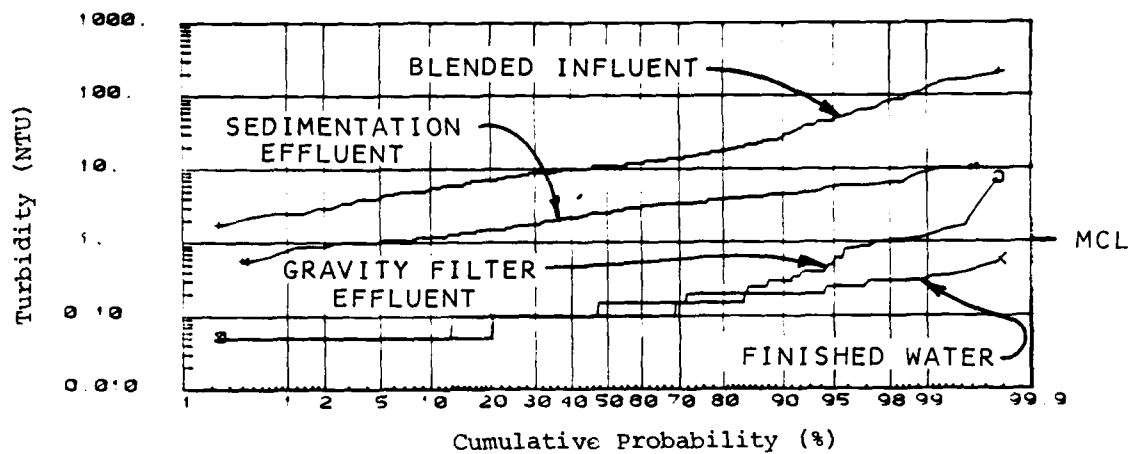
TABLE E.8-2 (Continued)
OPERATIONS SUMMARY FOR PHASES IIA AND IIB
(16 JULY 1982 TO 16 MARCH 1983)

Process	Major Design Criteria	Operating Criteria
Single Stage Recarbonation	Detention time: Compartment 1: 7.2 min (CO₂ application) Compartment 2: 16.6 min (holding) CO₂ source: Commercial grade liquid Diffusers: Coarse bubble	Operating period: Phase IIA & IIB Control: manual pH maintenance pH range: 7.4 to 8.0 Average CO₂ dose: 230 mg/L
Dual Media Gravity Filtration	Number: 2 Filter area ea: 5.57 sq m (60 sq ft) Filtration rate: Avg 2 L/m²-s (3 gpm/sq ft) Max 4 L/m²-s (6 gpm/sq ft) <u>Media</u> Anthracite Depth: 0.5 m (20 in) Eff. size: 1.4 mm Uniformity coefficient: 1.4 Sand Depth: 0.25 m (10 in) Eff. Size: 0.5 mm Uniformity coefficient: 1.4	Operating period: Phase IIA & IIB Control mode: constant rate with automatic effluent valve control <u>Backwash Rates</u> Low: 6.8 L/m²-min (10 gpm/sq ft) High: 11.5 L/m²-min (17 gpm/sq ft)
GAC Adsorption	Configuration: 2 pressure contactors in series EBCT ea: 15 min Surface loading rate: 3 L/m²-s (4.5 gpm/ft²) GAC Type: bituminous based, 12x40 mesh, Calgon F-400	Operating period: Phase IIA & IIB See text for details

Process Performance

TABLE E.8-2 (Continued)
OPERATIONS SUMMARY FOR PHASES IIA AND IIB
(16 JULY 1982 TO 16 MARCH 1983)

Process	Major Design Criteria	Operating Criteria
Final Disinfection Ozone	<u>Ozone Generator</u> Type: horizontal tube, corona discharge Capacity: 36 kg/d (80 lbs/day) (unit modified to reduce max output capacity to approx. <u>Contactor</u> Type: 4 pass vertical serpentine Diffusers: ceramic Detention time: 22 min @ 9,500 m³/d (0.25 mgd) Off-gas: thermally decomposed by after-burner heater	Operating period: 8/5/82 to 2/1/83 Ozone applied in counter-current passes 1 and 3 Avg. Applied O₃ dose: 1.3 mg/L O₃ Average O₃ residual: 0.20 mg/L O₃ Range 0.03 to 0.47 (After 22 min detention time)
Residual Disinfection - Chloramination	<u>Ammonia</u> Aqua-ammonia (30% NH₃-N) Fed to process with chemical metering pump <u>Chlorine</u> Std. gas chlorinator 150 lb cylinders <u>Contact Time</u> Type: serpentine Detention Time: 110 min @ 950 m³/d (0.25 mgd)	Operating period: Phase IIA & IIB Addition: NH₃ then Cl₂ Average NH₃ dose: 1.5 mg/L-N Average Cl₂ dose: 4.9 mg/L Average combined Cl₂ residual: 3.0 mg/L



DISTRIBUTION OF TURBIDITY
(PHASES IA AND IB)
FIGURE E. 8-3

Process Performance

TABLE E.8-3
OVERALL PROCESS PERFORMANCE
PHYSICAL/AESTHETIC PARAMETERS

	Blended Influent			Finished Water			Overall Removal	95% Confidence Interval	
	<u>Na</u>	<u>No. Detected</u>	<u>Geometric Mean</u>	<u>N</u>	<u>No. Detected</u>	<u>Geometric Mean</u>		<u>Lower</u>	<u>Upper</u>
Apparent Color MDL = 3 Color Units MBAS MDL = 0.03 mg/L	200	200	33.7	204	99	2.9	91	90.1	92.5
	261	259	0.063	267	165	0.032	49	44.8	53.2
Total Suspended Solids MDL = 3.6 mg/L Turbidity MDL = 0.05 NTU	203	202	13.35	208	12	NCb	>73c		
	3917	3917	11.07	3914	3910	0.11	99	99.0	99.0
Apparent Color MDL = 3 Color Units MBAS MDL = 0.03 mg/L Total Suspended Solids MDL = 3.6 mg/L Turbidity MDL = 0.05 NTU	13	13	44.9	14	12	4.9	89	85.9	91.1
	2	2	0.049	4	4	0.035	29	7.0	52.3
	11	11	19.79	14	0	NC	>81c		
	662	662	15.32	668	668	0.10	99	99.3	99.4

a. N = Number of Samples Analyzed

b. NC = Not Calculated

c. Overall Removal Calculated Using MDL as Effluent Concentration

Process Performance

TABLE E.8-4
OVERALL PROCESS PERFORMANCE
MAJOR CATIONS, ANIONS AND NUTRIENTS
PHASE 1A

Parameter	Blended Influent			Finished Water			Overall Removal (%)	95 Percent Confidence Intervals	
	Na	No. Detected	Geometric Mean	N	No. Detected	Geometric Mean		Lower	Upper
Alkalinity-CaCO ₃ MDL = 2.7 mg/L	274	274	58.14	282	282	37.69	35	30.6	39.4
Bromide MDL = 0.003 mg/L	272	265	0.0574	282	115	0.0022	96	94.2	97.0
Calcium MDL = 0.2 mg/L	276	276	45.62	281	281	47.18	-3	-8.2	1.1
Chloride MDL = 0.1 mg/L	275	275	42.43	284	284	46.37	-9	-14.0	-4.8
Cyanide, Total MDL = 0.0005 mg/L	283	180	0.0061	283	75	0.0024	60	46.5	71.0
Electroconductivity MDL = 0.1 umho/cm	2107	2107	446	201	201	465	-4	-6.6	1.9
Fluoride MDL = 0.1 mg/L	273	270	0.49	283	277	0.30	39	35.1	42.0
Hardness-CaCO ₃ MDL = 1.0 mg/L	276	276	147.2	280	280	150.7	-2	-7.0	2.0
Iodide MDL = 0.002 mg/L	246	237	0.0048	252	218	0.0032	33	26.9	39.0
Magnesium MDL = 0.1 mg/L	276	276	8.01	280	280	7.88	2	-3.0	6.0
Nitrogen Ammonia MDL = 0.02 mg/L -N	277	251	0.128	285	65	0.002	98	96.9	99.2
Nitrogen Nitrite+Nitrate MDL = 0.02 mg/L -N	276	276	6.9	285	284	6.9	0	-7.0	7.3
Nitrogen Total Kjeldahl MDL = 0.02 mg/L -N	269	253	0.82	30	21	0.29	65	51.7	74.0
Orthophosphate MDL = 0.01 mg/L -P	275	275	0.347	285	27	NC ^b	>34 ^c	NC	NC

Process Performance

TABLE E.8-4 (Continued)

Parameter	Blended Influent		Finished Water		Overall Removal (%)	95 Percent Confidence Intervals		
	N ^a	No. Detected	Geometric Mean	No. Detected		Lower	Upper	
Potassium								
MDL = 0.3 mg/L	276	276	5.92	281	280	5.98	-1	2.9
Silica								
MDL = 0.2 mg/L	276	276	6.49	283	283	5.43	16	21.2
Sodium								
MDL = 0.1 mg/L	276	276	29.10	281	281	28.73	1	6.0
Sulfate								
MDL = 0.6 mg/L	276	276	65.76	284	284	91.10	-39	-34.0
Total Dissolved Solids								
MDL = 10.0 mg/L	184	184	266.6	189	189	273.7	-3	1.4

a. N = number of samples analyzed.

b. NC = not calculated (less than fifteen percent above MDL).

c. Overall removal calculated using MDL as finished water concentrate.

TRACE METAL PARAMETERS

Process performance with respect to trace metal parameters during Phase IA is shown in Table E.8-5. In general, the levels of trace metals in the blended influent during both operating periods were quite low, with the exception of iron and manganese (two parameters included in the secondary drinking water regulations) and mercury (a parameter included in the primary regulations). Removals greater than approximately seventy percent were observed for the following metals: aluminum, arsenic, chromium, copper, iron, lead, and magnesium. Antimony, selenium and zinc, in contrast, increased during treatment. Corrosion within the treatment plant is the suspected source of the increase. The reason for the apparent increase in mercury is unknown. In any case, levels observed were quite low and not of health concern as discussed in Chapter E-9.

In general, the processes during Phases IA and IB were effective in reducing the levels of regulated metals further below the MCLs. Manganese was effectively removed by the Phase IB process. Proper control of pH with permanganate addition was also effective in reducing the manganese levels below the secondary MCL during Phase IA.

Manganese levels exceeded the secondary MCL in the blended influent in over 95 percent of the samples. Both Phases IA and IB process combinations were capable of reducing the finished water manganese levels below the secondary MCL of 0.05 mg/L.

RADIOLOGICAL PARAMETERS

The levels of radiological parameters in the blended influent during Phases IA and IB were considerably less than the maximum contaminant levels in the primary drinking water regulations. Thus, no treatment problems existed for these parameters.

MICROBIOLOGICAL PARAMETERS

Process performance for the microbiological parameters for Phase IA and IB are summarized in Tables E.8-6 and E.8-7. Influent coliform and standard plate count levels were high (generally greater than 20,000 MPN/100 ml) reflecting the contaminated nature of the EEWTP influent. The overall process in both phases achieved greater than a six log reduction in the level of total coliforms and approximately a five log reduction in standard plate count. Salmonella was reduced below detection limits by the overall treatment sequence.

The fate of total coliforms through the treatment process for Phases IA and IB is shown in Figure E.8-4. During Phase IA the maximum contaminant level of 1 MPN/100 ml was never exceeded in the finished water. However, in the carbon column effluent the total coliform level exceeded the standard in eight percent of the samples. Data indicated that total coliform levels increased across the granular activated carbon columns. This phenomena was not observed during Phase IB. However, the coliform levels in the effluent from the gravity filter

Process Performance

TABLE E-8-5
OVERALL PROCESS PERFORMANCE
TRACE METALS
PHASE IA

Parameter	Blended Influent			Finished Water			Overall Removal (%)	95 Percent Confidence Intervals	
	No. Detected	Geometric Mean'	N	No. Detected	Geometric Mean	Upper		Lower	Upper
Aluminum									
MDL = 0.003 mg/L	273	0.3166	279	226	0.0187	94		92.5	95.4
Antimony									
MDL = 0.003 mg/L	273	0.00014	278	133	0.00025	-79		-159.3	-23.6
Arsenic									
MDL = 0.0002 mg/L	274	0.00065	279	148	0.00021	68		57.4	75.5
Barium									
MDL = 0.002 mg/L	271	0.0291	277	266	0.0217	25		17.6	32.5
Beryllium									
MDL = 0.0008 mg/L	272	NC ^b	278	0	NC	NC		NC	NC
Boron									
MDL = 0.004 mg/L	274	0.0393	279	270	.03349	15		2.5	25.5
Cadmium									
MDL = 0.0008 mg/L	250	0.00041	253	33	NC	NC		NC	NC
Chromium									
MDL = 0.0008 mg/L	250	0.0022	253	6	NC	>64 ^c		NC	NC
Cobalt									
MDL = 0.003 mg/L	251	NC	253	6	NC	NC		NC	NC
Copper									
MDL = 0.008 mg/L	251	0.00609	253	174	0.00157	74		68.6	78.8
Iron									
MDL = 0.003 mg/L	272	1.0915	279	240	0.248	98		97.2	98.2
Lead									
MDL = .0003 mg/L	273	0.00158	279	153	0.00033	79		73.2	83.7
Lithium									
MDL = 0.001 mg/L	251	0.00494	251	242	0.00404	18		10.1	25.6
Manganese									
MDL = 0.001 mg/L	274	0.16456	279	279	0.03051	81		78.5	84.0
Mercury									
MDL = 0.00027 mg/L	267	0.00009	279	103	0.0002	-122		-234.5	-47.6

Process Performance

TABLE E.8-5 (Continued)
OVERALL PROCESS PERFORMANCE
TRACE METALS
PHASE IA

Parameter	Blended Influent		Finished Water		Overall Removal (%)	95 Percent Confidence Intervals	
	No. Detected	Geometric Mean	No. Detected	Geometric Mean		Lower	Upper
Molybdenum MDL = 0.002 mg/L	271	12	NC	NC	NC	NC	NC
Nickel MDL = 0.001 mg/L	268	253	0.00405	0.00239	41	32.5	48.4
Selenium MDL = 0.0002 mg/L	274	176	0.00039	0.00051	-31	80.1	5.0
Silver MDL = 0.0008 mg/L	251	37	NC	NC	NC	NC	NC
Thallium MDL = 0.0009 mg/L	273	2	NC	NC	NC	NC	NC
Tin MDL = 0.004 mg/L	270	79	0.00248	0.00128	48	22.1	65.8
Titanium MDL = 0.002 mg/L	271	233	0.0075	NC	>73 ^c	NC	NC
Vanadium MDL = 0.002 mg/L	272	199	0.00333	0.00249	25	6.0	40.5
Zinc MDL = 0.002 mg/L	250	250	0.02085	0.05913	-184	-208.2	-160.7

a. N = Number of Samples Analyzed

b. NC = Not Calculated

c. Overall removal calculated using the MDL as finished water concentration.

Process Performance

TABLE E-8-6
PROCESS PERFORMANCE - MICROBIOLOGICAL PARAMETERS
PHASE IA

	Blended Influent	Finished Water	% Removal	Over-All Log Removal
<u>Total Coliforms (MPN/100 ml)</u>				
Number of Samples	15 ^a	255		
No. Quantified	15	181		
Geometric Mean	6.4x10 ⁴	3.1x10 ⁻²	99.99995	6.3
Median	5.4x10 ⁴	2x10 ⁻²	99.99995	6.4
90% Value	3.5x10 ⁵	1.4x10 ⁻¹	99.99995	6.4
<u>Fecal Coliforms (MPN/100 ml)</u>				
Number of Samples	NA ^b	187		
No. Quantified		25		
Geometric Mean		NC ^c	NC	NC
Median		<1.8x10 ⁻²	NC	NC
90% Value		2x10 ⁻²	NC	NC
<u>Standard Plate Count (Colonies/ml)</u>				
Number of Samples	14 ^a	258		
No. Quantified	14	58		
Geometric Mean	2.9x10 ⁴	2x10 ⁻¹	99.9993	5.2
Median	3.2x10 ⁴	<1.0	>99.9969	>4.5
90% Value	8x10 ⁴	2.0	99.9975	3.6
<u>Salmonella (MPN/100 ml)</u>				
Number of Samples	4	10		
No. Quantified	4	0		
Geometric Mean	6.4x10 ⁻¹	NC	NC	NC
Median	5.1x10 ⁻¹	<2.2x10 ⁻²	>96	>1.4
90% Value	1.6	<2.2x10 ⁻²	>98	>1.9

a. Weekly Analysis Began at These Sites on 1 December 1981.

b. NA = Not Analyzed During Phase IA.

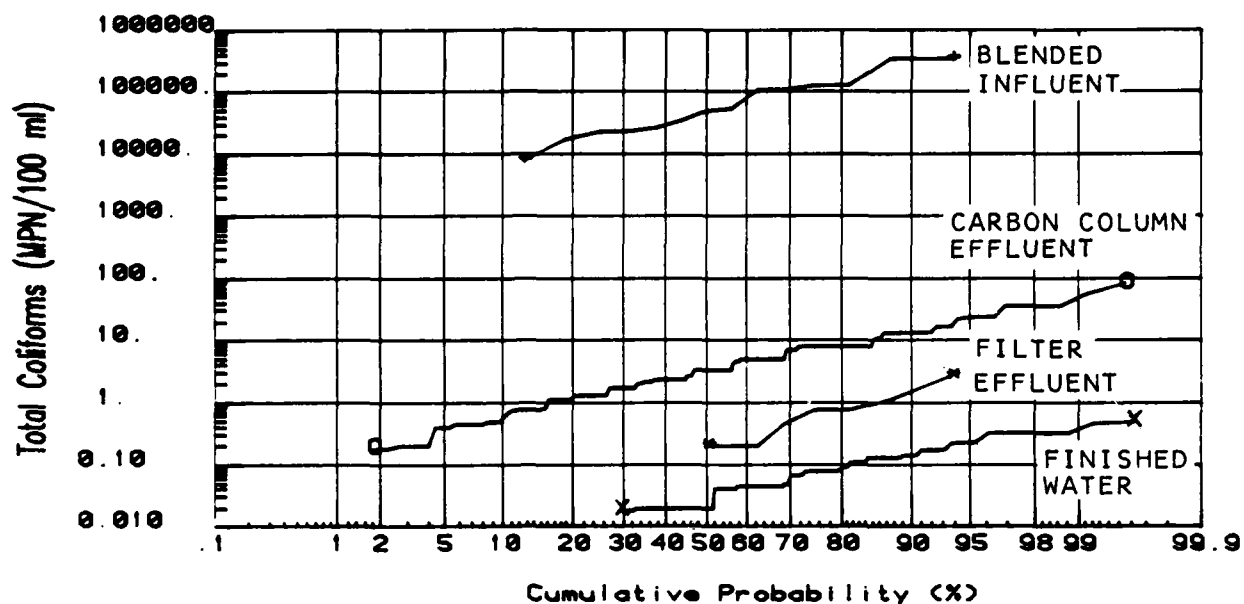
c. NC = Not Calculated.

Process Performance

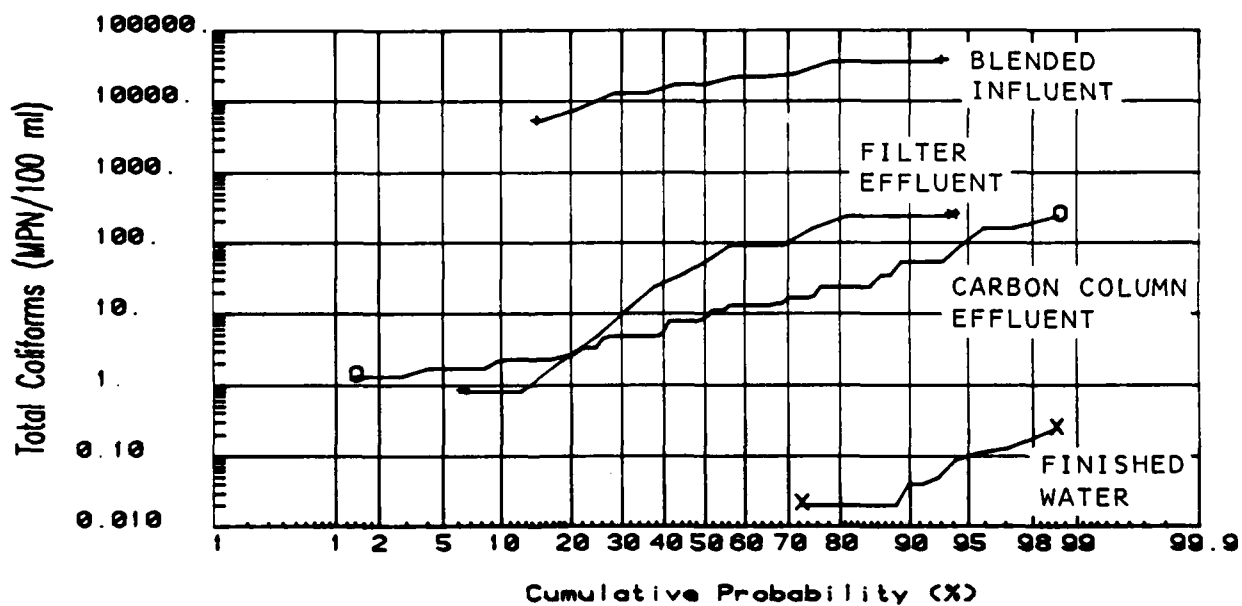
TABLE E.8-7
PROCESS PERFORMANCE - MICROBIOLOGICAL PARAMETERS
PHASE IB

		Blended Influent	Finished Water	% Removal	Over-All Log Removal
<u>Total Coliforms (MPN/100 ml)</u>					
Number of Samples	13	68			
No. Quantified	13	19			
Geometric Mean	2.2x10 ⁴	8x10 ⁻³	99.99996	6.4	
Median	2.2x10 ⁴	<1.8x10 ⁻²	>99.99991	>6.1	
90% Value	3.5x10 ⁴	2x10 ⁻²	99.99994	6.2	
<u>Fecal Coliforms (MPN/100 ml)</u>					
Number of Samples	13	71			
No. Quantified	13	3			
Geometric Mean	4.9x10 ³	NCA	NC	NC	
Median	4.9x10 ³	<1.8x10 ⁻²	>99.9996	>5.4	
90% Value	1.1x10 ⁴	<1.8x10 ⁻²	>99.9998	>5.8	
<u>Standard Plate Count (Colonies/ml)</u>					
Number of Samples	13	75			
No. Quantified	13	16			
Geometric Mean	1.6x10 ⁴	4x10 ⁻¹	99.9975	4.6	
Median	1.4x10 ⁴	<1	>99.9928	>4.1	
90% Value	3.8x10 ⁴	2.0	99.9947	4.3	
<u>Salmonella (MPN/100 ml)</u>					
Number of Samples	3	3			
No. Quantified	2	0			
Geometric Mean	>1.6x10 ⁰	NC		NC	
Median	2.2x10 ⁻¹	<2.2x10 ⁻²	>90	>1.0	
90% Value	2.2x10 ⁻¹	<2.2x10 ⁻²	>90	>1.0	

a. NC = Not Calculated



(a) Phase IA



(b) Phase IB

**DISTRIBUTION OF
TOTAL COLIFORM BACTERIA
(PHASES IA AND IB)
FIGURE E. 8-4**

Process Performance

were considerably higher than those observed during Phase IA. Total coliforms levels in the gravity filter effluent and carbon column effluent exceeded the MCL in almost all the samples.

During Phase IA, the suggested NRC goal of 0.1 MPN/100 ml in the finished waters was exceeded in twenty percent of the samples while in Phase IB this limit was only exceeded by five percent of the samples. With close control over free chlorine residuals during final disinfection, however, satisfactory coliform levels were achieved during both phases of operation. When high ammonia levels occurred in the blended influent, breakpoint chlorination was necessary to ensure adequate disinfection.

For the other microbial parameters, including viruses and parasites, the Phases IA and IB process combinations reduced levels below detection limits following gravity filtration.

ORGANIC PARAMETERS

Process performance with respect to trace organics is summarized for Phases IA and IB in Table E.8-8. Shown are the surrogate parameters, total organic carbon and total organic halide, and the trihalomethanes. As shown, the treatment processes were quite effective for reducing TOC during both phases with an overall removal of seventy percent or greater. Total organic halide was present in the influent at levels on the order of 80 µg/L-Cl. TOX was also produced during Phase IA intermediate oxidation/disinfection prior to the gravity filters. Thus, removals of TOX by GAC were low compared to Phase IB, where the GAC was capable of producing approximately seventy to eighty percent TOX reduction.

Frequency distributions for TOC removal across the treatment processes are shown in Figure E.8-5 for Phases IA and IB, respectively. TOC removals by coagulation, sedimentation and filtration were approximately forty percent. The distribution of TOC values in the GAC effluent was characteristic of the strategy used for operation of the GAC columns. The TOC levels in the GAC effluent during Phase IA remained below 2 mg/L in eighty percent of the samples. During Phase IB, increased removal of TOC by coagulation and filtration was observed. This increased TOC removal may have been due to the use of ozone as the intermediate oxidant. TOC levels in the GAC effluent were less than 2 mg/L in over ninety percent of the samples during Phase IB.

Shown in Figure E.8-6 is the fate of primary (targeted) organic compounds detected at least 15 percent of the time in the EEWTP influent during Phases IA and IB. Greater reduction in the primary compounds was observed in Phase IB. The treatment combinations tested during Phases IA and IB reduced most of the primary organic compounds to below instrument detection limits with the exception of THMs.

Process Performance

TABLE E.8-8
OVERALL PLANT PERFORMANCE
PHASES IA AND IB

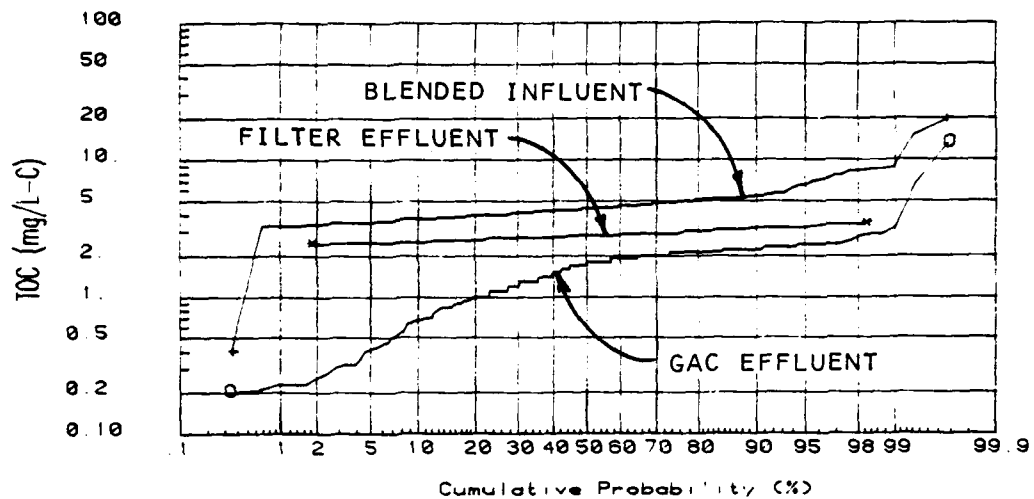
Compound	Blended Influent		GAC Effluent		Overall Removal % (95% CI) ^d
	Number Quant./ Number	Geometric Mean (SF) ^a	Number Quant./ Number	Geometric Mean (SF)	
REMOVAL OF SURROGATE ORGANIC PARAMETERS (COMPOSITE SAMPLES)					
Phase IA					
TOC (MDL = 0.06 mg/L-C)	293/293	4.50 (1.28)	308/308	1.42 (1.75)	68.4 (66.2-70.5)
TOX MDL = 3.9 µg/L-Cl)	298/298	84.98 (1.32)	304/309	42.88 (1.93)	49.5 (45.3-53.4)
Phase IB					
TOC	51/51	4.63 (1.21)	49/59	1.16 (1.54)	75.0 (71.3-78.1)
TOX	51/51	76.70 (1.25)	59/59	17.06 (1.80)	77.8 (73.7-81.2)
TRIHALOMETHANES - REMOVAL/FORMATION (COMPOSITE SAMPLES BY LLE)					
Phase IA					
CHCl ₃ (MDL = 0.3 µg/L)	90/93	1.54 (1.95)	89/97	2.31 (3.14)	-50 (-98-(-13))
CHCl ₂ Br (MDL = 0.3 µg/L)	44/93	0.27 (1.74)	69/97	0.64 (3.03)	-137 (-224(-73))
CHClBr ₂ (MDL = 0.2 µg/L)	25/93	0.16 (1.39)	50/97	0.21 (2.86)	-31 (-82-(-5))
CHBr ₃ (MCL = 0.2 µg/L)	5/93	NC ^c	2/97	NC	—
TTHMs (MDL = 0.2 µg/L)	92/93	1.92 (1.88)	89/97	2.93 (3.93)	-53 (-109-(-11))
Phase IB					
CHCl ₃	52/52	1.68 (1.44)	29/57	0.32 (3.79)	81.0 (68.1-88.6)
CHCl ₂ Br	29/52	0.29 (1.76)	7/57	0.1 ^b	65
CHClBr ₂	14/52	0.09 (3.03)	7/57	0.1 ^b	-11
CHBr ₃	3/52	NC	0/57	NC	—
TTHMs	52/52	2.11 (1.54)	33/57	0.28 (5.10)	87 (76.0-92.7)

a. SF = Spread Factor.

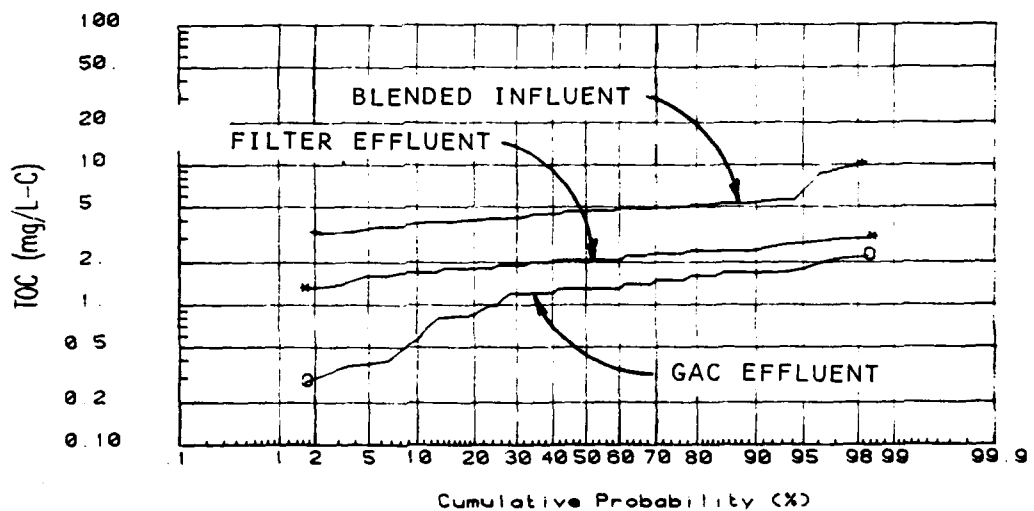
b. Geometric mean not quantified; to compute removals, IDL used.

c. NC = Not Calculated.

d. CI = Confidence Interval.

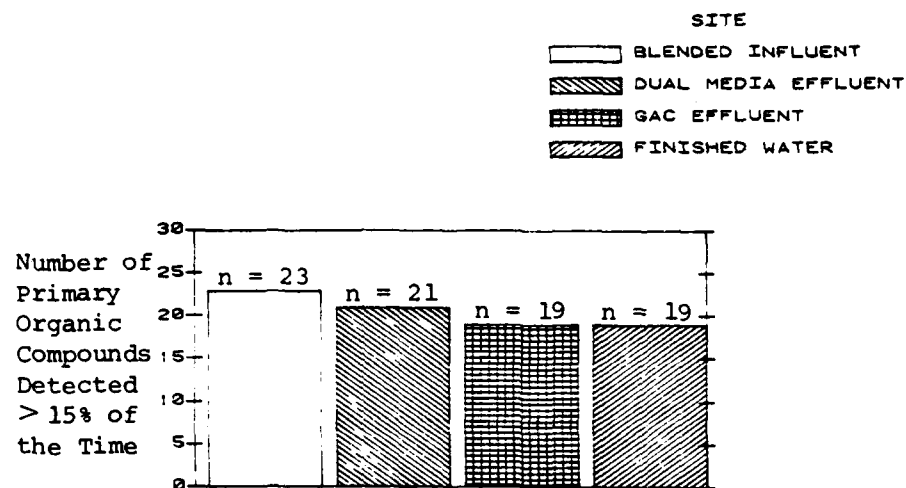


(a) Phase IA

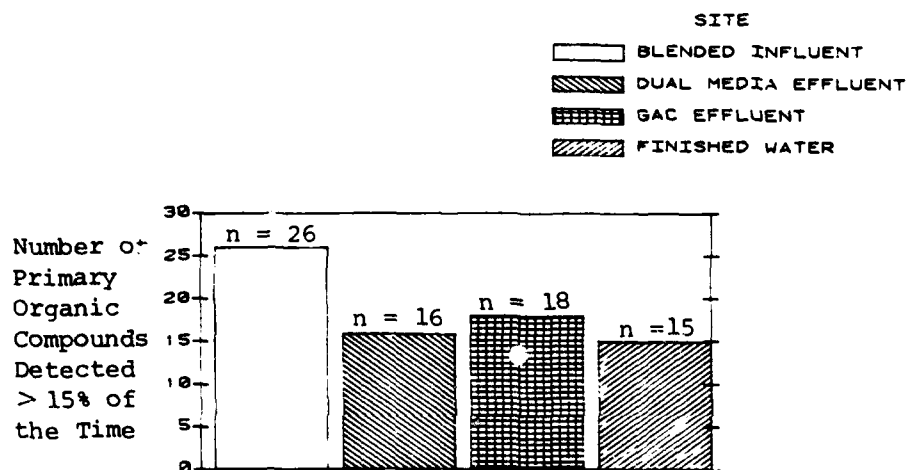


(b) Phase IB

**DISTRIBUTION OF TOC
(PHASES IA AND IB)
FIGURE E. 8-5**



(a). Phase IA



(b). Phase IB

FATE OF PRIMARY ORGANIC COMPOUNDS
ALL FRACTIONS
(PHASES IA AND IB)
FIGURE E. 8-6

AD-A136 861

OPERATION MAINTENANCE AND PERFORMANCE EVALUATION OF THE
POTOMAC ESTUARY E..(U) MONTGOMERY (JAMES M) CONSULTING
ENGINEERS INC PASADENA CA J M MONTGOMERY SEP 83
MWA-83-WA DACW31-80-C-0041

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END

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

Process Performance

Few compounds were observed in sufficient quantities to permit quantitation. One compound that could be traced through the treatment plant was tetrachloroethene (PCE), a known animal carcinogen. The fate of this compound is shown in Figure E.8-7 for Phase IA. Little removal was observed by coagulation, and filtration as expected. The GAC process, however, was capable of reducing the level of PCE such that values never exceeded 2 µg/L, a level below the estimated one-in-a-million cancer risk level of approximately 4 µg/L.

PROCESS PERFORMANCE - LIME PHASE

PHYSICAL/AESTHETIC PARAMETERS

The performance of the lime process combination for control of physical/aesthetic parameters is summarized in Table E.8-9. As anticipated this process was quite effective in reducing particulate matter including asbestos fibers. This process combination was less effective than the Phase IA or IB processes in reducing the level of color, although the geometric mean value in the finished water was consistently at or below the secondary MCL of 15 color units.

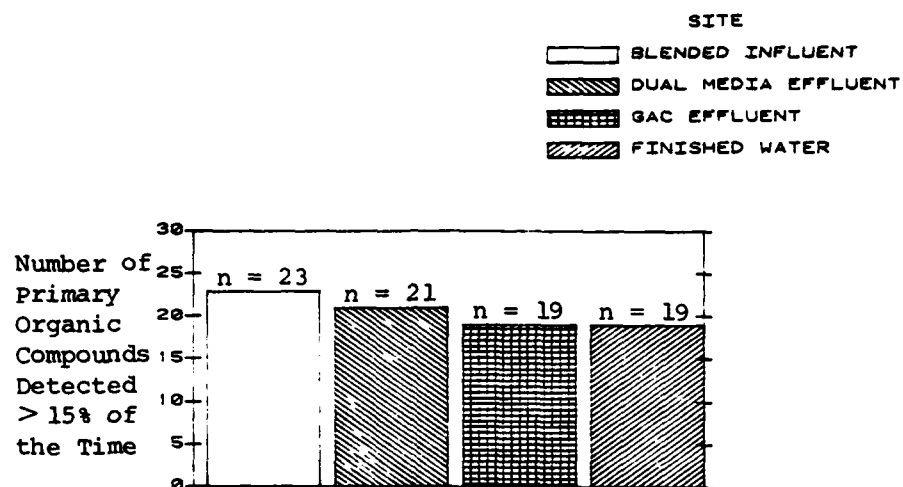
Figure E.8-8 shows the frequency distribution of turbidity at four monitoring sites within the process. For this combination, turbidity levels in the effluent of the gravity filter were below the primary MCL of 1 NTU in all samples. As expected, the lime process was capable of maintaining the Langelier Index within acceptable limits at all times. Odor levels shown in Figure E.8-9 were generally lower than observed during Phase IA or IB.

MAJOR CATIONS, ANIONS, AND NUTRIENT PARAMETERS

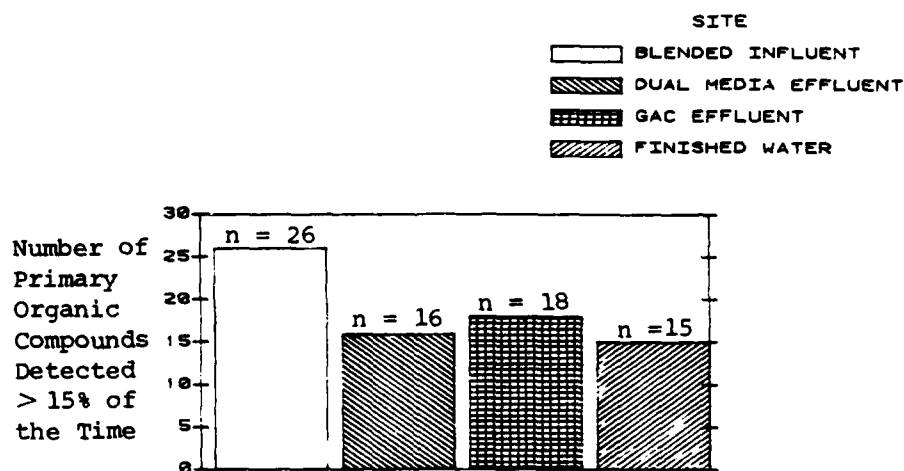
Table E.8-10 summarizes the overall process performance observed in Phase IIA with respect to the major cations, anions, and nutrients. Notable are the removals of orthophosphate (greater than ninety percent) and magnesium (53 percent). As expected, the levels of alkalinity, calcium, conductivity, and total dissolved solids increased due to use of lime as a coagulant. The increase in ammonia was due to the use of chloramines as the residual disinfectant. No significant change was observed in the levels of sodium and nitrate as was the case in Phases IA and IB. Figure E.8-10 shows the time series variation in the nitrate plus nitrite levels. As can be seen, the MCL of 10 mg/L-N was exceeded on one occasion. Generally, the nitrate levels were between 7 and 10 mg/L-N.

TRACE METAL PARAMETERS

Process performance for control of trace metals during Phase IIA is shown in Table E.8-11. The process was more effective for metals removals than the alum process, as was expected at the higher process pH. Again, levels of the trace metals in the blended influent were generally below MCLs specified in the primary and secondary drinking water regulations with the exception of manganese and iron. However, the process removed ninety percent of these metals. Selenium was the only trace metal during the lime phase which increased through the treatment process. The selenium source could not be identified.

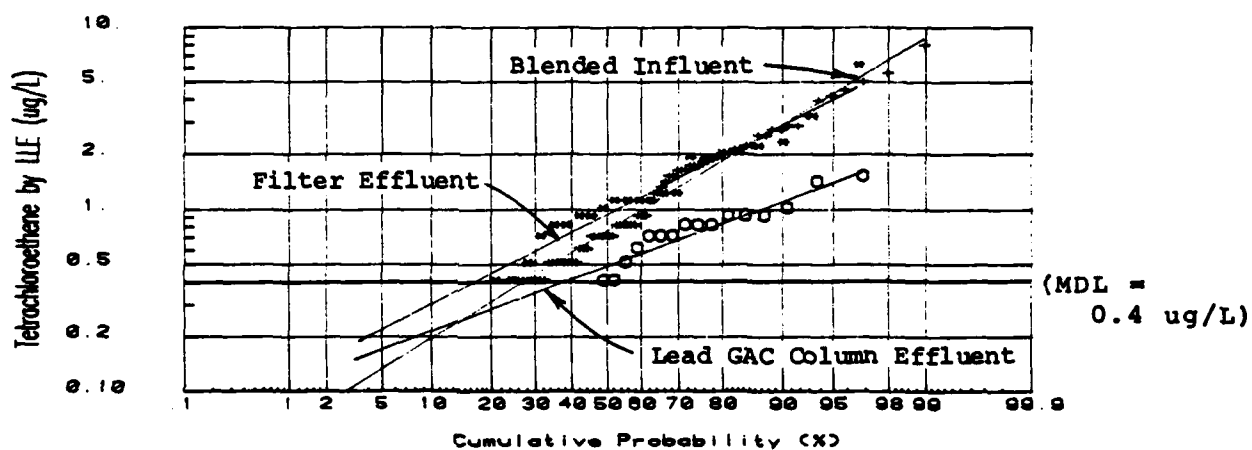


(a). Phase IA



(b). Phase IB

FATE OF PRIMARY ORGANIC COMPOUNDS
ALL FRACTIONS
(PHASES IA AND IB)
FIGURE E. 8-6



**EFFECT OF EEWTP UNIT PROCESSES ON
TETRACHLOROETHENE DISTRIBUTION
(PHASE IA)**

FIGURE E. 8-7

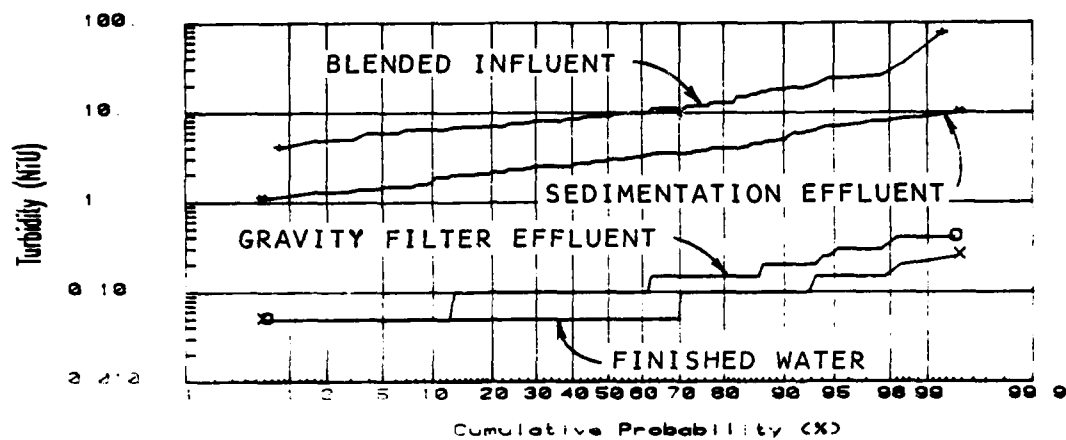
Process Performance

TABLE E.8-9
OVERALL PROCESS PERFORMANCE
PHYSICAL/AESTHETIC PARAMETERS
PHASE IIA

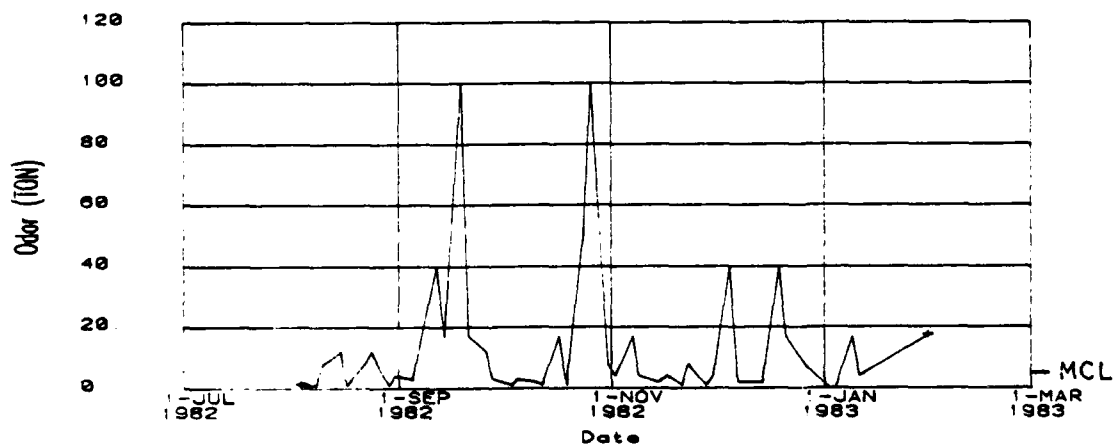
Parameter	Blended Influent		Finished Water		Overall Removal (%)	95 Percent Confidence Intervals	
	N ¹	No. Detected	Geometric Mean	No. Detected		Lower	Upper
Apparent Color MDL=3 color units	22	22	47.3	21	77.8	72.8	81.9
MBAS MDL=0.03 mg/l	6	6	0.075	3	73	43.2	96.2
Total Suspended Solids MDL=3.6 mg/L	24	22	10.65	NA ²			
Turbidity MDL=0.05 NTU	1080	1080	8.72	1079	99.3	99.1	99.5

1. N = Number of Samples Analyzed.

2. NA = Not Analyzed.



**DISTRIBUTION OF TURBIDITY
(PHASE IIA)
FIGURE E. 8-8**



**FINISHED WATER THRESHOLD ODOR NUMBER
(PHASE IIA)
FIGURE E. 8-9**

Process Performance

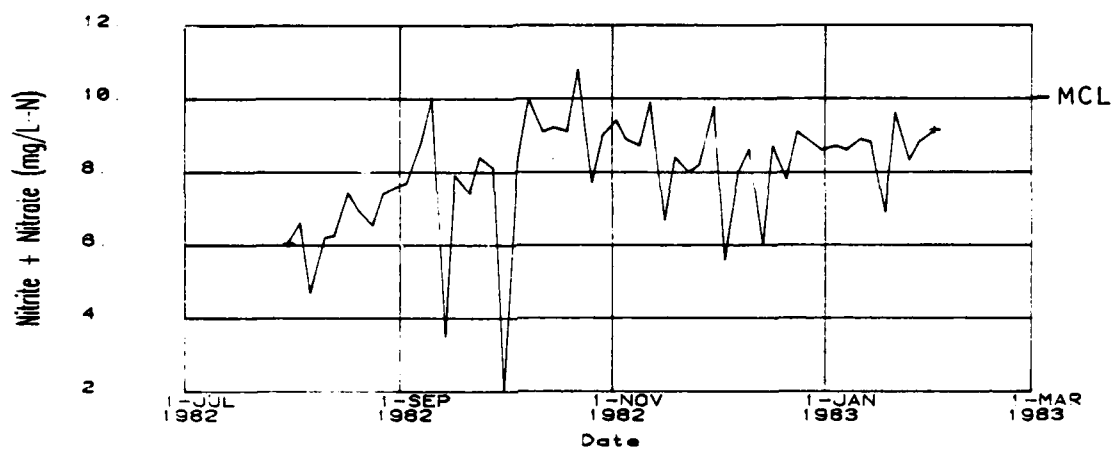
TABLE E.8-10
OVERALL PROCESS PERFORMANCE
MAJOR CATIONS, ANIONS AND NUTRIENTS
PHASE II

Parameter	N	Blended Influent		N	Finished Water		Overall Removal (%)	95 Percent Confidence Interval (%)
		Number Quantified	Geometric Mean		Number Quantified	Geometric Mean		
Alkalinity								
MDL=2.7 mg/L-								-47.3 to
CaCO ₃	52	52	71.7	53	53	96.09	-34.0	-21.9
Bromide								-6.1 to
MDL=0.003 mg/L	52	51	0.0312	53	49	0.0224	28.2	51.4
Calcium								-44.4 to
MDL=0.2 mg/L	55	55	51.07	55	55	68.67	-34.5	-25.2
Chloride								-13.7 to
MDL=0.1 mg/L	52	52	56.05	53	53	60.78	-8.4	-3.4
Cyanide, Total								-16.0 to
MDL=0.005 mg/L	54	18	0.0037	53	8	0.0021	43.2	72.2
Electroconductivity								-18.4 to
MDL=0.1 umho/cm	945	945	502.4	53	53	577.7	-15.0	-11.7
Fluoride								2.7 to
MDL=0.10 mg/L	52	52	0.52	53	53	0.47	9.6	16.1
Hardness								
MDL=1.0 mg/L-								-24.4 to
CaCO ₃	55	55	164.8	55	55	193.7	-17.5	-11.1
Magnesium								43.9 to
MDL=0.1 mg/L	55	55	9.01	55	55	4.26	52.7	60.1
Nitrogen, Ammonia								-331.6 to
MDL=0.02 mg/L-N	52	49	0.177	53	48	0.491	-177.4	-78.3
Nitrogen, NO ₂ , NO ₃								-9.0 to
MDL=0.02 mg/L-N	52	52	7.72	53	53	7.71	0.1	8.5
Nitrogen, TKN								-4.8 to
MDL=0.2 mg/L-N	52	52	1.05	53	52	0.89	15.2	31.5
Orthophosphate								97.4 to
MDL=0.01 mg/L-P	52	51	0.230	53	9	0.001	99.6	99.9

Process Performance

TABLE E.8-10 (Continued)
OVERALL PROCESS PERFORMANCE
MAJOR CATIONS, ANIONS AND NUTRIENTS
PHASE II

Parameter	N	Blended Influent Number Quantified	Geometric Mean	N	Finished Water Number Quantified	Geometric Mean	Overall Removal (%)	95 Percent Confidence Interval (%)
Potassium	55	55	6.26	55	55	6.21	0.8	-3.4 to 4.9
MDL=0.3 mg/L								3.6 to 20.1
Silica	52	52	5.47	53	53	4.80	12.2	-8.6 to 3.0
MDL=0.2 mg/L								-9.4 to 5.4
Sodium	55	55	30.77	55	55	31.57	-2.6	-19.7 to -9.1
MDL=0.1 mg/L								
Sulfate	52	52	53.69	53	53	54.61	-1.7	
MDL=0.6 mg/L								
Total Dissolved Solids	52	52	263.8	53	53	301.5	-14.3	
MDL=1 mg/L								



**FINISHED WATER
NITRITE + NITRATE LEVELS
(PHASE IIA)
FIGURE E. 8-10**

Process Performance

TABLE E.8-11
OVERALL PROCESS PERFORMANCE
TRACE METALS
PHASE II

Parameter	Na	Blended Influent		N	Finished Water		Overall Removal (%)	95 Percent Confidence Interval (%)
		Number Quantified	Geometric Mean		Number Quantified	Geometric Mean		
Aluminum								
MDL=0.003 mg/L	55	55	0.2173	55	45	0.0128	94.1	91.0 to 96.1
Arsenic								
MDL=0.0002 mg/L	55	48	0.00058	55	48	0.00037	36.2	16.8 to 51.1
Barium								
MDL=0.002 mg/L	55	55	0.0303	55	55	0.0166	45.2	38.7 to 51.1
Boron								
MDL=0.0040 mg/L	55	55	0.0519	55	54	0.03877	25.4	13.6 to 35.6
Cadmium (furnace AAS)								
MDL=0.0002 mg/L	55	4	NQ ^b	55	2	NQ	NQ	NQ
Chromium (furnace AAS)								
MDL=0.0002 mg/L	54	52	0.0407	55	53	0.00123	69.8	56.9 to 78.8
Copper (flame AAS)								
MDL=0.0012 mg/L	55	54	0.00788	55	22	0.00096	87.8	80.3 to 92.5
Iron								
MDL=0.003 mg/L	55	55	0.7903	55	38	0.0071	99.1	98.5 to 99.5
Lead								
MDL=0.0003 mg/L	55	53	0.0021	54	13	0.00012	94.3	87.8 to 97.3
Lithium (Flame AA)								
MDL=0.0004 mg/L	54	54	0.00611	55	55	0.00561	8.2	-0.9 to 16.5
Manganese								
MDL=0.0010 mg/L	55	55	0.11041	55	17	0.00039	99.6	99.1 to 99.9
Mercury								
MDL=0.00027 mg/L		55	6	NQ	55	10	NQ	NQ
Nickel								
MDL=0.0010 mg/L	55	49	0.00406	55	30	0.00121	70.2	56.3 to 79.7

TABLE E-8-11 (Continued)
 OVERALL PROCESS PERFORMANCE
 TRACE METALS
 PHASE II

Parameter	N	Blended Influent Number Quantified	Geometric Mean	N	Finished Water Number Quantified	Geometric Mean	Overall Removal (%)	95 Percent Confidence Interval (%)
Selenium								
MDL=0.0002 mg/L	55	31	0.00028	55	39	0.00046	-64.3	-195.3 to 8.6
Silver (furnace AAS)								
MDL=0.0002 mg/L	55	29	0.0002	55	2	NQ	NQ	NQ
Titanium								
MDL=0.0020 mg/L	55	51	0.00962	55	2	NQ	>79c	NQ
Vanadium								
MDL=0.0020 mg/L	55	51	0.00459	55	38	0.00266	42.0	29.0 to 52.7
Zinc								
MDL=0.0012 mg/L	55	55	0.01540	55	55	0.0083	46.1	33.4 to 56.4

a. N = Number of Samples Analyzed.

b. NQ = Not Quantified.

c. Overall removal calculated using MDL as effluent concentration.

Process Performance

RADIOLOGICAL PARAMETERS

As in Phases IA and IB, the levels of these parameters in the blended influent were far below the maximum contaminant levels as specified in the primary drinking water regulations, and, thus, no treatment problems were encountered.

MICROBIOLOGICAL PARAMETERS

The Phase IIA process was generally more effective in the reduction of microbiological parameters than Phases IA or IB. Relevant statistics are shown in Table E.8-12. The geometric mean values for fecal and total coliform were not quantified in the finished water due to the small number of positive results. Based on median values, greater than a six log reduction was observed for total coliforms with greater than a 5.5 log reduction for fecal coliforms. The standard plate count levels were reduced to near the detection limit with the median value being below the detection limit of one colony per ml.

Figure E.8-11 shows the fate of total coliforms through the treatment process. The Phase IIA process was reasonably efficient in reducing coliform levels. However, the elimination of the intermediate oxidant resulted in poorer microbiological quality following filtration and granular activated carbon. The MCL of 1 MPN/100 ml was exceeded in more than eighty percent of the samples leaving the carbon columns. The final disinfection process consisting of ozonation plus chloramine was effective in reducing the coliforms to acceptable levels, however. Generally, the ozonation process was effective in eliminating all positive coliform levels.

With respect to specialized microbiological parameters including viruses, parasites and the Salmonella species, none of these parameters were detected in any process site downstream from the gravity filters.

ORGANIC PARAMETERS

Table E.8-13 summarizes the overall efficiency during Phase IIA for removal of total organic carbon and total organic halide. Also shown are the removals of the trihalomethane species. Elimination of chlorine as the intermediate oxidant and the revised operational criteria for the GAC resulted in substantially increased overall removals of both TOC and TOX. Removals exceeding 85 percent were observed for both parameters. Compared to Phases IA and IB, the lime coagulation process was somewhat less effective in removing TOC than alum. The TOC level rarely exceeded 1.5 mg/L in the GAC effluent, however, which indicated that the capacity of the bituminous carbon for TOC removal was never exhausted after nearly eight months of operation (treatment of nearly 24,000 bed volumes of water).

The fate of primary (targeted) organic compounds detected in more than fifteen percent of the samples during Phase IIA is shown in Figure E.8-12. The number of compounds decreased during treatment. Compared to Phases IA and IB operation, fewer targeted compounds were observed in the finished water, a consequence of the more conservative design and operational criteria for the GAC contactors as well as the revised disinfection strategy.

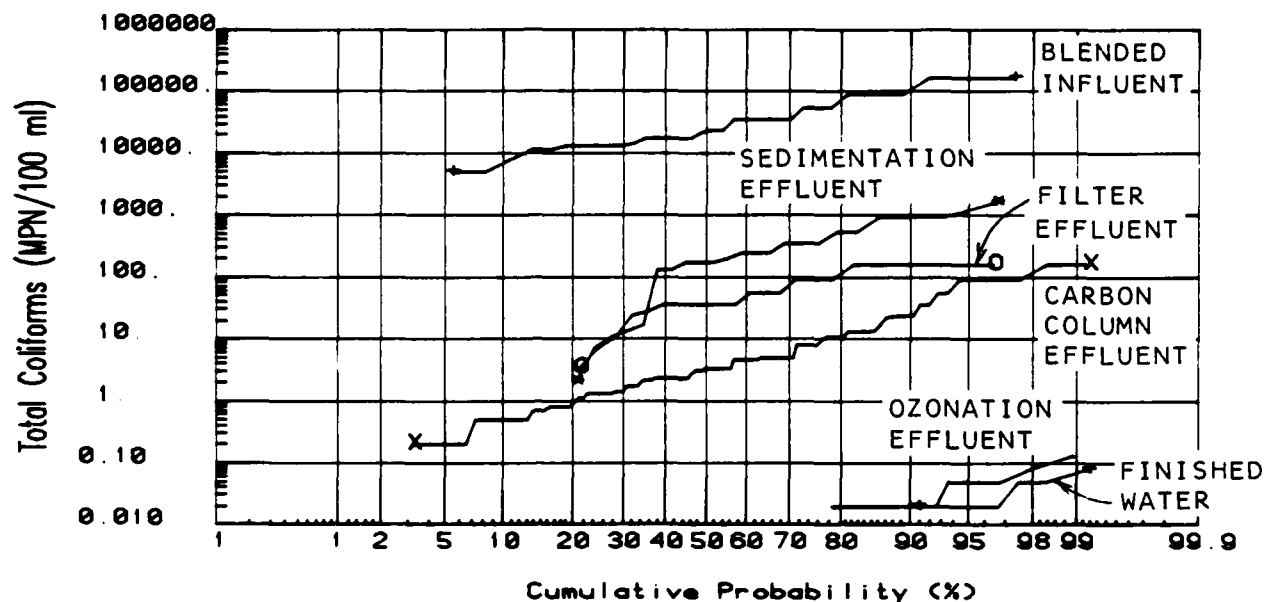
Process Performance

TABLE E.8-12
OVERALL PROCESS PERFORMANCE
COLIFORM AND STANDARD PLATE COUNT
PHASE IIA

	Blended Influent	Finished Water	% Removal	Overall Log- Reduction
Total Coliforms (MPN/100 ml)				
N ¹	36	119		
No. Quantified	36	11		
Geometric Mean	28,990	NC ²	NC	NC
Median	24,000	<0.02	>99.99992	>6.1
90% Value	160,000	<0.02		
Fecal Coliforms (MPN/100 ml)				
N	31	114		
No. Quantified	31	1		
Geometric Mean	7,085	NC	NC	NC
Median	7,000	<0.02	>99.99971	>5.5
90% Value	24,000	<0.02		
Standard Plate Count (colonies/ml)				
N	34	112		
No. Quantified	34	29		
Geometric Mean	13,548	0.4	99.99705	4.5
Median	15,000	<1.0	>99.99333	>4.2
90% Value	28,500	2.0		

1. N = Number of Samples Analyzed.

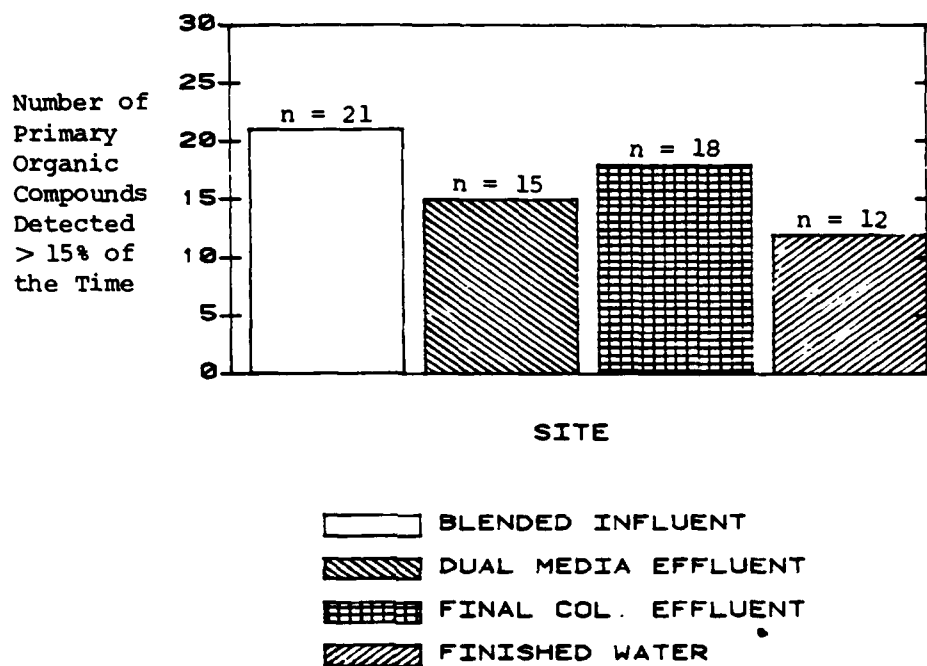
2. NC = Not Calculated.



DISTRIBUTION OF
TOTAL COLIFORM BACTERIA
(PHASE IIA)
FIGURE E. 8-11

TABLE E-8-13
OVERALL PLANT PERFORMANCE
PHASE IIA

Parameter	Blended Influent		GAC Effluent		Percent Removal (95% CI)
	No. Quant./ N	Geometric Mean (SF)	No. Quant./ N	Geometric Mean (SF)	
REMOVAL OF SURROGATE ORGANIC PARAMETERS (COMPOSITE SAMPLES)					
TOC (MDL=0.06 mg/L-C)	109/109	4.46 (1.26)	105/105	0.64 (1.79)	85.7 (79.6-89.9)
TOX (MDL=3.9 µg/L-CI)	107/107	115.83 (1.28)	89/105	16.07 (2.85)	86.1 (82.6-88.9)
REMOVAL OF TRIHALOMETHANES (COMPOSITE SAMPLES BY LLE)					
CHCl ₃ (MDL = 0.3 µg/L)	108/108	1.81 (1.30)	65/107	0.48 (3.78)	73.5 (63.0-81.0)
CHCl ₂ Br (MDL = 0.3 µg/L)	108/108	0.40 (1.44)	3/107	NC	—
CHCl Br ₂ (MDL = 0.2 µg/L)	67/108	0.21 (1.48)	0/107	NC	—
CH Br ₃ (MDL = 0.2 µg/L)	5/108	NC	0/107	NC	—



**FATE OF PRIMARY ORGANIC COMPOUNDS
ALL FRACTIONS
(PHASE IIA)**

FIGURE E. 8-12

CHAPTER E-9

EVALUATION OF FINISHED WATER QUALITY

The principal objective of the EEWTP project was to determine the technical feasibility of using the estuary as a supplemental source of water supply for the MWA. Because of the limitations in the current federal primary and secondary drinking water regulations as criteria for determining the acceptability of a finished water for human consumption obtained from a heavily contaminated source definition of technical feasibility required additional criteria. A finished water was considered of acceptable quality if it could be shown that the levels of water quality parameters, with known or suspected adverse health effects, were less than or not significantly different in the EEWTP than levels observed in local water treatment plants. Where levels of EEWTP water quality parameters were observed to be greater than levels in the local water treatment plants, it was necessary to demonstrate that possible adverse health effects were either non-existent or of negligible significance.

MWA DRINKING WATER

Data used to characterize the quality of drinking water from major MWA water systems were obtained from routine monitoring conducted at three local water treatment plants designated as WTP1, WTP2, and WTP3. Finished waters from the three local plants were monitored for the same parameters and at the same frequency as in the EEWTP finished waters. For purposes of characterizing water quality from the local water treatment plants, data from the entire sampling period, 16 March 1981 to 1 February 1983 were utilized.

FINISHED WATER QUALITY PARAMETERS SELECTED FOR CLOSER EVALUATION

The strategy followed in evaluating finished water quality has been described in Chapter 2 of this Executive Summary. The evaluation level for any given water quality parameter was dependent on whether the parameter exhibited known or suspected health effects and/or aesthetic impacts in the finished water.

The levels of evaluation for various parameters were as follows:

1. All monitored parameters were reviewed for unusually high or especially significant results. Median values were compared and generalized findings presented.
2. For those parameters regulated by the National Interim Primary Drinking Water Regulations (NIPDWR), the levels in the EEWTP finished water were compared to the established Maximum Contaminant Level (MCL). For parameters specified in the National Secondary Drinking Water

Evaluation of Finished Water Quality

Regulations levels in the EEWTP finished water were evaluated relative to the Secondary MCL (SMCL).

3. For all regulated parameters and other selected non-regulated parameters of known or suspected health concern, results for the EEWTP finished water and the three monitored MWA water treatment plants (WTP1, WTP2, and WTP3) were compared.
4. For parameters of special health or aesthetic concern and for which EEWTP finished water levels were higher than those in all the local plants, the significance of the results was evaluated. This included discussion of available health risk information, review with available information from other water supplies, and comparison with alternative criteria.

The principal findings of this comparative evaluation are summarized below by parameter group.

PHYSICAL/AESTHETIC PARAMETERS

Table E.9-1 summarizes the finished water quality at the EEWTP and that observed in the local WTPs for physical/aesthetic parameters. The median or 50 percentile is shown for illustrative purposes. Of the thirteen physical/aesthetic parameters monitored, only the parameters pH, color, and odor were observed to have median values greater than the highest value in a local WTP.

Table E.9-2 summarizes those physical/aesthetic parameters in the EEWTP finished water which exceeded the maximum contaminant levels in either the primary or secondary regulations at least once. The only other parameter included in the regulations is methylene blue activated substances (MBAS) with a MCL of 0.5 mg/L. The EEWTP finished water never exceeded this MCL. Turbidity levels exceeded the MCL in less than 0.1 percent of the samples during Phase IA.

During Phase IA, low pH values were observed in over 38 percent of the samples. These occurred primarily during the first few months of plant operation and were subsequently corrected. As seen in Phase IB and Phase IIA, very few pH values exceeded the recommended limits in the secondary regulations of pH 6.5 to 8.5.

Odor was the one physical/aesthetic parameter exceeding the SMCL in the majority of samples during all operating periods. Some reduction in the odor levels was achieved in Phase IIA. Even under those conditions, however, the odor SMCL of 3 TON was exceeded in sixty percent of the samples. As discussed, the high odor levels in Phase IA were generally described as "chlorinous" in origin by the odor panel, and may have been caused by the presence of high ammonia levels, and the formation of odorous byproducts of the chlorine-ammonia reactions. The observed levels also reflect the subjective nature of the odor analysis, and an odor panel which appeared to be more sensitive to chlorinous odors compared to other observers. As a consequence, the technical feasibility of the treatment process with respect to this particular parameter must be based on a comparison between the odor levels in the EEWTP and the local WTPs rather than comparison to the SMCL.

Evaluation of Finished Water Quality

TABLE E.9-1
SUMMARY OF PHYSICAL/AESTHETIC PARAMETERS
IN FINISHED WATERS

Parameter	Units	Median Values					
		EEWTP					
		Phase IA	Phase IB	Phase IIA	WTP1	WTP2	WTP3
Parameters Affecting Water Treatment							
Temperature	deg. C	18.0	17.0	19.7	17.0	17.5	18.0
pH	pH Units	6.8	7.6	7.4	7.6	7.8	7.6
Dissolved Oxygen	mg/L	8.1	8.0	8.5	NA ³	NA	NA
Free Chlorine	mg/L-Cl	1.6	2.5	0.1	2.1	NA	NA
Total Chlorine	mg/L-Cl	1.8	2.7	3.0	2.3	NA	NA
Parameters of Health and/or Aesthetic Concern							
Turbidity (grab samples)	NTU	0.10	0.10	0.05	0.32	0.20	0.18
Apparent Color	Color Units	<3	5	15	<3	8	8
MBAS	mg/L	0.03	0.03	<0.03	0.04	0.03	0.03
Taste	Taste Units	17	NA	NA	12	NA	NA
Odor	TON	17	12	4	12	8	8
Chrysotile Asbestos Fibers	MF/L ¹	ND ²	ND	ND	ND	ND	ND
Amphibole Asbestos Fibers	MF/L	ND	ND	ND	ND	ND	ND

1. MF/L = million fibers per liter.

2. ND = Not Detected

3. NA = Not Analyzed

Evaluation of Finished Water Quality

TABLE E.9-2

SUMMARY OF PHYSICAL/AESTHETIC PARAMETERS IN FINISHED WATERS EXCEEDING MCLs AT LEAST ONCE

Parameter	MCL (Units)	Number Samples Exceeding MCL/Number Samples (Percent Exceeding)		
		Alum-IA	Alum-IB	Lime-IIA
Turbidity	1 TU (turbidity units)	2/3914 (0.05)	0/674 (0)	0/760 (0)
pH (lower limit)	≤6.5	826/2158 (38)	3/1305 (0.2)	0/761 (0)
pH (upper limit)	≥8.5	6/2158 (0.3)	1/1305 (0.08)	0/761 (0)
Apparent Color	15 cu (color units)	1/204 (0.5)	0/14 (0)	0/21 (0)
Odor	3 TON (threshold odor number)	265/267 (99.2)	22/23 (95.6)	27/46 (58.7)

Evaluation of Finished Water Quality

This comparison is shown in Table E.9-3 in addition to comparisons for turbidity and color. As shown, the EEWTP turbidity levels were always less than the highest value in the local WTPs with a significant difference observed at the five percent significance level. In contrast, color levels in Phase IIA in the EEWTP were significantly higher than the highest value in the local WTP level. However, the MCL was never exceeded during Phase IIA. Odor levels during Phase IA were significantly greater than the highest geometric mean value in the local plants. Although odor levels exceeded levels in the local plants (see Figure E.9-1) during Phase IA, during equivalent monitoring periods, the odor levels were comparable to levels observed in the local plant (See Figure E.9-2). In Phases IB and IIA the geometric mean odor levels were lower than the highest level in the local plants.

MAJOR CATIONS, ANIONS, AND NUTRIENT PARAMETERS

A summary of median values for all parameters in this group is shown in Table E.9-4. In general, the level of these parameters observed in the EEWTP finished water during all three phases of operation was higher than levels observed in local WTPs. This was an expected consequence of the selected blend of equal parts of nitrified effluent and estuary water and reflects the addition of dissolved salts due to municipal and industrial water use.

Although the levels of these parameters exceeded levels in the local plants, the concentrations for the operating phases were generally lower than the primary or secondary MCLs. On some occasions, however, the water quality levels in the EEWTP finished water exceeded these MCLs as summarized in Table E.9-5. Nitrate values exceeded the MCL of 10 mg/L-N in 10 out of 285 samples in Phase IA. As discussed previously, these events occurred exclusively when the influent was comprised solely of nitrified effluent from Blue Plains.

Table E.9-6 summarizes the statistical comparison between the EEWTP finished waters and the finished water from any single local plant exhibiting the highest geometric mean value of the designated parameter, for those water quality parameters with health or aesthetic significance.

TDS

TDS levels were significantly higher in the EEWTP finished waters, compared to levels in the local water treatment plants, but rarely exceeded the secondary MCL. These higher TDS levels in the EEWTP finished waters will not create adverse health risks to consumers.

Sulfate

Sulfate levels in the EEWTP were significantly higher than the local WTPs during phases IA and IB. Again, this was anticipated given the increase in sulfate due to municipal and industrial use, and the use of aluminum sulfate (alum) as the chemical coagulant. In Phase IIA, without the use of alum, sulfate levels were similar to levels in one of the three local WTPs. The observed values in the EEWTP were considerably lower than the secondary MCL of 250 ml/L, however, and the higher levels are of no adverse health or aesthetic concern.

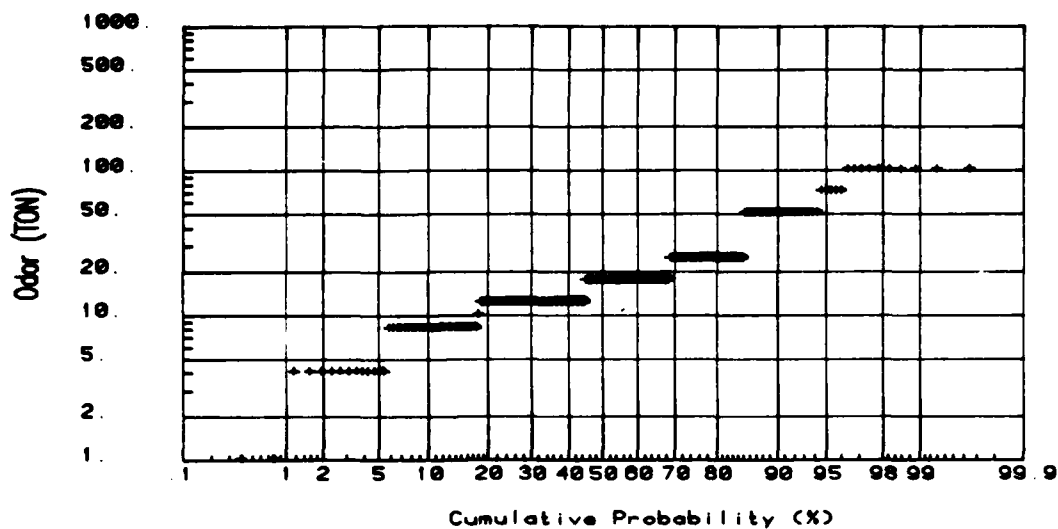
Evaluation of Finished Water Quality

TABLE E.9-3

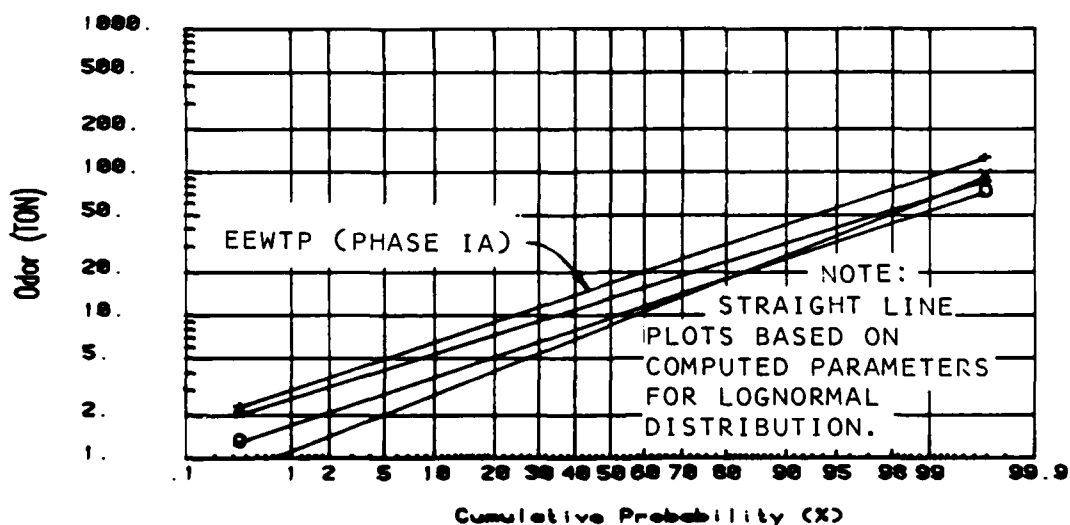
PHYSICAL/AESTHETIC PARAMETERS IN FINISHED WATERS STATISTICAL COMPARISON BETWEEN EEWTP AND LOCAL WATER TREATMENT PLANTS (PARAMETERS OF HEALTH OR AESTHETIC SIGNIFICANCE)

Parameter (units)	Geometric Mean, Highest Local WTP	EEWTP Phase of Operation	Geometric Mean at EEWTP	Significant ¹ Difference
Turbidity (TU)	0.33	Alum-IA	0.11	EEWTP<WTP1
		Alum-IB	0.10	EEWTP<WTP1
		Lime-IIA	0.06	EEWTP<WTP1
Color (CU)	7.5	Alum-IA	2.9	EEWTP<WTP3
		Alum-IB	4.9	EEWTP<WTP3
		Lime-IIA	10.5	WTP<EEWTP
Odor (TON)	13.1	Alum-IA	16.7	WTP3<EEWTP
		Alum-IB	10.4	EEWTP<WTP1
		Lime-IIA	5.2	EEWTP<WTP1

1. Significant difference based on t-test at 0.05 significance level.



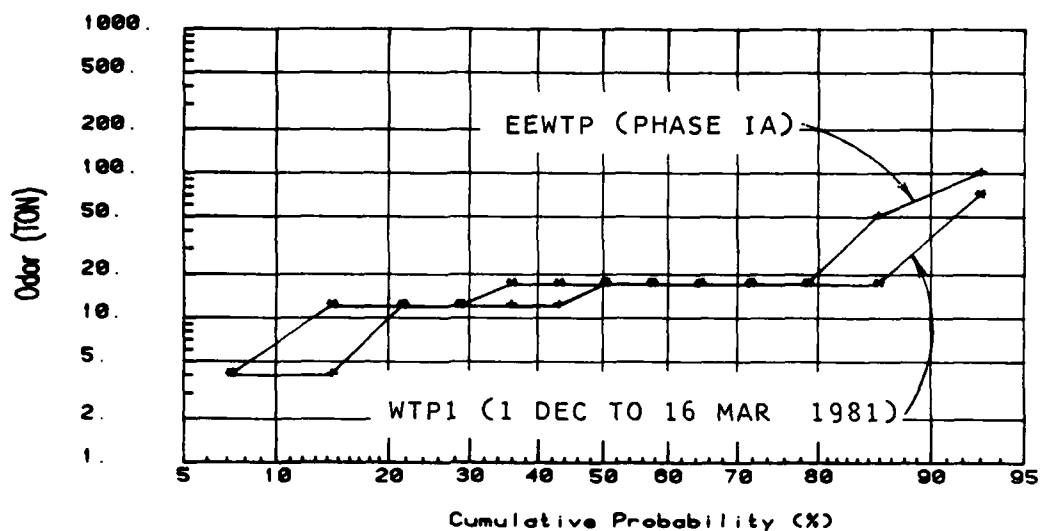
(a) Odor results in EEWTP finished water
(16 March 1981 to 16 March 1982 - Phase IA)



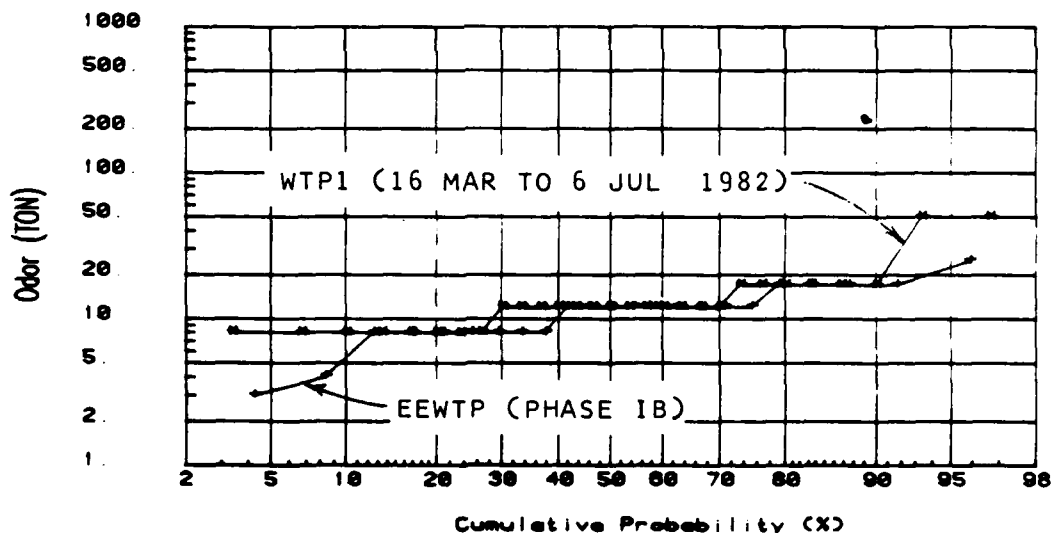
(b) Odor results in EEWTP finished water (Phase IA)
and at three local WTPs (all available data)

ODOR RESULTS IN EEWTP FINISHED WATER AND AT THREE LOCAL WTPs (PHASE IA)

FIGURE E. 9-1



(a) Odor results from equivalent monitoring period
(1 December 1981 to 16 March 1982 - Phase IA),
EEWTP and WTP1 finished waters



(b) Odor results from equivalent monitoring period
(16 March 1982 to 6 July 1982 - Phase IB),
EEWTP and WTP1 finished waters

**ODOR RESULTS IN EEWTP FINISHED WATER
COMPARED TO RESULTS FROM WTP1
(PHASES IA AND IB)
FIGURE E. 9-2**

TABLE E.9-4
SUMMARY OF MAJOR CATIONS, ANIONS, AND NUTRIENTS
IN FINISHED WATERS

Parameter	Units	Median Values					
		EEWTP					
		Phase IA	Phase IB	Phase IIA	WTP1	WTP2	WTP3
Total Dissolved Solids (by addition)	mg/L	293	246	303	188	123	168
Electroconductivity	$\mu\text{mho/cm}$	470.0	460.0	580.0	335	230	330
Major Cations							
Calcium	mg/L	47.1	51.7	65.9	42.3	25.0	40.1
Hardness	mg/L-CaCO ₃	153	156	190	138	80	133
Magnesium	mg/L	7.9	6.8	5.4	7.5	4.4	7.4
Potassium	mg/L	6.1	5.0	6.3	2.6	2.9	2.7
Sodium	mg/L	29.8	24.9	33.3	11.4	11.9	11.3
Anions							
Alkalinity	mg/L-CaCO ₃	37.6	61.0	96.0	80.0	41.6	67.0
Bromide	mg/L	<0.003	<0.003	0.031	<0.003	<0.003	<0.003
Chloride	mg/L	48.0	47.0	63.0	20.0	20.0	36.0
Cyanide	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoride	mg/L	0.3	0.3	0.5	0.9	0.9	0.9
Iodide	mg/L	0.003	—	—	0.003	0.002	—
Silica	mg/L	5.7	6.0	4.7	4.3	7.5	4.6
Sulfate	mg/L	90.0	62.0	55.4	47.1	30.0	30.0
Nutrients							
Nitrogen: Nitrate + Nitrite	mg/L-N	7.6	6.9	8.3	1.4	0.9	1.6
Nitrogen: Ammonia	mg/L-N	<0.02	<0.02	0.80	<0.02	0.45	<0.02
Nitrogen: Total Kjeldahl	mg/L-N	0.3	<0.2	1.0	0.3	0.7	0.3
Orthophosphate	mg/L-P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Evaluation of Finished Water Quality

TABLE E.9-5

MAJOR CATIONS, ANIONS AND NUTRIENT PARAMETERS
EXCEEDING MCLs AT LEAST ONCE

Parameter	MCL (Units)	Number Samples Exceeding MCL/Number Samples (Percent Exceeding)		
		Alum-IA	Alum-IB	Lime-IIA
Nitrate + Nitrite	10 mg/L-N	10/285 (3.5)	0/29 (0)	1/53 (2)
TDS	500 mg/L	0/216 (0)	0/28 (0)	1/53 (2)

Evaluation of Finished Water Quality

TABLE E.9-6

MAJOR CATIONS, ANIONS AND NUTRIENT PARAMETERS STATISTICAL COMPARISON BETWEEN EEWTP AND LOCAL WATER TREATMENT PLANTS (PARAMETERS OF HEALTH OR AESTHETIC SIGNIFICANCE)

Parameter (units)	Geometric Mean Highest Local WTP	EEWTP Phase of Operation	Geometric Mean at EEWTP	Significant ¹ Difference
Total Dissolved Solids (mg/L)	182	Alum-IA	299	WTP1<EEWTP
		Alum-IB	231	WTP1<EEWTP
		Lime-IIA	302	WTP1<EEWTP
Sulfate (mg/L)	51	Alum-IA	91	WTP1<EEWTP
		Alum-IB	59	WTP1<EEWTP
		Lime-IIA	55	WTP1<EEWTP
Sodium (mg/L)	11.5	Alum-IA	29	WTP1<EEWTP
		Alum-IB	16	WTP1<EEWTP
		Lime-IIA	32	WTP1<EEWTP
Cyanide (mg/L)	0.0022	Alum-IA	0.0024	No Signif. Diff.
		Alum-IB	NC ²	
		Lime-IIA	0.0021	No Signif. Diff.
Nitrate + Nitrite (mg/L-N)	1.3	Alum-IA	6.9	WTP3<EEWTP
		Alum-IB	5.1	WTP3<EEWTP
		Lime-IIA	7.7	WTP3<EEWTP

1. Significant difference based on t-test at 0.05 significance level.

2. Insufficient quantified data for estimation of geometric mean in EEWTP finished water.

Evaluation of Finished Water Quality

Sodium

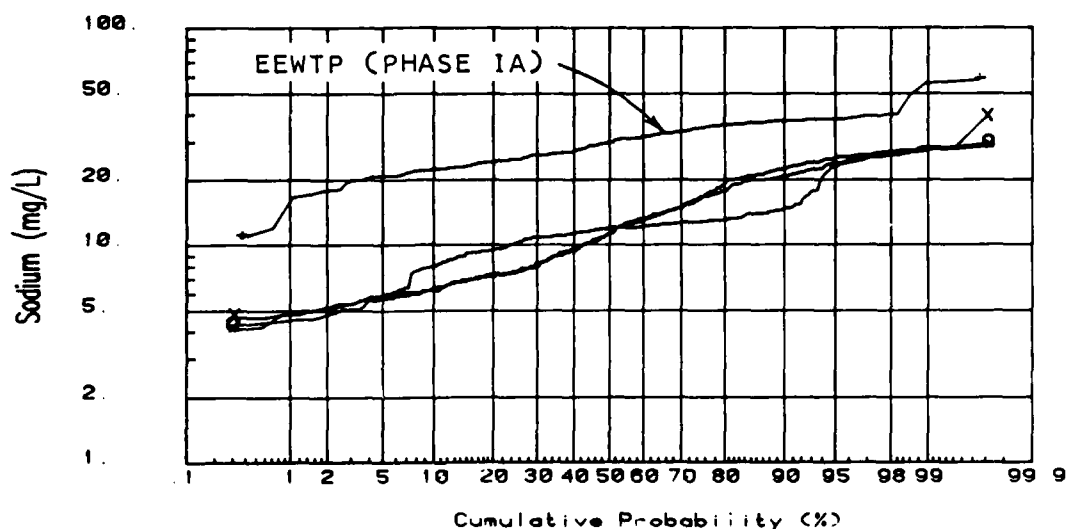
Sodium levels exceeded the levels in the local plants in all samples, (See Figure E.9-3) and the mean values exceeded the EPA suggested "optimum" level of 20 mg/L. However, surveys of sodium levels in public supplies indicate that nearly forty percent of the supplies have sodium concentrations exceeding 20 mg/L and 23 percent had over 50 mg/L. Thus, the higher sodium levels in the EEWTP are not expected to pose unacceptable health risks to the majority of consumers compared to a large number of supplies in the U.S. Nonetheless, this parameter is of special concern to selected segments of the population and may require special attention should an estuary plant be built.

Nitrate

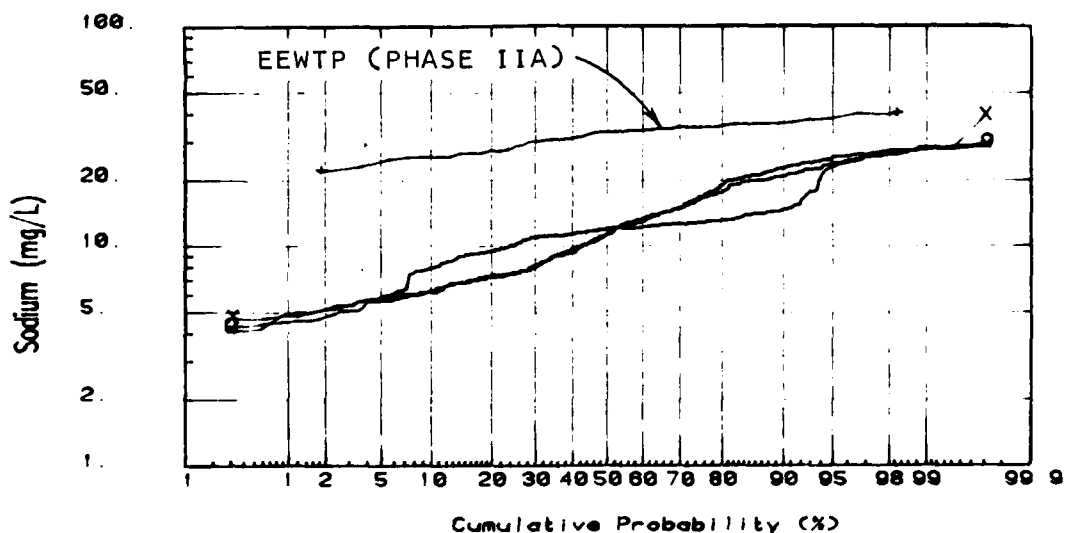
Nitrate levels in the EEWTP exceeded levels observed in the local WTPs in all samples, as shown in Figure E.9-4. Mean EEWTP values were significantly different than local WTP values in all three operational phases. These high nitrate levels are of potential health concern, and would indicate greater health risks to that segment of the exposed population sensitive to high nitrate levels (generally infants less than three months old). The high nitrate levels are not sufficient grounds to reject the acceptability of the EEWTP finished waters for human consumption, however, because the levels do not exceed the MCL. Excluding those operating periods when the influent to the EEWTP was only treated wastewater, the EEWTP nitrate levels never exceeded the primary MCL of 10 mg/L-N. However, the observed levels provide almost no safety factor for sensitive segments of the population.

A second question is whether or not the high nitrate levels exceed those expected in the estuary under the assumed hydrologic and water quality boundary conditions. As shown in Chapter E-7, the projected maximum NO_3 level in the estuary during a drought event was 8.9 mg/L-N. This approximates the 90th percentile value (9.1 mg/L-N) of nitrate observed in the EEWTP blended influent. The samples with nitrate levels above 9 mg/L-N thus represent levels that are unlikely to occur in the estuary under the assumed hydrologic boundary conditions. This fact minimizes concerns that nitrate levels might exceed the MCL in the finished water from an estuary water treatment plant.

Prior to construction of any estuary water treatment plant, however, additional assessment of expected NO_3 levels in the estuary are recommended. Because of the uncertainties in the expected nitrate levels in the estuary during drought conditions, and uncertainties on the health risks associated with suitable levels greater than 5 mg/L-N, but less than the current standard of 10 mg/L-N, nitrate levels remain a source of potential health concern regarding the acceptability of the finished water for human consumption. The estuary source is acceptable for use without nitrate removal processes (demineralization), because the MCL is unlikely to be exceeded.

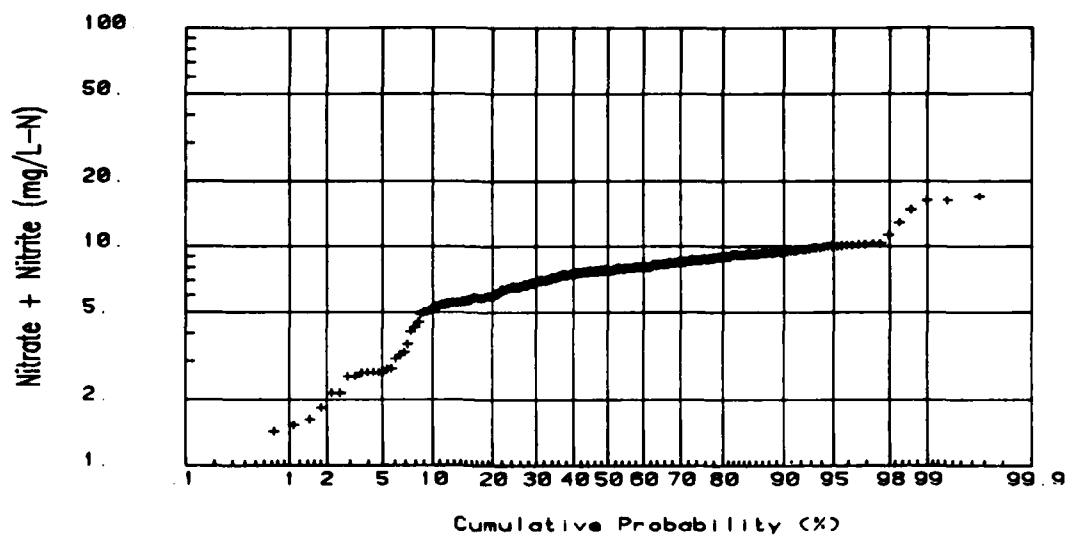


(a) Sodium in EEWTP finished water (16 March 1981 to 16 March 1982 - Phase IA) and at three local WTPs (all available data)

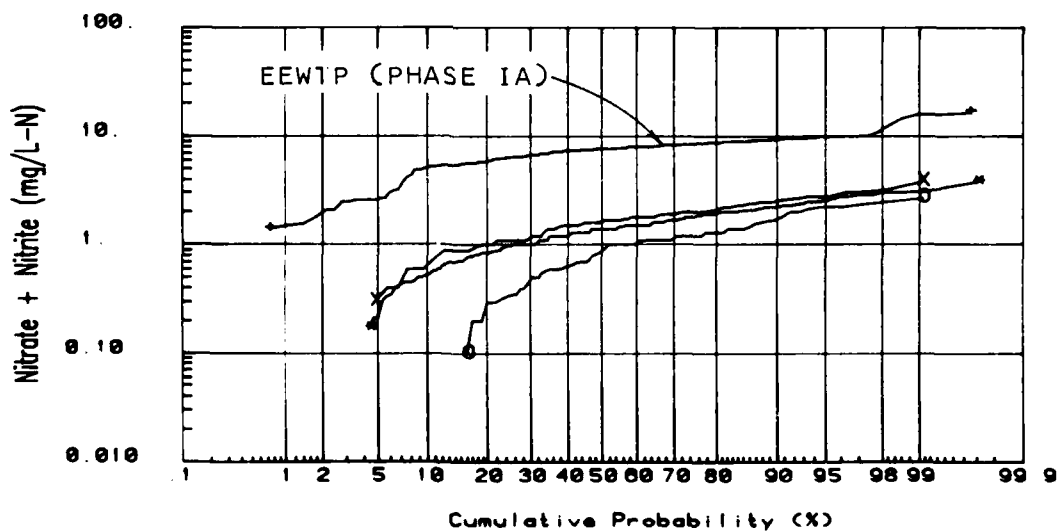


(b) Sodium in EEWTP finished water (16 July 1982 to 1 February 1983 - Phase IIA) and at three local WTPs (all available data)

**SODIUM IN EEWTP FINISHED WATER
AND AT THREE LOCAL WTPs
FIGURE E. 9-3**



(a) Nitrate + Nitrite in EEWTP finished water
(16 March 1981 to 16 March 1982 - Phase IA)



(b) Nitrate + Nitrite in EEWTP finished water (Phase IA)
and at three local WTPs (all available data)

**NITRATE + NITRITE IN EEWTP FINISHED WATER
AND AT THREE LOCAL WTPs
(PHASE IA)
FIGURE E. 9-4**

Evaluation of Finished Water Quality

Hardness

Hardness levels in the EEWTP finished waters have no known or suspected adverse health effects, and are not of concern with respect to acceptability for human consumption. However, relatively high levels of hardness were associated with the EEWTP finished from Phase IIA, which had a geometric mean value of 198 mg/L-CaCO₃. These elevated levels might have adverse impacts on commercial, industrial or residential uses of water other than for drinking.

TRACE METAL PARAMETERS

Over 24 trace metals were routinely measured in the project monitoring program, twelve of which are included in the primary or secondary drinking water regulations because they pose some health risks or affect the aesthetic qualities of the water. Median values from the EEWTP finished waters are compared to the median values in the local WTPs in Table E.9-7. Observed median values during three phases of plant operation are quite low and often close to or below instrument detection limits. The Phase IIA process was generally more effective in removing trace metals than the alum processes (Phases IA and IB) especially with respect to parameters of potential aesthetic concern, such as manganese and iron.

Those trace metals in the EEWTP finished water that exceeded the MCLs at least once are summarized in Table E.9-8. Only three of the twelve metals in the regulations, mercury, iron and manganese, exceeded MCLs. Manganese levels during Phase IA exceeded the secondary MCL of 0.05 mg/L in 34 percent of the samples. These levels of manganese would be unacceptable in a finished water and consequently, close control of this parameter would be required in a future estuary treatment plant. The three process combinations monitored were demonstrated to be capable of meeting the secondary MCL for manganese, provided that proper doses of oxidants and proper pH control are used in plant operations.

The secondary MCL for iron was also exceeded in approximately three percent of the samples during Phases IA and IB. These iron levels were easily controlled by pH increases following sedimentation.

Of some concern to the acceptability for human consumption of Phase IA finished water are the violations of the mercury MCL observed in three of the samples (about one percent). The cause these high values could not be identified. However, the health effects associated with mercury are of a chronic nature, and the arithmetic mean is the critical statistic for evaluating the significance of mercury levels. During Phase IA, the mean value was 0.0003 mg/L, based on 279 samples, as compared to the MCL of 0.002 mg/L. Thus, while mercury values exceeded the MCL on occasions, the average values were low, and are not expected to be of health concern.

A summary of the statistical comparison between the levels of metals observed from the EEWTP and the local WTPs is presented in Table E.9-9. Metals observed to exceed levels in the local WTPs include manganese, mercury, nickel and zinc.

Evaluation of Finished Water Quality

As discussed, manganese is important for aesthetic acceptance of the water and close operational control of the treatment processes would be necessary to maintain the manganese levels below the MCL. Occasional high levels of mercury should not pose additional adverse health risks. For nickel and zinc, EEWTP levels exceeded those of the local WTP, although the levels were far below the secondary MCLs. EEWTP nickel levels are not of health concern. Nickel appears to have very low toxicity to humans and the values observed in the EEWTP were similar to values observed in the local WTPs.

TABLE E.9-7
SUMMARY OF TRACE METALS
IN FINISHED WATERS

Parameter	Units	Median Values					
		EEWTP			WTP		
		Phase IA	Phase IB	Phase IIA	WTP 1	WTP 2	WTP 3
Aluminum (ICP)	mg/L	0.020	0.150	0.020	0.070	0.190	0.70
Antimony (furnace AAS)	mg/L	<0.0003	—	—	<0.0003	<0.0003	<0.0003
Arsenic (furnace AAS)	mg/L	0.0002	0.0006	0.0003	0.0004	0.0003	0.0003
Barium (ICP)	mg/L	0.024	0.024	0.016	0.035	0.027	0.029
Beryllium (ICP)	mg/L	<0.0008	—	—	<0.0008	<0.0008	<0.0008
Boron (ICP)	mg/L	0.0442	0.0449	0.0431	0.0150	0.0273	0.0170
Cadmium (furnace AAS)	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Chromium (furnace AAS)	mg/L	0.0007	0.0011	0.0012	0.0021	0.0009	0.0017
Cobalt (furnace AAS)	mg/L	0.0005	—	—	0.0004	0.0002	0.0004
Copper (flame AAS)	mg/L	0.0023	<0.0013	<0.0012	0.0019	0.0032	0.0022
Iron (ICP)	mg/L	0.032	0.017	0.007	0.026	0.027	0.051
Lead (furnace AAS)	mg/L	0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Lithium (flame AAS)	mg/L	0.0046	0.0042	0.0058	0.0031	0.0007	0.0032
Manganese (ICP)	mg/L	0.0380	0.0059	<0.0010	0.0022	0.0088	0.0044
Mercury (cold vapor)	mg/L	<0.00027	<0.00027	<0.00027	NR ^a	<0.00027	<0.00027
Molybdenum (ICP)	mg/L	<0.002	—	—	<0.002	<0.002	<0.002
Nickel (ICP)	mg/L	0.0028	0.0020	0.0013	0.0027	<0.0010	<0.0010
Selenium (furnace AAS)	mg/L	0.0007	<0.0002	0.006	0.0005	0.0005	0.0005
Silver (furnace AAS)	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Thallium (furnace AAS)	mg/L	<0.0009	—	—	<0.0009	<0.0009	<0.0009
Tin (ICP)	mg/L	<0.0040	—	—	<0.0040	<0.0040	<0.0040
Titanium (ICP)	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Vanadium (ICP)	mg/L	0.0024	<0.0020	0.0029	<0.0020	<0.0020	<0.0020
Zinc (flame AAS)	mg/L	0.0180	0.0077	0.0087	0.0026	0.0023	0.0023

a. Sample contamination from sampling area; data not reported (NR).

Evaluation of Finished Water Quality

TABLE E.9-8

TRACE METAL PARAMETERS EXCEEDING MCLs AT LEAST ONCE

Parameter (Units)	MCL	Number Samples Exceeding MCL/Number Samples (Percent Exceeding)		
		Alum-IA	Alum-IB	Lime-IIA
Mercury (mg/L)	0.002	3/279 (1)	0/32 (0)	0/55 (0)
Iron (mg/L)	0.3	7/278 (2.5)	1/32 (3)	0/55 (0)
Manganese (mg/L)	0.05	94/278 (34)	1/32 (3)	0/55 (0)

Evaluation of Finished Water Quality

TABLE E.9-9

TRACE METAL PARAMETERS IN FINISHED WATERS STATISTICAL COMPARISON BETWEEN EEWTP AND LOCAL WATER TREATMENT PLANTS (PARAMETERS OF HEALTH OR AESTHETIC SIGNIFICANCE)

Parameter (units)	Geometric Mean Highest Local WTP	EEWTP Phase of Operation	Geometric Mean at EEWTP	Significant ¹ Difference
Arsenic (mg/L) MCL = 0.05	0.0004	Alum-IA	0.0002	EEWTP < WTP1
		Alum-IB	0.005	WTP1 < EEWTP
		Lime-IIA	0.0004	No Signif. Diff.
Manganese (mg/L) SMCL=0.05	0.007	Alum-IA	0.03	WTP2 < EEWTP
		Alum-IB	0.0046	EEWTP < WTP2
		Lime-IIA	0.0004	EEWTP < WTP2
Mercury (mg/L) MCL=0.02	0.00015	Alum-IA	0.0002	WTP3 < EEWTP
		Alum-IB	0.0002	WTP3 < EEWTP
		Lime-IIA	0.00009	EEWTP < WTP3
Nickel (mg/L)	0.002	Alum-IA	0.002	WTP1 < EEWTP
		Alum-IB	0.001	No Signif. Diff.
		Lime-IIA	0.001	EEWTP < WTP1
Zinc (mg/L) SMCL=5	0.003	Alum-IA	0.022	WTP1 < EEWTP
		Alum-IB	0.009	WTP1 < EEWTP
		Lime-IIA	0.008	WTP1 < EEWTP
Lead (mg/L) MCL=0.05	0.00028	Alum-IA	0.00033	No Signif. Diff.
		Alum-IB	0.00016	EEWTP < WTP3
		Lime-IIA	0.00012	EEWTP < WTP3

1. Significant difference based on t-test at 0.05 significance level.

Evaluation of Finished Water Quality

RADIOLOGICAL PARAMETERS

The radiological parameters monitored include gross alpha, gross beta, strontium-90, and tritium. Because the levels of gross alpha were generally below the 5 picocuries/liter (pCi/L) standard, no measurements were required for radium. All five radiological parameters were always below the primary MCLs in the blended influent. Consequently, the levels observed in the finished water from all phases of operation never exceeded maximum contaminant levels. The gross alpha levels observed in the EEWTP finished water were not significantly different from the highest level found at a local WTP. During Phase IA however, gross beta levels were higher in the EEWTP finished water than in the highest local WTP. Again, however, the ninety percent value was significantly lower than the gross beta MCL of 15 pCi/L. Although the higher levels of the gross beta parameter in the EEWTP finished water indicate a slightly increased risk to consumers compared to the local WTPs, the implied dose is quite low. Thus, gross beta radiation is not considered to be an issue of concern with respect to consumption of the water produced by the EEWTP.

MICROBIOLOGICAL PARAMETERS

The microbiological parameters monitored include total and fecal coliform, standard plate count, Salmonella, viruses, parasites and endotoxin. A summary of the results for total and fecal coliform and standard plate count is shown in Table E.9-10. During alum Phases IA and IB, the total coliform levels, as characterized by the percentage of positive findings, the median, the 90th percentile value and the maximum value, were greater than the values observed in the local WTPs. However, the coliform levels in the finished water for both Phases IA and IB, never exceeded the MCL of 1 MPN/100 ml. Figure E.9-5 illustrates the frequency distribution of total coliforms observed in the finished water during Phase IA. Many of the positive coliform results were observed in the first four months of Phase IA operation, when free chlorine residuals were lower. As shown in Figure E.9-5, if the data from these four months of operation are excluded, the microbiological quality in the finished water from the EEWTP shows considerable improvement. Ninety percent of the time, the coliform levels are less than 0.1 MPN/100ml, which meets the recommended criteria proposed by the National Research Council for microbiological quality of a finished water obtained from a source subjected to contamination.

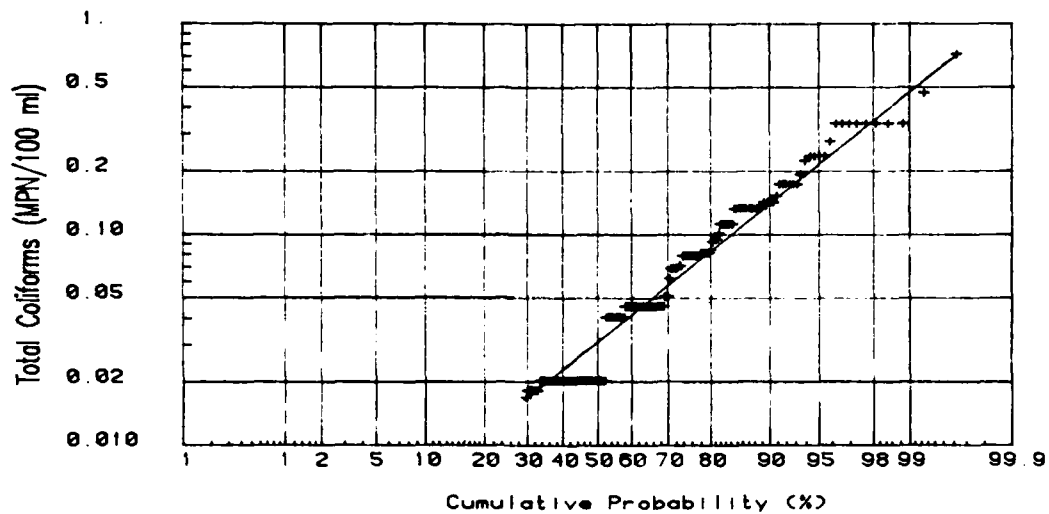
Nevertheless, the coliform levels observed in the finished water during Phase IA are a potential health concern and demonstrate a need for close control of the disinfection process should a similar process combination be used in an estuary water treatment plant. With proper operational controls, however, it is technically feasible to meet proposed standards for total coliforms in the Phase IA process.

For the Phase IIA process, improved reliability in controlling microbiological quality was obtained through use of the ozone and chloramine as the primary and residual disinfectants, respectively. For the Phase IIA process, as shown in Table E.9-10, the total coliform levels were superior to those observed in the highest local WTP for both total and fecal coliforms.

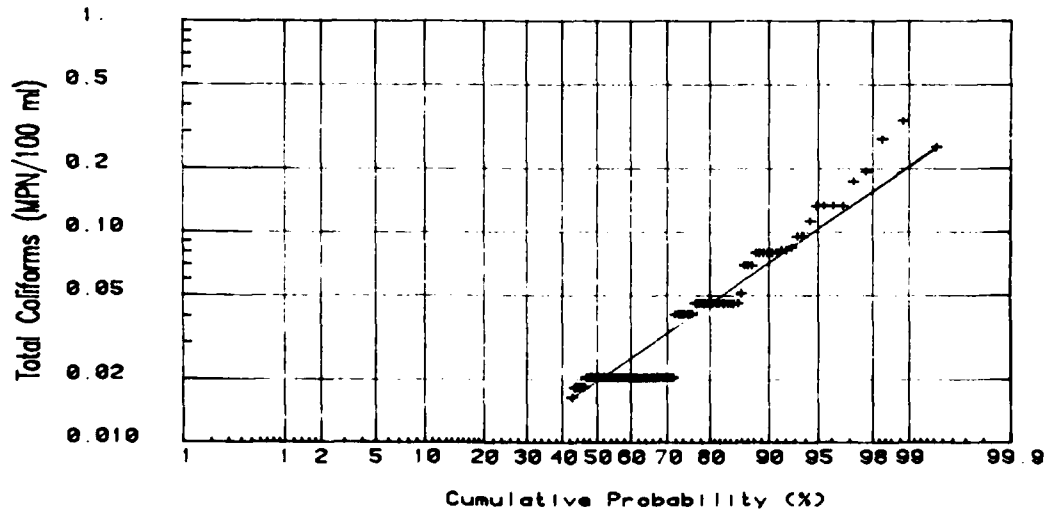
Evaluation of Finished Water Quality

TABLE E.9-10
MICROBIOLOGICAL PARAMETERS
COMPARISON OF FINISHED WATERS

Parameter (Units)	Alum-IA	Alum-IB	Lime-IIA	WTP1	WTP2	WTP3
Total Coliform, Confirmed (MPN/100 ml)	N=255	68	119	448	283	282
Median	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
90 Percentile	0.14	0.04	<0.02	<0.02	<0.02	<0.02
Maximum	0.49	0.23	0.08	0.05	0.23	0.13
% Positive	71	28	9.2	2.0	6.4	8.2
Fecal Coliform, Confirmed (MPN/100 ml)	N=187	71	114	375	216	213
Median	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
90 Percentile	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Maximum	0.08	0.02	0.02	0.02	0.02	0.02
% Positive	13	4	0.9	0.3	0.5	0.9
Standard Plate Count (Colonies/ml)	N=258	75	112	432	274	271
Median	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
90 Percentile	2.0	2.0	2.0	2.0	4.0	7.0
Maximum	300	14	29	340	78	83
% Positive	23	21	26	19	42	46



(a.) Total coliforms in EEWTP finished water (16 March 1981 to 16 March 1982 - Phase IA)



(b.) Total coliforms in EEWTP finished water (1 July 1981 to 16 March 1982 - Phase IA, excluding first 3 1/2 months.)

TOTAL COLIFORMS IN EEWTP FINISHED WATER

FIGURE E. 9-5

Evaluation of Finished Water Quality

Standard plate count levels during all phases compared favorably to levels observed in the local WTPs with respect to both median, 90 percentile and maximum values and the percent positives.

Extensive virus and parasite monitoring of all finished waters was conducted during this project. No positive parasite or virus results were observed in the EEWTP finished waters. Salmonella species were also monitored on a monthly basis in all finished waters. No positive results were observed in the EEWTP finished waters. Over the course of the project approximately 56 samples of the EEWTP finished waters were taken for the determination of enteric viruses. Although viruses were detected and identified in the influent to the EEWTP, no positive results were observed the finished waters.

Endotoxin analyses were conducted during the first operating phase of the project in both the finished waters and the local WTPs. Approximately ten samples were collected. The levels of endotoxin, based on median values, ranged between 2.5 to 5 ng/L in the local WTPs. A value of 5 ng/L was observed at the EEWTP finished water. The levels were quite low and were not considered to be of health concern.

ORGANIC PARAMETERS

One of the principal concerns regarding the use of unprotected water supply sources subjected to extensive contamination from treated wastewater is the unknown health impacts of ingesting small amounts of organic chemicals of industrial origin that could be present in such sources. Consequently, a major objective of the monitoring program was the identification and quantitation of the levels of trace organic compounds in the finished waters.

The trace organic parameters can be conveniently classified into three separate categories, surrogate organic parameters, targeted or primary organic compounds, and non-targeted or secondary organic compounds. The two surrogate parameters monitored were total organic carbon (TOC) and total organic halide (TOX), a measure of the total amount of halogenated organics. Neither of these parameters is included in the drinking water regulations. Approximately 149 targeted organic chemicals were usually monitored during the project, the majority of these representing synthetic organic chemicals (SOCs) with the remainder of either of natural origin, or products of the oxidation processes used in the treatment plants. Targeted compounds are those compounds routinely searched for from the beginning of the project. For most of these compounds, precision and accuracy data were developed and standards were used for confirmed identification. Of these compounds, only seven are currently regulated by EPA standards, including four pesticides, two herbicides, and the total trihalomethanes.

In addition to these compounds, a number of peaks were observed in the organic fractions analyzed for which no standards were run. Some of these compounds, designated non-targeted or secondary compounds could be tentatively identified by comparison to compound structures catalogued in a mass spectra library, and could be approximately quantitated by reference to the peak heights observed on the chromatographs. Nearly 100 additional organic compounds were

Evaluation of Finished Water Quality

tentatively identified in the finished waters from all sites and nearly 200 other compounds were tentatively identified in the plant influent.

Regulated Organic Parameters

A summary of results from all finished waters for the seven regulated trace organic parameters is shown in Table E.9-11, in comparison to the specified MCLs. The six pesticides and herbicides were not detected in the EEWTP finished waters.

Total trihalomethane levels in the EEWTP finished waters were lower than values observed in the local plants in all samples measured. This result was a consequence of the low values of TOC and lower chlorine doses used in the EEWTP finished water. The THM levels cannot be compared to the MCL for THMs because samples were taken before release to a distribution system. In all phases of operation, however, it was shown that THM formation in the EEWTP finished waters was unlikely to exceed the MCL after seven days of contact with free chlorine.

Thus with respect to the regulated organic parameters in the primary drinking water regulations, the EEWTP finished waters from all phases of operation easily meet the MCLs. In addition, the values of THMs in the EEWTP finished waters were quite low (relative to the MCL), thus providing a greater margin of safety for the THMs.

Non-Regulated Organic Parameters

Table E.9-12 summarizes the median values for several non-regulated organic parameters of potential health concern observed in the finished waters. Shown are the levels of the two surrogate parameters (TOC and TOX), and the individual trihalomethane compounds.

TOC and TOX values in the EEWTP finished waters were significantly lower than values observed in the local water treatment plants. (See Figure E.9-6 and E.9-7.) This was a consequence of the use of granular activated carbon at the EEWTP. Bromoform was the only trihalomethane compound observed to exceed levels in the local plants. However, the levels were generally less than 1 µg/L, and thus not expected to pose any unacceptable health risks. Because animal testing data are not currently available for bromoform, no absolute estimate of adverse health risks can be made.

Other Targeted Primary Organic Chemicals

Several additional organic compounds found in drinking water are known or suspected of causing chronic health effects. Many of these compounds were detected at least once in the EEWTP finished waters, but in all cases levels observed were never greater than 1 µg/L. Figure E.9-8 compares the number of targeted compounds detected at least once in the finished waters. Compared to the total number of compounds included in the organic fractions analyzed, the number of compounds detected at least once was relatively small. Comparing number detected at least once in the Phase IA and Phase IIA phases, values are comparable to or less than those observed in the local WTPs.

Evaluation of Finished Water Quality

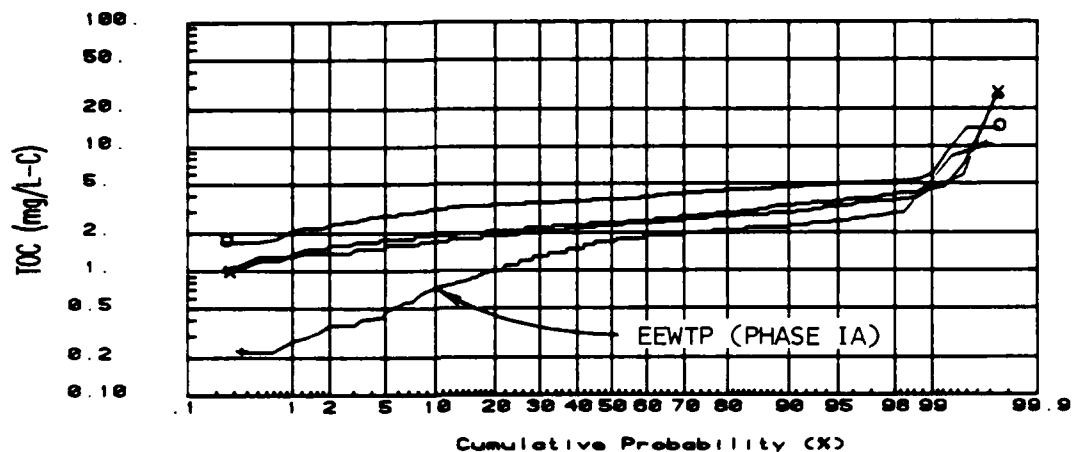
TABLE E.9-11
SUMMARY OF TRACE ORGANICS IN FINISHED WATERS
REGULATED ORGANIC PARAMETERS
MEDIAN VALUES (µg/L)

Parameter (Units)	MCL ^a	Alum-IA	Alum-IB	Lime-IA	WTP1	WTP2	WTP3
Total Trihalo- Methanes	100	9.5	10.1	1.1	67.3	63.2	50.8
Endrin	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lindane	4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	100	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Toxaphene	5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-D	100	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4,5-TP Silvex	10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

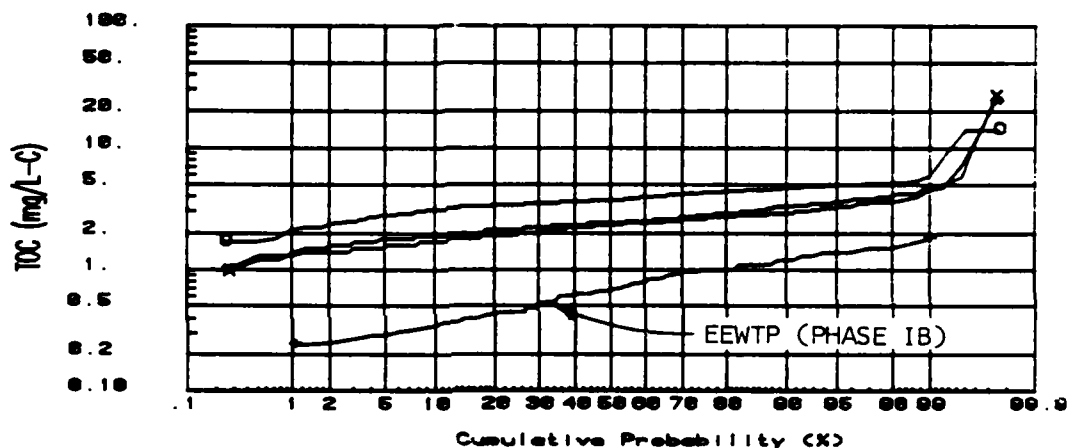
a. MCL = Maximum Contaminant Level.

TABLE E.9-12
SUMMARY OF TRACE ORGANICS IN FINISHED WATERS
NON-REGULATED ORGANICS OF POTENTIAL HEALTH CONCERNS
MEDIAN VALUES

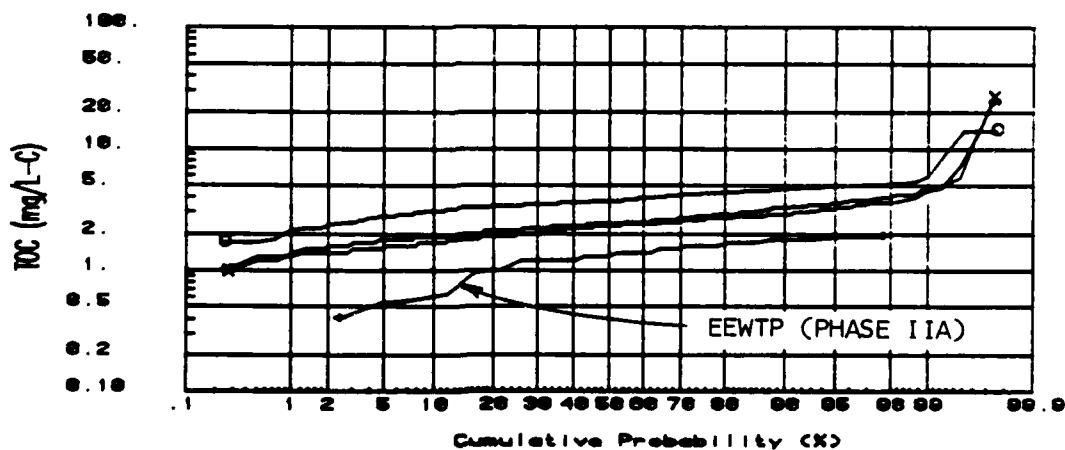
Parameter (Units)	Alum-IA	Alum-IB	Lime-IA	WTP1	WTP2	WTP3
Total Organic Carbon (mg/L-C)	1.7	1.3	0.7	2.3	3.7	2.4
Total Organic Halide (μ g/L-Cl)	90	40	30	280	285	240
Chloroform (μ g/L)	5.0	2.1	0.8	54.0	52.0	38.0
Bromodichloromethane (μ g/L)	2.5	2.5	<0.3	12.0	7.4	9.4
Dibromochloromethane (μ g/L)	1.6	3.9	<0.2	0.8	0.7	1.6
Bromoform (μ g/L)	0.2	1.1	<0.1	<0.1	<0.1	<0.1



(a) Total Organic Carbon (TOC) in EEWTP Finished Water (16 March 1981 to 16 March 1982 - Phase IA) and at Three Local WTPs (All Available Data)

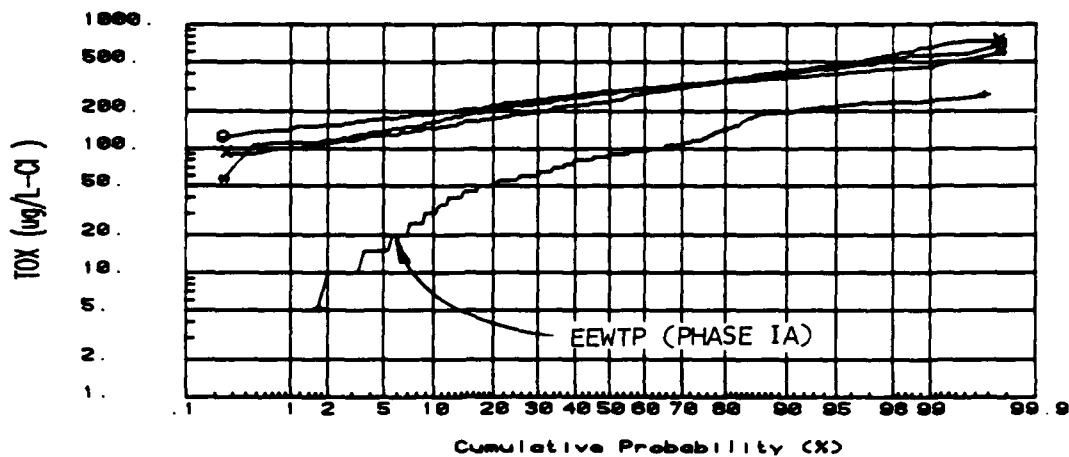


(b) Total Organic Carbon (TOC) in EEWTP Finished Water (16 March 1982 to 6 July 1983 - Phase IB) and at Three Local WTPs (All Available Data)

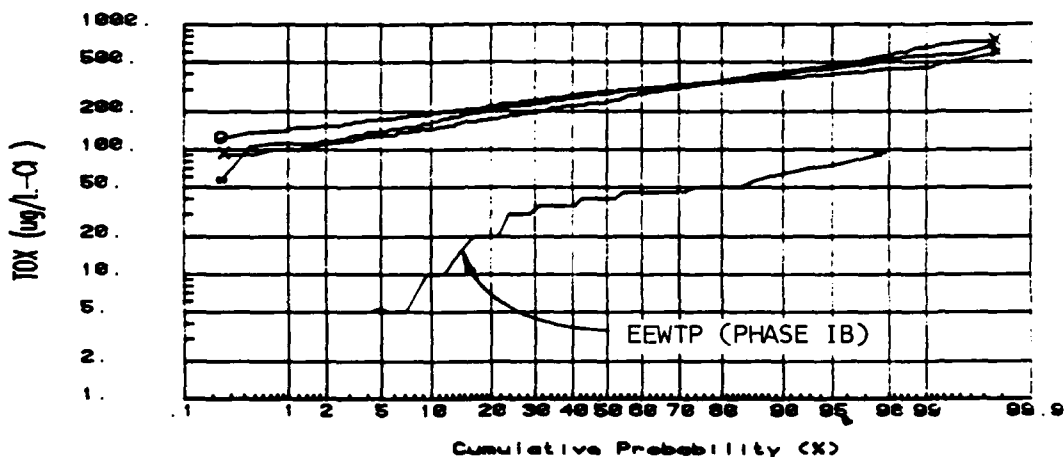


(c) Total Organic Carbon (TOC) in EEWTP Finished Water (16 July 1982 to 1 February 1983 - Phase IIA) and at Three Local WTPs (All Available Data)

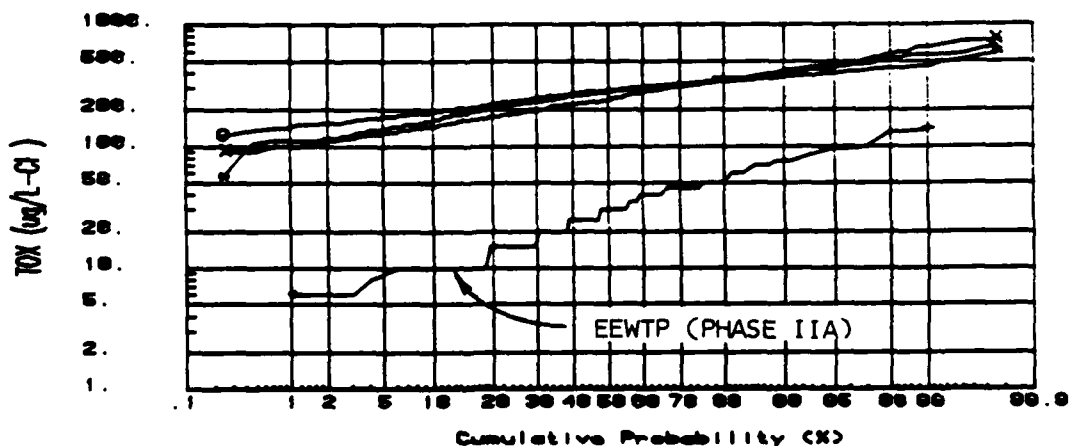
**TOTAL ORGANIC CARBON (TOC) IN EEWTP FINISHED WATER
AND AT THREE LOCAL WTPs
FIGURE E. 9-6**



(a) Total Organic Halides (TOX) in EEWTP Finished Water (16 March 1981 to 16 March 1982 - Phase IA) and at Three Local WTPs (All Available Data)



(b) Total Organic Halides (TOX) in EEWTP Finished Water (16 March 1982 to 6 July 1982 - Phase IB) and at Three Local WTPs (All Available Data)



(c) Total Organic Halides (TOX) in EEWTP Finished Water (16 July 1982 to 1 February 1983 - Phase IIA) and at Three Local WTPs (All Available Data)

**TOTAL ORGANIC HALIDES (TOX) IN EEWTP FINISHED WATER
AND AT THREE LOCAL WTPs
FIGURE E. 9-7**

Evaluation of Finished Water Quality

Very few compounds in the finished waters could be quantified in more than 15 percent of the samples. In those cases where the primary compounds were quantified more than 15 percent of the time, the computed geometric means were generally less than 0.1 $\mu\text{g/L}$. The only primary compounds observed in the finished water at levels greater than 1 $\mu\text{g/L}$ were the trihalomethanes. For compounds with estimated geometric means, the EEWTP compared favorably to local supplies for all but three (PCE, naphthalene, and 1-3/1-4 Xylene) which had geometric mean values of 0.5 $\mu\text{g/L}$ or less. No volatile organic chemicals were detected at levels comparable to proposed standards, which range from 1 to 1,000 $\mu\text{g/L}$.

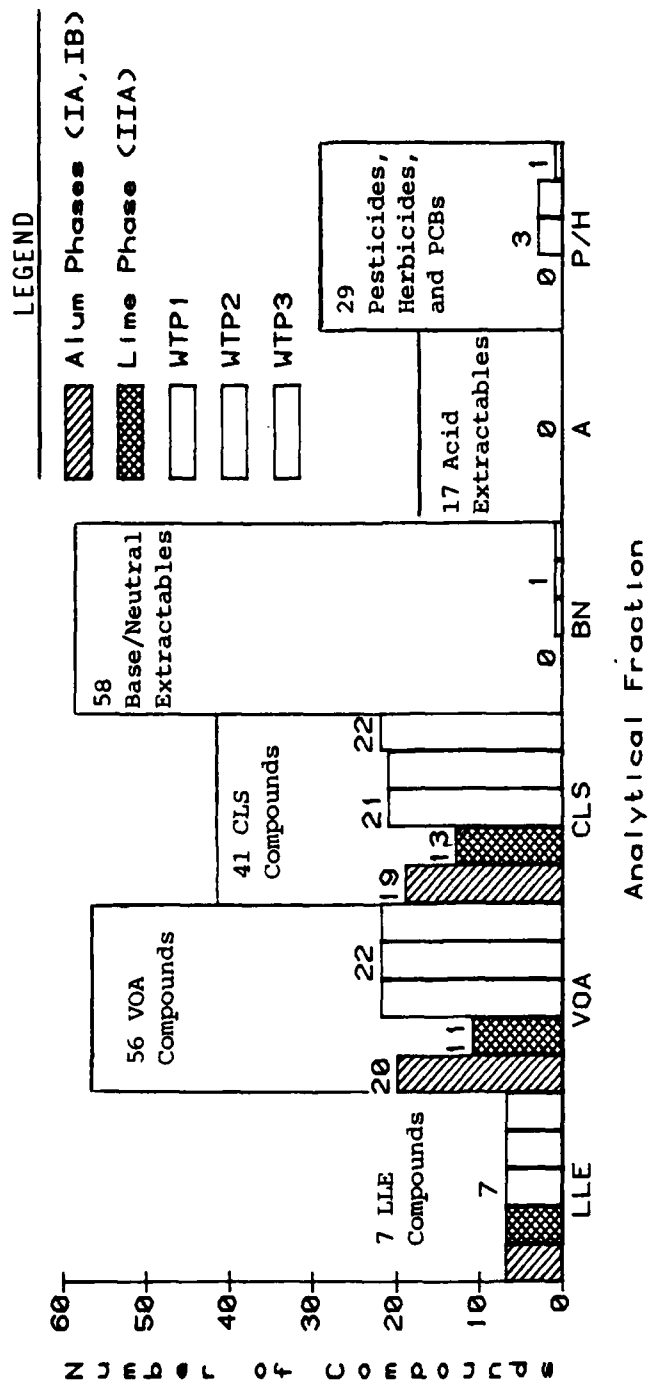
Secondary Organic Chemicals

The number of non-targeted or secondary organic compounds detected at least once in the EEWTP finished waters was lower than the number detected in the local WTPs. Only one compound (2,2-Oxybispropane) was tentatively identified in over fifteen percent of the EEWTP finished water and not detected at the local plants. The maximum estimated concentration for this compound (determined by VOA) was on the order of 1 $\mu\text{g/L}$ with the compound not detected in 13 of 18 samples during Phase IA, and even less frequently in the other phases of operation. Greater numbers of secondary compounds were especially evident with the closed-loop-stripping technique, which is capable of detecting compounds at the part per trillion level. It was not unexpected that trace concentrations of compounds would be detected in finished waters at treatment plants not equipped with a barrier for the control of such compounds.

The estimated levels of these compounds detected were considerably less than 1 $\mu\text{g/L}$ however, with a few samples containing in the one to two $\mu\text{g/L}$ range. Because of the lack of health effects data, however, it was not possible to evaluate the absolute risk of the presence of these compounds in the EEWTP finished waters. Because the number of secondary compounds in the EEWTP was lower than those observed in the local WTPs, it was concluded that for those organic compounds capable of detection by the techniques used, the water produced by the EEWTP finished water was of a quality acceptable for human consumption.

TOXICOLOGICAL PARAMETERS

The two in vitro toxicological parameters monitored were the Ames Salmonella microsome test and the mammalian cell transformation test. These are screening tests used to determine whether chemicals found in drinking water may cause genetic mutations in bacteria or cellular transformations in mammalian cells. Both of these tests were included in the in vitro toxicity tests recommended by the National Research Council, as an evaluation of the acceptability of water for human consumption in cases where the source water is highly contaminated. Although additional tests were also recommended by the National Research Council, budget and time constraints did not permit the use of the more extensive tests recommended.



NUMBER OF TARGETED ORGANIC COMPOUNDS
DETECTED AT LEAST ONCE IN FINISHED WATER

FIGURE E. 9-8

Evaluation of Finished Water Quality

Ames Test Results

Two independent criteria were applied to Ames test results for classifying samples as being positive or negative with respect to mutagenic activity. The first was defined as the mutagenic ratio which is the ratio of the total number of revertants to the number of spontaneous revertants on a control plate. When this ratio exceeds two at the highest nontoxic dose of organic extract, the sample is defined as "positive" for mutagenicity. In addition, results were analyzed for specific mutagenic activity which was defined as the slope of the least squares regression of the dose-response data. The sample was considered positive with respect to specific activity if the slope of the lower bound of the 95 percent confidence interval was positive.

A summary of the Ames test results for Phases IA is presented in Table E.9-13. Shown are the test results for both Salmonella tester strains. Both the mutagenic activity and mutagenic ratio are shown. Generally, the mutagenic activity observed was quite low in the EEWTP finished waters and usually lower than the values in the local WTPs. Mutagenic activity in the local WTPs was also considered quite low, although it is impossible to determine the health significance of these levels at this time. In general, it has been found that in nearly all water treatment plants using free chlorine as the final disinfectant, some mutagenic activity has been observed.

It is not possible to compare the results of mutagenic tests observed in this project to those observed elsewhere because of the non-standard protocols currently used for sampling and analysis. While the local WTPs had higher activity and mutagenic ratios than the EEWTP, no conclusions can be drawn regarding any potential health risks to the consumer. The National Research Council has stated that "because of the complex nature of water concentrates, the assumption that positive results and short term tests are predictive of carcinogenicity may or may not be valid."

Mammalian Cell Transformation Test

The mammalian cell transformation test is an in vitro test used to determine the potential carcinogenicity of chemical compounds or mixtures of chemicals. The test is in an early stage of development and little data are currently available regarding the health significance of test results.

On this project, the mammalian cell transformation assay developed by Dr. Charles Heidelberger was used. The system utilizes a specific cell line (C3H/10T1/2) obtained from mice. The cell line exhibits an extremely low rate of spontaneous transformation as well as very flat morphology making it relatively easy to evaluate with respect to defined cellular transformations. Transformations are generally of a morphological nature. When the cell shape is altered by the chemicals or chemical mixtures, this indicates a potential for carcinogenicity.

Evaluation of Finished Water Quality

TABLE E.9-13
PHASE IA AMES TEST RESULTS
RANKING OF SPECIFIC ACTIVITY AND MUTAGENIC RATIO

Strain	Parameter	Lowest Value			Highest Value
TA98	% Positive S.A. ^a	EEWTP	WTP1	WTP3	WTP2
	Mean S.A.	EEWTP	WTP3	WTP1	WTP2
	Median S.A.	EEWTP	WTP1	WTP3	WTP2
	Maximum S.A.	EEWTP	WTP3	WTP1	WTP2
	% Positive M.R. ^b	EEWTP	WTP3	WTP1	WTP2
	Mean M.R.	EEWTP	WTP3	WTP1	WTP2
	Median M.R.	EEWTP	WTP3	WTP1	WTP2
	Maximum M.R.	EEWTP	WTP3	WTP1	WTP2
TA98 + M.A. ^c	% Positive S.A.	EEWTP	WTP3	WTP1	WTP2
	Mean S.A.	EEWTP	WTP3	WTP1	WTP2
	Median S.A.	EEWTP	WTP3	WTP1	WTP2
	Maximum S.A.	EEWTP	WTP3	WTP2	WTP1
	% Positive M.R.	EEWTP	WTP2	WTP3	WTP1
	Mean M.R.	EEWTP	WTP3	WTP2	WTP1
	Median M.R.	EEWTP	WTP3	WTP1	WTP2
	Maximum M.R.	EEWTP	WTP3	WTP2	WTP1
TA100	% Positive S.A.	EEWTP	& ^d WTP3	WTP1	WTP2
	Mean S.A.	EEWTP	WTP1 &	WTP3	WTP2
	Median S.A.	WTP3	EEWTP	WTP1	WTP2
	Maximum S.A.	EEWTP	WTP3	WTP1	WTP2
	% Positive M.R.	EEWTP	WTP1	WTP3	WTP2
	Mean M.R.	EEWTP	WTP3	WTP1	WTP2
	Median M.R.	EEWTP	& WTP1	WTP3	WTP2
	Maximum M.R.	EEWTP	WTP3	WTP2	WTP1
TA100 + M.A.	% Positive S.A.	EEWTP	WTP1	WTP3	WTP2
	Mean S.A.	EEWTP	WTP1	WTP3	WTP2
	Median S.A.	EEWTP	WTP1	WTP3	WTP2
	Maximum S.A.	EEWTP	WTP3	WTP1	WTP2
	% Positive M.R.	WTP3	EEWTP	WTP2	WTP1
	Mean M.R.	EEWTP	& WTP3	WTP1	WTP2
	Median M.R.	EEWTP	& WTP1	WTP2 &	WTP3
	Maximum M.R.	WTP3	EEWTP	WTP2	WTP1

- a. S.A. = Specific Activity
b. M.R. = Mutagenic Ratio
c. M.A. = Metabolic Activation
d. & indicates equal value

Evaluation of Finished Water Quality

The mammalian cell assay was performed monthly on all finished waters from the EEWTP and local WTPs using organic extracts prepared as for the Ames test. Assays were negative in over ninety percent of the samples. This indicated that cell transformations were rare events. On occasion some positive transformations were observed; however, this usually occurred in one or two of the ten to fifteen plates utilized in the assay.

Again, the significance of these results is difficult to interpret because of the very limited database currently available for assessing the meaning of the test results. The very low number of positive cell transformation assays indicated that the transformation activity in the EEWTP finished waters was not significantly different than that observed in the local WTPs.

Compared to the current battery of toxicological tests recommended by the NRC for determining the acceptability of a finished water for human consumption, the EEWTP finished waters compared favorably for two of the recommended in-vitro tests in the first tier of a three tier program. Time and budget constraints did not permit more extensive testing of either the EEWTP finished waters or those finished waters from the local MWA water treatment plants. Within the constraints of this project, the results indicate that the toxicological quality of the EEWTP finished waters compared favorably to that observed in the three local WTPs.

SUMMARY OF RESULTS

In summary, all process sequences monitored during the two year operating period were shown to be technically capable of producing a water acceptable for human consumption. All of the water quality parameters monitored which are included in the primary drinking water regulations were observed to be at levels well below the MCLs with some exceptions. Table E.9-14 summarizes the ratios of the MCL for parameters in the primary regulations to the 90th percentile values observed during the three phases of operation.

As can be seen, the observed 90th percentile values for physical/aesthetic, microbiological, and most trace metals, with the exception of mercury, were five to ten times lower than the primary MCLs. The 90th percentile nitrate values are close to the MCL of 10 mg/L, however. Mercury and selenium levels were observed to be two to three times less than the MCLs. With respect to radiological parameters, the values observed in the EEWTP finished waters were considerably less than the MCLs. Strontium-90 was a factor of four lower than the MCL during Phase IA. Finally for trihalomethanes, 90th percentile values were observed to be four to twenty times less than the MCL of 0.1 mg/L depending upon the phase of EEWTP operation.

A similar analysis is presented in Table E.9-15 for the secondary regulations. Generally, the 90th percentile values observed in the EEWTP finished waters were lower than the MCLs with the exception of odor and manganese during Phase IA. Odor levels in the EEWTP during Phases IB and IIA were comparable to those observed in the finished waters from the local WTPs, however.

Evaluation of Finished Water Quality

TABLE E.9-14

SUMMARY OF RESULTS COMPARISON OF PRIMARY DRINKING WATER REGULATIONS MCLs TO EEWTP FINISHED WATER 90TH PERCENTILE VALUES

Parameter Group/ Parameter	MCL (Units)	Ratio MCL/90th Percentile		
		Alum-IA	Alum-IB	Lime-IIA
Physical/Aesthetic Turbidity	1 NTU	5	6.7	10
Microbiological Total Coliform	1 MPN/100 ml	7.1	25	>50
Major Cations, Anions, Nutrients ^e				
Nitrate-NO ₃ -N	10 mg/L	1.08	1.25	1.04
Fluoride	1.4-2.4 mg/L	— ^a	—	—
Trace Metals (mg/L)				
Arsenic	0.05	55.6	50	55.6
Barium	1.0	31.3	31.3	41.7
Cadmium	0.01	11.1	16.7	50
Chromium	0.05	20.8	19.2	13.1
Lead	0.05	20.8	19.2	13.1
Mercury	0.002	2.8	4.0	5.0
Selenium	0.01	3.8	25.0	6.7
Silver	0.05	>250	>250	>250
Radiological (pCi/L)				
Radium ^b	5	NM ^c	NM	NM
Gross Alpha	15	25	16.7	>150
Tritium	20,000	>20	>20	>20
Strontium-90	8	4.2	NM ³	8.9
Trace Organics ^d				
Total Trihalomethanes	0.01 mg/L	4	7.1	23.2

a. Fluoride not added to EEWTP. 90th percentile values less than 0.6 mg/L for all phases.

b. Gross alpha never exceeded 5 pCi/L. Thus radium not measured.

c. NM = Not Measured.

d. Organics includes six pesticides. Values were ND or NQ for pesticides during all phases of operation.

e. Sodium is included in primary standards, but no MCL has been set.

Evaluation of Finished Water Quality

In summary, the water produced by the three processes monitored was observed to be of acceptable quality for human consumption when compared to the primary and secondary drinking water regulations. For those parameters not regulated as well as other parameters of health concern, the EEWTP finished waters were observed to be of comparable or superior quality to that in the local WTPs. In those cases where the levels of some parameters in the EEWTP finished water exceeded levels in the local WTPs, an evaluation of the health significance of these results indicated that the water was still of acceptable quality for human consumption.

Therefore, it is concluded that at least two of the three process combinations monitored (Phases IA and IIA) were technically feasible for producing a water suitable for human consumption under the influent water quality conditions observed. Because of concerns over process reliability for the control of microbial parameters when ammonia levels increase above 0.5 mg/L-N, the Phase IB process combination may not provide a sufficient level of reliability during all periods of plant operation. Thus, this process was dropped from further consideration in the cost analysis.

Evaluation of Finished Water Quality

TABLE E.9-15

SUMMARY OF RESULTS COMPARISON OF SECONDARY DRINKING WATER REGULATIONS MCLs TO EEWTP FINISHED WATER 90TH PERCENTILE VALUES

Parameter Group/ Parameter	SMCL (Units)	Ratio SMCL/90 Percentile		
		Alum-IA	Alum-IB	Lime-IIA
Physical/Aesthetic				
Color	15 CU	2.1	2.1	1
Odor	3 TON	0.06	0.18	0.08
MBAS	0.5 mg/L	10	12.5	16.7
Trace Metals (mg/L)				
Copper	1	116	416	322
Iron	0.3	3.6	5.4	7.9
Manganese	0.05	0.46	2.5	6.2
Zinc	5	105	174	277
Major Cations, Anions Nutrients (mg/L)				
Chloride	250	4.1	4.6	3.7
Sulfate	250	2.1	3.6	3.5
Total Dissolved Solids	500	1.4	1.9	1.4

CHAPTER E-10

SPECIAL TESTING AND EVALUATION

In addition to routine monitoring and evaluation of plant performance, several special studies were conducted during the two-year testing program to further characterize and optimize plant processes and to investigate other potential treatment processes not evaluated in the EEWTP. These studies were part of a Testing Program for Process Adjustment and Modifications (TPPAM) conducted during the project. The two major objectives of the studies were:

1. EEWTP process characterization and optimization.
2. Investigation of alternative processes designs not included in the EEWTP.

Tables E.10-1 and E.10-2 summarize the special studies conducted in this project.

TABLE E.10-1
SPECIAL STUDIES FOR PROCESS CHARACTERIZATION
AND OPTIMIZATION

Special Study	Major Objective(s)
Coagulation Bench Testing	Evaluation and optimization of alternative chemical combinations for TOC and turbidity removal.
Filtration Testing	Evaluation of filtration rate and filter aid selection.
GAC Special Study	Qualitative evaluation of synthetic organic chemicals adsorbed on plant GAC, including compounds at undetectable levels in source waters.
Manganese Removal Study	Characterization of EEWTP processes with respect to iron and manganese removal; evaluation of alternative methods of removal.
THM/TOX Formation Study	Evaluation of THM/TOX formation potential in EEWTP process waters as well as EEWTP and local MWA finished waters.
Corrosion Study	Evaluation of the corrosivity of the EEWTP finished water under different operating conditions as encountered over the course of the study.
Hydraulic Characterization	Evaluation of the hydraulic characteristics of fundamental unit processes employed at the EEWTP, in order to locate potential problem areas and to aid evaluation of process performance.

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TABLE E.10-2
SPECIAL INVESTIGATIONS OF ALTERNATIVE PROCESS DESIGNS

Process	Major Objective(s)
Granular Activated Carbon Adsorption	- Modeling of the GAC adsorption process for three carbons including characterization of appropriate isotherm and rate model parameters for TOC and one SOC. - Evaluation of GAC design alternatives at different treatment objectives, and optimization of design criteria with respect to empty bed contact time. - Modeling of alternative design scenarios and estimation of costs.
Packed Tower Aeration	- Evaluation of mass transfer coefficients in EEWTP influent water for selected SOC's with a selected tower packing. - Evaluation and optimization of alternative designs for a selected influent scenario and estimation of costs.
Reverse Osmosis	- Evaluation of the performance of a polyamide reverse osmosis process with respect to selected inorganic and organic parameters; estimation of costs.

PROCESS CHARACTERIZATION AND OPTIMIZATION

COAGULATION BENCH TESTING

Bench-scale coagulation tests were conducted during the alum (Phase IA) and lime (Phase IIA) operating periods to determine the optimum chemical combinations for the coagulation process. Chemical conditions (coagulant type, dose, pH) were evaluated with respect to removals of turbidity and total organic carbon (TOC), and sludge production, under various influent raw water conditions.

Alum Coagulation

Bench testing with aluminum sulfate (alum) alone and in combination with a variety of polymeric coagulant aids indicated that an alum dose of between 40 to 60 mg/L as $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ should be anticipated for effectively treating an influent water of the quality observed at the EEWTP. Turbidity and TOC removals in this dosage range were approximately 90 and 35 percent, respectively.

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Addition of a high molecular weight polyelectrolyte, of anionic, cationic, or nonionic charge is recommended to aid in the settling of floc solids. However, no benefits with respect to removal of dissolved TOC could be demonstrated. TOC removals on the order of 30 to 35 percent were the highest that could be achieved with cost effective alum doses, and were similar to removals achieved at plant scale. Alum doses up to 240 mg/L were evaluated for removal of TOC. TOC removals never exceeded forty percent, even at the high doses, indicating the difficulties in coagulating and settling the naturally occurring organic compounds in the EEWTP influent. As anticipated from other studies, the optimum pH for TOC removal with alum was in the range of 6.5 to 7.0.

Lime Coagulation

Lime coagulation test results indicated that lime, when used as sole coagulant in sufficient quantity to produce a pH of 11.0, provided better turbidity and TOC removal (95 and 45 percent) than did alum alone. At this pH, lime clarification demonstrated an additional advantage of microbiological removals with greater than 99 percent reduction or deactivation (2.5 logs) of total coliforms. The disadvantages of the high lime dose requirement are the associated sludge volumes and finished water hardness. The addition of soda ash (Na_2CO_3) for alkalinity adjustment was evaluated as a means of reducing the finished water calcium hardness. However, full-scale use of soda ash was rejected for reasons of economy and practicality.

Bench testing of lime/coagulant aid combinations indicated that ferric chloride (FeCl_3) was most effective in reducing the lime dose required for effective settling of turbidity and TOC equivalent to lime alone removals. Comparable performance could not be achieved with lime and selected polymers. Successful operation was demonstrated at process pH levels of 10.5 to 11 and with a ferric chloride dose of 2 mg/L, which coincides with bench-scale results. Jar testing indicated an associated lime dose of 100 to 150 mg/L-CaO would be required with this ferric dose, depending upon influent water quality. This produced a pH between 10 and 11.0. Plant-scale operation revealed that a lower lime dosage range of 70 to 80 mg/L-CaO could be used. Turbidity and TOC removals up to 95 and 35 percent were achieved, respectively.

FILTRATION TESTING

During the alum phase, optimum filtration rates were evaluated using pilot filter columns with hydraulic capacities of 1 gpm. The filters were operated under loading rates of 3, 6, and 9 gpm/ft². The EEWTP filters were designed for a loading rate of 3 gpm/ft², a rate considered to be more conservative than necessary given that the filters were followed by granular activated carbon in the treatment sequence. Results indicated that above 6 gpm/ft², a polymer flocculant aid was needed in order to retard breakthrough of turbidity in the filter effluent. The tests demonstrated, however, that operation of the filters at 6 gpm/ft² would provide similar water quality. The reduced filter area requirements would lead to some capital cost savings. Consequently, the 6 gpm/sq ft rate was evaluated at the full-scale plant during both Phase IA and IIA operation.

Special Testing and Evaluation

Results were ambiguous during Phase IA, with increased filter effluent turbidity, but adequate filter water production. During Phases IB and IIA, however, plant scale testing of the higher rate yielded satisfactory results both with respect to filter effluent quality and water production. Consequently, the higher 6 gpm/ft² filter loading rate is recommended for further consideration prior to full scale design. Tests at plant scale were not of sufficient duration to permit use of the higher loading rates in the cost estimates for the full-scale estuary water treatment plant.

MANGANESE REMOVAL STUDY

Manganese levels in the EEWTP finished waters frequently exceeded the secondary MCL of 0.05 mg/L during the first weeks of Phase IA operation. Consequently, manganese removal studies were conducted to determine the appropriate operational strategies for satisfactory control of this contaminant. Bench and full-scale tests were conducted to determine the rate of oxidation of manganese with permanganate under various pH conditions. Several strategies evaluated in bench-scale were then tested in the EEWTP.

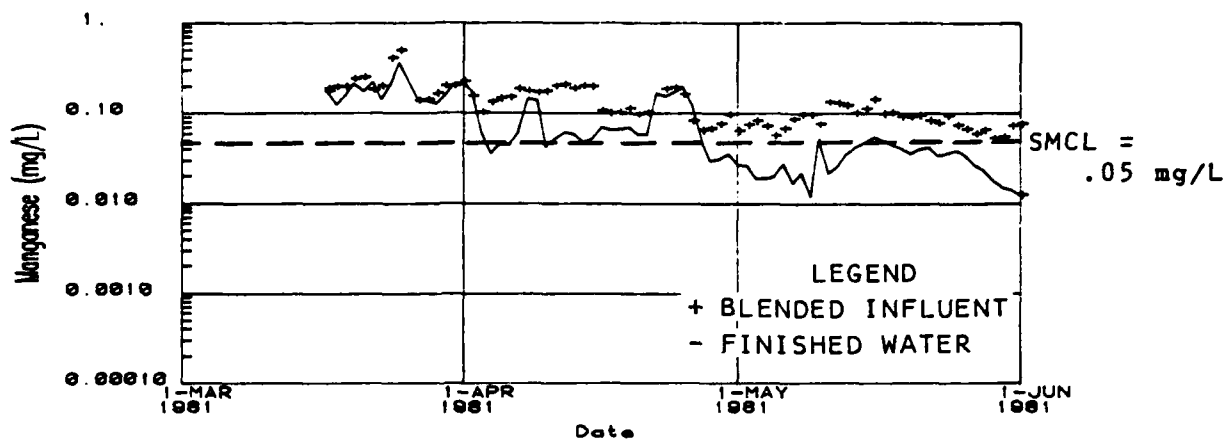
The results of the full-scale tests of the strategies for manganese removal in the EEWTP are summarized in Figure E.10-1, which shows the time-series of manganese levels during the two-year operational period for the EEWTP. Satisfactory control of manganese was achieved by three strategies:

1. Addition of permanganate to blended influent with pH control of pH 7.5 following sedimentation.
2. Intermediate ozonation with similar pH control.
3. Lime coagulation.

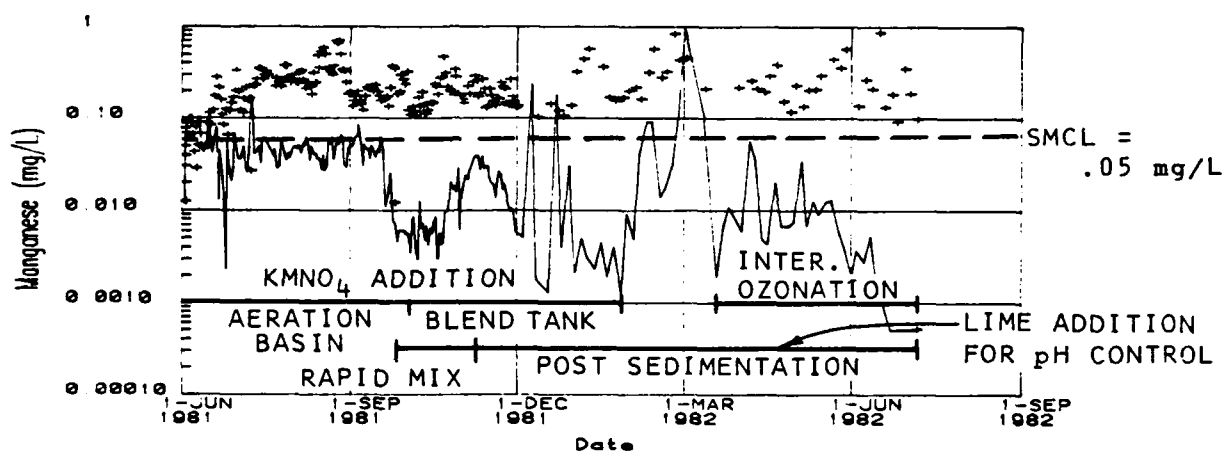
GAC SPECIAL STUDY

A study was conducted to identify organic chemicals adsorbed on the granular activated carbon in the contactors at the EEWTP, and to compare the range of chemicals identified with the levels of organic chemicals detected or quantified in the blended influent to the EEWTP. Carbon samples were taken from the GAC contactors after approximately three months of operation and subjected to solvent extraction and thermal desorption techniques. Organic chemicals in the extracts were then identified by mass spectra and retention indices using GC/FID (Flame Ionization Detector) and GC/MS. The results indicated that GAC was effective to some degree in removing at least twenty-six specific synthetic organic chemicals.

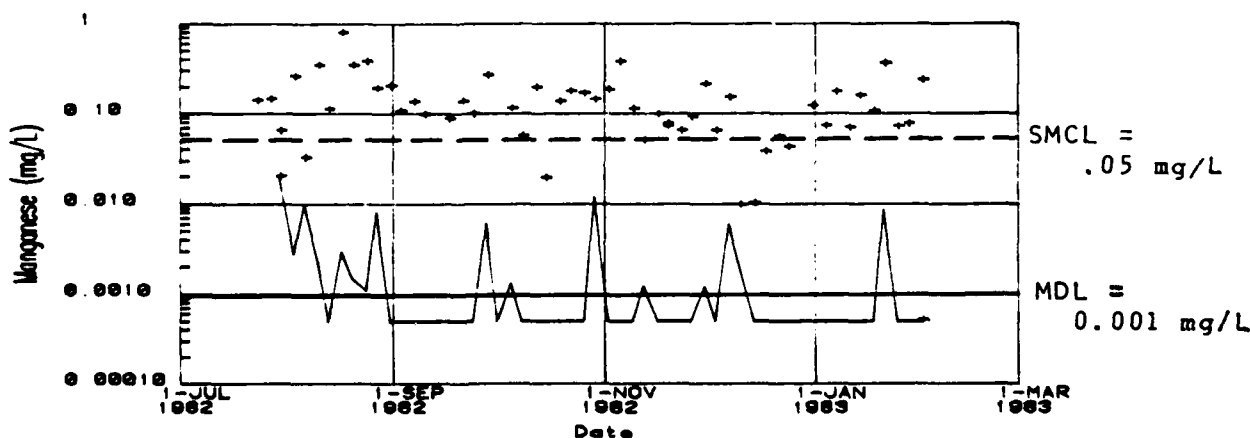
Ten chemicals were identified which had not been previously identified, either tentatively or confirmed, in the EEWTP influent waters. These compounds were most likely present in concentrations below analytical detection limits, and were concentrated and stored over time by the carbon. It is also possible,



(a) Manganese removal during alum phase without pH control measures



(b) Manganese removal during alum phase with control measures



(c) Manganese removal during lime phase

**MANGANESE REMOVAL
(PHASES I AND II)
FIGURE E. 10-1**

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however, that a spike of these compounds may have passed through the plant unnoticed (i.e., not sampled), or that the compounds were formed on the carbon through reactions between compounds in the water and the carbon.

In any event, it is unlikely that chronic doses of any of the additional detected compounds were sufficiently high to be of health concern. The results of this study did not alter the evaluation of EEWTP finished water quality.

THM/TOX FORMATION STUDY

Bench-scale tests were conducted to determine the rate of formation of THMs and total organic halide (TOX) under varying water quality conditions encountered at the EEWTP. Factors evaluated included temperature, pH, and chlorine dose as specified by the ratio of chlorine to total organic carbon. Formation studies were conducted on filtered effluent, and effluent from the GAC contactors, with approximate average TOC values of 3 mg/L-C and 1.5 mg/L, respectively. Tests were conducted during both Phase IA and IIA. Study objectives were to determine the expected levels of THMs and TOX for varying levels of TOC, using free chlorine as a disinfectant.

The result of THM formation tests using the EEWTP finished water during Phases IA and IB indicated that THM levels would not be expected to exceed the 0.10 mg/L MCL after seven days contact at 20°C in the presence of a free chlorine residual. The seven-day yields of THMs as a function of TOC levels ranged from 25 to 50 µg TTHM/mg TOC depending upon the test conditions (pH, TOC levels, Cl₂:TOC ratio, Br). These results suggested that a GAC effluent TOC of 2 mg/L would not lead to TTHM levels exceeding the MCL.

In addition, it appeared that free chlorine disinfection of the gravity filter effluent (TOC = 3 mg/L-C) would also not produce THMs exceeding the THM standard, although higher THM levels were formed at this TOC concentration. Thus, justification for inclusion of the GAC adsorption in the full-scale estuary water treatment plant must be based primarily on reduction of non-regulated organics, and on providing a barrier to unexpected levels of organic contaminants.

THM and TOC formation both increased with increasing applied free chlorine dose and temperature. THM formation also increased with increasing pH. For TOX, however, limited data suggested that the rate of TOX formation may decrease with increasing pH. Additional tests are needed to verify these results.

CORROSION STUDY

Corrosivity in a finished drinking water is a subject of some concern, not only with respect to economic impacts on distribution system maintenance, but also because of potential health concern related to the dissolution of toxic inorganic substances from distribution piping—most notably, lead and cadmium. During initial operation of the EEWTP under the alum phase of operation, pH and alkalinity levels in the finished water were observed to be relatively low, which

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resulted in a Langelier index (LI) of less than -2.0 in the EEWTP finished water. A slightly positive LI is desirable. Because of concern over expected rates of corrosion in the EEWTP finished water, a corrosion testing program was conducted to determine quantitatively, the rates of corrosion under the water quality conditions encountered in the EEWTP finished waters, during Phases IA, IB and IIA.

Corrosivity was determined using the ISWS machined nipple test, which permits an estimate of corrosion rates, based on weight loss of pipe inserts maintained in continuous contact with the finished water. With respect to the three metals tested (copper, black iron, and galvanized steel), weight loss and penetration rates were always highest for black iron and lowest for copper. The Phase IIA corrosion test results indicated an increase in the corrosion rates for copper and galvanized steel relative to the Phase IB results, despite the fact that calculated corrosion indices suggest Phase IIA was less corrosive than Phase IB. Corrosion test results for black iron followed the tendencies suggested by the corrosion indices, Phase IB being more corrosive than Phase IIA.

The plant-scale test results indicated that Phase IB finished water was less corrosive than Phase IIA water for two of the metals tested. pH control measures, in the form of lime addition at the sedimentation effluent and sodium hydroxide addition at the GAC effluent served to reduce the corrosivity of the water and are recommended for full scale application.

With respect to Phase IIA operation, the corrosion indices (buffer intensity, Langelier index and Larson's ratio) suggest that there is no need for additional corrosion control. However, corrosion test results indicated a potential for corrosion (including noticeable pitting in black iron) which was not fully resolved. On the hypothesis that such corrosion is related to the use of ozone, the selection of process piping following ozonation should be carefully considered.

INVESTIGATIONS OF ALTERNATIVE PROCESS DESIGNS

The EEWTP finished water quality was the product of the combination of unit processes designed and operated at the EEWTP. Although operating criteria were sometimes adjusted in efforts to optimize plant performance, design criteria such as loading rates, contact, or detention times, could not be changed beyond the range of conditions permitted by plant flow. Cost constraints prohibited inclusion of alternative process facilities, such as packed aeration towers or demineralization equipment, in the plant-scale process train. Moreover, proper process demonstration dictated that the number of plant scale combinations be limited in order to allow monitoring over longer periods of time and different seasons of the year.

With these constraints on plant scale investigation as background, a series of investigations was undertaken at bench-scale and at pilot-scale on sidestreams of plant flow. These investigations were aimed at evaluating performance and developing design criteria for potential design modifications to the future estuary water treatment plant which might offer significant cost savings and/or

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improvements in finished water quality. Alternative design scenarios for GAC adsorption, packed tower aeration, and reverse osmosis were considered in detail.

GAC ADSORPTION

Granular activated carbon adsorption was the principal barrier in the EEWTP for control of organics contamination. However, preliminary cost estimates for a future estuary water treatment plant consisting of the processes monitored in the EEWTP indicated that the costs of GAC could represent up to fifty percent of the capital and O&M cost requirements. Thus, cost optimization of this process was a major objective of the engineering studies.

The emphasis of the investigation was targeted toward resolution of two fundamental issues:

1. Optimization of GAC Design. Choice of carbon and selection of empty bed contact time are important aspects of design which influence treatment costs and finished water quality. These criteria were evaluated using GAC bench and pilot-scale tests, and computer modeling techniques to evaluate various design criteria and operation alternatives for GAC design.
2. Evaluation of GAC Usage Rates. The EEWTP utilized two GAC contactors in series which were operated to ensure that consistent breakthrough in excess of 2.0 mg/L TOC did not occur. Alternative criteria for carbon regeneration, however, could be recommended for full-scale plant operation in an estuary plant, such that costs would be reduced without significant reduction in water quality.

Optimization of GAC design and operational strategies were developed using a computer model of adsorption, which had been demonstrated to provide a reasonably accurate estimate of optimum carbon design parameters for the control of total organic carbon (TOC). The model describes physical-chemical adsorption of TOC on granular carbon using the appropriate differential equations describing the kinetics and mass transfer processes in a carbon column. The model, known as the Homogeneous Surface Diffusion Model (HSDM) required calibration and verification using bench and pilot-scale adsorption tests under water quality conditions similar to the expected water quality in a full-scale plant.

For the two pretreatment conditions, alum and lime coagulation, design parameters to be optimized for GAC contactors were type of carbon (three types tested) and empty bed contact time (EBCT) (simulation of 15, 30 and 60 minutes) for several treatment objectives based on achieving certain TOC levels in the GAC treated water.

Bench-scale isotherm and batch rate tests were conducted to determine adsorption equilibrium parameters and mass transfer parameters needed for calibration of the HSDM model. The parameters were adjusted based on

Special Testing and Evaluation

comparison of predicted and observed TOC effluent histories from 1 gpm pilot columns.

The calibrated HSDM model was then verified by comparing predicted TOC removals to that observed in the full-scale EEWTP GAC contactors. The verified HSDM model for a single carbon (Filtersorb F-400, bituminous based carbon), was then used to estimate carbon usage rates for given influent TOC levels under several scenarios for treatment objectives and for several EBCTs. Model calibration results are shown in Figure E.10-2 for the lime pretreated water with F-400 GAC, and model parameters as shown. Isotherm and batch rate studies provided the model parameters. Model verification for the lime system with F-400 is shown in Figure E.10-3. The predicted effluent history or breakthrough curve using the HSDM compares well with the actual TOC data from the lead GAC column operated in Phase IIA with lime pretreatment.

Using the calibrated and verified HSDM model, carbon usage rates for a 200 MGD plant were computed for three TOC treatment objectives and varying EBCT, with the treatment objective applied to a single column effluent and to the blended effluent from columns operated in parallel, as shown in Figure E.10-4. The regeneration criteria, based on single column effluent levels, is more stringent and thus more costly giving higher usage rates as shown. For the same treatment objective, parallel operation and regeneration based on a blended effluent criteria reduces carbon usage significantly.

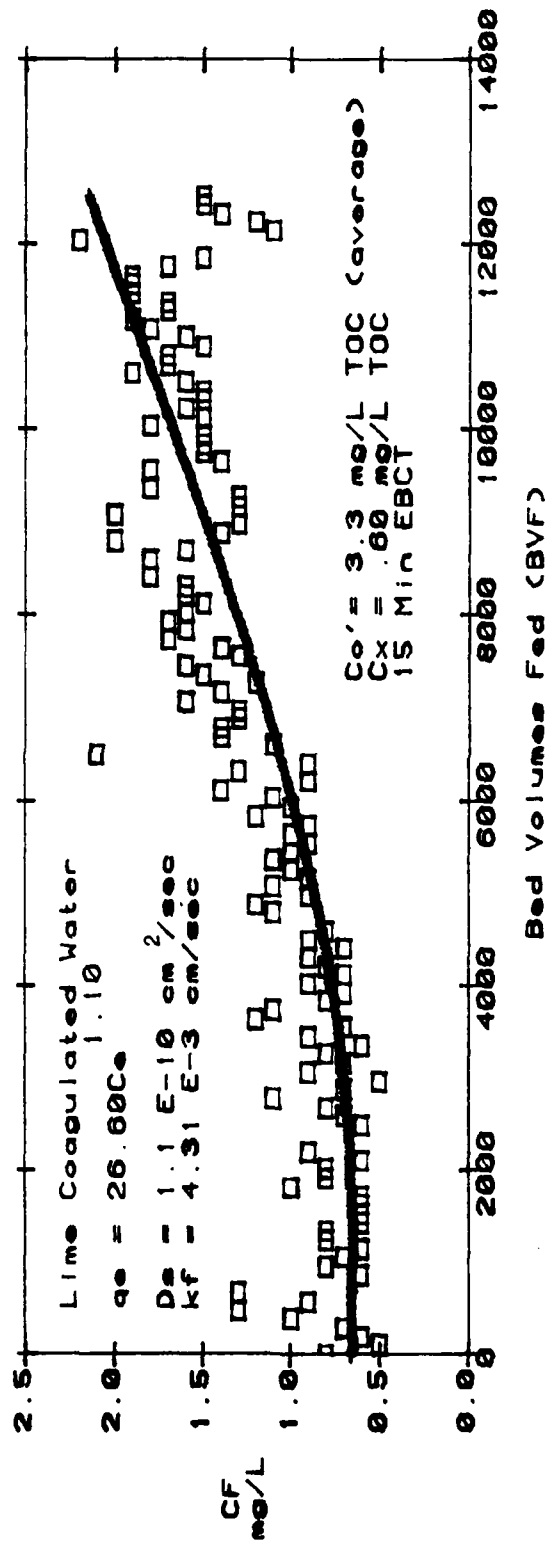
For parallel GAC contactors operated with a single column regeneration criteria, longer EBCTs reduce the carbon usage only if stringent effluent treatment objectives are imposed. These potential savings must be compared to increased capital costs for longer EBCTs.

AIR STRIPPING

Multiple treatment barriers are often recommended when treating a heavily contaminated source for the control of organic contaminants. One such barrier is the use of packed tower aeration for the control of volatile organic chemicals found in the blended influent. The packed tower aeration process could be used either to replace granular activated carbon or as pretreatment ahead of the GAC process. Advantages of the latter would be the removal of volatile organic chemicals prior to the GAC, thus extending the life of the carbon with respect to removal of VOCs. Packed tower aeration has also been shown to be a much more cost effective process for control of these chemicals than activated carbon.

A pilot packed tower aeration unit was used to investigate the operational criteria needed for the design of an air stripping tower in a full-scale estuary plant. Five volatile organic compounds were selected for testing, to represent a range of Henry's constants of compounds in the blended influent. The compounds represented a range of volatilities from bromoform, with a Henry's constant of 50 atmospheres at 20°C to carbon tetrachloride with a Henry's constant of 1,280 atms at 20°C.

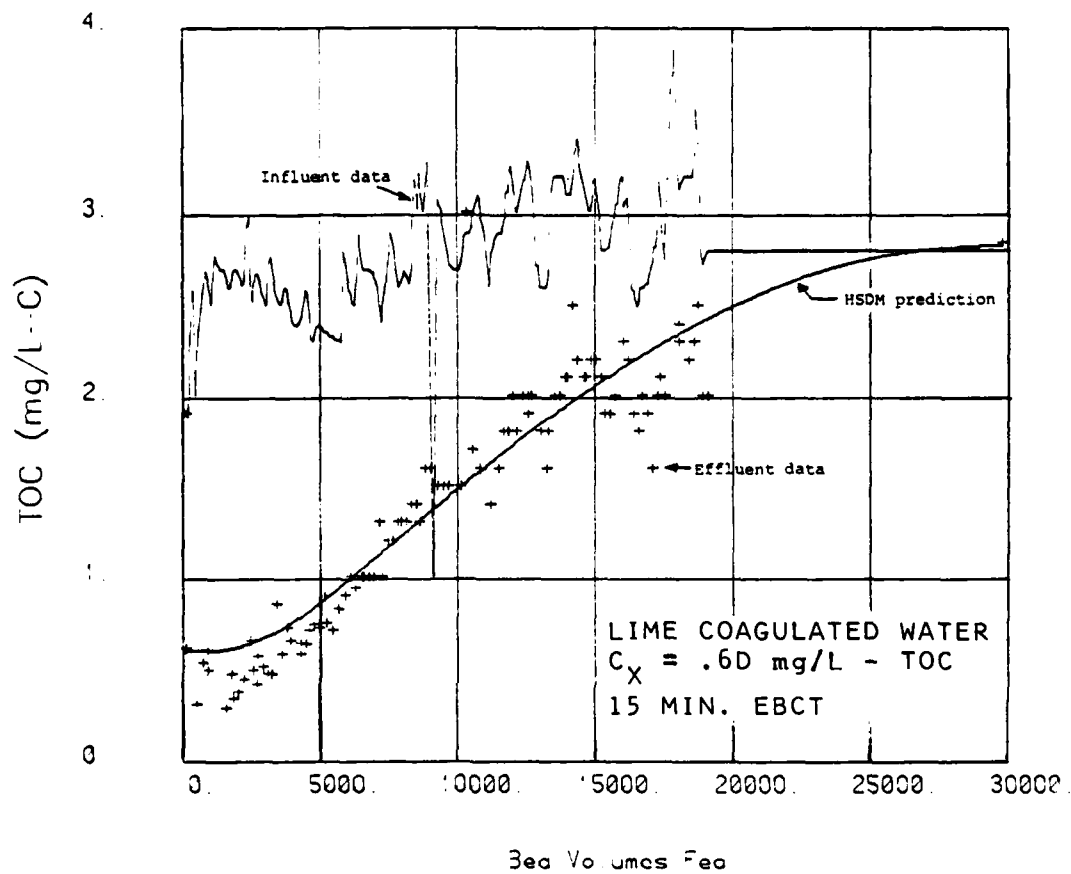
F-400 Lime TOC Pilot-Column



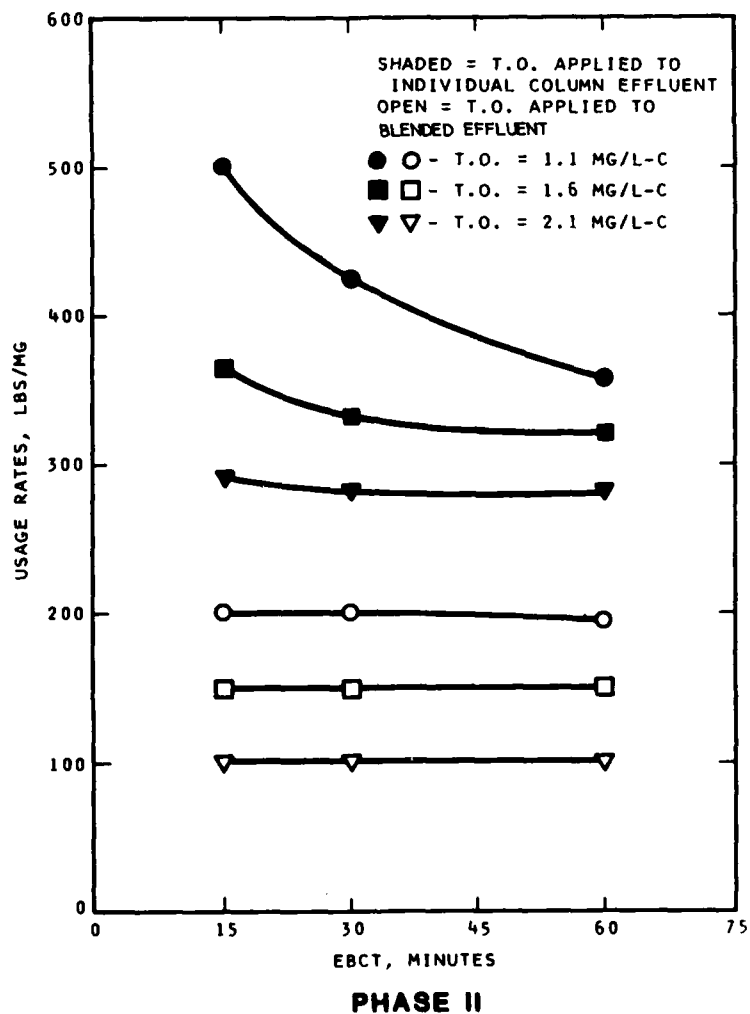
PILOT - COLUMN TEST

PHASE II

FIGURE E. 10-2



**TOC BREAKTHROUGH CURVE
PLANT-SCALE, F-400
(PHASE II)
FIGURE E. 10-3**



**F-400 USAGE RATES
INDIVIDUAL AND 31 PARALLEL COLUMNS
FIGURE E. 10-4**

Special Testing and Evaluation

The pilot plant was operated to provide mass transfer data on the five compounds evaluated. Mass transfer data combined with pressure drop information can then be utilized to design a packed tower stripping aeration unit for possible inclusion in the full-scale treatment plant using a well established mass transfer model of the air stripping process.

The design scenario selected for consideration was the control of chloroform with removals defined to be greater than ninety percent at all temperature conditions. Results of this cost optimization are shown in Figure E.10-5. These results indicate that packed tower air strippers are a feasible alternative for control of volatile organic chemicals and appeared to be a relatively inexpensive solution for removal of such compounds. For example, in the 200 MGD plant, the relative costs for 97 percent reduction in chloroform at 20°C is approximately 2¢/1,000 gallons at the optimum air to water ratio and air pressure drop through the packing. In contrast, use of GAC for control of chloroform would cost at least ten times the estimated cost of air stripping.

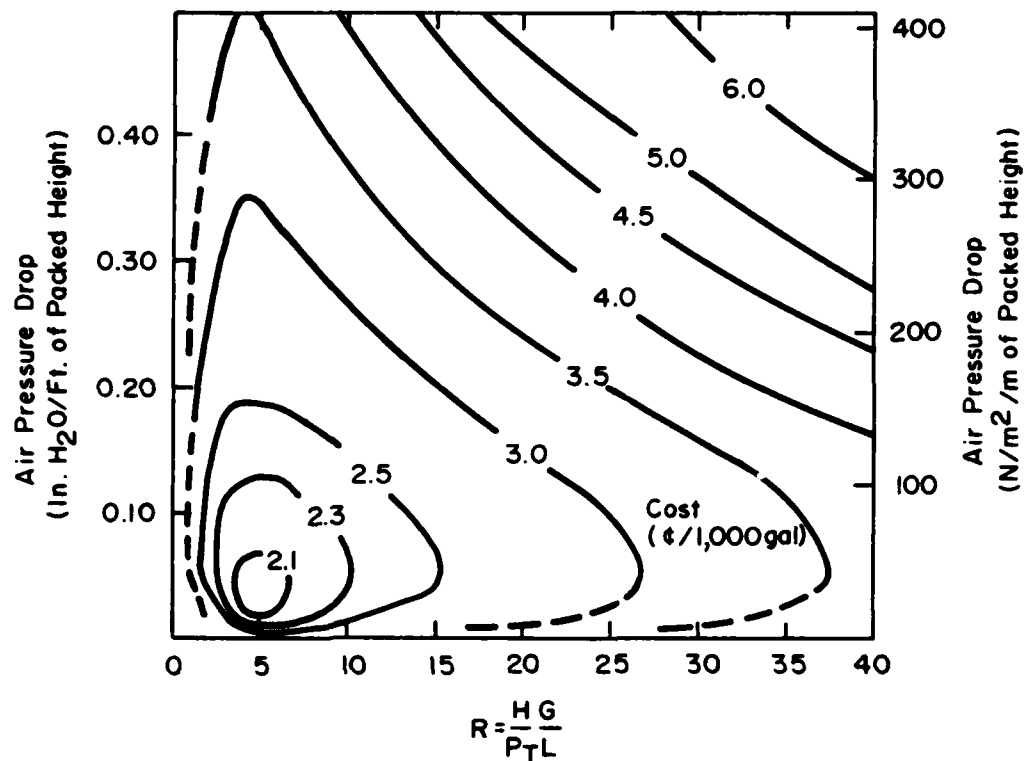
REVERSE OSMOSIS

Results of the DEM modeling indicated that total dissolved solids in the estuary under drought conditions would not exceed the secondary MCL of 500 mg/L. On the other hand, it was observed that levels of nitrate in the EEWTP influent were shown to approach the primary MCL of 10 mg/L-N and sodium levels were above those at local WTPs. Furthermore, recent studies completed at the U.S. Army Corps of Engineers Chesapeake Bay model have indicated the possibility that total dissolved solids levels could exceed 1,000 mg/L as far up the estuary as Chain Bridge. For these reasons, an investigation was conducted to evaluate reverse osmosis as an alternative process both for control of organics as well as the possible need for removal of total dissolved salts including sodium and nitrate under severe drought conditions.

Tests were conducted over a ten week period using a polyamide hollow fiber RO membrane operated at a constant pressure of 350 psig with appropriate pretreatment (lime coagulation, recarbonation, granular media filtration and cartridge filtration, pH adjustment). The membranes were operated to achieve approximately 75 percent recovery of the product water, with the remainder of the flow discharged as brine waste.

Test results indicated expected reductions of TDS greater than 97 percent and similar high removals of other dissolved salts (nitrate reduction >95 percent; sodium reduction >90 percent). Removals of trace metals generally exceeded 65 percent. Because ammonia levels were low during the RO operations, it was not possible to determine the effectiveness of RO to remove this parameter. In addition, the RO membranes effectively reduced the levels of TOC, and TOX, showing a TOX removal of greater than 99 percent. Reduction of volatile organic compounds was on the order of fifty percent, however.

The RO process was thus demonstrated to be capable of excellent removals of most dissolved inorganic salts, as well as selected dissolved organic contaminants. The process appears capable of replacing GAC as an organic



RELATIVE COST (¢/1000 Gal)
CHLOROFORM, $X_i/X_o = 30$ ($T = 20^\circ C$)

FIGURE E. 10-5

Special Testing and Evaluation

control barrier with the added and expected benefit of dissolved salts removal. The process is very costly, however, and would only be justified if removal of TDS, nitrate, or sodium were required because of potential or perceived adverse health risks and/or aesthetic effects related to potable use.

CHAPTER E-11

COSTS

As presented in previous chapters in the Executive Summary, two water treatment process combinations monitored in the EEWTP have been demonstrated to produce a finished water of a quality which appears to be acceptable for human consumption. These were the Phase IA process and the Phase IIA process¹. This assumes that a hypothetical plant using these processes would operate with criteria similar to that used at the EEWTP. In order to assess the economic feasibility of an estuary water treatment plant compared to other suggested alternatives under consideration in the MWA Water Supply Study, cost estimates must be made. This chapter summarizes the estimated capital costs and unit costs (including operation, maintenance, and amortization costs) for both process combinations meeting the technical feasibility criteria.

Cost estimates for an estuary water treatment plant are complicated by the uncertainties surrounding the plant construction and operation of the plant. These include the following:

- Location of plant intake
- Method of distribution of the finished water to residents in the MWA
- Site of estuary treatment plant given the land use patterns around the Potomac River estuary
- Uncertain operational strategy (continuously, intermittantly) should an estuary water treatment plant ever be built

Consequently, cost estimates were prepared for the treatment plant only, consisting of those unit processes monitored at the EEWTP, with additional facilities as required to provide a complete, but isolated water treatment facility.

In particular, several costly components of an actual water treatment plant have been excluded from the cost estimates. These include the following:

1. The Phase IB process was excluded because of potential concerns regarding the free chlorine disinfection process and operational control of ammonia removal without intermediate chlorination.

Costs

1. River intake structure.
2. River pumping station.
3. Raw water reservoirs.
4. Finished water pumping station.
5. Finished water reservoirs.
6. Finished water distribution piping.
7. Land purchase.
8. Major site preparation.
9. Fluoridation

Costs for these facilities would substantially increase the cost of an estuary water treatment plant. These cost increases must be considered when comparing the cost estimates included in this report with the cost of other alternatives for meeting future water supply needs of the MWA.

BASIS FOR COST ESTIMATES

Cost estimates were prepared for a 200 MGD estuary water treatment plant treating water obtained from the Potomac River estuary and assumed to exhibit a water quality equivalent to the simulated influent blend tested in the EEWTP. The plant was assumed to be operated at full hydraulic capacity (200 MGD) throughout the year. The treatment process combinations included in the plant correspond to those monitored during the two-year testing program.

Because it was not possible to demonstrate all processes that would be included in a 200 MGD plant (carbon regeneration facilities, lime recalcining furnaces, sludge handling), some processes were selected based on engineering judgement. In general, however, selected design and operational criteria reflect criteria used in operation of the demonstration plant. Carbon usage rates have been calculated based on the actual quantity of carbon used during the duration of the individual phases of plant operation. Although this usage rate would be higher than probable usage rates in a full-scale plant, the rate reflects the scaled-up costs required to produce a water quality similar to that produced by the EEWTP.

COSTS OF ALUM-CHLORINE PROCESS COMBINATION

The alum-chlorine process combination would consist of the following processes:

- Alum/Coagulation
- Flocculation
- Sedimentation
- Intermediate Oxidation with Chlorine
- Dual-Media Gravity Filtration
- GAC Feed Pumping
- Adsorption on Granular Activated Carbon (Lignite based carbon)
- Disinfection with Free Chlorine

Generally, the design criteria used in the cost estimate matched the criteria tested during Phase IA for the alum-chlorine process.

Costs

Costs and key design criteria are summarized in Table E.11-1. Capital costs for such a 200 MGD plant are estimated to be approximately \$122 million (1983 dollars). Annual O&M plus amortization costs (based on 8 percent, 20 year loan) would be nearly 34 cents/1,000 gallons treated. Carbon costs represent approximately 45 percent of the annual unit treatment costs. Excluding GAC reduces unit costs for the estuary plant to 19 cents/1,000 gallons. This would represent the cost for a treatment plant comparable to so-called "conventional" water treatment plants, widely used in the U.S. for treating river sources.

COSTS OF PHASE IIA PROCESS COMBINATION

The Phase IIA process combination was shown to produce a finished water with a quality superior to that observed in the alum-chlorine process with respect to several key water quality parameters: turbidity, odor, total and fecal coliforms, manganese, other trace metals, total organic carbon (TOC), total organic halide (TOX), trihalomethanes and other primary or targeted organic compounds. This superior quality was due to the use of a more conservative operating criteria for the GAC process and replacement of free chlorine with ozone and chloramine for final disinfection. Lime coagulation was responsible for improved removals of several metals.

Processes included in this process combination are:

- Lime Coagulation
- Sedimentation
- Recarbonation
- Dual-Media Gravity Filtration
- Adsorption on Granular Activated Carbon (Bituminous based carbon)
- Primary Disinfection with Ozone
- Residual Disinfection with Chloramine

Design criteria used in the cost estimate generally matched those tested during Phase IIA.

Costs and key design criteria are summarized in Table E.11-2. As with the Phase IA process, the carbon usage rate in the GAC process represents the actual carbon used during the monitoring period. This usage rate corresponds to the level of carbon usage required to produce a finished water of quality similar to that observed in the monitoring program.

Capital costs for an estuary water treatment plant using these processes are estimated to be \$174 million (1983 dollars), or a 42 percent increase compared to the alum process. Annual O&M and amortization costs (unit costs) - (8 percent, 20 year), increase by approximately 39 percent compared to the alum process. The total unit costs are projected to be 47.6 cents/1,000 gallons. As with the alum process, GAC dominates both the capital and annual costs for the estuary plant, representing nearly 28 percent and 45 percent of the capital and unit costs, respectively.

TABLE E.11-1

COSTS AND MAJOR DESIGN CRITERIA - PHASE IA PROCESS COMBINATION

Process	Major Design Criteria	Capital Cost (Million \$)	Unit Costs ^a	
			(\$/1000 m ³)	(¢/1000 gals)
Alum Coagulation	Alum (50 mg/L), Polymer (0.1 mg/L), Lime (15 mg/L), 3 stage flocculation 24 minutes detention	4.0	(20.9)	7.9
Sedimentation	Surface overflow rate 41/m ³ /m ² /day (1,000 gpd/ft ²)	11.4	(7.7)	2.9
Granular Media Filtration	Dual media, 2 L/m ² /s (3 gpm/ft ²)	16.2	(13.6)	5.1
GAC and Regeneration	EBCT = 15 min Lignite carbon 64 gravity contactors 3 L/m ² /s (5 gpm/ft ²) 10% GAC makeup Carbon usage = 30 g/m ³ (250 lb/MG) Multiple Hearth Furnace	36.1	(40.5)	15.3
Chlorination (Intermediate and Final)	Total applied dose = 4.5 mg/L Contact time (final) = 60 min	2.9	(3.0)	1.1
Sludge Treatment and Disposal	Thickener/centrifuge	3.6	(3.5)	1.3
Other	Admin, laboratory	0.6	(1.5)	0.6
TOTAL PROCESS		74.8	(90.7)	34.2
Construction		17.7		
Other (Engineering, legal, contingency (10%))		29.8		
	TOTAL	122.3		

a. Unit costs include operating and maintenance costs plus amortization costs based on eight percent interest, 20 year loan.

TABLE E.11-2

COSTS AND MAJOR DESIGN CRITERIA - PHASE II PROCESS COMBINATION

Process	Major Design Criteria	Capital Cost (Million \$)	Unit Costs ^a	
			(\$/1000 m ³)	\$/1000 gals
Lime Coagulation	pH = 11 Dose, CaO = 75 mg/L FeCl ₃ @ 3 mg/L 3 stage flocculation 24 minutes detention	3.6	(9.8)	3.7
Sedimentation	Overflow rate 41 m ³ /m ² /d (1000 gpd/ft ²)	11.4	(7.9)	3.0
Recarbonation	Detention = 20 min	2.6	(2.4)	0.90
Granular Media Filtration	Dual Media 2 L/m ² /s (3 gpm/ft ²)	16.2	(13.9)	5.3
GAC and Regeneration	EBCT = 30 min Bituminous carbon 64 gravity contactors 3 L/m ³ /s (5 gpm/ft ²) 10% GAC makeup Carbon usage = 42 g/m ³ (350 lb/MG) Multiple hearth furnace	49.4	(56.5)	21.4
Ozone Disinfection	Applied dose = 2 mg/L Detention = 20 min	7.4	(7.1)	2.7
Chloramination	Dose, NH ₃ = 1 mg/L Dose, Cl ₂ = 3 mg/L	2.8	(2.9)	1.1
Sludge Treatment and Disposal and Recalcination	Thickener/centrifuge Multiple hearth furnace	13.0	(23.5)	8.9
Other	Admin, laboratory	0.6	(1.5)	0.6
TOTAL PROCESS		107.0	(125.50)	47.6
Construction		25.3		
Other (engineering, legal, interest, contingency (10%))		42.0		
	TOTAL	174.3		

^a. Unit costs include operation and maintenance costs plus amortization costs based on 8 percent interest and 20 year loan.

Costs

Thus, higher quality water can be produced by the Phase IIA process combination as compared to the Phase IA process, but at a substantial increase in unit cost.

COSTS OF ALTERNATIVES NOT MONITORED

Based on the results of the engineering studies, several alternative process combinations were analyzed with respect to cost and finished water quality implications compared to the two monitored processes that were selected for a cost analysis. These alternatives include the following:

- Phase IA with revised GAC regeneration criteria and parallel operation of GAC contactors.
- Phase IIA with revised GAC regeneration criteria and parallel operation of the GAC contactors.
- Phase IA with packed tower air stripping prior to GAC.
- Phase IA without GAC, but with Reverse Osmosis (RO) treatment of half the plant capacity.

Each of these process combinations provides either cost savings or provides an additional treatment barrier, thus potentially increasing the plant process reliability for an estuary WTP.

A summary of these cost and water quality issues is shown in Table E.11-3. The estimated unit costs for a conventional water treatment plant without GAC is also shown for reference.

Operation of the GAC process with parallel contactors would decrease unit costs by 3 to 7 cents/1,000 gallons, depending on the target TOC level in the blended GAC effluent. Although a regeneration criterion of 2 mg/L of TOC is less conservative than the criterion used during the EEWTP operation, the finished water quality would likely still be of acceptable quality, because of the small number and concentrations of organic compounds observed in the EEWTP influent.

The air stripping alternative would provide an additional barrier for control of volatile organic chemicals, with only a modest (ten percent) increase in unit cost.

Finally, the reverse osmosis process combination would provide removal of potentially undesirable inorganic parameters including TDS, nitrate, and sodium. Such treatment would be costly however, as the estimated costs are nearly double the Phase IA unit costs.

TABLE E.11-3
UNIT COSTS OF VARIOUS PROCESS COMBINATIONS CONSIDERED

Process Designation	Main Unit Processes	Comment	Water Quality Implications (Relative to Monitored Processes)	Costs	
				Cost Cents/1,000 Gal ^a (\$/1,000 m ³)	
IA (No GAC)	Alum+Cl ₂ +Filt+Cl ₂	Conventional Water Treatment Process	Decreased removal of organics. No barriers to SOC _s	19.0 (50.5)	
IA	Alum+Cl ₂ +Filt+GAC+Cl ₂	As operated at EEWTP	As monitored in Phase IA	34.2(90.7)	
IIA	Lime+Filt+GAC+O ₃ + (Cl ₂ +NH ₃)	As operated at EEWTP	As monitored in Phase IIA	47.6 (125.8)	
IA with revised regeneration criteria and more optimum design	Same as IA	Regenerate carbon as required to maintain blended effluent at: a. 1.0 mg/L TOC b. 2.0 mg/L TOC	Similar to IA at end of GAC run. Higher concentration of organics.	a. 32.2 (85.0) b. 29.8 (78.7)	
IIA with revised regeneration criteria and more optimum design	Same as IIA	Regenerate carbon as required to maintain blended effluent at: a. 1.0 mg/L TOC b. 2.0 mg/L TOC	Similar to IIA at end of GAC run. Higher concentration of organics.	a. 40.7 (107.5) b. 38.3 (101.1)	
IA with air stripping	Same as IA with air stripping prior to GAC	Air stripping tested at pilot-scale at EEWTP	Additional barrier to VOCs	37.1 (98.1)	
IA (no GAC) with reverse osmosis	Alum+Cl ₂ +Filt+RO+Cl ₂	RO tested at pilot-scale at EEWTP	TDS, NO ₃ , and Na removal. Modified removal of SOC _s	69.3 (183.9)	

a. Costs as of April 1983.