5010-06-01

AMENDMENT 1
to the
DELTA DIABLO SANITATION DISTRICT RECYCLED WATER FACILITY PROJECT TITLE 22 ENGINEERING REPORT

July 1999

Prepared for:

Delta Diablo Sanitation District

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Engineering Report
for the
Delta Diablo Sanitation District
Recycled Water Facility

AMENDMENT 1

July 1999

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Tables and Figures

Purpose of Amendment

Delta Diablo Sanitation District (DDSD) is submitting this Amendment to "Engineering Report for the Delta Diablo Sanitation District Recycled Water Facility," previously submitted to the California Department of Health Services on June 25, 1999. The purpose of this Amendment is to demonstrate that this Recycled Water Facility project will not significantly impact DDSD's effluent discharge quality, and will not impact DDSD's ability to meet its current NPDES permit (Permit No. CA0038547).

Project implementation is on an aggressive schedule to ensure that facilities are constructed and recycled water is available by the time the power plant startup occurs. Both power plants are currently in the permitting and design stages. All information contained in this Amendment is based on currently available information and the expressed intent of all involved parties. Any significant future changes to the project will be brought to the attention of the Department of Health Services (DHS) in the form of subsequent amendments.

This document consists of the following sections:

- Summary of Results
- Introduction
- Background
- Estimated Effluent Water Quality Impacts
- Appendices

Summary of Results

The potential impacts of the Recycled Water project on DDSD's ability to comply with its existing NPDES permit conditions were examined. The following conclusions were reached as a result of this study:

- The change in DDSD final effluent constituent concentrations due to the evaporation of recycled water in the power plant cooling towers and discharge of the blowdown return streams back to DDSD will not cause violations of the existing DDSD NPDES pollutant concentration limits;
- The total mass of constituents in DDSD final effluent will decrease as a result of this project in comparison to future conditions without recycling;
- The power plant return streams will not cause or contribute to a measurable increase in the acute toxicity of DDSD effluent;
- The reduction of DDSD final effluent flow rate due to diversion of secondary effluent to the Recycled Water Facility will not negatively impact the initial dilution achieved by the outfall; and
- The power plant return streams will not have a significant impact on DDSD final effluent temperature.

Introduction

The proposed Recycled Water Facility will produce recycled water for delivery to two proposed power plants. The primary recycled water use at the power plants will be cooling tower makeup water. Through the evaporative cooling process, the volume of the recycled water will be reduced in the cooling towers. The power plants will discharge a blowdown stream from the cooling towers back to the DDSD water pollution control facility (WPCF), in combination with other discharge streams from auxiliary processes, hereinafter collectively referred to as the "return streams". DDSD will receive the return streams at the influent to the existing chlorine contact basins. The combined return streams and remaining secondary effluent will be disinfected in the existing chlorine contact basins, dechlorinated, and discharged through the DDSD outfall to the New York Slough.

The diversion of a portion of the WPCF secondary effluent to the Recycled Water Facility will reduce the amount of final effluent being discharged to the outfall which may affect outfall dilution. The return stream discharge to the existing chlorine contact basins may affect the final effluent constituent concentrations. The purpose of this Amendment is to examine these potential effects and show that they will not impact DDSD's ability to comply with their existing NPDES permit.

Background

This section provides additional details on the potential recycled water users beyond what was provided in the original Title 22 Engineer's Report. The discussion in this section is based on data provided by the power plants, and is the basis of estimates of water quality impacts provided in subsequent sections of this Amendment.

Power Plant Recycled Water Use

The two potential recycled water users are as follows:

- Pittsburg District Energy Facility (PDEF): Expected online January 2001; 2.4 mgd average recycled water demand.
- Delta Energy Center (DEC): Expected online fourth quarter 2001; 5.3 mgd average recycled water demand.

The primary use of the recycled water in these power plants will be for cooling tower makeup water. Approximately two-thirds of the recycled water delivered to the power plants will be evaporated in the cooling towers. The remaining one-third will be returned to DDSD for disposal in a blowdown return stream. This return stream will contain approximately the same mass of dissolved and suspended constituents (solid particles, dissolved metals, etc.) as the delivered recycled water since evaporation only removes pure water. Ammonia may not increase however, and may actually decrease across the cooling tower process, due to the addition of bromine for biocide at the power plants. In addition, there are other potential minor recycled water uses planned at the power facilities. These other uses may slightly influence the mass of certain constituents, but the significantly lower demands of these other uses will limit the effects.

This Amendment is based on the following assumptions:

- DDSD will treat and deliver an average recycled water flow of 7.7 mgd and a peak flow of 12.2 mgd to the two power plants for cooling water.
- Both power plants will discharge a return stream to the DDSD WPCF upstream of the existing disinfection facilities and existing NPDES sampling location. The discharges will be covered under DDSD's NPDES permit.

Other Potential Uses

DDSD has identified additional potential irrigation and industrial recycled water use that may be served in the future as flow to DDSD increases and the recycled water supply is adequate. Specifically, there are two park/greenbelt projects proposed in the Pittsburg area near the power plant projects that would use recycled water. The use of recycled water for irrigation will not result in additional wastewater discharges to DDSD. Therefore, providing recycled water to these additional users will not impact DDSD's ability to comply with its NPDES permit.

Estimated Effluent Water Quality Impacts

Effluent Mass and Concentration Impacts

The recycled water produced by DDSD will be used in the PDEF and DEC power plants primarily as cooling tower makeup water. Through the process of evaporation, the volume of the recycled water will be reduced by approximately two-thirds, leaving a concentrated water stream requiring disposal.[1] This return stream will contain approximately the same mass of dissolved and suspended constituents (solid particles, dissolved metals, etc.) as the delivered recycled water since evaporation only removes water, not dissolved constituents.

Figure 5-1 is a water balance diagram showing recycled water production, recycled water distribution to the power plants, and return stream discharge back to DDSD. Average water flow rates are shown, based on estimates provided by the power plants. The diagram shows that the power plants will use a combined average of approximately 7.7 mgd of recycled water, and return a combined average of approximately 3.0 mgd of return stream to DDSD. Under average conditions, this return stream will be blended with 5.3 mgd of remaining DDSD secondary effluent, disinfected in the existing chlorine contact basins, and discharged through the existing outfall at a combined average flow rate of 8.3 mgd.

The total mass of constituents in the DDSD effluent will decrease as a result of this project in comparison to predicted future conditions without water recycling implementation. The coagulation/ sedimentation and filtration processes will achieve significant removal of particulates and potentially some removal of dissolved constituents (through adsorption). The coagulation/ sedimentation sludge will be pumped back to the primary clarifiers where most of the solids will be settled and sent to the solids handling processes. The filter backwash will be pumped back to secondary treatment and retreated. This results in an additional level of treatment performed on a portion of DDSD's wastewater stream which will reduce the overall mass of constituents in DDSD effluent. The potential distribution of recycled water to future irrigation customers will remove additional constituent mass from the system and therefore further decrease DDSD final effluent mass.

The proposed coagulation/settling and filtration treatment system is expected to perform nearly complete removal of total suspended solids (TSS) from the secondary effluent. The removal of metals by the proposed Recycled Water Facility will depend on the ratio of dissolved to particulate metals in DDSD secondary effluent wastewater, which will be different for each metal. In general, particulate metals will be removed at a removal rate which is proportional to the TSS removal rate. Some adsorption of dissolved metals may also be achieved. For the sake of discussion, a metals removal rate of 10% is assumed with tertiary treatment.

Figure 5-2 is a conceptual graph which compares the mass of TSS and an example metal, cadmium (Cd), in DDSD final effluent with and without Recycled Water Facility implementation for three points in time: present, after implementation of the Recycled Water Facility (2001), and at DDSD service area buildout (approximately 2020). Without Recycled Water Facility

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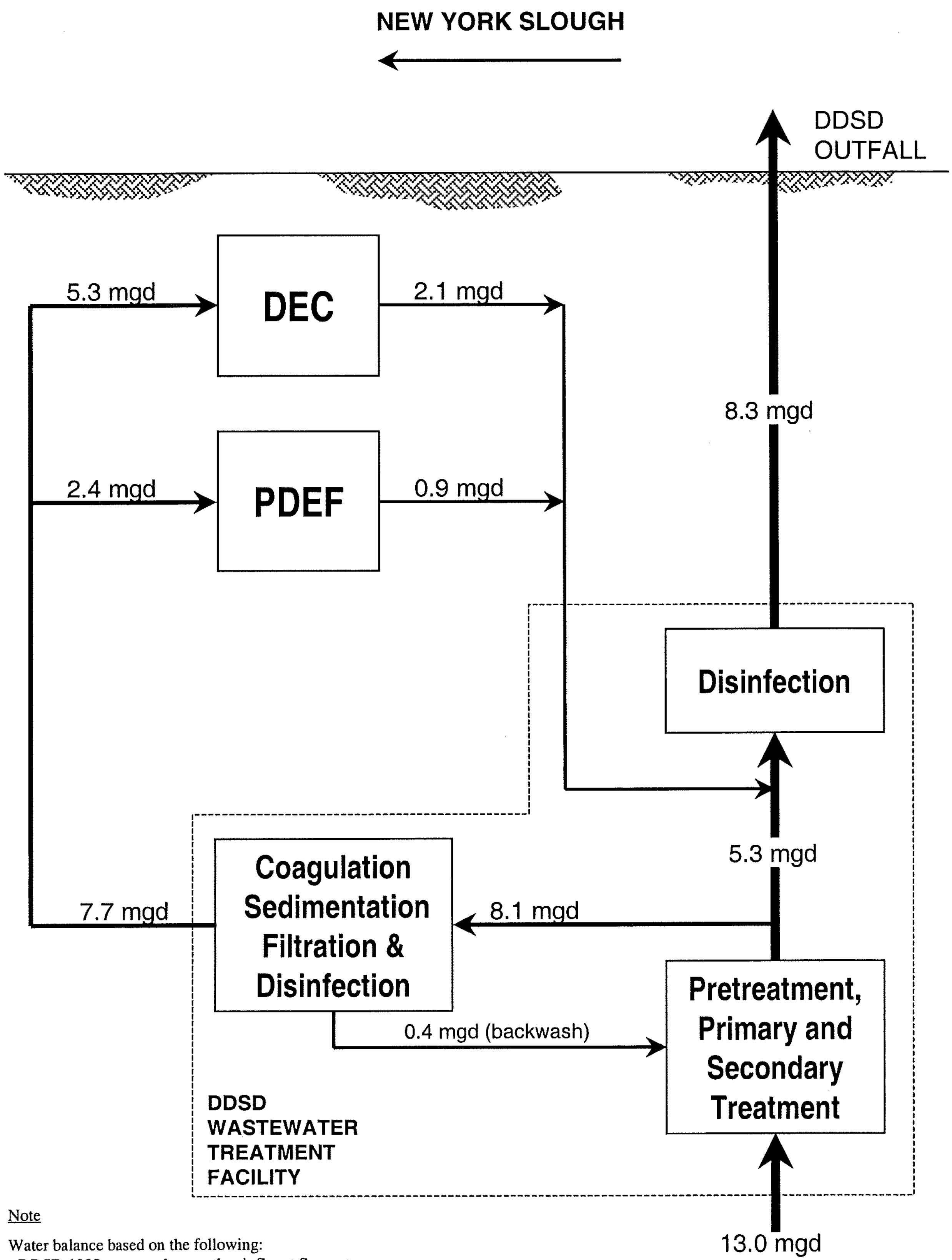
[1] A small portion of the recycled water delivered to the power plants (approximately 5%) will be used in plant processes other than the cooling towers. The discharge streams from these processes will be combined with the cooling tower blowdown into a blended return stream that will be discharged to DDSD. These other discharge streams will have a minor influence on the mass of constituents in the return stream as compared to the recycled water.



Note

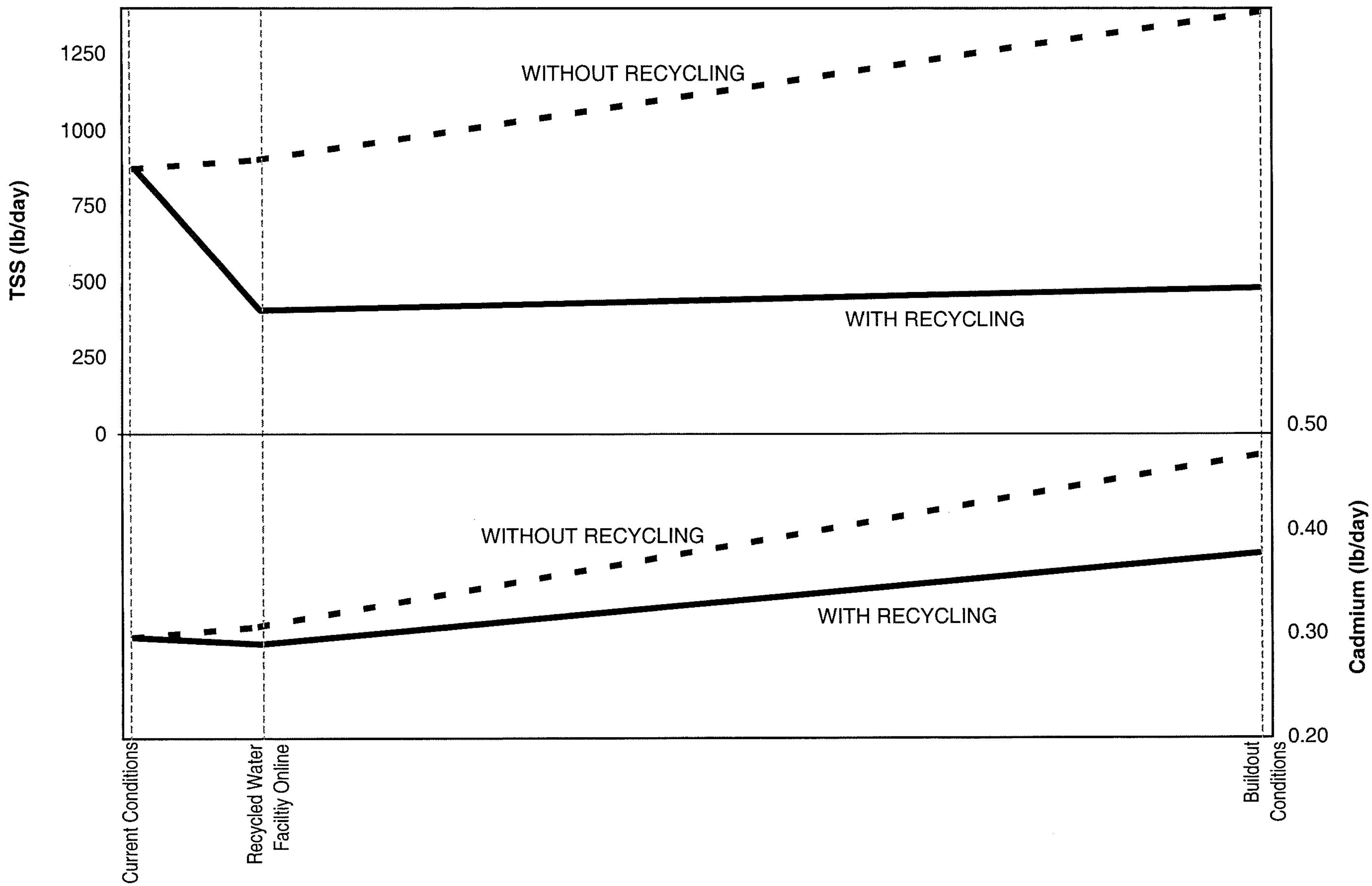
Water balance based on the following:

- DDSD 1998 average dry weather influent flow rate
- Estimated average power plant demands and return stream flow rates at an ambient temperature of 60°F

Figure 5-1
Water Balance for DEC and PDEF

RMC

fig 12-1 water balance.ppt 6/23/99



Notes
1. Current conditions based on 1998 average DDSD flow rate, TSS, and Cd concentrations.
2. Mass projections based on 1998 average DDSD effluent TSS and Cd concentrations with a Recycled Water Facility removal rate of 100% for TSS and 10% for Cd.
3. Mass projections based on future DDSD average plant flow rates obtained from "Wastewater Treatment Master Plan Report" prepared for DDSD by HDR Engineering, Inc. in March 1997.
3. Buildout conditions assume 10.8 mgd of industrial cooling tower recycled water use (7.7 mgd for PDEF and DEC plus 3.1 mgd of other industrial cooling uses which have been identified by DDSD) plus 0.2 mgd of irrigation and 3.1 mgd of other non-cooling industrial use.

Figure 5-2: Predicted Effects of Water Recycling on DDSD Effluent Constituent Mass

implementation, a gradual increase in final effluent constituent mass would occur due to the increase in wastewater flow in the DDSD service area (assuming no change in effluent concentrations). This increase would also occur with implementation of the Recycled Water Facility, but at a lesser rate as shown in the figure.

The recycled water demand of the power plants has the potential to vary during a typical day from no demand at all (when the power plants are offline) to a peak demand that can potentially consume the entire available supply from DDSD. When there is no recycled water demand, DDSD will operate as it currently does today, treating the entire flow of raw wastewater to disinfected secondary effluent standards and discharging it through the existing outfall without any diversion to recycled water treatment and without any return stream inflow to the chlorine contact basins. When both power plant demands are at peak, a scenario can occur (depending on DDSD WPCF plant flow rate) where all secondary effluent will be diverted to the recycled water facility, treated, and delivered to the power plants, and the entire volume of water discharged through the existing DDSD outfall will consist of the undiluted power plant return streams. The latter scenario is considered the worst-case in terms of effluent constituent concentrations. Estimates for future effluent concentrations provided in this Section are based on this worst-case scenario. It is important to recognize that this worst-case scenario will be an infrequent occurrence under normal operating conditions, because high power plant recycled water demand would not normally be expected to occur at the same time that WPCF wastewater flow is low[2].

Table 5-1 provides estimated future DDSD WPCF final effluent concentrations which assume that return streams are being discharged without dilution from remaining secondary effluent. These estimates are based on the geometric mean of historical DDSD effluent concentration data (also shown in the table) and on estimated power plant process concentration factors provided by the power plants. Current NPDES concentration limits for DDSD are also shown in the table. A comparison of the estimated future concentrations with the concentration limits shows that this project is not expected to cause violations of the current DDSD NPDES permit limits.

Effluent Temperature Impact

Table 5-2 compares the current temperature range of DDSD final effluent to the expected temperature range of the power plant return streams. The data shows that on the average there will be a minor temperature increase of about 1 - 2 °F in the power plant return streams as compared to the delivered recycled water (which is assumed to be the same temperature as DDSD effluent). Under worst-case conditions when only undiluted return streams are being discharged in the DDSD outfall, the DDSD final effluent temperature will increase from current values by about 1 - 2 °F (not taking into account the cooling that may occur in the return stream pipelines, particularly in the 3.4 mile long PDEF pipeline). On a daily average basis, the temperature increase of DDSD final effluent is expected to be less due to dilution by remaining secondary effluent.

[2] The greatest demand for power typically occurs during the daytime hours, when WPCF wastewater flow exceeds the maximum expected recycled water demand. The WPCF experiences low flow conditions during the night, when power demands are normally low. Therefore, peak power plant demand is not expected to coincide with low DDSD wastewater flow rate under normal conditions.

Table 5-1: Estimated Project Impact to DDSD Effluent Quality

Constituent	Units	Current DDSD Effluent Concentration[1]	DDSD Effluent Concentration After Return Streams[2] (Average)	DDSD Effluent Concentration After Return Streams[2] (Worst-Case)[3]	Current DDSD Permit Limitation (most stringent)
Arsenic	ug/l	2.22	4.6	8.8	50
Cadmium	ug/l	2.63	5.3	9.9	10.7
Chromium	ug/l	4.01	8.2	15.5	110
Copper	ug/l	7.81	15.7	29.8	78
Cyanide	ug/l	4.87	10.3	20.0	25
Lead	ug/l	2.09	4.3	8.3	23
Mercury	ug/l	0.01	0.02	0.04	0.08
Nickel	ug/l	3.41	6.9	13.0	71
Silver	ug/l	0.44	0.96	1.87	23
Zinc	ug/l	28.2	57.4	108.9	1055
BOD_5	mg/l	11	<30	<30	30
TSS	mg/l	7.75	<30	<30	30
Oil & Grease	mg/l	2.08	<10	<10	10
Phenols	ug/l	4.64	<30	<30	3000
Benzene	ug/l	0.81	1.7	3.2	3.4
Chloroform	ug/l	4.99	9.6	17.7	1000
Toluene	ug/l	1.12	2.2	4.0	100,000
G-BHC	ug/l	0.019	0.036	0.066	0.19

[1]Based on the geometric mean of DDSD concentration data (from September 1991 – September 1997); with the exception of BOD_5, suspended solids, TSS, and oil & grease, which are based on the geometric mean of monthly average data for 1997. Because the data contains a significant number of non-detect values at relatively high detection limits, non-detect values were not used in all cases. Non-detects were converted to a number equal to one-half the detection limit when the detection limit was less than the highest measured concentration of the constituent. Non-detects that did not fit this criteria were excluded from the geometric mean.

[2]Based on estimated power plant process concentration factors provided by DEC and PDEF. The values were derived from estimates of influent water constituent concentrations, changes within the various processes contributing to the wastewater streams, and the proportional amount of flow represented by each waste stream to the overall discharge flow. The concentration factors resulting from the power plant processes will be less than the number of cycles through the cooling towers because not all of the water in the power plant return streams will have passed through the cooling towers or other constituent-concentrating processes, and not all of the source water will be obtained from DDSD.

[3]Assumes peak recycled water demands, i.e. effluent consists entirely of undiluted return streams.

Table 5-2: Temperature Comparison of Current DDSD Effluent and Future Return Streams

	Maximum Daily Temperature (°F)	*Average Daily Temperature (°F)*
Winter		
DDSD Effluent	73	64.8
Power Plant Return Streams	68	65.7
Increase	*-5*	*0.9*
Summer		
DDSD Effluent	81.7	78.8
Power Plant Return Streams	82.9	80.6
Increase	*1.2*	*1.8*

Note: DDSD effluent temperature data from 4/1/97 - 3/31/98. Power plant estimated return stream temperatures obtained from DEC in April 1999. The temperatures reported by DEC are representative of both the DEC and PDEF power plants due to their similar design.

Acute Toxicity Impacts

The issue of acute toxicity impacts was addressed through pilot testing using a trailer-mounted cooling tower pilot lab. The toxicity testing was done in April 1999. This test trailer contained a bench-scale representation of the power plant processes. Recycled water was produced from DDSD secondary effluent using the existing gravity filter system. This water was fed to the test trailer, where it was passed through the bench-scale power plant processes in order to produce a simulated return waste stream that accurately represented the actual return stream that would be produced by the full scale power plants. This return stream was delivered to the DDSD bioassay lab where it was fed without dilution to bioassay test chambers for acute toxicity using the same test protocol, although with reduced volumes, that DDSD uses to verify NPDES compliance. The complete test procedure, protocols, and results are provided in Appendix A.

Results from the tests indicate that the simulated effluent exhibited no signs of acute toxicity to either the three-spined sticklebacks or the fathead minnows with survival rates of 100% for both species following the 96-hour exposure period. These results are typical of normal routine toxicity test results from DDSD final effluent. Therefore, based on this set of toxicity tests, the processes that DDSD effluent underwent during this investigation did not cause or contribute to a measurable increase in toxicity of the wastewater.

Outfall Dilution Impacts

Outfall dilution modeling was performed to examine the potential effects of the project on the effluent dilution achieved by the DDSD outfall. The DDSD NPDES permit requires a minimum initial dilution of 10:1 at all times. The effects of a change in effluent flow rate on this initial dilution were examined. "Farfield" dilution affects were also examined.

Implementation of this recycled water project will reduce the average flow rate of effluent discharged to New York Slough through the DDSD outfall. The modeling results show that a reduction in outfall flow rate *increases* the corresponding initial dilution achieved by the outfall.

The modeling studies also showed that, following initial dilution, the wastewater plumes are rapidly mixed with the receiving water and very high dilutions are achieved within a short distance from the discharge location. Modeling results showed worst case dilutions of about 350:1 at the CCWD Mallard Slough and City of Antioch water supply intakes. This dilution would be far greater under normal Delta outflow conditions.

The modeling study concluded that the project **would not** have any adverse effect or impact on outfall initial dilution or on drinking water supply intakes upstream or downstream of DDSD's discharge location.

A detailed report of the modeling effort and the results is provided in Appendix B.

Appendix A: Acute Toxicity Test Description and Results

Introduction

The following sections describe the procedures and results of the acute toxicity testing that was performed on a simulated return stream produced from DDSD recycled water. Throughout this Appendix, reference is made to the Pittsburg District Energy Facility (PDEF) power plant only. However, the procedures and results of this testing are equally applicable to both power plant facilities, because the two facilities are of similar design.

DDSD Recycled Water Facility Project
Acute Toxicity Protocol Description
and
Test Results

NALCO

Acute Toxicity Testing Protocol and Results for Determining Impacts of Cooling Tower Blowdown from the PDEF Power Generation Facility on Final Effluent Quality of the Delta Diablo Sanitary District NPDES Discharge

Pilot testing was conducted to determine the effects of cooling tower blowdown generated by the PDEF power generation facility (PDEF) on the final effluent quality of the Delta Diablo Sanitary District (DDSD) NPDES waste discharge. As described in the sections above, secondary treated effluent from DDSD underwent further tertiary treatment to provide Title 22 makeup water for a scaled-down pilot cooling tower trial. The cooling tower trial was conducted as described in the test protocol, and involved the simulation of cooling tower blowdown as well as the simulation of discharge water from other power plant auxiliary processes that will use recycled water in the full-scale facilities. Aquatic toxicity testing as well as a number of chemical analyses were performed on the undiluted simulated power plant return stream to determine what impact, if any, the effluent from the PDEF operation will have on final effluent quality and subsequent compliance with DDSD NPDES permit limits.

Compliance with DDSD NPDES permit limits for acute toxicity is currently determined using 96-hour flow-through bioassays. Therefore, acute toxicity of the simulated effluent to the two compliance species, fathead minnows and three-spine sticklebacks, was determined using the 96-hour flow-through protocol as described in EPA/600/4-90/027, "Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms". This test protocol is also referenced in Table 1A, 40 CFR Part 136 regulations and, therefore, constitute approved methods for acute toxicity tests.

The DDSD bioassay laboratory is currently certified under the Environmental Laboratory Accreditation Program (ELAP) for conducting acute toxicity tests using both flow-through and static-renewal methods. Since the test protocol mentioned above is currently being used by the DDSD bioassay testing laboratory for the routine compliance tests associated with their NPDES acute toxicity compliance requirements, all pertinent QA/QC practices are already in place and adhered to. These include, but are not limited to:

1) adherence to approved standard operating procedures (SOP's) for toxicity testing, instrument calibration, and sample chain-of-custody,
2) provision of adequate, qualified technical staff and suitable lab space and equipment to assure reliable data,
3). proper effluent sampling and handling,
4) source and condition of test organisms,
5) adequate replication,
6) use of reference toxicants,

7) record keeping and data evaluation.

The results from the acute toxicity tests should provide a reliable basis for determining whether the addition of the PDEF wastestream will impair DDSDs ability to comply with their current NPDES acute toxicity permit limits.

Acute Toxicity Test Procedure

The NALCOLab delivered approximately 95 ml per minute (34 gallons per day) of simulated effluent that was used to conduct flow-through bioassay testing with fathead minnows and three-spine sticklebacks. In addition to toxicity testing, a daily aliquot of simulated effluent was collected for a number of chemical analyses including alkalinity, hardness, residual chlorine, and ammonia. Other analyses such as dissolved oxygen, pH, conductivity, and temperature were performed on test solution in the test chambers.

In order to perform the flow-through bioassays according to EPA approved test protocol, some minor modifications to the current DDWTF bioassay testing equipment were required. These modifications are described below.

The volume in each test chamber was reduced to 2.5 liters. This volume fulfilled the EPA required fish loading capacity of 4.75 grams of live fish per liter of test solution. The fish loading requirement minimizes the depletion of dissolved oxygen, the accumulation of problematic metabolic waste products, and stress induced by crowding, any of which could significantly affect test results. In addition, this volume allowed for the recommended test solution renewal rate of five 90% replacements of water volume in each test chamber every 24 hours.

Approximately 34 gallons of simulated effluent was collected in a 55-gallon polyethylene drum and transported to the bioassay testing facility on a daily basis. Two drums were utilized, as one drum was filling with new simulated effluent while the other was used in the bioassay facility. Prior to use, the drums were filled with fresh water and allowed to stand for 24 hours. The drums were then emptied and rinsed twice with fresh water and emptied again. Once filled with simulated effluent, the drum was transported to the DDSD bioassay laboratory. There, a Tygon suction line was placed into the 55-gallon drum and a peristaltic pump was used to deliver a minimum of 20 ml/minute of sample into each of four test chambers (2 for fathead minnows and 2 for sticklebacks). A flow rate of 20 ml/minute into a tank with 2.5 liters satisfied the requirement of a minimum of five water replacements per day.

Results of Acute Toxicity Tests

96-hour acute flow-through toxicity tests using three-spined sticklebacks and fathead minnows were conducted on composite samples of simulated effluent generated by methods described in the previous section. The tests were conducted, by an ELAP certified laboratory, according to procedures described in EPA/600/4-90/027, "Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and

Marine Organisms". Based on acceptable survival rates in control samples and results from the reference toxicant tests performed on the test organisms, the following test results are deemed valid. Raw data sheets for the simulated effluent and reference toxicity tests are presented in the attachments.

Results from the tests indicate that the simulated effluent exhibited no signs of acute toxicity to either the three-spined sticklebacks or the fathead minnows with survival rates of 100% for both species following the 96-hour exposure period. These results are typical of normal routine toxicity test results from Delta Diablo Sanitary District (DDSD) final effluent. Therefore, based on this set of toxicity tests, the processes that DDSD effluent underwent during this investigation did not cause or contribute to a measurable increase in toxicity of the wastewater.

D.E. A... SANITATION DISTRICT

FLOW THROUGH BIOASSAY

NIST Traceable Thermometer Deg C.: 19.3 Thermograph ~~Green~~ Red Pen (Control) Deg C.: 19.4 Thermograph ~~Red~~ Blue Pen (Effluent) Deg C.: 19.3

THREE-SPINE STICKLEBACKS (Gasterosteus Aculeatus) Batch # FB99-16
% Survival: ____

FATHEADS (Pimephales Promelas) Batch # FB99-9
% Survival: ____

NALCOLAB SIMULATED EFFLUENT

		Control Tank #1	Control Tank #2	Flow through A	Flow through B	Control Tank #3	Control Tank #4	Flow Through C	Flow through D
INITIAL Analyst: JJ Date: 4/18/99 Time: 1205	Flow mL/min	22.4	22.4	20.8	23.2	22.4	4/18 ~~22~~ 21.6	22.4	22.4
	pH			7.34	7.30			7.36	7.36
	Conductivity umhos/cm			3050	3052			3049	3051
	DO mg/L	7.84	7.48	6.92	6.62	8.12	8.12	7.00	7.03
	Temp deg C	19.8	19.7	20.2	20.1	19.6	19.6	20.0	20.2
	Total Chlorine	0	0	0	0	0	0	0	0
24 hours Analyst: JJ Date: 4/19/99 Time: 1027	Flow mL/min	23.2	27.2	20.8	22.4	23.2	24.8	21.6	21.6
	pH			7.26	7.28			7.32	7.34
	Conductivity umhos/cm			3033	3048			3041	3055
	DO mg/L	8.05	7.90	5.92	5.67	8.27	8.32	6.38	6.16
	Temp deg C	19.7	19.6	19.7	19.7	19.5	19.5	19.7	19.7
	Total Chlorine	0	0	0	0	0	0	0	0
	# dead fish	0	0	0	0	0	0	0	0
48 hours Analyst: GG Date: 4/20/99 Time: ~~1230~~ 1310	Flow mL/min	22.4	24.8	20.8	21.6	27.2	28.0	22.4	23.2
	pH			7.50	7.49			7.65	7.60
	Conductivity umhos/cm			3249	3230			3234	3168
	DO mg/L	7.64	7.86	3.96	3.91	8.14	7.91	6.11	5.62
	Temp deg C	20.2	19.8	19.5	19.5	19.6	20.1	19.4	19.5
	Total Chlorine	0	0	0	0	0	0	0	0
	# dead fish	0	0	0	0	0	0	0	0

Number test animals per concentration=10 Flow:minimum of ~~85~~ 20 mL/min=5 tank turnovers Volume of test solution=~~10L~~ 2.5 L, Depth =~~12cm~~ 1.6 cm Aeration with Oil-less air pump

Acclimatization : 7 days at 18 - 22 degrees centigrade Dead Fish in acclimatization tank <10% Control water source=Filtered and Dechlorinated tap water

4/29/98

Comments 4/18/99 Test for Encon / OCSD recycled water project. Using effluent produced from Nalco Co. test trailer (on-site) for flow thru-test, using 2.5 Liter tanks & approx. 20 ml/min. of sample flow. Also sample is stored in 55 gallon plastic (black) drums and brought to the bioassay lab. The first drum was brought to lab @ 1000 and temp. was about 20°C and D.O. = 5.71 mg/L.
4/19/99 1620 change out barrel w/ new sample. 4/20/99 Per G.G. drum was close to empty at 1100. Nalco brought new 1/2 drum, temp. of sample was 29°C. Restarted flow to test at 1310. Cooling sample by running tubing thru the water bath. 4/20/99 John L. - Nalco adjusted effluent sample flow in afternoon (time?)

A

Reviewed By: [signature] Date: 4-29-99

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DELTA DIABLO SANITATION DISTRICT

FLOW THROUGH BIOASSAY

THREE-SPINE STICKLEBACKS (Gasterosteus Aculeatus) Batch #______	Control Tank #1	Control Tank #2	Flow through A	Flow through B		Control Tank #3	Control Tank #4	Flow Through C	Flow through D
						FATHEADS (Pimephales Promelas) Batch #______			
Flow mL/min	23.2	20.8	20.0	22.4	72 hours	26.4	22.4	21.6	22.4
pH			7.05	7.06				7.14	7.13
Conductivity umhos/cm			3290	3305				3235	3308
DO mg/L	8.12	8.05	4.36	4.15	Analyst: J	8.29	8.34	4.87	4.80
Temp deg C	19.2	19.2	19.2	19.2	Date: 4/21/99	19.1	19.1	19.2	19.2
Total Chlorine	0	0	0	0	Time: 1038	0	0	0	0
# dead fish	0	0	0	0		0	0	0	0
Flow mL/min	24.0	20.8	21.6	21.6	96 hours	21.6	20.0	21.6	21.6
pH			6.79	6.78				6.86	6.85
Conductivity umhos/cm			3903	3940				3941	3940
DO mg/L	7.88	7.79	4.29	4.05	Analyst: J	8.08	8.13	5.02	4.79
Temp deg C	19.4	19.3	19.6	19.5	Date: 4/22/99	19.2	19.3	19.4	19.3
Total Chlorine	0	0	0	0	Time: 1047	0	0	0	0
# dead fish	0	0	0	0		0	0	0	0
Total # dead fish	0	0	0	0		0	0	0	0

Number test animals per concentration=10 Flow:minimum of 85 mL/min=5 tank turnovers Volume of test solution=10L, Depth =12cm Aeration with Oil-less air pump 12/11/98

Acclimatization : 7 days at 18 - 22 degrees centigrade Dead Fish in acclimatization tank <10% Control water source=Filtered and Dechlorinated tap water

Comments 4/21/99 0951 Changed out barrel for 4/21/99 Changed out barrel at ~~top~~ 2036. for 4/22/99 Conductivity in the last barrel 3950 umhos ✓ J 4/22 verified conductivity w/ Steve Rock's conductivity meter against standard. J

Reviewed By:__________________ Date:______________

B

FLOW THROUGH FISH BIOASSAY CHEMISTRY DATA

Date		4/18/99	4/19/99	4/20/99	4/21/99	4/22/99
Sticklebacks	Ammonia mg/L	41.3	37.9	42.1	33.9	39.4
Gasterosteus aculeatus	Alkalinity mg/L	160	66	130	62	36
	Hardness mg/L	490	490	490	510	540
Fatheads	Ammonia mg/L	41.4	39.8	41.4	35.1	40.6
Pimephales promelas	Alkalinity mg/L	150	64	130	60	36
	Hardness mg/L	490	480	480	510	550

GG 4/28/99

Comments: NALCOLAB SIMULATED EFFLUENT

Analyst ____ Date: 4/22/99

Control tank: SBC #1

Control tank: FHC #3

Sticklebacks (*Gasterosteus aculeatus*)

	Weight (g)	Length (cm)
1	0.246	3.1
2	0.383	3.2
3	0.399	3.4
4	0.363	3.0
5	0.516	3.5
6	0.412	3.2
7	0.505	3.5
8	0.667	3.6
9	0.494	3.4
10	0.246	3.0
Average	0.423	3.3
Maximum	0.667	3.6
Minimum	0.246	3.0

GG 4/29/99

Fatheads (*Pimephales promelas*)

	Weight (g)	Length (cm)
1	0.1427	2.0
2	0.2871	2.6
3	0.1511	2.1
4	0.1543	1.3
5	0.1994	2.2
6	0.2510	2.6
7	0.2257	2.5
8	0.3206	2.6
9	0.1590	2.2
10	0.1073	2.1
Average	0.1994	2.2
Maximum	0.3206	2.6
Minimum	0.1073	1.3

GG 4/29/99

52

C

Analyst:________ Date:________

DDSD Recycled Water Facility Project
DDSD Standard Acute Toxicity Protocol

FLOW-THROUGH FISH BIOASSAY

TABLE OF CONTENTS

FLOW-THROUGH FISH BIOASSAY

1.0 METHOD:
Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, Third Edition, March 1985.

2.0 SCOPE AND APPLICATIONS:
This method can be used to determine the acute toxicity of the Wastewater Effluent. Flow-through tests have th advantage of detecting temporal changes in effluent toxicity, and the longer exposure period of the definitive tes increases the probability that the test period will include toxicity spikes, if they occur.

3.0 DETECTION LIMITS AND WORKING RANGES:
Detection limit and working range is 0 to 100 % survival of test organisms.

4.0 APPROXIMATE ANALYSIS TIME:
It takes 5 working days to complete the bioassay. Including testing, and record keeping, the analysis takes approximately 6 hours per day. Cleaning takes another five hours.

5.0 SUMMARY OF METHOD:
Fathead Minnows and Three Spine Sticklebacks are exposed to a continuous flow of effluent for a period of five days. The test solution is analyzed for pH, Ammonia, Dissolved Oxygen, Temperature, Conductivity, Alkalinity, Hardness, and Residual Chlorine each day. The number of dead fish are observed daily. The results are expressed as the percentage of survivors at the end of 5 days.

6.0 SAFETY:
Wear eye protection, gloves and a lab coat. Strong acids and volatile organic solvents employed in glassware cleaning must be used in a fume hood or under an exhaust canopy over the work area.

7.0 INTERFERENCES:
7.1 The tests must be conducted in areas of minimal disturbance from laboratory equipment and personnel. The area should be well ventilated and free of fumes, both to prevent contamination of test solutions and to protect personnel from volatile chemicals and waterborne pathogens that may be dispersed from bioassay chambers.

7.2 The specified temperature ranges for bioassays is maintained for the duration of the test. using a recirculating water bath.

8.0 EQUIPMENT:
8.1 Aquatic Technology bioassay flow-through system, including eight 10 liter test chambers, chiller, heater and pumps.
8.2 Two 25 gallon acclimation chambers for stock fish
8.3 YSI Model 51B Dissolved Oxygen Meter (See the appropriate SOP for calibration and operation)
8.4 pH TestR 3 (See the appropriate SOP for calibration and operation)
8.5 Oakton Conductivity Meter (See the appropriate SOP for calibration and operation)
8.6 Analytical balance capable of weighing to 0.0001 g (See the appropriate SOP for calibration and operation)
8.7 Pneumatic Pump, Liquid Metronics Inc. Model A151-191 or equivalent
8.8 Fish nets
8.9 Ruler

8.10 Continuos recording thermograph for control and test chambers (Fulscope ER/C Instrument or equivalent).
8.11 Thermometer capable of reading to 0.1°C. in the -1 to 51°C. range.
8.12 Glassware and equipment necessary to test for Alkalinity, Hardness, Ammonia, and Residual Chlorine.. (See the appropriate SOP's).
8.13 AquaClear 200 power filter. Purchase at an aquarium supply store.
8.14 AquaClear 200 Foam Filter Insert. Purchase at an aquarium supply store.
8.15 AquaClear 200 Activated Carbon Insert. Purchase at an aquarium supply store.
8.16 Tetra Luft Air Pump or equivalent
8.17 1 Liter plastic bottles
8.18 Ten (10) two (2) gallon squat fish bowls. Purchase at an aquarium supply store
8.19 Tygon tubing, glass tubing and gang valves for delivering air to fish bowls.
8.20 100 mL Graduated Cylinder
8.21 Watch with second hand.

9.0 CALIBRATION:

The Analytical Balance, Dissolved Oxygen Meter, pH TestR 3, and the Conductivity Meter must be calibrated each day. See the appropriate SOP'S for calibration and procedures.

10.0 REAGENTS:

10.1 Sierra Springs distilled water
10.2 Sodium Thiosulfate Solution: Prepare five gallons by adding approximately 70 g of $Na_2S_2O_3*5H_2O$ to five gallons of Sierra distilled water container. Mix by shaking. Record in the Standard/Reagent Preparation Logbook.
10.3 Moderately Hard Synthetic Fresh Water (MHSFW): Dissolve 1.81 g $NaHCO_3$, 1.13 g $CaSO_4*2H_2O$, 1.13 g $MgSO_4$ (or 2.31 g $MgSO_4*7H_2O$), and 0.076 g KCl in 5 gallons of Sierra distilled water. Record in the Standard/Reagent Preparation Logbook.
10.4 Tetramin Flake Food. Purchase at an aquarium supply store.
10.5 Frozen Brine Shrimp. Purchase at an aquarium supply store. Store in the freezer.
10.6 Sodium Dodecyl Sulfate stock solution, 1000 ppm: Add 1000 mg of Sodium Dodecyl Sulfate to about 800 mL of distilled water in a volumetric flask. Mix until it dissolves. Adjust the volume to 1000 mL. Prepare four liters for each toxicity test.
10.7 Synthetic Sea Water. Purchase at an aquarium supply store.
10.8 Reagents and standards necessary for testing pH, Ammonia, Temperature, Dissolved Oxygen, Conductivity, Chlorine Residual, Alkalinity and Total Hardness (See appropriate SOPs)

10.9 Test Fish: (Record all observations and test results in the Fish Bioassay Receiving and Acclimation Logbook. See section 15.1 and Appendix A):

10.91 *Gasterosteus Aculeatus* (threespine stickleback)

10.92 *Pimephales Promelas* (fathead minnow)

10.93 Purchase from either:

10.931 Sticklebacks Unlimited (707) 644-6997, PO Box 7754, Vallejo, CA 94590-1754 (William Puttnam).

10.932 Aquatic Resources: (707) 829-1194, 2610 Meir Rd, Sebastopol, CA 95472

10.94 All organisms of the same species should be approximately the same age and should be taken from the same source.

10.95 Acclimating Tanks:

10.951 Acclimation tanks are filled with freshly prepared moderately hard synthetic freshwater.

10.952 The water is filtered using the AquaClear 200. Clean the inserts with each new batch of fish.

10.96 Receiving Fish:

10.961 Upon receipt assign a batch # to each new batch of fish. Record the; Date Received, Vender, Age, and Number of fish.

10.962 Measure and record the Dissolved Oxygen and the Temperature of the shipping water to determine if the organisms were subjected to undue thermal stress.

10.97 Acclimating Fish:

10.971 Place the bag containing the fish in acclimation tank for approximately 10 minutes for temperature acclimation.

10.972 Test and record the Conductivity of the acclimation tank and the shipping water. If the conductivity is more than 25% different adjust the acclimation chamber using synthetic sea water.

10.973 Feed the fish as much as they will eat at least once per day with both Tetramin Flake Food and Frozen brine shrimp.

10.974 If the organisms are obtained from a source known to have a healthy stock, a minimum observation period of 48 hours is required. Otherwise, acclimate the fish for seven days prior to use.

10.975 During the acclimation period record the Analyst, Date, Feeding of Fish, Temperature, pH, and the number of dead fish daily.

10.976 A group of organisms must not be used for a test if they appear to be unhealthy, discolored, or otherwise stressed, or if mortality appears to exceed 10% preceding the test.

10.977 If more than 10% mortality occurs during the seven day acclimation period destroy the entire batch of fish. Clean the holding tanks with a weak solution of bleach and replace the filter inserts.

11.0 SAMPLE COLLECTION:

The test solution is Final Effluent. It is piped from the Chlorine Contact Basin directly and continuously to the Bioassay Trailer. Needle valves are used to regulate the amount of test solution flowing into each chamber. The pipeline must be back-flushed with tap water for 10 minutes before and after each test.

12.0 PROCEDURE:

(Record all observations and test results in the Flowthrough Bioassay Logbook. See section 15.2 and Appendix B)

12.1 Bioassay Setup:

12.11 Set up two 10 liter flow-through test chambers and two 10 liter control chambers, for each species. Place the test chambers in the recirculating water bath and attach the standpipe to the chamber.

12.12 Flow-Through Chambers: Open the control valve to the plant final effluent. Control the flow so that there is a minimum of 85 mL/min of final effluent. This amount will produce a minimum of five 90% replacements of the water volume in the test chamber every 24 hours. Measure and record the flow using a 100 mL graduated cylinder and a watch with a second hand.

12.13 Control Chambers:

12.131 De-chlorinate the tap water used for the control chambers using sodium thiosulfate solution. Insert the pneumatic pump hose into the five gallons of sodium thiosulfate solution. Adjust the stroke on the pump to 20 and the speed to the lowest setting (near 5).

12.132 Open the control valve to the tap water. Control the flow so that there is a minimum of 85 mL/min. This amount will produce a minimum of five 90% replacements of the water volume in the test chamber every 24 hours. Measure and record the flow using a 100 mL graduated cylinder and a watch with a second hand.

12.14 Allow all of the chambers to equilibrate for a minimum of two hours.

12.15 Test the Dissolved Oxygen of the chambers. When surface absorption does not maintain Dissolved Oxygen levels above 40% of air saturation, oxygen may be supplied by controlled aeration during the test. Use the TetraLuft air pump and adjust the rate of aeration to maintain a Dissolved Oxygen reading of 3-4 mg/L (no more than 100 bubbles per minute). If aeration is necessary all test solutions must be aerated.

12.16 Temperature:

12.161 Temperatures must be maintained at 20 ± 2°C. for the duration of the test. The temperature is monitored continuously using a continuous recording thermograph.

12.161 Insert one temperature probe into one of the control chambers and the other probe in one of the test chambers. Insert a new temperature chart on the recording thermograph. Write date and test # on the charts.

12.162 Insert an NIST calibrated thermometer in the same chamber as the temperature probe and compare the temperature readings from both. These readings must agree within 1°C. (If the difference is greater than 1°C., corrective action must be taken). Record the temperature difference.

12.2 Transferring Fish:

12.21 Capture 40 of each species from the stock chambers using a fish net and transfer to a 1 gallon plastic bottle. Transport fish to the bioassay trailer. Any specimen that does not appear healthy or has been dropped or mishandled during transfer must be rejected.

12.22 Transfer 10 stock fish to each of the test chambers and control chambers. There will be 2 test chambers and 2 control chambers for each species.

12.3 Duration of Test:

A test begins when the organisms are first exposed to the potential toxicant and extends for 96 hours. Fish mortalities and environmental conditions must be recorded every twenty-four hours.

12.4 Feeding of the Fish:

Do not feed the fish during the test period.

12.5 Physical and Chemical Determinations:

12.51 See the appropriate SOP's for calibrations and procedures.

12.52 Control Chambers: Measure and record daily: Flow, Dissolved Oxygen, Temperature, and Residual Chlorine.

12.53 Effluent Flow-through Test Chambers: Measure and record daily; Flow, Dissolved Oxygen, Temperature, Residual Chlorine, pH, Conductivity, Total Alkalinity, Hardness, and Ammonia.

12.54 The temperature is recorded continuously using the continuos recording thermograph .

12.6 Biological Data:

Dead fish must be removed as soon as they are observed with the total number of dead in each test chamber counted and recorded every 24 hours. Fish are considered dead in the absence of gill movement and loss of all ability to move or respond to stimuli.

12.7 Completion of the Test:

12.71 Count the total number of dead fish. In order for the test to be valid there must be no more than 10% mortality for each species of control fish.

12.72 An individual test may be conditionally acceptable if Temperature, Dissolved Oxygen, and other specified conditions fall outside specifications, depending on the degree of the departure. The acceptability of the test will depend on the experience and professional judgement of the laboratory analyst and the reviewing staff of the regulatory authority. Any deviation from test specifications must be noted when reporting data from a test.

12.73 All fish must be destroyed at the completion of the testing. Capture the fish in the net and run hot water over the fish to kill them.

12.74 Weigh and measure 10 of each kind of fish from the control chambers individually. Record average, maximum, and minimum weight and length in the Fish Bioassay Receiving and Acclimation Logbook. Weigh to 0.01 g and Measure to 0.1 cm.

13.0 DATA ANALYSIS AND CALCULATION:

Bioassay results are reported as percent survival:

$$\underline{A + B * 100} = \text{Percent survival}$$

C

Where:

A	=	Number of survivors in Flow-through chamber A
B	=	Number of survivors in Flow-through chamber B
C	=	Total of number of fish tested in A + B (20)

14.0 QUALITY CONTROL

Toxicity Sensitivity Using a Reference Toxicant:

(Record all observations and results in the Toxicity Sensitivity Logbook. See Section 15.4 and Appendix C).

14.1 A reference toxicant (Sodium Dodecyl Sulfate) is to be used to establish the validity of effluent toxicity data. The toxicity test must be run within the seven days immediately preceding an effluent toxicity test or concurrently with the test.

14.2 Setup:

14.21 A minimum of 2 hours before the start of the test prepare two sets of five bowls (one set for stickleback and one set for fathead minnows). Each type of fish will have one control and four dilution's of Sodium Dodecyl Sulfate.

14.22 Prepare four concentrations of Sodium Dodecy Sulfate. Select a geometric series such as 10 ppm, 20 ppm, 40 ppm, and 80 ppm such that the LC 50 is bracketed by two concentrations low and two concentrations high. Add the appropriate amount of Sodium Dodecyl Sulfate Stock Solution using a 100 mL graduated cylinder.

14.23 Adjust the bowls to 6 liters using moderately hard synthetic fresh water.

14.24 Set up the air supply using an aerator pump. Allow the bowls to equilibrate for a minimum of 2 hours.

14.25 Measure and record; Dissolved Oxygen, Conductivity, pH, and Temperature of each bowl. Measure and record; Total Alkalinity and Hardness in the control and the highest concentration.

14.3 Transferring Fish:

14.31 Add five sticklebacks to each bowl of one set and five fatheads to each bowl of the other set.

14.32 If 100% mortality has occurred in the higher concentrations after one hour, additional concentrations are added to the test at the lower end of the concentration series.

14.4 **After 24 and 48 hours** test Dissolved Oxygen, pH, and Temperature. Count, record and remove the dead fish from each bowl.

14.5 Data Analysis:

14.51 Determine the Trimmed Spearman-Karber Method LC50 using the computer program under F/Labdata/fish/TSK.

14.52 Enter the LC50 into the control charts on the NWA program.

14.53 Outliers, which are values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity are readily identified. If the toxicity value from a given test falls well outside the "expected range, the sensitivity of the organisms and the overall credibility of the test system are suspect. In this case, the test procedure should be examined for defects and should be repeated with a different batch of test organisms. By definition, the control limits will be exceeded 5% of the time, regardless of how well a laboratory performs. The width of the control limits should be considered in determining if data which exceed control limits should be rejected. Flag the data accordingly.

15.0 RECORD KEEPING:

15.1 Fish Bioassay Recieving and Acclimation Logbook (See Appendix A)

15.11 Upon Receipt record Batch #, Vender, Received By, Date Received, Species, and Number of Fish.

15.12 Test and record the Dissolved Oxygen, Temperature and Conductivity of the shipping water and stock chamber. Record any any adjustments made to the stock chamber.

15.13 Record Feedings, Temperature, pH and number of dead fish during the acclimation period.

15.14 Measure and record the Weight and Length of ten fish from the control at the end of the test. Record Analyst and Date.

15.2 Flow-through Bioassay Logbook (See Appendix B)

15.21 Record the Date and Time Started and the Date and Time Completed.

15.22 Record Daily analysis Analyst, Date and Time

15.23 Control Chambers: Measure and record daily: Flow, Dissovled Oxygen, Temperature, and Residual Chlorine.

15.24 Flow-through Chambers: Measure and record daily; Flow, Dissolved Oxygen, Temperature, Residual Chlorine, pH, Conductivity.

15.25 Daily: Remove and record the number of dead fish in each beaker.

15.26 Record the % Survival.

15.3 Total Alkalinty and Total Hardness and Ammonia Logbooks (See Appropriate SOP's)
Test and record Total Alkalinity and Total Hardness and Ammonia daily on the effluent test chambers.

15.4 **Toxicity Sensitivity Logbook** (See Appendix C)

15.41 Record the Analyst, Date and Time Started and the Date and Time Completed.

15.42 Record the ppm of Sodium Dodeyl Sulfate used in each beaker.

15.43 At the start of the test measure and record: Dissolved Oxygen, Conductivity, pH and Temperature of each bow. Measure and record Total Alkalinity, and Total Hardness in the control and in the highest concentration.

15.44 After 24 and 48 hours test and record Dissolved Oxygen, pH and Temperature in all beakers.

15.45 After 24 and 48 hours: Remove and record the number of dead fish in each beaker.

15.46 Record the LC 50.

15.5 **Fish Bioassay QC Binder:** Store the data chart from the NWA Quality Analyst the LC50 calculations, and the Temperature chart in the Fish Bioassay QC Binder.

16.0 CLEANUP:

All sample containers, test vessels and other equipment that have come in contact with the effluent shall be washed after use in the manner described below to remove surface contaminants:

16.1 Soak 15 minutes, and scrub with detergent in tap water, or clean in an automatic dishwasher.

16.2 Rinse twice with tap water.

16.3 Rinse once with fresh, dilute (10%, V:V) nitric acid or hydrochloric acid (add 10 mL of concentrated acid to 90 mL of distilled water) to remove scale, metals, and bases.

16.4 Rinse twice with tap water.

16.5 Rinse once with full-strength, acetone to remove organic compounds.

16.6 Rinse well with tap water

MODIFICATIONS TO SOP NO. AN-CH-001
FLOW-THROUGH FISH BIOASSAY
SUBSEQUENT TO ITS RELEASE

Page No.	Modification

Notes: Modifications contained here within will be incorporated into the next revision of this SOP.

Appendix A

FISH BIOASSAY RECEIVING AND ACCLIMATION LOGBOOK

Batch #____________ Vender:____________ Received By:__________ Date:________

Species:__________________ Age:__________ Number of Fish:_______

Shipping Water:
DO mg/L:__________ Temp. Deg C.:__________ Conductivity (umhos):__________

Conductivity of Stock Tank (umhos):________ Adjusted To:________

ACCLIMATION TANK

Date	Feeder	Temp	pH	# Dead
			Total Deaths:	

8/14/98

Stock Tank Cleaned: ________________________________

Comments: ________________________________

Reviewed By:______________ Date:__________

Appendix B-1
DELTA DIABLO SANITATION DISTRICT
FLOW THROUGH BIOASSAY

NIST Traceable Thermometer Deg C.:_______________ Thermograph Green Pen (Control) Deg C.:_______________ Thermograph Red Pen (Effluent) Deg C.:_______________

THREE-SPINE STICKLEBACKS (Gasterosteus Aculeatus) Batch #________ % Survival:__________						FATHEADS (Pimephales Promelas) Batch #__________ % Survival:__________			
	Control Tank #1	Control Tank #2	Flow through A	Flow through B		Control Tank #3	Control Tank #4	Flow Through C	Flow through D
Flow mL/min					INITIAL				
pH					Analyst:____				
Conductivity umhos/cm					Date:______				
DO mg/L					Time:______				
Temp deg C									
Total Chlorine									
Flow mL/min									
pH					24 hours				
Conductivity umhos/cm									
DO mg/L					Analyst:____				
Temp deg C					Date:______				
Total Chlorine					Time:______				
# dead fish									
Flow mL/min									
pH					48 hours				
Conductivity umhos/cm									
DO mg/L					Analyst:____				
Temp deg C					Date:______				
Total Chlorine					Time:______				
# dead fish									

Number test animals per concentration=10 Flow:minimum of 85 mL/min=5 tank turnovers Volume of test solution=10L, Depth =12cm Aeration with Oil-less air pump 4/29/98

Acclimatization : 7 days at 18 - 22 degrees centigrade Dead Fish in acclimatization tank <10% Control water source=Filtered and Dechlorinated tap water

Comments ____

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A Reviewed By:____________________ Date:____________________

Appendix B-2
DELTA DIABLO SANITATION DISTRICT
FLOW THROUGH BIOASSAY

THREE-SPINE STICKLEBACKS (Gasterosteus Aculeatus) Batch #________						FATHEADS (Pimephales Promelas) Batch #________			
	Control Tank #1	Control Tank #2	Flow through A	Flow through B		Control Tank #3	Control Tank #4	Flow Through C	Flow through D
Flow mL/min									
pH					72 hours				
Conductivity umhos/cm									
DO mg/L					Analyst:____				
Temp deg C					Date:______				
Total Chlorine					Time:______				
# dead fish									
Flow mL/min									
pH					96 hours				
Conductivity umhos/cm									
DO mg/L					Analyst:____				
Temp deg C					Date:______				
Total Chlorine					Time:______				
# dead fish									
Total # dead fish									

Number test animals per concentration=10 Flow:minimum of 85 mL/min=5 tank turnovers Volume of test solution=10L, Depth =12cm Aeration with Oil-less air pump 12/11/98

Acclimatization : 7 days at 18 - 22 degrees centigrade Dead Fish in acclimatization tank <10% Control water source=Filtered and Dechlorinated tap water

Comments ____

____

____

____

Reviewed By:____________________ Date:________________

B

Appendix B-3

FLOW THROUGH FISH BIOASSAY CHEMISTRY DATA

Date							
Sticklebacks	Ammonia mg/L						
Gasterosteus aculeatus	Alkalinity mg/L						
	Hardness mg/L						
Fatheads	Ammonia mg/L						
Pimephales promelas	Alkalinity mg/L						
	Hardness mg/L						

Comments: ______________________________

____

____

Analyst ________ Date: ________

Control tank: ________

Sticklebacks (*Gasterosteus aculeatus*)

	Weight (g)	Length (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		
Maximum		
Minimum		

Control tank: ________

Fatheads (*Pimephales promelas*)

	Weight (g)	Length (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		
Maximum		
Minimum		

C

Analyst________ Date:________

Appendix C

FLOWTHROUGH TOXICITY SENSITIVITY TEST

	Aeration	Test Start	24 Hours	48 Hours
Analyst				
Date				
Time				

MHSFW (Test Solution), ID#___________

Toxicant (Sodium Dodecyl Sulfate) ID #________

Three-Spine Sticklebacks (Gasterosteus Aculeatus) Batch #____________ **LC 50 =** ___________

	CONTROL			PPM			PPM			PPM			PPM		
	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr
# Dead															
DO															
Temperature, °C															
pH															
Conductivity umhos/cm															
Alkalinity mg/L															
Hardness mg/L															

Fatheads (Pimephales Promelas) Batch #____________ **LC50 =** ____________

	CONTROL			PPM			PPM			PPM			PPM		
	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr	Start	24 hr	48 hr
# Dead															
DO															
Temperature, °C															
pH															
Conductivity umhos/cm															
Alkalinity mg/L															
Hardness mg/L															

10/20/98

5 fish per bowl, 5 Liters per bowl, Aeration with Oil-less air pump

Bowls set up and aerated a minimum of 2 hours before test start

Reviewed By:_____________ Date:____________

DDSD Recycled Water Facility Project
Power Plant Return Stream Simulation Protocol

NALCOLab
PDEF/Patch Engineering/Calpine/DDWTF Project
Lab Instruction Sheet

Project Date: 4/16/1999

The primary goal of this project is to create a typical waste stream specifically for fish toxicity testing. The secondary goal of the project is to generate information that will help specify the appropriate chemical treatment of the future COGEN systems.

It will be important to watch the way we create the various streams that will be delivered to the bioassay lab across the street. Use the following batch chemistry instructions for the creation of the various water streams.

Make-Up Tank Disinfection:

The make up water will be supplied as filtered secondary wastewater. The make up water will be stored in 55 gallon (200 L) make up tanks under the trailer. These tanks will be used as contact chambers for the disinfection of the filtered secondary wastewater. The residence time in these tanks is well over the required 90 minutes for generation of Title 22 Tertiary treated water.

Nalco will use sodium hypochlorite (5.25%) to batch treat the make up tanks. The target dosage if 15 ppm.

For batch disinfection, add 43 ml to 55 gallons of tank volume to achieve 15 ppm. The expected chlorine demand and the chloramine generation should leave a 6 ppm total chlorine residual (not free residual).

Boiler Stream Simulation:

The boiler stream simulated water consistent of backwash water from pretreatment media filtration, RO reject water, neutralized Demineralizer regenerants, and boiler continuous blowdown. The computer simulation for the generated water stream shows that this stream ends up looking just like secondary waste water that has been filtered and cycled up two times.

Because of this, the boiler system wastewater can be generated by using cooling tower blowdown that has been diluted to the expected mineral concentrations to simulate the waste stream. The chemicals noted below are added to generate enough of the specific compounds that would be present in this stream. You will need to make two batches of the boiler system simulation blend (10 gallons) to add to the main 55 gallon collection drum.

Batch Simulation Blend:

1. Fill one clean 5 gallon bucket with 3.7 gallons of Cooling Tower Blowdown at 3 cycles (tower conductivity at 3900 umhos minimum). **This will require you to remove the tower blowdown lines from the main collection drum. Make sure the make up valves to the tower basin are closed when filling the bucket.**

2. Add 1.3 gallons of Demineralized water to the bucket. Mix

3. Add 3.7 grams (use lab scale) of sodium Sulfate to the bucket. This represents the excess salt generation caused the caustic and acid regenerants from the Demin System not already contained in the sample. Mix.

4. Add 0.99 ml of Nalco 22106. This will simulate the amount of boiler internal treatment present in the blowdown.(60 ppm of product).

5. Add 0.04 ml of Nalco 1800 Neutralizing Amine. This represents the expected concentration of amine after flashing to the steam. Use the 1 cc syringe to add this product to the batch.

6. Add 0.23 ml of Nalco 7280 RO Antisclent.

7. Mix the batch, and add the contents of the bucket to the main collection drum.

8. Repeat procedure again for the second 5 gallon batch

.

After creating the two 5 gallon batches, open the make up valves to the towers. This will dilute the water in the tower basins to below three cycles. Shut the blowdowns off on the towers and allow the system to cycle up to 3 cycles again. Then begin adding the blowdown to the main collection drum again.

<u>Cooling Tower Operations:</u>

1. Towers will be cycled up to 3 and maintained there by the auto conductivity controller.

2. The pH will be controlled at 7.0 – 7.2 using sulfuric acid injection.

3. The level of Nalco 97WT140 will be maintained at 100 - 120 ppm using TRASAR Controlling the injection pump.

4. The polyphosphate level will be maintained at 20 ppm as product using Nalco 7396 injection. Wet chemistry results will be used to adjust pump rate.

5. Tower Halogen residual will be held between 0.2 – 0.5 ppm of free halogen residual (combined Cl2/Br2). Add activate bromine solution as needed to maintain tower basin residuals.

Drum Transport to Bioassay Lab:

1. When a drum is full, obtain a 16oz retain sample for the Lab.

2. Call the operator on duty to arrange for a fork lift.

3. Place the bung hole caps back on the drum holes and hand tighten to prevent spilling during transport.

Wet Chemistry Schedule:

1. Water Analysis should be run once each day.

2. Record the wet chemistry for the following samples.

   Tower Make Up Tank Sample
   PCT #1 Sample
   PCT #2 Sample

3. The Boiler Simulation Batch should be sampled and tested each time it is created before it is added to the main collection drum.

4. The Main collection drum must be samples. The results of the test will be logged on to the log sheet. **Make sure that there is a zero total chlorine residual in the drum before shipping it to the Bioassay lab.** Use the Nalco 7408 sulfite to reduce the residual to zero before shipping if necessary. Add 0.5 ml to the drum and mix using the PVC mixing rod. Test the drum again for total residual. If zero, send to the lab.

DDSD Recycled Water Facility Project
Power Plant Return Stream Simulation Results

NALCOLab

PDEF/Patch/DDSD Project

Project Overview:

The test was designed to simulate the total plant effluent from a proposed PDEF COGEN facility to provide sufficient simulated waste water for acute fish toxicity testing. The use of the NalcoLab and the onboard Pilot Cooling system synthesized a realistic effluent for toxicity testing. The waste stream flow required a minimum of 80 ml/min of simulated combined effluent for continuous testing which was accomplished using both NalcoLab pilot cooling towers. This test used secondary treated municipal wastewater from the Delta Diablo treatment facility after filtration further treated in chlorine contact holding tanks to create Title 22 quality water

Strategy

Nalco's test strategy was to conduct an on-site pilot cooling tower test to generate a simulated cooling tower blowdown. This test will included the anticipated chemical treatments and concentration ratio to provide a blowdown stream accurately reflecting the expected contaminant loading rates. This cooling tower blowdown comprises 78% of the expected effluent from the facility. We then blend this cooling tower blowdown with the simulated boiler blowdown, the simulated RO reject, and the simulated demin regenerant waste.

The Simulated COGEN waste stream represented the expected worst case scenario for the actual PDEF power facility. The project strategy was to attempt to create the highest concentrations of expected contaminants in the waste stream. The project goal was to present this worst case simulated waste stream to the Acute Fish Toxicity test for the 96 hour period.

Pilot Cooling Tower

Tertiary Treated water from DDWTF was reservoired at the NalcoLab for disinfection by chlorination and filtration to meet Title 22 standards prior to its use as Make Up water to the pilot cooling tower.

The pilot cooling tower operates at three cycles of concentration. Operating conditions included pH control to pH 7.1 ± 0.1 and treatment with Nalco 22106 high stress polymer program at a dosage of 100 ppm, and Nalco 7396 polyphosphate corrosion inhibitor at a dosage of 4 ppm.as PO4 (20 ppm product). Microbiological control consists of treatment with activated bromine (a combination of sodium hypochlorite and sodium bromide) to a free halogen residual of 0.2 ppm. This represents standard practice.

Based on the operating conditions, the pilot cooling tower used in the test produced 90 ml/min of blowdown. This flow was just sufficient to generate the volume for the planned toxicity testing.

Simulated RO Reject - Boiler Blowdown Combination

Boiler blowdown is little more than pure water containing alkalinity in the form of sodium carbonate and sodium hydroxide, together with traces of scale inhibitors and condensate corrosion inhibitors. Planned operation of the reverse osmosis pretreatment includes pH adjustment to 7.2 with sulfuric acid, addition of an RO antiscalant at 8 ppm in the feed, and operation at 75% water recovery. Both of these operations are well understood in terms of the expected water chemistry.

The expected water chemistry from combining the RO reject and the boiler blowdown at the expected flow very closely corresponds to the raw water, neutralized, at two cycles of concentration. The main difference is the presence of an additional 200 mg/ℓ of sodium sulfate in the RO reject - boiler blowdown combination.

The boiler plant waste stream simulation was produced using the second pilot cooling tower on the mobile lab to provide the required evaporation for the **two cycles of concentration**.

- 200 mg/ℓ of sodium sulfate,
- 60 ppm of Nalco 22106 Boiler internal polymer Transport Plus with inert fluorescent tracer
- 2 ppm of Nalco 1800 Neutralizing Amine
- 16 ppm Nalco 7280 Reverse Osmosis scale inhibitor.

Simulated DI regeneration waste

Based on the expected RO product water and the expected performance of a mixed-bed DI polisher, the inclusion of a DI polisher in the boiler feedwater pretreatment train will result in the additional contribution of salts corresponding to 80 mg/ℓ of sodium sulfate. The additional contribution to the effluent volume is negligible and is contained in the additional 250 mg/l of sodium sulfate noted above.

Simulated filter backwash and other pretreatment wastewater

Including the anticipated sand filter backwash and other pretreatment wastewater corresponds to the addition of four gallons of tertiary treated municipal wastewater to the simulated RO reject - boiler blowdown combination.

Blending for the model effluent

The simulated effluent for toxicity testing was produced by blending the blowdown from the pilot cooling tower test with the simulated RO reject - boiler blowdown combination. The blended streams were combined into clean 55 gallon drums for transport to the Bioassay Lab ad DDWTF. The drums were changed out each day to provide a continuous feed of simulated COGEN plant blowdown to the toxicity test.

To address toxicity concerns regarding the proposed Pittsburg District Energy Facility (PDEF) project, toxicity testing was performed on a simulated combined wastestream, representative of full-

scale operating conditions, to determine if wastewater generated as a result of this project will impact compliance with DDSD's NPDES permit toxicity requirements.

<u>Bioassay for Acute Toxicity :</u>

Flow-through acute toxicity tests using DDSD's current compliance species, fathead minnows and three-spine sticklebacks, were performed on the simulated effluent by DDSD's certified bioassay laboratory. The tests were conducted using the same equipment and EPA protocols used for DDSD's routine NPDES compliance acute toxicity testing under RWQCB NPDES Permit #0038547.

<u>Bioassay for Chronic Toxcicity:</u>

Chronic toxicity tests were also performed to determine whether the wastestreams from the PDEF project would cause sublethal toxicity in DDSD's final effluent. The selection of organisms used in these tests was based on the three most sensitive species determined during a prior screening phase conducted as part of DDSD's NPDES permit requirement. The test organisms include *Menidia beryllina*, *Mysidopsis bahia*, and the echinoderm, *Dendraster excentricus*. The chronic tests were performed on samples of simulated effluent according to EPA protocol by a certified outside laboratory.

The results of these tests are attached to this report.

<u>Metals Testing:</u>

The power plant combined blow down was sampled and submitteded to DDWTF for metals testing. The local DDWTF lab performed the majority of the testing. The analysis for Mercury was performed at a capable local lab. The test results will be reported as soon as they are available.

<u>Water Preparation Analysis Data:</u>

The water test data averages are attached for the project. The data collected shows the qualtiy of water sent in for bioassay by recording selected target electrolytes. The selection of these electrolytes was based on the required work performed for PDEF. The scale and corrosion data generated is compared to the concentrations of these targets using mineral solubility prediction models. This innformation allows Nalco to confidently recommend the best chemical treatment of the water streams based on real time data collected during the project.

Water test data averages noted on the attached spread sheet are in close agreement with the water tesing performed during the bioassay. The total dissolved solids (measured in umhos as conductivity) of the combined test stream used in the bioassay testing stream was within +/- 5% of the predicted target.

NALCO CHEMICAL COMPANY
Water Analysis Summary Report

Date 4/26/99

File **Patch Engineering/ENRON/ DDWTF Project**

Analysis Results - Average Concentrations

Water Treatment Process Data

Units in ppm (Except as noted)		#1	#2	#3	#4	#5
		(a)	(b)	(c)	(d)	(e)
		Secondary from DDWTF	Tertiary from DDWTF	Cooling Tower at 3 cycles	Boiler Simulation	Combined Stream
Analysis	**as**					
Ca	$CaCO_3$	119	95	**344**	229.3	297.4
Mg	"	98	92	**324**	216.0	280.8
Na	"	480	480	**2121**	1414.0	1838.2
K	"	13	13	39	26.0	33.8
Al	"	0.11	0.2	0.6	0.4	0.5
Ba	"	NT		0	0.0	0.0
Fe+2	"	0.25	0.25	1.4	0.9	1.2
Mn+2	"	0.1	0.1	0.3	0.2	0.3
Sr	"	0.36	0.36	1.08	0.7	0.9
Cations						
HCO_3	$CaCO_3$	237	237	**149**	99.3	129.1
CO_3	"	0	12	0	0.0	0.0
OH	"	0	0	0	0.0	0.0
SO4	"	198	120	**946**	630.7	819.9
CL	"	368	368	**1900**	1266.7	1646.7
NO_3	"	1.1	1.1	3.3	2.2	2.9
F	"				0.0	
PO_4	"	9.48	4.5	7.5	5.0	6.5
Anions	"					
M Alk	"	237	249	**149**	**99.3**	129.1
P Alk	"	0	6	0	0.0	0.0
pH	pH	**7.3**	**8.1**	**7.1**	**7.5**	**6.5**
SiO2	SiO2	**28**	**26**	**78**	**52.0**	**67.6**
Fe	$CaCO_3$	0.25	0.1	0.3	0.2	0.3
Al	"	**0.1**	**0**	**0**	**0.0**	**0.0**
Mn	"	0.1	0.1	0.3	0.2	0.3
Conductivity	umhos	**1356**	**1356**	**3973**	**2649**	**3443**
Turbidity	NTU	**14**	**2.5**	**8**	5.3	**6.9**
TSS	ppm	18	1.4	4.2	2.8	3.6
Ammonia	N	**28**	**3.4**	**4.9**	**14.0**	**29.0**
Res-Cl_2	ppm	0	**0.3**	**0.1**	0.0	0.0
Res Br_2	ppm	0	0	**0.2**	0.0	0.0
BOD	ppm	14	1.2	2	1.3	1.7
Temp	Deg. F	70	**70**	90	**76.0**	**76**

End Notes: **Bold Notation Indicates Field Measurement**

(a). Water quality reflects the average Secondary Treated Water From DDWTF during Bioassay Testing.

(b). Tertiary Treated Analysis water based on actual plant operations 4/16 - 4/25.

(C). Cooling Tower water quality based on tests performed 4/16 through 4/25.

(d). Boiler Simulation Analysis

(h). Combined Stream represents Water sent to DDWTF Bioassay for Acute Fish Toxicity.

Prepared by S. Rock

NALCO blowdown summary data

Delta Diablo WWTF
Wet Chemistry

System: *Tertiary Treated Water*
Equipment: *Tower Make-Up Basins - Title 22 Quality*

Date	Time	Total Halogen Residual	Conductivity	ORP	Turbidity	Silica	Ammonia	Ortho PO4
04/17/99	17:10	>2.0	1514	290	2.75	29.4	3.9	6.1
04/19/99	8:00	5.6	1510	385	4.57	22	2.6	6.4
04/20/99	13:54	6	1528	395	3.52	25.7	3	6.3
04/21/99	10:52	9.1	1520	415	2.98	26.4	4	5.7
04/22/99	9:18	4.8	1531	430	2.45	27.2	3	4.8
04/26/99	10:20	0.98	853	225	1.3	18.4	4	2.4
04/27/99	11:06	1.11	776	270	1.04	17.9	3.5	2.1
04/28/99	11:35	3.95	1486	340	1.86	23.1	3.7	3.7
04/29/99	9:02	2.1	1492	290	1.63	22.6	3.3	2.8
Average		4.2	1356.7	337.8	2.5	23.6	3.4	4.5

Notes:

*** Times listed are times when sample was taken**

*** Samples on 4/26 & 4/27 were taken from PCT1 make-up basin**

*** Ammonia results were obtained using Test Strips beginning on the 20th**

Delta Diablo WWTF
Wet Chemistry

System: *97WT140 /7396*
Equipment: *Pilot Cooling Tower #1*

Date	Time	Total Halogen Residual	pH	Conductivity	Turbidity	Total Iron	M&P Alkalinity	Total Hardness	Ca Hardness	Mg Hardness	Chlorides	Sulfate	Silica	Aluminum	Ammonia	Ortho PO4	Total Inorganic Phosphate
04/17/99	17:20	0.11	7.05	3520	5.44	1.3	186	505	260	245	1605	530	53.5	N/A	6.1	7.5	15.6
04/21/99	8:11	0.12	7.26	3760	8.7	1.5	177	495	230	265	1490	750	37.3	0.026	5	3.6	17
04/21/99	21:45	0.11	7.1	3200	9.7	1.13	150	453	218	235	1870	670	38	0		4.4	22
04/24/99	10:12	0.2	7.2	4000	9.4	1.3	145	693	356	337	1967	870	42	0		5.8	24
04/26/99	10:46	0.21	7.28	4350	6.8	1.7	155	730	380	350	2480	1000	40.2	0	5	8.4	20
04/27/99	9:13	0.19	7.01	4780	7.38	1.63	135	910	480	430	2890	1460	59.9	0	4	11.2	19
04/28/99	11:51	0.15	7.07	3530	8.7	1.15	125	680	320	360	1910	880	52.1	0	5	8.4	21
04/29/99	9:10	0.18	7.01	4650	9.8	1.26	125	880	510	370	2760	1410	58.6	0	4	10.3	18
Average		0.2	7.1	3973.8	8.2	1.4	149.8	668.3	344.3	324.0	2121.5	946.3	47.7	0.0	4.9	7.5	19.6

Notes:
* Times listed are times when sample was taken
* Ammonia results were obtained using Test Strips beginning on the 20th

Delta Diablo WWTF
Wet Chemistry

System: *97WT140 / 7396*
Equipment: *Pilot Cooling Tower #2*

Date	Time	Total Halogen Residual	pH	Conductivity	Turbidity	Total Iron	M&P Alkalinity	Total Hardness	Ca Hardness	Mg Hardness	Chlorides	Sulfate	Silica	Aluminum	Ammonia	Ortho P04	Total Inorganic Phosphate
04/17/99	17:26	0.39	7.07	3900	36.8	1.8	100	595	305	290	1800	550	55.7	0	6.7	11.7	29
04/19/99	8:00	0.37	7.05	4050	30	3.1	60	545	275	270	2012	638	62.8	0	8.4	14.3	34.4
04/20/99	11:00	0.19	7.11	4920	38.8	2.2	90				1980	667	54	0	7.6		
04/21/99	8:11	0.26	7.44	4200	35.3	6.4	95	650	310	340	2670	780	45.2	0	5.9	15.1	17.2
04/21/99	21:45	0.57	7.2	4000	37	8.6	120				2357	725	67	0	4.7		
04/24/99	10:12	0.2	7.1	3980	32	7.6	120				2245	770	57	0	6.6		
04/27/99	9:13	0.2	7.4	6210	45.4	6.8	100	990	510	480	3910	1740	40.9	0	8.5	19.3	26
04/28/99	12:03	0.11	7.5	7430	56.4	12.2	130	1240	580	660	4960	1600	28.8	0	7.2	20	24
04/29/99	9:15	0.21	7.02	7420	58.2	12.1	69	1220	570	650	4950	1460	30.2	0	7.3	19.6	22.6
Average		0.3	7.2	5123.3	41.1	6.7	98.2	873.3	425.0	448	2987	992.2	49.1	0.0	7.0	16.7	25.5

Notes:
* Times listed are times when sample was taken
* Ammonia results were obtained using Test Strips beginning on the 20th

Delta Diablo WWTF
Wet Chemistry

System: *Secondary Treated Water*
Equipment: *Boiler Plant Simulation*

Date	Time	pH	Conductivity	Turbidity	Total Iron	M&P Alkalinity	Total Hardness	Ortho PO4	Mg Hardness	Chlorides	Silica	Sulfate	Sulfite	N-22106	Total Inorganic Phosphate		
04/16/99	14:00	7.4	2660	N/A	0.12	80	340	81	259	1100	N/A	N/A	0	54	N/A		
04/18/99	9:00	7.5	2740	3.52	0.13	83.5	352	84	267	1210	N/A	655	0	62	N/A		

Notes:
* Times listed are times when sample was taken

Delta Diablo WWTF
Wet Chemistry

System: *Boiler / Cooling Tower Blowdown*
Equipment: *Bio-assay Drum*

Date	Time	Total Halogen Residual	pH	Conductivity	Turbidity	Total Iron	M&P Alkalinity	Total Hardness	Ca Hardness	Mg Hardness	Chlorides	Sulfate	Silica	Aluminum	Ammonia	Halogen Res. After De-Chloro.	Total Inorganic Phosphate
04/17/99	9:00	0.07	7.35	3000	10	0.56	145	770	260	510	1107	490	50.3	0	22	0	12.8
04/19/99	16:00	0.05	7.58	3800	9.4	0.76	132	987	525	462	2520	382	78.6	0	29	0	18.4
04/21/99	9:15	0.03	7.2	3960	11	0.44	147	1044	477	567	1800	399	82	0	23	0	27
04/21/99	22:21	0.04	7.3	4020	13	0.32	165	865	445	420	1960	381	87	0	35	0	29
																0	
Average		0.05	7.4	3695	10.9	0.52	147	917	427	490	1847	413	74.5	0	27.25	0	21.8

Notes:
*** Times listed are times when sample was taken**

Appendix B: Estimated Impacts to Receiving Water Dilution and Dispersion

Introduction

The following report describes the procedures and results of dilution modeling performed to examine the effects of the Recycled Water Facility project on DDSD outfall dilution. This modeling was performed by a consultant for one of the two potential power plant customers, the Delta Energy Center (DEC), as part of their investigation into return stream discharge alternatives.

At the time that this modeling was conducted, the DEC was considering two return stream discharge alternatives: discharge through their own outfall under their own discharge permit, or discharge through DDSD's existing outfall. The modeling accounted for both the PDEF and the DEC power plants, and covered both DEC discharge alternatives. Currently, DEC plans to discharge its return stream to the existing DDSD chlorine contact basins. Therefore, discussions and modeling results relating to the "DEC Outfall" should be disregarded as this information is not consistent with DEC's current discharge plans. Only the modeling results for the DDSD outfall is of interest to this Amendment.

In their modeling effort, DEC assumed that PDEF would be discharging to DDSD headworks, instead of at the chlorine contact basin influent as is currently planned. If PDEF discharged to the headworks, which is upstream of recycled water diversion, the recycled water constituent concentrations would increase to higher equilibrium levels. This cycling effect is estimated to have the impact of increasing return stream concentrations by about 25%. Therefore the DEC modeling assumes higher return stream concentrations which is more conservative than required for the current project. Therefore the modeling results can still be applied to the current project, though constituent concentrations are over-estimated in these results by approximately 25%.

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4.0 Dilution and Dispersion

The predicted dilution and dispersion characteristics of the discharge from the DEC outfall and the modified discharge from the DDSD outfall are described below. Three scenarios are considered: the existing discharge from DDSD at 13 mgd, the case where the discharge from the DDSD outfall is reduced to 7.3 mgd and there is no discharge from DEC, and the case with a 5.2 mgd discharge from DDSD and a 2.1 mgd flow from the DEC outfall. The first case is taken to represent existing conditions and is used to evaluate the effects of the other two scenarios relative to baseline conditions. The simulation of the effects of these discharges requires the application of three levels of dilution and dispersion modeling. The overall approach is described below, and then the models and model predictions of each level is discussed and presented. Conclusions drawn from the model predictions are discussed.

4.1 Approach

The description of the effects of a discharge into the system under consideration requires the simulation of concentration levels of the effluent and its constituents, or equivalently the dilution of the effluent in space and time. Different physical processes operate at different space and time scales. A single integrated model is not available to provide descriptions at all of the scales of interest in this system. Therefore, a multiple set of models is applied.

The discharge is into a system that is influenced by both tidally driven and riverine flows. Although there is a net flow downstream, there are tidally reversing flows on a semi-diurnal basis. Therefore, material discharged into the system is not immediately flushed downstream to the ocean. This results in the accumulation of a long-term dynamic steady state concentration of effluent in the system. The prediction of this condition is best considered using a model of the entire system under consideration. The Delta Simulation Model (DSM2) was applied as described below. This model is also used to predict local flows and currents needed as input for the other models used in this analysis.

The DSM2 model does not reproduce the physics of the local, small scale, initial and secondary mixing processes. As the effluent is discharged from the outfall diffuser, very rapid mixing due to jet momentum and buoyancy effects takes place close to the diffuser. A variety of initial dilution models has been developed by USEPA and others to predict initial dilution. The model chosen for use in the analyses below is the USEPA model UDKHDEN. The model and rational for the selection of this model are discussed below.

Following initial dilution, while the discharge plume is still coherent, subsequent mixing occurs. This process is much less rapid than the initial dilution, being driven by passive diffusion in the water body. This stage is intermediate between the long-term background conditions described by DSM2 and the rapid initial dilution described by UDKHDEN. Another type of model is necessary if predictions of plume characteristics at this stage are required. The range of sophistication and complexity of such models is large. The simplest approach generally used is a subsequent dilution model often referred to as the Brooks Method. This method is also one of the most conservative available. (Through the discussion of dilution and dispersion the term conservative is taken to mean that the dilution is underpredicted, or the concentration of effluent is over-predicted.) Specific applications of the Brooks Method have been implemented for computer calculations. Models named CDIFF, RDIFF, and others are commonly used to carry out subsequent dilution calculations. For application to this study a spreadsheet application of these methods is used, and is described in more detail below.

The initial dilution and subsequent calculations performed by UDKHDEN, RDIFF and other dilution models implicitly assume that the effluent is diluted into uncontaminated water. In a tidally influenced system, previously discharged effluent is mixed throughout and results in a baseline or background ambient, long-term, dynamic steady state concentration. As described above, the DSM2 model, capable of simulating the requisite time and space scales, was employed to provide the background dilution at the discharge site. The results of the initial dilution model must then be adjusted to account for the fact that the receiving water is not uncontaminated. This is a reasonably straightforward process and can be accomplished by the following calculation:

$$S_e = \frac{(S_n \times S_f + 1)}{(S_f + S_n)}$$

where,

S_e is the effective or corrected dilution,

S_n is the initial dilution, and

S_f the background dilution.

Therefore, to best describe the dilution and dispersion characteristics of the existing and proposed discharge configurations, three models are applied and appropriately combined. Each of these models and the results are described below. In addition, it may also be required to account for the two distinct discharge plumes overlapping and mixing with each other. The methodology to do this depends on the nature of the physical processes involved. The potential of such overlap, and the approach to account for it, is considered in the description of the model results.

4.2 Background Dilution and Hydrodynamics

DSM2 was used to predict the long-term background or ambient dilutions in the immediate vicinity of the discharge. This model was also used to predict the expected currents and water surface elevations in the vicinity of the discharge, which are required as input for the initial and subsequent dilution models. DSM2 is a river, estuary, and land modeling system developed by the California Department of Water Resources (DWR, undated) . This model was selected for the dilution study because it is the currently accepted Delta model used by state and federal planning agencies. This is the model used in the Calfed program, which is managed by an interdisciplinary, interagency staff team assisted by technical experts from state and federal agencies and consultants. It is noteworthy that this program manages the following aspects of the San Francisco Bay - Sacramento-San Joaquin Delta operations:

- Water quality standards formulation
- Coordination of State Water Project and Central Valley Project operations with regulatory requirements
- Long-term solutions to problems in the Bay-Delta Estuary

4.2.1 Description of the Delta Simulation Model (DSM2)

DSM2 contains both a hydrodynamic module and a water quality module used for the predictions described below. The model's hydrodynamics module, HYDRO, calculates stages, flows, and velocities in rivers and tidal estuaries, given boundary stages, rim flows, and internal flows (sources and sinks). HYDRO was derived from the US Geological Survey's Four Point Model developed by Delong et al. (1995) . The model's water quality (transport) module, QUAL, calculates water quality concentrations in rivers and tidal estuaries, given previously calculated flows and stages from HYDRO, boundary concentrations, and internal sources and sinks. QUAL was derived from the U.S. Geological Survey's Branched Lagrangian Transport Model (BLTM) developed by Jobson and Schoellhamer (1992). DSM2 includes effects from land-based processes, such as consumptive use and agricultural runoff. Figure D.4-1 shows the Delta simulation model grid for the Sacramento-San Joaquin Delta (i.e., the DSM2 area).

4.2.2 Selected Hydrologic and Boundary Conditions

The boundary and hydrologic conditions were selected to characterize future conditions in a critical (dry, low flow) year. A variety of management scenarios can be used to simulate management scenarios throughout the Delta. Calfed alternative 1C was selected to characterize the future condition of the Delta for this study. This is considered the most likely scenario for the South Delta. Calfed alternative 1C uses the hydrologic boundary conditions (delta inflows and exports) and the monthly net Delta channel depletions obtained from DWRSIM (Department of Water Resources Simulation Model) Study 532A. Study 532A assumed a year 2020 level of development and water demands. Allocations of diversions and return flows to the Delta for islands and to DSM2 nodes were obtained for the year 2020 using the DWR's DICU model (DWR, 1995).

Calfed alternative 1C uses gate operations at the Delta Cross Channel, Suisun Marsh salinity control gates; South Delta flow control structures at Old River, Middle River, and Grant Line Canal; Head of Old River fish control structure and Clifton Court Forebay intake gate as shown in Table D.4-1. There are special operations at the South Delta flow control structures and priority-based operations at the intake gates to Clifton Court Forebay. More detailed explanations of special gate operations and priority-based operations are found in the status report on technical studies for the storage and conveyance refinement process (Calfed 1998a; 1998b).

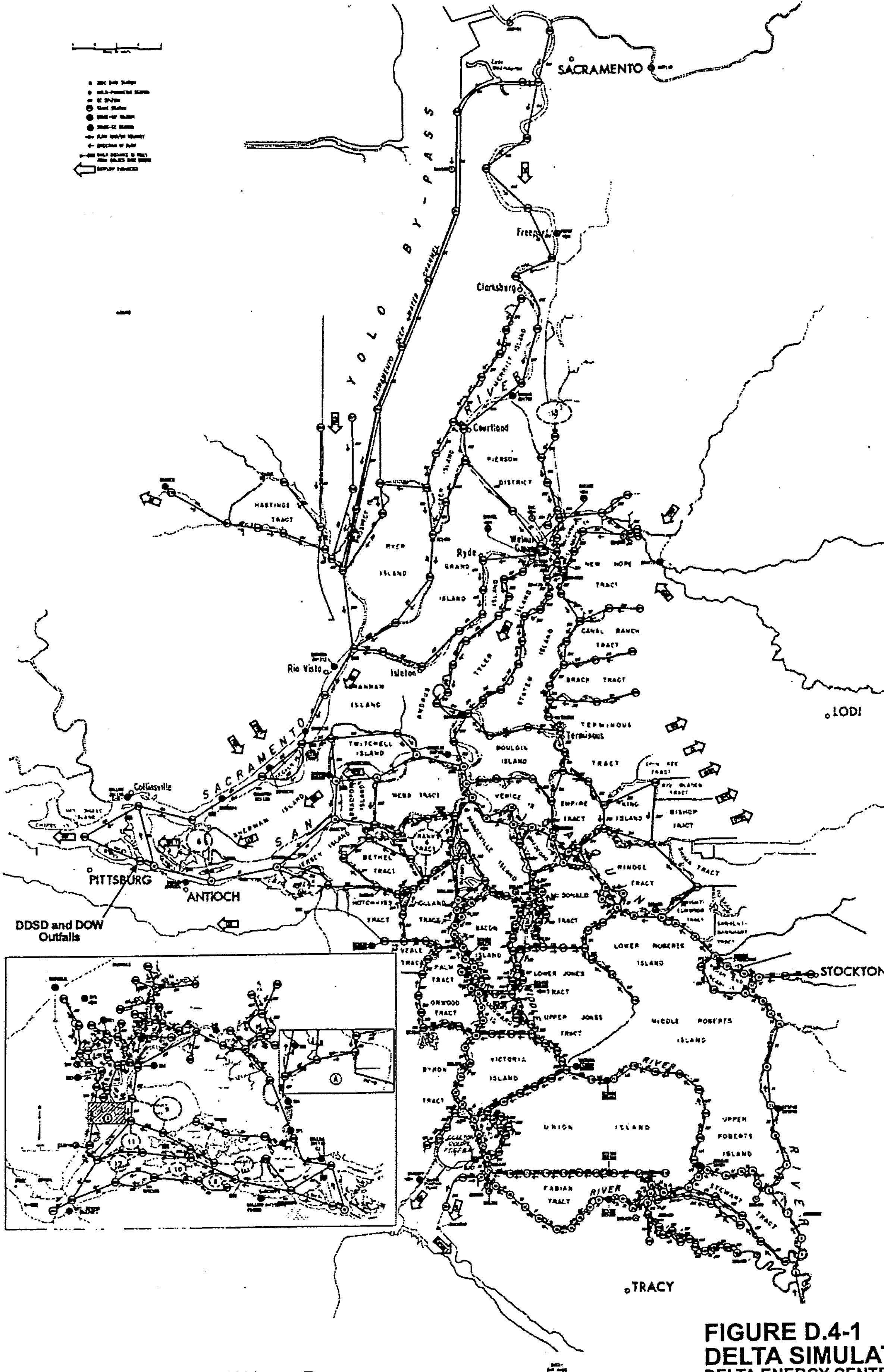


FIGURE D.4-1
DELTA SIMULATION MODEL GRID
DELTA ENERGY CENTER
PITTSBURG, CALIFORNIA

Source: Department of Water Resources, State of California

Table D.4-1: Operation of Delta Facilities under Alternative 1C

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Apr	May	Jun	Jul	Aug	Sep
South Delta Flow Control Structures													
1990	2	N	N	N	N	N	2	2	2	3A	3A	3A	3B
Head of Old River Fish Control Structure													
1990	O	O	N	N	N	N	N	0	0	N	N	N	N
Clifton Court Forebay Intake Gate Priority													
1990	4	4	4	4	4	4	3	3	3	3	4	4	4
Delta Cross Channel													
1990	N	O	O	O	O	O	O	O	O	O	N	N	N
Suisun Marsh Salinity Control Gates													
1990	O	O	O	O	O	O	O	O	O	N	N	N	N

Notes:
1. 'O' denotes gates are operating.
2. 'N' denotes gates are not operating
3. '2' denotes Old River and Middle River gates are operating but Grant Line Canal gates are not operating.
4. '3A' denotes Old River, Middle River and Grant Line Canal gates are operating. Grant Line Canal gates have special operation.
5. '3B' denotes Old River, Middle River and Grant Line Canal gates are operating. Grant Line Canal and Old River gates have special operation.
6. '3C' denotes Old River, Middle River and Grant Line Canal gates are operating. All three gates gates have special operation.
7. Priority '3' and '4' are described in Figure 4.

In addition to the management alternative, tidal and hydrologic conditions are specified to drive the model. The 19-year mean tide, at the downstream boundary of Martinez in the Carquinez Straits, was used for all months for all years (this tide is shown in Figure D.4-2). The dilution analysis was conducted for water year 1990, which was classified as the critical water year by SWRCB's 40-30-30 Sacramento Valley water year hydrologic classification scheme. Using a critical low flow year reduces the flushing action and thus reduces the ambient dilution predicted. It provides a conservative estimate compared to most years.

4.2.3 Background Dilution Analysis Model Approach and Results

The purpose of the dilution analysis was to provide a preliminary assessment of the impact of effluent discharged from the DDSD and DEC outfalls on the background dilution in the immediate area of the discharge. To predict the background dilution a node was introduced near Winter's Island in the original DSM2 model to account for a point source (set at 13 mgd) effluent flow into the model. In the DSM2 model, flow can enter into a channel or leave from a channel only at a node. Since the intent is to calculate a dilution, the rate of flow and the amount of tracer used is for convenience only, as long as the flows do not affect the hydrodynamics of the system. In this case 13 mgd is about 4 orders of magnitude less than typical flows in this location and therefore is negligible in terms of system hydrodynamics. Having calculated dilution, concentrations of any target constituent, or whole effluent, can be calculated for an arbitrary input (as long as the condition above is still met).

The new node is located 3,700 feet downstream of the existing node at the San Joaquin River, and just upstream of New York Slough. The downstream node is located 15,800 feet downstream from the outfall (new node). As discussed earlier, the HYDRO module of the DSM2 model provides for time-varying hydrodynamics (flow and stage information) needed for the QUAL module of DSM2. QUAL runs of DSM2 predicts the time varying dispersion of mass concentrations, and thus dilutions, along the Delta channels. A constant arbitrary release of mass concentration of 10,000 parts per cubic foot at the outfall was introduced in the discharge. Both HYDRO and QUAL modules were run to steady-state conditions of flow hydrodynamics and water quality. The dilution was calculated on a volume:volume basis (ratio of initial concentration to final concentration).

The monthly average flows at the channel, downstream of the outfall, are shown in Figure D.4-3. April was split into two parts (April 1 to 15 and 16 to 30) to accommodate the gate operations at the head of Old River during April. The fish control structure was operated during the second half of April. The estimated values reported here for the month of April are the averages of the two parts (April 1 to 15 and 16 to 30). The monthly average flow for December and January at New York Slough, downstream of the outfall, was negative for water year 1990 resulting in a net flow upstream of New York Slough towards the San Joaquin River. The monthly average flows are typically one to two orders of magnitude lower than instantaneous flows at the discharge site. The predicted instantaneous flows, on an hourly basis, were also used to provide mean channel velocities for use in the initial and subsequent dilution models and are described in more detail below.

Monthly average dilutions for the critical water year 1990 are shown in Figure D.4-4. The monthly average dilutions were estimated to be more than 300. During December and

Figure D.4-2. 19-Year Mean Tide at Martinez

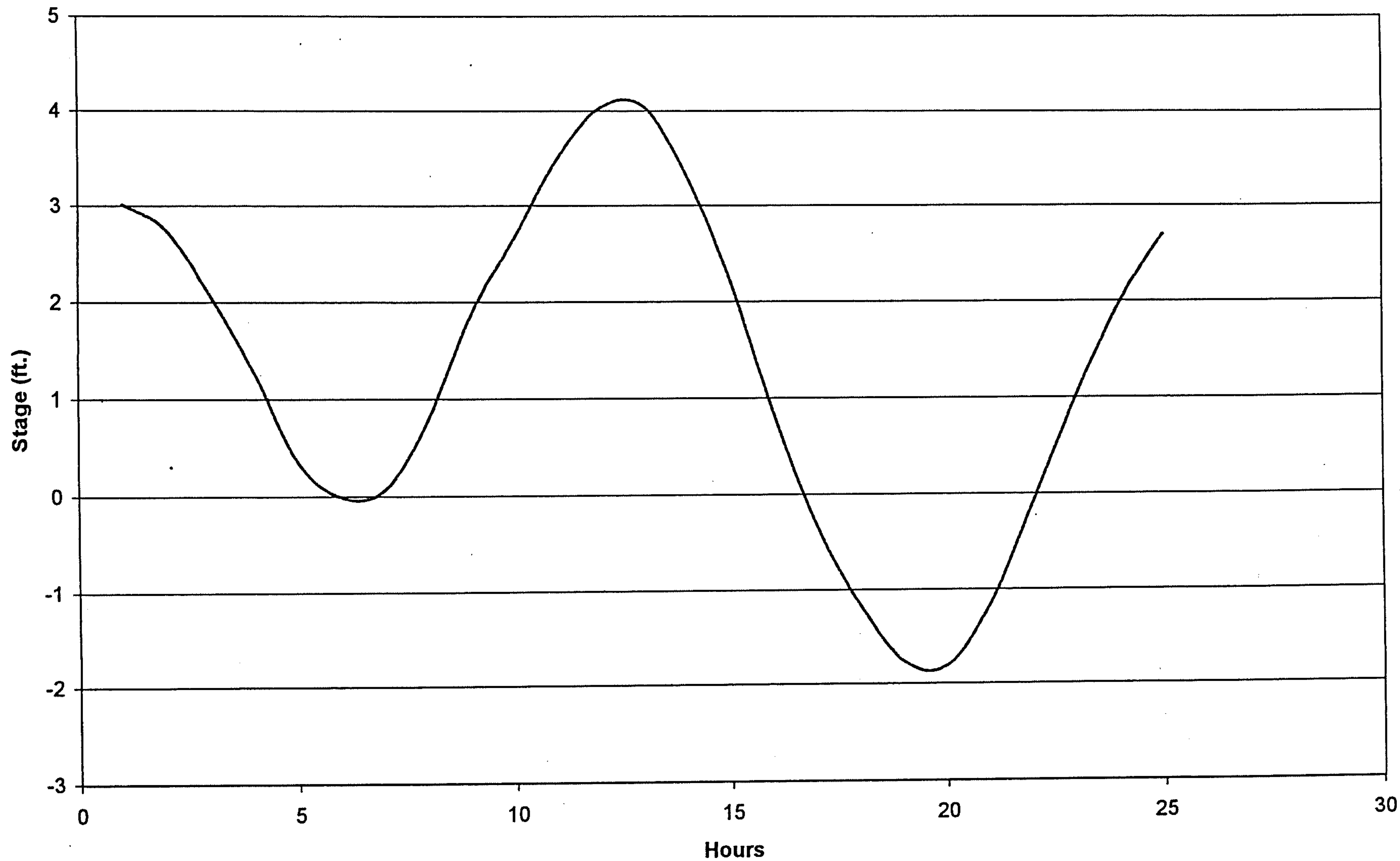


Figure D.4-3. Monthly Averaged Flow Channel Downstream of Outfall Water Year 1990 (Critical)

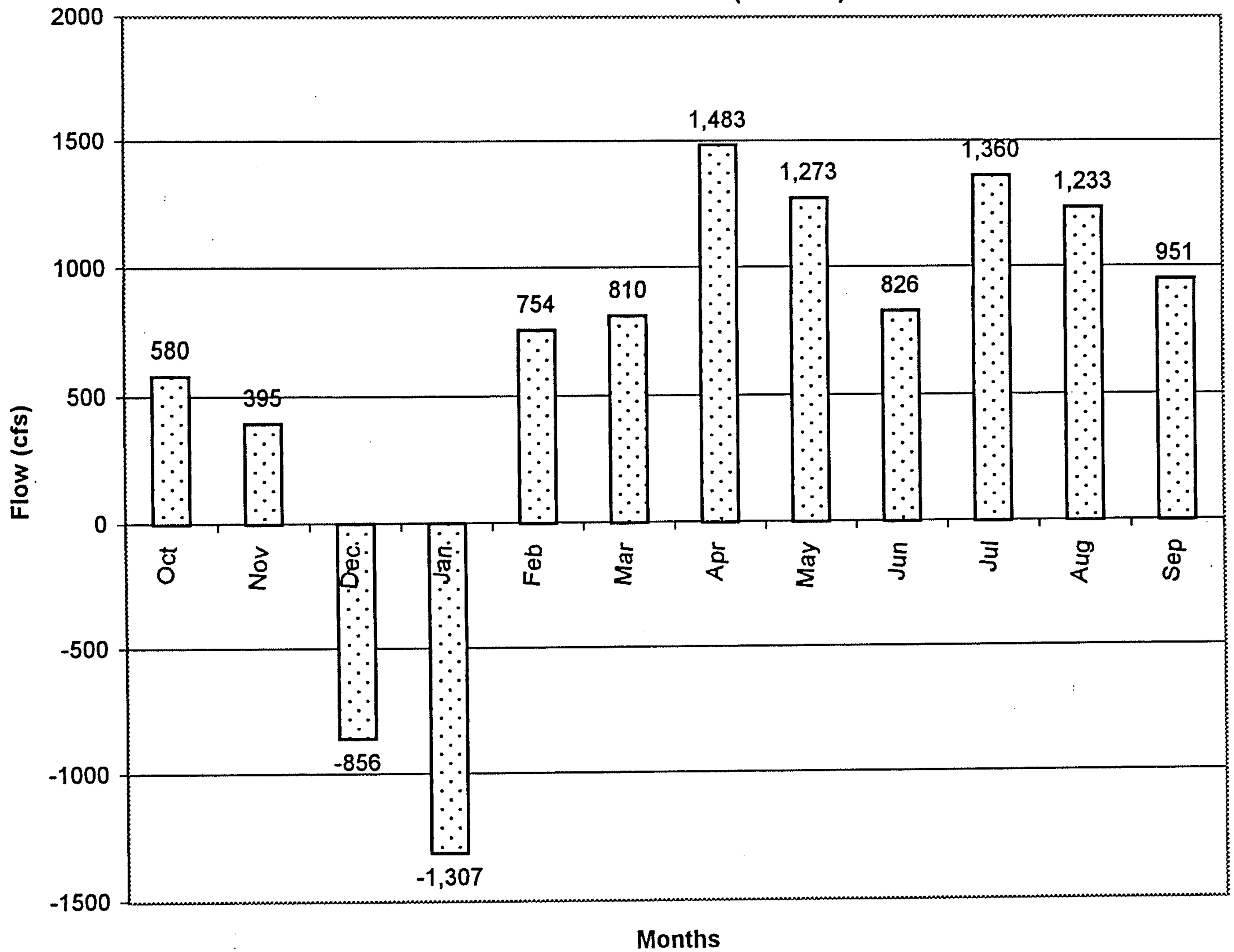
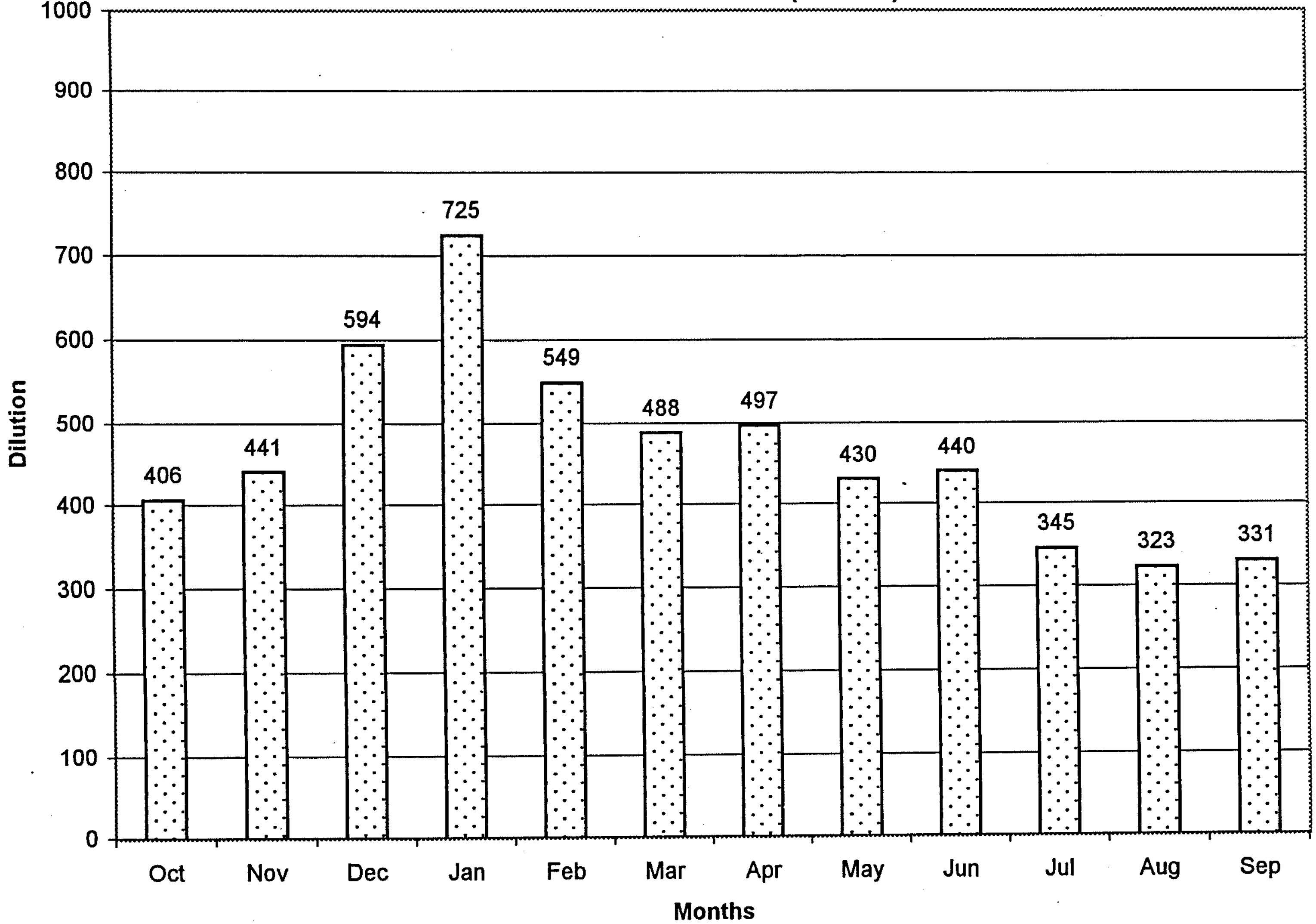


Figure D.4-4. Monthly Averaged Dilution at Outfall
Water Year 1990 (Critical)



Dilution is calculated as the ratio of initial concentration to the final concentration

January of Water Year 1990 when the monthly average flows are negative, the dilutions are predicted to be greater than other months. During these months, part of the plume from the outfall is flushed through the wider Broad Slough, just upstream of New York Slough. A snapshot of dynamic steady-state hourly dilutions at the outfall during November 1990 is shown in Figure D.4-5. The figure shows high hourly dilution variations ranging from approximately 220 to 890. This is partially a reflection of the variation in the tidal flows. The DSM2 model is the best approach to calculate long-term background dilutions. However, as discussed above, it is not an appropriate model for looking at small-scale spatial and temporal dilutions at the point of discharge over sub-tidal time scales. DSM2 could overestimate and underestimate local time dependent dilutions. Therefore, the initial dilution model described below was used and superimposed on the average dilution predicted by DSM2.

Monthly average dilutions for November and August at different channel sections downstream (towards sea) and upstream (towards Delta) of the outfall are shown in Figure D.4-6a and D.4-6b, respectively. The figure shows that the monthly average dilution increases with distance from the outfall. November is the month with the lowest monthly average flow and might be expected to be the critical month for background dilution (i.e., lowest background dilution). However, the minimum average monthly dilutions actually occurred in July to September. For this reason, August monthly dilutions are also shown. The model results, based on the Interim South Delta Program at the Year 2020 level of development and the demands for Critical Water Year 1990, indicate that the average dilution will be approximately 320:1 or higher in the vicinity of the discharge.

The modeling studies also show that, following initial dilution, the wastewater plumes are rapidly mixed with the receiving water and very high dilutions are achieved within a short distance from the discharge location. We specifically looked at dilutions and the potential for impacts at both the CCWD Mallard Slough water supply intake to the West and the City of Antioch intake located near the Antioch bridge. In the worst case conditions, dilution at the water supply intakes will be greater than 350:1. Under more normal Delta outflow conditions, the dilution will be much greater.

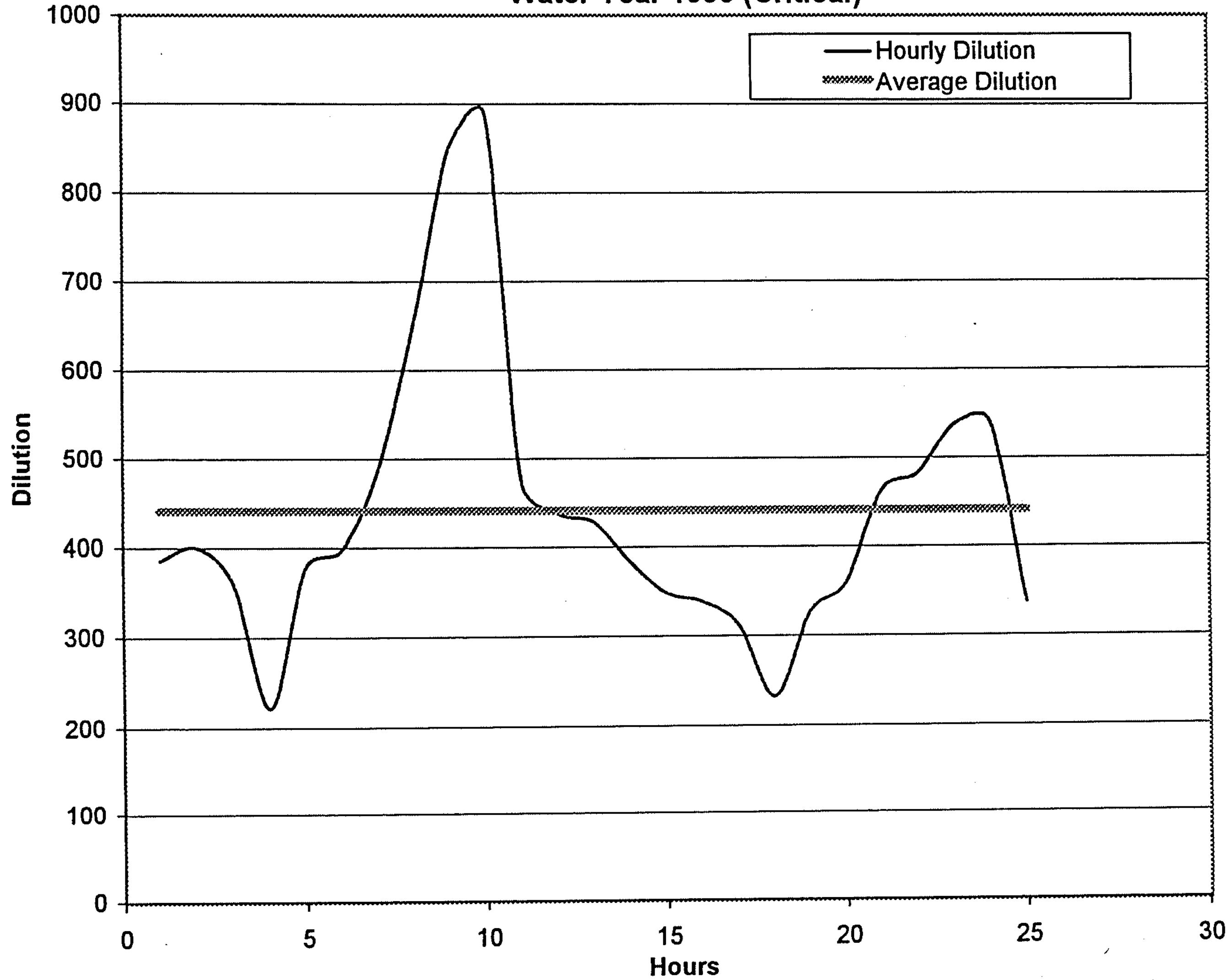
4.3 Initial Dilution

The region of initial dilution, immediately following discharge from the diffuser is the region of intense mixing driven by jet momentum and plume buoyancy. This is the region where most of the mixing of ambient water into the plume occurs. The rationale for the initial dilution model selection, a brief description of the model, and the results of applying the model to both outfall diffusers, for a range of environmental conditions, are described below.

4.3.1 Model Selection and Description

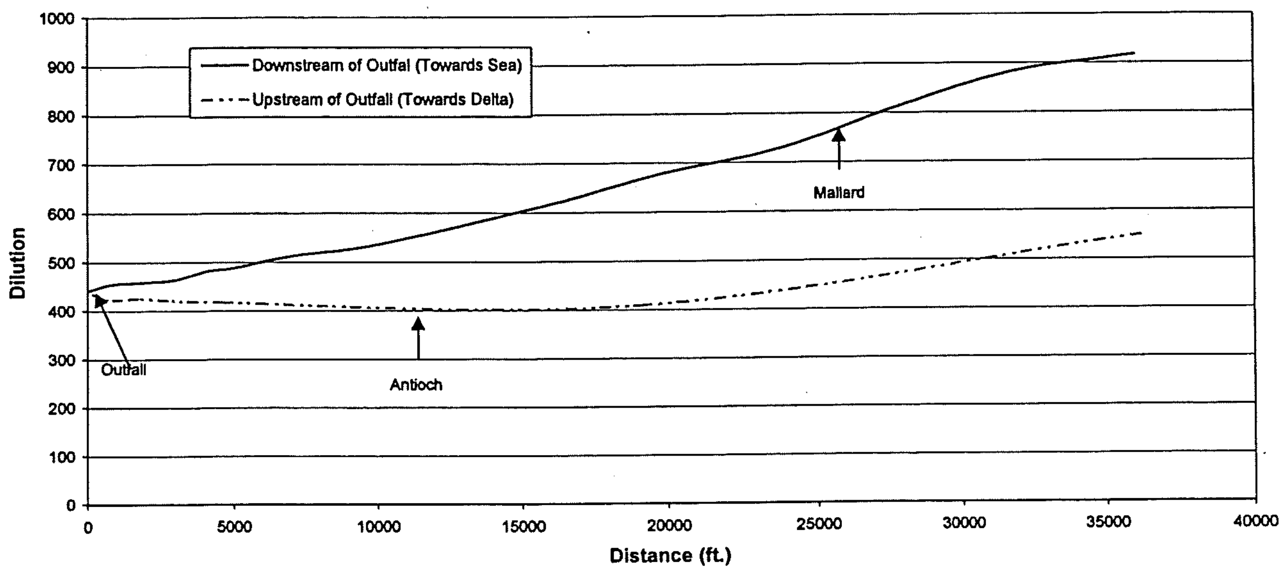
The model used to predict plume dilutions within this system should be able to account for effects of all of the effluent, ambient, and configurational variables. Specifically, the model, or models, used should account for the following:

Figure D.4-5. Hourly Dilution at Outfall for November Water Year 1990 (Critical)



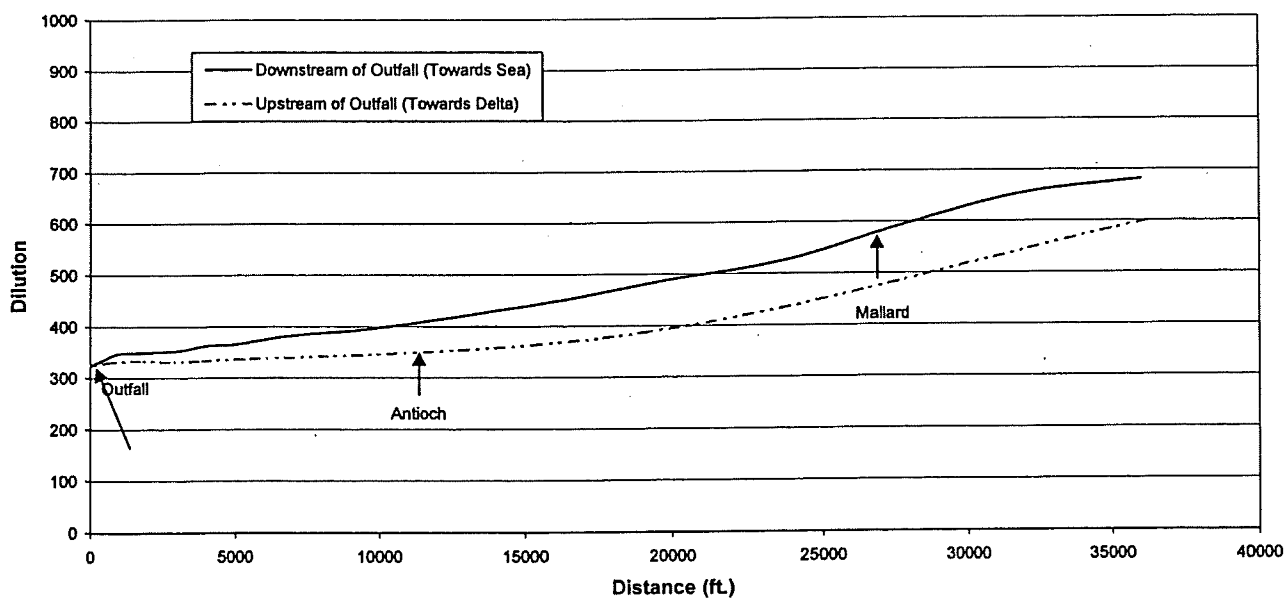
Dilution is calculated as the ratio of initial concentration to the final concentration

Figure D4-6a. Dilution vs. Channel Distance for November Water Year 1990 (Critical)



Dilution is calculated as the ratio of initial concentration to the final concentration

Figure D4-6b. Dilution vs. Channel Distance for August Water Year 1990 (Critical)



Dilution is calculated as the ratio of initial concentration to the final concentration

- Effluent flow variations: The model(s) should be able to predict relative and absolute changes in diffuser performance over the expected range of flow variability.

- Effluent densities: The model(s) should be able to account for differences, or reliably indicate the lack of effects for the differences, in effluent densities over the expected range.

- Ambient currents: The model(s) should be sufficiently sensitive to ambient current speeds within the range of relatively low current speeds. The model sensitivity to vertical changes in current speed should be sufficient to account for changes in diffuser performance, if any, for the changes in current speed and vertical profile of current speeds described above.

- Ambient density: The model(s) should be sufficiently sensitive to ambient density. It should be capable of using vertical density profiles with small variations in density.

- Diffuser port configuration: The model(s) should be capable of predicting changes in diffuser performance for a wide range of port size, spacing, relative orientation, and grouping. Model(s) should be able to account for a variety of port configurations internally or with appropriate minimal pre- and post-processing analyses.

- Diffuser orientation: The model(s) should be capable of accounting for ambient current directions relative to discharge jet direction over a wide, if not total, range of orientations. It should be able to reliably indicate differences in performance, if any, for relatively small differences in orientation.

Following initial dilution there is a region where the momentum and buoyancy driven mixing stops or becomes greatly reduced. Generally this is considered the point of onset of farfield processes (passive diffusion) as described below. However, there is a transition region between the nearfield initial dilution and the subsequent passive diffusion region. The plume transition from nearfield to farfield is a result of the vertical momentum of the rising plume causing it to overshoot the actual equilibrium height. The plume will then fall back deeper into the water column and result in some degree of buoyant spreading and related mixing processes. The mixing and dilution resulting from these processes are quite small compared to the initial dilution. The dilution occurring in this region is not considered significant in the case considered here because of the limited water depth, low density stratification, and high currents. The ability of a model to simulate these processes was not a factor in model selection for this study.

The following dilution models were considered for use in evaluating the discharges: PLUMES, a model interface and file manager that includes both plumes models UM and RSB (Baumgartner et al., 1994); the CORMIX family of models (Doneker and Jirka, 1990); and the three-dimensional hydrodynamic model UDKHDEN (Muellenhoff et al., 1985).

All of the initial dilution models share a limitation that the horizontal discharge angle of adjacent ports along a diffuser cannot vary; each port (with a different orientation) must be modeled separately. For the case considered here this is not a consideration.

4.3.1.1 UM (From the PLUMES family)

UM, an updated version of the UMERGE model (Muellenhoff et al., 1985), calculates the flux-average dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single port or multiport diffuser in either stagnant or flowing environments (Baumgartner et al., 1994). UM is a two-dimensional mathematical model that analyzes effluent discharges by tracing the position of the plume through its' trajectory path. The model approximates the plume development by using single one step integrations over discrete time increments. The PLUMES interface also contains farfield dilution algorithms based on equations developed by Brooks (1959), as described in more detail below.

The use of UM at horizontal discharge angles other than parallel to the current (90°) is generally not recommended except with relatively high ambient current speeds and low Froude numbers (i.e., discharge momentum). The model not only ignores current interaction with the plume, but also artificially spaces the discharge ports closer together to account for deviations from a horizontal discharge angle of 90°. The use of an "effective" port spacing causes the individual plumes to merge much sooner than is realistic. In this case, these effects would cause the UM model to under-predict dilution.

4.3.1.2 RSB (From the PLUMES family)

The Roberts-Snyder-Baumgartner (RSB) model is an updated version of the two-dimensional dilution model ULINE (Muellenhoff et al., 1985) and is also linked with the PLUMES file manager and interface (Baumgartner et al., 1994). RSB is intended as a deep water ocean model. RSB is an empirical model and should be considered for use under conditions appropriate to the range of conditions for which it has been calibrated. Since intermediate output results are not displayed, RSB provides no information on dilution except when the plume traps or surfaces, which can compromise its utility for some applications.

4.3.1.3 CORMIX2 (from the CORMIX family)

The CORMIX family of plume models, developed for the EPA at Cornell University, is an "expert" or rule-based system that classifies the interaction of the discharge and the receiving water (Jirka et al., March 1996). CORMIX2 is the specific model in this family for application to submerged multi-port diffusers. As an expert system, the program makes many of the decisions for the user based on the input parameters. The system was designed for the non-specialist model user, so that plume predictions could be made without having prior knowledge about dilution modeling.

The CORMIX models use empirically-derived curve fit equations to make dilution predictions. A jet-integral module (CORJET as a post-processing module) has been added to CORMIX2 (Version 3.2) that extends it's utility for some applications. The empirical equations are selected from length scales that are determined from parameters input by the user. A main advantage to using CORMIX in contrast to strictly jet-integral models, such as

UM or UDKHDEN, is that it does consider interactions with boundaries (i.e., shoreline contact). As in the case of RSB, the model is best suited to conditions within the range of conditions for which it was developed. CORMIX2 also contains farfield dilution algorithms based on equations developed by Brooks (1959) as described in more detail below.

4.3.1.4 UDKHDEN

UDKHDEN is a completely three-dimensional hydrodynamic model that considers variable ambient receiving water current and density profiles with depth (Muellenhoff et al., 1985). UDKHDEN uses a fourth-order integration routine along the centerline of the effluent plume to trace its position and average dilution over time. The model calculates the average dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single diffuser or single row of multiple diffuser ports in either stagnant or flowing environments. UDKHDEN is sensitive to water column density gradients and ambient velocities. Jet-integral plumes models, such as UDKHDEN, provide relatively conservative dilution estimates (i.e., they predict lower dilutions than are actually achieved), which are based on comparisons of field and dilution modeling results (Roberts and Wilson, 1990).

The model output of each UDKHDEN run provides sequential calculation of both dilution and plume distance from the port until initial dilution is completed, and this output can be used to summarize the dilutions and plume depth at the acute criteria zone boundary and at the completion of initial dilution. UDKHDEN is a nearfield (initial) dilution plume model only and as such does not provide farfield dilution predictions. Therefore, if UDKHDEN is used to model the diffuser in the nearfield, a separate model must be employed to predict subsequent dilutions.

4.3.1.5 Model Selection

The suite of models considered for application was described above. Based on the data and analyses provided above, and the model capabilities and limitations described in the previous memorandum, the model UDKHDEN was selected for use for this study. The author of the model has developed a method of running this model in an imaging method for shallow water depths. Such a technique may prove useful in future considerations of the details of the discharges being considered. The reasons for selecting this model are described in more detail below.

All of the initial dilution models considered will provide similar predictions up to the end-point defined by the trapping level of the plume. However, output from RSB, as currently configured, predicts dilutions only at the end of the "initial mixing region" and does not provide the information needed to predict the dilution at a specific distance from the discharge point. CORMIX2 has an included post-processing module (CORJET) that may provide the required information. PLUMES and UDKHDEN also provide information about the variation of dilution with distance from the discharge.

UDKHDEN and CORMIX2 appear to provide more detailed information about plume trajectory coordinates than PLUMES. In particular, PLUMES only predicts a two dimensional type of representation of the plume trajectory (plume elevation and horizontal distance from the discharge; x,z coordinates). UDKHDEN and CORMIX2 provide three dimensional plume trajectory coordinates (x,y,z). This may be an important feature since it is anticipated that a variety of horizontal angles between the discharge direction and the current direction may need to be considered, resulting in curvilinear plume trajectories. The need to consider plume overlap from closely spaced discharges requires, a three dimensional specification (x,y,z) of plume trajectory.

CORMIX2 does not allow complex vertical gradients. UDKHDEN will accommodate such gradients, and in addition, experience with this model indicates sufficient sensitivity to density and current variations needed to assess effects of small changes on dilution. The plume model UDHKDEN has the flexibility and sensitivity required, the output format needed, and has been successfully used and verified in many other similar locations.

4.3.2 Diffuser Characteristics

Initial dilution is a process of entrainment of surrounding water into the discharge plume, rather than the more classical turbulent diffusion process of equal exchange between fluid elements. The rate of entrainment is a function of the diffuser design characteristics, the effluent characteristics, and receiving water conditions. The depth and distance offshore of the discharge can be a factor governing achievable dilutions if the plume reaches the surface or the shoreline is nearby. The important ambient conditions, current speed and density structure, are discussed below. The diffuser configuration, location, and effluent characteristics for both diffusers are listed in Table D.4-2 below. Figures D.4-7 and D.4-8 show the schematics of the diffuser configurations. Figure D.4-9 shows the location of the two discharge points.

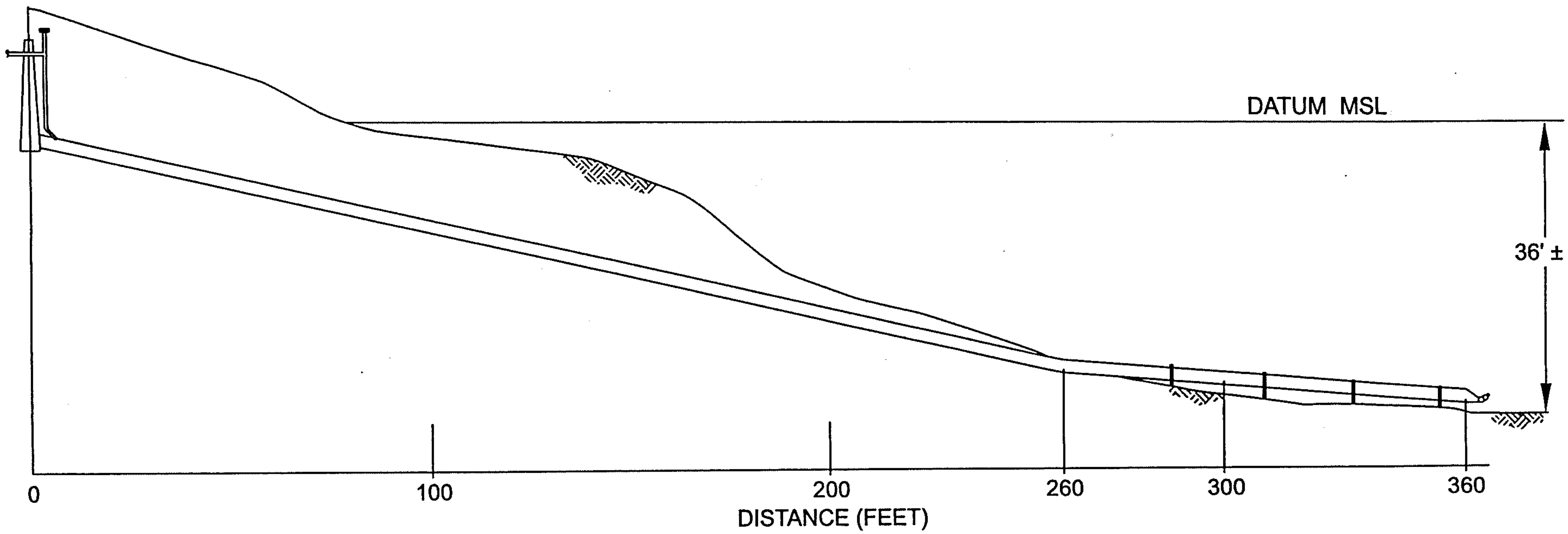
Table D.4-2
Diffuser and Discharge Characteristics Used in Initial Dilution Modeling

Parameter	Units	DDSD Diffuser	DEC Diffuser
Effluent Flow	mgd	13, 7.3, and 5.2	2.1
EFFLUENT DENSITY[1]	g/cm^3	0.9971	0.9971
Diffuser Depth[2]	feet	21	29
Diffuser Orientation		45 degrees to channel	90 degrees to channel
Diffuser Location	feet	Starts 300 ft from shore	Starts 200 ft from shore
Diffuser Length	feet	420 feet	120 feet
Barrel Diameter	inches	42	18
Number of Ports		50	10
Port Diameter	inches	3	3.375
Port Spacing	feet	8	10
Port Orientation		20° from horizontal	vertical
Port Structure		Orifice 20° above center, alternating sides of barrel	Orifice in top of pipe

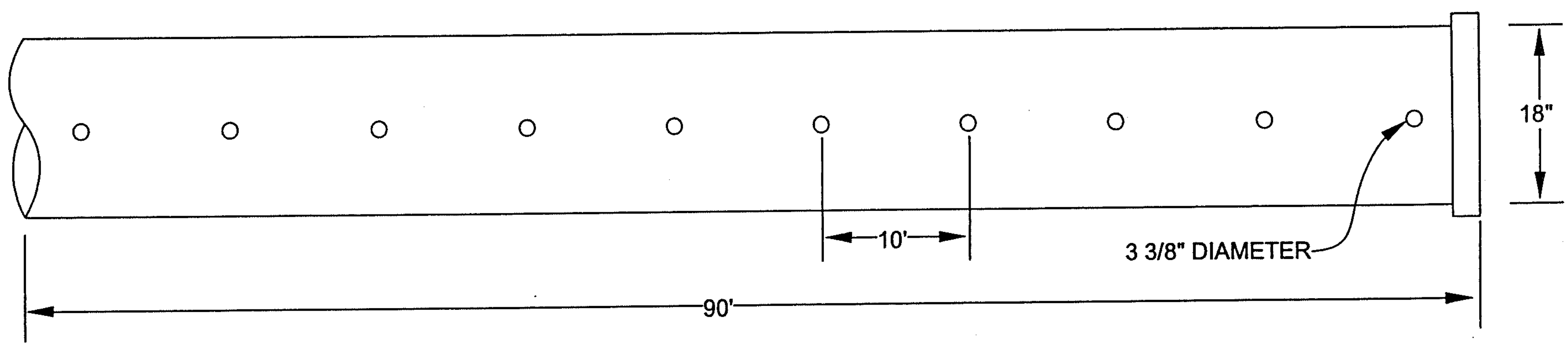
[1] Assumed effluent temperature of 25°C
[2] Relative to MLLW

Three scenarios are identified in terms of flows from each of the two outfalls. The scenarios are summarized below in Table D.4-3

CROSS SECTION A–A'



SCHEMATIC DETAIL OF DIFFUSER: PLAN VIEW



NOTE

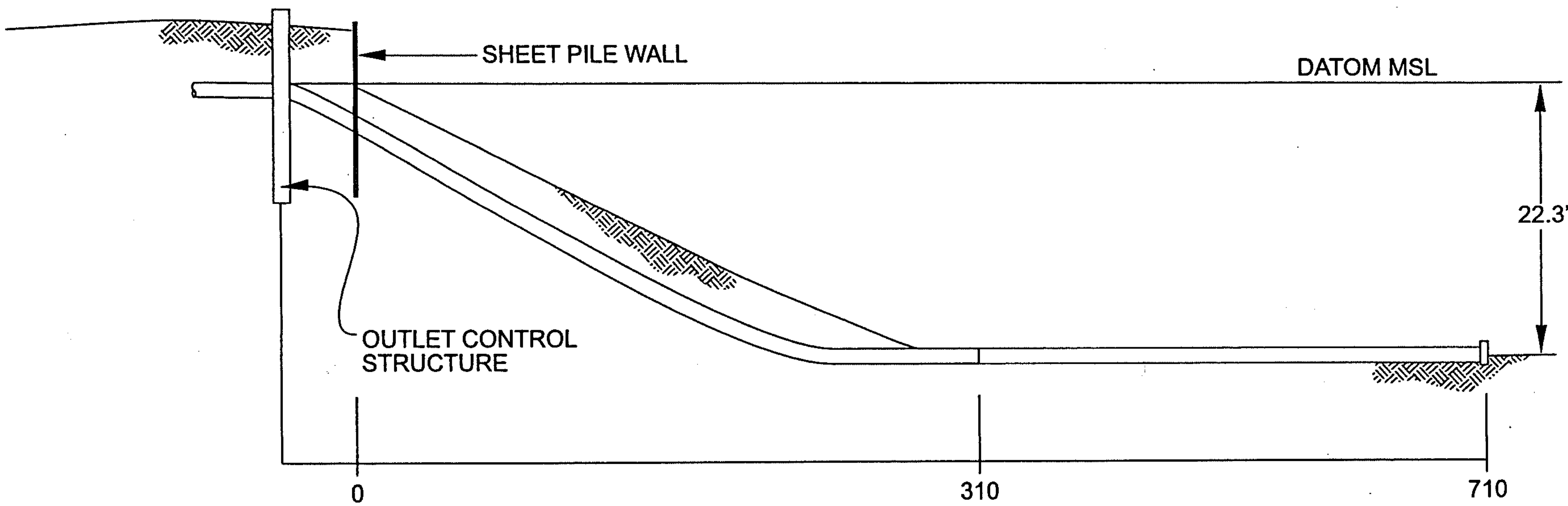
Diffuser dimensions as shown. Not to scale.

FIGURE D.4-7
DEC OUTFALL CHARACTERISTICS
DELTA ENERGY CENTER
PITTSBURG, CALIFORNIA

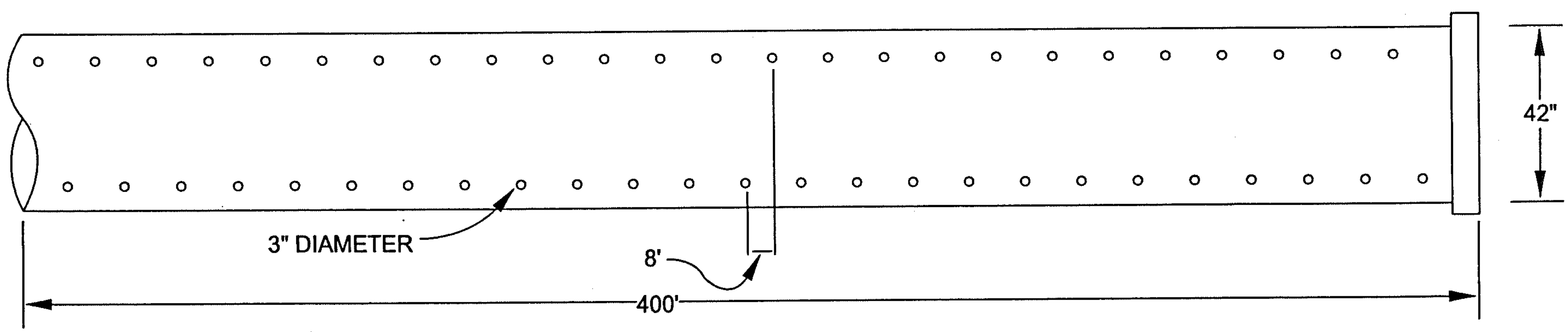
CH2MHILL

SAC–E–148323.tm.wr.np DEC 02.fh8 (3/23/99)tb

CROSS SECTION B–B'



SCHEMATIC DETAIL OF DIFFUSER: PLAN VIEW



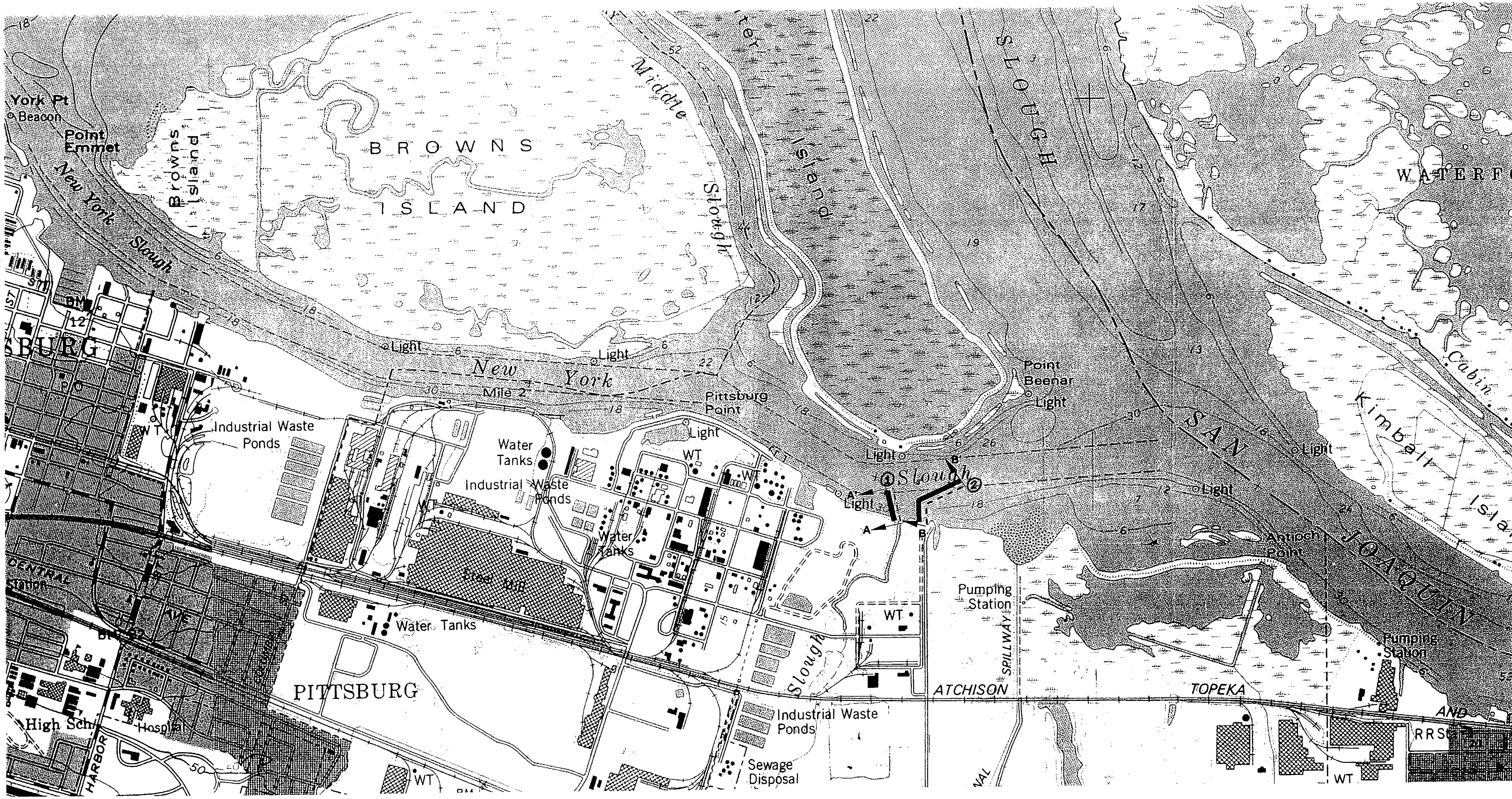
NOTE

Diffuser dimensions as shown. Not to scale.

FIGURE D.4-8
DDSD OUTFALL CHARACTERISTICS
DELTA ENERGY CENTER
PITTSBURG, CALIFORNIA

CH2MHILL

SAC–E–148323.tm.wr.np DEC 03.fh8 (3/23/99)tb



N

0 750 1500 FEET

SCALE IS APPROXIMATE

LEGEND

① DEC OUTFALL

② DDSD OUTFALL

A A' CROSS-SECTION LOCATION SHOWN ON FIGURE

FIGURE D.4-9
LOCATION OF DEC AND DDSD OUTFALLS
DELTA ENERGY CENTER
PITTSBURG, CALIFORNIA

CH2MHILL

SAC-E-148323.tm.wr.np map02.fh8 (3/23/99)tb

Table D.4-3 Flow Scenarios Considered			
SCENARIO	DDSD Flow - mgd	DEC Flow -mgd	Total Flow - mgd
Existing Condition	13	0	13
DEC Return to DDSD	7.3	0	7.3
No DEC Return	5.2	2.1	7.3

4.3.3 Ambient Conditions

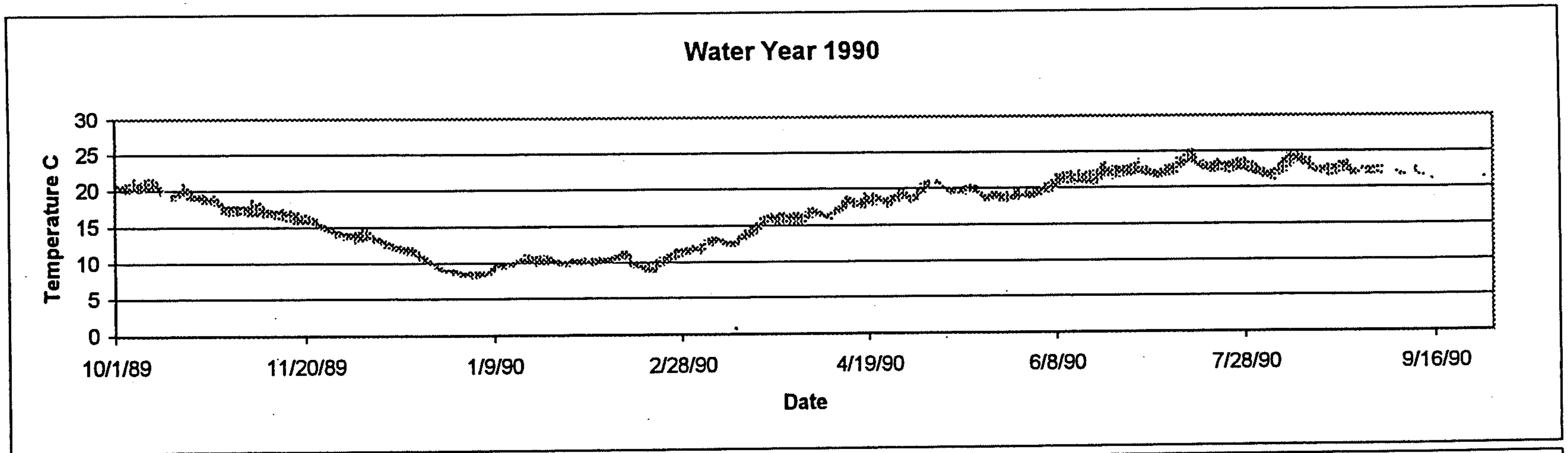
Receiving water conditions required for initial dilution calculations are the receiving water density, the vertical structure of the water column, and the current speeds in the receiving water. Two data sets were examined to characterize the water column density structure. The current speed was determined from the output of the DSM2 model runs for each month of 1990.

Surface water data for a station at Pittsburg, CA, just downstream of the discharge locations, provide surface temperature and conductivity data (USGS, undated). From these data, shown in Figure D.4-10, the extreme water column densities were determined. The screening level initial runs described below were done using these two extremes.

Data for water column profiles for the years 1988 through 1997, at approximately monthly intervals, in the vicinity of the discharge were also examined (USGS, undated). These profiles were evaluated to determine a worst case ambient condition and used in formulating the critical conditions initial dilutions described below. As described below, the critical condition results in the lowest dilution and is represented by the density profile exhibiting the strongest stratification. Stratification was characterized by examination of the tabulation of the difference in density between surface and bottom. A cumulative frequency distribution of the density differences (stratification) is shown in Figure D.4-11.

To select the most critical stratification, the most highly stratified water column profiles were examined in more detail. The highest stratification (10 Dec 91 profile) and the second highest stratification (26 Oct 94 profile), were found to result in higher overall dilutions than the third highest recorded on 2 Nov 88. This is because the slope of the 2 Nov 88 profile is the steepest in the vicinity of the discharge depth and therefore more intensely suppresses initial mixing and limits the plume height of rise. Therefore, the 1 Nov 88 profile was taken as the most critical stratification condition. Figure D.4-12 shows the selected profiles used to perform the analyses, and also shows the 10 December 91 profile for comparison. The entire data set is shown in Appendix A.

DSM2 was used, as described above, to generate flows and calculate corresponding mean channel velocities and water surface elevations in the vicinity of the discharge. The average monthly flows with the average tide imposed downstream were applied for each month of the year. These data were then used to determine the frequency distribution of the currents shown in Table D.4-4. The monthly summaries are provided in Appendix B.



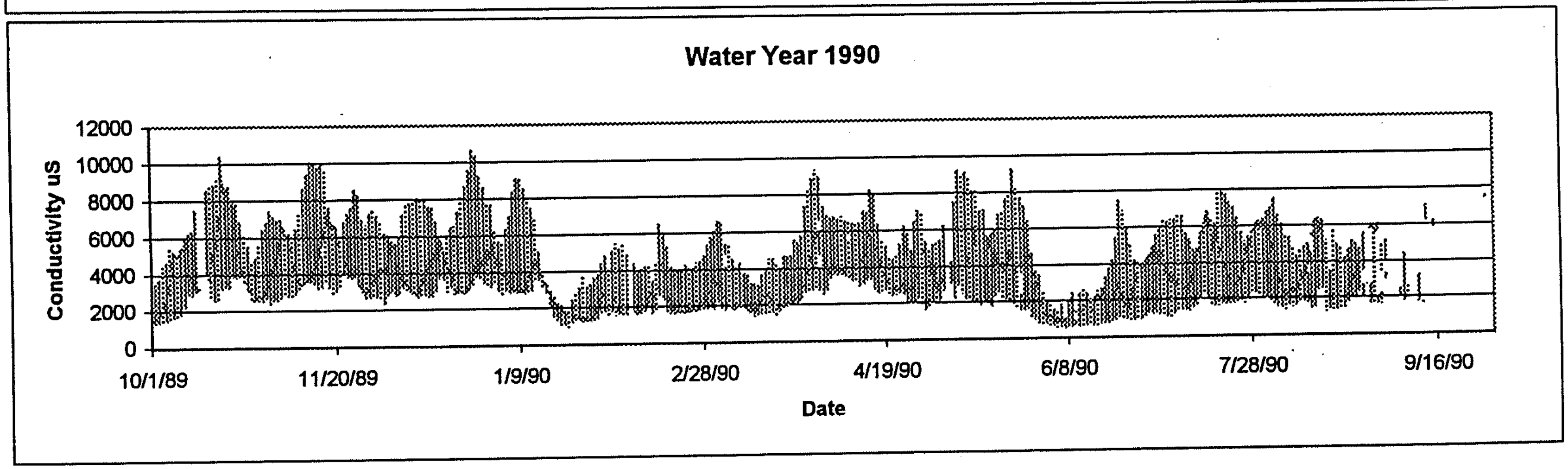


Figure D.4-10
Surface Water Temperature and Conductivity
Water Year 1990 (Source: California DWR)

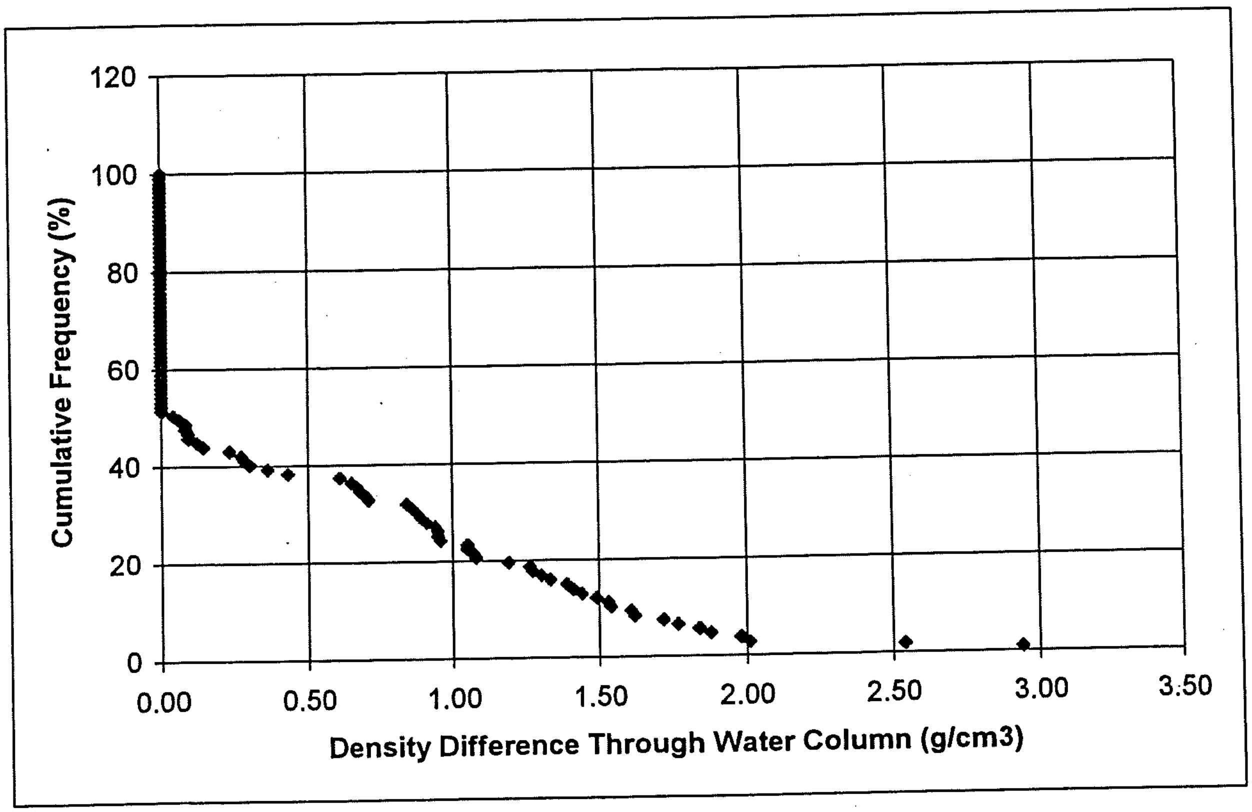


Figure D.4-11
Frequency of Density Differences
in Water Column near Antioch
(1988-1997)

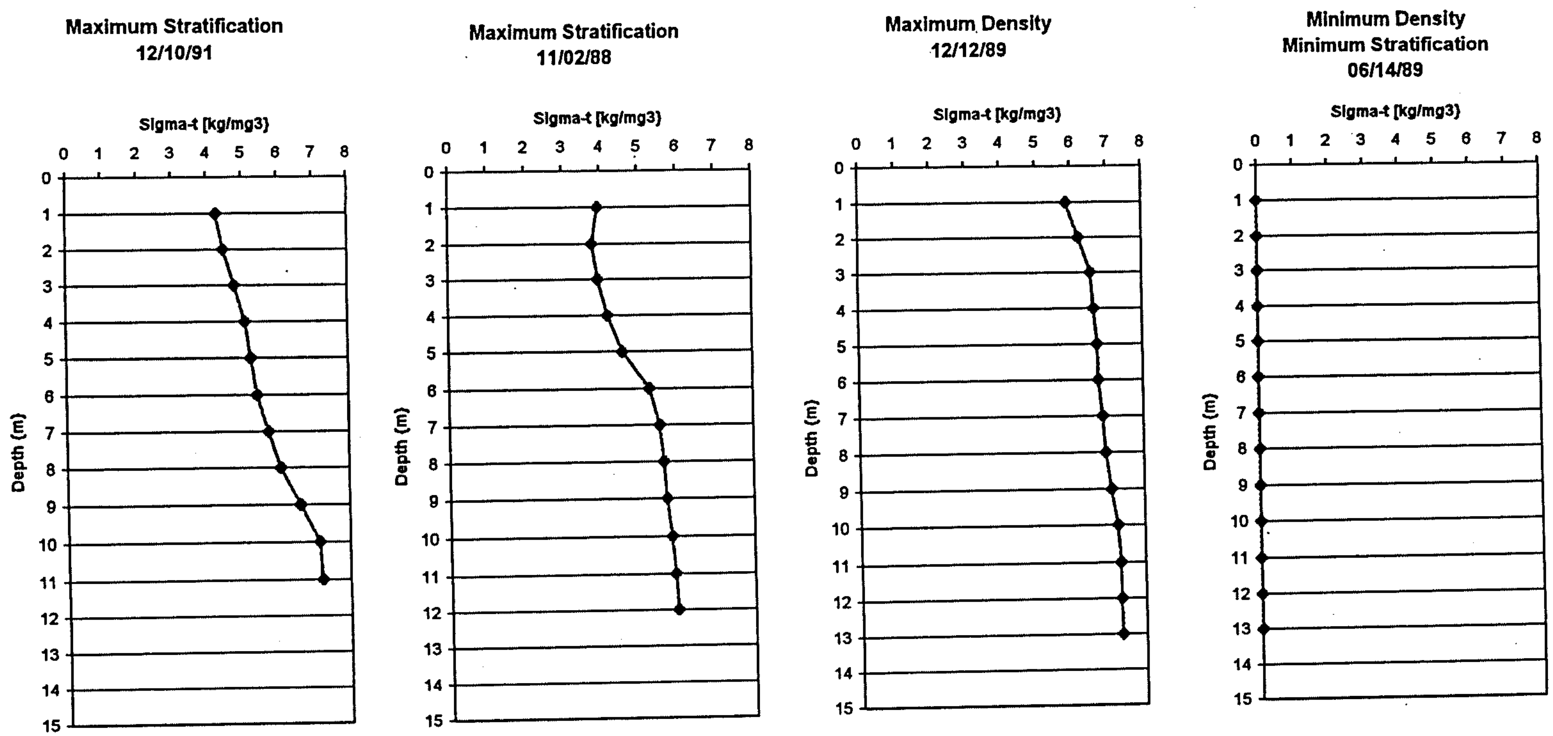


Figure D.4-12
Selected Extreme Density Profiles
(Source: USGS)

Table D.4-4 Percentile of Ambient Current Speed (fps) for Water Year 1990														
Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Apr	May	Jun	Jul	Aug	Sep	Water Year 1990
1%	0.24	0.15	0.15	0.13	0.21	0.21	0.21	0.21	0.19	0.14	0.21	0.20	0.20	0.19
5%	0.30	0.24	0.23	0.23	0.27	0.26	0.25	0.26	0.25	0.21	0.26	0.26	0.26	0.25
10%	0.52	0.47	0.58	0.61	0.48	0.47	0.41	0.42	0.42	0.41	0.42	0.43	0.44	0.47
20%	1.18	1.22	1.20	1.18	1.20	1.21	1.24	1.24	1.23	1.24	1.23	1.23	1.22	1.22
30%	1.47	1.46	1.48	1.49	1.46	1.46	1.46	1.46	1.47	1.49	1.47	1.47	1.48	1.47
40%	1.87	1.81	1.83	1.85	1.83	1.83	1.81	1.81	1.81	1.81	1.84	1.84	1.84	1.83
50%	2.10	2.08	2.05	2.05	2.10	2.10	2.14	2.14	2.13	2.13	2.15	2.15	2.15	2.11
60%	2.28	2.29	2.27	2.27	2.27	2.27	2.29	2.30	2.30	2.32	2.31	2.32	2.31	2.29
70%	2.57	2.54	2.61	2.65	2.55	2.54	2.52	2.52	2.52	2.54	2.54	2.54	2.54	2.55
80%	2.76	2.74	2.72	2.72	2.74	2.74	2.74	2.75	2.75	2.77	2.78	2.78	2.78	2.75
90%	2.91	2.93	2.91	2.93	2.92	2.92	2.93	2.93	2.93	2.93	2.93	2.93	2.92	2.93
95%	3.06	3.07	3.03	3.04	3.06	3.06	3.09	3.09	3.09	3.10	3.12	3.12	3.10	3.08
99%	3.11	3.13	3.10	3.09	3.13	3.13	3.16	3.16	3.15	3.17	3.17	3.17	3.15	3.14

4.3.4 Screening Runs

Screening level runs for initial dilution were performed for a range of ambient current speeds, including zero current, to investigate the effect of speed on the plume behavior. Typically, the critical conditions for a tidal system are not run at a zero current speed because in a tidal system the speed seldom if ever falls to zero. Only in idealized one-dimensional systems is there true null point in tidal currents. Three-dimensional effects generally result in a rotating vector, which gets small with the turning of the tide, but maintains some value above zero. For this reason, State regulatory agencies generally follow the USEPA guidelines that provide for the use of the 10-percentile current for evaluating critical dilution conditions. Table D.4-4 shows the 10-percentile level as well as other percentiles to characterize the currents in the area.

4.3.4.1 DEC Screening Runs

A series of initial dilution screen runs for the DEC diffuser was conducted to investigate the approximate range of initial dilution performance to be expected under a wide range of environmental conditions. For the diffuser configuration, as currently described, simulation results for the range of discharge flow, current speeds, and ambient densities considered are shown in Table D.4-5 below. The density range is approximate and was estimated from the extreme values observed for 1990 described above. More detailed predictions for vertical profile density data are considered under the critical condition runs below.

The screening set of runs confirms that the diffuser performs well over the range of variables expected without major modification. Note that the dilutions reported are directly from the model predictions and have not been corrected for background dilutions. More rigorous analyses are provided in the calculations for critical conditions described below.

4.3.4.2 DDSD Screening Runs

A series of initial dilution screen runs for the DDSD diffuser was conducted for the same range of conditions as described above for the DEC diffuser. For the diffuser configuration, as currently described, simulation results for the range of discharge flow, current speeds, and ambient densities considered are shown in Table D.4-6 below. The density range is approximate as in the case of the DEC screening runs. More detailed predictions using vertical profile density data are considered under the critical condition runs below.

Table D.4-5
Screening Level Run Results for the DEC Diffuser

Output File	Run No.	Flow (mgd)	Ambient Density	Current (fps)	Trapping Level [1]	Dilution[2]
DEC_S01.out	1	1.2	High	0.00	0	97.00
DEC_S02.out	2	1.2	High	0.19	0	505.24
DEC_S03.out	3	1.2	High	0.47	0	1135.73
DEC_S04.out	4	1.2	High	2.11	***	***
DEC_S05.out	5	1.2	High	3.14	***	***
DEC_S06.out	6	1.2	Low	0.00	0	63.05
DEC_S07.out	7	1.2	Low	0.19	0	496.03
DEC_S08.out	8	1.2	Low	0.47	0	1100.38*
DEC_S09.out	9	1.2	Low	2.11	***	***
DEC_S10.out	10	1.2	Low	3.14	***	***
DEC_S11.out	11	2.1	High	0.00	0	71.51
DEC_S12.out	12	2.1	High	0.19	0	307.34
DEC_S13.out	13	2.1	High	0.47	0	643.35
DEC_S14.out	14	2.1	High	2.11	0	2893.34
DEC_S15.out	15	2.1	High	3.14	***	***
DEC_S16.out	16	2.1	Low	0.00	0	50.45
DEC_S17.out	17	2.1	Low	0.19	0	294.78
DEC_S18.out	18	2.1	Low	0.47	0	657.04
DEC_S19.out	19	2.1	Low	2.11	0	2961.35
DEC_S20.out	20	2.1	Low	3.14	***	***

*** = Out of range of model simulation capabilities
[1] Runs 1-20, Plume Hit Surface
[2] Dilutions uncorrected for background

As in the case of the DEC diffuser, the screening set of runs confirms that the diffuser will perform well over the range of variables expected without major modification. Note that the dilutions reported are directly from the model predictions and have not been corrected for background dilutions. More rigorous analyses are provided in the calculations for critical conditions described below.

Table D.4-6
Screening Level Run Results for the DDSD Diffuser

Output File	Run No.	Flow (mgd)	Ambient Density	Current (fps)	Trapping Level [1]	Dilution[2]
DDSD_S01.out	1	13	High	7.5	S	56.02
DDSD_S02.out	2	13	High	7.5	S	185.65
DDSD_S03.out	3	13	High	7.5	S	371.18
DDSD_S04.out	4	13	High	7.5	S	1506.53
DDSD_S05.out	5	13	High	7.5	S	2110.41
DDSD_S06.out	6	13	Low	0.0	S	50.19
DDSD_S07.out	7	13	Low	0.0	S	206.61
DDSD_S08.out	8	13	Low	0.0	S	406.22
DDSD_S09.out	9	13	Low	0.0	S	1614.08
DDSD_S10.out	10	13	Low	0.0	0.7	2124.10
DDSD_S11.out	11	7.3	High	7.5	S	65.83
DDSD_S12.out	12	7.3	High	7.5	S	296.06
DDSD_S13.out	13	7.3	High	7.5	S	620.40
DDSD_S14.out	14	7.3	High	7.5	S	2466.00
DDSD_S15.out	15	7.3	High	7.5	S	3562.91
DDSD_S16.out	16	7.3	Low	0.0	0.5	50.65
DDSD_S17.out	17	7.3	Low	0.0	S	303.20

DDSD_S18.out	18	7.3	Low	0.0	S	631.37
DDSD_S19.out	19	7.3	Low	0.0	S	2646.28
DDSD_S20.out	20	7.3	Low	0.0	1.6	2805.98
DDSD_S21.out	21	6.1	High	7.5	S	72.80
DDSD_S22.out	22	6.1	High	7.5	S	333.42
DDSD_S23.out	23	6.1	High	7.5	S	725.23
DDSD_S24.out	24	6.1	High	7.5	S	3032.20
DDSD_S25.out	25	6.1	High	7.5	S	4438.49
DDSD_S26.out	26	6.1	Low	0.0	S	54.47
DDSD_S27.out	27	6.1	Low	0.0	0.4	334.11
DDSD_S28.out	28	6.1	Low	0.0	S	763.33
DDSD_S29.out	29	6.1	Low	0.0	S	3037.49
DDSD_S30.out	30	6.1	Low	0.0	1.8	3067.94
DDSD_S31.out	31	5.2	High	7.5	S	79.85
DDSD_S32.out	32	5.2	High	7.5	0.3	368.94
DDSD_S33.out	33	5.2	High	7.5	S	837.25
DDSD_S34.out	34	5.2	High	7.5	S	3471.96
DDSD_S35.out	35	5.2	High	7.5	S	5112.21
DDSD_S36.out	36	5.2	Low	0.0	S	58.65
DDSD_S37.out	37	5.2	Low	0.0	6.26	393.32
DDSD_S38.out	38	5.2	Low	0.0	6.11	826.03
DDSD_S39.out	39	5.2	Low	0.0	6.42	3600.82
DDSD_S40.out	40	5.2	Low	0.0	4.30	3341.69

4.3.5 Critical Case Runs and Effective Dilution

For a given diffuser configuration, and given effluent flow rates and density, the critical or reasonable worst case condition for the ambient parameters is that condition that results in the lowest initial dilution. The critical environmental conditions used for the critical case runs presented below include:

- For a surfacing plume the minimum depth over the discharge (all other variables being equal) will result in the minimum dilution. All of the simulations discussed in this study are run at MLLW, which is a good representation of minimum depth.
- For a surfacing plume the maximum density in the receiving water will be the critical condition. For a trapped plume, which generally results in a lower dilution than a surfacing plume for similar conditions of other parameters, the strongest stratification results in the critical condition. As mentioned above, the USGS data was searched for the maximum and minimum density and the strongest stratification resulting in the lowest overall dilution. These conditions were used in the critical case simulations.
- The critical ambient current is the lowest current expected. As previously discussed the conventional and accepted approach for a tidal system is to use the 10-percentile level. Both the 10-percentile and the 1-percentile levels are used for the critical case runs. The lower levels are considered extremely conservative.

The lowest current and the minimum depth do not necessarily occur at the same time. In fact, at the study site the minimum elevation occurs closer in time to maximum currents than minimum currents. Therefore, using minimum depths and currents at the same time is a conservative approach. Similarly, the maximum density and often the maximum stratification occur at high water. Again using a combination of the minimum depth and the maximum density or stratification is overly conservative.

The results of the critical condition simulations for each diffuser, for a range of flows, are shown in Tables D.4-7 and D.4-8 for the DEC and the DDSD outfalls, respectively. These flows correspond to the scenarios described above. Both the 1-percentile and 10-percentile currents are considered. The maximum stratification is the most critical condition. This level of stratification was only measured once during the entire time of data availability (10 years). Tables D.4-7 and D.4-8 also list the corresponding effective dilution, calculated as previously described. The effective dilution is based on the minimum background concentration of 323:1. The effective of this level of background on initial dilution is shown in Figure D.4-13.

Table D.4-7
Initial and Effective Initial Dilution – Critical Case Simulations for the DEC Outfall Diffuser

Outfall	Flow (mgd)	Ambient Current	Density Profile	Trapping Level (m) (Notes 1 & 2)	Initial Dilution	Effective Dilution
DEC	2.1	1 percentile	Max Stratification	6.36	56.06	47.77
			Max Density	4.92	115.13	84.87
			Min Density	S	> 157.57 & < 302.26	>105.91 & < 156.14
DEC	2.1	10 percentile	Max Stratification	6.75	85.01	67.30
			Max Density	6.33	120.9	87.97
			Min Density	S	> 347.96 & < 675.46	> 167.51 & < 218.51

Note: 1. Trapping levels are expressed as depth below surface.
2. S = Plume has surfaced

Table D.4-8
Initial and Effective Initial Dilution – Critical Case Simulations for the DDSD Outfall Diffuser

Outfall	Flow (mgd)	Ambient Current	Density Profile	Trapping Level (m) (Notes 1 & 2)	Initial Dilution	Effective Dilution
DDSD	5.2	1 percentile	Max Stratification	5.52	35.74	32.18
			Max Density	3.91	139.6	97.47
			Min Density	S	> 207.65 & < 397.45	>126.40 & < 178.19
DDSD	7.3	1 percentile	Max Stratification	5.50	34.42	31.11
			Max Density	3.73	122.11	88.61
			Min Density	S	> 76.50 & < 303.3	> 61.85 & <156.42
DDSD	13	1 percentile	Max Stratification	5.46	32.53	29.56
			Max Density	3.41	98.72	75.61
			Min Density	S	> 109.64 & < 201.03	> 81.86 & < 123.91
DDSD	5.2	10 percentile	Max Stratification	5.68	49.19	42.69
			Max Density	4.41	215.97	129.43
			Min Density	S	> 449.88 & < 874.01	> 188.01 & < 235.84
DDSD	7.3	10 percentile	Max Stratification	5.66	47.03	41.06
			Max Density	4.3	187.48	118.62
			Min Density	S	> 338.54 & < 656.15	> 165.30 & < 216.45
DDSD	13	10 percentile	Max Stratification	5.62	43.93	38.67
			Max Density	4.11	148.31	101.64
			Min Density	S	> 214.23 & < 413.32	> 128.80 & < 181.31

Note: 1. Trapping levels are expressed as depth below surface.
2. S = Plume has surfaced

The initial dilutions listed in Tables D.4-7 and D.4-8 above, for the maximum stratification condition, are the dilutions predicted as the plume passes through the trapping level and continues on to maximum height. A starting point for subsequent dilution calculations, not only in terms of dilution (concentration), but also required plume geometric characteristics, is better represented by the plume conditions at maximum rise. These conditions are summarized in Table D.4-9. The plume geometry is shown in elevation view, for the various plumes in the table, in Figure D.4-14.

Table D.4-9
Initial and Effective Initial Dilution – Maximum Stratification Simulations For the DEC and DDSD Outfall Diffusers at Maximum Rise of Plume

Outfall	Flow (mgd)	Ambient Current	Density Profile	Level of Maximum Rise (m) [1]	Initial Dilution At Maximum Rise	Effective Dilution
DEC	2.1	1 percentile	Max Stratification	2.54	78.03	62.85
DDSD	5.2	1 percentile	Max Stratification	0.92	60.09	50.67
DDSD	7.3	1 percentile	Max Stratification	0.95	56.97	48.43
DDSD	13	1 percentile	Max Stratification	1.03	55.16	47.12

[1] Maximum rise levels are expressed as distance from the bottom to plume centerline.

The results of the initial dilution simulations indicate that the discharge scenario with discharge through two outfalls results in a higher overall (flux averaged) dilution then either the existing condition or the return to DDSD with discharge through a single outfall. This is the case for dilution at the trapping level and the maximum plume rise level and is true for both the 1 percentile and 10 percentile ambient currents. The effective initial dilution for each scenario is shown in Table D.4-10 below.

Table D.4-10
Effective Dilution for Flow Scenarios Considered

SCENARIO	DDSD Flow (mgd)	DEC Flow (mgd)	Total Flow (mgd)	Effective Initial Dilution [1]
Dilution at Trapping Level for 1-percentile Ambient Current and Critical Density Profile				
Existing Condition	13	0	13	29.56
DEC Return to DDSD	7.3	0	7.3	31.11
No DEC Return	5.2	2.1	7.3	**36.67**
Dilution at Maximum Rise for 1-percentile Ambient Current and Critical Density Profile				
Existing Condition	13	0	13	47.12
DEC Return to DDSD	7.3	0	7.3	48.43
No DEC Return	5.2	2.1	7.3	**54.17**
Dilution at Trapping Level for 10-percentile Ambient Current and Critical Density Profile				
Existing Condition	13	0	13	38.67
DEC Return to DDSD	7.3	0	7.3	41.06
No DEC Return	5.2	2.1	7.3	**49.77**
Dilution at Maximum Rise for 10-percentile Ambient Current and Critical Density Profile				
Existing Condition	13	0	13	62.86
DEC Return to DDSD	7.3	0	7.3	62.77
No DEC Return	5.2	2.1	7.3	**70.97**

[1] Initial dilution corrected for background of 323:1. Flux averaged for the case of two outfalls.

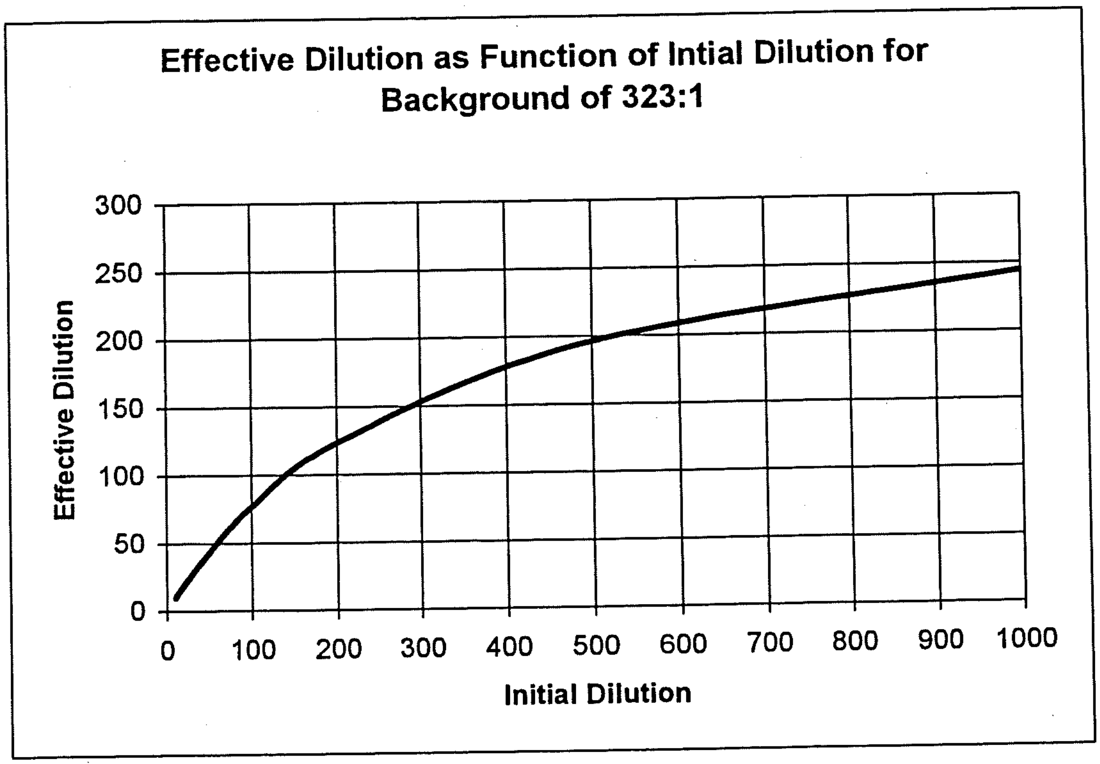


Figure D.4-13
Effect of Background Dilution on Initial Dilution
(Background Dilution = 323:1)

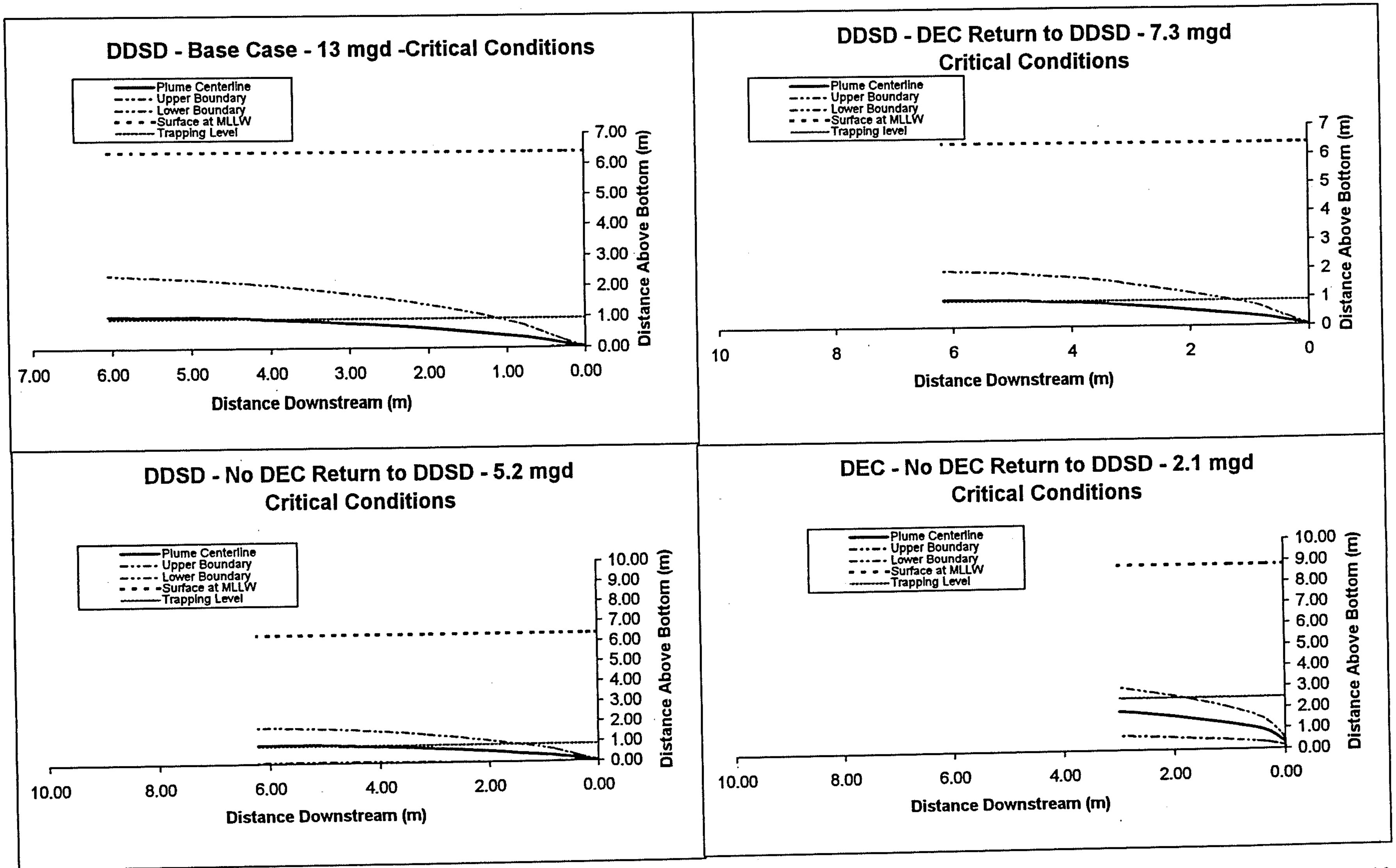


Figure D.4-14

Longitudinal Plume Sections For Initial Dilution

Critical Conditions (1percentile Speed, Maximum Stratification)

The variation of hourly effective initial dilution for the DEC and DDSD outfall diffusers at trapping level for the critical density profile and ambient current of August 1990 tidal hours is shown in Figures D.4-15 and D.4-16. August was chosen as the representative month because the lowest predicted current speed over the tidal cycle was the same as the annual lowest 1 percentile speed (0.19 fps at hour 3, Appendix B, Table B-12). The hourly effective initial dilution is predicted to be within 30 to 90 for all the scenarios. The results also confirm that the discharge scenario with discharge through two outfalls results in higher overall dilution.

The existing run was for an effluent temperature of 25°C (77° F). The temperature range of the effluent is about 60° to 90° F, resulting in the effluent density range to be 0.99905 to 0.99509 g/m3. The variation of effective initial dilution with temperature is shown in Figures D.4-17 and D.4-18. The dilution increases with the increase in temperature (i.e. decrease in effluent density). The results also confirm that the dilution is higher for the scenario with two outfall discharge.

The seasonal increase in receiving water temperature due to effluent mixing is shown in Table D.4-11 for all the scenarios considered. The minimum temperature of receiving water for each season was selected to have the worst case of temperature increase.

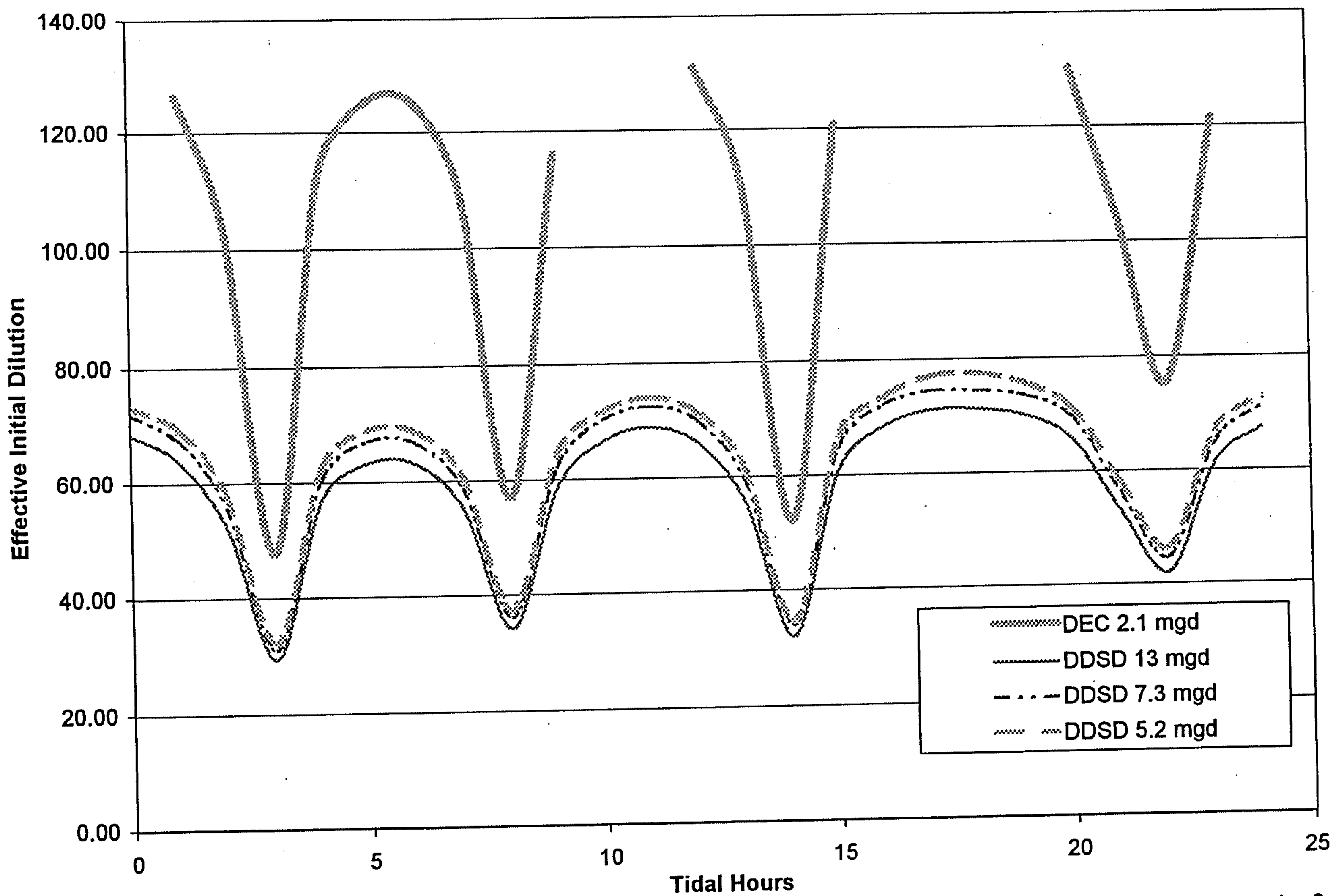
The variation of effective initial dilution with the increase in the DEC outfall discharge and DDSD outfall discharge is shown in Figures D.4-19 and D.4-20 respectively. The results showed that the effective initial dilutions remained more than 26, even for higher outfall discharge from DEC and DDSD. The decrease in the effective dilution appears to be nominal with increase in outfall discharge at the higher end of outfall discharge (> 7 mgd for DEC and > 12 mgd for DDSD).

The seasonal increase in receiving water temperature due to effluent mixing is shown in Table D.4-11 for the "No DEC Return (DEC 2.1 mgd + DDSD 5.2 mgd) scenario. The minimum temperature of receiving water for each season was selected to represent the worst case scenario for temperature increase. The predicted increase in temperature of the receiving water is less than 1° F in almost every case, except for fall and winter for effluent temperatures of 90°F. This case is very unlikely because the effluent temperatures would not be expected to reach 90°F during these seasons. During summer, there is a decrease in receiving water temperature for effluent temperatures up to 70°F. This case is also considered unlikely because the minimum receiving water temperature is expected to be higher during this period.

The variation of effective initial dilution with the increase in the DEC outfall discharge and DDSD outfall discharge is shown in Figures D.4-19 and D.4-20, respectively. The results showed that the effective initial dilution increases with decrease in outfall discharge. The results also showed that the decrease in the effective dilution appears to be nominal with increase in outfall discharge at the higher end of outfall discharge range. In fact, the dilution remained nearly constant for discharge > 7 mgd for DEC and > 12 mgd for DDSD.

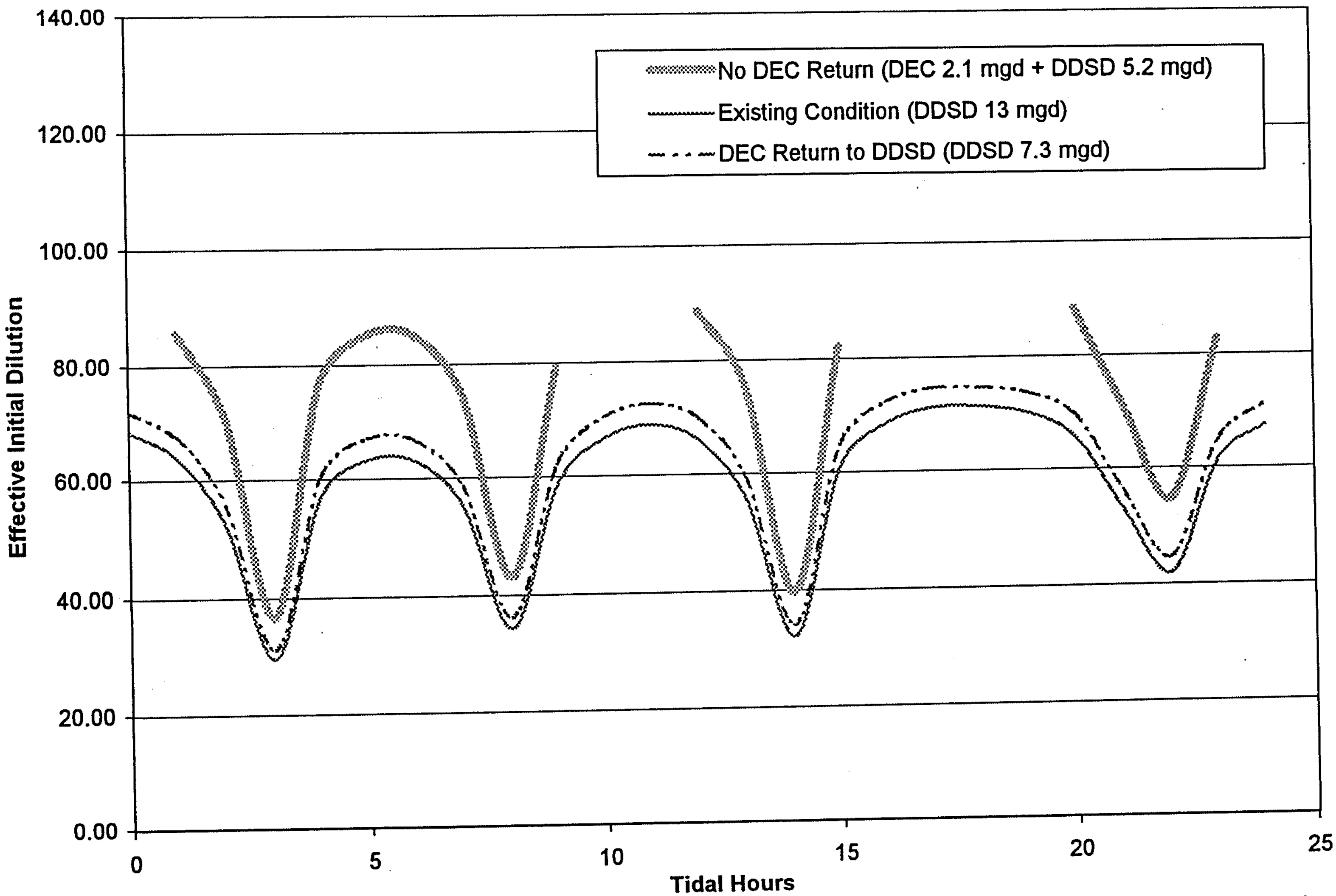
The effect of increase in effluent density on initial and effective dilutions is shown in Table D.4-12. The effective dilutions were computed using effluent density at a salinity

Figure D.4-15. Hourly Efflective Initial Dilution for the DEC and DDSD Outfall Diffusers At Trapping Level for Critical Density Profile for Ambient Current of August 1990 Tidal Hours



Note: Breaks in Effective Initial Dilution for DEC 2.1 mgd are due to UDKHDEN limitation in predicting higher dilution for current > 2.54 fps

Figure D.4-16. Hourly Efflective Initial Dilution for Flow Scenarios Considered At Trapping Level for Critical Density Profile for Ambient Current of August 1990 Tidal Hours



Note: Breaks in Effective Initial Dilution for No DEC Return are due to UDKHDEN limitation in predicting higher dilution for current > 2.54 fps for DEC

Figure D.4-17. Effective Initial Dilution versus Effluent Temperature for the DEC and DDSD Outfall Diffusers At Trapping Level for 1-percentile Ambient Current and Critical Density Profile

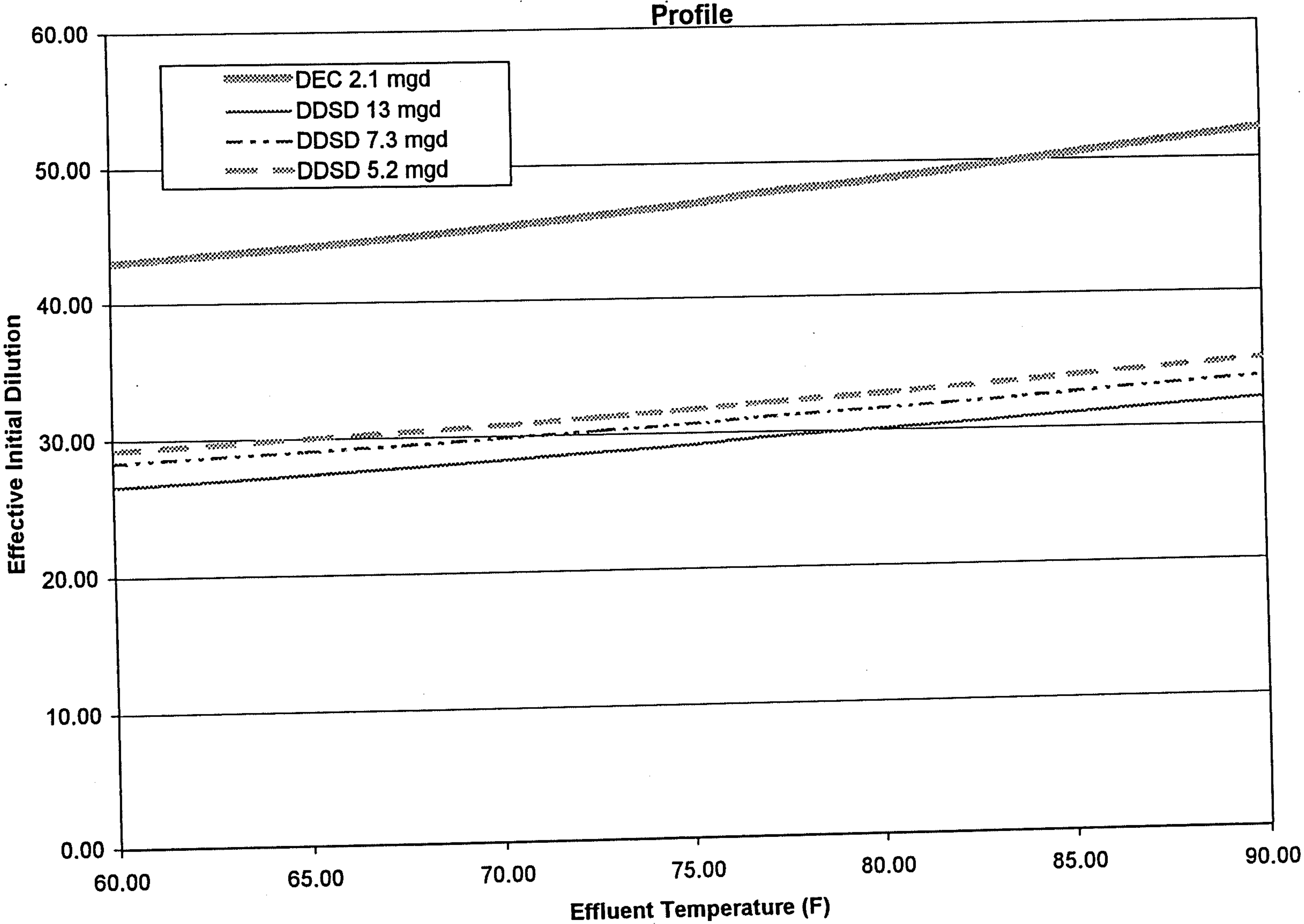


Figure D.4-18. Effective Initial Dilution versus Effluent Temperature for Flow Scenario Considered At Trapping Level for 1-percentile Ambient Current and Critical Density Profile

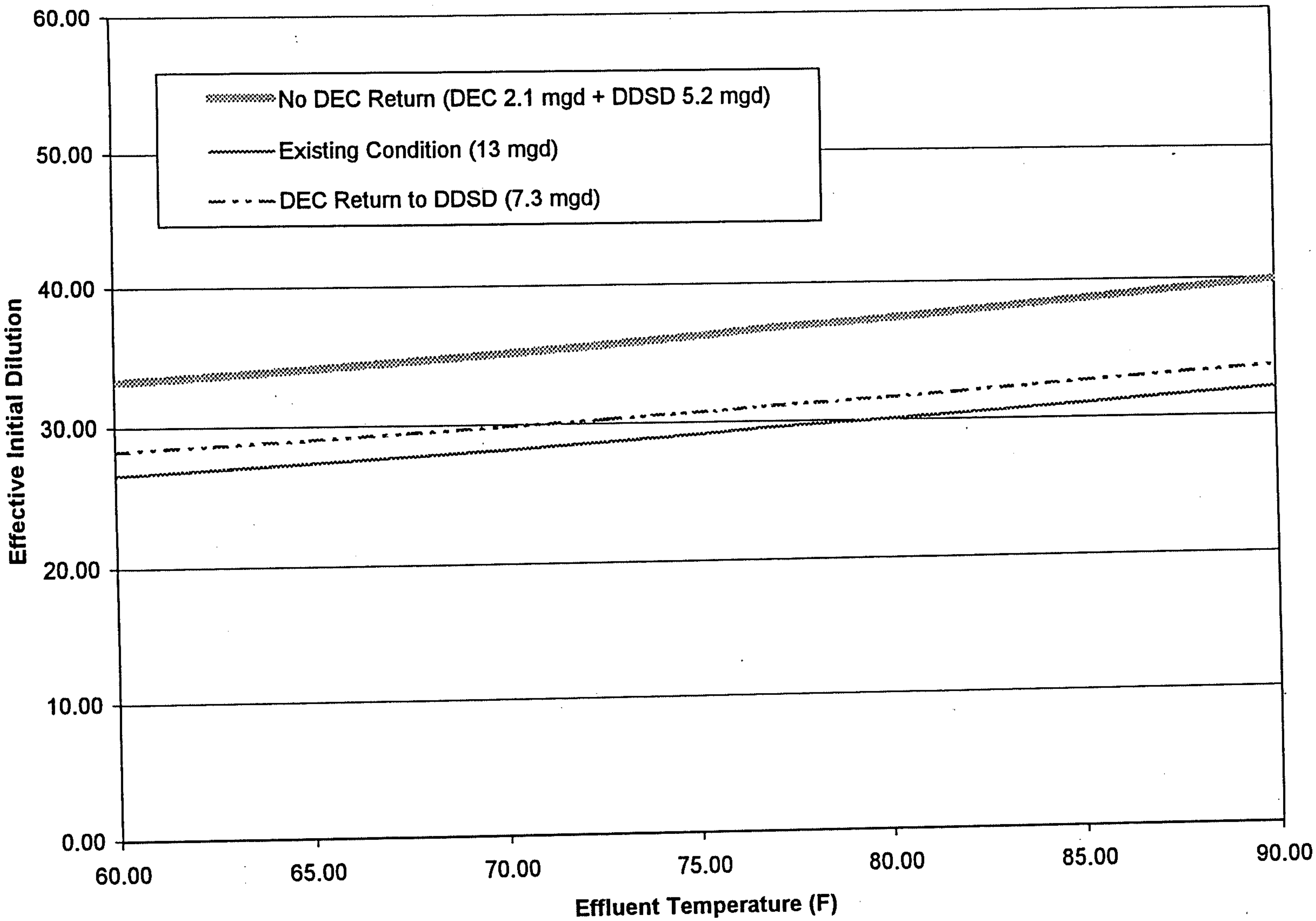


Table D.4-11: Increase in Temperature of Receiving Water due to Effluent Mixing

Scenario - No DEC Return (DEC 2.1 mgd + DDSD 5.2 mgd)

Season	Minimum Temperature of Receiving Water (F)	Effluent Temperature (F)							
		60	65	70	75	77	80	85	90
		Efflective Initial Dilution - No DEC Return (DEC 2.1 mgd + DDSD 5.2 mgd)							
		33.18	34.05	35.03	36.11	36.67	37.29	38.58	39.93
		Increase in Temperature of Receiving Water (F)							
Fall (October - December)	47.3	0.37	0.51	0.63	0.75	0.79	0.85	0.95	1.04
Winter (January - March)	47.1	0.38	0.51	0.64	0.75	0.79	0.86	0.96	1.05
Spring (April - June)	59.4	0.02	0.16	0.30	0.42	0.47	0.54	0.65	0.75
Summer (July - September)	70.2	-0.30	-0.15	0.00	0.13	0.18	0.26	0.37	0.48

Note: Negative value indicates the decrease in the temperature of receiving water due to effluent mixing.

1% ambient current was used in the analysis.

Figure D.4-19. Effective Initial Dilution Versus the DEC Outfall Discharge At Trapping Level for Critical Density Profile

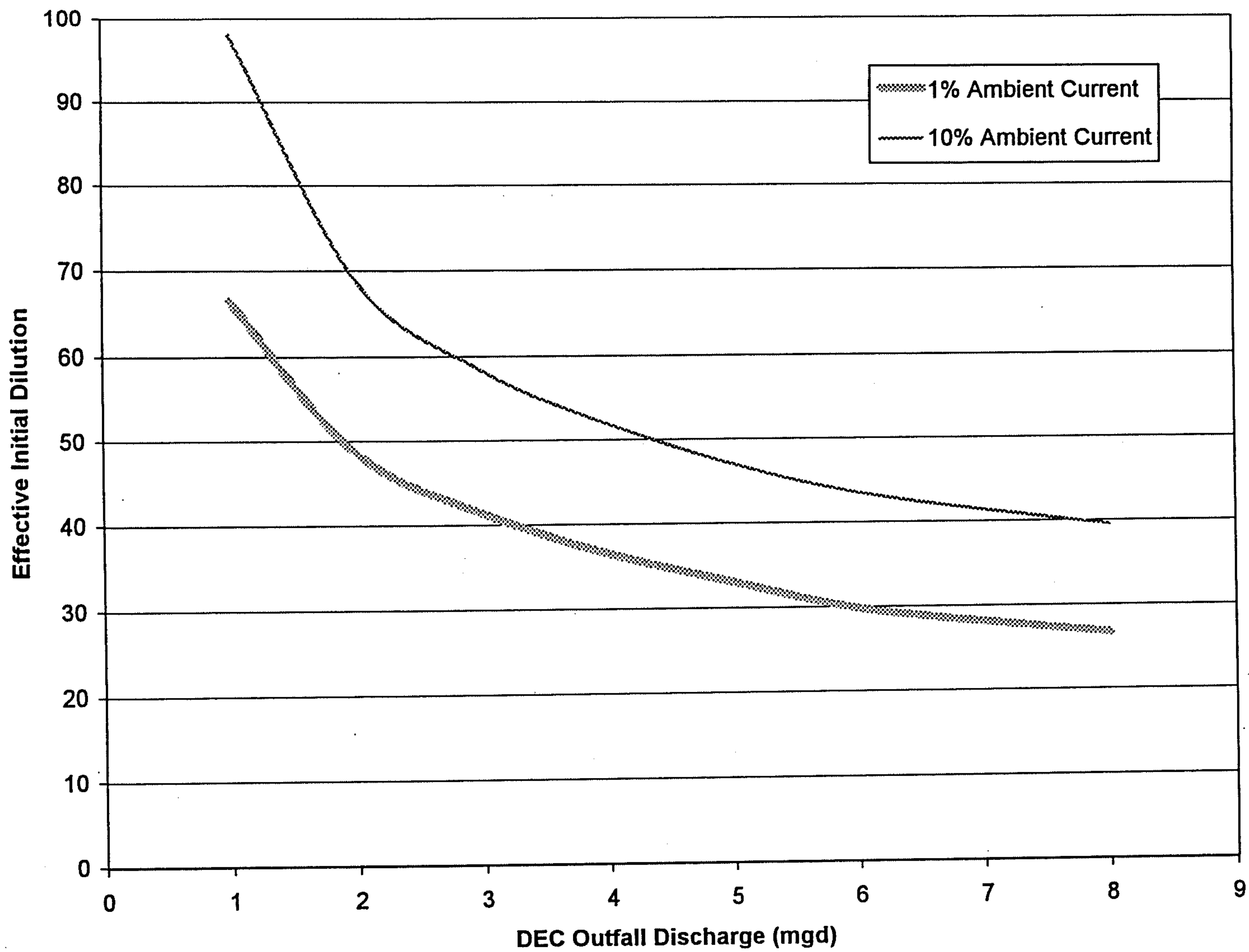


Figure D.4-20. Effective Initial Dilution Versus the DDSD Outfall Discharge
At Trapping Level for Critical Density Profile

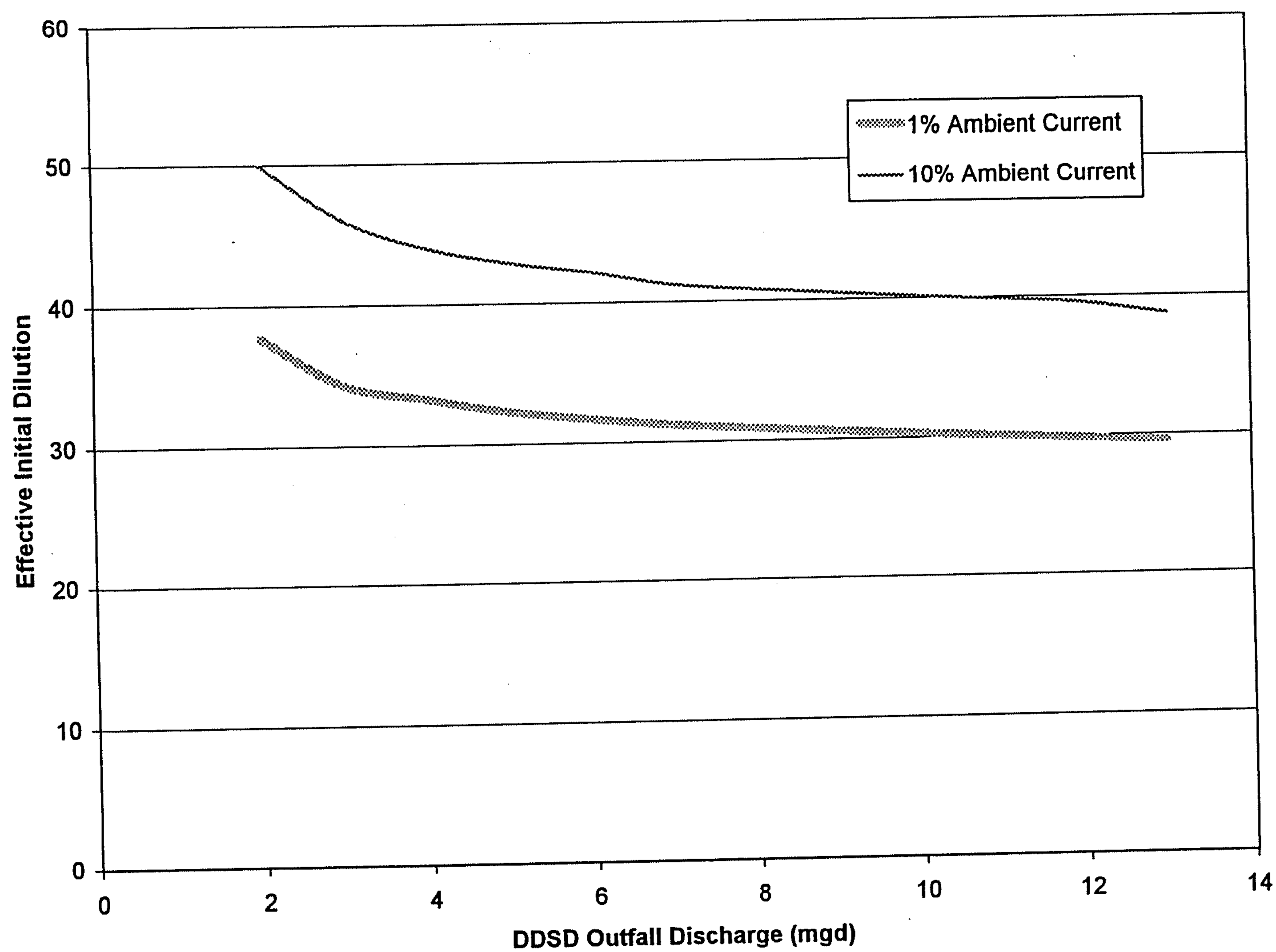


Table D.4-12: Effect of Effluent Density on Dilutions

Temperature (°C)	Salinity (ppt)	Density (g/cm3)	Initial Dilution at Trapping Level	Effective Initial Dilution at Trapping Level	Decrease in Dilution with respect to Salinity of 0.1 ppt (%)
Scenario - Existing Condition (DDSD 13 mgd)					
25.00	0.10	0.9971	32.53	29.56	-
25.00	1.00	0.9979	31.21	28.46	3.70%
25.00	3.50	0.9997	27.48	25.33	14.31%
Scenario - DEC Return to DDSD (DDSD 7.3 mgd)					
25.00	0.10	0.9971	34.42	31.11	-
25.00	1.00	0.9979	33.18	30.09	3.27%
25.00	3.50	0.9997	29.68	27.19	12.61%
Scenario - No DEC Return (DEC 2.1 mgd + DDSD 5.2 mgd)					
25.00	0.10	0.9971	41.17	36.52	-
25.00	1.00	0.9979	39.87	35.49	2.81%
25.00	3.50	0.9997	35.46	31.96	12.50%
Note: 1% ambient current was used in the analysis					

concentration of 0.1 parts per thousand (ppt) . When the effluent density is increased to a salinity concentration of 1 ppt, the effective dilutions were decreased by 2 to 4% compared to the dilutions at 0.1 ppt salinity. When the effluent density is increased to a salinity concentration of 3.5 ppt, the effective dilutions were decreased by 12 to 15% of the dilutions at 0.1 ppt salinity. The effective initial dilutions are predicted to be higher than 25 for all the scenarios with the effluent density of at a salinity concentration of 3.5 ppt.

4.4 Subsequent Dilution

Following the establishment of a fully developed plume in which all of the rapid initial dilution and subsequent transition processes are complete, a farfield passive diffusion model may be required to carry the plume to points of interest, or assess the potential effects of plume overlaps for adjacent discharges. Three farfield modeling approaches were considered: the lateral spreading approach initially developed by Brooks (1959), a modified Brooks approach that permits consideration of vertical diffusion, and a three dimensional transport model that could account for time varying currents.

Considering the time scales involved and the scope of the project a fully three dimensional model is probably not required. The DSM2 model discussed above provides the information needed from such a model. However, vertical diffusion may be a significant effect for the plume to be considered and the conventional Brooks approach, which ignores vertical diffusion, may be overly conservative. Riverine applications of the Brooks approach often assume immediate complete vertical mixing that may be overly optimistic. It may be most appropriate to employ a variety of the simplified approaches. The range of available approaches and the rationale for selecting those used is described below. The results of subsequent dilution calculations are then presented.

4.4.1 Subsequent Dilution Model Selection and Description

Subsequent to the initial dilution, and potential transition region mixing, the plume buoyancy (density) and momentum (velocity) are in equilibrium with the surrounding ambient water. Additional mixing and spreading of the plume will occur as passive diffusion driven by the turbulent diffusion processes within the ambient water mass. The plume will be trapped on the surface or at depth. The vertical diffusion is much smaller than horizontal, but the area normal to the vertical direction is much larger than for the horizontal, and vertical diffusion may be important. Therefore, the farfield approach may need to incorporate three-dimensional capabilities, or at least account for three-dimensional effects.

There is a wide range of model types, and available models, for assessing farfield or subsequent mixing processes. For application to unbounded systems there are two common approaches: simplified solutions to lateral spreading of plumes advected by ambient currents, and two and three-dimensional advective-diffusive numerical models. As described above the DSM2 model provides most of the information required, and only an analysis of the processes of farfield dilution occurring while the plume is still an identifiable water mass is required. Using the modified Brooks Method is no more difficult than using the original method, since a spread sheet application incorporating both has been developed. This approach is essentially identical in physical basis and results as the USEPA subsequent dilution models CDIFF and RDIFF. The original Brooks Method and the modification of the Brooks Method that adds vertical diffusion to the calculation, and a more generic discussion of advective–diffusive approach are briefly presented below.

4.4.1.1 The Brooks Method

Typically, the method of Brooks (1959) is used to develop dilution predictions in the farfield, usually at the mixing zone boundary. This approach is included as a linked module in the PLUMES and CORMIX family of models. However, because UDKHDEN provides nearfield dilution estimates only, dilution predictions at the mixing zone boundary must be developed using a subsequent (farfield) dilution model.

As a stand alone model, the Brooks' farfield dilution algorithms are contained within an Excel 5.0 workbook entitled "FARFIELD.XLS", which was developed by Greg Pelletier at the Washington State Department of Ecology's Environmental Investigations/Laboratory Services (EILS). This workbook is useful for estimating dilution of a discharge beyond the range of nearfield (initial) dilution models such as UDKHDEN. The Brooks' model is applied in the workbook using the algorithm of EPA's PLUMES model (Baumgartner et al., 1994) and with the addition of a linear diffusivity algorithm as described by Grace (1978). The method is also available as a stand alone application in the RDIFF/CDIFF models developed by John Yearsley at EPA Region 10 (Yearsley, 1989).

The Brooks method specifies the intensity of lateral diffusion by application of a diffusion coefficient. This coefficient is held constant, or scaled by a length scale of the plume width, or by the 4/3 power of this length. The latter (the 4/3 power law) is generally applied to systems that are not influenced by lateral boundaries. As in any diffusion model, the specification of the diffusion coefficient is the most difficult aspect of applying the method. This coefficient can range over many orders of magnitude for different systems and environmental conditions. Since it is difficult to determine and justify an appropriate value for the coefficient, extremely conservative values are often used. During the model selection process, the selection and justification of site specific diffusion coefficients for the Brooks method, or similar values for the models described below, must be considered.

4.4.1.2 Modified Brooks Method

One of the limitations of the Brooks Method is that only lateral dispersion is considered. For a continuous source plume being carried by an ambient current, neglecting longitudinal dispersion is not usually expected to have a substantial effect on predictions. For a plume that is much wider in the lateral direction than thicker in the vertical direction, neglecting vertical diffusion may result in needlessly conservative results. For small plumes this is not a concern since the vertical diffusion is typically one or two orders of magnitude smaller than horizontal diffusion. However, if the plume is much wider than its thickness, resulting in a large surface area for vertical diffusion, the vertical mixing may be as important as in the lateral direction. It should be noted that in narrow channels and streams the vertical mixing can be quite rapid at sufficiently high current speeds, and the process of vertical diffusion can be ignored with almost complete vertical mixing being assumed. In a tidal channel such as New York Slough, both extremes of vertical mixing (negligibly slow and nearly instantaneous) can occur at different times in the tidal cycle.

A model like RDIFF can be formulated and executed to simulate nearly instantaneous vertical mixing, or can be run with vertically mixing entirely suppresses. RDIFF and similar models can not simulate the intermediate condition of non-negligible but fairly slow vertical mixing. A modification of the Brooks Method to include vertical diffusion was developed during an assessment of the effects of open ocean waste disposal (EPA, 1989). This formulation has been incorporated into an Excel spreadsheet application by CH2M HILL and applied to the disposal of waste in the open ocean. The formulation, consistent with the Brooks method, assumes a line source of constant strength. The model accounts for vertical diffusion by applying a non-dimensional concentration reduction factor based on a Fickian diffusion coefficient (K_v). The basic model formulation is given by a dimensionless expression of the form:

$$\frac{C_{\max}}{C_o} = \frac{H/4}{\sqrt{2K_v t + \frac{H^2}{16}}}\, erf\left[\sqrt{\frac{1.5}{\left(1+\frac{8At}{L^{(2/3)}}\right)^3 - 1}}\right]$$

where C_{max}/C_0 is the ratio of the centerline plume concentration to the initial concentration, L is a plume width parameter, A is a horizontal dissipation coefficient equal to the horizontal turbulent diffusion coefficient (ε) divided by $L^{4/3}$ with units of $[L]^{2/3}/[t]$, *erf* indicates the error function, H is the initial vertical plume dimension defined as the vertical extent of the plume at the starting point of the plume, with H/4 as the distance from the surface to the point of C_{max}, and is a vertical dimension used to account for the effect of vertical diffusion in the farfield model. Travel time along the plume trajectory is represented by t. The equation above without the leading factor on the right hand side (that is, keeping only the erf term) is the expression of the Brooks method. The multiplier factor is essentially applied to the calculated centerline concentration $(C_{max})_{CL}$ predicted by the Brooks equation to obtain an adjusted value $(C_{max})_{ADJ\text{-}CL}$ accounting for vertical diffusion as:

$$(C_{max})_{ADJ\text{-}CL} = (C_{max})_{CL} \cdot \{(H/4) / (2 \cdot K_v \cdot t + H^2/16)^{0.5}\}$$

Both the lateral diffusion coefficient (ε) and the vertical diffusion coefficient (K_v) must be selected appropriately.

4.4.1.3 Advective-Diffusive Numerical Transport Models

Even with the addition of the vertical diffusion capability to the Brooks method, the simplifications inherent in the development of the equations may still result in conservative (under prediction of dilution) results. There are a plethora of finite element and finite difference advective-diffusive two-dimensional and three-dimensional transport models that have been developed in recent years. Most of these models are relatively cumbersome and require extensive input development. EPA's model WASP5 is one example that was considered (EPA, 1993). For application to the case considered here many of these models are overly complex. Since the time and space scales under consideration are both limited, current specification can be taken as gradually varied, and ambient currents can reasonably be held constant for the simulation. CH2M HILL recently developed a relatively simple transport model that was considered for application if the Brooks method appeared overly conservative during the detailed model selection process (EPA, 1997). This model was initially developed for sediment transport and deposition, but is equally applicable to dissolved phase transport as described below.

The CH2M HILL-developed model is a three dimensional model that accounts for transport in a set of layered horizontal rectangular grids, or three-dimensional cells. The number and size of the grids and the number and depth of the layers is user selected. The model calculates the transport into and out of each model cell at user selected time increments for a specified length of time. The time step is input (not internally calculated) and must be chosen based on the size of the model cells and the various water flows. Constituents can be divided into a user-selected number of classes and each class is transported and accounted for individually. For the application to this study only one class, effluent would be required. Each cell is treated essentially as a completely stirred tank reactor with value of suspended or dissolved concentration updated after each time step.

The transport mechanisms included in the model are as follows:

- Advective transport includes: transport by ambient currents in all three coordinate directions, transport by horizontal currents related to the inflow plume (as determined by a nearfield plume model described above)
- Diffusive transport includes: transport by turbulent diffusion in all three coordinate directions based on user specified eddy diffusivities

Advection is calculated essentially using an explicit difference scheme where each coordinate direction is considered separately in the form:

$$\left.\frac{\delta c}{\delta t}\right|_{advection} = u \cdot \frac{\delta c}{\delta x} \qquad (1)$$

where

c = concentration

t = time

u = velocity in the x direction

The finite difference formulation for advection accounts for the spatial variability in velocity and the velocity fields are mapped at the center of each cell (for the application considered here, currents would be constant). Therefore each cell requires application of a set of six difference equations and velocities at the cell edges are calculated at each time step as averages of the cell-centered values.

The velocities used in the advective calculation include ambient speeds and plume induced speeds, if applicable. Ambient velocities can be managed, based on user selection, in a variety of ways that include:

- A constant velocity field (constant in space and time, with the ability to specify different x, y, and z components)

- A spatially varying field of time invariant velocities
- A time varying field of spatially constant velocities, for which time interpolation is conducted and the time history repeats for as many cycles as required
- A sinusoidal periodic spatially constant field can be input with a specified phase lag between the two horizontal components
- A time and space varying field of tabular values can be input (and the program will interpolate for each cell at each time step) for specific points in the model grid

The plume velocities can originate from any cell, and multiple cells, within the model but, as currently configured must initially be normal to the vertical cell wall. The induced velocities are then calculated based on radial spreading at an angle specified by the user. For application to the case considered here the angular spreading would be defined by the plume geometry at the end of initial dilution. The input flow rate is specified as an input parameter. The induced velocities are then calculated based on conservation of mass at each cell center at the level at which the flow is introduced (horizontal spreading only is currently implemented).

Diffusive transport is calculated for each coordinate direction separately in the form:

$$\left.\frac{\delta c}{\delta t}\right|_{diffusion} = D_x \cdot \frac{\delta^2 c}{\delta x^2} \qquad (4)$$

where

> D_x = a user specified diffusivity in the x coordinate direction, and other terms are as defined above.

Discharge inputs into the model grid can take place through any vertical cell boundary within the model grid, as mentioned above. The input of discharge is specified as a boundary condition with total volume flow and concentration of each class (if required) through the appropriate number of cell boundaries. Flows and concentrations are allowed to vary from cell to cell if input is through more than one cell. The flows are assumed to be normal to the cell boundary, as the model is presently implemented. This may require rotation of the model grid to align with the discharge source. The input could be easily generalized to non-normal cases in the future, if required.

Boundaries can be closed or open. If open, any material that is transported through the boundary is lost from the model system. Although this sounds undesirable, it may be the best choice for most boundaries. The approach is to make the model grid large enough to capture the contour of importance (for example, predict the 1000:1 dilution contour) and to keep the loss of mass from the system to an acceptable level (for example, account for 99-percent of the mass discharged). In the case of invariant current fields, as considered for this application, only the former condition is important and the use of open boundaries poses no problems.

Although the model formulation is somewhat simplistic, all of the important processes are included in a fashion that is physically consistent and realistic. The model has been constructed with subroutines for each of the important elements to allow easy modification or revision when and if required or desired. As with all other farfield approaches, the definition of realistic and justifiable diffusion coefficients is the major challenge, particularly since the value for the coefficients may be influenced by the cell size and total model grid size selected. The ability to select appropriate coefficients was considered during the model selection for this study.

4.4.1.4 Subsequent Dilution Model Selection

The modified model based on Brooks' approach (EPA, 1989) allows the potential vertical diffusion to be accounted for and provides all of the information required, when combined with the output from the DSM2 model. This approach will invariably result in conservative predictions (under-predict dilution). If the result appears overly conservative, a model such as RDIFF can be applied to the same case allowing complete vertical mixing. The procedure will generate a range of dilutions, which can be expected to contain the actual value.

Although a more realistic result will be obtained from a more sophisticated model, such as an advective-diffusive transport model, the application of such a model is only appropriate if the simpler approach indicates problematic dilution characteristics in the farfield. As illustrated in the above discussion, the application of a more sophisticated model requires considerably more information and complex hydrodynamic specification than is available. If the simpler models yield results that are acceptable, and understanding that these results are conservative (under-predict dilution), then there is no practical need for more elaborate models.

The selection of diffusivity coefficients, both vertical and horizontal, is a consideration for any farfield model and need to be carefully reviewed. Published values, known to be conservative, were applied in this study. The values used are those commonly used and accepted for regulatory purposes. For example, the horizontal dispersion coefficient of 1.07 ft^2/sec (Brooks, 1959) was used for simulations reported below. Vertical mixing was included in some cases for comparison.

In the case of subsequent dilution, the dilution almost always decreases at a specified distance as the ambient current increases. This is because the smaller travel time more than compensates for any increase in diffusion rate. Therefore, the 50 percentile current is generally taken to be representative, rather than the 1 or 10 percentile current. Combining the initial dilution predicted using the low (1 percentile) current and the subsequent dilution predicted using the high current (50 percentile) is unrealistic, but yields conservative values of dilution, and is an approach often used.

4.4.2 Subsequent Dilution for DDSD Discharge

The plume from the DDSD discharge (for any of the cased considered) is predicted to hit the southern shoreline of New York Slough approximately 2,500 to 5,000 feet downstream of the discharge under average conditions (the 50 percentile current speed). It is not predicted to hit the northern shoreline within New York Slough.

The farfield dilution at a distance approximately 25,000 feet downstream of the discharge, on the southern shoreline, is predicted to be approximately 2:1 with no vertical mixing. Applying this number directly to the starting effective dilution of 48:1 for the (Table 14, 1 percentile flow, critical density profile, 7.3 mgd flow) gives a shoreline dilution of about 96:1 at a location on the shoreline representative of Mallard Island. Accounting for vertical mixing increases this number to about 263:1. This means that the effect of recent discharges, at this distance from the outfall, will not be discernable from the long-term background levels described above.

The value of 96:1 is a very conservative number because of the nature of the model used. It is also conservative since it was derived assuming the background dilution was the same everywhere. In the downstream direction, the background dilution increases with distance from the discharge and is approximately a minimum of 1.5 times the value at the discharge point at a distance of 25000 feet downstream. Thus, the 96:1 estimate of shoreline dilution should be considered a conservative lower limit. However, it is a useful number to compare to the results of other cases.

Regardless of the conservative approach and assumptions employed, the dilutions for the reduced flow, no return scenario slightly higher than for the existing discharge. In the farfield, the reduced flow, with return flow to DDSD, scenario is the same as the reduced flow no return to DDSD case. The two sources a few hundred feet apart will appear as a single source at a large distance. The effects closer to the discharge of two outfalls is described below.

4.4.3 Subsequent Dilution for DEC Discharge

The plume from the DEC discharge is, just as for the DDSD outfall described above, predicted to hit the southern shoreline of New York Slough approximately 2500 to 5000 feet downstream of the discharge under average conditions (the 50 percentile current speed). It is not predicted to hit the northern shoreline within New York Slough.

For the scenario where the DEC and DDSD outfalls are both discharging, the potential effect of plume overlap is of concern. The two outfalls are approximately 360 feet apart. The initial dilution processes are complete within about 10 to 30 feet (to the point of maximum rise for the critical conditions described above). The subsequent dilution model indicates that there is very little additional dilution prior to plume overlap, and there is little plume spreading. The most conservative approach is to assume no subsequent dilution prior to plume overlap.

When the two plumes mix the process is essentially Fickian passive diffusion ("two-way mixing") with equal exchange, a rather than the entrainment ("one-way mixing") process characterizing the initial dilution processes. Therefore the lowest possible dilution, using an effective dilution basis to account for background, resulting from the two plumes completely mixing is calculated as follows for the 1 percentile, critical case with both outfalls discharging:

$$\frac{(Q_{DDSD} + Q_{DEC})}{\left[\frac{Q_{DDSD}}{S_{DDSD}} + \frac{Q_{DEC}}{S_{DEC}}\right]} = 54:1$$

where Q represents flows and S represents effective dilutions at maximum height of rise. This dilution is compared to the dilution for discharge only through the DDSD outfall at a total flow of 7.3 mgd, which is 48:1. Thus, it can be concluded that, not only is the flux average dilution higher for the case of two outfall operation, but even accounting for with plume overlap, the dilution is better for two outfalls.

A more realistic calculation would be to examine the trajectories of each plume and base the mixing on the portions that overlap. The DEC plume is smaller, and only overlaps the portion of the DDSD plume that is closer to shore. Thus, the DEC plume mixes with the edge of the DDSD plume. The subsequent dilution model indicates that the portion of the DDSD plume that is overlapped has a dilution of approximately twice the plume average. Thus, the dilution in the overlapped portion would be somewhat higher than calculated above (approximately 86:1). The above calculations are presented assuming no vertical mixing to compare the various cases. In reality, there would be vertical mixing between the two discharges that would substantially increase the dilution of the individual and overlapped plumes.

4.4.4 Dilutions and Plume Trajectory in the Extreme Farfield

At the downstream end of New York Slough the discharge plume is virtually indistinguishable from the receiving water. The fate and transport path of the discharge plume in this area, characterized as extreme farfield, is essentially the same as the water leaving New York Slough. To investigate the downstream behavior, the water exiting the Slough was treated as a surface plume discharge into Suisun Bay. The surface plume model PDS was used to evaluate the subsequent behavior of this plume.

PDS was run for two representative downstream flows (from New York Slough) and currents (ebb tidal current in Suisun Bay): a low flow, low current condition representative of the beginning or end of ebb, and a high flow, high current representative of the strength of ebb. Appropriate flows and currents were estimated using the DSM2 results. The results were similar for both cases. About 10,000 feet downstream of the confluence of the Bay and Slough, approximately at Mallard Island on the southern shore, PDS predicts that the plume (New Your Slough discharge) extends from the shoreline to about 60 percent of the way across the Bay. For the low flow, low current case the centerline of the plume is predicted to be about 500 feet offshore and the plume is trapped along the shoreline. For the high flow, high current case the center of the plume is predicted to be about 700 feet offshore and the edge of the plume is just along the shoreline.

The similarity of the two cases is not unexpected. During low flow periods the discharge from the Slough does not penetrate into the Bay very far before being deflected downstream by the current. In the case of high flow, the higher currents available to deflect the discharge plume downstream offset the potential of the plume penetrating further into the Bay. The overall result is a remarkable similar plume trajectory and geometry for both cases. The dilutions of the plumes, as predicted by the PDS model, are also quite similar and are in the range of 9:1 to 10:1. However, since the discharge has already been diluted to nearly the background level, the additional dilution in this reach has little effect on concentrations of effluent. Also, as indicated above, the nature of the discharge source, one or two outfalls, has no effect on the results in the extreme farfield.

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Table A-1

	Density (sigma-t in kg/m³) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station											
Depth (meters)	05/03/88	05/26/88	06/23/88	07/07/88	07/21/88	08/04/88	08/18/88	09/01/88	09/15/88	10/06/88	11/02/88	11/30/88
1	0.72	0.10	0.39	0.45	1.58	1.35	1.76	3.68	3.64	1.62	3.95	1.27
2	0.79	0.11	0.39	0.66	1.58	1.35	2.19	3.69	3.64	1.63	3.79	1.30
3	1.10	0.13	0.41	0.88	1.61	1.40	2.33	3.70	3.64	1.67	3.95	1.41
4	1.14	0.22	0.43	0.93	1.71	1.39	2.39	3.69	3.67	1.72	4.21	1.51
5	1.16	0.28	0.62	0.97	1.94	1.41	2.52	3.70	3.69	1.79	4.58	1.70
6	1.21	0.45	0.90	1.10	2.06	1.44	2.64	3.71	3.71	1.87	5.29	1.97
7	1.28	0.61	0.96	1.23	2.10	1.44	2.74	3.71	3.72	2.03	5.54	2.16
8	1.28	0.70	1.06	1.37	2.11	1.44	2.81	3.72	3.72	2.09	5.63	2.36
9	1.36	0.85	1.31	1.45	2.12	1.44	2.81	3.73	3.72	2.13	5.71	2.62
10	1.38	0.95	1.45	1.54	2.16	1.44	2.81	3.72	3.72	2.17	5.83	2.74
11	1.40	0.96	1.94	1.60	2.25	1.44	2.81	3.72	3.73	2.30	5.90	2.85
12	1.43	0.96	2.01	1.72		1.44	2.81		3.73	2.46	5.96	2.94
13	1.43											3.06
14												3.25
15												

Table A-2

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	01/31/89	02/28/89	03/21/89	04/12/89	05/10/89	06/14/89	07/11/89	08/09/89	10/04/89	12/12/89	02/27/90	04/18/90
1	3.21	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.89	2.66	0.06
2	3.25	01/02/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/06/00	01/02/00	01/00/00
3	3.32	01/02/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/00/00	01/06/00	01/02/00	01/00/00
4	3.44	2.34	0.00	0.00	0.00	0.00	0.00	0.00	0.22	6.65	2.73	0.09
5	3.54	2.49	0.00	0.00	0.00	0.00	0.00	0.00	0.38	6.73	2.73	0.25
6	3.76	2.66	0.00	0.00	0.00	0.00	0.00	0.00	0.67	6.75	2.74	0.41
7	4.01	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.80	6.86	2.73	0.44
8	4.20	2.88	0.00	0.00	0.00	0.00	0.07	0.00	0.96	6.93	2.73	0.54
9	4.24	2.97	0.00	0.00	0.00	0.00	0.15		1.18	7.09	2.73	0.58
10	4.28	3.28	0.00	0.00	0.00	0.00	0.21		1.32	7.24	2.73	0.59
11	4.29	3.49	0.00			0.00	0.29		1.62	7.31	2.74	0.60
12			0.00			0.00	0.48		1.80	7.32		0.67
13			0.00			0.00	0.68		1.88	7.33		0.76
14												
15												

Table A-3

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	05/30/90	06/28/90	07/30/90	08/22/90	12/06/90	01/07/91	02/06/91	03/11/91	04/11/91	05/08/91	06/05/91	08/01/91
1	0.00	0.00	0.95	0.00	3.63	3.33	2.93	0.09	0.00	1.58	0.40	0.44
2	0.00	01/00/00	01/00/00	01/00/00	01/03/00	01/03/00	01/03/00	01/00/00	01/00/00	01/01/00	01/00/00	01/00/00
3	0.00	01/00/00	01/00/00	01/00/00	01/03/00	01/03/00	01/03/00	01/00/00	01/00/00	01/01/00	01/00/00	01/00/00
4	0.00	0.00	1.00	0.00	4.05	3.50	3.23	0.13	0.00	1.72	0.55	0.40
5	0.00	0.00	1.02	0.00	4.34	3.53	3.31	0.13	0.00	1.73	0.54	0.46
6	0.00	0.00	1.04	0.00	4.62	3.58	3.43	0.13	0.00	1.76	0.58	0.55
7	0.00	0.00	1.10	0.00	4.87	3.77	3.49	0.14	0.00	1.78	0.55	0.61
8	0.00	0.00	1.16	0.00	4.97	3.88	3.57	0.14	0.00	1.79	0.54	0.68
9	0.00	0.00	1.24	0.00	5.04	3.93	3.69	0.14	0.00	1.80		0.80
10	0.00	0.00	1.49	0.00	5.08	3.96	3.77	0.14		1.81		
11	0.00	0.00	1.69	0.00	5.11	3.98	3.88	0.15				
12	0.00		1.73	0.00	5.12							
13			1.91		5.14							
14					5.17							
15					5.17							

Table A-4

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	05/03/88	05/26/88	06/23/88	07/07/88	07/21/88	08/04/88	08/18/88	09/01/88	09/15/88	10/06/88	11/02/88	11/30/88
1	0.72	0.10	0.39	0.45	1.58	1.35	1.76	3.68	3.64	1.62	3.95	1.27
2	0.79	0.11	0.39	0.66	1.58	1.35	2.19	3.69	3.64	1.63	3.79	1.30
3	1.10	0.13	0.41	0.88	1.61	1.40	2.33	3.70	3.64	1.67	3.95	1.41
4	1.14	0.22	0.43	0.93	1.71	1.39	2.39	3.69	3.67	1.72	4.21	1.51
5	1.16	0.28	0.62	0.97	1.94	1.41	2.52	3.70	3.69	1.79	4.58	1.70
6	1.21	0.45	0.90	1.10	2.06	1.44	2.64	3.71	3.71	1.87	5.29	1.97
7	1.28	0.61	0.96	1.23	2.10	1.44	2.74	3.71	3.72	2.03	5.54	2.16
8	1.28	0.70	1.06	1.37	2.11	1.44	2.81	3.72	3.72	2.09	5.63	2.36
9	1.36	0.85	1.31	1.45	2.12	1.44	2.81	3.73	3.72	2.13	5.71	2.62
10	1.38	0.95	1.45	1.54	2.16	1.44	2.81	3.72	3.72	2.17	5.83	2.74
11	1.40	0.96	1.94	1.60	2.25	1.44	2.81	3.72	3.73	2.30	5.90	2.85
12	1.43	0.96	2.01	1.72		1.44	2.81		3.73	2.46	5.96	2.94
13	1.43											3.06
14												3.25
15												

Table A-5

Depth (meters)	09/29/92	11/04/92	12/02/92	01/27/93	02/24/93	03/31/93	04/15/93	05/12/93	06/15/93	07/13/93	08/10/93	09/08/93
	Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station											
1	4.78	4.09	3.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	4.76	4.30	3.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	4.78	4.51	4.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	4.91	4.63	4.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5.08	4.67	4.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5.32	4.72	5.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	5.50	4.78	5.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	5.74	4.91	5.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	5.83	4.94	5.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	5.84	5.01	5.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	5.84	5.02	5.60	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
12	5.84	5.03	5.67	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
13	5.84		5.71	0.00	0.00	0.00			0.00	0.00	0.00	
14	5.83			0.00	0.00						0.00	
15												

Table A-6

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	10/06/93	11/08/93	12/07/93	01/18/94	02/16/94	03/16/94	04/19/94	05/17/94	06/15/94	07/28/94	08/30/94	09/27/94
1	0.49	1.13	2.47	0.62	0.00	0.00	0.00	0.00	0.21	0.33	1.30	0.89
2	0.48	1.26	2.56	0.67	0.00	0.00	0.00	0.00	0.21	0.33	1.39	0.89
3	0.47	1.40	2.60	0.73	0.00	0.00	0.00	0.00	0.22	0.33	1.77	0.90
4	0.47	1.53	2.61	0.81	0.00	0.00	0.00	0.00	0.21	0.45	1.88	1.21
5	0.68	1.69	2.67	0.86	0.00	0.00	0.00	0.00	0.22	0.63	1.93	1.77
6	1.00	1.85	2.83	0.96	0.00	0.00	0.00	0.00	0.24	0.73	2.01	1.87
7	1.18	2.03	3.06	1.11	0.00	0.00	0.00	0.00	0.25	0.76	2.25	2.12
8	1.28	2.27	3.19	1.33	0.00	0.00	0.00	0.00	0.28	0.76		2.61
9	1.43	2.43	3.34	1.44	0.00	0.00	0.00	0.00	0.29	0.76		
10	1.58	2.51	3.38	1.74	0.00	0.00	0.00	0.00	0.29	0.76		
11	1.65	2.54		1.92	0.00	0.00		0.00	0.29			
12	1.75				0.00							
13					0.00							
14												
15												

Table A-7

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	10/26/94	11/29/94	01/18/95	02/07/95	03/07/95	04/04/95	04/18/95	05/02/95	06/13/95	07/18/95	08/16/95	09/21/95
1	3.05	3.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2	3.30	3.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	3.60	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3.71	3.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4.09	3.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	4.34	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	4.44	3.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	4.59	4.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	5.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	5.49	4.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	5.55		0.00	0.00	0.00	0.00		0.00	0.00	0.00		0.00
12	5.59											
13												
14												
15												

Table A-8

Density (sigma-t in kg/m^3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station

Depth (meters)	10/23/95	01/11/96	02/06/96	03/06/96	04/03/96	05/01/96	06/12/96	07/17/96	08/13/96	09/11/96	10/16/96	11/13/96
1	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	4.87
2	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	4.85
3	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	4.88
4	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	5.06
5	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41	5.16
6	1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.63	5.32
7	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.96	5.79
8	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.27	5.95
9	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	5.95
10	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35	5.96
11	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36	5.96
12		0.00	0.00	0.00		0.00		0.00		0.00		5.95
13				0.00		0.00		0.00		0.00		5.94
14								0.00		0.00		5.94
15								0.00				

Table A-9

Depth (meters)	Density (sigma-t in kg/m3) Calculated From Salinity and Temperature by USGS as Measured at Pittsburg Station										
	12/17/96	01/28/97	02/26/97	04/01/97	04/22/97	05/14/97	06/10/97	07/15/97	08/05/97	09/09/97	10/07/97
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.71
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.91
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.17
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.19
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.19
10	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	3.20
11	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	3.20
12	0.00	0.00	0.00	0.00	0.00			0.00	0.00		
13		0.00	0.00		0.00				0.00		
14		0.00	0.00								
15											

Table B-1. October WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.47	-82,962.34	-2.76	2.76	0	0
1	2.51	-65,590.35	-2.18	2.18	-8892	8892
2	2.25	-35,127.97	-1.18	1.18	-14940	23832
3	1.67	7,009.72	0.23	0.23	-16650	40482
4	1.07	45,726.36	1.59	1.59	-13374	53856
5	0.72	61,093.42	2.15	2.15	-6642	60498
6	0.5	59,460.72	2.1	2.1	1008	61506
7	0.66	37,454.88	1.32	1.32	7164	68670
8	1.5	-12,828.57	-0.44	0.44	8748	77418
9	2.19	-52,794.21	-1.77	1.77	4770	82188
10	2.84	-78,521.18	-2.59	2.59	-3078	85266
11	3.44	-88,692.14	-2.87	2.87	-12906	98172
12	3.68	-77,113.09	-2.48	2.48	-22536	120708
13	3.42	-44,393.67	-1.44	1.44	-29592	150300
14	2.66	8,039.99	0.26	0.26	-31716	182016
15	1.82	56,938.19	1.93	1.93	-27774	209790
16	1.19	79,824.54	2.76	2.76	-19332	229122
17	0.54	87,553.46	3.09	3.09	-8802	237924
18	-0.1	86,548.23	3.12	3.12	2376	240300
19	-0.61	80,136.11	2.94	2.94	13284	253584
20	-0.76	65,580.74	2.42	2.42	22932	276516
21	-0.29	32,563.56	1.18	1.18	29412	305928
22	0.66	-18,335.84	-0.64	0.64	30384	336312
23	1.4	-57,460.72	-1.98	1.98	25668	361980
24	2.02	-79,560.41	-2.69	2.69	17262	379242
24.84	2.47		-2.76		9021.6	388263.6

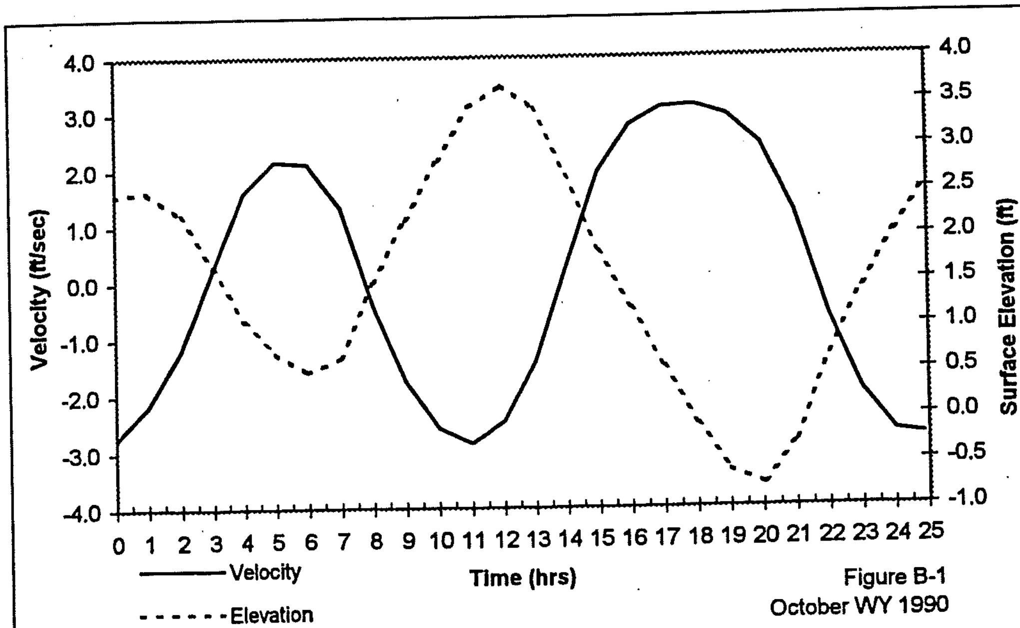

Figure B-1
October WY 1990

Table B-2. November WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.48	-82,832.54	-2.76	2.76	0	0
1	2.51	-65,962.19	-2.19	2.19	-8910	8910
2	2.23	-36,311.12	-1.22	1.22	-15048	23958
3	1.63	4,347.43	0.14	0.14	-16992	40950
4	1.03	42,723.36	1.48	1.48	-14076	55026
5	0.69	59,103.62	2.08	2.08	-7668	62694
6	0.49	58,793.12	2.08	2.08	-180	62874
7	0.68	37,739.61	1.33	1.33	5958	68832
8	1.53	-11,374.68	-0.39	0.39	7650	76482
9	2.21	-51,312.80	-1.72	1.72	3852	80334
10	2.86	-77,586.26	-2.56	2.56	-3852	84186
11	3.46	-88,214.58	-2.86	2.86	-13608	97794
12	3.69	-77,219.25	-2.48	2.48	-23220	121014
13	3.41	-45,121.50	-1.46	1.46	-30312	151326
14	2.63	6,022.83	0.2	0.2	-32580	183906
15	1.8	55,014.44	1.87	1.87	-28854	212760
16	1.17	78,922.10	2.73	2.73	-20574	233334
17	0.54	87,474.06	3.09	3.09	-10098	243432
18	-0.09	87,121.71	3.14	3.14	1116	244548
19	-0.59	80,978.44	2.97	2.97	12114	256662
20	-0.74	66,488.79	2.45	2.45	21870	278532
21	-0.28	33,569.59	1.22	1.22	28476	307008
22	0.67	-17,069.79	-0.6	0.6	29592	336600
23	1.41	-56,512.86	-1.94	1.94	25020	361620
24	2.03	-78,971.13	-2.67	2.67	16722	378342
24.84	2.48		-2.76		8511.84	386853.84

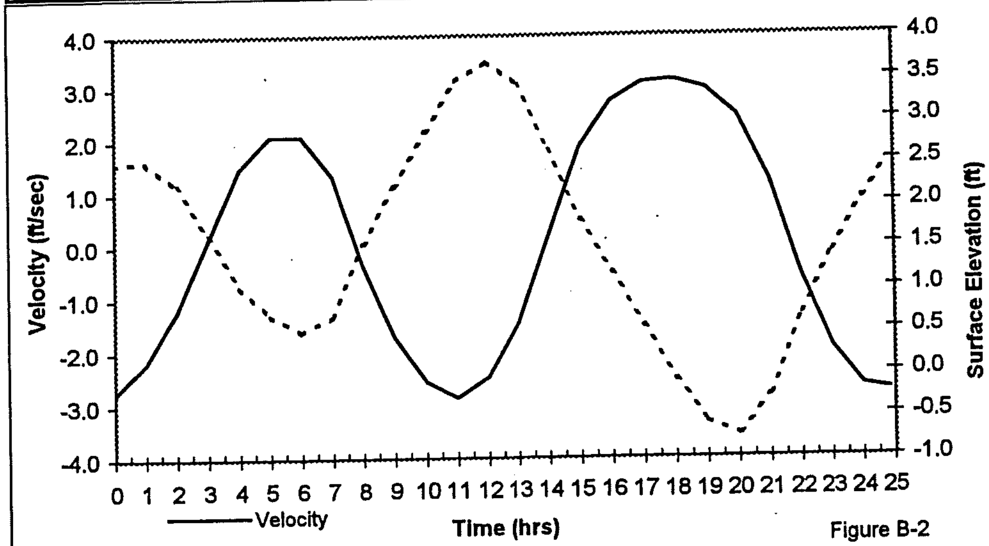

Figure B-2
November WY 1990

Table B-3. December WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.49	-83,379.85	-2.78	2.78	0	0
1	2.54	-66,159.37	-2.2	2.2	-8964	8964
2	2.26	-36,320.38	-1.22	1.22	-15120	24084
3	1.65	4,460.46	0.15	0.15	-17046	41130
4	1.05	42,540.84	1.48	1.48	-14112	55242
5	0.68	58,603.06	2.06	2.06	-7740	62982
6	0.47	57,929.77	2.05	2.05	-342	63324
7	0.65	36,080.50	1.27	1.27	5634	68958
8	1.51	-14,769.30	-0.5	0.5	7020	75978
9	2.17	-54,616.88	-1.83	1.83	2826	78804
10	2.84	-80,036.55	-2.64	2.64	-5220	84024
11	3.46	-89,645.62	-2.9	2.9	-15192	99216
12	3.7	-78,145.13	-2.51	2.51	-24930	124146
13	3.43	-45,884.61	-1.48	1.48	-32112	156258
14	2.65	5,116.18	0.16	0.16	-34488	190746
15	1.8	53,998.27	1.83	1.83	-30906	221652
16	1.16	77,860.18	2.7	2.7	-22752	244404
17	0.52	86,552.90	3.06	3.06	-12384	256788
18	-0.11	86,097.73	3.11	3.11	-1278	258066
19	-0.62	79,622.04	2.92	2.92	9576	267642
20	-0.77	64,697.31	2.38	2.38	19116	286758
21	-0.29	31,322.77	1.13	1.13	25434	312192
22	0.66	-19,579.79	-0.69	0.69	26226	338418
23	1.41	-58,256.02	-2	2	21384	359802
24	2.04	-80,052.58	-2.7	2.7	12924	372726
24.84	2.49		-2.78		4638.24	377364.24

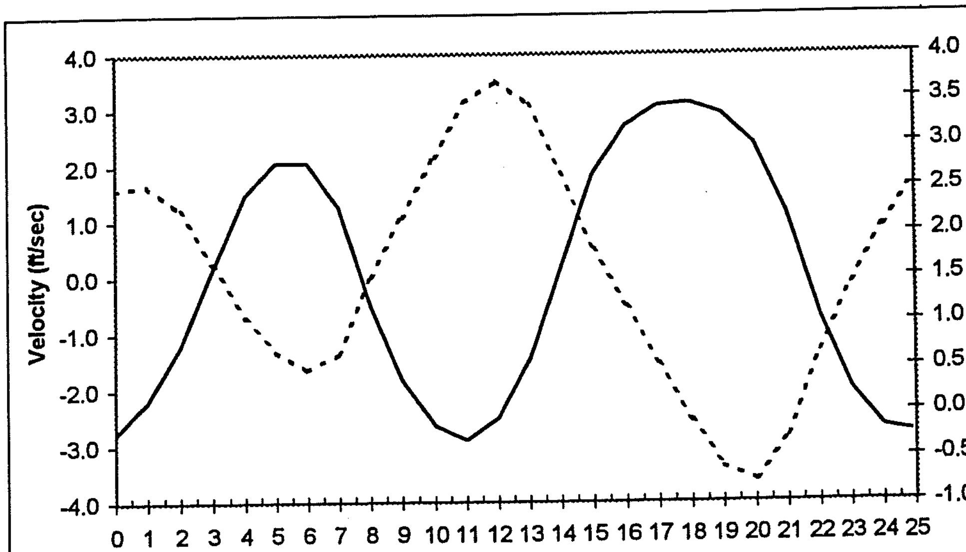

Figure B-3
December WY 1990

Table B-4. January WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.53	-83,613.51	-2.78	2.78	0	0
1	2.57	-66,141.58	-2.2	2.2	-8964	8964
2	2.28	-35,870.21	-1.2	1.2	-15084	24048
3	1.68	4,679.57	0.15	0.15	-16974	41022
4	1.06	42,734.93	1.48	1.48	-14040	55062
5	0.68	58,581.20	2.06	2.06	-7668	62730
6	0.47	57,857.65	2.05	2.05	-270	63000
7	0.66	35,693.43	1.25	1.25	5670	68670
8	1.5	-15,627.66	-0.53	0.53	6966	75636
9	2.16	-55,689.80	-1.87	1.87	2646	78282
10	2.84	-81,208.04	-2.68	2.68	-5544	83826
11	3.47	-90,831.53	-2.94	2.94	-15660	99486
12	3.71	-79,141.22	-2.54	2.54	-25524	125010
13	3.44	-46,813.99	-1.51	1.51	-32814	157824
14	2.67	4,106.36	0.13	0.13	-35298	193122
15	1.81	53,447.70	1.81	1.81	-31806	224928
16	1.16	77,536.19	2.69	2.69	-23706	248634
17	0.52	86,480.02	3.06	3.06	-13356	261990
18	-0.11	85,996.49	3.1	3.1	-2268	264258
19	-0.61	79,369.10	2.91	2.91	8550	272808
20	-0.77	64,329.84	2.37	2.37	18054	290862
21	-0.29	30,838.16	1.12	1.12	24336	315198
22	0.67	-20,509.64	-0.72	0.72	25056	340254
23	1.41	-58,891.86	-2.02	2.02	20124	360378
24	2.05	-80,444.07	-2.71	2.71	11610	371988
24.84	2.53		-2.78		3309.12	375297.12

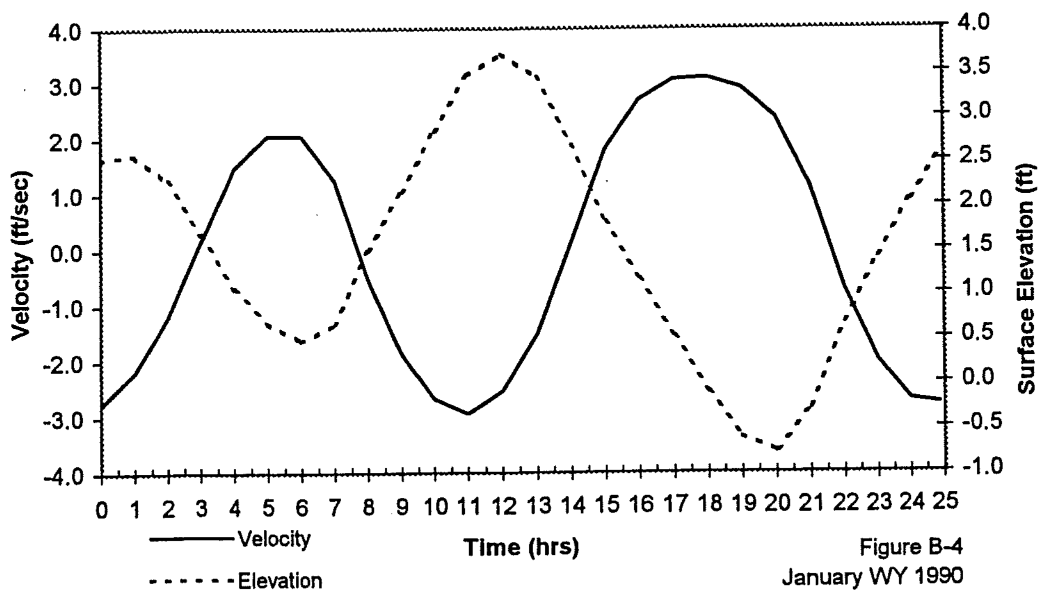

Figure B-4
January WY 1990

Table B-5. February WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.52	-82,338.97	-2.74	2.74	0	0
1	2.56	-65,077.63	-2.16	2.16	-8820	8820
2	2.27	-34,885.99	-1.17	1.17	-14814	23634
3	1.68	6,175.94	0.21	0.21	-16542	40176
4	1.08	44,454.42	1.54	1.54	-13392	53568
5	0.71	60,248.96	2.12	2.12	-6804	60372
6	0.5	59,475.78	2.1	2.1	792	61164
7	0.68	37,944.27	1.33	1.33	6966	68130
8	1.53	-11,978.50	-0.41	0.41	8622	76752
9	2.21	-52,074.53	-1.75	1.75	4734	81486
10	2.87	-77,965.92	-2.57	2.57	-3042	84528
11	3.49	-88,392.15	-2.86	2.86	-12816	97344
12	3.72	-77,059.88	-2.48	2.48	-22428	119772
13	3.45	-44,559.08	-1.44	1.44	-29484	149256
14	2.67	7,008.84	0.23	0.23	-31662	180918
15	1.83	55,569.97	1.89	1.89	-27846	208764
16	1.2	79,096.55	2.74	2.74	-19512	228276
17	0.55	87,527.97	3.09	3.09	-9018	237294
18	-0.08	87,020.85	3.14	3.14	2196	239490
19	-0.58	80,695.19	2.96	2.96	13176	252666
20	-0.73	66,115.78	2.43	2.43	22878	275544
21	-0.27	33,423.26	1.21	1.21	29430	304974
22	0.69	-16,941.41	-0.59	0.59	30546	335520
23	1.44	-56,118.94	-1.93	1.93	26010	361530
24	2.06	-78,477.03	-2.65	2.65	17766	379296
24.84	2.52		-2.74		9616.32	388912.32

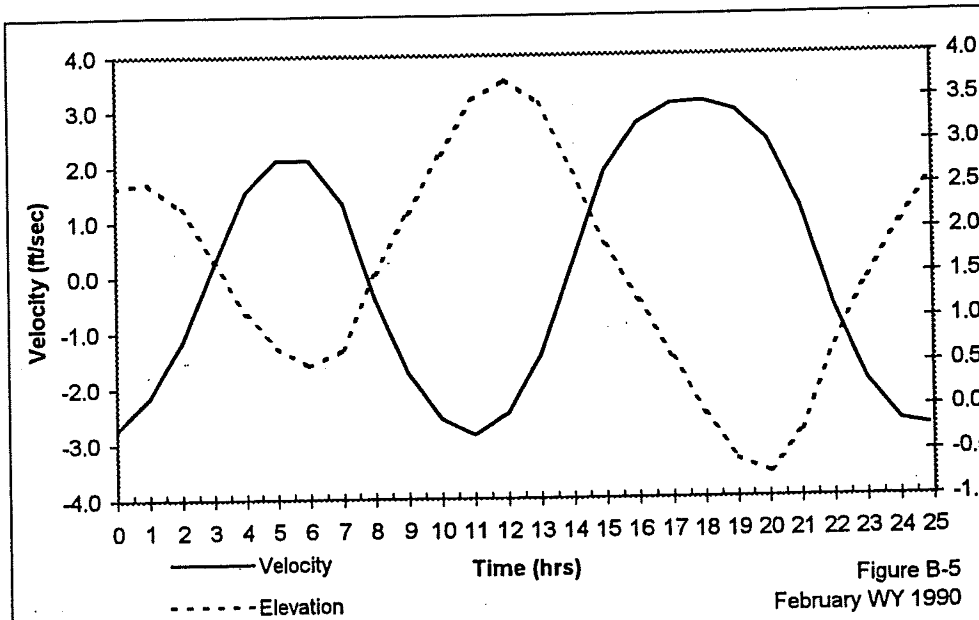

Figure B-5
February WY 1990

Table B-6. March WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.5	-82,259.41	-2.74	2.74	0	0
1	2.54	-65,149.67	-2.16	2.16	-8820	8820
2	2.26	-35,177.86	-1.18	1.18	-14832	23652
3	1.66	5,937.68	0.2	0.2	-16596	40248
4	1.07	44,082.17	1.53	1.53	-13482	53730
5	0.71	60,138.05	2.11	2.11	-6930	60660
6	0.5	59,413.87	2.1	2.1	648	61308
7	0.67	38,035.30	1.34	1.34	6840	68148
8	1.53	-11,647.84	-0.39	0.39	8550	76698
9	2.21	-51,580.62	-1.73	1.73	4734	81432
10	2.87	-77,659.13	-2.56	2.56	-2988	84420
11	3.48	-88,195.40	-2.85	2.85	-12726	97146
12	3.71	-76,927.49	-2.47	2.47	-22302	119448
13	3.43	-44,574.60	-1.44	1.44	-29340	148788
14	2.66	6,973.81	0.23	0.23	-31518	180306
15	1.82	55,579.13	1.89	1.89	-27702	208008
16	1.19	79,136.74	2.74	2.74	-19368	227376
17	0.55	87,572.15	3.09	3.09	-8874	236250
18	-0.08	87,113.51	3.14	3.14	2340	238590
19	-0.58	80,866.23	2.96	2.96	13320	251910
20	-0.74	66,329.02	2.44	2.44	23040	274950
21	-0.27	33,597.60	1.22	1.22	29628	304578
22	0.68	-16,790.41	-0.59	0.59	30762	335340
23	1.43	-56,049.79	-1.93	1.93	26226	361566
24	2.05	-78,447.53	-2.65	2.65	17982	379548
24.84	2.5		-2.74		9832.32	389380.32

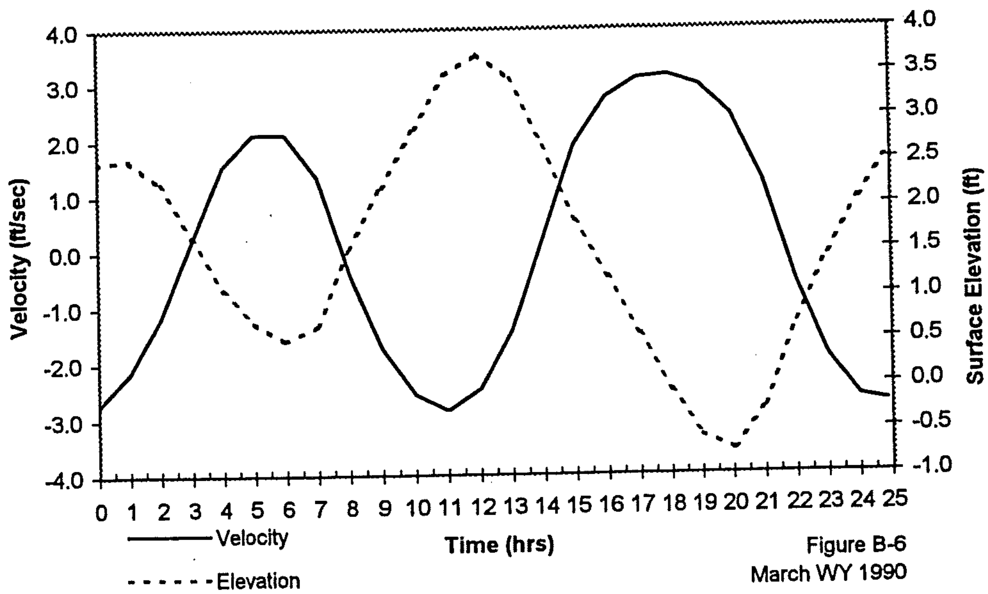

Figure B-6
March WY 1990

Table B-7. April WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.5	-82,045.72	-2.74	2.74	0	0
1	2.53	-65,441.74	-2.17	2.17	-8838	8838
2	2.25	-35,940.47	-1.18	1.18	-14868	23706
3	1.66	4,970.03	0.2	0.2	-16632	40338
4	1.07	43,910.01	1.55	1.55	-13482	53820
5	0.73	60,398.54	2.14	2.14	-6840	60660
6	0.52	60,289.66	2.14	2.14	864	61524
7	0.69	40,190.16	1.39	1.39	7218	68742
8	1.54	-7,555.93	-0.31	0.31	9162	77904
9	2.23	-48,686.53	-1.66	1.66	5616	83520
10	2.87	-75,693.24	-2.53	2.53	-1926	85446
11	3.47	-87,063.91	-2.84	2.84	-11592	97038
12	3.7	-76,831.76	-2.47	2.47	-21150	118188
13	3.43	-45,226.35	-1.44	1.44	-28188	146376
14	2.66	5,821.05	0.24	0.24	-30348	176724
15	1.83	55,183.62	1.91	1.91	-26478	203202
16	1.21	78,889.03	2.76	2.76	-18072	221274
17	0.57	87,253.30	3.12	3.12	-7488	228762
18	-0.06	86,906.18	3.17	3.17	3834	232596
19	-0.56	81,066.76	2.99	2.99	14922	247518
20	-0.72	67,299.55	2.47	2.47	24750	272268
21	-0.27	35,615.00	1.25	1.25	31446	303714
22	0.68	-14,716.90	-0.56	0.56	32688	336402
23	1.43	-54,699.75	-1.91	1.91	28242	364644
24	2.05	-77,376.04	-2.64	2.64	20052	384696
24.84	2.5		-2.74		11917.44	396613.44

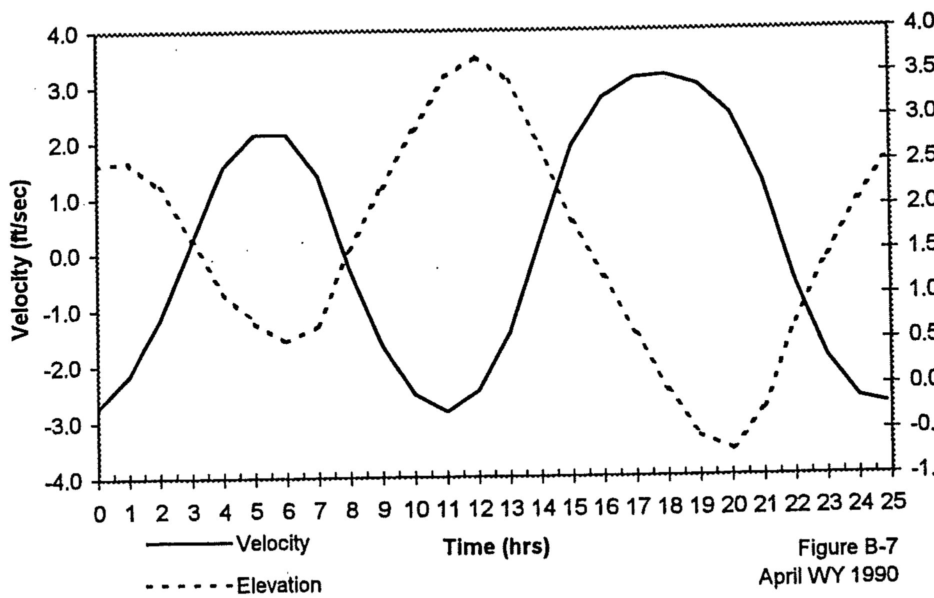

Figure B-7
April WY 1990

Table B-8. April (2) WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.49	-82,100.96	-2.74	2.74	0	0
1	2.54	-65,743.87	-2.18	2.18	-8856	8856
2	2.25	-35,915.41	-1.18	1.18	-14904	23760
3	1.66	5,071.93	0.2	0.2	-16668	40428
4	1.07	43,897.64	1.55	1.55	-13518	53946
5	0.73	60,481.35	2.14	2.14	-6876	60822
6	0.52	60,289.94	2.14	2.14	828	61650
7	0.69	40,126.58	1.39	1.39	7182	68832
8	1.54	-7,800.74	-0.32	0.32	9108	77940
9	2.23	-48,829.26	-1.67	1.67	5526	83466
10	2.87	-75,725.21	-2.53	2.53	-2034	85500
11	3.47	-87,043.80	-2.84	2.84	-11700	97200
12	3.7	-76,787.91	-2.47	2.47	-21258	118458
13	3.43	-45,191.15	-1.44	1.44	-28296	146754
14	2.66	5,990.78	0.24	0.24	-30456	177210
15	1.83	55,464.81	1.92	1.92	-26568	203778
16	1.21	79,072.60	2.77	2.77	-18126	221904
17	0.57	87,309.74	3.12	3.12	-7524	229428
18	-0.06	86,876.07	3.17	3.17	3798	233226
19	-0.56	80,992.44	2.99	2.99	14886	248112
20	-0.72	67,206.04	2.47	2.47	24714	272826
21	-0.27	35,560.70	1.25	1.25	31410	304236
22	0.68	-14,784.42	-0.56	0.56	32652	336888
23	1.43	-54,742.27	-1.91	1.91	28206	365094
24	2.05	-77,419.43	-2.64	2.64	20016	385110
24.84	2.49		-2.74		11881.44	396991.44

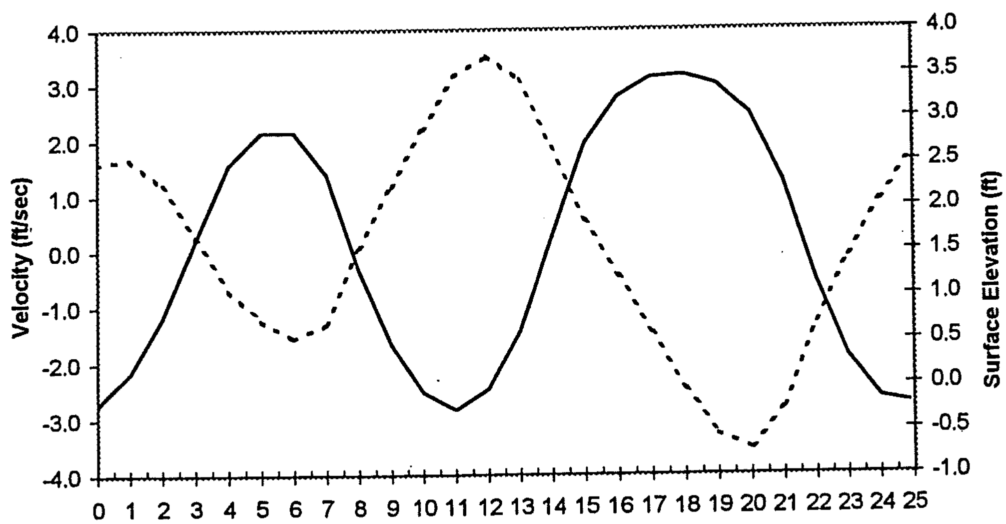

Figure B-8
April (2) WY 1990

Table B-9. May WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.47	-82,208.34	-2.75	2.75	0	0
1	2.51	-65,693.90	-2.18	2.18	-8874	8874
2	2.23	-36,278.98	-1.19	1.19	-14940	23814
3	1.64	4,455.45	0.18	0.18	-16758	40572
4	1.05	43,412.66	1.53	1.53	-13680	54252
5	0.71	60,073.01	2.13	2.13	-7092	61344
6	0.52	59,925.14	2.13	2.13	576	61920
7	0.69	39,926.69	1.38	1.38	6894	68814
8	1.54	-7,866.54	-0.32	0.32	8802	77616
9	2.22	-48,900.69	-1.67	1.67	5220	82836
10	2.86	-75,789.91	-2.53	2.53	-2340	85176
11	3.45	-87,049.24	-2.84	2.84	-12006	97182
12	3.68	-76,867.56	-2.47	2.47	-21564	118746
13	3.41	-45,348.57	-1.45	1.45	-28620	147366
14	2.64	5,579.23	0.23	0.23	-30816	178182
15	1.81	55,112.34	1.91	1.91	-26964	205146
16	1.19	78,905.20	2.77	2.77	-18540	223686
17	0.55	87,151.98	3.12	3.12	-7938	231624
18	-0.08	86,786.28	3.16	3.16	3366	234990
19	-0.57	80,993.20	2.99	2.99	14436	249426
20	-0.73	67,177.44	2.47	2.47	24264	273690
21	-0.28	35,394.72	1.24	1.24	30942	304632
22	0.67	-15,047.53	-0.57	0.57	32148	336780
23	1.42	-55,007.41	-1.92	1.92	27666	364446
24	2.03	-77,612.39	-2.65	2.65	19440	383886
24.84	2.47		-2.75		11275.2	395161.2

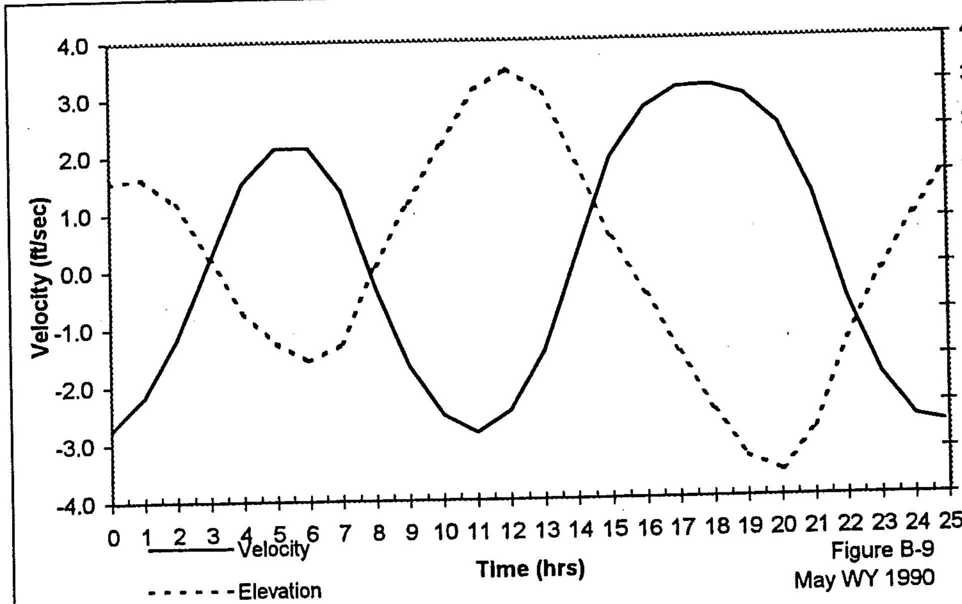

Figure B-9
May WY 1990

Table B-10. June WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.49	-82,874.85	-2.78	2.78	0	0
1	2.54	-67,265.95	-2.23	2.23	-9018	9018
2	2.25	-37,761.72	-1.24	1.24	-15264	24282
3	1.64	2,960.86	0.13	0.13	-17262	41544
4	1.06	42,735.41	1.51	1.51	-14310	55854
5	0.72	60,153.28	2.13	2.13	-7758	63612
6	0.53	60,543.38	2.15	2.15	-54	63666
7	0.71	40,976.84	1.42	1.42	6372	70038
8	1.54	-6,806.52	-0.28	0.28	8424	78462
9	2.25	-49,103.21	-1.68	1.68	4896	83358
10	2.89	-76,342.22	-2.54	2.54	-2700	86058
11	3.47	-87,413.06	-2.85	2.85	-12402	98460
12	3.71	-78,399.06	-2.52	2.52	-22068	120528
13	3.43	-46,606.94	-1.48	1.48	-29268	149796
14	2.64	4,443.45	0.19	0.19	-31590	181386
15	1.83	54,567.71	1.89	1.89	-27846	209232
16	1.21	78,969.39	2.77	2.77	-19458	228690
17	0.57	87,586.90	3.13	3.13	-8838	237528
18	-0.06	87,158.76	3.18	3.18	2520	240048
19	-0.56	81,021.30	2.99	2.99	13626	253674
20	-0.73	66,964.98	2.46	2.46	23436	277110
21	-0.28	35,019.58	1.23	1.23	30078	307188
22	0.68	-15,714.99	-0.6	0.6	31212	338400
23	1.44	-56,013.11	-1.96	1.96	26604	365004
24	2.05	-78,641.29	-2.68	2.68	18252	383256
24.84	2.49		-2.78		9996.48	393252.48

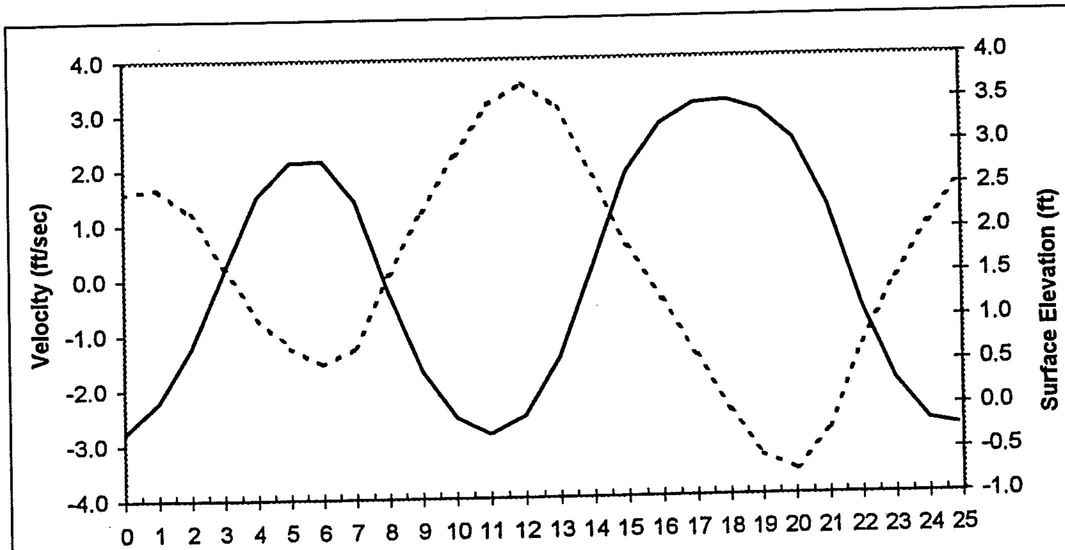

Figure B-10
June WY 1990

Table B-11. July WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.47	-83,031.97	-2.77	2.77	0	0
1	2.52	-66,488.53	-2.21	2.21	-8964	8964
2	2.24	-36,037.14	-1.21	1.21	-15120	24084
3	1.64	6,046.21	0.2	0.2	-16938	41022
4	1.06	45,328.93	1.57	1.57	-13752	54774
5	0.73	61,706.73	2.17	2.17	-7020	61794
6	0.54	60,996.68	2.15	2.15	756	62550
7	0.71	40,050.48	1.41	1.41	7164	69714
8	1.53	-8,908.78	-0.3	0.3	9162	78876
9	2.24	-50,542.58	-1.69	1.69	5580	84456
10	2.88	-77,412.53	-2.55	2.55	-2052	86508
11	3.45	-87,906.72	-2.85	2.85	-11772	98280
12	3.69	-77,806.08	-2.5	2.5	-21402	119682
13	3.42	-44,910.32	-1.45	1.45	-28512	148194
14	2.64	7,750.77	0.25	0.25	-30672	178866
15	1.82	57,275.11	1.94	1.94	-26730	205596
16	1.2	81,240.68	2.81	2.81	-18180	223776
17	0.58	89,347.58	3.15	3.15	-7452	231228
18	-0.05	88,297.48	3.18	3.18	3942	235170
19	-0.57	81,749.65	2.99	2.99	15048	250218
20	-0.74	66,976.37	2.47	2.47	24876	275094
21	-0.29	33,931.85	1.23	1.23	31536	306630
22	0.67	-17,133.60	-0.6	0.6	32670	339300
23	1.43	-57,063.55	-1.96	1.96	28062	367362
24	2.03	-79,404.84	-2.68	2.68	19710	387072
24.84	2.47		-2.77		11469.6	398541.6

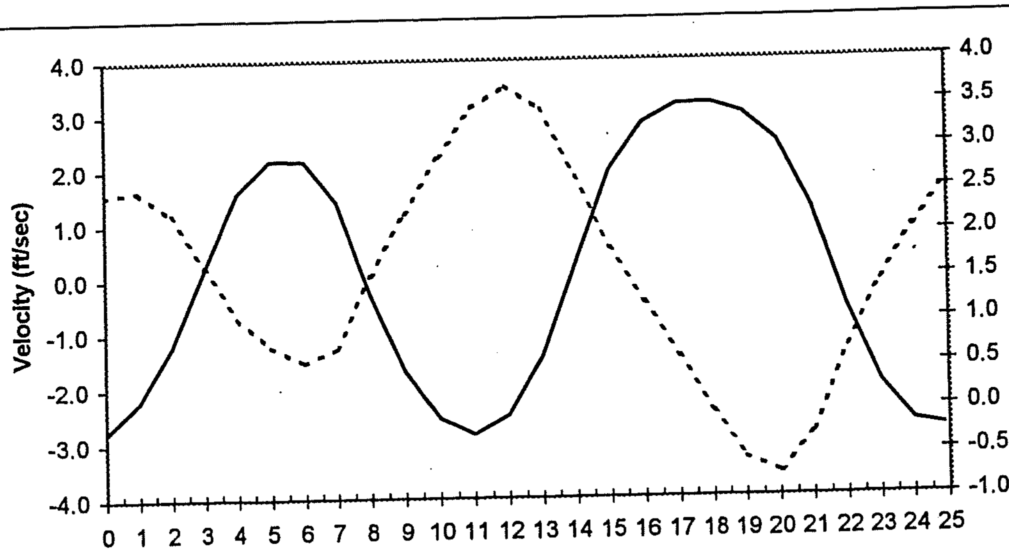

Figure B-11
July WY 1990

Table B-12. August WY 1990 - Predicted Flow and Surface Elevations Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.46	-83,093.54	-2.77	2.77	0	0
1	2.52	-66,643.56	-2.22	2.22	-8982	8982
2	2.23	-36,123.45	-1.21	1.21	-15156	24138
3	1.64	5,731.30	0.19	0.19	-16992	41130
4	1.05	45,018.78	1.56	1.56	-13842	54972
5	0.72	61,518.21	2.16	2.16	-7146	62118
6	0.53	60,799.63	2.15	2.15	612	62730
7	0.7	39,764.57	1.4	1.4	7002	69732
8	1.53	-9,187.09	-0.31	0.31	8964	78696
9	2.24	-50,641.51	-1.7	1.7	5346	84042
10	2.87	-77,444.87	-2.55	2.55	-2304	86346
11	3.45	-87,886.09	-2.85	2.85	-12024	98370
12	3.69	-77,814.61	-2.5	2.5	-21654	120024
13	3.41	-44,926.25	-1.45	1.45	-28764	148788
14	2.64	7,590.40	0.25	0.25	-30924	179712
15	1.81	57,090.11	1.94	1.94	-26982	206694
16	1.2	81,087.48	2.81	2.81	-18432	225126
17	0.57	89,162.90	3.15	3.15	-7704	232830
18	-0.06	88,126.25	3.18	3.18	3690	236520
19	-0.57	81,624.61	2.99	2.99	14796	251316
20	-0.74	66,904.17	2.46	2.46	24606	275922
21	-0.29	33,840.39	1.23	1.23	31248	307170
22	0.67	-17,241.03	-0.6	0.6	32382	339552
23	1.43	-57,154.45	-1.96	1.96	27774	367326
24	2.03	-79,480.47	-2.68	2.68	19422	386748
24.84	2.46		-2.77		11181.6	397929.6

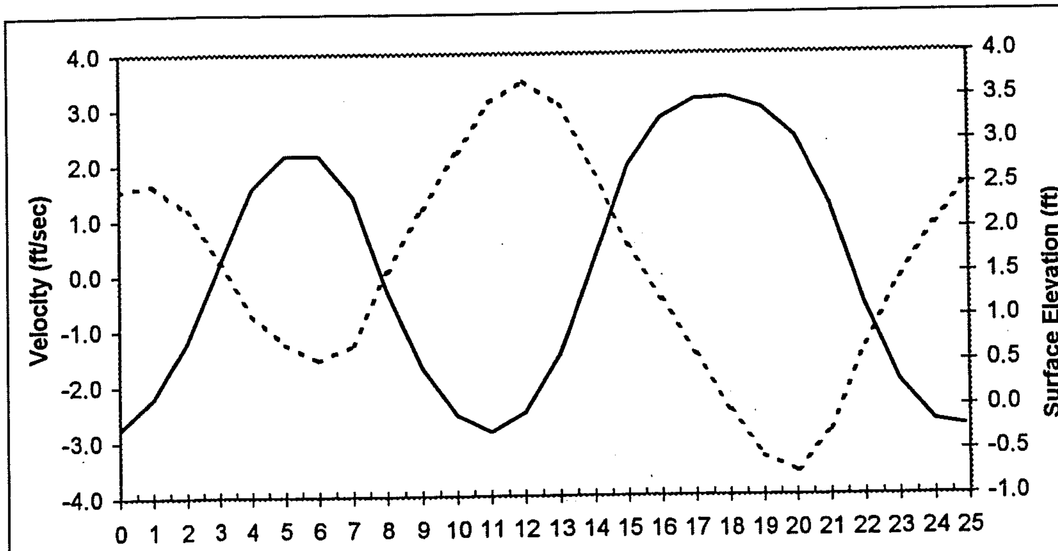

Figure B-12
August WY 1990

Table B-13. September WY 1990 - Predicted Flow and Surface Elevations
Planning Tide and Monthly Average Flow

Time (hrs)	Stage (ft)	Flow (cfs)	Velocity (ft/sec)	Speed (fps)	Displacement (ft)	Travel Distance (ft)
0	2.46	-83,354.50	-2.78	2.78	0	0
1	2.52	-66,777.03	-2.22	2.22	-9000	9000
2	2.24	-36,335.86	-1.22	1.22	-15192	24192
3	1.64	5,664.18	0.19	0.19	-17046	41238
4	1.05	44,907.48	1.56	1.56	-13896	55134
5	0.72	61,428.00	2.16	2.16	-7200	62334
6	0.53	60,747.75	2.15	2.15	558	62892
7	0.7	39,537.91	1.39	1.39	6930	69822
8	1.53	-9,545.07	-0.32	0.32	8856	78678
9	2.23	-51,126.83	-1.71	1.71	5202	83880
10	2.87	-77,601.18	-2.55	2.55	-2466	86346
11	3.45	-87,991.95	-2.85	2.85	-12186	98532
12	3.69	-77,949.18	-2.51	2.51	-21834	120366
13	3.42	-45,073.34	-1.46	1.46	-28980	149346
14	2.64	7,357.57	0.24	0.24	-31176	180522
15	1.81	56,910.63	1.93	1.93	-27270	207792
16	1.19	80,597.79	2.79	2.79	-18774	226566
17	0.56	88,682.87	3.13	3.13	-8118	234684
18	-0.07	87,648.00	3.16	3.16	3204	237888
19	-0.59	80,961.51	2.97	2.97	14238	252126
20	-0.75	66,347.33	2.44	2.44	23976	276102
21	-0.29	33,270.89	1.2	1.2	30528	306630
22	0.67	-17,716.44	-0.62	0.62	31572	338202
23	1.43	-57,433.35	-1.97	1.97	26910	365112
24	2.03	-79,680.69	-2.69	2.69	18522	383634
24.84	2.46		-2.78		10251.36	393885.36

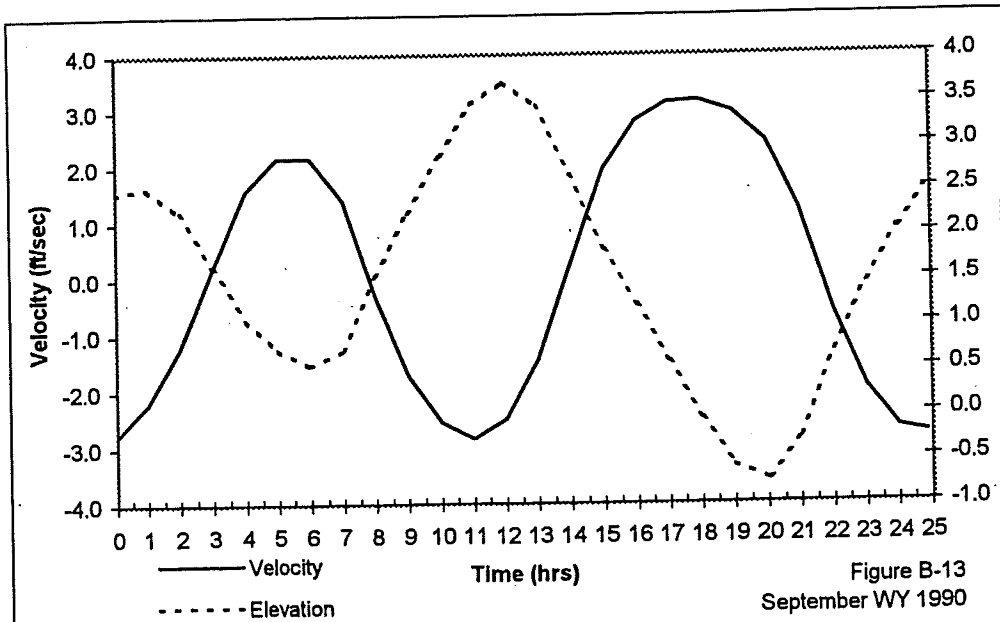

Figure B-13
September WY 1990