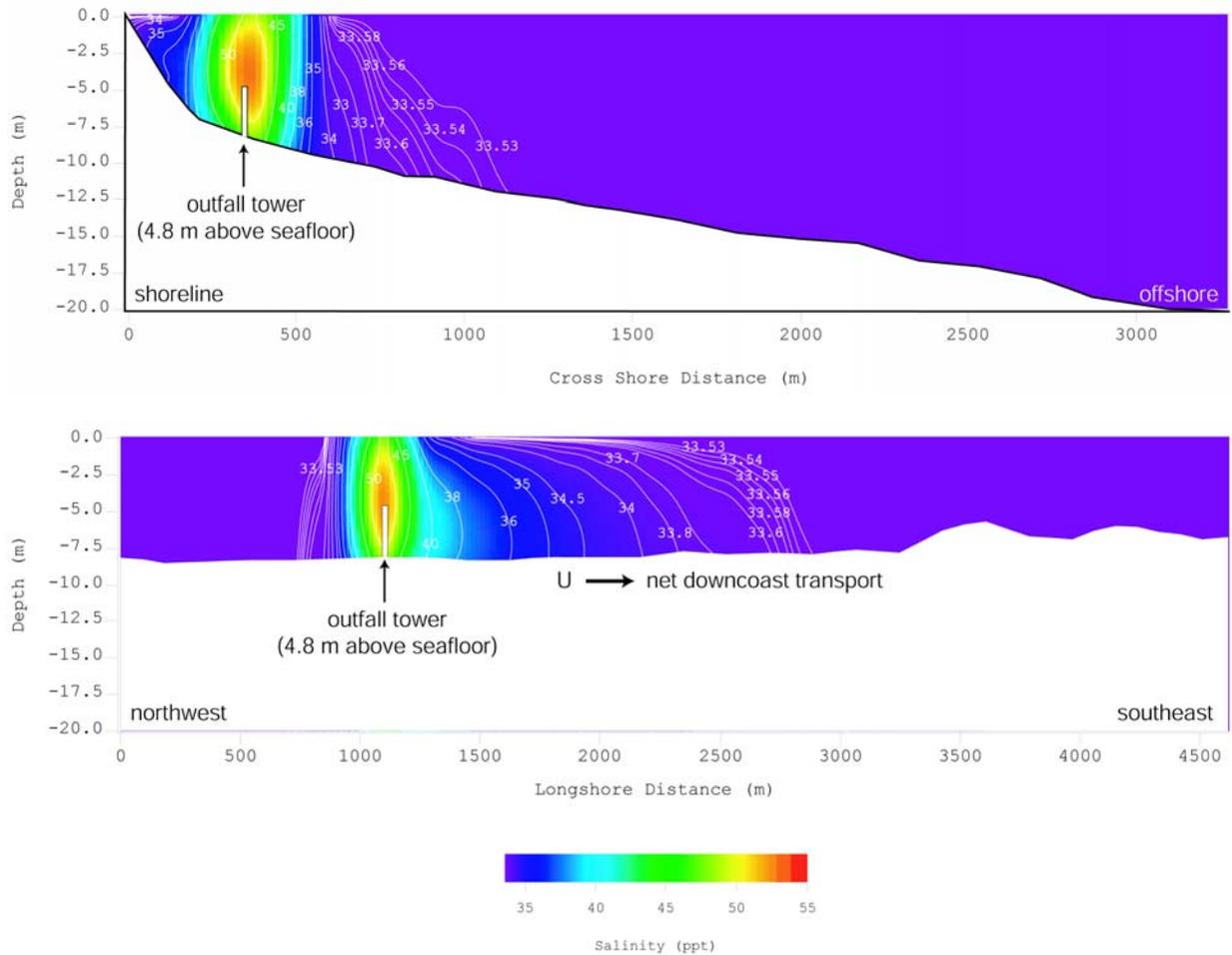


APPENDIX K

*Hydrodynamic Modeling Report and supplement
Prepared by Scott A. Jenkins Consulting,
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HYDRODYNAMIC MODELING OF SOURCE WATER MAKE-UP AND CONCENTRATED SEAWATER DILUTION FOR THE OCEAN DESALINATION PROJECT AT THE AES HUNTINGTON BEACH GENERATING STATION



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Hydrodynamic Modeling of Source Water Make-Up and Concentrated Seawater Dilution for the Ocean Desalination Project at the AES Huntington Beach Generating Station

by Scott A. Jenkins, Ph. D. and Joseph Wasyl

Executive Summary

California experiences multi-decadal climate variability in rainfall leading to alternating periods of dry and wet climate, each lasting 20-30 years. A dry period extended from about 1945-1977, followed by an episodically wet period from 1978-1998, that included the occurrence of six strong El Niño events. Because of the previous durations of these climate cycles, we are likely at an end of a wet cycle and due to return to a period of dry climate similar to what prevailed in California from 1945-1977. Such a transition in climate would put increasing pressures on already limited supplies of fresh water, making the development of alternative sources in California a necessity.

Poseidon Resources plans to construct and operate a reverse osmosis (RO) desalination plant in the southeastern portion of the City of Huntington Beach adjacent to the AES Huntington Beach Generating Station (HBGS). Up to 50 million gallons per day (mgd) of treated water from this plant will be blended with other supplies to provide supplemental water to water utilities located in southern California. The source of water for the desalination plant will be seawater drawn from the ocean about 1,840 ft (561 m) offshore. The source water will be pre-treated and filtered through reverse osmosis membranes to produce high quality drinking water. The plant's product drinking water will be blended with other sources and distributed to consumers. The concentrated seawater produced by the reverse osmosis process will be mixed with the cooling water and then conveyed

through the existing outfall structure located about 1,500 ft (460 m) offshore. The physical effect of desalinating seawater by reverse osmosis is in principle no different to the ocean environment than the effects of evaporation; except that it would take 2000 desalination plants of the size being proposed by Poseidon Resources at Huntington Beach to match the evaporative losses occurring naturally in the waters of the Southern California Bight.

Hydrodynamic modeling of water mass dilution and dispersion was performed in a nearshore domain surrounding the HBGS which extends seaward to the edge of the continental shelf and alongshore from Seal Beach to Crystal Cove State Beach. (The model used in this study is *SEDXPORT*, developed at Scripps Institution of Oceanography for the US Navy's Coastal Water Clarity Program. It has been thoroughly peer reviewed, and has been extensively calibrated and validated in numerous applications throughout the Southern California Bight). The model studied the ocean response to the proposed 50 mgd desalination plant using two separate modeling approaches: 1) event analyses of theoretical extreme cases, and 2) continuous long term simulations using the historical sequence ocean and plant operating variables. The latter approach was applied to two distinct historical periods: one resulting in 7,523 modeled solutions between 1980 and mid 2000 that characterized the period before HBGS was re-powered; the other involving 578 modeled solutions that characterized the post re-powering period using data collected between 1 January 2002 and 30 July 2003.

The event analysis involved some potential situations for operating the desalination plant when the generating plant is operating at very low generating levels. We refer to these as "*low flow cases*" and they produce the highest in-the-pipe concentrations of sea salts from the desalination process. The most extreme of

these low flow cases occurs when the generating plant is in *standby* mode, producing no power and providing no heating of the discharge water. The term “standby mode” broadly refers to a condition when the generating station is spinning an arbitrary collection of pumps with unheated discharge. But, not all possible combinations of pumps during “standby mode” are adequate for the desalination plant to produce product water at a rate of 50 mgd. Throughout this study, we will consider only those cases of standby mode when at least two circulation pumps are on-line (producing 126.7 mgd), because a minimum flow of 100 mgd is required to produce 50 mgd of product water. (No other pump combinations are available within the hydraulic architecture of the generating station that will provide flow rates between 100 mgd and 126.7 mgd).

The low flow cases are evaluated in combination with extreme conditions in the ocean environment involving tranquil, dry weather, La Niña type summer climate. By superimposing two conditions that seldom occur together (low plant flow cases and a calm ocean) the maximum potential impact of the desalination plant on the local ocean environment can be assessed because the dose level of sea salts is highest when the dilution of those salts by mixing and ventilation is lowest. The event analysis also evaluated an “*average case*” based on seasonal mean ocean conditions and average plant flow rates to determine the most likely degree of dilution of desalination plant discharge in nearshore waters.

Numerical modeling of the dilution and dispersion of concentrated seawater discharge from the proposed desalination plant has found that salinities of the receiving water become elevated above mean seawater salinities near the bottom in the immediate neighborhood of the outfall, and only then, when a number of extreme environmental and plant operating conditions occur simultaneously.

Between 1980 and mid 2003, the low flow case resulting from only one generating unit being on line occurred 37 % of the time while the unheated standby mode accounted for less than 1 % of the occurrences. On the other hand, the occurrence of the benign environmental extremes is about 1 week every 3 to 7 years, primarily in summer during strong La Niña conditions. The joint probability for the simultaneous occurrence of these operating and environmental extremes is between 0.27% and 0.64% for the low-flow cases involving active power generation, and between 0.04 % and 0.1% for the standby mode, depending on the length of ENSO (El Niño Southern Oscillation) cycles. In the model simulation of low flow case, these conditions were extended over 30 days, so that the recurrence interval for the low-flow results of this study are actually about 1 month every 13 to 31 years. The extreme operational conditions of the generating plant (low power generation and cooling water consumption) are mutually exclusive with these extreme environmental conditions. Because of this, dilution and dispersion of the concentrated seawater by-product were repeated using more nominal plant operating conditions and average climate conditions. Based on historical data representative of these conditions, the study made the following findings regarding dilution and dispersion of concentrated seawater by-product.

Dilution and Dispersion Before Completion of HBGS Re-Powering:

The dilution and dispersion results for the vent analyses are summarized in Table ES-1. Maximum event impacts during the low flow conditions produce an initial vertical jet of high salinity water that breaches the surface and subsequently sinks to the seafloor, spreading outward from the base of the outfall tower. The highest salinities in the core of the discharge jet are 55.0 ppt at mid-depth (Figure

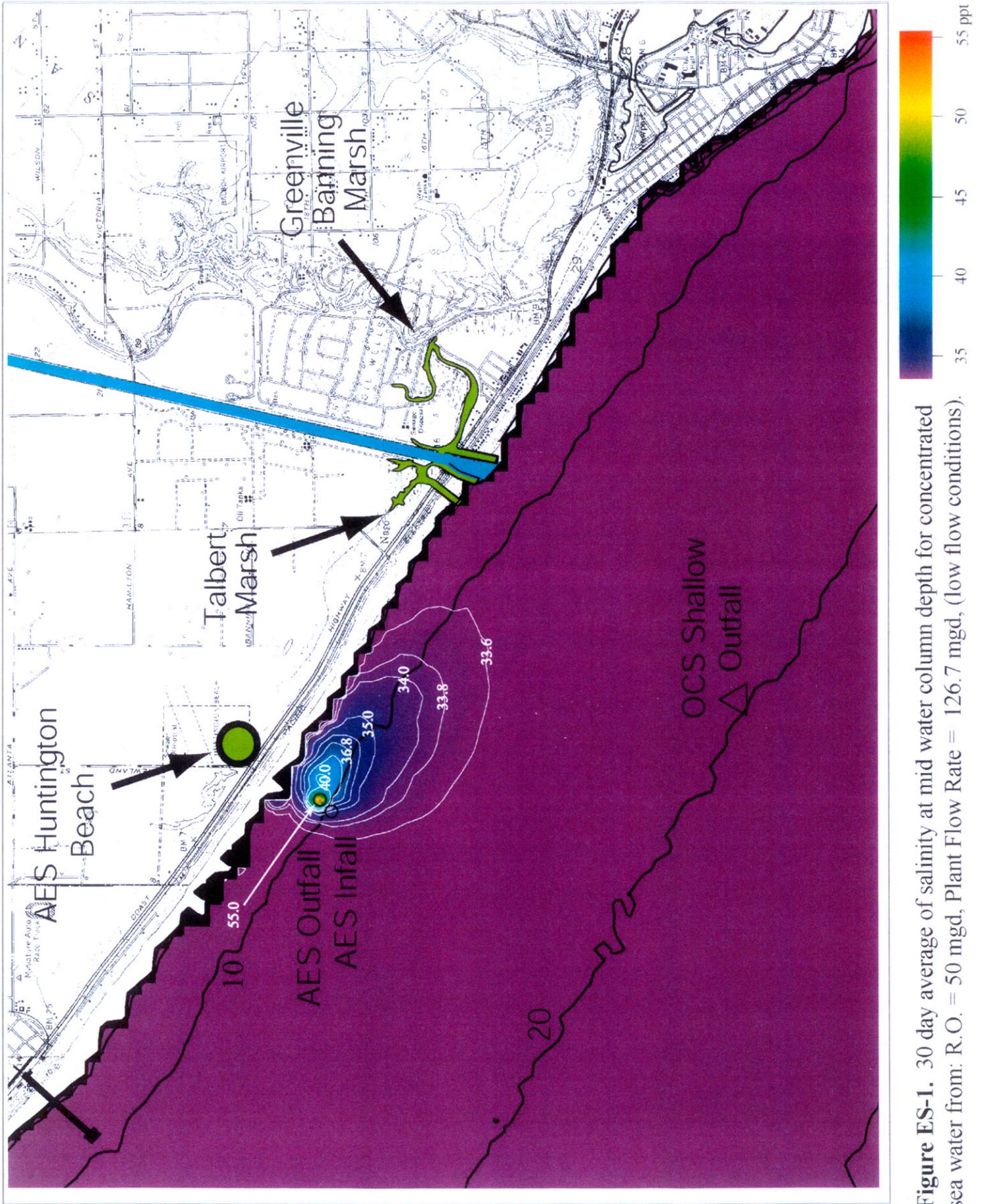


Figure ES-1. 30 day average of salinity at mid water column depth for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

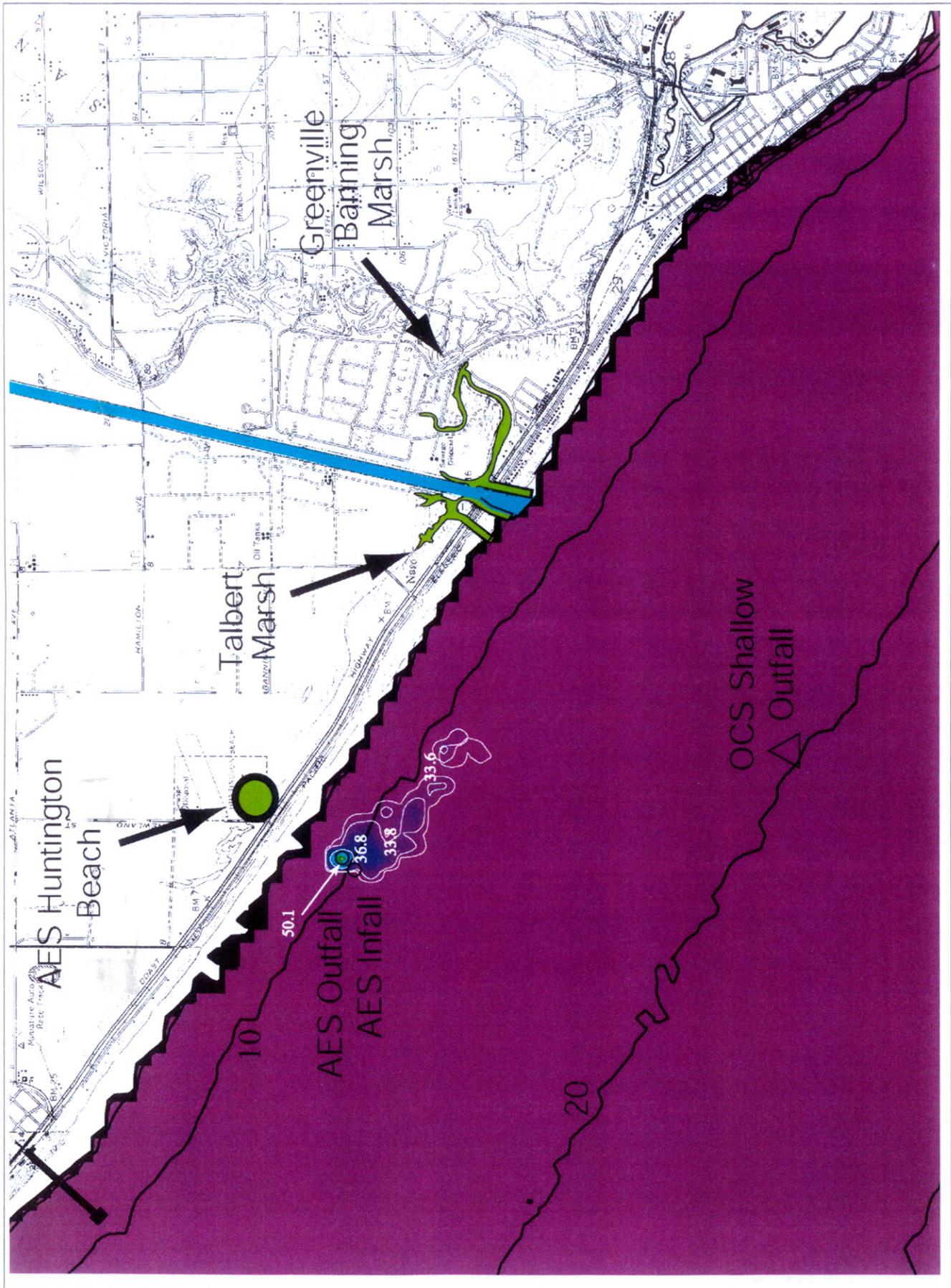


Figure ES-2. 30 day average of salinity on sea surface for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

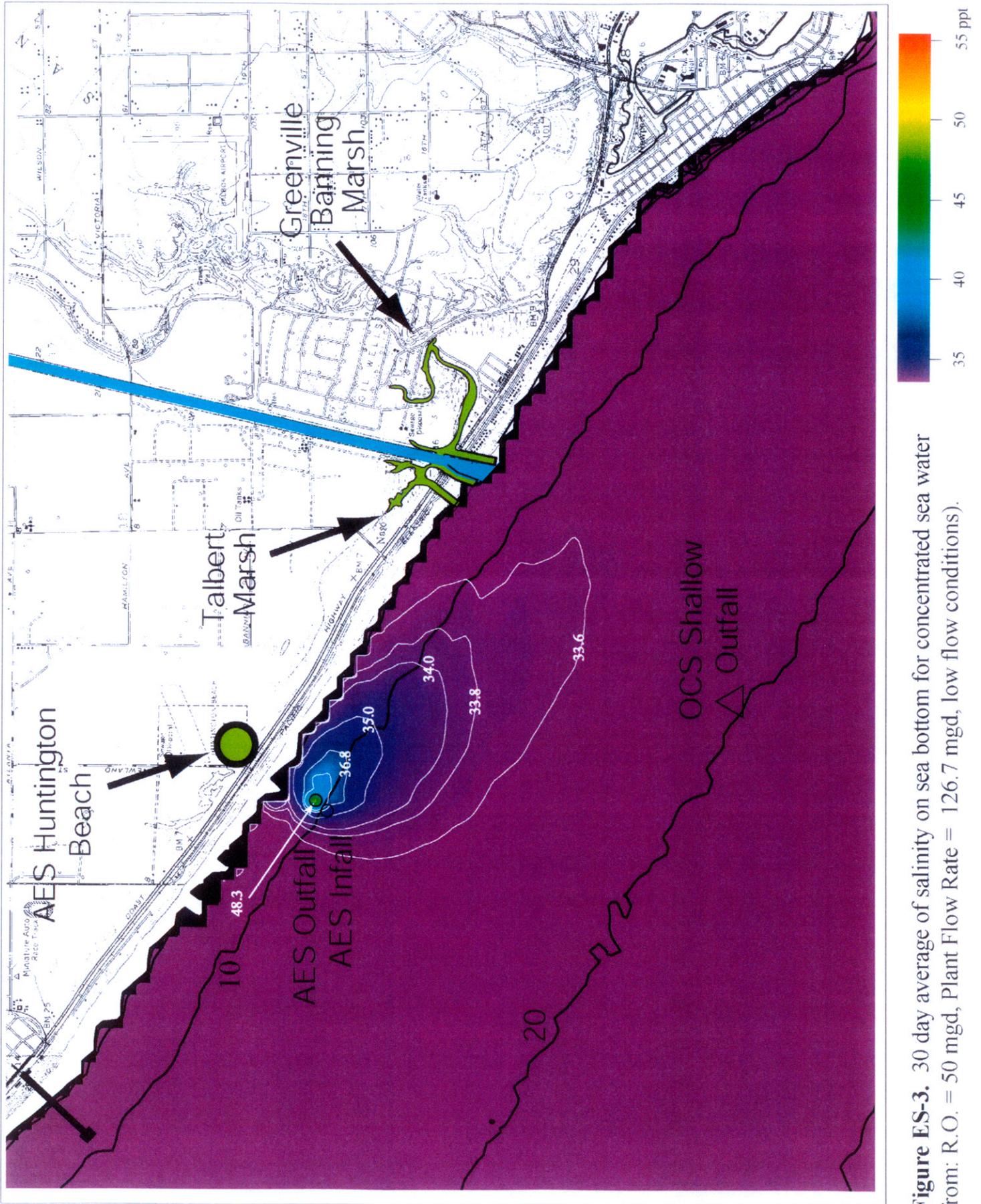


Figure ES-3. 30 day average of salinity on sea bottom for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, low flow conditions).

ES-1), falling to 50.1 ppt on the sea surface directly above the outfall tower (Figure ES-2). The highest salinities on the seafloor are 48.3 ppt at the base of the outfall tower, rapidly decreasing with increasing distance from the tower (Figure ES-3). At most, 15.6 acres of benthic area are impacted by an increase in salinity that exceeds 36.9 ppt, that is 10% above the average ambient level of 33.5 ppt. Bottom salinities exceed ambient levels by more than 1% over an area of 263 acres. These elevated salinities effect only sandy, soft bottom habitat with no low relief exposed rocky substrate, and no surf grass or eel grass beds. The maximum area of pelagic habitat subjected to elevated salinity exceeding 10% of ambient is 18.3 acres while 151 acres of pelagic habitat experience an increase in salinity exceeding ambient by more than 1%. Minimum dilution of the concentrated seawater by-product at the shoreline is 32 to 1, (Figure ES-4) consistent with dye measurements from the recent study commissioned by the California Energy Commission (KOMEX, 2003). Two percent of the concentrated seawater by-product may be re-circulated in a sustained low flow case.

Dispersion and dilution contours of sea salts for the theoretical extreme of the standby mode are very similar to those shown in Figures ES-1 through ES-4. The absence of power plant heat produces a heavier combined discharge that is more slowly assimilated by the receiving waters. As a result, Table ES-1 indicates that the impacted benthic area around the outfall is marginally increased during standby mode to 18.2 acres, while the impacted pelagic area increases to 20.1 acres.

Table ES-1: Summary of Event Analysis of Dispersion and Dilution

Model Conditions	Composite Low-flow Month	Composite Average Month	Composite Standby Month
Recurrence Probability	0.27% - 0.64%	50.0%	0.04% - 0.1%
Maximum Seabed Salinity	48.3 ppt	37.6 ppt	50.4 ppt
Maximum Mid-Water Column Salinity	55.0 ppt	41.7 ppt	55.2 ppt
Maximum Surface Salinity	50.1 ppt	38.3 ppt	53.1 ppt
Maximum Benthic Area of 10% Saline Anomaly	15.6 acres	6.8 acres	18.2 acres
Maximum Pelagic Area of 10% Saline Anomaly	18.3 acres	8.3 acres	20.1 acres
Maximum Benthic Area of 1% Saline Anomaly	263 acres	172 acres	284 acres
Maximum Pelagic Area of 1% Saline Anomaly	151 acres	130 acres	163 acres
Dilution of Concentrated Seawater at Plant Infall ^a	100 to 1	500 to 1	90 to 1
Minimum Saline Dilution 305 m from Discharge Structure ^a	10 to 1	20 to 1	8 to 1
Minimum Saline Dilution at Shoreline ^a	32 to 1	190 to 1	30 to 1

^a Dilution of Raw Concentrate from RO Process

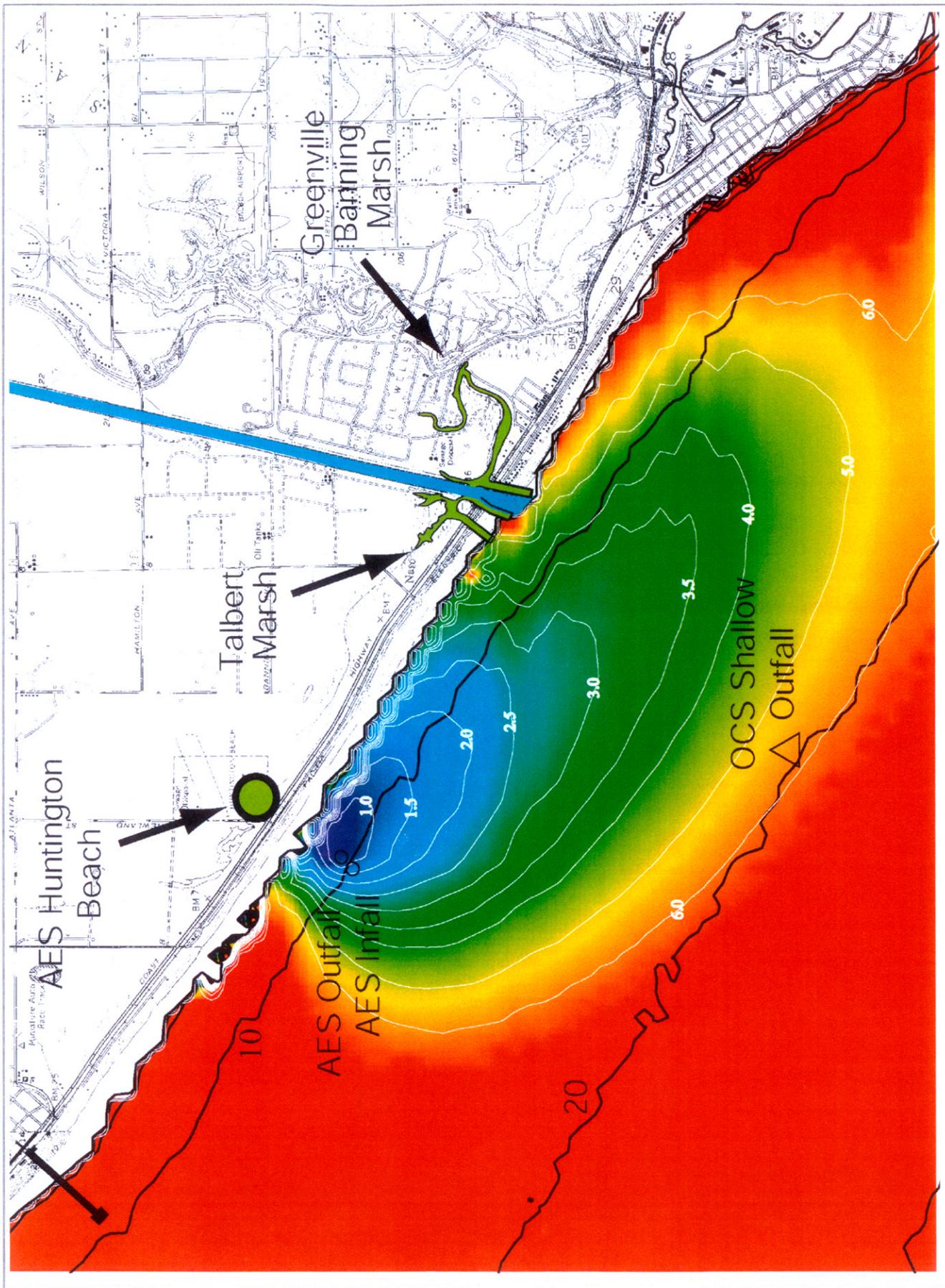


Figure ES-4. 30 day average dilution of concentrated sea water, mid water column depth, from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

For average case events, the salinity in the water column directly above the discharge tower reaches 41.7 parts per thousand, (Figure ES-5), dropping to 38.3 ppt on the sea surface above the outfall tower (Figure ES-6). Maximum salinity on the sea bed is 37.6 ppt at the base of the outfall structure (Figure ES-7). The maximum area of benthic habitat subjected to a 10% increase in salinity is only 6.8 acres, while the area of pelagic habitat experiencing a similar increase is 8.3 acres. The benthic footprint of the 1% saline anomaly is 172 acres and the pelagic footprint is 130 acres. Except for the initial core of the discharge jet salinities under average conditions are everywhere within the range of natural variability. The percentage of re-circulated concentrated seawater by-product under average conditions is only 0.7%. Minimum dilution of the raw concentrate at the shoreline is 190 to 1 (Figure ES-8).

In vertical cross sections through the outfall in the cross-shore and longshore directions, the numerical hydrodynamic model finds that the saline plume emitted from the combined flows of the generating plant cooling water and the concentrated seawater of the desalination plant consists of a higher saline core between the surface and the bottom surrounded by a broad-scale salt wedge feature with weakly elevated salinities. (Salt wedge is a feature common to estuaries and coastal waters near river mouths. It refers to a vertical distribution of salinity in which heavier, higher salinity water forms a wedge-shaped water mass under lighter, lower salinity water). The core is formed in the immediate vicinity of the outfall by a jet of combined effluent discharged vertically upward from the top of the outfall tower. The core typically extends 40-50 meters away from the outfall with salinities of about 50 parts per thousand (ppt) for low flow-case conditions and 38 ppt for average case conditions. Maximum core salinity reaches

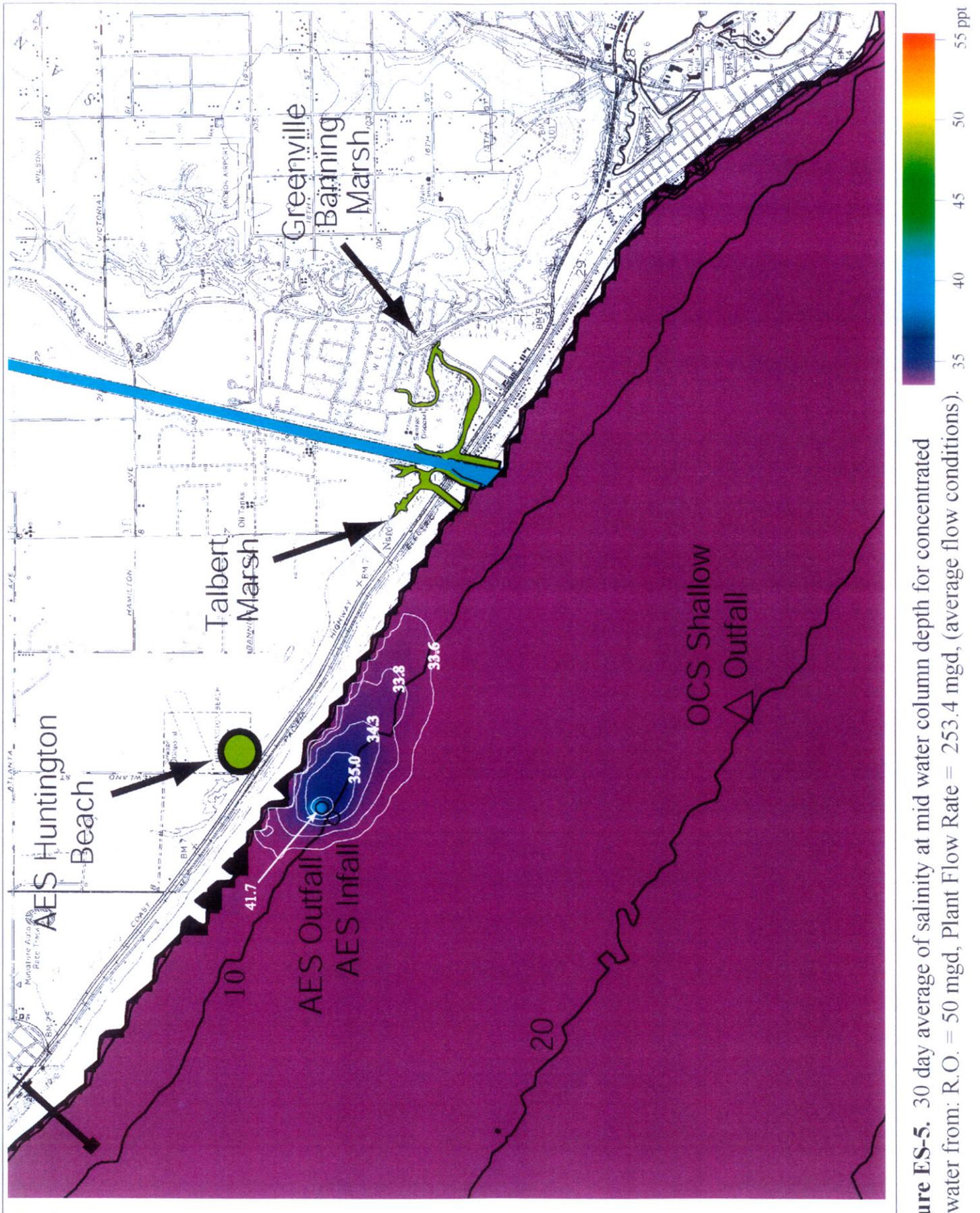


Figure ES-5. 30 day average of salinity at mid water column depth for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).

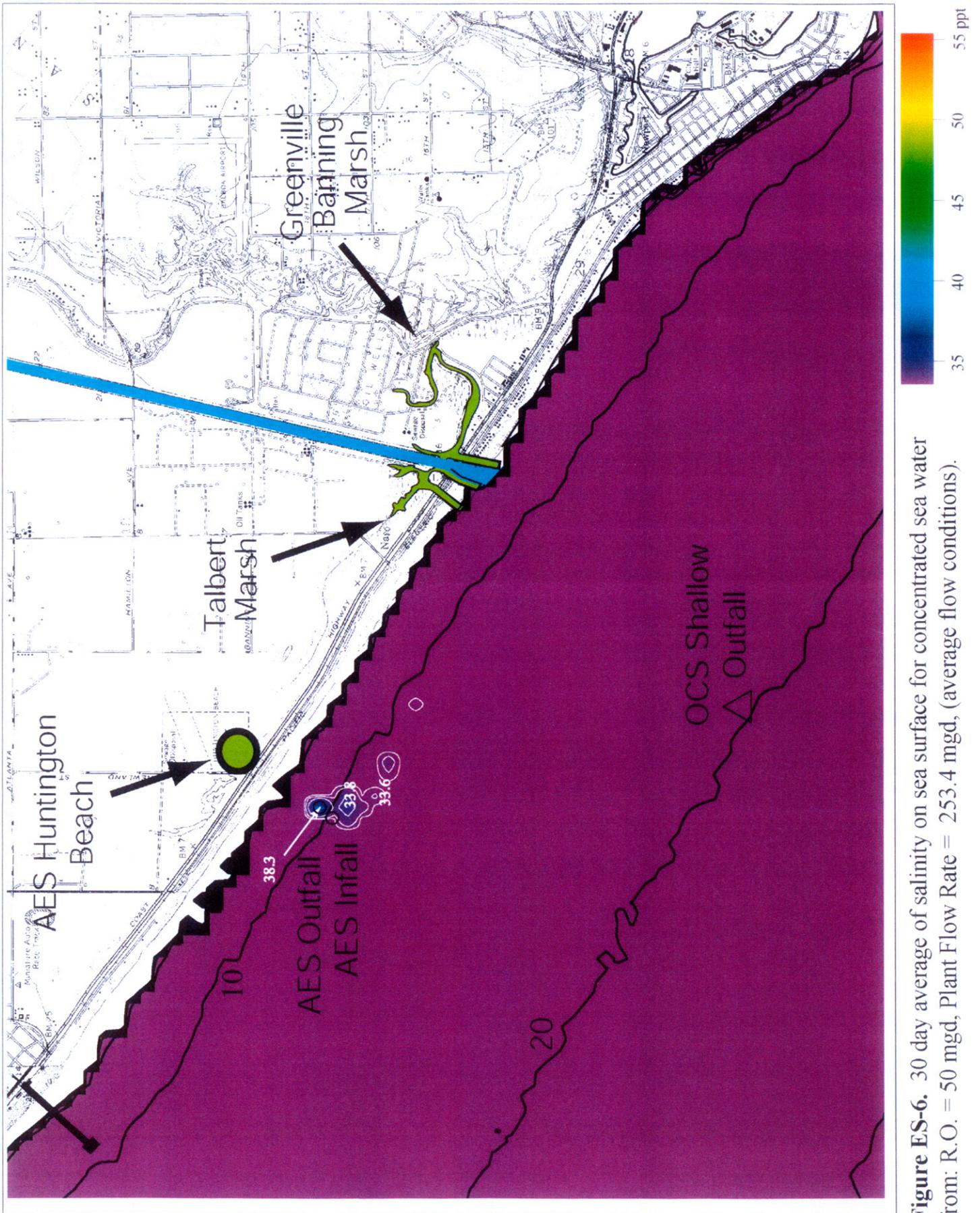


Figure ES-6. 30 day average of salinity on sea surface for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).

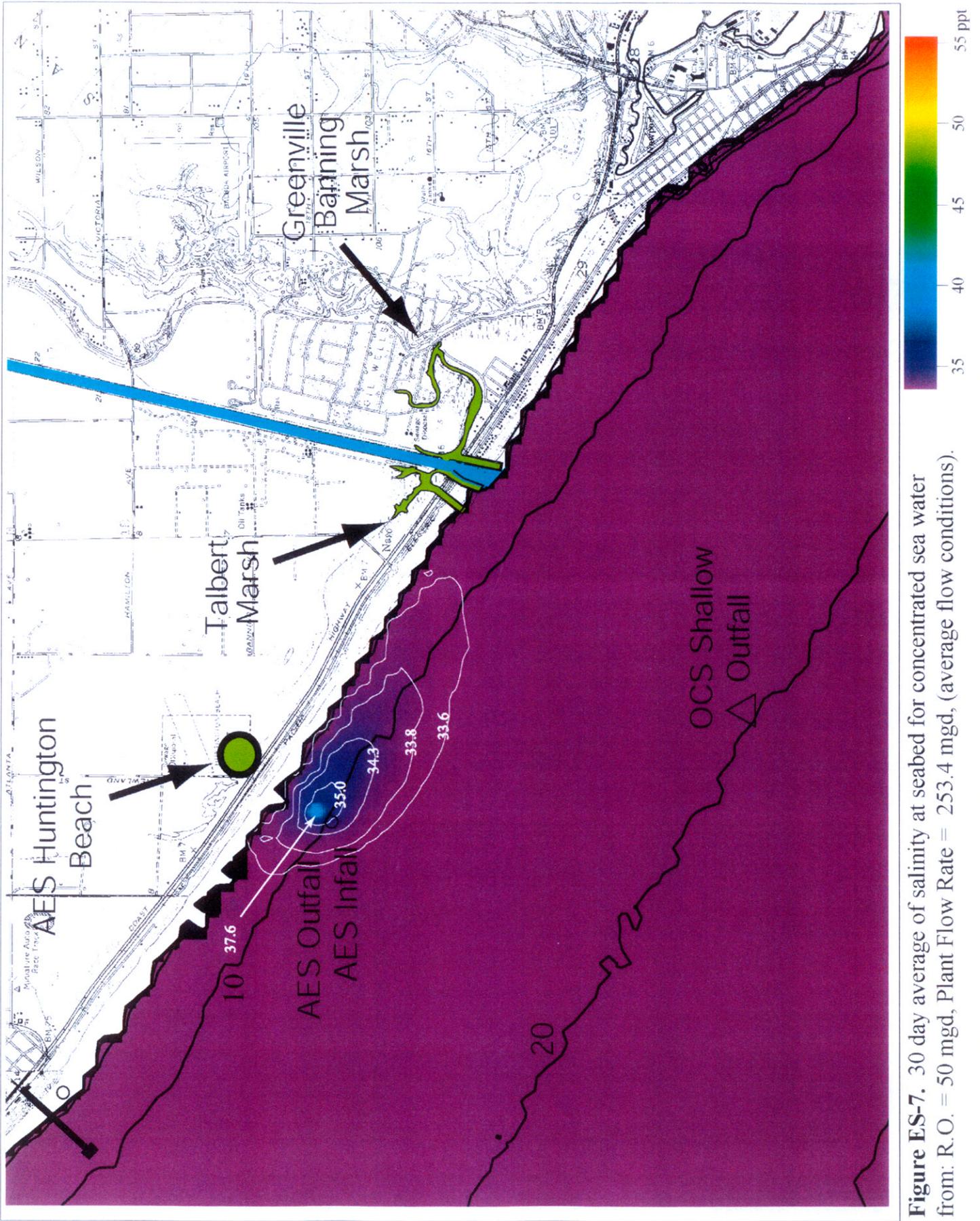


Figure ES-7. 30 day average of salinity at seabed for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).

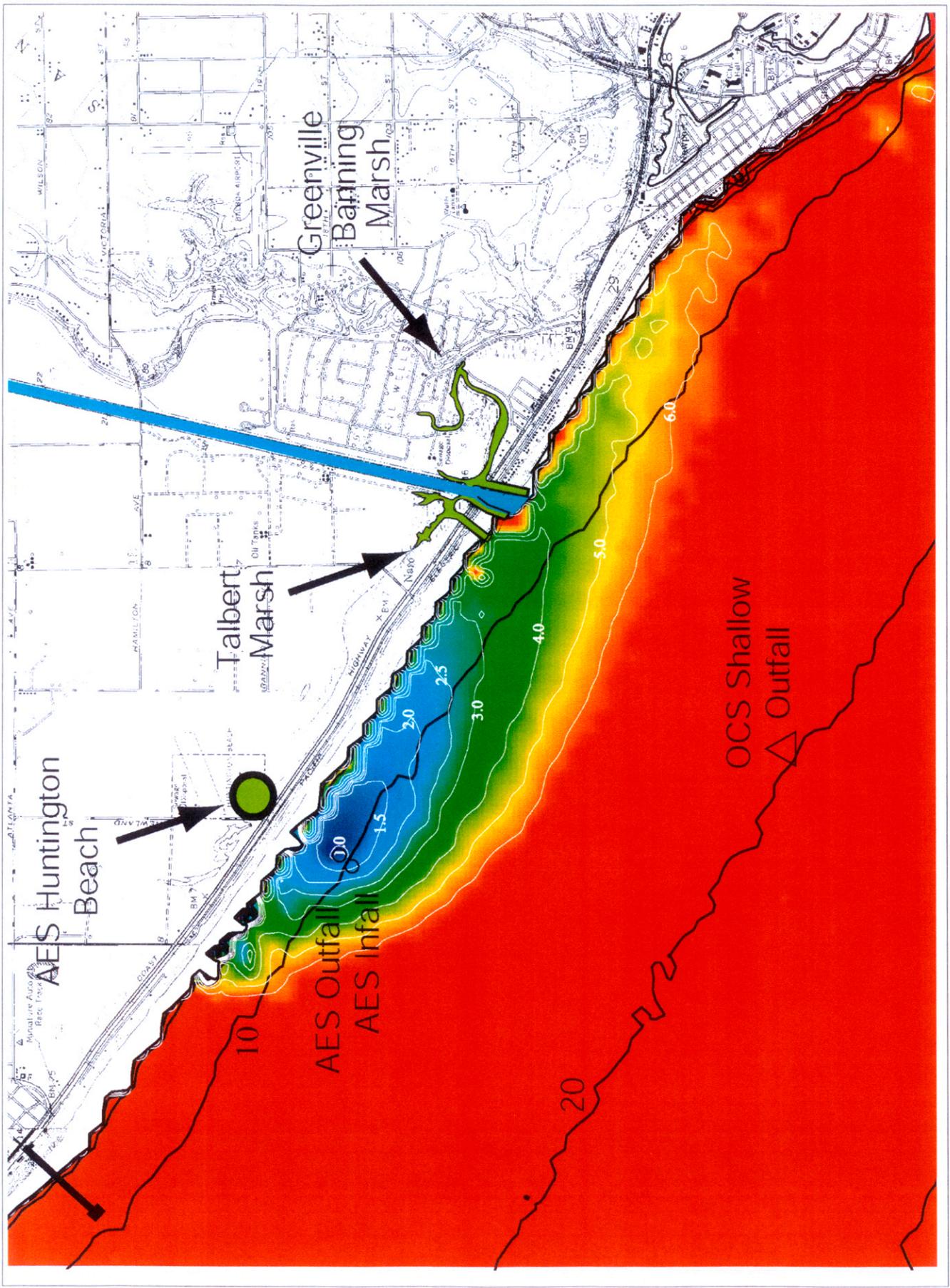
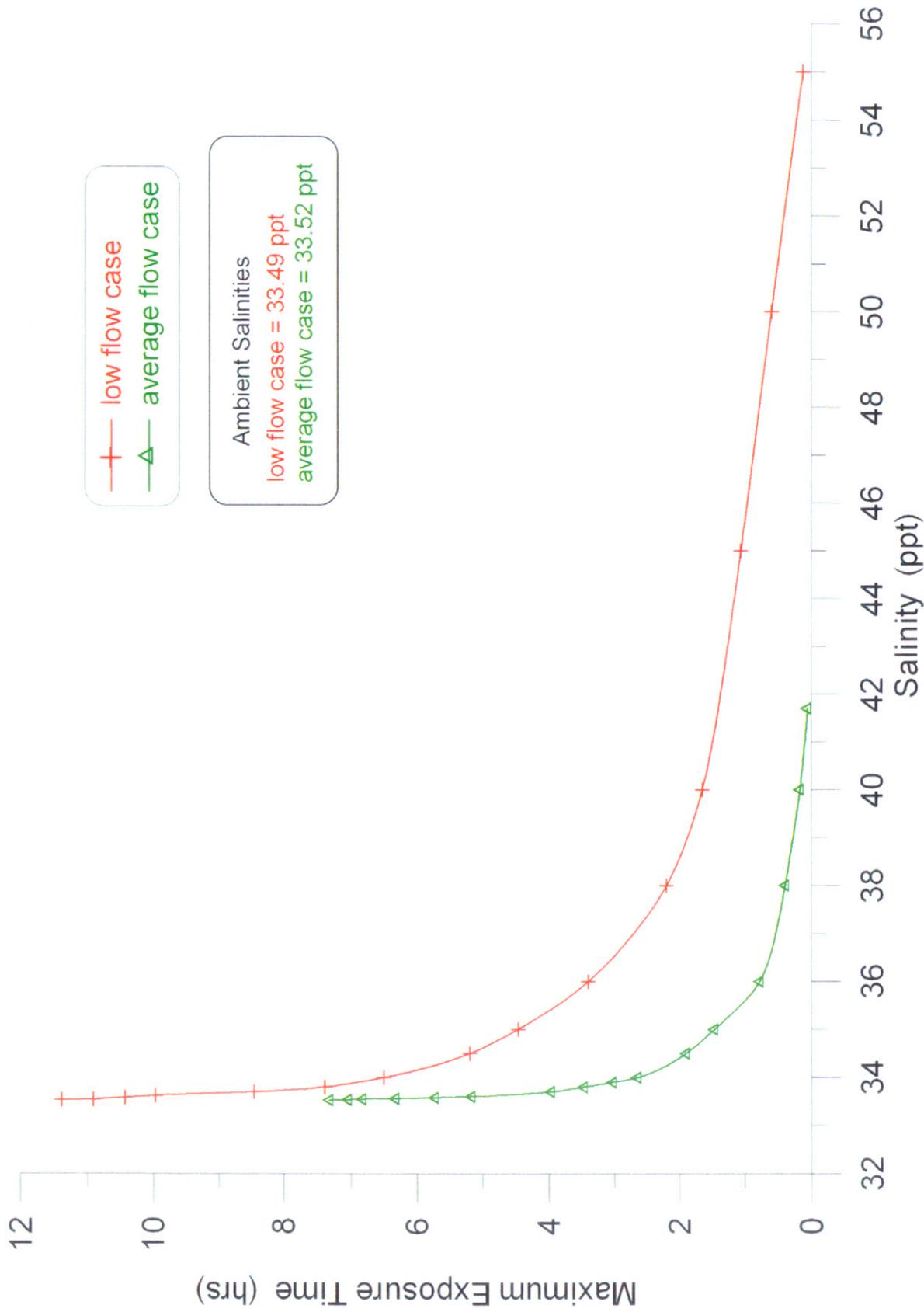


Figure ES-8. 30 day average dilution of concentrated sea water, mid water column depth, from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions). 0 1 2 3 4 5 6 7 (Dilution) (log)

55.0 ppt in the discharge jet immediately above the outfall tower for low flow case and 41.7 ppt for average case. Because of density differences the higher salinity water surrounding the core of the plume behaves like a distinct layer comparable to a “salt wedge” in an ocean/estuarine mixing environment. In the salt wedge, salinities vary from a couple to only a fraction of a ppt over ambient mean ocean salinities. Salt wedge salinities for both low flow and average case are within the envelope of natural variability. The salt wedge extends offshore for about 800 meters seaward of the outfall for low flow case and about 600 meters for average case. The total along shore dispersion of the detectable limits of the salt wedge is 2,150 meters for low flow case and 3,000 meters for average case, both with a downdrift bias toward the southeast.

The predominant net current around the outfall is alongshore directed toward the southeast. Organisms drifting with this current will pass through the saline plume and be exposed to elevated salinities for varying periods of time depending on whether they pass through the narrow, high salinity core or the broad-scale salt wedge with its weakly elevated salinities. In a low flow case scenario drifting organisms would be subjected to maximum salinities of the core (53-55 ppt) for at most 7 minutes, but may linger in the salt wedge at 0.1 ppt above ambient ocean salinities for as long as 10 hours (Figure ES-9). Exposure times at salinities 10 % above ambient levels would be 2.7 hours for the low flow case and 30 minutes under average conditions. Exposure to maximum core salinities under average conditions (40- 41.7 ppt) would be no more than 10 minutes while exposure to the weakly elevated salt wedge salinities would be no more than 7 hours.



+ low flow case
 Δ average flow case

Ambient Salinities
 low flow case = 33.49 ppt
 average flow case = 33.52 ppt

Figure ES-9. Maximum exposure time of a drifting organism passing through the discharge plume of concentrated seawater from the AES Huntington Beach outfall for low flow case conditions (red, plant flow rate = 126.7 mgd) and average case conditions (green, plant flow rate = 253.4 mgd).

In the long-term analysis, the hydrodynamic model solves for 7,523 daily outcomes from the uninterrupted monitoring data of ocean conditions and plant operating conditions that have occurred between 1980 and mid 2000. The objective of this portion of the analysis is to resolve all the intermediate cases that are possible between the low flow and average case event scenarios. In addition, the long term analysis examines the changes to the dispersion of the saline plume resulting from cold water discharges from HBGS occurring during standby mode when the *Delta-T* (ΔT) of the discharge stream is zero. (ΔT is the temperature difference between ocean water and plant discharge).

The modeled long-term outcomes were the result of 20.5 year long continuous time series of daily records for seven controlling operational and environmental inputs. These seven variables may be organized into *boundary conditions* and *forcing functions*. The boundary conditions control the source strength (concentrated sea salts) and background conditions and include: ocean salinity, generating plant flow rates, ocean temperature, and ocean water levels. The period of record from 1980 until July 2000 was the longest period for which an unbroken record of all seven variables could be obtained and wave data was the limiting data base. However, the latter portion of this period was probably atypical from the present operational stand point because the generating station was under going re-fit and equipment modernization. Although there were instances of the plant operating with three and four generating units in the first seven years of the 1980- July 2000 period of record the preponderance of the record shows that the plant seldom supplied other than 2 different flow rates (127.6 or 253.4 mgd) most of the time. This historic 2 mode operational pattern introduced a *bimodal* statistical pattern into the model results (Figure ES-10).

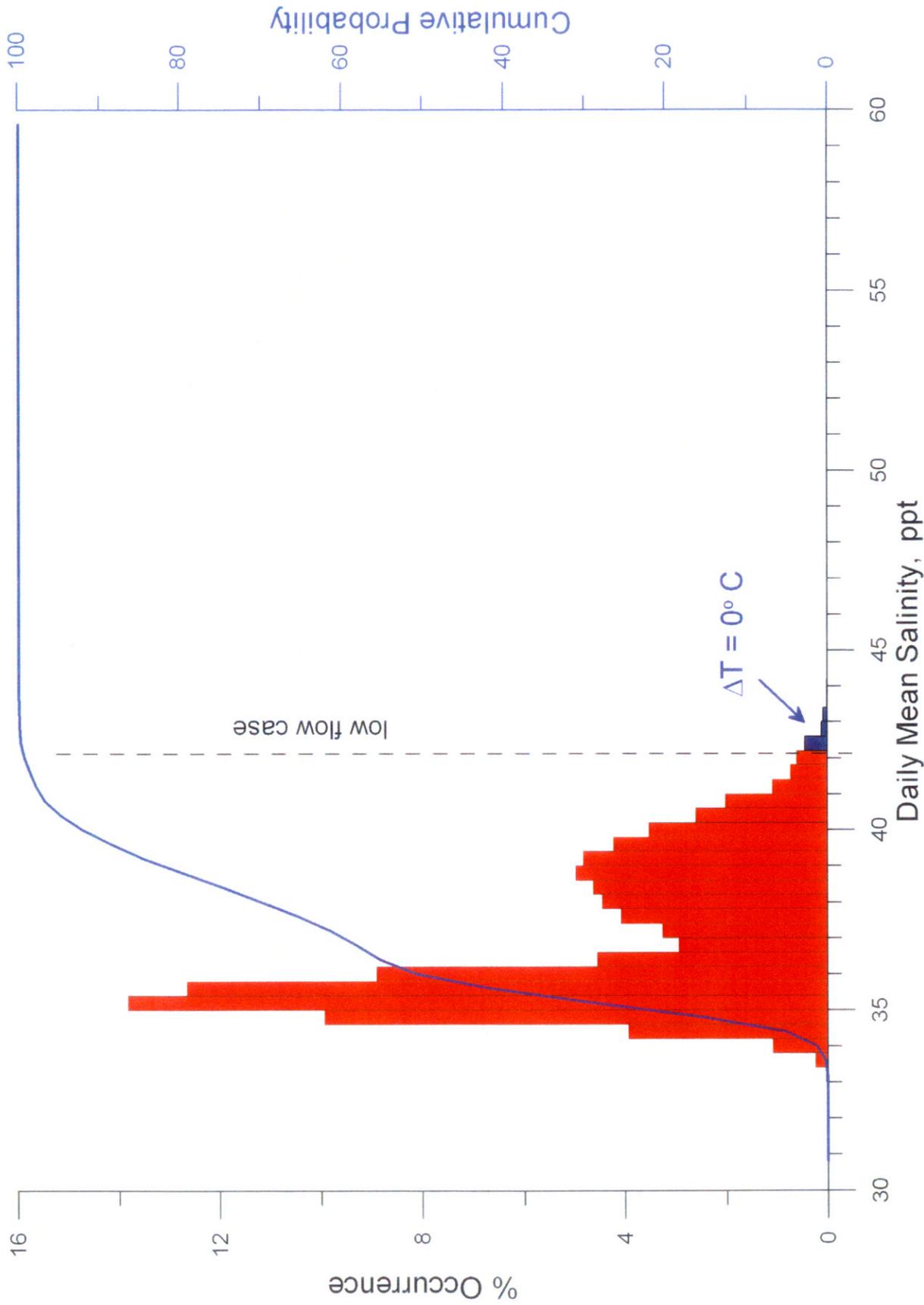


Figure ES-10. Histogram of daily maximum salinity at mid-depth and 150 meters from the AES outfall for desalination production rate of 50 mgd. Percent occurrence based on historic observations of ocean mixing and water mass mass properties, and AES daily plant flow rates, 1980-2000.

Over the 20.5 year simulation period, the combined end-of-pipe salinity was found to vary from a minimum of 37 ppt with all 4 generating units on line, to a maximum of 56.4 ppt for cold water discharges during standby mode ($\Delta T = 0$ °C). The two predominantly recurring peaks in the probability density function for end-of-pipe salinity are centered at 41.6 ppt and 55.2 ppt, consistent with the average and low flow case values, respectively. The results are summarized in Table ES-2. The high salinity peak (low-flow rate peak) was attributed to the operation of only one generating unit, while the lower salinity peak (mid-flow rate peak) resulted from operation of two generating units. The salinities of the low-flow rate peak start out at 55 ppt in the water column above the outfall and fall off to 39 ppt at 150 meters away (the approximate outer limit of the 10 % salinity anomaly), accounting for between 42% and 48% of the modeled outcomes (Figure ES-10). On the sea floor, the low-flow rate operational condition (one generating unit) produces salinities that typically range from 47.5 ppt at the foot of the outfall to 37.0 ppt at 150 meters from the outfall (Figure ES-11) having the same recurrence rates as found in the water column. During times when two generating units (or more) were operated (mid-flow rate peak), salinities varied in the water column from 41.6 ppt at the outfall to 35.2 ppt at 150 meters away with a recurrence rate of 52 % to 58%. On the sea floor, 2 generating unit operation (mid-flow rates) causes salinity to range from 38.6 ppt at the foot of the outfall to 34.8 ppt at 150 meters away with the same recurrence rate as for the water column.

Beyond 150 meters from the outfall, the probability density distribution for the discharge plume salinities no longer exhibits bi-modal character. Because the salinity contrast with the ambient water is greater for the low-flow rate peak, it becomes smeared by higher mixing rates promoted along stronger concentration

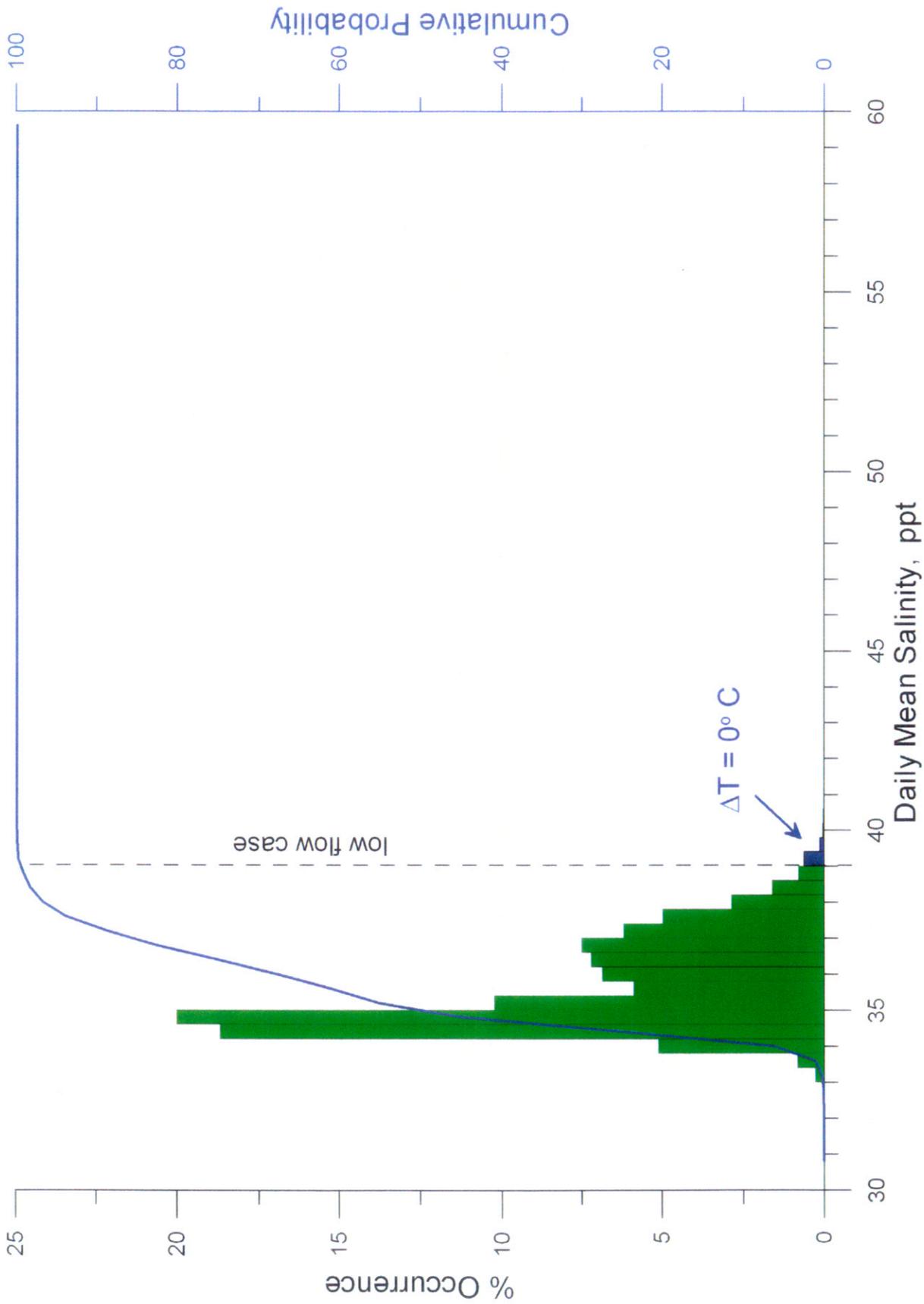


Figure ES-11. Histogram of daily maximum salinity at the bottom and 150 meters from the AES outfall for desalination production rate of 50 mgd. Percent occurrence based on historic observations of ocean mixing and water mass mass properties, and AES daily plant flow rates, 1980-2000.

Table ES-2. Generalized Salinity Plume from 7,523 outcomes, 1980- July 2000

Distance from Outfall (m)	One Generating Unit ^a		Two Generating Units	
	Characteristic Salinity (ppt)	Recurrence Rate (%)	Characteristic Salinity (ppt)	Recurrence Rate (%)
0 Mid-depth	55.2	48%	41.6	52%
0 Bottom	47.5	48%	38.6	52%
50 Mid-depth	45.4	48%	37.4	52%
50 Bottom	40.0	48%	36.0	52%
100 Mid-depth	43.0	47%	36.6	53%
100 Bottom	37.8	43%	35.0	57%
150 Mid-depth	39.0	42%	35.2	58%
150 Bottom	37.0	42%	34.8	58%
300 Mid-depth	36.2	40%	34.6	60%
300 Bottom	36.0	40%	34.6	60%
500 Mid-depth	35.0	25%	34.0	75%
500 Bottom	35.2	30%	34.4	70%
1000 Mid-depth	34.0	18%	33.6	82%
1000 Bottom	34.2	18%	33.6	82%
2000 Mid-depth	33.5	100%	33.5	100%
2000 Bottom	33.5	100%	33.5	100%

^a includes cold water discharges, $\Delta T = 0$ °C

^b red indicates values associated with bimodal probability density distributions

^c green indicates values associated with uni-modal probability density distributions

gradients and it merges with the mid-flow rate peak in the distribution to form an asymmetric uni-modal distribution. The characteristics of this distribution are a mid-flow rate peak at lower salinities with a low-flow rate shoulder extending into higher salinity ranges. Salinities in the mid-flow rate peak of this distribution range from 34.6 ppt at 300 meters from the outfall and decay down to ambient ocean salinity at 2,000 meters from the outfall with a recurrence rate of 60% to 82% before reaching ambient ocean salinity levels. Salinities are only a fraction of a ppt greater on the bottom than in the water column over this range. For the low-flow rate shoulder of the probability density distribution, salinities vary from 36.2 ppt at a distance of 300 meters from the outfall, decaying to ambient salinity 2,000 meters away, with recurrence rate of 40 % down to 18% before reaching ambient ocean salinity levels.

The bi-modal statistical bias imprinted on the model results by the historical plant flow rates throughout the re-fitting period appears to exhibit itself only in the nearfield of the outfall. The recurrence pattern of two distinct outcomes of approximately equal likelihood, one of high salinity and the other of more moderate salinity, is only apparent in the inner and outer core of the discharge plume, extending out to about 150 meters from the out fall (Figures ES-10 & ES-11). This is an area of about 17.5 acres. In the salt wedge portion of the plume from 500 meters out and beyond, operational patterns do not appear to alter the results by more than about 1 ppt, with salinities occurring between 34 ppt and 35 ppt or less regardless of historic operational tendencies. In the intermediate zone between 150 and 500 meters from the outfall, operational patterns cause salinity variations between 36 ppt or about 34.5 ppt. Such variations mean the difference between exceeding the upper limit of the natural ocean salinity range for this location, or not.

Among the 7,523 model solutions derived from the historic database prior to re-powering the generating station (1980-2000), there were no outcomes producing salinities in the receiving water that exceeded those of the low flow event scenario, so long as electrical power was being generated ($\Delta T > 0$ °C). However, a relatively rare subset of these 7,523 solutions involved standby mode occurrences when the plant was spinning at least 2 circulation pumps but not generating electricity ($\Delta T = 0$ °C). These standby mode outcomes produced salinities in the receiving waters that exceeded the low flow event scenario by no more than 1 ppt, but accounted for less than 1% of all possible outcomes (Figures ES-10 & ES-11) involving adequate flow to produce 50 mgd of desalinated product water. Therefore, the low flow event scenario as characterized in ES-1 through ES-4 and in Table ES-1 is a reasonable representation of a long-term worst case when the generating station is producing power.

Dilution and Dispersion After Completion of HBGS Re-Powering:

After completion of the re-powering of the AES Huntington Beach Generating Station in late 2001, higher generation levels and plant flow rates have been maintained that exceed those observed for the late 1980's and throughout the 90's. To determine the implications of this shift in operational patterns on the probable dispersion and dilution of sea salts from the desalination plant, the long-term analysis methodology was repeated for the post re-powering period, 2 January 2002 - 30 July 2003. The dilution results for the post re-powering period are summarized in Table ES-3 with salinity probability density functions shown in Figures ES-12 and ES-13 at 150 meters away from the outfall. Comparing Figures ES-12 and ES-13 with Figure ES-10 with ES-11 we find that the low flow rate

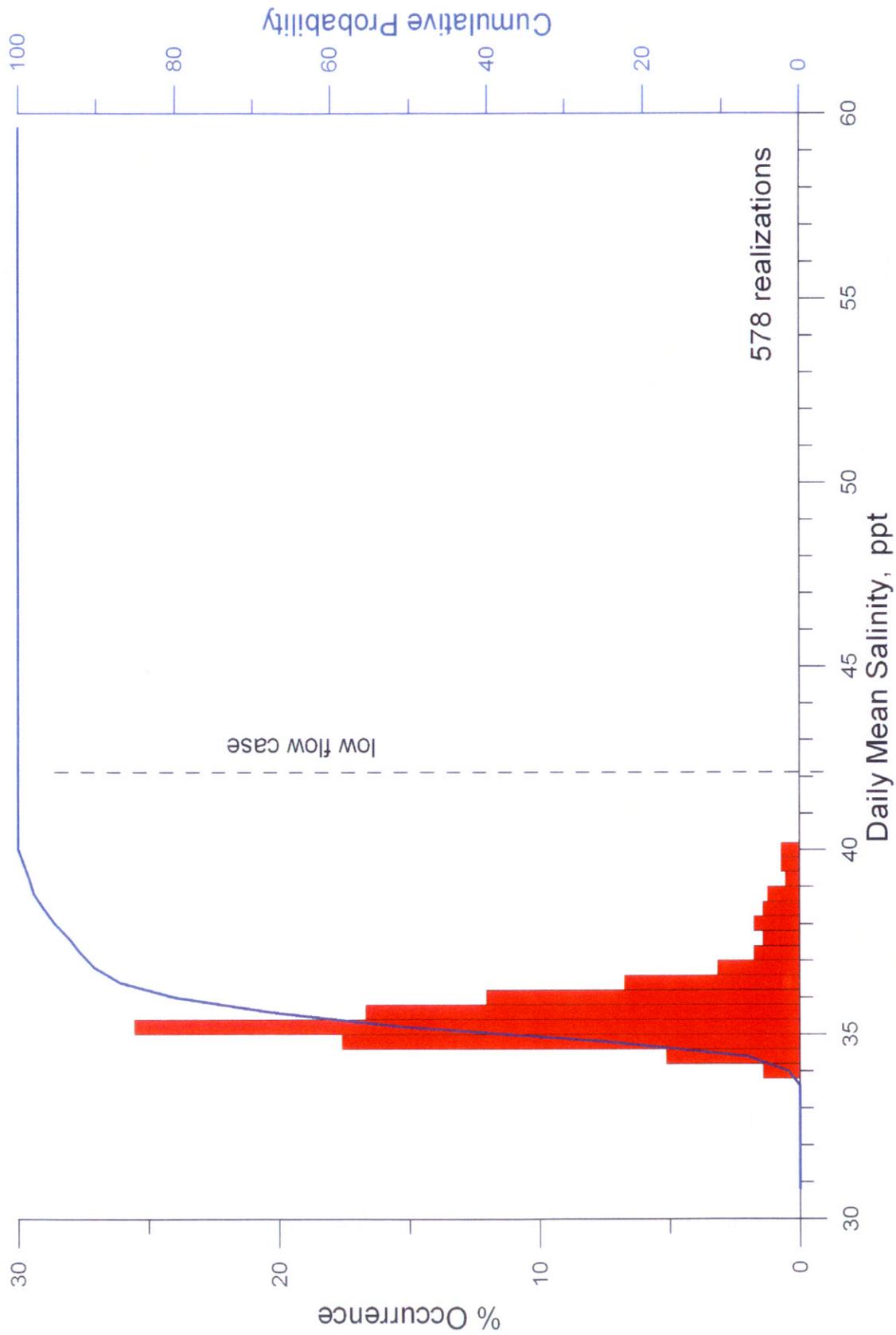


Figure ES-12. Histogram of daily maximum salinity at mid-depth and 150 meters from the AES outfall for desalination production rate of 50 mgd. Percent occurrence based on historic observations of ocean mixing and water mass mass properties, and AES daily plant flow rates for the post re-powering period, 1 Jan 2002 - 30 July 2003.

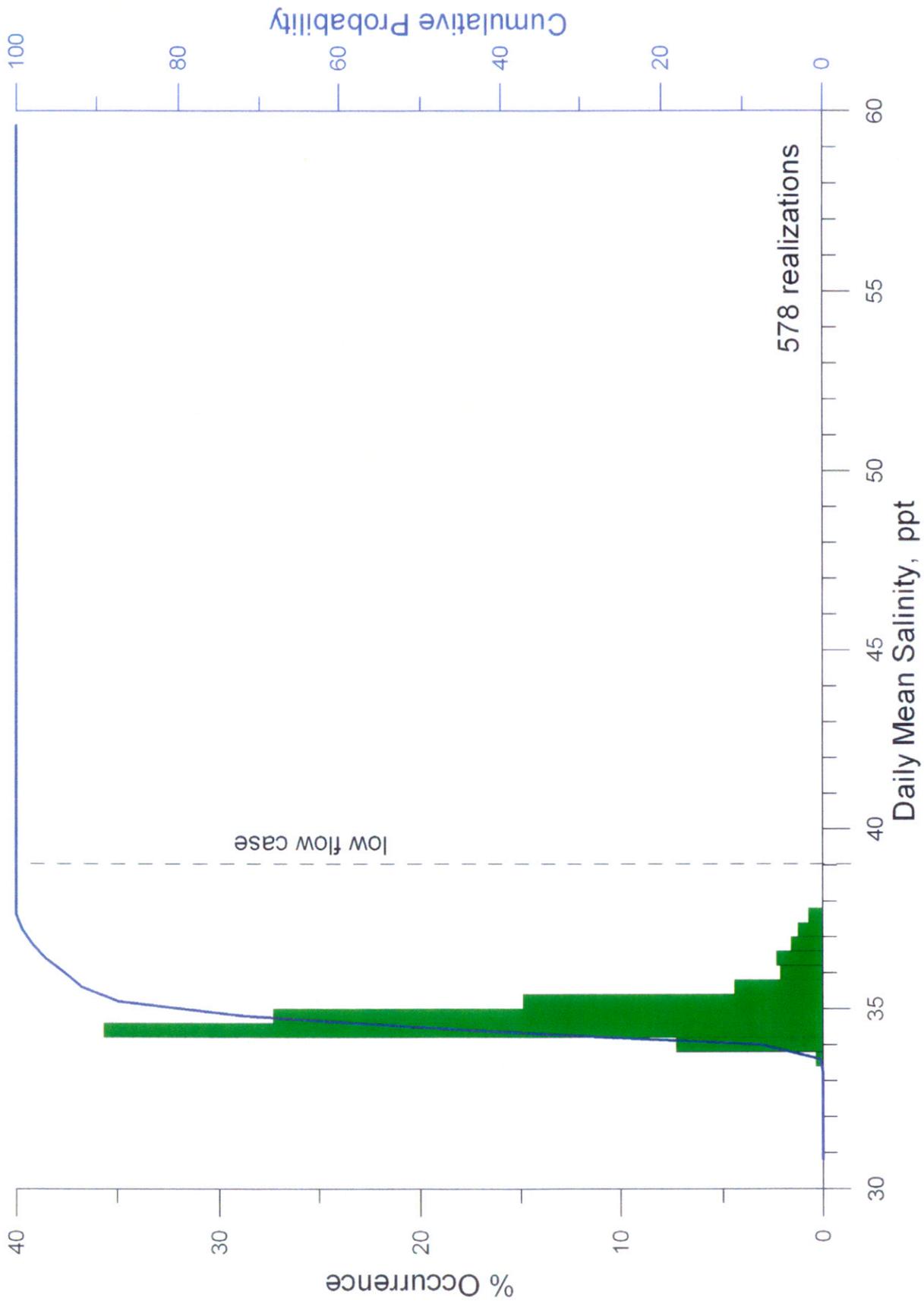


Figure ES-13. Histogram of daily maximum salinity at the bottom and 150 meters from the AES outfall for desalination production rate of 50 mgd. Percent occurrence based on historic observations of ocean mixing and water mass properties, and AES daily plant flow rates for the post re-powering period, 1 Jan 2002 - 30 July 2003.

Table ES-3. Generalized Salinity Plume from 578 outcomes, January 02- July 03

Distance from Outfall (m)	Low Flow Rate Condition ^a		Nominal Flow Rate Condition	
	Characteristic Salinity (ppt)	Recurrence Rate (%)	Characteristic Salinity (ppt)	Recurrence Rate (%)
0 Mid-depth	55.2	9%	43.0	91%
0 Bottom	47.5	9%	39.0	91%
50 Mid-depth	45.4	9%	38.0	91%
50 Bottom	40.0	9%	35.0	91%
100 Mid-depth	42.8	8%	37.4	92%
100 Bottom	37.8	6%	35.6	94%
150 Mid-depth	38.0	6%	35.4	94%
150 Bottom	37.2	6%	35.2	94%
300 Mid-depth	36.0	3%	34.6	97%
300 Bottom	36.0	3%	34.6	97%
500 Mid-depth	35.0	1%	34.0	99%
500 Bottom	35.2	1%	34.2	99%
1000 Mid-depth	33.6	100%	33.6	100%
1000 Bottom	33.8	100%	33.8	100%
2000 Mid-depth	33.5	100%	33.5	100%
2000 Bottom	33.5	100%	33.5	100%

^a includes all operating conditions pumping 126.7 mgd or less

^b red indicates values associated with bimodal probability density distributions

^c green indicates values associated with uni-modal probability density distributions

peak at is greatly reduced and represents only about 6% of the 578 daily outcomes during the post re-powering period. After re-powering, the histogram distribution at 150 meters from the outfall is predominantly unimodal and centered on 35 ppt with 92% of the outcomes giving salinities elevated less than the 10 % above ambient. Beyond 150 meters away from the outfall, no outcomes from the 7 controlling variables during the post re-powering period give rise to salinities exceeding 40 ppt. Furthermore, no outcomes at any distance from the outfall during post re-powering conditions produce salinities in the receiving waters as high as the low flow event scenario in ES-1 through ES-4 and Table ES-1. If the flow rate history of the generating station during the post re-powering period (January 2002- July 2003) is representative of the foreseeable future, then salinities in the receiving waters due to the low flow event scenario are unlikely to ever be exceeded.

Source Water Quality at HBGS Intakes

In the remaining sections of this report (Sections 6-9) a hydrodynamic modeling study was conducted to determine if storm water and waste water are possible constituents of the source water at the intake to desalination plant. The storm water analysis considered flood discharges of the Santa Ana River and Talbert Channel watersheds and was also extended to include computations of recirculation of generating plant effluent between the offshore outfall and in-fall. Analysis of source water make-up further considered the dispersion of the wastefield from the 120" diameter deep ocean outfall located offshore of the Santa Ana River and operated by Orange County Sanitation District (OCSD).

The source water quality modeling was performed for a nearshore domain surrounding the AES Huntington Beach plant which extends alongshore from Seal Beach to Crystal Cove State Beach. The model was initialized for three sets of

extreme environmental conditions to evaluate low flow case effects: 1) a wet weather El Niño winter condition to determine the quantity of ocean water and storm water from the Santa Ana River and the Talbert Channel reaching the AES intakes; and, 2) a summer El Niño condition when net transport by waves and currents flows northward to determine if the OCSD wastefield and Talbert Marsh tidal discharges can reach the AES intakes. The El Niño modeling scenarios provide a reasonable prediction of the maximum quantity of storm water runoff and OCSD wastefield reaching the AES intakes. The conclusions of the source water quality analysis are as follows:

Based on representative and historical data, the investigation provided a reasonable estimate of the likely mix of seawater and storm water at the AES Huntington Beach Generating Plant intakes during a period with extremely high storm runoff from both the Santa Ana River and Talbert Channel:

Over the 24-hour extreme runoff period, source water drawn at the infall is comprised of 0.0003% storm water from the Santa Ana River and Talbert Channel (Figure ES-14). Dilution of Santa Ana River and Talbert Channel storm water is 316 thousand to 1 at the depth of the infall velocity cap.

Over the seven-day extreme runoff period spanning the peak flood runoff event, source water drawn at the infall is comprised of only 0.0001% storm water from the Santa Ana River and Talbert Channel. Santa Ana River and Talbert Channel storm water is diluted to 1 million to 1 at the depth of the infall velocity cap.

For the duration of the 30-day extreme runoff period, the average make-up of the source water reaching the intakes would contain no detectable amount of

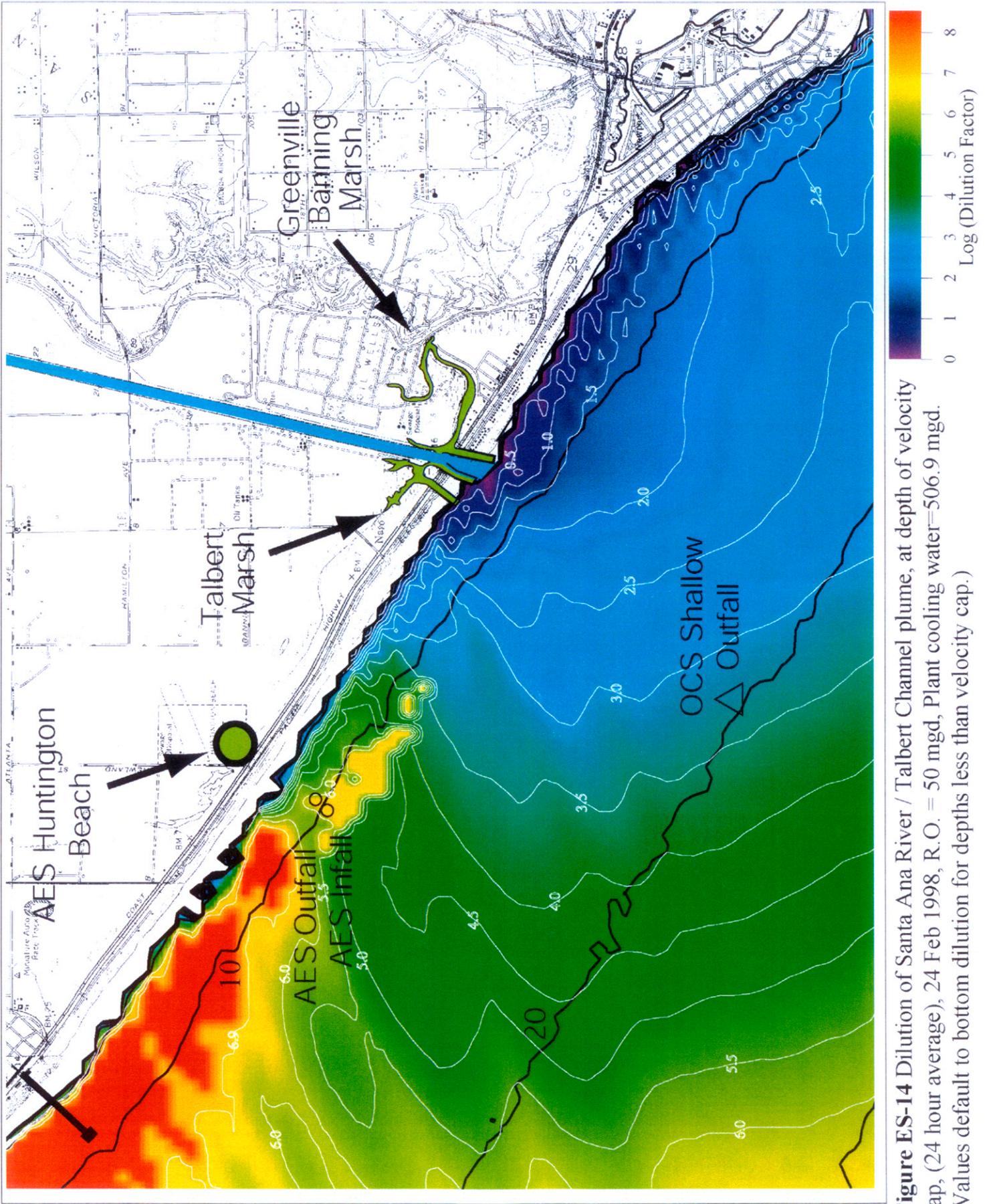


Figure ES-14 Dilution of Santa Ana River / Talbert Channel plume, at depth of velocity cap, (24 hour average), 24 Feb 1998, R.O. = 50 mgd, Plant cooling water=506.9 mgd. (Values default to bottom dilution for depths less than velocity cap.)

storm water (Figure ES-15). Dilution of Santa Ana River and Talbert Channel storm water at the infall velocity cap is 10 million to 1.

For sustained high runoff and low flow operational conditions over a 7-day period of extreme wet weather, only a negligible amount of generating station storm water is re-circulated from the outfall to the infall. At most, 0.3% of the combined plant discharge is recirculated of which no more than 2.1% can be plant storm water based on NPDES permit restrictions. Hence plant storm water is at most 0.007% of the source water in a low flow case scenario (Figure ES-16). For maximum power plant generating levels, only 0.0004% of the source water can be expected to be recirculated plant storm water and about 0.003% for normal power generating levels. At all generation levels, the addition of the concentrated seawater by-product to the discharge of the AES power generating plant eliminates the positive buoyancy of the thermal plume and thereby reduces the size and temperature anomaly of the thermal footprint in the offshore waters. On average, the addition of concentrated sea water by-product to the thermal effluent of the generating station will reduce the size of the thermal plume by about 46%.

For low flow case summer El Niño conditions during flood tide (when typical coastal transport is most likely to reverse and flow northward), the wastefield of the OCSD deep outfall was found to disperse no closer than the 15 meter depth contour off Huntington Beach, about 2 km offshore (Figure ES-17). Dilution of the wastefield at the intake to AES Huntington Beach was calculated at 1 part per thirty million, indicating that even without the OCSD Disinfection Resolution of 2002, no total coliforms from the wastefield would be detectable in the source water. Similar calculations on the dispersion of tidal flux from the Talbert Marsh during spring tides found dilution of marsh waters to be 1 part per

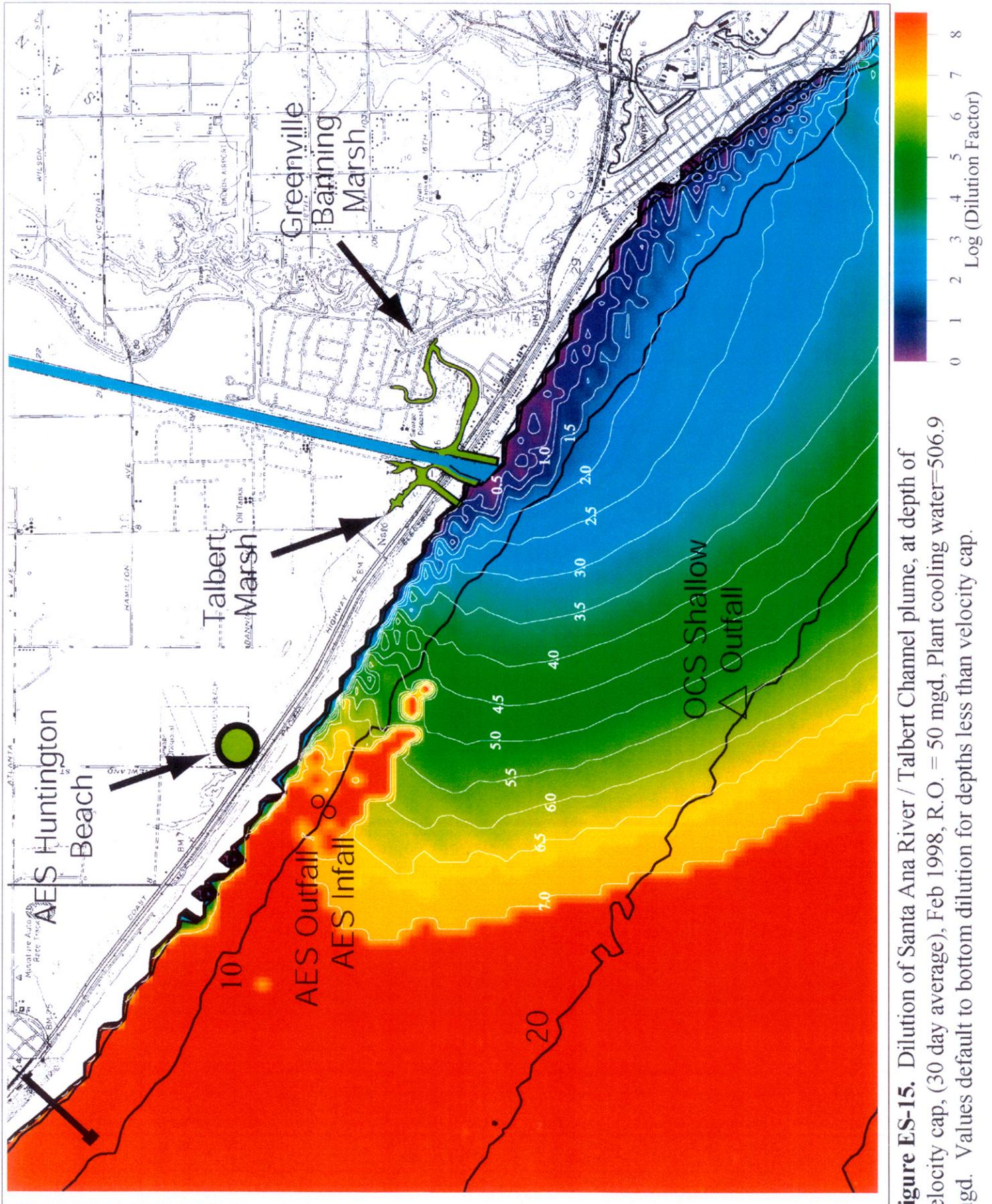


Figure ES-15. Dilution of Santa Ana River / Talbert Channel plume, at depth of velocity cap, (30 day average), Feb 1998, R.O. = 50 mgd, Plant cooling water=506.9 mgd. Values default to bottom dilution for depths less than velocity cap.

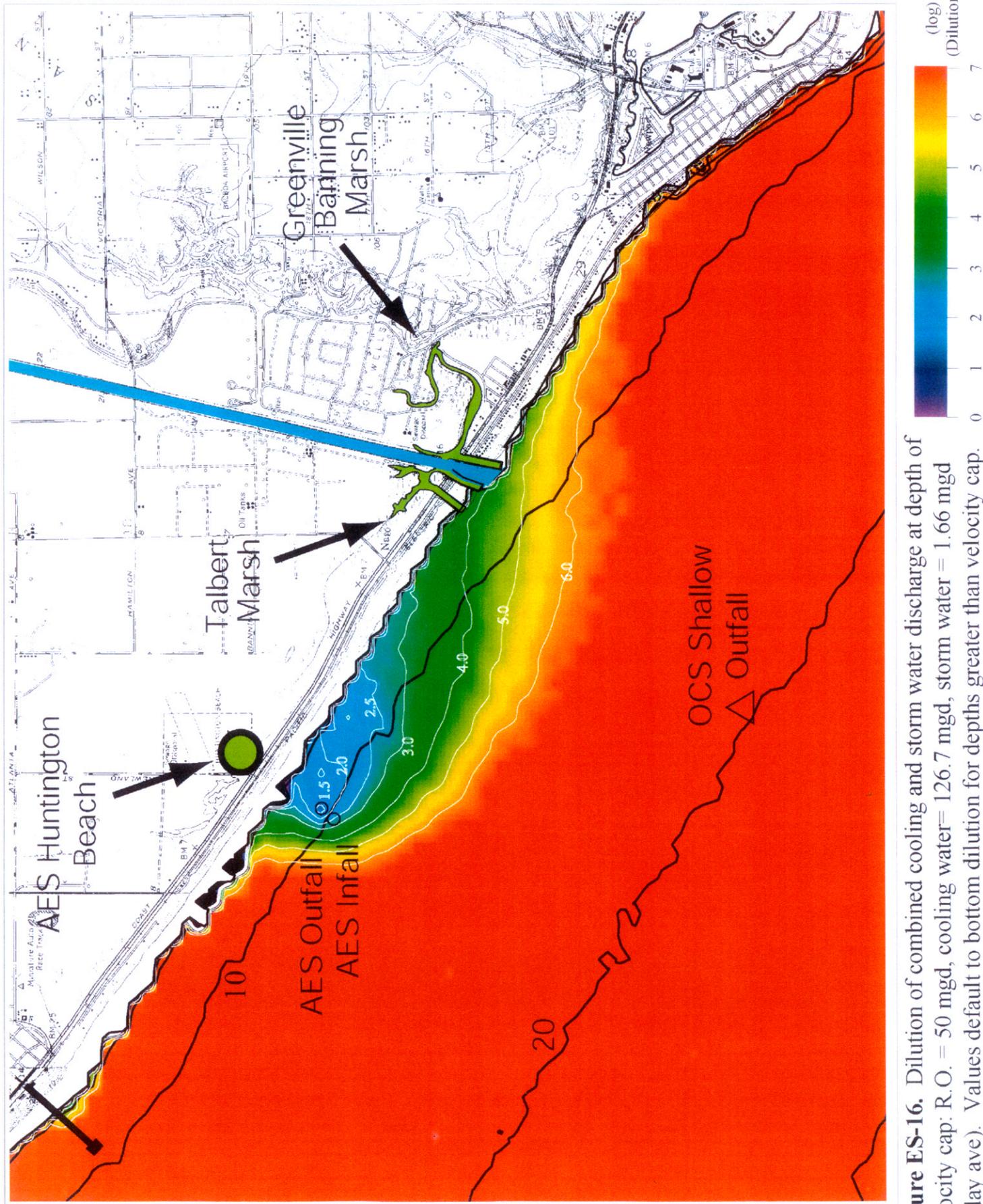


Figure ES-16. Dilution of combined cooling and storm water discharge at depth of velocity cap: R.O. = 50 mgd, cooling water= 126.7 mgd, storm water = 1.66 mgd (7 day ave). Values default to bottom dilution for depths greater than velocity cap.

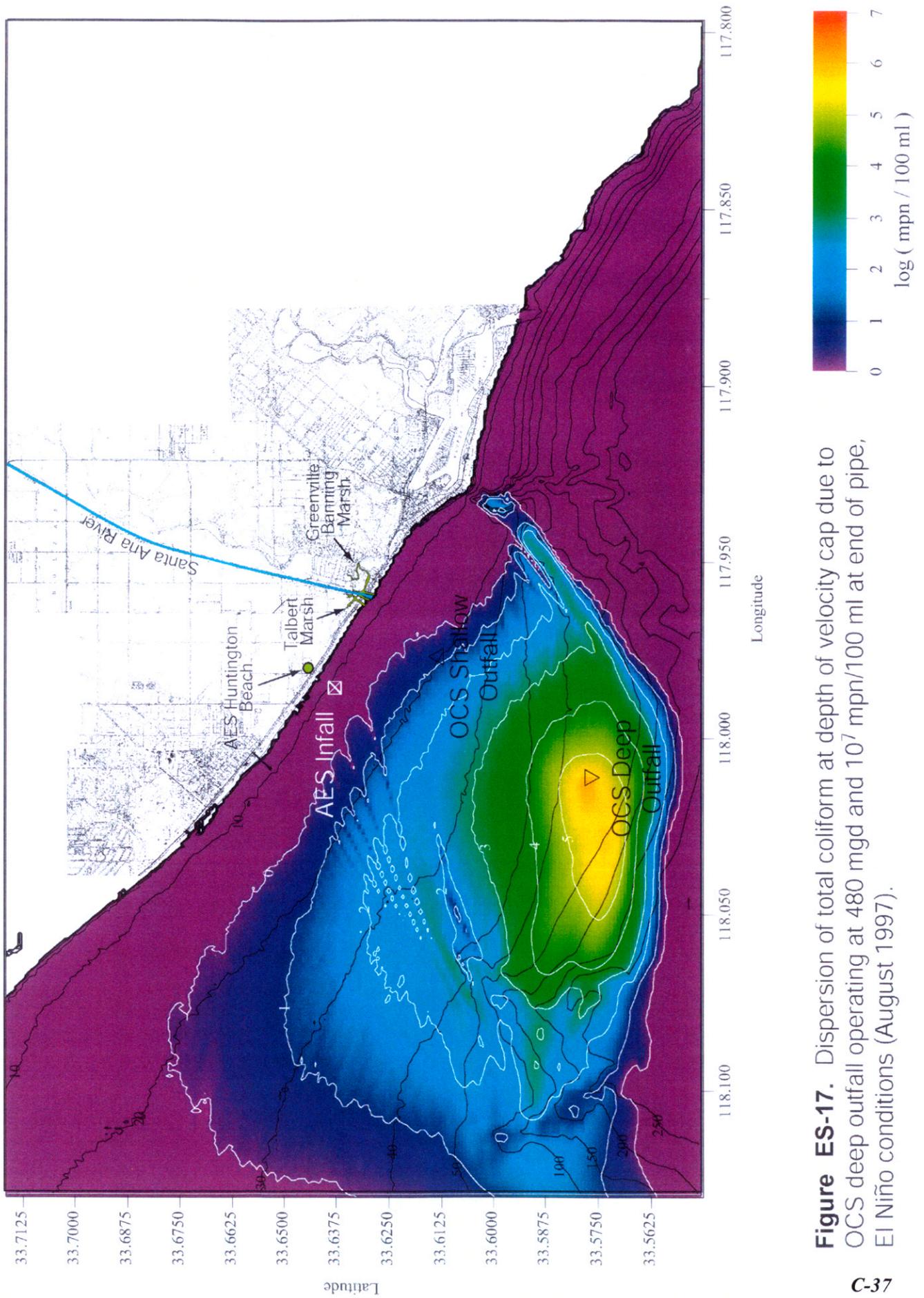


Figure ES-17. Dispersion of total coliform at depth of velocity cap due to OCS deep outfall operating at 480 mgd and 10^7 mpn/100 ml at end of pipe, El Niño conditions (August 1997).

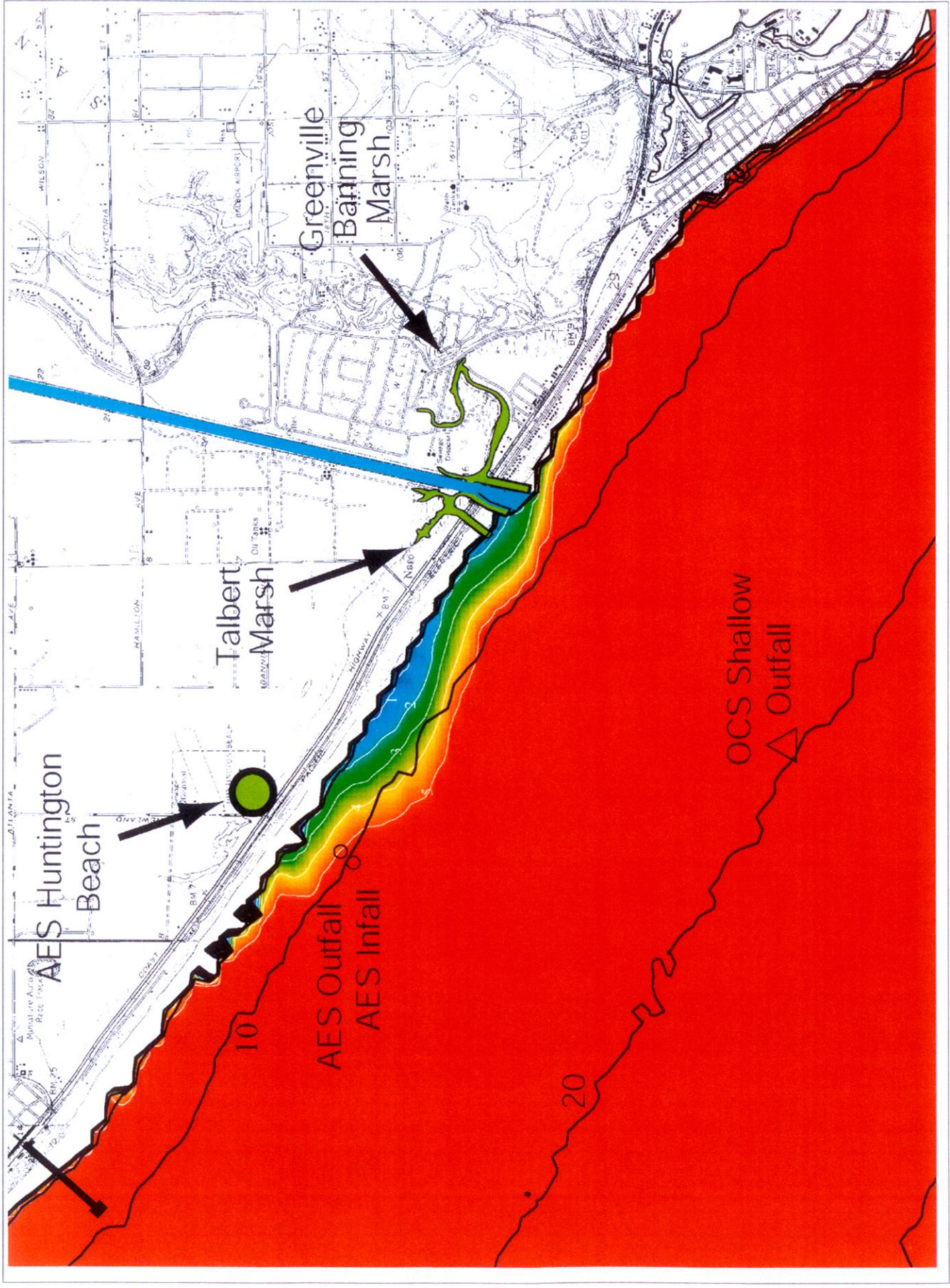


Figure ES-18. Total coliform dilution from Talbert Marsh tidal flush, 8 August 1997, 10:20 PDT.

one hundred thousand at the intake, indicating that marsh coliforms would be non-detectable in source water (Figure ES-18).

SECTION 1: INTRODUCTION

1) Introduction

A) Physical Setting

This study investigates basic water quality issues related to the proposed Huntington Beach Desalination Project to be sited in the southeastern portion of the City of Huntington Beach adjacent to the AES Huntington Beach Generating Station (HBGS). The proposed desalination project would be connected to the existing cooling water circulation system of the generating station. Physical specifications for the cooling water infall and outfall are listed in the NPDES permit #CA 0001163 (CRWQCB, 1993). The NPDES permit does not give a latitude and longitude for the infall location. Consequently, Poseidon Resources contracted an offshore surveying company (Tenera Environmental) to locate the infall using sidescan sonar and Trimble Geoexplorer differential GPS to obtain a precise fix on the infall location. Based on these survey techniques, the cooling water infall was determined to be located at latitude 33° 38' 18.8" N, longitude 117° 59' 01" W, (see Tenera, 2004), approximately 1,840 ft (561 m) offshore from the mean high tide line (Figure 1.1). Water is drawn through a velocity cap atop a rectangular infall tower (Figure 1.2) located 15.8 feet (4.8 meters) above the ocean floor where the total water depth 34.1 feet (10.4 meters) below mean sea level (MSL), based on National Ocean Survey digital bathymetry. The maximum mean water velocity at the inlet to the conduit is 2.0 feet per second (fps) (0.6 m/sec). Intake water velocity at the mean lower-low tide elevation above the velocity cap is nil.

The cooling water discharges from a seafloor structure identical in dimension to the infall tower except for the absence of a velocity cap (Figure 1.2). Instead, the discharge tower is capped with a debris screen having a 12" x 18"

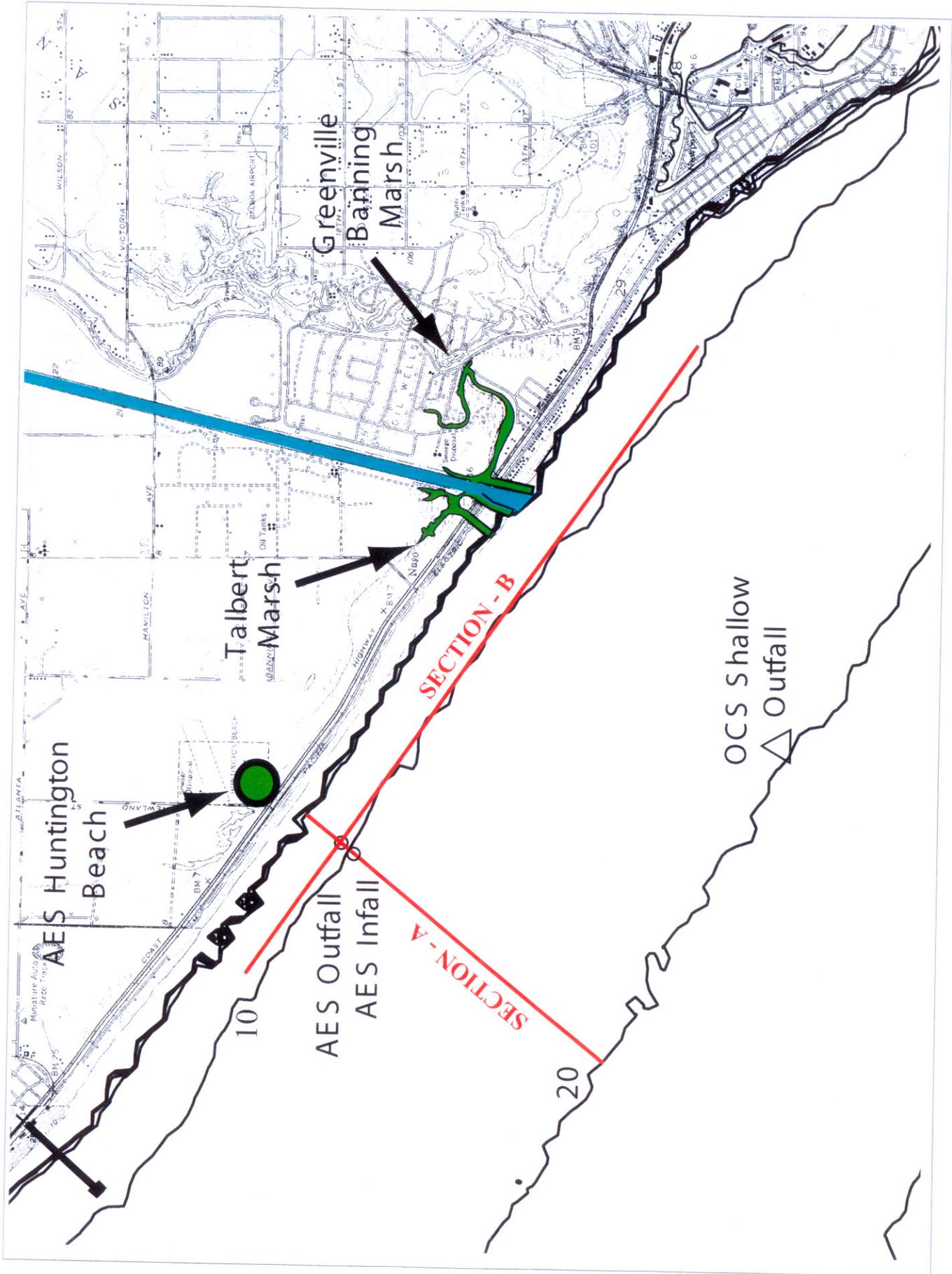


Figure 1.1. Location map for salinity profiles of source water and dilution modeling.

mesh constructed from 1" x 3" flat bar. The discharge tower is located at latitude 1.1 33° 38' 19" N, longitude 117° 58' 57" W, (Figure 1.1). The outfall terminates approximately 1,500 feet (457 meters) offshore where the seabed is 27.9 feet (8.5 meters) below mean sea level, based on National Ocean Survey digital bathymetry. The certified maximum plant flow rate is 516 million gallons per day (mgd). Discharges to the outfall consist almost entirely of condenser cooling water (with a maximum rated flow rate after re-powering of 507 mgd). A small amount of in-plant waste streams are discharged into the condenser cooling water. The maximum daily discharge of in-plant waste streams (including plant storm water) certified under the NPDES permit is 1.66 mgd, or 0.3% of the certified maximum discharge. Except during storm events, the daily discharge of in-plant waste streams is typically 0.1 mgd. The NPDES monitoring data on plant discharges for 1998, 1999 and 2000 are contained in Appendix A and show that the maximum daily discharge of in-plant waste streams was 0.73 mgd, occurring during February 1998. These in-plant waste streams contain oil and grease residues limited and monitored under the terms of the NPDES permit, plus suspended solids from the storm water runoff of the generating station's impervious surfaces.

Because the plant in-fall is only 340 ft (103.5 m) seaward of the plant outfall, an operational concern of the desalination proposal is the potential for re-circulation of the in-plant waste stream through the plant in-fall. A mitigating physical feature for this re-circulation concern is the configuration of the existing in-fall structure (Figure 1.2) which draws in water from approximately the middle of the water column where slightly more than 10 meters of local water depth is available for dilution (Figure 1.1). The addition of concentrated seawater by-product to the waste stream will render it denser than ambient seawater, causing it

to sink below the depth of the velocity cap on the infall tower (Figure 1.2). These physical processes pertaining to re-circulation of the combined discharge of the generating station and desalination plant are studied in Sections 4 and 6 by means of numerical hydrodynamic modeling techniques.

Approximately 9,000 ft (2.7 km) from the infall to AES Huntington Beach is the mouth of the Santa Ana River and adjacent Talbert Channel (Figure 1.1). The Santa Ana River has a drainage area of about 4,400 km², much of which is comprised of impervious urban surfaces that produce daily mean discharges of storm water as high as 8,000 cubic ft per second (cfs). The Santa Ana River also drains the adjacent Greenville Banning Marsh through a diversion channel (Figure 1.3). The Talbert Channel located about 400 m upcoast of the Santa Ana River mouth drains the Talbert Marsh into which the Huntington Beach Channel discharges storm water from the City of Huntington Beach through a system of storm drains and pumping stations. Therefore the proximity of these combined sources of storm water to the AES infall present a potential water quality concern for the source water which a desalination plant would ingest. These concerns are evaluated in Sections 7 and 8 of this study as well as Archibald (2002, 2004).

The technical approach used to evaluate the scenarios for these re-circulation and dilution issues involved the use of hydrodynamic transport models driven by historic wave, current and river flow rate data for known events. The production of concentrated seawater by-product by the proposed desalination plant was overlaid on these events to determine the potential range of variability in dilution and re-circulation outcomes.

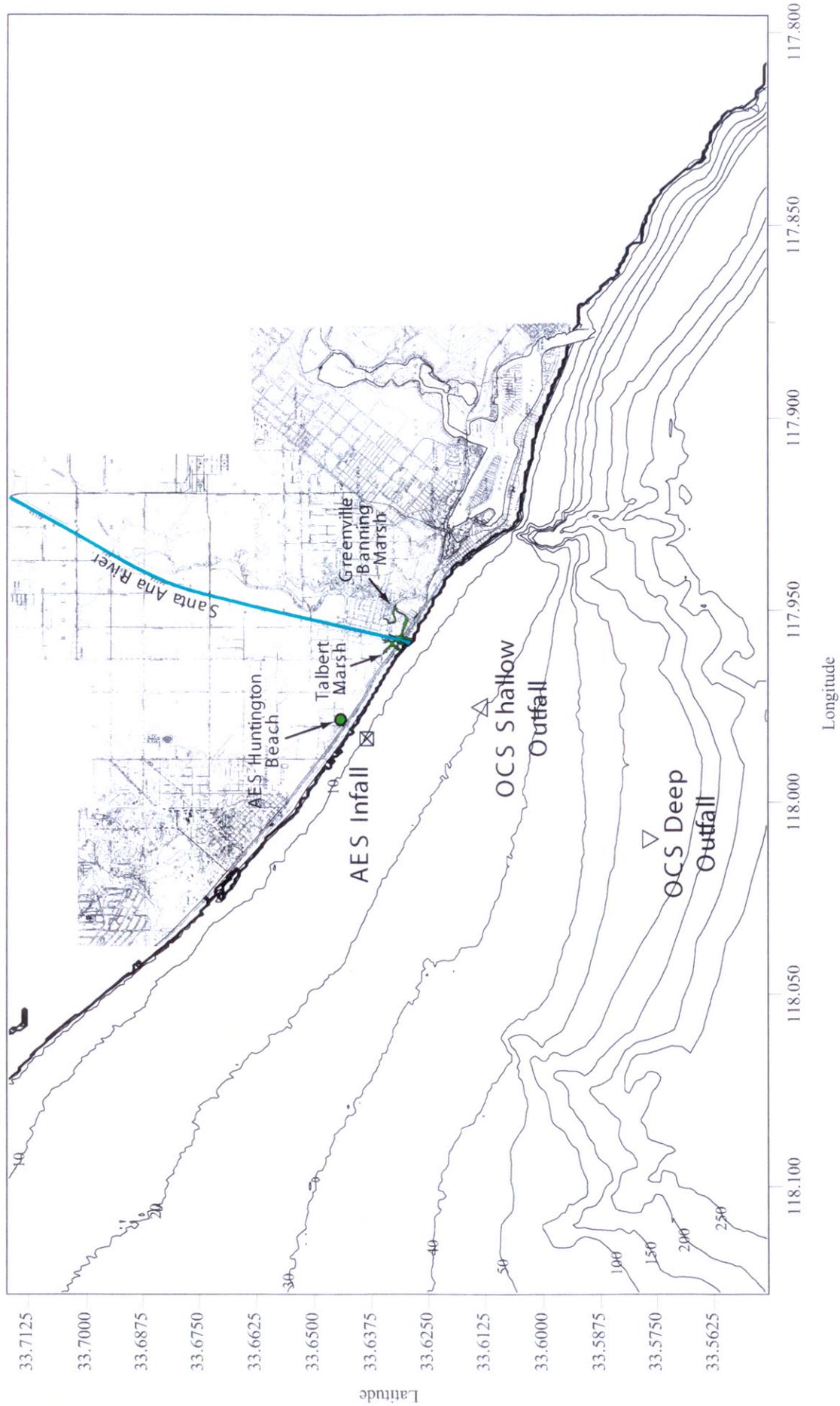


Figure 1.3. Location map for source-water modeling analysis due to fluxes from farfield sources.

B) Climate Variations and Fresh Water Supplies

The California coast is subject to climate cycles of about 20-30 years duration known as the Pacific/ North American pattern (for atmospheric pressure) or the Pacific Decadal Oscillation (for sea surface temperature). A dry period extended from about 1945-1977, followed by an episodically wet period from 1978-1998 that included the occurrence of 6 strong El Niño events (Inman and Jenkins 1997; and Goddard and Graham 1997). Based on the historic duration of these cycles, 1998 was likely the end of the wet cycle of climate in California with a return to the dry climate that prevailed from 1945-1977 (White and Cayan 1998).

To illustrate the historical evidence for these dry and wet climate cycles in Southern California, we evaluate the rain gage records for Santa Ana, Laguna Beach and San Diego (panel-a of Figures 1.4-1.6). The records were analyzed for climate trends using the Hurst (1951, 1957) procedure that was first used for determining decadal climate effects on the storage capacity of reservoirs (Inman and Jenkins, 1999). Climate trends become apparent when the data are expressed in terms of cumulative residuals Q_n taken as the continued cumulative sum of departures of annual values of a time series Q_i from their long term mean value Q_a such that $Q_n = \sum_0^n (Q_i - Q_a)$ where n is the sequential value of the time series.

The records for the total period of rainfall and their cumulative residual graphs are shown in Figures 1.4-1.6. All records show decadal scale climate changes (panel-b of Figures 1.4-1.6). Dry periods are shown by segments of the cumulative residuals having negative (downward) slopes while the wet periods have positive (upward) slopes. A dry period is found in all three records from 1945-1997, (negative slopes) while a wet period (positive slope) is shown from

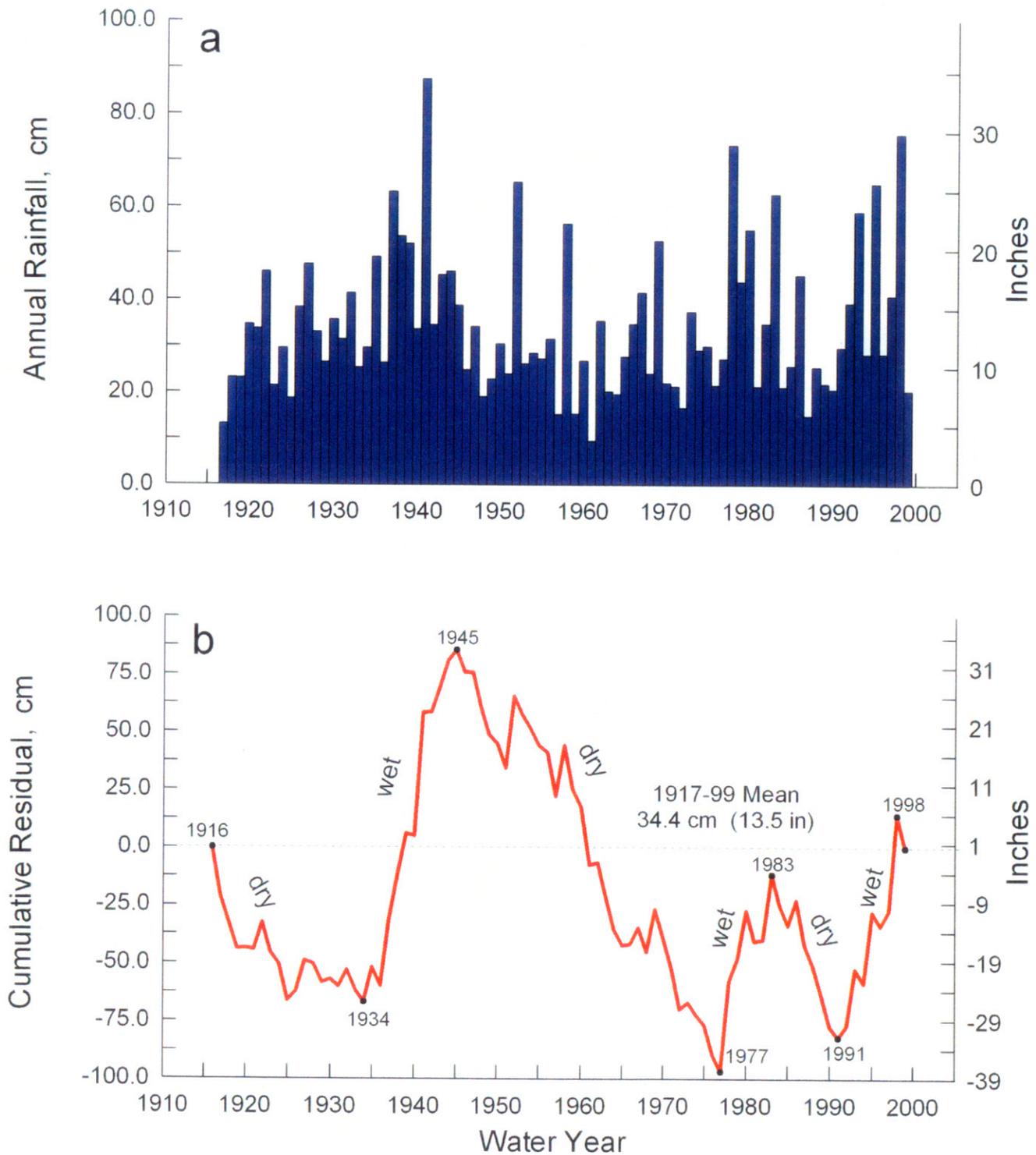


Figure 1.4. a) Total record of annual rainfall, Santa Ana, CA (National Weather Service) and b) Cumulative residual of the annual rainfall for the the period 1917-1999.

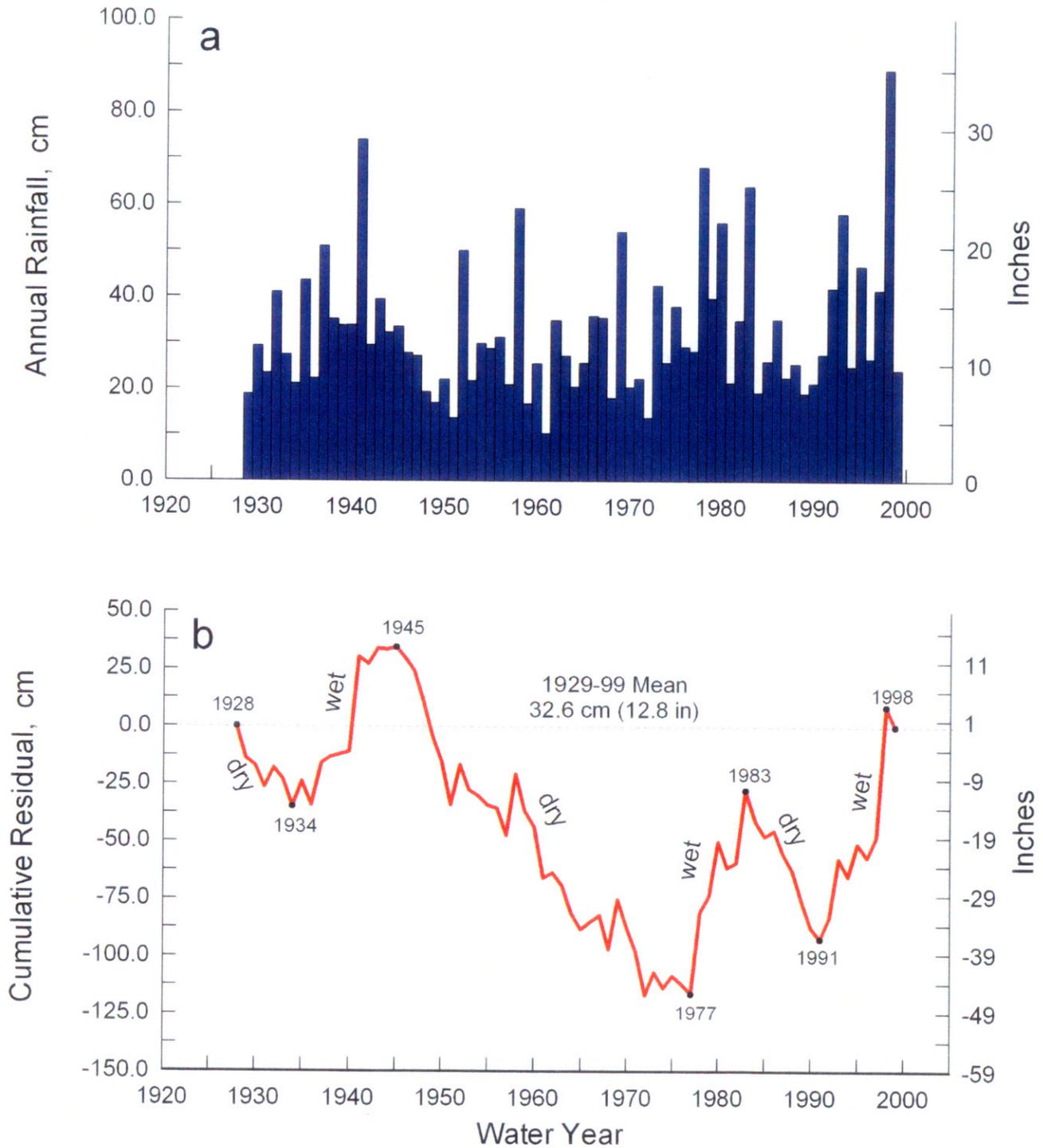


Figure 1.5. a) Total record of annual rainfall, Laguna Beach, CA (National Weather Service) and b) Cumulative residual of the annual rainfall for the the period 1929-1999.

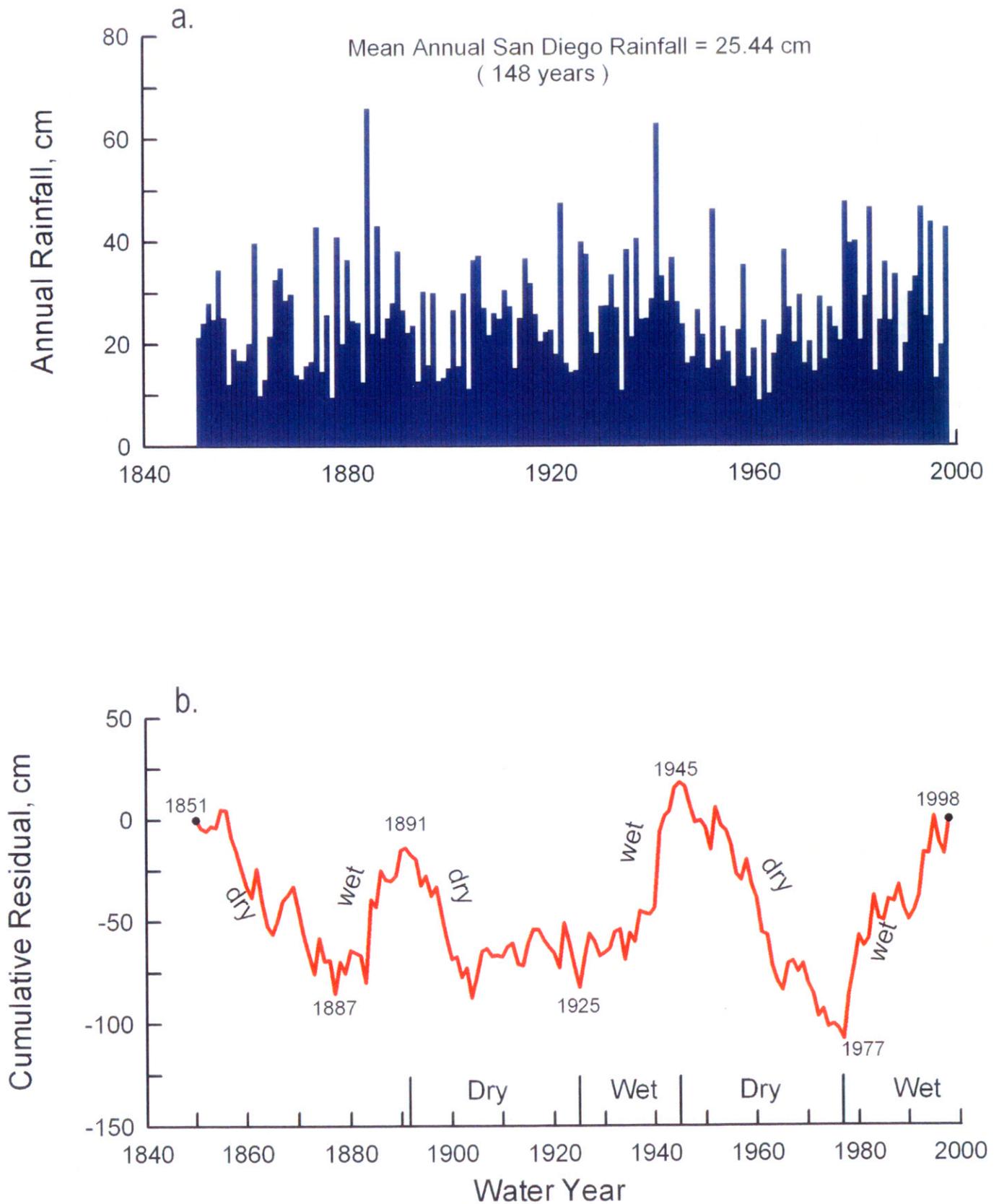


Figure 1.6 Annual rainfall histogram (a) and cumulative residual (b) for the city of San Diego, California.

1978-1998. The wet period of the climate cycle is more irregular caused by 6 strong El Niño events (water years 1978, 80, 83, 93, 95, and 98) and one 4 year period (1987-1990) of low rainfall.

The analysis shows that the average annual rainfall increased by about 38% from the dry to the wet portions of the cycle. Furthermore, both the minimum and maximum ranges in rainfall are higher in the wet period, while the averages of the 6 major rainfall events in 21 year periods before and after the climate change (1977/78) are about 8 to 9 inches greater during the wet period. Therefore, the expected transition back into the dry period for the next 20-30 years is likely to cause severe reductions in terminal storage levels of Southern California reservoirs. The development of alternative fresh water sources such as the proposed desalination project at AES Huntington Beach is likely to prove extremely timely while addressing a significant societal need.

The physical effect of desalinating seawater by reverse osmosis is in principle no different than the effects of evaporation. CalCOFI ocean surveys of the Southern California Bight have measured evaporative losses at 93.4 cm/yr (Roemmich, 1989; Bograd, et. al., 2001). The surface area of coastal waters inside the continental margin of the Southern California Bight is 160,000 km². Factoring evaporation rate over surface area, it is concluded that the coastal ocean of the Southern California Bight loses 1.49×10^{11} m³ of pure water constituent to evaporation each year. In contrast, a desalination plant producing product water at a rate of 50 mgd will extract 6.9×10^7 m³ of pure water constituent from the coastal ocean in one year's time, (but even then, only if it were operated continuously without any down time for maintenance). Consequently, it would take 2,163 desalination plants the size of the Huntington Beach project to match the

evaporative losses from the ocean that occur naturally in the Southern California Bight each year.