SPECIAL PUBLICATION SJ2007-SP3

EVALUATION OF POTENTIAL IMPACTS OF DEMINERALIZATION CONCENTRATE DISCHARGE TO THE INDIAN RIVER LAGOON (STUDY)

Task 2.G
Final Report

For the

Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon (Study)
Contract #SH341AA

for

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TABLE OF CONTENTS

DATA ATTACHMENTS

List of Tables

List of Illustrations

List of Acronyms and Abbreviations

ATM	Applied Technology and Management, Inc.
C.5 Report	Final Report on Five Potential Seawater Demineralization Project Sites –Task C.5
CH3D	Curvilinear Hydrodynamic 3-Dimensional (Model)
CIP	Clean in Place
DMR	Data Monitoring Report
CCMP	Comprehensive Conservation and Management Plan
DO	Dissolved Oxygen
FDEP	Florida Department of Environmental Protection
FIM	Fisheries Independent Monitoring
FMRI	Florida Marine Research Institute
FP	Fibropapillomatosis
FPL	Florida Power & Light
FFWCC	Florida Fish and Wildlife Conservation Commission
FWRI	Florida Wildlife Research Institute
HSPF	Hydrologic Simulation Program Fortran
ICW	Intracoastal Waterway
IMAP	Inshore Marine Monitoring and Assessment Program
IRL	Indian River Lagoon
IRLDS	Indian River Lagoon Demineralization Study
IRLNFS	Indian River Lagoon North Feasibility Study
IRLPLR	Indian River Lagoon Pollutant Load Reduction
IWR	Impaired Waters Rule
MEG	Model Evaluation Group
MGD	Million Gallons per Day
MINWR	Merritt Island National Wildlife Refuge
Na-EDTA	Ethylaminediaminetetraacetic Acid
NASA	National Aeronautics and Space Administration
NEP	National Estuary Program
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OFW	Outstanding Florida Water
PCA	Principal Component Analysis
PLRG	Pollutant Load Reduction Goal
ppm	Parts per Million
ppt	Parts per Thousand
PWRCA	Priority Water Resource Caution Areas
RO	Reverse Osmosis
SAV	Submerged Aquatic Vegetation
SJRWMD	St. Johns River Water Management District
SWIM	Surface Water Improvement Act
TMDL	Total Maximum Daily Loads
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) has identified the potential impacts of projected water use through year 2025 on the water resources in the district (SJRWMD 2006). SJRWMD has identified areas in which the proposed water supply plans of major users, if implemented, will result in unacceptable impacts to environmental resources. These areas, referred to as priority water resource caution areas (PWRCA), include all or portions of Orange, Osceola, Seminole, Volusia, Marion, Lake, Flagler, and Brevard counties.

SJRWMD has identified the need to investigate the technical, environmental, and economic feasibility of alternative water supply and water resource strategies as a means of preventing the identified potential problems. As part of these investigations, SJRWMD has initiated this study to evaluate the potential impacts of demineralization concentrate discharge to the Indian River Lagoon (IRL).

The area of study focuses on the portion of the IRL located between Ponce inlet at the north end of Mosquito Lagoon and Sebastian inlet south of the project site. The potential collocated discharges to be evaluated were identified in *Special Publication SJ2004-SP6, Final Report on Five Potential Seawater Demineralization Project Sites – Task C.5* (Beck 2004). This work was performed under the Seawater Demineralization Feasibility Investigation and was completed in January 2004. Based upon the evaluations within this report, two sites were identified for further evaluation: the Reliant Indian River Power Plant and the Florida Power & Light (FPL) Cape Canaveral Power Plant, both located in Port St. John, approximately 9 and 11 miles south, respectively, of the city of Titusville in Brevard County, Florida.

Under Phase I of the project, an evaluation was made relative to the applicability of an existing model of the IRL developed by the University of Florida. The University applied the Curvilinear Hydrodynamic Model 3-D (CH3D) to the IRL for the Indian River Lagoon Pollutant Load Reduction (IRLPLR) project. This model was modified by the SJRWMD following delivery by the University of Florida. For the purposes of this report, this model application is termed the IRLPLR hydrodynamic model.

The existing IRLPLR model was reviewed by a panel of experts and recommendations for the use of the model were made. It was determined that the existing hydrodynamic model (IRLPLR) was suitable for use in the evaluation of the concentrate discharge, with minor modifications and additional data collection. The modifications to the model included;

- Increase in the horizontal resolution of the model in the area of the discharges
- Increase in the vertical resolution of the model
- Dynamic simulation of the temperature
- Refined analyses of the freshwater inflow within the North IRL
- Dynamic simulation of the demineralization plant operations relative to salinity and temperature

- Verification of the simulation of the near field circulation using measured temperatures from the existing power plants

Under Phase II, these changes were made to the IRLPLR model application by SJRWMD staff with assistance from the District consultant. For the purposes of this report, this model application is termed the Indian River Lagoon Demineralization Study (IRLDS) model.

Under Phase II the goals were to identify the environmental and operational issues of concern, develop a list of scenarios under which to run the model to evaluate the potential environmental impacts, develop the methodologies to assess impact, and evaluate the impacts based upon the model simulations. Under the environmental issues, consideration was given to quantification of the abundance and availability of habitat and key organisms in the area of the proposed project, as well as the definition of sentinel organisms and their tolerance to salinity concentrations and fluctuations. The goal was to compile the available water quality and biological data and identify methods to assess the effects of the demineralization operations on the environmental conditions in the lagoon. Under the operational issues, consideration was given to recirculation, impingement and entrainment, cooling water flow, temperature issues, collocation issues, equipment maintenance, and National Pollutant Discharge Elimination System (NPDES) permitting issues.

Based upon the methodologies developed for assessing the impacts and utilizing the model simulations of salinity, temperature, and circulation, the impacts from the operation of the demineralization plants under varying water supply production rates were quantified. The analyses examined water production rates of 30 MGD, 20 MGD, 10 MGD and 5 MGD at each of the facilities individually and together.

For the impact analyses, 12-year simulations were run. The inputs for the 12-year simulations were based upon repeating the measured 1997 to 2000 conditions. Based upon analyses of the total rainfall and the frequency of return for the 2000 year drought, these simulations represented a conservative analysis of the potential impacts. The 12-year long simulations were required in order to assure that the system had reached a condition where the net build up of salinity had leveled out. The results were analyzed and the impacts to the system quantified.

The impacts included four primary categories: operational impacts, physical impacts, water quality/regulatory impacts, and ecological impacts. For all of the ecological analyses, the final four years of the model simulation (years 9 to 12) were used. This assured that the ecological impact assessments reflected the full potential build up of salinity with the plants operating.

The results of the physical impact analyses (salinity) showed that the critical changes to the system occurred over a broad area of the lagoon, not simply within the immediate discharge zones of the power plants. These “far field” salinity changes became the primary issue for the ecological impact assessments. Based upon the salinity simulations, the difference between collocation of a demineralization plant either at the Indian River power plant site or at the Cape Canaveral power plant site did not significantly alter the far field results. Therefore, for the ecological analyses, the simulations with the demineralization plant collocated at the Indian River site were utilized. The Indian River site represents a slightly more critical situation given its location further north and lower cooling water intake and discharge rates.

The results of the model were evaluated, and the long-term maximum and average salinity changes were presented along with the acres of salinity change at various concentrations. The salinity began to reach a dynamic equilibrium at between 6 and 8 years of demineralization plant operation. For the 30 MGD and 20 MGD scenarios, significant salinity changes were seen throughout the North IRL; these extended into Mosquito Lagoon, Banana River, and south along the IRL. The results show that the net long-term flow through Haulover Canal is altered, which pulls in higher saline water from Mosquito Lagoon. For the 10 MGD scenario, the overall levels of impact are reduced in comparison with the 30 MGD and 20 MGD scenarios, with salinity changes generally near 2 ppt with higher levels seen local to the discharge. Comparatively, the 30 MGD and 20 MGD scenarios showed changes of 6-7 ppt and 4-5 ppt respectively.

Assessment of the potential concentration of pollutants showed that compared to baseline conditions, for some parameters, and based upon available data, water quality criteria may be violated. The operation of the facilities has the potential to concentrate those pollutants and those concentration increases (due to antidegradation requirements) may limit the feasibility of the proposed projects. It is important to note that this evaluation was conservative in nature, and that pre-treatment at the facilities may remove some quantities of pollutants at the facility, but the level of removal would need to be defined through pilot studies which are beyond the present scope. Additionally, the validity of the available data for the baseline conditions, which identifies existing water quality violations for various metals, has been brought into question through the peer review process of this study. Recommendations made herein, relative to the feasibility of demineralization, do not consider the concentration of pollutants, but rather it is recommended that additional data collection be completed to establish baseline conditions if further action is taken on demineralization at these two facilities.

The results of the ecological assessments were presented based upon changes to stratification, temperature, and salinity. Temperature showed no significant level of change due to the operation of the demineralization plants at all production rates. Stratification levels also did not show any significant levels of change due to the operation of the demineralization plants at all production rates.

Salinity changes were significant and ecological impacts were assessed based upon the percent of baseline habitat that would move from the preferred salinity range to outside of the preferred salinity range based upon the median conditions. The median condition is the acreages of preferred habitat where, under baseline conditions, 50 percent of the time the acreage of preferred habitat is greater, and 50 percent of the time it is less. It should be noted that areas within the North IRL continuously move into and out of the preferred salinity ranges for various species under present conditions. Species survive outside of the preferred range and, therefore, it should not be assumed that movement out of the preferred range constitutes a complete loss of the species.

Some areas of the Indian River Lagoon have experienced decreased salinities due to increased freshwater inflow from urbanization. The North IRL, where the power plants are located, has limited watershed inflow and has not seen a significant freshening over natural levels. Therefore the benefit to be theoretically gained from the increased salinity conditions in the North IRL is considered negligible.

For the operation of a 30 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 14 percent increase in the preferred salinity habitat for commercial shrimp to a 45 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 30 percent, 20 percent, 31 percent, and 30 percent, respectively. A net loss of seagrass preferred habitat was seen with a 29.8 percent reduction for *Ruppia* and an 8 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the operation of a 20 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 13 percent increase in the preferred salinity habitat for commercial shrimp to a 32 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 21 percent, 14 percent, 19 percent, and 15 percent, respectively. A net loss of preferred seagrass habitat was seen overall, with a 20 percent reduction for *Ruppia* and a 0.3 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the operation of a 10 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 9 percent increase in the preferred salinity habitat for commercial shrimp to a 16 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 10 percent, 7 percent, 9 percent, and 8 percent, respectively. A change of preferred seagrass habitat was seen with a 11 percent reduction for *Ruppia* and a 3 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the various species, spatial duration plots identified where preferred salinity ranges changed in duration with and without the demineralization facilities. The results showed that any gains in the duration of preferred habitat occurred south of the plants in areas that typically had lower salinity from freshwater inflow. Decreases in the time that salinity levels were within the preferred range were greatest near the plants and decreased at greater distances.

Various acceptable levels of habitat loss are defined within the literature, and based upon similar studies conducted throughout Florida. Shaw and colleagues' peer review panel

(Shaw et al. 2005) found the 15 percent loss benchmark to be "reasonable and prudent" for the Middle Peace River Minimum Flows and Level evaluations. This benchmark was further supported by the Upper Myakka River Minimum Flows and Levels peer review panel (SWFWMD Peer Review Panel 2005). Literature values range between 10 percent and 33 percent as acceptable levels of habitat loss. Minimum Flows and Levels studies provide present thinking within the State of Florida relative to allowable level of habitat loss. The choice of an appropriate level of acceptable habitat loss, or shift out of a preferred habitat range, needs to be based upon various ecological and physical factors. The present state of the habitat needs to be considered, i.e., is that habitat degraded. Additionally, different percentages could be applied to different species, different areas, or at different times.

While no definitive acceptable level of habitat loss has been defined, evaluation of all of the results allows for a determination of the feasibility of collocating a demineralization plant at the Reliant Indian River site and/or the FPL Cape Canaveral site. The following recommendations are made;

- At the Indian River power plant site, a 30 MGD or a 20 MGD facility is not feasible based upon the potential level of ecological impacts as well as potential impingement and entrainment (I&E) increases due to makeup water needs.
- At the Cape Canaveral power plant site, a 30 MGD or a 20 MGD facility is not deemed feasible based upon the potential level of ecological impacts.
- Combined water production rates for two facilities totaling 20 or 30 MGD are not deemed feasible based upon the potential level of ecological impacts.
- Potential water quality issues, i.e., concentration of pollutants, may make any water production rate unfeasible due to the need to not degrade the water quality. Pilot testing will be needed in order to determine if pre-treatment would alleviate the potential concentration of pollutants. Presently, peer review of the study has identified potential errors in the existing metals data. Additional baseline data therefore would be necessary prior to further consideration of the proposed co-located facilities.
- Depending upon the choice of an allowable level of acceptable loss of preferred habitat, total plant capacities less than or equal to 10 MGD, either as a single plant or combined, may be feasible. It should be noted though that present analyses show a net loss of preferred seagrass habitat for all scenarios. This is in conflict with present IRL goals for restoration of seagrass habitat. Appendix I presents excerpts from the IRL Comprehensive Conservation and Management Plan (CCMP) discussing goals and targets for the IRL.
- The lateral extent of the salinity changes even under these reduced–production scenarios is significant and will make permitting of the demineralization facilities difficult.

- Presently the model does show salinity changes within Outstanding Florida Waters (OFW). Therefore, under the permitting process, the feasibility will need to consider the anti-degradation rules and the 62-4.242 Antidegradation Permitting Requirements; Outstanding Florida Waters; Outstanding National Resource Waters; Equitable Abatement. This rule provides specific criteria that would need to be satisfied to obtain a discharge permit.

This study provides an estimate of levels of preferred habitat loss, based on different scenarios of demineralization concentrate discharge at project sites collocated with existing power plants, but does not define what losses may be acceptable or not acceptable to stakeholders, government agencies, and the general public. The identification of acceptable changes to preferred habitat is a multi-agency, high-level policy decision. This will need to be done at a time when there is a utility sponsor who wishes to proceed with a project, and the perceived need for new water supply becomes urgent and widely recognized.

1.0 INTRODUCTION

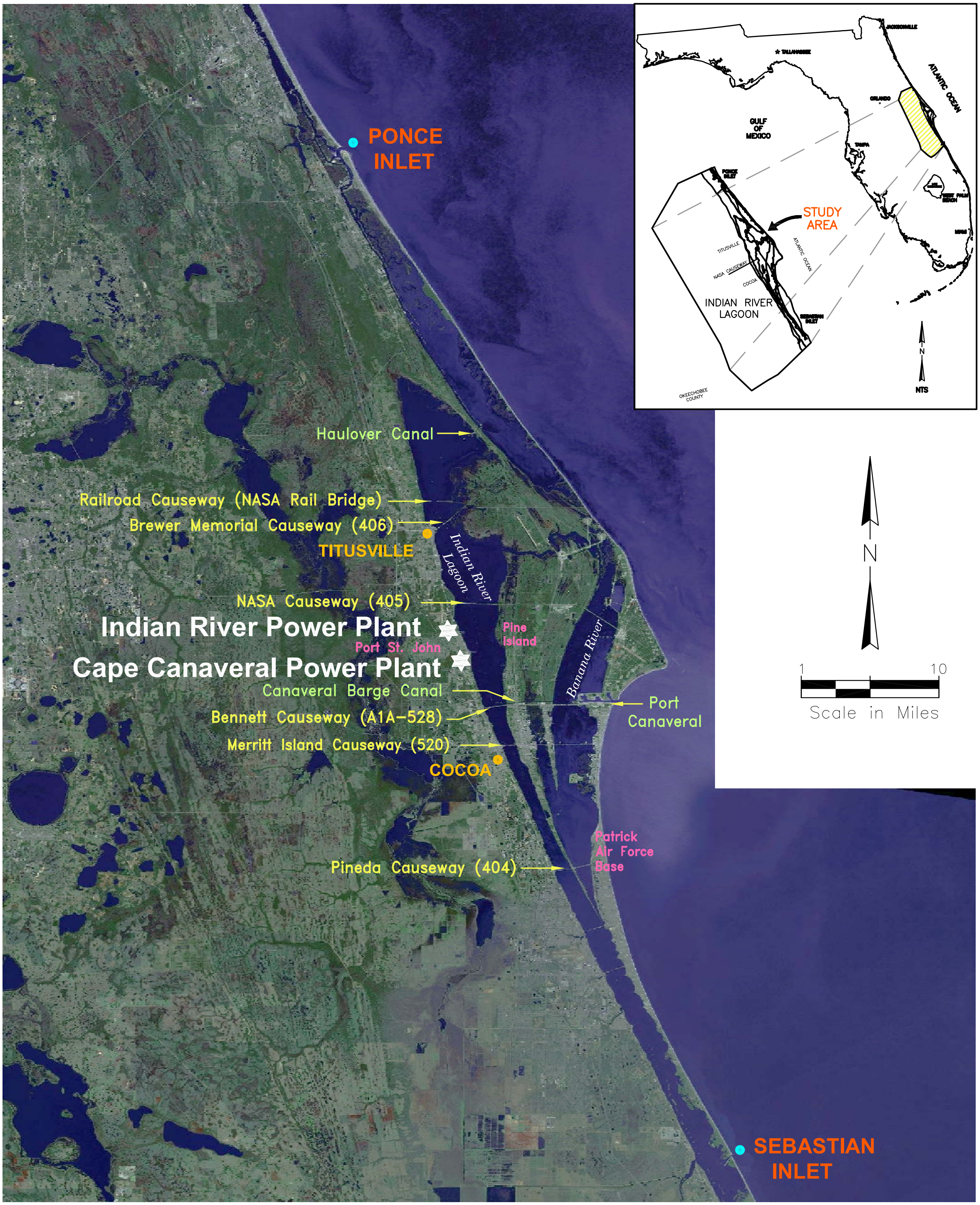
1.1 General Project Overview

The St. Johns River Water Management District (SJRWMD) has identified the potential impacts of projected water use through year 2025 on the water resources in the district (SJRWMD 2006). SJRWMD has identified areas in which the proposed water supply plans of major users, if implemented, will result in unacceptable impacts to environmental resources. These areas, referred to as priority water resource caution areas (PWRCA), include all or portions of Orange, Osceola, Seminole, Volusia, Lake, Marion, Flagler, and Brevard counties and may extend to new areas as the planning process continues.

SJRWMD has identified the need to investigate the technical, environmental, and economic feasibility of alternative water supply and water resource strategies as a means of preventing the identified potential problems. As part of these investigations, SJRWMD has initiated this study to evaluate the potential impacts of demineralization concentrate discharge to the Indian River Lagoon (IRL). The area of study focuses on the portion of the IRL located between Ponce inlet at the north end of Mosquito Lagoon and Sebastian inlet at the south of the project site. The potential collocated discharges were identified in Special Publication SJ2004-SP6, *Final Report on Five Potential Seawater Demineralization Project Sites – Task C.5* (Beck 2004). This work was performed under the Seawater Demineralization Feasibility Investigation, and was completed in January 2004. Based upon the evaluations within this report, two sites were identified for further evaluation: the Reliant Indian River Power Plant and the Florida Power & Light (FPL) Cape Canaveral Power Plant, both located in Port St. John, approximately 9 and 11 miles south, respectively, of the city of Titusville in Brevard County, Florida. Figure 1 shows the location of these two plants along the IRL. Figure 2 provides an enlarged view of the power plant locations.

This study was conducted in two phases starting in September of 2004. Phase I ran through January of 2005, Phase II from January 2005 through June of 2006. The following describes the work conducted under each phase.

Under Phase I of the project, an evaluation was made of the applicability of an existing model of the IRL (Curvilinear Hydrodynamic 3-Dimensional Model, or CH3D) developed by SJRWMD for use in the evaluation of the impacts of concentrate discharge. It was determined that the existing hydrodynamic model was suitable for use in the evaluation of the concentrate discharge, with minor modifications and additional data collection. The original model developed for the Indian River Lagoon Pollutant Load Reduction (IRLPLR) Project, is termed the IRLPLR model for the purposes of this study.



04948-TM2G-Fig 1.dwg Study Area 6/6/06

Figure 1
Study area within Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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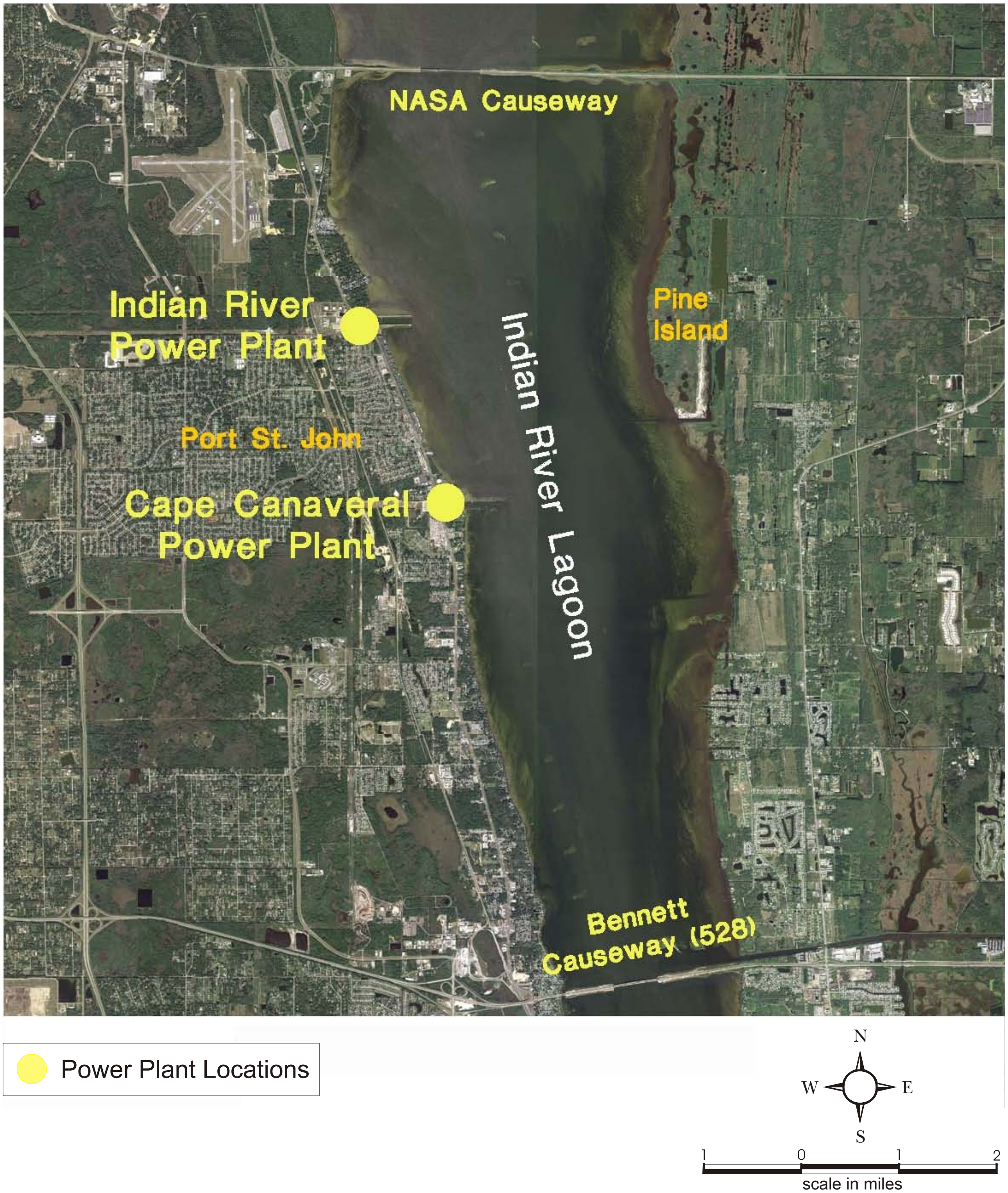

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Figure 2
FPL Cape Canaveral and Reliant Indian River Power Plants
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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Phase II of this project identified the key environmental and operational issues of concern, including the identification of potentially important biological organisms that could be impacted. The environmental issues of concern for this project relate to the biological resources that have a reasonable potential for impact by the concentrate discharge, and/or changes in the magnitude of impingement and entrainment at one or both candidate facilities. Specific environmental impacts that could potentially affect the biological resources are:

- changes in salinity,
- changes in temperature,
- changes in stratification,
- increases in existing ambient pollutant levels due to concentration through the demineralization facility,
- introduction of pollutants related to the operation of the demineralization facilities, and
- changes in impingement and entrainment (I&E) compared to baseline conditions at the power plants.

Among the biological resources of concern, are those organisms and life stages that may be responsive to direct and indirect effects of the concentrate discharge, and those that may be relatively non-responsive to the concentrate discharge. With respect to specific organisms, SJRWMD personnel, project participants, and the public identified a list of taxa of concern. These taxa included:

- seagrasses,
- benthic macroinvertebrates (hard clam, oysters),
- horseshoe crabs,
- shrimp,
- spotted seatrout,
- red drum,
- common sea trout and baitfish,
- birds and waterfowl,
- sea turtles, and
- manatees.

Available data were compiled for the focus species, and methodologies were developed for linking the model results with the ecological resources to determine the potential impacts of the collocated demineralization facilities. Using the methodologies, the impacts from the proposed project were quantified. This included model development/modifications, model application, and resource impact evaluation.

1.2 Purpose and Contents of Report

This report presents the results of all tasks completed under this study, Phases I and II. The remainder of the report is broken down into six sections these are:

- Section 2: Characterization of the Study Area
- Section 3: Hydrodynamic Model Review and Approach
- Section 4: Environmental/Operational Issues of Concern
- Section 5: Assessment Methodologies
- Section 6: Hydrodynamic Model Development
- Section 7: Impacts Assessment
- Section 8: Summary and Conclusions

Section 2 provides a characterization of the IRL, including the physical, hydrodynamic, hydrologic, chemical, and ecological conditions. Additionally, the characteristics of the existing power plant discharges are presented. The summary provides a baseline understanding of the system when evaluating the findings throughout the report.

Section 3 summarizes the findings from Phase I, where the existing IRLPLR model was reviewed for use in the evaluation of the demineralization discharge impacts. Additionally, the recommendations made for model refinements are discussed along with the Model Expectations Document (MED). The MED provided the criteria that the model was to meet relative to the needs of the environmental impact assessment.

Section 4 summarizes the key environmental and operational issues of concern. Under the environmental issues, consideration is given to quantification of the abundance and availability of habitat and key organisms in the area of the proposed project and their tolerance to salinity changes from the proposed project. Under the operational issues, consideration is given to recirculation, I&E, cooling water flow, temperature, collocation issues, equipment maintenance, and National Pollutant Discharge Elimination System (NPDES) permitting issues.

Section 5 summarizes the methodologies utilized in the impact analyses. This includes the operational impacts assessment, the physical impacts assessment, the water quality assessment, and the ecological impacts assessment.

Section 6 presents the results of the hydrodynamic model refinement and validation. It is important to note that for this project, an existing hydrodynamic model was utilized with minor modifications to the input files. Additionally, the model was modified to dynamically simulate the temperature and the power plant operations. A detailed model calibration/validation was not completed under this project. The detailed model calibration/validation was completed under the IRLPLR project. This included significant peer review by a panel of experts. Section 6 also presents data demonstrating that the model accuracy is not impacted by the modifications made, and that the refinements are sufficient for simulation of the near field plume dynamics at the power plants.

Section 7 presents the results of the impact assessments, including the physical impacts (salinity, circulation, and temperature), the operational impacts, the water quality/regulatory impacts, and the ecological impacts.

Section 8 presents a summary of the findings of the study, including recommendations on the feasibility of the various water production rates at the two collocated discharges.

2.0 CHARACTERIZATION OF STUDY AREA

2.1 Physical

The IRL is an example of a water body that is both an estuary and a lagoon (i.e., a lagoonal estuary). The classification system, which is typically used to classify natural systems, is influenced by the non-natural anthropogenic influences on the IRL (e.g., rerouting of freshwater conveyances into the IRL for flood control). Lagoons are shallow, semi-enclosed coastal bodies of water, which lie between the mainland and a barrier island. Inlets, either natural or artificial, cut through barrier islands and allow water transport and tidal mixing with the ocean. Lagoons are typically shallow and strongly influenced by precipitation and evaporation, which results in fluctuating water temperature and salinity.

Estuaries are also semi-enclosed coastal water bodies, but they are generally located directly on the coast and are open to nearshore areas. The main difference between lagoons and estuaries is the dependency of estuaries on freshwater inflow from rivers. Barrier or bar-built estuaries form when a barrier island separates freshwater discharge from coastal rivers and the ocean. When an estuary is separated by a barrier island, it can also be considered a lagoon or, vice versa, if a lagoon receives freshwater discharge from coastal rivers, it is also considered an estuary. Therefore, the IRL is an example of a water body that is both an estuary and a lagoon.

The IRL is on Florida's east coast and spans 156 miles in length. It is a restricted lagoon, meaning it has more than one channel (i.e., inlets) connecting it to the ocean and there is a well-defined exchange and a tendency to have a net seaward transport of water. Wind patterns can create surface currents, which help transport water in a downwind direction. Wind patterns also increase mixing in lagoons, both vertically within the water column and laterally.

Additional properties of lagoons vary according to size and other physical characteristics. Due to the great length of the IRL, it is significantly longer than it is wide, researchers have divided the lagoon into three sub-basins (Hill 2001):

1. Northern sub-basin = area north of Sebastian inlet
2. Central sub-basin = between Fort Pierce inlet and Sebastian inlet
3. Southern sub-basin = area between St. Lucie inlet and Fort Pierce inlet

Each of the three sub-basins is characterized by differing tidal amplitudes, excursion (i.e., horizontal transport distance with either flood or ebb tide), and current speeds. Tidal amplitude, excursion, and current speed are lowest in the northern sub-basin and increase to the south (Hill 2001). An exception to this generalization occurs around inlets, where current speeds during maximum flood or ebb tide can be greater due to the constricting effects of the channels. Around inlet mouths, tidal forcing is important, whereas in the lagoon interior, mixing is predominantly wind driven. Therefore, in the IRL, there is a decreasing tidal transport away from the inlets (Hill 2001). For this study, the primary focus is on the Northern Sub-Basin. This is the area where the two power plants are located, and the properties of this area of the lagoon govern the feasibility of collocation. For the purpose of this study, we will call this area the North IRL.

The North IRL is a shallow system with limited exchange with the Atlantic Ocean. The study area presented in Figures 1 and 2 includes the following canals, causeways and inlets (Woodward-Clyde 1994):

- Haulover Canal
- Railroad Causeway (NASA Rail Bridge)
- Brewer Memorial Causeway (406)
- NASA Causeway (405)
- Bennett Causeway (A1A-528)
- Merritt Island Causeway (520)
- Pineda Causeway (404)
- Port Canaveral inlet
- Canaveral Barge Canal

In the North IRL, the dredging of the ICW created a deep-water channel with a maintenance depth of 12 feet in an otherwise shallow system, with typical depths between 3 and 6 feet (Woodward-Clyde 1994). Figure 3 presents a plot of the bathymetric conditions in the North IRL. The creation of the ICW modified the North IRL by functioning as a sediment trap and acting as a conduit for denser seawater to enter from the inlets (Woodward-Clyde 1994). Dredge spoil from the ICW was often deposited directly on salt marsh, mangrove, and seagrass habitats. The ICW also functions as a hydraulic link between the North IRL and Mosquito Lagoon by cutting through the Cape Canaveral complex at Haulover Canal (Woodward-Clyde 1994).

Port Canaveral inlet is artificial and stabilized with a system of locks. These locks isolate the Banana River from the ocean by limiting the exchange of water. It was constructed in the early 1950s in an area known to be a safe anchorage for shipping because of the protection of the Cape. Banana River and the North IRL are connected through the Canaveral Barge Canal.

2.2 Hydrodynamics

The hydrodynamic conditions within the North IRL are dominated by wind because of the distance to the nearest inlet. The nearest open inlets to the study area are Sebastian inlet to the south and Ponce de Leon inlet in Mosquito Lagoon on the other side of Haulover Canal. The degree of damping of the tidal wave can be seen in Figure 4, which presents the measured tides at Sebastian inlet and the Melbourne Causeway. The tide in the immediate vicinity of the two power plants is completely damped out, with only the long-term mean water level fluctuations seen

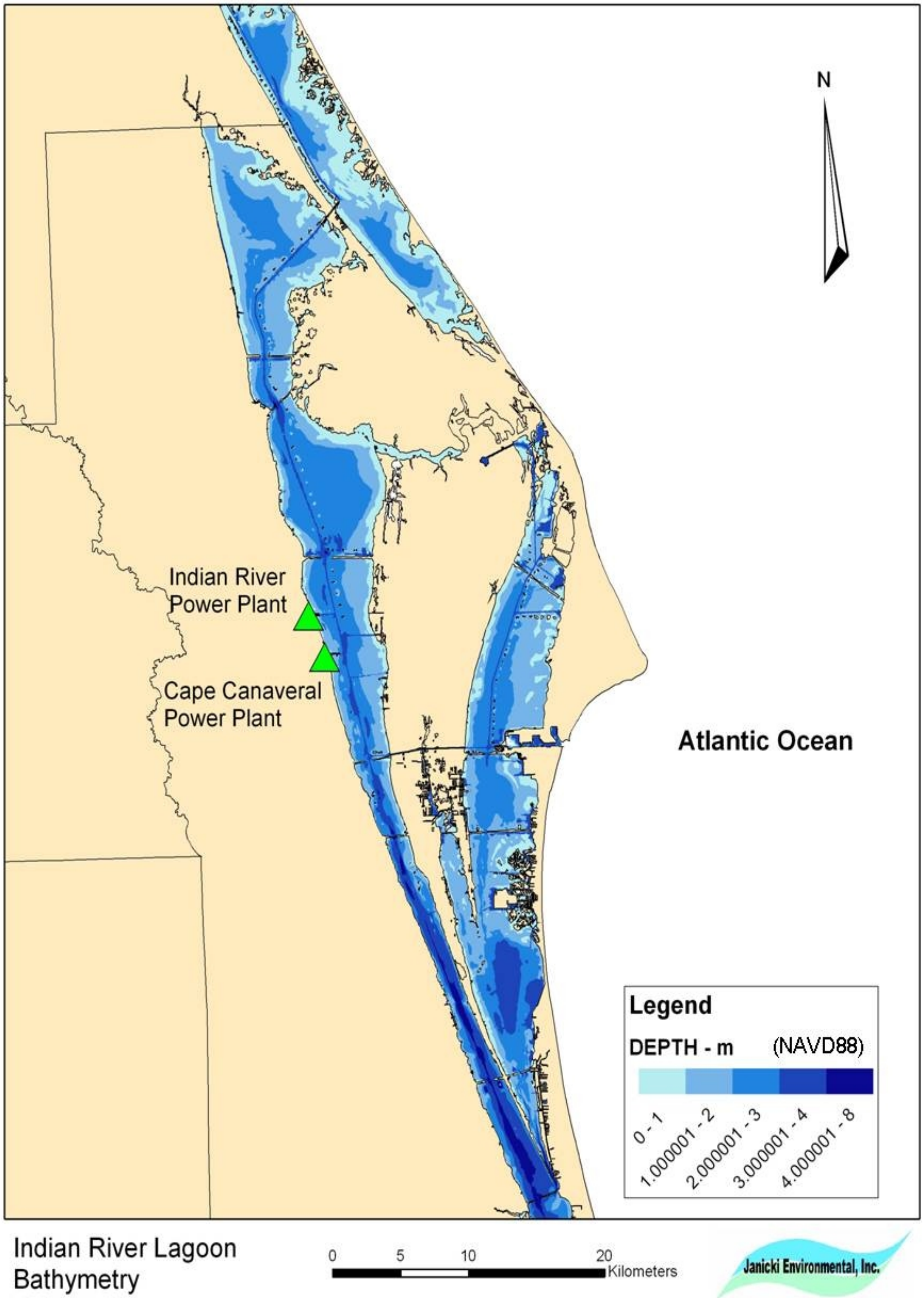

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Figure 3
Bathymetric conditions within Northern Indian River Lagoon (source: NOAA)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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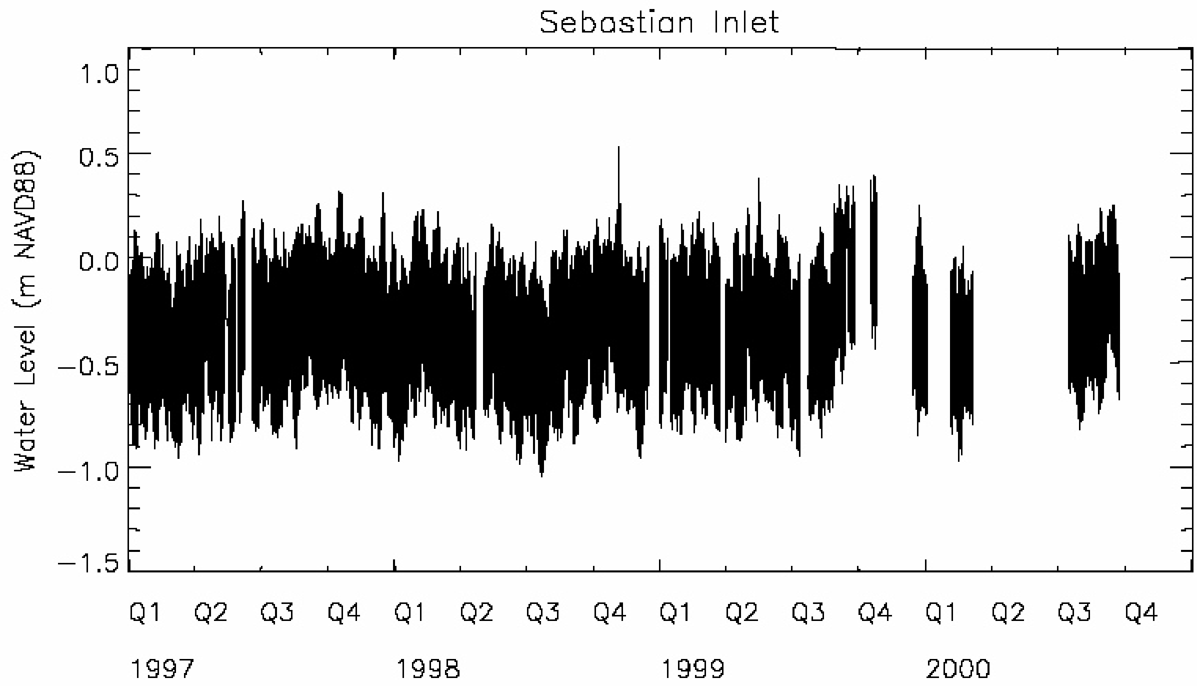

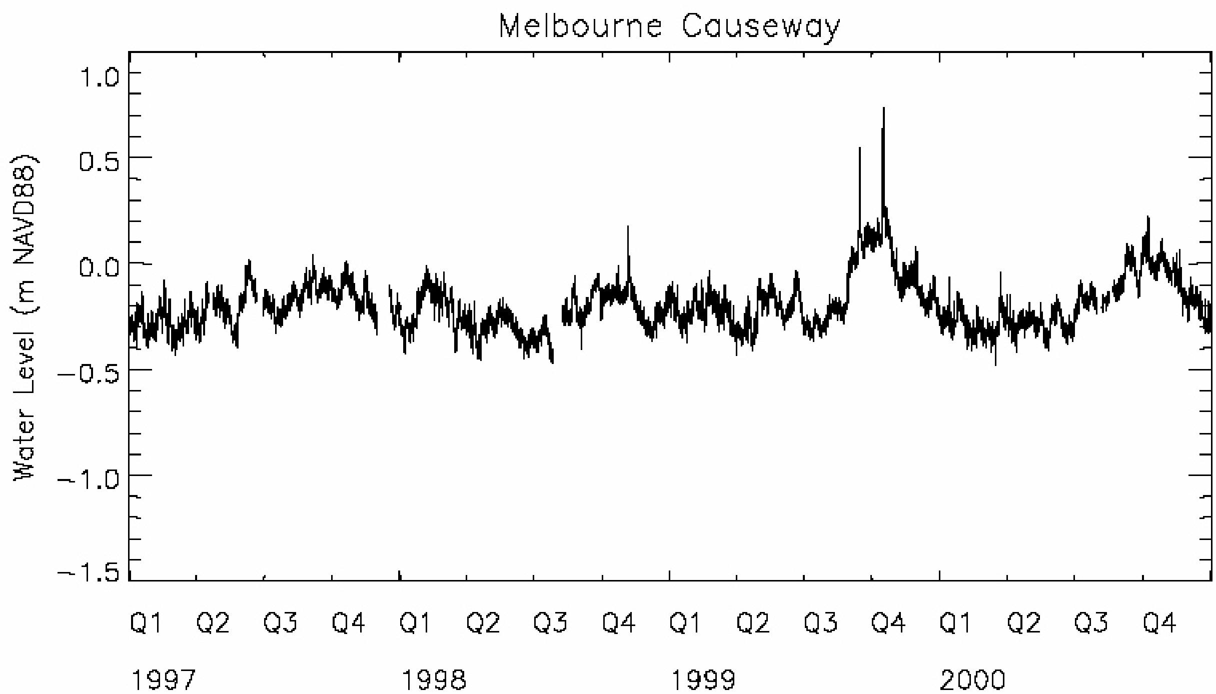

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Figure 4
Tidal conditions at Sebastian inlet and Melbourne Causeway
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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in the measured data. Extensive studies were conducted by SJRWMD personnel to evaluate the forcing mechanisms that drive water level fluctuations in the North IRL. The analysis broke the measured water surface elevations into three components:

- Tidal, with periods less than 30 hours
- Synoptic, with periods between 30 hours and 12 days
- Ultra-low-frequency (ULF), with periods greater than 12 days

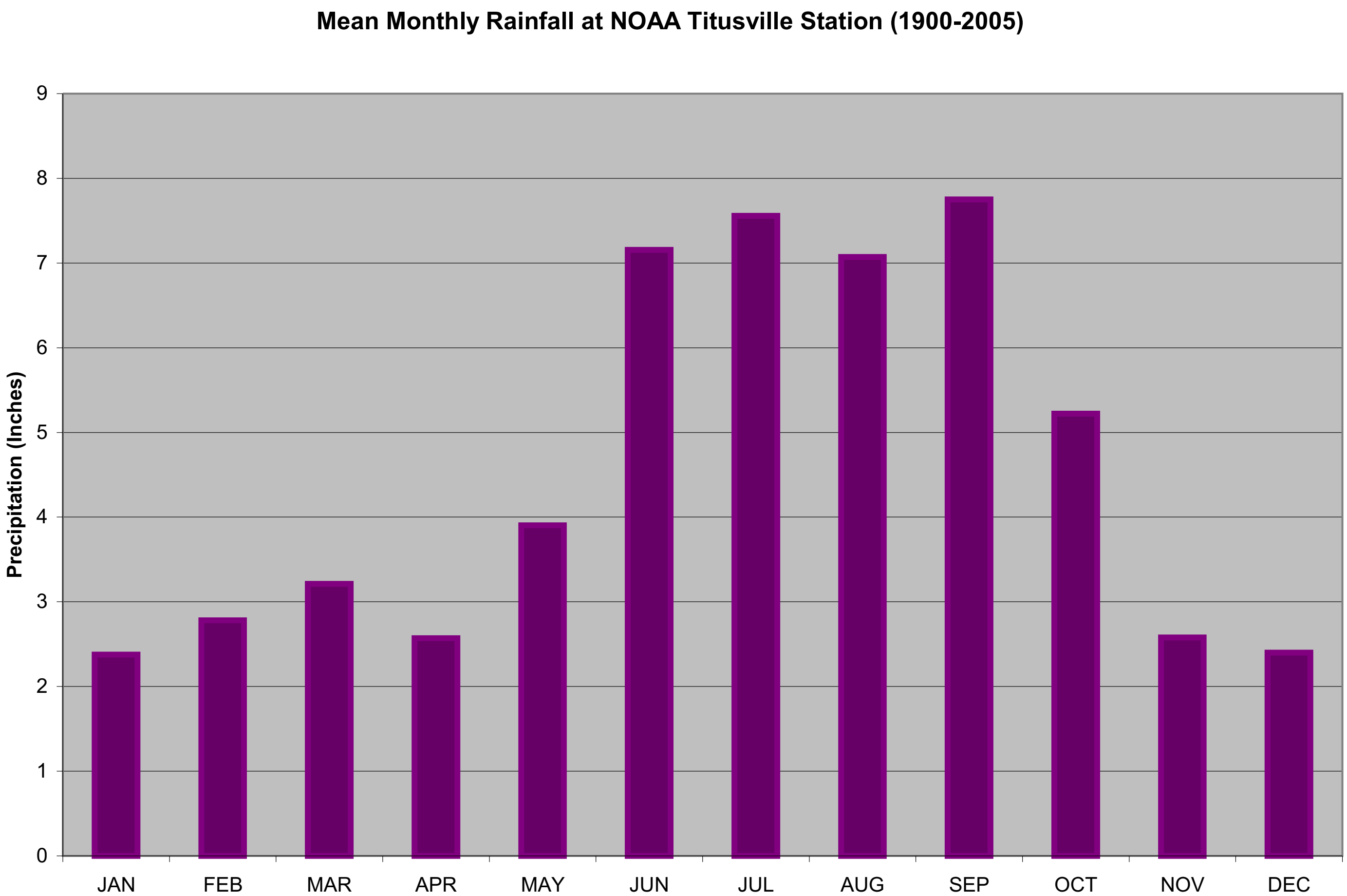
Analysis of the data north of the Melbourne Causeway showed that the low-frequency water level accounts for over 98 percent of the total variance, with 90 percent attributed to ULF fluctuations of the mean water level. This leaves approximately 8 percent of the signal based upon the synoptic period, which would be attributable to local wind forcing (Sucsy, Belaineh, and Christian 2005). Data Attachment A provides detailed reports that discuss the tidal conditions and circulation in the Northern IRL and the mechanisms that drive that circulation.

2.3 Meteorology/Hydrology

Key drivers of the salinity conditions in the North IRL are the rainfall (and resulting freshwater inflow), local evaporation, and flow through Sebastian inlet and Haulover Canal. The annual average rainfall to the IRL is 53.5 inches. This annual rainfall varies on a monthly basis, with November to May typically the dry period, and June through October typically the wet period. Figure 5 presents the monthly average rainfalls based upon data from 1900 through 2005 at the NOAA Titusville Station.

Within the North IRL above Cocoa, where the project site is located, the contributing watershed areas are small in relation to the surface area of the lagoon. Examining the watersheds north of Cocoa, the ratio of watershed area to lagoon surface area is 1.89 within the IRL proper, and 1.22 in Mosquito Lagoon (Sucsy, Belaineh and Christian 2005). In comparison, the ratios moving south range from 5 up to 20 based upon manmade drainage through canals. This creates a situation where the freshwater inflow to the project area and the adjacent waters is small in comparison to the overall freshwater inflow to the IRL system. Historical measured salinity conditions reflect this reduced freshwater inflow, with periods of time where salinities are higher than ocean conditions due to evaporation. Detailed discussions of the hydrology of the system are presented in the reports in Data Attachment A.

The evaporation also plays a significant role in the baseline salinity conditions in the system. While rainfall shows significant seasonal and interannual variability, evaporation does not show significant variations. The annual average evaporation calculated for a 4-year period (1997 to 2000) was 62 inches, which is higher than the annual average rainfall.



04948 TechMemo2G Fig 5 5/18/06

Figure 5
Historic monthly average precipitation at NOAA Titusville station
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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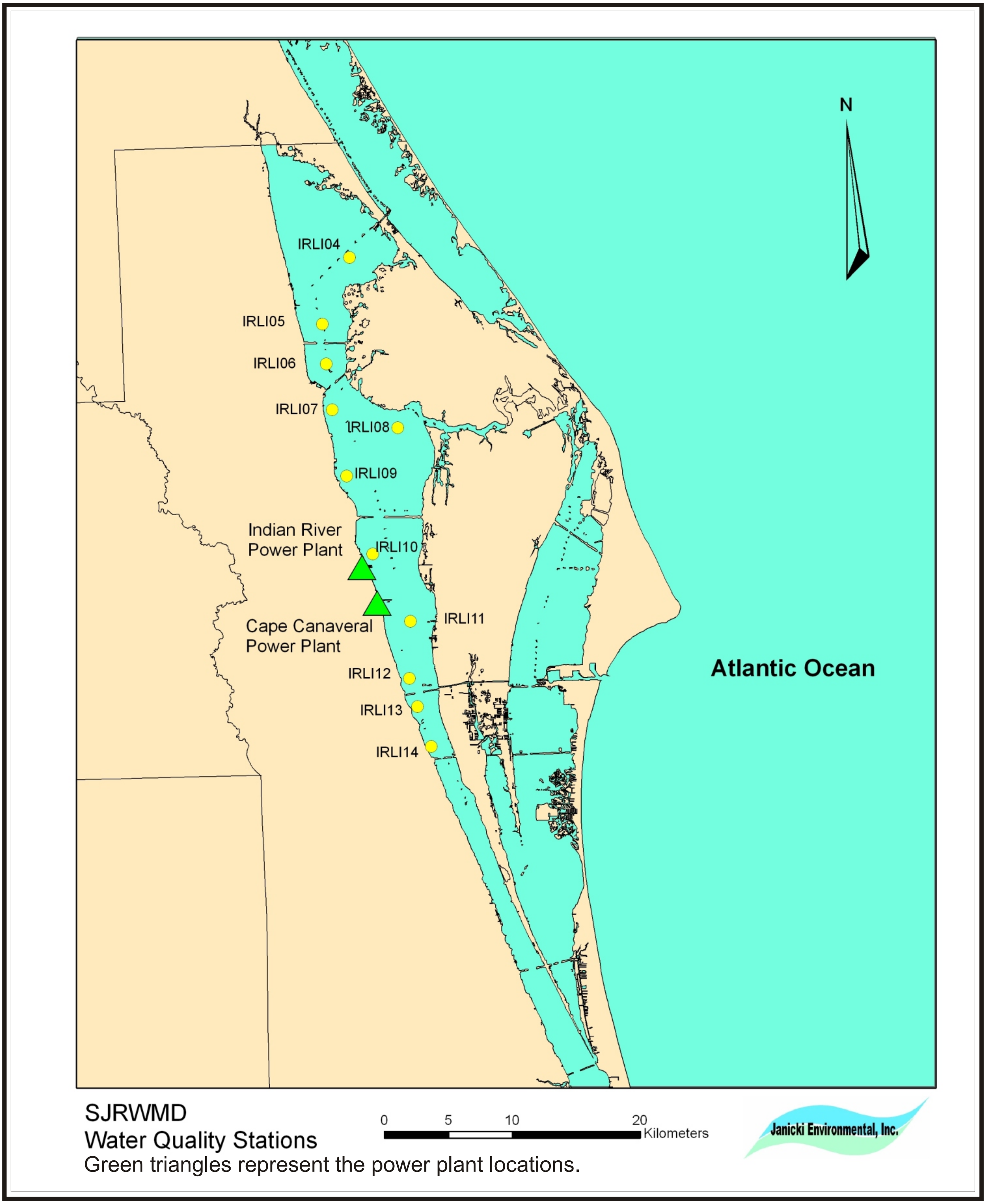
2.4 Water Quality and Regulatory

Water quality data used for this project were available from both the SJRWMD (Figure 6) and the Florida Department of Environmental Protection comprehensive Impaired Waters Rule database or IWR database (Figure 7). The IWR database was developed to compile water quality data meeting criteria specified in the Impaired Waters Rule for the purposes of implementing the Rule. With respect to pollutants of interest for this study (e.g., metals that have the potential to be concentrated by the demineralization process), the IWR database was utilized. For this study, the IWR database included the following sources: FDEP, National Park Service, Marine Resource Council, Florida Lake Watch, Brevard County, and SJRWMD. Quality control information recorded in the databases were used to screen data, as well as plots to identify potential outliers related to errors in data entry.

FDEP surface water classes within the IRL are Class II or Class III-marine. Class II waters are designated as shellfish propagation and harvesting and generally have the same, or in some cases, stricter standards than Class III. Class III waters are designated for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In the immediate vicinity of the potential collocation sites, waters are Class II (Figure 8). Class II waters are also located in the northern most portion of the lagoon (north of Titusville and in Mosquito Lagoon), as well as in southern portions of the lagoon. Additionally, there are waters within the area that are classified as Outstanding Florida Waters, these are portions of the Banana River and Mosquito Lagoon. These waters are shown as Aquatic Preserve Areas on Figures 31 and 32.

Presently the SJRWMD has developed segments for the IRL. These segments aid in the definition of goals and programs for the restoration and enhancement of the system. Figure 9 presents the segments presently being utilized by the SJRWMD for the Northern Indian River Lagoon.

Using the segments presented in Figure 9, analyses were performed on the SJRWMD data for salinity. Figure 10 presents box and whisker plots (top) of the salinity along with a time series plot that shows the variations at the SJRWMD sites (bottom). The data within the box and whisker plots are ordered within each of the areas, i.e. north to south in the IRL, south to north in the Banana River, and Mosquito Lagoon. Area 5, presented in the middle of the plots, is where the two proposed collocated facilities are located. Examination of the salinity plots shows the high degree of variation in the North IRL. The data show the highest salinity within Mosquito Lagoon with mean salinity conditions near 32 ppt. Mean salinity conditions decrease moving south within the IRL, with mean conditions within Segment 5 (the project segment) near 28 ppt. The high degree of fluctuation, as well as the overall high salinity levels within the Northern IRL is significant to the potential impacts created by the collocated facilities.



04948 TechMemo2G Fig 6 5/24/06

Figure 6
SJRWMD Indian River water quality monitoring stations that were assessed for water quality trends
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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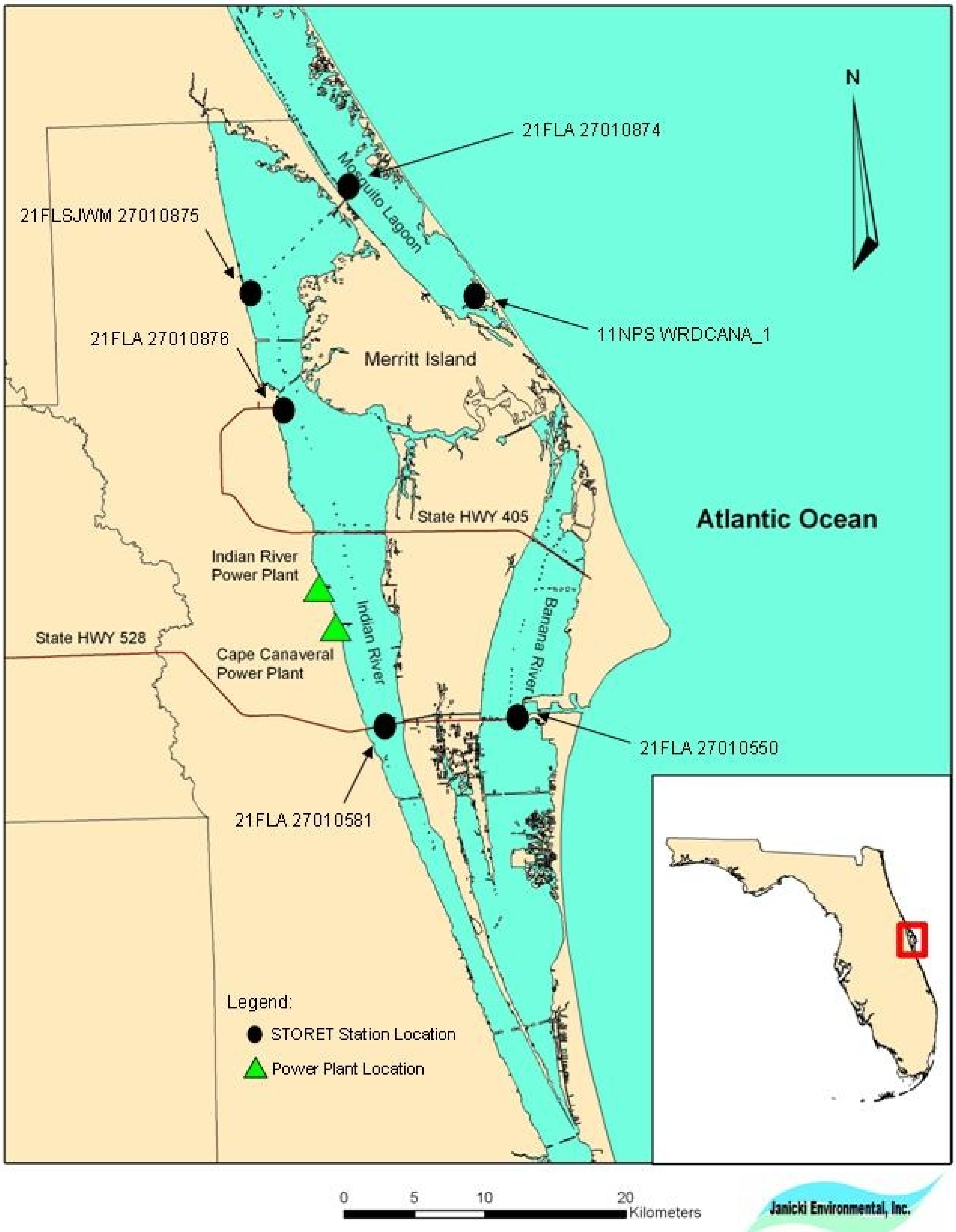

04948 TechMemo 2G Fig 7 5/24/06

Figure 7
FDEP Impaired Waters Rule/STORET database water quality stations within Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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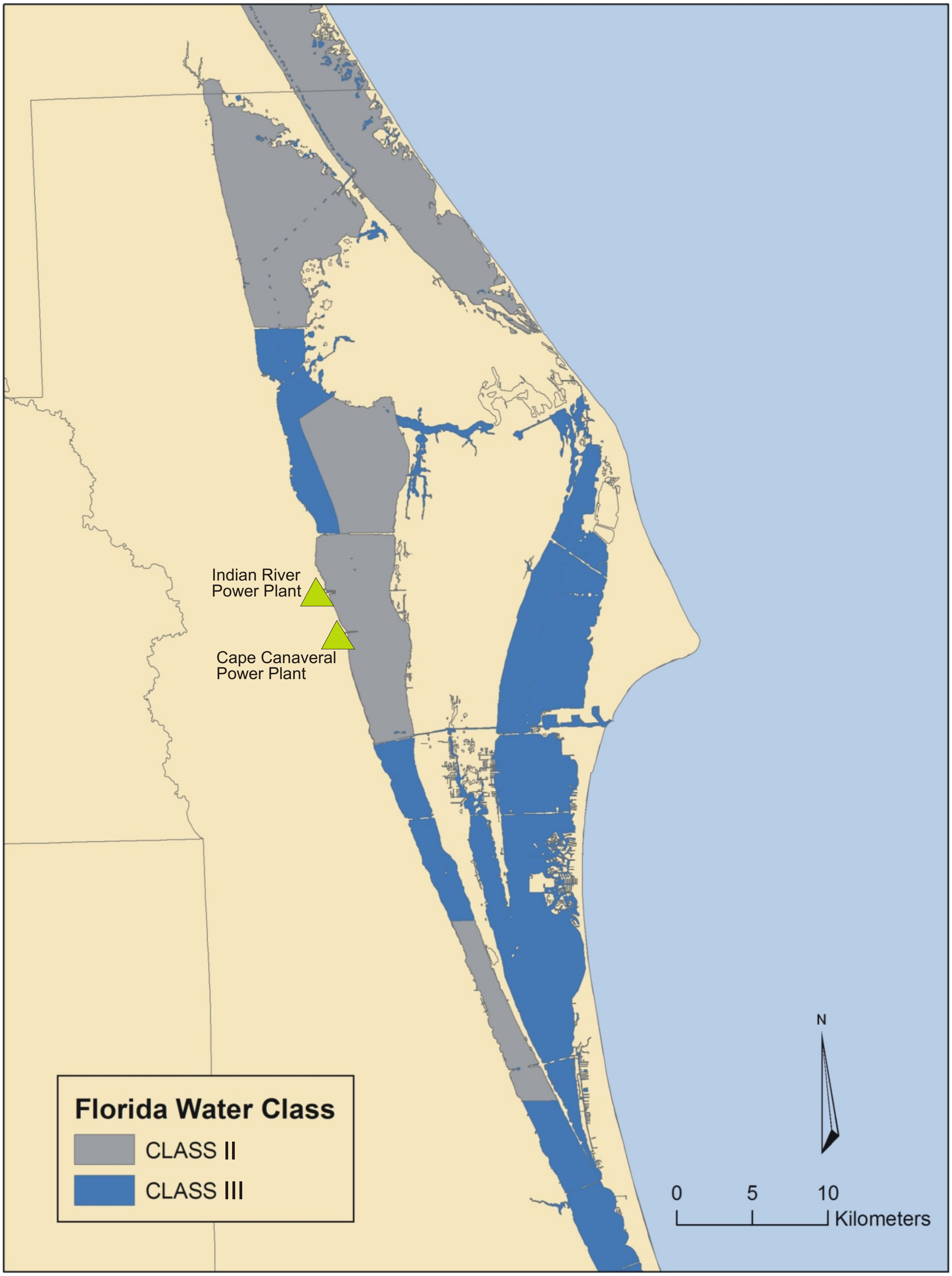

04948 TechMemo 2G Fig 8 6/30/06

Figure 8
Florida water use classification for key water bodies within the IRL study area (source: FDEP)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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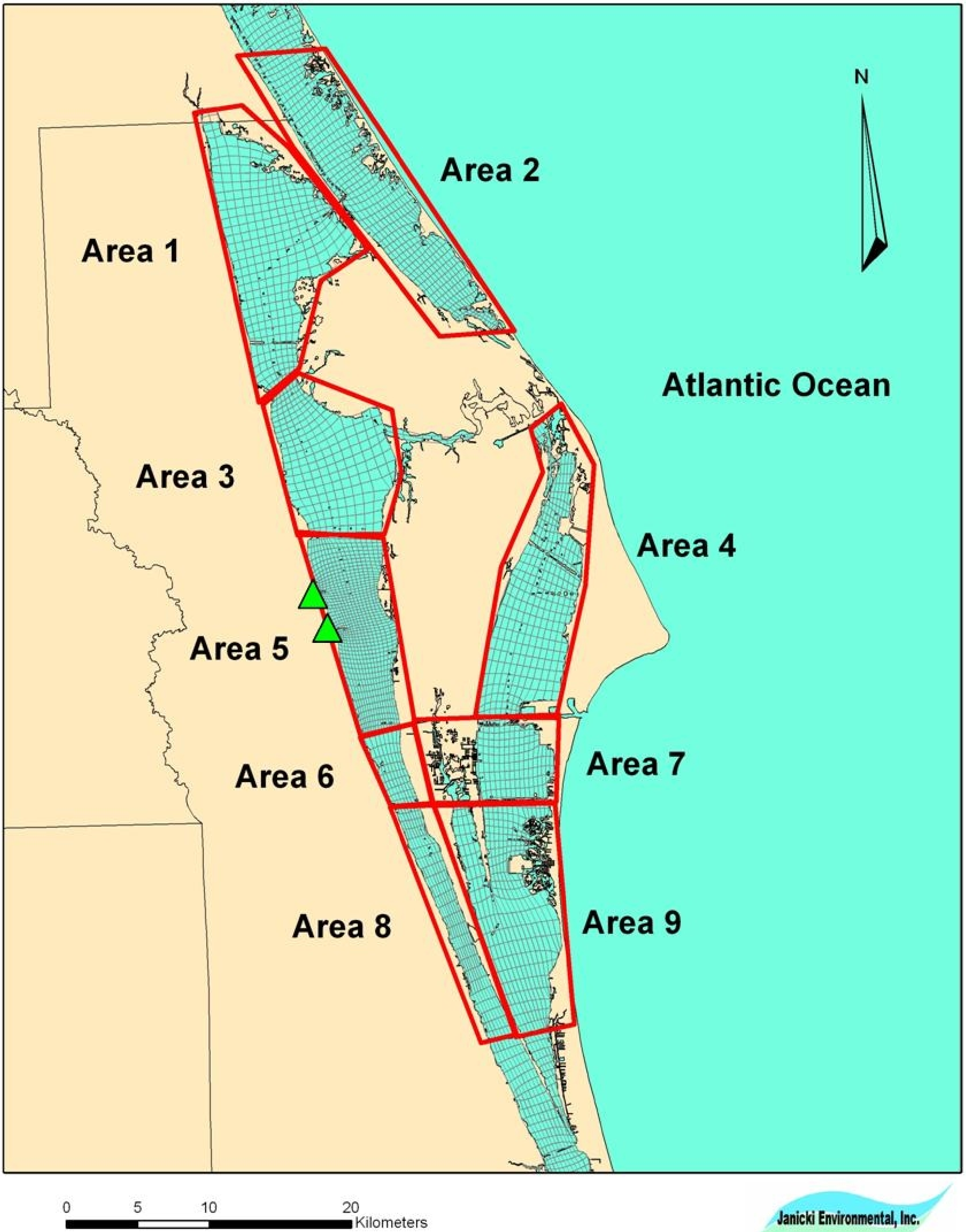

Green triangles represent the power plant locations.

04948 TechMemo2G Fig 9 5/24/06

Figure 9
Indian River Lagoon segmentation
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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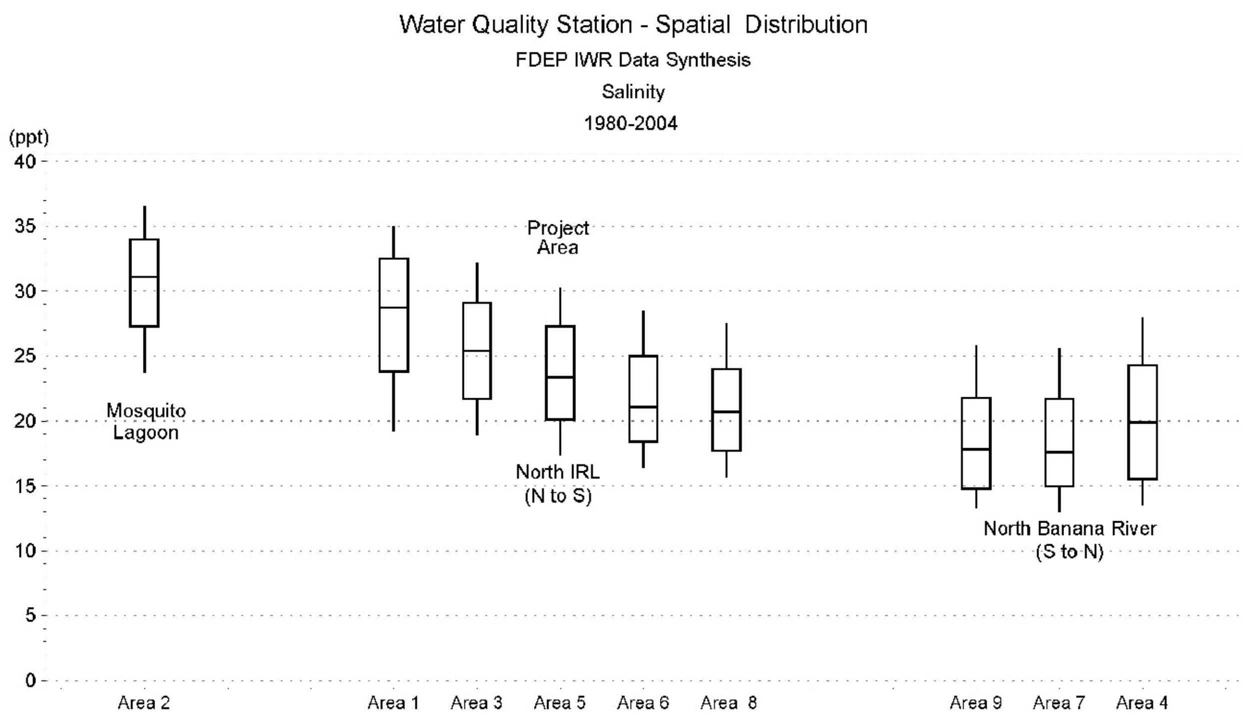
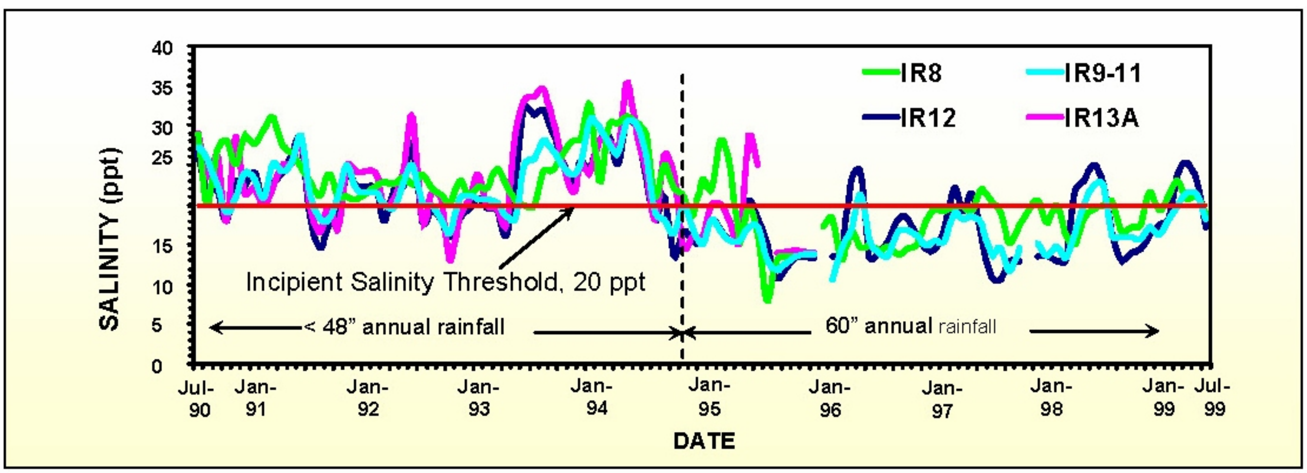


The box represents the inter-quartile range (horizontal line is the median, top of the box is the 75th percentile, and lower part of the box is the 25th percentile). The thin lines extending from the top and bottom of the box represent the 95th and 5th percentiles, respectively. The project area corresponds to area 5.



Monthly salinity levels from 1990 to 1999 in the North Indian River Lagoon area (SJRWMD, 2002)

04948 TechMemo2F Fig 10 6/30/06

Figure 10
Box and whisker plots of salinity by sub-areas and monthly salinity levels from 1990 to 1999 in the North Indian River Lagoon area
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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Figures 11 and 12 present the spatial distribution of the average salinity and temperature by season for Segment 5 (the project segment). The results show typical seasonal temperature fluctuations. Salinity results show the higher salinities typically in the winter months (Jan to Mar) with decreasing salinity though the spring and fall periods. Average salinities range from 30 down to 15 ppt. Data Attachment J provides statistical water quality analyses throughout the system from the available data.

2.5 Ecological

2.5.1 Seagrass

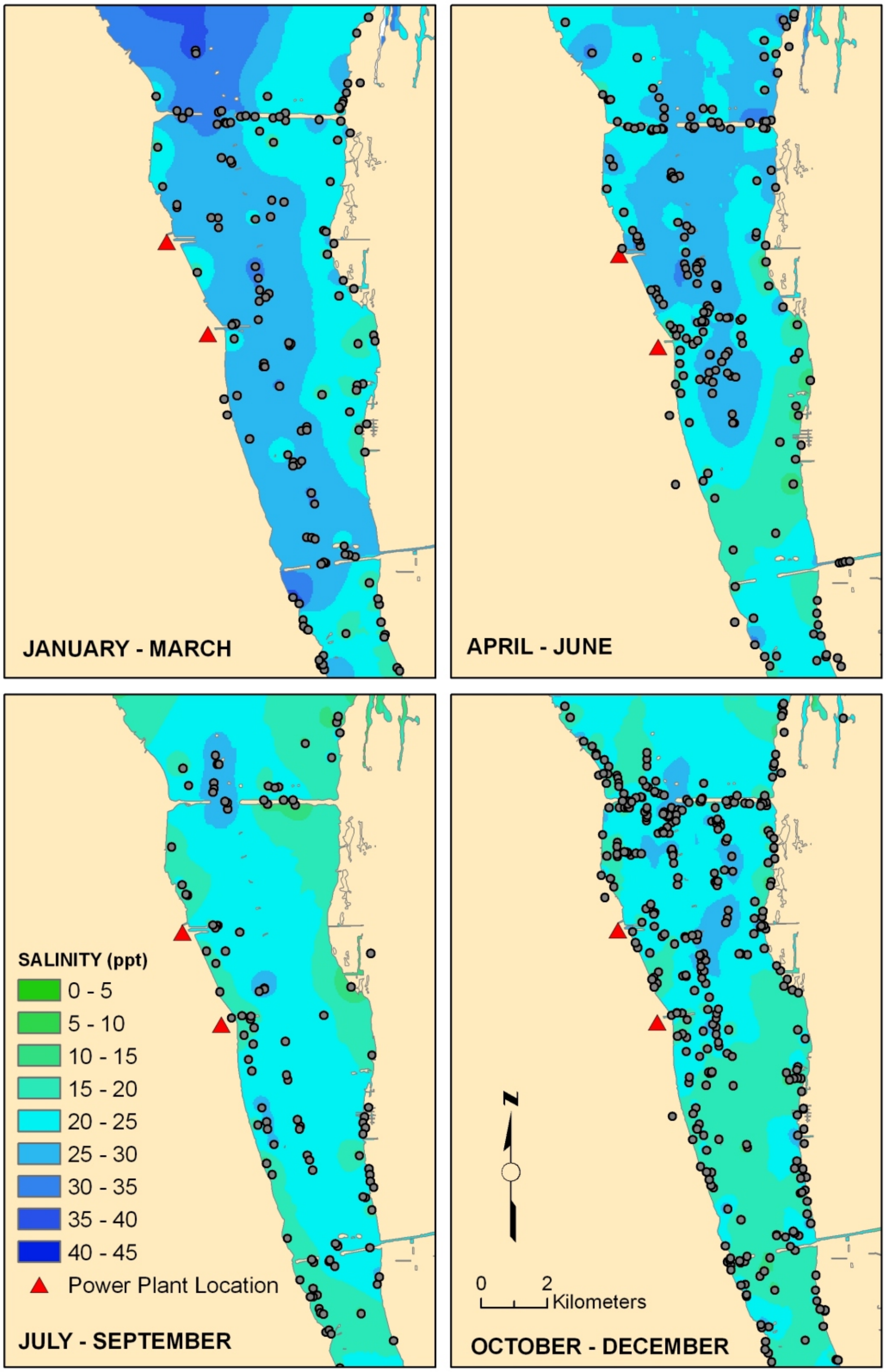
Seagrasses and drift algae are the major macrophytes (macroscopic plants) in the Indian River Lagoon. Seagrasses and macroalgae serve as habitat for epiphytic plant and animal species by providing surface area for colonization. Additionally, seagrasses aid in stabilizing sediments and contribute significantly to the total primary productivity in the food web. Although seagrasses are composed largely of indigestible cellulose, a few species, such as the manatee, feed directly on the macrophytes. Other species simply graze on the epiphytes that colonize the leaf blades. While there is limited direct feeding on living parts of the seagrass, dead fragments play an important role in the detrital food web. Detritivores ingest the dead particles and breakdown the cellulose into forms other organisms (fish and invertebrates) can assimilate.

While seven species of seagrass occur throughout the entire Indian River Lagoon system, the following four species have occurred in the immediate vicinity of the power plants over the past several years (SJRWMD, 2002):

- Shoal Grass –*Halodule wrightii*
- Manatee Grass-*Syringodium filiforme*
- Widgeon Grass- *Ruppia maritima*
- Star Grass- *Halophila engelmannii*

Halodule wrightii is the only species to be consistently abundant since the 1980's (Applied Biology, 1980) continuing through 2004. In a 1980 joint study of the power plants, *Syringodium filiforme* and *Halodule wrightii* were listed as the most abundant seagrass species (Applied Biology, 1980). In the more recent past, *Ruppia maritima* and *Halophila engelmannii* were present, but as of 2004 have dropped out. All seagrass species in the Indian River Lagoon also exhibit seasonality in terms of growth and biomass, with peaks occurring in April-May and June-July respectively. Peak cover was reported to occur in July (Applied Biology, 1980).

Indian River Bottom Salinity (1990 - 2003)



Black dots represent actual sampling points and inverse distance weighted interpolation was used to create maps from these data points.

04948 TechMemo2G Fig 11 5/24/06

Figure 11
Spatial distribution of bottom salinity in the study area during 1990-2003
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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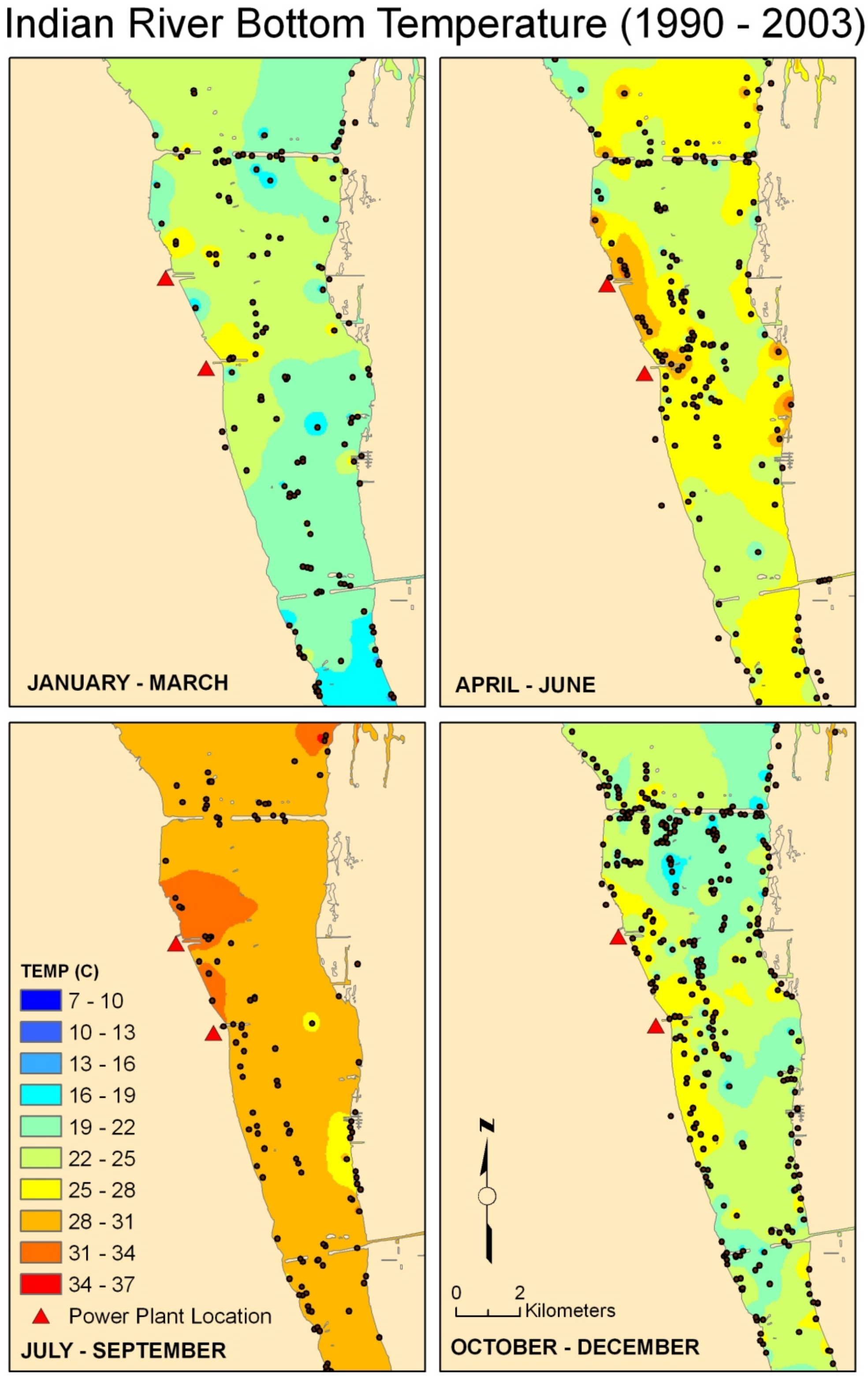

Black dots represent actual sampling points and inverse distance weighted interpolation was used to create maps from these data points.

04948 TechMemo2G Fig 12 5/24/06

Figure 12
Spatial distribution of bottom temperature in the study area during 1990-2003
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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The major drift algal species were reported in 1980 as *Gracillaria verrucosa, Acanthophora spicifera, Hypnea cervicornis* and *Hypnea musciformis* (Applied Biology, 1980). Drift algae was documented as the most abundant vegetation in the 1980 report and is considered an important component of the ecosystem because of its role in supporting benthic fauna and was considered comparable to that of shoal grass habitat in terms of supporting species diversity and density (Applied Biology, 1980). However, it is not a focus of the remainder of this section because drift algae were not considered good indicators of anthropogenic impacts or habitat quality in a given area. This is true because drift algae are unattached and at the mercy of winds, currents and storms, which tend to pile up the algae in certain areas, unrelated to the health or biomass in the particular area (Applied Biology, 1980).

In the 1980 report, seagrass cover was reported to be greater on the east shore, whereas drift algae dominated the west shore (Applied Biology, 1980). It should be noted that the 2003 seagrass map shows algal cover primarily on the eastern shore (Appendix B). These variations in the location of drift algae are expected considering it is unattached and susceptible to wind driven circulation patterns. The greatest seagrass cover was seen in areas up to 1.2 meters deep (Applied Biology, 1980). Although the power plants are located on the west shore, these differences were attributed to variations in bottom topography and sediment conditions on the two shores (Applied Biology, 1980). The east shore has more shallow areas for seagrass to colonize, whereas drift algae can photosynthesize at greater depths, explaining their abundance on the west shore. The west shore area also experiences heavier grazing by manatees due to their congregating in winter around the warm water discharge. Although cover was greater on the east shore, biomass estimates from both shores were similar (Applied Biology, 1980).

In general, seagrass growth and establishment is light limited. Light attenuation in the water column is influenced by water depth, turbidity, and the presence of floating plant species on the water surface. In addition to light, salinity often determines which species are present in which locations, and at what depths, based on differing salinity tolerances and preferences for each species. The species of seagrass in the study area are all well adapted to the wide ranging salinity conditions found in estuaries and lagoons. Other important ecological factors include water clarity, depth, sediment compositions, and epiphyte loads.

Light limitation is considered the most important factor currently influencing seagrass growth in the Indian River Lagoon (Rey and Rutledge, 2001). Light transmittance through the water column is generally low, and seagrasses in the lagoon typically exhibit growth rates near the lower limits of the range. Additional increases in light limitation could further limit seagrass growth and productivity (Rey and Rutledge, 2001). Primary causes of light limitation (Rey and Rutledge, 2001) that affect seagrass growth include the following.

1. Increased chlorophyll, as a consequence of blooms of phytoplankton and/or macroalgae, limits light penetration. Such blooms are typically a consequence of increased concentrations of nutrients. Badylak & Philips (2004) working in the Indian River Lagoon, have shown in a set of field observations that both temperature and salinity may modify the response to nutrient inputs. They showed that even though a given species was present over a relatively wide range of temperature and salinity, blooms were observed to occur at a lower level of salinity and a higher temperature. In general, lower salinity and higher temperature values are correlated with higher nutrient loadings during wet season months in the IRL, and nutrient enrichment is expected to be the primary factor for elevated chlorophyll.
2. Increased concentrations of suspended or dissolved solids, often a consequence of anthropogenic activities, will, also directly enhance light attenuation.
3. Increased color, caused by increases in dissolved organic material, also effectively limits light penetration.
4. Eutrophication will affect light attenuation by stimulating the growth of phytoplankton, macroalgae (as noted above), and epiphytes.

Typically, seagrass loss due to light limitation begins in the deeper, outer reaches of the seagrass beds and gradually increases to shallower areas as conditions further deteriorate. Additionally, the presence of chemicals, such as pesticides, herbicides, and industrial and commercial runoff, can directly impact seagrass beds in the localized area and cause die backs.

Seagrass data were available from the St. Johns River Water Management District in two forms: seagrass coverage maps and seagrass transects. The seagrass coverages were available for 1943, 1992, 1996, 1999 and 2003. The coverages differentiate between algae, continuous grass and patchy grass coverage. Maps of seagrass coverage are shown for 1943 and 2003 in Data Attachment O. In 1943, patchy seagrass was the dominant cover, whereas in 2003 continuous seagrass and algae are more prevalent. The transect data provide percent composition of the various species present at each transect over the years (1994-2005) and are recorded in both the summer (August) and winter (February).

2.5.2 Benthos and Sediments

Benthos

The earliest studies of the benthos of the IRL are those conducted by the Harbor Branch Consortium in the mid-1970s (Young 1974; Young 1975; Young & Young 1977). Among the objectives of these early efforts were to develop an inventory of species, and especially to investigate the interactions of benthos and seagrasses.

Other early studies included the masters theses of Thomas (1974) and Wiederhold (1976). Both investigations focused on northern portions of the IRL. In Thomas'

(1974) the numerical dominants included *Caecum pulchellum* (*Gastropoda*), *Phascolion* sp. (*Sipuncula*), the polychaetes *Exogone "hebes"* and "*Fabricia sabella"*, and two myodocopid ostracods, *Parasterope pollex* and *Sarsiella americana*. Generally, there were more taxa found in shallower waters than in deeper waters and deposit feeders predominated. Wiederhold (1976) found that the dominants also included *Phascolion* as well as *Exogone dispar* and the brittlestar *Ophiophragmus filograneus*.

In the late 1970s, benthic monitoring was conducted near the power plants in the study area (Applied Biology, 1980). These studies showed that four distinct habitats could be identified: unvegetated sand, submerged aquatic vegetation (SAV), drift macroalgae, and channel habitats. Characteristic species included the mussel *Brachidontes exustus* (SAV and drift algae), *P. pollex* (sand), and the bivalve *Mulinia lateralis* (channel). *Syringodium filiforme* (manatee grass) supported the greatest numbers of taxa. However, because drift algae and another seagrass species (*Halodule wrightii)* occupied larger portions of the study area, these latter habitats were determined to be more important to the structure and function of the benthos as a whole. This study also pointed to the effects of sediment type on the benthos, with finer-grained sediments along the eastern shoreline supporting a richer fauna.

The most recent sampling has been done by the State of Florida's Inshore Marine Monitoring and Assessment Program (IMAP). Fifty-nine benthic samples were collected during 2002 and 2003 (McRae *et al*. 2003) under this program. The Florida Fish & Wildlife Commission (McRae et al. 2003) has not yet rigorously analyzed these data. Numerical dominants in the IMAP samples included *P. pollex*, *C. pulchellum*, the amphipod *Ampelisca abdita*, and *M. lateralis*. There were four species of gastropods, four polychaete worms, and three amphipods among the 20 dominant species. Of these dominant species the most ecologically significant are:

- Prey Species (Polychaetes, Amphipods, Tanaids, Bivalves)
- Filter feeding taxa (Bivalves)
- Bioturbators (tube builders-Amphipods)

Several studies have summarized the composition and distribution of particular taxonomic groups for the IRL.

Molluscs: Mikkelsen *et al*. (1995) summarized the available data from over 4,500 records of mollusks from the IRL. They listed more than 400 species, including at least 258 gastropods and 156 bivalves. The most speciose family of gastropods was the Pyramellidae (23 species) and the *Veneridae* were the most speciose family of bivalves (18 species). The most frequently collected and most abundant species were the gastropod *Bittiolum varium* and the mussel *B. exustus*. Species that were most widespread in the IRL included the bivalves *B. exustus*, *Crassostrea virginica*, *Mercenaria mercenaria*, and *M. lateralis*. More than 150 species were found in association with SAV.

Myodocopid Ostracods: Although ostracods are not typically considered part of the macrobenthos, they have been identified and counted in a number of the IRL benthic studies.

Kornicker (1977) recorded five species of myodocpoid ostracods from the IRL, and the IMAP samples added 11 (16 total). Based upon the IMAP sampling *P. pollex* and *Eusarsiella zostericola* appear to be the most abundant. *Eusarsiella disparalis* also appears to be common in the IRL.

Isopods: Kensley *et al*. (1995) and Kensley & Schotte (1999) report 36 species of free-living isopods from the IRL. Many of these species are associated with SAV (eight species) and/or algae (11 species). Ten species were reported in the IMAP database (McRae *et al*. 2003). None, however, were among the 50 most frequently collected or most abundant taxa.

Amphipods: Nelson *et al*. (1995) listed 69 species of amphipods from the IRL, of which at least 44 are found in conjunction with algae and artificial seagrass; at least 30 species are found within SAV beds or on unvegetated sediments. At least 33 species have been reported in the IMAP database (McRae *et al*. 2003). *Grandidierella bonieroides* and *A. abdita* were the two most frequently occurring species in the IMAP samples and *A. abdita*, *Cerapus benthophilus* and *G. bonnieroides* were the most abundant (Data Attachment O). Grizzle (1979) also observed that *G. bonnieroides* was the most abundant at the unvegetated sediments he studied in northern IRL.

Sipuncula: Rice *et al*. (1995) reported that 18 species of sipunculids have been identified from the IRL. The most widely distributed species is *Phascolion cryptum*. Preferred habitats include SAV, sands, and seawalls. More species were found proximate to inlets than at sites removed from the Atlantic Ocean.

Bryozoa: Winston (1995) reported the occurrence of at least 36 species of ectoproct bryozoans from the IRL. Preferred habitats included SAV, drift macroalgae, oyster bars and man-made structures (seawalls, docks, etc.). Only 12 of the 36 species were collected at salinities <30 ppt.

Ecological Preferences and Tolerances

Quantitative data on the relationships between benthic species and abiotic variables specific to the IRL have yet to be developed. Provided are some preliminary analyses using logistic regression to estimate tolerance ranges and optimum values for temperature and salinity using the available data collected under IMAP specifically in the IRL. It is noted that the IMAP data do not represent the range of environmental conditions (salinity and temperature) normally observed in the northern IRL. Specifically, the salinity and temperature ranges of the IMAP data appear truncated on the lower end of both salinity and temperature. For the purposes of this study, the general salinity and temperature ranges are estimated, but caution is needed in interpreting the ranges and optimums in an absolute sense. Knowing that the IMAP data do not include lower temperature ranges, we can say that this species has an optimum temperature in the lower end of its range, but the specific temperature listed must be used cautiously.

A comprehensive compilation of all available data on the distribution of benthic macroinvertebrates in the IRL could provide the larger sample sizes necessary to develop these relationships specifically for the IRL. Such relationships are currently being developed for Gulf coast estuarine species using data from more than 2500 observations from 12 tidal rivers (Janicki Environmental Inc., in prep.) and may have wider application. Other data on habitat preferences and tolerances for Florida estuarine benthic species that may be relevant include that of Grabe et al. (in revision) for gammaridean amphipods and both Grabe et al. (1995) and Grabe (2005) for myodocopid ostracods.

With respect to temperature, the narrowest range of preferred temperatures were observed for *A. abdita*, *C. pulchellum*, *E. zostericola*, *Haplocytheridea setipunctata*, *Leptochelia* sp., *Mediomastus* spp., *M. lateralis*, *B. varium*, and *Halmyrapseudes*. The widest range of preferred temperatures was observed for two polychaetes (*Branchiomma nigromaculata* and *Fabricinuda trilobata*), *P. pollex*, *Phascolion strombi* and the multispecies assemblage of tubificid oligochaetes.

Logistic regression analysis was conducted on 20 taxa in order to estimate salinity optima and tolerance ranges. Seven of the 20 taxa appeared to be "high stenohaline" species, preferring salinities in the euhaline range (>30 ppt). This group included two amphipods, *A. abdita* and *G. bonnieroides*. This distribution is not, however, consistent with that observed by Grabe et al. (in revision) and may be an artifact of the small sample size in the IMAP database.

Based upon data summarized by Grabe et al. (in revision) the "optimal" habitat for *A. abdita* (Grabe et al. In revision) is high mesohaline (12-18 ppt) very fine sands (11.35 to 25.95% silt+clay) in shallow (<2-m) waters. However, its "tolerance" covers almost a 20 ppt range in salinity and >40% range in silt+clay content. *Grandidierella bonnieroides* was a species characteristic of the lower salinity zones of the tributaries to Tampa Bay. The "optimal" habitat was tidal freshwater (<0.5 PPT) fine sands (4.5 to 11.35 % silt+clay) (Grabe et al. in revision).

The *capitellid* polychaete *Mediomastus* and the ostracod *P. pollex* appeared to prefer the lowest salinities (<22 ppt) of the taxa studied. Grabe (2005) observed that *P. pollex* was collected over a wide salinity range (17.5 to 29.7 ppt) and had an optimal salinity of 23.6 ppt.

Species tolerating the widest ranges of salinities included *Acteocina canaliculata* (Gastropoda), *Halmyrapseudes* sp. A, *Mitrella lunata*, and the tubificid oligochaetes. A number of species appear to have narrow salinity ranges, towards both extremes, given the observed salinity ranges expressed in the data set.

While salinity and temperature ranges are provided for all species, only a subset of species had statistically significant relationships with salinity and/or temperature. These results are show in Data Attachment K.

Distribution within Indian River Lagoon

The spatial distributions of selected taxa were mapped using the IMAP 2002-2003 data and are provided in Data Attachment O. One of the species was found throughout the IRL: *A. canaliculata*. Both *A. abdita* and *B. varium* were more common to the south whereas the Actiniaria were less frequently collected in the southern portion of the IRL. *Caecum pulchellum* was found in both the southern and upper reaches of the system, but was rare in the Banana River.

Sediment Types

The distributions of infaunal benthic macroinvertebrates are intimately related to both sediment grain size characteristics and geochemistry. Fine grained sediments are preferred by deposit feeding organisms such as capitellid polychaetes and coarser grained sediments are preferred by fossorial species such as oedicerotid and phoxocephalid amphipods. Tubiculous organisms such as ampeliscid amphipods have distinct size preferences for the sediments used to construct their tubes. Some species fulfill an important role as bioturbators, in which large, deep burrowing species, such as callinassid shrimps, disturb the sediment. These activities bring suspended sediments into contact with the water column. In this way sediment nutrients and pollutants may be translocated and sediments may become more oxygenated.

Benthic macroinvertebrates, especially gammarid amphipods, are also sensitive to the presence of sediment contaminants, including trace metals and organic compounds (e.g., pesticides, polycyclic aromatic hydrocarbons, and PCBs). In “high” concentrations such contaminants may be acutely toxic to the benthos. At lower concentrations these contaminants may exert sublethal effects (e.g., altered reproductive success) that could alter the structure and function of benthic communities.

Trefry et al. (1990) conducted a system wide survey to determine the extents of “muck’ (sediments with >10% “loss on ignition”; Trefry et al. 1990). The northern IRL was found to have sand-sized sediments, with somewhat finer sands along the western shoreline; no muck was found. Sediments in the Intracoastal Waterway (ICW) west of the Haulover Canal are primarily fine-grained muck. From the canal south to Titusville muck again predominates in the ICW as well as other canals and channels. In the Banana River, fine-grained sediments are characteristic of the area where the river joins the IRL proper as well as in canals. The ICW from Wabasso south to Vero Beach was mainly sandy sediment and fine-grained sediments were less frequently observed. South of Vero Beach muck sediments again become predominant in the ICW until Fort Pierce. South of Fort Pierce the finer-grained sediments were mainly found in canals. Overall, approximately 60% of the samples analyzed could be defined as muck, but they were considered to represent <10% of the IRL's total area.

2.5.3 Shellfish Harvest and Lease Areas

Shellfish (i.e. oysters and clams) are filter-feeding organisms that are important recreational and commercial species for human consumption. Filter-feeding organisms feed by removing particles from the water column and can accumulate any toxins that may be present in the area. Shellfish harvested from polluted areas represent a significant public health concern. In Florida, shellfish harvesting areas are established by the Florida Department of Agriculture and Consumer Services, Division of Aquaculture and classified as Approved, Conditionally Approved, Conditionally Restricted or Prohibited based on public health and safety concerns. Management plans exist for the harvesting areas and they call for temporary closure following heavy rainfall events, which can impact and degrade water quality conditions by delivering excess amounts of pollutants into the estuary. The main water quality concern is fecal coliform bacteria, which enters the water from residential septic tanks and sewage treatment plants. Under certain conditions, oysters and clams may be removed from restricted areas and planted elsewhere and allowed to "purify" for a period of time before they can be harvested.

Within the shellfish harvesting areas are two types of lease areas: aquaculture leases and shellfish leases. The majority of aquaculture leases consist of the planting of young clams in soft muddy substrate. The clams are planted in mesh bags to protect them from predation as they mature. In areas with harder substrate, oysters may be planted. Shellfish leases predominately consist of oyster cultivation efforts. This usually consists of putting out oyster shells and allowing oysters and larvae to congregate and attach to the shell. Shellfish leases were granted before 1985, many of them as early as the 1930's. These leases were granted in perpetuity and are no longer given out. It is estimated that over half of the current leases are not "active" (Wanda Prentice, pers. comm.). Currently, all new leases come in the form of aquaculture leases. Aquaculture leases are dependent on environmental criteria as well as minimum planting criteria and are granted for a number of years.

For the purposes of this study, shellfish harvesting areas represent where shellfish species are located within the study area. Within the Indian River Lagoon, eight shellfish harvesting areas are located between Ponce inlet to the north and Sebastian inlet to the south. Maps for all the harvest areas are provided in Data Attachment L. Shellfish harvesting area 77 (Body C) corresponds to the immediate study area, containing the two potential collocation sites (i.e. the power plants). Within this harvesting area, conditional zones have been established for December-February and March-November.

2.5.4 Fish

The Florida Wildlife Research Institute's Fisheries Independent Monitoring (FIM) program conducts routine monitoring of fish and selected invertebrate populations (hereon referred to as fish) in several major estuaries in Florida. Since 1990, the FIM program has sampled in the Indian River Lagoon (IRL) and adjacent Banana River and Mosquito Lagoon using small mesh seines and trawls to collect information on small resident fishes and juvenile recruits of estuarine dependent species. The FIM program also has used multi-panel gillnets for several years to collect information on larger fishes inhabiting the IRL, many of which are considered to be of recreational importance.

Initially, probabilistic seine and trawl sampling was conducted seasonally from 1990 to 1995, and intensified to year round monitoring in 1996. Gillnet sampling was also conducted seasonally until 1998 when it was replaced with a large shoreline oriented haul seine. While the sampling intensity has changed during this study period, the FIM program monitoring data represent a consistent fish sampling presence in the IRL using standardized methodologies and serves well to characterize the ichthyofaunal assemblages and assess long-term changes in fish populations related to either natural variability or anthropogenic perturbations.

The following sections present an overview of the fish data collected by the FIM to relate the distribution and occurrence of dominant fish within the study area of interest (i.e. the northern part of the IRL near the Indian River and Cape Canaveral power plants).

Summary of Fish Collections

The objective of summarizing the FIM fish data in the IRL was to compare the fish collections in the project study area relative to collections in the IRL as a whole. A dominance metric was calculated to evaluate those taxa that were both common and abundant in the IRL and within the study area. The dominance metric was calculated for each type of sampling gear using the following equation:

Dominance= $P_o * P_a$

where:

P_o = The proportion of samples that contained the taxon of interest.

P_a= The proportion of the total abundance that the taxon represented.

The dominance scores were ranked to represent the dominant taxa within each gear type.

In addition to the dominant taxa, several taxa were selected that were of special interest due to their recreational or commercial value, because they serve as prey to those species. These taxa of special interest include *Farfantepenaeus sp.* (commercial shrimp), *Callinectes sapidus* (blue crabs), *Limulus polyphemus* (horseshoe crabs), baitfish species and species of recreational and commercial importance (e.g. *Cynoscion nebulosus*-spotted seatrout, *Sciaenops ocellatus*-red drum, *Centropomus undecimalis* snook).

Dominant Species Summary

Gillnets

Collections from gillnet samples in the localized project area closely resembled those from the IRL and contained a rich diversity of fishes, many of which are considered to be of special interest. *Brevoortia sp.* (menhaden) and *Arius sp.* (catfish) were dominant in both areas and the taxa of special interest were ranked in the top 10 in both areas. *Elops saurus* (ladyfish) were collected more frequently in the project area, contributing more to the total abundance when compared to total abundance in the rest of the IRL. *Sciaenops ocellatus* (red drum), *Cynoscion nebulosus* (spotted seatrout) and *Leiostomus xanthurus* (spot) were almost equally encountered in both areas. *Harengula jaguana* (scaled sardine) was less frequently encountered in the project area, but had a higher relative contribution to the total abundance. Generally, the dominance rankings were very similar when comparing the project area to the IRL, though a total of 47 taxa were collected in the project area, while 75 taxa were encountered in the IRL. Tables showing the dominance rankings are provided in Data Attachment M.

Trawls

Although gillnet samples in the localized project area closely resembled those samples taken in the IRL as a whole, trawl samples were less similar throughout the IRL. One exception was *Gobiosoma robustum* (code goby) being the dominant taxa in both areas. *Micropogonias undulatus* (Atlantic croaker) was prevalent in both areas, but contributed more to the total abundance in the IRL, than in the localized project area. *Callinectes sapidus* (blue crabs) were caught in both areas and these taxa represent the only two taxa of special interest within the top 10 dominant species collected. *Orthopristis chrysoptera* (pigfish) and *Leiostomus xanthurus* (spot) were collected more frequently and contributed to a higher percent of the total abundance in the IRL as a whole then in the localized project area, but *Cynoscion nebulosus* (spotted seatrout) was equally dominant in both areas. In general, the trawls collected fewer species of special interest than other gear types. Tables showing the dominance rankings are provided in Data Attachment M.

Seines

Seine gear summaries include samples taken with several sampling methodologies including nearshore seine, shoreline seines, and larger haul seines. Together these gear represent collections along the shallow water near shore areas of the IRL. The dominant taxa in seine collections were small estuarine resident prey species such as *Anchoa mitchilli* (bay anchovy) and *Fundulus* sp. (killifish). Few of the dominant species were of special interest. *Brevoortia* sp. (menhaden) and *Leiostomus xanthurus* (spot) represented a higher proportion of the total catch in the project area while *Lagodon rhomboides* (pinfish) was conspicuously absent from samples in the project area. Otherwise, taxa of special interest were caught in similar frequency and abundance in both areas.

Species of Special Interest:

To visualize the spatial and temporal trends in distribution and abundance of species of special interest, their occurrence and relative abundance in each sample was plotted. Quartiles of abundance (Fish/set) for each species were calculated and then each sample was geo-referenced and assigned its respective quartile rank within the IRL. In the figures discussed below the grid is overlain in order to show generally what results from the hydrodynamic model will be used in future baseline versus impact evaluations.

For example, *Cynoscion nebulosus* (spotted seatrout) was well represented in seines in the summer and fall and in gillnet collections in winter and spring. Samples located near the power plants often contained *Cynoscion nebulosus* (spotted seatrout) either as juvenile recruits or adults. Comparatively, *Opisthonema oglinum* (Atlantic thread herring) was absent in collections near the power plant and sparsely collected within the project area. *Brevoortia tyrannus* (Atlantic menhaden), *Lagodon rhomboides* (pinfish) and *Cynoscion arenarius* (sand seatrout) were also conspicuously sparse in samples within the project area, while *Cynoscion regalis* (Atlantic weakfish) and *Sciaenops ocellatus* (red drum) were seasonally present. *Farfantepenaeus* sp. (commercial shrimp) and *Leiostomus xanthurus* (spot) were frequently collected within the project area. These temporal and spatial distributions can be compared to the temporal and seasonal distributions in the IRL as a whole to compare their overall distribution patterns relative to their patterns within the project area. These maps are included in Data Attachment O.

Additionally, horseshoe crab data from 2000 were available from Gretchen Ehlinger. The data were graphed and placed on a locator map showing her study areas throughout the lagoon. The horseshoe crab distribution over time and space was observed to be extremely variable with pulses of concentrated mating animals present during spawning events. The three-year data collection period is not sufficient to quantify biological trends in horseshoe crab abundance, or to develop ecologically meaningful trend assessments. The conclusions that may be drawn from these data are that the inter-annual variability in horseshoe crab abundance was observed to be high, and the geographic variability in the region was observed to be high. The vicinity of the potential demineralization facilities was not identified as a location of high horseshoe crab abundance from these relatively limited available data

2.5.5 Sea Turtles

The Indian River Lagoon, including areas surrounding the power plants, include habitats that could support juvenile sea turtles. However, turtles have not commonly been reported within the central portion of the lagoon away from inlets (J. Provancha, pers. comm.). Nonetheless, five species of sea turtles utilize the beaches near the Indian River Lagoon, with the first two species being the most common in the IRL (Ehrhart, 1988):

- *Caretta caretta* (loggerhead)
- *Chelonia mydas* (green turtle)
- *Dermochelys coriacea* (leatherback)
- *Lepidochelys kempii* (Kemps-Ridley), and
- *Eretmochelys imbricate* (hawksbill).

Caretta caretta (loggerhead) is a federally listed threatened species and is the most common sea turtle in Florida. Ninety percent of loggerhead nesting within the United States occurs in Florida, with most activity on the east coast of Florida. In 2003, over 20,000 loggerhead nests were located in Brevard County beaches. Loggerheads typically nest from April through September. *Dermochelys coriacea* (leatherback) are listed as endangered under the U.S. Federal Endangered Species Act. They nest almost exclusively on the east coast of Florida, between the months of April and July. *Chelonia mydas* (green turtle) are also federally endangered species and they nest in Florida from June through late September. Nesting has been reported in almost all coastal counties in Florida, with the majority occurring along the southeast coast, specifically in Brevard and Palm Beach counties.

A number of factors threaten sea turtle survival including : fishing nets, dredging activities, erosion and renourishment projects on nesting beaches, hatchling disorientation related to artificial light, exotic vegetation on sand dunes, and increased human presence on nesting beaches. Green sea turtles in the Indian River system have been reported to have fibropapillomatosis (FP), which is a disease characterized by non-cancerous fibrous tumors located on the soft tissues. FP can be debilitating, by impairing vision and normal swimming activities, as well as increasing potential for entanglement. In severe cases the disease can be fatal. Half of all green turtles caught in the Indian River system had tumors of varying severity (Ehrhart et al, 1986). The disease also occurs in green turtle populations in Florida Bay and the Keys. While the etiology of FP is not clear, there is strong evidence that it occurs more commonly in animals occupying degraded habitats (J. Provancha, pers. comm.).

Sea turtle data were available from the Florida Fish and Wildlife Conservation Commission Marine Atlas of 2000 (1989-1999) and is presented in Data Attachment O.

2.5.6 Manatees

Trichechus manatus latirostris (Florida manatee), is a sub-species of *Trichechus manatus* (West Indian manatee) and is listed as an endangered species at both the federal and state level. *Trichechus manatus latirostris* (Florida manatee) is a sub-tropical species that occupies the northern limit of it range and is dependent on seeking warm water refuge during the winter (Reynolds and Odell 1991, in Van Meter, 1989). In the winter, manatee populations are concentrated in peninsular Florida and rely on warm water sources, which include natural springs and industrial sources of thermal discharge (USFWS, 2001). Manatee occurrence at power plants is highly dependent on the severity and timing of cold fronts. During the summer, some manatees have an expanded range out into marine waters off the coast. Aside from boating injury or death, the next most significant mortality factor for manatees is related to the long-term availability of warm water refuges, as cold temperatures make manatees more susceptible to respiratory illness and other ailments (USFWS, 2001)

Manatees are biologically adapted to a wide range of salinity conditions (Van Meter, 1989; Ortiz et al., 1998). Manatees also seek out freshwater from rivers, drainage ditches, floodgates, sewage outfalls and even boat dock hoses (Hartman 1974, Shane 1980, cited in Applied Biology, 1980). Studies have shown that they possess highly evolved systems of osmoregulation, as evidenced by constant plasma electrolytes and osmolalities over a broad range of salinities (Ortiz et al, 1988). Manatees can spend between 6 and 8 hours a day feeding. They consume submerged and floating vegetation. The precise amount of vegetation they consume in the wild is unknown, but captive manatees eat between 30 and 50 kg of vegetation per day (Applied Biology, 1980). Environmental impacts on their food resources could affect manatees, in terms of the areas they inhabit, proximity to warm water refuges, and how long they have to travel to consume enough food. Manatees reproduce slowly and gestation can take over 12 months.

During cold periods, when ambient water temperatures drop below 20°C, very significant numbers of east coast manatees congregate around the warm effluents from the Reliant Energy Plant and Florida Power and Light (FPL) Canaveral Plant

(Reynolds, 2004). These facilities represent the northern-most remaining artificial warm water refuge on the east coast. Florida Power and Light conducts annual aerial surveys of manatees at selected power plants throughout the state, following winter cold fronts. FPL reported a mean count of 469, and a high count of 588 manatees at the Canaveral and Reliant Plants during 2003-2004 (Reynolds, 2004). The mean count of manatees sighted in this area represents approximately 44% of the manatees sighted for the five east coast power plants included in the FPL aerial surveys (Reynolds, 2004).

Manatee data were also available from the Florida Fish and Wildlife Conservation Commission. An overview of all the counts (adults and calves, all years) is presented in Data Attachment O. A map showing the distribution of manatees near the power plants for the most recent year of data (2004) is also shown.

2.5.7 Birds

The bird resources of the Indian River Lagoon and its vicinity are numerous and varied. Illustrating this point is the Merritt Island National Wildlife Refuge (MINWR), which serves as a habitat to the most diverse bird populations within the study area. Indeed, the 310 species that are found at the MINWR comprise one of the most diverse bird communities on the North American continent. Additionally, a number of wetlands maintained as mosquito impoundments by the Brevard County Mosquito Control Department function similarly for many of these species. This region provides habitat for many year-round denizens, for dozens of migratory waterfowl, particularly during the fall and spring seasons, and for six Federally-listed endangered (*Mycteria americana* -wood stork and peregrine falcon) or threatened (bald eagle, Florida scrub jay, roseate tern, and piping plover) species. Thirty other species of special concern, or non-game birds of management concern, are also located in the region, designated as such by the Fish and Wildlife Commission.

Among the stated management priorities of the MINWR are optimizing habitat for wading birds and for overwintering fowl. While it is not believed that the proposed actions will have a direct effect on the bird species of the Indian River Lagoon region and these goals, their food sources, particularly plants and the benthos, may be affected by changes in temperature and salinity precipitated by the proposed actions. For example, *Mycteria americana* (wood stork), an endangered large wader native to wetlands and open water of the area, has a diet that may be directly affected by ecosystem changes. *Mycteria americana* subsists almost exclusively on fish and aquatic invertebrates, species that would be more directly affected by changes in temperature and salinity in the Indian River Lagoon's receiving waters. *Aythya affinis* (lesser scaup), a diving duck that winters in large numbers in the Indian River Lagoon, is another such species that could be affected by changes to the estuary. Its diet consists of primarily green plant matter and seeds, and in lesser quantities, aquatic invertebrates. These lower trophic levels are among the most directly susceptible to changes in temperature and salinity, due to their inherent immobility.

Plants, benthos, aquatic invertebrates, fish and other parts of the ecosystem will be analyzed in this study as to their preferences and tolerances to temperature and salinity changes caused by concentrate discharge from proposed desalination plants. The extent of such ecological changes can then be extended to the bird resources of the IRL to determine the potential effect on those species.

2.6 Power Plants

Figures 1 and 2 presented the locations of the Reliant Indian River and the FPL Cape Canaveral power plants that are being evaluated for the feasibility of collocation. These two plants are located on the western side of the IRL between the NASA and Bennett Causeways approximately 2 miles apart. Figures 13 and 14 present the layouts of the two power plants with their intake and discharge locations shown.

The Reliant plant is shown in Figure 13. The intake for the Reliant plant is located in the entrance channel between the two jetties that extend approximately 2000 feet into the lagoon. The discharge is located north of the jetties within a narrow channel cut into the upland. The discharge is located at the head of the channel and is well mixed by the time it leaves the channel and enters into the lagoon. Figure 15 presents the monthly average/maximum discharge and temperature from the Reliant facility. The data show that flows at the site are highly variable and range from around 100 MGD up to over 700 MGD, with discharge temperatures ranging from 59°F up to 115°F. The high degree of flow variability is due to it being an intermediate load plant. An intermediate load power plant, due to its operational and economic properties, is used to cover the intermediate load. This means that it operates on a need basis rather than continuously as a base load plant would do.

The FPL plant is shown in Figure 14. The intake is located south of the large jetty structure that extends approximately 2500 feet into the IRL. The discharge is located to the north of the jetty structure and consists of two surface outfalls that discharge along the shoreline of the lagoon. The locations of the two discharges are shown. Flows at the FPL plant are less variable (Figure 16). Discharge temperatures are relatively consistent between the two outfalls and range from as low as 59°F up to 118°F.

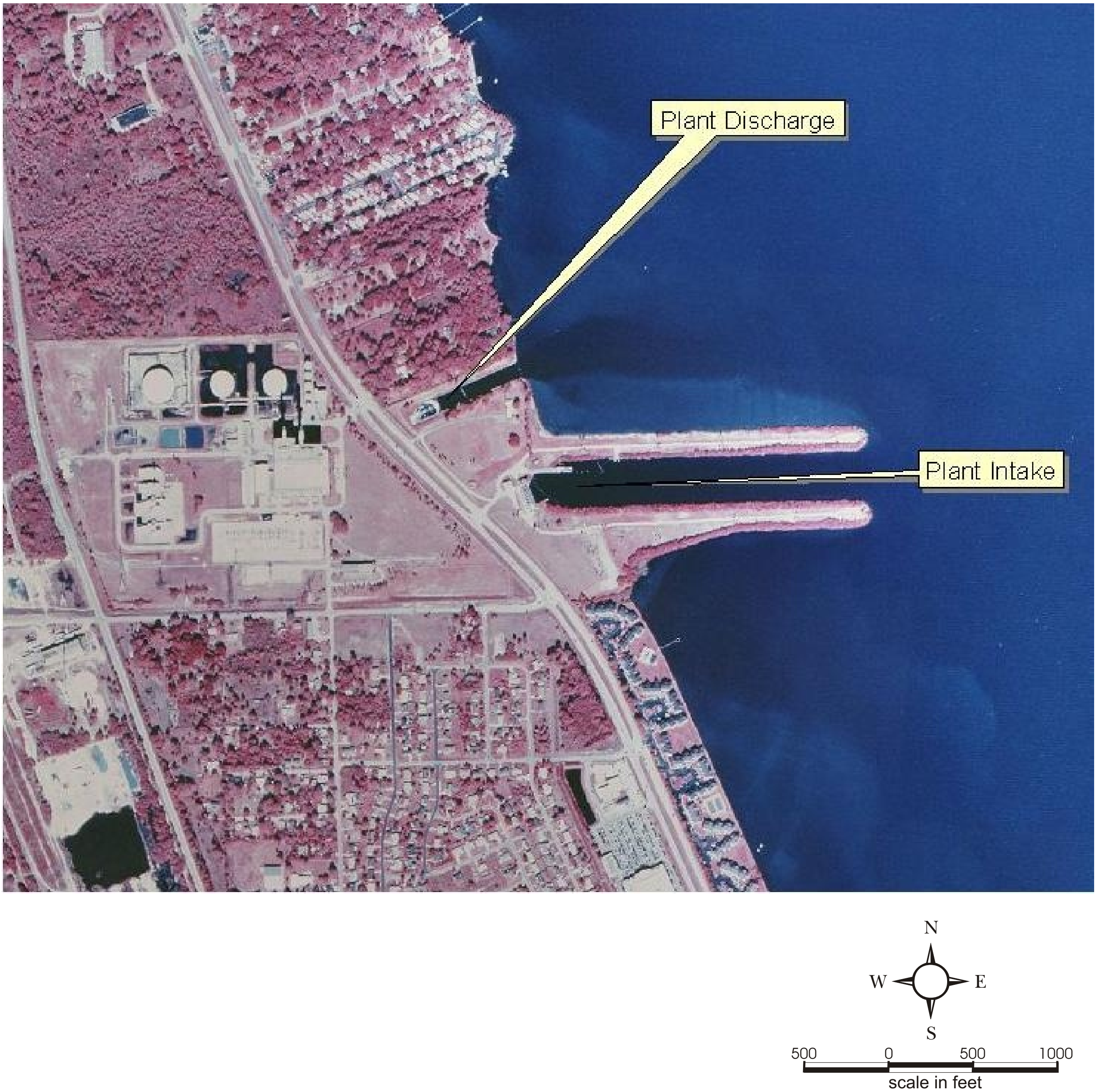

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Figure 13
Configuration of intake and discharge at the Reliant Indian River Plant
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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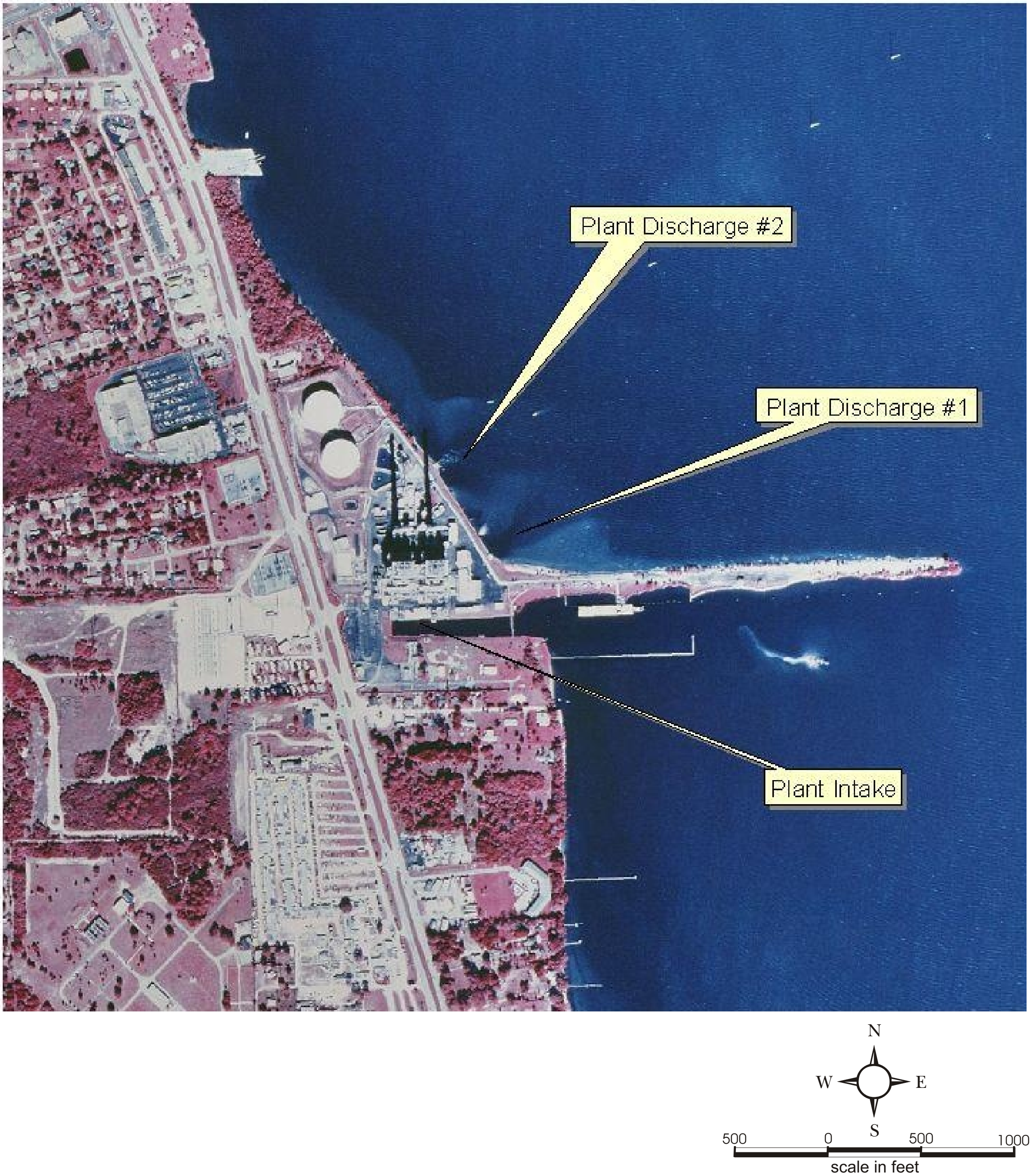

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Figure 14
Configuration of intake and discharge at the FPL Cape Canaveral Plant
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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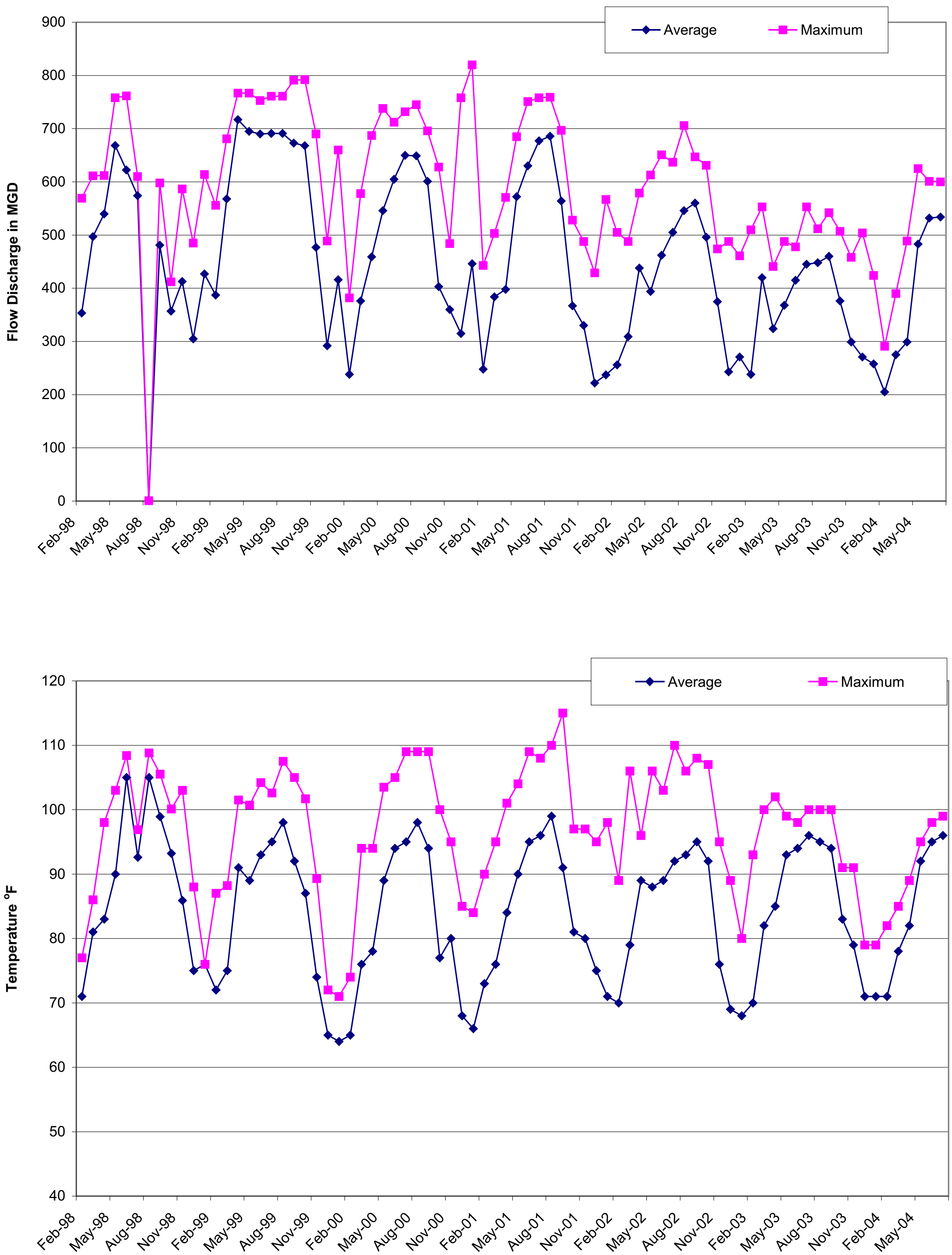

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Figure 15
Monthly average/maximum flows and discharge temperatures for Reliant Indian River Plant 1998 to 2004.
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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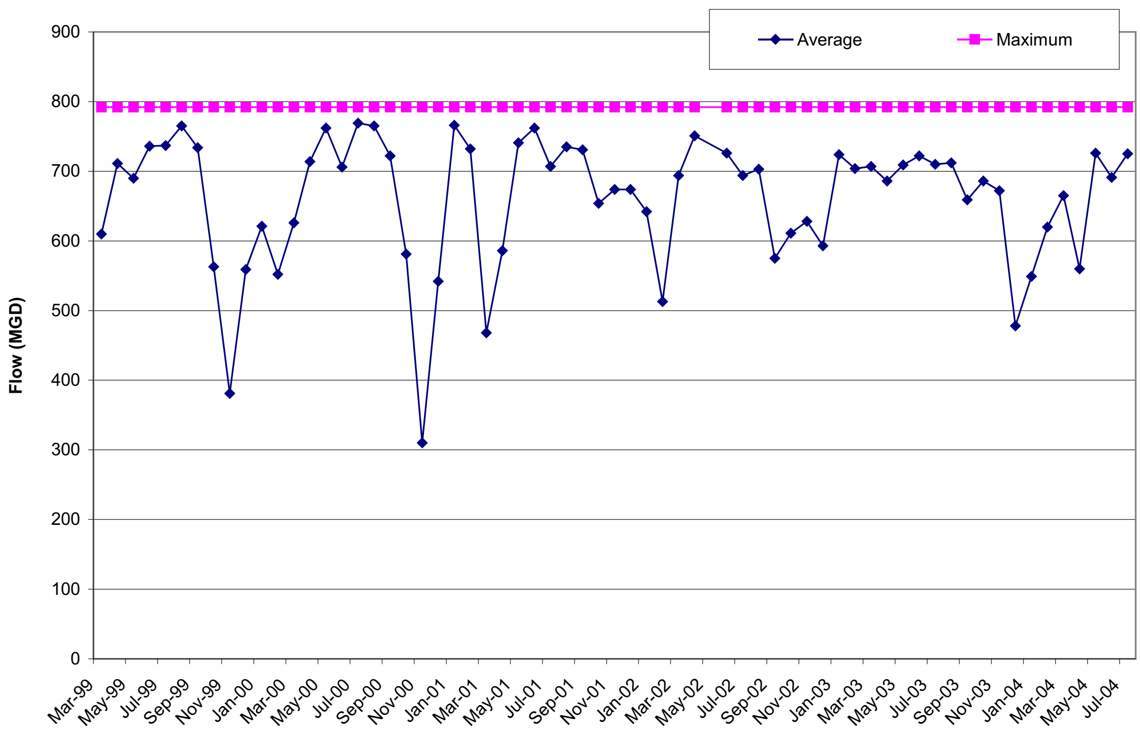

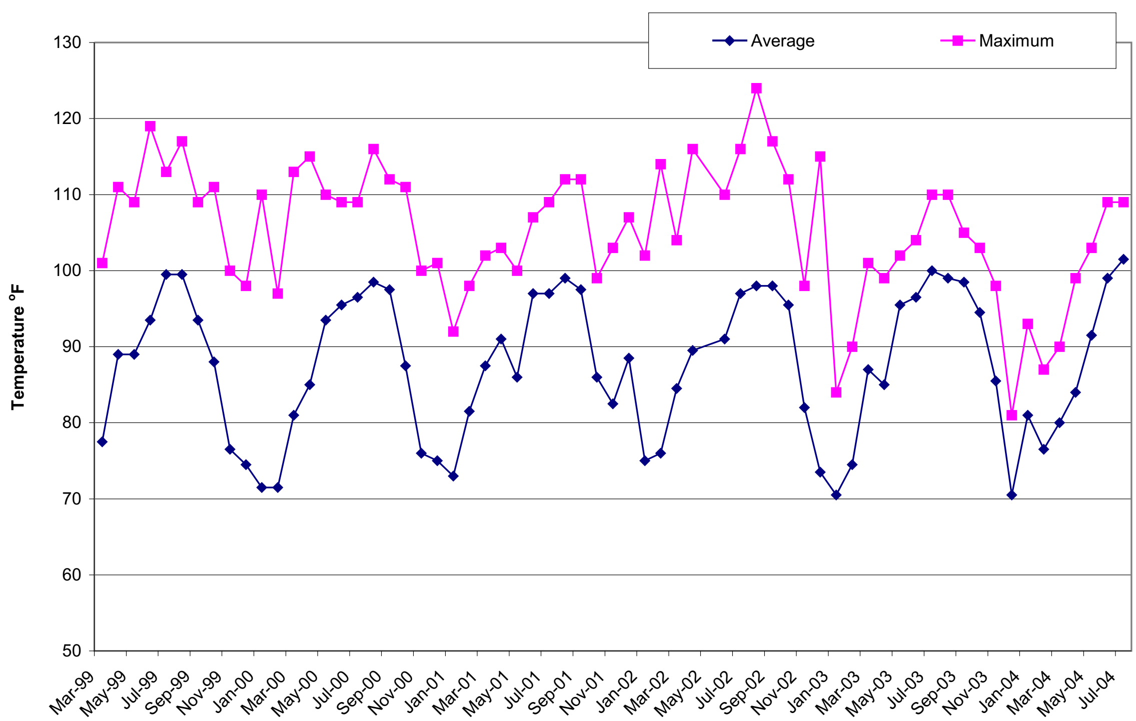

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Figure 16
Monthly average/maximum flows and discharge temperatures for FPL Cape Canaveral Plant 1999 to 2004.
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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3.0 HYDRODYNAMIC MODEL REVIEW AND APPROACH

3.1 Introduction and Overview of Phase I

Under Phase 1, various work tasks and activities were performed, including:

- Review of reports and data relevant to the project and the model
- Development of a Model Expectations Document
- Modeling Work Session
- Ad Hoc Advisors meeting
- Florida Department of Environmental Protection (FDEP) meeting
- Technical Advisors meeting

The first step within Phase I was for the project team members to review available relevant literature and data related to the project, the study area, and the IRLPLR Hydrodynamic model. Based upon this review, a Model Expectations Document (MED) was prepared that outlined the following:

- Preliminary evaluation of resource issues of concern
- Identification of model simulation expectations relative to the spatial and temporal resolution
- Identification of model simulation expectations relative to accuracy and model validation

Appendix C presents the complete MED. Following the development of the MED, a Modeling Work Session was convened that included a three-member panel of modeling experts, an independent model reviewer, biologists, the district staff who developed the IRLPLR Hydrodynamic model, and other district representatives. The goal was to evaluate the model in light of the needs outlined in the MED, evaluate the suitability of the model for use in the demineralization discharge impacts analysis, and make any recommendations for model improvements. Appendix D presents a full summary of the Modeling Work Session.

Finally, three meetings were held to solicit input from external sources. The first meeting included a group of ad hoc advisors consisting of interested parties and local representatives. The second meeting included a group of external technical advisors formed by the SJRWMD for direct peer review. The final meeting included representatives from the Florida Department of Environmental Protection (FDEP) to discuss potential permitting and technical issues. Summaries of the FDEP meeting interactions are presented in Appendix E.

3.2 Model Expectations Document

Under Phase I, a MED was prepared that defined specific environmental-related criteria that the model needed to meet in order to be used in Phase II. The MED is presented in full in Appendix C. The following summarizes the specific model criteria recommendations.

3.2.1 Model Criteria and Expectations

Based upon the biological resources of concern, the following model characteristics were recommended:

- A salinity resolution and level of precision of 2 parts per thousand (ppt). This equates to 80 percent of the salinity predictions being within +/- 2 ppt of the observed values. Also, a change in salinity due to the operation of the demineralization facility should be discernible to a level of precision of 2 ppt or less. The 2 ppt level of resolution and precision should be generally attainable throughout the modeled time series.
- A minimum horizontal spatial resolution of 1 hectare (100 m x 100 m) closest to the potential demineralization facility discharge points. This horizontal spatial resolution is recommended in recognition of the fact that a coarser level of resolution may be practical at a distance away from the potential demineralization facility discharge points.
- A minimum of two layers in the vertical (surface and bottom). This vertical spatial resolution is relative to ecological impact assessment needs, and recognizes that additional layers may be required from a physical processes standpoint in order to capture the near field processes.

The vertical and horizontal resolutions prescribed by the MED were the minimum necessary to meet the needs of the ecological analyses. As will be seen in Section 6.0 the actual resolutions utilized were finer.

3.3 Model Review

The following summarizes the findings from the model review. This review reflects the discussions from the Modeling Work Session described previously, which examined in detail the calibration results from the IRLPLR Hydrodynamic model in relation to the MED, and the general physics represented in the UF-CH3D model (the general model used for the IRLPLR application).

3.3.1 Physical Processes

The existing UF-CH3D model is a non-orthogonal, curvilinear grid, 3-dimensional, hydrodynamic model that is capable of dynamically simulating water levels, currents, and salinity. The general UF-CH3D model has been utilized in numerous similar coastal lagoon and estuarine systems within Florida and throughout the United States. In these applications, the model inputs (boundaries, grid, etc) are modified to reflect the physical conditions of the system being modeled. The UF-CH3D model has similar physics to models being used throughout the United States for this type of system, and has a long track record of successful applications. Based upon standard modeling practice, the general physics within the UF-CH3D model are appropriate for the type of system found within the study area.

The model uses a sigma-stretched grid to represent the vertical water column with a total of four layers equally spaced over the depth. At the time of the model review, there were two model applications for the Indian River Lagoon, a coarse grid model and a fine grid model. The coarse grid model had an average horizontal spacing of approximately 1,000 meters, while the fine grid model had an average spacing of approximately 400 meters. The results for the coarse grid simulations were provided for the review. Figure 17 presents the coarse grid in the area of the study.

The existing UF-CH3D model has a fully dynamic simulation of density and density-driven currents, with density a function of salinity. UF-CH3D has implemented a Z-grid correction that eliminates the historic sigma-grid problem of artificial horizontal transport between layers. This correction is necessary for proper simulation of the Intracoastal Waterway dynamics and local stratification.

UF-CH3D at the time of the review, did not provide dynamic simulation of temperature; temperature was an input to the model. Based upon the data presented for the two power plants, the local simulation of temperature will be an important process.

Figures 15 and 16 present the monthly maximum and average temperatures of cooling water discharge from the Reliant Indian River Power Plant and the FPL Cape Canaveral Power Plant. These discharges create higher local ambient temperatures around the discharge point. The data show that during the summer months there are periods of time where the discharge temperature can reach between 115 and 120°F, and times in the winter months where the discharge temperature can reach between 90 and 100°F. These temperatures are sufficiently above typical ambient conditions to create local temperature stratification and density currents.

3.3.2 Inputs and Boundary Conditions

The application of the general UF-CH3D model to the Indian River Lagoon is termed the IRLPLR model. The IRLPLR model has the following boundary forcing conditions;

- Measured water levels at Ponce de Leon, Sebastian, Fort Pierce and St. Lucie inlets (referenced to NAVD 88). Ponce de Leon inlet mean water levels have been altered to match the mean water levels at the other three inlets.
- Freshwater Inflow at 60 locations. Approximately 10 of these freshwater inflows were measured. The others, and specifically those in the area of the study, were derived from Hydrologic Simulation Program Fortran (HSPF) model simulations.

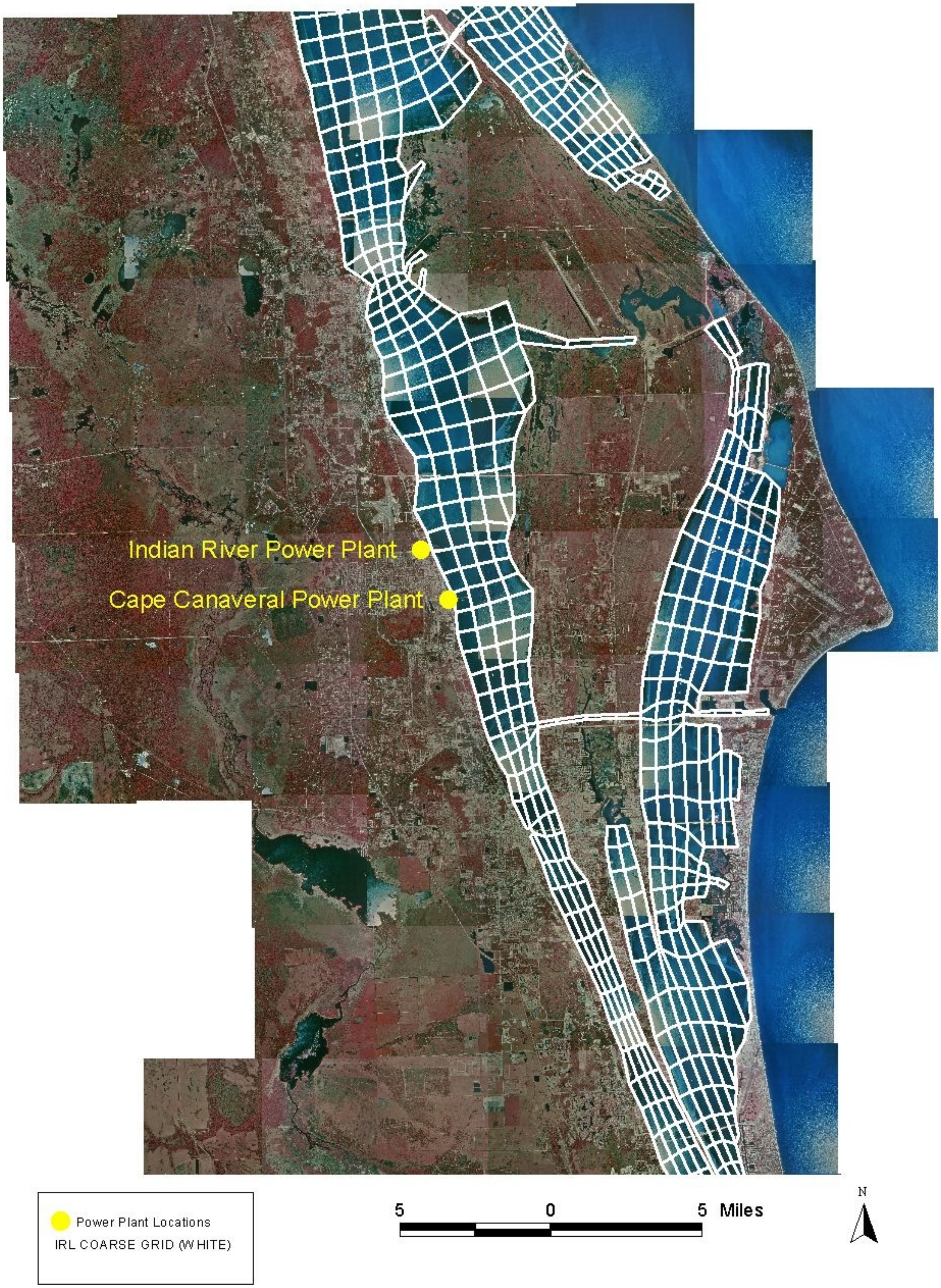

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Figure 17
Existing coarse grid used in UF-CH3D model
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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- Winds were derived from 4 gages distributed throughout the system, gages located at Ponce inlet, Titusville, Carters Cut, and Ft. Pierce inlet. One gage located at Haulover Canal was not utilized following review of the data and determination of problems with the gage.
- Daily evaporation was calculated for the model based on measurements of direct evaporation from the IRL using the Bowen ratio energy-budget method (Sumner and Belaineh, 2004)
- Bathymetry within the study area based upon a detailed survey conducted by Coastal Planning and Engineering (CPE).

Analysis of the measured water levels used for the boundary forcings at the four inlets identified a 13-cm mean water level difference between Ponce de Leon inlet in the north and the three inlets to the south (Sebastian, Fort Pierce, and St. Lucie).

When the data were utilized directly, it created an unrealistic net flow through Haulover Canal. For the IRLPLR application reviewed, a 13-cm shift was applied to the measured data at Ponce de Leon inlet. When this was done, the model provided good simulation of the residual flow through Haulover Canal in relation to the measured data. The model review team felt that the adjustment of the Ponce de Leon water level boundary condition was reasonable and appropriate, and would not adversely impact the models ability to be utilized for this study. The remaining water level forcing assumptions were deemed appropriate also.

At the time of the review, the model was able to account for the primary forcing associated with atmospheric pressure variations through the use of measured surface elevations at the inlets. The atmospheric pressure variations are reflected in long-term fluctuations of the offshore water level and are propagated into the system through the inlet forcing.

The salinity forcing utilized in the model at the open boundary conditions was set to a constant value during inflow. Because the water level open boundary conditions were defined immediately at the inlets, it was determined that the dynamic nature of the actual salinity conditions would not be captured by a constant salinity boundary condition, especially during wet weather. The movement of these boundary conditions further offshore to provide some volume of mixing for the outflow of fresh water was deemed a more realistic boundary condition.

The freshwater inflows in the area of the project were based upon HSPF simulations. The HSPF simulations within the study area utilized 11 rain gages. While appropriate for the larger scale simulations under the Pollutant Load Reduction Goal (PLRG) development, it was determined that the existing resolution was not sufficient to represent the local variations in the freshwater inflow.

The wind stress field utilized in the model was developed by performing distance weighted averaging on the four wind gages described previously. It was determined that this methodology was sufficient to provide the detailed localized wind fields for simulating the transport of the demineralization concentrate discharge. In addition, the detailed studies that provided the evaporation utilized in the model were also deemed sufficient for use in a more localized study of the concentrate discharge.

The resolution provided in the bathymetric survey of the system was sufficient to allow an accurate grid representation in the immediate receiving waters. The survey transects were taken at a relatively fine interval (100 meters), and based upon the lack of historic changes in the bathymetric conditions in this area, it was deemed that sufficient bathymetric data were available for the more localized study.

3.3.3 Spatial and Temporal Resolution

The MED indicates the need for a minimum 100-meter horizontal grid resolution in the immediate vicinity of the discharge canals for evaluation of the environmental impacts. Based upon the potential for localized temperature-driven density currents, and re-circulation, the model review indicated an even finer grid necessary in the immediate vicinity of the discharge canals. The average grid cell in the vicinity of the power plants was approximately 1,000 meters on a side for the coarse grid and 400 meters on a side for the fine grid. It was determined that the resolutions in both grids were not sufficient for use in the demineralization concentrate discharge analysis.

The IRLPLR model application at the time of the review utilized four layers to represent the vertical dimension in the model. Typically, to sufficiently resolve vertical structure, a minimum of five layers is desired. Given the shallow nature of the system in the vicinity of the project, no greater than 5 layers were recommended.

The existing IRLPLR model application utilized a 120 second time step. This time step was deemed sufficient for all environmental evaluation needs, i.e., development of daily conditions as prescribed by the MED. Therefore, the models temporal resolution was sufficient for the project needs.

3.3.4 Model Calibration/Validation and Accuracy

At the time of the review, the existing IRLPLR model was calibrated through the simulation of conditions over a 4-year period from 1/1/97 to 12/31/2000. Through this period a broad range of actual water surface elevation, wind, freshwater inflow and seasonal variations occurred. For hydrodynamic simulations, where limited tuning parameters are available, and simulation accuracies are based primarily on the accuracy of the input conditions, this length of simulation provided sufficient assurance the model is capturing the physical processes of the system.

The data available for comparison with the model included continuous water surface elevations and salinities at nine locations throughout the system. The nine continuous monitoring stations are spaced longitudinally along the Indian River Lagoon, Mosquito Lagoon, and the Banana River. Two of these stations (Titusville and Cocoa) are located above and below the power plants. The locations of the data comparison stations are provided in the reports in Data Attachment A. The model calibration is described in detail in the model calibration reports. This includes the variations in bottom roughness used in the model, as well as the sensitivity of the model to key parameters and forcing mechanisms.

Within the study area, analysis of the data showed that water level variations are primarily the result of low-frequency water level changes in the ocean as well as localized winds. Freshwater inflow was not found to have a significant influence on the water level in the system. Examination of the water level simulations indicated that the model accuracy is sufficient for use in the study, and the model accurately simulates the complex distribution of water levels throughout the system and the high level of tidal damping that occurs through the inlets and physical constrictions. This includes both the localized wind-driven variations, and the low-frequency offshore variations.

The MED outlines specific salinity simulation accuracy criteria. Tables 1 through 4 present various model error statistics from the continuous salinity gages throughout the system at the time of the review. The reports in Data Attachment A provide the locations of the continuous stations.

Table 1 presents the correlation coefficient (with slope and intercept), the Root Mean Square (RMS) errors, and the Median Relative Error (MRE). These data are vertically averaged results. RMS errors are one of the most common statistics utilized in hydrodynamic simulation comparisons. Examination of the results showed errors on the order of the 2 ppt criteria defined under the MED for the RMS error. For the stations immediately upstream and downstream of the study area, the RMS errors are 1.8 and 2.0 ppt respectively.

Table 1. Statistical comparison of simulated and observed daily-averaged salinity by station (based upon vertical averaging of measured and modeled salinity):
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Station	R^2	Slope	Intercept (ppt)	RMS Error (ppt)	Median Relative Error (%)
New Smyrna	0.46	0.70	11.2	2.4	-4.3
Haulover	0.87	0.95	0.0	2.1	4.6
Titusville	0.66	0.54	10.9	1.8	-0.2
Cocoa	0.63	0.61	9.5	2.0	-2.6
Banana R	0.72	0.66	6.1	1.3	-3.4
Carters Cut	0.72	1.1	1.0	2.2	-11.0
Melbourne	0.71	0.86	4.1	2.8	-4.2
Vero Bridge	0.56	0.80	7.0	3.3	-7.6
North Beach	0.44	0.46	18.3	2.1	-2.4

Source: SJRWMD staff supplied (based upon model simulations in October 2004)

The Median Relative Error (MRE) demonstrated the general bias of the system toward higher simulated salinities. Discussions through the model review identified the potential for this bias to be a function of the use of a constant high salinity boundary condition at the inlet throats, with this assumption creating problems during periods of higher freshwater inflow.

Tables 2, 3, and 4 present the data directly compared with the salinity accuracy criteria outlined within the MED at the time of the review. Table 2 presents the 80 percentile errors for four quartiles. The four quartiles represent different levels of salinity in the system to allow comparison of the model performance under higher versus lower salinity conditions. Table 3 presents the quartile distributions for each station. Table 4 presents the percent of errors for each station below the 2.0 ppt criteria. Table 4 is the most directly comparable to the MED. To meet the MED requirements, each station within Table 4 should have percentages greater than 80. Based upon an overall evaluation, the model did not satisfy the accuracy requirements outlined in the MED. For the stations in the north and south of the study area, the percentiles range from 46 to 81 percent for quartiles 2 through 4 (higher salinities) with much lower percentiles seen in quartile 1 (low salinities). It was determined that these errors could possibly be reduced through removal of the bias in the model and altering the open boundary conditions.

Table 2. 80th-percentile of absolute salinity difference between simulated and observed daily salinity)

Station		N	Q1 (ppt)	Q2 (ppt)	Q3 (ppt)	Q4 (ppt)
New Smyrna	Surface	734	5.3	2.9	1.5	1.6
	Bottom	964	8.3	4.3	2.1	2.8
Haulover	Surface	862	3.4	3.4	2.6	4.0
	Bottom	711	3.6	3.9	3.0	3.5
Titusville	Surface	751	4.4	2.4	2.4	2.5
	Bottom	994	3.0	2.3	3.6	3.2
Cocoa	Surface	798	5.5	3.9	2.0	2.2
	Bottom	843	4.1	4.8	2.1	2.3
Banana R	Surface	686	0.8	1.4	1.2	5.5
	Bottom	840	1.2	1.1	1.3	4.5
Carters Cut	Surface	784	3.3	2.8	5.3	5.2
	Bottom	752	2.6	1.9	5.4	5.6
Melbourne	Surface	1160	4.1	3.4	5.9	5.2
	Bottom	1012	3.0	6.6	5.4	5.0
Vero	Surface	1003	6.5	5.0	6.0	4.8
	Bottom	1019	7.4	7.0	5.1	2.6
North Beach	Surface	1031	9.3	4.1	1.7	1.5
	Bottom	1049	5.2	2.3	1.2	2.9

Table 3. Salinity ranges that were utilized for each quartile in the error analyses
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Station		Q1 (ppt)	Q2 (ppt)	Q3 (ppt)	Q4 (ppt)
New Smyrna	Surface	22.3-31.1	31.1-33.3	33.3-34.9	34.9-40.3
	Bottom	19.8-29.3	29.3-32.7	32.7-34.6	34.6-41.5
Haulover	Surface	18.8-28.3	28.3-32.7	32.7-36.8	36.8-41.4
	Bottom	18.9-28.5	28.5-33.5	33.5-37.0	37.0-41.5
Titusville	Surface	15.0-20.3	20.3-23.3	23.3-25.9	25.9-31.0
	Bottom	15.7-21.9	21.9-25.5	25.5-29.0	29.0-37.7
Cocoa	Surface	11.8-18.7	18.7-20.6	20.6-23.1	23.1-36.2
	Bottom	14.0-18.5	18.5-20.9	20.9-22.8	22.8-35.7
Banana R	Surface	12.0-15.1	15.1-16.9	16.9-19.6	19.6-29.4
	Bottom	11.8-15.7	15.7-16.8	16.8-18.9	18.9-28.3
Carters Cut	Surface	10.1-13.7	13.7-16.0	16.0-18.2	18.2-26.1
	Bottom	11.1-15.1	15.1-17.1	17.1-19.9	19.9-29.0
Melbourne	Surface	6.3-14.2	14.2-18.2	18.2-23.3	23.3-37.1
	Bottom	10.4-15.0	15.0-19.2	19.2-24.3	24.3-36.2
Vero	Surface	11.4-20.9	20.9-24.2	24.2-28.1	28.1-37.6
	Bottom	14.2-22.1	22.1-26.2	26.2-31.1	31.1-38.2
North Beach	Surface	14.7-28.4	28.4-31.8	31.8-34.4	34.4-37.8
	Bottom	18.4-31.1	31.1-33.7	33.7-35.4	35.4-38.0

Table 4. Percentage of time that absolute salinity difference between simulated and observed daily salinity is less than or equal to 2 ppt

Station		N	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)
New Smyrna	Surface	734	20.7	49.5	90.2	85.8
	Bottom	964	10.4	31.1	79.3	71.7
Haulover	Surface	862	63.9	37.5	54.9	65.1
	Bottom	711	71.3	48.3	65.7	55.9
Titusville	Surface	751	18.6	70.7	77.1	66.8
	Bottom	994	57.4	74.3	46.0	56.0
Cocoa	Surface	798	11.0	56.6	81.4	76.4
	Bottom	843	27.5	56.4	79.6	74.8
Banana R	Surface	686	95.9	95.9	91.2	48.0
	Bottom	840	89.1	95.7	95.2	45.0
Carters Cut	Surface	784	45.2	56.6	53.6	39.5
	Bottom	752	64.6	84.6	37.2	34.8
Melbourne	Surface	1160	59.1	70.0	33.8	25.3
	Bottom	1012	68.5	57.7	41.5	34.9
Vero	Surface	1003	35.1	36.3	16.7	44.4
	Bottom	1019	25.5	21.2	23.1	68.1
North Beach	Surface	1031	6.2	22.1	85.7	87.2
	Bottom	1049	29.7	71.4	09.8	54.2

Note: N = number of measurements compared

General consensus was reached that the model does a sufficient job in simulating the overall processes and the relative salinity changes. The refined model, if utilized in a relative sense, would be sufficient for the evaluations, but at the time of the model review, the level of accuracy was not deemed sufficient for absolute salinity projections.

Through the various coordination meetings, questions were raised relative to the validation of the model. Specifically, questions were raised on the Verification, Validation, and Accreditation (VVA) done for the model. While this terminology is not widely used in estuarine and coastal modeling, the basic concepts are utilized.

Verification is the process of determining if the model code was developed correctly and is free of errors. When a general model code such as the UF-CH3D model is developed, it undergoes extensive testing such as comparison against analytic solutions, and peer review of the model and model code. UF-CH3D has been extensively peer reviewed and its code evaluated for over 15 years since its base development. This is the advantage of using legacy models such as UF-CH3D. Appendix M provides a history of the development of UF-CH3D.

Accreditation is the process of determining if the model is appropriate for the use intended. CH3D and similar types of models (i.e. that solve the same equations using similar methodologies) were designed specifically for, and have been used extensively in these types of shallow coastal embayments and for the specific purpose of simulating salinity transport.

The final issue is one of Validation. That is the process of determining if the model is accurately representing the real world at hand. This is the item that was directly addressed in the review process. The general finding was that the model reasonably simulated the general physics of the overall system (with the addition of temperature needed), but that the accuracy needs to be slightly improved, and there is a need for validation of the simulation of the near field (or local to the power plant) circulation and mixing.

3.3.5 Model Review Summary

The IRLPLR model at the time of the review was not deemed sufficient for use in the evaluation of the demineralization concentrate discharge. Specific refinements to the model were identified and are elaborated below. General consensus was reached that the model could be utilized for use in the project if the recommendations made were implemented. If the model accuracy did not improve through the refinements, the model could be utilized in a relative impact evaluation mode.

3.4 Recommendations

The following outlines specific recommendations that were made based upon the model review process.

3.4.1 Physical Processes

The existing IRLPLR hydrodynamic model needed to be modified in order to provide for dynamic simulation of temperature. This included a representation of the heat flux terms in line with other similar models. In addition, full boundary conditions, and solution of the advection/diffusion equations for temperature identical to that used in the salinity simulations must be implemented.

3.4.2 Vertical and Horizontal Grid Resolution

The horizontal grid resolution within the existing model needed to be modified in order to provide the spatial resolution necessary within the study area, with minimum grid dimensions in the immediate vicinity of the discharge capable of simulating the localized temperature variations and density driven currents. The minimum grid resolution in this immediate area was recommended to be 100 meters on side, with higher resolution locally around the discharge canals.

It was recommended that the process for providing finer spatial resolution occur within the existing model grid rather than using a sub-grid of the immediate area. Additional horizontal resolution will be added to the area of the discharges within the existing grid, and the full grid run with the refinements. This will keep the character of the overall solution of the lagoon system in tact, and will allow for long-term simulations of discharge impacts on the entire system as well as the local impacts.

The model should be run with a minimum of five layers in the vertical. This recommendation is consistent with other technical recommendations made under the PLRG program.

3.4.3 Freshwater Inflows

A more refined distribution of freshwater inflows should be developed for the area between the Titusville and Cocoa continuous monitoring stations. This may include refinement of the subwatersheds within the existing HSPF model simulations or a redistribution of the freshwater flows defined under the existing watershed delineations.

3.4.4 Calibration/Validation

Based upon the modifications suggested above, the revised model must be run over the full simulation period and the statistics compared to the original model simulations to assure no loss in the simulation of the overall processes. Additionally, for the model to be utilized directly in the projection of future salinity conditions, the existing bias in the model must be reduced and the calibration statistics improved to more fully meet the Model Expectations Criteria outlined in Appendix C. If the model accuracy is not improved following the model refinements, then the refined model may be utilized in a relative analysis sense with existing data providing the baseline conditions upon which changes are added.

3.4.5 Additional Data Needs

Given the refinement of the model within the study area, it would be advantageous to provide some additional data that would allow for validation of the model's ability to simulate the localized mixing phenomena. This additional data could include:

- Use of available flows measured at the causeways in the vicinity of the project (these data have previously not been utilized).
- Use of available discrete salinity/temperature data in the immediate vicinity of the discharges.
- Additional of local data in the vicinity of the power plant discharges in coordination with Plant Owners.

3.4.6 Model Runs

Model runs that are used to evaluate the long-term impacts of the proposed demineralization plant(s) will need to be run long enough for the model to reach an equilibrium condition. This will assure that any impact evaluations account for the potential for long-term build up of salinity within the system.

Additionally, prior to the development of the refined grid, initial simulations that utilize a “point” evaporation in the area of the proposed discharges, equivalent to the potential removal of water from the system, will be performed to provide a first look at potential long-term build up of salinity. This will provide an initial screening of the potential impacts.

3.5 Implementation of Model Review Recommendations and MEG Review

Following the completion of Phase I and through portions of Phase II the existing IRLPLR model was refined based upon recommendations made in Phase I of this study, and based upon input from an independent group of peer reviewers termed the Model Evaluation Group (MEG). The MEG made specific recommendations relative to the overall resolution of the model. These recommendations lead to the use of a finer grid model for the overall simulations and for the evaluation of the demineralization discharges. Additionally, these recommendations lead to the movement of the tidal boundaries further offshore. The MEG also provided an external review of the hydrodynamic model and determined that it reasonably simulated the hydrodynamic conditions throughout the system.

The specific recommendations from Phase I of this study were implemented under Phase II, this included;

- Development of a refined model grid in the vicinity of the discharges
- Refinement of the freshwater inflows in the Northern IRL
- Verification of the near field simulations through comparison with temperature measurements.
- Inclusion of temperature simulation to the model
- Inclusion of 5-layers in the vertical

The results of the model refinement and comparison with the IRLPLR simulations are presented in Section 6.0.

4.0 ENVIRONMENTAL/OPERATIONAL ISSUES OF CONCERN

Under this Section the key operational, physical, and environmental/biological issues dealt with under this study are summarized. These are the issues whose impacts are quantified in Section 7.0.

Under the operational issues, consideration is given to recirculation, impingement and entrainment, cooling water flow, temperature issues, collocation issues, equipment maintenance, and National Pollutant Discharge Elimination System (NPDES) permitting issues, and water quality. Under the physical issues, consideration is given to overall circulation, salinity, temperature, and stratification impacts. Under the environmental/biological issues, consideration is given to key resources of concern listed earlier.

4.1 Operational Issues

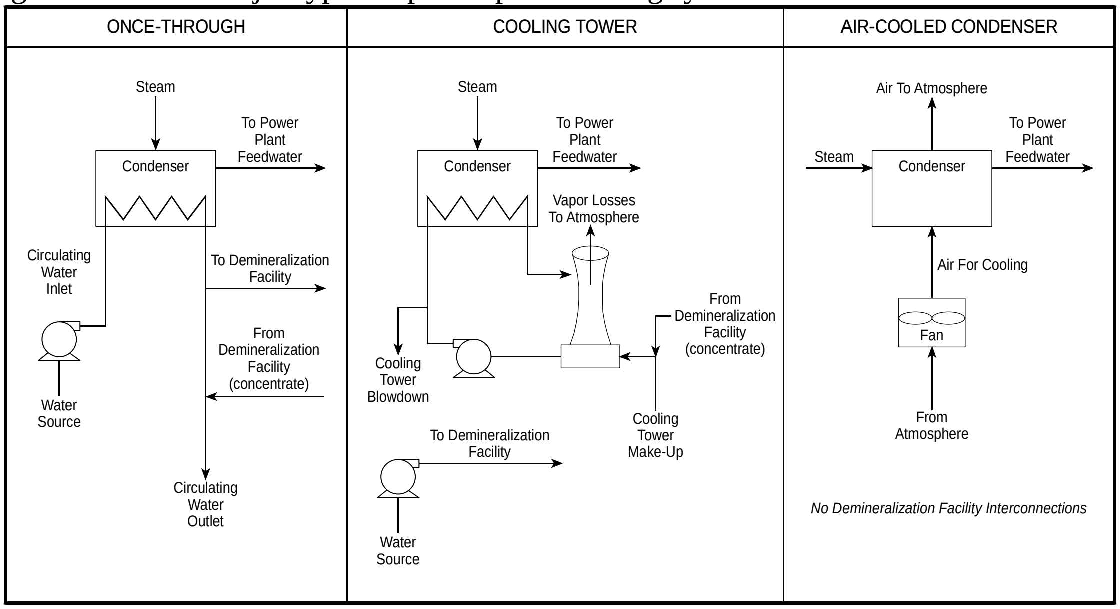
4.1.1 Site Criteria for Collocation

The advantages of collocation of a demineralization facility using a reverse osmosis (RO) process with a power plant are very dependent upon the configuration of the power plant cooling systems and operation of the power plant. The primary advantages include the use of the power plant's intake and discharge infrastructure, access to a source of heated water as raw water, and the possibility of blending the concentrate from the demineralization process with the power plant's cooling water discharge.

Only certain power facilities are suitable as candidates for collocation. Typically, the operating regime and projected future service life of the power plant and the demineralization facility must be compatible; the quality, quantity, and reliability of the power plant's cooling water must be satisfactory for use by the demineralization facility; and the environmental impacts from the addition of a new demineralization facility at the site must be acceptable.

Power plants generally use three types of cooling systems: once-through cooling, a wet cooling tower, and an air-cooled condenser. Figure 18 shows schematics of these configurations.

Figure 18. Three major types of power plant cooling systems



A power plant with a once-through cooling configuration provides the optimal cooling water system for collocation. With this configuration, the power plant circulates cooling water through the plant's condenser once and discharges the heated water to the environs. Since the allowable cooling water temperature rise is typically limited as a condition of the power plant's NPDES permit, a large amount of cooling water is typically needed for cooling purposes. As a result, this configuration allows heated water to be reused as raw water for a demineralization facility after the cooling water exits the power plant's condenser. Then, the intake of any additional ambient water is minimized so that additional aquatic animal impingement and entrainment or mortality due to the demineralization facility is minimized as well. In addition, if the flow of power plant cooling water is sufficient, the concentrate from the demineralization process may be blended with the power plant's cooling water discharge to mitigate the environmental impacts of the concentrate stream. Since power plants with once-through cooling water systems generally use substantial amounts of water, their cooling water flow is often sufficient to accommodate concentrate blending.

A power plant with cooling towers reuses its cooling water rather than discharging it. In this configuration, the cooling water is heated as it passes through the power plant's condenser. Then it is cooled by evaporation in a cooling tower so that it can be reused as a cooling medium. The evaporation in the cooling tower causes the impurities in the cooling water to increase or "cycle-up." Consequently, some of the cooling water needs to be discharged or "blown down" from the cooling tower to reduce the amount of contaminants that build up in the cooling process. Make-up water is added to the cooling loop to compensate for evaporative losses and blowdown water. Since the cooling tower configuration does not provide a source of heated water for the demineralization facility and may not have a large flow of cooling tower blowdown to provide capacity for blending the RO concentrate, the cooling tower configuration does not offer as many advantages as a once-through cooling water system. However, depending on the quality of the power plant's cooling water and make-up water, and the quality of the concentrate from the demineralization facility, some collocation advantages may exist. In specific instances where the cooling tower water chemistry can be adjusted to compensate for the additional salt, it may be possible to take advantage of the evaporative effect to dispose of some or all of the demineralization facility's concentrate by adding it as a portion of the makeup to the cooling tower.

Some power plants use air-cooled condensers. In this cooling process, air instead of water is used to cool a power plant's condenser. These facilities use a very small amount of water for power generation and none for cooling purposes. Therefore, power plants with air-cooled condensers typically do not offer significant collocation advantages for RO demineralization processes.

In addition to the cooling system configuration, a power plant's operating regime should also be evaluated to determine if the regime is suitable for collocation. Power plant operating regimes may be classified in three categories: base-load, peaking, and base-load/peaking. A power plant with multiple base-load electric generating units typically offers the most collocation advantages.

A base-load electric generating unit generates power more or less continuously. Consequently, this type of electric generating unit rarely goes offline and provides a constant source of power and a consistent cooling water flow. A power plant with multiple base-load electric generating units improves the reliability of the power and cooling water sources, as multiple electric generating units help prevent interruptions due to scheduled or unscheduled outages of any of the individual electric generating units at the power plant.

At a peaking power plant, power generation is normally restricted to operation during the periods of highest daily, weekly, or seasonal loads. Therefore, electric generation and cooling water usage are intermittent, based upon the need for power. As a result, a power station with a peaking type of operating regime will not provide a continuous or reliable source of electricity (if the RO facility is directly connected to the power plant for electricity supply) or cooling water for an RO demineralization facility.

An intermediate load power plant, due to its operational and economic properties, is used to cover the intermediate load. This means that it operates on a need basis rather than continuously as a base load plant would do.

A base-load/peaking power plant is usually generating some power. However, the plant may operate on a reduced or low power production basis for the majority of time. If it is a power plant with multiple electric generating units, some are typically shut down during periods of reduced electric demand. Since the individual electric generating units may be operated intermittently, this type of facility does not provide a consistent cooling water flow or electric generation output.

Due to its operating regime, a power plant with multiple base-load electric generating units and once-through cooling offers the most advantages for collocation, since it provides a consistent and reliable cooling water flow that can be used as raw water for an RO process and for blending concentrate. Collocation with power plants that consist of one or two electric generating units or other operating regimes may limit demineralization facility availability, if an insufficient amount of raw water or cooling water for potable water production or for concentrate blending is available. While collocation with these facilities may be economically feasible, each situation should be carefully evaluated on an individual basis. Reduced RO facility production will increase unit water production costs ($/MG) for two reasons: (1) the debt service for the facility would be distributed over a reduced product water quantity and (2) the consumption of electricity per unit of water production could increase due to efficiency losses at reduced RO facility output. Therefore, it is more economical to operate the demineralization facility on a full-time basis and near its production peak to minimize the unit cost of product water, due to the economic effect of debt service for the facility.

4.1.2 Collocation Issues

The Cape Canaveral and Reliant Indian River RO facilities would both be collocated with existing power plants. Figure 19 provides a simplified diagram of the RO facility collocation configuration concept.

The Cape Canaveral and Reliant Indian River sites both have power plant facilities with once-through cooling systems. Consequently, both facilities will take advantage of the existing power plant circulating water flow and discharge canal by obtaining source water from the discharge lines and discharging concentrate to the discharge canal.

Data contained in NPDES Discharge Monitoring Reports (DMRs) for the Cape Canaveral and Reliant Indian River Power Plants show that circulating water is typically available at both sites on a routine basis. However, as illustrated by Figures 15 and 16, the magnitude of the circulating water flow is higher at the Cape Canaveral site and less variable at flows of less than 500 million gallons per day (MGD) than the flows at the Reliant Indian River site. Therefore, assuming other environmental factors are not limiting, it is conceivable that the Cape Canaveral site could support a larger RO facility than the Reliant Indian River site.

The RO facility source water will have passed through the power plant condenser prior to the point of withdrawal from the power plant discharge canal and, therefore, will typically be heated above ambient. Membrane manufacturers commonly establish a continuous service temperature limit between 95°F to 104°F for RO membrane operation. Consequently, the RO facilities will also have a

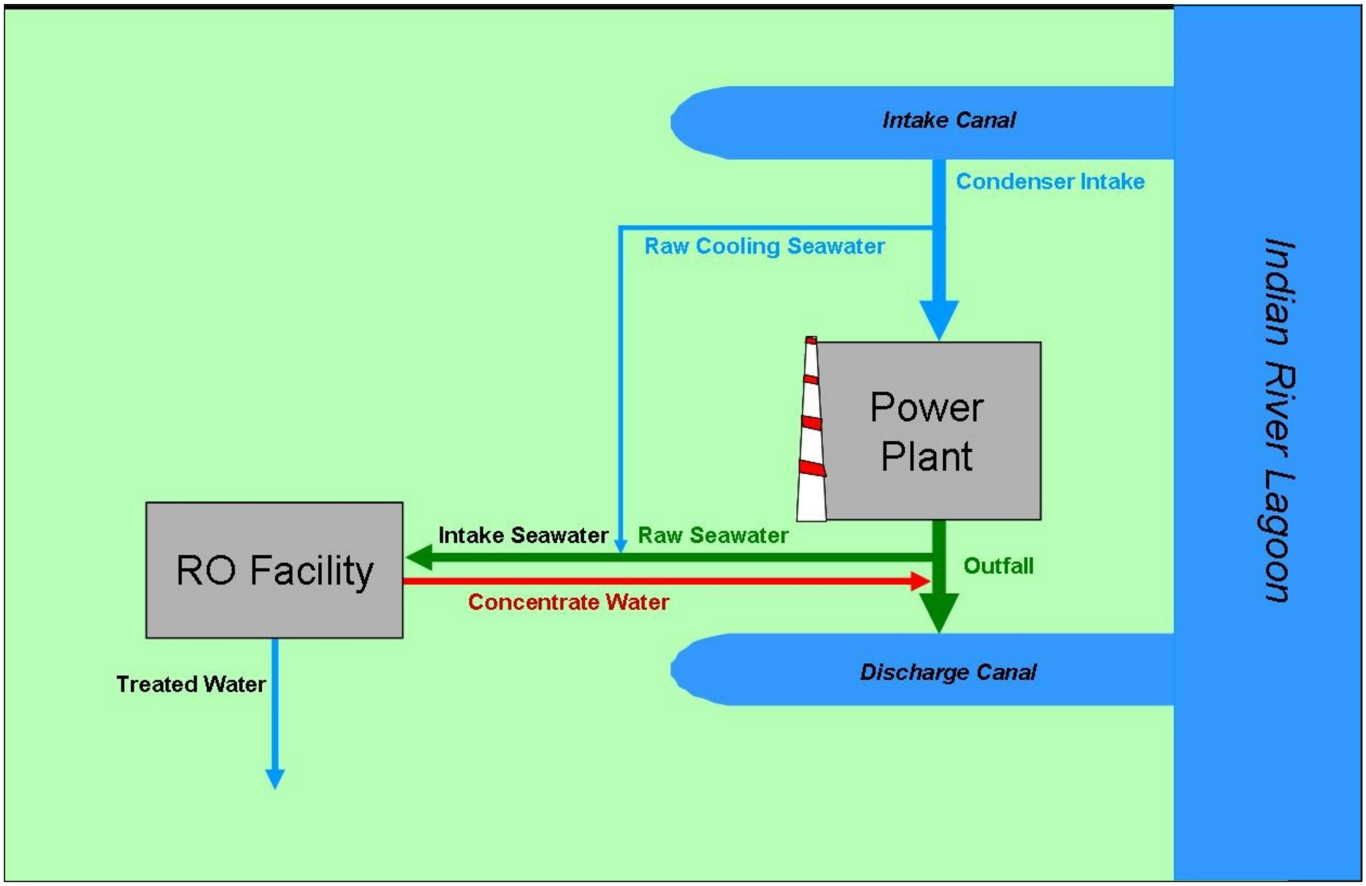


Figure 19
Demineralization plant schematic
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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cooling water supply from the intake of the power plant to accommodate membrane operation whenever the temperature of RO Facility source water (power plant condenser discharge water) exceeds membrane manufacturer guidelines. As a result, there could be some additional impingement and entrainment issues associated with the cooling water intake, and the design would require a Florida Department of Environmental Protection (FDEP) evaluation since it would be a new use.

Using the existing power plant intake as a source for cooling water could help to mitigate impingement and entrainment issues however. If the power plant's intake is used, the cooling water would be a small fraction of the total intake flow. Consequently, the resulting intake velocity increase would be small and, therefore, the overall impingement and entrainment impact would likely be small as well. For this configuration, the RO facility's cooling water withdrawal point should be located in the power plant's intake canal upstream of the power plant's circulating water pumps. Then, there would be no effect on the power plant's circulating water flow. This is important because most power plant operators would likely be unwilling to allow any reduction in their circulating water flow. The circulating water flow is a critical factor for power plants. Reductions in circulating water can reduce electricity production and thermal efficiency.

The DMR data indicate that the circulating water temperature varies from 59 to 115°F at the Reliant Indian River site and from 59 to 120°F at the Cape Canaveral site. The variations in temperature could likely affect the RO membrane system sizing requirements and impact concentrate dispersion characteristics. Considering the effect of temperature and salinity on buoyancy characteristics, a colder, higher salinity stream would not mix as well as a higher temperature, lower salinity stream. Thus, a concentrate stream based on a source water salinity of 37 parts per thousand (ppt) and a temperature of 59°F is likely the worst case in terms of dispersion modeling.

The viability of the long-term plan for continued operation of the power plants is a critical factor in site evaluation. Conversation with FPL's contact for the Cape Canaveral site has revealed that the site has two 400-megawatt (MW) units that are 40 years old and that both units load-follow (their historical capacity factor is about 30 to 35%). While the boilers have been rebuilt, other auxiliary equipment is old. Further, because there are only two active units and both load-follow, unit outages could affect raw water availability. Consequently, future power plant operations should be investigated and a plan for continued operation of the RO facility should be developed if power plant operation ceases or is temporarily suspended for an extended outage. Due to the age of the plant, the same issues about raw water availability are a potential concern for the Reliant Indian River site.

In addition, separate concentrate discharge and/or intake diffusers may be required to promote dispersion if power plant circulating water at either site is unavailable or diminished and the RO facility at the site continues to operate. This would likely require additional permitting efforts as the potential impact on the receiving water could change.

4.1.3 Source Water Salinity Issues

As a general practice, pretreatment requirements should be established on the basis of a thorough raw water characterization and the RO equipment manufacturer's requirements. In addition, they should be verified by pilot testing on the actual source water during the conceptual design phases of facility development activities. Therefore, when practical, the pilot testing program schedule and duration should be sufficient to show that the pretreatment processes are effective for the full range of source water characteristics selected for the facility's design basis. The source water at both sites is variable. Based upon available data, source water salinity has ranged from 13 to 37 ppt. The variability in salinity implies that there is a considerable amount of fresh water and/or runoff during the low salinity periods and that the water has salt concentration levels near and above seawater during other periods when fresh water and/or runoff are low. The significance of the salinity variation is that the treatability characteristics of the source water are likely highly variable as well. Consequently, the duration of source water treatability testing will need to be conducted over a period that is sufficient to assure that seasonal variations in source water quality have been evaluated so that the RO facility pretreatment system design can be adequately verified.

4.1.4 Equipment Maintenance Issues

The volume and frequency of wastewater generation from the membrane Clean-In-Place (CIP) is a function of the raw water characteristics, the size of the plant and the pretreatment and RO systems designs. Prior to piloting studies, there is limited information to suggest typical ranges for these values. The wastewater characteristics can also vary dependent on the raw water characteristics and the pretreatment and RO systems designs. Designers would prefer that RO systems be cleaned at frequencies greater than 6 months to assure a reasonable life for the RO membranes. A single 4 million gallon per day train of RO pressure vessels can generate from 50,000 to 175,000 gallons of waste per cleaning. A twenty million gallon per day plant with a six month CIP cleaning cycle, five 4-MGD RO trains and a 100,000 gallon CIP wastewater production per cleaning would then create on average roughly 2,740 gallons per day of wastewater (5 trains x 2 cleanings per year x 100,000 gallons per CIP divided by 365 days per year). The design basis for the wastewater generation rate should be higher to allow for irregular schedules for CIP cleanings and an adequate safety margin. Desalination plant designs typically include wastewater storage tanks to assure low flow discharge rates into the disposal facilities.

RO membrane cleaning is generally considered to be the primary equipment maintenance activity that can affect RO facility discharge characteristics. These cleaning processes use a variety of solutions to remove membrane fouling and restore membrane flux and pressure performance. The cleaning solutions can include chemicals such as citric acid, sodium hydroxide, sulfuric acid, sodium tripolyphosphate, sodium salt of ethylaminediaminetetraacetic acid (Na-EDTA), and sodium salt of dodecylbenzene sulfonate. Permitting precedents at an operating seawater RO facility in Tampa, Florida demonstrate that the disposal of these chemicals and the materials removed from the RO membranes can be effectively controlled so that they are not significant NPDES issues.

The NPDES permit for the Tampa, Florida facility referenced above states that, at a minimum, the initial volume of spent cleaning wastes must be discharged offsite, and the permittee is authorized to discharge purge water for cleaning wastes only, and only when they reach a pH between 6.5 to 8.5 (there is no pH adjustment or other treatment for these wastes). Consequently, the facility can only discharge purge water that complies with the requirements of its NPDES permit. The other membrane cleaning wastes are discharged to a municipal wastewater treatment plant (WWTP) in a controlled manner pursuant to the terms of the sewer use permit. Consequently, the RO membrane cleaning solutions are not expected to be a major NPDES issue.

The sewer use permit for the facility referenced above dictates the mass loading of pollutants in the RO membrane cleaning wastes discharged to a WWTP via sanitary sewer pipe connection. The permit links the allowable discharge flow rate to the concentration of pollutants in the discharge stream. Thus, the permit effectively protects the WWTP from slug loadings of pollutants from the RO membrane cleaning wastes that could have deleterious effects on the WWTP treatment processes. Offsite trucking could be used for transport of cleaning wastes if a suitable WWTP is not available via a sewer pipe connection. In the event trucking is used, a controlled off-loading rate could be implemented at the WWTP to protect the waste treatment process.

4.1.5 NPDES and Water Quality Issues

One potential major facility discharge/NPDES issue was identified during the course of this study. CDM results show that NPDES criteria could effectively limit RO facility size at the Reliant Indian River site. Florida Administrative Code 62-302 mandates a maximum circulating water chloride level rise of 10%. Figure 15 shows the Reliant Indian River Power Plant circulating water flow can be less than 300 MGD for extended periods of time. Figure 20 shows that a minimum power plant circulating water flow of 300 MGD is required for an RO facility with a 30 MGD capacity in order to adhere to the 10% chloride rise criterion. Consequently, the capacity of a collocated demineralization facility at the Reliant Indian River site will be heavily dependent on circulating water flows and regulatory requirements.

The project’s technical advisors and ad hoc advisors raised questions about other discharge constituents of concern and their concentrations during various stages of plant activity such as nitrogen, phosphorus, pesticides, various metals (copper, iron and mercury) and other pollutants. Seawater typically has naturally occurring, concentrations of these constituents (except for pesticides). Higher concentrations

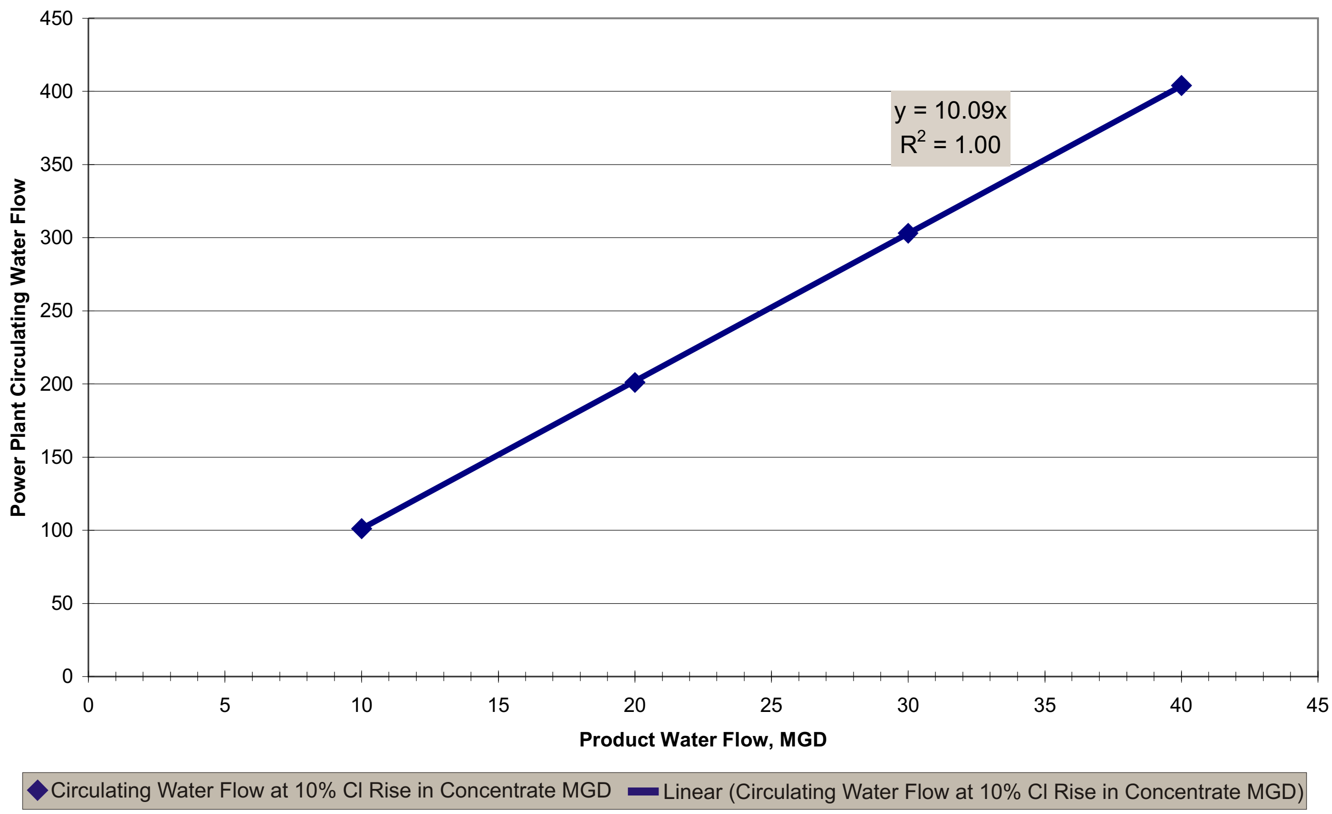

Figure 20
Minimum circulating water flow
(10% rise in circulating water chloride concentration level)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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of these constituents may be present in the local waters and these base levels will need to be considered during impact evaluation. Additionally, under NPDES permitting process, pilot testing and other permitting activities will need to assure that Class III water quality standards are not violated.

Except for possibly iron, none of these materials are added during the demineralization process. Seawater RO facilities typically employ a coagulation/flocculation step as part of their pretreatment processes to condition their source water to meet RO membrane manufacturer's guidelines for feedwater quality. However, phosphorus and metals levels are typically too low to be effectively treated via these steps under conventional treatment configurations for fresh water. Consequently, as a worst case, these materials would be concentrated in the facility's concentrate effluent stream by the following relationship:

Equation (1) $C_c = C_f/(1-R)$ where:

C_c = the concentration in the concentrate stream;

C_f = the concentration in the RO facility source water; and

R = the overall recovery rate for the RO facility or the ratio of the RO facility product water flow to the RO facility source water flow.

To aid the coagulant/flocculation process, RO facilities commonly add either ferric sulfate or ferric chloride in their pretreatment systems. However, RO membrane manufacturers' feedwater quality guidelines typically limit ferric iron concentration to less than 0.05 ppm since iron is a foulant material for their membranes. Assuming RO membrane manufacturers' feedwater quality guidelines are typically met, little of the iron added in the pretreatment process actually passes through to the RO membranes. Consequently, little of the iron added in the pretreatment process would typically be found in the concentrate stream.

Due to the potential for the conversion of iron from the ferrous to ferric state, RO membrane manufacturers will typically recommend minimizing ferrous iron levels as well. One manufacturer, Dow, recommends 4 ppm as a limit for ferrous iron, and RO membrane feedwater with approximately 0.5 to 1.0 ppm is not atypical. Based on Equation 1, iron levels in the range of 0.8 to 6.5 ppm could be expected. With a minimum blending ratio of power plant circulating water to RO facility concentrate of approximately 10:1, the blended effluent increase in iron would vary from approximately 0.081 to 0.65 ppm of iron.

Forchhammer's Principle, also known as the Principle of Constant Proportions, states that the ratio of major salts in samples of sea water from many locations is constant. Although water may be saltier in one place than another, the percentages of the various salts tend to be the same. The ocean is in a chemical equilibrium because the proportion of dissolved salts per unit volume is nearly constant.

The source water for the Cape Canaveral and Reliant Indian River sites is from estuarine waters rather than direct seawater sources. Consequently, the influence of river, stream, groundwater, and runoff water on the concentration of the constituents of the source water for the RO facilities will be quantified during the impact assessment based upon available local water quality data. The concentration equation (Equation 1), along with issues of recirculation of discharge water, will then be used to evaluate the concentrate discharge and degree of dilution from the model used to show potential impacts. Similarly, pilot testing is strongly recommended to confirm source water treatability and facility recoveries during the preliminary stages of RO facility design and permitting.

4.1.6 Impingement and Entrainment

In addition to environmental impacts related to water quality changes, the physical operation of the demineralization facility brings about the potential for increases in impingement or entrainment of organisms. Impingement involves fish and other aquatic organisms getting trapped against water intake filters, while entrainment describes organisms getting drawn into the facility with the process water. It should be noted that present power plant operations create impingement and entrainment issues within the system. The goal of this study therefore is to identify any changes in I/E that may occur due to the collocation of the demineralization facility.

One potential mitigating factor for impingement and entrainment is that by collocating the demineralization facility with existing power plants, new water withdrawal points will not have to be constructed. However, the demineralization facilities may require additional volumes of water be withdrawn by the power plants, volumes greater than what they require to cool the power plants. Thus the potential for impingement and entrainment may be increased by the demineralization facility.

Consideration will need to be given to the volumes of increased water withdrawals, and importantly, the seasonal timing of any increased water withdrawal in order to assess the potential impact on biological resources in the Indian River Lagoon.

4.2 Physical Issues of Concern

4.2.1 Circulation

The operation of a demineralization facility will withdraw water from the Northern IRL. This net withdrawal of water has the potential to impact overall circulation and exchange conditions. This is especially significant in the North IRL due to the limited tidal exchange that occurs within this area.

4.2.2 Salinity

Salinity has traditionally been regarded as a central parameter for estuarine analysis, especially as an indicator of hydrography and habitat potential. Salinity is defined as the total amount of dissolved minerals in seawater. The major constituents of seawater that comprise more than 99% of the dissolved salts (Thurman, 1993) include:

- Chloride – 55.04%
- Sodium – 30.61%,
- Sulfate – 7.68%,
- Magnesium – 3.59%,
- Calcium – 1.16%, and
- Potassium – 1.10%.

Salinity is an important determinant of the distribution of estuarine organisms. The vital role that coastal systems play in maintaining populations of marine fishes, shellfishes, and other organisms has long been recognized (Bulgar et al., 1993). Efforts to subdivide coastal waters as a function of salinity have traditionally been based on the observation that estuarine species are not evenly distributed across estuarine salinity gradients. Descriptions of estuarine species have yielded more than a dozen salinity classification schemes with recurring patterns across taxa and geographic zones. One of the most well known zonation schemes is the Venice System (Anonymous, 1959), which has largely superseded earlier classification schemes. The empirical basis for the zonation of the Venice System was not reported in the original 1959 document and is mostly descriptive. Nevertheless, the descriptive purpose is and will continue to be very valuable. The Venice System breaks down estuarine salinity ranges into five zones:

- limnetic: 0 - 0.5 ppt,
- oligohaline: 0.5 - 5 ppt,
- mesohaline: 5 - 18 ppt,
- polyhaline: 18 - 30 ppt, and
- euhaline: > 30 ppt.

A more recent classification scheme (Bulgar et al., 1993) derives biologically-based estuarine salinity zones from multivariate analysis. Principal Component Analysis (PCA) was used to derive estuarine salinity zones based on field data of the salinity ranges for 316 species/life stages in the mid-Atlantic region. Application of PCA to the data matrix showed that the structure underlying a diversity of salinity distributions could be represented by only five Principal Components corresponding to the following five overlapping salinity zones:

- Freshwater – 4 ppt,
- 2 – 14 ppt,
- 11 – 18 ppt,
- 16 – 27 ppt, and
- 24 ppt – marine.

The derived salinity zonations showed both differences and similarities to the Venice System. However, unlike the descriptive Venice System, the newer method allows researchers to establish biologically-relevant local salinity zones and develop hypotheses about the processes that give rise to the resulting patterns (Bulgar et al., 1993).

With respect to potential salinity effects, it is important to note that the living resources of the study area are biologically adapted to the dynamic estuarine conditions that result in relatively wide changes in salinity over time and space due to tidal cycles, wind driven circulation, and stratification of the water column. Thus, the salinity tolerances of these organisms are relatively broad, and the level of resolution needed to identify the tolerance ranges is also reported in the literature to be broad. Because the organisms are adapted to a range of salinities, any potential impacts of the demineralization facility will be evaluated with respect to shifts in the distribution of salinity in the study area, or possibly a truncation of the distribution of salinity in the study area (e.g., an increase in the periodically occurring lowest salinity values).

4.2.3 Temperature

Water temperature is an important physical parameter in aquatic systems. Water temperature (in combination with salinity) controls ecosystem functioning by directly influencing the physiology of aquatic organisms and indirectly by influencing the types of habitats that may develop in a given location. Temperature and salinity largely determine the geographic distribution of aquatic species for the above listed reasons. Photosynthesis, respiration, growth, reproduction, and migration are all biological processes that are affected by temperature. The density and saturation states of minerals in seawater are also affected by temperatures. The rates of biochemical reactions are known to double as temperature increases by 10°C within the temperature tolerance range of a given organism. The Q_{10} rule also applies to microbial process involved in chemical transformations. Temperature can serve as an environmental cue for spawning and migration in a number of fish species. Seagrass flowering and reproduction has also been linked to certain temperature ranges. Additionally, unnatural changes in water temperature can serve as an indicator of water quality conditions.

Temperature varies naturally in coastal systems as a result of daily and seasonal fluctuations caused by air temperature, currents, and local hydrodynamic conditions. Certain anthropogenic activities (e.g. changes in freshwater inflow, discharge of cooling water) can cause unnatural temperature changes. However, well mixed systems are somewhat buffered from thermal pollution.

Thermal stratification occurs when a layer of warmer water overlies a layer of cooler, denser water. The potential for thermal stratification exists if mixing is not adequate. Additionally, warm water discharge to surface waters could increase the potential for thermal stratification. One consideration of the demineralization facilities is that the demineralization process could potentially affect salinity and temperature jointly in a manner that could result in undesirable stratification. The impacts of this potential stratification will be evaluated through the modeling simulations.

In general the primary impacts to temperature would come through the need for additional cooling water draw for the R/O process. This would have the effect of reducing the discharge temperature. Based upon the expected volumes for the cooling water it is not anticipated that significant temperature changes will occur. Section 7 provides quantification of the potential changes.

4.2.4 Stratification/Dissolved Oxygen

Oxygen is produced by photosynthesis of aquatic plants, particularly microscopic algae (phytoplankton), and consumed by plants, animals, and bacteria living in the environment. Oxygen levels often display a diel cycle, meaning levels are higher during the day and are lowest late in the evening through to the early morning. In surface waters that are not saturated with oxygen, exchange will take place via the air-water interface.

The amount of dissolved oxygen in water is a function of both temperature and salinity. Solubility decreases as both temperature and salinity increase (Richards, 1957). Where density stratification exists (due to temperature and/or salinity differences within the water column), deeper waters may not exchange oxygen with surface waters. As a consequence, respiration by animals and bacteria, may cause the dissolved oxygen (DO) concentration to decline, often to the point at which it is detrimental to the survival and well-being of aquatic life. In cases where large amounts of organic material (e.g., decaying phytoplankton from a “bloom”) sink to the bottom of the water column respiration may exceed photosynthesis and DO concentrations will decline as a result (Richards, 1957).

When oxygen levels are low (typically 2-3 mg/l), then the water is considered hypoxic. Hypoxia typically occurs in waters that are not well mixed, such as in near shore areas and estuaries, or in waterbodies that are eutrophic. Hypoxic conditions negatively affect biological organisms, most harshly affecting non-mobile organisms, such as benthic invertebrates (i.e. clams), and young fish. Organisms higher in the food chain, such as fish eating birds and mammals, which rely on these organisms for prey are also impacted. Adult fish can often temporarily move out of hypoxic waters if all the surrounding waters are not oxygen depleted as well. However, spawning and nursery grounds can be negatively affected.

The principal potential for impacts from dissolved oxygen could occur through modifications in the local stratification, altering the aeration levels of the bottom waters. This potential is quantified in Section 7.

4.3 Biological/Ecological Resources of Concern

The following biological resources are listed as having the potential to be impacted by the previously outlined environmental concerns. Identification and quantification of specific biological impacts are addressed in Section 7.

Among these biological resources are expected to be those organisms and life stages that may be responsive to direct and indirect effects of the concentrate discharge, and those that may be relatively non-responsive to the concentrate discharge. Thus, the most responsive organisms and life stages may provide sentinels as proxy for the complete set of biological resources. In particular, it will be important for the hydrodynamic model to be developed to make inferences regarding the organisms that would be expected to be the first responders to changes related to the concentrate discharge (i.e., an early warning system). For example, sessile organisms with relatively short life cycles such as benthic macroinvertebrate organisms may respond before mobile animals with longer life cycles such as the spotted seatrout.

With respect to potential salinity effects, the living resources of the study area are biologically adapted to the dynamic estuarine conditions which result in relatively wide changes in salinity over time and space. These fluctuations are related to tidal cycles, wind driven circulation, and stratification of the water column. Thus, the salinity tolerances of these organisms are relatively broad, and the level of resolution needed to identify the tolerance ranges is also reported in the literature to be broad. Because the organisms are adapted to a range of salinities, any potential impacts of the demineralization facility will be evaluated with respect to shifts in the distribution of salinity in the study area, or possibly a truncation of the distribution of salinity in the study area (e.g., an increase in the periodically occurring lowest salinity values).

With respect to specific organisms, SJRWMD and project participants have identified an initial list of taxa of concern for this project. These taxa include:

- seagrasses,
- benthic macroinvertebrates (hard clam),
- Shellfish Harvest and Lease Areas,
- horseshoe crabs,
- shrimp,
- spotted seatrout, red drum, common sea trout and baitfish,
- birds and waterfowl utilizing Merritt Island and mosquito impoundments in the North IRL (including the lesser scaup),
- sea turtles, and
- manatees.

Section 2.0 presented a detailed characterization of these resources of concern within the Indian River Lagoon. This resource base is what is to be protected through the evaluation of the potential impacts from the proposed demineralization plants.

4.3.1 Aquatic Vegetation

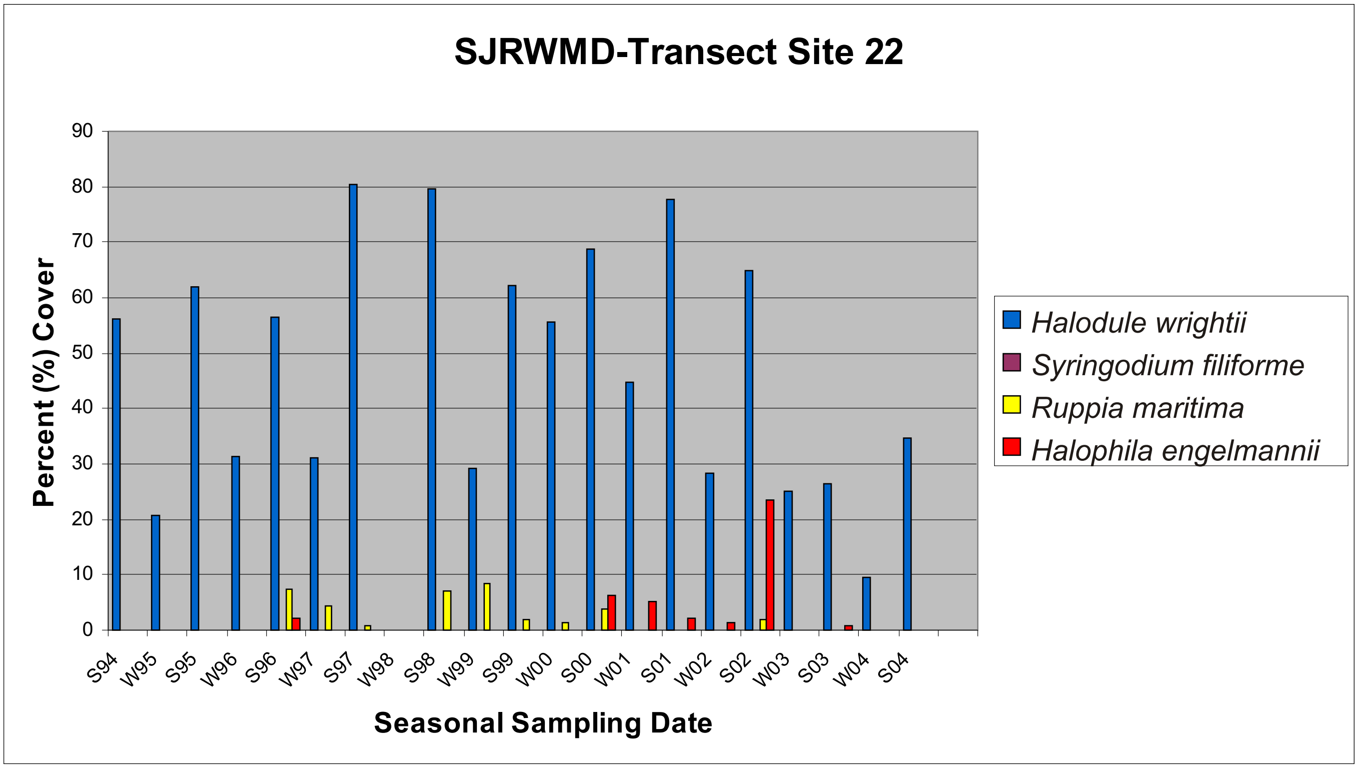
Seagrass beds are one of the most important habitats in the Indian River Lagoon (Rey and Rutledge, 2001). Seagrasses are flowering vascular plants that live their entire lifecycle in seawater, occupying shallow portions of oceans, estuaries and lagoons (Rey and Rutledge, 2001). In general, seagrass growth and establishment is light limited. Light attenuation in the water column is influenced by water depth, turbidity, and the presence of floating plant species on the water surface. In addition to light, salinity often determines which species are present in which locations, and at what depths, based on differing salinity tolerances and preferences for each species. All seagrass species in the Indian River Lagoon also exhibit seasonality in terms of growth and biomass, with peaks occurring in April-May and June-July respectively.

The species of seagrass in the study area are all well adapted to the wide ranging salinity conditions found in estuaries and lagoons. Currently, the primary seagrass species near the potential demineralization facilities is *Halodule wrightii* (SJRWMD, unpublished data, 2005). Several shifts in seagrass species composition have occurred over the past 15 years (Figure 21). Between 1990-1999, data showed that the two prime seagrass species in the immediate project area were *Halodule wrightii*, followed by *Ruppia* maritime (SJRWMD, 2002). Over the next several years (2001-2003) *Ruppia* was replaced by *Halophila engelmannii*, making *Halodule wrightii* and *Halophila* the dominant species (Figure 22). The most recent shift in dominance, as observed in data from 2004, show neither *Ruppia* or *Halophila* present in the area, leaving *Halodule* as the only persistent species (SJRWMD, unpublished data, 2005; Figure 21).

It is expected that salinity may be one of the ecological factors that influences species composition and distribution in the study area (Figure 22) (SJRWMD, 2002). Other important ecological factors include water clarity, depth, sediment compositions, and epiphyte loads.

Light limitation is considered the most important factor currently influencing seagrass growth in the Indian River Lagoon (Rey and Rutledge, 2001). Light transmittance through the water column is generally low and seagrasses in the lagoon typically exhibit growth rates near the lower limits of the range. Additional increases in light limitation could further limit seagrass growth and productivity (Rey and Rutledge, 2001). Light limitation could be caused by increases in the following factors, which are usually associated with increased nutrient loading (Rey and Rutledge, 2001):

- absorption of light by other aquatic vegetation (i.e. floating species),
- suspended or dissolved solids,



Transects were sampled twice annual:
August (S=summer)
February (W=winter).

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Figure 21

Percent cover of four seagrass species present in SJRWMD transect No. 22 on Indian River Lagoon. (Source: Lori Morris SJRWMD)
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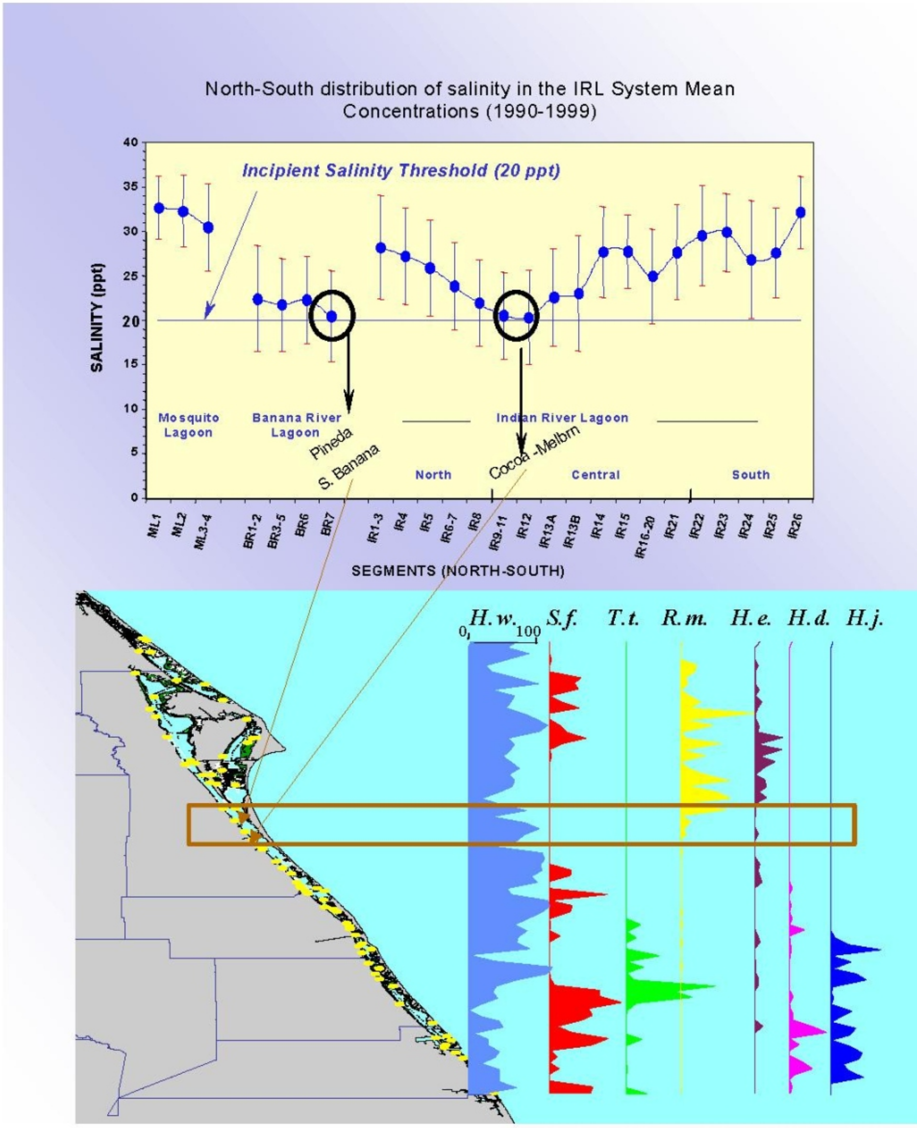

10-year mean salinities +/- S.D. in the IRL system by segment (top plot) and the relative abundance and diversity of seagrasses with an emphasis on the south Banana River Lagoon and Cocoa-Melbourne reach (bottom graphic) where both low salinities and low seagrass abundance and diversity exist

Seagrass Species:
H.w. – *Halodule wrightii* **S.f.** – *Syringodium filiforme* **T.t.** – *Thalassia testudinum*
R.m. -- *Ruppia maritima* **H.e.** – *Halophila engelmannii* **H.d.** – *Halophila decipiens*
H.j. – *Halophila johnsonnii*

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Figure 22
Salinity and seagrass species distribution in the north Indian River Lagoon (SJRWMD, 2002)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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- color caused by increases in dissolved organic material, and
- eutrophication of the system.

Typically, seagrass loss due to light limitation begins in the deeper, outer reaches of the seagrass beds and gradually increases to shallower areas as conditions further deteriorate.

Additionally, the presence of chemicals, such as pesticides, herbicides, and industrial and commercial runoff, can directly impact seagrass beds in the localized area and cause die backs.

The following seven species of seagrasses are found within the Indian River Lagoon system. The first four are the primary species found in the immediate vicinity of the potential desalination facility locations (Figures 21 and 22):

- Shoal Grass –*Halodule wrightii*
- Manatee Grass-*Syringodium filiforme*
- Widgeon Grass- *Ruppia maritime*
- Star Grass- *Halophila engelmannii*
- Turtle Grass-*Thalassia testudinum*
- Paddle grass-*Halophila engelmannii*
- Johnson's Sea Grass- *Halophila johnsoni*

Shoal Grass (*Halodule wrightii*)
Shoal grass is found throughout the north to south geographic extent of the Indian River Lagoon in varying adundances (Figure 22). Shoal grass occurs in intertidal habitats as well as deep water areas, and can occur closer to the beach than other seagrass species. It is reported to be eurythermal and occupies sediments ranging from silty mud to course sand with varying amounts of mud. The optimal salinity range for shoal grass is reported to be between 22 ppt to 34 ppt., and the tolerance range between 1 ppt to 45 ppt (Woodward and Clyde 1994). Shoal grass is able to withstand salinities in the low end of its range for only a short time period (Robert Virnstein, project team personal communication). It has been reported as withstanding freshwater conditions for an unknown time period in the St. Lucie River, but can not withstand prolonged freshwater conditions (Hill, 2001).

Widgeon Grass (*Ruppia maritima*)
Widgeon grass is distributed patchily in the Indian River Lagoon, mainly in very shallow areas. However, it can also occur in mixed species beds with Shoal grass, usually at slightly greater depths than when found in a monotypic bed. Overall depth range is from the intertidal zone out to approximately 7 feet. Higher density growth was seen at depths of 2-4 feet (mean high tide). The optimal salinity range for widgeon grass is expected to be less than 25 ppt., and the tolerance range is reported to be from 5 ppt. to 32 ppt. (Woodward and Clyde 1994). In addition, information from the project team indicates that widgeon grass tolerances may be

wider (0 ppt. to 60 ppt) than these reported values (Robert Virnstein, project team personal communication).

Ruppia overwinters in the Tampa Bay area where a range of 22 degrees (13-35) was observed. It has also been reported to withstand temperatures as low as 7°C in February and 39.4°C in July, although the duration of these extreme temperature events is not known (Hill, 2001). Beds of *Ruppia* increase in abundance during warm spring temperatures, reaching a high during the flowering period. For growth and development, temperatures ranging from 20-25°C are postulated as being most favorable (Hill, 2001).

Paddle Grass (*Halophila decipiens)* and Star Grass (*Halophila engelmannii*)
Paddle grass can be locally abundant and dense in deeper waters throughout the southern half of the Indian River Lagoon, which is south of the general study area for this project (Figure 22). It has been observed to occur in depths between 5-100 meters (Hill, 2001). Paddle grass is a stenohaline species, exhibiting a relatively narrow salinity tolerance range of 24 ppt. to 38 ppt. (Woodward and Clyde 1994). Paddle grass is also reported to be stenothermal, although no temperature ranges were provided (Hill, 2001).

Star grass is patchily distributed in the Indian River Lagoon, being most common in the northern portion of the lagoon in mixed beds with Manatee and Shoal grass, and in deeper waters (Hill, 2001). It has been observed to depths of up to 14.4 meters. Overall salinity tolerance is thought to be narrow, from 29 ppt. to 31 ppt (Woodward and Clyde 1994). In addition, information from the project team indicates that star grass tolerances may be wider and lower than these reported values (Robert Virnstein, project team personal communication).

Manatee Grass (*Syringodium filiforme*)
Manatee grass occurs at mid depths throughout the Indian River Lagoon and is rarely seen in shallow areas. It often forms mixed beds with other species (turtle and shoal grass). The species absence in areas of poor water quality has been documented (Hill, 2001). Densest growth occurs at depth between 2-4.5 feet (at mean low tide). The maximum depth is thought to be approximately 10 ft. Syringodium filiforme is eurythermal, as it occurs from North Florida throughout the Caribbean, although it is typically thought of as a tropical species. When temperatures drop to 20°C, leaf kill is observed and the effect of cold on the rhizomes is unknown. The optimal salinity range for manatee grass is expected to be 20 ppt to 28 ppt., and the tolerance range is reported to be from 10 ppt to 36 ppt (Woodward and Clyde 1994). The optimal and tolerance ranges for the Indian River Lagoon study area may be lower than these reported values for long term conditions (Robert Virnstein, project team personal communication). It is speculated that the presence of Thalassia in dense stands probably forces Syringodium into lower salinity areas (Hill, 2001).

Turtle Grass (*Thalassia testudinum*)

Turtle grass (*Thalassia testudinum*) has the highest salinity tolerance of the seagrass species of the Lagoon system. This species is found within the general region of the study area (Figure 22), but is south of the specific candidates sites for the demineralization facility. The optimal salinity range is expected to be 24 ppt to 35 ppt., and 16 ppt. is probably the lower limit for normal growth (Woodward and Clyde 1994). The tolerance range is reported to be from 16 ppt. to 48 ppt. (Woodward Clyde, 1994). However, a recent laboratory experiment using turtle grass reported that exposure to 6 ppt. salinity for 43 days stopped blade production and blade length decreased, and it reported that results for higher salinity treatments of 12 ppt., 18 ppt., 25 ppt. and 35 ppt. did not elicit these adverse responses after 43 days of exposure (Doering and Chamberlain, 2000). Temperature limits the northern distribution of *Thalassia* in Florida. Temperatures on the high end in on the east coast of Florida (35-40°C) will kill the leaves of *Thalassia* (Hill, 2001).

Johnson's Sea Grass (*Halophila johnsoni*)

Johnson's sea grass is a species unique to coastal lagoons of east Florida, ranging from Sebastian inlet in the north, to Biscayne Bay in the south (Hill, 2001). It occurs in the southern half of the Indian River Lagoon and occurs in dense patches in deep water and on shoals (Hill, 2001). It can be found in monospecific and mixed species beds. Johnson's seagrass is both a federally and state listed threatened species. The observed salinity range for *H. johnsoni* was between 24.3-38 ppt, and a high salinity of 43 ppt was documented (Hill, 2001). When compared to another *Halophila* species that occurs in deeper water (i.e. paddle grass), *H. johnsoni* shows a greater tolerance to salinity variations. It is also thought to be more tolerant of temperature variations, and its presence was noted during temperatures ranging from 21-36°C (Hill, 2001).

4.3.2 Invertebrates

Aquatic invertebrates occupy a very important niche within the ecosystem. From a bottom up approach invertebrates act as processors of organic material acting as an essential link in the food web structure to higher organisms such as fish and waterfowl. Unlike species in higher trophic levels most invertebrates lack the mobility to withstand large fluctuations in habitat which may in turn act to degrade commercial or recreationally important fish species.

Diverse benthic communities typically thrive in healthy habitats, where water quality and sediments have adequate oxygen and minimal presence of pollutants. However, certain benthic macroinvertebrate species can withstand hypoxic or contaminated conditions. These are typically species that are able to adapt and take on an opportunistic role in utilizing unhealthy habitat. Only a limited number of organisms occupy contaminated or hypoxic sediments, meaning a healthy and diverse benthic community will not be found under these conditions, rather an overabundance of one or two particular taxa might be. In general benthic invertebrates are relatively immobile and are therefore considered to be good indicators of sediment and water quality conditions.

Benthic invertebrates and benthic community structure can be useful biological indicators in estuarine systems. Many characteristics qualify benthos to be relevant and measurable indicators of estuarine health and condition (Aller 1982; Boesch and Rosenberg 1981; Dauer et al. 1982; Dauer 1993; Hartley 1982; Hargrave and Theil 1983; Gray et al. 1988; Pearson and Rosenberg 1978; Philips and Segar 1986; Warwick 1986; Warwick et al. 1990; Weston 1990):

- benthos are relatively immobile compared to most estuarine inhabitants , meaning they cannot readily relocate or otherwise escape the effects of environmental stress and therefore they reflect local conditions integrated over time;
- benthos are found predictably, as their presence and location is not in flux with tidal or diurnal cycles;
- benthos reside directly in the bottom sediments where contaminants accumulate and hypoxia most often occurs;
- benthic communities are often comprised of organisms that exhibit varying degrees of sensitivity and/or resistance to chemical and hypoxic stress based on differing physiological capabilities and adaptations;
- established paradigms exist for the responses of benthos to changes in habitat quality; and
- benthic organisms are ecologically important because of their role in cycling nutrients and chemicals between the sediments and the water column, and supporting commercially important species of fish and shellfish.

Shellfish Harvest and Lease Areas

Shellfish are filter feeding organisms (e.g. oysters, clams and mussels) that live in estuarine environments. Filter feeders get food and oxygen by pumping large quantities of water across their gills, subsequently ingesting bacteria, viruses and chemical contaminants. Filter feeders play an important ecological role by improving water quality conditions. However, these impurities can become concentrated in their digestive systems and tissues. Because shellfish are important recreational and commercial species, shellfish harvested from polluted areas are a health hazard if consumed. Because of this, most shellfish harvesting areas in Florida are classified Conditionally Approved, with management plans that call for temporary closure following heavy rainfall events which can impact and degrade water quality conditions by delivering excess amounts of pollutants into the estuary.

Hard Clam (*Mercenaria mercenaria*)

The hard clam is a commercially important invertebrate species that burrows into either mud or sandy sediments. In the Indian River Lagoon, the hard clam is most abundant in shell-containing soft bottom areas. They are also found on sand flats and muddy bottoms. Clams found in seagrass beds have had both higher densities and larger size than those found on sand flats (HiIl, 2001). Clams are filter feeders and consume primarily single celled algae and diatoms. In the Indian River Lagoon, clam farming is active and the hard clam has a high local value.

While the hard clam typically spawns in summer (temp. 22-30°C) through out its range, it spawns during fall in the Indian River Lagoon when temperatures drop below 23°C (Hill, 2001). Optimum growth is thought to occur around 20°C, with no growth occurring at temperatures below 9°C or above 31°C. At 4°C, *Mercenaria* can survive lower temperatures by entering into a hibernation phase where no growth occurs. Maximum larval growth occurs at temperatures between 22.5°C and 36.5°C, and a minimum temperature requirement of 12.5°C is needed for any growth.

Salinity of *Mercenaria* changes over the course of its life. *Mercenaria*'s tolerance to lower salinity increases as they age, but is also proportional to temperature (Hill, 2001). That is, development and survival decrease sharply when salinity is low and temperature is high. Normal egg development is restricted to salinities between 20-32.5 ppt. Percentage of eggs developing at salinities less than 17.5 ppt or over 35 ppt is 0-1%. Larval growth occurs at salinities between 21-30 ppt. Below 15 ppt, larval growth stops and mortality is high. Juvenile hard clams can tolerate low salinity better than larvae, but are still vulnerable if salinity drops below 15 ppt for an extended period of time. Older clams can withstand low salinities, but growth is impeded at salinities below 20 ppt. Adult clams can close their valves and this allows them to withstand long periods of low salinity (e.g. survive salinity at 10 ppt for 4-5 weeks). Long period of valve closure can lead to decreases in growth and reproduction (Hill, 2001). The oxygen requirement for normal embryo development is at least 0.5 mg/l. Larval growth is reported to be low at oxygen levels of 2.4 mg/l and is optimal at or above 4.2 mg/l (Hill, 2001).

Shrimp (*Penaeus* spp.)
Four species of shrimp are commercially important in the study area: brown shrimp (*Penaeus aztecus*), pink shrimp (*Penaeus duorarum*), white shrimp (*Penaeus setiferus*), and rock shrimp (*Sicyonia brevirostris*). Each of these species significantly contributes to the state and/or national commercial catch.

Juvenile brown shrimp have been captured at temperatures between 10-32°C, although physiological stress was reported (Larson et al. 1989). Past studies have shown salinity tolerances as low as 0.2 ppt and as high as 69 ppt (Williams 1960). In response to low temperatures, brown shrimp can burrow into sediments (Aldrich et al. 1968). At salinities outside of the 27 ppt-35 ppt range, hatching and larval survival rates were reduced (Cook and Murphy 1969). Other research has suggested that extreme salinities (5-40 ppt) alone were not a significant impact unless coupled by extreme temperatures (Zein-Eldin 1963).

The pink shrimp (*P. duorarum*) has the greatest tolerance to cold temperatures of the three commercially important peneaids, with the ability to withstand temperatures as low as 3°C. (Hill, 2001). Nocturnal activity is greatest when temperatures are between 26 – 27°C. (Fuss and Ogren 1966). Below temperatures of 14°C activity is significantly reduced and ceases completely at temperatures below 10°C. *Penaeus duorarum* can be found in areas of higher salinity than the P. aztecus and P. setiferus. P. duorarum is reported to possess better osmoregulatory capabilities than either *P. aztecus* or *P. setiferus*; however, its regulatory ability is diminished at temperatures below 8°C (Hill, 2001).

Penaeus setiferus, the white shrimp, displays the best growth at temperatures of greater than 20°C (Etzold and Christmas 1977), with growth stopping at temperatures lower than 16°C. Inadequate temperature and food supply has been reported as more limiting to growth rates in *P. setiferus* than salinity differences in the range between 2 – 35 ppt (Perez-Farfante 1969). Burrowing has been studied as a behavioral response to low temperatures (Aldrich et al. 1968). Juvenile white shrimp tend to move into the upper reaches of estuaries to the low salinity areas more so than pink or brown shrimp (Williams 1958). The lowest recorded salinity from which white shrimp have been reported was in the northern Gulf of Mexico, where salinity measures 0.42 ppt.

Horseshoe Crab (*Limulus polyphemus*)

The American Horseshoe crab is an extremely hardy species that occupies estuaries, lagoons and coastal embayments, where environmental conditions fluctuate widely (Ehlinger, 2004). Both salinity and temperature affect the rate of crab development, but studies have shown that only extreme conditions impact survival (Ehlinger, 2004). High temperatures (i.e. greater than or equal to 35°C) have been shown to have the most negative impact, more so than high salinity (Ehlinger, 2004). The adult horseshoe crab occupies subtidal areas where salinity typically ranges between 5 to 34 ppt (Ehlinger, 2004). The highest densities of horseshoe crabs tend to occur in the areas with the highest salinity, although use of lower salinity habitat does occur. Adult horseshoe crabs also occur in lagoons where shallow conditions and high rates of evaporation cause salinity to display an even greater range (5-55 ppt) than typically seen in an estuary (Ehlinger et al. 2003; Ehlinger 2004). The greatest larval survival occurred at salinities between 10-70 ppt and showed marked decline at salinities outside this range (Ehlinger, 2004). Horseshoe crab eggs are reported to be more sensitive to high temperatures than high salinity. In the Indian River Lagoon, optimal temperatures are reported at 30-33°C, with temperatures of 35°C or greater are lethal to eggs and adversely affect larval development (Ehlinger, 2004). Other studies have reported slightly lower optimal temperatures between 25-30°C (Laughlin, 1983). Overall, temperature and salinity ranges tolerated by the horseshoe crab are higher in the Indian River Lagoon than in the northern extent of their range; their ability to tolerate higher temperatures and salinities may be a result of acclimatization (Ehlinger, 2004).

In the Indian River Lagoon, adult horseshoe crabs are present but numbers of larvae are low compared to other areas. This is attributed to relatively little tidal exchange in the IRL, with the exception of the areas in the immediate vicinity of the inlets (Ehlinger et al 2003, Ehlinger 2004). Additionally, during the spawning season (i.e. late spring/early summer) conditions can be as extreme as 45°C and 55 ppt. While spawning adults can tolerate these conditions, and are frequently present in the lagoon, the low numbers of larvae may indicate the conditions at spawning are too extreme (Ehlinger, 2004).

Horseshoe crabs are an important food source for sea turtles, wading and shore birds, and fish. They also help to aerate the bottom sediments through their feeding activities. The decline in horseshoe crabs over the past 20 years has caused concern and may be linked to the decreased presences of juvenile loggerhead sea turtles.

4.3.3 Fish

Many species of fish are important as prey for other fish or water birds. Additionally, many fish taxa are also important in terms of recreational or commercial fishing. While adult fish can often move out of areas of local hypoxia or contamination, assuming there are nearby suitable habitats to move into, larval and juvenile fish are much more restricted in this aspect as they are closely tied to specific nursery habitats that offer food and protective cover.

Baitfish

In general, estuarine fish communities are quite variable and large amounts of variation in species composition and abundance are observed (Tremain and Adams, 1995; Livingston, 1987). This is also true of baitfish populations, which include *Anchoa* spp. and *Menidia* spp. as well as other species.

The bay anchovy, *Anchoa mitchilli*, is an important foraging species for recreationally and commercially important species and piscivorous birds. *Anchoa mitchilli* is a eurythermal species that has been reported to withstand temperatures exceeding 32°C near the thermal discharge point for a power plant in Galveston, Texas (Gallaway and Strawn, 1974). Spawning occurs between temperatures of 9-31°C, with peak spawning at 20°C (Dovel, 1971). Salinity places little restriction on bay anchovy distribution, as they have been captured in freshwater, as well as in hypersaline waters. In Chesapeake Bay, anchovies spawned at salinities greater than 9 ppt and peaked between 13-15 ppt (Dovel, 1971).

Another baitfish is the Atlantic silverside (*Menidia menidai*). Juveniles can tolerate temperatures ranging from 3-31°C, with preferred temperatures between 18-25°C. Avoidance behavior was seen when temperatures were between 11-14°C (Meldrim and Gift, 1971) while the upper lethal limit appears to be around 32°C (Pearce, 1969). Optimum salinity for hatching was reported at 30 ppt, with decreased and delayed hatching at lower salinities (Fay et al., 1983). Juvenile and adult silversides can tolerate a wide range in salinity, from freshwater to 37. 8 ppt (Tagatz, 1967).

Spotted Seatrout (*Cynoscion nebulosus*)

Spotted seatrout are an important recreational species in the Indian River Lagoon. This species is an estuarine resident, and the juveniles and adults are well adapted to a wide range of salinities. The reported optimal salinity for spotted seatrout ranges from 15 ppt. to 35 ppt., and the salinity tolerance range is from 0.2 ppt. to 77 ppt. (Woodward and Clyde, 1994). The salinity tolerance for juvenile spotted seatrout was recently reported from an intensive multi-year fisheries independent monitoring program (Florida Fish and Wildlife Research Institute Fisheries Independent Monitoring Program) in the form of a logistic regression model (Figure 23) and associated estuarine distribution map (Figure 24) from the Alafia River in Florida (Janicki Environmental, 2003).

Early life stages are most critical and likely to be impacted by changes. Spawning has been noted in deeper holes and scoured channels of seagrass flats, as well as in estuaries, outside of estuaries, in passes near barrier islands, bayous and tidal streams (Hill, 2001). Spawning sites may be more related to salinity and temperature than other physical parameters (Hill, 2001).

Red Drum (*Sciaenops ocellatus*)

Red drum is also an important recreational species in the Indian River Lagoon. This species typically spawns offshore, but has been documented as spawning inshore in the Indian River Lagoon (specifically Mosquito Lagoon) (Johnson and Funicelli, 1991). The juveniles and adults are well adapted to a wide range of salinities. Data from Tampa Bay suggest that the smaller juvenile red drum prefer salinities from 0.5 ppt to 18 ppt. (Woodward and Clyde, 1994). The salinity tolerance for juvenile red drum was recently reported from an intensive multi-year fisheries independent monitoring program (Florida Fish and Wildlife Research Institute Fisheries Independent Monitoring Program) in the form of a logistic regression model (Figure 25) and associated estuarine distribution map (Figure 26) from the Alafia River in on the west coast of Florida (Janicki Environmental, 2003).

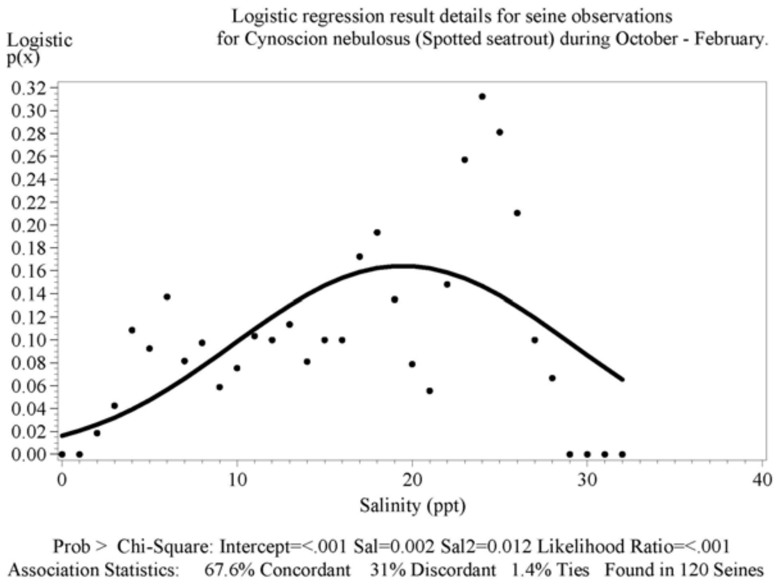

Figure 23 Salinity tolerance for spotted seatrout juveniles expressed as a logistic model. P(x) represents the probability of occurrence at a given salinity.

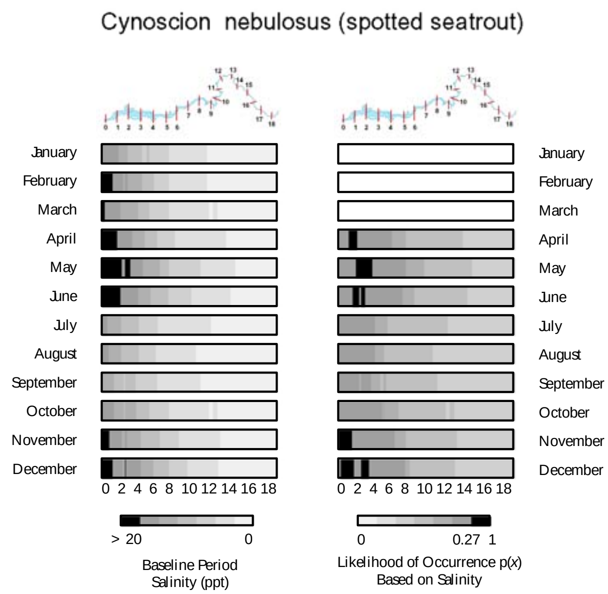

Figure 24 Salinity tolerance for spotted seatrout juveniles expressed as an expected distribution along a salinity gradient (Alafia River estuary) based on a logistic model. P(x) represents the probability of occurrence at a given salinity.

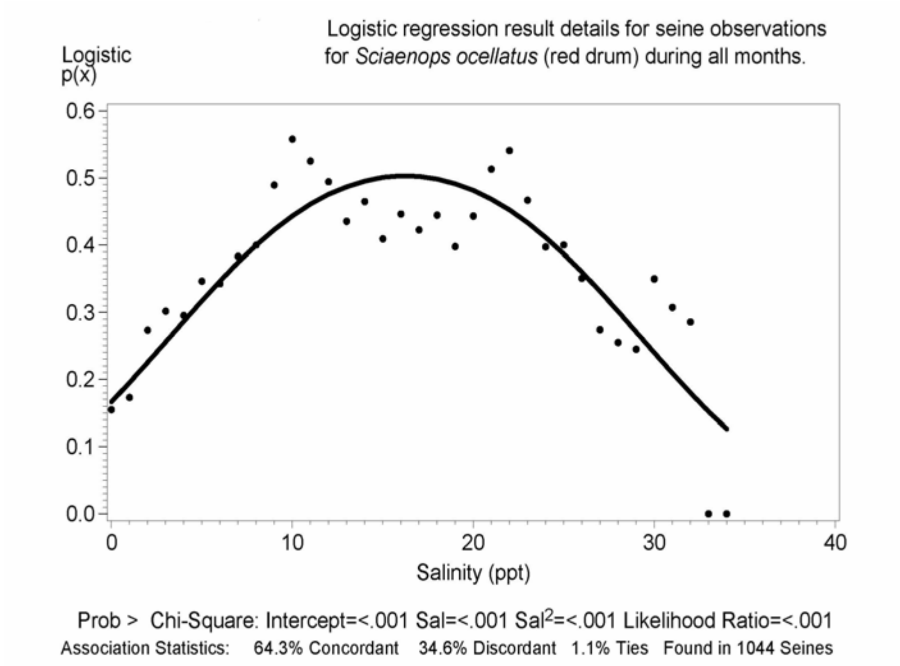

Figure 25 Salinity tolerance for red drum juveniles expressed as a logistic model. P(x) represents the probability of occurrence at a given salinity.

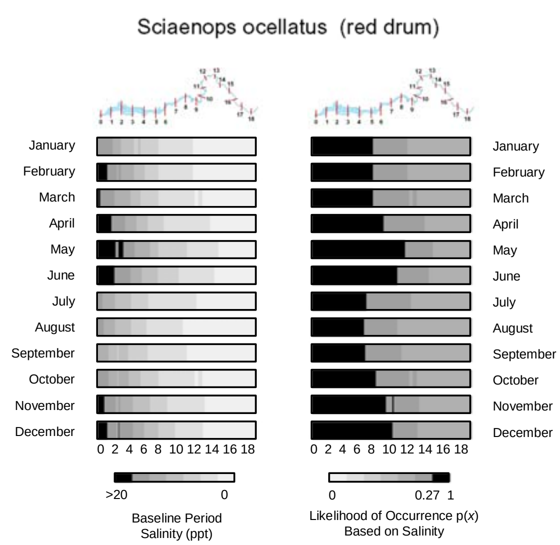

Figure 26 Salinity tolerance for red drum juveniles expressed as an expected distribution along a salinity gradient (Alafia River estuary) based on a logistic model.

4.3.4 Reptiles

Several species of sea turtles utilize the Indian River Lagoon: the Loggerhead (*Caretta caretta*), Leatherback (*Dermochelys coriacea*), Kemps-Ridley (*Lepidochelys kempii*), and Hawksbill (*Eretmochelys imbricate*). The Loggerhead sea turtle is listed as threatened and the remaining species are listed as endangered under the U.S. Federal Endangered Species Act. Because many factors affect the presence or absence of sea turtles in the IRL, it is not likely they will be used in the future analysis, although they remain a consideration.

4.3.5 Birds

While the expected range of environmental change will not directly affect the Merritt Island bird/waterfowl populations, their food sources (e.g., aquatic vegetation, benthic macroinvertebrates, small fishes) may be susceptible to environmental changes. Therefore, at this stage of the project, birds associated with the study area are under consideration for potential adverse effects, although it is likely more sensitive, directly impacted taxa will be selected.

4.3.6 Mammals

Florida Manatee (*Trichechus manatus latirostris*)
Manatees are large, herbivorous mammals that inhabit shallow coastal waters, rivers and springs. The Florida manatee (*Trichechus manatus latirostris*), is a sub-species of the West Indian manatee (*Trichechus manatus*) and is listed as an endangered species at both the federal and state level. The Florida manatee inhabits both coasts of Florida and other southeastern states.

Manatees are biologically adapted to a wide range of salinity conditions (Van Meter, 1989; Ortiz et al., 1998). Studies have shown that they possess highly evolved systems of osmoregulation, as evidenced by constant plasma electrolytes and osmolalities over a broad range of salinities (Ortiz et al, 1988). Additionally, manatees are found in both clear and turbid waters, with preferred depths of at least 3-7 feet (Van Meter, 1989), Manatee travel along the coast generally occurs in waters 10-16 feet deep, with manatees rarely being seen in waters greater than 20 feet deep (Reynolds and Odell, 1991 cited in Van Meter, 1989).

The Florida manatee is a sub-tropical species that occupies the northern limit of its range and is dependent on seeking warm water refuge during the winter (Reynolds and Odell 1991, in Van Meter, 1989). In the winter, manatee populations are concentrated in peninsular Florida and rely on warm water sources, which include natural springs and industrial sources of thermal discharge (USFWS, 2001). During the summer, manatees have an expanded range out into marine waters off the coast.

Aside from boating injury or death, the next most significant mortality factor for manatees is related to the long-term availability of warm water refuges (USFWS, 2001). Cold associated deaths may occur due to hypothermia, or other cold related illness, or as a result of manatees not eating properly during long-term exposure to the cold (Worthy, 2000; Van Meter, 1989). Feeding habits become irregular at temperatures of 64-66°F and feeding may stop completely at 50°F (Van Meter, 1989). Figure 27 presents the manatee protection zones currently designated for boaters in the vicinity of the potential demineralization facility collocation sites.

In the Indian River Lagoon, manatees are known to utilize and congregate around the warm effluents from power plants (Reynolds, 2004). Two such power plants are located within our study area: the Reliant Indian River Power Plant and the FPL Cape Canaveral Power Plant. Annual aerial surveys of manatees conducted by FPL reported a mean count of 469, and a high count of 588 manatees, at the Canaveral and Reliant Plants during 2003-2004 (Reynolds, 2004). The mean count of manatees sighted in this area represents approximately 44% of the manatees sighted for the five east coast power plants included in the FPL aerial surveys (Reynolds, 2004).

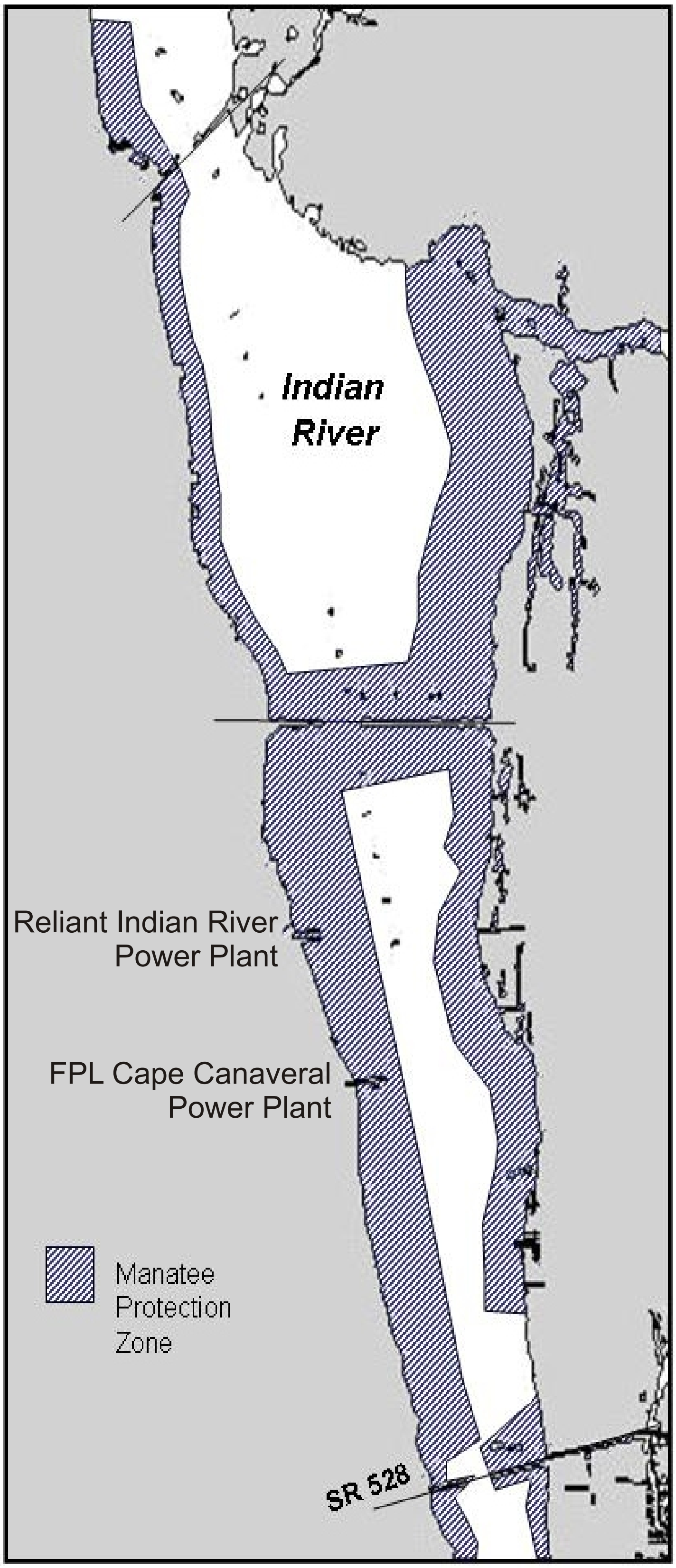

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Figure 27
Manatee protection zones near the potential demineralization facilities (Source: Fish and Wildlife Conservation Commission).
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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5.0 ASSESSMENT METHODOLOGY

The following presents the methodologies used in the development of the impacts associated with the operation of the collocated demineralization facilities. These methods are utilized and presented in the impacts analyses in Section 7.0. Additionally, the relationship of this project to the Regional Restoration Goals, including the SWIM and CCMP Plans is discussed.

5.1 Relationship of Demineralization Project with Regional Restoration Goals

5.1.1 Demineralization Study Goals

The goals of this study (i.e., the Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon Study) are part of the planning phase in support of the demineralization project. The goals of this study are to:

- Identify the environmental and operational issues of concern associated with the collocation of a desalinization plant at two locations along the Indian River Lagoon (FPL Cape Canaveral Power Plant and the Reliant Indian River Power Plant).
- Utilize the results of the hydrodynamic model runs and other analyses to quantify the potential environmental impacts of demineralization concentrate discharge to the IRL.
- Determine the feasibility of collocating a demineralization plant at one or both of the proposed locations.

5.1.2 Demineralization Project Goals

The demineralization project, defined as a proposed desalination plant at one or both of the power plant sites in Brevard County, includes goals that will need continual refinement as feasibility investigations move incrementally forward. These goals must be coordinated with the goals of regional environmental programs. The demineralization project goals are as follows.

- Develop an alternative, economical, potable water supply source that complies with all local, state, and federal rules and regulations.
- Maintain coordination and consistency with ongoing IRL environmental restoration programs.
- Implement the demineralization project at the Brevard County power plant site(s) in a manner that monitors and controls concentrate discharge and

associated salinity changes to the IRL, to avoid or minimize potentially adverse impacts.

In meeting the primary goal of the demineralization project related to developing a new water supply source, implementers of the project will need to incorporate an environmental stewardship approach to the lagoon, consistent with regional environmental programs.

5.1.3 Regional Environmental Programs

The goals of regional environmental programs seek to restore, maintain, and enhance habitat and suitable environmental conditions for avian, aquatic, and terrestrial biological resources. The biological resources of concern for the demineralization project and study are representative of the biological resources of concern for the estuarine portions of the Indian River Lagoon as a region, resources that are also the focus of regional environmental programs. Three major regional environmental programs for the IRL that the demineralization project must coordinate with are the SWIM and CCMP plans, the NEP, and the IRLNFS.

5.1.4 SWIM Plan

The 1987 Surface Water Improvement (SWIM) Act designated the Indian River Lagoon (IRL) as a priority water body in need of restoration and special protection. The three main goals of the IRL SWIM Plan are:

- Goal I: To attain and maintain water and sediment of sufficient quality in order to support a healthy, macrophyte-based, estuarine lagoon ecosystem.

- Goal II: To attain and maintain a functioning macrophyte-based ecosystem which supports endangered and threatened species, fisheries and wildlife.

- Goal III: To achieve heightened public awareness and coordinated interagency management of the Indian River Lagoon ecosystem that result in the accomplishment of the two aforementioned goals.

The demineralization project must exhibit consistency with, and not be in major conflict with, water and sediment quality goals of the SWIM plan. The demineralization study will evaluate hydrodynamic model results regarding concentrate discharge and make recommendations on project feasibility with direct consideration of SWIM plan goals. An objective of the demineralization study is to identify potential adverse impacts, from the demineralization scenarios being evaluated, to environmental conditions and habitat availability for biological resources of concern.

There are several proposed projects in the SWIM plan and Comprehensive Conservation and Management Plan (CCMP), unrelated to the demineralization project, that focus on reducing adverse impacts caused by excessive storm water flows to the lagoon. These projects are part of the National Estuary Program.

5.1.5 Total Maximum Daily Loads (TMDLs) and the SJRWMD SWIM Plan

FDEP is the lead state agency working with the EPA to develop Total Maximum Daily Loads (TMDL) for the Indian River Lagoon. A TMDL is the maximum amount of a given pollutant that a water body can absorb and still maintain its designated uses. Based upon the federal Clean Water Act Section 303(d) and the Florida Watershed Restoration Act, TMDLs must be developed for all waters that are not meeting their designated uses and, consequently, are defined as "impaired waters."

SJRWMD, as part of the SWIM program, seeks to establish state-mandated Pollutant Load Reduction Goals (PLRG) for priority water bodies, which includes the IRL. PLRGs may then be used as a basis for helping to establish TMDLs for the estuary. There will be a PLRG established for fresh water, due to the adverse impacts that extreme storm events have caused in the IRL. The TMDL and PLRG are conceptually related and similar procedures are used to develop the programs.

5.1.6 National Estuary Program (NEP)

The SWIM plan goals are shared by the Indian River Lagoon National Estuary Program (NEP). In 1990 the IRL became part of the NEP. In 1996, the CCMP was adopted, and it is being implemented along with the IRL SWIM Plan. The CCMP adopted the same three goals as the SWIM program, along with a fourth goal "to identify and develop long-term funding sources for prioritized projects and programs to preserve, protect, restore and enhance the Indian River Lagoon System." To enhance efficiencies in implementation of the SWIM and CCMP plans, the SJRWMD established the IRL Project Office in 1996 to promote and manage projects identified within both plans.

As one key aspect of the restoration of the IRL is the increase in coverage for seagrasses, any potential impacts from the demineralization plant discharges must be weighed carefully against the overall goals of the CCMP. Appendix G provides excerpts from the CCMP document relative to the seagrass restoration goals.

With an emphasis on water quality considerations, but unrelated to the demineralization project, the following projects are being cooperatively implemented by the IRL Project Office to manage adverse impacts of stormwater runoff from extreme storm events in proximity to the FPL Cape Canaveral Power Plant and the Reliant Indian River Power Plant:

1. Chain of Lakes Regional Stormwater Park in North Titusville
2. Lake George Water Quality Retrofit on Merritt Island
3. Kennedy Point Marina Stormwater Weir (south Titusville)
4. Titusville Marine Basin Stormwater Retrofit 4.6-Acre Detention Pond
5. Titusville Garden Street Basin and Alum Pond

6. Pine Island marsh restoration and stormwater treatment area on Merritt Island

The demineralization project must incorporate an environmental stewardship approach to the IRL. While it does not have a goal to restore, improve, or enhance water quality, habitat availability, or fisheries, the project goals support the avoidance of potentially undesirable impacts to these resources.

5.1.7 North Feasibility Study

The Indian River Lagoon North Feasibility Study (IRLNFS) resulted from the Central and Southern Florida Project Comprehensive Review Study (also known as the "Restudy"). The objective of the IRLNFS is to evaluate the Indian River Lagoon North area and to assess what types of modifications would be necessary to restore habitat, ecological conditions, and water quality in the lagoon. The goals of the IRLNFS are to:

1. Improve Ecological Values:

- Reduce excessive freshwater inflows and pollutant loadings to the IRL,
- Improve water quality in the lagoon,
- Improve habitat for lagoon biota, with emphasis on seagrass
- Increase spatial extent and functional quality of submerged vegetation and watershed wetlands,
- Increase functional quality of native upland habitat, and
- Maintain or improve diversity and abundance of native plant and animal species, including federal, state, and local listed species.

2. Improve Economic Values and Social Well Being:

- Maintain or improve water supply,
- Maintain or improve flood protection,
- Improve opportunities for tourism, recreation, and environmental education, and
- Improve commercial and recreational fisheries and associated industries.

The demineralization project does not seek to improve ecological values but where benefit or support to these goals can be accomplished through implementation of the project, they will serve to maintain consistency with IRLNFS goals.

For improvement to economic values and social well-being, the demineralization project also seeks to improve regional water supplies, through development of desalination as an alternative water supply source, using surface water from the IRL. If the IRL were to be used as a source for public water supply, then subsequent watershed management efforts could serve to promote a higher level of protection for the lagoon.

5.1.8 IRLNFS Projects

For coordination purposes, and to stay aware of project activities within the vicinity of the potential demineralization plant locations, there are specific IRLNFS projects that should be noted. These projects, unrelated to the demineralization project, include those to improve ecological value in the lagoon by reducing excessive freshwater inflows and pollutant loadings, improve overall water quality conditions, improve habitat for biota, and to increase the spatial extent and functional abilities of submerged aquatic vegetation (SAV) and wetlands within the watershed. These projects include the following:

1. Rehabilitation or Restoration of Impounded Wetlands: reconnect remaining wetland impoundments identified in the IRL SWIM Plan, 2002 Update.
2. Shoreline and Dragline Ditch Restoration: restore dragline-impacted wetlands identified in the IRL SWIM Plan, 2002 Update.
3. Mosquito Lagoon Dredged Material Utilization: restore dragline impacted wetlands identified in the IRL SWIM Plan, 2002 Update
4. North Merritt Island/KSC Storm Water Treatment Plan

5.1.9 Program and Agency Coordination

If specific goals or consequences of the desalination project emerge that are in conflict with one or more goals of the IRLNFS, SWIM, or NEP, then these consequences will be documented or resolved as part of this study.

In support of the goals of the regional environmental programs referenced above, the study coordinated with the following agencies:

- St. Johns River Water Management District (SJRWMD) in relation to SWIM plan goals and PLRGs,
- Indian River Lagoon National Estuary Program (IRL NEP) and its partner agencies in relation to CCMP goals,
- U.S. Army Corp of Engineers, regarding the North Feasibility Study goals,
- Brevard County Water Supply Board for water supply development,
- Florida Department of Environmental Protection (FDEP) for Total Maximum Daily Loads (TMDLs) and regarding discharge to surface waters,
- Merritt Island National Wildlife Refuge (MINWR),
- U.S. Fish and Wildlife Service (USFWS),
- U.S. Geological Survey (USGS),
- Fish and Wildlife Conservation Commission (FFWCC),
- National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NOAA Fisheries Service),
- South Atlantic Fisheries Management Council, and
- Brevard County Office of Natural Resources Management.

If based upon the results of this study, further project implementation is considered, it will require a utility provider or water supply developer to participate in the next phase of investigation. That entity, in partnership with SJRWMD, will also need to continue coordination with the programs and agencies described in this section.

5.2 Assessment Methodology

5.2.1 Operational Impacts

In Section 4.0 various operational issues were raised and discussed. Under the direct impacts assessment, where impacts are quantified, the evaluation of the operational impacts will focus on two components:

- Potential increases in impingement and entrainment associated with the increased flow to cool the demineralization plant inflow and provide the needed dilution to meet the FDEP requirements for the maximum-allowed 10 percent increase in chlorides.
- Recirculation impacts, i.e., the degree that recirculation creates conditions where intake salinities are significantly above the typical ambient conditions.

For the impingement and entrainment evaluations, the operational data from the power plants were analyzed to determine the degree to which the need for increased cooling water flow and makeup water flow increase the flow into the power plants. This analysis was based upon percent increases in flow and, therefore, velocity. This analysis was performed for the 30, 20, 10, and 5 MGD scenarios for each of the plants.

For the recirculation impacts, the model simulations were analyzed against the baseline condition to determine the increase in local ambient salinity and, therefore, the associated impacts to the RO facility in processing the higher saline water.

5.2.2 Physical Impacts

The physical impacts assessment will focus on the changes to salinity and circulation conditions within the North IRL as these are the key physical aspects that the collocated facilities could change.

The maximum and average salinity changes over the baseline condition for each of the demineralization plant water production capacities will be presented as spatial contour plots showing both the far field (North IRL area) and near field (between the causeways and near the plants) differences in salinity versus the baseline conditions. While the contour plots of the maximum salinity differences will be the maximums over the full 12-year simulation period, the averages will focus solely on the final 4-year period of the simulations based upon the model reaching dynamic equilibrium conditions as discussed in Section 6.

Circulation impacts will be based upon the evaluation of changes in the net flow through various cross-sections above and below the discharge area. These changes represent alterations in the overall exchange in the system and may have impacts on how the system behaves. In general the withdrawals are not sufficient to create significant localized changes in water level or currents. The changes created will be more long-term and based upon exchange rates.

While temperature has been identified as a physical issue of concern, the expected changes in temperature created by the intake of additional cooling water will not be significant and will only serve to cool the existing discharge which would provide an ecologic benefit given the super heated nature of the present discharge.

5.2.3 Water Quality Impacts

5.2.3.1 Concentration of Pollutants

The concentration of pollutants has been identified as a potential area of concern with the operation of the demineralization plant(s). In order to evaluate the potential impacts, baseline water quality conditions for key parameters of concern for concentration (primarily metals) were defined. These baseline conditions establish the starting point upon which concentration impacts are assessed. Using salinity as the conservative tracer, concentration factors were determined in the immediate vicinity of the plant discharges. These concentration factors were then applied to the baseline water quality conditions to define potential post-project concentration levels. The concentration factors defined for the plant operations are based upon the end of the 12-year simulation period, i.e. full build up conditions.

It should be noted that this is a conservative evaluation of the potential concentration impacts. Pre-treatment processes that will occur at the demineralization plants could remove portions of these pollutants, but the degree of that removal would need to be defined under pilot testing which is not part of this preliminary feasibility study. Recommendations made by experts in the operation of the demineralization plants are to use this conservative estimate at this stage.

5.2.3.2 Stratification

The potential effects of stratification changes estimated for each of the demineralization scenarios were evaluated with respect to baseline conditions.

Thermal stratification occurs when a layer of warmer water overlies a layer of cooler, denser water. The potential for thermal stratification exists if mixing is not adequate. Additionally, warm water discharge to surface waters could increase the potential for thermal stratification. One consideration of the demineralization facilities is that the demineralization process could potentially affect salinity and temperature jointly in a manner that could alter local stratification.

The amount of dissolved oxygen in water is a function of both temperature and salinity. Solubility decreases as both temperature and salinity increase. Where density stratification exists (due to temperature and/or salinity differences within the water column), deeper waters may not exchange oxygen with surface waters. As a consequence, respiration by animals and bacteria may cause the dissolved oxygen concentration to decline, often to the point at which it is detrimental to the survival and well-being of aquatic life.

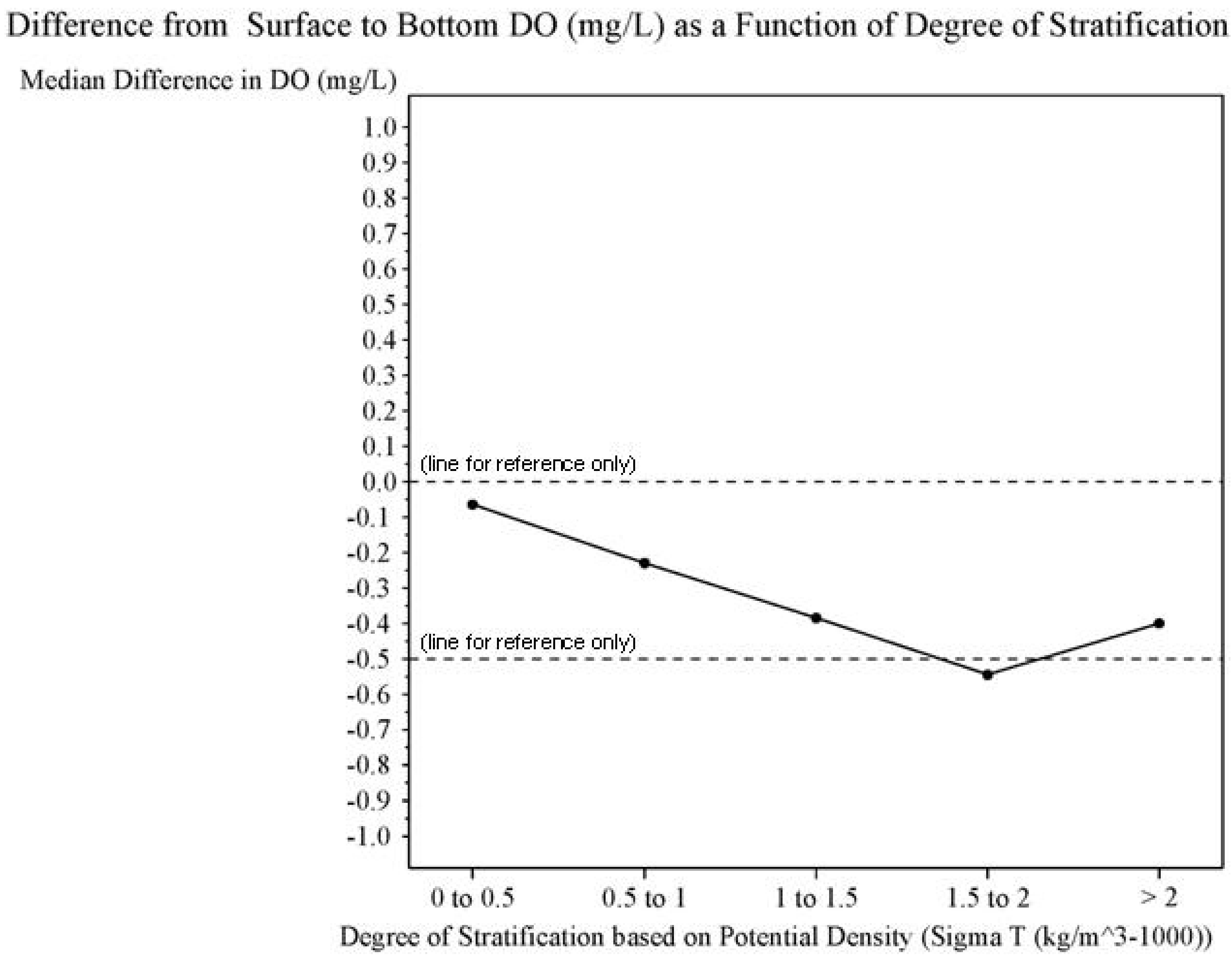
To define the degree of stratification, density was first calculated from salinity and temperature using the International Equation of State of Sea Water (Pond and Pickard 1983). The densities of the water at the surface and at the bottom were expressed as sigma-t values in the units of Kg/m^3.

Difference (delta) values were calculated for dissolved oxygen and sigma-t (i.e., bottom value-surface value) for the SJRWMD IRL ambient water quality data. Delta sigma-t values were grouped in 0.5 increments and the differences in dissolved oxygen values, based on these groups, were described using the 50th percentile (i.e., median) value. Figure 28 presents the minimal stratification observed in the data. Almost all median differences between top and bottom dissolved oxygen were within 0.5 mg/L, with the slightly higher deviation in the 1 to 1.5 sigma-t group. Overall, the data show minimal stratification. This plot corresponds with expectations established by the EPA recognizing stratification as low if sigma-t was less than 1 and high if sigma-t was greater than 2 (Hyland et al. 1996). Following the EPA guidance, stratification was defined for this project as a sigma-t difference of 1 or greater between surface and bottom water at any given location.

5.2.4 Biological/Ecological Impacts

The hydrodynamic model outputs from the baseline scenario and from each demineralization scenario will be quantitatively evaluated with respect to the potential effects of the demineralization operations on the environmental conditions and biological resources in the lagoon.

Indicator-stressor paradigms were identified so that they could be developed for quantitative application to the overall evaluation approach. The indicators were defined as the living resources that could be potentially affected by the environmental issues previously identified. In particular, benthic macroinvertebrate species and early life stages of fish species were identified as sentinel indicators, which could respond in relatively short time scales to potential changes in salinity and temperature regimes. These organisms have relatively limited mobility and possess a degree of dependence on habitats available in the project area. A particular focus was given to dominant fish and invertebrate species and the project biological resources of concern for which sufficient data were available to quantify indicator-stressor paradigms. The stressors in the indicator-stressor paradigms were defined as the project environmental issues (previously listed). Particular focus was given to the magnitude and duration of exposure to salinity and temperature values.



04948 TechMemo 2G Fig 28 6/30/06

Figure 28
Median difference from surface to bottom dissolved oxygen as a function of degree of stratification using historical Indian River Lagoon ambient water quality data
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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The overall approach to the evaluation is presented in Figure 29. This approach is particularly relevant to the evaluation of potential salinity and temperature effects.

The first step of the overall approach was to link the mapped distributions (e.g., seagrass areas, fish abundance areas, manatee thermal refuge areas) or critical locations (e.g., shellfish lease locations) for each calendar month and biological resource of concern to the hydrodynamic model geographic grid. This information was also specific to surface and bottom levels depending on the biological resources of concern.

The second step of the overall approach was to link the temperature and salinity requirements to the biological resources of concern. Seasonally specific requirements will be applied where data are available (e.g., fish requirements). Temperature and salinity requirement information was compiled where available for the key species listed previously. Data Attachment N provides plots showing the compiled distribution plots for the salinity and temperature.

Fish salinity and temperature tolerances were statistically quantified as observed and modeled probabilities of occurrence for the species of concern and biologically dominant species in the project area. These tolerances were compiled using the large amount of primary data reported for the project area by the Florida Wildlife Research Institute.

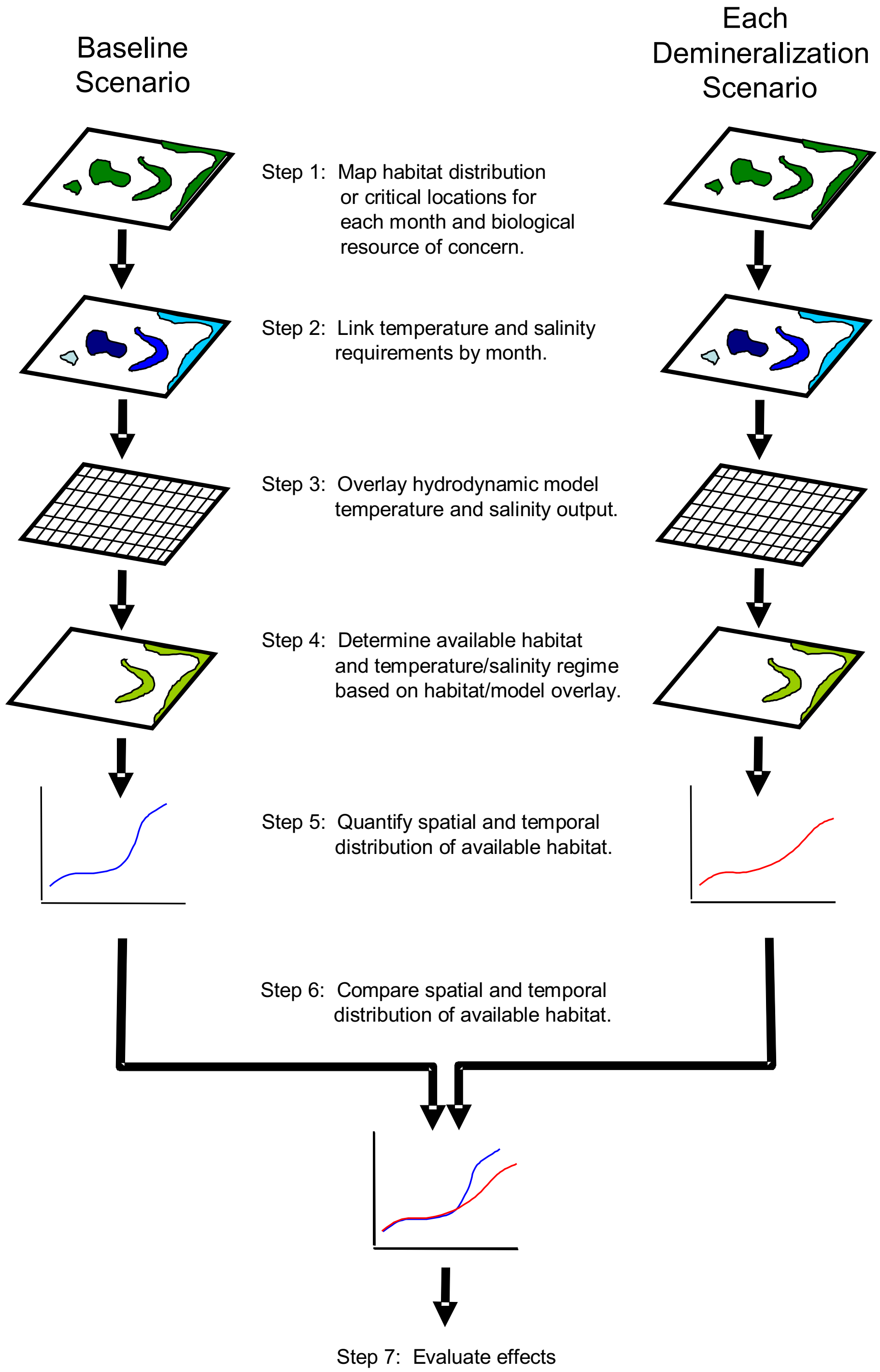
The third step of the overall approach was to overlay the hydrodynamic model output for the baseline scenario and each demineralization scenario on the habitat distributions and environmental requirements data. This provided a spatial (hydrodynamic model grid cell and surface/bottom layer) and temporal (daily) compilation of the resource and requirements data.

The fourth step of the overall approach was to quantify the available habitat and temperature/salinity regimes of the available habitat for each biological resource and day of the time series based on the results of the third step.

The fifth step of the overall approach was to quantify the spatial and temporal distributions of the available habitats and the temperature/salinity regimes of the available habitat for each biological resource and month.

The sixth step of the overall approach was to compare the spatial and temporal distributions of the available habitats and the temperature/salinity regimes of the available habitat between the baseline scenario and each demineralization scenario.

The seventh step was to work with SJRWMD and stakeholders to evaluate the comparisons of the spatial and temporal distributions of the available habitats.



04948 TechMemo 2G Fig 29 6/30/06

Figure 29
Overall evaluation methodology approach
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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5.2.4.1 Salinity Impact Evaluation

The salinity regimes for each of the demineralization scenarios will be evaluated with respect to baseline conditions, biologically important salinity regimes, and salinity tolerances of the biological resource of concern (e.g., early life stages of fish, invertebrates, seagrass) and other dominant biological resources in the study area.

Salinity has traditionally been regarded as a central parameter for estuarine analysis, especially as an indicator of hydrography and habitat potential. Salinity is defined as the total amount of dissolved minerals in seawater. The major constituents of seawater that comprise more than 99% of the dissolved salts (Thurman, 1993) include:

- Chloride – 55.04%
- Sodium – 30.61%,
- Sulfate – 7.68%,
- Magnesium – 3.59%,
- Calcium – 1.16%, and
- Potassium – 1.10%.

With respect to potential salinity effects, it is important to note that the living resources of the study area are biologically adapted to the dynamic estuarine conditions which result in relatively wide changes in salinity over time and space due to tidal cycles, wind driven circulation, the balance between freshwater inflow and evaporation, and stratification of the water column. Thus, the salinity tolerances of these organisms are relatively broad, and the level of resolution needed to identify the tolerance ranges is also reported in the literature to be broad. Because the organisms are adapted to a range of salinities, any potential impacts of the demineralization facility will be evaluated with respect to shifts in the distribution of salinity in the study area, or possibly a truncation of the distribution of salinity in the study area (e.g., an increase in the periodically occurring lowest salinity values).

Salinity in the north Indian River Lagoon is dynamic, and it typically ranges between 10 ppt and 35 ppt (St. Johns River Water Management District, 2002). Salinity is affected by tidal cycles, wind driven circulation, the balance between freshwater inflow and evaporation and stratification in the water column. It is likely that rainfall is the primary hydrodynamic forcing function of the inter-annual variability in salinity in this study area.

Fish Salinity Tolerance Evaluation Tool

In addition to the fish distribution information provided in Section 2.0, a fish salinity tolerance evaluation tool was developed for this project to statistically quantify probabilities of occurrence for the species of concern and also for the biologically dominant species in the project area. A similar tool was also developed for fish temperature tolerances.

An extensive database of primary fish data was acquired from the Florida Wildlife Research Institute for the 1990 to 2003 period of record, and these data allowed a specific analytical tool to be developed for the demineralization scenario evaluation methodology.

The dominant fish species in the project area were identified for each of three gear types (seines, trawls, and gillnets) and two geographic areas (the local hydrodynamic model inset grid in the vicinity of the two project power plants, and the regional Indian River Lagoon as a whole).

For each gear type, geographic area and species, species composition (C) was first calculated as:

$$C_{species} = \frac{\sum_{i=1}^{I} A_{species}}{\sum_{i=1}^{I}\sum_{j=1}^{J} A_{i,j}}$$

where

$A_{species,i}$ = the abundance of the species of interest in the ith sample,

$A_{I,J}$ = the abundance of the kth species in the ith sample,

I = the total number of biological samples collected, and

J = the total number of species observed.

Relative occurrence (O) was calculated as:

$$O_{species} = \frac{n_{species}}{I}$$

where $n_{species}$ = the number of samples in which the species was found, and

I = the total number of samples collected.

Finally, the dominance measure (D) was calculated as the product of the species composition (C) and relative occurrence (O) for each species:

$$D_{species} = C_{species} \times O_{species}$$

The species were then ranked by dominance. Tables of the detailed dominant species results were presented for each gear type, geographic area, and species and are presented in Data Attachment M.

Each of these species that had a minimum of sixty (60) occurrences from the 1990 to 2003 dataset was included as a biologically dominant species, and the dominant species were included with the previously identified fish species of concern in development of the salinity tolerance evaluation tool. The resulting dominant fish species for the study area are presented in Table 5.

Table 5. Dominant Fish and Invertebrate Species Reported from the Study Area from 1990-2003.

Species	Common Name	Study Area Gillnet Rank	Study Area Seine Rank	Study Area Trawl Rank	IRL Gillnet Rank	IRL Seine Rank	IRL Trawl Rank
Farfantepenaeus spp.	Commercial shrimp	*	*	11	*	44	13
Callinectes sapidus	Blue crab	*	*	9	14	34	7
Dasyatis sabina	Atlantic stingray	8	21	12	12	25	14
Elops saurus	Ladyfish	3	*	*	4	38	*
Brevoortia spp.		2	5	*	1	13	*
Anchoa mitchilli	Bay anchovy	*	3	5	*	1	2
Arius felis	Hardhead catfish	1	*	6	2	24	9
Strongylura notata	Redfin needlefish	*	10	*	*	19	*
Cyprinodon variegatus	Sheepshead minnow	*	9	*	*	10	*
Lucania parva	Rainwater killifish	*	1	*	*	2	4
Floridichthys carpio	Goldspotted killifish	*	4	*	*	4	30
Menidia spp.		*	2	*	*	3	*
Syngnathus scovelli	Gulf pipefish	*	11	4	*	18	6
Caranx hippos	Crevalle jack	5	*	*	8	46	*
Eucinostomus spp.		*	15	*	*	7	23
Eucinostomus harengulus	Tidewater mojarra	*	17	*	*	17	33
Cynoscion nebulosus	Spotted seatrout	7	18	*	6	21	20
Bairdiella chrysoura	Silver perch	*	13	2	13	14	8
Leiostomus xanthurus	Spot	6	8	*	3	12	11

The salinity tolerance relationships were quantified based on the observed relationships between salinity at capture and the seasonal location of particular fish species. The relationships were quantified using two methods, logistic regression and a moving salinity window compilation of the observed percent occurrence. The relationships were quantified by species and season. Bottom salinity data were related to trawl data, and vertically averaged salinity data were related to seine and gillnet data. The tool was developed to allow further sub-setting of the primary data by specific geographic location, gear type (e.g., net mesh size), and specific date range if needed. Any potential subsetting of the data will be applied based on the initial review of the results from each hydrodynamic model scenario.

A logistic approach was developed to quantify the relationships of fish salinity and temperature regimes in the project area for this project. This approach was based in part on previous work available from scientific literature. The logistic regression method of quantifying the relationship between salinity and probability of occurrence (Ysebaert et al. 2002) was applied to each species and season. Logistic regression analysis generates the probability of a species presence, p(y), as a function of an environmental variable, such as salinity. It reduces count data to a binary variable (presence/absence). For modeling with a linear regression, the form of the logistic equation is best expressed as:

$$g(y) = \log\left[\frac{p(y)}{1-p(y)}\right] = \beta_0 + \beta_1 x + \beta_2 x^2$$

where x = salinity,

$p(y)$ = probability of a species being present, as a function of x,

$g(y)$ = linear transformation of p(y), and

$\beta_0, \beta_1 and \beta_2 =$ regression coefficients.

A number of diagnostic statistics were generated for the results of the logistic regression analysis. Significance of each logistic regression model was assessed based on a likelihood ratio chi-square test, which compared the likelihood of each fitted logistic regression model with a logistic regression model without any explanatory variables (e.g. a logistic regression model without salinity or any other similar variable). Similarly, chi-square tests were used to select salinity and salinity^2 terms for the model, and to select either a one term or two term salinity model. Additionally, concordant pairs tabulation was used as an internal measure of classification success for the model. Every possible pair of seine samples for an observed presence and an observed absence of the species being considered was tabulated with respect to concordance. A pair of observations was defined as concordant if the observation of presence (1) was estimated to have a higher predicted value p(y) based on the model, than the observation of absence (0). If the reverse was found to be true, that the observation of absence (0) had a higher predicted value from the model than an observation of presence (1), then the pair was defined as discordant. If both observations had the same predicted value, it was defined as a tie.

The results of the logistic regression analysis and a moving salinity window compilation of the observed percent occurrence are presented in Data Attachment N for each species and season. Relationships which were not found to be statistically significant indicate one of several possibilities. First, the available data may not have a large enough sample size to elucidate the underlying relationship. Second, the organism may have a broad tolerance to the physical factor being modeled. Third, other factors such as seasonality, migration, predation, fishing mortality may influence the relationships expressed in the observed data. Where statistically significant relationships were not found, the available data will not be applicable to the assessment methodology.

Evaluation of Spatial and Temporal Distribution Effects

The salinity tolerances and the results of the salinity tolerance evaluation tool described above were evaluated quantitatively for each hydrodynamic model scenario using the approach previously discussed and presented in Figure 29. The data from these analyses were summarized for each comparison between baseline scenario and demineralization scenario in several ways:

- Overall descriptive statistics of the temporal and spatial distribution of salinity were compiled (e.g., median monthly salinity for each scenario, median monthly salinity plotted against distance from the demineralization facilities, the change from the baseline scenario for median monthly salinity for each demineralization scenario).

- Overall descriptive statistics of the spatial extent (e.g., surface area, volume) of changes in salinity expected for each scenario. For example, the total acres of habitat with salinity increases of 2 ppt from baseline to demineralization scenario were described.

- The statistical distributions (percentile plots) were compared for the duration (measured in days) of exceedances of important biologically based salinity thresholds for biological resources of concern at specific key locations (e.g., locations of seasonal high relative abundance for fishes, shellfish lease areas, seagrass beds). The spatial and temporal distribution of the biological resources of concern were presented in Section 2.0. The specific hydrodynamic model grid cells of these key locations were selected based on initial reviews of the zones of salinity effect (i.e. change from baseline conditions) from the model output for each scenario, and were located at appropriate distances from the demineralization facilities along a gradient of salinity change. The analysis was completed for each calendar month to characterize potential seasonal effects.

The consultants worked with the District to evaluate the comparisons of the spatial and temporal distributions of the exceedances. A lost habitat in this case is defined as a time duration and geographic area for which an important salinity value was exceeded.

Spatial Extent and Duration of Salinity Regimes

The spatial extent and duration of biologically important salinity regimes was evaluated between the baseline scenario and each demineralization scenario. Descriptive statistics of the spatial extent (e.g., surface area, volume) of changes in the habitat availability for these salinity regimes was evaluated for each scenario.

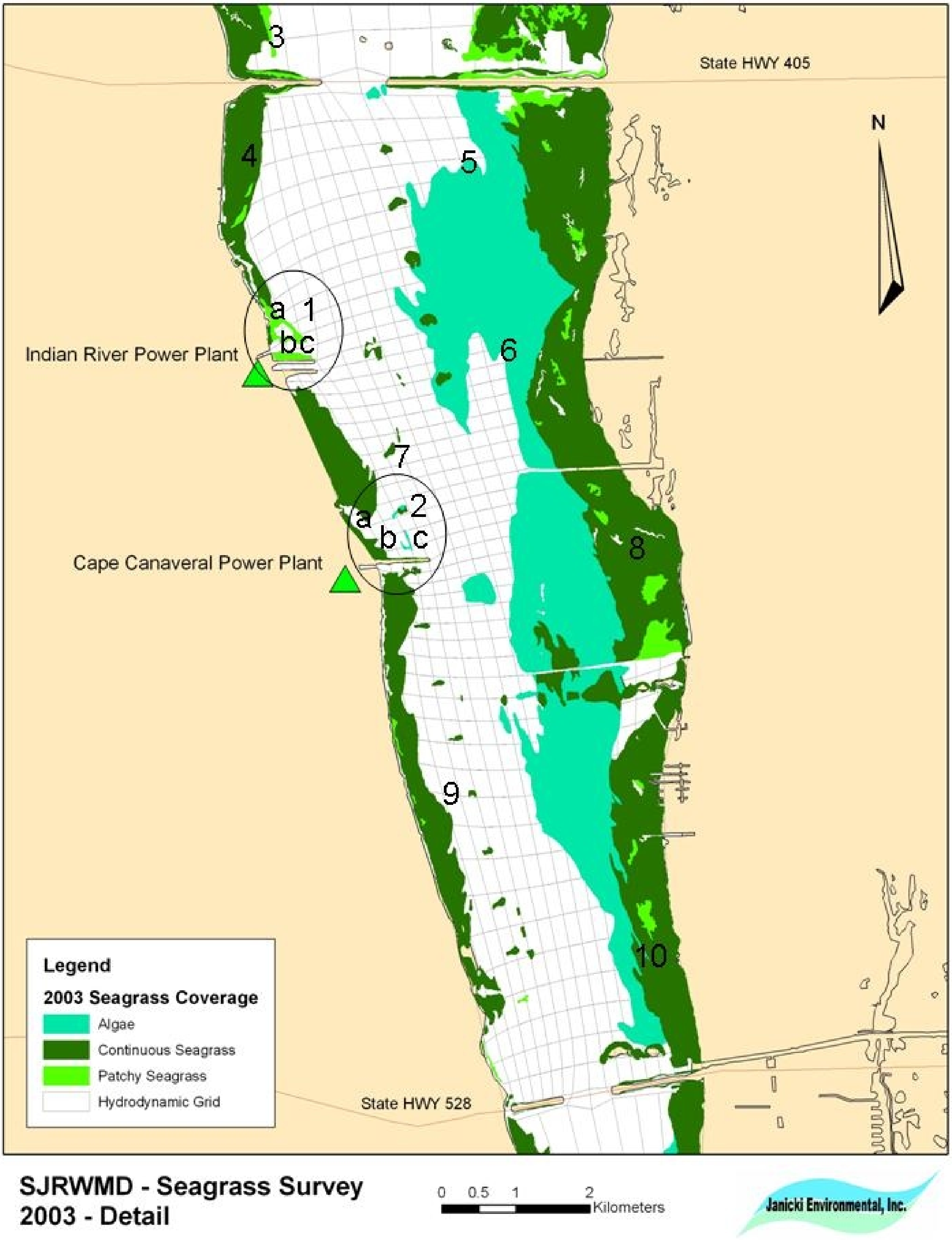
The analyses resulted in cumulative probability of occurrence curves that can be compared with and without the demineralization discharge to look at changes in preferred habitat extent as acres. Additionally, spatial maps showing the percent change in duration for each of the proposed species of concern were developed to allow visualization of the locations of greatest impact to the duration of time salinity resides within the preferred range.

Spatial and Temporal Variation at Reference Sites

The spatial and temporal variation at specific reference sites was quantified independently to provide more specific information regarding the potential for more localized impacts. The frequency distribution was constructed for salinity and temperature conditions for each reference site, surface versus bottom depth, and demineralization operation scenario.

Fourteen initial reference sites were selected based on one or more of the following: proximity to the demineralization discharge locations, presence of seagrass meadows, presence of shellfish harvesting areas, observed fish concentration areas, and shallow versus deep water locations (Figure 30). The near field reference sites are shown on Figure 30 as 1 a,b,c and 2 a,b,c.

Aquatic preserves and National Wildlife Refuges within the study area were also habitats of special concern (Figures 31 and 32). Eight reference sites were selected either within aquatic preserves/National Wildlife Refuges (Figure 33) or at connected inlets to aquatic preserves/National Wildlife Refuges. These are stations P1 to P8. It should be noted that the aquatic preserve areas also define those waters in the area classified as Outstanding Florida Waters. The aquatic preserve reference sites and inlet sites were chosen to be the closest hydrologically connected reference locations in or near the aquatic preserves that were also included in the hydrodynamic model domain.



04948 TechMemo 2G Fig 30 6/30/06

Figure 30
Locations of reference sites relative to shoreline and seagrass habitat
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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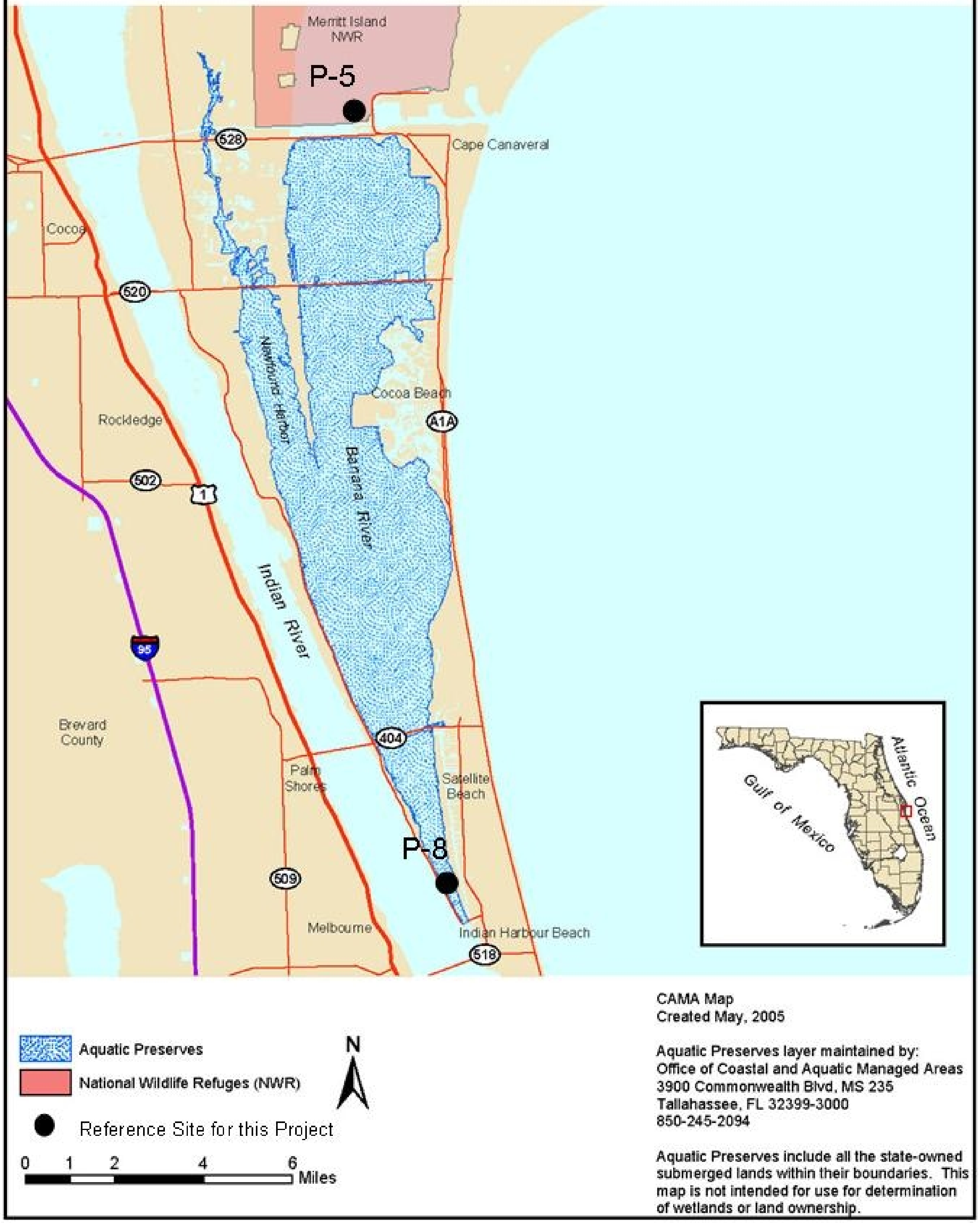
Banana River Aquatic Preserve



CAMA Map
Created May, 2005

Aquatic Preserves layer maintained by:
Office of Coastal and Aquatic Managed Areas
3900 Commonwealth Blvd, MS 235
Tallahassee, FL 32399-3000
850-245-2094

Aquatic Preserves include all the state-owned submerged lands within their boundaries. This map is not intended for use for determination of wetlands or land ownership.

Figure 31
Location of Banana River Aquatic Preserve and a subset of the relevant reference sites for this study
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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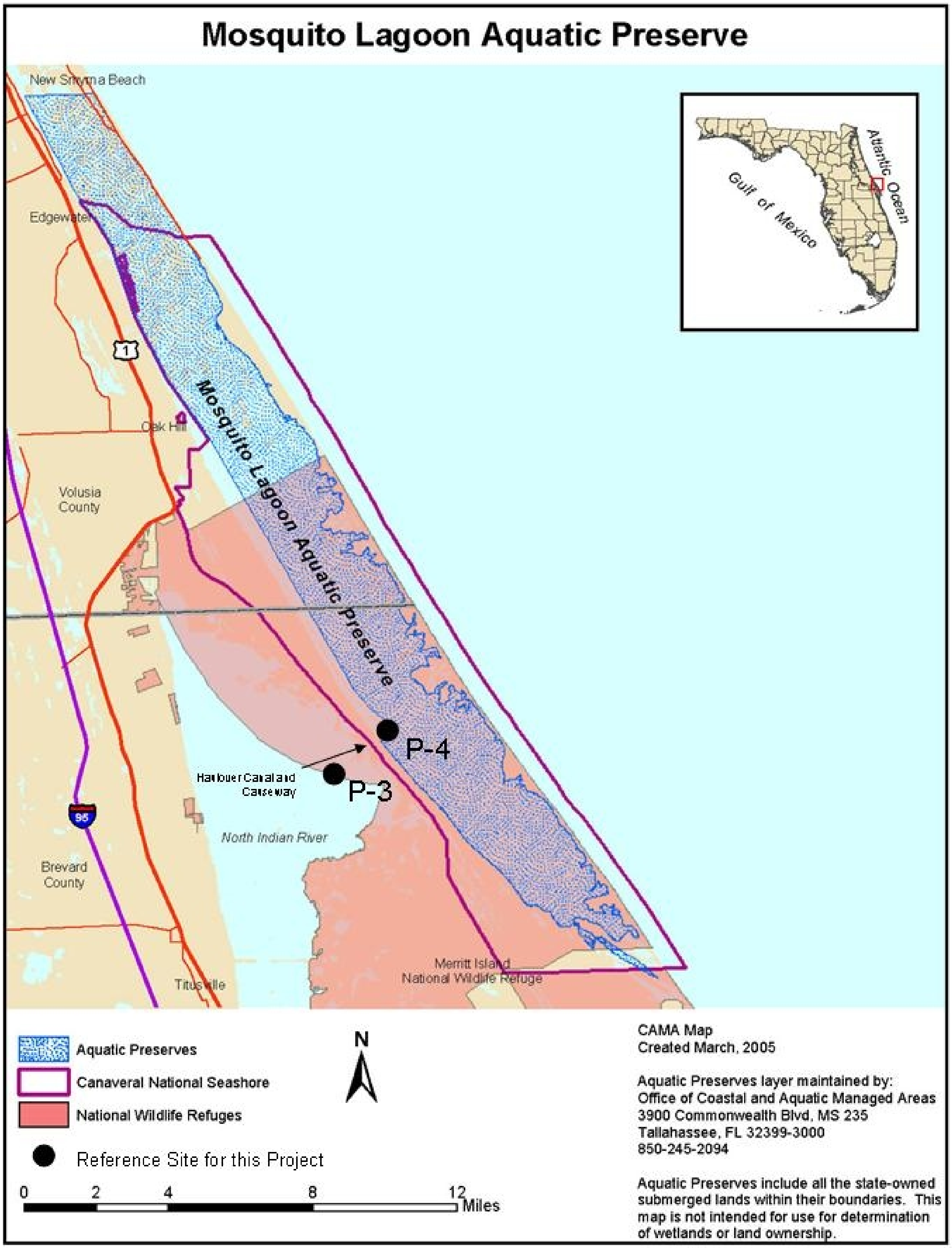

04948 TechMemo 2G Fig 32 6/30/06

Figure 32
Location of Mosquito Lagoon Aquatic Preserve and a subset of the relevant reference sites for this study
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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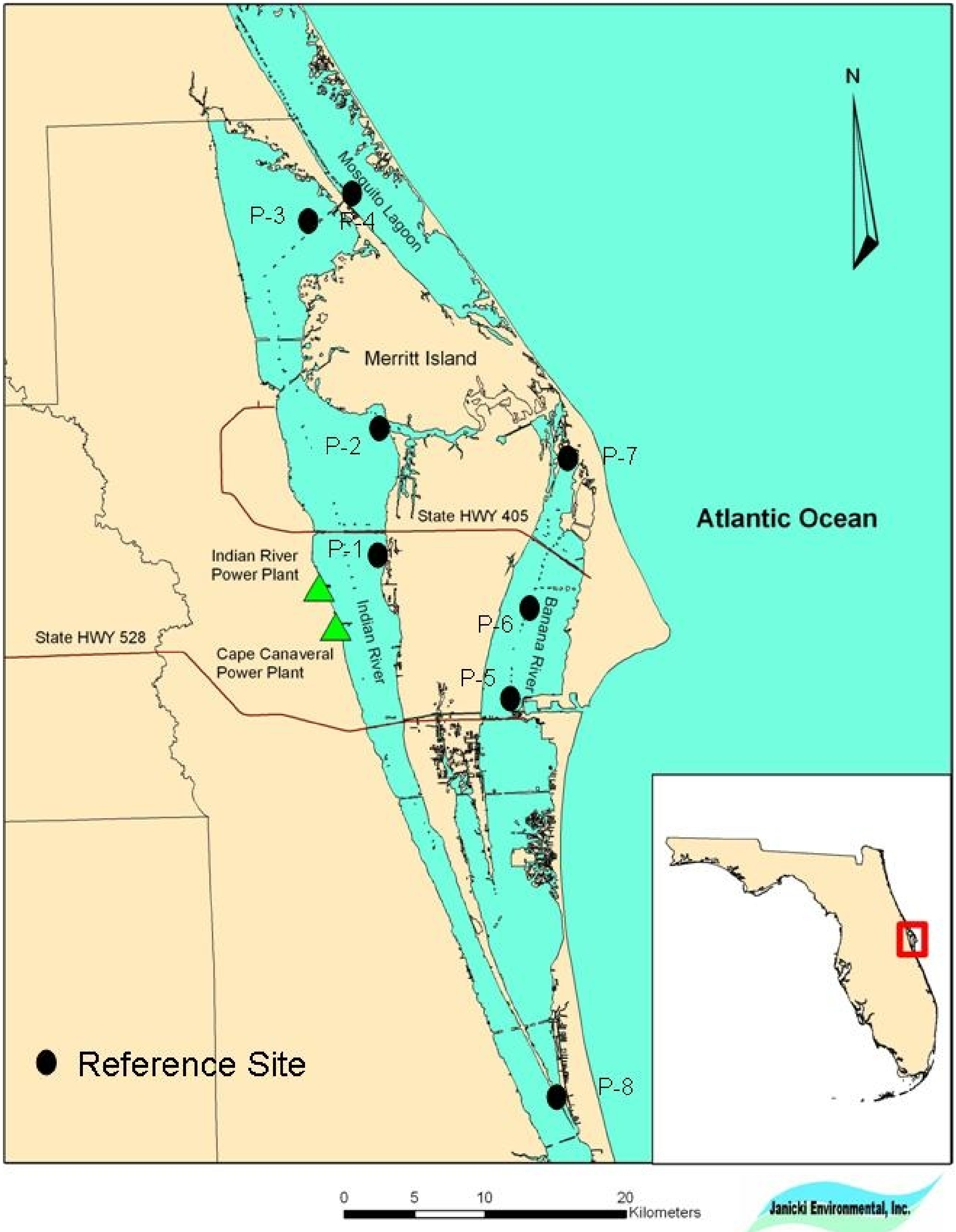

04948 TechMemo 2G Fig 33 6/30/06

Figure 33
Locations of reference sites located in Aquatic Preserves/National Wildlife Refuges or near connecting inlets to the Aquatic Preserves/ National Wildlife Refuges
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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6.0 HYDRODYNAMIC MODEL DEVELOPMENT

In Phase I of this project, it was determined that the IRLPLR hydrodynamic model would be utilized for the evaluation of the demineralization plant discharges with minor modifications. The following provides a brief description of the baseline IRLPLR hydrodynamic model, and the work that was done for its development and calibration. Detailed reports outlining the full model development and calibration for the IRLPLR model are provided in Data Attachment A. The refinements to the IRLPLR model that were done based upon the recommendations under Phase I are presented, including the grid refinement, the freshwater inflow refinements, the simulation of dynamic temperature, and dynamic simulation of the power plant operations. For the purposes of this study, the refined model will be termed the IRL Demineralization Study (IRLDS) hydrodynamic model. Comparative statistics between the IRLPLR hydrodynamic model and the IRLDS hydrodynamic model are presented to demonstrate that the accuracy of the simulations was not lost through the model refinement process. Finally, the model scenarios utilized in the impacts evaluation are presented and discussed.

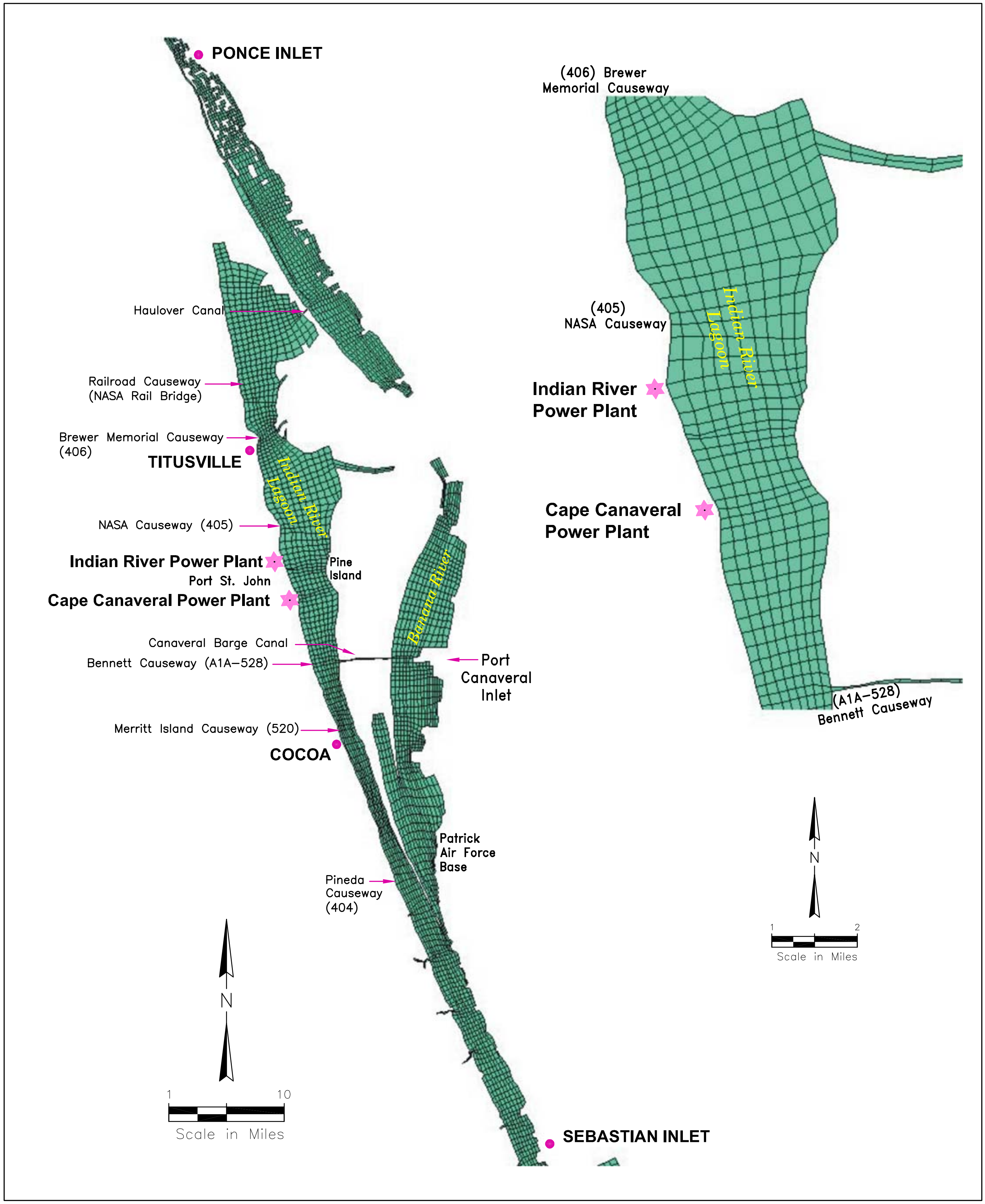
6.1 IRLPLR Baseline Model

The existing IRLPLR hydrodynamic model is a non-orthogonal, curvilinear grid, 3-dimensional, hydrodynamic model that is capable of dynamically simulating water levels, currents, and salinity. It is based upon the CH3D model code developed at the University of Florida. The CH3D model has undergone extensive peer review and testing since its development. It has been utilized on numerous studies of this nature throughout the United States. Appendix M presents an overview of the development history of CH3D.

The IRLPLR model application of CH3D to the Indian River Lagoon was originally developed by the University of Florida and delivered to the SJRWMD. The model uses a sigma-stretched grid to represent the vertical water column. For the IRLPLR hydrodynamic model, four layers are used to represent the vertical variations in the water column. The IRLPLR model grid has an average spacing of approximately 400 meters. Figure 34 presents the IRLPLR model grid within the North IRL.

The existing IRLPLR hydrodynamic model has a fully dynamic simulation of density and density-driven currents, with density a function of salinity. The IRLPLR hydrodynamic model has implemented a Z-grid correction that eliminates the historic sigma-grid problem of artificial horizontal transport between layers. This correction is necessary for proper simulation of stratification.

The IRLPLR hydrodynamic model prior to this study did not provide dynamic simulation of temperature; temperature was an input to the model. Under the Phase I recommendations, temperature was added and this modification is discussed below.



04948–TM2G–Fig 1.dwg Figure 34 6/6/06

Figure 34
IRLPLR model grid for the Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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The application of the IRLPLR hydrodynamic model has the following boundary forcing conditions:

- Measured water levels at Ponce de Leon, Sebastian, Fort Pierce and St. Lucie inlets (referenced to NAVD 88).
- Freshwater inflow at 60 locations. Approximately 10 of these freshwater inflows were measured. The others, and specifically, those in the area of the study, were derived from Hydrologic Simulation Program Fortran (HSPF) model simulations.
- Winds were derived from four gages distributed throughout the system, located at Ponce inlet, Titusville, Carters Cut, and Ft. Pierce inlet. One gage located at Haulover Canal was not utilized following review of the data and determination of problems with the gage.
- Daily evaporation was calculated for the model based on measurements of direct evaporation from the IRL using the Bowen ratio energy-budget method (Sumner and Belaineh 2004). This was a single station established over the water within the IRL.
- Bathymetry within the study area is based upon a detailed survey conducted by Coastal Planning and Engineering (CPE).

The model was initially calibrated to a comprehensive data set that extended from 1997 through 2000. This data set included long-term measurements of salinity, water levels, temperature and flows throughout the lagoon. The details of the model set-up and calibration are presented in the report *Evaluation of the Indian River Lagoon Pollution Load Reduction Hydrodynamic and Salinity Model for the Period 1997-2000*, prepared by SJRWMD in October of 2005. This report is included in Data Attachment A.

As part of the IRLPLR project, a Model Evaluation Group (MEG) was established. The MEG reviewed the IRLPLR model system and provided recommendations for improvements to the model. The review panel consisted of experts in hydrodynamics/salinity, water quality, light attenuation, and suspended sediment transport. After a thorough review of all of the model components, the experts were convened in Palatka, Florida on December 15, 2004 to present their opinions and suggestions to improve the model accuracy and provide recommendations. The following recommendations were made for improvements to the hydrodynamic model:

- Move the open water boundaries out onto the ocean shelf,
- Perform a grid convergence test to determine the appropriate level of grid refinement.
- Evaluate the impact of the ICW on the system.

The following modifications were made based on the recommendations:

- The model boundary was extended eastward about 5 km from the inlets out into the ocean
- In order to account for the tidal prism through Ponce inlet, the northern boundary was extended northward about 10 km from the inlet into Halifax River.
- The grid convergence test was completed, and the revised IRLPLR model reflects the grid spacing that optimizes the CPU usage with model accuracy.
- Results from tests representing the ICW showed that the inclusion of the ICW showed minor changes in transport and circulation patterns. To avoid adding unnecessary computational burden to the model, the ICW was excluded.
- The new model was recalibrated to the 1997 to 2000 dataset.

Data Attachment A presents a report detailing the model enhancement work done in relation to the MEG recommendations entitled *Indian River Lagoon Pollutant Load Reduction Model Enhancement, Part 1: Hydrodynamics/Salinity Model Enhancement*. Additionally this report provides the recommendations and comments made by the MEG reviewers. The final IRLPLR model utilized as the baseline model for this study represents a fully peer-reviewed, accepted hydrodynamic model.

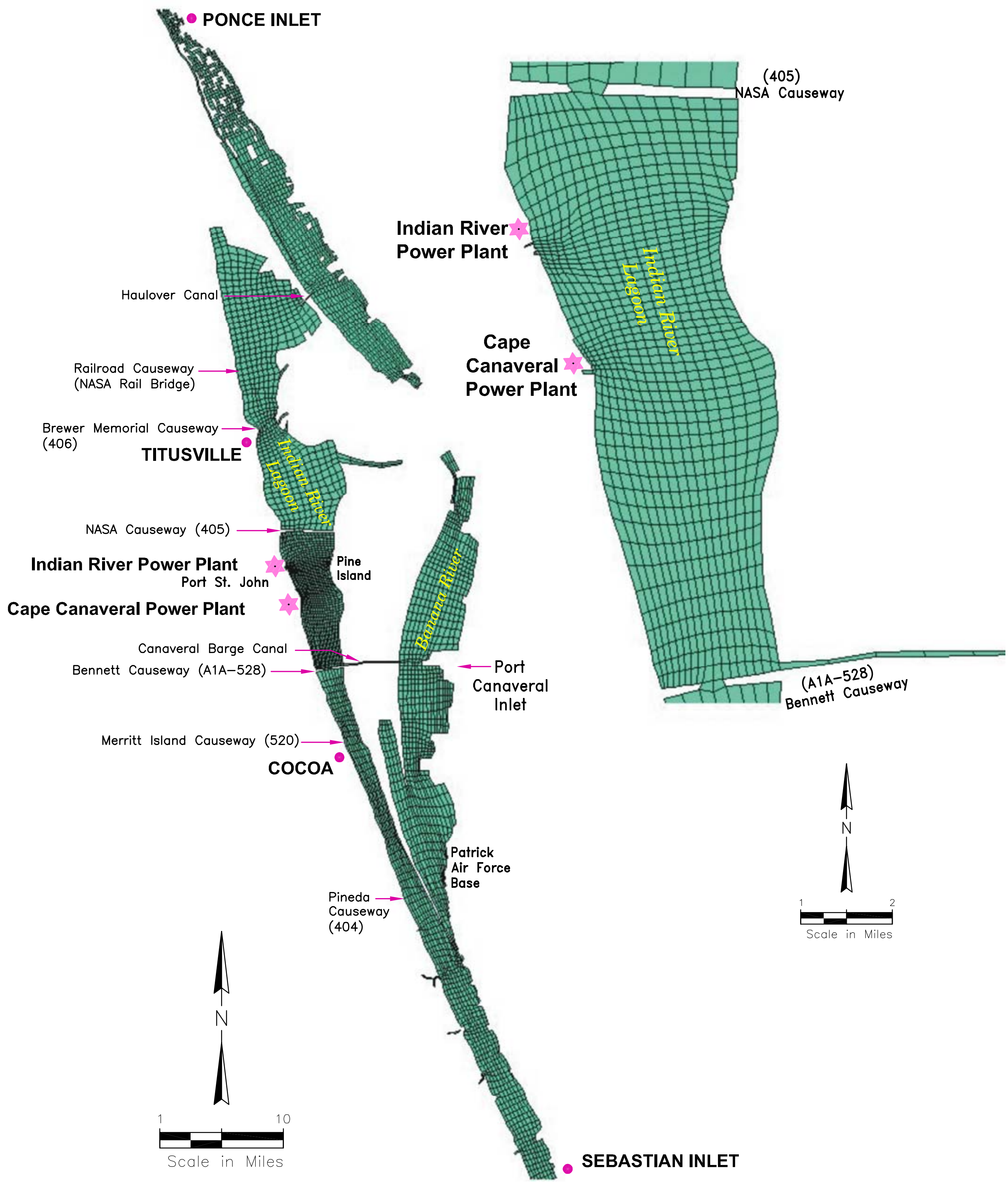
6.2 Model Refinements

6.2.1 Model Grid Refinement

In accordance with the vertical and horizontal grid resolution recommendations from outlined in Section 3.0, existing IRLPLR model horizontal grid resolution near the project site, (as shown in Figure 34) was modified to provide the higher grid resolution necessary for localized circulation near the power plants. The minimum horizontal grid resolution in the immediate study area was refined to approximately 100 meters on a side, with higher resolution locally around the discharge canals.

The existing model grid was refined, rather than using a sub-grid of the immediate area, in order to keep the character of the overall solution of the lagoon intact. For this refinement, boundary points were added along the coastline from Bennett Causeway up to NASA Causeway. In the local study area, additional boundary points were added in both the horizontal and vertical directions.

Figure 35 presents the refined grid in the area of the project. The only changes occurred between Bennett Causeway and NASA Causeway; the grid geometry remained identical in all other areas.



04948–TM2G–Fig 1.dwg Figure 35 6/6/06

Figure 35
IRLDS model grid for demineralization plant study
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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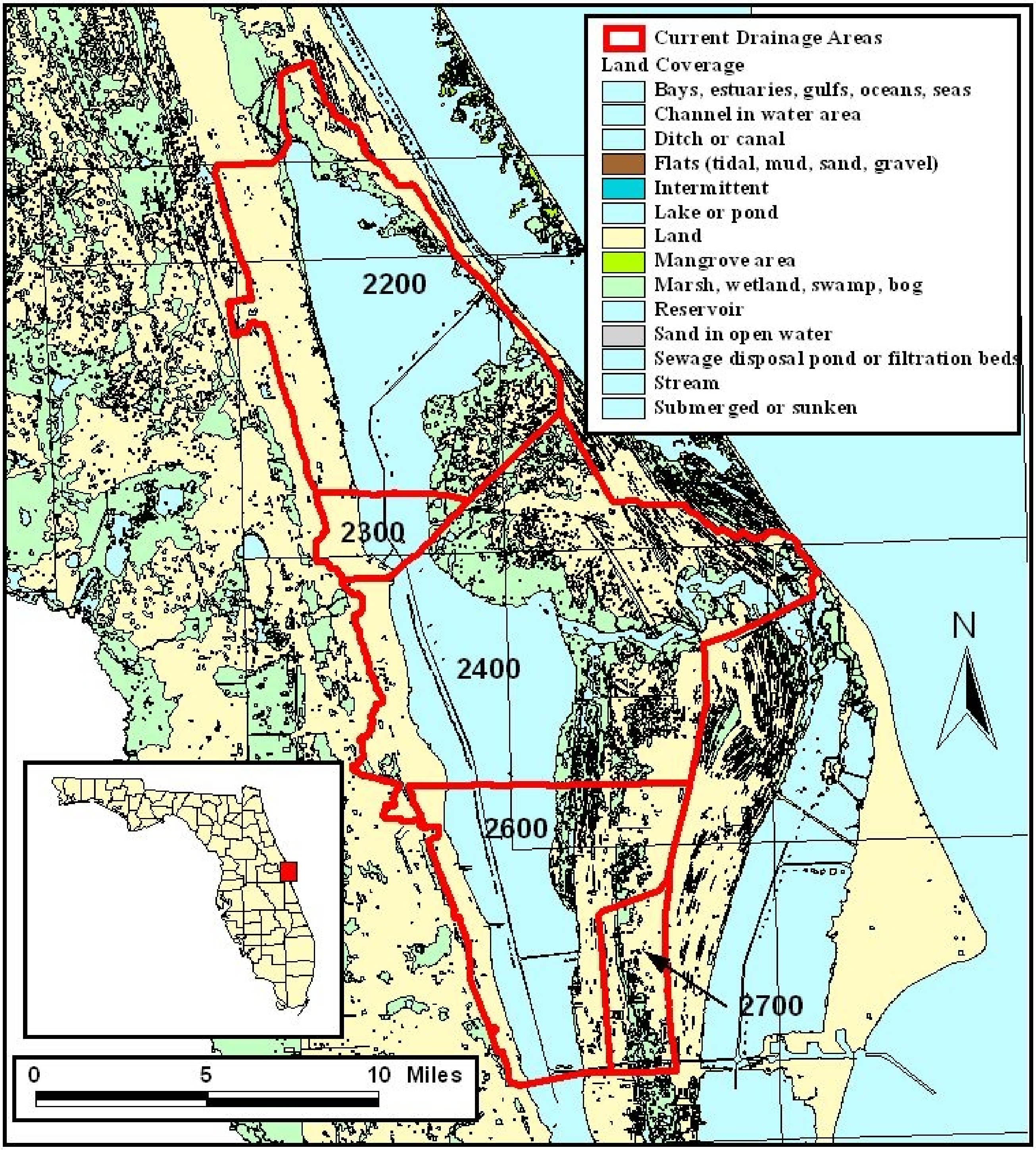
6.2.2 Model Watershed Delineation Refinement

In accordance with the freshwater inflow recommendation outlined in Section 2.0, the resolution of the current HSPF subwatershed delineations were reviewed to determine the appropriate resolution needed to quantify the freshwater inflow. Figure 36 shows the existing HSPF subwatershed delineations for the North IRL between Titusville and Cocoa, superimposed onto a map of the hydrographic features in Brevard and Volusia counties. These subwatersheds were received from SJRWMD Engineering Division staff. The five drainage areas shown have drainage area IDs 2200, 2300, 2400, 2600, and 2700.

A review of the current IRLPLR hydrodynamic input control file showed that inflows from these five drainage areas are partitioned and provided to 12 disparate locations of the receiving water model. For subwatersheds 2200, 2300, 2400, and 2600, the partitioning is based on the orientation of the land surface parcels and the waterbody within the drainage area. Since only one HSPF output file is generated for each drainage area, the percentage of drainage area runoff assigned to each partition is based on the relative area within the partitioned parcel. For example, inflows from subwatershed 2200 are provided to three separate locations. For subwatershed 2700, one third of the HSPF-generated runoff is provided to the Cocoa portion of Indian River via the Canaveral Barge Canal, one third is provided to the Banana River via the Canaveral Barge Canal, and one third is provided to the Banana River via Sykes Creek.

Multiple efforts are currently ongoing at the SJRWMD to establish hydrologically consistent surface drainage areas for the entire district. The IRL drainage areas from this development effort were acquired from the SJRWMD. Unfortunately, these hydrologic drainage areas are not any more detailed than those used for the current HSPF application. However, there are some differences in the catchment boundaries that have been incorporated into this analysis. A second, less formal, subwatershed development effort was conducted within the SJRWMD Engineering Division and partitions the five current HSPF IRL subwatersheds into 21 catchments. While this layer provides a more comprehensive basis from which to determine individual drainage areas contributing to runoff in the IRL, there are still some catchments in the layer that are grossly delineated (e.g. the portion of Merritt Island draining west to the Indian River). In order to establish revised subwatersheds that are more appropriate for use with the refined grid model, an integrated approach, using both of the newer catchment layers, along with some sub-delineations and minor corrections based on USGS quadrangle map information, was employed.

Figure 37 shows the recommended and implemented revisions to the HSPF subwatersheds for use with the IRLDS model grid. This subwatershed delineation includes 29 separate catchments. The most significant differences between this catchment layer and the currently used drainage area layer are noted as follows:



04948 TechMemo2G Fig 36 6/30/06

Figure 36
IRLPLR watershed model sub-basins for Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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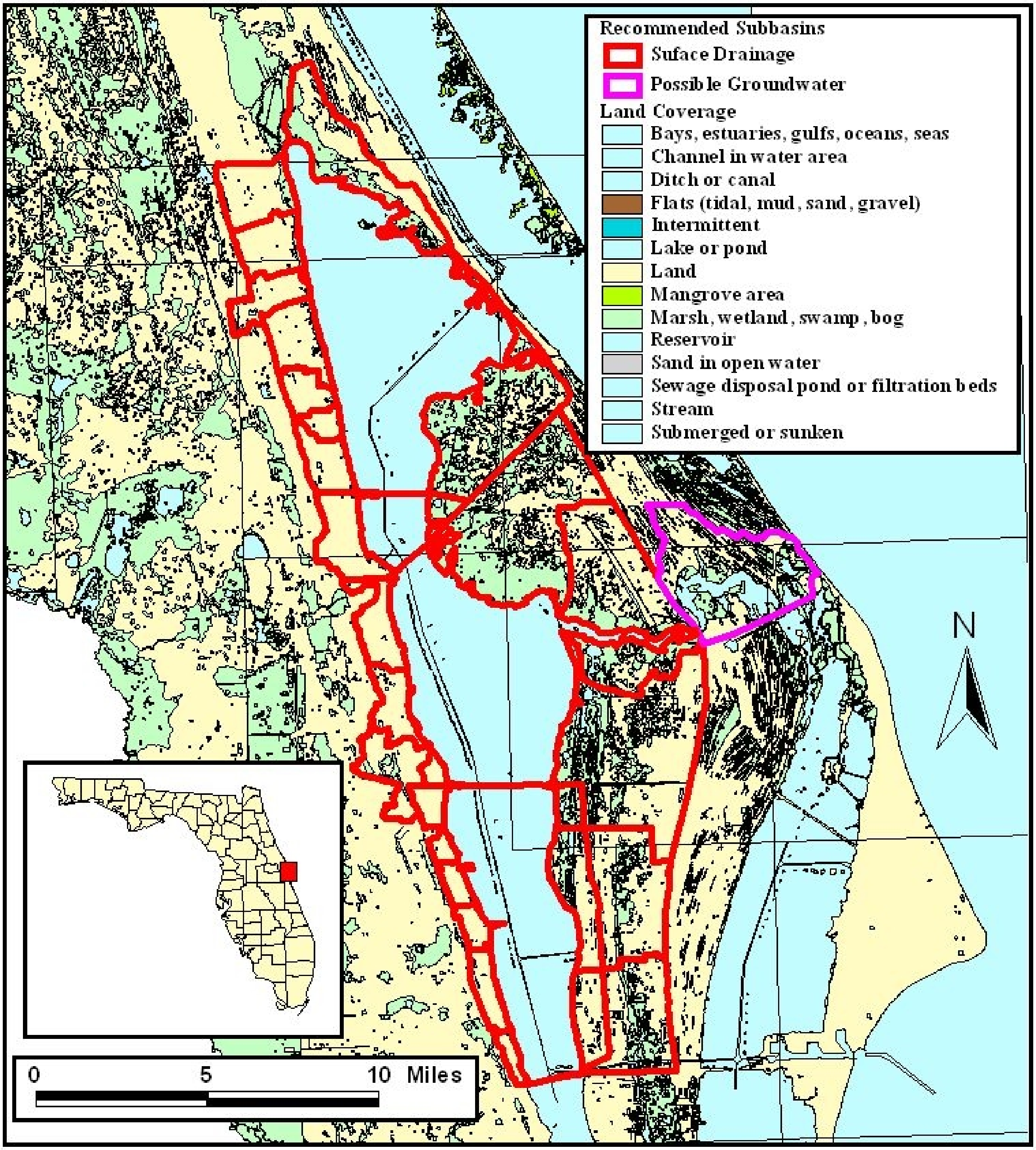

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Figure 37
IRLDS watershed model sub-basins for Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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- This catchment delineation has 29 drainage areas. The current delineation includes just five drainage areas for the same areal domain and partitions the simulated results into 12 separate time series.
- The mainland drainage area parcels, which drain to Indian River from the west, have been increased from 4 to 17.
- The portion of Merritt Island draining west to Indian River has been split into four (or five) catchments.
- A portion of Merritt Island, south of NASA Parkway West and west of Kennedy Parkway South, is now identified as draining to the catchment north of NASA Parkway West also.
- The portion of Merritt Island that is coincident with drainage area 2700 has been revised to include a slightly larger area. The redelineation also explicitly includes the parcels immediately adjacent to the Canaveral Barge Canal. As was discussed earlier, the current distribution of flows from this area splits the HSPF-generated runoff into thirds and routes it to either the Indian River or the Banana River.

This subwatershed redelineation provides a more accurate spatial distribution of the freshwater inflows to the North IRL and results in more realistic inflows from the contributing areas, including Merritt Island. Also, since the redelineated subwatersheds conform to the spatial extent of the five existing drainage areas, these 29 subwatersheds replace the existing five without disrupting the adjacent subwatersheds of the HSPF domain.

6.2.2.1 Addition of Temperature Simulation

Based upon recommendations made in Phase I, the simulation of temperature was added to the model. This recommendation was implemented by SJRWMD staff into the existing CH3D model code. Appendix L presents an overview of the changes made to the model to simulate temperature, and the tests performed to verify the model changes.

6.2.2.2 Demineralization Plant Simulation

In order to simulate the demineralization plant operations, it was determined that a dynamic plant operations model would need to be developed that would allow the concentrate discharge to be determined dynamically within the hydrodynamic modeling framework based upon the simulated ambient conditions. This would assure that any recirculation and potential buildup issues would be properly simulated.

Figure 19 shows a simplified schematic diagram of the flows within the proposed collocated facilities. The general operation of the power plants shows the intake water entering the plant drawn from the intake canal. This water then passes through the plant and is heated through the cooling process. The heated effluent then discharges out from the power plant to the discharge canal. The demineralization plant then draws water from the heated power plant effluent to the demineralization plant. The demineralization plant extracts a portion of the freshwater from the saline intake water, and returns a concentrated effluent. The amount of extracted freshwater (treated water) and the concentration of the effluent is dependant upon the recovery rate of the plant. One other component of the system is that when the effluent temperatures from the power plant get too high (above 104°F), there is a need for additional cooling water to be drawn from the intake side and added to the demineralization intake water to get the temperature to an optimal level for use with the RO membranes.

The goal of the plant operation model is to provide a methodology that calculates the RO facility concentrate salinity and temperature for the Cape Canaveral and Reliant Indian River power plant sites based upon the dynamic ambient conditions at their intakes. The model also estimates the maximum RO facility water production, which will result in a 10 percent increase in chloride concentration in the power plants' circulating water systems. This limitation is based on Florida Administrative Code 63-302, which limits chloride concentrations in discharges to surface waters to 10 percent above background.

A detailed presentation of the assumptions and calculations for the plant operation model is presented in Appendix H. These equations were then programmed into the IRLDS model and run with the revised grid and input conditions. Therefore, at each time step, the model takes the simulated ambient conditions at the intake, runs them through the plant operations model based upon actual power plant flow conditions, and calculates the discharge salinity concentration. Tests performed on the plant operations model are discussed below.

6.3 Model Validation

As discussed previously, under Phase I of this project, it was determined that the IRLPLR model was suitable for use in this project with some modifications to the code and to the model input files. The changes that were made and the methodologies utilized for those changes were discussed in Sections 1.1 and 1.2. The following presents discussion of the verification that was done to assure that the changes made to the model did not significantly alter the simulation of the hydrodynamics and salinity of the IRLPLR model, and to demonstrate the near field predictive capabilities of the refined model in the region of the power plants.

6.3.1 IRLPLR Model Calibration Overview

As discussed earlier, the development and calibration of the IRLPLR hydrodynamic model occurred over a 10-year process. The SJRWMD utilized the CH3D hydrodynamic model developed by Dr. Peter Sheng of the University of Florida. This model has been utilized in numerous waterbodies throughout the United States.

The IRLPLR hydrodynamic model development and calibration process is presented in reports within Data Attachment A. These reports outline the model formulation, inputs, assumptions and calibration. Data Attachment A provides a detailed report entitled *Evaluation of the Indian River Lagoon Pollution Load Reduction Hydrodynamic and Salinity Model for the Period 1997-2000.* This report provides an overview of the model development and input conditions. This report has not been previously released by the SJRWMD. In conjunction with the demineralization study, the model has undergone improvements based upon recommendations made by the Model Evaluation Group (MEG). These recommendations were implemented and the documentation of the changes are presented in Data Attachment A in a report entitled *Indian River Lagoon Pollutant Load Reduction Model Enhancement, Part 1: Hydrodynamic/Salinity Model Enhancement.*

The present version of the IRLPLR hydrodynamic model provides accurate simulation of the full hydrodynamic processes in the IRL. Of particular importance for the demineralization study is the simulation of the overall water balance and the exchange of waters within the North IRL, Mosquito Lagoon, and the Banana River. The present version of the IRLPLR hydrodynamic model provides this far field simulation capability and this has been verified through external expert peer review.

6.3.2 Overview of IRLDS Model Far Field Validation

With the existing IRLPLR hydrodynamic model accurately simulating the far field hydrodynamic processes, it is important to verify that the changes to the model (IRLDS hydrodynamic model) do not significantly alter the simulation of the far field hydrodynamic processes including salinity. Additionally, it is important to verify that the model simulations using the IRLDS hydrodynamic model meet the criteria outlined in Phase I of the project. This criterion states that over 80 percent of the model to data comparisons should be within 2 ppt. Finally, it is necessary to provide verification of the model's near field predictive capabilities in the vicinity of the power plants. As stated earlier, the changes made to the model include:

- Refinement of the grid in the vicinity of the power plants
- Refinement of the freshwater inflow to the North IRL
- Simulation of the dynamic power plant operations
- Simulation of the dynamic temperature

To determine if the model refinements altered the simulation of the far field conditions, model calibration statistics were developed for the IRLPLR model and the IRLDS model. These statistics included the correlation coefficient (R2), the Route Mean Square Error (RMS) error, the Mean Error (ME), and the 2 ppt percentile error. Under Phase I, criteria were outlined for the 2 ppt percentile error level.

Table 6 provides the full statistics for the salinity for all of the IRLPLR measurement stations throughout the lagoon. While statistics are presented for all years, some deficiencies in the data from 1997 were noted in earlier SJRWMD reports. Therefore, the statistics for 1997 are not considered as reliable as later years.

The stations generally move from north to south with the locations provided within the reports in Data Attachment A. While the results show some variation, in general, the two models have similar levels of accuracy at the IRLPLR stations. Difference in RMS error between the two models is generally less than 0.5 ppt with similar correlation coefficients. One area where the IRLDS model shows slightly improved results is for the mean error. This indicates that the IRLDS model, in general, is providing a more accurate simulation of the overall levels of salinity in the system.

Comparison of the two models to the Phase I criteria show that in the North IRL stations, the criterion is met at times. Two ppt percentiles range between 60 and 90 percent with the overall average at the North IRL stations around 70 percent. Key stations near the project (i.e., Melbourne Causeway) show levels that do meet the criteria, with the stations to either side of the project showing values around 75 percent on average. As the model results do not quite meet the criteria overall, it is recommended that the model be used in a comparative sense as outlined under the Phase I recommendations.

Tests on the temperature simulation routine and its determination of the heat flux and heat balance were conducted by SJRWMD personnel following the implementation of the routines into the model. Appendix L provides an overview of the tests performed to verify the temperature simulation routines.

Finally, the simulation of the dynamic plant operation was verified through mass balance tests in the vicinity of the project. These mass balance tests assure that the flow of water removed by the plant operations is balanced with flows moving into the system. A control volume was placed around the immediate vicinity of the project from the NASA Causeway down to the Bennett Causeway. Therefore, flows across this control volume could occur through the openings in the two causeways as well as through the Barge Canal into Banana River. Various water production rate scenarios were run, and the net flows through each opening in the control volume were calculated from the model output. Table 7 provides the results of the mass balance, with production rates at each of the plants ranging from 30 MGD down to 5 MGD. The results show near perfect mass balance, with the total of the simulated net flow rates across each of the three openings equal to the total rate of water withdrawal.

Table 6. Comparison of Salinity Statistics of the IRLPLR Model and the IRLDS Model

	IRLDS Model (1997)					IRLPLR Model (1997)			
Station	N	R2	RMS Error	Mean Error	2ppt Percentile	R2	RMS Error	Mean Error	2ppt Percentile
Continous Stations									
New Smyrna Beach (Surface)	154	0.06	9.9	7.2	23%	0.06	9.7	7.0	26%
New Smyrna Beach (Bottom)	149	0.06	3.2	1.8	64%	0.04	3.1	1.6	66%
Haulover (Surface)	101	0.02	2.9	2.1	53%	0.01	3.2	2.6	44%
Haulover (Bottom)	110	0.40	1.9	0.4	67%	0.13	2.3	1.0	48%
Titusville (Surface)	132	0.27	4.7	4.2	12%	0.24	4.1	3.5	27%
Titusville (Bottom)	87	0.82	3.5	3.2	16%	0.83	2.7	2.5	37%
Cocoa (Surface)	104	0.33	0.9	0.6	96%	0.43	1.2	1.1	91%
Cocoa (Bottom)	150	0.60	0.4	0.1	100%	0.68	0.7	0.5	100%
Banana River (Surface)	99	0.69	1.3	1.0	90%	0.72	1.2	0.9	90%
Banana River (Bottom)	97	0.73	0.9	0.4	100%	0.66	1.0	0.3	95%
Carters Cut (Surface)	145	0.35	2.1	0.2	71%	0.30	2.2	0.6	73%
Carters Cut (Bottom)	146	0.24	2.8	-1.7	52%	0.23	2.5	-1.2	57%
Melbourne (Surface)	92	0.65	2.4	0.8	65%	0.68	2.1	1.4	65%
Melbourne (Bottom)	135	0.37	2.9	1.1	53%	0.36	2.7	0.5	53%
Synoptic Stations									
IRLB02	57	0.03	2.9	2.2	28%	0.03	3.1	2.5	25%
IRLB04	44	0.47	1.0	-0.2	91%	0.52	1.0	0.1	98%
IRLB06	54	0.59	1.0	-0.6	91%	0.72	0.7	-0.2	100%
IRLB09	45	0.67	1.3	-0.9	89%	0.67	1.2	-0.7	89%
IRLI02	53	0.65	4.0	-3.8	9%	0.61	4.2	-3.9	8%
IRLI07	53	0.39	2.0	-1.0	62%	0.39	1.9	-0.6	74%
IRLI10	48	0.62	1.1	0.3	92%	0.66	1.0	0.0	98%
IRLI13	56	0.48	1.1	-0.1	91%	0.55	1.2	-0.7	82%
IRLI15	48	0.51	1.1	-0.1	100%	0.58	1.3	-0.8	83%
IRLI18	44	0.77	1.0	-0.3	96%	0.77	1.2	-0.7	100%
IRLI21	44	0.87	1.5	-1.1	86%	0.88	1.5	-1.0	82%
IRLI23	54	0.87	2.8	-2.3	54%	0.86	2.5	-1.9	54%
IRLI27	47	0.77	3.8	-0.6	21%	0.73	4.0	0.4	23%
IRLML02	58	0.05	3.9	2.0	36%	0.05	3.8	1.8	36%
IRLV05	53	0.04	2.4	0.7	60%	0.05	2.4	0.5	59%
IRLV11	53	0.11	2.6	-0.4	51%	0.16	2.7	-0.7	43%
IRLV17	43	0.45	2.9	-0.5	35%	0.50	3.1	-0.9	21%

Note: N represents the number of values used in the statistics

Table 6. Comparison of Salinity Statistics of the IRLPLR Model and the IRLDS Model

	IRLDS Model (1998)					IRLPLR Model (1998)			
Station	**N**	**R2**	**RMS Error**	**Mean Error**	**2ppt Percentile**	**R2**	**RMS Error**	**Mean Error**	**2ppt Percentile**
Continuous Stations									
New Smyrna Beach (Surface)	258	0.44	5.6	2.8	63%	0.47	5.5	2.8	63%
New Smyrna Beach (Bottom)	240	0.44	4.1	2.8	38%	0.44	4.1	2.8	36%
Haulover (Surface)	249	0.87	1.2	0.1	90%	0.87	1.8	1.3	72%
Haulover (Bottom)	218	0.87	1.3	0.0	90%	0.89	1.7	1.2	72%
Titusville (Surface)	274	0.24	2.3	0.7	56%	0.27	3.5	2.8	23%
Titusville (Bottom)	312	0.64	1.4	0.0	80%	0.62	2.6	2.1	46%
Cocoa (Surface)	201	0.10	3.5	1.4	60%	0.06	3.4	1.9	55%
Cocoa (Bottom)	205	0.02	1.9	0.6	89%	0.41	1.7	1.0	90%
Banana River (Surface)	328	0.83	1.2	-0.7	90%	0.85	0.9	0.1	97%
Banana River (Bottom)	353	0.76	1.2	-0.6	89%	0.76	1.0	0.2	96%
Carters Cut (Surface)	341	0.87	1.9	-0.6	76%	0.89	1.6	-0.5	82%
Carters Cut (Bottom)	225	0.91	1.9	-1.3	70%	0.94	1.5	-1.0	77%
Melbourne (Surface)	317	0.93	1.8	-1.4	63%	0.94	1.8	-1.3	73%
Melbourne (Bottom)	223	0.87	3.2	-2.5	53%	0.87	3.2	-2.5	50%
Synoptic Stations									
IRLB02	52	0.33	3.2	-1.3	71%	0.35	2.9	-0.6	73%
IRLB04	48	0.69	1.2	-0.6	81%	0.71	1.0	0.2	98%
IRLB06	56	0.86	2.7	-2.3	48%	0.86	1.9	-1.3	61%
IRLB09	50	0.94	2.1	-1.7	56%	0.94	1.8	-1.3	78%
IRLI02	51	0.73	5.8	1.1	78%	0.75	6.0	2.3	71%
IRLI07	47	0.30	5.3	0.0	62%	0.26	5.8	2.1	83%
IRLI10	49	0.55	1.4	-0.9	86%	0.56	1.2	0.4	94%
IRLI13	46	0.44	1.6	-0.9	89%	0.37	1.4	-0.5	89%
IRLI15	49	0.40	1.8	-1.2	63%	0.43	1.6	-0.9	69%
IRLI18	47	0.75	1.6	-0.8	81%	0.81	1.4	-0.8	81%
IRLI21	48	0.93	1.4	-1.0	90%	0.93	1.3	-0.9	94%
IRLI23	47	0.95	1.8	-1.5	68%	0.95	1.8	-1.4	77%
IRLI27	54	0.96	1.7	-0.4	67%	0.94	1.8	0.1	76%
IRLML02	58	0.20	4.9	0.5	40%	0.26	4.9	1.5	48%
IRLV05	76	0.74	3.4	2.6	37%	0.73	3.4	2.6	36%
IRLV11	61	0.88	2.5	2.1	46%	0.88	2.4	2.1	43%
IRLV17	49	0.79	2.7	2.1	49%	0.80	2.7	2.2	43%

Note: N represents the number of values used in the statistics

Table 6. Comparison of Salinity Statistics of the IRLPLR Model and the IRLDS Model

Station	IRLDS Model (1999)					IRLPLR Model (1999)			
	N	R2	RMS Error	Mean Error	2ppt Percentile	R2	RMS Error	Mean Error	2ppt Percentile
Continuous Stations									
New Smyrna Beach (Surface)	292	0.72	2.8	2.0	53%	0.73	2.8	2.1	49%
New Smyrna Beach (Bottom)	361	0.63	2.9	1.9	52%	0.65	2.9	1.9	54%
Haulover (Surface)	257	0.89	1.9	0.0	65%	0.89	2.0	0.6	65%
Haulover (Bottom)	257	0.88	2.0	0.5	54%	0.89	2.3	1.1	53%
Titusville (Surface)	254	0.76	2.1	-0.2	60%	0.71	2.8	2.0	46%
Titusville (Bottom)	248	0.67	2.6	-0.7	65%	0.62	2.8	1.3	42%
Cocoa (Surface)	290	0.37	1.6	-1.1	82%	0.37	1.2	0.4	88%
Cocoa (Bottom)	309	0.56	1.5	-1.2	85%	0.53	1.0	0.4	95%
Banana River (Surface)	180	0.68	1.2	-0.7	92%	0.67	1.3	0.8	90%
Banana River (Bottom)	299	0.13	2.5	-1.3	66%	0.19	1.9	0.3	76%
Carters Cut (Surface)	278	0.76	1.5	-1.2	80%	0.76	1.0	0.0	98%
Carters Cut (Bottom)	364	0.87	2.0	-1.7	63%	0.89	1.1	-0.6	92%
Melbourne (Surface)	364	0.87	1.9	-1.2	70%	0.87	1.5	-0.3	80%
Melbourne (Bottom)	325	0.74	2.7	-1.2	69%	0.75	2.4	-0.3	72%
Synoptic Stations									
IRLB02	45	0.67	1.8	-0.8	64%	0.70	1.7	0.7	82%
IRLB04	36	0.72	1.4	-0.7	89%	0.77	1.4	0.9	81%
IRLB06	40	0.61	1.8	-1.4	70%	0.63	1.1	0.3	93%
IRLB09	40	0.91	1.7	-1.4	70%	0.91	0.8	0.1	100%
IRLI02	48	0.92	2.2	0.7	69%	0.92	2.6	1.4	50%
IRLI07	35	0.86	2.2	-1.7	57%	0.76	1.6	0.4	71%
IRLI10	35	0.83	2.2	-1.9	51%	0.76	1.3	-0.1	89%
IRLI13	35	0.60	1.8	-1.4	60%	0.59	1.2	0.2	94%
IRLI15	46	0.54	1.7	-1.4	63%	0.44	1.0	-0.1	100%
IRLI18	44	0.77	1.1	-0.3	93%	0.70	1.4	0.5	93%
IRLI21	36	0.81	1.6	-0.7	89%	0.79	1.5	0.1	81%
IRLI23	35	0.83	2.3	-1.3	86%	0.84	1.9	-0.6	89%
IRLI27	37	0.88	2.8	-0.8	49%	0.89	2.5	-0.2	65%
IRLML02	48	0.73	3.3	1.8	52%	0.74	3.8	2.5	46%
IRLV05	48	0.60	3.1	1.9	29%	0.61	3.1	2.0	27%
IRLV11	36	0.56	3.5	1.7	14%	0.59	3.5	1.9	14%

Note: N represents the number of values used in the statistics

Table 6. Comparison of Salinity Statistics of the IRLPLR Model and the IRLDS Model

Station	IRLDS Model (2000)					IRLPLR Model (2000)			
	N	R2	RMS Error	Mean Error	2ppt Percentile	R2	RMS Error	Mean Error	2ppt Percentile
Continuous Stations									
New Smyrna Beach (Surface)	218	0.63	2.9	2.1	50%	0.67	2.9	2.1	50%
New Smyrna Beach (Bottom)	211	0.27	5.4	4.2	35%	0.29	5.4	4.2	35%
Haulover (Surface)	352	0.86	2.1	-1.8	59%	0.92	1.4	-1.0	85%
Haulover (Bottom)	234	0.77	2.5	-2.2	47%	0.86	1.5	-1.3	83%
Titusville (Surface)	319	0.07	3.6	0.9	57%	0.11	4.8	3.5	42%
Titusville (Bottom)	321	0.85	2.4	-2.0	47%	0.78	1.7	0.4	76%
Cocoa (Surface)	337	0.87	4.0	-3.7	11%	0.85	2.0	-1.1	67%
Cocoa (Bottom)	345	0.91	3.9	-3.7	8%	0.89	1.9	-1.0	71%
Banana River (Surface)	70	0.93	6.4	-6.4	0%	0.93	2.9	-2.8	10%
Banana River (Bottom)	142	0.89	6.3	-6.2	0%	0.91	3.3	-3.0	18%
Carters Cut (Surface)	63	0.42	1.8	-1.6	73%	0.45	0.9	0.5	97%
Carters Cut (Bottom)	63	0.27	2.3	-2.2	48%	0.25	0.9	-0.1	97%
Melbourne (Surface)	329	0.91	3.5	-3.0	33%	0.89	2.9	-2.1	46%
Melbourne (Bottom)	314	0.93	3.3	-2.9	37%	0.92	2.7	-2.0	54%
Synoptic Stations		0.00				0.00			
IRLB02	36	0.71	7.3	-7.0	0%	0.72	4.0	-3.5	8%
IRLB04	24	0.88	5.2	-4.8	0%	0.87	2.3	-1.5	63%
IRLB06	24	0.95	5.4	-4.9	4%	0.95	3.1	-2.1	50%
IRLB09	35	0.88	4.3	-3.8	26%	0.90	3.0	-1.9	51%
IRLI02	33	0.38	5.7	-1.0	33%	0.30	6.0	-0.1	46%
IRLI07	24	0.70	3.7	-3.3	25%	0.76	1.5	-0.4	79%
IRLI10	25	0.78	3.8	-3.5	20%	0.82	1.2	-0.3	88%
IRLI13	24	0.68	3.9	-3.6	17%	0.61	1.7	-0.7	75%
IRLI15	34	0.58	4.3	-3.6	21%	0.46	2.8	-1.0	77%
IRLI18	36	0.89	3.9	-3.3	33%	0.92	3.0	-1.6	50%
IRLI21	24	0.83	4.0	-3.2	46%	0.84	3.2	-2.0	54%
IRLI23	24	0.82	4.3	-3.3	46%	0.82	3.9	-2.5	46%
IRLI27	24	0.40	6.1	-1.1	42%	0.42	5.9	-0.8	50%
IRLML02	35	0.85	4.4	-3.8	26%	0.88	3.7	-3.1	26%
IRLV05	33	0.35	2.0	-0.6	64%	0.39	2.0	-0.6	64%
IRLV11	22	0.53	2.0	-1.1	73%	0.58	1.9	-1.1	73%
IRLV17	22	0.71	2.0	-0.9	73%	0.74	1.8	-0.9	73%

Note: N represents the number of values used in the statistics

Table 7. Results of Mass Balance Tests on Hydrodynamic Model

Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Plant		Flow Path			Total Flows		Percent Flows		
Reliant (MGD)	Cape (MGD)	NASA Causeway (MGD)	Bennett Causeway (MGD)	Barge Canal (MGD)	Desal Total (MGD)	Flow Into Area (MGD)	NASA Causeway	Bennett Causeway	Barge Canal
30	0	11.3	-7.4	-11.2	30	30.0	37.8	24.7	37.5
30	5	12.0	-9.7	-13.3	35	35.1	34.2	27.8	38.0
30	10	13.7	-10.8	-15.5	40	40.0	34.2	26.9	38.8
30	20	16.7	-13.3	-20.0	50	50.0	33.3	26.7	40.0
30	30	20.0	-15.1	-24.9	60	60.0	33.4	25.2	41.5
20	0	7.3	-5.4	-7.3	20	20.0	36.5	27.1	36.5
20	5	8.2	-7.5	-9.3	25	25.0	32.6	30.2	37.2
20	10	0.0	0.0	0.0	30	0.0			
20	20	12.6	-11.8	-15.6	40	40.0	31.6	29.4	39.0
20	30	16.1	-13.6	-20.3	50	50.0	32.2	27.2	40.6
10	0	0.0	0.0	0.0	10	0.0			
10	5	5.0	-4.4	-5.5	15	15.0	33.4	29.7	36.9
10	10	6.7	-5.6	-7.6	20	20.0	33.8	28.1	38.0
10	20	10.9	-7.2	-11.8	30	30.0	36.4	24.2	39.5
10	30	14.0	-9.6	-16.3	40	40.0	35.1	24.1	40.8
5	0	2.6	-0.6	-1.8	5	5.0	51.4	11.7	36.9
5	5	4.3	-1.8	-3.9	10	10.0	43.1	18.1	38.8
5	10	5.3	-3.9	-5.7	15	14.9	35.5	26.3	38.2
5	20	9.1	-5.9	-10.0	25	25.0	36.4	23.6	40.0
5	30	11.5	-9.2	-14.2	35	35.0	33.0	26.4	40.6
0	0	0.0	0.0	0.0	0	0.0			
0	5	2.3	-0.7	-2.0	5	5.0	46.0	14.7	39.4
0	10	4.1	-1.9	-4.0	10	10.0	41.2	18.5	40.3
0	20	7.6	-4.3	-8.0	20	20.0	38.0	21.7	40.2
0	30	10.8	-7.0	-12.2	30	30.0	35.9	23.3	40.8

6.3.3 Overview of IRLDS Near Field Validation

In order to evaluate the model's ability to simulate the near field mixing at the discharges of the two power plants, a study was undertaken to measure the near field temperature characteristics and compare those measurements to model simulations of temperature. The study involved continuous and discrete measurements of temperature in the immediate discharge area of both the Reliant Indian River and FPL Cape Canaveral power plants as well as simulation of the temperature plume. Appendix K presents a detailed write up of the measurement program and the simulation results. The following provides a brief summary of the study and findings.

A 1-week field effort was conducted to analyze the local, near field temperature field in the vicinity of both the Reliant Indian River and the FPL Cape Canaveral plants. Handheld temperature readings were taken to estimate the probable extent of the thermal plume. The results were analyzed and a series of temperature sensors with data loggers were then deployed in a pattern intended to capture the extent and variability of the temperature in the area affected by the discharge. The data loggers were retrieved after 5 days. Several of the data loggers deployed were not found and a few suffered equipment failure but the overall data set presents a good picture of the near field temperature field in the region of both outfalls.

The most apparent variation of the temperatures is diurnal heating and cooling, peaking between about 5:00 pm and 6:00 pm each day. Some variation exists between the stations but it is small in relation to the diurnal swing. Transect 6 starts near the outfall canal, (Station P1) and progresses offshore (B1 to A1). Clearly some of the diurnal signal is attributable to atmospheric (solar and air temperature) heating and cooling and some to the thermal effluent variation during the course of a day. In that some of the stations farther from the shore do not show the magnitude of the diurnal pattern that the closer stations present is an indication that the signal is a feature of the thermal effluent. A similar situation exists in near field regions around both power stations.

The thermistor data temperature fields were then compared with model predictions for similar conditions. The operating conditions at the Reliant facility during the field program were analyzed and daily average values were determined for the plant volume flow, delta temperature (intake – outfall) as well as the environmental conditions (air temperature) to define the temperature forcing on the system. An excess temperature was calculated from the difference between a thermistor time series at the outfall and the control thermistor farther to the south, and daily average values calculated.

The model input thermal load, (delta temperature and flow) and air temperature were analyzed and specific dates matching the field program conditions were logged. In-situ water temperatures at cells corresponding to the thermistor data logger locations were extracted for the logged dates, daily averaged and base line statistics were developed.

While the comparisons do not show exact agreement the results clearly indicate that the model predictions vary over the same range as the observed and are in the correct order of magnitude. There are enough uncertainties in the two data sets to understand that a difference might exist. For example, although the daily average air temperature is the same for each data set for the specific day, the variability within that day and the temperature on the preceding day are quite possibly different. Taking all that into account, the model predictions in the near field region of the power stations appear to be an adequate representation of the present conditions in the lagoon.

7.0 IMPACTS ASSESSMENT

The following presents the results of the impact assessments performed for the various demineralization plant scenarios. Four areas of impacts were assessed:

- Operational Impacts
- Physical Impacts
- Water Quality Impacts
- Ecological Impacts

Section 5.0 presented the methodologies to be utilized in each of the analyses. The following sections present the results. Water quality impacts are assessed within the Operational Impacts section. Section 7.1 presents a discussion of the lengths of simulation required to achieve full build up of salinity or dynamic equilibrium.

7.1 Critical Condition Development and Dynamic Equilibrium Analysis

The long-term increase of salinity in the North IRL due to the operation of the proposed demineralization plants is a paramount concern under this project. Therefore, it is important that the model simulations are run for a sufficient period of time that any buildup in the system has come to a dynamic equilibrium or balance with the overall exchange with the ocean. Additionally, it is important that the boundary forcing conditions (i.e., freshwater inflow, tides, winds) represent a sufficiently critical time period such that reasonable worst-case conditions are simulated. For this project, as salinity or buildup is the most critical component, the freshwater inflow (or precipitation) becomes the most important aspect for scenario development.

For the model calibration, a 4-year period was utilized from 1997 to 2000. For this period, tides and winds were measured as well as freshwater inflow to the system. This period of time was significant in that the overall precipitation to the area was less than the average, and the year 2000 represented a significant drought period (1 in 125 years). Table 8 presents a 4-year and 12-year frequency analysis for the Titusville rainfall station. The table presents the total rainfall over a 4-year or 12-year period and what that total rainfall equates to in relation to return period. The total rainfall from 1997 to 2000 at Titusville was 198 inches. For this 4-year period, this represents a 1 in 7 year event and it is below the average rainfall for any 4-year period (208 inches).

Table 8 4-Year and 12-Year Frequency Analysis for IRL Long-Term Rainfall Stations (in inches)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Frequency (years)	Titusville	
	4-Year	12-Year
200	170	563
100	174	572
50	179	582
25	185	593
10	194	610
5	202	627
2	218	659

The next step was the determination of the period of time over which the model would need to be run in order to assure that no further increases in salinity in the system would occur. Using the 4-year 1997 to 2000 period in sequence allowed for the development of any length of simulation desired. The sequencing was developed by repeating the 4-year period matching conditions at the tail end with conditions at the beginning. The only parameter where this presented any issues was for the tides, where the results needed to blend with the tidal conditions, to do this a 3-hour period was removed from the 4-year matching cycle, creating a slightly shorter 4-year repeated period following the first 4-years.

The model was run using the repeated 4-year periods as boundary conditions to simulate the long-term operations of the plants. Various water production rate scenarios were run and the results evaluated. In order to determine if the system came to a dynamic equilibrium and that further net buildup of salinity would not occur in the system, the acreages of salinity difference between the baseline (no plant operations) and the scenario runs (30, 20, 10, and 5) were calculated over time. Plots of these are presented in Appendix J as well as in Figures 40, 43, and 46. The results show that the system comes to a dynamic equilibrium between 6 and 8 years into the plant operations. Therefore, the model simulations for all of the scenarios presented were run over a 12-year period and the last 4 years utilized in the ecological impacts evaluation.

Using the data in Table 8, the total rainfall over the 12-year simulation period represents a 1 in 25 year event. This is for the total rainfall over the full simulation period. It is important to note that during this 12-year simulation, the record drought that occurred in 2000 is repeated three times, the record drought represented a 1 in 125 year event. Statistical analysis of this 1 in 125 year event occurring 3 times in a 12-year period represents a 1 in 700 year event. Based upon these analyses, it is deemed that the 12-year simulation period chosen for the scenario development is of a sufficiently critical nature for this project.

7.2 Model Scenarios

Table 1 presents the list of scenarios that were evaluated in the impacts assessment. These include single plant operations of 30, 20, and 10 at each of the facilities, and both facilities running at 30, 20, 10, and 5, respectively. The results of these scenarios, which are presented in Section 5, show that the operation of the demineralization plants at either the Reliant or the FPL facility show very similar overall impacts to the salinity changes throughout the system. Only minor near field differences are seen between the two facilities, this will be demonstrated under the physical impacts assessments below. Near field refers to the immediate zone of influence of the discharges. Therefore, the detailed ecological impact assessments will focus upon the simulation of the single plant operation at one facility, while the operational and physical impacts assessments present all scenarios. The Reliant facility is presented for the detailed ecological impacts assessments.

Table 9. Discharge scenarios (a baseline scenario without demineralization process will also be included)

Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

	Water Production Rate (MGD)			Concentrate Discharge Rate (MGD)*			
Scenario Number	Cape Canaveral	Indian River	Total	Cape Canaveral	Indian River	Total	Comment
1	0	30	30	0	47.5	47.5	One Plant 30 MGD
2	0	20	20	0	31.7	31.7	One Plant 20 MGD
3	0	10	10	0	15.8	15.8	One Plant 10 MGD
4	30	0	30	47.5	0	47.5	One Plant 30 MGD
5	20	0	20	31.7	0	31.7	One Plant 20 MGD
6	10	0	10	15.8	0	15.8	One Plant 10 MGD
7	30	30	60	47.5	47.5	95	Both Plants at 30
8	20	20	40	31.7	31.7	63.4	Both Plants at 20
9	10	10	20	15.8	15.8	31.6	Both Plants at 10
10	5	5	10	7.9	7.9	15.8	Both Plants at 5

Notes:
Assumed Recovery Rate = 38.7%
*Concentrate Discharge Rates are subject to change based on treatment process

7.3 Operational Impacts Assessment

7.3.1 Impingement and Entrainment

Section 2 presented the operational flows and temperatures for the power plants from 1997 to the present. The plots showed that each of the facilities operate at a range of flow and temperature conditions.

The Reliant plant operational data show that daily flows range from below 100 MGD to near 700 MGD, with temperatures at times as high as 115°F. The data show the response of the plant to the power needs, with the winter months showing low flow conditions while the summer months show higher flow conditions.

The data from the Cape Canaveral plant show flows ranging between 300 MGD to near 800 MGD. Maximum temperatures for the Cape Canaveral plant reached 118°F, based upon the historical data.

In Section 4, the operational restrictions for the demineralization plants collocated with the power plants were identified. Two operational restrictions that have the potential for creating additional flow needs for the power plants are as follows:

- Increased flow to provide cooling water to bring the temperature of the demineralization plant source water down to its maximum temperature of 104°F.
- Increased flow to assure that the NPDES requirement of 10 percent increase in effluent salinity concentrations is not violated.

Plots and analyses presented in Appendix I show the changes in flow that would result from the operation of the demineralization plant at water production rates of 30, 20, 10, and 5 MGD. The calculations are based upon the additional draw of cooling water plus the additional draw of water to meet the NPDES requirements.

Examination of the results for the Reliant plant show that for a 30 MGD or a 20 MGD plant (during the winter months when flows are low) the percent flow increases can be as high as 70 to 150 percent and 30 to 70 percent, respectively. These flow increases are significant in relation to the flows that would have occurred without the demineralization plant. For the 10- and 5-MGD conditions, no flow increases would have been necessary. Historical records show times where the temperatures at the Reliant plant have reached 115°F. This condition occurred under high flow conditions, i.e., flows greater than 400 MGD. Based upon the results presented in Appendix I, cooling water flow needs would always be less than 2 percent. Therefore, the results show that for a 30 MGD or 20 MGD plant additional flow needs would be significant, ranging from 70 to 152 percent and 30 to 72 percent respectively. For a 10 MGD or 5 MGD plant, additional flow needs would be less than 2 percent.

Examination of the results for the Cape Canaveral plant show that the flows generally remain above 300 MGD during operations. This means that additional draw water would not be required to meet the FDEP requirement of less than 10 percent increase over intake salinity conditions. Therefore, the additional draw water would only be required for cooling water purposes. Historic records show times where the temperatures at the Cape Canaveral plant have reached 120°F. This condition occurred under high flow conditions, i.e., flows greater than 700 MGD. Based upon the data presented in Appendix I, additional flow for cooling water needs would always be less than 1 percent. Therefore, the total cooling water flow needs for the Cape Canaveral plant would always be less than 1 percent.

Presently, impingement and entrainment (I&E) mortality at the plants is of significant concern. If operation of the demineralization plants significantly increases the present I&E, the demineralization project could become unfeasible without offsetting mitigation. Examination of the results indicates that for the Reliant site, I&E impacts are significant for the 30 MGD and 20 MGD water production rates, while for the 10 MGD and 5 MGD cases the impacts are less significant. For the Cape Canaveral site, due to its generally high baseflow, I&E increase issues are not significant.

7.3.2 Recirculation

The model simulations that are presented and discussed in detail in Section 7.4, show that the change in salinity locally extends well beyond the immediate vicinity of the discharge. The simulations show that salinity changes extend out a sufficient distance that the intake waters for both of the plants will receive the higher saline water and reprocess it through the demineralization plant. This higher saline water entering the plant will create additional burden on the demineralization plant and create higher concentrations at the outfall. Appendix J presents contour plots of the maximum and average salinity differences seen throughout the system and in the near field.

The results show that for a 30 MGD simulation at the Reliant plant, maximum salinity changes on the order of 10 ppt can be seen at the intake after the system reaches a dynamic equilibrium condition (years 9 to 12 of the simulations). Average salinity differences are on the order of 6 ppt at the intake. For a 20 MGD scenario, maximum salinity changes at the intake are on the order of 6 ppt at the intake, with averages near 4 ppt. For a 10 MGD scenario, the maximum salinity differences at the intake are near 4 ppt with averages near 2 ppt. In all cases, the level of demineralization removal will be impacted by the local increases in average salinity and the recirculation issues.

7.3.3 Water Quality Impacts Assessment

As discussed previously, a number of pollutants are present in the Indian River Lagoon under ambient conditions. The potential for concentration of these pollutants, via the production of demineralization concentrate, was identified as a potential environmental issue. The concentration of salinity was modeled using the previously described hydrodynamic model. From the hydrodynamic model output, a concentration factor was derived, based on the conservative mass assumption, and it was used to predict the potential for increasing the concentration of these substances. The objective of this section was to quantify the potential concentration of ambient pollutants and to compare baseline and concentrated levels of these pollutants to established water quality standards.

The FDEP and U.S. Environmental Protection Agency have recently initiated a process to formally establish which water bodies are impaired on a repeating 5 year cycle. The Indian River Lagoon, in the project study area, is part of FDEP Basin Group 5, and this group has not been classified yet. However, review of the 1998 303(d) list established that sections of the lagoon are set as high priority to have a TMDL established in 2006 for nutrients and mercury. A section northern most in the study area is classified as low priority and is set to have a TMDL established in 2011 for iron and lead.

7.3.3.1 Baseline Conditions

Two water quality datasets were used in this assessment: the SJRWMD fixed station data and the FDEP STORET database used for the FDEP IWR assessments statewide (both described in Section 2). From these datasets, parameters with surface water quality standards established under the 62-302.530, Criteria for Surface Water Quality Classifications were selected. Standards were developed by the FDEP based on designated use of the waterbodies within a Class, such as Class I: Potable Water Supply, Class II: Shellfish Propagation or Harvest, Class III: Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife (separate standards for Freshwater and Marine Waters Apply), etc.

After review of the available datasets, it was determined that two of the stations in the FDEP STORET IWR dataset (Figure 7) contained the parameters under evaluation. These two stations are Station 21FLA27010876 to the north of the power plants and Station 21FLA27010581 to the south of the power plants. The data for these two stations are reflected in Table 10. The STORET data available were primarily reported from 1991 to 1998, and samples sizes were relatively small.

Table 10. Baseline Water Quality Conditions near Power Plants for Key Constituents
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Parameter	Abbreviation (sample size)	Units	Class II and III (marine) Standards	90^{th} Percentile Value (dataset used)
Cadmium	Cd (41)	Micrograms/L	<=9.3	10 (STORET IWR)
Copper	Cu (43)	Micrograms/L	<=3.7	50 (STORET IWR)
Iron	Fe (53)	Micrograms/L	<=300	390 (STORET IWR)
Nickel	Ni (21)	Micrograms/L	<=8.3	25 (STORET IWR)
Zinc	Zn (39)	Micrograms/L	<=86	340 (STORET IWR)

The Indian River Lagoon is comprised of both Class II and Class III Waters. Class II standards are generally more stringent than Class III and as a conservative measure for this screening level analysis of the potential demineralization facility, Class II Standards were applied for all potential pollutants that were recorded in the datasets described above. These parameters and standards are listed in Table 10. Since the FDEP allows a 10 percent exceedance rate for surface water standards in the IWR process, the 90th percentile value for the study area for each parameter is provided for all pollutants with a minimum sample size of 20.

7.3.3.2 Estimate of Concentration of Pollutants via the Demineralization Process

The potential worst-case concentration factor was determined based on the median salinity distribution at a cell directly outside the discharge pipe. The concentration factor for the 10 MGD scenario is 1.1, the concentration factor for the 20 MGD scenario is 1.2, and the 30 MGD is 1.3. These concentration factors were applied to all of the parameters at the 90th percentile values to determine an expected increase in concentration of the constituent due to the operation of the demineralization plant. It should be noted that this provides a worst-case potential concentration as the demineralization plants have the potential to remove some of the constituents through pre-treatment, but the level of this removal would need to be defined through pilot testing. For this level feasibility, this conservative estimate is made.

As seen in Table 10 with the results in Table 11, based on this analysis of the 90th percentile value of these relatively limited sample sizes, all of these metals are above the Class II and Class III marine standards. Based on the worst-case concentration expected from the demineralization facility, all parameters would exceed the Class II and Class III marine standards at this worst-case location (even at the baseline and 10 MGD scenarios). Some of these parameter values from the referenced data sets have been questioned by a peer reviewer and others as seeming to be unreasonably high. Therefore, any further consideration of desalination plant feasibility with respect to water quality impacts should include additional data collection for parameters of interest.

Table 11. Results of Water Quality Concentration Estimates near Power Plants
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Parameter	Units	90th Percentile Value	Concentrated Value for 10 MGD Scenario	Concentrated Value for 20 MGD Scenario	Concentrated Value for 30 MGD Scenario
Cadmium	Micrograms/L	10	11	12	13
Copper	Micrograms/L	50	55	60	65
Iron	Micrograms/L	390	429	468	507
Nickel	Micrograms/L	25	27.5	30	32.5
Zinc	Micrograms/L	340	374	408	442

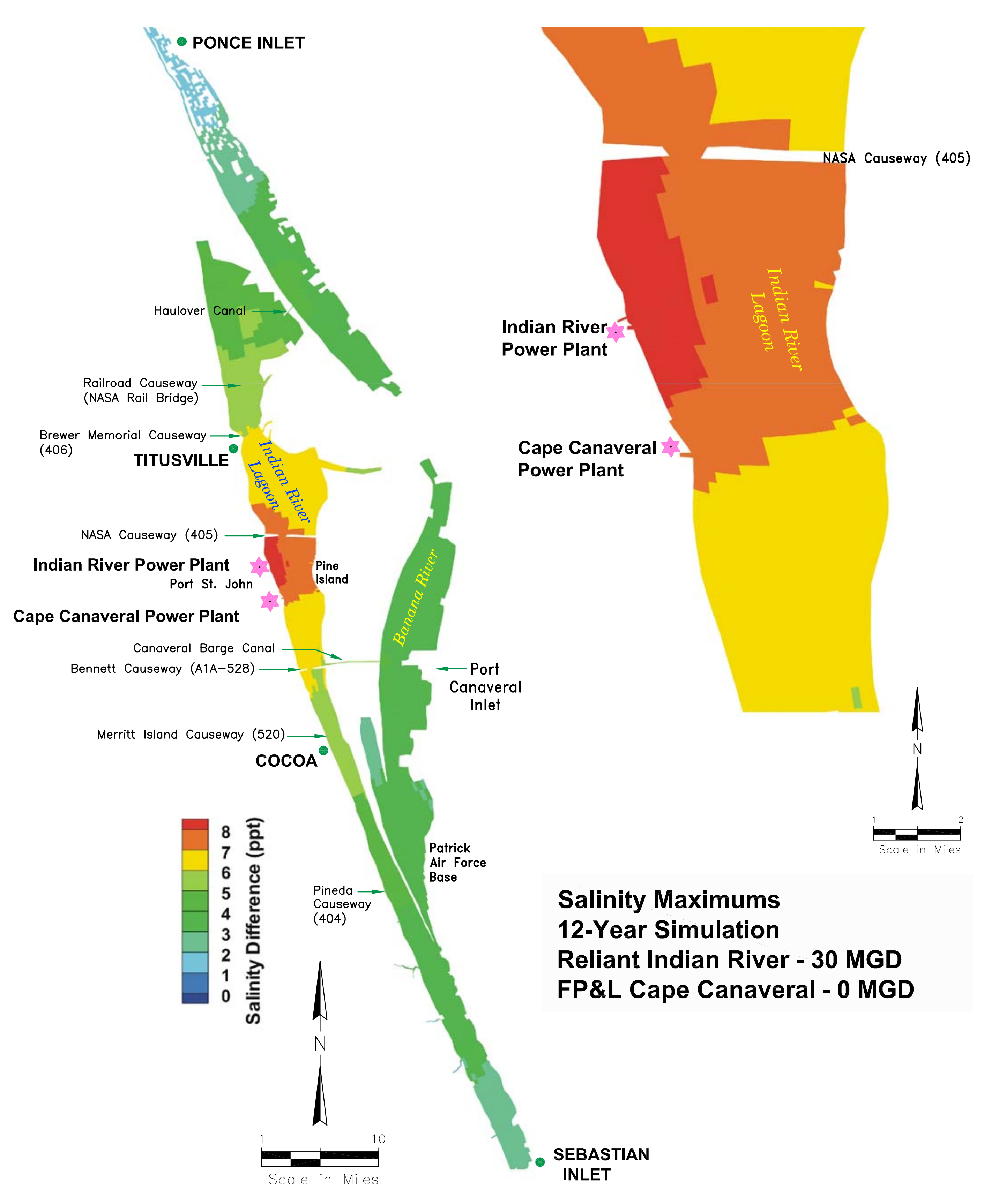
It is important to note that the water quality data for this set of available parameters are relatively limited with respect to sample size, age (1991-1998), and geographic coverage. For these reasons, the dataset presented above would not result in impaired waters following the FDEP IWR process. In addition, it is possible that the pre-treatment process of the demineralization facility would remove some of these pollutants from the treatment stream prior to being concentrated at the demineralization membranes. For these reasons, while the data indicate limited feasibility of the plants relative to water quality impacts, a strong recommendation regarding the feasibility of the demineralization facility cannot be made using this information, and it is recommended that additional pollutant data collection be a component of any future pilot study.

7.4 Physical Impacts Assessment

The primary physical impacts to the system from the proposed project are alterations to the salinity and the overall circulation in the system. The impacts to circulation are limited generally to long-term net flow and exchange between the North IRL and the adjacent water bodies, Mosquito Lagoon, Banana River, and the Indian River south of the Bennett Causeway. The water that is withdrawn from the system will eventually be made up from ocean water entering the inlets. In the ecological impacts section, analyses of the potential changes in temperature are presented but the results show insignificant change in the temperature regime due to the operation of the demineralization plants.

In Section 6, a mass balance test was conducted that quantified the changes in net exchange due to the operation of the demineralization plants. Table 7 presented the results. Examination of the results showed that the withdrawal of water from the North IRL due to the plants is made up through net flow from three locations, from Mosquito Lagoon through Haulover Canal, from the Banana River through the Barge Canal, and from the IRL south through Bennett Causeway. Based upon the magnitude of water withdrawal at the plants, the percents that come from each source vary. The flows from the north through Haulover Canal range from 32 to 51 percent, depending upon which plant is operating at which rate. The flows through the Barge Canal range from 36 to 42 percent of the total, and the flows from the south range from 12 to 30 percent of the total. While these values generally would not be significant in relation to tidal prism in an estuarine system, they are significant in the North IRL given the limited exchange. For example, while the flows through Haulover Canal on a daily basis are much greater than this, the long-term net average flow through the canal is on the order of 30 to 60 MGD. Therefore, the introduction of the net withdrawal from the plants has the potential to alter the long-term net exchange between Mosquito Lagoon and the North IRL.

Figures 38 through 46 present contour plots of the average and maximum salinity changes within the North IRL under a 30, 20, and 10 MGD water production rate at the Reliant plant. The data used to develop these plots were daily average simulated salinity. The plots present the bottom salinities and, therefore, represent the highest salinities expected at any location, although there is limited stratification in the system. The maximums presented are for the entire 12-year period, while the averages are based upon the final 4 years, when the system has reached a dynamic equilibrium. Additionally, for each scenario the acreages of bottom salinity where changes are greater than 1 ppt, 3 ppt, and 5 ppt are presented over time for the full 12-year simulation period. Appendix J provides plots of the salinity changes under varying production rates for the remaining scenarios along with plots of the baseline salinity conditions. In comparing the acreage changes in the model it should be noted that the total model area excluding the offshore zones is 228,730 acres.



04948–TM2G–Fig 1.dwg Figure 38 6/6/06

Figure 38
Maximum salinity increases over baseline for the 30 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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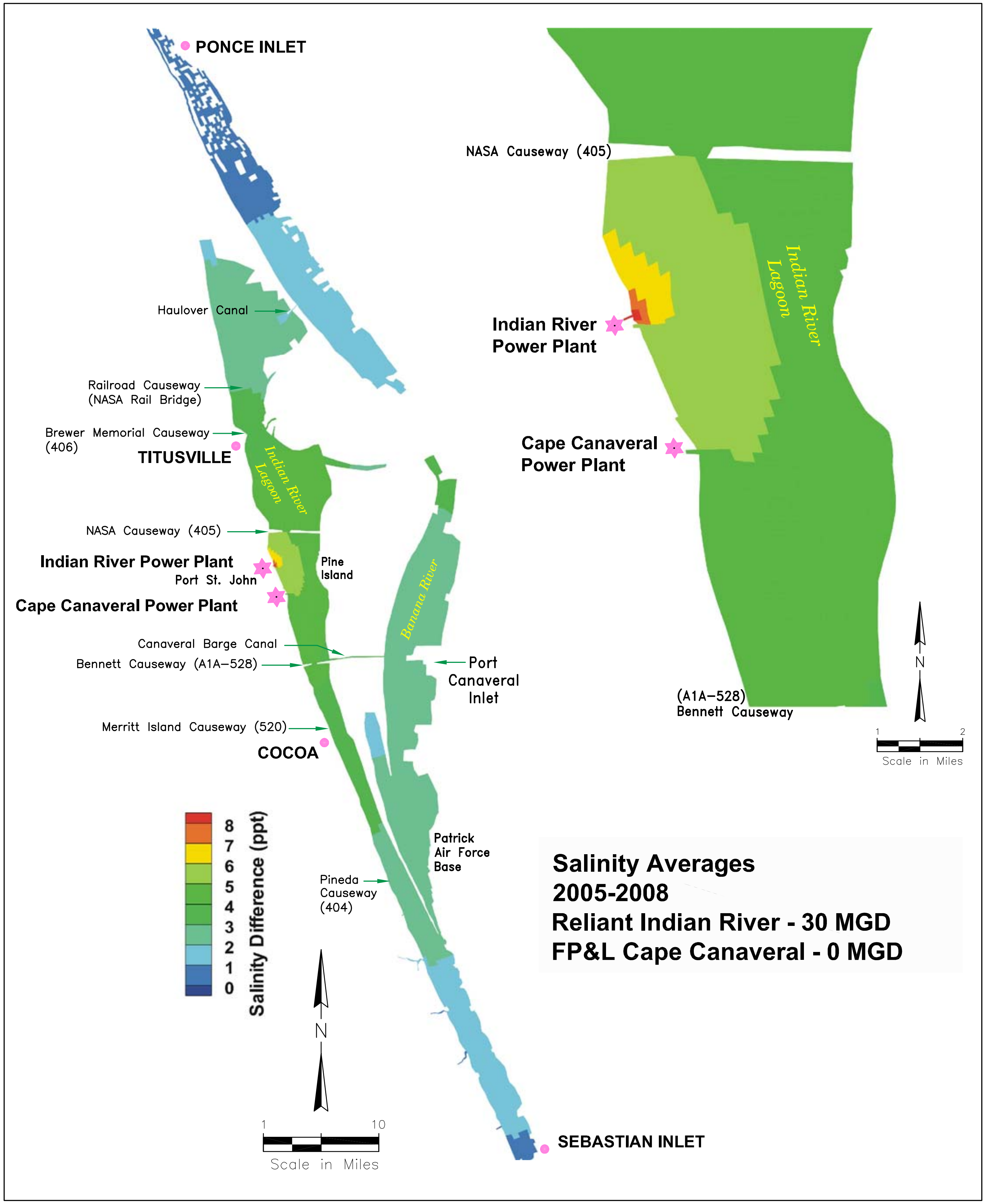

04948–TM2G–Fig 1.dwg Figure 39 6/6/06

Figure 39
Average salinity increases for years 9 through 12
for the 30 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization
Concentrate Discharge to the Indian River Lagoon

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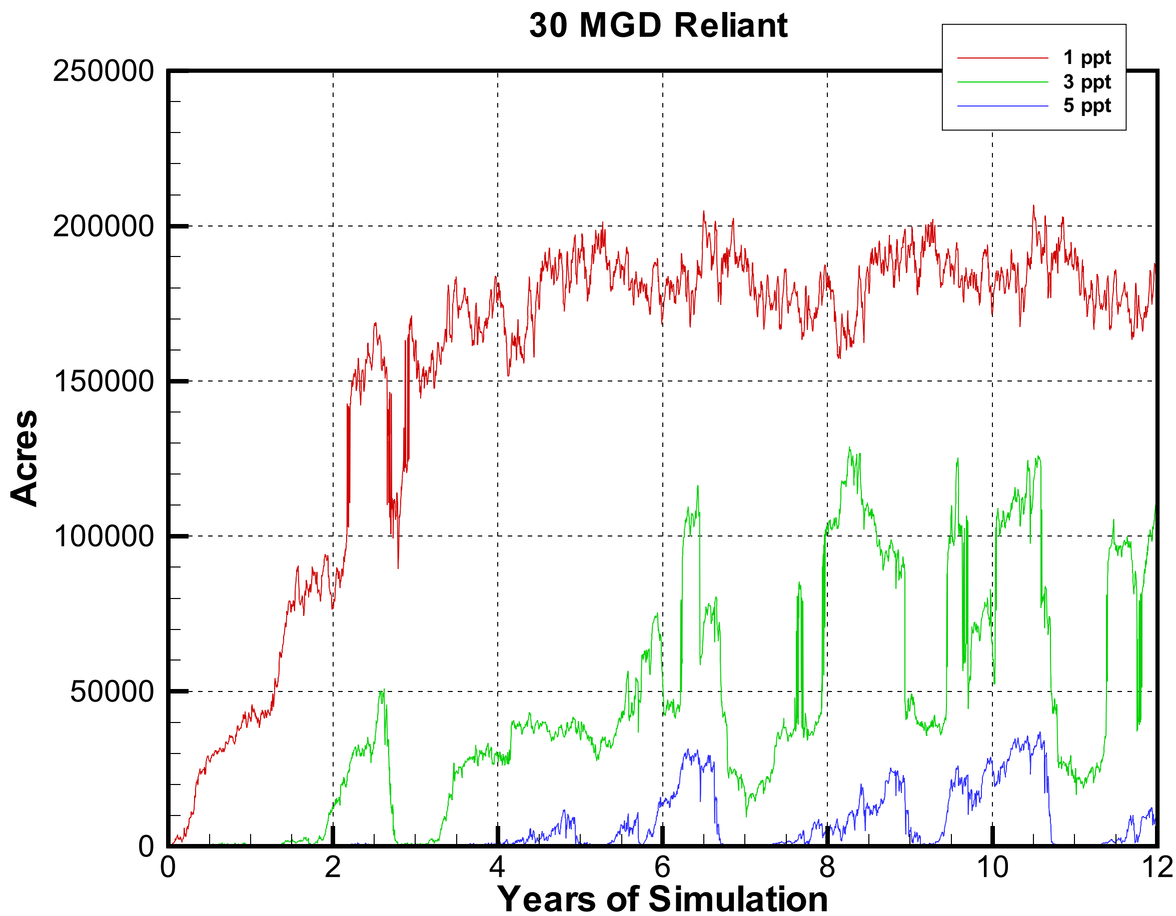

Figure 40
Acreages of salinity increases greater than 1, 3, and 5 ppt vs. time for the 12-year simulation period (30 MGD-Reliant scenario)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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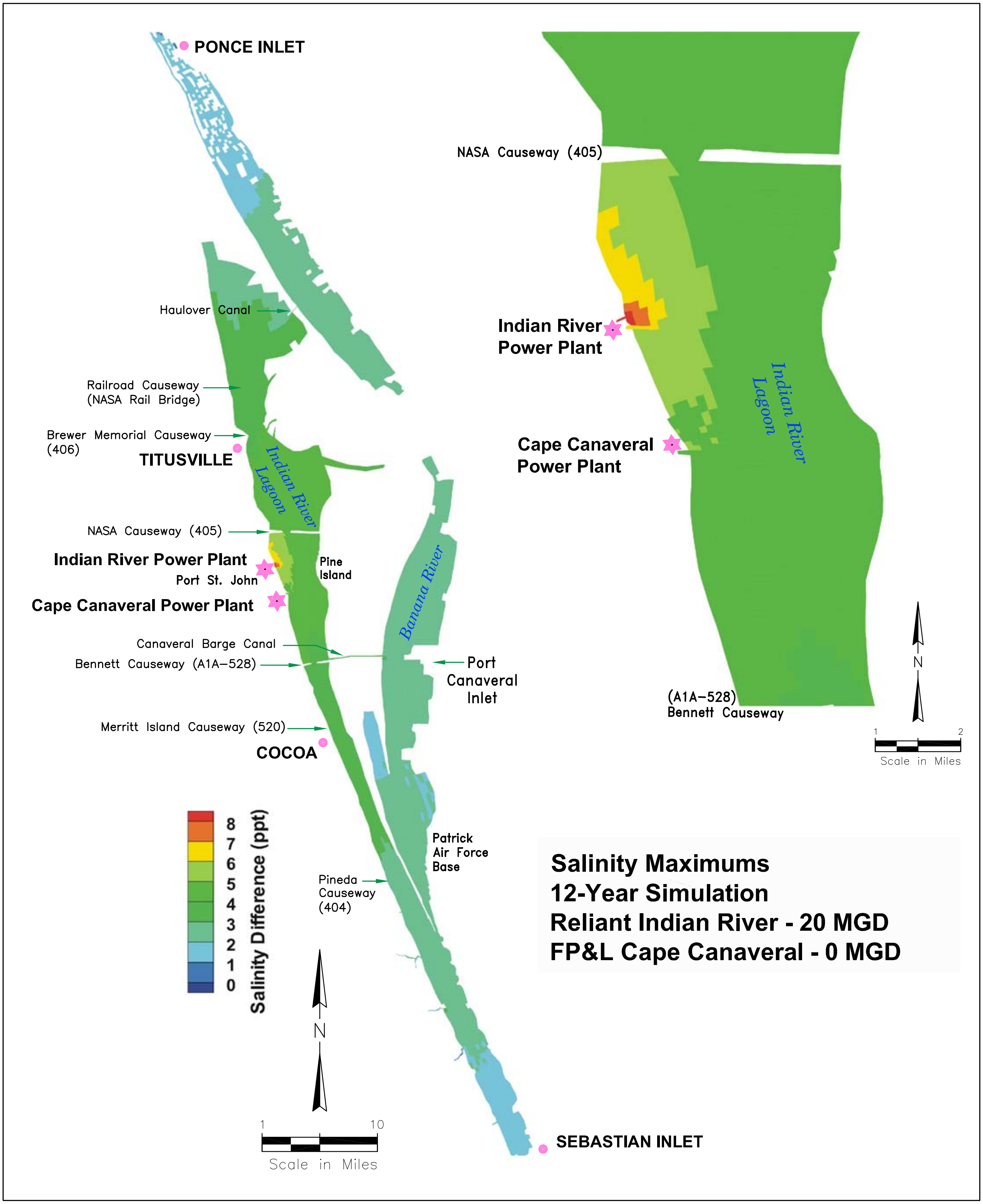

04948–TM2G–Fig 1.dwg Figure 41 6/6/06

Figure 41
Maximum salinity increases over baseline for
the 20 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization
Concentrate Discharge to the Indian River Lagoon

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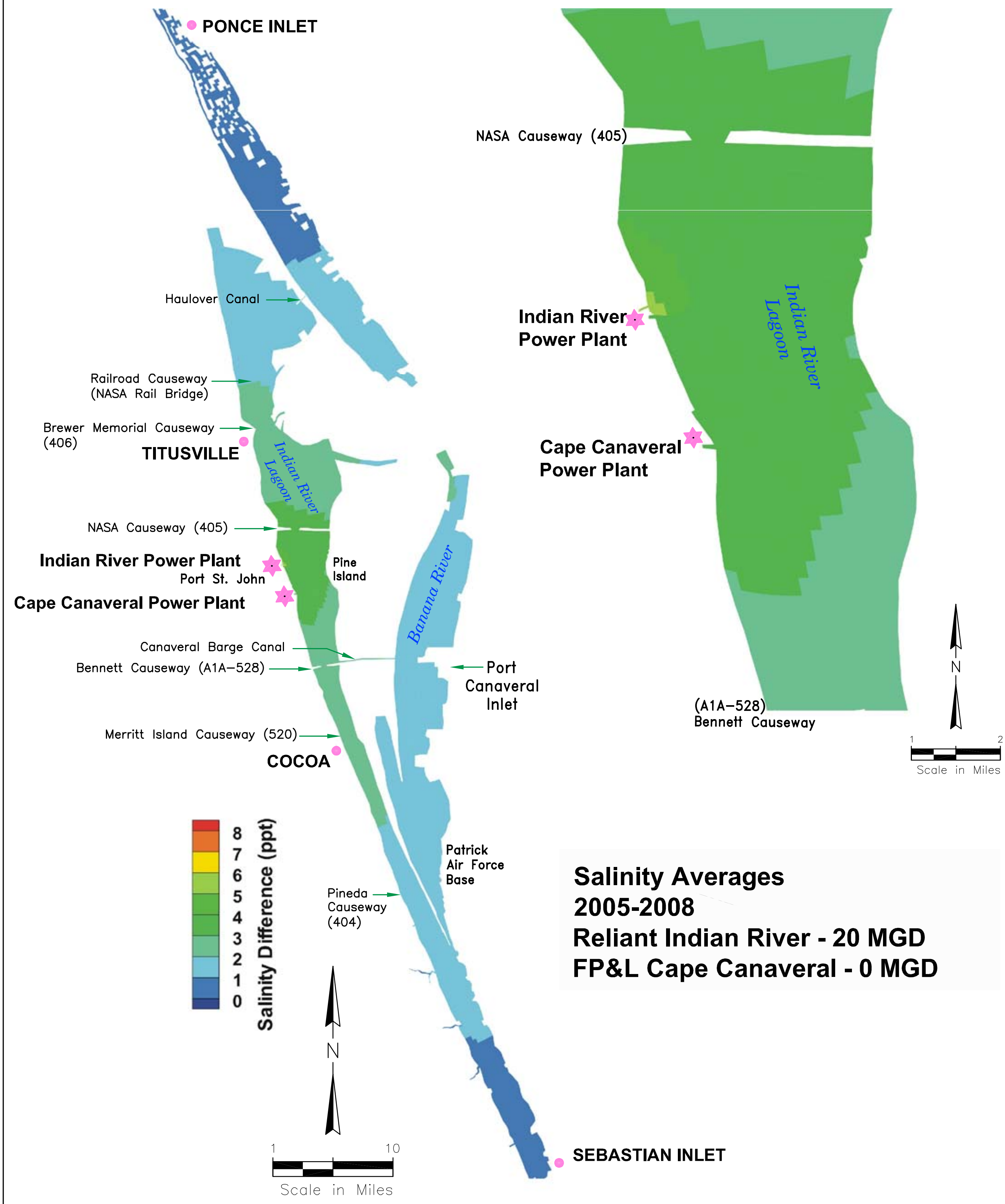

04948–TM2G–Fig 1.dwg Figure 42 6/6/06

Figure 42
Average salinity increases for years 9 through 12
for the 20 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization
Concentrate Discharge to the Indian River Lagoon

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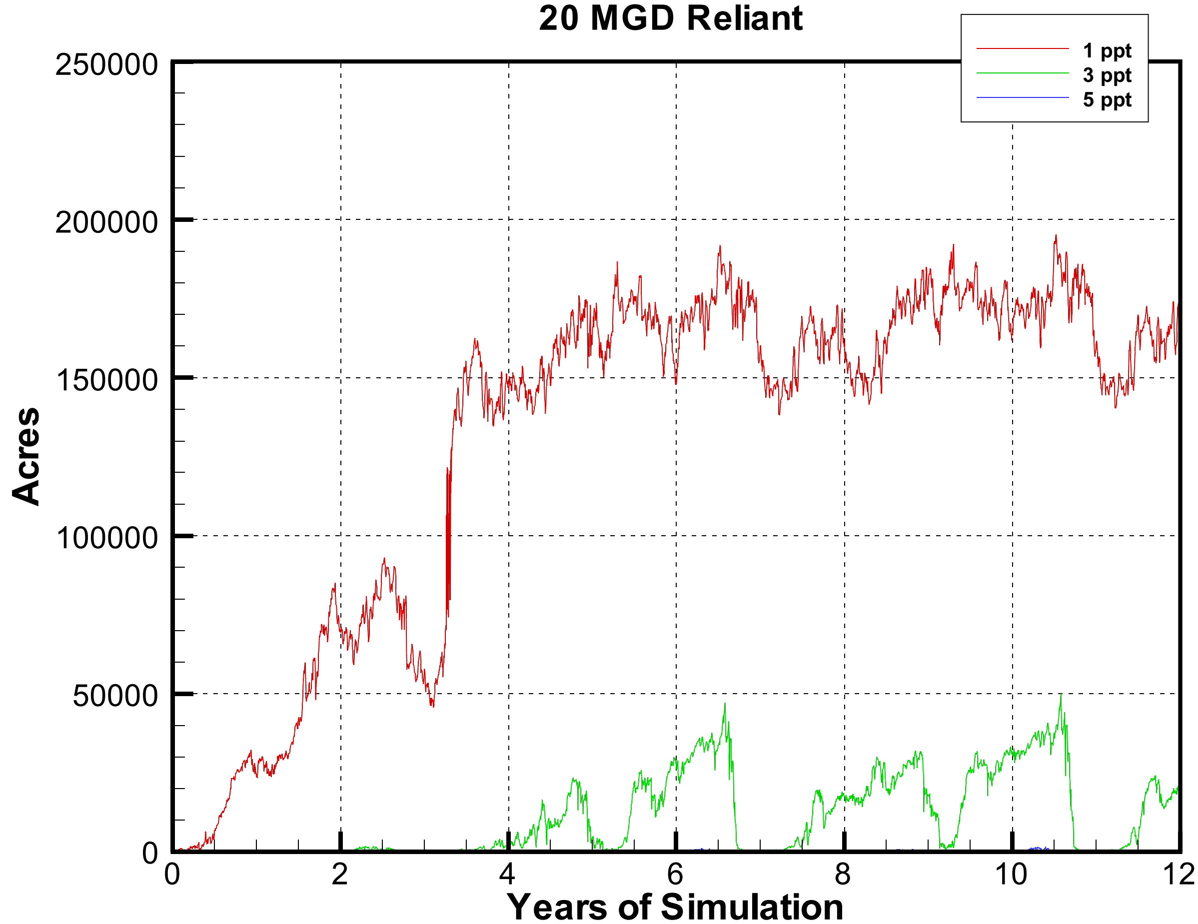

04948 TechMemo 2G Fig 43 6/30/06

Figure 43
Acreages of salinity increases greater than 1, 3, and 5 ppt vs. time for 12-year simulation period (20 MGD-Reliant scenario)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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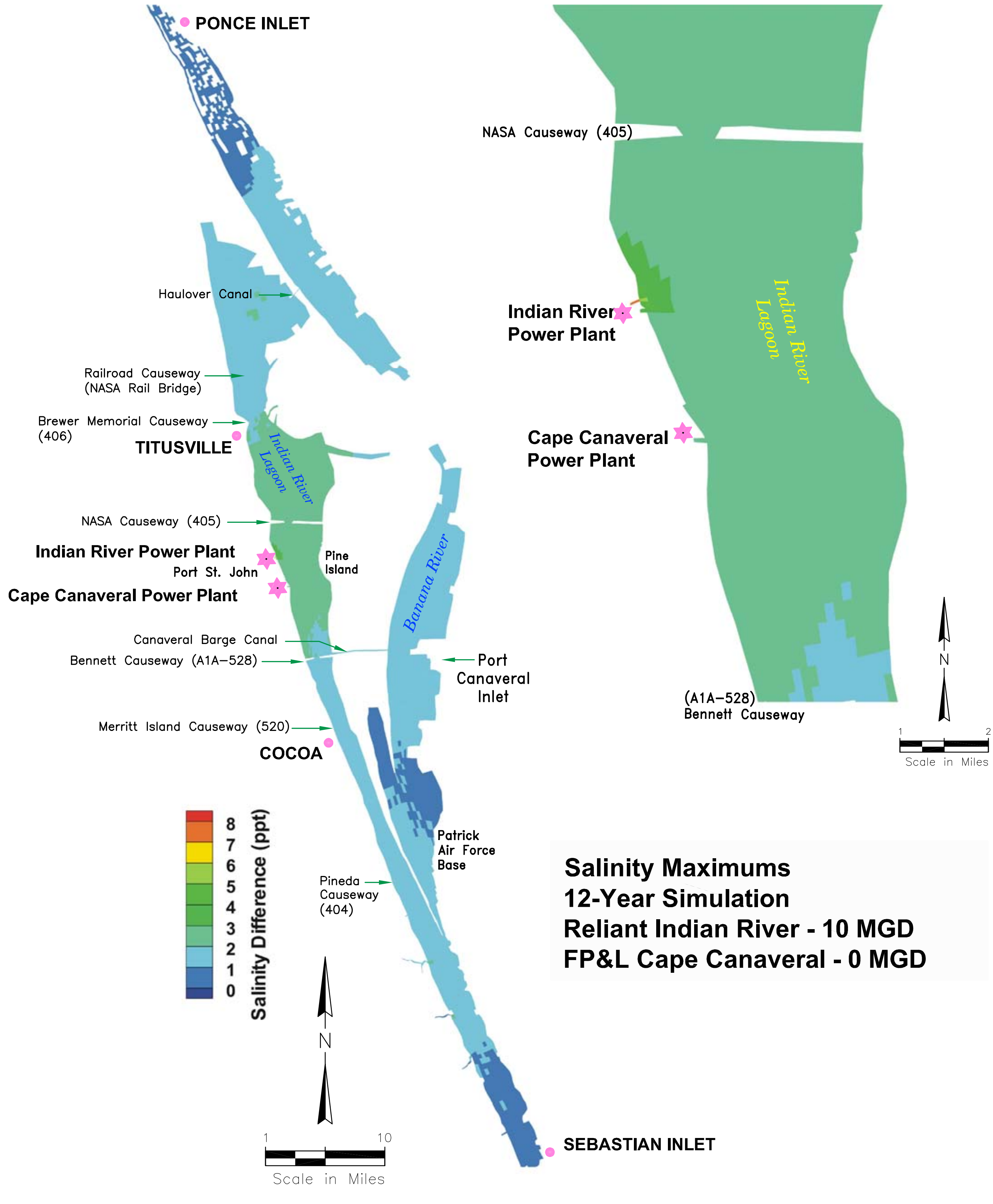

04948–TM2G–Fig 1.dwg Figure 44 6/6/06

Figure 44
Maximum salinity increases over baseline for the 10 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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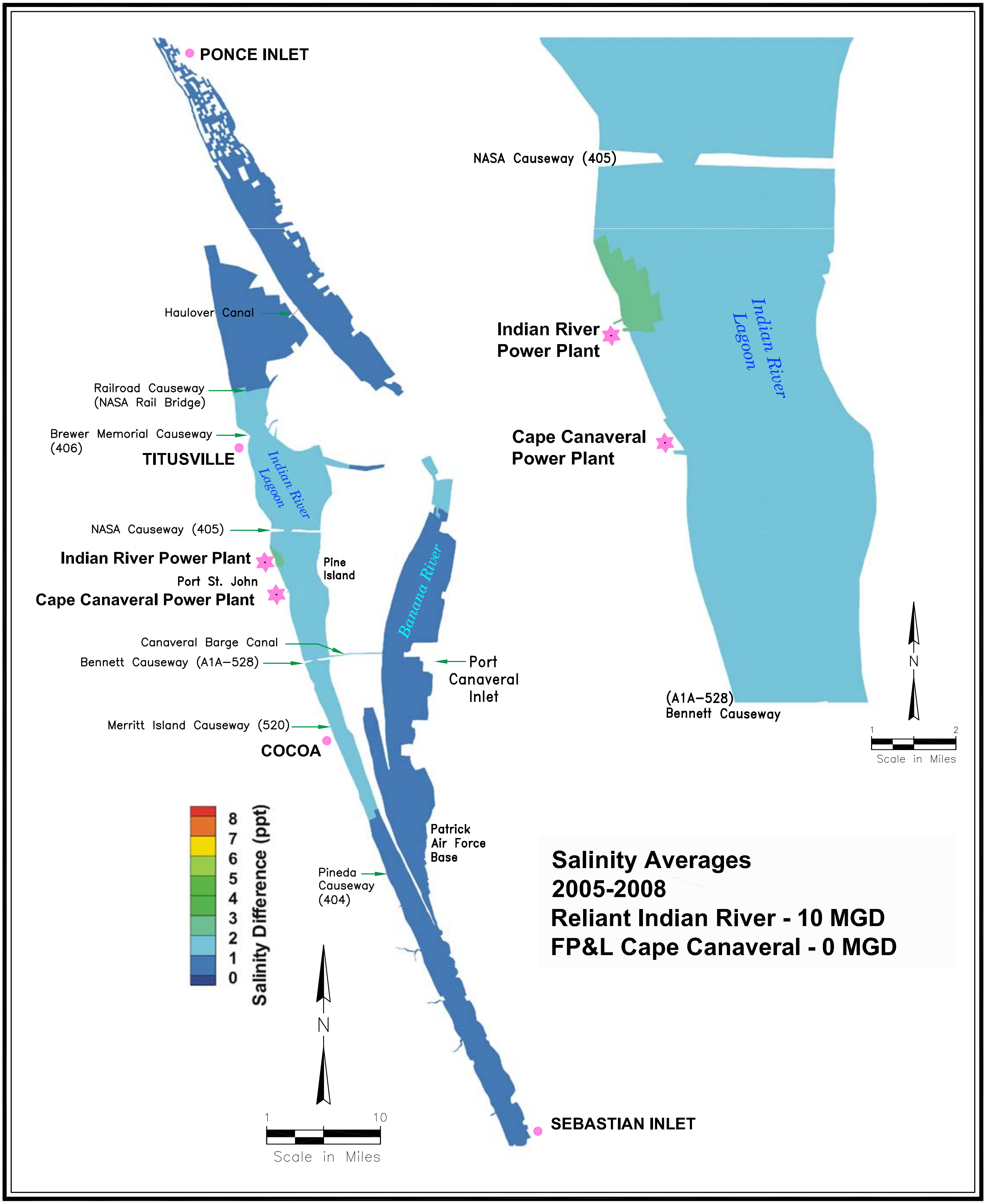

Figure 45
Average salinity increases for years 9 through 12
for the 10 MGD Reliant scenario
Evaluation of Potential Impacts of Demineralization
Concentrate Discharge to the Indian River Lagoon

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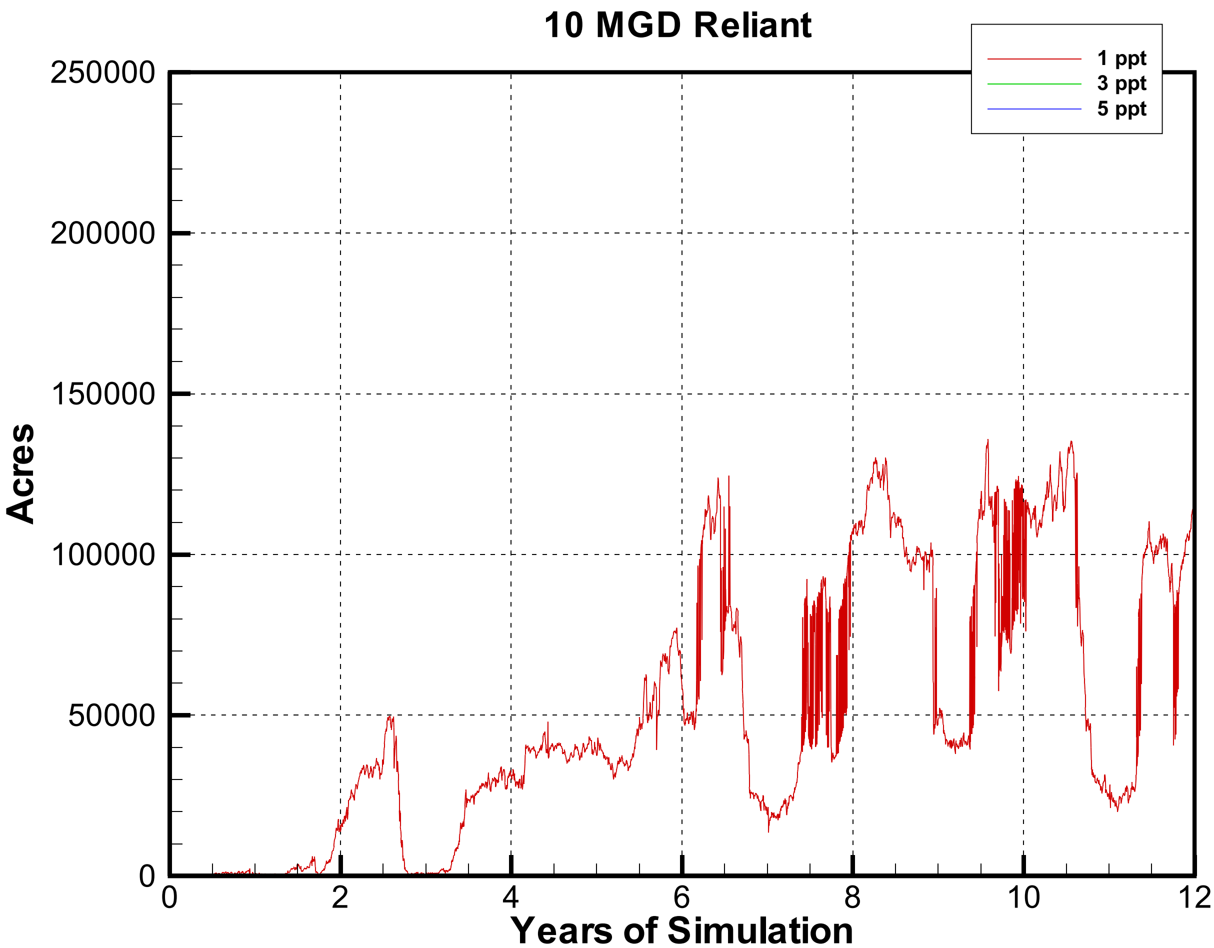

Figure 46
Acreages of salinity increases greater than 1, 3, and 5 ppt vs. time for 12-year simulation period (10 MGD-Reliant scenario)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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04948 TechMemo 2G Fig 46 6/30/06

Examination of the results for the 30 MGD scenario show significant levels of salinity change in the system. Maximum salinity changes near the Reliant plant are greater than 8 ppt, with maximum salinity changes greater than 6 ppt extending to the Titusville and Melbourne Causeways. Significant salinity changes are felt throughout the system, including in Mosquito Lagoon and the Banana River. Averages for the salinity changes over the final 4 years of the simulation show levels greater than 2 to 3 ppt extending throughout the North IRL and into the Banana River. Examination of the acreages greater than 1 ppt, 3 ppt and 5 ppt show that the influence of the plant operations at 30 MGD production rate impact a large area in the system. This area varies over time, with the greatest impact in the case of the changes greater than 3 and 5 ppt being seen during the dry weather periods. Total acres impacted above 1 ppt are upwards of 200,000 acres, while total acres above 3 ppt are upwards of 120,000.

Examination of the results for the 20 MGD scenario also show significant levels of salinity change in the system. Maximum salinity changes near the Reliant plant are also greater than 8 ppt but much more localized to near the plant. Between the Titusville and Melbourne Causeways, the maximum salinity changes are around 4 ppt. As with the 30 MGD scenario, significant salinity changes are felt throughout the system, including in Mosquito Lagoon and the Banana River. Averages for the salinity changes over the final 4 years of the simulation show levels greater than 2 to 3 ppt extending throughout the North IRL and into the Banana River. Examination of the acreages greater than 1 ppt, 3 ppt and 5 ppt show that the influence of the plant operations at the 20 MGD production rate impact a large area in the system. The area above 5 ppt is much smaller, with maximum acreage impacts on the order of 1,500 for the 5 ppt level. Total acres impacted above 1 ppt are upwards of 170,000 acres, while total acres above 3 ppt are near 50,000.

Examination of the results for the 10 MGD scenario show salinity changes ranging as high at 3 to 4 ppt, but these changes are isolated to the immediate area of the discharge. Changes greater than 4 ppt are only seen within the discharge canal. Maximum salinity changes of 2 ppt extend out to the Melbourne and Titusville Causeways, with all areas outside of these causeways showing less than 2 ppt changes. Changes between 1 and 2 ppt extend out to all of the North IRL, including within Mosquito Lagoon and Banana River. Average salinity changes are all generally less than 2 ppt, except in the immediate vicinity of the discharge. Average salinity changes over the final 4 years between 1 and 2 ppt do extend above the Titusville Causeway and well below the Melbourne Causeway. Acres of salinity change above 1 ppt range up to near 130,000 acres during low flow periods.

7.5 Ecological Impacts Assessment

The expected environmental conditions resulting from the baseline, 10 MGD, 20 MGD, and 30 MGD Reliant demineralization facility scenarios were compared to ecological requirements in the study area to assess potential ecological impacts.

The overall objective of this assessment was to use available IRL specific biological data to:

- compare the variation in expected ecological response for each scenario to the variation in the response for the baseline scenario within the context of the natural inter-annual and intra-annual variation.

The methods for the ecological impact assessment were described in Section 5.

Among the biological resources of concern are those organisms and life stages that may be responsive to direct and indirect effects of the concentrate discharge, and those that may be relatively non-responsive to the concentrate discharge. Thus, the most responsive organisms and life stages may provide sentinels as proxy for the complete set of biological resources. In particular, organisms that would be expected to be the first responders to changes related to the concentrate discharge would include sessile organisms and organisms with relatively low mobility such as seagrasses and seagrass associated early life history stages of fishes (e.g., red drum).

7.5.1 Potential Stratification Regime Change Impacts

Using the conservative definition of stratification described previously as a change in sigma t value of greater than 1.0, no stratification was observed in the hydrodynamic model output for the baseline, 10 MGD, 20 MGD, or 30 MGD scenarios. The greatest sigma t values reported were 0.7 for the baseline period, 0.8 for the 10 MGD scenario, 0.7 for the 20 MGD scenario, and 0.7 for the 30 MGD scenario. These higher sigma t values were typically estimated during the mid-summer (e.g., August) time of year. These values indicated that the waters of the relatively shallow study area were well mixed for the time conditions modeled.

Overall, the median sigma t values were 0.00 for all four scenarios. This indicated that the waters were very well mixed for most of the locations and time periods estimated by the hydrodynamic model.

Since no stratification was observed for the modeled time period, the spatial and temporal changes from baseline conditions were not quantitatively assessed.

7.5.2 Potential Temperature Regime Change Impacts

Temperature regime changes due to the operation of the demineralization facility (and collocated power plant) were observed to be very minimal for the study area during the years modeled. The only relevant temperature change was a slight 0.5 median °C reduction in temperature at the bottom near the facility discharge point (Reference Site 1c, Figure 47). No relevant changes in temperature were observed away from the discharge point or in the aquatic preserve reference sites. Data Attachment H presents the complete statistical distribution of bottom temperature changes at each of the 22 reference sites. Data Attachment I presents the same information for surface temperature.

04948 TechMemo 2G Fig 47 6/30/06

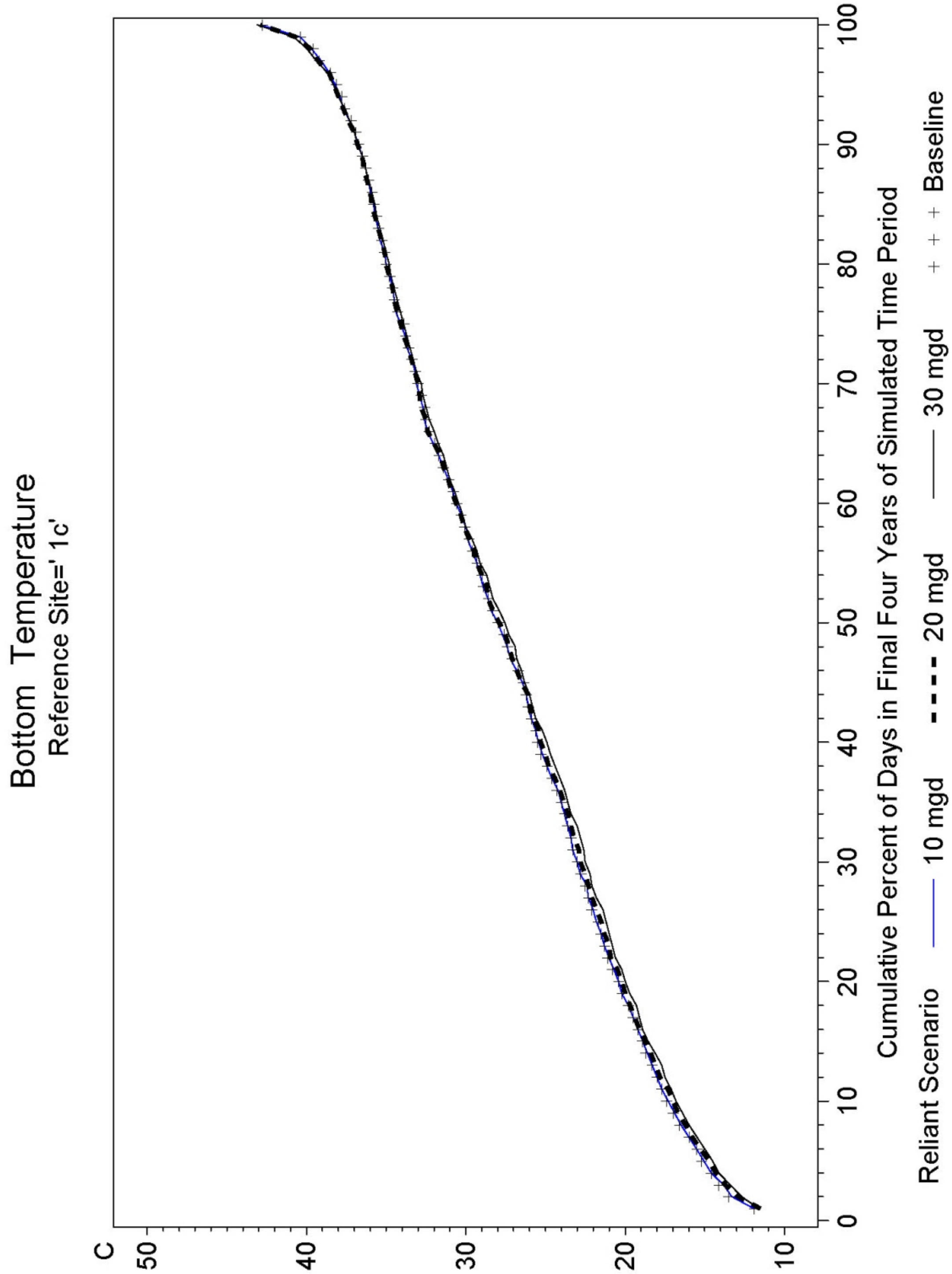

Figure 47
Temporal variation in bottom temperature at reference site 1c.
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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This temperature change is most relevant to the Florida Manatee (*Trichechus manatus latirostris*), which uses the habitats near the power plant discharge points as thermal refuges in the colder winter months. Aside from boating injury or death, the next most significant mortality factor for manatees is related to the long-term availability of warm water refuges (USFWS 2001). Cold-associated deaths may occur due to hypothermia, or other cold-related illness, or as a result of manatees not eating properly during long-term exposure to the cold (Worthy 2000; Van Meter 1989). The lower temperature refuge threshold of 20°C was observed less than 20 percent of the time in the baseline condition (Figure 47), and the change in temperature between the baseline and the greatest potential impact tested 30 MGD scenario was also very small (i.e., less than 0.5°C) at this lower temperature range.

7.5.3 Potential Salinity Regime Change Impacts

Clearly, the greatest expected physical impacts of the demineralization facility operations were salinity changes. The spatial extent and magnitude of the physical changes in salinity regimes were quantified in Section 7.4. With respect to potential ecological effects of the expected salinity changes, an extensive analysis was conducted for the biological resources of concern where salinity preference information were available or modeled as described above and in Sections 2 and 5.

It is important to note that the living resources of the study area are biologically adapted to dynamic estuarine conditions that result in relatively wide changes in salinity over time and space. Section 2.0 presented a characterization of the salinity variations and showed the variations statistically as a function of location within the North IRL. These fluctuations are primarily related to low frequency tidal cycles, wind driven circulation, and freshwater inflow. Thus, the salinity tolerances of these organisms are relatively broad. Because the organisms are adapted to a range of salinities, potential impacts of the demineralization facility were evaluated with respect to shifts in the distribution of salinity in the study area, or possibly a truncation of the distribution of salinity in the study area (e.g., an increase in the periodically occurring lowest salinity values).

7.5.3.1 Seagrass

The species of seagrass in the study area are all well adapted to the wide ranging salinity conditions found in estuaries and lagoons. Currently, the primary seagrass species near the potential demineralization facilities is *Halodule wrightii* (SJRWMD unpublished data 2005). Between 1990 and 1999, data showed that the two prime seagrass species in the immediate project area were *Halodule wrightii*, followed by *Ruppia maritima*. Over the next several years (2001-2003), *Ruppia* was replaced by *Halophila engelmannii*, making *Halodule wrightii* and *Halophila* the dominant. The most recent shift in dominance, as observed in data from 2004, show neither *Ruppia* or *Halophila* present in the area, leaving *Halodule* as the only persistent species (SJRWMD unpublished data 2005).

It is expected that salinity may be one of the ecological factors that influences species composition and distribution in the study area. Other important ecological factors include water clarity, depth, sediment compositions, and epiphyte loads.

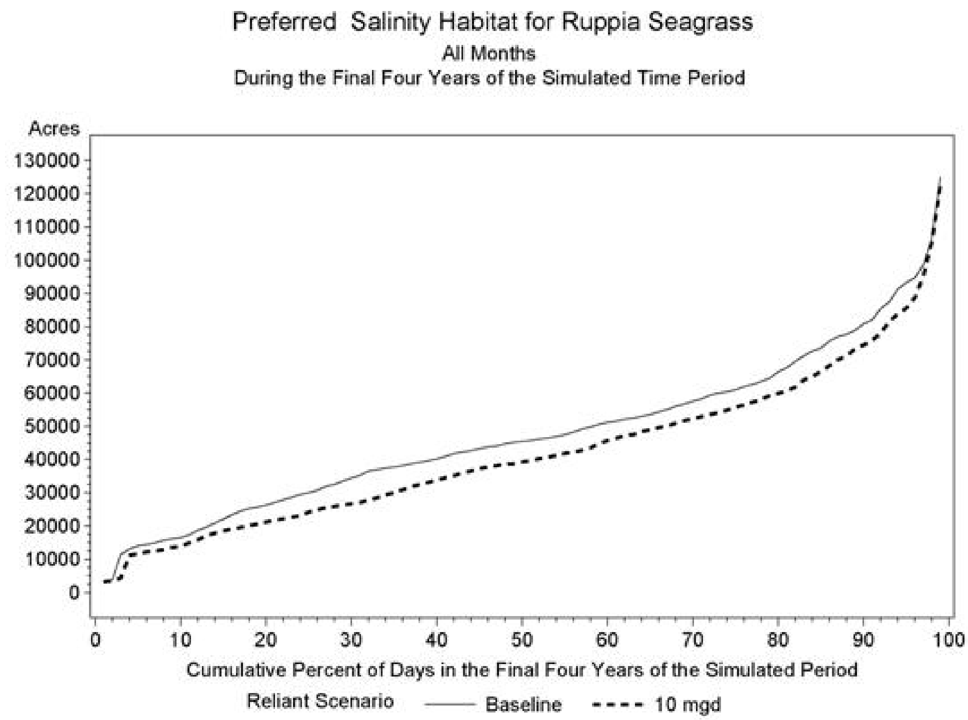
With respect to spatial and temporal variation of the extent of preferred habitat, one of the seagrass species of interest (*Ruppia*) was observed to be most at risk for a potential impact from the demineralization facility operation. This seagrass has a preferred salinity range of less than 25 ppt. The extent of available *Ruppia* habitat was estimated to be highly variable over time (Figure 48). The 10 MGD scenario was estimated to reduce the median extent of available preferred *Ruppia* habitat by 4,350 acres. In other words, the median number of acres over time of preferred habitat under the 10 MGD scenario was 4,350 acres less than the median number of acres over time under the baseline scenario. This estimate represents a 10.7 percent reduction in available preferred salinity habitat over the baseline condition (Table 12 and Figure 48). The 20 MGD scenario was estimated to reduce the median extent of available preferred *Ruppia* habitat by 8,650 acres. This estimate represents a 19.7 percent reduction in available preferred salinity habitat over the baseline condition (Table 13 and Figure 49). The 30 MGD scenario was estimated to result in a 13,150 acre (29.8 percent) reduction in available preferred habitat (Table 14 and Figure 50).

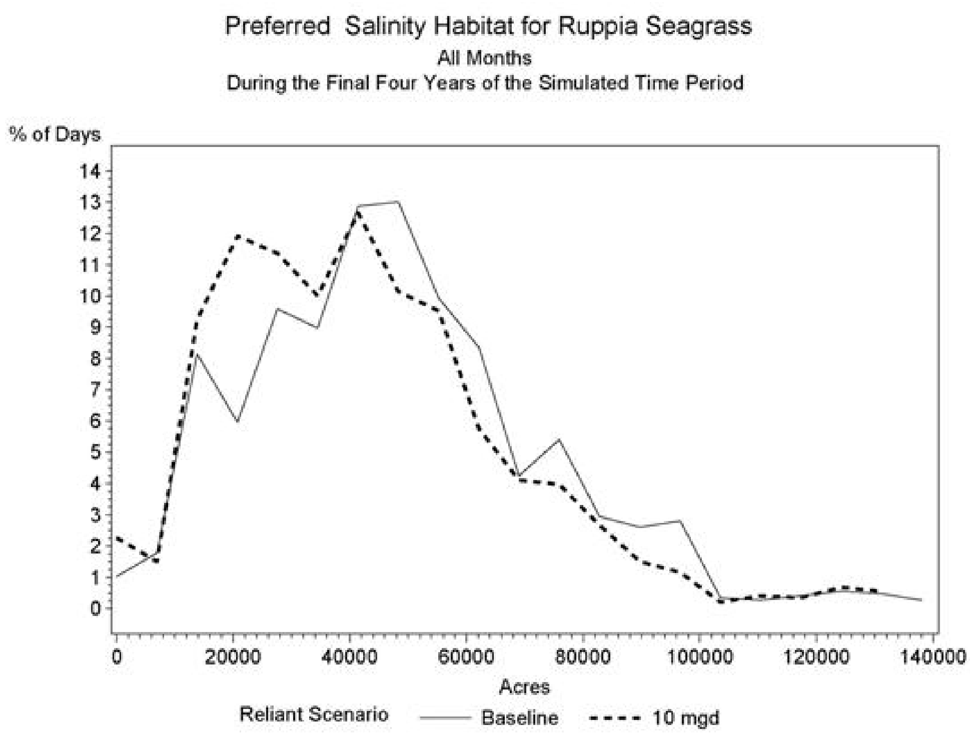
Syringodium has a preferred salinity range of 20 to 28 ppt. *Syringodium* was estimated to have a 2,400-acre (4.8 percent) reduction in available preferred habitat under the 10 MGD scenario, a 7,050-acre (13.4 percent) reduction in available preferred habitat under the 20 MGD scenario, and a 21,200-acre (21.1 percent) reduction in available preferred habitat under the 30 MGD scenario. *Halodule* has a preferred salinity range of 22 to 34 ppt, and *Halophila* (translated to "*salt loving*") has a preferred salinity range of 29 to 31 ppt. These species were estimated to be less impacted by the demineralization scenarios. *Halodule* was estimated to have a 450-acre (0.5 percent) reduction in available preferred habitat under the 10 MGD scenario, a 2,850-acre (3.5 percent) reduction under the 20 MGD scenario, and a 4,600-acre (5.6 percent) reduction under the 30 MGD scenario. *Halophila* was estimated to have a 400-acre (3.13 percent) increase in available preferred habitat under the 10 MGD scenario, a 50-acre (0.3 percent) increase in available preferred habitat under the 20 MGD scenario, and a 1,100-acre (8.3 percent) increase in available preferred habitat under the 30 MGD scenario.

With respect to reference sites, the potentially most affected site, Site 1a (a site with current patchy seagrass existence), would only rarely (less than 20 percent of the time) be expected to have preferred *Ruppia* salinity habitat (<25 ppt) under the baseline condition. Data Attachment C presents the complete set of statistical distributions of salinity responses at the reference sites. Site 1a would be expected to support the preferred *Halodule* and *Halophila* habitat almost all of the time under the baseline condition, most of the time under the 10 MGD scenario, and less than 30 percent of the time under the 30 MGD scenario.

Table 12. Expected changes in preferred habitat availability from the Baseline Scenario to the 10 MGD Reliant Scenario. Results are season specific.

Season	Taxon	Preferred Salinity Range (ppt)	Expected Change in Preferred Habitat Acres (%)	Sample Size Occurrences of Samples (%)
All Months	*Ruppia* seagrass	0-25	-4,350 (-10.7%)	Not Applicable
	Benthos Group B	0-25	-6,950 (-9.6%)	Not Applicable
	Benthos Group C	0-21	-3,550 (-8.7%)	Not Applicable
	Benthos Group A	0-28	-5,850 (-6.3%)	Not Applicable
	Syringodium Seagrass	20-28	-2,400 (-4.8%)	Not Applicable
	Oyster	10-30	-5,100 (-4.6%)	Not Applicable
	Hard Clam	21-30	-1,850 (-2.1%)	Not Applicable
	Halodule Seagrass	22-34	-450 (-0.5%)	Not Applicable
	*Halophila S*eagrass	29-31	+400 (+ 3.1%)	Not Applicable
January to March				
	Menidia spp.	10.0-25.2	-3950 (-13.6%)	485 of 2522 (19%)
	Sheepshead minnow (*Cyprinodon variegatus*)	10.0-17.2	-650 (-10.5%)	131 of 2522 (5%)
	Clown goby (*Microgobius gulosus*)	10.0-20.4	-1800 (-9.9%)	372 of 2522 (15%)
April to June				
	Atlantic stingray (*Dasyatis sabina*)	16.0-23.0	-5300 (-16%)	783 of 5100 (15%)
	Southern kingfish (*Menticirrhus americanus*)	14.8-26.4	-2200 (-9.4%)	404 of 5100 (8%)
	Lined sole (*Achirus lineatus*)	17.2-32.8	-1150 (-3.1%)	449 of 5100 (9%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.8-31.0	-300 (-0.6%)	42 of 5100 (1%)
July to September				
	Hardhead catfish (*Arius felis*)	12.0-29.4	-6950 (-6.6%)	628 of 2149 (29%)
	Ladyfish (*Elops saurus*)	10.0-18.4	-200 (-6.2%)	368 of 2149 (17%)
	Atlantic stingray (*Dasyatis sabina*)	14.0-31.4	-3650 (-3.0%)	475 of 2149 (22%)
	Silver perch (*Bairdiella chrysoura*)	20.0-35.2	-3250 (-1.8%)	561 of 2149 (26%)
	Code goby (*Gobiosoma robustum*)	17.6-38.0	-2500 (-1.4%)	546 of 2149 (25%)
	Lined sole (*Achirus lineatus*)	18.4-33.0	-400 (-0.9%)	245 of 2149 (11%)
	Striped burrfish (*Chilomycterus schoepfi*)	19.0-33.4	-400 (-0.9%)	228 of 2149 (11%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.4-30.2	+400 (+1.3%)	79 of 2149 (4%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.0-30.2	+1300 (+3.9%)	33 of 2149 (2%)
October to December				
	Red drum (*Sciaenops ocellatus*)	10.0-13.0	-250 (-9.5%)	601 of 5561 (11%)
	Ladyfish (*Elops saurus*)	10.0-14.2	-250 (-7.7%)	494 of 5561 (9%)
	Bay anchovy (*Anchoa mitchilli*)	10.0-24.2	-6050 (-7.4%)	1556 of 5561 (28%)
	White mullet (*Mugil curema*)	10.0-17.2	-650 (-7.1%)	846 of 5561 (15%)
	Brown shrimp (*Farfantepenaeus aztecus*)	10.0-14.8	-150 (-5.7%)	21 of 5561 (<1%)
	Atlantic weakfish (*Cynoscion regalis*)	16.0-26.6	-1550 (-5.4%)	116 of 5561 (2%)
	Menidia spp.	10.0-30.4	-3250 (-4.2%)	932 of 5561 (17%)
	Southern kingfish (*Menticirrhus americanus*)	15.8-28.6	-950 (-2.7%)	741 of 5561 (13%)
	Lined sole (*Achirus lineatus*)	15.2-32.2	-100 (-0.2%)	675 of 5561 (12%)
	Southern puffer (*Sphoeroides nephelus*)	15.6-31.2	-100 (-0.2%)	591 of 5561 (11%)
	Silver perch (*Bairdiella chrysoura*)	18.0-40.0	+1450 (+0.7%)	1088 of 5561 (20%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.0-37.2	+2800 (+8.5%)	372 of 5561 (7%)





Upper panel is presented as cumulative percent of days.
Lower panel is presented as percent of days.

04948 TechMemo 2G Fig 48 6/30/06

Figure 48
Comparison of preferred salinity habitat for *Ruppia* seagrass between the baseline scenario and 10 MGD scenario
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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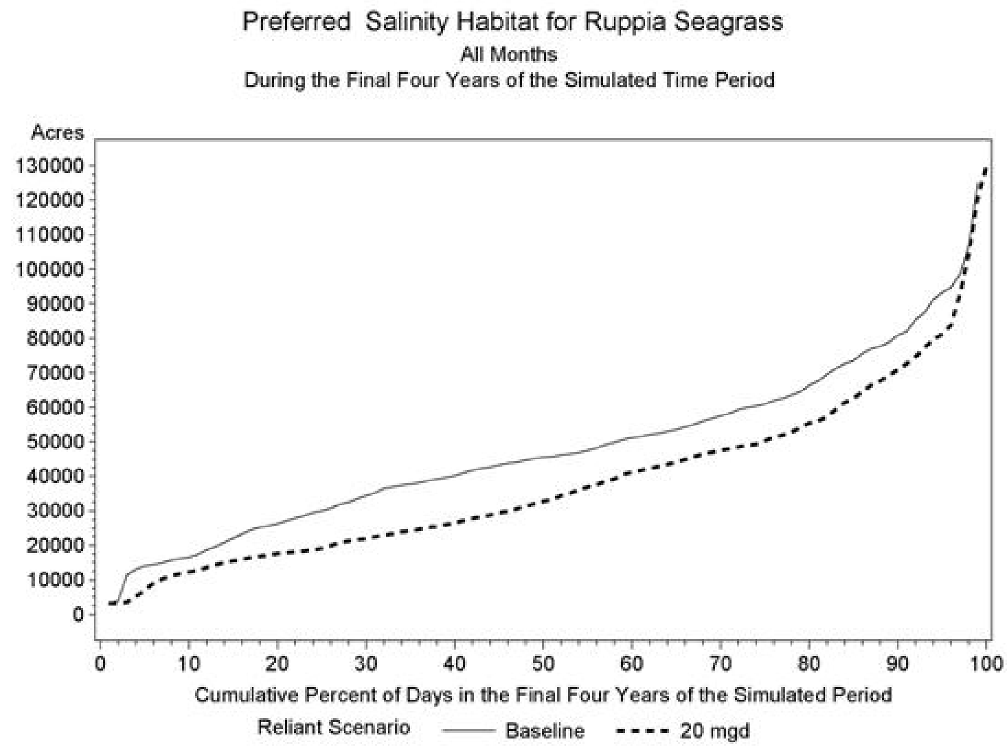
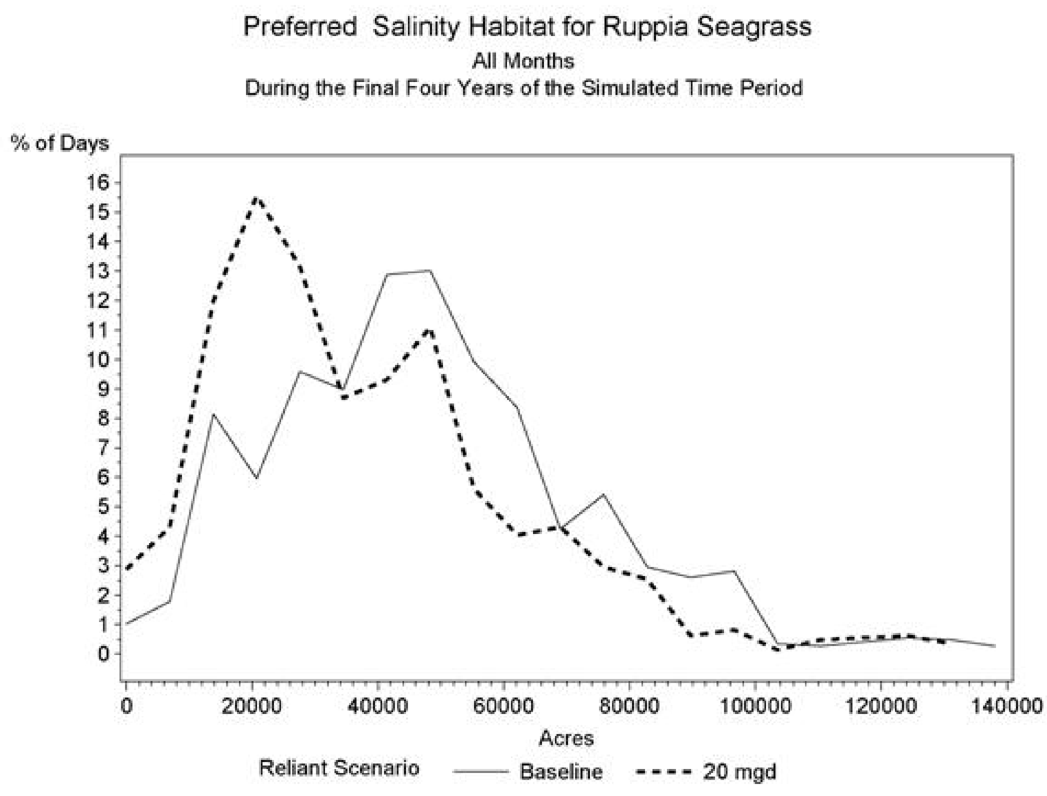
Table 13 Expected changes in preferred habitat availability from the Baseline Scenario to the 20 MGD Reliant Scenario. Results are season specific.

Season	Taxon	Preferred Salinity Range (ppt)	Expected Change in Preferred Habitat Acres (%)	Sample Size Occurrences of Samples (%)
All Months				
	Ruppia seagrass	0-25	-8,650 (-19.7%)	Not Applicable
	Benthos Group B	0-25	-14,350 (-18.1%)	Not Applicable
	Benthos Group C	0-21	-6,550 (16.6%)	Not Applicable
	Benthos Group A	0-28	-13,400 (-13.7%)	Not Applicable
	Syringodium Seagrass	20-28	-7,050 (-13.4%)	Not Applicable
	Oyster	10-30	-11,400 (10.5%)	Not Applicable
	Hard Clam	21-30	-4,900 (-5.7%)	Not Applicable
	Halodule Seagrass	22-34	-2,850 (-3.5%)	Not Applicable
	Halophila Seagrass	29-31	+50 (+0.3%)	Not Applicable
January to March				
	Menidia spp.	10.0-25.2	-7050 (-21.3%)	485 of 2522 (19%)
	Sheepshead minnow (*Cyprinodon variegatus*)	10.0-17.2	-1050 (-20.0%)	131 of 2522 (5%)
	Clown goby (*Microgobius gulosus*)	10.0-20.4	-4600 (-26.9%)	372 of 2522 (15%)
April to June				
	Atlantic stingray (*Dasyatis sabina*)	16.0-23.0	-10950 (-31.6%)	783 of 5100 (15%)
	Southern kingfish (*Menticirrhus americanus*)	14.8-26.4	-4600 (-19.4%)	404 of 5100 (8%)
	Lined sole (*Achirus lineatus*)	17.2-32.8	-2850 (-8.2%)	449 of 5100 (9%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.8-31.0	-1600 (-5.5%)	42 of 5100 (1%)
	Ladyfish (*Elops saurus*)	10.0-12.0	<1 (<1%)	493 of 5100 (10%)
July to September				
	Hardhead catfish (*Arius felis*)	12.0-29.4	-14250 (-13.4%)	628 of 2149 (29%)
	Ladyfish (*Elops saurus*)	10.0-18.4	-400 (-12.8%)	368 of 2149 (17%)
	Atlantic stingray (*Dasyatis sabina*)	14.0-31.4	-12250 (-8.9%)	475 of 2149 (22%)
	Silver perch (*Bairdiella chrysoura*)	20.0-35.2	-11300 (-6.4%)	561 of 2149 (26%)
	Code goby (*Gobiosoma robustum*)	17.6-38.0	-6300 (-3.2%)	546 of 2149 (25%)
	Lined sole (*Achirus lineatus*)	18.4-33.0	-1000 (-2.2%)	245 of 2149 (11%)
	Striped burrfish (*Chilomycterus schoepfi*)	19.0-33.4	-1000 (-2.2%)	228 of 2149 (11%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.4-30.2	350 (1.1%)	79 of 2149 (4%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.0-30.2	2500 (7.7%)	33 of 2149 (2%)
	Brevoortia spp.	10.0-13.4	-50 (-7.6%)	209 of 2149 (10%)
October to December				
	Red drum (*Sciaenops ocellatus*)	10.0-13.0	-450 (-20.6%)	601 of 5561 (11%)
	Ladyfish (*Elops saurus*)	10.0-14.2	-550 (-15.6%)	494 of 5561 (9%)
	Bay anchovy (*Anchoa mitchilli*)	10.0-24.2	-13450 (-15.3%)	1556 of 5561 (28%)
	White mullet (*Mugil curema*)	10.0-17.2	-1200 (-13.6%)	846 of 5561 (15%)
	Brown shrimp (*Farfantepenaeus aztecus*)	10.0-14.8	-250 (-12.7%)	21 of 5561 (<1%)
	Atlantic weakfish (*Cynoscion regalis*)	16.0-26.6	-3200 (-10.3%)	116 of 5561 (2%)
	Menidia spp.	10.0-30.4	-6000 (-8%)	932 of 5561 (17%)
	Southern kingfish (*Menticirrhus americanus*)	15.8-28.6	-3250 (-9.5%)	741 of 5561 (13%)
	Lined sole (*Achirus lineatus*)	15.2-32.2	-100 (-0.2%)	675 of 5561 (12%)
	Southern puffer (*Sphoeroides nephelus*)	15.6-31.2	-400 (-1.1%)	591 of 5561 (11%)
	Silver perch (*Bairdiella chrysoura*)	18.0-40.0	950 (0.5%)	1088 of 5561 (20%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.0-37.2	4000 (12.5%)	372 of 5561 (7%)





Upper panel is presented as cumulative percent of days.
Lower panel is presented as percent of days.

04948 TechMemo 2G Fig 49 6/30/06

Figure 49
Comparison of preferred salinity habitat for *Ruppia* seagrass between the baseline scenario and 20 MGD scenario
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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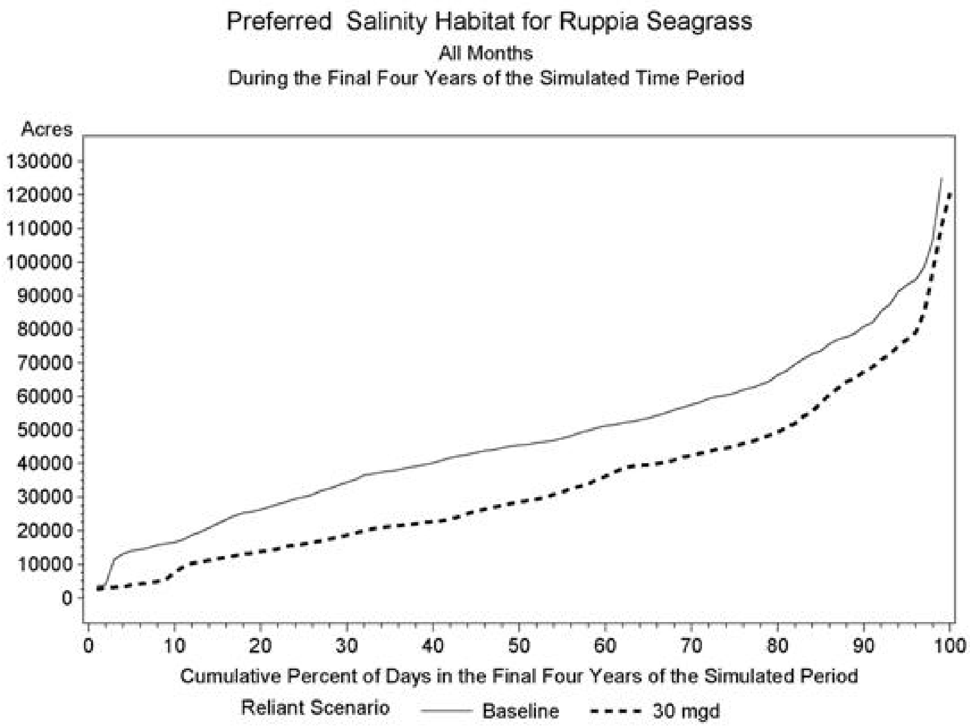
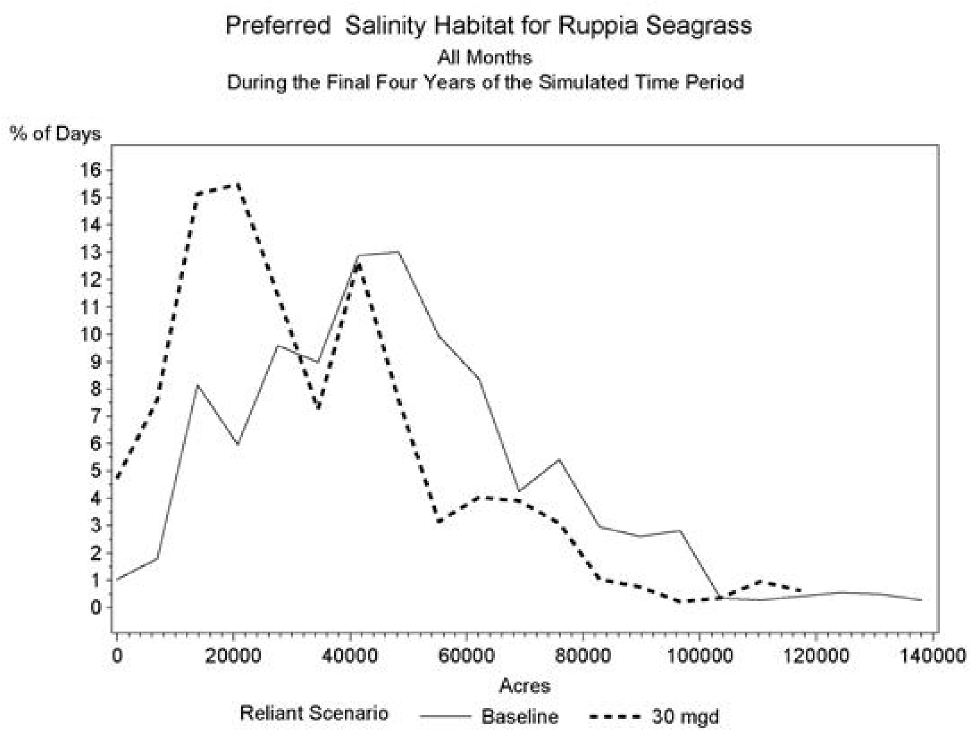
Table 14 Expected changes in preferred habitat availability from the Baseline Scenario to the 30 MGD Reliant Scenario. Results are season specific.

Season	Taxon	Preferred Salinity Range (ppt)	Expected Change in Preferred Habitat Acres (%)	Sample Size Occurrences of Samples (%)
All Months				
	Ruppia seagrass	0-25	-13,150 (-29.8%)	Not Applicable
	Benthos Group B	0-25	-22,450 (-28.2%)	Not Applicable
	Benthos Group C	0-21	-10,350 (-24.3%)	Not Applicable
	Benthos Group A	0-28	-10,900 (-21.9%)	Not Applicable
	Syringodium Seagrass	20-28	-21,200 (-21.1%)	Not Applicable
	Oyster	10-30	-21,450 (-16.7%)	Not Applicable
	Hard Clam	21-30	-9,600 (-10.4%)	Not Applicable
	Halodule Seagrass	22-34	-4,600 (-5.6%)	Not Applicable
	Halophila Seagrass	29-31	+1,100 (+8.3%)	Not Applicable
January to March				
	Sheepshead minnow (*Cyprinodon variegatus*)	10.0-17.2	-1300 (-32.9%)	131 of 2522 (5%)
	Menidia spp.	10.0-25.2	-11850 (-28.9%)	485 of 2522 (19%)
	Clown goby (*Microgobius gulosus*)	10.0-20.4	-7700 (-42.4%)	372 of 2522 (15%)
April to June				
	Atlantic stingray (*Dasyatis sabina*)	16.0-23.0	-17600 (-44.5%)	783 of 5100 (15%)
	Southern kingfish (*Menticirrhus americanus*)	14.8-26.4	-8350 (-31.1%)	404 of 5100 (8%)
	Lined sole (*Achirus lineatus*)	17.2-32.8	-6300 (-16.8%)	449 of 5100 (9%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.8-31.0	-5900 (-15.6%)	42 of 5100 (1%)
July to September				
	Hardhead catfish (*Arius felis*)	12.0-29.4	-23250 (-19.2%)	628 of 2149 (29%)
	Ladyfish (*Elops saurus*)	10.0-18.4	-550 (-17.3%)	368 of 2149 (17%)
	Atlantic stingray (*Dasyatis sabina*)	14.0-31.4	-21750 (-15.1%)	475 of 2149 (22%)
	Silver perch (*Bairdiella chrysoura*)	20.0-35.2	-17750 (-10.1%)	561 of 2149 (26%)
	Code goby (Gobiosoma robustum)	17.6-38.0	-14300 (-7.1%)	546 of 2149 (25%)
	Lined sole (*Achirus lineatus*)	18.4-33.0	-5200 (-12.3%)	245 of 2149 (11%)
	Striped burrfish (*Chilomycterus schoepfi*)	19.0-33.4	-5200 (-12.3%)	228 of 2149 (11%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.4-30.2	+1000 (+4.5%)	79 of 2149 (4%)
	Baitfish - Yellowfin menhaden (*Brevoortia smithi*)	25.0-30.2	+3100 (+8.6%)	33 of 2149 (2%)
October to December				
	Red drum (*Sciaenops ocellatus*)	10.0-13.0	-700 (-30.4%)	601 of 5561 (11%)
	Ladyfish (*Elops saurus*)	10.0-14.2	-850 (-22.8%)	494 of 5561 (9%)
	Bay anchovy (*Anchoa mitchilli*)	10.0-24.2	-29350 (-30.4%)	1556 of 5561 (28%)
	White mullet (*Mugil curema*)	10.0-17.2	-1750 (-20.3%)	846 of 5561 (15%)
	Brown shrimp (*Farfantepenaeus aztecus*)	10.0-14.8	-350 (-19.5%)	21 of 5561 (<1%)
	Atlantic weakfish (*Cynoscion regalis*)	16.0-26.6	-4900 (-15.2%)	116 of 5561 (2%)
	Menidia spp.	10.0-30.4	-10550 (-13.2%)	932 of 5561 (17%)
	Southern kingfish (*Menticirrhus americanus*)	15.8-28.6	-5000 (-14.5%)	741 of 5561 (13%)
	Lined sole (*Achirus lineatus*)	15.2-32.2	-850 (-2.3%)	675 of 5561 (12%)
	Southern puffer (*Sphoeroides nephelus*)	15.6-31.2	-2800 (-8.1%)	591 of 5561 (11%)
	Silver perch (*Bairdiella chrysoura*)	18.0-40.0	+500 (+0.2%)	1088 of 5561 (20%)
	Commercial shrimp (*Farfantepenaeus* spp.)	22.0-37.2	+4250 (+13.8%)	372 of 5561 (7%)





Upper panel is presented as cumulative percent of days.
Lower panel is presented as percent of days.

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Figure 50
Comparison of preferred salinity habitat for *Ruppia* seagrass between the baseline scenario and 30 MGD scenario
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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The aquatic preserve sites were estimated to have a relatively consistent 1 ppt increase in salinity across all time percentiles over the baseline condition for the 10 MGD scenario, a 2 to 3 ppt increase in salinity across all time percentiles over the baseline condition for the 20 MGD scenario, and a greater than 6 ppt increase in salinity across percentiles for the 30 MGD scenario.

Appendix N provides spatial plots of the change in the days where salinity ranges fall within the preferred range for a given species of seagrass. The results plot both the decreases in duration (associated with loss of preferred habitat) and increases in duration (associated with gain). This allows examination of where the losses and gains occur and how severe they are.

7.5.3.2 Shellfish

Shellfish were assessed with respect to hard clams and oysters. Clams and Oysters were both identified by the Peer Review Committee as the most important shellfish resource for this study. The hard clam (*Mercenaria mercenaria*) burrows into either mud or sandy sediments. In the IRL, the hard clam is most abundant in shell-containing soft bottom areas. They are also found on sand flats and muddy bottoms. In the IRL, clam farming is also active.

For the purposes of this assessment, the preferred salinity range for hard clams was defined as 21 to 30 ppt, and the preferred salinity range for oysters was defined as 10 to 30 ppt.

With respect to spatial and temporal variation of the extent of available preferred habitat, hard clams were estimated to have a 1,850-acre (2.1 percent) reduction in available preferred habitat under the 10 MGD scenario, a 4,900-acre (5.7 percent) reduction under the 20 MGD scenario, and a 9,600-acre (10.4 percent) reduction under the 30 MGD scenario. Oysters were estimated to have a 5,100-acre (4.6 percent) decrease in available preferred habitat under the 10 MGD scenario, a 11,400-acre (10.5 percent) decrease under the 20 MGD scenario, and a 21,450-acre (16.7 percent) decrease in available preferred habitat under the 30 MGD scenario.

With respect to reference sites, the potentially most affected site, Site 7 (a site with current conditionally approved shellfish harvesting and near concentrated shellfish harvest lease areas), would have preferred oyster and clam salinity habitats most of the time under the baseline and 10 MGD scenarios. However, the 20 MGD scenario would be expected to result in salinities greater than the upper preferred value for clams and oysters of 30 ppt for more than 55 percent of the time. The 30 MGD scenario would be expected to result in salinities greater than the upper preferred value for clams and oysters of 30 ppt for more than 75 percent of the time. Data Attachments C through F presents the complete set of statistical distributions of salinity responses at the reference sites.

Appendix N provides spatial plots of the change in the days where salinity ranges fall within the preferred range for a given species of shellfish. The results plot both the decreases in duration (associated with loss of preferred habitat) and increases in duration (associated with gain). This allows examination of where the losses and gains occur and how severe they are.

7.5.3.3 Benthos

Three groups of benthos taxa were identified according to salinity range as follows:

- <28 ppt salinity group (*Actiniaria, Mulinia lateralis, Phoronis*),
- <25 ppt salinity group (*Eusarsiella zostericola*, *Leptochelia*, *Pectinaria gouldii*), and
- <21 ppt salinity group (*Mediomastus*, *Parasterope pollex*).

The <28 ppt salinity group of benthos was estimated to have a 5,850-acre (6.3 percent) reduction in available preferred habitat under the 10 MGD scenario, a 13,400-acre (13.7 percent) reduction under the 20 MGD scenario, and a 21,200 acre (21.1 percent) reduction under the 30 MGD scenario. The <25 ppt salinity group of benthos were estimated to have a 6,950-acre (9.6 percent) reduction in available preferred habitat under the 10 MGD scenario, a 14,350-acre (18.1 percent) reduction under the 20 MGD scenario, and a 22,450-acre (28.2 percent) reduction under the 30 MGD scenario. The relatively more rare preferred habitat for the <21 ppt salinity group of benthos was estimated to have a 3,550-acre (8.7 percent) reduction in available preferred habitat under the 10 MGD scenario, a 6,550-acre (16.6 percent) reduction under the 20 MGD scenario, and a 10,335-acre (24.3 percent) reduction under the 30 MGD scenario.

Appendix N provides spatial plots of the change in the days where salinity ranges fall within the preferred range for given benthos. The results plot both the decreases in duration (associated with loss of preferred habitat) and increases in duration (associated with gain). This allows examination of where the losses and gains occur and how severe they are.

7.5.3.4 Fish

The expected response in available preferred salinity habitat for fish was estimated for specific IRL combinations of season(s), depth range(s), and preferred salinity ranges for each species. The depth ranges and seasons were operationally defined as described previously.

Logistic regression models were fit for species and season combinations with sufficient data, and statistically significant models at the alpha level of 0.01. The preferred salinity boundaries were operationally defined using the logistic models, so that beyond the preferred salinity range, one would expect a 25 percent or greater drop in the probability of occurrence of a species in a season of interest.

A subset (66 models) of the fish species and season combinations were selected for the ecological assessment based on the following criteria:

- sufficient data were available (≥60 samples with the species present),
- a statistically significant model (alpha level = 0.01) was found to predict probability of occurrence as a function of salinity in a particular season, and
- a relationship where increasing salinity was estimated to reduce the probability of occurrence for a species).

Since fish are expected to be mobile in the study area, the species were assessed with respect to spatial and temporal variation in the extent of total available preferred habitat. The preferred habitat assessments were restricted to the appropriate depth categories based on the relative occurrence of each species in shallow water seines and gill nets, and deep water trawls by season. The detailed results of the spatial and temporal extent analyses are presented graphically in Data Attachment B, and the reference site results are presented for each season in Data Attachments D through G.

The results are summarized across species and seasons in Table 12 for the 10 MGD scenario compared to the baseline scenario, Table 13 for the 20 MGD scenario, and in Table 14 for the 30 MGD scenario compared to the baseline scenario. The species are sorted within season by the expected change in available preferred salinity habitat, and the preferred salinity range, sample size, and relative occurrence are summarized by species and season. Overall, these fish results indicate a typically less than 10 percent reduction in available preferred salinity habitat under the 10 MGD scenario, an often greater than 15 percent reduction in available preferred habitat under the 20 MGD scenario, and a typically greater than 15 percent reduction in available preferred salinity habitat under the 20 and 30 MGD scenarios. The greatest expected impacts are for the Atlantic stingray during the April to June time period. The Atlantic stingray was observed to be a commonly occurring fish in the study area during this summer time period (present in 15 percent of samples). In the fall, red drum are expected to be the most potentially impacted fish species assessed. This recreationally important species was also reported to be relatively commonly found in the fish samples in the study area.

Appendix N provides spatial plots of the change in the days where salinity ranges fall within the preferred range for a given species of fish. These results reflect the seasons defined for each in Tables 12 through 14. The results plot both the decreases in duration (associated with loss of preferred habitat) and increases in duration (associated with gain). This allows examination of where the losses and gains occur and how severe they are.

8.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The SJRWMD initiated this study to determine the feasibility of collocation of one or more demineralization facilities. The potential collocated discharges evaluated were identified in *Special Publication SJ2004-SP6, Final Report on Five Potential Seawater Demineralization Project Sites – Task C.5* (Beck 2004). This work was performed under the Seawater Demineralization Feasibility Investigation and was completed in January 2004. Based upon the evaluations within this report, two sites were identified for further evaluation: the Reliant Indian River Power Plant and the Florida Power & Light (FPL) Cape Canaveral Power Plant, both located in Port St. John, approximately 9 and 11 miles south, respectively, of the city of Titusville in Brevard County, Florida.

Under Phase I of this study, an evaluation was made relative to the applicability of an existing model of the IRL developed by the University of Florida. The University applied the Curvilinear Hydrodynamic Model 3-D (CH3D) to the IRL for the Indian River Lagoon Pollutant Load Reduction (IRLPLR) project. This model was modified by the SJRWMD following delivery by the University of Florida. For the purposes of this report, this model application was termed the IRLPLR hydrodynamic model.

The existing IRLPLR model was reviewed by a panel of experts and recommendations for the use of the model were made. It was determined that the existing hydrodynamic model (IRLPLR) was suitable for use in the evaluation of the concentrate discharge, with minor modifications and additional data collection. The modifications to the model included;

- Increase in the horizontal resolution of the model in the area of the discharges
- Increase in the vertical resolution of the model
- Dynamic simulation of the temperature
- Refined analyses of the freshwater inflow within the North IRL.
- Dynamic simulation of the demineralization plant operations relative to salinity and temperature
- Verification of the simulation of the near field circulation using measured temperatures from the existing power plants.

Under Phase II, these changes were made to the IRLPLR model application by SJRWMD staff with assistance from the District consultant. For the purposes of this TM, this model application is termed the Indian River Lagoon Demineralization Study (IRLDS) model.

Under Phase II the goals were to identify the environmental and operational issues of concern, develop a list of scenarios under which to run the model to evaluate the potential environmental impacts, develop the methodologies to assess impact, and evaluate the impacts based upon the model simulations. Under the environmental issues, consideration was given to quantification of the abundance and availability of habitat and key organisms in the area of the proposed project, as well as the definition of sentinel organisms and their tolerance to salinity concentrations and fluctuations. The goal was to compile the available water quality and biological data and identify methods to assess the effects of the demineralization operations on the environmental conditions in the lagoon. Under the operational issues, consideration was given to recirculation, impingement and entrainment, cooling water flow, temperature issues, collocation issues, equipment maintenance, and National Pollutant Discharge Elimination System (NPDES) permitting issues.

Based upon the methodologies developed for assessing the impacts and utilizing the model simulations of salinity, temperature, and circulation, the impacts from the operation of the demineralization plants under varying water supply production rates were quantified. The analyses examined water production rates of 30 MGD, 20 MGD, 10 MGD and 5 MGD at each of the facilities individually and together.

For the impact analyses, 12-year simulations were run. The inputs for the 12-year simulations were based upon repeating the measured 1997 to 2000 conditions, and based upon analyses of the total rainfall and the frequency of return for the 2000 year drought. These simulations represented a conservative analysis of the potential impacts. The 12-year long simulations were required in order to assure that the system had reached a condition where the net build up of salinity had leveled out. The results were analyzed and the impacts to the system quantified. The impacts included four primary categories: operational impacts, physical impacts, water quality/regulatory impacts, and ecological impacts. For all of the ecological analyses, the final four years of the model simulation (years 9 to 12) were used. This assured that the ecological impact assessments reflected the full potential build up of salinity with the plants operating.

The results of the physical impact analyses (salinity) showed that the critical changes to the system occurred over a broad area of the lagoon, not simply within the immediate discharge zones of the power plants. These “far field” salinity changes became the primary issue for the ecological impact assessments. Based upon the salinity simulations, the difference between collocation of a demineralization plant either at the Indian River power plant site or at the Cape Canaveral power plant site did not significantly alter the far field results. Therefore, for the ecological analyses, the simulations with the demineralization plant collocated at the Indian River site were utilized. The Indian River site represents a slightly more critical situation given its location further north and lower circulating-water flow rates.

The results of the model were evaluated and the long-term maximum and average salinity changes were presented along with the acres of salinity changes at various levels. The salinity began to reach a dynamic equilibrium at between 6 and 8 years of demineralization plant operation. For the 30 MGD and 20 MGD scenarios, significant salinity changes were seen throughout the North IRL and extended into Mosquito Lagoon, Banana River, and south along the IRL. The results show that the net long-term flow through Haulover Canal is altered, which pulls in higher saline water from Mosquito Lagoon. For the 10 MGD scenario, the overall levels of impact are reduced in comparison with the 30 MGD and 20 MGD scenarios, with salinity changes generally near 2 ppt with only higher levels seen local to the discharge. Comparatively, the 30

MGD and 20 MGD scenarios showed changes on the order of 6-7 ppt and 4-5 ppt respectively.

Assessment of the potential concentration of pollutants showed that compared to baseline conditions, for some parameters, and based upon available data, water quality criteria may be violated. The operation of the facilities has the potential to concentrate those pollutants and those concentration increases (due to antidegradation requirements) may limit the feasibility of the proposed projects. It is important to note that this evaluation was conservative in nature, and that pre-treatment at the facilities may remove some quantities of pollutants at the facility, but the level of removal would need to be defined through pilot studies which are beyond the present scope. Additionally, the validity of the available data for the baseline conditions, which identifies existing water quality violations for various metals, has been brought into question through the peer review process of this study. Recommendations made herein, relative to the feasibility of demineralization, do not consider the concentration of pollutants, but rather it is recommended that additional data collection be completed to establish baseline conditions if further action is taken on demineralization at these two facilities.

The results of the ecological assessments were presented based upon changes to stratification, temperature and salinity. Temperature showed no significant level of change due to the operation of the demineralization plants at all production rates. Stratification levels also did not show any significant levels of change due to the operation of the demineralization plants at all production rates.

Salinity changes were significant and ecological impacts were assessed based upon the percent of baseline habitat that would move from the preferred salinity range to outside of the preferred salinity range based upon the median conditions. The median condition is the acreages of preferred habitat where, under baseline conditions, 50 percent of the time the acreage of preferred habitat is greater and 50 percent of the time it is less. It should be noted that areas within the North IRL continuously move into and out of the preferred salinity ranges for various species. Species survive outside of the preferred range and, therefore, it should not be assumed that movement out of the preferred range constitutes a complete loss of the species. It should be noted that some areas of the Indian River Lagoon have experienced decreased salinities due to increased freshwater inflow from urbanization. The North IRL, where the power plants are located, has limited watershed inflow and has not seen a significant freshening over natural levels.

For the operation of a 30 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 14 percent increase in the preferred salinity habitat for commercial shrimp to a 45 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 30 percent, 20 percent, 31 percent, and 30 percent, respectively. A net loss of seagrass preferred habitat was seen with a 29.8 percent reduction for *Ruppia* and an 8 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the operation of a 20 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 13 percent increase in the preferred salinity habitat for commercial shrimp to a 32 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 21 percent, 14 percent, 19 percent, and 15 percent, respectively. A net loss of preferred seagrass habitat was seen with a 20 percent reduction for *Ruppia* and a 0.3 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the operation of a 10 MGD demineralization plant at the Indian River power plant site, the range of preferred salinity habitat change was from a 9 percent increase in the preferred salinity habitat for commercial shrimp to a 16 percent decrease for Atlantic Stingray. The net loss in preferred salinity habitat for other key species, i.e. Red Drum, Ladyfish, Kingfish, and Bay Anchovy was 10 percent, 7 percent, 9 percent, and 8 percent, respectively. A net loss of preferred seagrass habitat was seen with a 11 percent reduction for *Ruppia* and a 3 percent increase in *Halophila*. Losses in preferred habitat were seen for all shellfish and benthos.

For the various species, spatial duration plots identified where preferred salinity ranges changed in duration with and without the demineralization facilities. The results showed that any gains in the duration of preferred habitat occurred south of the plants in areas that typically had lower salinity from freshwater inflow. Decreases in the time that salinity levels were within the preferred range were greatest near the plants and decreased at greater distances.

Various acceptable levels of preferred habitat loss are defined within the literature and based upon similar studies being conducted throughout Florida. Shaw and colleagues' peer review panel (Shaw et al. 2005) found the 15 percent loss benchmark to be "reasonable and prudent" for the Middle Peace River Minimum Flows and Level evaluations. This benchmark was further supported by the Upper Myakka River Minimum Flows and Levels peer review panel (SWFWMD Peer Review Panel 2005). Literature values range between 10 percent and 33 percent as acceptable levels of habitat loss. The choice of an appropriate level of acceptable preferred habitat loss, or shift out of a preferred habitat range, needs to be based upon various ecological and physical factors. The present state of the habitat needs to be considered, i.e., is that habitat degraded. Additionally, different percentages could be applied to different species, different areas, or at different times.

While no definitive acceptable level of habitat loss has been defined, evaluation of all of the results allows for a determination of the feasibility of collocating a demineralization plant at the Reliant Indian River site and/or the FPL Cape Canaveral site. The following recommendations are made;

- At the Indian River power plant site, a 30 MGD or a 20 MGD facility is not feasible based upon the potential level of ecological impacts as well as potential impingement and entrainment (I&E) increases due to makeup water needs.

- At the Cape Canaveral power plant site, a 30 MGD or a 20 MGD facility is not deemed feasible based upon the potential level of ecological impacts.
- Combined water production rates for two facilities totaling 20 MGD or 30 MGD are not deemed feasible based upon the potential level of ecological impacts.
- Potential water quality issues, i.e., concentration of pollutants, may make any water production rate unfeasible due to the need to not degrade the water quality. Pilot testing will be needed in order to determine if pre-treatment would alleviate the potential concentration of pollutants. Presently, peer review of the study has identified potential errors in the existing metals data. Additional baseline data therefore would be necessary prior to further consideration of the proposed co-located facilities.
- Depending upon the choice of an allowable level of acceptable loss of preferred habitat, total plant capacities less than or equal to 10 MGD, either as a single plant or combined, may be feasible. It should be noted though that present analyses show a net loss of preferred seagrass habitat for all scenarios. This is in conflict with present IRL goals for restoration of seagrass habitat. Appendix I presents excerpts from the IRL CCMP discussing goals and targets for the IRL. Additionally, the lateral extent of the salinity changes even under these reduced–production scenarios is significant and will make permitting of the demineralization facilities difficult.
- Presently the model does show salinity changes within OFW waters. Therefore, under the permitting process, the feasibility will need to consider the anti-degradation rules and the 62-4.242 Antidegradation Permitting Requirements; Outstanding Florida Waters; Outstanding National Resource Waters; Equitable Abatement. This rule provides specific criteria that would need to be satisfied to obtain a discharge permit.

This study provides an estimate of levels of preferred habitat loss, based on different scenarios of demineralization concentrate discharge at project sites collocated with existing power plants, but does not define what losses may be acceptable or not acceptable to stakeholders, government agencies, and the general public. The identification of acceptable changes to preferred habitat is a multi-agency, high-level policy decision. This will need to be done at a time when there is a utility sponsor who wishes to proceed with a project, and the perceived need for new water supply becomes urgent and widely recognized.

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Appendix A

Overview of Comments and Responses

Indian River Lagoon Salinity Study
Overview of Comments, Responses and Meetings

Through this study, various Technical Memoranda were prepared that summarized the work to date. These Technical Memoranda were reviewed by SJRWMD Personnel, various Peer Reviewers, Agency Reviewers, and other interested parties. The final report document brings all of the Technical Memoranda into a final report that covers all aspects of the study. The Technical Memoranda submitted previously include;

- TM 1.B – Description of Hydrodynamic Model and Approach
- TM 2.B and 2.C – Environmental/Operational Issues of Concern and Discharge Scenario Development
- TM 2.D and 2.E – Compilation of Data and Coordination Requirements and Environmental Assessment Methodology
- TM 2.F – Hydrodynamic Model Development and Impact Assessment

Within each of these Technical Memoranda, the comments and associated responses for the SJRWMD Personnel, the Peer Reviewers, Agency Reviewers, and other interested parties were provided as appendices. Additionally, for each TM, various meetings took place. Within each TM, relevant meeting summaries were also provided. The following provides an outline of who provided comments for each TM and where the responses were provided, as well as meeting summary notes provided along with the dates of the meetings.

TM 1.B: Meeting Summaries, Comment and Response Documents

- Ad Hoc Advisors Meeting Summary (September 15, 2004)
- Ad Hoc Advisors Meeting Summary (October 29, 2004)
- FDEP Meeting Summary (November 15, 2004)
- Technical Advisors Meeting Summary (November 12, 2004)
- Comments with Responses:
    - Technical Advisor Meeting
    - Ad Hoc Advisors Meeting
    - Dr. John R. Proni (Peer Reviewer)
    - Jane Provancha (Peer Reviewer)
    - Dr. Barney Austin (Peer Reviewer)

TM 2.B and 2.C: Meeting Summaries, Comment and Response Documents

- Technical Advisors Teleconference Summary (February 2, 2005)
- Peer Review Teleconference Summary (March 14, 2005)
- Peer Review Teleconference Summary (March 28, 2005)

- Public Meeting Summary (March 10, 2005)
- Peer Review Comments and Responses
  - Dr. Barney Austin
  - Dr. John Proni
  - Jane Provancha
- St. Johns River Water Management District Comments and Responses
- FDEP Comments and Responses
- Comments and Responses on TM 1.B Received after 1.B was Finalized and Published
  - Grant Gilmore
  - Mike Myjak
  - Gary Zarillo
  - Maureen Rupe

TM 2.D and 2.E: Meeting Summaries, Comment and Response Documents

- Technical Advisor Teleconference Summary (April 18, 2005)
- Project Meeting Summary (May 12, 2005)
- Peer Review Comments and Responses
  - Dr. John Proni
  - Dr. Barney Austin
  - Jane Provancha
- Comments from St. Johns District Staff

TM 2.F: Meeting Summaries, Comment and Response Documents

- Comments from SJRWMD Staff
- Peer Review Comments and Responses
  - Jane Provancha
  - Dr. Barney Austin
  - Dr. John Windsor
  - Dr. Gary Zarillo

Appendix B

Baseline Resource Maps

Figure: B-1
Manatee distribution within Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

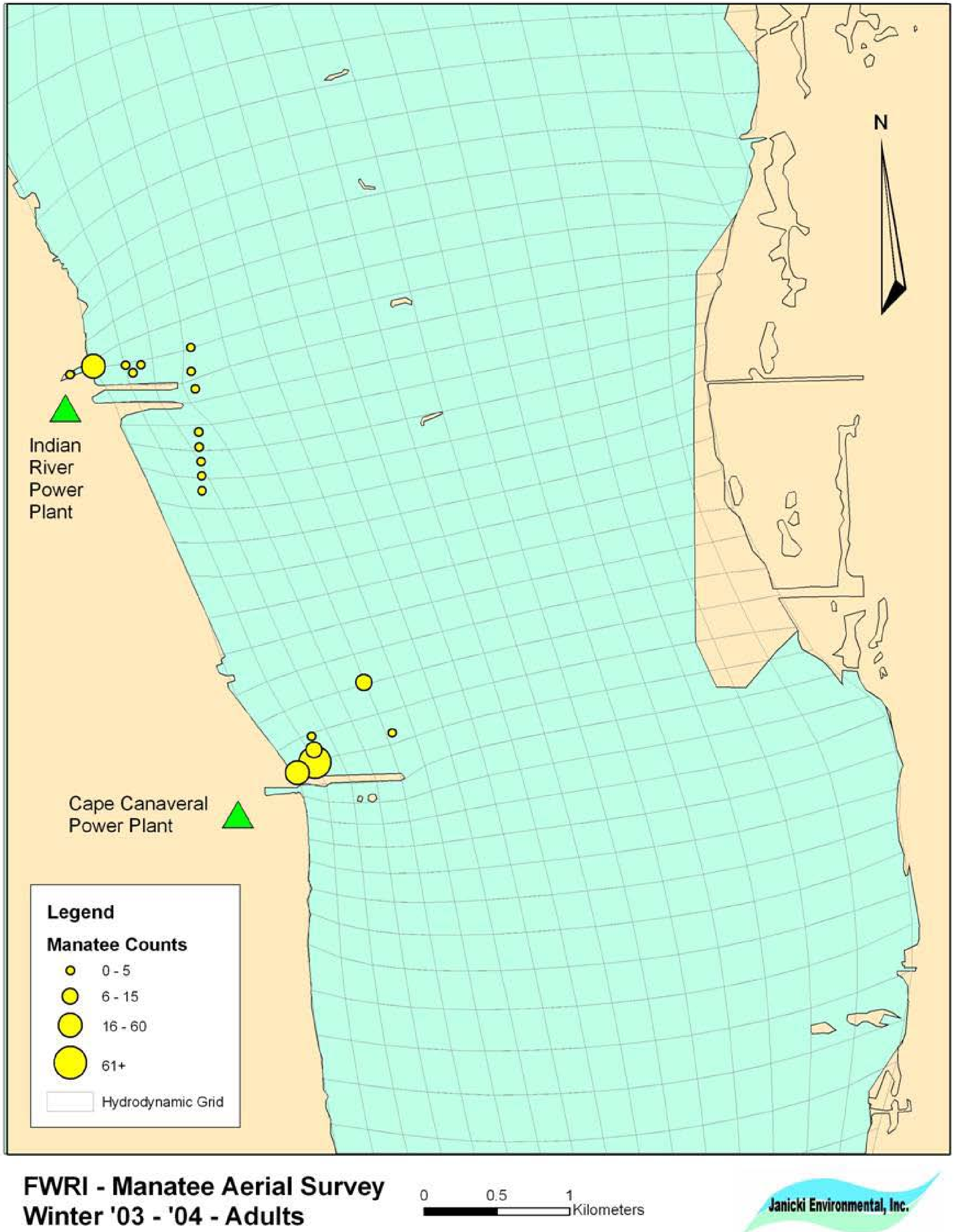

Figure: B-2
Manatee calves distribution within Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

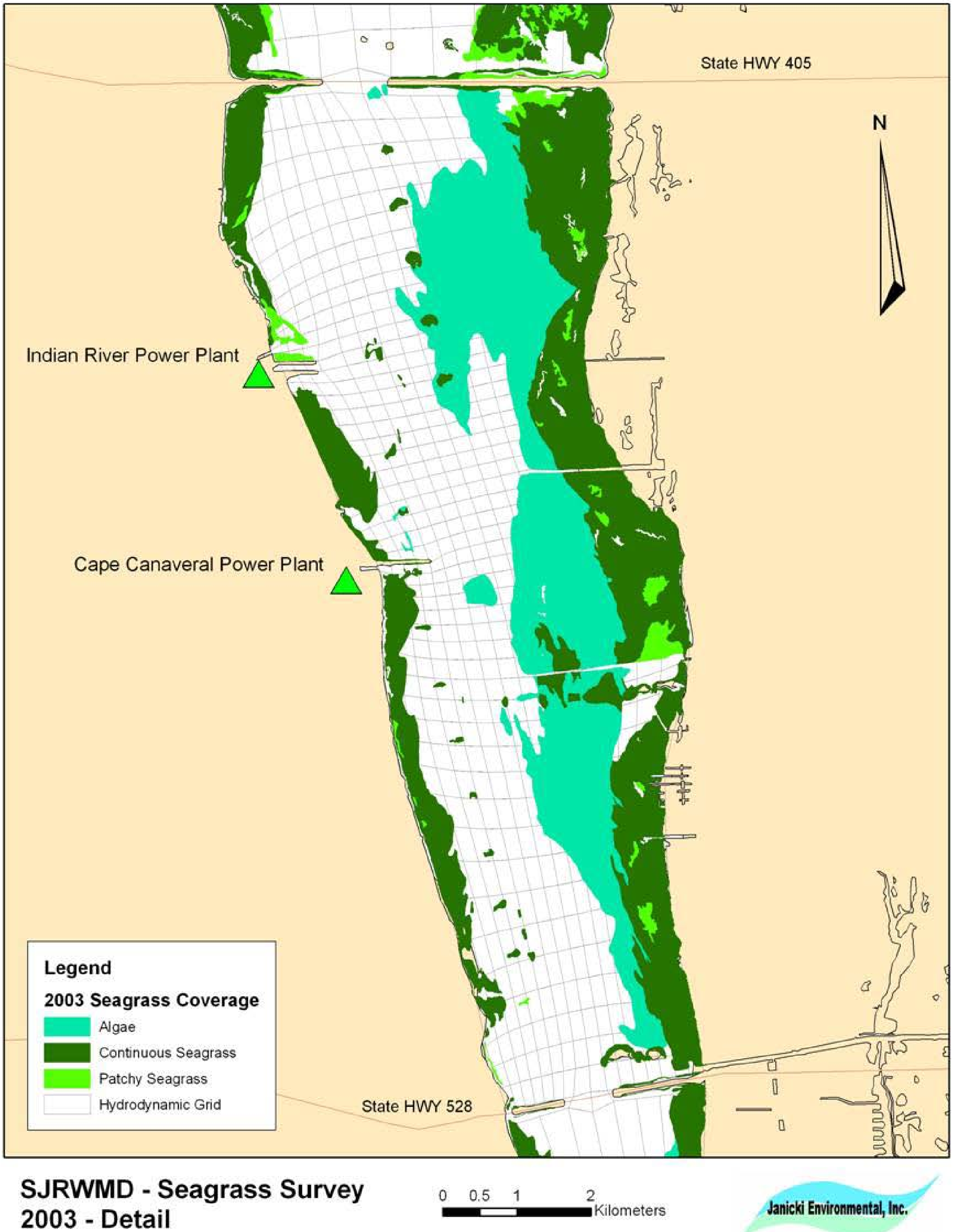

Figure: B-3
Seagrass map of Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

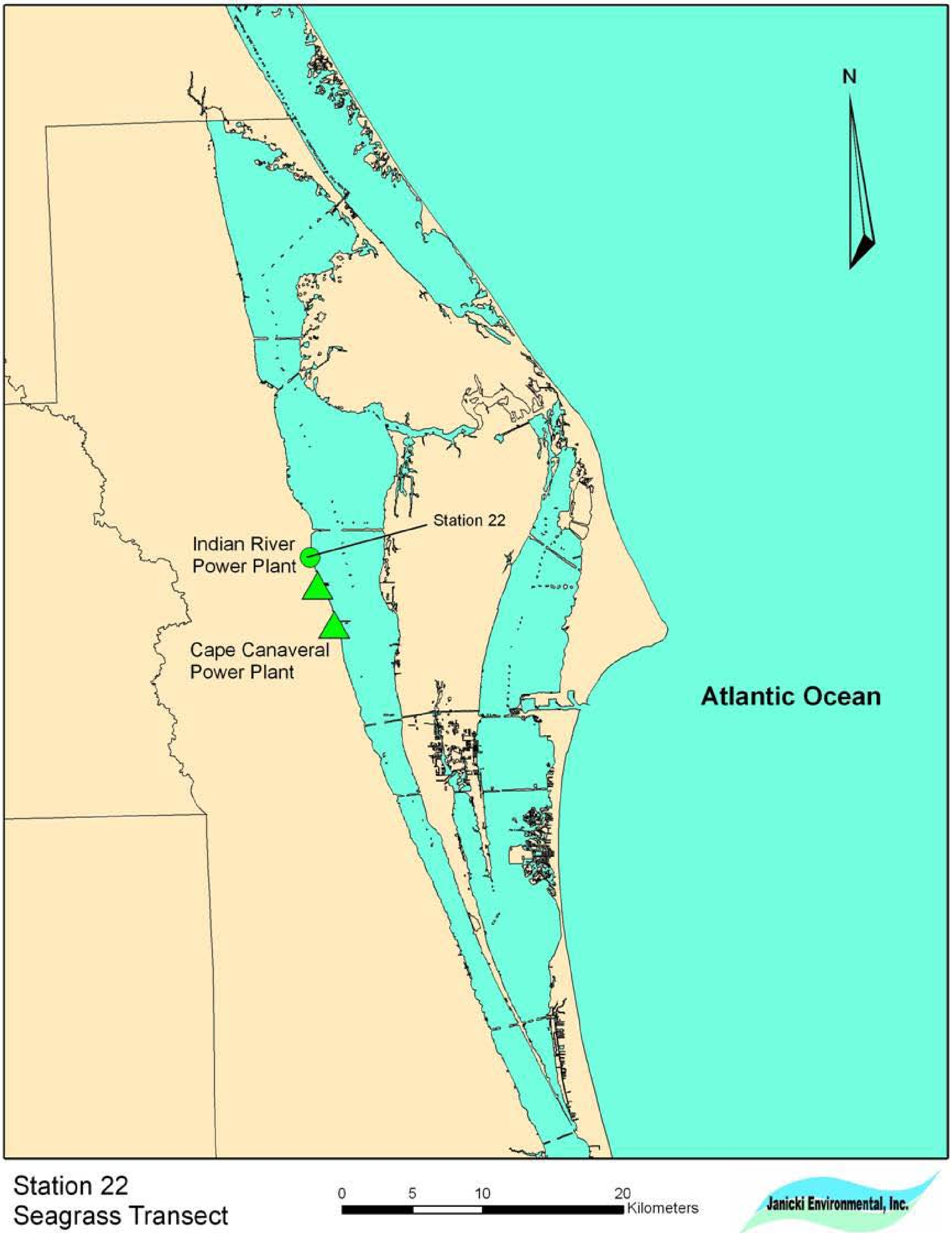

Figure: B-4
Seagrass transects within Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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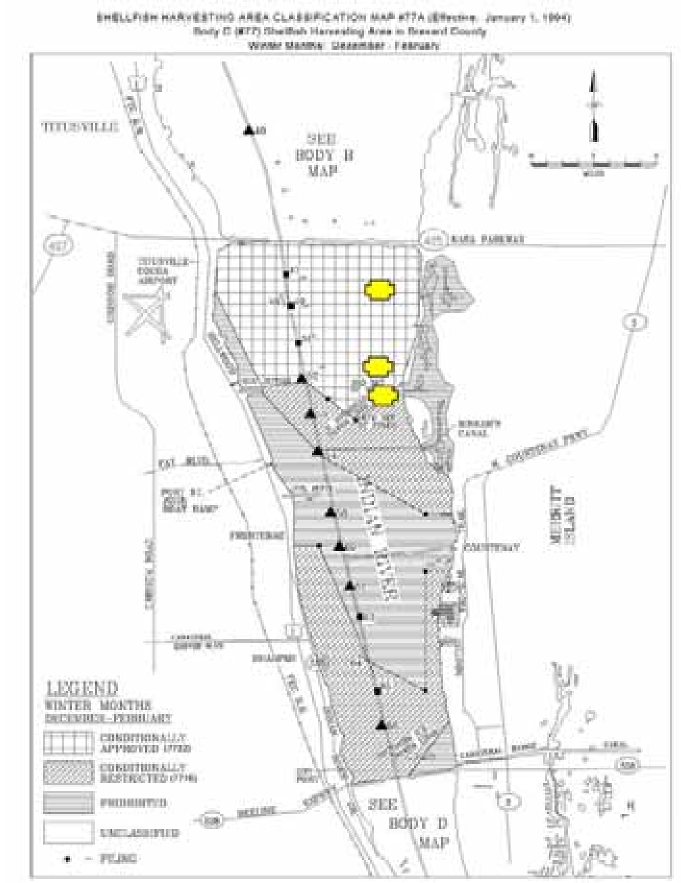

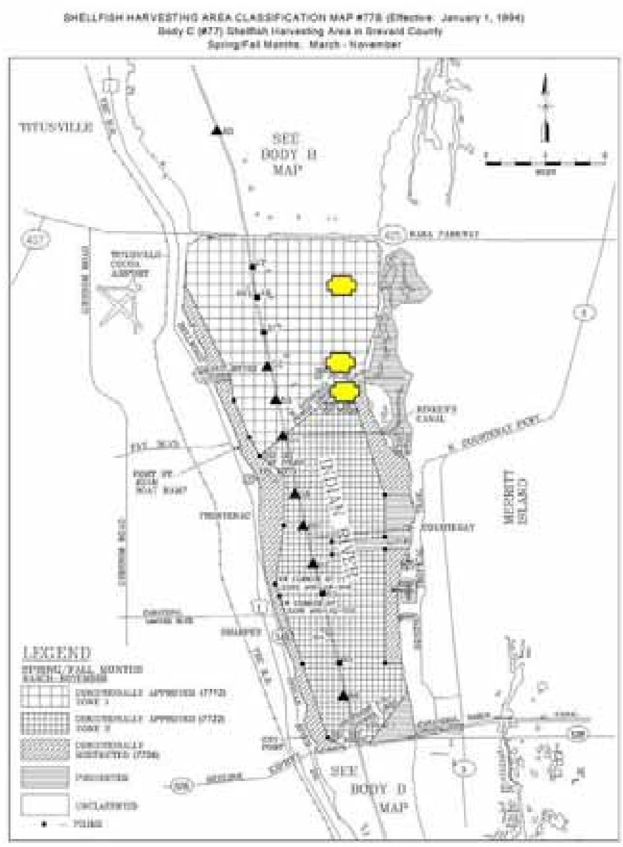

High-density lease area

Figure: B-5
Shellfish harvest areas within Northern Indian River Lagoon
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

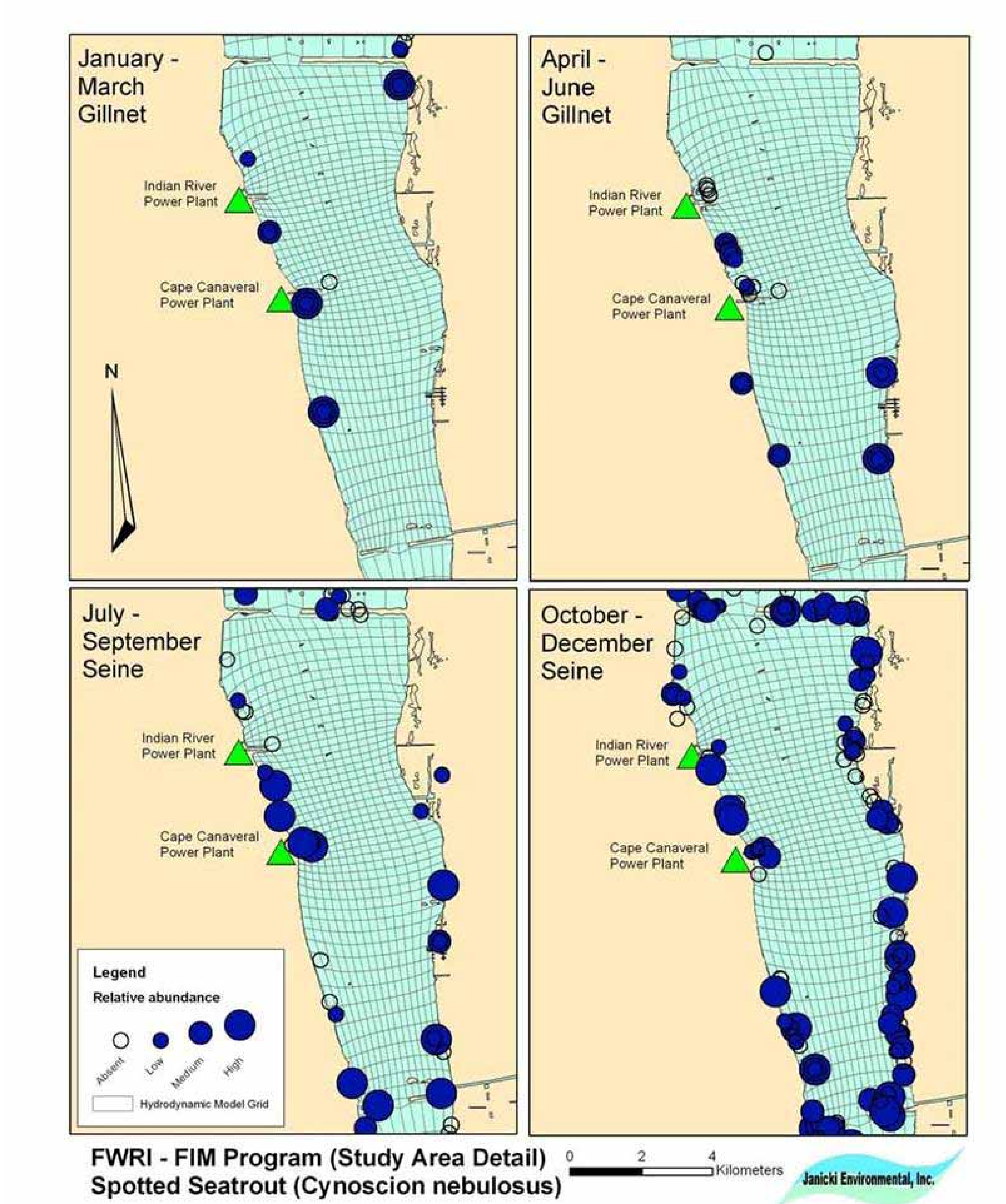

Figure: B-6
Seatrout maps by season
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

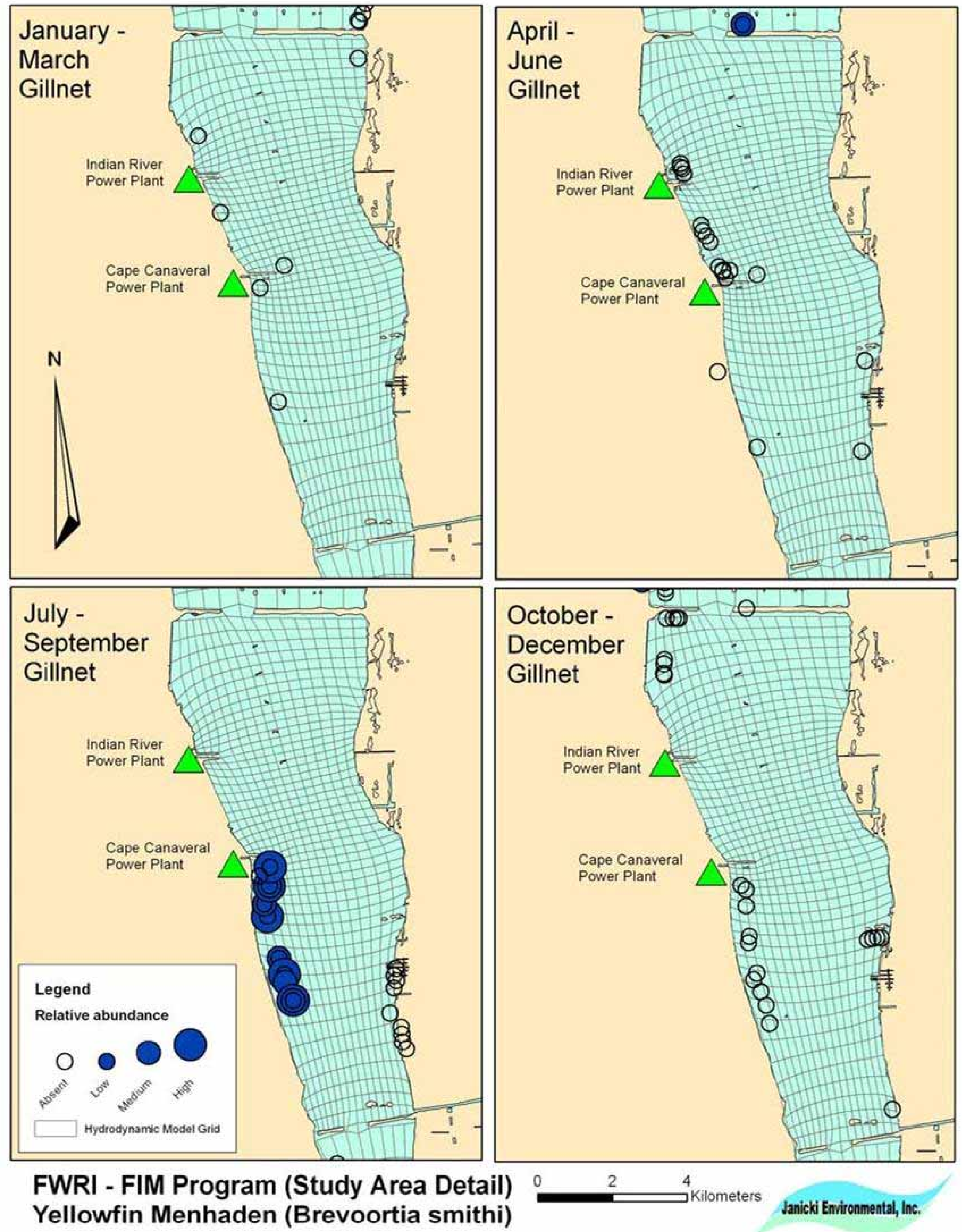

Figure: B-7
Baitfish maps by season (4 panels)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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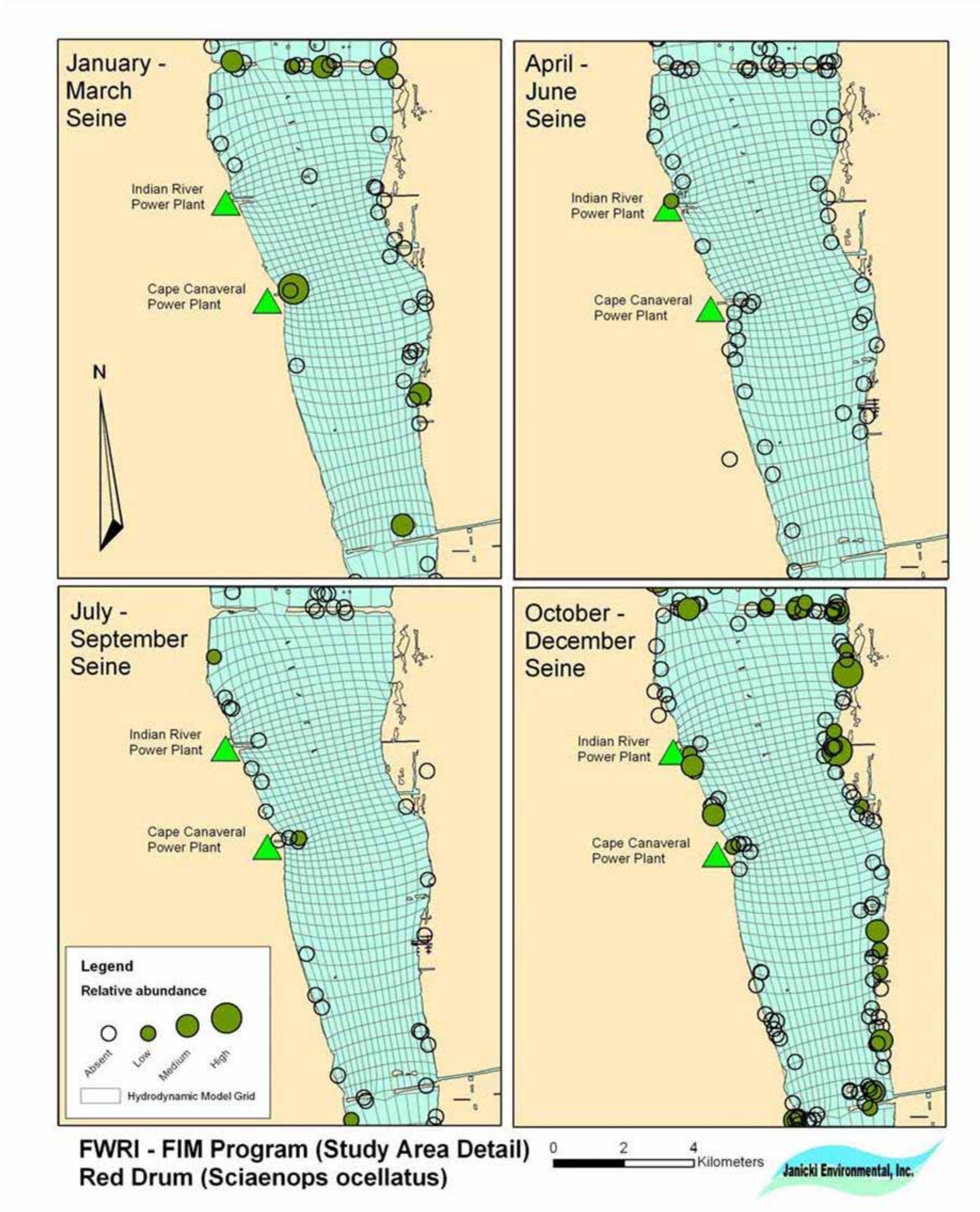
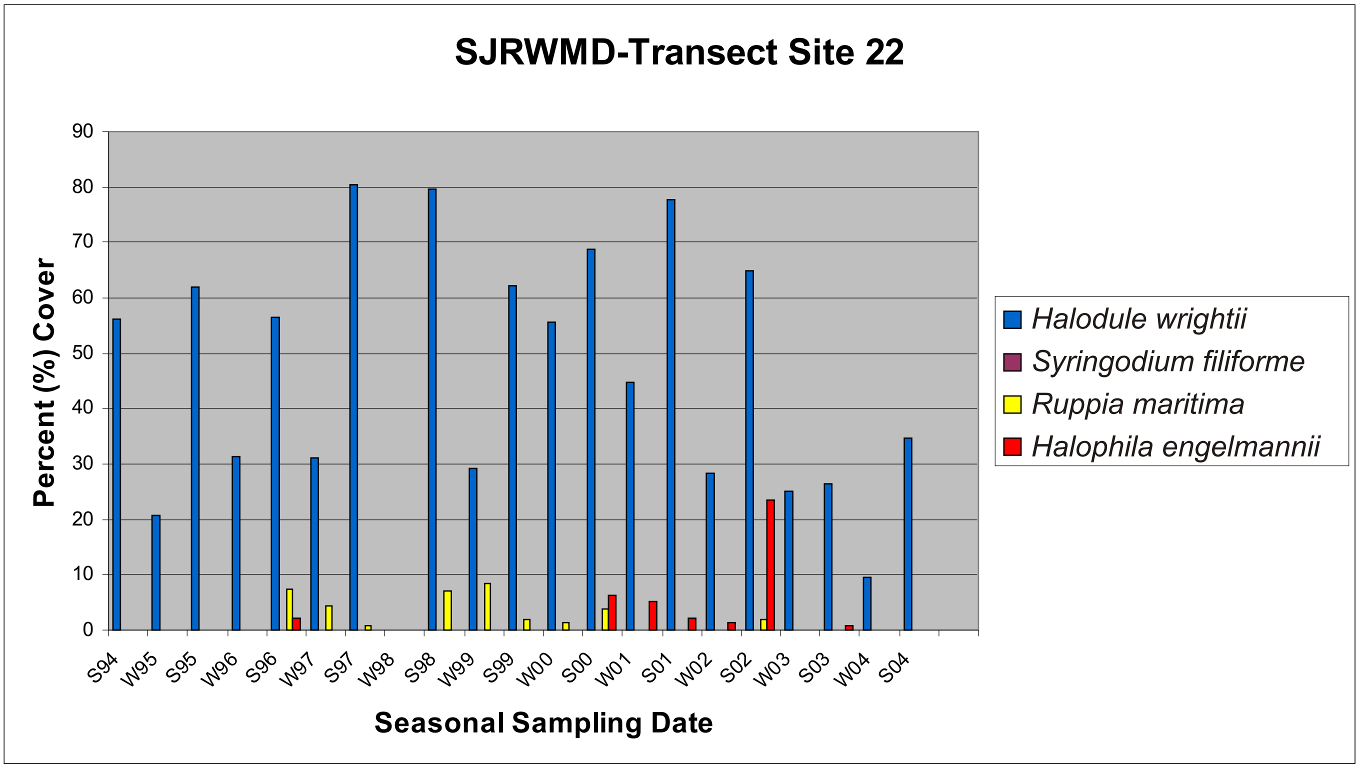


Figure: B-8
Most impacted taxa maps by season (4 panels)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT



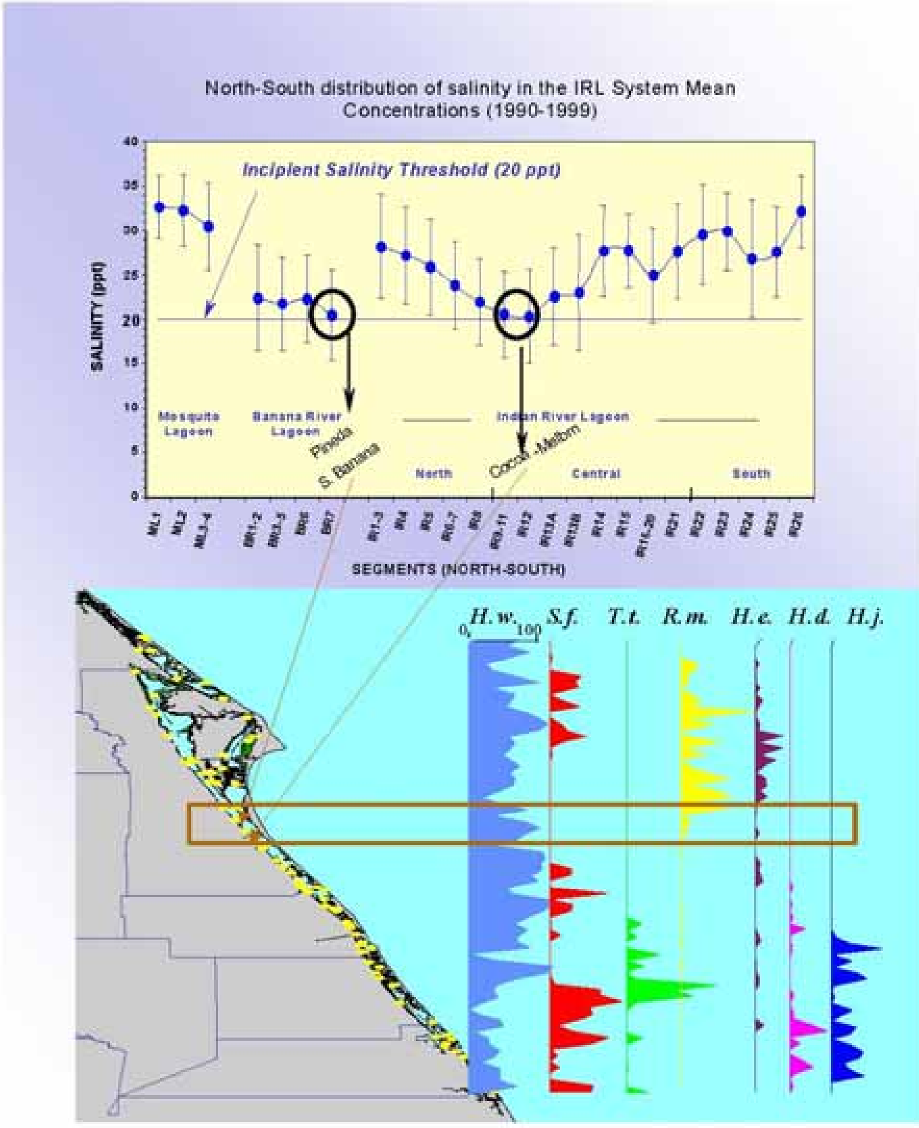
Transects were sampled twice annual:
August (S=summer)
February (W=winter).

Figure B-9

Percent cover of four seagrass species present in SJRWMD transect No. 22 on Indian River Lagoon. (Source: Lori Morris SJRWMD)

Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT, INC.



10-year mean salinities +/- S.D. in the IRL system by segment (top plot) and the relative abundance and diversity of seagrasses with an emphasis on the south Banana River Lagoon and Cocoa-Melbourne reach (bottom graphic) where both low salinities and low seagrass abundance and diversity exist

Seagrass Species:
H.w. – *Halodule wrightii* **S.f.** – *Syringodium filiforme* **T.t.** – *Thalassia testudinum*
R.m. -- *Ruppia maritima* **H.e.** – *Halophila engelmannii* **H.d.** – *Halophila decipiens*
H.j. – *Halophila johnsonnii*

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Figure B-10
Salinity and seagrass species distribution in the north Indian River Lagoon (SJRWMD, 2002)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT, INC.

Appendix C

Model Expectations Document

EVALUATION OF POTENTIAL IMPACTS OF DEMINERALIZATION CONCENTRATE DISCHARGE TO THE INDIAN RIVER LAGOON

MODEL EXPECTATIONS DOCUMENT

Prepared for:
St. Johns River Water Management District
Palatka, Florida

Prepared by:
Janicki Environmental, Inc.
St. Petersburg, Florida

December 17, 2004

Table of Contents

List of Figures

1. Background

The St. Johns River Water Management District (SJRWMD) has initiated a project to investigate the technical, environmental, and economic feasibility of alternative water supply and water resource strategies associated with two candidate seawater demineralization facilities to be potentially collocated at power plants. One or both of these two candidate facilities may be constructed. One of the candidate facilities would be collocated at the Reliant Indian River Power Plant (approximately 9 miles south of the City of Titusville in Brevard County) (Figure 1-1), and the other would be collocated at the Florida Power and Light Cape Canaveral Power Plant (approximately 11 miles south of the City of Titusville) (Figure 1-2). These areas are near Port St. John. The surrounding study area is focused on the portion of the Indian River Lagoon basin located between the two ocean passes: Ponce Inlet at the north end of Mosquito Lagoon near New Smyrna Beach, Sebastian Inlet near Sebastian. The coastal distance between these two passes is approximately 100 miles.

The purpose of this project is to evaluate potential impacts of demineralization concentrate discharge to the Indian River Lagoon. This document provides technical recommendations for one element of this larger project.

A hydrodynamic model or models will be used to evaluate the potential impacts of demineralization concentrate discharge on the living resources in the study area. The hydrodynamic model will describe the variation in physical conditions such as salinity over time and space. The variation in the physical conditions responds to hydrodynamic forcing functions that include freshwater inflows, tide induced circulation, wind induced circulation, the circulation effects of the power plant cooling systems, and the potential demineralization concentrate discharge. The physical conditions are also influenced by the unique geographic features and anthropomorphic features of the study area including the extreme long and narrow shape of the lagoon system, the Intracoastal Waterway and other connecting channels, the stabilized channels at the inlets, dredge spoil islands, causeways, mosquito ditches, and relief bridges.

Given the dynamic nature of the hydrodynamic conditions in the study area and the complex geographic features in the study area, SJRWMD must identify the appropriate temporal and spatial resolution for the hydrodynamic model. The spatial and temporal resolution must be sufficient to describe the hydrodynamic conditions with confidence, and they must also be sufficient with respect to how the model will be ultimately applied to make inferences regarding potential impacts of the demineralization concentrate discharge.

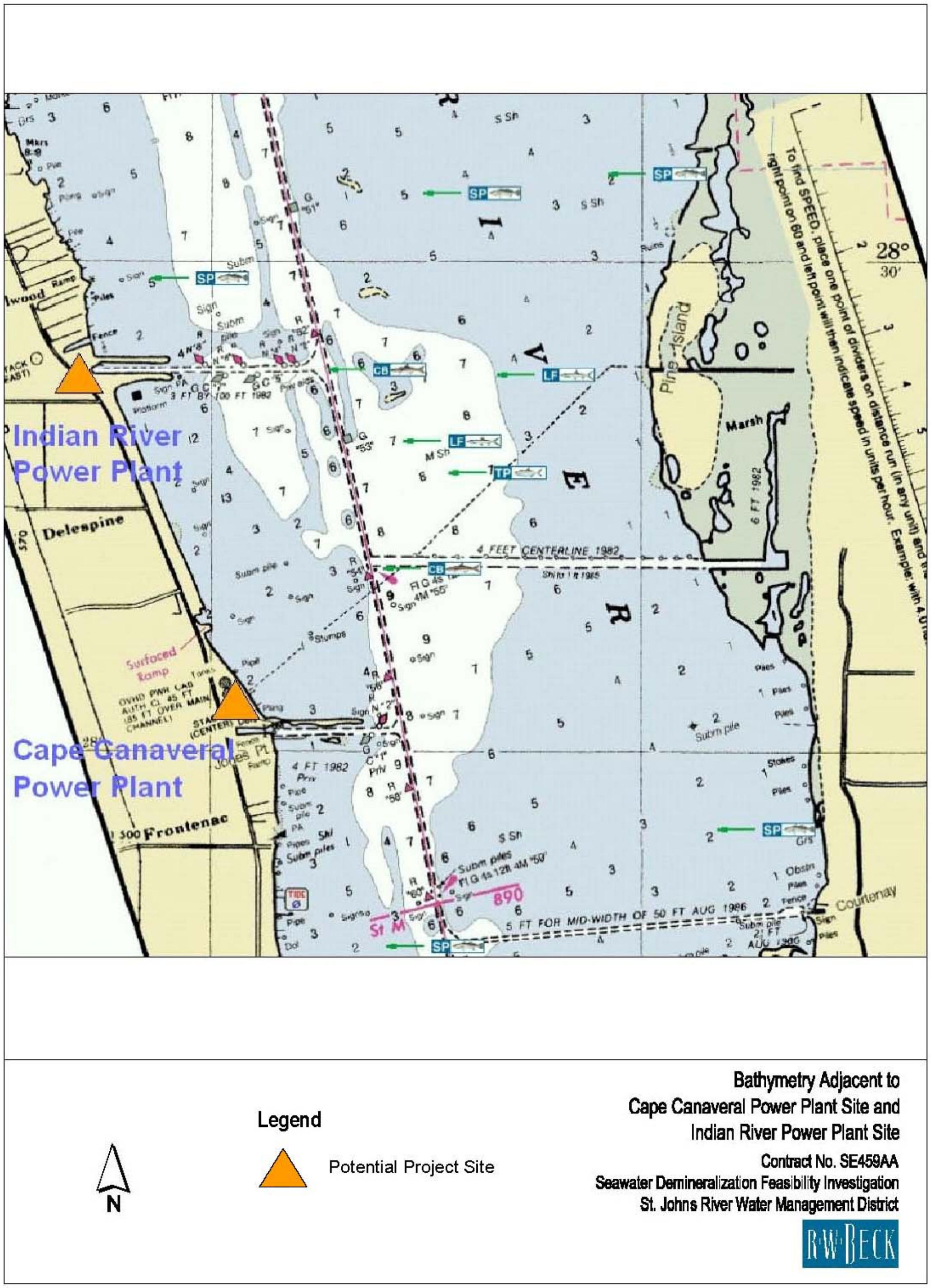


Figure 1-1 Location of the potential collocation sites (Figure Source RW Beck, 2004).

Inferences on the potential impacts of the demineralization concentrate discharge will include consideration of potential impacts to living resources in the study area. In order to complete a robust and technically defensible evaluation of these potential impacts to living resources, the hydrodynamic model output spatial and temporal resolution will need to be compatible with the scales of potential responses of these living resources.

The purpose of this document is to identify the spatial and temporal output needs of the hydrodynamic model for use in evaluation of the proposed impacts of the concentrate discharge to living resources.

2. Resources of Concern

The resources of concern for this project are the living resources in the Indian River Lagoon that would be reasonably expected to be potentially impacted by the concentrate discharge and/or entrainment from one or both candidate facility locations. Since the focus of this document is on the spatial and temporal output needs of the hydrodynamic model, this document focuses on living resources that may be potentially impacted by the concentrate discharge. The resources are comprised of estuarine aquatic vegetation, planktonic organisms and life stages, benthic macro invertebrates, fishes, bird species that utilize the Indian River Lagoon, and manatees.

Among these biological resources are expected to be those organisms and life stages that may be responsive to direct and indirect effects of the concentrate discharge, and those that may be relatively non-responsive to the concentrate discharge. Thus, the most responsive organisms and life stages may provide sentinels as proxy for the complete set of biological resources. In particular, it will be important for the hydrodynamic model to be developed to make inferences regarding the organisms that would be expected to be the first responders to changes related to the concentrate discharge (i.e., an early warning system). For example, sessile organisms with relatively short life cycles such as benthic macroinvertebrate organisms may respond before mobile animals with longer life cycles such as the spotted seatrout.

The potential demineralization processes that may impact these living resources include changes in salinity, circulation and stratification (including temperature changes or dissolved oxygen changes), residence time, and potential concentration of demineralization pre-treatment process chemicals or ambient pollutants (e.g., pesticides, herbicides, metals already present in the environment surrounding the potential facility). The pollutants that may be concentrated by the demineralization process are typically not present in dissolved form in estuarine environments, and for the purposes of this expectations document and initial model development they may be treated as conservative substances.

With respect to potential salinity effects, it is important to note that the living resources of the study area are biologically adapted to the estuarine conditions which result in relatively wide changes in salinity over time and space due to offshore mean water level, and wind driven circulation, and stratification of the water column. Thus, the salinity tolerances of these organisms are relatively broad, and the level of resolution needed to identify the tolerance ranges is also reported in the literature to be broad. Because the organisms are adapted to a range of salinities, any potential impacts of the demineralization facility will be evaluated with respect to shifts in the distribution of salinity in the study area, or possibly a truncation of the distribution of salinity in the study area (e.g., an increase in the periodically occurring lowest salinity values).

With respect to specific organisms, SJRWMD has identified an initial list of taxa of concern for this project. These taxa include:

- seagrass,
- the spotted seatrout (particularly spawning seatrout),
- red drum,
- manatees,
- Merritt Island birds in general, and
- ducks that utilize the mosquito impoundments in the North Indian River Lagoon.

Other taxa and groups of taxa were also identified by the project participants to include:

- benthic macroinvertebrates,
- baitfish,
- horseshoe crabs,
- sea turtles,
- Shellfish Lease Area east of the Intracoastal Waterway,
- Lesser Scaup,
- shrimp,
- Weakfish (common sea trout), and
- Fiddler crabs.

The salinity tolerances of the living resources of the study area will be described in greater detail in a later technical phase of this project, and may include particular species focuses on endangered species, known nursery areas, potentially commercially significant resources (e.g. clams), and public use resources.

3. Overview of Salinity Tolerances of Living Resources

The salinity tolerances of the living resources of the study area will be described in detail in a later technical phase of this project. However, for the purposes of identifying temporal and spatial resolution needs for the hydrodynamic model, an overview of the temporal and spatial scale of salinity tolerances is provided.

Salinity as a Key Indicator of Potential Impact of Concentrate Discharge

Salinity has traditionally been regarded as a central parameter for estuarine analysis, especially as an indicator of hydrography and habitat potential. There are several reasons to study estuarine salinity:

- Salinity is a direct measure of the relative influence of marine and freshwater sources,
- Salinity is an outstanding hydrographic tracer, as it is a conservative property and illustrates the movement and exchange of water masses, and
- Salinity dominates the density structure of an estuary and thus exerts significant controls on currents and turbulence.

Seawater consists of a dilute solution of a mixture of dissolved salts. The major constituents of seawater that comprise more than 99% of the dissolved salts (Thurman, 1993) include:

- Chloride – 55.04%
- Sodium – 30.61%,
- Sulfate – 7.68%,
- Magnesium – 3.59%,
- Calcium – 1.16%, and
- Potassium – 1.10%.

Erosion and transport of minerals from the land surfaces that drain to coastal waters is the ultimate source of these dissolved salts. The demineralization process is expected to concentrate these minerals in the same proportions that they are found in the Indian River Lagoon waters, and they are expected to be diluted quickly when they are reintroduced into the Lagoon system by the discharge process.

Salinity in the Indian River Lagoon

Salinity in the north Indian River Lagoon is dynamic, and it typically ranges between 10 ppt. and 35 ppt. depending on antecedent hydrodynamic conditions (Figure 3-1) (St. Johns River Water Management District, 2002). It is likely that rainfall is the primary hydrodynamic forcing function of the inter-annual variability in salinity in this study area.

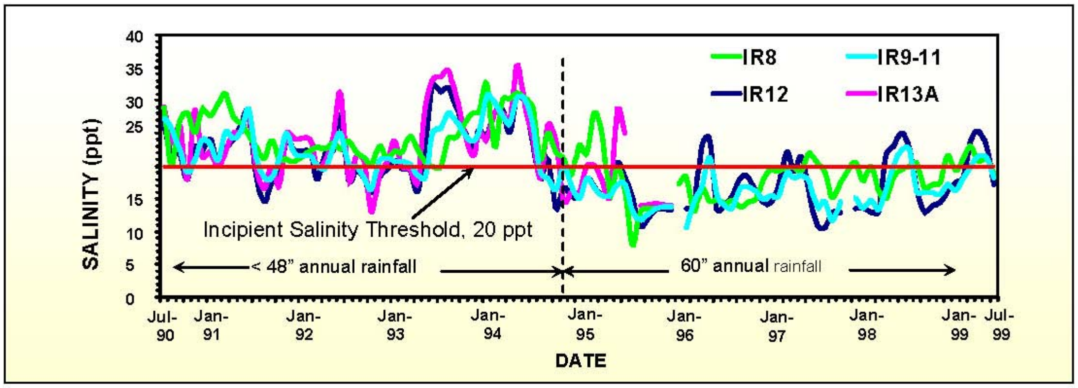


Figure 3-1 Monthly salinity levels from 1990 to 1999 in the North Indian River Lagoon area (IR8-IR13A are sub segments as mapped in Figure 3-2) (SJRWMD, 2002).

Salinity as an Ecological Forcing Function for Living Resources

Salinity is an important determinant of the distribution of estuarine organisms. The vital role that estuaries play in maintaining populations of marine fishes, shellfishes, and other organisms has long been recognized (Bulgar et al., 1993). Efforts to subdivide estuaries as a function of salinity have traditionally been based on the observation that estuarine species are not evenly distributed across estuarine salinity gradients. Descriptions of estuarine species have yielded more than a dozen salinity classification schemes with recurring patterns across taxa and geographic zones. One of the most well known zonation schemes is the Venice System (Anonymous, 1959), which has largely superseded earlier classification schemes. The empirical basis for the zonation of the Venice System was not reported in the original document and is mostly descriptive. Nevertheless, the descriptive purpose is and will continue to be very valuable. The Venice System breaks down estuarine salinity ranges into five zones:

- limnetic: 0 - 0.5 ppt,
- oligohaline: 0.5 - 5 ppt,
- mesohaline: 5 - 18 ppt,
- polyhaline: 18 - 30 ppt, and
- euhaline: > 30 ppt.

A more recent classification scheme (Bulgar et al., 1993) derives biologically-based estuarine salinity zones from multivariate analysis. Principal Component Analysis (PCA) was used to derive estuarine salinity zones based on field data of the salinity ranges for 316 species/life stages in the mid-Atlantic region. Application of PCA to the data matrix showed that the structure underlying a diversity of salinity distributions could be represented by only five Principal Components corresponding to the following five overlapping salinity zones:

- Freshwater – 4 ppt,
- 2 – 14 ppt,

- 11 – 18 ppt,
- 16 – 27 ppt, and
- 24 ppt – marine.

The derived salinity zonations showed both differences and similarities to the Venice System. However, unlike the descriptive Venice System, the newer method allows researchers to establish biologically-relevant local salinity zones and develop hypotheses about the processes that give rise to the resulting patterns (Bulgar et al., 1993).

The living resources of the study area are biologically adapted to the dynamic estuarine conditions which result in relatively wide changes in salinity over time and space due to mean water level fluctuations, wind driven circulation, and stratification of the water column. Thus, the salinity tolerances of these organisms are relatively broad, and the level of resolution needed to identify the tolerance ranges is also reported in the literature to be broad. These living resources may be potentially impacted directly by the concentrate discharge (e.g., the seagrass species have particular physiological salinity limits), or that may be impacted indirectly by the concentrate discharge through ecosystem processes (e.g., a duck species may be impacted by salinity tolerances of aquatic vegetation used by it for a food source). The impacts may also affect specific processes in the life cycles of the living resources (e.g., the spawning of a particular fish may be effected where the adults would not be).

3.1 Seagrass

In general, seagrasses have physiological adaptations that allow them to live in a saline environment. Unlike their terrestrial relatives, seagrasses do not have stomata (tiny pores in the leaves where gas exchange takes place) and they contain no specialized organs for salt excretion like other intertidal or halophytic angiosperms. Alternatively, evidence suggests that all of the epidermal leaf cells are capable of osmoregulation, as they appear somewhat analogous to the basal cells of salt glands in *Spartina* and osmoregulatory cells of the brine shrimp *Artemia salina*. The precise physiological mode for secretion cannot be deduced from existing information. However, structural and physiological evidence suggests that salt secretion in *Thalassia* occurs directly through the cell membrane and is not regulated through micro vacuoles or vesicles.

The species of seagrass in the study area are all well adapted to the wide ranging salinity conditions found in estuaries. The primary seagrass species in the vicinity of the potential demineralization facilities include *Ruppia* and *Halophila* species. It is expected that salinity may be one of the ecological factors that influences species composition and distribution in the study area (Figure 3-2) (SJRWMD, 2002). Other important ecological factors include water clarity, depth, sediment compositions, and epiphyte loads.

Turtle Grass (*Thalassia testudinum*)

Turtle grass (*Thalassia testudinum*) has the highest salinity tolerance of the seagrass species of the Lagoon system. This species is found within the general region of the study area (Figure 3-2), but is found relatively far south of the specific candidates sites for the demineralization facility. The optimal salinity range is expected to be 24 ppt to 35 ppt., and 16 ppt. is probably the lower limit for normal growth (Woodward and Clyde 1994). The tolerance range is reported to be from 16 ppt. to 48 ppt. (Woodward Clyde, 1994). However, a recent laboratory experiment using turtle grass reported that exposure to 6 ppt. salinity for 43 days stopped blade production and blade length decreased, and it reported that results for higher salinity treatments of 12 ppt., 18 ppt., 25 ppt. and 35 ppt. did not elicit these adverse responses after 43 days of exposure (Doering and Chamberlain, 2000).

Shoal Grass (Halodule wrightii)

The optimal salinity range for shoal grass is expected to be 22 ppt to 34 ppt., and the tolerance range is reported to be from 1 ppt to 45 ppt (Woodward and Clyde 1994). Shoal grass is reported to be able to withstand low salinities only for a short period (Robert Virnstein, project team personal communication).

Manatee Grass (*Syringodium filiforme*)

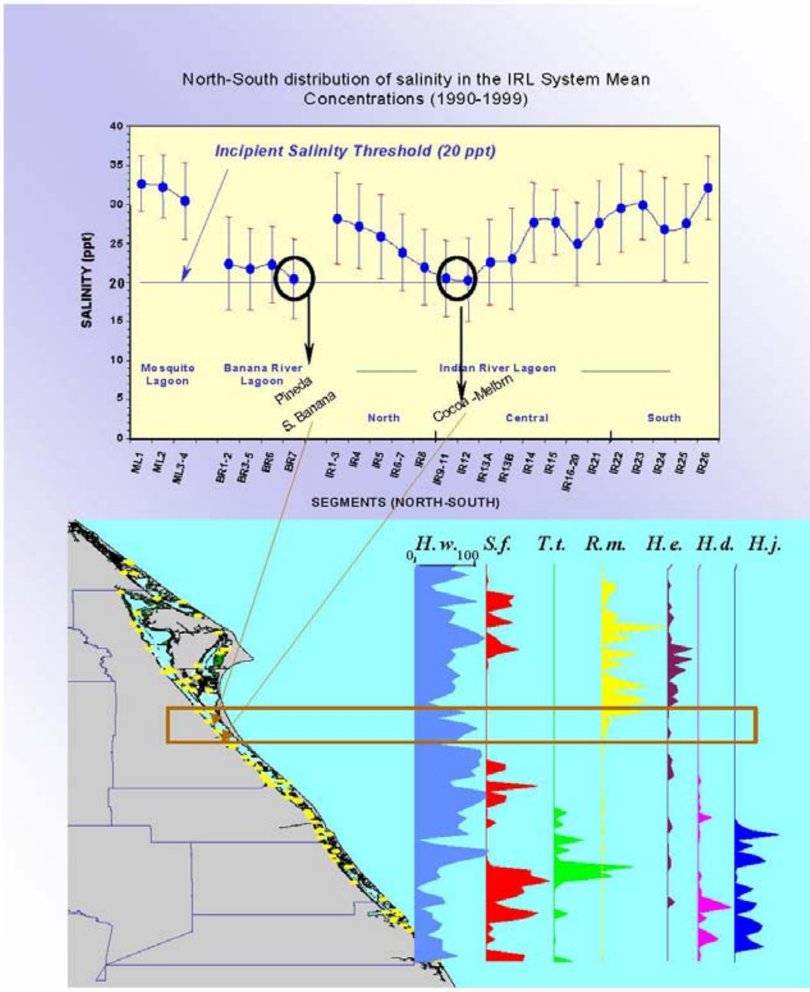
The optimal salinity range for manatee grass is expected to be 20 ppt to 28 ppt., and the tolerance range is reported to be from 10 ppt to 36 ppt (Woodward and Clyde 1994). The optimal and tolerance ranges for the Indian River Lagoon study area may be lower than these reported values for long term conditions (Robert Virnstein, project team personal communication).

Widgeon Grass (*Ruppia maritima*)

The optimal salinity range for widgeon grass is expected to be less than 25 ppt., and the tolerance range is reported to be from 5 ppt. to 32 ppt. (Woodward and Clyde 1994). In addition, information from the project team indicates that widgeon grass tolerances may be wider (0 ppt. to 60 ppt) than these reported values (Robert Virnstein, project team personal communication).

Paddle Grass (*Halophila decipiens*) and Star Grass (*Halophila englemanni*)

Paddle grass although found in the general region of the study area (Figure 3-2), is reported from an area relatively far to the south of the candidate demineralization facility locations. The salinity tolerance range for paddle grass is reported to be from 24 ppt. to 38 ppt., and the tolerance range for star grass is reported to be from 29 ppt. to 31 ppt. (Woodward and Clyde 1994). In addition, information from the project team indicates that star grass tolerances may be wider and lower than these reported values (Robert Virnstein, project team personal communication).



10-year mean salinities +/- S.D. in the IRL system by segment (top plot) and the relative abundance and diversity of seagrasses with an emphasis on the south Banana River Lagoon and Cocoa-Melbourne reach (bottom graphic) where both low salinities and low seagrass abundance and diversity exist

Seagrass Species:
H.w. – *Halodule wrightii* **S.f.** – *Syringodium filiforme* **T.t.** – *Thalassia testudinum*
R.m. -- *Ruppia maritima* **H.e.** – *Halophila engelmannii* **H.d.** – *Halophila decipiens*
H.j. – *Halophila johnsonnii*

Figure 3-2 Salinity and seagrass species distribution in the north Indian River Lagoon (SJRWMD, 2002).

3.2 Spotted Seatrout (*Cynoscion nebulosus*)

Spotted seatrout are an important recreational species in the Indian River Lagoon. This species is an estuarine resident, and the juveniles and adults are well adapted to a wide range of salinities. The reported optimal salinity for spotted seatrout ranges from 15 ppt. to 35 ppt., and the salinity tolerance range is from 0.2 ppt. to 77 ppt. (Woodward and Clyde, 1994). The salinity tolerance for juvenile spotted seatrout was recently reported from an intensive multi-year fisheries independent monitoring program (Florida Fish and Wildlife Research Institute Fisheries Independent Monitoring Program) in the form of a logistic regression model (Figure 3-3) and associated estuarine distribution map (Figure 3-4) from the Alafia River in Florida (Janicki Environmental, 2003).

3.3 Red Drum (*Sciaenops ocellatus*)

Red drum are also an important recreational species in the Indian River Lagoon. This species spawns offshore, and the very small juvenile fish are recruited into estuaries such as the Indian River Lagoon. The juveniles and adults are well adapted to a wide range of salinities. Data from Tampa Bay suggest that the smaller juvenile red drum prefer salinities from 0.5 ppt to 18 ppt. (Woodward and Clyde, 1994). The salinity tolerance for juvenile red drum was recently reported from an intensive multi-year fisheries independent monitoring program (Florida Fish and Wildlife Research Institute Fisheries Independent Monitoring Program) in the form of a logistic regression model (Figure 3-5) and associated estuarine distribution map (Figure 3-6) from the Alafia River in Florida (Janicki Environmental, 2003).

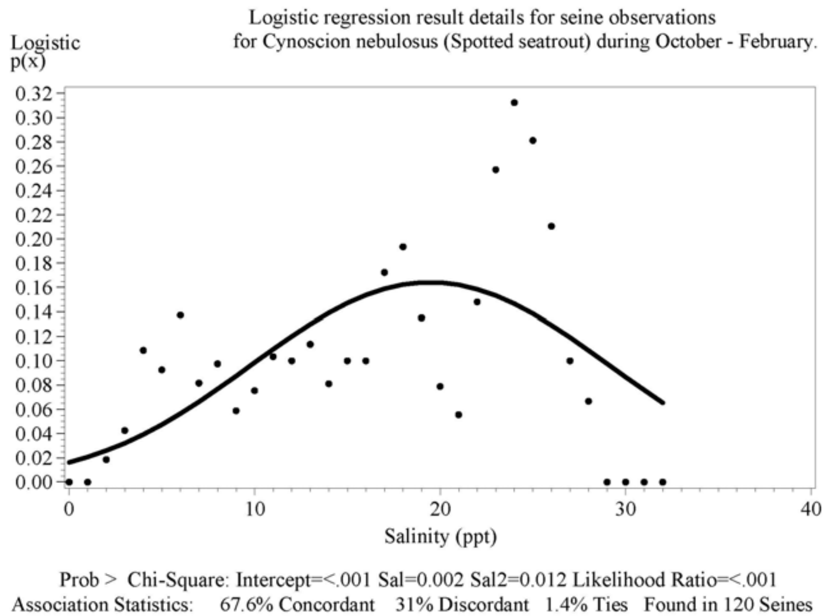


Figure 3-3 Salinity tolerance for spotted seatrout juveniles expressed as a logistic model. P(x) represents the probability of occurrence at a given salinity.

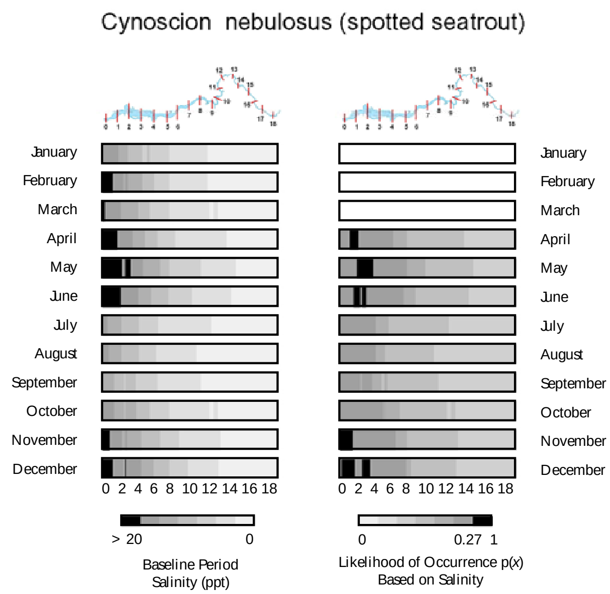


Figure 3-4 Salinity tolerance for spotted seatrout juveniles expressed as an expected distribution along a salinity gradient (Alafia River estuary) based on a logistic model. P(x) represents the probability of occurrence at a given salinity.

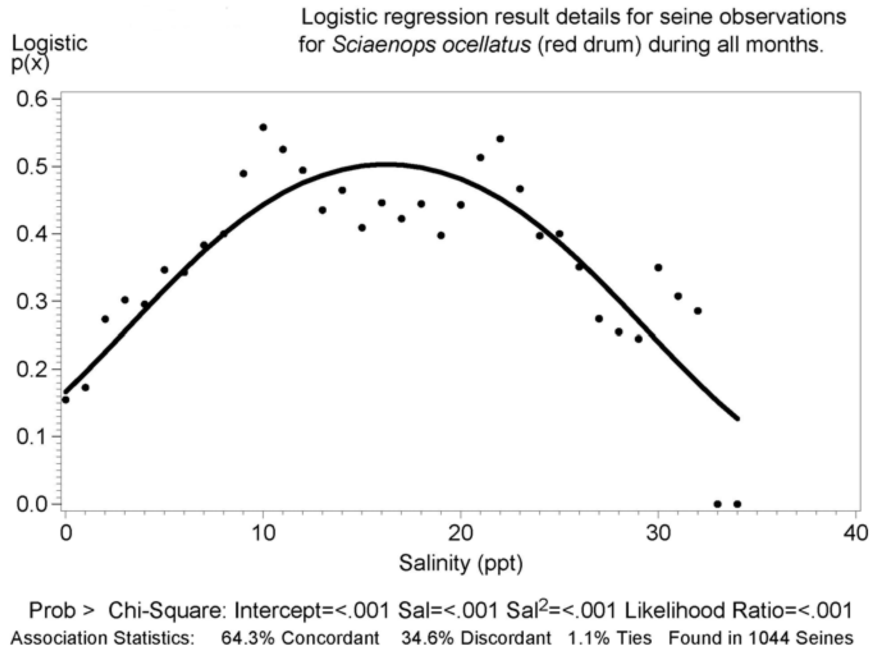


Figure 3-5 Salinity tolerance for red drum juveniles expressed as a logistic model. P(x) represents the probability of occurrence at a given salinity.

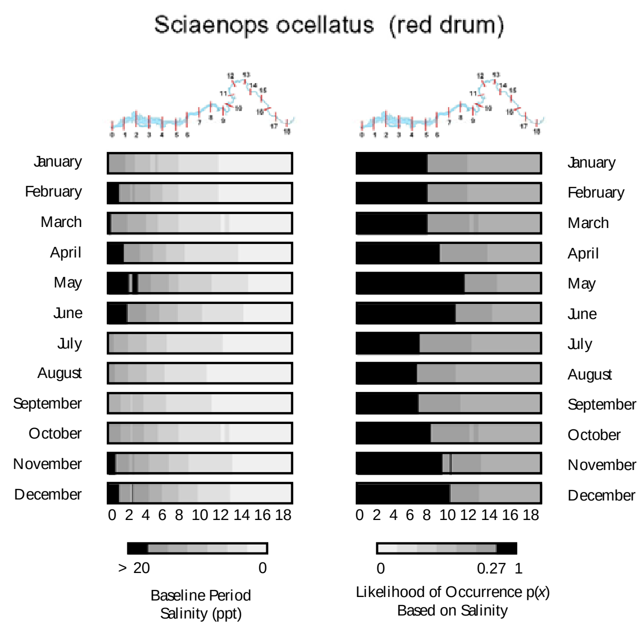


Figure 3-6 Salinity tolerance for red drum juveniles expressed as an expected distribution along a salinity gradient (Alafia River estuary) based on a logistic model.

3.4 Manatees (*Trichechus manatus*)

Manatees are important marine mammal species in the study area. With specific reference to the potential demineralization facilities, manatees utilize the warm effluents from the power plants as thermal refuges at certain times of the year. Figure 3-7 presents the manatee protection zones currently defined in the vicinity of the potential demineralization facility co-location sites.

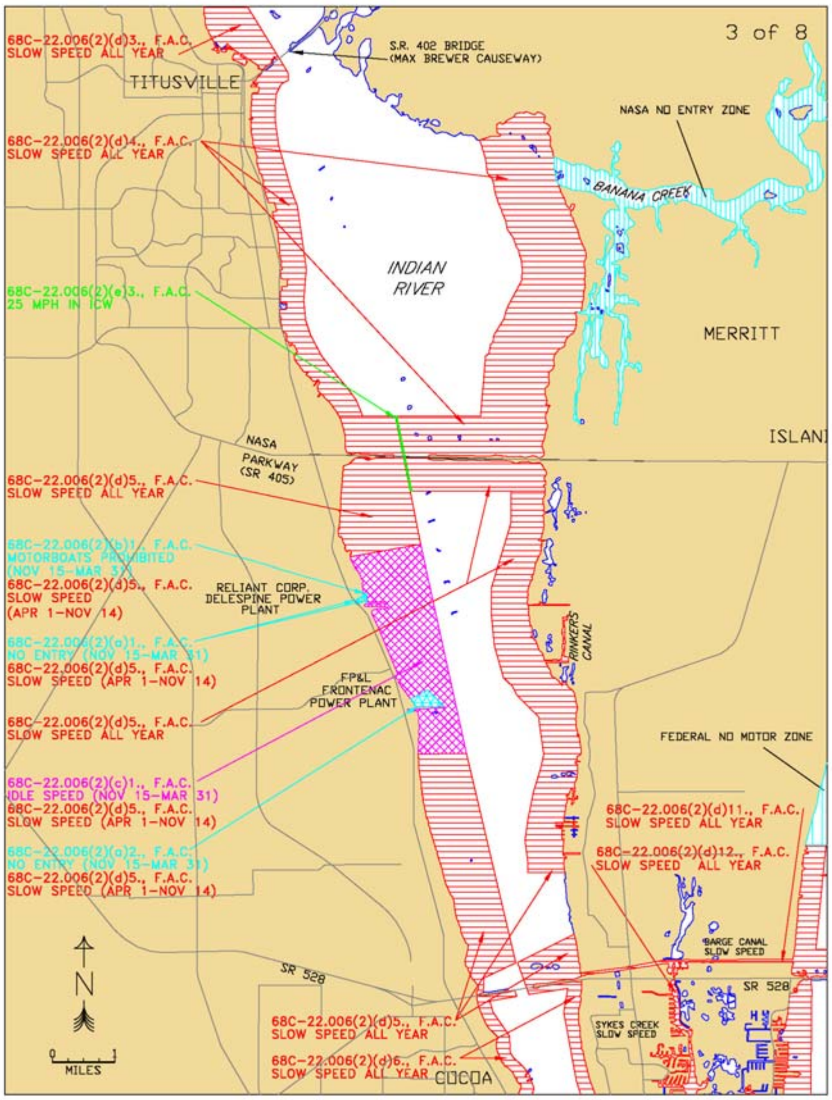


Figure 3-7 Manatee protection zones in the vicinity of the potential demineralization facilities (Figure source Fish and Wildlife Conservation Commission).

Manatees are biologically adapted to a wide range of salinity conditions. They possess highly evolved systems of osmoregulation. Marine vertebrates possess renal structures and endocrine mechanisms necessary to tolerate a hyperosmostic habitat. Except for manatees, marine mammals have lobulate kidneys, which allow them to drink salt water and to concentrate their urine while maintaining water balance and a constant plasma osmolality. However, manatees and dugongs do possess renal structures that indicate their ability to conserve water via urine concentration, which suggests these animals have the ability to inhabit marine environments. West Indian manatees are primarily found in freshwater but can inhabit regions with salinities as high as 35 ppt (Ortiz et al., 1998). In 1998, Ortiz et al. studied osmoregulation in wild and captive West Indian manatees (Trichechus manatus). Blood samples were analyzed from manatees held in fresh and salt water and from wild animals captured in fresh-, brackish, and salt water for concentrations of aldosterone, arginine, vasopressin, plasma renin activity, sodium, potassium, chloride, and osmolality. Two separate experiments were also conducted on captive animals to evaluate osmoregulatory response to acute saltwater exposure and freshwater deprivation. Generally, plasma electrolytes and osmolalities were constant over a broad range of salinities, suggesting that West Indian manatees are good osmoregulators regardless of the environment.

3.5 Merritt Island Birds

While the expected range of salinity change will not directly affect the Merritt Island bird populations, their food sources (e.g., aquatic vegetation, benthic macroinvertebrates, small fishes) may be susceptible to salinity changes. The food preferences will be identified and the salinity tolerances/preferences for the food organisms will be defined.

4. Spatial and Temporal Output Needs

Based on the expected range of salinity tolerances of the key living resources in the study area and the spatial and temporal variation in salinity in the study area, we recommend that the hydrodynamic model outputs be consistent with the following characteristics:

- A salinity resolution and level of precision of 2 ppt.

  The overall spatial and temporal resolution of the model should enable the model to have a salinity resolution and level of precision of 2 ppt. Eighty-percent (80%) of the salinity predictions should be within +/- 2 ppt. of the observed values, and a change in salinity due to the operation of the demineralization facility should be discernible to a level of precision of 2 ppt. or greater. The 2 ppt. level of resolution and precision should be generally attainable throughout the modeled time series, and it should generally hold true for the various quantiles of salinity (e.g., 10^{th} percentile, median, 90^{th} percentile, etc…).

- A minimum horizontal spatial resolution of 1 hectare closest to the potential demineralization facility discharge points.

  This horizontal spatial resolution is recommended in recognition of the fact that a coarser level of resolution may be practical at a distance away from the potential demineralization facility discharge points.

- A minimum vertical spatial resolution of two layers in the water column (surface and bottom).

  This vertical spatial resolution is recommended in recognition of the fact that additional layers may be required from a mathematical requirement in order to apply the hydrodynamic model equations.

- A minimum temporal resolution of daily salinity estimates.

  This temporal resolution is recommended in recognition of the fact that a finer temporal resolution may be required for technical hydrodynamic modeling purposes in order to attain confidence in the model with respect to wind event and tidal event cycles. However, the biological evaluation may be completed using daily estimates and post-model-run aggregation of the daily data (e.g., monthly percentiles).

5. Literature Cited

R.W. Beck, Inc. 2004. Final Report on Five Potential Seawater Demineralization Project Sites – Task C.5. Prepared for St. Johns River Water Management District, Palatka, Florida. Prepared by R.W. Beck, Inc. Orlando, Florida.

Appendix D

Modeling Work Session Summary

MEMORANDUM

TO: Project Team

FROM: Steven Peene

DATE: October 25, 2004

RE: SH341AA: Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon.

Summary of the Modeling Work Session held on October 14, 2004

The following presents a summary of the Modeling Work Session held on October 14, 2004. The attendees included:

- Dr. Steven Peene
- Dr. Anthony Janicki
- Dr. Mark Luther
- Danny Mendelsohn
- Glenn Forrest
- Jim Gross
- Ron Brockmeyer
- Bob Day
- Tim Cera
- Peter Sucsy
- Randy Stevens
- Detong Sun
- David Christian
- Dr. Billy Johnson (by phone)

The purpose of the meeting was to provide the following:

- a detailed discussion of the model reviewers findings after reviewing all model materials,
- an evaluation of the model in relation to the Model Expectations Document,
- provide initial detailed model recommendations.

The summary follows the agenda and format of the meeting. The meeting agenda is attached to this document along with the slides presented. The order of presentations made at the meeting was altered and the following is presented in the order from the meeting.

INTRODUCTION AND MODEL REQUIREMENTS

Presentation: General Overview of Discharge Scenarios

Dr. Peene presented a very brief overview of the discharge characteristics of the existing power plants as well as some very preliminary characteristics for the discharge. The presentation showed the ranges of temperature and flows from the two power plants based upon Discharge Monitoring Reports (DMR) data obtained through the public records. The discharge characteristics were also presented based upon the results presented in the RW Beck report entitled "Final Report on Five Potential Demineralization Discharge Sites". The presentation listed the potential salinity increases within the outflows of the two power plants based upon a maximum 30 Million Gallons per Day (MGD) production at each location, and low average plant cooling water flow conditions. The assumptions that defined the percent increases were based upon a 40 percent production of freshwater assumption. Comments were made that a more realistic number would be 50-60 percent production. A request was made that even though discharge scenarios are to be a part of Phase 2, some work should go into Phase 1 to define a flow chart of flows and the processes in the desal process to show more realistic numbers and be available for public presentation.

Presentation: Model Criteria Document

Dr. Janicki presented an overview of the draft Model Criteria Document. The document addresses desired criteria for evaluating the suitability of the District's CH3D model for analyzing the dispersion effects of concentrate discharge to the Indian River Lagoon. The UF-CH3D model is a 3-dimensional curvilinear grid hydrodynamic model that was developed for use in defining the Pollutant Load Reduction Goals for the Indian River Lagoon (IRL). The resource issues of concern that were considered in the Model Criteria Document were presented, they were:

- Red drum
- Spotted Sea Trout
- Manatee
- Seagrass
- Merritt Island birds
- Bait fish
- Benthic species

Ron Brockmeyer indicated the need for additional resource issues to be considered, these were:

- Horseshoe crabs
- Sea turtles
- Shellfish lease area east of the Intracoastal
- Lesser Scaup
- Shrimp
- Weak fish
- Fiddler crabs

It was identified that Dynamac Corporation has done extensive work in the area defining critical resources of concern and should be consulted under the project.

Specific issues that the model will need to address were listed in the presentation. The specific issues listed were:

- Salinity
- Circulation
- Residual circulation
- Residence time
- Other potential pollutants
- Other ambient pollutants

Comments were made based upon similar work within Tampa Bay for the Tampa Bay Water demineralization plant, which indicated that other potential pollutants were not a significant issue, many are removed as sludge. Ambient pollutants can be a problem as their concentrations are increased through the demineralization process.

Dr. Janicki presented the criteria for use in the model review. These are;

- A salinity resolution and a level of precision of 2 parts per thousand (ppt)
- 80 percent of predictions shall be within $\pm$ 2 ppt of measured data
- 100-meter grid resolution (area of 1 hectare)
- 2-layer minimum vertical resolution
- Daily average estimates of salinity
- Model runs over 1 year

Based upon whether or not the model is able to meet the salinity accuracy criteria listed above there will be two plans. Plan A would be utilized if the model is able to meet the criteria and the absolute levels of salinity can be utilized. Plan B would be utilized if the model did not meet the criteria, the model under this condition would be utilized in a relative analysis mode rather than absolutes. The horizontal resolution of 100 meters applies in the near field of the discharges, a coarser grid could be utilized away from the discharge points.

Questions were raised on where the 2 ppt salinity accuracy number came from. Dr. Janicki commented that this is an estuary: organisms experience changing salinity daily and the 2 ppt represents a level of standard deviation within the system. Additionally, the 2 ppt is based upon external recommendations on acceptable salinity errors in models.

Dr. Johnson provided recommendations based upon the model criteria presented, these included:

- Consider doing grid convergence testing, this consists of providing finer horizontal or vertical grid resolution and quantifying the change in the model results, a model is said to be convergent if additional resolution does not significantly modify the results.
- Some concern on the 2-layer resolution as sufficient to represent the vertical density structure, generally 5-layers needed to properly resolve the vertical issues
- General model criteria identify relative mean errors (RME) for salinity < 25 percent

Dr. Luther agreed that 5-layers is better for representing the vertical structure. Some discussion took place on the need for resolving the Intracoastal Waterway. Mr. Cera commented that sensitivity testing of the model has not demonstrated that the Intracoastal has a significant influence on the overall circulation in the system.

Presentation: Existing District Indian River Lagoon Model (UF-CH3D)

Mr. Cera presented a brief overview of the existing District IRL model (UF-CH3D). The presentation outlined the Pollution Load Reduction (PLR) model development and the overall grid utilized. Mr. Cera identified that the first 6-9 months of the data collected had problems but the remaining data utilized in the model development had been QA/QC'd and verified.

Some key points identified in the presentation:

- 60 freshwater inputs currently
- Improved evaporation estimates in the model
    - Calibrates well with measured data
    - Developing improved evaporation model
- No groundwater input
    - Based upon limited available studies on actual groundwater inflow <5% of total freshwater input comes from groundwater
- Rainfall from multiple gages

Mr. Cera was asked if the SJRWMD can make code-level changes to model and he indicated that with their present staffing they have the capability to perform code level changes.

Mr. Cera discussed the study “Preliminary Study of the Effects of Causeway Removals in the IRL”. He identified that the causeways had minimal impact on residence time, and they act as wind breaks to minimize resuspension of sediment from wind-waves. Also, he identified that water level changes in the system are primarily the result of low-frequency water level changes in the ocean as well as winds, and not freshwater inflow. Tidal influences are minimal within the area of the proposed plant locations.

Mr. Cera discussed the present grid resolution. Poster boards with the grid overlain upon an aerial were passed around focusing upon the area where the plants are located.

MODEL EVALUATION

Following the presentations given above, the work session was conducted as an open discussion reviewing various aspects of the model in light of the information presented on the model criteria, the discharge characteristics, and the model overview. The following summarizes the discussions and findings from each section.

Physical Processes

This discussion focused upon the general processes that the CH3D model is capable of simulating and a discussion on if the model is capable of properly simulating the processes of concern. The following discusses the issues raised and the resolution of each:

- Z-grid correction: the question was asked if the existing model has a z-grid correction for the transport. The model presently does have this correction. No action required.
- Temperature Simulation: the question was asked if the existing model can simulate temperature. The model does not simulate temperature, it is presently an input condition. Dr. Luther commented that for the Tampa Bay desal work there was an active temperature plume and it became an important parameter in the simulations. Mr. Cera commented that measurements did show some significant thermal stratification in the area. The reviewers (Dr. Peene, Dr. Luther, Dr. Johnson, Mr. Mendelsohn, Dr. Janicki) were individually polled to see if this is an important issue, it was unanimously decided that it is. The question was posed if the model could be coded to include temperature simulations, the answer was yes. Action required: modify code to simulate temperature.
- Simulation of Transport of other Parameters: Agreement that model can simulate other potential parameters of concern as conservative tracers. No action required.

Model Inputs and Boundary Forcings

This discussion focused upon how the model presently handles inputs, boundary conditions, and forcing functions. The following specific inputs and boundaries were discussed:

- Tidal Forcing/Ocean Boundaries: Tides are forced at the four inlets (Ponce de Leon, Sebastian, Fort Pierce, and St. Lucie) and at each location, water levels and salinities are prescribed. For the purpose of this study no issues were raised on the ocean boundary forcing at the inlets.
- Freshwater Inflows: The discussion focused upon the freshwater inputs north of Melbourne Causeway. Dr. Sucsy identified that all freshwater inflows are simulated using the Hydrologic Simulation Program Fortran (HSPF) model and, specifically, the Merritt Island side flows are simulated with a relatively coarse watershed representation. It was identified that various detailed discharges exist in the area of Merrit Island such as Pine Island Canal. He identified that the present spatial resolution may not be sufficient for our more localized study. Also, the issue of simulation of the Mosquito Impoundments was discussed. It was identified that 11 rain gages were utilized in order to provide the precipitation input for the HSPF model simulations. It was determined that the present spatial resolution of freshwater inflow may not be sufficient. Action required: additional investigation of existing HSPF model and recommendations for more detailed simulation of flows in local area, also

use of more dense precipitation data available from NASA or perhaps the use of NEXRAD data.

- Wind: The discussion focused upon what wind data were available to use to define winds in the model. There was general agreement that the wind gages are sufficient to represent the system even on local scale. Some recommendations to use power plant data and NASA data if available. Action required: Investigate additional data sources.
- Evaporation: Data deemed sufficient. No action required.
- Bathymetry: Discussion focused on what bathymetric data are available and what resolution is available in the vicinity of the power plants. Coastal Planning and Engineering (CPE) did transects at a relatively fine interval in immediate area. General recommendations that existing bathymetric data sufficient for local evaluation. No Action Required.

Spatial/Temporal Resolution

The discussion focused on the present spatial resolution both vertical and horizontal, as well as the temporal resolution of the model. The following recommendations were made on each component.

- Horizontal Resolution: Present horizontal resolution is not sufficient to represent the conditions within the study area. Dr. Luther identified that lateral salinity gradients need to be represented. Dr. Johnson indicated that the changes in temperature may create horizontal density gradients. Dr. Johnson also indicated that the 100 meter grid spacing is sufficient to represent the salinity and temperature gradients. Mr. Mendelsohn indicated that in the region of the canals the grid resolution may actually need to be less than 100 meters in order to represent the discharge through the canals and to represent any possible recirculation issues. Some cells in the canals will need to be represented.
- Vertical Resolution: Recommendations on the appropriate vertical resolution indicated the possible need for up to 5 layers to simulate the potential vertical gradients. Currently there are 4 layers.
- Temporal Resolution: The present temporal resolution is sufficient for the modeling of the demineralization concentrate discharge. The time steps under a more refined model will be less than the present.

Model Calibration/Validation

The discussion focused on the present model calibration and if that calibration is sufficient for the desal concentrate discharge evaluation.

An extensive discussion relative to the alterations done to the Ponce Inlet boundary conditions in order to achieve the present calibration was conducted. The mean water level for the water level boundary forcing at Ponce Inlet was set at 13 cm lower than measured mean water level at Ponce Inlet. This roughly matched the mean water level conditions at Sebastian, Ft. Pierce, and St. Lucie Inlet. This was needed in order to represent the net flows through Haulover Canal. This 13 cm drop was equivalent to the mean water level difference that the data showed between Sebastian, Ft Pierce and St. Lucie Inlets. Dr. Luther indicated that one would expect to set the four inlets at the same mean water level, the correction used was deemed reasonable.

It was requested that the SJRWMD modelers provide the statistics for the existing model that would allow comparison to the model criteria document statistics, e.g. 4-year simulation providing the 80th percentile values for the salinity error statistics and the percentiles that are below 2.0 ppt difference.

Based upon the recommendation for a more refined horizontal resolution, the method for providing the local resolution was discussed. Two options were discussed. Option A is to add additional model grid lines in both the I and J directions in order to provide the needed resolution within the area of the project. The location of this model refinement would be located between causeways with the upstream and downstream extent based upon some preliminary model simulations using the existing model with withdrawals and discharge. The goal would be to resolve in the area where significant impacts were seen. Option B would be to develop a subgrid model whose boundary conditions would be forced by the larger model. As with Option A, the subgrid would extend out past the area where significant impacts were seen based upon preliminary model runs. Additionally, discussions took place relative to the use of an alternate model that presently has the ability to simulate temperature versus code changes that would be needed in CH3D to simulate temperature. General consensus of the group was to utilize the CH3D model with code changes to simulate temperature and to develop a single large model with additional refinement of the existing grid in the area of the project to get the needed resolution (Option A). A recommendation was made prior to the final decision to develop a matrix of pros and cons for Options A and B.

Appendix E

FDEP Meeting Summary (December 16, 2004) and FDEP Comments on Task 2G with Responses

Meeting Summary

DATE: December 16, 2004

FROM: Steven Peene

TO: Glenn Forrest

COPY TO: Jim Gross

SUBJ: Evaluation Of Potential Impacts Of Demineralization Concentrate Discharge to the Indian River Lagoon (a.k.a. "IRL Salinity Study"), FDEP Meeting, Tallahassee, Florida, November 15, 2004

Attendees

Steven Peene, ATM
Tony Janicki, Janicki Environmental
Jim Gross, SJRWMD
Glenn Forrest, Taurant
Allen Hubbard, FDEP
Wayne Magley, FDEP
Jan Mandrup Poulson, FDEP
Richard Drew, FDEP
Christina Ferraro (by phone)

Purpose

The goal of this meeting was to provide FDEP an overview of the preliminary findings from the Phase 1 work and to solicit comments or input on issues of concern. Additionally, the goal of this meeting was to incorporate any suggestions or changes from FDEP to the overall project approach.

The following is a summary of items discussed at the meeting:

1. **Introduction and Background –** The meeting began at approximately 3:00 pm. Glenn Forrest provided an overview of the proposed project and introduced the ATM team members and their roles in the project. Steven Peene and Tony Janicki then provided a brief overview of the Model Expectations Document (MED) including the MED recommendations relative to the model. Following the overview of the MED, Dr. Peene provided a brief overview of the activities in Phase 1 and the findings of the Phase 1 work as summarized in Technical Memorandum B.1 which had been submitted in draft form. Dr. Peene's presentation included the suggested recommendations for the model. Following Dr. Peene's presentation, a general discussion began on the project.

2. **Group Discussion –** This was a general discussion between all parties within the room.

    - Darryl Joiner asked if the 2 ppt criteria for the salinity accuracy is sufficient given the potential for change at the discharge point which would be near the 2 ppt accuracy level. Dr. Peene responded that while the 2 ppt accuracy reflected an absolute accuracy of the model, its ability to simulate changes in salinity would be much better.

- Allen Hubbard led a discussion on the history of the power plant permitting and the 316 studies that were conducted there. He described that the studies were fairly old and that not much new work has been completed. He described that there were no detailed thermal studies on the plants that he was aware of. It was identified that historically DOT had done some modeling in the area relative to the culverts. Also, it was brought up by Wayne Magley that the EPA Athens lab may have done some dye study work in the Cocoa area.
- Regulatory issues were brought up and discussed including entrainment issues, and the lack of potential for additional once through cooling plants such as these to be permitted. Additionally, the 316 assessments were discussed with comments including that the assessments documented heavy impacts due to entrainment and that some new technologies for thermal discharges will need to be implemented such as cooling towers. It was indicated that future permitted facilities will not be the same types.
- Darryl Joiner asked if we felt that smaller than 100 meter square grid cells were needed in the vicinity of the discharges. Dr. Peene stated that smaller grid cells would be utilized in the vicinity of the discharges. Darryl asked if a more simplified mixing zone type model could be utilized. Dr. Peene identified that potential recirculation and salinity build up could not be addressed with the simplified mixing zone models.
- Wayne Magley asked if we were using the EMAP data. Tony Janicki identified that we would be.
- A questions was raised by FDEP staff if there was any evaluation of offsite options.
- Jan Mandrup Poulson identified that we would need to characterize the extent of benthic changes and asked if we were coordinating with the IRL NEP program and if there were any conflicts with their plans. Glenn Forrest answered that we were coordinating with IRL FDEP staff throughout the project.
- Mr. Poulson identified that there is presently an EPA interim PLRG established.

The meeting concluded at approximately 4:00 p.m.
The above represents a summary from the writers' notes and the writers' understanding of items discussed. If clarification or correction is needed on the above summary, please contact the writer.

End of Meeting Summary.

Comments from Christianne Ferraro, P.E.,
Central District FDEP office

1. The issue of the projected service life of the 2 existing power plants under consideration for co-location and the reliability of the power plant operation (outages or temporary suspension) with respect to the cooling water operation are a concern that needs evaluation as stated in the report. Are there any future changes planned with respect to the operation of either plant that are known at this time?

   It may be wise to include a discharge scenario that would evaluate the impact of a desalination plant discharge without the benefit of the cooling water stream to understand the future ramifications of changes in power plant operating regime where it is not in continuous operation. The report indicates that the plants operate in the load-follow mode (their historical capacity factor is about 30 –35 %). This term "load-follow" is not explained, and does it mean that they only operate at 30-35% capacity? Do they operate or does the cooling stream operate continuously? Would storage of concentrate help with this concern so it could be stored until a continuous flow was re-established?

At present, there are not plans for the power plant to drop in its service provisions. Under the present scope of work it is assumed that the power plants will continue to operate for determination of the environmental impacts. The minimum cooling water flows necessary for the desalination plant to meet the FDEP requirements of 10% dilution will be maintained and the desalination plant will not be assumed to operate outside of this boundary.

2. On page 12, under Section 2.4 Equipment Maintenance Issues, an NPDES permit for a desalination plant is discussed. Is this the NPDES permit for the Tampa Bay Water desalination plant? If so, it should be identified.

This is for the Tampa Plant. The text will be altered to reflect this.

3. Also in this same section, RO membrane cleaning wastes are discussed. It should be noted that the Port St. John WWTP may not be of adequate size to accommodate these wastes and a larger facility may be needed which would likely require the off-site trucking. What is the typical volume of these wastes generated, say, on a monthly basis? What is the frequency typically of the membrane cleaning?

The volume and frequency of wastewater generation from the membrane Clean-In-Place (CIP) is a function of the raw water characteristics, the size of the plant and the pretreatment and RO systems designs. Prior to piloting studies there is limited information to suggest typical ranges for these values. The wastewater characteristics can also vary dependent on the raw water characteristics and the pretreatment and RO systems designs. Designers would prefer that RO systems be cleaned at frequencies *greater than 6 months to assure a reasonable life for the RO membranes. A single 4 million gallon per day train of RO pressure vessels can generate from 50,000 to 175,000 gallons of waste per cleaning. A twenty million gallon per day plant with a six month CIP cleaning cycle, five 4 mgd RO trains and a 100,000 gallon CIP wastewater production per cleaning would then create on average roughly 2,740 gallons per day of wastewater (5 trains X 2 cleanings per year X 100,000 gallons per CIP divided by 365 days per year). The design basis for the wastewater generation rate should be higher to allow for irregular schedules for CIP cleanings and an adequate safety margin. Desalination plant designs typically include wastewater storage tanks to assure low flow discharge rates into the disposal facilities.*

4. On page 13, and elsewhere in the report (page 37), 63-302, Florida Administrative Code is referenced. Please note that it should be 62-302, instead.

Comment noted and the text will be changed.

5. The Department agrees that local source water data should be evaluated, and as mentioned before there is some limited data available from a pilot testing research project for the FPL Cape Canaveral plant I believe. That testing program was funded by the SJRWMD and so should be available.

This data will be brought in under Task 2D.

6. The Department has water quality data available for the Indian River Lagoon, since we are beginning our watershed activities in this region. Impaired waters and the parameters of concern causing impairment will be an important issue to address in the permitting stage. The pretreatment processes should help in this regard, by reducing levels of some pollutants.

Comment noted.

7. Is there a more recent source for levels of copper, iron and mercury in seawater? 1968 seems kind of outdated, especially with the advances in testing methods. We would advise testing source water for all parameters in 62-302 with limits for Class III marine waters so it is known what parameters could present permitting issues in advance.

Under this study no additional data collection for local water quality is scoped. We will gather all available data under Task 2D.

8. Impingement and entrainment will be important issues as mentioned in the report since by withdrawing additional water, these potential impacts could increase.

Intake structure reports (316B) have been requested from the FDEP under the data collection effort in Tasks 2D and E. This will allow for an assessment of the current degree of impingement and entrainment. If greater amounts of water pass through the *intake structures at the power plants, it is possible impingement and entrainment could increase and will be evaluated in the impacts evaluation under Task 2F. It should be kept in mind that the relative increase in flows due to the need for additional cooling water will be small. In addition, the periods of time where additional cooling water flow will be needed will be when the plant is operating well below its permitted flow levels or levels under which it presently operates, therefore not increasing the intake flow above where it presently reaches.*

9. A few typographical errors:

    a. Page 24 – an extra **"to"** in first sentence of second paragraph.
    b. Page 30 – under the discussion on hard calms – should be "**found"** on sand flats.

Comments noted and Text will be updated.

10. In summary, the report provided a thorough review of the issues of concern and was very well written. Due to the variable operation of the plants and the source water quality, these desalination plants will likely be very challenging projects to implement.

Comment noted.

Meeting Summary

DATE: January 13, 2006

FROM: Steven Peene

TO: Glenn Forest

COPY TO: Jim Gross

SUBJ: Evaluation Of Potential Impacts Of Demineralization Concentrate Discharge to the Indian River Lagoon (a.k.a. "IRL Salinity Study"), FDEP Meeting, Tallahassee, Florida, January 13, 2006

Attendees

Steven Peene, ATM
David Wade, Janicki Environmental
Glenn Forrest, Taurant
Wayne Magley, FDEP
Jan Mandrup Poulson, FDEP
Richard Drew, FDEP
T.S. Wu, FDEP
Doug Gilbert, FDEP

Christina Ferraro (by phone)

Purpose

The goal of this meeting was to provide an overview of the work performed to date with specific emphasis on reviewing the model development and calibration, the salinity and temperature change results provided by the model for various scenarios, and the environmental assessment methodology that was outlined in TM 2D/E. Additionally, the goal of this meeting was to incorporate any suggestions or changes from FDEP to the overall project approach.

The following is a summary of items discussed at the meeting:

1. **Introduction and Background** – The meeting began at approximately 1:00 pm. Glenn Forest provided an introduction and overview of where the project is at the moment.
2. **Overview of Model Development and Calibration** – Steven Peene provided an overview of the modeling work done. This was a power point presentation provided, the following provides a summary of the general discussion during and following the power point presentation.
3. **Notes from Glenn Forrest**:

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Tallahassee, FL 32312
Email: speene@appliedtm.com
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Mobile (850) 591-1888

- ATM explained that the equilibrium analysis indicated the need to go to a 12 year duration for the simulations in order to see the full impacts. FDEP's reaction was that this may imply longer resident times for higher salinity levels.
- FDEP commented that the extensive assessment being done under this study is a "freebee" of sorts to the power companies, who can use this data to further evaluate their 316b scenarios (currently being required by FDEP).
- FDEP suggested that a System Salt Mass Balance be performed, and that effects on ground water inflow be considered. S. Peene replied that District staff (Tim Cera) is doing this as part of the Task F submittal.
- Regarding the symptotic shape to the run of peaks on the equilibrium results graph, there is still the perception of a slightly positive slope. Referring back to the Tampa Bay Water (TBW) / TECO desal plant permitting experience, this positive slope, however slight, will continue to be focused on by project detractors.
- FDEP suggested a sensitivity analysis be performed on the salinity concentration and dispersion results, e.g. drought-type years, near-drought, no drought. This could be accomplished using the various repeat-year scenarios that have already been simulated. FDEP appeared to agree with the concept that the system "resets" itself, e.g. after a wet year. FDEP also suggested a 4-year running average approach.
- There was discussion about the possibility of re-thinking the nature of fresh water inflow to the IRL, given the results of taking 30 mgd of fresh water out. There was concurrence that fresh water inflow in the north IRL is not nearly as great as in the southern portions of the IRL.
- FDEP expressed concern over stratification issues, similar to issues with the TBW desal project. Denser water sits on bottom and DO cannot penetrate warmer top layers, leading to adverse habitat issues. The TBW actual data was discussed, e.g. cumulative change in salinity is less than 1 ppt, compared to 3 ppt in the IRL in our study, this difference is significant. ATM/ Janicki replied that the study will indicate variance but not sure yet how to show seasonal changes on temperature and salinity. May consider a percent-saturation approach instead of an absolute – mg/l approach. Lagoon-wide contours may also be used. Density could be used as a "surrogate" for stratification prediction since there is little to no DO data for the IRL.
- Regarding water quality and habitat information, FDEP requested that the study be sure to include Harbor Branch data on benthos, particularly in the Merritt Island and Haulover Canal areas. FDEP (R. Drew) also asked if different types of seagrass would be evaluated. D. Wade replied yes. However, since there is apparently one primary seagrass taxa, the ATM team stated they weren't planning on heavily evaluating many different types.
- Clams versus oysters – which are more important? Effects of concentrate will be different. ATM/ Janicki stated that the study results will likely show that there

will be both “winners” and “losers.” Drill were discussed since high salinities would likely discourage their presence (predator of oyster).

- Aquatic preserves were discussed. G. Forrest expressed knowledge about Mosquito Lagoon A. P. and the Banana River A. P. but none known in the immediate area of the power plants. However, any change in salinity reaching into preserves will require special attention. ATM to re-review limits of preserves (see F. S. 62-302, but OFW boundaries could be slightly larger) (contact Janet Klemm of FDEP for GIS coverages). Direct effect, versus effect to contiguous areas, are treated differently. If there are “losers” in an OFW, the desal project with concentrate discharge to the IRL would have little to no chance of moving forward.
- FDEP stated that ecological impacts should consider overlap, e.g. drum versus shrimp was discussed. Is salinity the best indicator? Temperature should be considered (but we’re not affecting temperature). With and without power plants should be evaluated.
- FDEP inquired about ground water inflow. It was stated that some studies indicate as much as 30 to 50% contribution. S. Peene described University of Florida report that concluded that the contribution is much less, and that sensitivity analyses were performed on this aspect of inflow.

4. Notes from Steve Peene:

- FDEP staff indicated that the definition of stratification should include more information on DO change distributions (e.g., box plot, samples sizes), and should consider seasonality and temperature. The effects of stratification on DO saturation should also be investigated.
- FDEP staff indicated that historical benthic data from the study area are available from Harbor Branch, Bob Virnstein was an original investigator on the data collection efforts.
- FDEP staff indicated that Harbor Branch also collected historical fish, phytoplankton, and zooplankton data in the study area.
- FDEP staff noted that 316B studies demonstrated thermal effects of power plants on biota.
- FDEP staff indicated that oyster populations should be considered.
- An initial FDEP comment in response to the study team’s presentation of methodology using acres of habitat as a response variable was that habitats should be broken down by type. The study team then provided additional methodology indicating that responses would be quantified for key habitat locations (e.g., seagrass meadow, shellfish lease area, site of observed fish abundance, etc…).
- FDEP staff and study team agreed that the pretreatment process should be considered with respect to the demineralization facility’s potential for concentrating ambient pollutants.

- FDEP staff stressed as an important point that any predicted salinity changes in the Aquatic Preserve area would be considered a more important impact, and should be given more weight than other potential impacts.
- FDEP staff indicated that the legal descriptions/boundaries of the Aquatic Preserve are available from Janet Klemm (FDEP). FAC 62-302.

5. The meeting concluded with an overview of the schedule of tasks to be completed and the present task deliverable timeframes. FDEP will provide comments on draft documents.

The meeting concluded at approximately 3:00 p.m.

The above represents a summary from the notes taken at the meeting by various persons on the ATM Team and SJRWMD. If clarification or correction is needed on the above summary, please contact the writer.

End of Meeting Summary.

FDEP Comments - June 16, 2006

Draft Technical Memorandum 2.G - Final Report
Evaluation of Potential Impacts of Demineralization Concentrate Discharge on the Indian River Lagoon (Study) Contract # SH341AA

The Central District FDEP staff has reviewed the various Technical Memorandums that were associated with this project, including the recent Draft Final Report and has the following comments:

1. This study, evaluating the impacts that could potentially occur with co-location of a desalination facility for production of potable water with the two power plants that currently withdraw cooling water from the Indian River Lagoon was a very worthwhile undertaking. Much knowledge has been gained as a result that will greatly aid any utility that must decide whether to use desalination at either of these two locations and what size facility may be feasible.

   Comment noted.

2. The Department greatly appreciates the SJRWMD and its contractor involving our technical water quality assessment staff in decision-making as to the direction of the study and model development. We will be happy to participate in other future coordination efforts as well. Technical staff made a number of suggestions that were incorporated into the project and for a project such as this study, that coordination was crucial.

   Comment Noted.

3. As to the conclusions of the Final Report, the Department recognizes that the model that was developed is conservative in nature, but that this model clearly shows that unacceptable impacts to the salinity regime of the Indian River Lagoon are likely to occur with construction of a desalination facility over 10 MGD. The Department had reservations about the feasibility of co-location of a desalination facility of any considerable size with these power plants due to the closed nature of the Indian River Lagoon in this area. The study results support this concern. It is interesting to note that these potential predicted impacts are not just due to the discharge of demineralization concentrate, but are also due to the withdrawal of water for desalination purposes pulling in saltier ocean water through Ponce Inlet and the Mosquito Lagoon. Even though this may be the case, concerns remain about potential impacts to the Mosquito Lagoon, which is designated as an Outstanding Florida Water. The report recognizes these concerns and is up-front in identifying them as a potential obstacle.

However, the concepts used in determination of Minimum Flows and Levels (MFL) for a water body and subsequent determination of acceptable habitat loss as discussed in the Draft Final Report is very, very, different than the permitting of a point source discharge, even for a potable water facility. In setting an MFL, some decision must be made as to where to draw the line – that is not the case for a permitting scenario for a surface water discharge. This is a very important point. The Draft Final Report infers that an agreement with the FDEP as to an acceptable level of habitat loss is more feasible than it is likely to be.

4. Therefore, it will be very important for any utility planning to pursue construction of a desalination facility in this area to meet with the Department technical and upper management staff on potential impacts to the Indian River Lagoon that may occur with such a facility. OFW rules do not allow for **any** degradation of water quality to occur, and our Anti-degradation rules are a paramount consideration for this potential permitting scenario. The following is an excerpt from our Anti-degradation Rules that is very pertinent to the potential permitting scenario:

"62-4.242 Antidegradation Permitting Requirements; Outstanding Florida Waters; Outstanding National Resource Waters; Equitable Abatement.
(1) Antidegradation Permitting Requirements.

(a) Permits shall be issued when consistent with the antidegradation policy set forth in Rule 62-302.300, F.A.C., and, if applicable, Rule 62-302.700, F.A.C.

(b) In determining whether a proposed discharge which results in water quality degradation is necessary or desirable under federal standards and under circumstances which are clearly in the public interest, the department shall consider and balance the following factors:

1. Whether the proposed project is important to and is beneficial to the public health, safety, or welfare (taking into account the policies set forth in Rule 62-302.300, F.A.C., and, if applicable, Rule 62-302.700, F.A.C.); and
2. Whether the proposed discharge will adversely affect conservation of fish and wildlife, including endangered or threatened species, or their habitats; and
3. Whether the proposed discharge will adversely affect the fishing or water-based recreational values or marine productivity in the vicinity of the proposed discharge; and
4. Whether the proposed discharge is consistent with any applicable Surface Water Improvement and Management Plan that has been adopted by a Water Management District and approved by the Department."

The Antidegradation Rules do not apply to the determination of Minimum Flows and Levels. The presence of the Merritt Island National Wildlife Refuge and the fact that this area is part of the National Estuary Program complicate the permitting even further, knowing that impacts are likely to preferred habitats for seagrass and wildlife species.

5. It will have to be demonstrated by any utility proposing to permit such a project that there really are **no feasible alternatives to the proposed project.** The Department believes that there are other regional alternatives or alternative locations that would be more feasible that a desalination project co-locating with the power plants in this part of the Indian River Lagoon. These other alternatives that should be evaluated include construction of a desalination facility at Port Canaveral, or the coastal ocean desalination alternatives that are currently also under study. Using reclaimed water for irrigation to the maximum extent possible is another important element that must be fully exhausted before consideration of permitting of one of these desalination scenarios.

The project team acknowledges and concurs with the comments provided by FDEP. MFL concepts utilized in the analyses for this project were available guidelines for defining acceptable levels of impact. The project team acknowledges that under a permitting process these may not apply, especially within the OFW. Within the text under the discussion of feasibility, it was stated that specific conditions within the IRL (i.e. programs and their objectives, in particular the NEP goals and objectives) may make any changes unfeasible. Additional language will be provided within the report executive summary and conclusions to also acknowledge the OFW issues.

The Department appreciates the SJRWMD involving us in this study and does consider it to be a very valuable undertaking, even if the outcome from the standpoint of implementing alternative water supplies was not as positive as we would have hoped. We will continue to support the SJRWMD in its effort to implement alternative water supplies and hope that we can continue to have a close coordination on the various water resource development projects that are underway or that may occur in the future.

Appendix F

Elemental Composition of Seawater

Elemental Composition Of Seawater In Parts Per Million For Major Components

Source: Karl K Turekian: Oceans, 1968, Prentice-Hall

Hydrogen H_2O	110,000	Molybdenum Mo	0.01
Oxygen H_2O	883,000	Ruthenium Ru	0.0000007
Sodium NaCl	10,800	Rhodium Rh	.
Chlorine NaCl	19,400	Palladium Pd	.
Magnesium Mg	1,290	Argentum (silver) Ag	0.00028
Sulfur S	904	Cadmium Cd	0.00011
Potassium K	392	Indium In	.
Calcium Ca	411	Stannum (tin) Sn	0.00081
Bromine Br	67.3	Antimony Sb	0.0
Helium He	0.0000072	Tellurium Te	.
Lithium Li	0.170	Iodine I	0.064
Beryllium Be	0.0000006	Xenon Xe	0.000047
Boron B	4.450	Cesium Cs	0.0003
Carbon C	28.0	Barium Ba	0.021
Nitrogen ion	15.5	Lanthanum La	0.0000029
Fluorine F	13	Cerium Ce	0.0000012
Neon Ne	0.00012	Praesodymium Pr	0.00000064
Aluminium Al	0.001	Neodymium Nd	0.0000028
Silicon Si	2.9	Samarium Sm	0.00000045
Phosphorus P	0.088	Europium Eu	0.0000013
Argon Ar	0.450	Gadolinium Gd	0.0000007
Scandium Sc	<0.000004	Terbium Tb	0.00000014
Titanium Ti	0.001	Dysprosium Dy	0.00000091
Vanadium V	0.0019	Holmium Ho	0.00000022
Chromium Cr	0.0002	Erbium Er	0.00000087
Manganese Mn	0.0004	Thulium Tm	0.00000017
Ferrum Fe	0.0034	Ytterbium Yb	0.00000082
Cobalt Co	0.00039	Lutetium Lu	0.00000015
Nickel Ni	0.0066	Hafnium Hf	<0.000008
Copper Cu	0.0009	Tantalum Ta	<0.0000025
Zinc Zn	0.005	Tungsten W	<0.000001
Gallium Ga	0.00003	Rhenium Re	0.0000084
Germanium Ge	0.00006	Osmium Os	.
Arsenic As	0.0026	Iridium Ir	.
Selenium Se	0.0009	Platinum Pt	.
Krypton Kr	0.00021	Aurum (gold) Au	0.000011
Rubidium Rb	0.120	Mercury Hg	0.00015
Strontium Sr	8.1	Thallium Tl	.
Yttrium Y	0.000013	Lead Pb	0.00003
Zirconium Zr	0.000026	Bismuth Bi	0.00002
		Thorium Th	0.0000004
Niobium Nb	0.000015	Uranium U	0.0033
		Plutonimu Pu	.

Concentrations may change due to depth, temperature, location, and a host of other factors.

CONCENTRATIONS OF THE MAJOR COMPONENTS

Source: Karl K Turekian: Oceans, 1968, Prentice-Hall

Component	g/kg
Chloride	19.53
Sodium	10.76
Sulphate	02.72
Magnesium	01.294
Calcium	00.413
Potassium	00.387
Bicarbonate	00.142
Bromide	00.067
Strontium	00.008
Boron	00.004
Fluoride	00.001

Concentrations may change due to depth, temperature, location, and a host of other factors.

Appendix G

Seagrass Action Plan Excerpt from CCMP for Indian River Lagoon

LIVING RESOURCES
NATURAL COMMUNITIES
1.0 SEAGRASS ACTION PLAN

RELATED GOAL
Goal I, Water and Sediment Quality
Goal II, Habitat Preservation and Restoration

OBJECTIVE
To protect and restore the seagrass integrity and functionality in the Indian River Lagoon by attaining and maintaining water quality capable of supporting a healthy submerged aquatic vegetation community to a depth of 1.7 meters.

PRIORITY PROBLEM
Seagrasses and macroalgae are perhaps the most important habitat in the Indian River Lagoon. SAV ecosystems (seagrass and macroalgae) are highly productive areas exhibiting levels of primary productivity that often exceed highly manipulated crop lands (Zieman, 1982). SAV also provides: (1) crucial habitats for numerous invertebrates and fishes; (2) a major contribution to the detrital food web of the Lagoon; (3) critical areas for nutrient cycling; and (4) sediment stabilization and shoreline protection.

Overview of Actions
SG-1 **Page 175** ***Implement a program of restoration and management activities needed to maintain, protect and restore the seagrass/SAV community of the Indian River Lagoon.***

Related SWIM Projects
SWIM Projects Title Major Issue
IR-2-201-D, F, M Seagrass Preservation/Restoration Habitat/Loadings
IR-2-204-M Land Acquisition Habitat/Loadings
IR-6-503-M SWIM/Local Government Planning All

The increasing human population of the coastal zone has impacted water quality of rivers, estuaries and nearshore waters. Water transparency, which dictates the amount of light available to support primary production, is highly affected by man's activities. The relationship between declines in water transparency and declines in the abundance and distribution of seagrasses is well documented (Lewis et al., 1983; Orth and Moore, 1983; Wetzel and Penhale, 1983; Cambridge and McComb, 1984; Livingston, 1987). Examples include overall declines in seagrass coverage of 50 percent in Tampa Bay and 75 percent in Virginia's portion of Chesapeake Bay. In the Indian River Lagoon, certain areas have seen declines in SAV coverage exceeding 95 percent over the last 20 years while other areas have remained relatively stable (Haddad and Harris, 1985). More recent studies show declines in coverage of up to 50 percent over large segments of the Lagoon between the 1970s and 1992 (Woodward-Clyde, 1994g).

The transparency of water depends upon its optical properties which, in turn, are dependent upon the suspended and dissolved constituents in the water, such as sediments, chlorophyll and dissolved organic matter (Preisendorf, 1961; Kirk, 1983, 1988). Those characteristics which affect the ability of water to attenuate light have the greatest impact on water clarity. Irradiance in the photosynthetically active wavelengths (400-700 nm) is known as Photosynthetically Active Radiation (PAR). For seagrasses, the availability of PAR determines how productive seagrasses will be and to what depth they will grow (Duarte, 1991; Kenworthy and Haunert, 1991; Goldsborough and Kemp, 1988; Stevenson et al., 1993; Dennison et al., 1993).

The recognition of the relationship between seagrass growth, light availability and water quality has led to the realization that existing water quality criteria and water quality standards and/or their enforcement is inadequate to protect seagrasses. The Submerged Aquatic Vegetation Initiative (SAVI) is the instrument through which a strategy to increase the amount and quality of seagrasses in the Indian River Lagoon will be carried out.

IN GENERAL, SAVI MAY BE UNDERSTOOD AS FOLLOWS:
Beyond the technical goals of SAVI is the intention of building a link in the public's mind between activities occurring in the watershed, clean water and the health of the Lagoon. The premise of this plan is based on the following conceptual model depicting relationships between management, water quality, SAV and biological productivity (Figure C-4). This model is based on the assumption that biological productivity is dependent on healthy seagrasses which depend on good water quality, and which, in turn, is dependent on the establishment and use of good management practices within the watershed. Included in this assumption is the belief that a healthy SAV community will result in desirable animal productivity and diversity. By defining the water quality-to-SAV link, it should be possible to predict the response of SAV to changes in water quality parameters. By coupling this model with the continued monitoring of the seagrass community and water quality, management activities may be reassessed and refined based upon their effectiveness in reaching water quality goals. Therefore, the majority of the SAVI effort will be expended in determining which management practices are needed to provide water quality sufficient to protect seagrass.

As previously stated, general scientific consensus shows that light availability is the single most important factor affecting the distribution and vigor of seagrasses. However, no such consensus exists concerning the factors affecting light availability.

Therefore, SAVI concentrates on determining the factors which have the greatest effect on light availability and upon determining what practices must be implemented to provide sufficient light for seagrasses (Virnstein and Morris, 1996). The preliminary goal of SAVI is to improve or maintain water clarity to a point that SAV could increase bottom coverage throughout the Indian River Lagoon (as modified by local conditions) to a depth of 1.7 meters (approximately 6 feet). This goal not only includes areal coverage, but also diversity, such as number of species within segments or depth zones

The depth target of 1.7 meters is based upon the depth of SAV found in “good” areas but would be modified to meet local conditions. Currently, on a Lagoon-wide basis 38 percent of the bottom areas which are less than 1.7 meters in depth are covered by seagrass. Coverage within specific segments varies from 0 percent to 96 percent (Woodward-Clyde, 1994g). This depth is an approximation of the photosynthetically active zone and is being used in other estuarine management programs, such as those in Chesapeake Bay and Tampa Bay (Orth, 1993; Ries, 1993).

Sub-objectives of SAVI include the following:
• Coordination and definition of the roles and funding resources of the agencies and institutions involved in management, regulation and research of the SAV community;
• Development and implementation of resource-based (SAV) water quality targets for the Indian River Lagoon;
• Use of resource-based (SAV) water quality targets in the development and implementation of watershed management practices; and
• Monitoring to support reporting on the effectiveness and progress of watershed management practices in meeting the overall SAV goal.

The *Seagrass Preservation and Restoration Diagnostics Plan for the Indian River Lagoon* (Virnstein and Morris, 1996) has identified the steps necessary to protect, restore and enhance seagrasses throughout the Indian River Lagoon. Only after the source of the problem is identified can specific, targeted solutions be sought. Linking seagrass “health” to water quality is the major thrust of the SAVI diagnostic studies. Development of a model which relates the relative impacts of various water quality parameters in light extinction will be the primary vehicle providing this link. The five general steps included in the *Seagrass Preservation and Restoration Diagnostics Plan* are:

1. Identification of “healthy” and “problem” areas through Lagoon-wide mapping.

Lagoon-wide maps, based on aerial photographs, provide an overall picture of seagrass resources in the Lagoon. The maps identify: (a) potential “healthy” areas that may deserve special protection efforts and (b) potential “problem” areas that require further investigation. Comparisons with maps of historical seagrass distribution will be used to help detect changes and set targets for seagrass distribution. The maps can also document recovery of a large area due to management actions.

Lagoon-wide maps, however, have limited application for the following reasons: (1) the interval between mapping is 2-3 years; (2) beds smaller than a half-acre are not mapped; (3) *Halophila* species or areas of sparse SAV often are not visible in aerial photos and thus are not usually mapped; and (4) locating the "edge" of a bed may have errors of tens or occasionally even hundreds of meters. Lagoon-wide maps are not suitable for detecting short-term or local changes or species composition.

Yearly mapping or, at a minimum, yearly aerial photography would improve resolution of temporal patterns or trends. Because of these limitations, additional methods of monitoring seagrass coverage are needed. The following three steps describe methods to obtain more detailed information on seagrass coverage.

2. Local inspection and confirmation through fixed transects and mapping.
This step will determine whether local areas (selected from aerial photos and Lagoon-wide maps) are healthy or stressed, and whether conditions are stable, improving or declining and by how much. Transects also provide ground-truth information for Lagoon-wide mapping. More than 70 fixed transects have been established in seagrass areas throughout the Lagoon. Seagrass transects are monitored bi-annually (summer and winter) using non-destructive ground-truthing methods including video. Underwater video is used to collect data rapidly and inexpensively and to provide a permanent archival record of the distribution and condition of seagrass along the transect.

Measurements are made every 10 meters along each transect. These measurements include water depth, percent coverage and canopy height of each seagrass species present, and shoot counts conducted at the center and deep edge of the seagrass bed. Repeated monitoring of these same transects is a powerful tool for detecting short-term or local change. Seagrass changes could then be correlated with changes in water quality.

3. Determining causes of the problem by site-specific monitoring.
At sites identified in the previous steps, intensive site-specific monitoring is used to determine the "health" of seagrasses and the causes of stress. The objective of this component is to examine the ecological status of seagrasses (e.g., density, growth rate, epiphyte load) and their relationship with specific water quality parameters (e.g., nutrients, turbidity, color, suspended solids, light extinction).

Besides the water column effects on light attenuation, epiphytes growing on seagrass blades typically have greater biomass than the seagrass beds themselves (Zimba and Hanisak, 1994) and reduce the amount of light reaching seagrass blades by 50-80 percent (Nelson, pers, comm.). High concentrations of water column nutrients and low populations of epiphyte grazers (snails, amphipods, small shrimps) exacerbate the problem. Monitoring will provide the major effort in linking water quality to seagrass health and abundance. Once fully developed, these site-specific techniques will need to be applied to all problem areas in the Lagoon. However, only after the source and components of a local problem are identified can specific, targeted solutions to the problem be developed and applied.

4. Relating PAR and water quality through models.
This step will define and model the linkages between light attenuation and water quality. These linkages are mediated through water column light attenuation due to epiphytes. The primary vehicle providing this link will be an optical model developed to relate the impacts of various water quality parameters (e.g., suspended solids, phytoplankton chlorophyll and color) to light extinction in the water column.

In addition to light attenuation in the water column, epiphytes also reduce light reaching the surface of seagrass blades. An optical model and an epiphyte model will be incorporated into a larger integrated hydrodynamic/water quality model to provide the final linkages among watershed pollutant inputs, water quality and light attenuation. Optical water column and epiphyte models predict light attenuation based on water quality. Using this integrated model it will be possible to predict the effects of a decrease in loading of a particular pollutant on conditions for seagrass growth.

5. Setting management targets.
After identifying “healthy” and “problem” areas and determining what causes “problems,” setting restoration targets will be the next step. Targets for seagrass coverage will be set segment-by-segment. These targets will be based on an evaluation of available information on present and historical seagrass coverage, water quality, sub-basin characteristics and bathymetry. Seagrass targets will be described by a combination of acreage, maximum growth depth and maps of targeted seagrass distribution.

Areal coverage targets will then be translated into water quality targets necessary to protect or restore seagrass. Water quality targets will be based on the results of site-specific monitoring and output of the optical model.

The main management use of the seagrass/water quality link will be to establish Pollutant Load Reduction Goals (PLRGs). For most sub-basins, PLRGs will be based on the light requirements of seagrass. PLRGs could then be translated into basin specific rule criteria by the water management districts or local governments. The establishment of consistent policies at all levels of government and in all aspects of resource management (e.g., water quality, watershed land-use planning, habitat protection, land acquisition) is a crucial strategy in the seagrass initiative.

One of the first applications will be to develop total suspended solids (TSS) and nutrient PLRGs to reduce excessive loadings of these pollutants to the Lagoon. Initial loading reductions will be accomplished through reduction of freshwater discharge volume. TSS and nutrient PLRGs will be further refined when a quantitative understanding of the relationship between TSS and nutrient concentrations and seagrass health is determined.

Actual management steps to protect and restore seagrass decline will require the involvement and action of other agencies, local governments and the residents of the Lagoon region. Because impacts to seagrass come from many sources, often from locations remote from the Lagoon, management practices must be multifaceted and directed at the sources; that is, a fence around a seagrass bed will not protect it; rather, solutions must be sought “upstream.”
These solutions will depend largely on other components of the IRLCCMP and will involve several steps, including:
1. Formulating goals, policies and watershed management strategies;
2. Setting water quality targets;
3. Implementing watershed management plans; and
4. Monitoring the effectiveness of watershed management.

POSSIBLE FUNDING SOURCES

Ad Valorem Taxes
Affinity
Boat Registration Fees
Emissions/Discharge-Based Fees
EPA Office of Research and Development - Water Pollution Control Grant
FDEP - Marine Resources Grant Program
- Section 310 Non-Point Source Management Grant
Florida Advisory Committee on Environmental Education
- Environmental Education Grant
General Sales and Use Taxes
Hard-To-Dispose Taxes
Motor Fuel Taxes
NOAA - Financial Assistance for Ocean Resource Conservation and Assessment Program
- Habitat Conservation Grants
Pollutant Taxes Trust Fund
Real Estate Transfer Taxes
Rental Car Taxes
Revenue Bonds
Severance Taxes
Tax Increment Funding
Tourist Development Taxes
U.S. Fish and Wildlife Service - Coastal Wetlands Grant Program
- Endangered Species Conservation Grants

- Sport Fish Restoration Grants
- Wildlife Restoration Grants

U.S. Geological Survey - Water Resources Grant Program
Watercraft Sales Tax
Water Management Districts - Florida's Water Management District Grants and Cost
Sharing Programs

Implement a program of restoration and management activities needed to maintain, protect and restore the seagrass community of the Indian River Lagoon.

BACKGROUND AND EXPECTED BENEFITS

Seagrass/SAV communities are vital to the health of the Indian River Lagoon. The extent and health of the seagrass/SAV community has decreased significantly due to declines in water quality, especially water clarity. Current water quality standards are not based on the biological needs of seagrasses and are inadequate to guarantee conditions suitable to maintain a healthy seagrass community. By implementing the Seagrass Preservation and Restoration Diagnostics Plan for the Indian River Lagoon (Virnstein and Morris, 1996), water quality goals will be developed which, when implemented and enforced, should improve water quality and the extent and condition of the Indian River Lagoon seagrass/SAV community.

PRIORITY

High

HOW

1.01 Implement the *Seagrass Protection and Restoration Diagnostics Plan for the Indian River Lagoon.*

WHO

Primary: SJRWMD
Support: SFWMD, FDEP, academia and research institutions, local governments (counties and cities)

WHERE

Throughout the Indian River Lagoon region.

MEASURE OF PROGRESS

Number of acres of seagrass gained.

RELATED ACTIONS

FSD-3, FSD-6, FSD-10, FSD-12, W-6

Appendix H

Demineralization Plant Operations Calculations

Indian River Lagoon Salinity Study
Demineralization Plant Concentrate Discharge Algorithm

To predict the effect of the desalination process on the power station effluent, a demineralization plant concentrate discharge model simulator was developed. The model algorithm was first developed by engineers at R.W. Beck, Inc. for demineralization plant intake/effluent calculations and is coded from a spreadsheet application. The verified demineralization plant algorithm was implemented as a subroutine in the SJRWMD Indian River Lagoon (IRL) application of the University of Florida's CH3D model system.

The IRL demineralization algorithm is designed to piggyback the demineralization plant on the effluent flow of a power station once-through cooling cycle. The demineralization plant intake is taken from the power station effluent at some prescribed volume flow rate, but accepts the effluent temperature and salinity as calculated by the hydrodynamic model. Makeup feedwater directly from offshore is added to the demineralization input flow if a threshold temperature or low power station flow is reached. The demineralization plant model then calculates the demineralization plant effluent flow rate, temperature and chloride concentration based on the plant operating statistics and product water flow. The demineralization plant effluent is then added back to the power station effluent and discharged.

The time variable, runtime inputs to the demineralization calculation routine include:

- power plant circulating water canal intake flow
- ambient water salinity at the intake
- ambient water temperature at the intake
- power plant dT to determine circulating canal water temperature

and the outputs predicted by the desalination process are:

- power plant circulating water canal discharge flow
- power plant circulating water canal discharge salinity
- power plant circulating water canal discharge temperature
- desalination plant cooling water intake flow

where the cooling water intake flow is determined iteratively based on the preliminary demineralization plant calculations. The following sheets provide the basis of the R.W. Beck spreadsheet algorithm.

Final

CALCULATION CONTROL SHEET

Project # 05-01140-10101 ATM Project	Discipline: Waste & Water Resources	Date: February 16, 2005

SYSTEM	Concentrate Discharge

SUBJECT	System Model
STARTED BY	Howard Steiman

AUTHORIZED BY	Mike Kuhn

PROBLEM STATEMENT: Develop model to estimate desalination facility concentrate salinity and temperature for the Cape Canaveral and Indian River sites. Since the desalination facility would discharge concentrate to a power plant circulating water system, the model shall estimate the maximum desalination facility production at a 10% chloride concentration rise in the power plant circulating water system. The model will be used by ATM for environmental impact modeling.

DESIGN BASIS
Description of Cape Canaveral and Indian River desalination facility sites in the "Final Report on Five Potential Seawater Demineralization project Sites – Task C.5."

SUMMARY/CONCLUSIONS
N/A

REFERENCES (Specifications, drawings, codes, calculation sets, texts, reports, computer data, etc.)
"Final Report on Five Potential Seawater Demineralization project Sites – Task C.5" prepared by R.W. Beck, Inc. dated 1/23/04. The report was prepared for the Seawater Demineralization Feasibility Investigation, Contract SE459AA for the St. John's River Water Management District.

TOTAL NUMBER OF COMPUTATION SHEETS:

FINISHED BY Howard E Steiman 2/17/05 CHECKED BY Joseph Mcthing

APPROVED BY [signature]

R·W·BECK

Cape Canaveral and Indian River Desalination Facilities
Concentrate Discharge Model

Prepared by: R.W. Beck
Dated: February 17, 2005

Final

Input Data

Physical Data

Facility Overall Recovery	38.7%	MGD
Product Water MGD	30.00	MGD
Circulating Water Flow MGD	200.00	MGD
Circulating Water Temperature	105.0	°F
Cooling Water Temperature	85.0	°F
RO Feedwater Temperature Set Point	95.0	°F

Seawater Quality Data

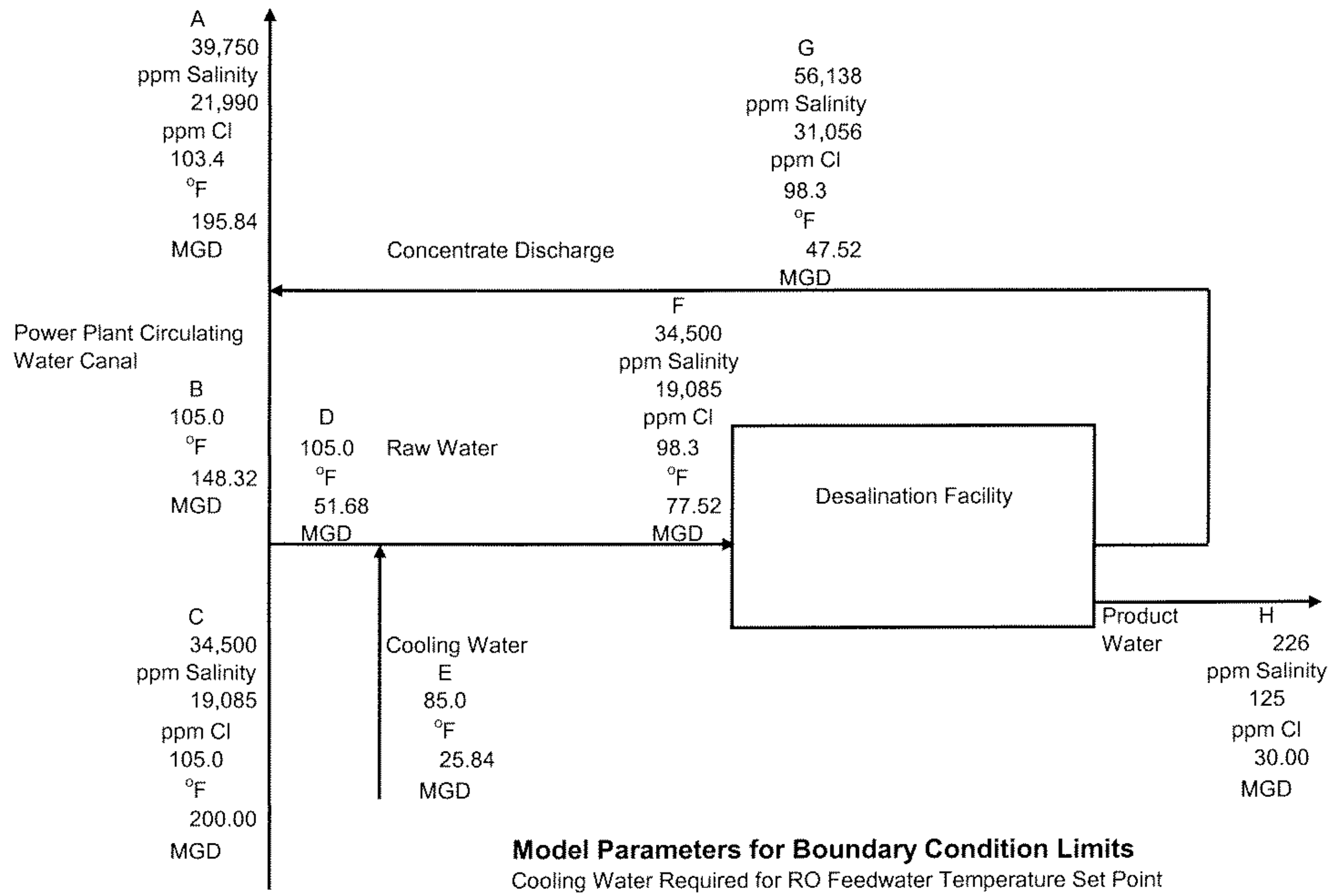
Salinity	34,500	ppm
Maximum Rise in Circulating Water Cl Concentration	10%	

Product Water Data

Maximum Product Water Cl Concentration	125	ppm

Final

Cape Canaveral and Indian River Desalination Facilities
Concentrate Discharge Model



Model Parameters for Boundary Condition Limits

Cooling Water Required for RO Feedwater Temperature Set Point	38.76	MGD
Calculated Cooling Water Flow	25.84	MGD
Calculated Raw Water Flow	51.68	MGD
Calculated RO Feedwater Flow	77.52	MGD
Cooling Water Pump Capacity (1/3 RO Feedwater Flow)	25.84	MGD
Maximum Membrane Operating Temperature	113.00	°F
Calculated % Rise in Circulating Water Cl Concentration	15.2%	
Raw Seawater Flow (Circulating Water + Cooling Water)	225.84	MGD
Product Water Flow at 10% Circulating Water Cl Concentration Rise	20.65	MGD

Table 1 Standard seawater composition*

Ion	Concentration (mg/L)	
Calcium	410	
Magnesiun	1,310	
Sodium	10,900	
Potassium	390	
Barium	0.05	
Strontium	13	
Iron	<0.02	
Manganes(	<0.01	
Silica	0.04	8
Chloride	19,700	
Sulfate	2,740	
Fluoride	1.4	
Bromide	65	
Nitrate	<0.7	
Bicarbonat	152	
Boron	4	5
Other		
TDS	35,000	
pH	8.1	

Table 2 Inorganic composition of seawater with different salinity*

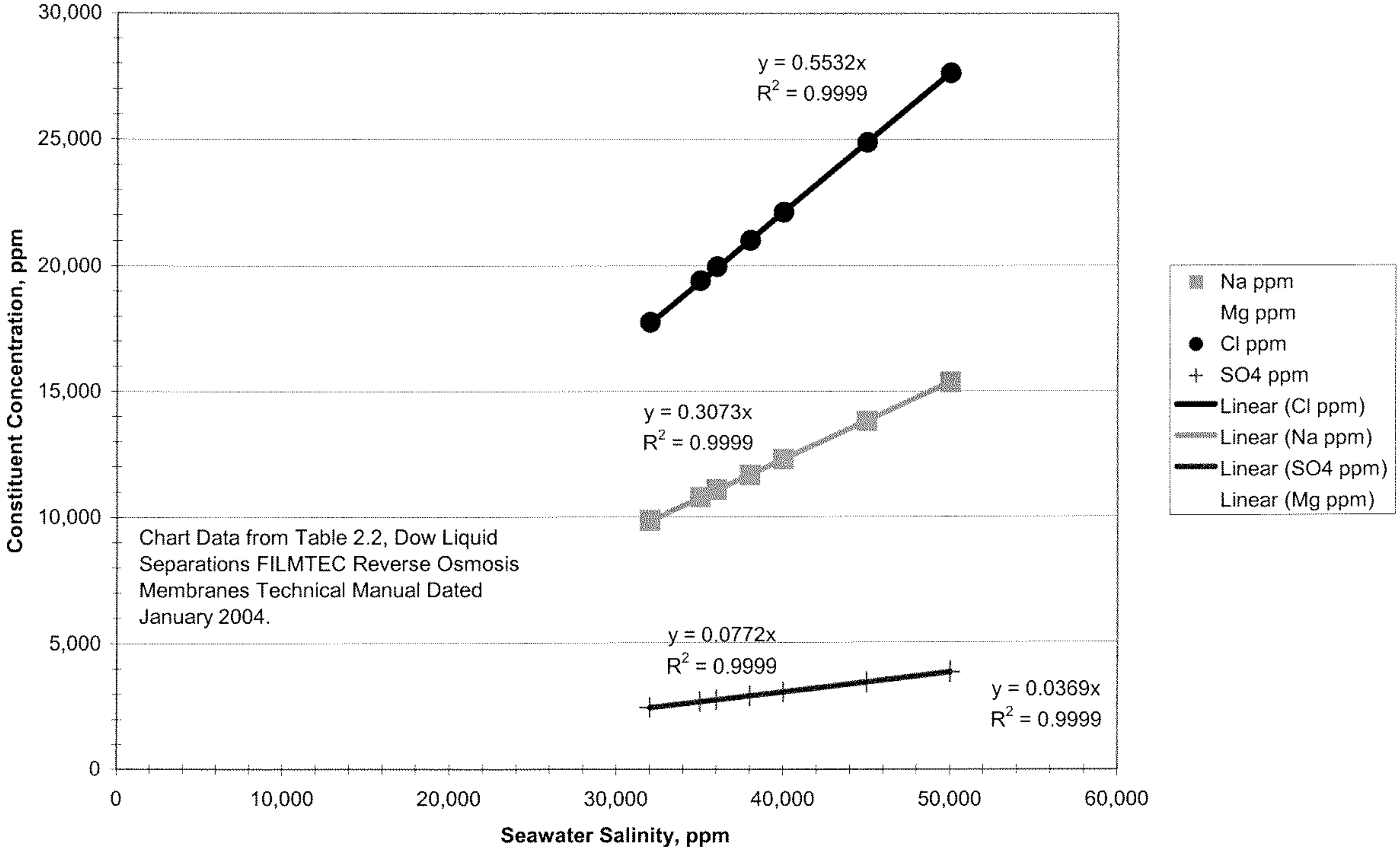
Standard Seawater ppm	K ppm	Na ppm	Mg ppm	Ca ppm	HCO3 ppm	Cl ppm	SO4 ppm	SiO2 ppm
32,000	354	9,854	1,182	385	130	17,742	2,477	0.9
35,000	387	10,778	1,293	421	142	19,406	2,710	1.0
36,000	398	11,086	1,330	433	146	19,960	2,787	1.0
38,000	419	11,663	1,399	456	154	20,999	2,932	1.0
40,000	441	12,278	1,473	480	162	22,105	3,086	1.1
45,000	496	13,812	1,657	539	182	24,868	3,472	1.2
50,000	551	15,347	1,841	599	202	27,633	3,858	1.4

* Data from Tables 2.1 and 2.2, Dow Liquid Separations FILMTEC Reverse Osmosis Membranes Technical Manual Dated January 2004

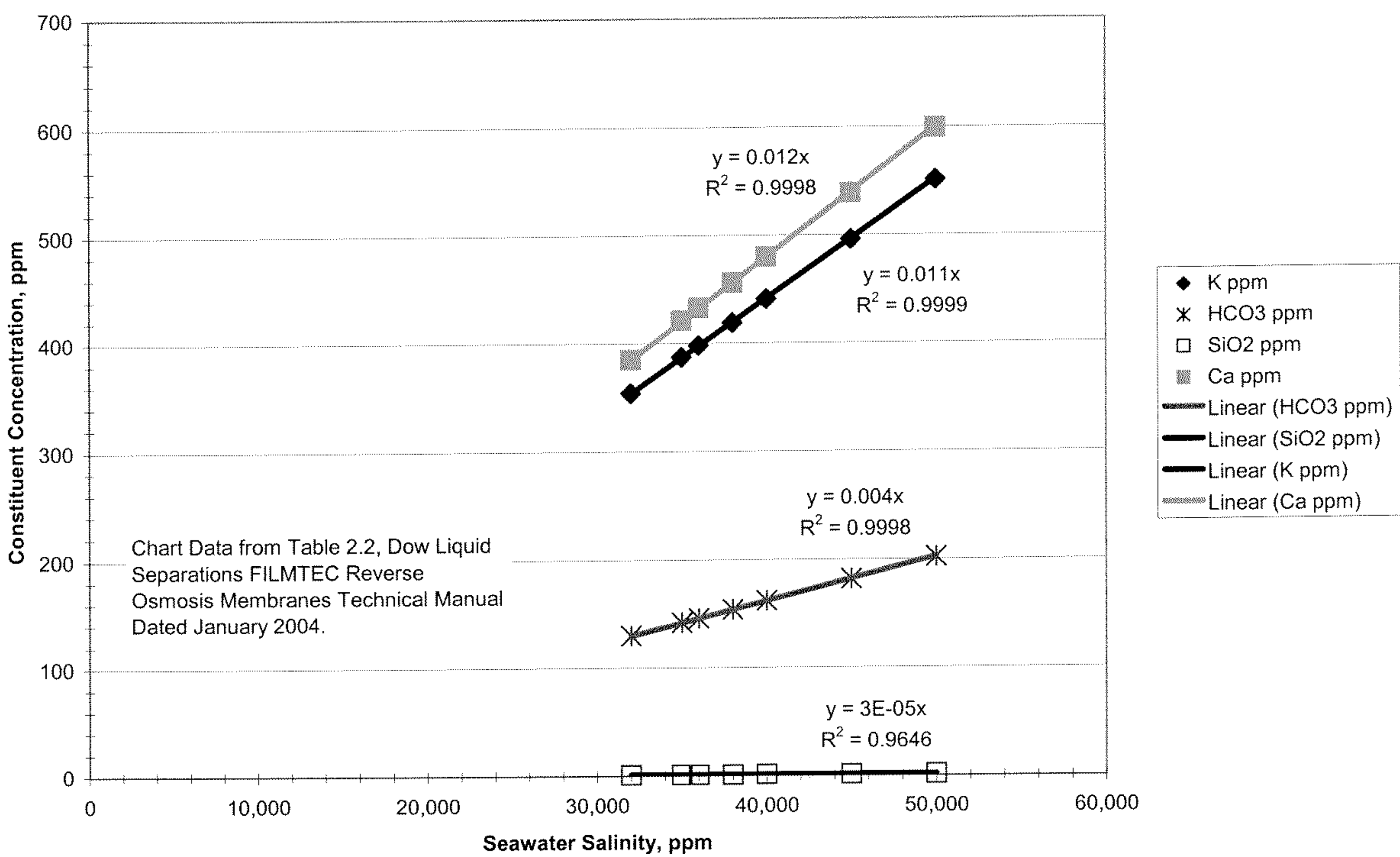
Prepared by: R.W. beck
Dated: February 17, 2005

Cape Canaveral and Indian River Desalination Facilities
Concentrate Discharge Model

Standard Seawater Composition



Standard Seawater Composition



Prepared by: R.W. Beck
Dated: February 14, 2005

Final

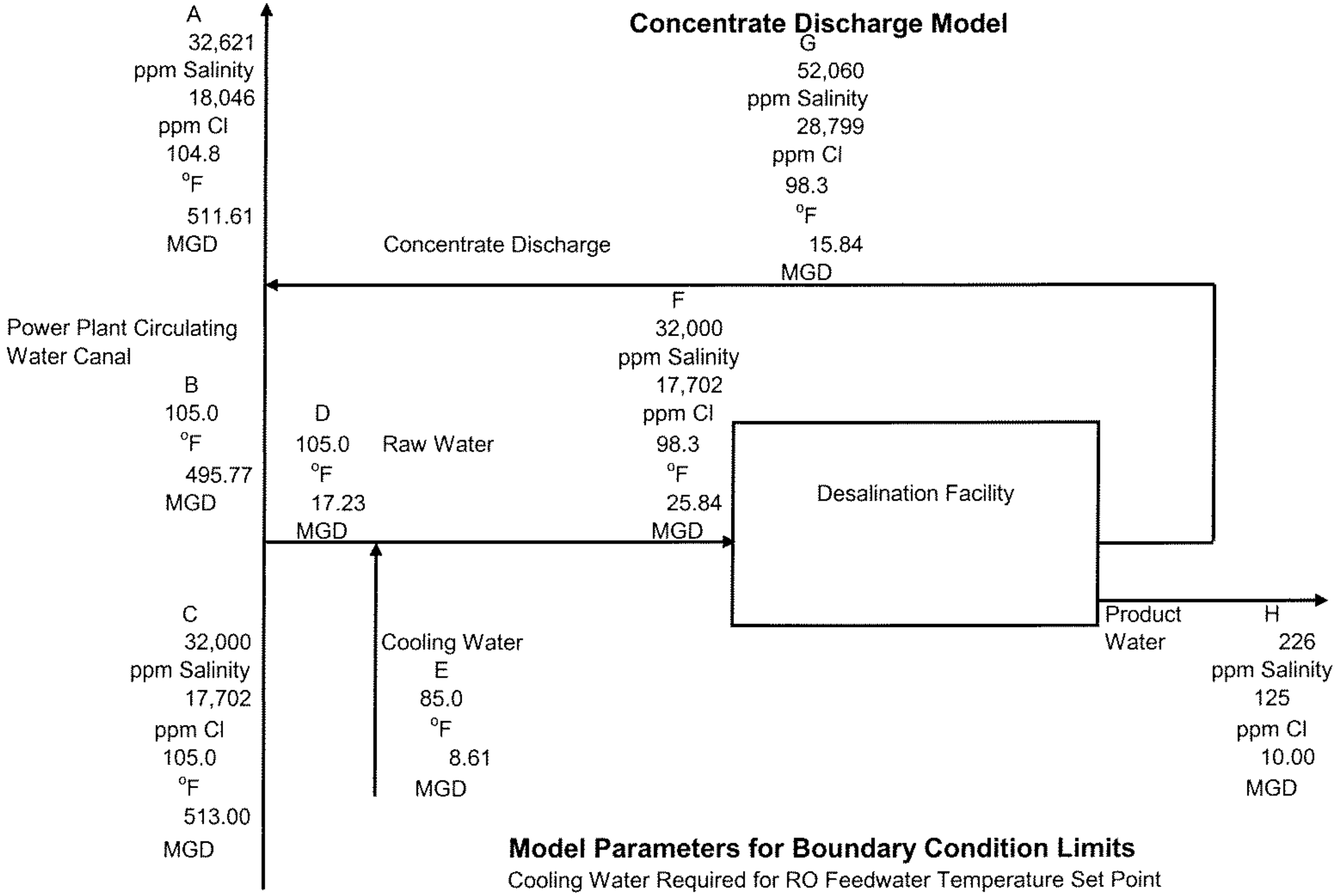
Cape Canaveral and Indian River Desalination Facilities Concentrate Discharge Model

Input Data

Physical Data		
Facility Overall Recovery	38.7%	MGD
Product Water MGD	10.00	MGD
Circulating Water Flow MGD	513.00	MGD
Circulating Water Temperature	105.0	°F
Cooling Water Temperature	85.0	°F
RO Feedwater Temperature Set Point	95.0	°F
Seawater Quality Data		
Salinity	32,000	ppm
Maximum Rise in Circulating Water Cl Concentration	10%	
Product Water Data		
Maximum Product Water Cl Concentration	125	ppm

Final

Cape Canaveral and Indian River Desalination Facilities Concentrate Discharge Model



Model Parameters for Boundary Condition Limits

Cooling Water Required for RO Feedwater Temperature Set Point	12.92	MGD
Calculated Cooling Water Flow	8.61	MGD
Calculated Raw Water Flow	17.23	MGD
Calculated RO Feedwater Flow	25.84	MGD
Cooling Water Pump Capacity (1/3 RO Feedwater Flow)	8.61	MGD
Maximum Membrane Operating Temperature	113.00	°F
Calculated % Rise in Circulating Water Cl Concentration	1.9%	
Raw Seawater Flow (Circulating Water + Cooling Water)	521.61	MGD
Product Water Flow at 10% Circulating Water Cl Concentration Rise	47.73	MGD

Final

Table 2.1 Standard seawater composition*

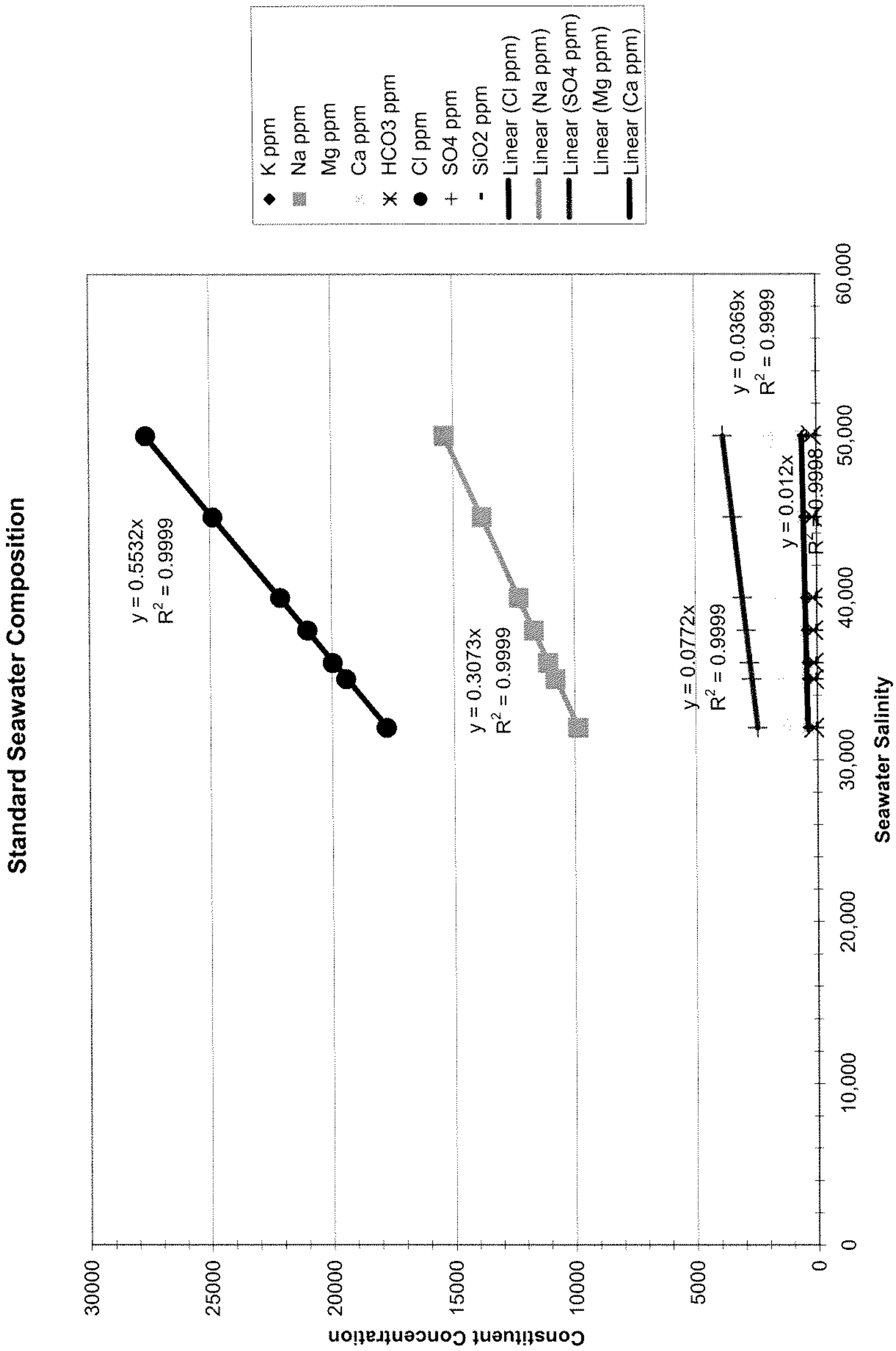
Ion	Concentration (mg/L)	
Calcium	410	
Magnesiun	1,310	
Sodium	10,900	
Potassium	390	
Barium	0.05	
Strontium	13	
Iron	<0.02	
Manganes	<0.01	
Silica	0.04	8
Chloride	19,700	
Sulfate	2,740	
Fluoride	1.4	
Bromide	65	
Nitrate	<0.7	
Bicarbonat	152	
Boron	4	5
Other		
TDS	35,000	
pH	8.1	

Table 2.2 Inorganic composition of seawater with different salinity*

Standard Seawater ppm	K ppm	Na ppm	Mg ppm	Ca ppm	HCO3 ppm	Cl ppm	SO4 ppm	SiO2 ppm
32,000	354	9,854	1,182	385	130	17,742	2,477	0.9
35,000	387	10,778	1,293	421	142	19,406	2,710	1.0
36,000	398	11,086	1,330	433	146	19,960	2,787	1.0
38,000	419	11,663	1,399	456	154	20,999	2,932	1.0
40,000	441	12,278	1,473	480	162	22,105	3,086	1.1
45,000	496	13,812	1,657	539	182	24,868	3,472	1.2
50,000	551	15,347	1,841	599	202	27,633	3,858	1.4

* Data obtained from Dow Liquid Separations FILMTEC Reverse Osmosis Membranes Technical Manual Dated January 2004

Final



Standard Seawater Composition
Constituent Concentration
Seawater Salinity
30000
25000
20000
15000
10000
5000
0
10,000
20,000
30,000
40,000
50,000
60,000
y = 0.5532x
R2 = 0.9999
y = 0.3073x
R2 = 0.9999
y = 0.0772x
R2 = 0.9999
y = 0.0369x
R2 = 0.9999
y = 0.012x
K ppm
Na ppm
Mg ppm
Ca ppm
HCO3 ppm
Cl ppm
SO4 ppm
SiO2 ppm
Linear (Cl ppm)
Linear (Na ppm)
Linear (SO4 ppm)
Linear (Mg ppm)
Linear (Ca ppm)

Appendix I

Analyses of Power Plant Intake and Discharge

Indian River Lagoon Salinity Study
Plant Intake and Discharge Evaluation

Data from the Reliant Indian River and the FPL Cape Canaveral power plants were analyzed to define the typical characteristics of the intakes and discharges. Specifically, the evaluation focused on the need for additional cooling water intake as well as additional water intake required to satisfy the 10 percent increase limit on ambient salinity conditions.

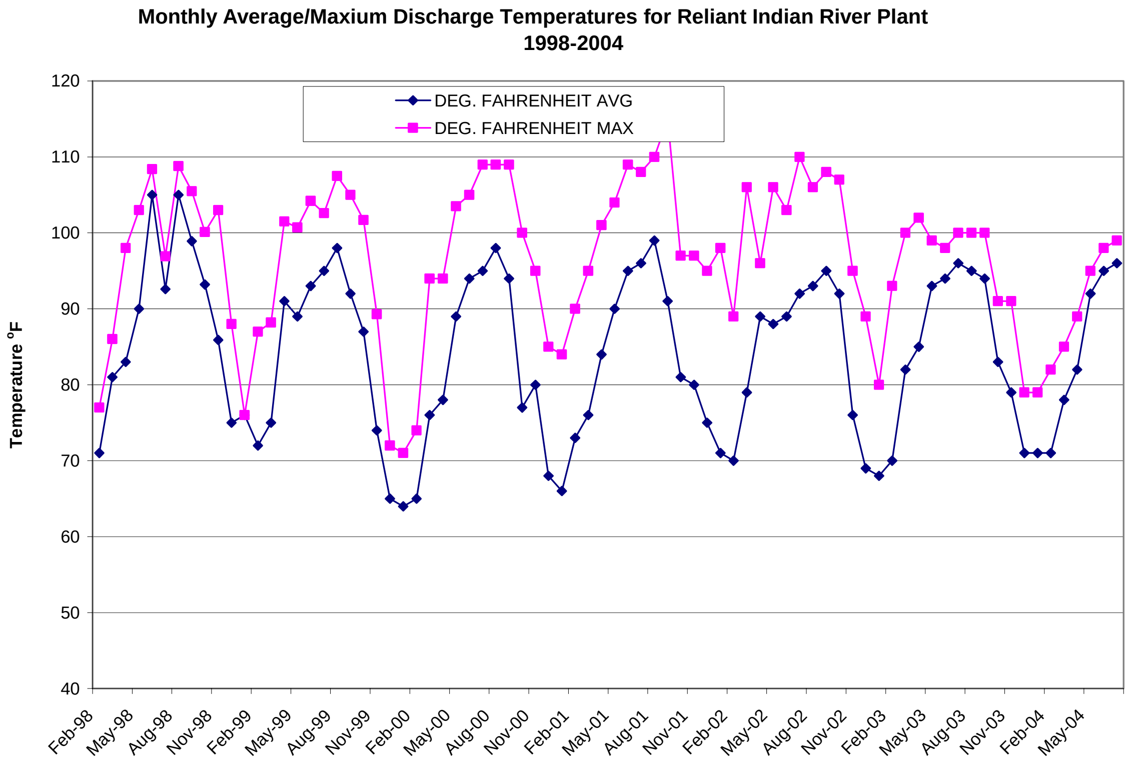
Figures I-1 and I-2 present the measured flows and temperatures for each of the power plants over a 5-year period from 1999 to 2004. These data are taken from NPDES Discharge Monitoring Reports (DMRs) for the Cape Canaveral and Reliant Indian River Power Plants. The figures show that circulating water is typically available at both sites on a routine basis. However, as illustrated, the magnitude of the circulating water flow is higher at the Cape Canaveral site and less variable than the flows at the Reliant Indian River site.

One potential major facility discharge/NPDES issue was identified in Technical Memorandum 2.B and 2.C. Florida Administrative Code 62-302 mandates a maximum circulating water chloride level rise of 10 percent. Figure I-1 shows the Reliant Indian River Power Plant circulating water flow is less than 300 MGD for extended periods. This was further born out based upon data obtained from the Reliant plant for daily flows and temperatures. A minimum power plant circulating water flow of 300 MGD is required for an RO facility with a 30 MGD capacity in order to adhere to the 10 percent chloride rise criterion. Subsequently, a 20 MGD plant will require a flow of 200 MGD, and a 10 MGD plant will require a flow of 100 MGD. Consequently, in order for the co-located plant to operate during periods where the flow drops below the allowable for the RO plant water production rate, additional flow will need to be drawn in. Under this scenario, the co-location of the plant will create a condition that might exacerbate the present levels of impingement and entrainment.

The RO facility source water will have passed through the power plant condenser prior to the point of withdrawal from the power plant discharge canal and, therefore, will typically be heated above ambient. Membrane manufacturers commonly establish a continuous service temperature limit between 95°F to 104°F for RO membrane operation. Consequently, the RO facilities will also have a cooling water supply from the intake of the power plant to accommodate membrane operation whenever the temperature of RO Facility source water (power plant condenser discharge water) exceeds membrane manufacturer guidelines. As a result, there could be some additional entrainment issues associated with the cooling water intake.

In order to quantify the potential for each of the facilities to have increased I&E, the data from each of the plants was analyzed to define periods of time where additional cooling water flow or NPDES makeup water flow will be required. As the Cape Canaveral facility flows do not drop below 300 MGD, cooling water is the primary mechanism for increased

I&E. The Reliant plant, on the other hand, does have periods of time when the flows drop below 300 MGD and even below 200 MGD. In each case, the additional cooling water flow and/or the additional NPDES makeup water flow were determined as a percent increase and plotted in Figures I-3 and I-4. The results show that while the Reliant plant will need significant flow increases in order to operate at 30 and 20 MGD (168 and 80 percent flow increases respectively), the Cape Canaveral plant will need very low flow increases in order to operate (all less than 0.6 percent). In terms of additional I&E issues, the flow changes for the Reliant plant at 30 and 20 MGD are significant. At 10 MGD and below, the Reliant plant has no significant I&E issues. The Cape Canaveral plant has no significant I&E increase issues at all production rates defined for this study.



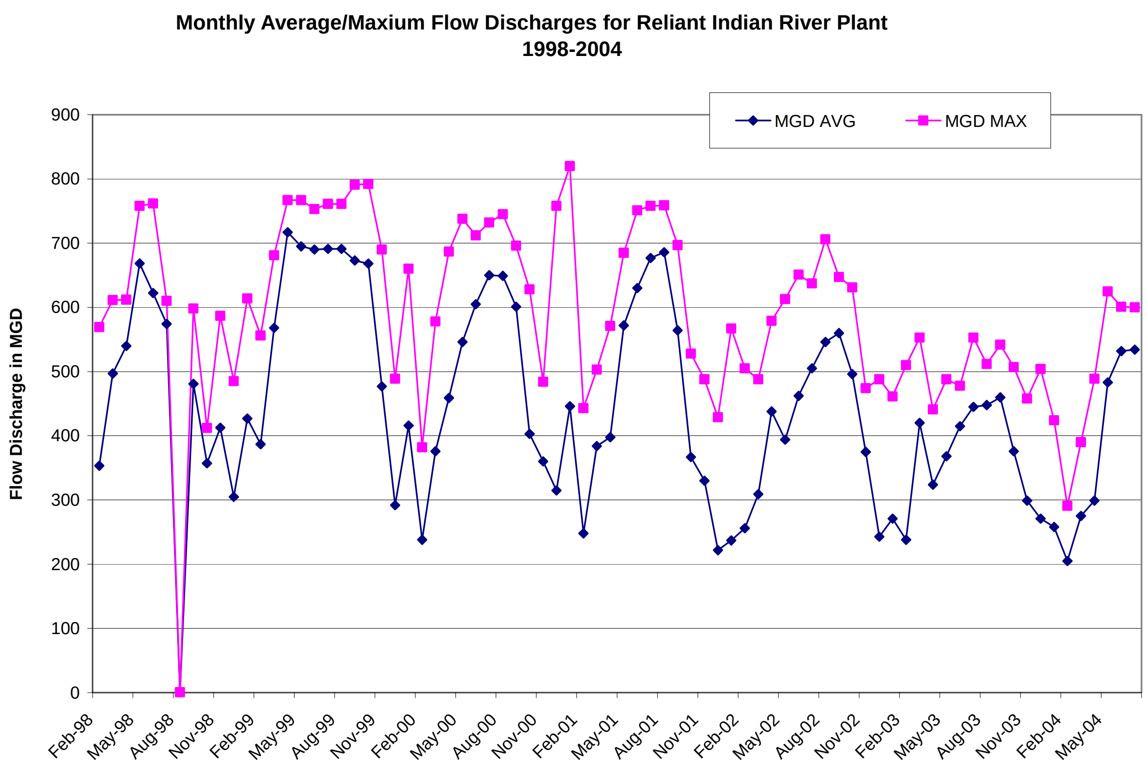


Figure I-1
Monthly Average/Maximum Flows and Discharge Temperatures for Reliant Indian River Plant 1997 to 2000.
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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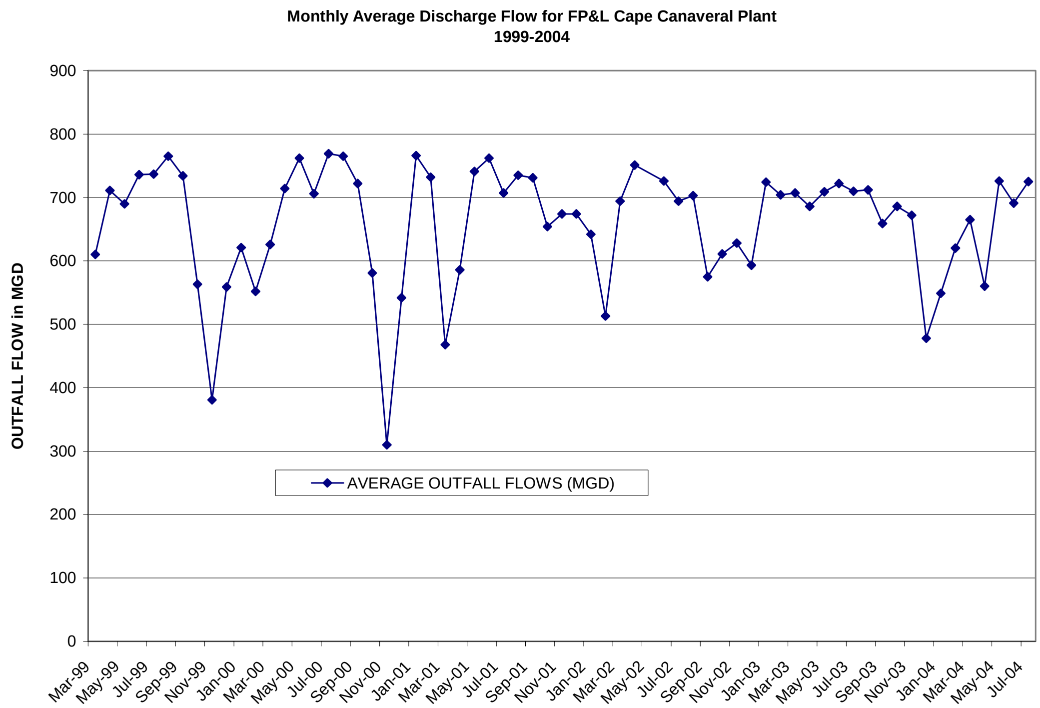

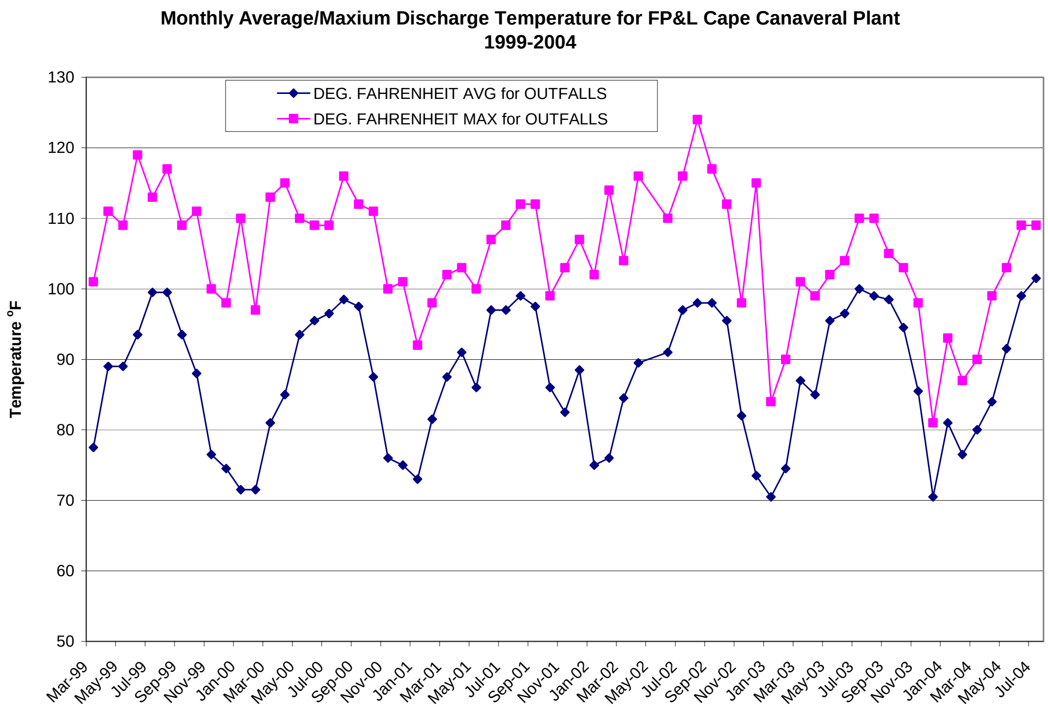

Figure I-2
Monthly Average/Maximum Flows and Discharge Temperatures for FP&L Cape Canaveral Plant 1997 to 2000.
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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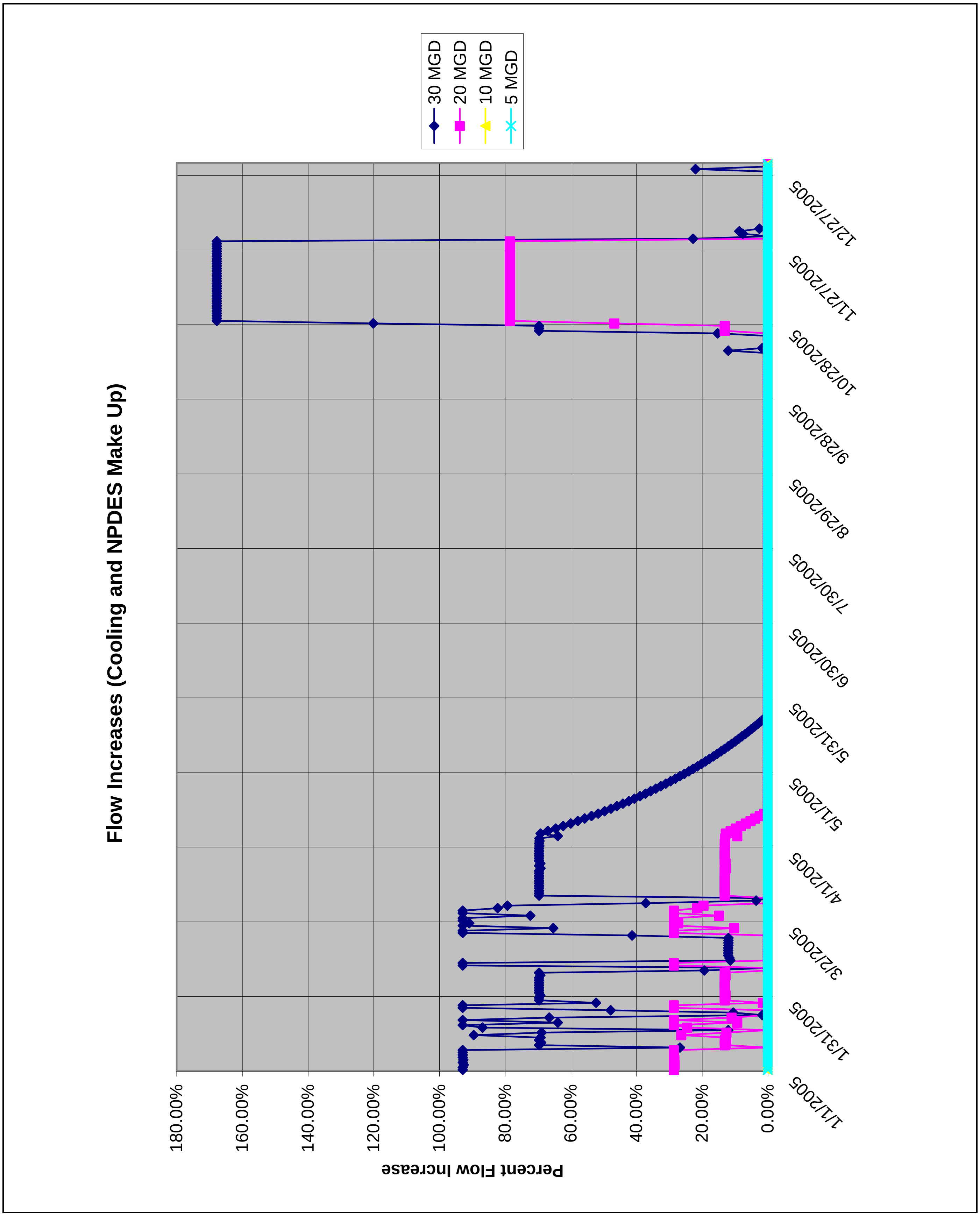

Figure I-3
Percent Velocity Changes at the Reliant Indian River Power Plant
due to Operation of the Demineralization Plant
Evaluation of Potential Impacts of Demineralization Concentrate Discharge
to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

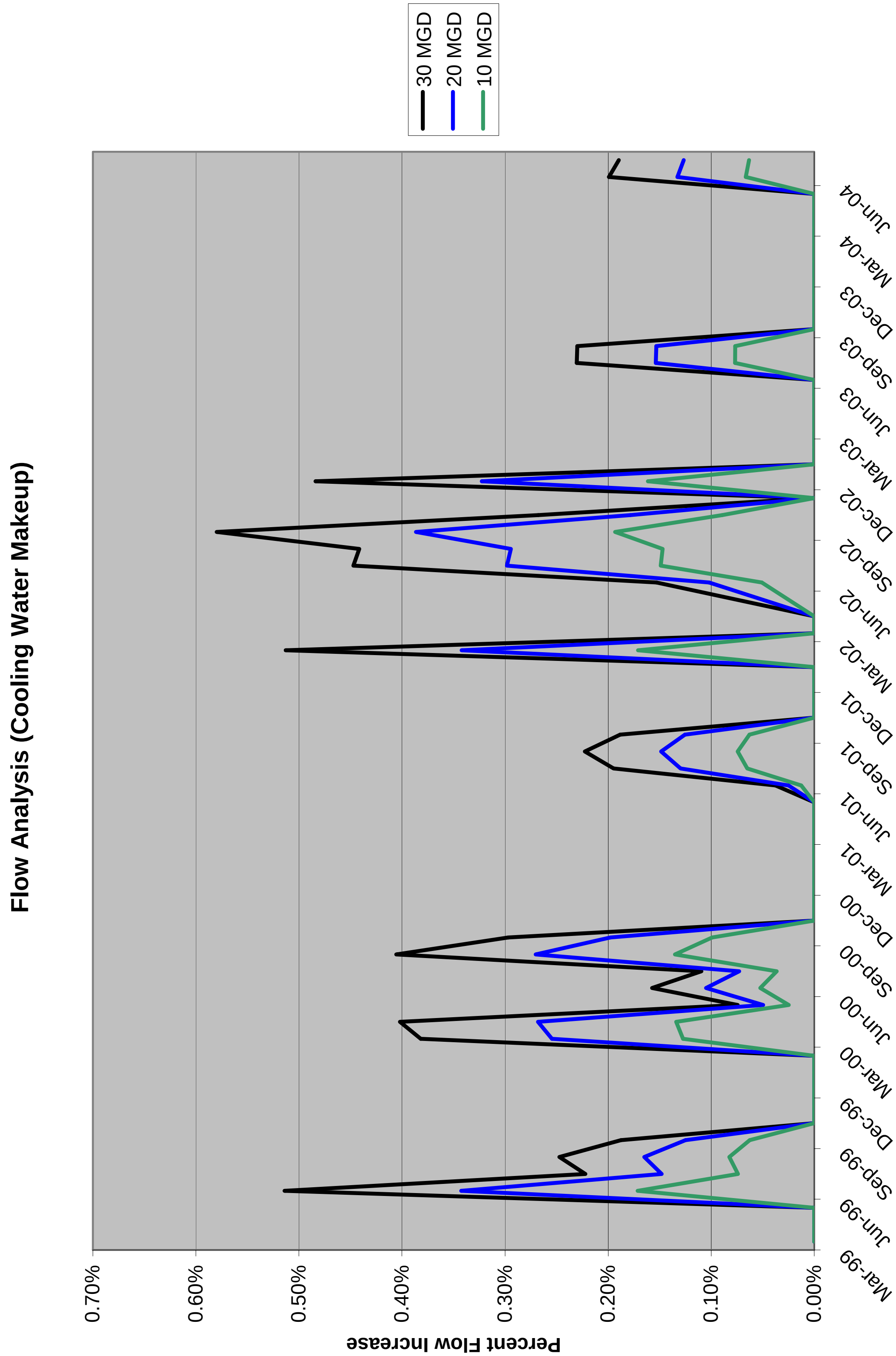

Figure I-4
Percent Velocity Changes at the FP&L Cape Canaveral Power Plant due to Operation of the Demineralization Plant
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

Appendix J

Analyses of Salinity Changes under Varying Water Production Rates

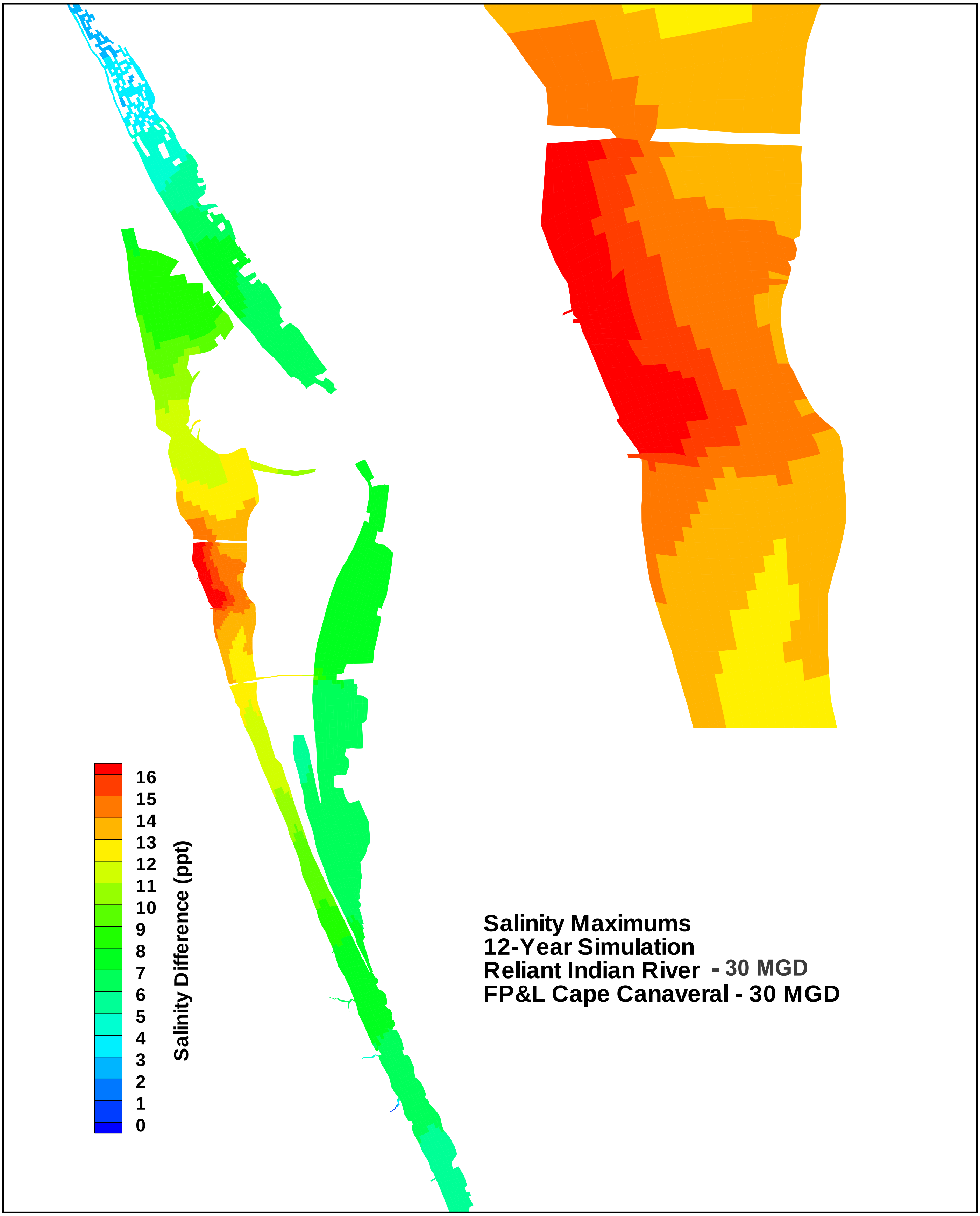

Figure J-1
Daily Average Salinity Changes Over Baseline for the 30MGD(Reliant)/30MGD(Cape Canaveral) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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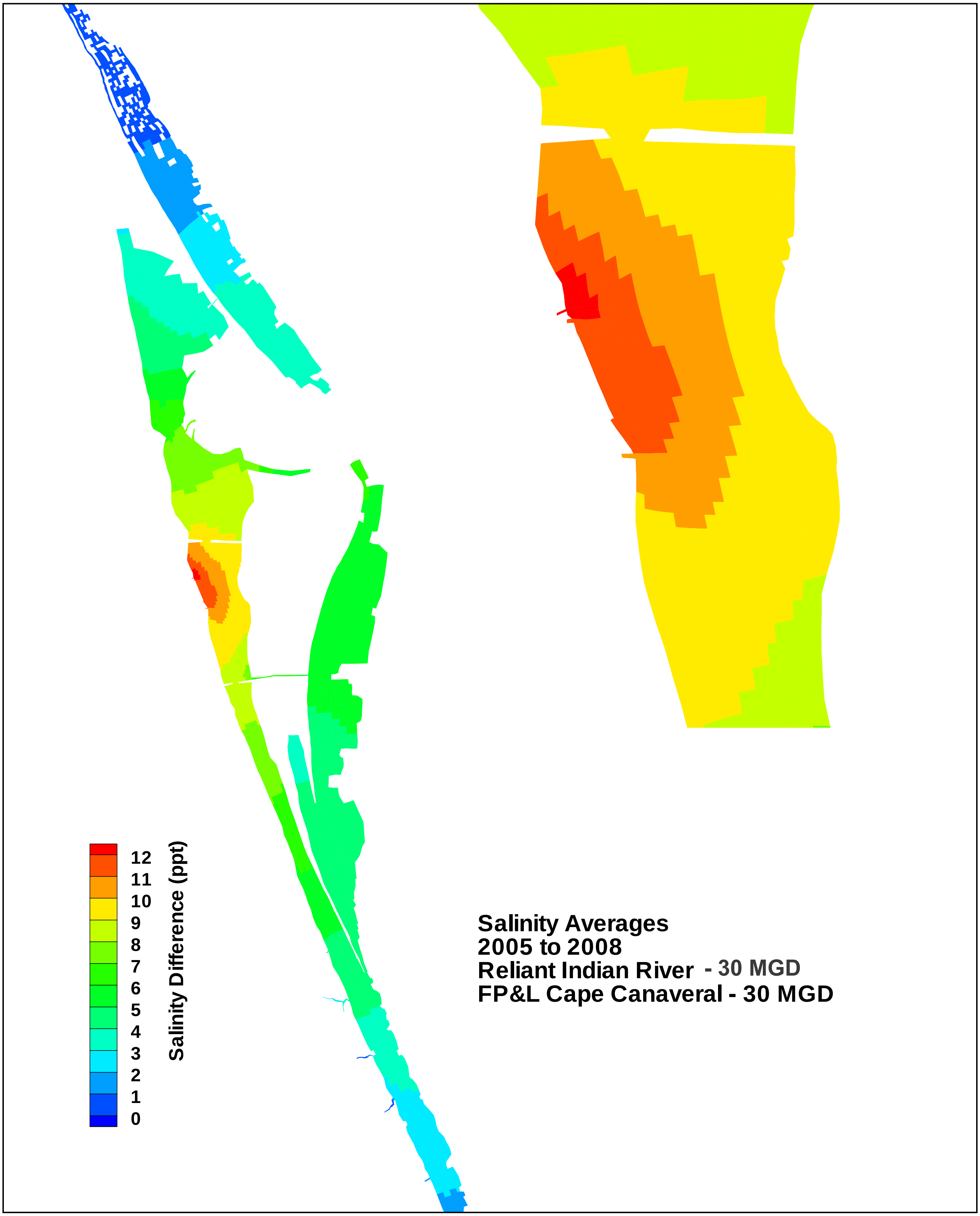

Figure J-2

Daily Average Salinity Changes Over Baseline for the 30MGD(Reliant)/30MGD(Cape Canaveral) Scenario (Average for Years 9 to 12)

Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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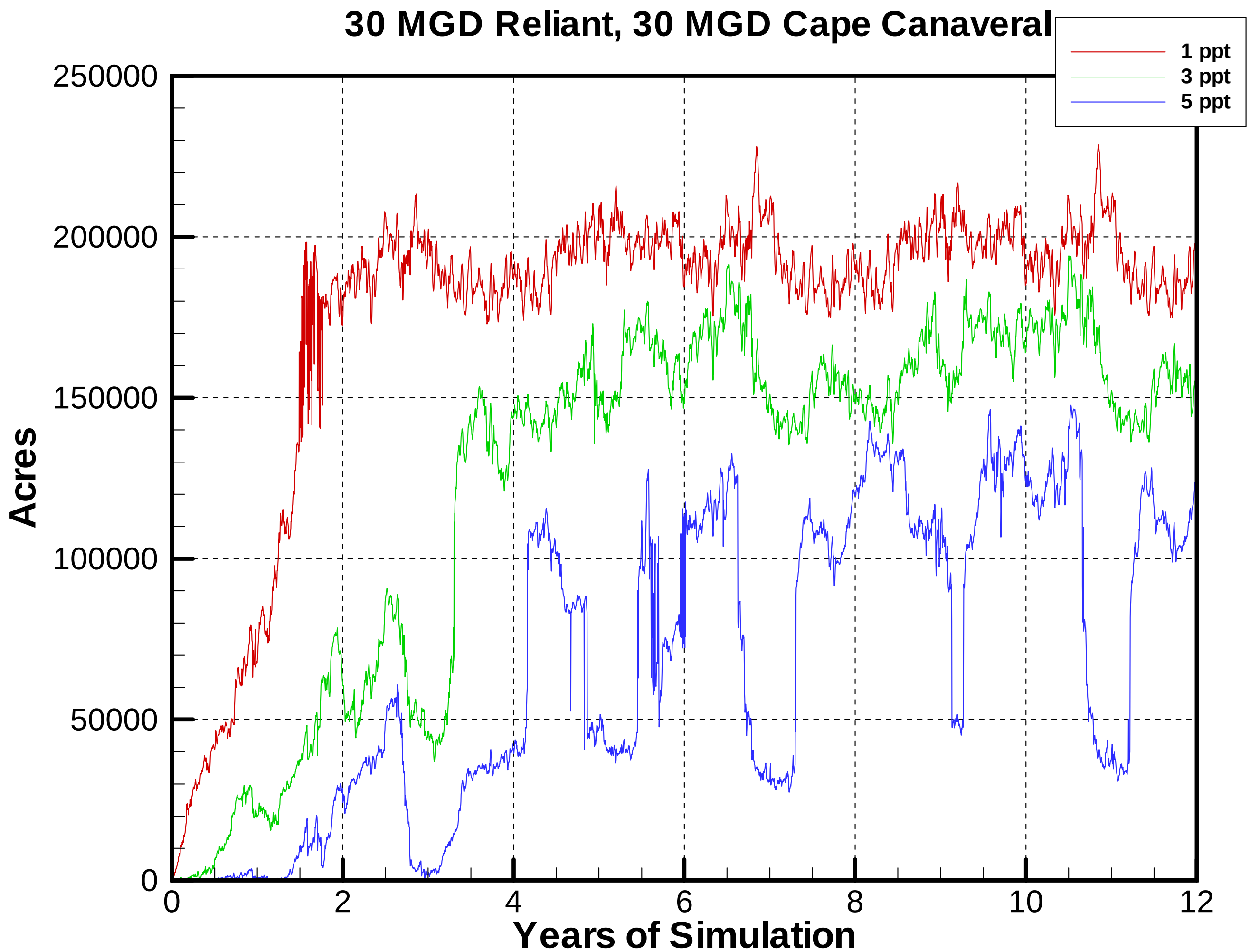

Figure J-3

Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (30MGD-Reliant, 30MGD -Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

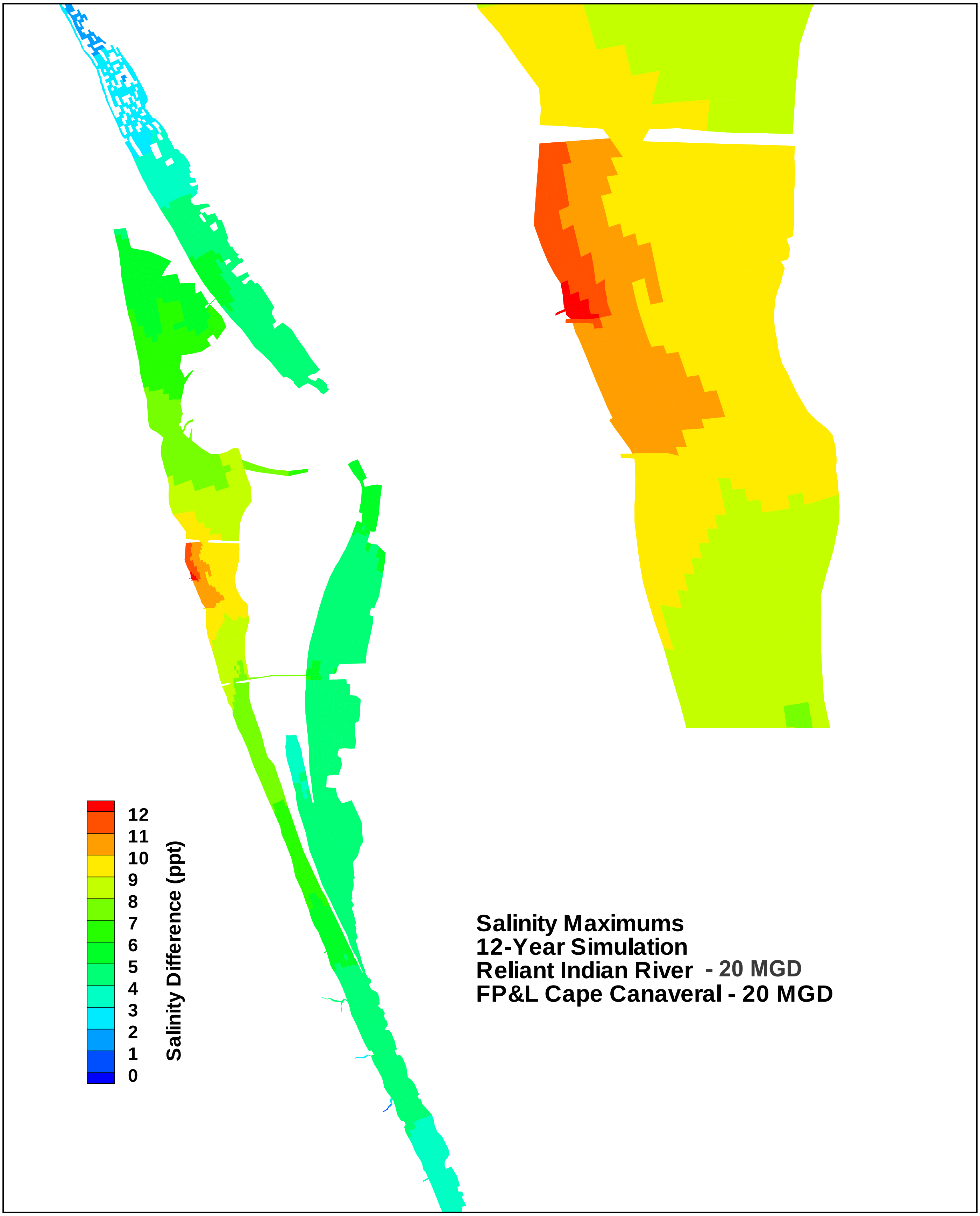

Figure J-4
Daily Average Salinity Changes Over Baseline for the 20MGD(Reliant)/20MGD(Cape Canaveral) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

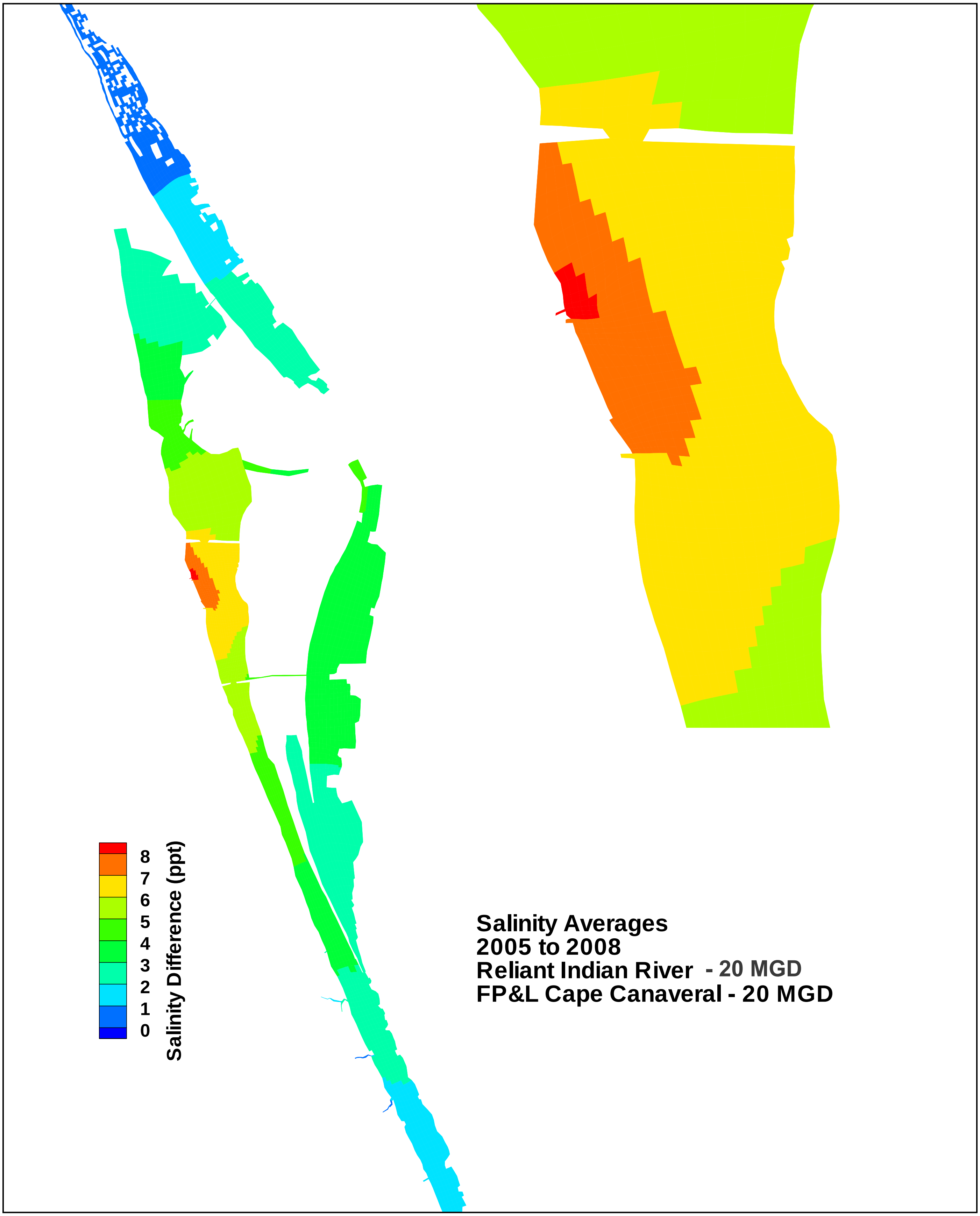

Figure J-5
Daily Average Salinity Changes Over Baseline for the 20MGD(Reliant)/20MGD(Cape Canaveral) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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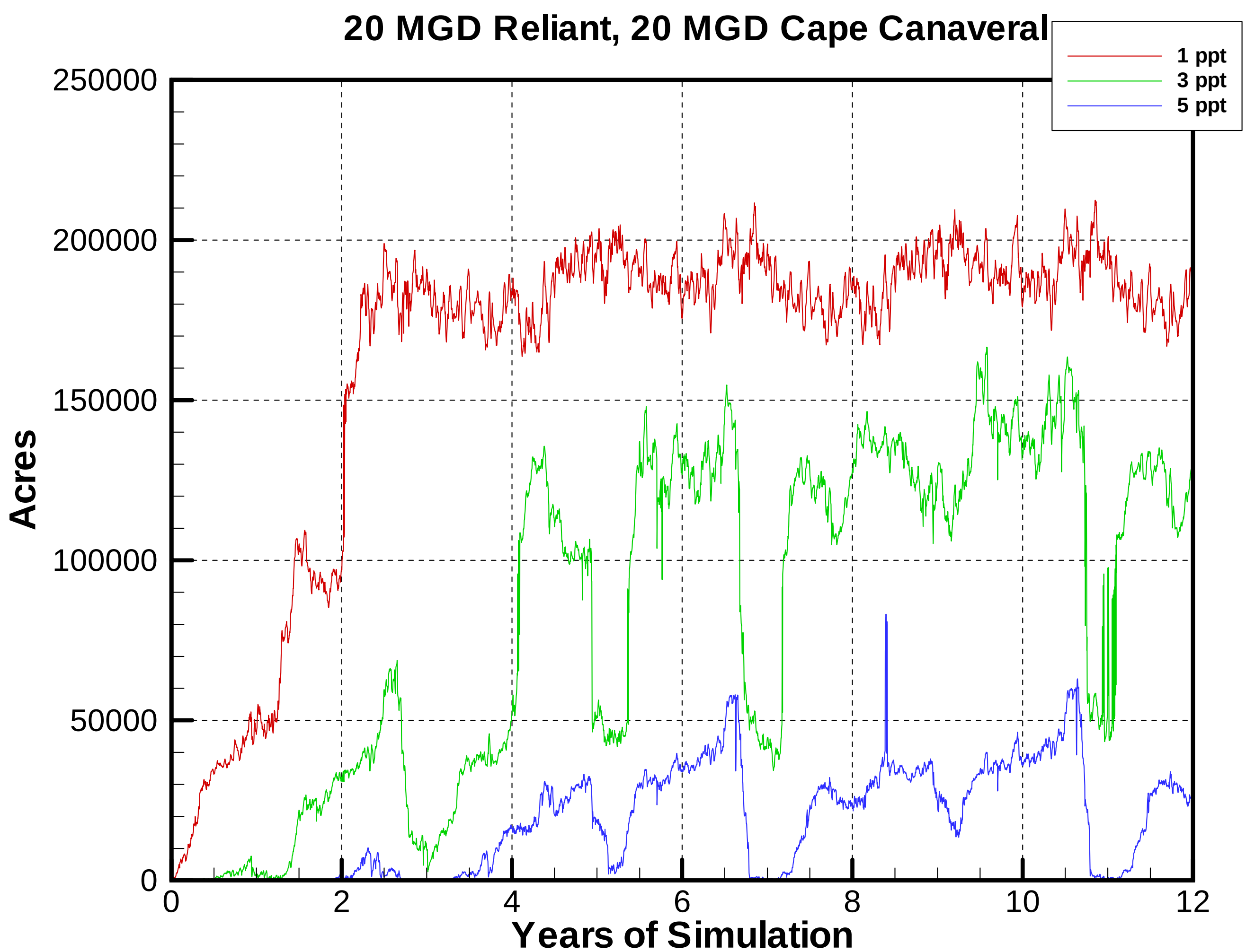

Figure J-6
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (20MGD-Reliant, 20MGD -Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

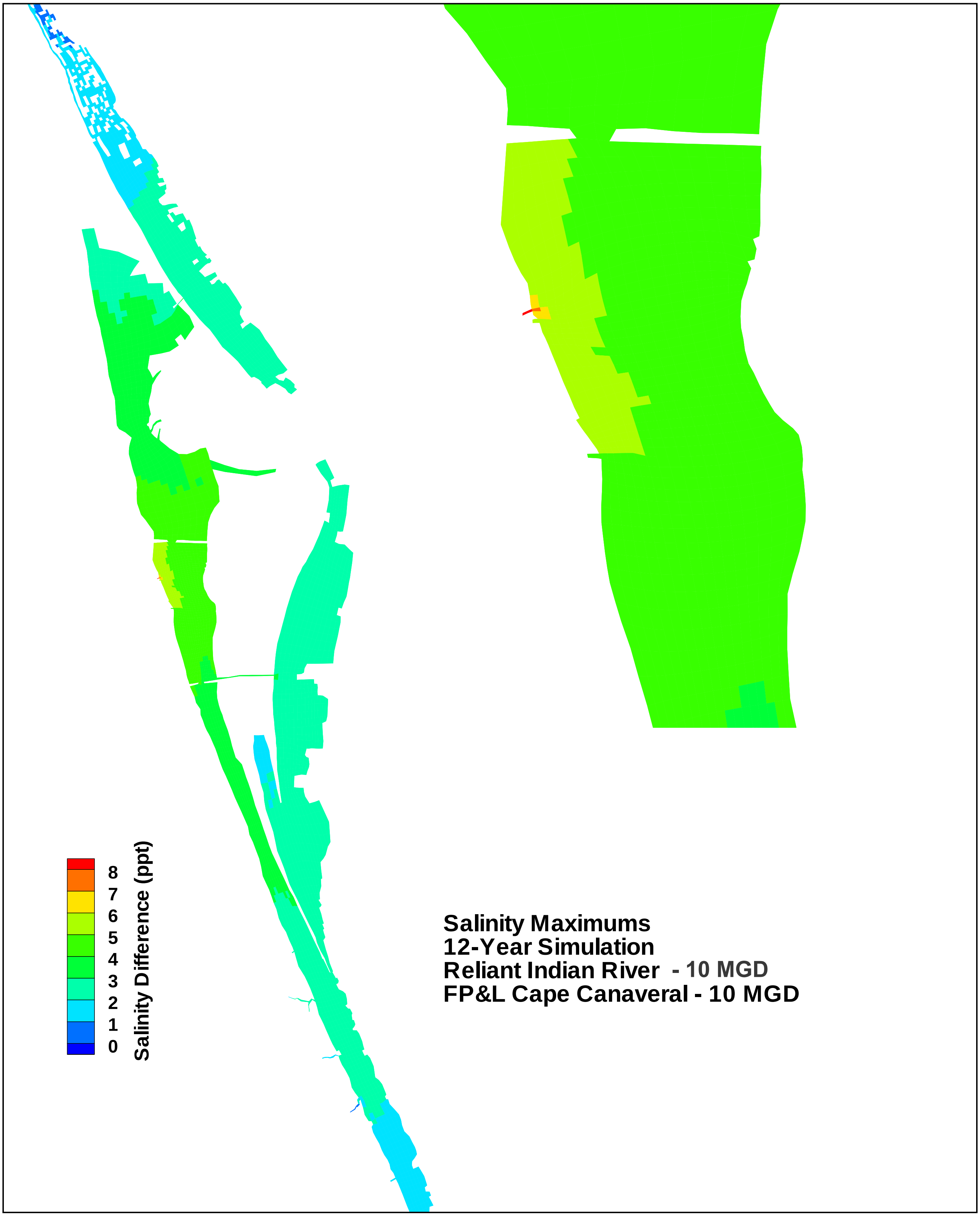

Figure J-7
Daily Average Salinity Changes Over Baseline for the 10MGD(Reliant)/10MGD(Cape Canaveral) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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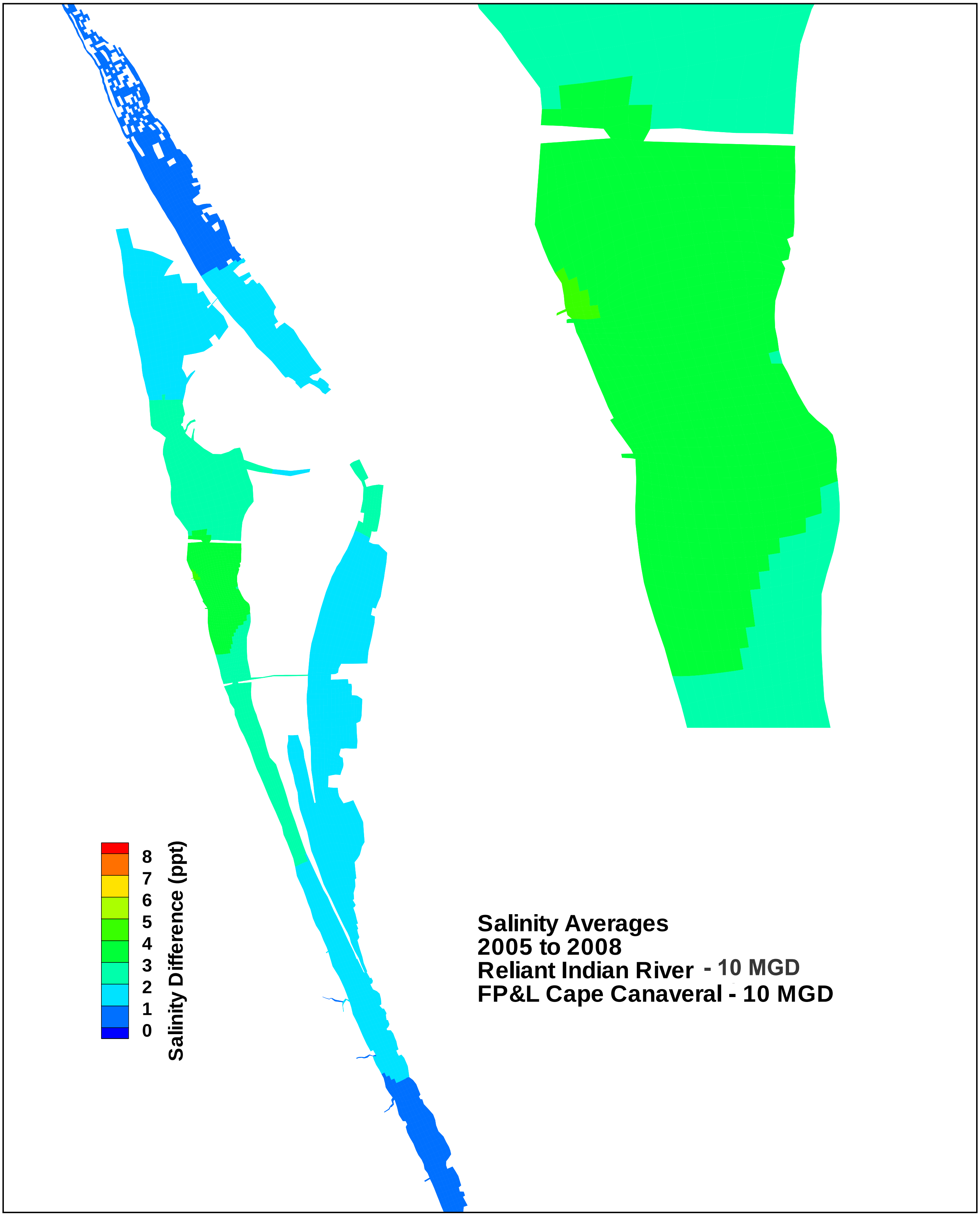

Figure J-8
Daily Average Salinity Changes Over Baseline for the 10MGD(Reliant)/10MGD(Cape Canaveral) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

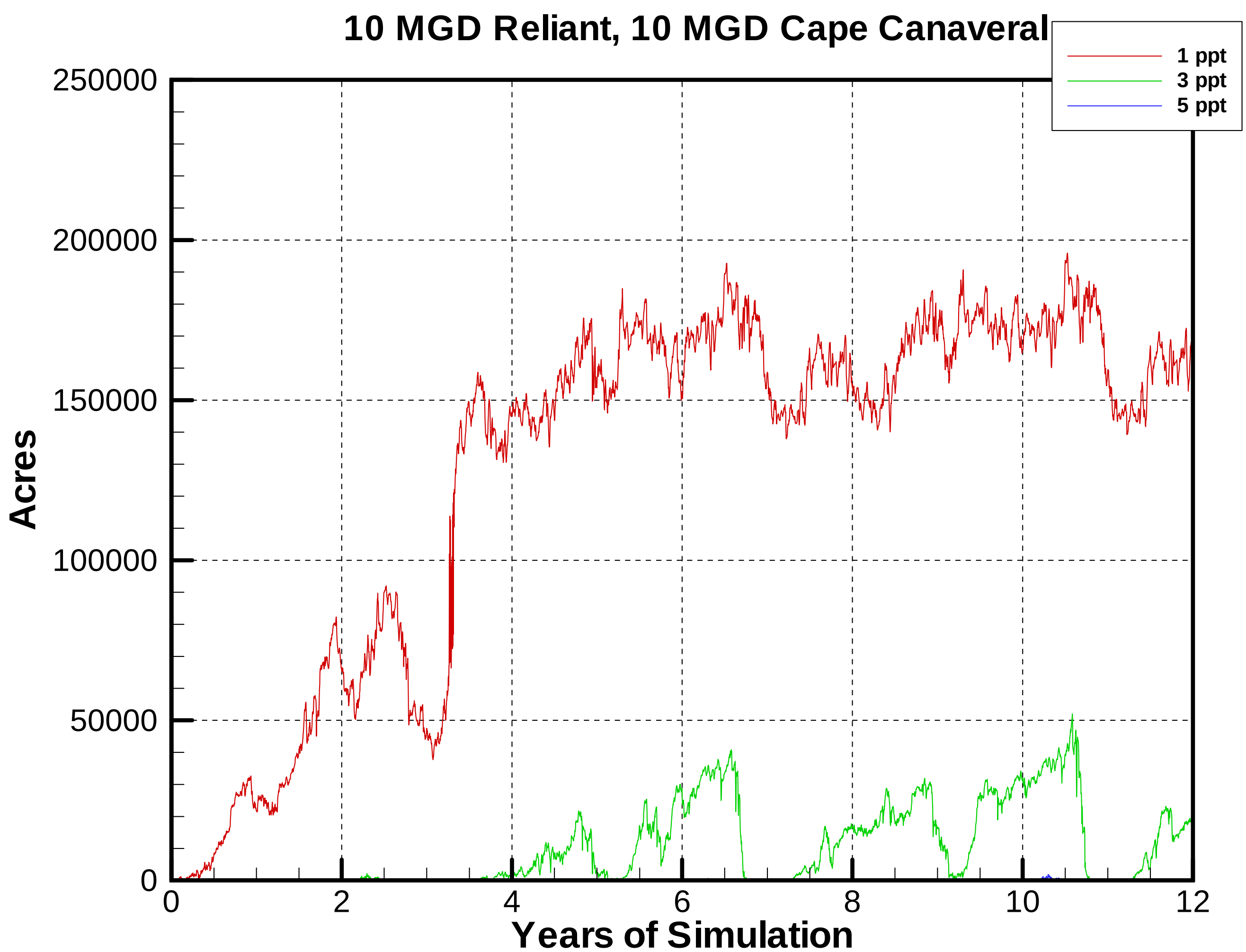

Figure J-9
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (10MGD-Reliant, 10MGD -Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

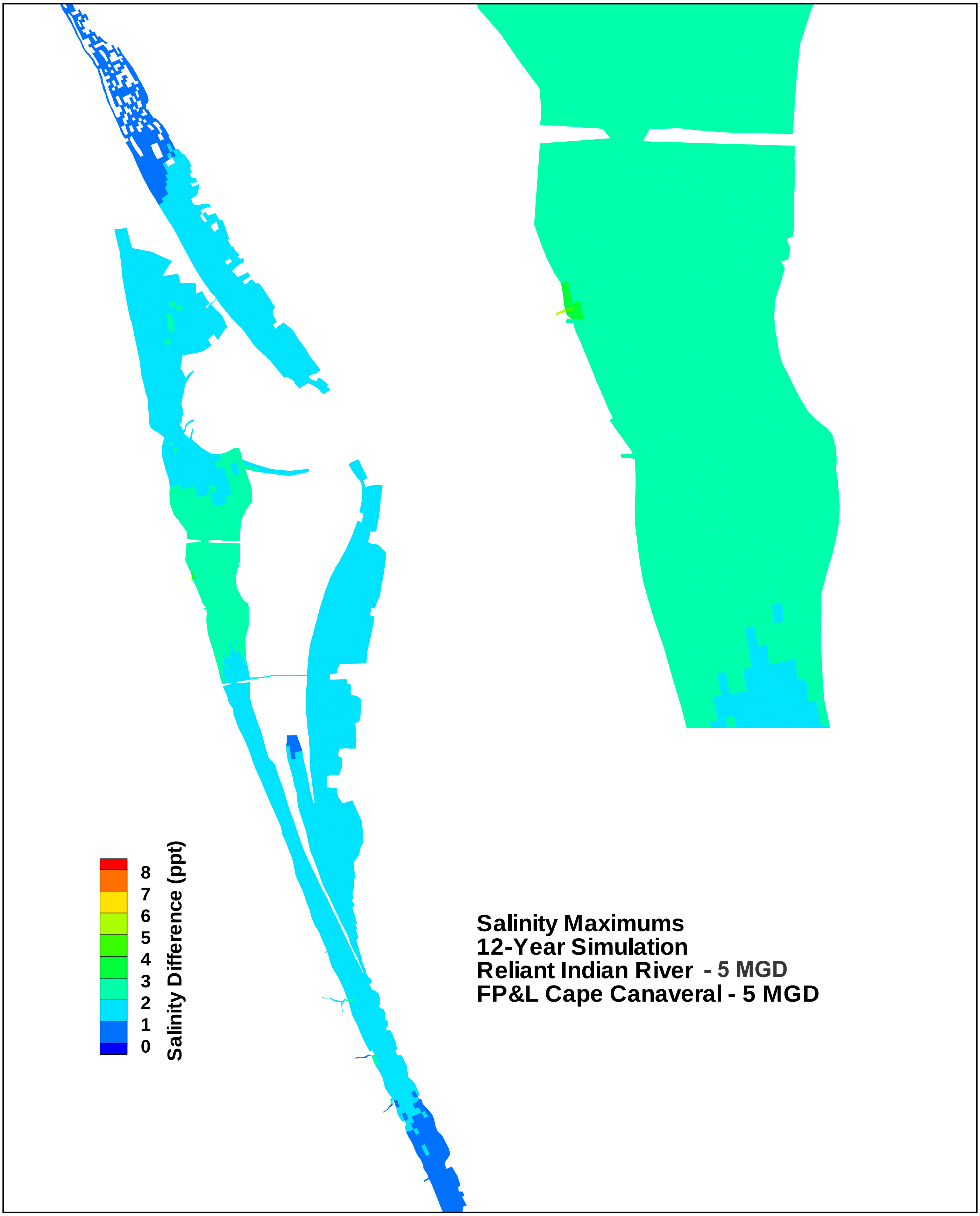

Figure J-10
Daily Average Salinity Changes Over Baseline for the 5MGD(Reliant)/5MGD(Cape Canaveral) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

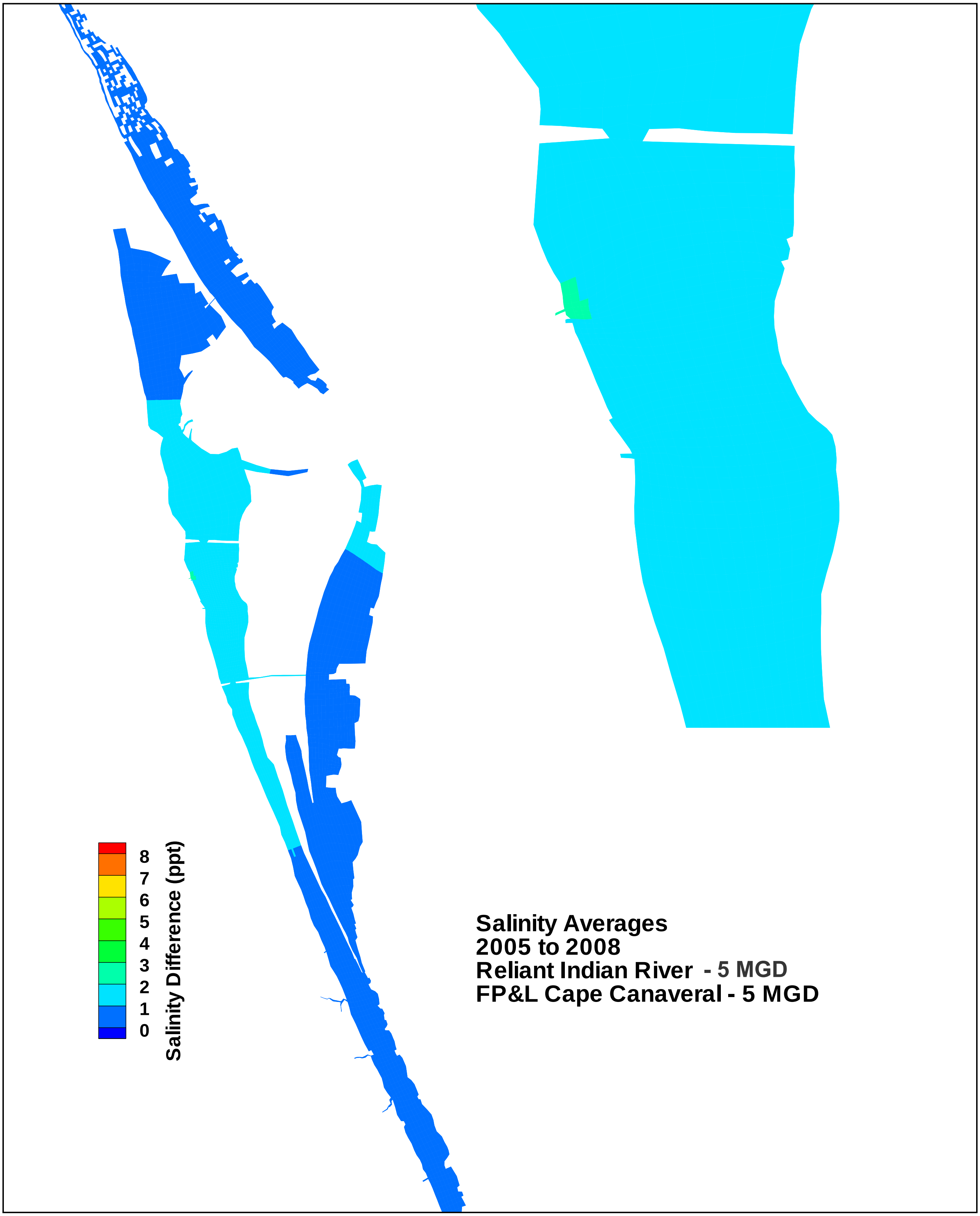

Figure J-11
Daily Average Salinity Changes Over Baseline for the 5MGD(Reliant)/5MGD(Cape Canaveral) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

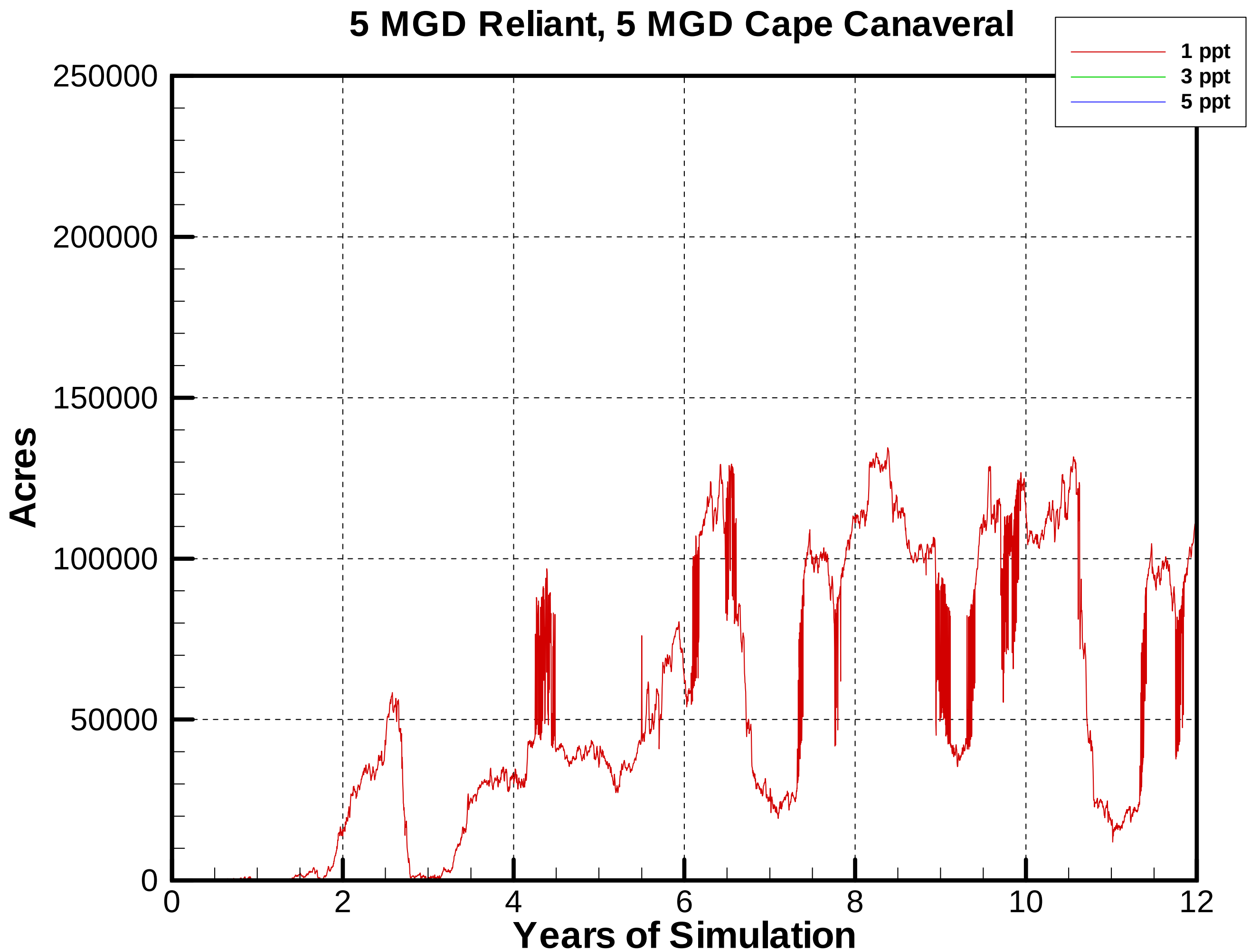

Figure J-12
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (5MGD-Reliant, 5MGD -Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

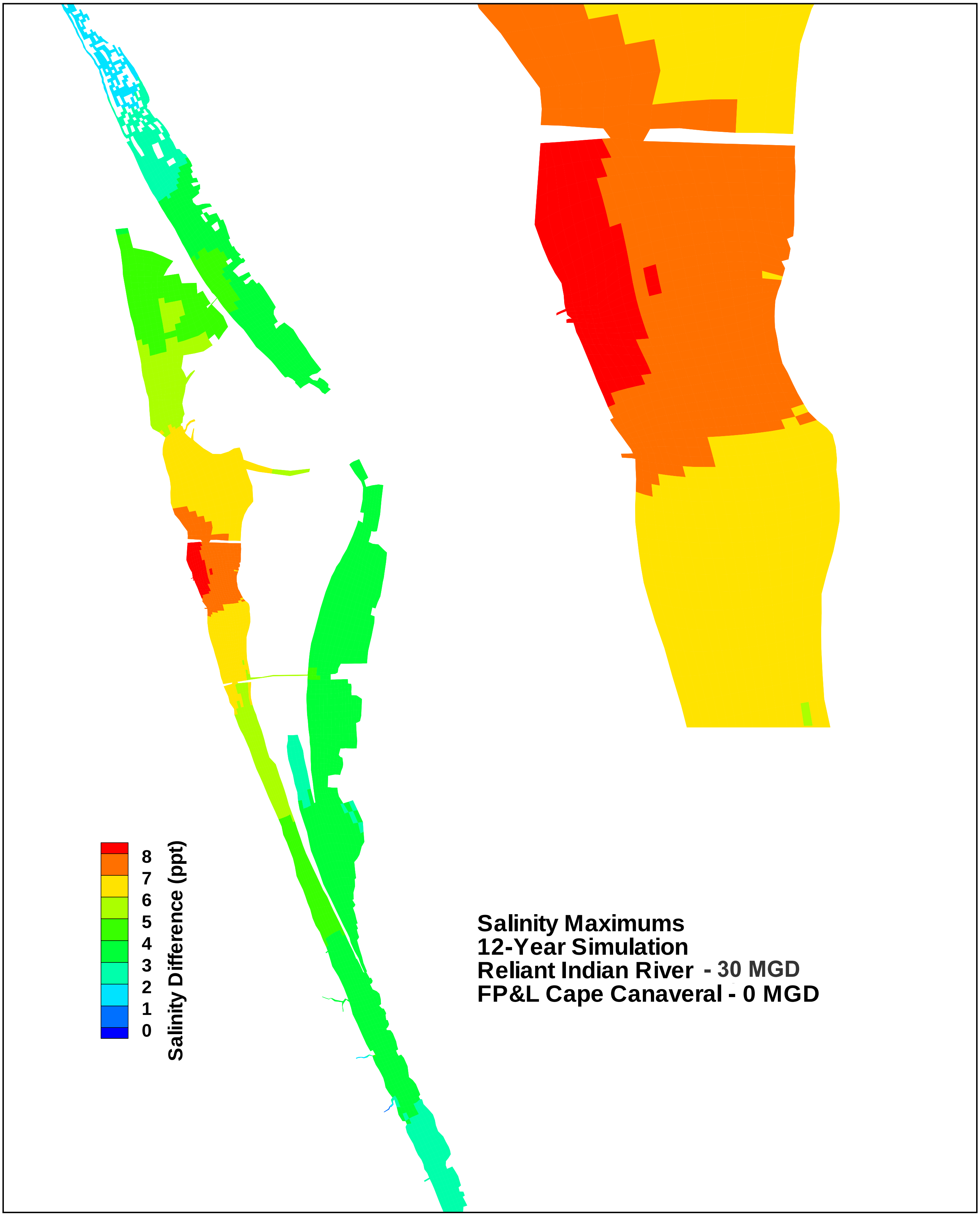

Figure J-13
Daily Average Salinity Changes Over Baseline for the 30MGD(Reliant) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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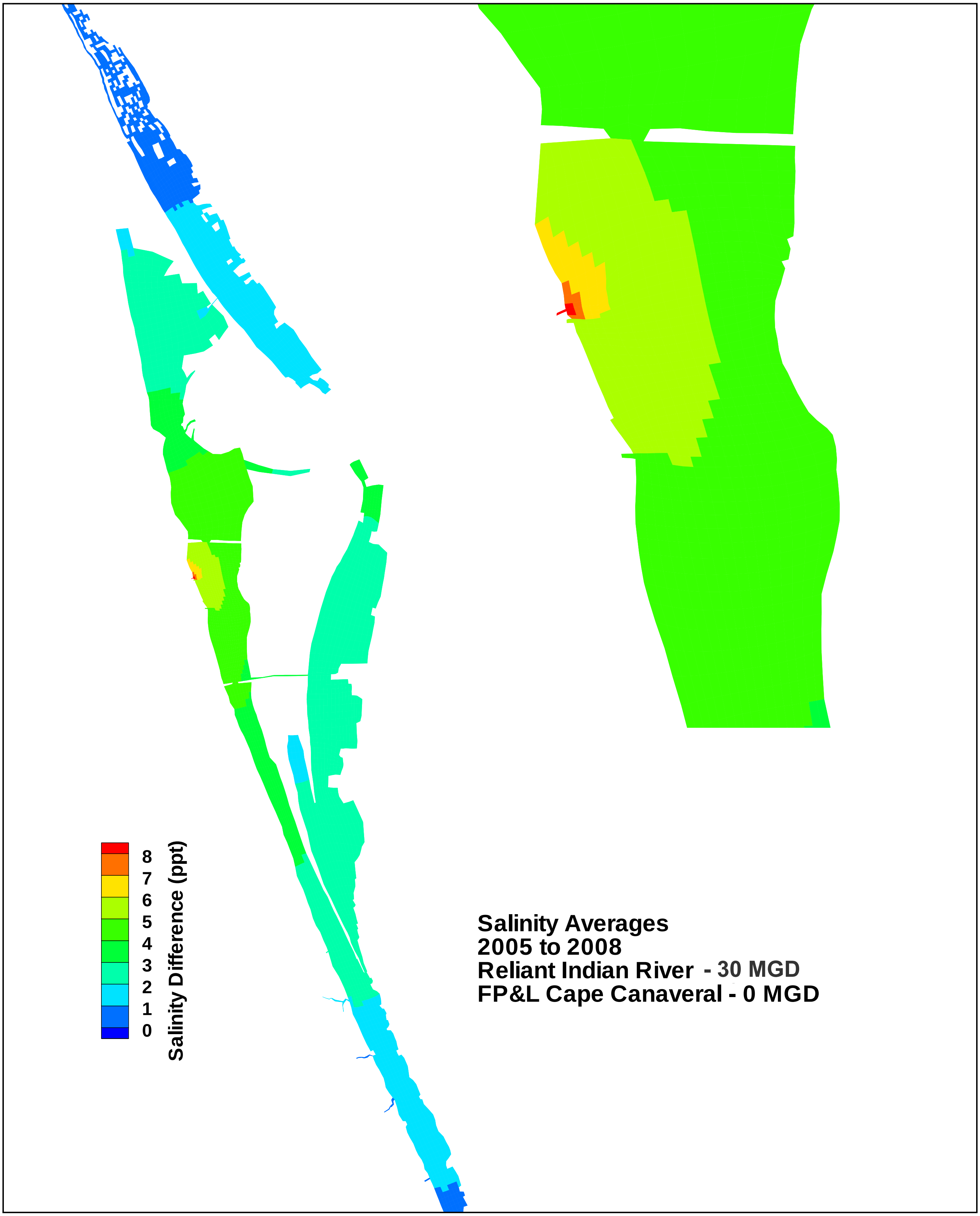

Figure J-14
Daily Average Salinity Changes Over Baseline for the 30MGD(Reliant) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

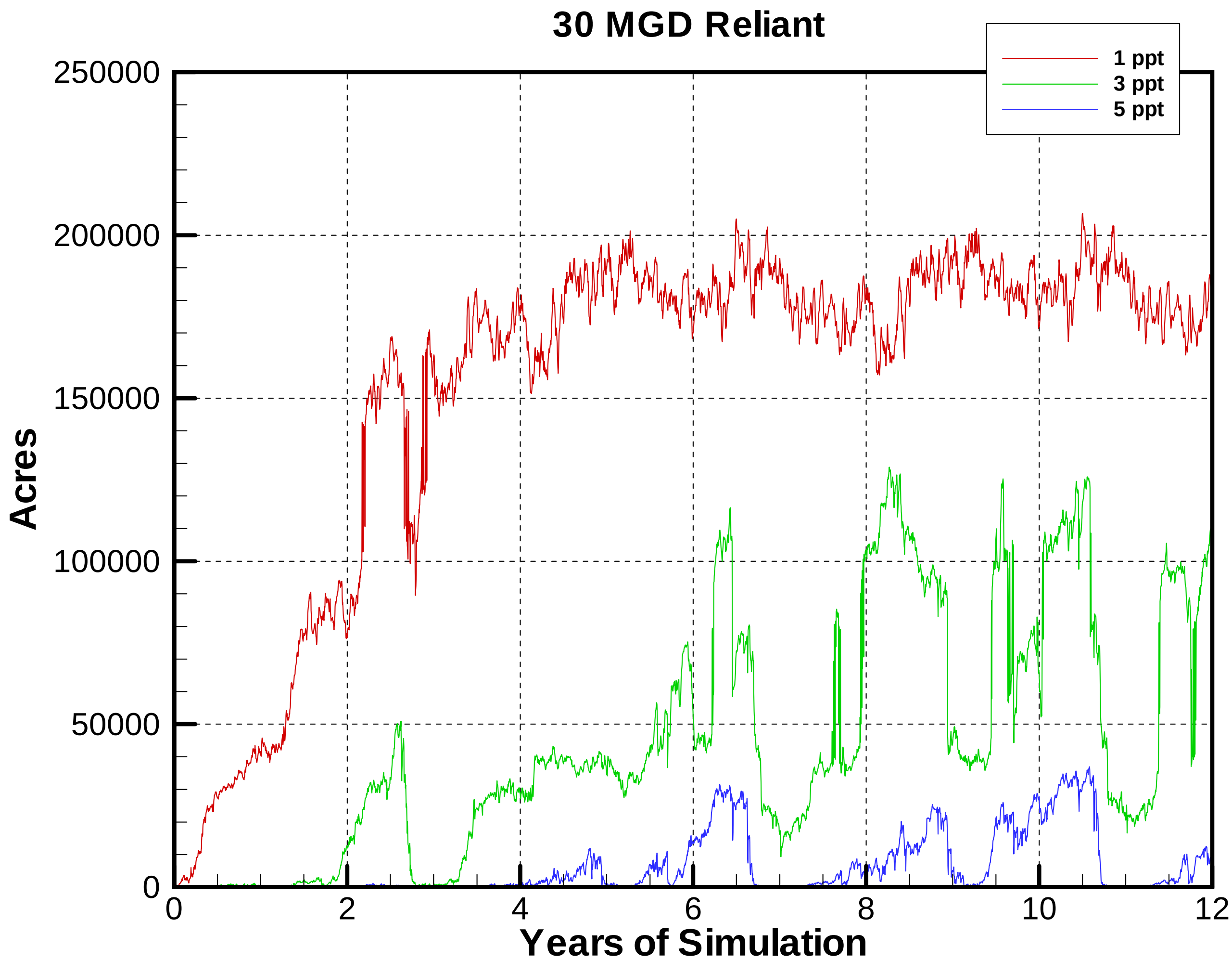

Figure J-15
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (30MGD-Reliant)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

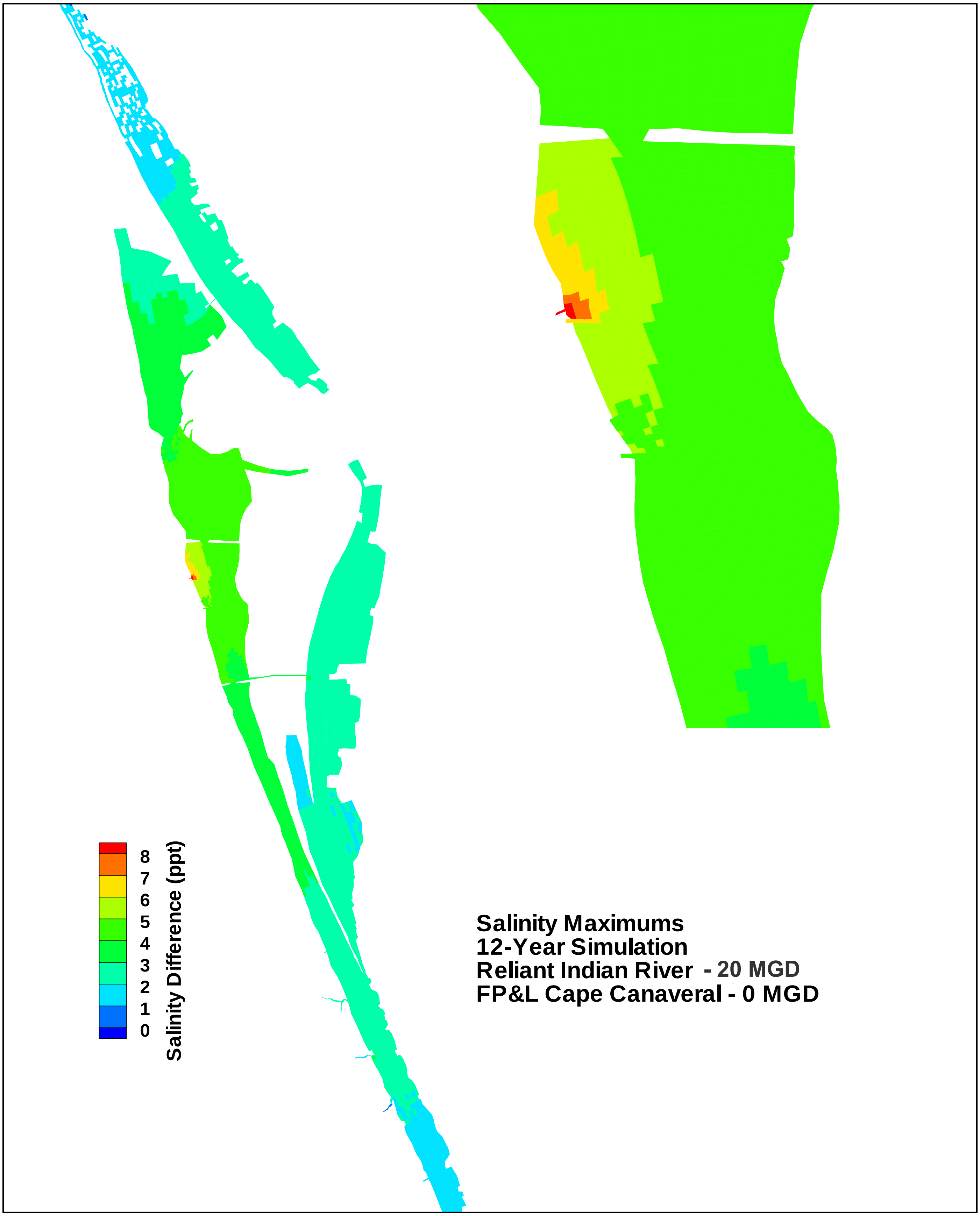

Figure J-16
Daily Average Salinity Changes Over Baseline for the 20MGD(Reliant) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

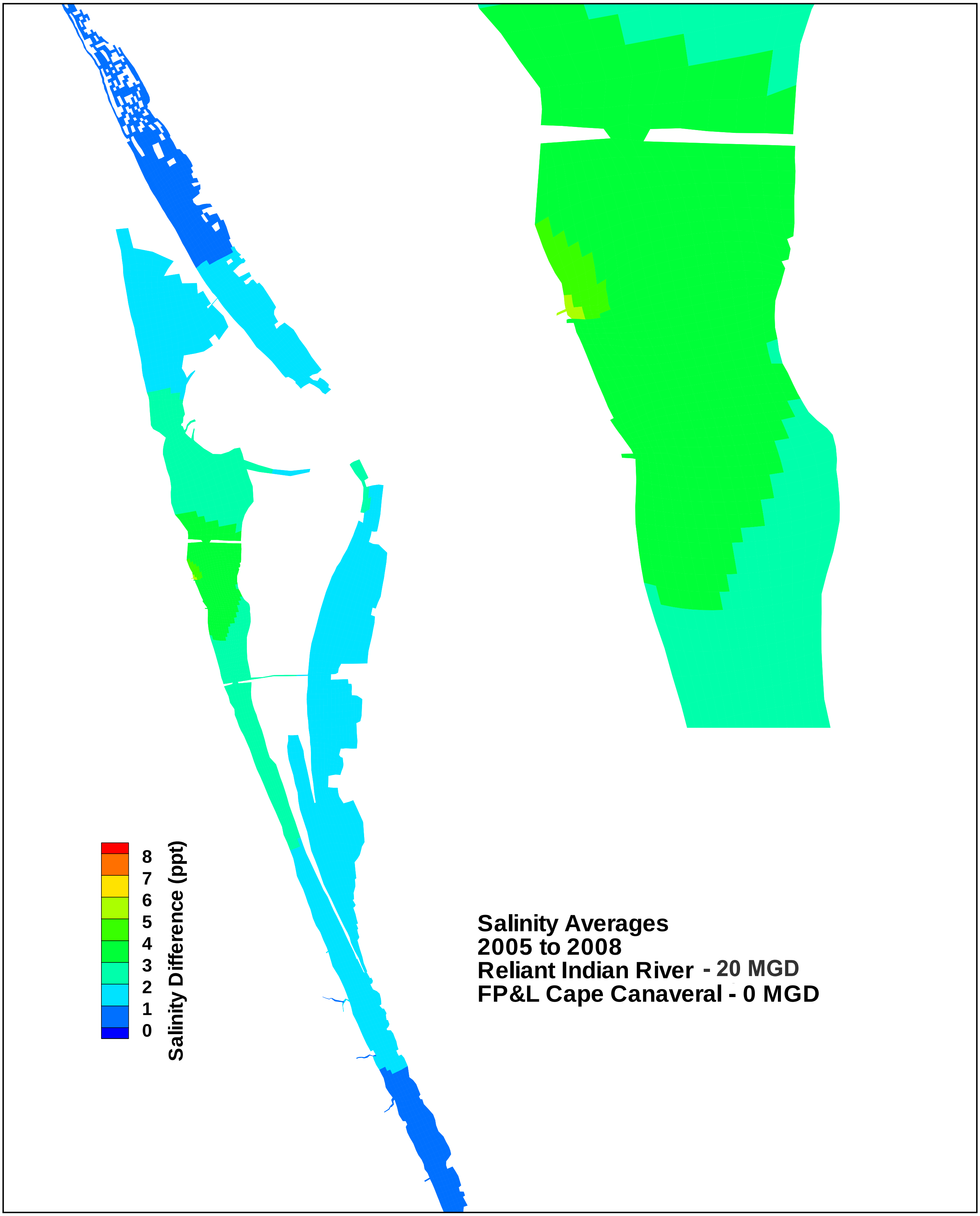

Figure J-17
Daily Average Salinity Changes Over Baseline for the 20MGD(Reliant) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

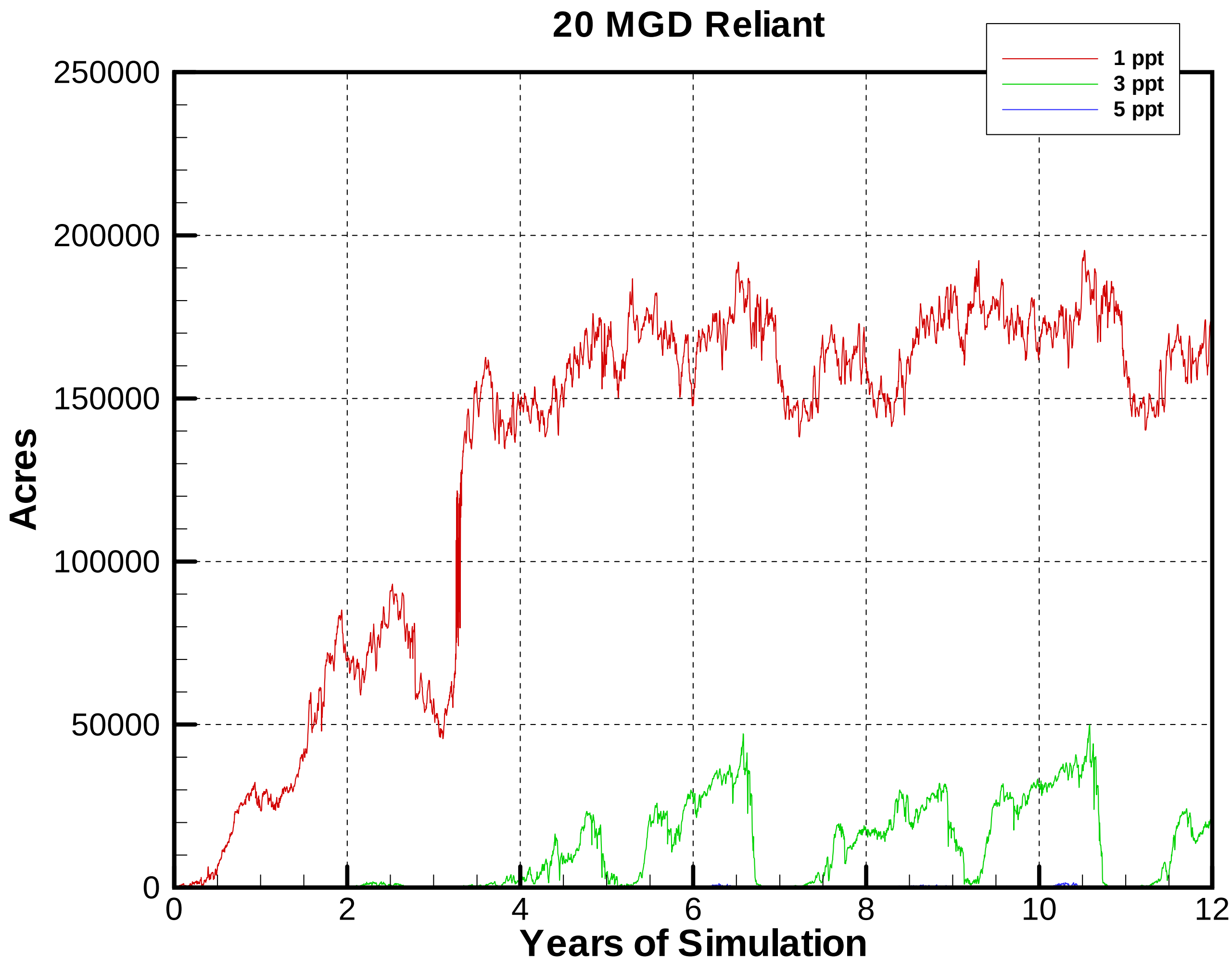

Figure J-18
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (20MGD-Reliant)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

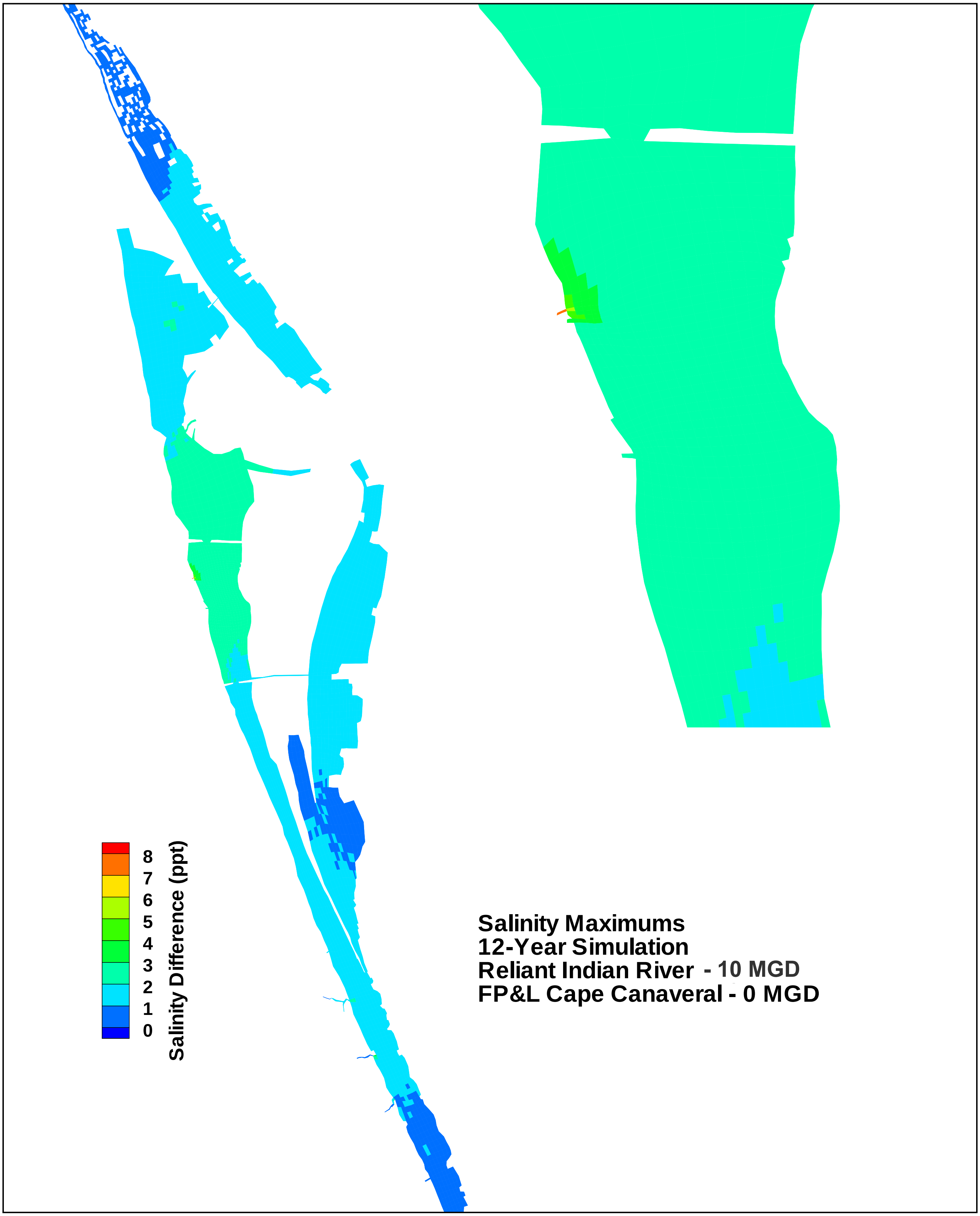

Figure J-19
Daily Average Salinity Changes Over Baseline for the 10MGD(Reliant) Scenario (12-Year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

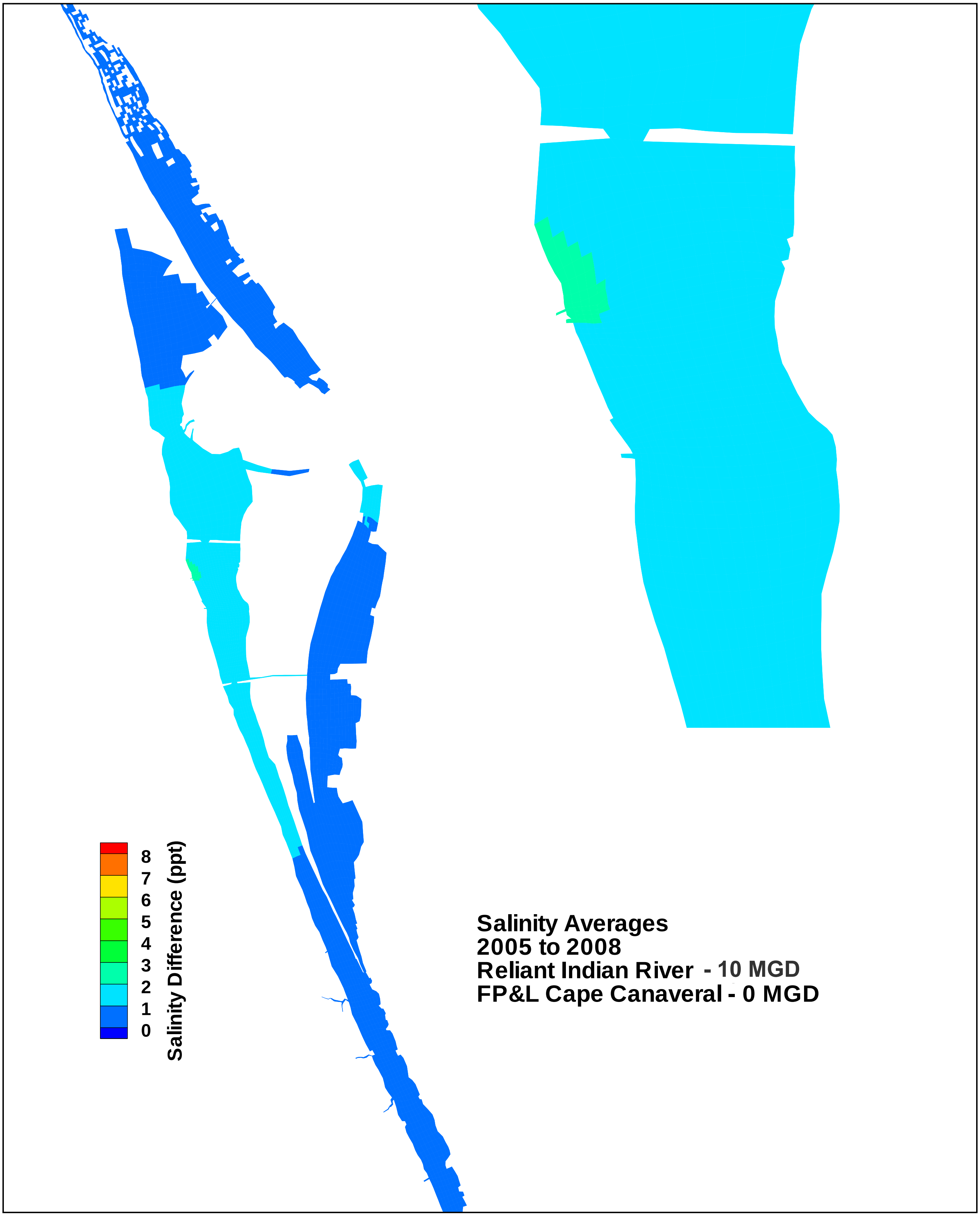

Figure J-20
Daily Average Salinity Changes Over Baseline for the 10MGD(Reliant) Scenario (Average for Years 9 to 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

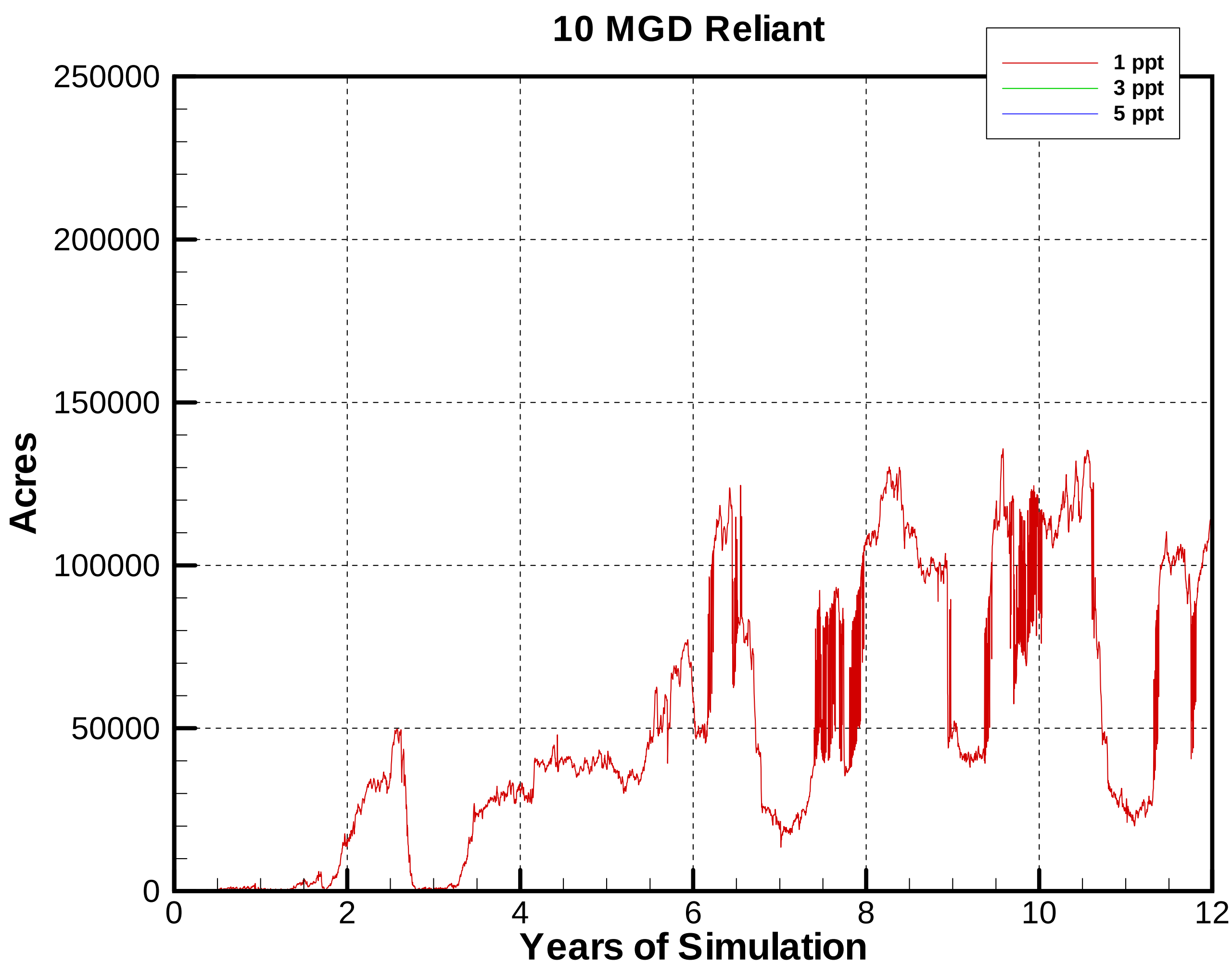

Figure J-21
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12 Year Simulation Period (10MGD-Reliant)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

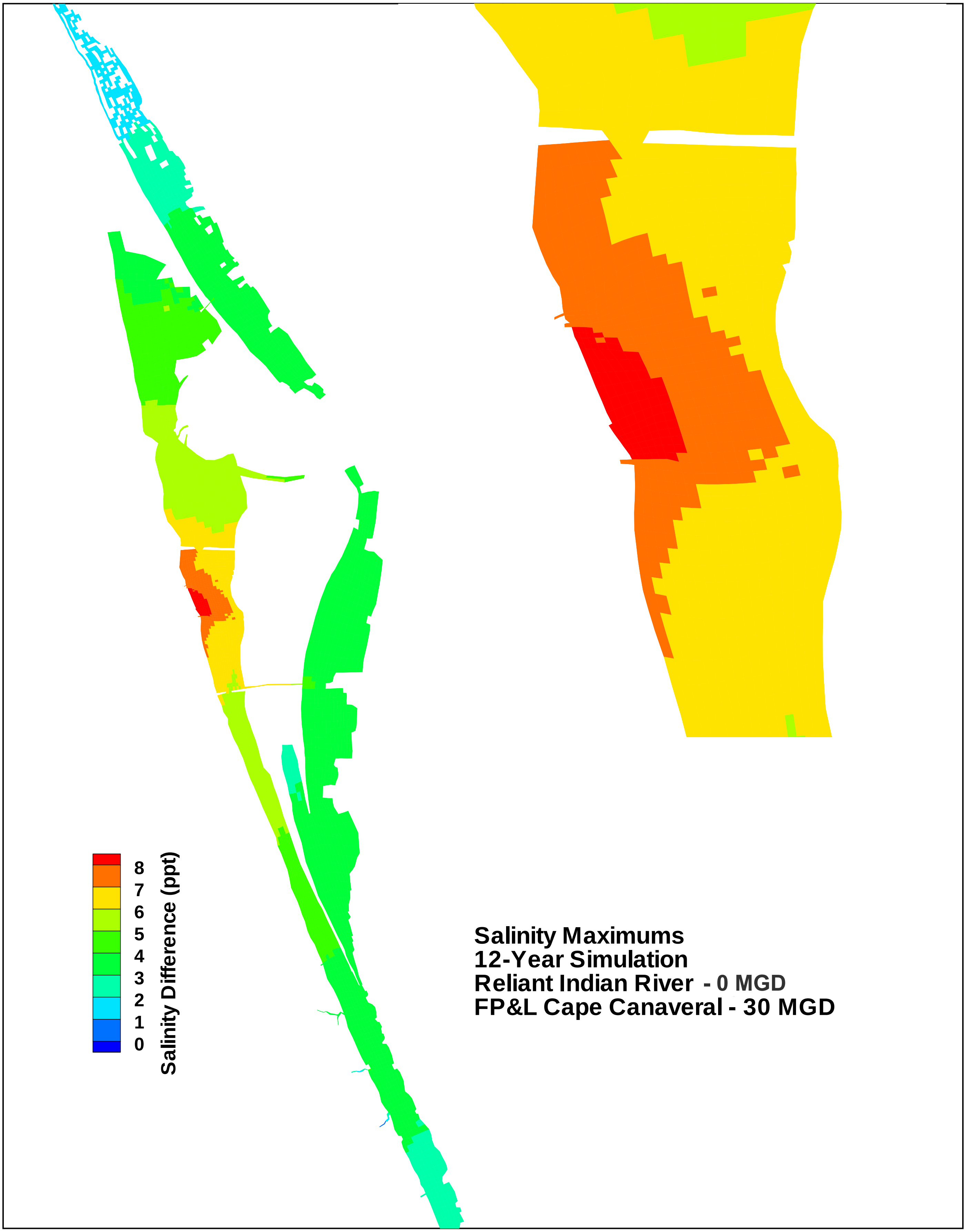

Figure J-22
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/
30MGD(Cape Canaveral) Scenario (12-year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

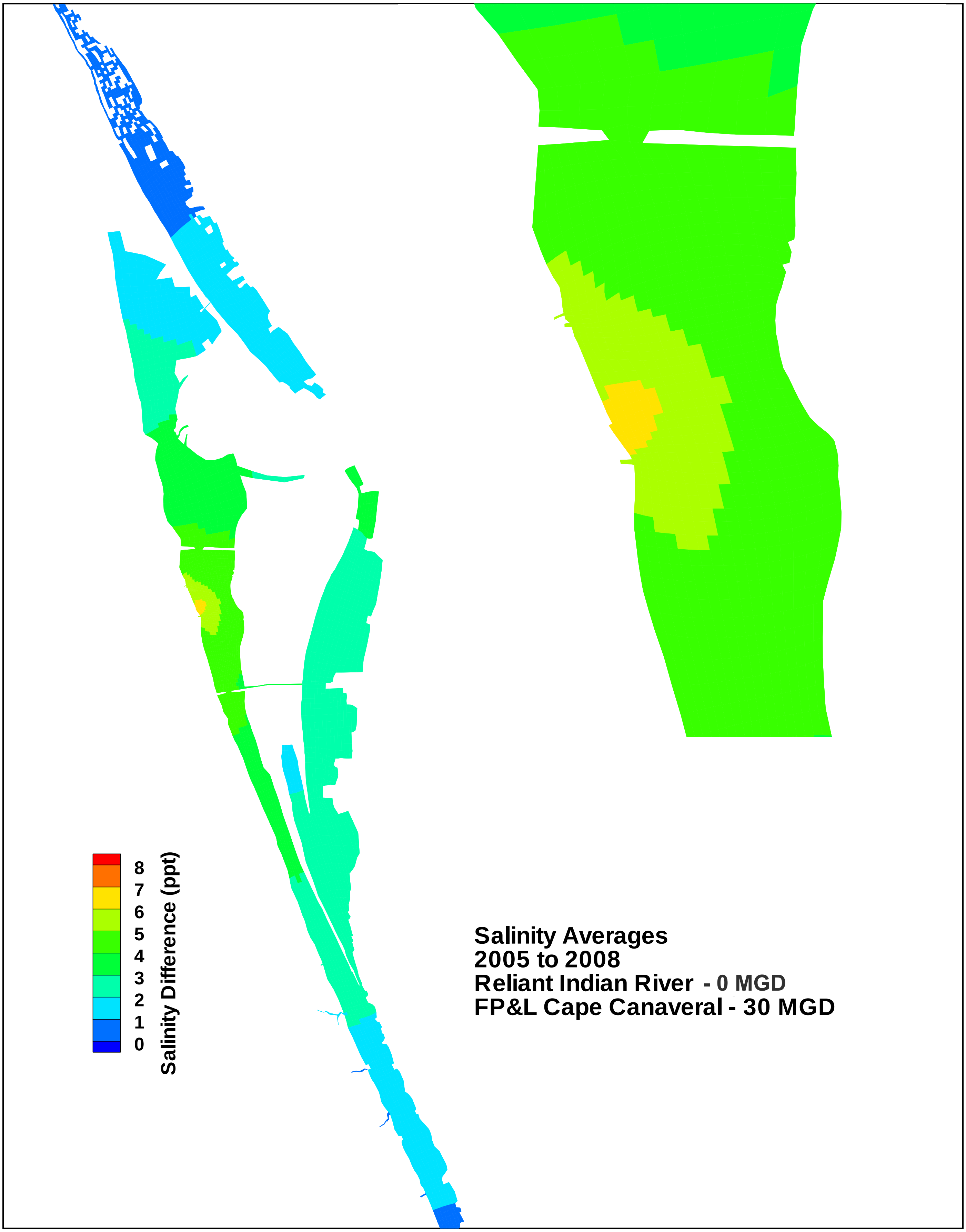

Figure J-23
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/ 30MGD(Cape Canaveral) Scenario (Average for Years 9 through 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

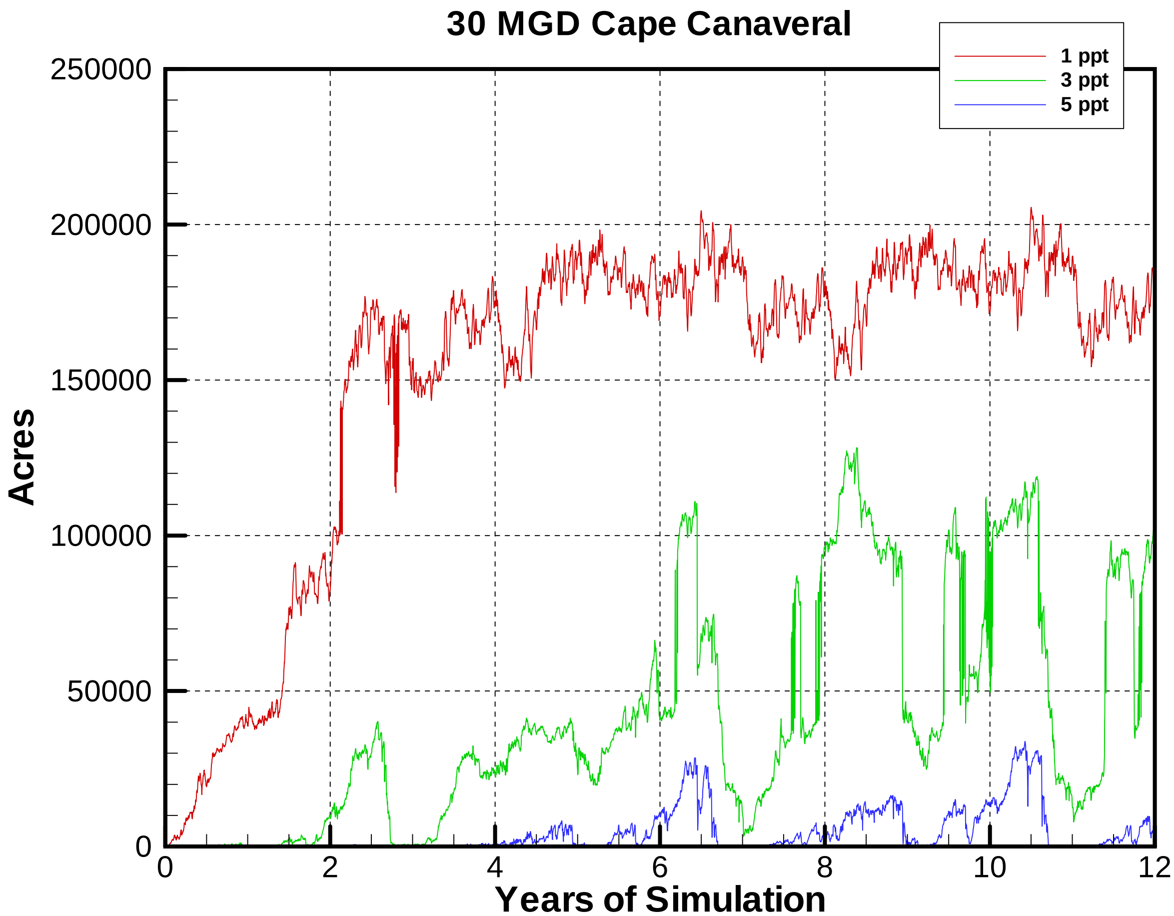

Figure J-24
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12-Year Simulation Period 0MGD(Reliant)/30MGD(Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

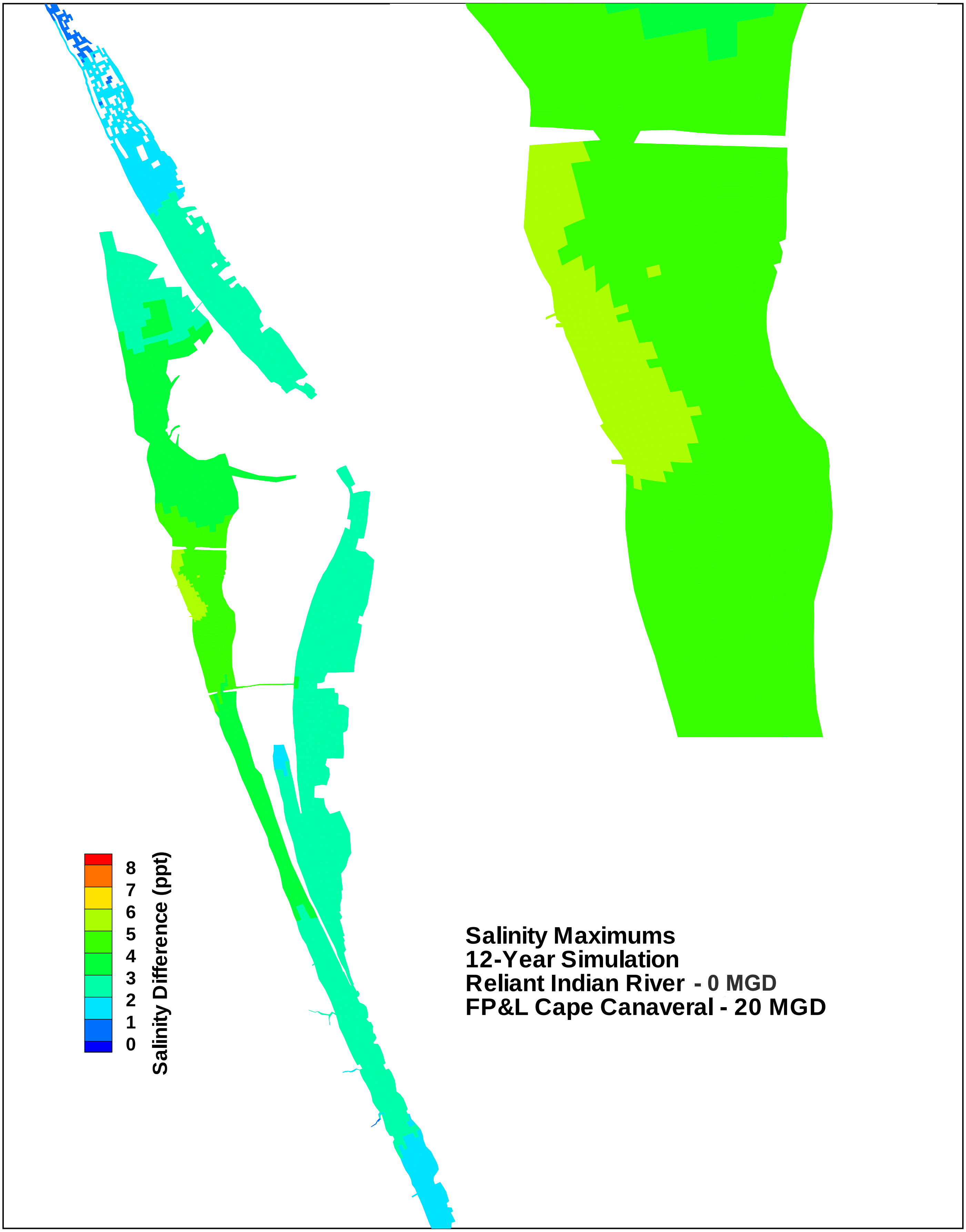

Figure J-25
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/
20MGD(Cape Canaveral) Scenario (12-year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

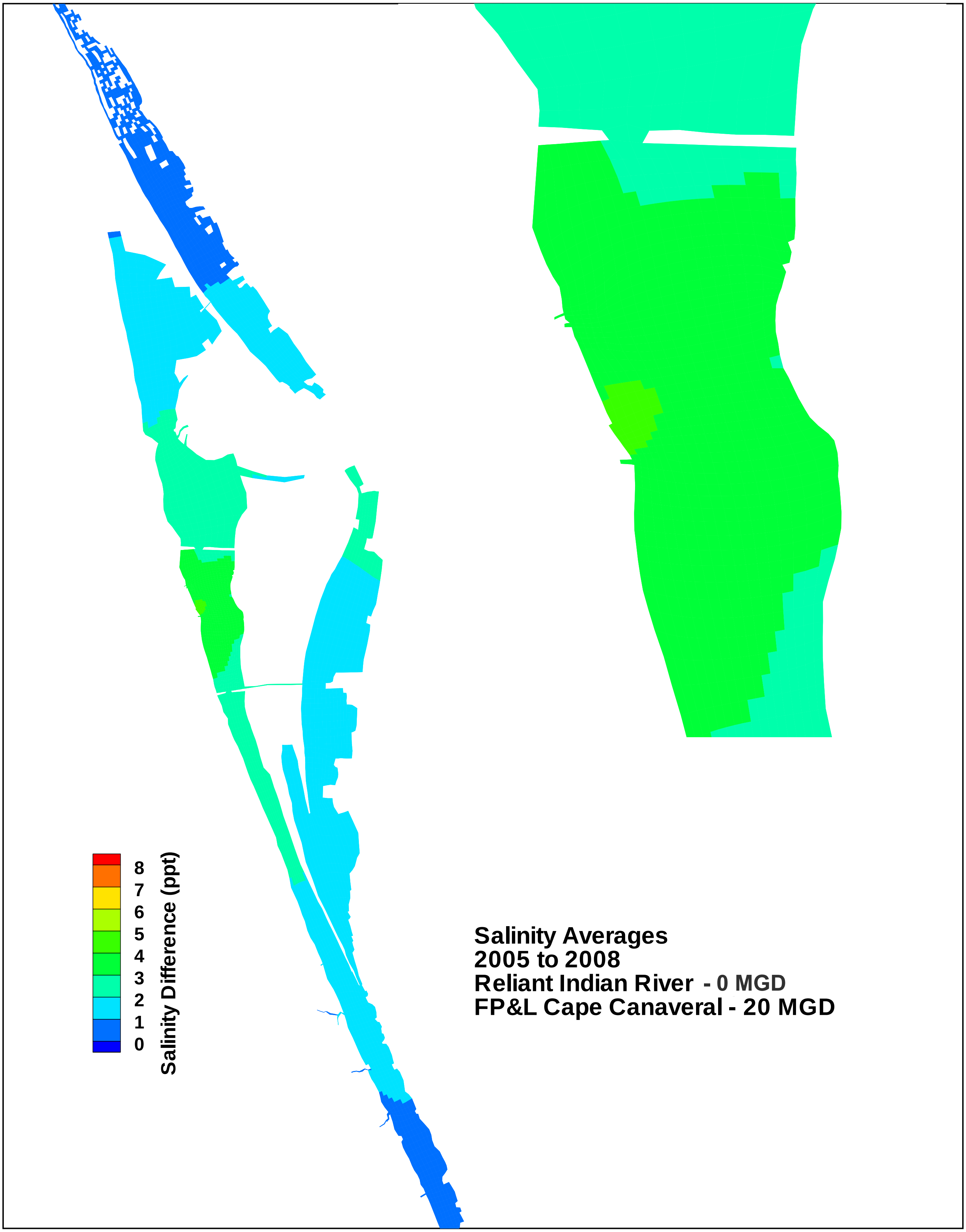

Figure J-26
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/
20MGD(Cape Canaveral) Scenario (Average for Years 9 through 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

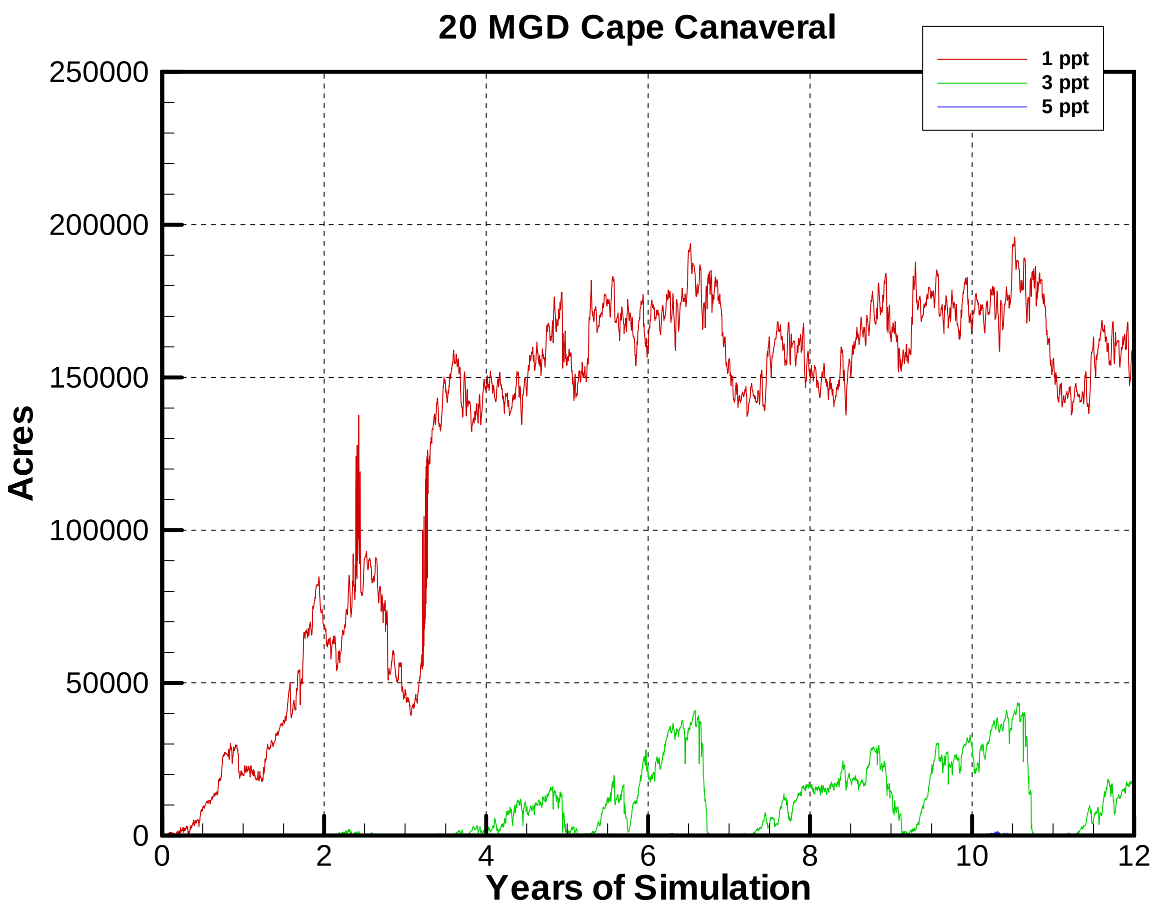

Figure J-27
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12-Year Simulation Period 0MGD(Reliant)/20MGD(Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

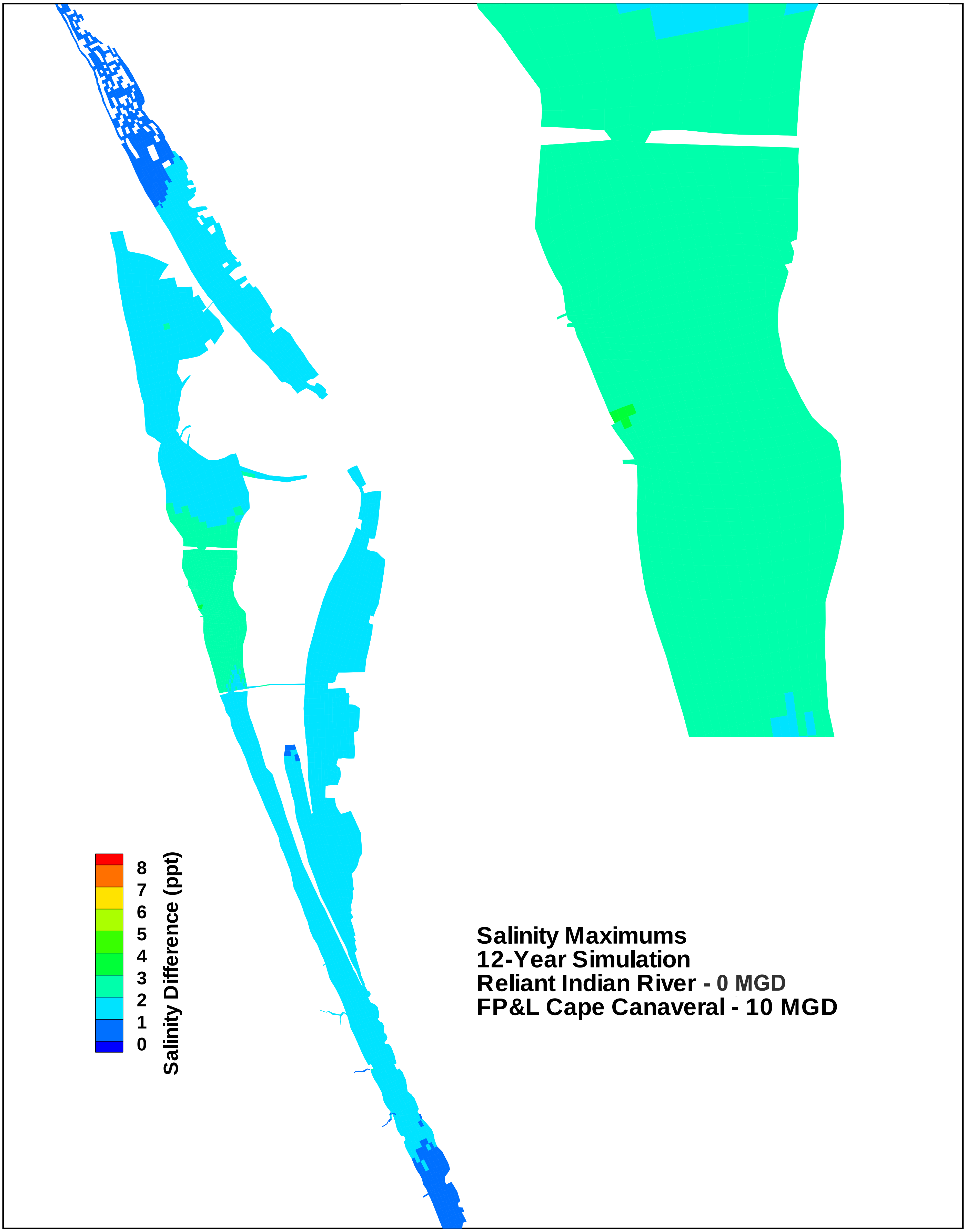

Figure J-28
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/
10MGD(Cape Canaveral) Scenario (12-year Simulation Period Maximum)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

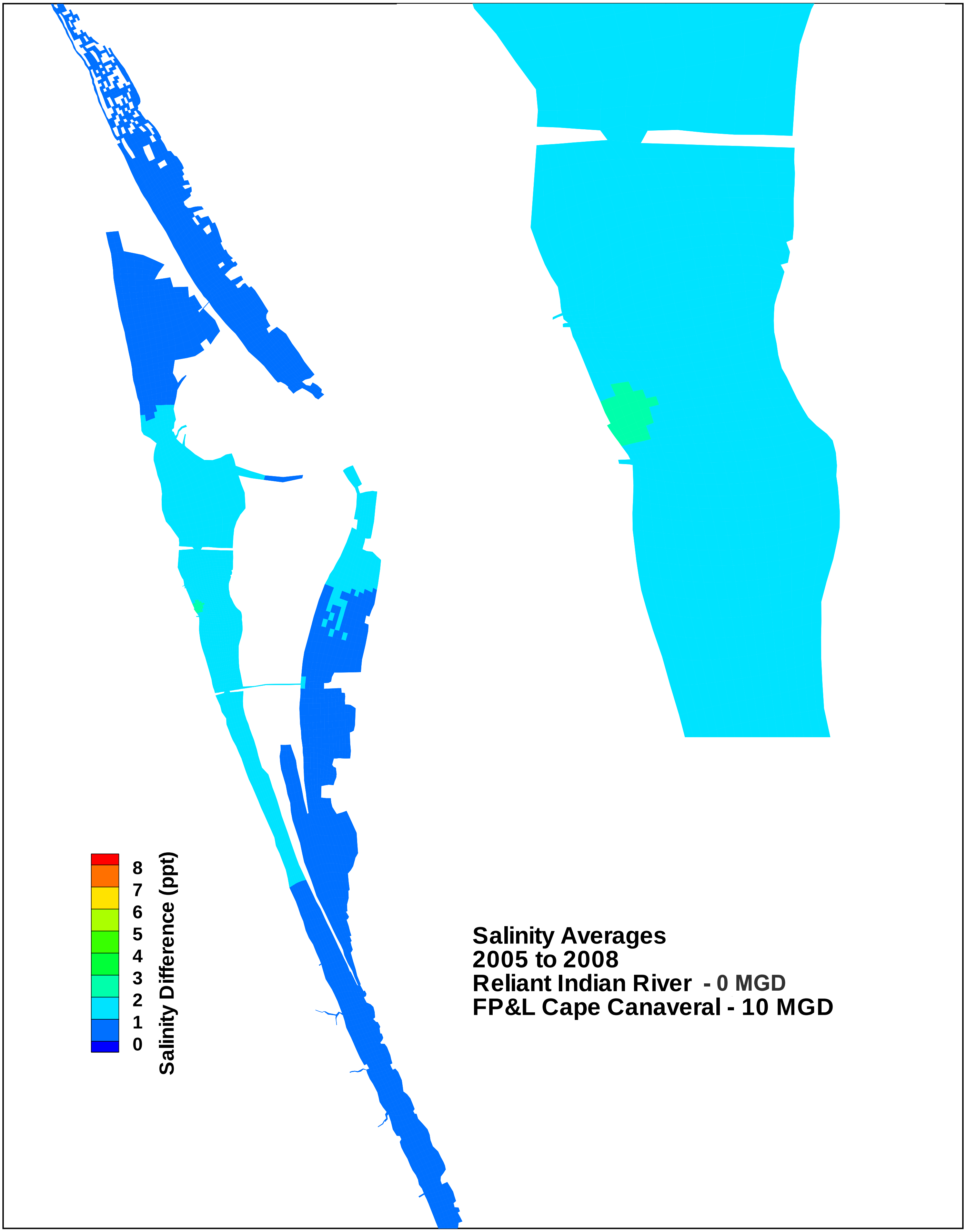

Figure J-29
Daily Average Salinity Changes Over Baseline for the 0MGD(Reliant)/
10MGD(Cape Canaveral) Scenario (Average for Years 9 through 12)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

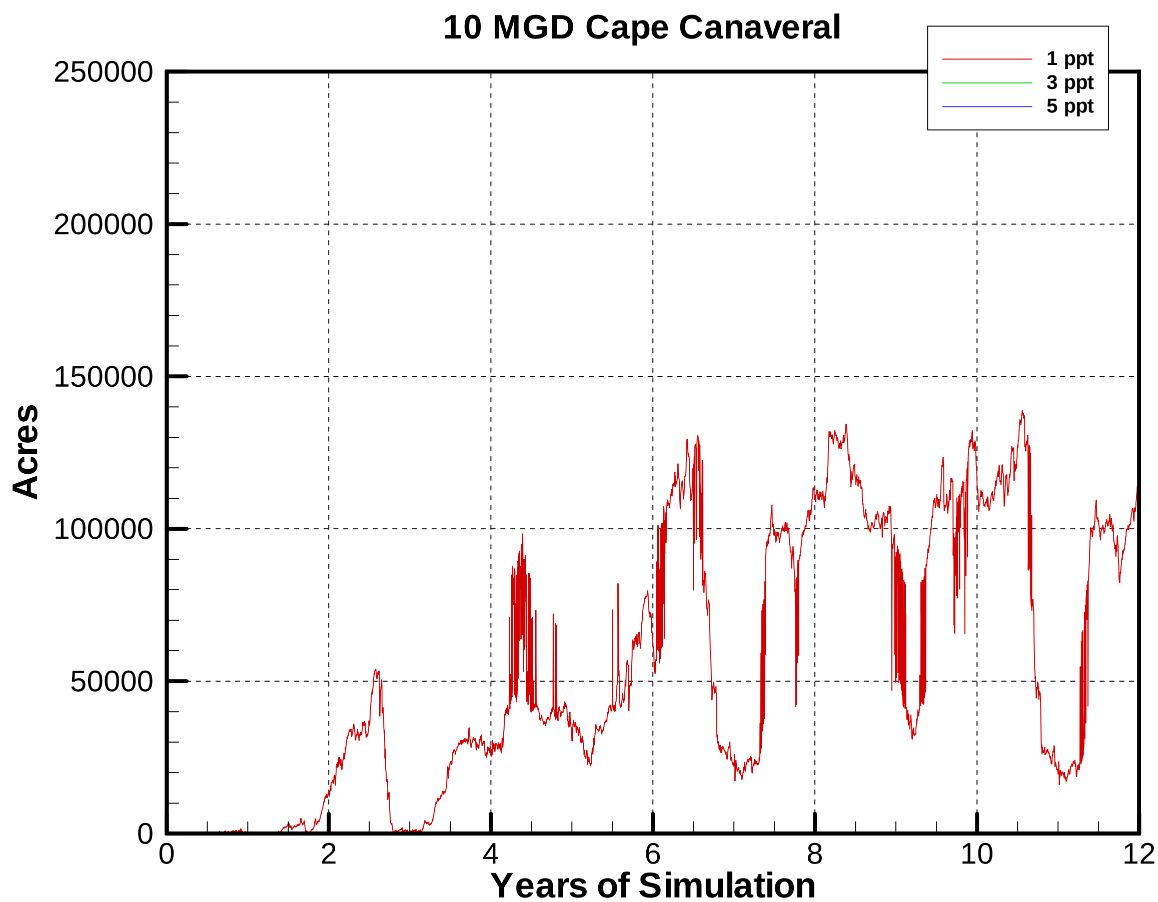

Figure J-30
Acreages with Daily Average Salinity Greater than 1, 3, and 5 ppt vs. Time for 12-Year Simulation Period 0MGD(Reliant)/10MGD(Cape Canaveral)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

Appendix K

Near Field Measurement and Simulation of Temperature near Power Plants

Indian River Lagoon Temperature Field Program and Model Comparison

1. INTRODUCTION

While water surface elevation and salinity in the Indian River Lagoon are quite well understood, detail is lacking in the understanding of temperatures in the region of the Reliant Indian River Lagoon Power Plant and the FP&L Cape Canaveral Power Plant (Figure 1-1) being studied here. In order to better understand the predictive capability of the hydrodynamic, salinity and temperature model for use in the desalinization impacts analysis, additional field observations were necessary to quantify the effects of the power station thermal effluents on their respective receiving waters.

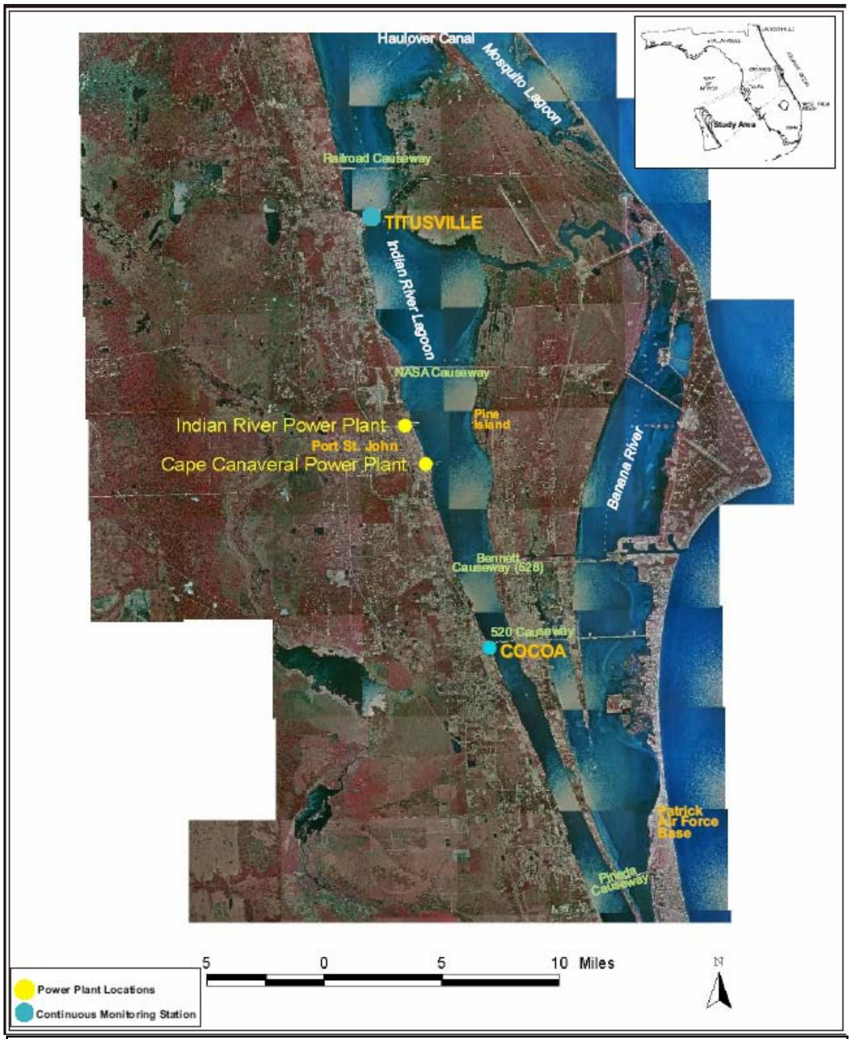

Figure 1-1 **Study area map showing the locations of the Reliant Indian River power station and FP&L Cape Canaveral power station.**

2. FIELD PROGRAM DESCRIPTION

A one week field effort was conducted to analyze the local temperature field in the vicinity of both the Reliant and the Cape Canaveral plants. Initially, handheld temperature readings were taken in the area where it was anticipated that the thermal plume from the power plant outlets would be detected. The handheld data was used to estimate the probable extent of the thermal plume. The results from the handheld temperature data were analyzed and a series of temperature sensors with data loggers were then deployed in a pattern intended to capture the extent and variability of the temperature in the area affected by the discharge. Figures 2-1 and 2-2 show the deployment locations of the temperature sensors in the regions offshore of the Cape Canaveral and the Reliant plants, respectively.

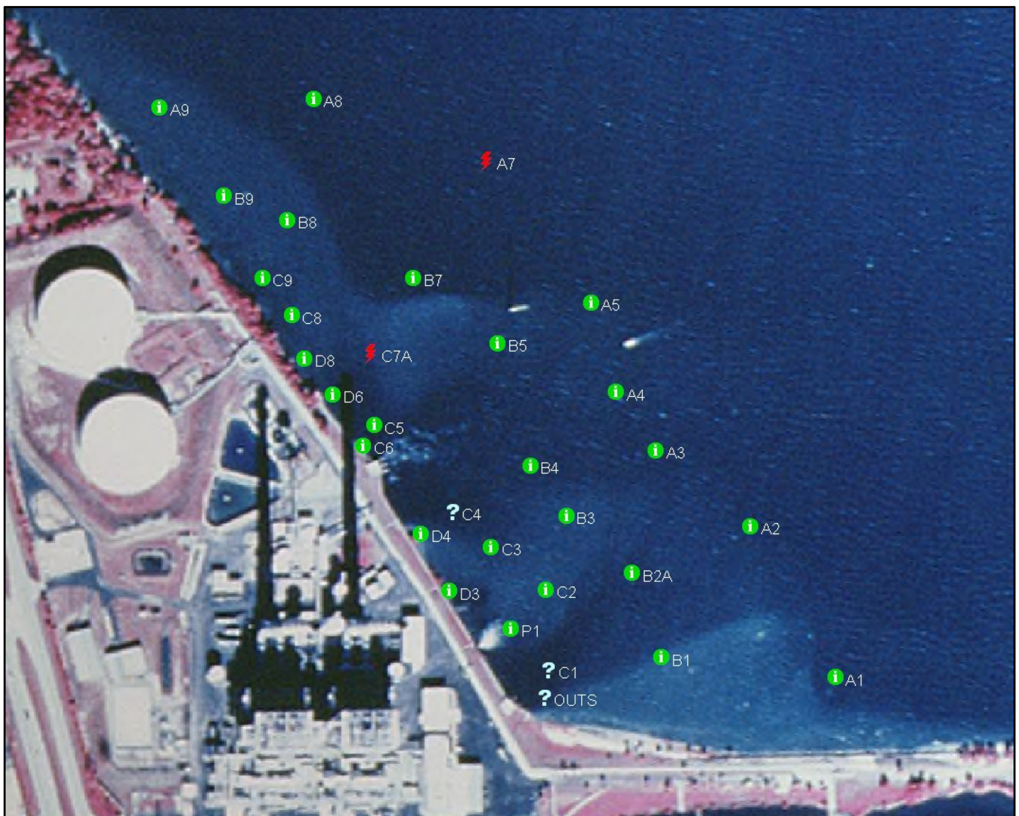

Figure 2-1 **Data Logger deployment Locations in the waters offshore of the Cape Canaveral power station.**

The data loggers were retrieved after five days using the GPS coordinates that were taken at deployment. Of the thirty-one data loggers deployed at the Cape Canaveral site, three were not found (blue question marks in Figure 2-1.) and two failed due to mechanical and human error (red lightning bolts).

Figure 2-2 **Data Logger deployment Locations in the waters offshore of the Reliant power station.**

Similar to the Canaveral study, the thermistors deployment at the Reliant station also suffered some loss of temperature gages and equipment failures. In Figure 2-2, showing the temperature gage deployment at Reliant, missing gages are indicated by blue question marks and failed equipment is shown as red lightning bolts.

3. TEMPERATURE DATA ANALYSIS

3.1 Cape Canaveral Station Temperature Data

In order to facilitate analysis of the temperature time series data, 7 transects were drawn through the data collection points as shown in Figure 3-1. Three transects were drawn perpendicular to the shore one near each outfall (Transect 2 and 5) and one in-between the two outfalls (Transect 4). Four transects were drawn parallel to the shore; one north of the furthest north outfall (Transect 1), one south of the furthest south outfall (Transect 6) and two in the middle one close to shore (Transect 3) and one offshore (Transect 4). Transects 3 and 1 were also joined to analyze the temperature along the entire length of the shoreline (see dotted line).

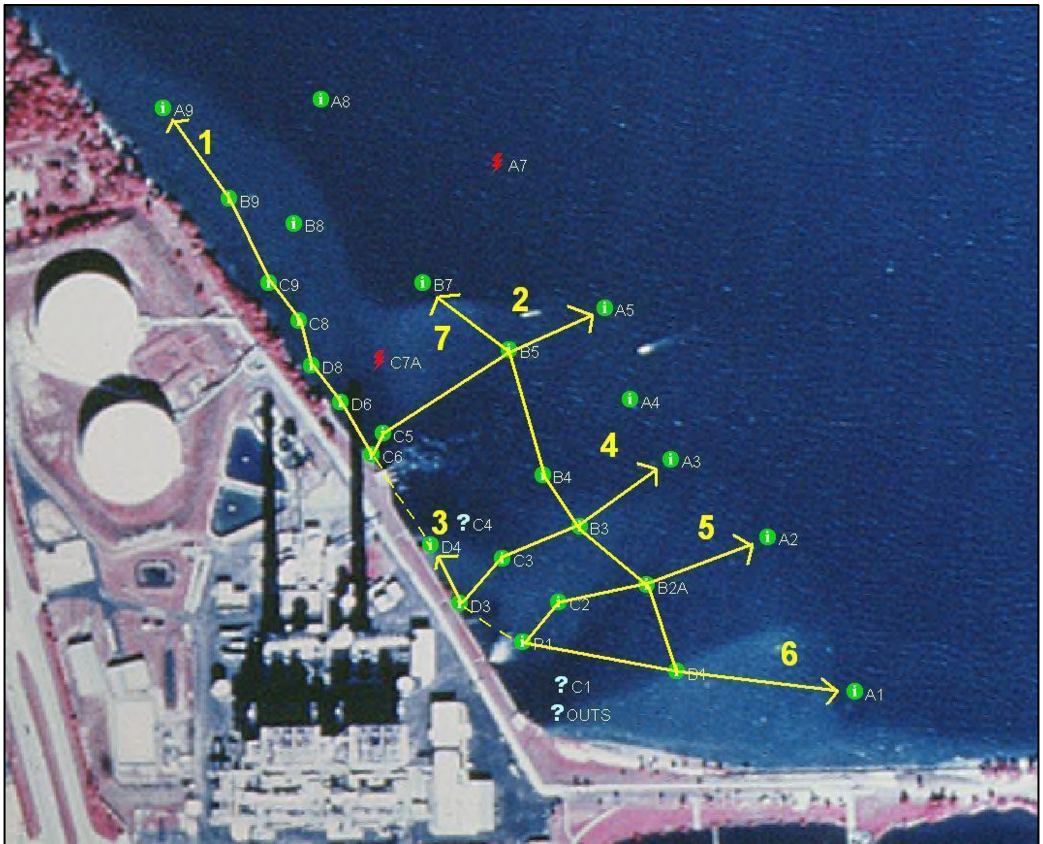

Figure 3-1 **Data Logger Transects at Canaveral Station for Time Series Plots**

Temperature time series plots were created for Transects 1 through 6, (Figures 3-2 through 3-6). For the plots, the time history of each of the thermistors along the individual transect was overlain to indicate how the temperature varied in both space and in time. The x-axis represents the date and time of each measurement and the y-axis shows the water temperature in degrees C.

Referring to Figure 3-2 for Transect 1, the most apparent variation of the temperatures is diurnal heating and cooling, peaking between about 5:00pm and 6:00pm each day. There is some variation between the stations but it is small in relation to the diurnal swing. The thermistors along Transect 1 are all close to shore and the region of the outfalls. It is unclear at this point what contribution in the diurnal signal is attributable to atmospheric (solar and air temperature) heating and cooling how much to the thermal effluent variation during the course of a day. In that some of the stations farther from the shore do not show the magnitude of the diurnal pattern that the closer stations present is an indication that the signal is a feature of the thermal effluent.

A similar pattern is seen for two of the thermistors along Transect 2 (Figure 3-3), but the third (A5, the station that lies farthest offshore) shows a considerably smaller signal on the last two days. This is an indication that the thermal effluent is exerting a more consistent and greater influence on the stations closer to the outfall, as would be expected. Transects 4, 5 and 6 show a pattern similar to that seen in Transect 2, with the temperature signal significantly decreasing as the distance from the outfall increases as can be seen in Figures 3-4, 3-5 and 3-6, respectively.

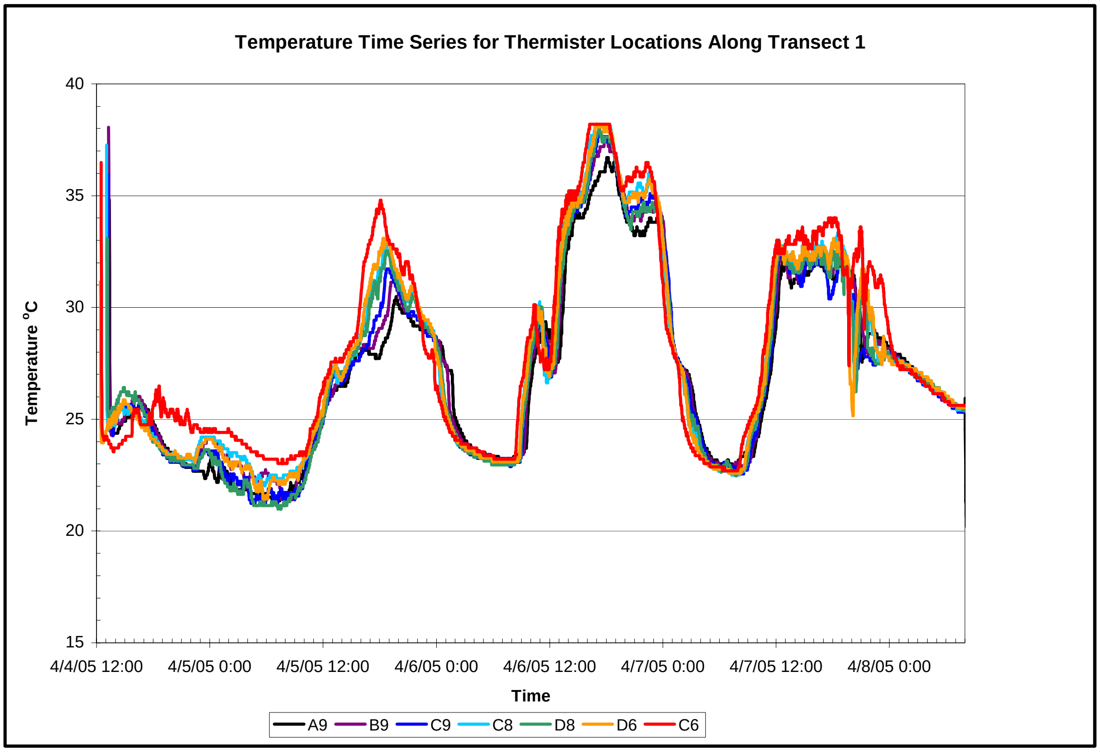

Figure 3-2 **Temperature Time Series for Thermistor Locations along Transect 1**

Thermistors closer to the shore, in the region of the outfalls also show an apparent topping out of the temperature measurement. This is seen in each of the figures on 4/6/05 as the flat top to the temperature time series (Figure 3-4). The thermistors apparently did not record temperatures over 38°C during that period.

A temperature versus distance along shore (measured from the breakwater) comparison was plotted for Transect 1 combined with 3 (Figure 3-7) and 7 (Figure 3-8) to further analyze the heating patterns. Various times on the graph are represented by different colored lines. Figure 3-7 shows the temperature variation along Transects 1&3 on 4/5/05. There is a clear indication that as the temperature rises in the area of the thermal effluents, a distinct thermal gradient develops resulting from cooler temperatures at the farther north areas, outside of the direct effluent impacted area.

A little farther offshore at Transect 7, shown in Figure 3-8, the lines have a small signal variation between the two outfall locations around 175m from the breakwater (data logger location B3) however for the most part the lines remain fairly flat with no large peaks. There is a slight temperature decrease at the northern end of the transect (350m) at the warmest time (18:00) potentially indicating the edge of the initial mixing zone for the effluents.

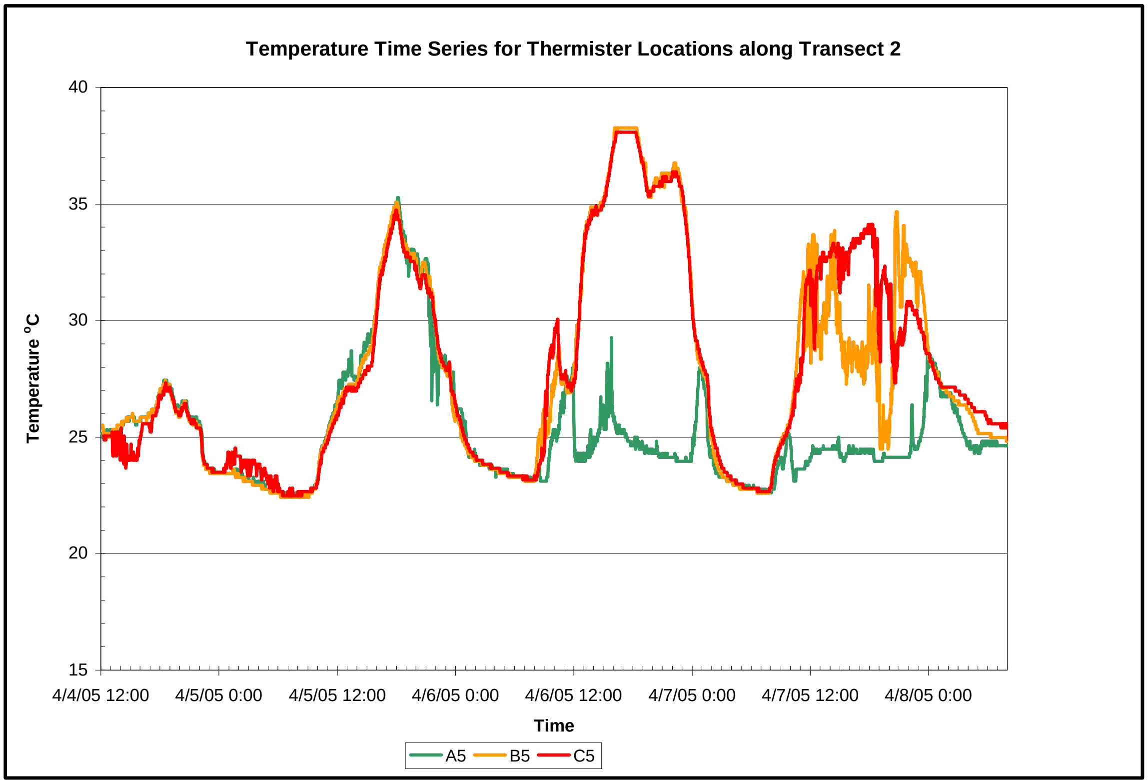

Figure 3-3 Temperature Time Series for Thermistor Locations along Transect 2

In addition to the temperature time series and line plots, a series of temperature contours on the map have been developed. These plots show the temperature at all of the stations simultaneously for a single time. The contours were prepared by laying a fine mesh over the study area and distance weighting the thermistor station temperatures onto the mesh to create a continuous temperature field. Figure 3-9 shows an example color coded temperature contour field on the map, for 4/5/05 at 16:00.

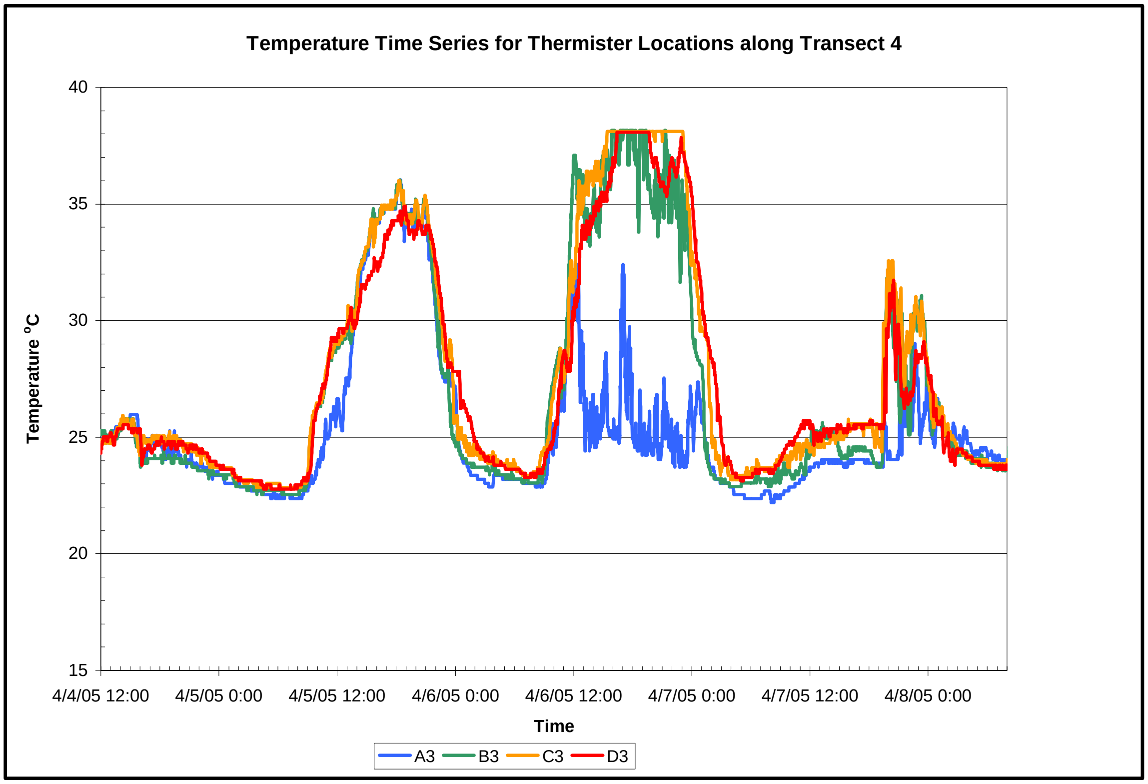

Figure 3-4 **Temperature Time Series for Thermistor Locations along Transect 4**

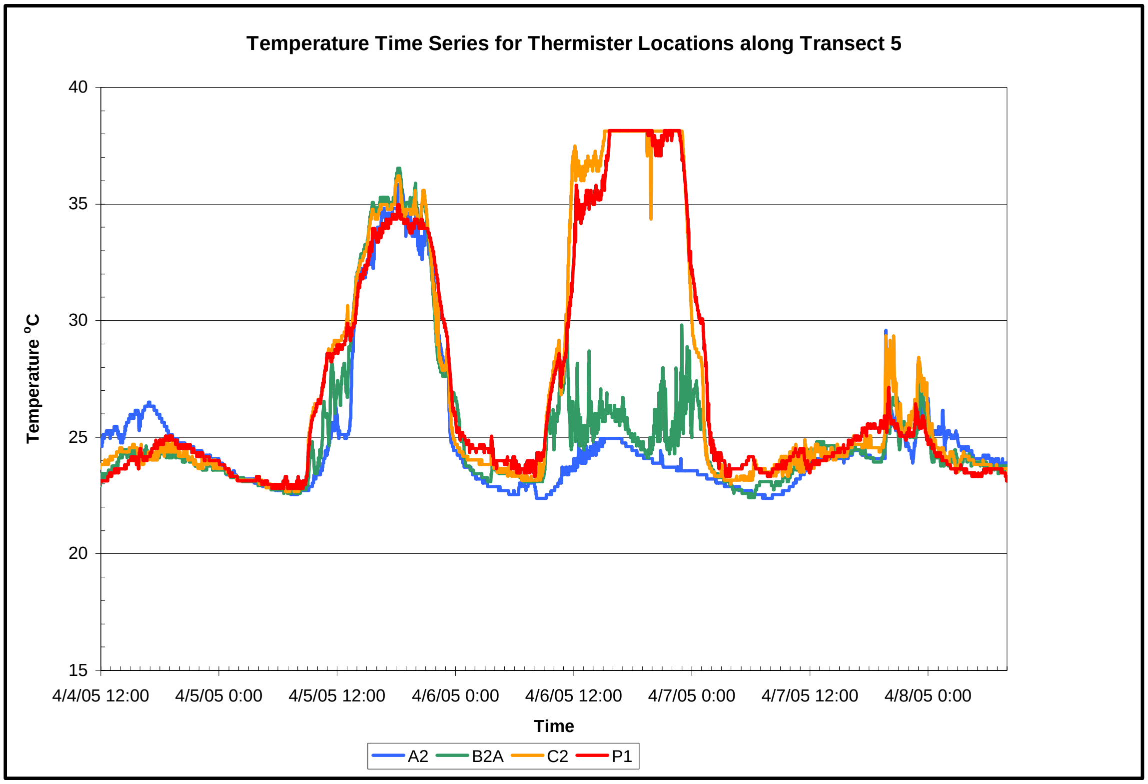

Figure 3-5 **Temperature Time Series for Thermistor Locations along Transect 5**

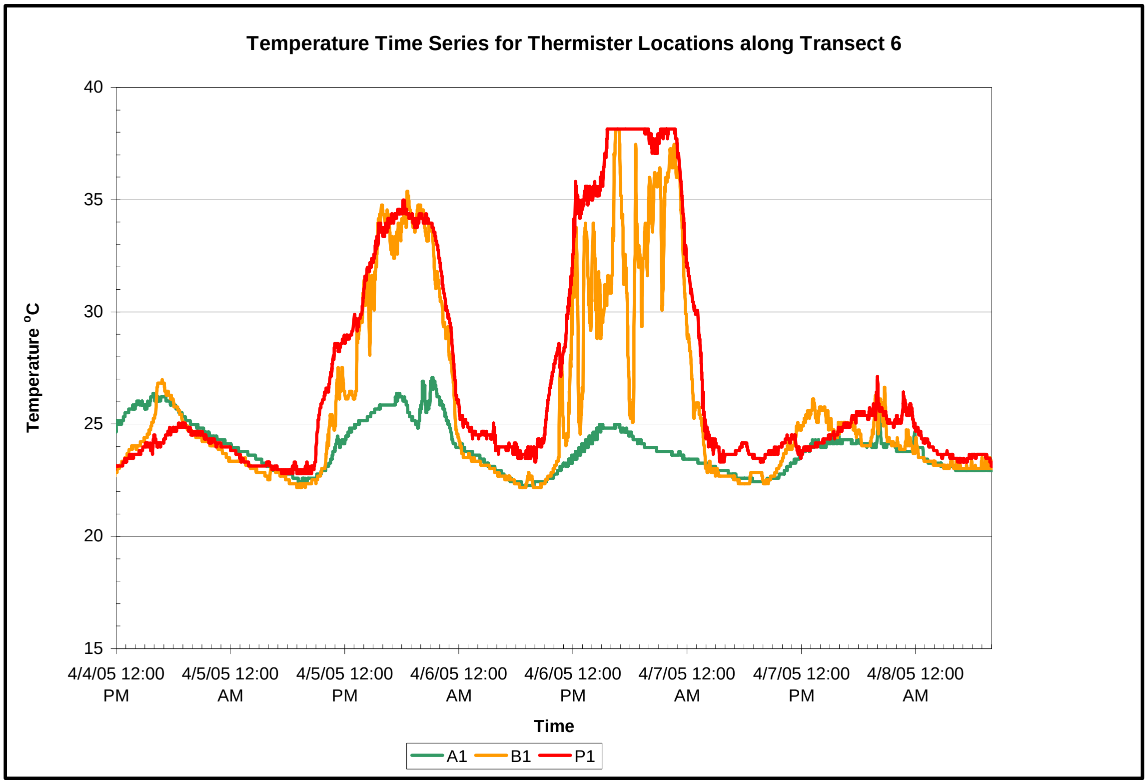

Figure 3-6 **Temperature Time Series for Thermistor Locations along Transect 6**

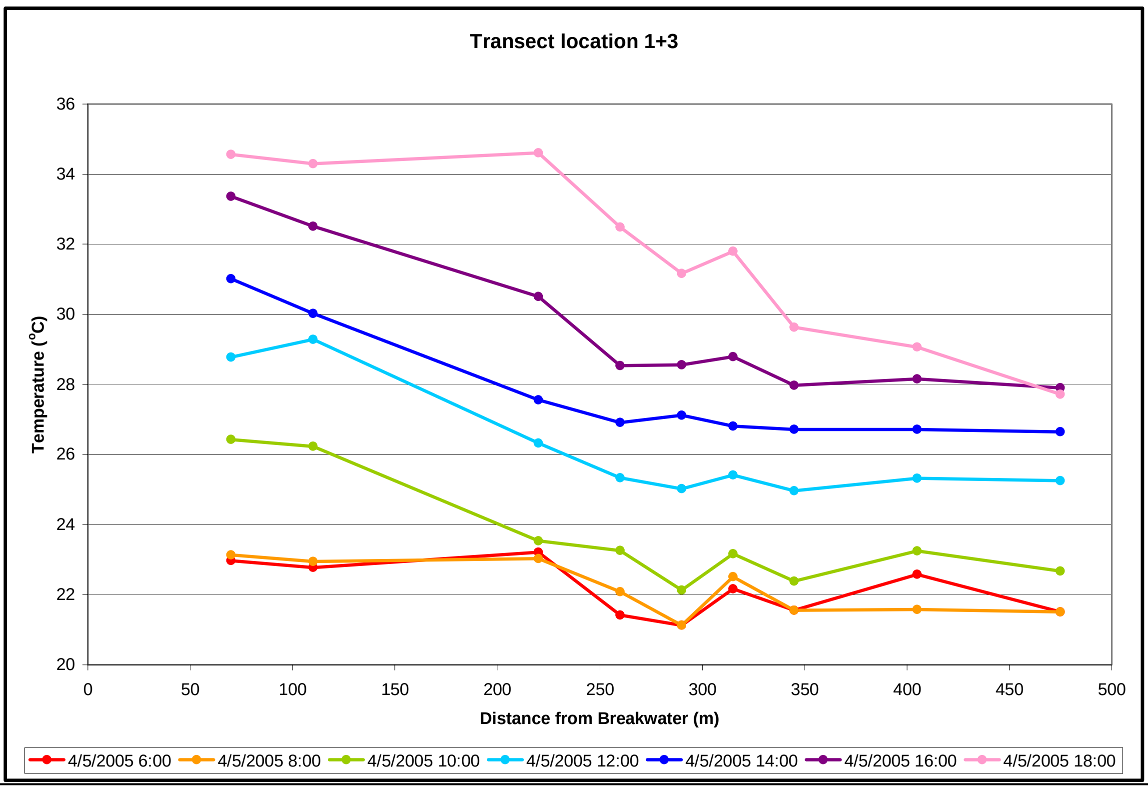

Figure 3-7 **Temperature vs. Distance from Breakwater Comparison for Thermistor Locations along Transect 1+3**

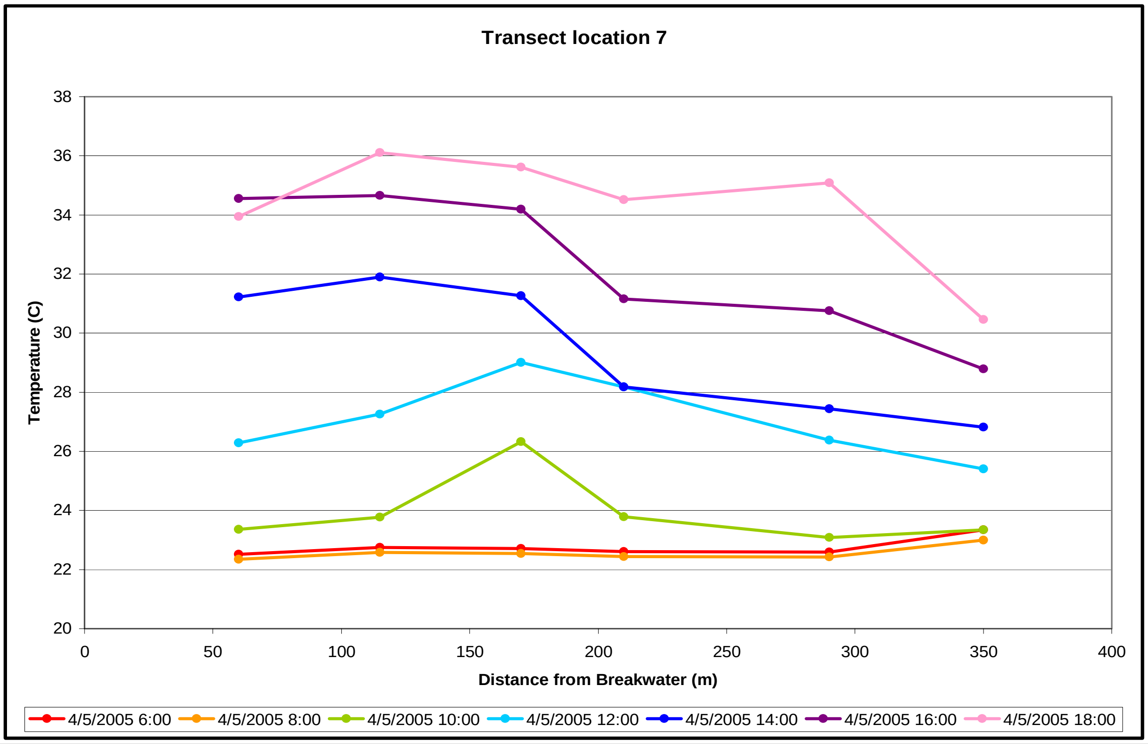

Figure 3-8 **Temperature vs. Distance from Breakwater Comparison for Thermistor Locations along Transect 7**

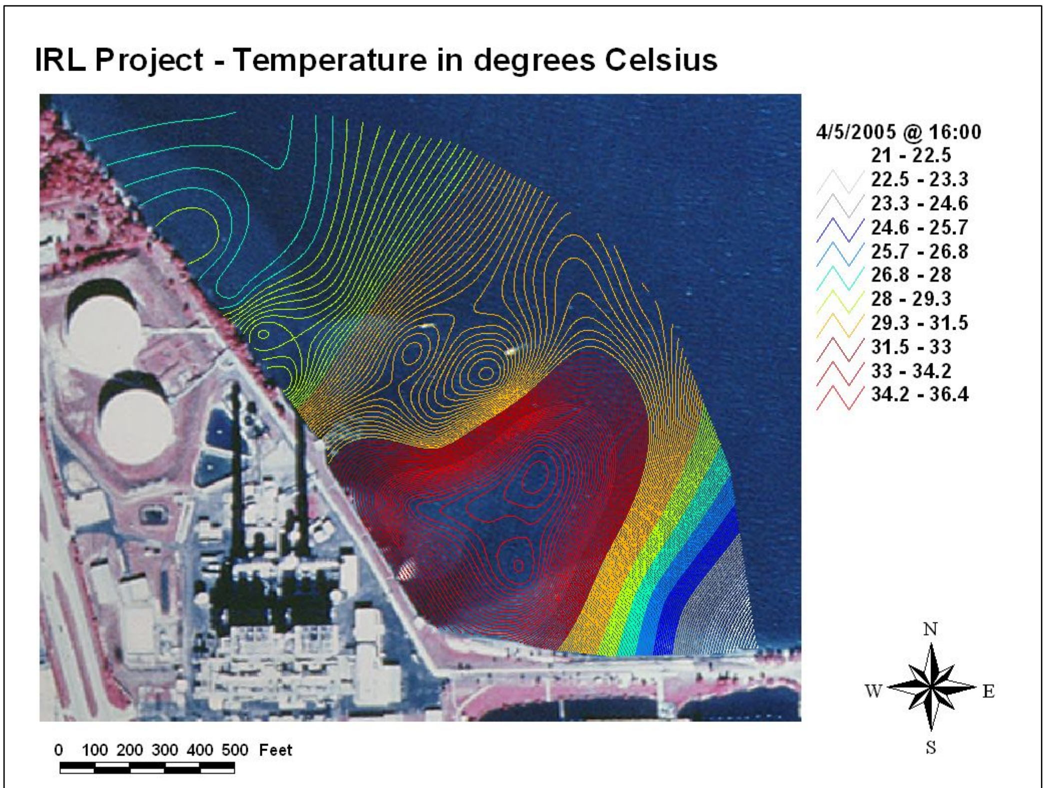

Figure 3-9 **Example color coded temperature contours for 4/5/2005 at 16:00**

3.2 Reliant Station Temperature Data

As with the Cape Canaveral station described in the previous section, to facilitate analysis of the temperature time series data, a series of transects were drawn through the data collection points, as shown in Figures 3-10a and b. Three transects were drawn parallel to the shore; just offshore of the outfall (Transect 1), and progressing further offshore (Transects 2 and 3). Three transects were also drawn perpendicular to the shore; Transect 4 just north of the outfall canal, Transect 5 just south of the outfall and transect 6 half way between outfall and the north jetty of the intake canal (Figure 3-10b).

Figure 3-10a Data Logger Transects at Reliant Station for Time Series Plots

Figures 3-11 through 3-16 show temperature time series plots for each of the thermistor at the Reliant plant. Referring to Figure 3-11, a similar diurnal temperature signal can be seen in each of the thermistor data sets as was seen in the Cape Canaveral data. The comparison of the temperature in the region just offshore of the outfall canal, with the reference station (labeled Control 4) on the south side of the intake jetties (Figure 3-16) indicates that a significant, but not all of the observed diurnal signal is associated with the thermal effluent. The reference signal is significantly flatter than data in the region of the effluent plume. Figure 3-17 shows an example color coded temperature contour field on the map, for 5/31/05 at 20:00.

The diurnal swing in the area around the Reliant outfall is considerably smaller than at Canaveral as can be seen in the figures. The excess temperatures can be determined by inspection of Figure 3-16. The magnitude of the near field temperature increase above the control temperatures to the south of the intake jetties is also considerably smaller at Reliant than at the Cape Canaveral facility, remaining below 5^{o}C while the Canaveral excess temperatures often exceed 10^{o}C for the time period of the field program.

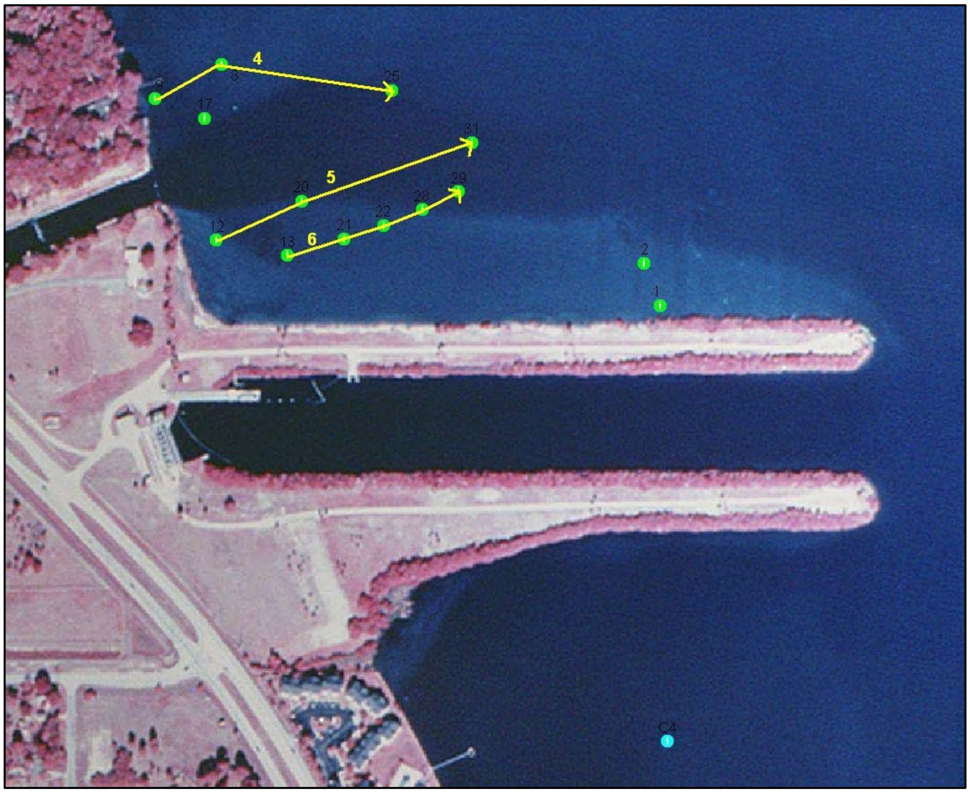

Figure 3-10b Data Logger Transects at Reliant Station for Time Series Plots

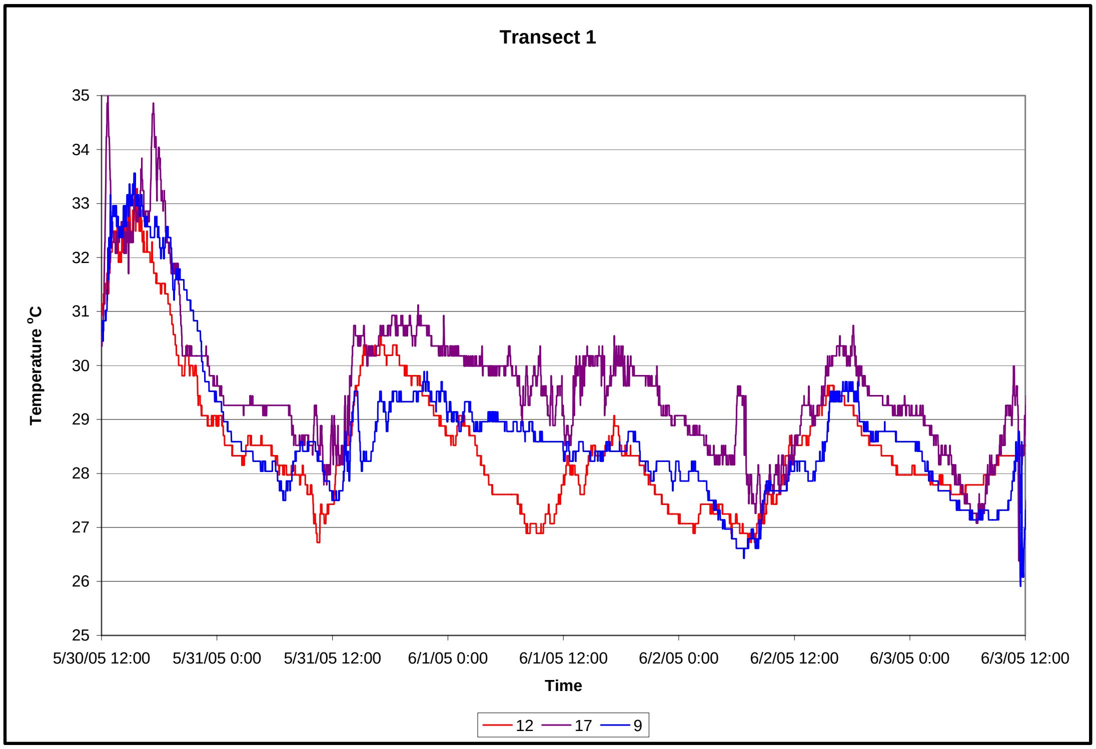

Figure 3-11 Temperature Time Series for Thermistor Locations along Transect 1

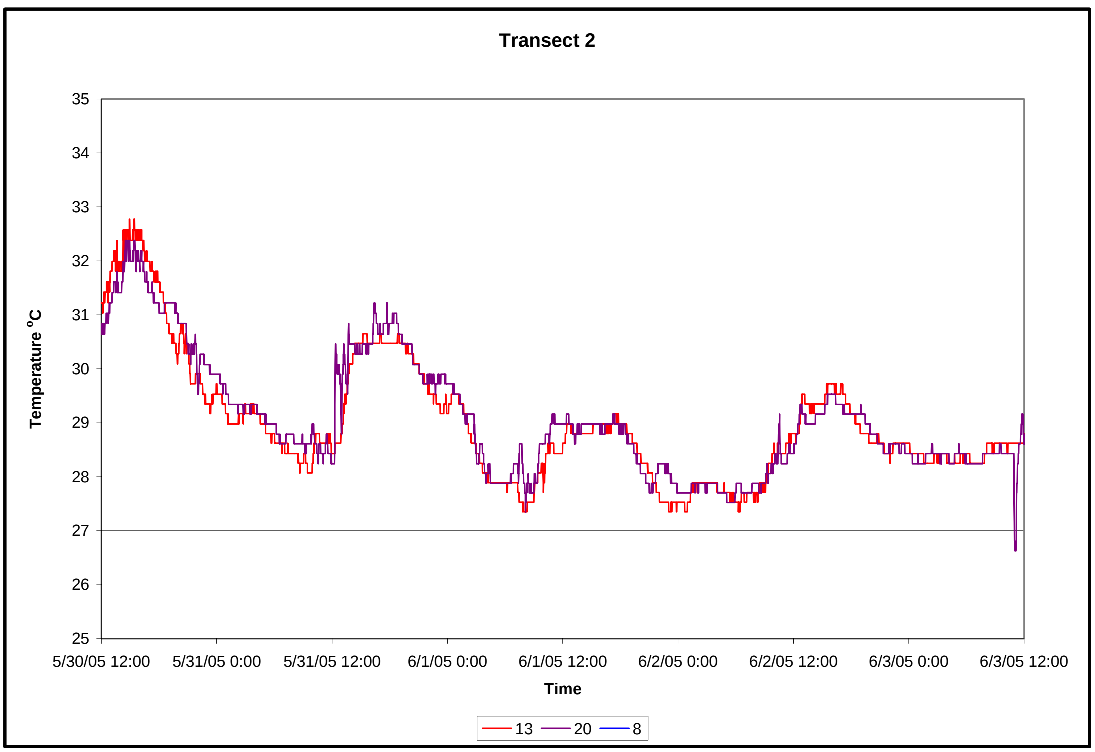

Figure 3-12 Temperature Time Series for Thermistor Locations along Transect 2

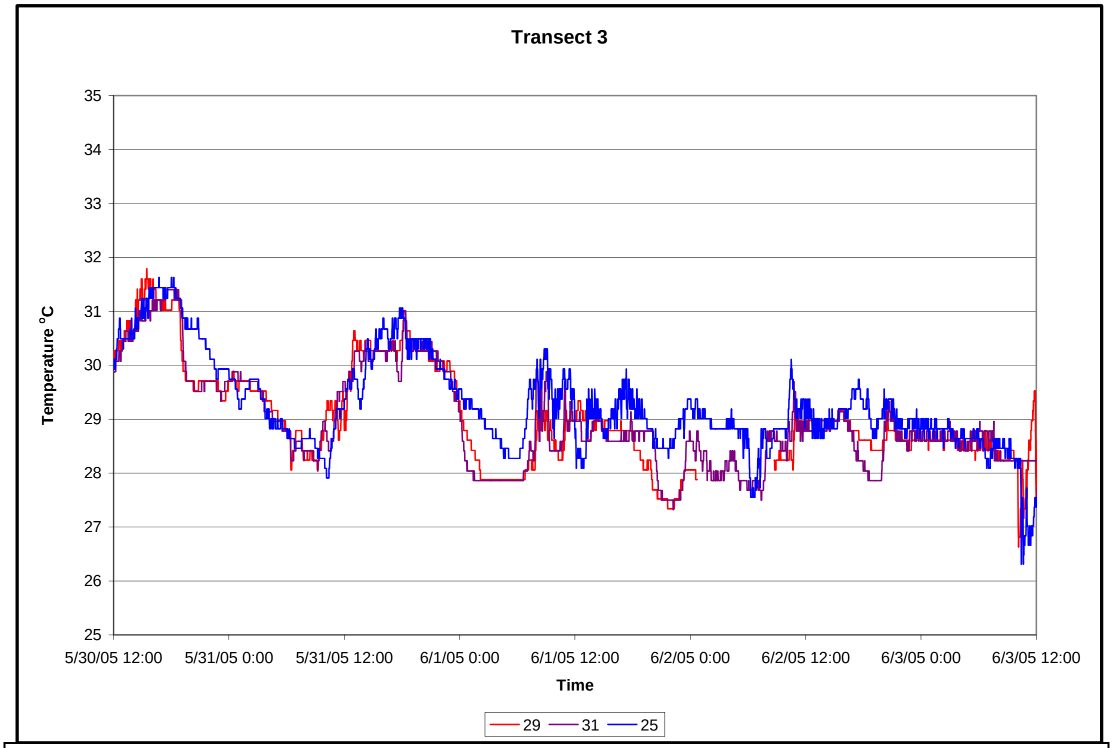

Figure 3-13 **Temperature Time Series for Thermistor Locations along Transect 3**

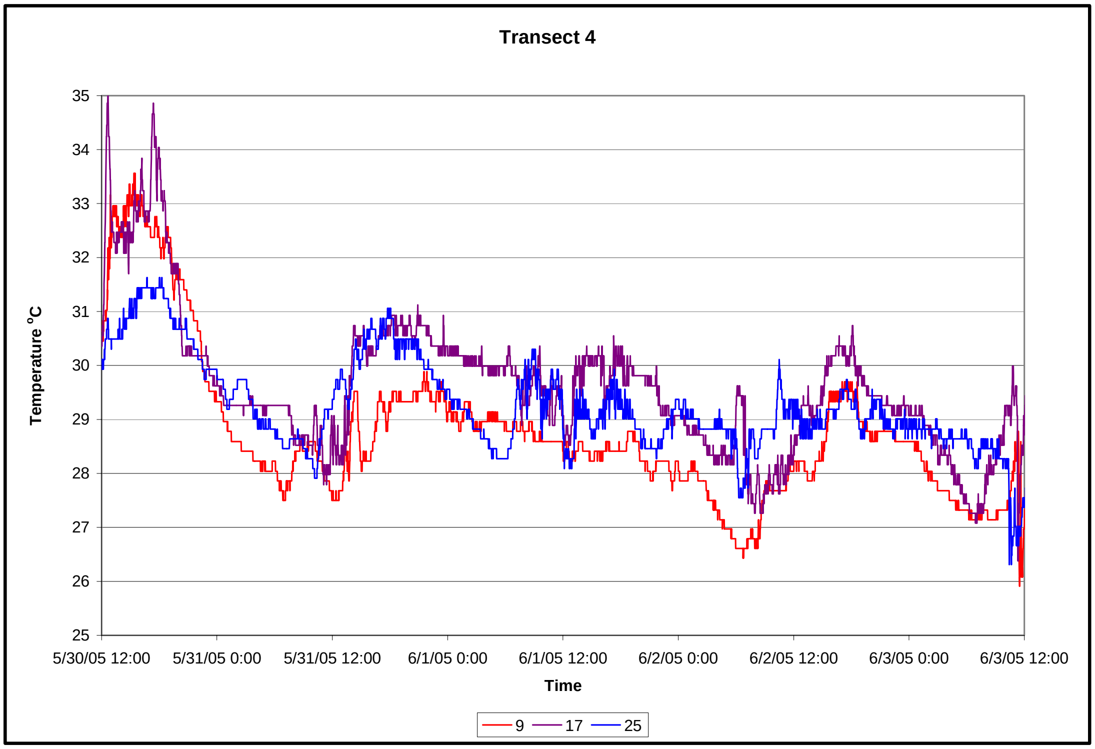

Figure 3-14 **Temperature Time Series for Thermistor Locations along Transect 4**

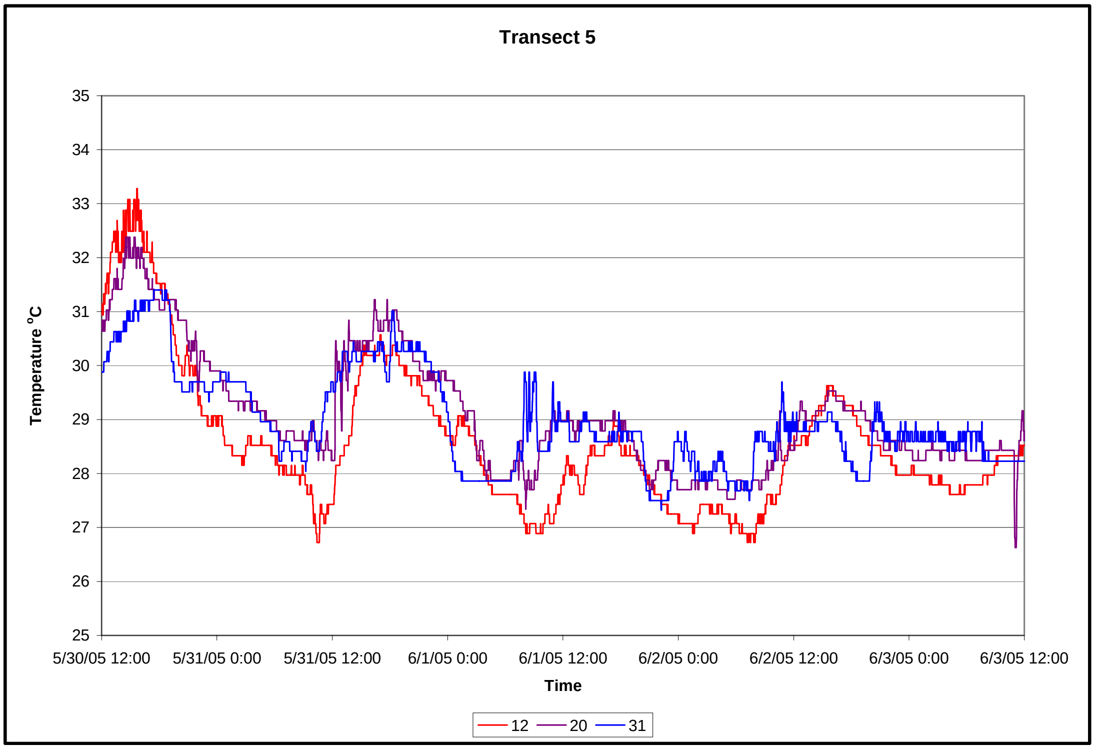

Figure 3-15 Temperature Time Series for Thermistor Locations along Transect 5

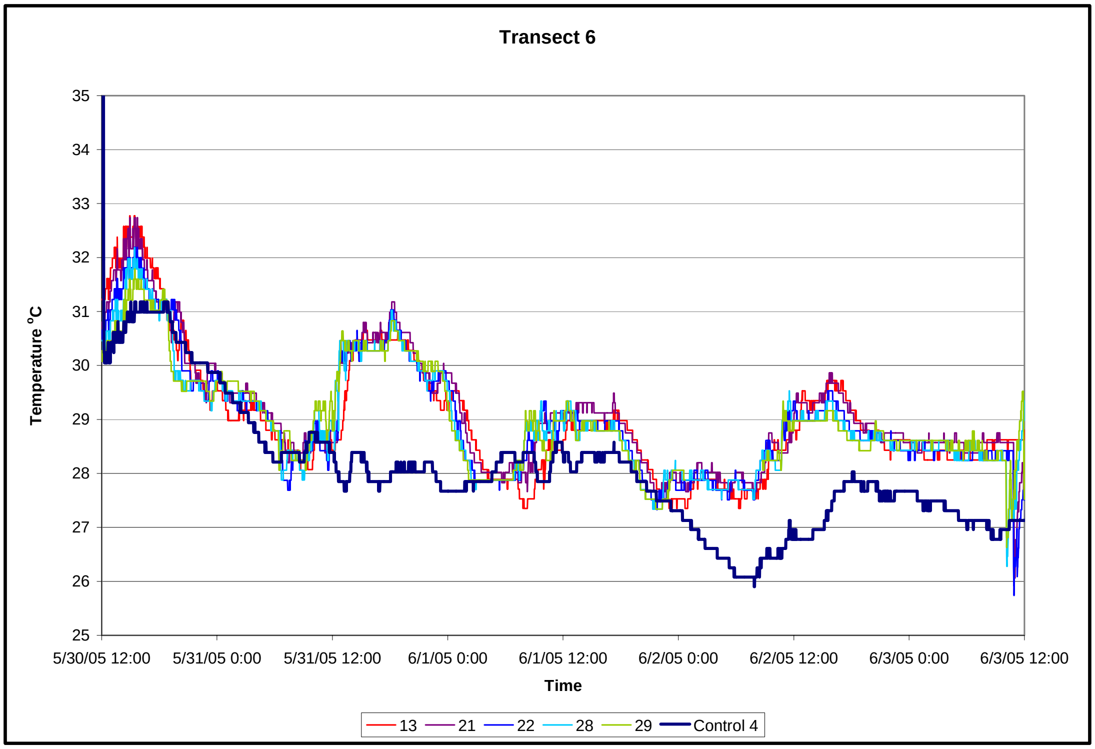

Figure 3-16 Temperature Time Series for Thermistor Locations along Transect 6

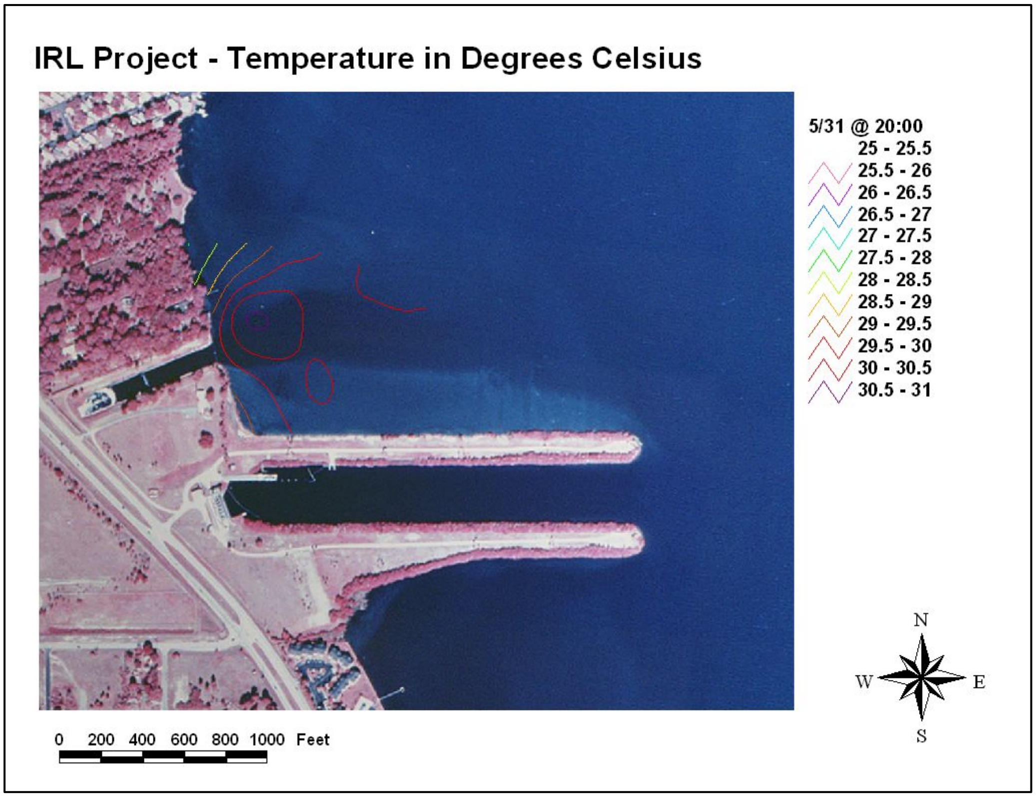

Figure 3-17 Example color coded temperature contours for 5/31/2005 at 20:00

4. MODEL/OBSERVATIONS TEMPERATURE COMPARISON

In order to evaluate the models ability to simulate the near field mixing at the discharges of the two power plants, the near field temperature characteristics were compared to model simulations of temperature. To evaluate the model's predictive capability in terms of potential changes in water temperature as a result of changes in the thermal effluent the model should first be capable of predicting the influence of the thermal effluent on the Indian River Lagoon under present conditions. The thermistor data described in the previous sections was used to make a comparison of model predictions in the region of the outfalls with the in-situ temperature observations under similar conditions.

The temperature comparison focused on the data set taken in the receiving waters at the Reliant power facility. The thermistor field program was implemented between 5/30/05 and 6/03/05. Unfortunately the present conditions model scenarios were only run for a time span between 1/1/97 and 1/1/01, so a direct hindcast of conditions was not possible. As an alternative, the operating conditions at the Reliant facility during the field program were analyzed and daily average values were determined for the plant volume flow, delta temperature (intake – outfall) as well as the environmental conditions (air temperature). This essentially defined the temperature forcing on the system.

Table 1 Mean conditions at Reliant during the thermistor field program.

Reliant								
Date	Volume Flow (MGD)	Volume Flow (m3/s)	Avg. Plant dTemp (F)	Avg. Plant dTemp (C)	Heat Load (MW)	Avg Discharge Temp (F)	Avg Discharge Temp (C)	Mean Air Temp (F)
5/30/05	316.8	13.88	2.7	1.5	89	85.9	29.9	81
5/31/05	319.4	13.99	4.0	2.2	131	85.8	29.9	76
6/1/05	322.0	14.11	6.4	3.5	211	85.1	29.5	72
6/2/05	324.6	14.22	7.1	4.0	238	84.2	29.0	74
6/3/05	327.2	14.33	6.9	3.8	231	83.5	28.6	76

To evaluate the receiving water temperature impacts, an excess temperature was calculated from the difference between a thermistor time series at the outfall and the control thermistor farther to the south (see Figure 2-2). Daily average values of the excess temperature were then calculated from the difference time series.

In order to make a useful comparison, similar conditions needed to be determined for the time period over which the model simulations were run. The four year time series of thermal load, (delta temperature and flow) and air temperature were analyzed and specific dates matching the field program conditions were logged. In-situ water temperatures at cells corresponding to the thermistor data logger locations were extracted for the logged dates, daily averaged and base line statistics were developed.

The comparison between the model predictions and the observations for the present conditions at Reliant are shown in Figure 4-1. The markers show the minimum, mean and maximum, daily average excess temperatures on each day of the field program, for the model predictions (asterisks) and the range of the observations (diamonds).

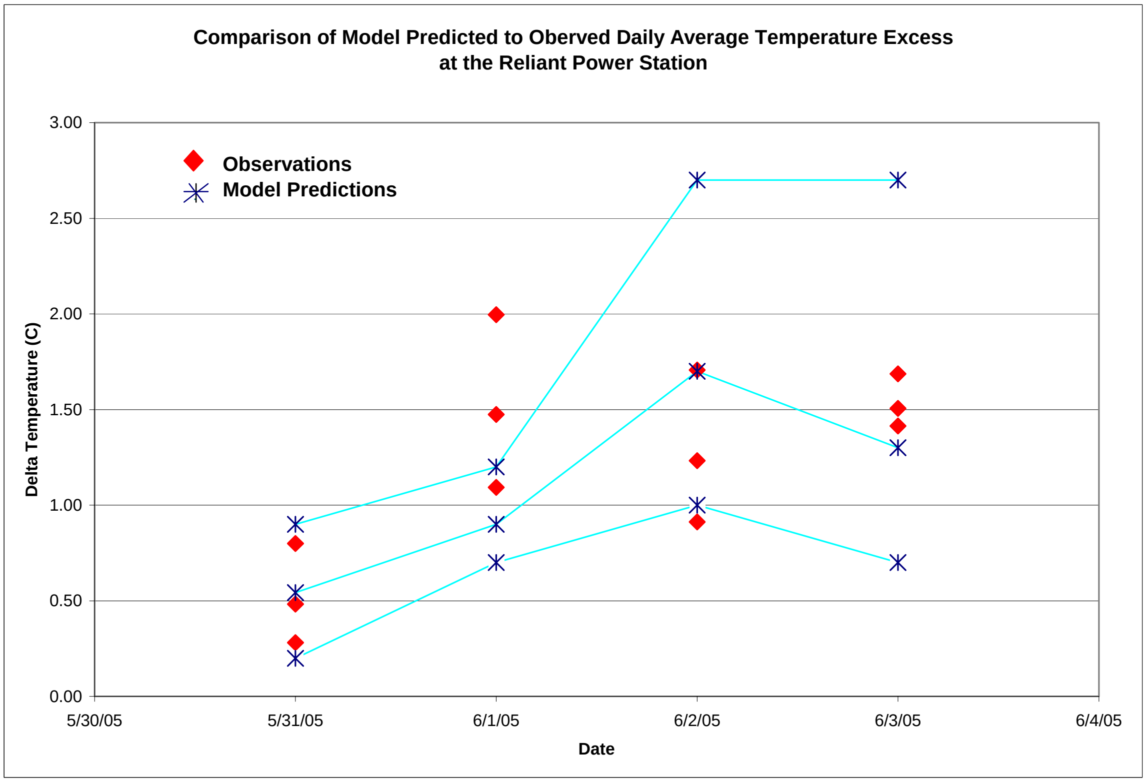

Figure 4-1	**Comparison of model predictions and observations for the daily average excess temperature at the Reliant Power Station**

While the comparisons do not show exact agreement the results clearly indicate that the model predictions vary over the same range as the observed and are in the correct order of magnitude. Recalling the time series data plotted in the figures in the previous sections, the excess temperature in the near field region is on the order of 0-3^{o}C at Reliant (see Figure 3-16) while excess temperatures in the region around the Cape Canaveral plant often exceed 10 ^{o}C considerably (as can be determined by inspection of Figure 3-6). The effluent from the two power stations is, on average quite similar. During the field program however, the output from the Reliant facility was considerably smaller, which was reflected both in the data and in the model predictions.

There are enough uncertainties in the two data sets to understand that a difference might exist. For example, although the daily average air temperature is the same for each data set for the specific day, the variability within that day and the temperature on the preceding day are quite possibly different. Taking all that into account the model predictions in the near field region of the power stations appear to be an adequate representation of the present conditions in the Lagoon.

Appendix L

Temperature Simulation Addition to CH3D

Surface Heat Flux and Temperature Model for CH3D

Temperature (energy content) in estuaries, lakes, coastal and oceanic water bodies is primarily governed by heat exchanges at the water surface. The net heat exchange at the water surface includes solar radiation, back radiation from the water surface, atmospheric radiation, evaporation (heat loss), and conduction (sensible heat) as expressed in the following (Martin & McCutcheon, 1998):

$$H_n = H_{sw} + H_h - H_b - H_l - H_s$$

where H_{sw} is the short-wave radiation absorbed, H_h is the long-wave back radiation from atmosphere, H_b the back radiation from the water surface, H_l is the heat loss due to evaporation and H_s is the convective (sensible) heat transfer.

Short wave radiation can be measured directly, using relatively inexpensive radiometers. On the Florida east coast, such measurements are available in Daytona Beach and Cocoa Beach. The measurements are performed by Cooperative Network for Renewable Resource Measurements (CONFRRM), (http://rredc.nrel.gov/solar/new_data/confrrm/) which is a cooperative effort between National Renewable Energy Laboratory (NREL) and other agencies to conduct long-term solar radiation and wind measurements at selected locations in the United States. In places where such measurements are not available, short-wave radiation can be estimated from the radiation striking the earth's atmosphere and the atmospheric conditions that affect its reflection and absorption. For details, see Martin & McCutcheon (1998).

The long-wave radiations consist of two parts, one is the back radiation from the water surface, which is a loss of heat for the water body; the other part is the back radiation from the atmosphere, which often is the greatest source of heat at the water surface on cloudy days. This second part of long-wave radiation is due to the fact that part of the short-wave solar radiation is absorbed by the clouds and atmosphere, in turn, the heat is reflected at longer wave lengths. The amount of long-wave radiation is generally described assuming the back radiation is black-body radiation using the Stefan-Boltzmann law. The back radiation from water surface can be estimated from:

$$H_b = e_w s\,(T_s + 273.16)^4$$

where T_s is the surface water temperature (C) , σ is the Stefan-Boltzmann constant and has a value of 5.67x10 –8 $Wm^{-2}\ K^{-4}$ and ε is the emissivity and is approximately 0.97. Atmospheric radiation is computed similarly to the back radiation from the water surface, using the Stefan-Boltzmann law modified for the emissivity of the air:

$$H_h = e_a s\,(T_a + 273.16)^4$$

where, T_a is the air temperature (C), ε_a is the emissivity of air, which depends on a number of factors, such as cloud height and vapor pressure. One of the commonly used expressions for ε_a was proposed by Swinbank (1963) and modified by Wunderlich (1968):

$$e_a = a_0(1+0.17C_l)(T_a+273.16)^2$$

where α_0 is a constant with a value of 0.937x10^{-5}, C_l is the fraction of the sky covered by clouds, and T_a is the air temperature measured at 2 m above the water surface. The net long-wave back radiation is the incoming radiation minus the amount reflected. The reflectance at the water surface is generally assumed to be 3% (Wunderlich, 1972). Therefore the resulting net long-wave radiation is:

$$H_h = s\,(0.97)a_0(1+0.17C_l)(T_a+273.16)^6$$

Heat loss due to evaporation is dependent on the difference between the vapor pressures of the water and the air and is also dependent on the wind speed. This can be written as (Thomann and Muller, 1987; Edinger et al. 1974):

$$H_L = (19.+0.95U_w{}^2)(e_a - e_w)$$

where U_w is the wind speed 10 m above water surface, e_a and e_w are the vapor pressures at air temperature and water surface temperature respectively. Similarly, the rate of convection heat transfer between the water surface and the air depends on the temperature difference between the two and also depends on the wind speed (Thomann and Muller, 1987; Edinger et al. 1974):

$$H_L = C_B(19.+0.95U_w{}^2)(T_a - T_s)$$

where C_B is the Bowen coefficient (0.47 $^oC^{-1}$)

The temperature model is a statement of conservation of heat energy and can be written in the horizontally non-orthogonal curvilinear and vertically sigma coordinate as:

$$\frac{\partial(HT)}{\partial t} + \frac{1}{A}[\frac{\partial(AHuT)}{\partial x} + \frac{\partial(AHvT)}{\partial h}] + \frac{\partial(wT)}{\partial s} = DIFF + \frac{1}{H}\frac{\partial}{\partial s}(A_v\frac{\partial T}{\partial s}) + \frac{1}{rC_pH}\frac{\partial Q}{\partial s}$$

where H is the total depth, T is water temperature, t is time, A is Jacoby, ξ and η are curvilinear coordinates, σ is the vertical coordinate, u and v are the contravariant velocity components in ξ and η direction respectively, ω is the vertical velocity in σ coordinate, ρ is the water density, C_p is the specific heat of water, and Q is the absorption rate of solar radiation of water and Q can be expressed as:

$$Q = H_{sw}\exp(K_dHs)$$

where K_d is the distinction factor. And DIFF, the horizontal diffusion term can be written as:

$$DIFF = \frac{1}{A}\{\frac{\partial}{\partial x}[A_HA(g^{11}H\frac{\partial T}{\partial x} + g^{12}H\frac{\partial T}{\partial h})] + \frac{\partial}{\partial h}[A_HA(g^{12}H\frac{\partial T}{\partial x} + g^{22}H\frac{\partial T}{\partial h})]\}$$

where g^{ij} is the product of the contrvariant base vectors.

The surface boundary condition for the above equation is:

$$\frac{1}{H}A_v\frac{\partial T}{\partial s} = \frac{1}{rC_p}(H_h - H_b + H_L + H_s)$$

At bottom, the vertical temperature gradient is assumed zero. For the open boundary conditions, observed temperature values are specified at the river and ocean boundaries.

The model was coded in Fortran. The solution algorithm for the advection-diffusion equation is the same as for the salinity equation in CH3D. A test run has been performed for the IRLPLR model with the added temperature component. The model was run starting from August 5, 1997 to December 31, 1999. Figure 1 shows the model results very well compared with observations at Titusville Brew Causeway and Merritt Island West.

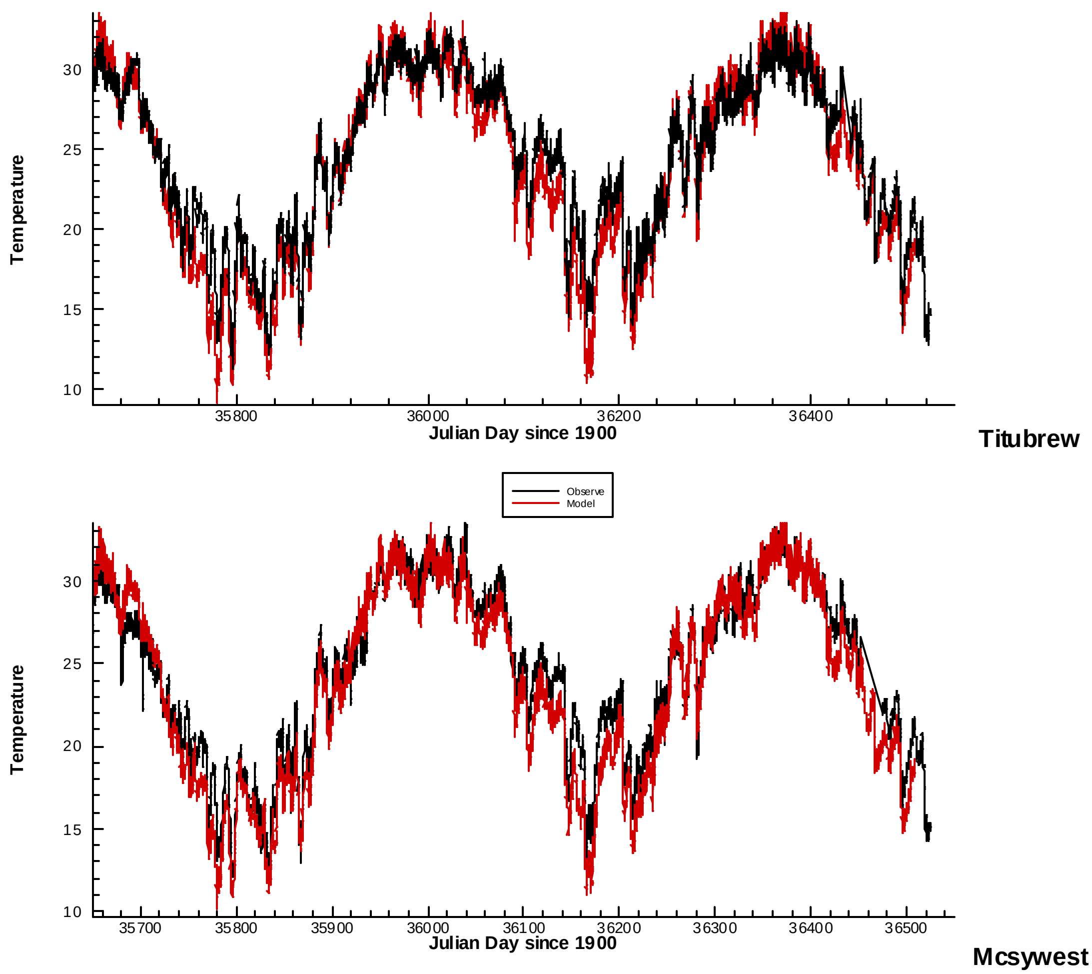

Figure 1. Modeled temperatures (red) compared with observations (black) at Titusville Brew Causeway and Merritt Island West from August 1997 to December, 1999.

Another test was run for cold water intrusion to a spring. The case is similar to Blue Spring in Volusia County situated on the side of St. John's River (Sucsy et. al., 1998). In this test case, the spring water has a discharge of 3.6 m3/s with a constant temperature of 23 ^{o}C. The river temperature is assumed to be 10 ^{o}C and the river stage at 1. m above NGVD 29. Depths (NGVD 29) for the spring range from .5 m at the head to approximately 2.5 m at the mouth. The length of the spring is approximately 600 m.

There are 20 cells (grid size approximately 30 m) along the spring and three grid cells (grid size approximately 20 m) across the spring and eight vertical layers. Upstream of the river, a constant stage of 1.0 m was specified. At downstream of the river, a discharge of approximately 6000 cfs was specified. The model was run for approximately 6 hours to reach steady state. Figures 2 and 3 show the temperature at the surface and the bottom layer respectively. Figure 4 shows a vertical transect at the centerline of the spring. The intrusion length (from the mouth) in this case is approximately 200 m. These results are qualitatively similar to the EFDC model results (Sucsy et. al., 1998)

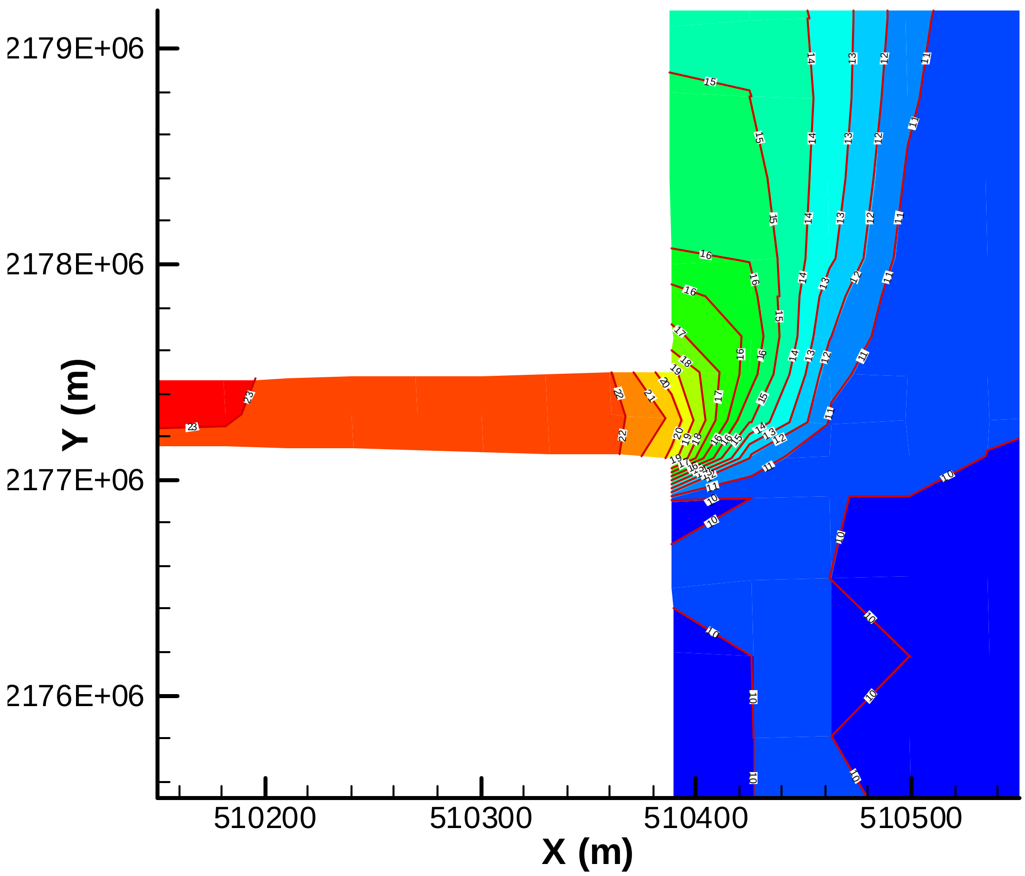

Figure 2. Modeled surface temperature for the cold water intrusion case.

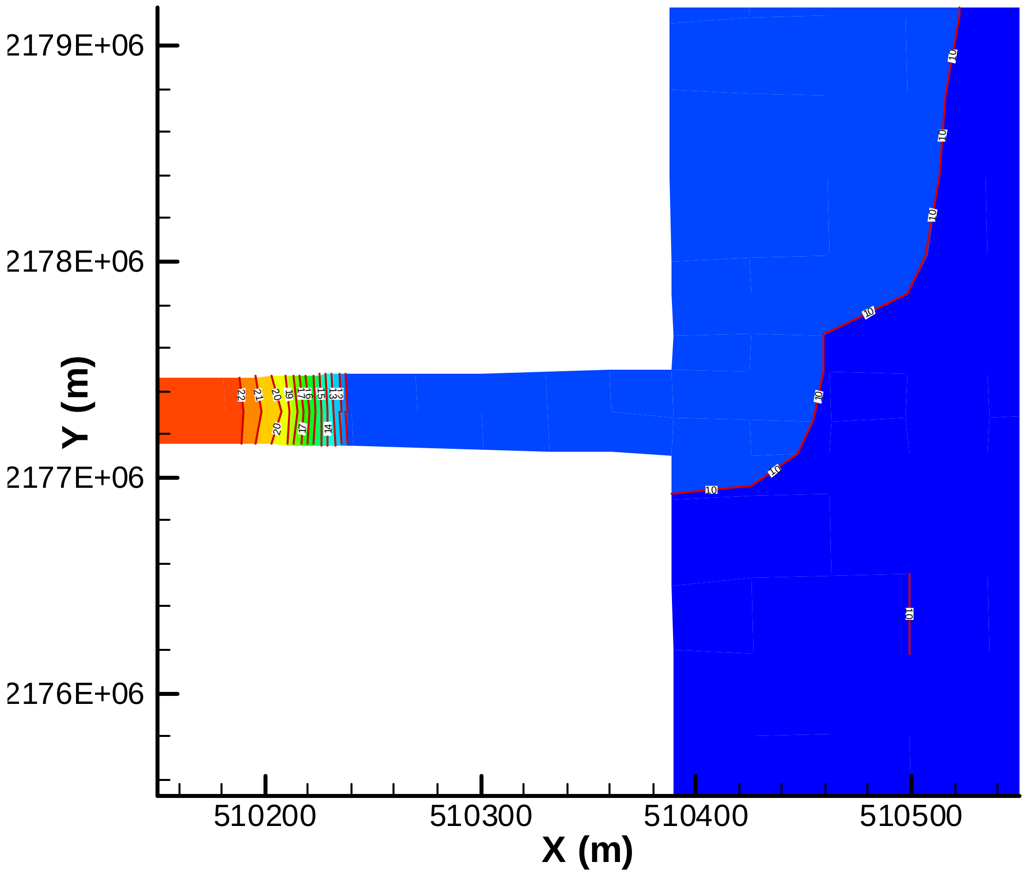

Figure 3. Modeled bottom temperature for the cold water intrusion case.

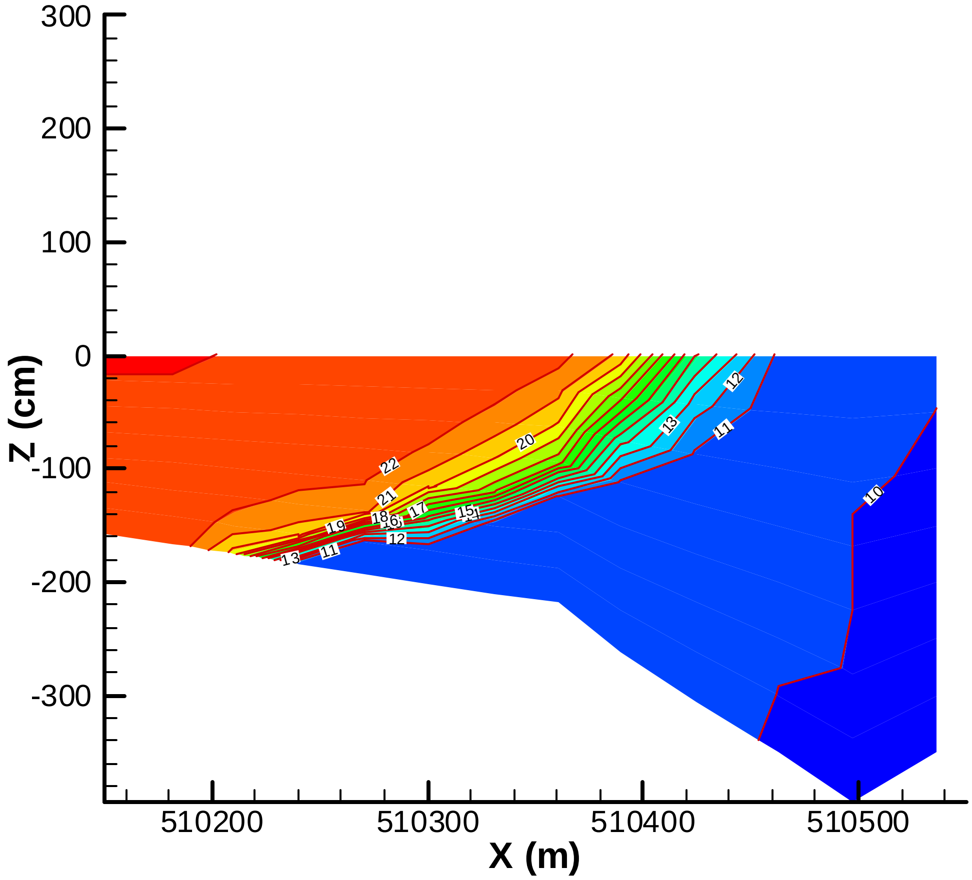

Figure 4. A vertical transect showing modeled temperature at the centerline of the spring.

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Appendix M

Development History of CH3D Model

Indian River Lagoon Salinity Study
Overview and History of CH3D Model

The following provides an overview of the CH3D taken from a description provided at the University of Florida Web site for the model and various USACE sites.

CH3D is a Curvilinear-grid Hydrodynamics 3D model developed originally by Dr. Y. Peter Sheng at the Aeronautical Research Associates of Princeton, Inc. (ARAP, now part of Titan Corporation) during 1983-1986. (Sheng 1986, ARAP Tech Report; Sheng 1987, in "Three-Dimensional Models of Marine and Estuarine Hydrodynamics", Elsevier). After moving to the University of Florida (UF) in 1986, Dr. Sheng applied the CH3D to Chesapeake Bay (e.g., Sheng 1989; Sheng et.al, 1989; and Johnson et al., 1989; all in the Proceedings of the First International Symposium on Estuarine and Coastal Modeling) and James River (Sheng et al., 1989). Since 1989, Dr. Sheng's group (Advanced Coastal Environmental Simulations Lab) at the University of Florida has substantially enhanced the processes, numerical algorithms, and coding of the CH3D model through numerous studies on complex shallow estuaries, including;

- (Indian River Lagoon
- Tampa Bay
- Sarasota Bay
- Roberts Bay
- Florida Bay
- Charlotte Harbor
- West Florida Shelf
- St. Johns River
- Biscayne Bay
- Gulf of Mexico
- Lake Okeechobee
- Lake Apopka

The latest version of CH3D is coded in Fortran 90 and runs on parallel platforms (e.g., SGI3400, SGI300, SGI2000, SUN, Intel-based systems, and Beowulf clusters) with a variety of operating systems (Unix, Linux, and Windows), and is substantially more efficient and robust than the earlier CH3D or other generic versions of CH3D out there. CH3D and CH3D-IMS are updated from time to time when a new process is added or a new algorithm is implemented, following sound software engineering principles.

The CH3D model uses a horizontally boundary-fitted curvilinear grid and a vertically sigma grid, and hence is suitable for application to coastal and nearshore waters with complex shoreline and bathymetry. The non-orthogonal grid enables CH3D to more accurately represent the complex geometry than the orthogonal grid, which is used by most other ocean circulation models. The model contains a robust turbulence closure model (Sheng and Chiu,1986; Sheng and Villaret, 1989, JGR) which enables accurate simulation of stratified flows in estuaries and lakes.

Following its initial development, a version of the CH3D model was used by the USACE for various projects and presently, the USACE version of the model is maintained by the USACE and is housed within its Shoreline Modeling System (SMS). As part of the USACE suite of tools, CH3D has undergone significant peer review and testing. Testing of the model and its algorithms has been performed throughout its development history and this model is a well accepted and known model throughout the coastal modeling community.

Under the USACE program, CH3D has been applied to numerous waterbodies through the United States and Florida, these include:

- Chesapeake Bay
- Pudget Sound
- Hoosatonic River

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Appendix N

Spatial Variation in Preferred Habitat Duration for Years 9 to 12

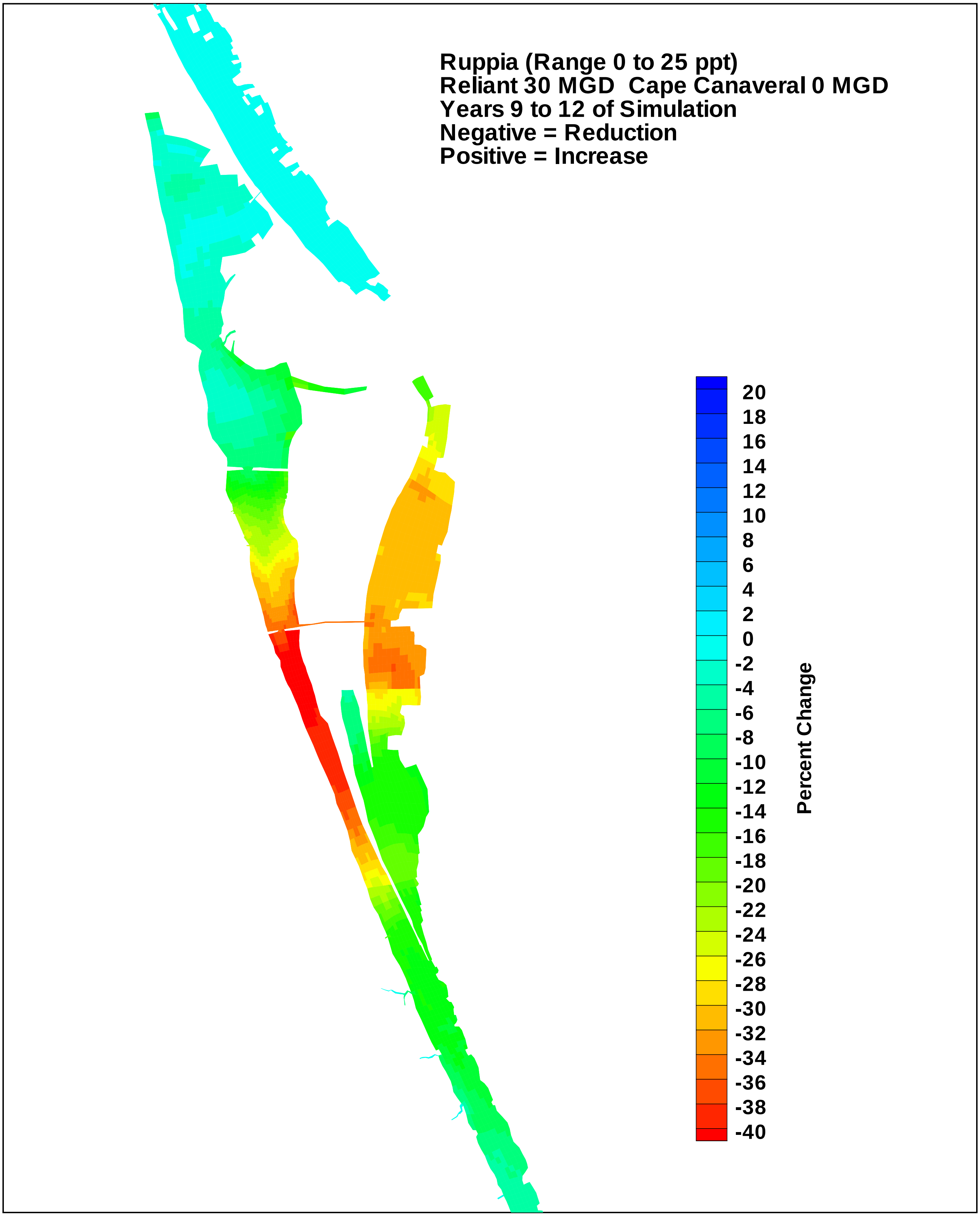

Figure N-1
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Ruppia Seagrass (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

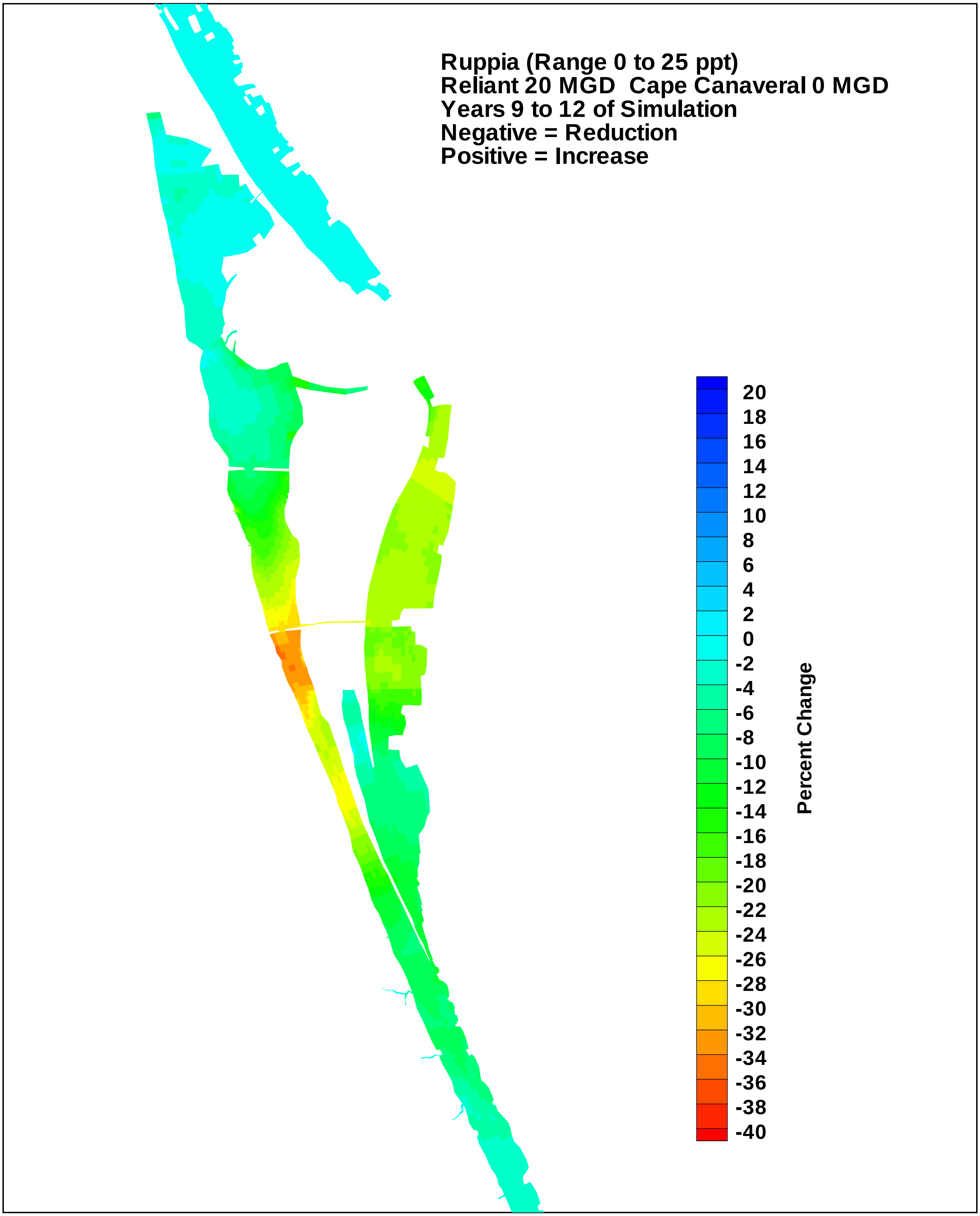

Figure N-2
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Ruppia Seagrass (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

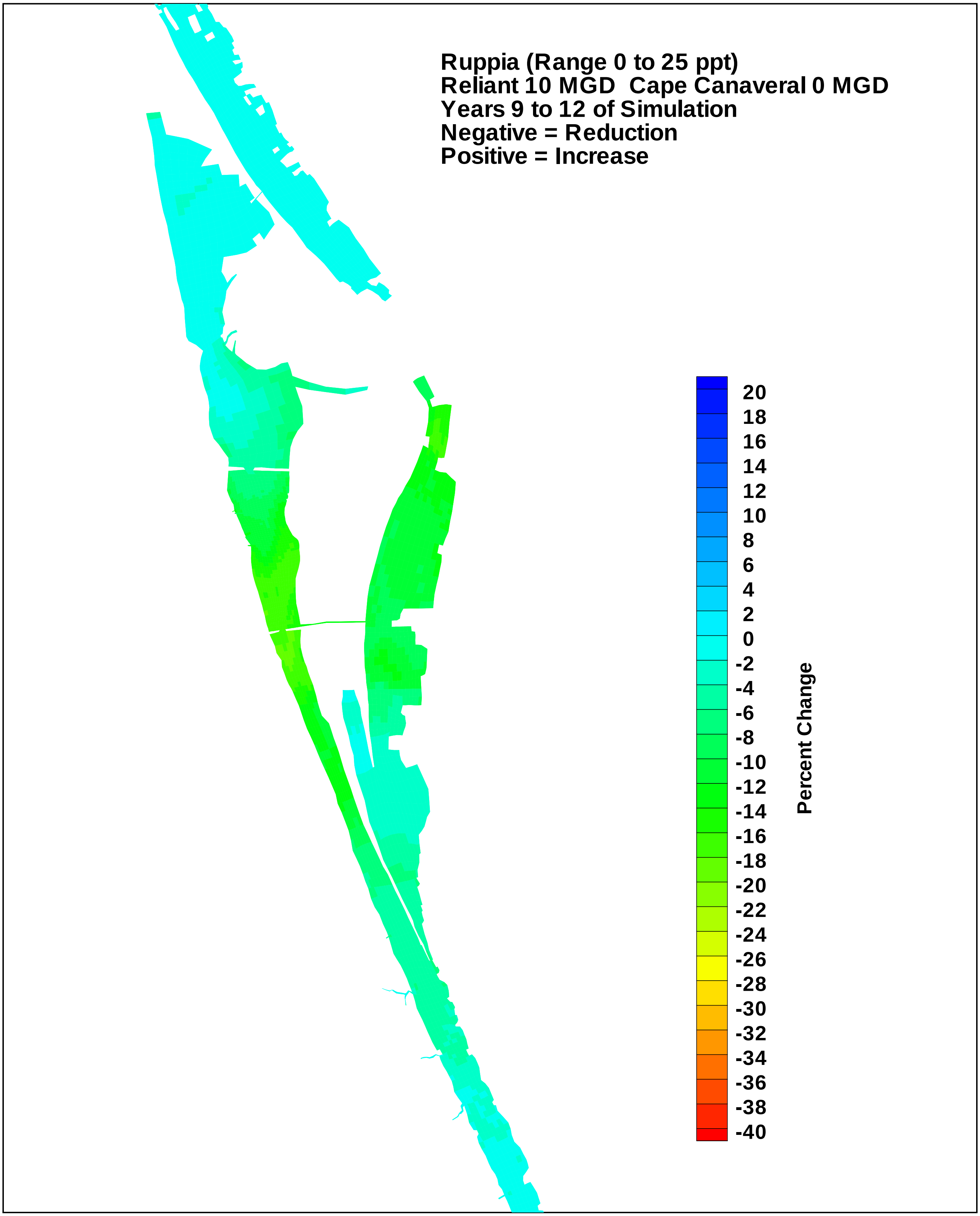

Figure N-3
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Ruppia Seagrass (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

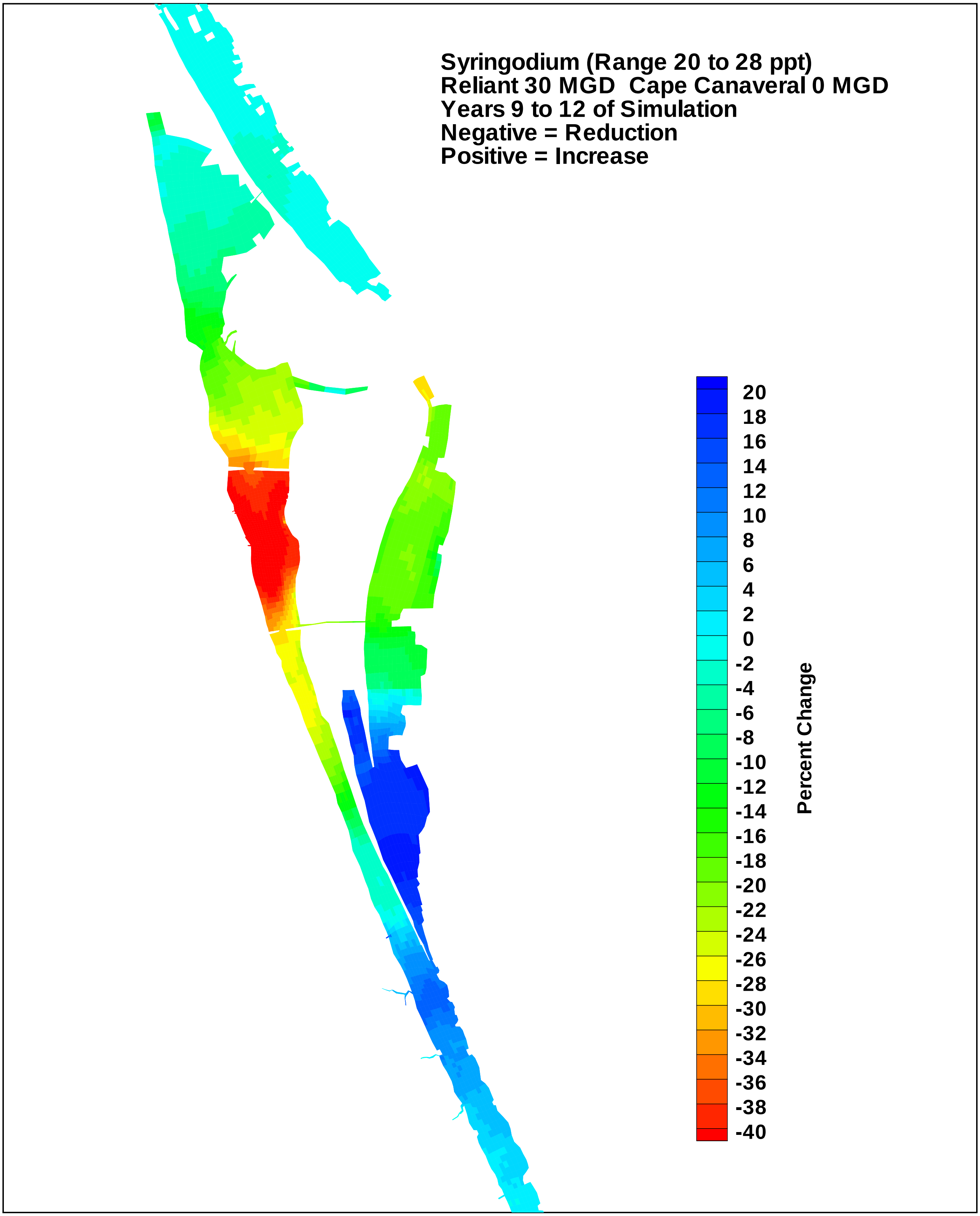

Figure N-4
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Syringodium Seagrass (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

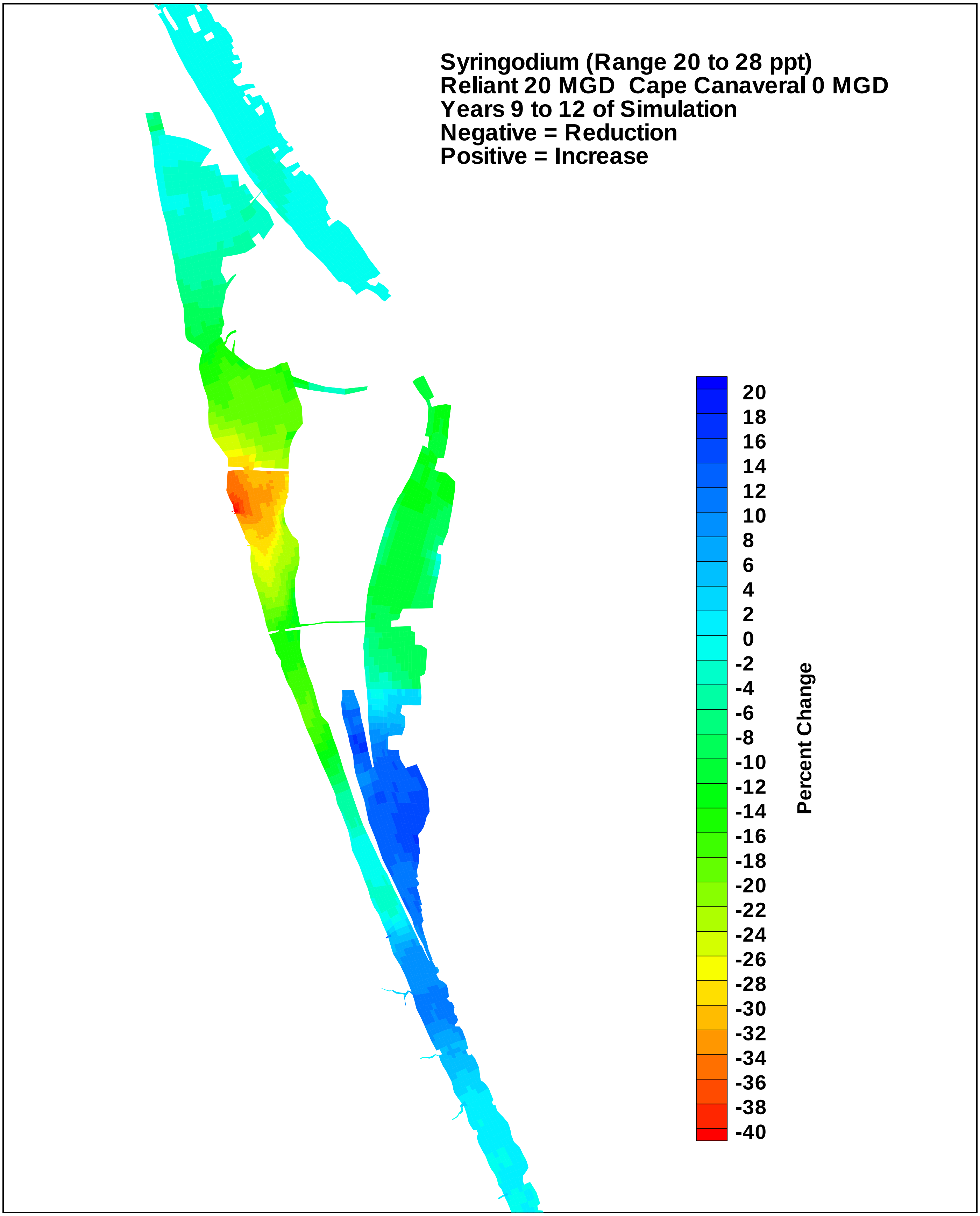

Figure N-5
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Syringodium Seagrass (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

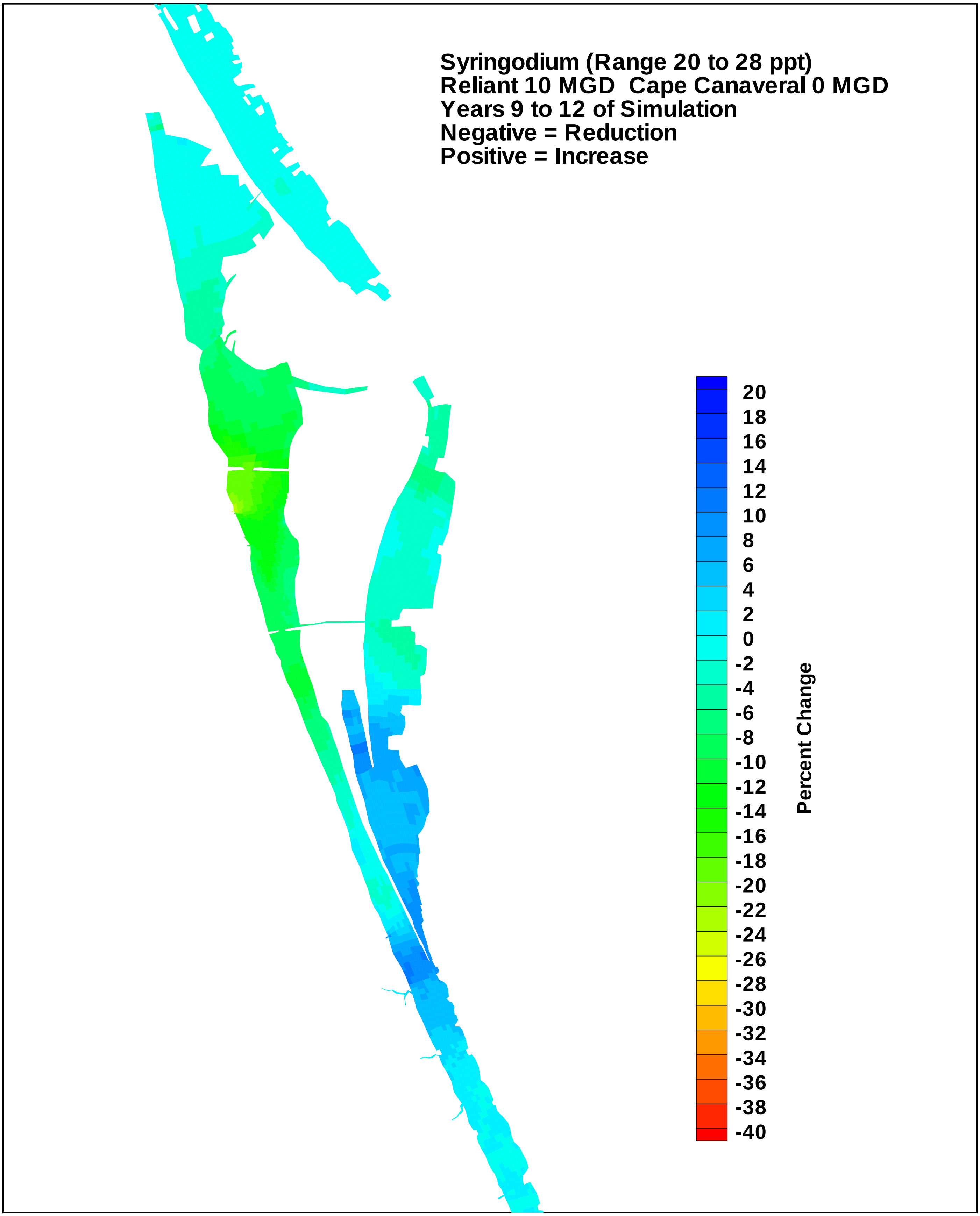

Figure N-6
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Syringodium Seagrass (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

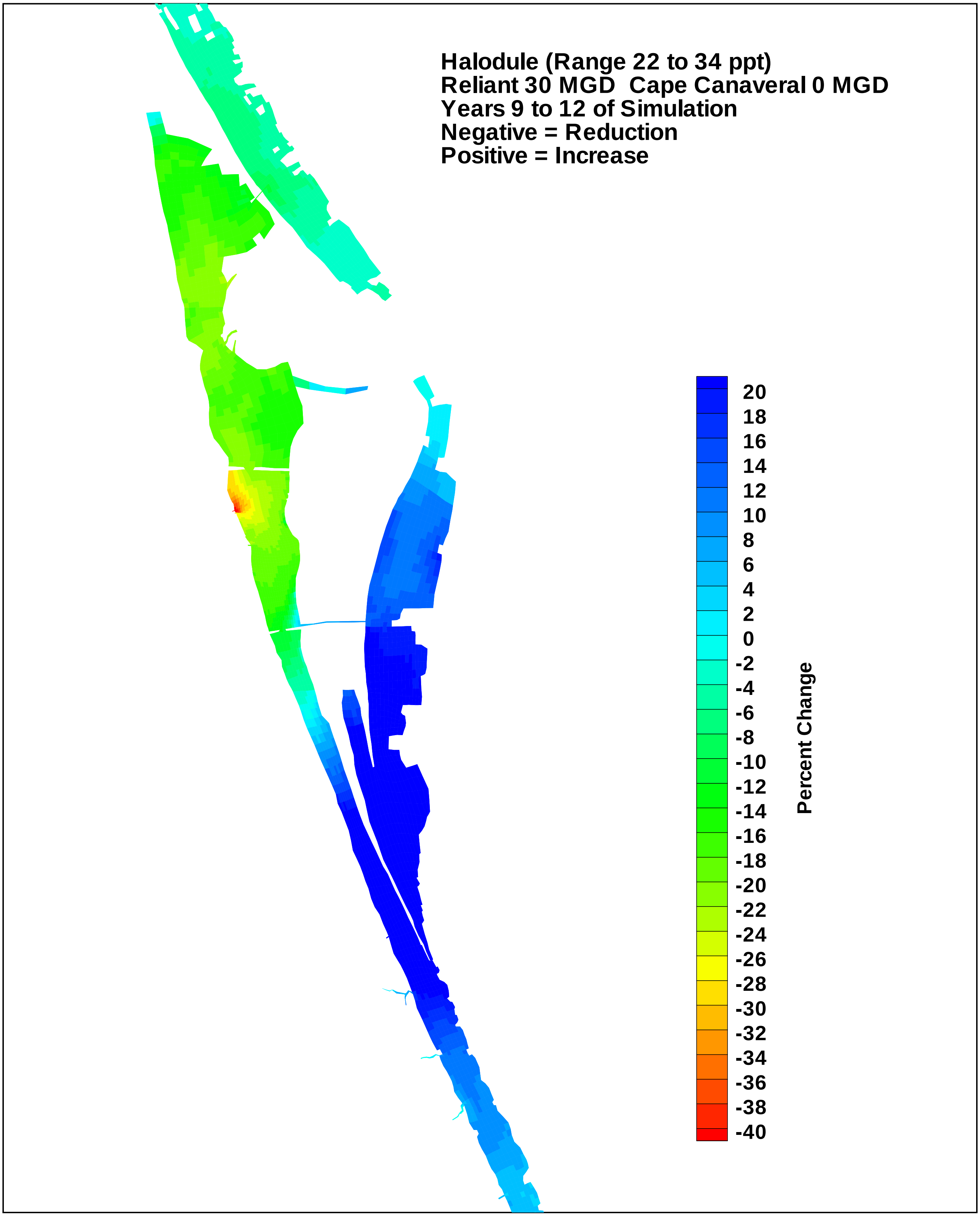

Figure N-7
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Halodule Seagrass (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

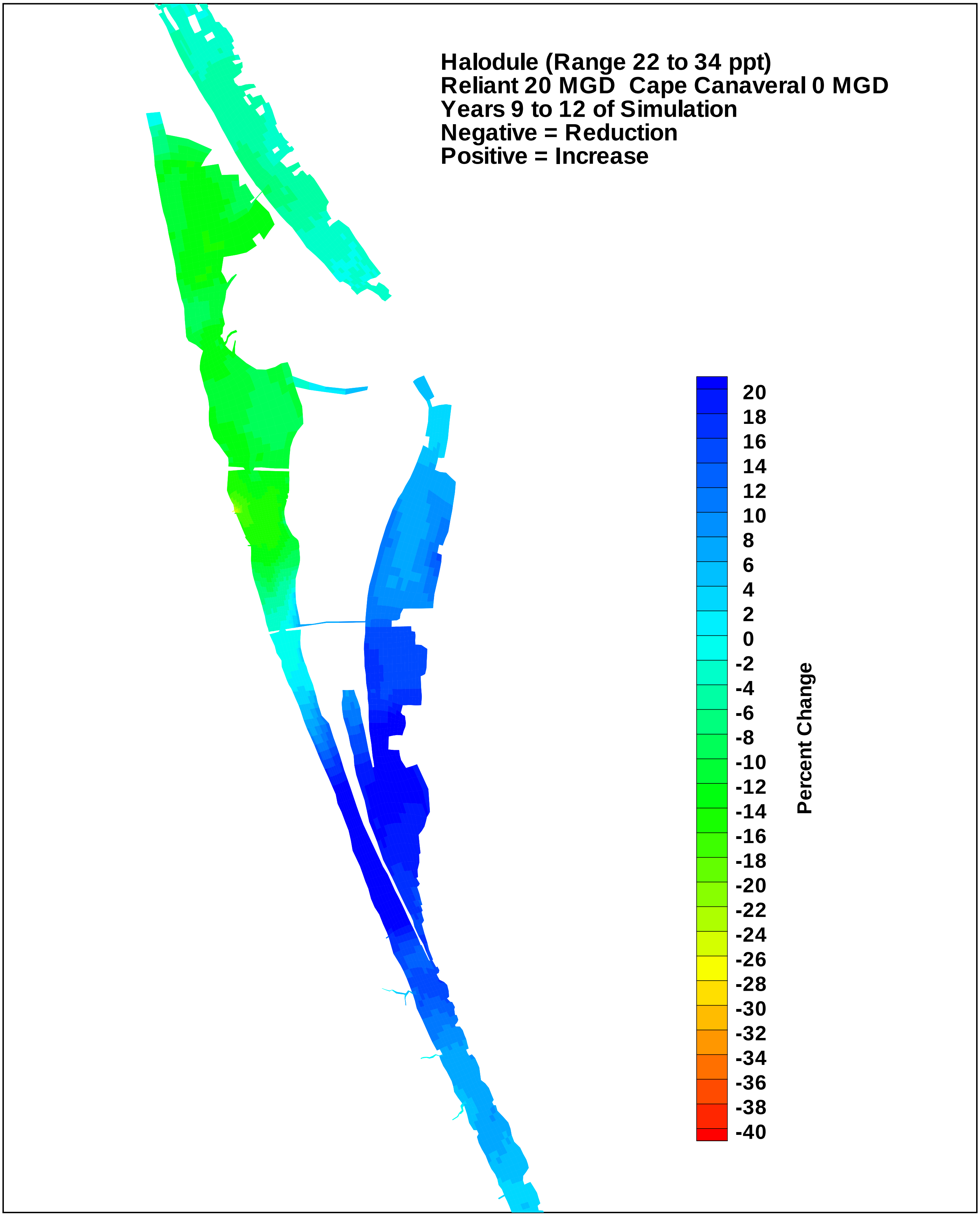

Figure N-8
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Halodule Seagrass (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

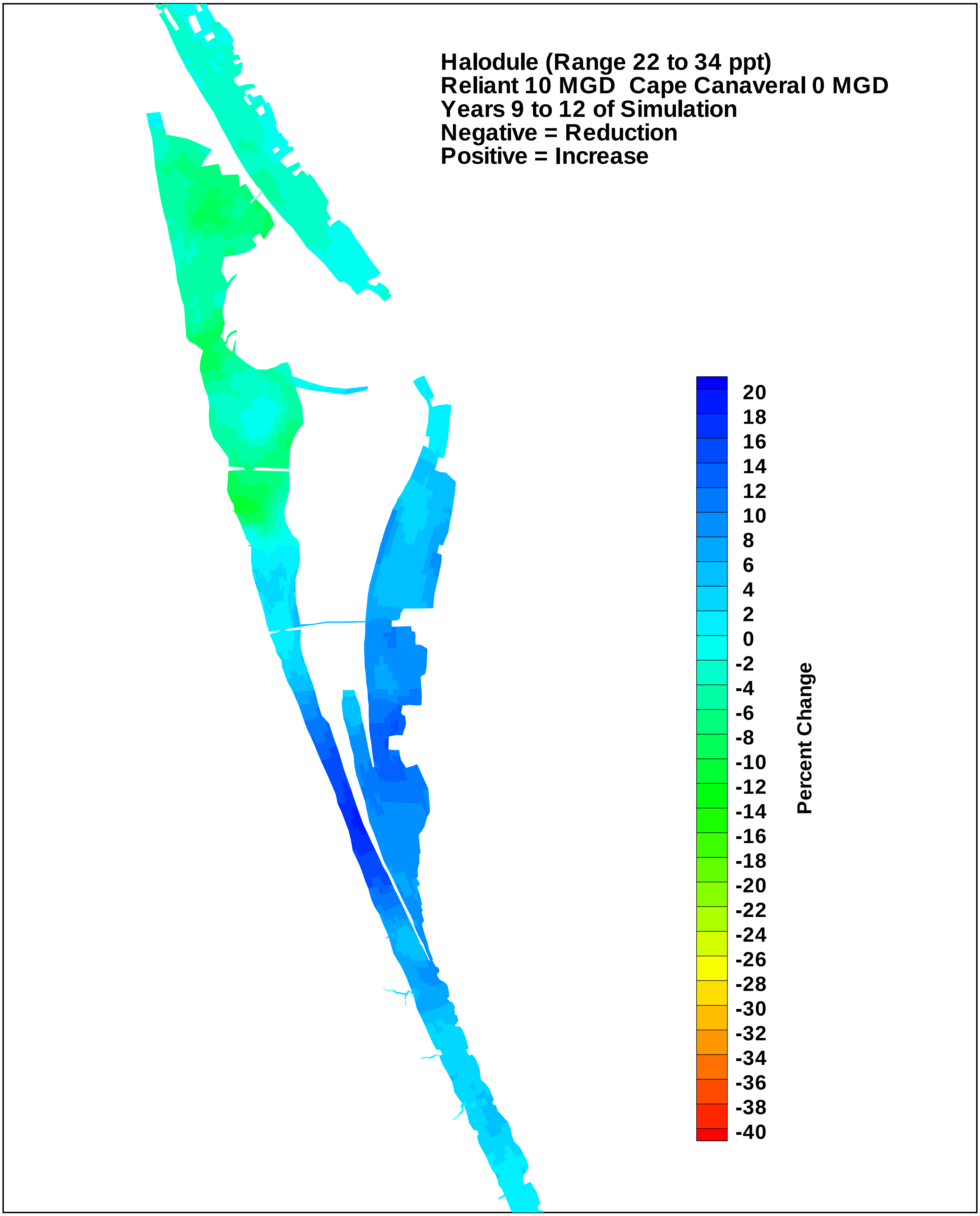

Figure N-9
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Halodule Seagrass (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM APPLIED TECHNOLOGY & MANAGEMENT

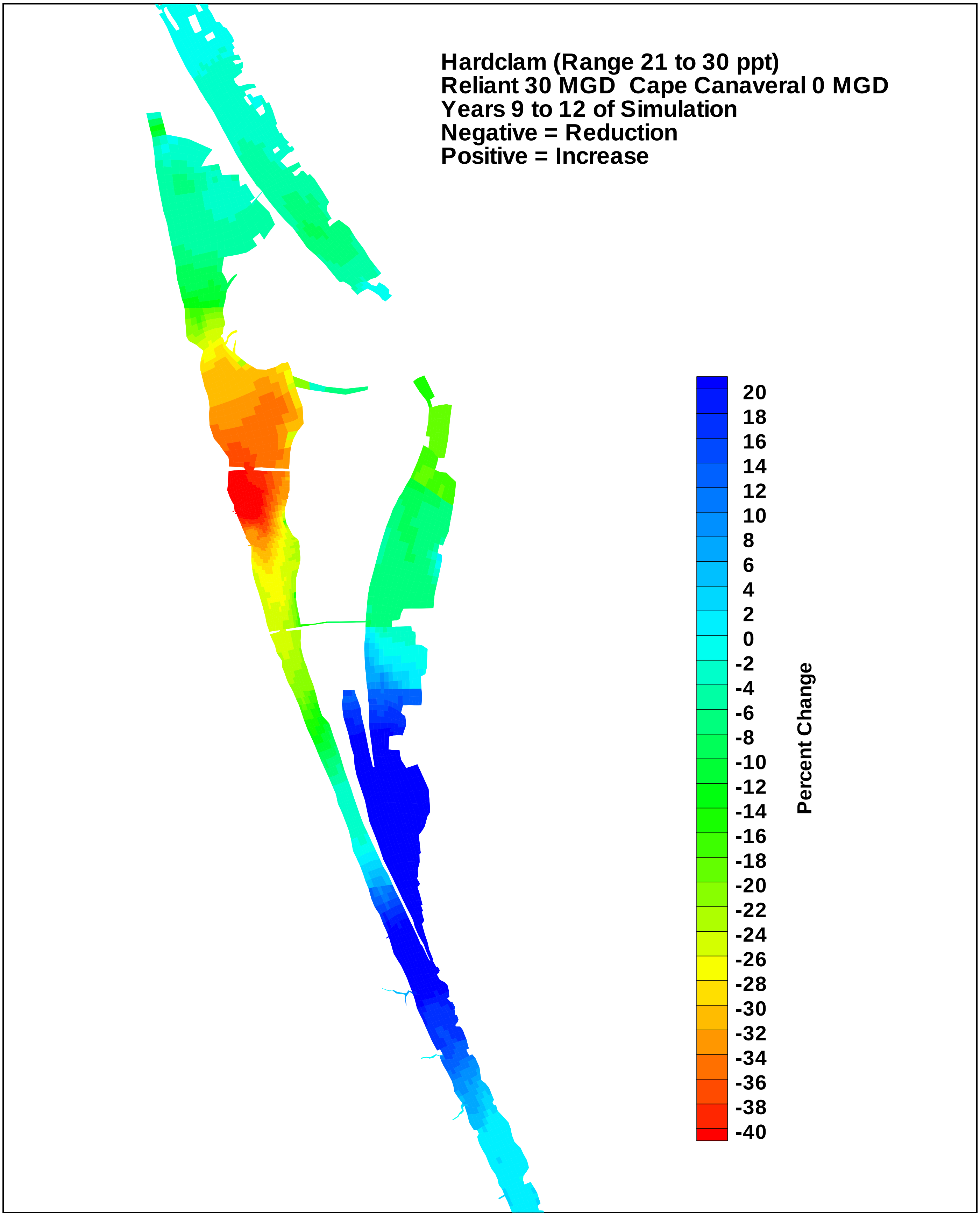

Figure N-10
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Hard Clams (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

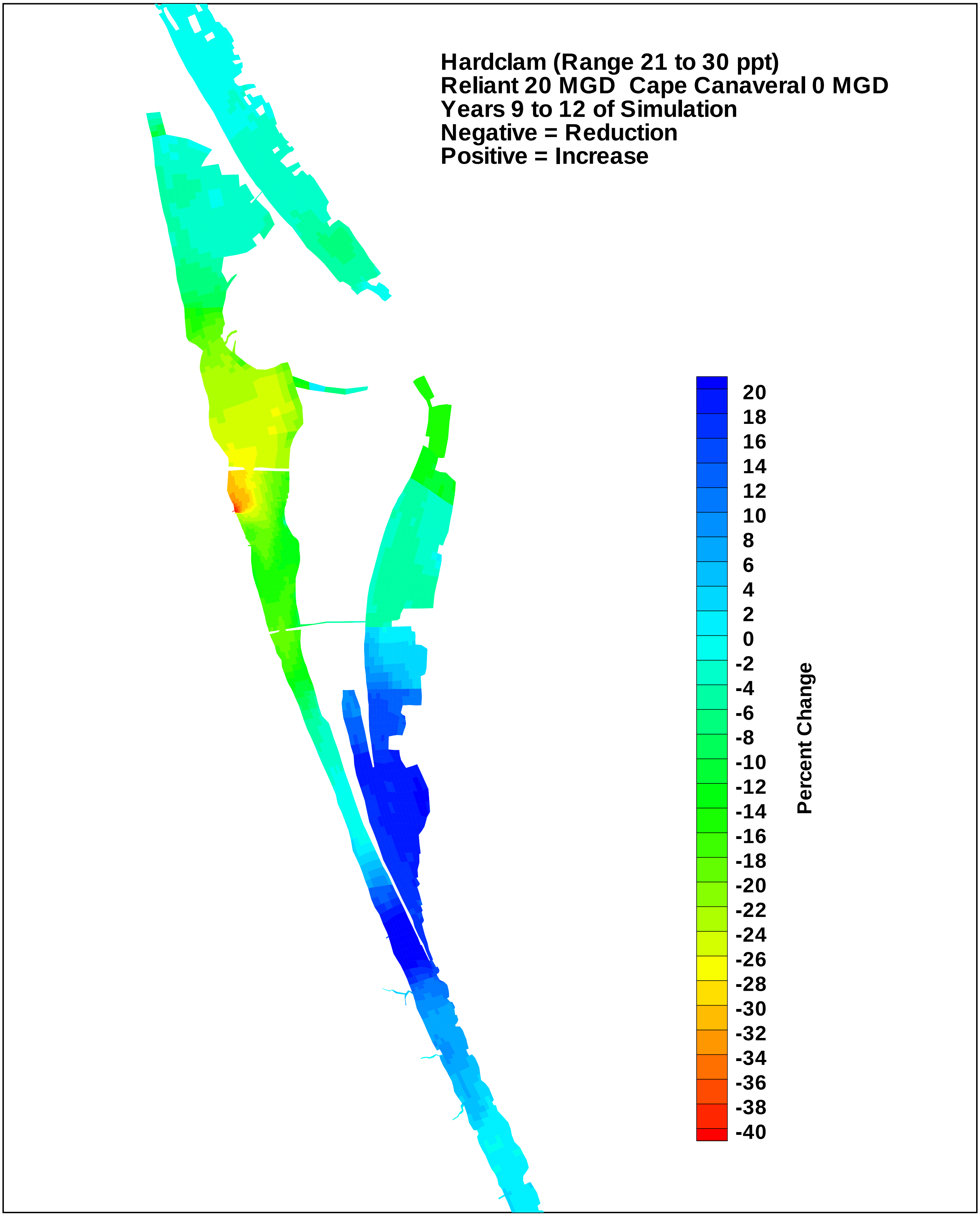

Figure N-11
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Hard Clams (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

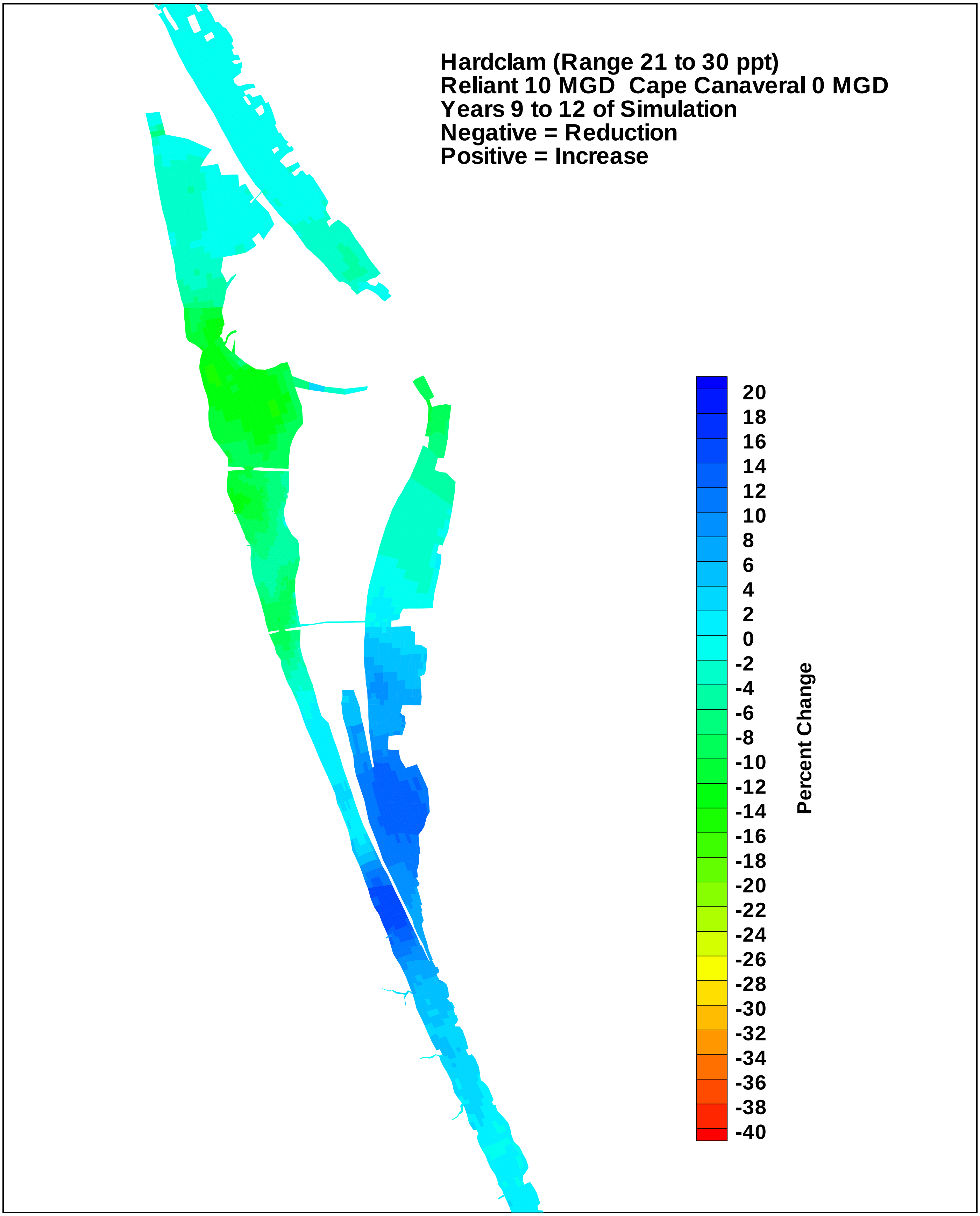

Figure N-12
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Hard Clams (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

ATM
APPLIED TECHNOLOGY & MANAGEMENT

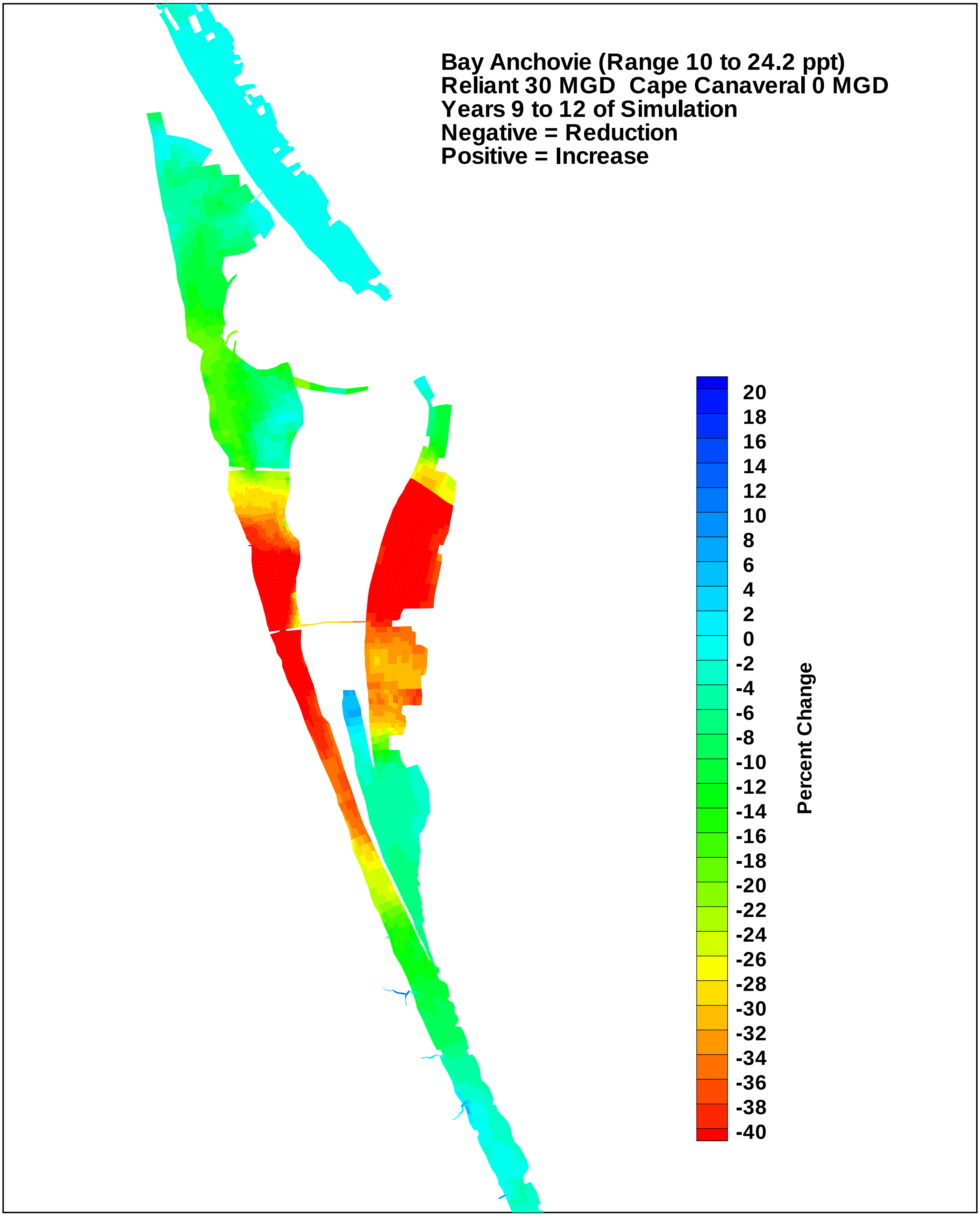

Figure N-13
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Bay Anchovie (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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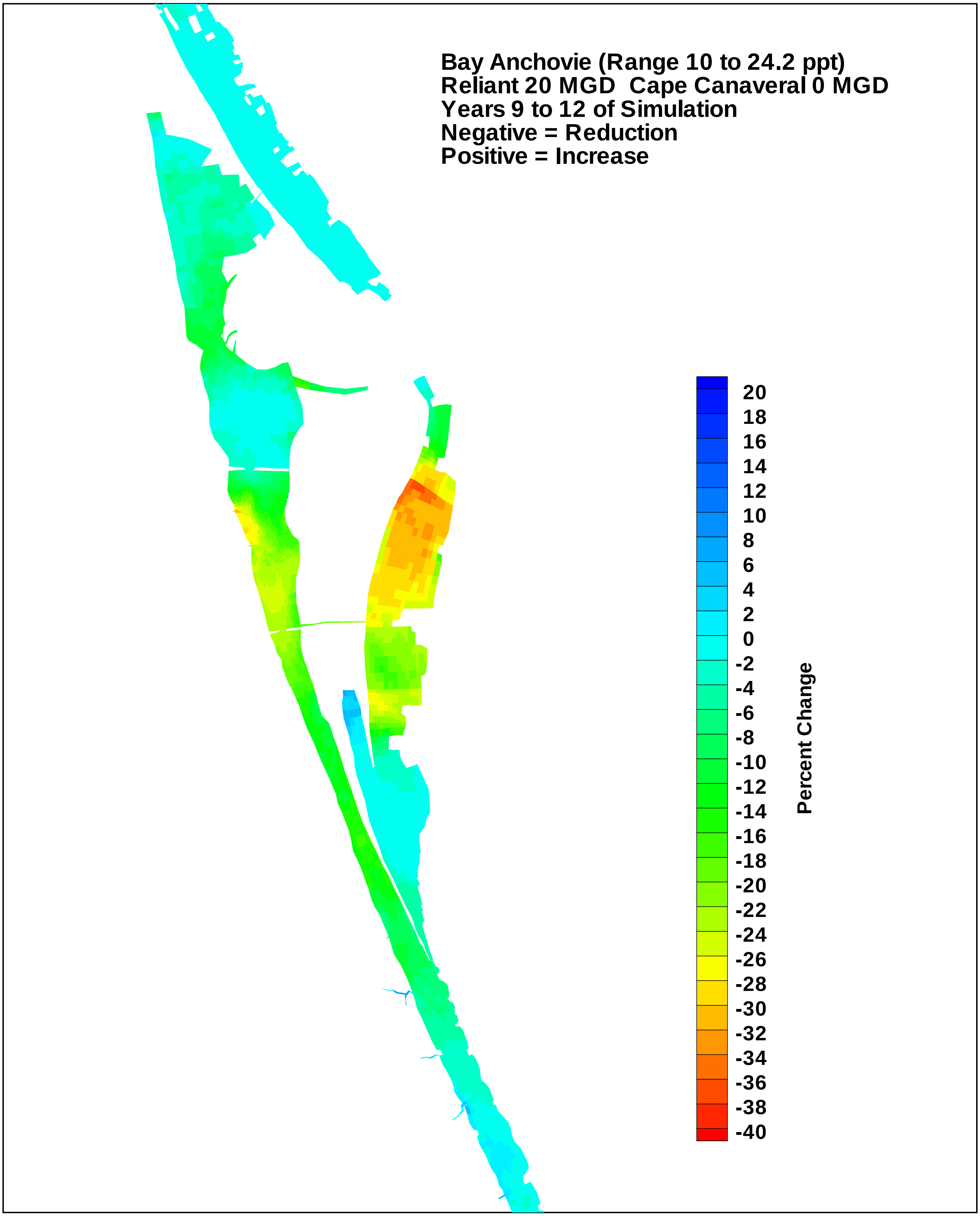

Figure N-14
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Bay Anchovie (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

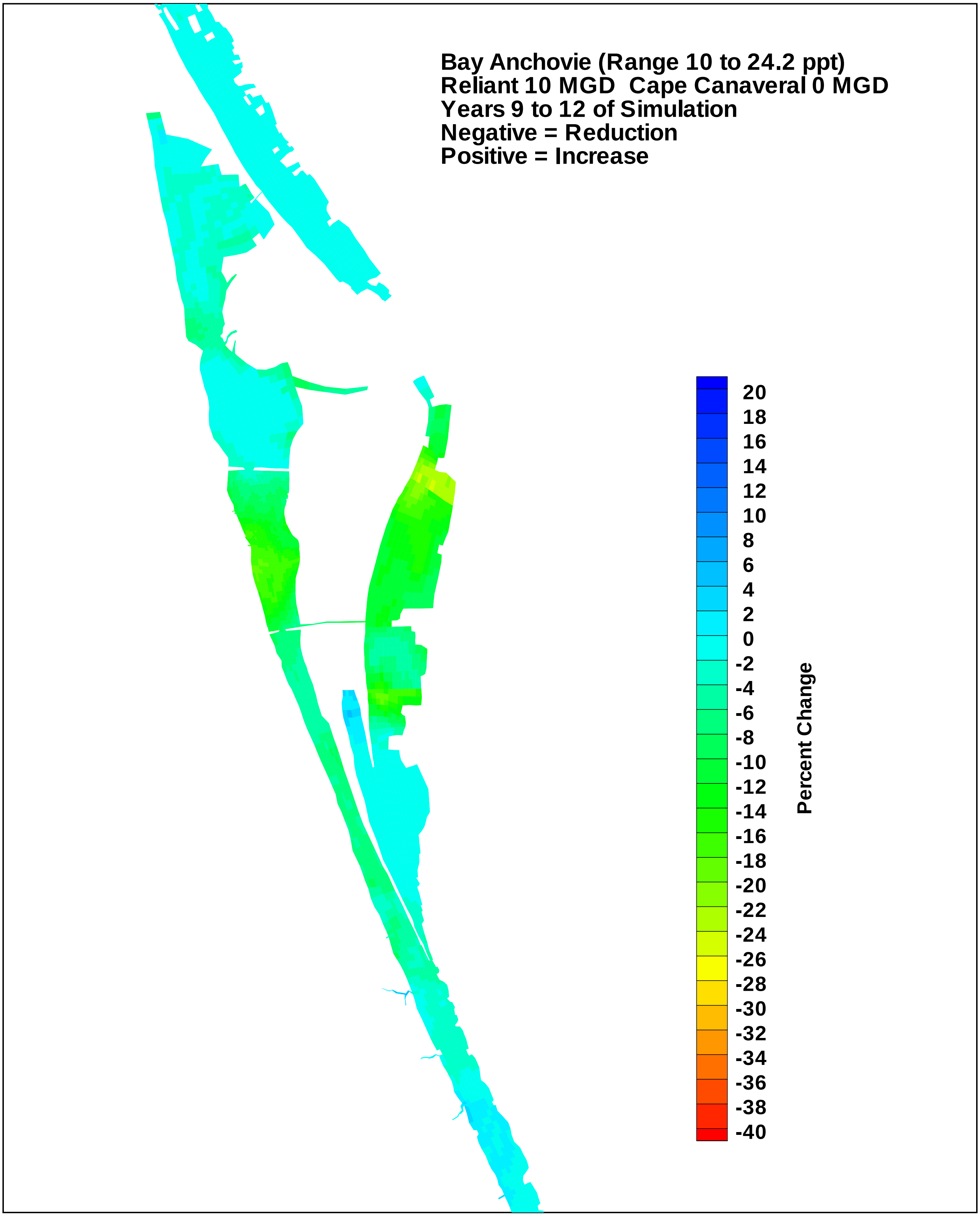

Figure N-15
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Bay Anchovie (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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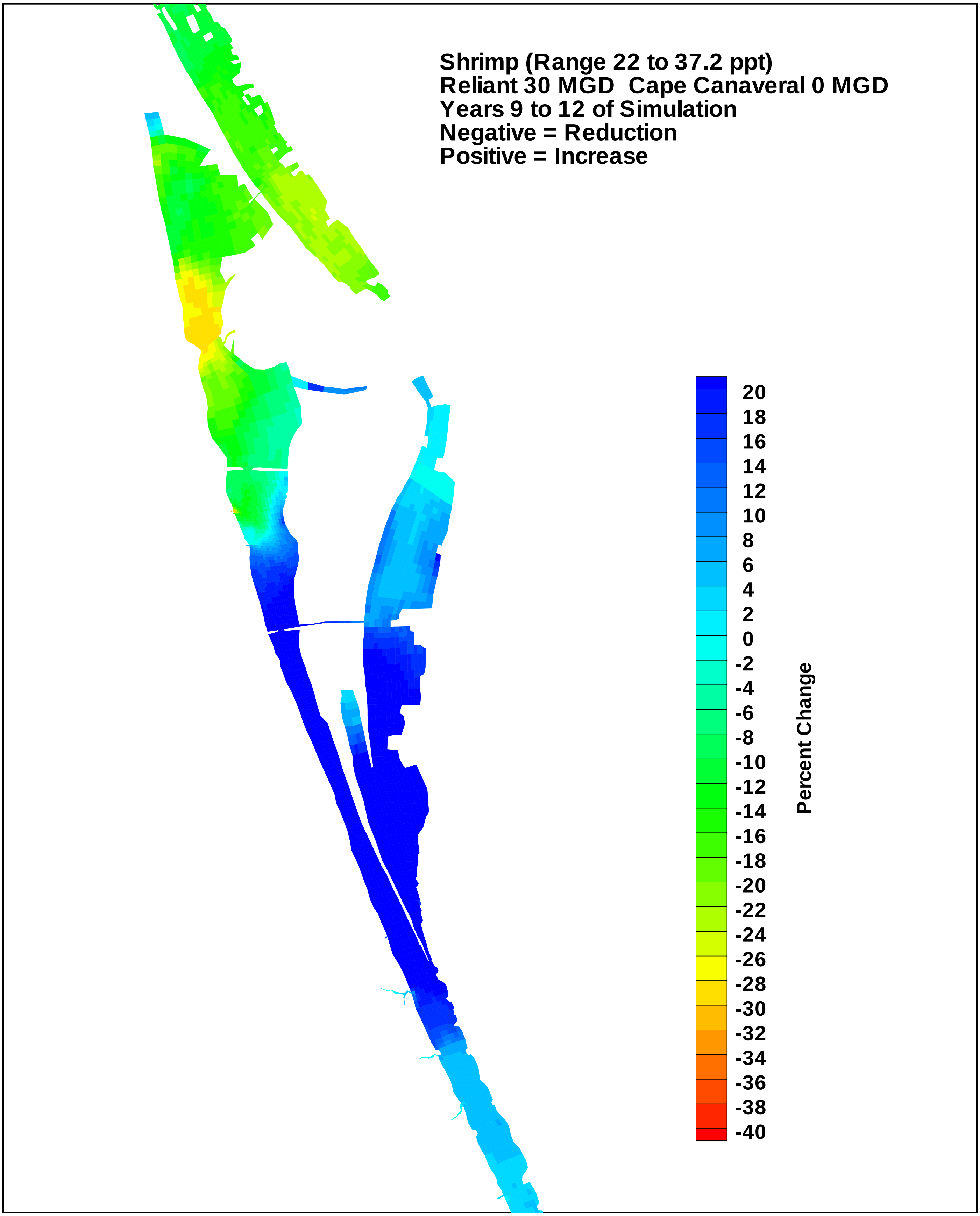

Figure N-16
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Shrimp (Reliant 30 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

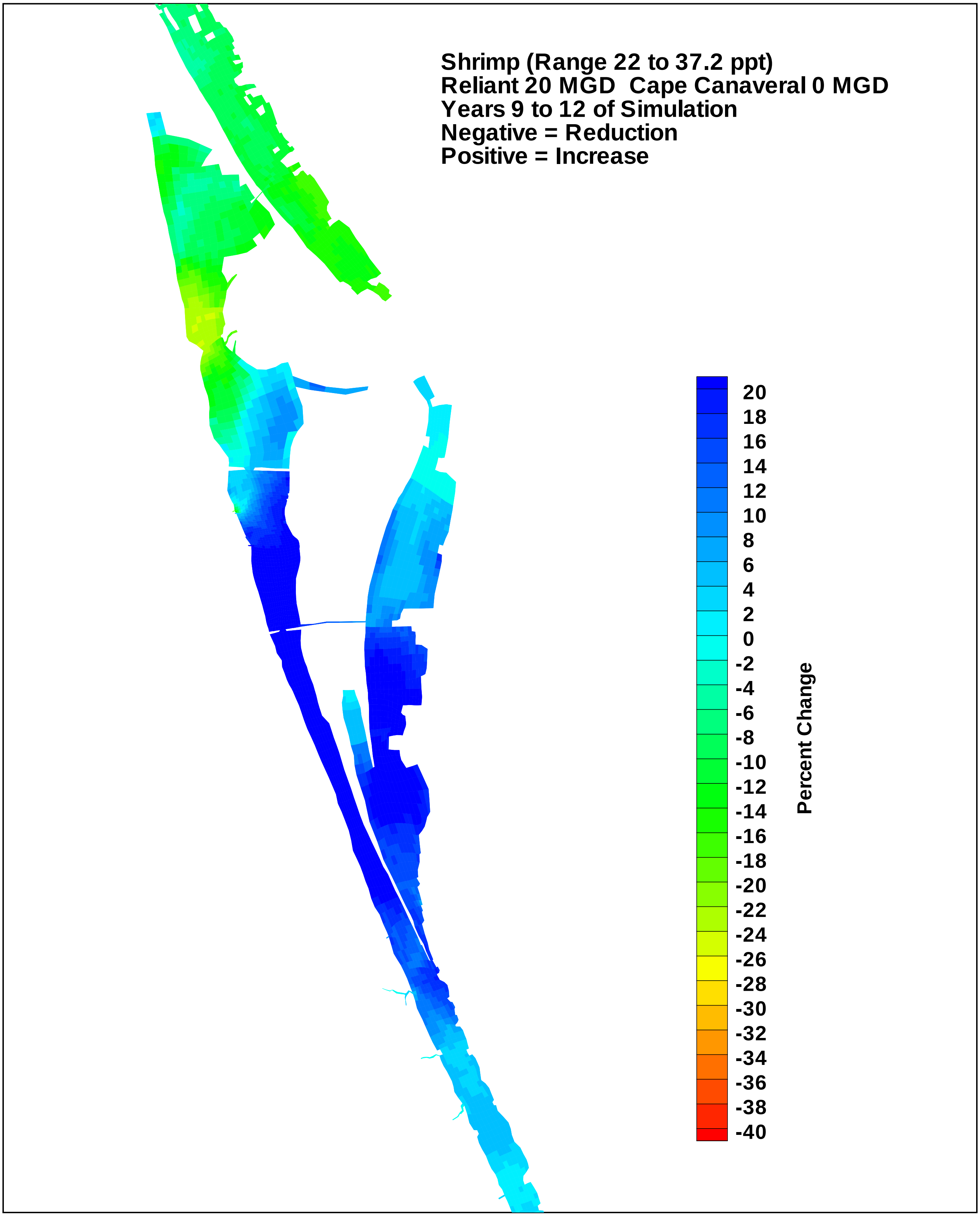

Figure N-17
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Shrimp (Reliant 20 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

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APPLIED TECHNOLOGY & MANAGEMENT

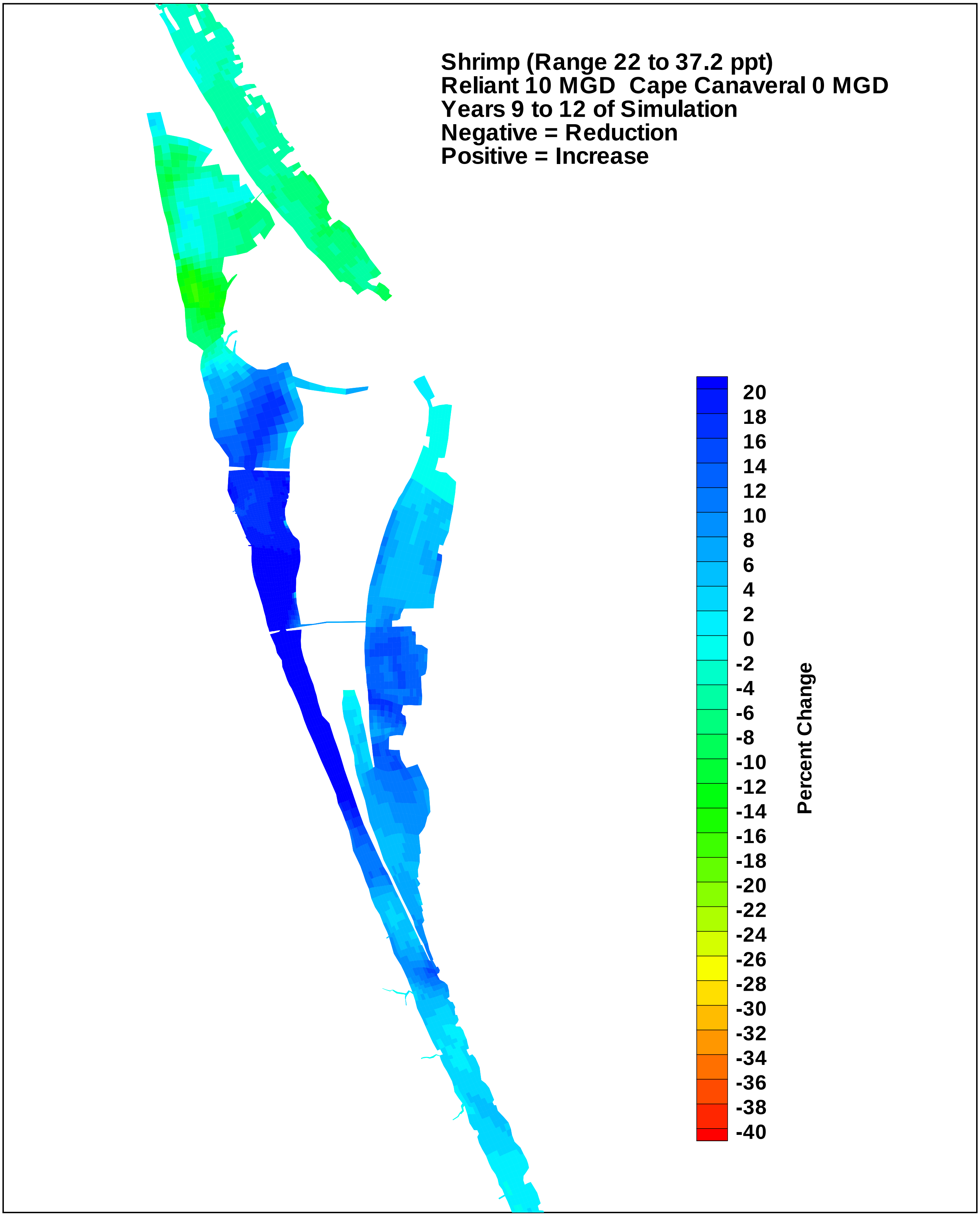

Figure N-18
Spatial Distribution of Changes in Percent of Days Where Salinity is Within the Preferred Habitat Range for Shrimp (Reliant 10 MGD, FP&L 0 MGD)
Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon

APPLIED TECHNOLOGY & MANAGEMENT

Appendix O

District Comments and Responses

GLENN E FORREST PE INC

June 20, 2006

Dr. Steven Peene, Ph. D.
Applied Technology & Management, Inc.
2770 NW 43rd Street, Suite B
Gainesville, Florida 32606

Re: Contract SH341AA – Evaluation of Potential Impacts of Demineralization Concentrate Discharge to the Indian River Lagoon,
Review Comments on Final Report - Task 2.G

Dear Dr. Peene:

Please refer to the following review comments prepared by District staff, myself, and others on the draft Final Report dated May 19, 2006 for the above referenced Task 2.G.

1. **Page 13, Section 2.4, 2nd and 3rd paragraphs –** Please clarify and correct reference to Class II waters and state District, not NEP, as originators of segment labeling for the IRL. Below are the suggested revisions, for ATM consideration. RD

   In the immediate vicinity of the potential collocation sites, waters are Class ~~III~~ II (Figure 8).

   Presently the ~~IRL National Estuary Program (IRLNEP)~~ St. Johns River Water Management District (SJRWMD) has developed segments for the IRL. These segments aid in the definition of goals and programs for the restoration and enhancement of the system. Figure 9 presents the segmentation scheme presently being utilized by the SJRWMD ~~and the IRLNEP~~ for the Northern Indian River Lagoon.

   Changes made to document.

2. **Pages 27 to 28, paragraph before Section 2.5.3 –** Please clarify use of terms "muck" and "sediment" and correct reference to the Intra Coastal Waterway. Below are the suggested revisions, for ATM consideration. RD

   Sediments in the ~~The~~ ~~Inter~~ Intra Coastal Waterway (ICW) west of the Haulover Canal ~~is, however,~~ are primarily fine-grained muck ~~sediments~~.

   South of Vero Beach muck sediments again become predominant in the ICW until Fort Pierce.

   Changes made to document.

3. **Page 28, Section 2.5.3, 1st paragraph –** Please add additional harvesting area classification. Below is the suggested revision, for ATM consideration. RD

   In Florida, shellfish harvesting areas are established by the Florida Department of Agriculture and Consumer Services, Division of Aquaculture and classified as Approved, Conditionally Approved, Conditionally Restricted or Prohibited based on public health and safety concerns.

   Change made to document.

4. **Page Page General Comment –** According to conversation G. Forrest had with FDEP representative on 6-21-06, aquatic preserves are to considered synonymous with OFW's. Please revise report accordingly.

   Changes made to the report to reflect this comment.

5. Cover sheet shouldn't say "Technical Memorandum." Instead insert words "Task 2.G" Final Report. Same with page headers.

   Change made to cover page.

6. TOC – define acronym MEG, missing 7 subcategories after 4.3, check correctness of 5.2.4.xx and page number (85 not 86?).

   Changes made to the report. The MEG stands for the Model Evaluation Group that was formed to review the SJRWMD model for the PLRG program.

7. Data Attachments – Are they each referenced in the report text so reader knows their relevance? Which DA has the preferred habitat curves showing the 75% ranges?

   The data attachments are referenced. Data Attachments N and K provide the information. The ranges are arrived at through statistical analysis of available data on existing habitats. The data are used to develop a frequency distribution and the percentages come from the distribution.

8. Acronym List – prepositions should be lower case, consider striking out FWC, add OFW

   Changes made.

9. Exec Summary – remove references to technical memorandum since this is a final report, not a TM. Check first bullet list – either use periods or don't. Where "entrainment" is used, it should also say "impingement and…"

   Changes made.

10. Exec Summary, Page 4, last paragraph – Please add explanation of relevance of MFL criteria. Page 5 – change third bullet to say “totaling 20 mgd or 30 mgd.” Page 5 – add another (6^{th}) bullet for the last sentence of the 5^{th} bullet.

    Changes made.

11. Figure 10 – Please rearrange to provide better spatial explanation, corresponding to continuity of each of the 9 areas. Add Figures 8 and 10 from TM 2B 2C and associated text to make a stronger point of the historical variability of salinity in the lagoon.

    Figure 9 has been modified and figure 8 from 2BC has been added along with additional text to discuss the historical variability.

12. Page 19 – Halodule is 10x to 20x more abundant than other seagrass types. Should Figure 9 from TM 2B 2C be added to 2G to illustrate this point? The 1980-2004 salinity data shows that 90% of the time, salinity is 17 to 30.5 ppt for the Area with Transect 22. If the increase in salinity for 10 mgd in this area is 1 to 2 ppt, why wouldn’t Halodule increase if its preferred habitat is 22 to 34 ppt?

    Figure 9 has been added from 2BC. The salinities provided in the plots are for a 24 year period while the salinities for our baseline are for a 4 year dry period. It is not expected that the salinity baseline would be exactly the same as that provided for the 24 year period. The use of the 4-year dry period reflects a conservative approach to the determination of the impacts to the system.

13. Page 68, third line – is should be are.

    Change made.

14. Page 68, last paragraph – Section 2.0 doesn’t cover seagrass as comprehensively as TM 2B 2C (e.g. Section 3.4); please review and add additional information from previous TM.

    The seagrass descriptions from 2BC have been brought into Section 4 which identified the ecological resources of concern.

15. Page 79, third paragraph – Data Attachment reference may need to change from H, to B through I. Further down (step 4?) – would this be appropriate location to mention 75% preferred habitat approach? The 75% PH approach does not seem prominent in the report.

The appropriate Data Attachment reference is actually N. This will be changed in the document. The 75th percentile of the probability was utilized to establish the preferred salinity range, i.e. there is a 75 percent chance of the species occurring within the preferred range.. This means that there are instances of species existing outside of the preferred range. This make the analysis a relatively conservative one.

16. Page 81, third line – Did the evaluation consider the relative importance of each species? Again page 85, third line from bottom.

    The final evaluation actually did not account for the importance of each species other than through the discussion of the frequency of occurrence in the tables. These statements have been removed.

17. Page 85 to 86 – Tense should be changed from future to past. Discussion of reference sites should list them as far field (P1 to P8 as far field, except P1) and near-field (1a, b, c, 2, a, b, c, 3-10). This may also be appropriate location to state that aquatic preserves are also OFW's.

    Changes made.

18. Figure 37 – font should be consistent throughout report.

    Captions in figures changed to have consistent format throughout.

19. Page 127, Section 7.5 – Discussion in report should have greater emphasis on how impacts relate to historical variations of salinity.

    Within the report in Section 7.5.3 there is a discussion which emphasizes the salinity variations and refers back to the characterizations.

20. Page 132, Table 12 – Wouldn't Benthos Group C have the highest percent loss if its preferred habitat range was the lowest? How can a preferred salinity range (PSR) have a lower range value of zero? Should table indicate distinction between mobile and non-mobile species?

    If the data do not show reductions in the species as salinity goes to zero, the salinity tolerance can go to zero. The mobile versus non-mobile species seem evident in the tables. It doesn't seem necessary to identify them. As the lower end of salinity preference for Benthos Group C is zero and goes to a low value (21 ppt), the base habitat may be in the lower area of the IRL and therefore not located in the area of the highest impact, that most likely resulted in the lower changes in acreage and differing percentage.

21. Page 134, Table 12 – April to June Ladyfish PSR is shown as 10 to12, but Figure E-51 shows overall range of 10 to 40, please explain. Same for July to

September. Please also check Brevoortia, July to September. Code Goby in Figure E-121 indicates greater abundance of that species in October to December, but it's not listed in table; please explain.

The curve for ladyfish is inverted and therefore does not follow the typical evaluation. The data do show the greater abundance in the 10 to 12 range. The curve for Ladyfish for July to September also shows the same conditions but with a lower slope that accounts for the higher upper level. The Code Goby was not evaluated in the analyses, this period of the species analysis was missed. As stated earlier, the use of the 75th percentile as the preferred habitat provides a conservative evaluation of impacts as the species is found outside of the PH range..

22. Appendix E – January 2006 meeting summary is missing.

    FDEP Meeting has been included.

23. Figure N-3 – Anticipated frequency of occurrence of Ruppia in Area 1 in existing conditions is probably less than 10%.

    Comment noted.

24. Figure N-6 – Existing conditions in Areas 7 and 4 is 15 to 22 ppt 50% of the time.

    Comment noted.

25. Figure N-9 – Figure 38 shows average 1 to 2 ppt increase for 10 mgd scenario, max 2 to 3 ppt increases. If existing conditions 50% of the time is 20 to 27 ppt, or 90% of the time is 17 to 30.5 ppt, then why wouldn't this area show a plus change for 90% of its coverage? Same comment Figure N-12.

    Existing data presented in earlier chapters reflects conditions over 24 years and probably represents a more normal condition than the 1997 to 2000 conditions used for the baseline in the ecological analysis which represented a dry period..

26. General comment – An empty page insert should appear after the last page of the report.

    Change made.

We look forward to working with the ATM team toward finalizing this Technical Memorandum, for District acceptance. Please submit written responses to comments, and discuss deliverables with the District Project Manager, prior to production of the final TM for submittal prior to end of contract.

Please contact me at 407-677-8600 if clarification is desired concerning this letter.

Very truly yours,

Glenn E. Forrest, P. E.
In Association with Taurant Consulting

Copy to: Jim Gross, SJRWMD

Appendix P

Peer Review Comments and Responses

RESPONSE TO PEER REVIEW COMMENTS
Draft Technical Memorandum 2G

Dr. Barney Austin Comments:

I have read the documents and generally concur with the findings. The conclusions are well supported, the research well conducted, the models well formulated and the analyses are rigorous. The only mild, but lingering concern I have is on the issue of potential stratification, which we discussed in at least conference calls and in our meeting in Florida.

While the amount of vertical mixing may well be sufficient in the Indian Lagoon to negate the possibility of stratification and possible onset of hypoxic conditions in the vicinity of the discharge, I'm not sure I've seen any conclusive evidence to support that assumption. Allow me to share our most recent results on data collection and modeling of the Corpus Christi Bay area, where the state of Texas is considering construction of a desalination facility to provide drinking water to the City of Corpus Christi.

The Indian River Lagoon system is similar to the Corpus Christi Bay system on the Texas Gulf Coast in the sense that both water bodies are shallow(generally <4 m deep) and often considered to be fully mixed. The main differences between these two systems are that evaporation is greater in the Corpus Christi Bay area than in the Indian River Lagoon area, and that rainfall is greater in the Indian River Lagoon area. We have observed benthic hypoxia in portions of Corpus Christi Bay adjacent to the shallower secondary bays in the system (ie Oso Bay and Laguna Madre). Based on field measurements in 2005, we are confident that the hypoxia results from density current underflow of no more than 0.5 ft in thickness that prevent oxygen transfer to the benthos even during periods of high winds. These underflow are created as evaporation in the secondary bays produces high-temperature (33 C) and high-salinity (40-50 PPT) water that flows under tidal influence along the bottom of Corpus Christi Bay. Studies by Paul Montagna of the University of Texas Marine Science Institute have linked the occurrence of benthic hypoxia to the lack of benthic biodiversity in portions of Corpus Christi Bay.

In our attempt to assess the feasibility of discharging desalination brine into Oso Bay, we developed a hydrodynamic model of the entire Corpus Christi Bay system and high-resolution model of the interface between Oso Bay and Corpus Christi Bay. Using the high-resolution model, we were able to determine the vertical grid cell resolution requirements for properly resolving the observed salinity stratification. This work was performed by Paula Kulis, a Ph.D. candidate at the University of Texas at Austin under the direction of Associate Professor Ben Hodges. They concluded that by using 3 cm vertical cells in near the benthos (and 150 cells across the entire 3-m deep domain) they were able to reasonably reproduce the observed stratification (sigma-t of 4.5 from surface to bottom).

However if they were to use a model grid with poor vertical resolution (3-5 cells), they could not properly resolve the stratification observed (sigma-t of 0.8 from surface to bottom).

Based on our observations within Corpus Christi Bay and the modeling results from Paula Kulis, I feel that the IRLPLR model used for the Indian River Lagoon simulations is too poorly resolved in the vertical to adequately address the question of whether stratification and hypoxia might result from discharging desalination brine from either site on the Indian River Lagoon. While increasing the vertical resolution is computationally expensive, it should be feasible to do so for a more localized sub-model of the discharge area. It is also necessary to determine if the Indian River Lagoon system is sufficiently wind mixed to break up a density underflow resulting from a brine discharge. This requires either sophisticated modeling of the underflow and vertical distribution of wind mixing (which I do not believe is feasible with ANY existing hydrodynamic mixing model as existing turbulence closure schemes are not accurate enough for this purpose) or doing an actual field study where a slug of ultra-high salinity water is introduced at the discharge location and its movement/dispersion is tracked with field equipment (including water-quality/DO probes). The tracking should continue until salinity conditions have reached ambient conditions. If this occurs quickly or if no density undercurrent is observed, then that would be great information and additional support for the proposed project. If a density undercurrent is observed, then I feel it is necessary tore-model the discharges with a high vertical resolution and attempt tore-quantify salinity changes in all areas of the Lagoon (including the far-field).

I think that without a high-vertical resolution model for simulating the potential existence of density currents, the habitat loss assessments are potentially not as accurate as they might be. This is especially true for shellfish and benthos assessments, for these creatures will be directly affected by the existence of high-salinity underflow and the resulting hypoxic conditions.

Responses by District Consultant:

Within Corpus Christi Bay, the existing data show a condition where stratification levels reach a relatively high value, i.e. a difference in sigma-t of 4.5 from surface to bottom. Additionally, in the area discussed within Corpus Christi Bay, the depths are on the order of 3 meters, or around 10 feet. In the area of the discharges within Indian River Lagoon, the maximum measured sigma-t is always less then 2 from surface to bottom. The depths are generally less than 2 meters. While there are similarities, the lack of an existing condition that is a problem, reduces the level of concern in the Indian River versus Corpus Christi Bay. Additionally, hypoxic conditions were measured presently within Corpus Christi Bay, where this wasn't measured in the Indian River Lagoon.

In regard to the vertical resolution of the model, the number of layers prescribed for the simulation was deemed sufficient by a panel of modeling experts for the depth and stratification conditions seen, and the model did not show any appreciable change in the local stratification. It should be noted that with the discharge temperatures being as high as they are, and the limit of 10 percent increase in the discharge salinity (versus intake), the decrease in buoyancy from the increased salinity would be somewhat balanced by the increased buoyancy due to higher temperatures.

<u>Additional Response Provided by Tim Cera (SJRWMD):</u> This issue would be relevant for any future studies that may be required for environmental permits. A couple of things could lead to this not being an issue in the IRL. The discharge cannot have a greater salinity than 10% over ambient (not sure what the high saline water is in Corpus Christi Bay above ambient, but likely much higher if they are getting salinities of 40-50). Another issue is that Dr. Austin suggests that tide causes some of the stratification, and though I don't particularly understand that part of the Corpus Christi Bay hydrodynamics, this area of the IRL is microtidal. Generally we would probably get a better answer from using the equations of state (to calculate density) given typical temperature and salinity ranges. For example, calculate the density as 25 degrees C and 25 PSU compared to density at 35 degrees C and 27.5 PSU.

25 degrees C and 25 PSU -> 1015.806 kg/m3
35 degrees C and 27.5 PSU -> 1014.362 kg/m3

So, under the above scenario, the temperature would still bring the plume to the surface. This wouldn't always be the case and one would want to include the scenarios where the power plants are "turned off". But even with the power plants turned off, one has the situation where the maximum increase that the bottom would experience, or be allowed to experience, is 10% over ambient.

<u>Dr. Gary Zarrillo Comments:</u>

I leave it to others to comment on the ecologic and biologic portions of the study, but I think that the approach using the various project layers to make an assessment is very good. No doubt some will argue forever either for or against a desal facility in the NIRL. It is interesting that the project team makes a firm statement against the larger volume facility and suggests a 10 MGPD facility might be feasible, but with some impact and habitat loss. I think that the contractor is objective and conservative on this issue. No one can make a serious statement that the project was a white wash of the issue.

The modeling effort is very good in my opinion, and maybe as good at it gets with respect to model calibration using present model technology. Again the contractor was conservative on this issue by stating that the model can only be used in a relative sense. I know that there is plenty of dissent about the model calibration, validation, and verification. However, in my experience the modeling team and the model performed very well.

Responses by District Consultant:

Comments noted.

Dr. John Proni Comments:

(1) In my view the modeling approach taken, together with the present environmental data available, has yielded acceptable and reasonable results. I have no concerns regarding the methodologies used.

(2) The recommendations made are consistent with the results of the study and illustrate the difficulty of carrying out a discharge process within a biologically rich lagoon.

(3) While there are some uncertainties in acceptable habitat loss, concentrate discharge would likely result in a habitat area in opposition to the goals of the IRL restoration program.

Beyond the Final Draft Report, it appears to me that the alternative of coastal ocean concentrate discharge has now to be seriously regarded by the District. Coupled with renewable energy sources coastal ocean desalination can become attractive.

Responses by District Consultant:

Comments noted.

Ms. Jane Provancha Comments:

The effort put forth for this work was considerable and commendable by the ATM/District team. The graphic displays and maps are also very well done.

The following comments are provided for clarity and simple editorial improvements. The page numbers I use to reference the comments are based on reviewing the MS Word document which totals 165 pages and also a few references are made to the appendices within the PDF file.

In the main word document, the Executive Summary and the Conclusions section still needs a little clarification. Values related to the scenarios that resulted in changes in preferred salinity for key species were added per recommendations however, the statements do not indicate whether the changes were negative or positive (net gain or loss), leaving the reader confused as to impacts. (I believe they were all negative but not stated).

Responses by District Consultant:

The comment relative to the positive/negative components of the impacts within the Executive Summary and the Conclusions is noted and changes have been made to reflect the comments.

Editorial Comments below have been addressed

Page, Section	**Comment**
Pg 33	Spelling --- detritivore
Pg 33	Spelling ---maritima
Pg 36	“increased chlorophyll “as” vs. “is”
Pg 36	“However” not sure why using this introductory word?
Pg 42	“extert” vs.”exert”
Pg 44	Spelling---Brevoortia
Pg 44	Croaker spelling “undulates vs. undulatus”?
Pg 45	2.5.4 “draw” vs. “drawn”
Pg 46	Spelling Chelonia
Pg 46	Sea turtle --- is two words
Pg 65	3.3.5 –drop one of the uses of “evaluation” in the first sentence.
Section 5	General grammar with term“data” (were vs. was) plural nature= were
Section 5.2.3.1	Use of tense--- were vs. was throughout
Appendices-B-9	Within the legend--Spacing in words for species incorrect
Appendices B-10	Excellent graphic!

Comments on Draft TM 2G
John Windsor
June 15, 2006

Identifying additional sources of drinking water is an important mission for the District. The idea of demineralizing surface estuarine water seemed like a reasonable idea to investigate. Contractors in collaboration with District personnel have conducted a carefully crafted study of the potential impacts of the co-location of a estuarine demineralization plant with two power plants along the Indian River Lagoon.

The study was effectively carried out within the budgetary and time constraints for this project. The major conclusions drawn from the study are well supported and clearly show the difficulties in permitting facilities greater than 10MGD. Throughout the study period contractors and District staff have responded positively to requests from peer review, as well as the general public. For example, a panel of experts reviewed the IRLPLR model and suggested important modifications before using it for modeling the effects of the demineralization plants on IRL. Those recommendations included an increase the horizontal resolution of the model in the area of the discharges; an increase in the vertical resolution of the model, dynamic simulation of the temperature; a refined analyses of the freshwater inflow within the North IRL; the dynamic simulation of the demineralization plant operations relative to salinity and temperature; and, verification of the simulation of the near field circulation using measured temperatures from the existing power plants. These recommended changes were made to the IRLPLR model application by SJRWMD staff. For the purposes of this TM, this model application was termed the Indian River Lagoon Demineralization Study (IRLDS) model.

During Phase II the environmental and operational issues of concern were developed and based on those concerns a list of scenarios was developed under which to run the model to evaluate the potential environmental impacts. In addition, reasonable methodologies were developed to assess impact, and evaluate the impacts based upon the model simulations. The approaches are logically developed, based on sound scientific principles and are clearly described in the report. Although scenarios of up to 60MGD were considered, results of the model suggested far greater salinity impacts than anticipated by most at much lower demineralization rates. Therefore, much of the remaining effort focused on the impacts of the lower rates of demineralization, a logical pathway from the modeling studies.

One of the most interesting and important results of this study was the physical impact analyses (salinity) showing that the critical changes to the system occurred over a broad area of the lagoon, not simply within the immediate discharge zones of the power plants. These “far field” salinity changes became the primary issue for the ecological impact assessments. Although other issues were raised during peer review and by the general public, (e.g., chemical contaminants, manatees and others) recognizing the salinity impact, even at the lowest rates of demineralization is a very important and unexpected outcome of this study.

By recognizing the importance of this long term salinity change, the ecological assessment becomes critical. The consultants have used a statistically sound approach for describing the optimum habitat for key species of the Indian River Lagoon. The results describing the loss of optimum habitat loss provide a valuable management tool to use for assessing the feasibility of locating the demineralization facilities along the IRL.

From TM 2G "The definition of acceptable levels of preferred habitat loss is a multi-agency, high-level policy decision. This will need to be done at a time when there is a utility sponsor who wishes to proceed with a project, and the perceived need for new water supply becomes urgent and widely recognized."

The report presents valuable modeling results and an important data set that can be used as a management tool. The discussion of acceptable habitat loss is beyond the scope of this project, although the report does contain some relevant literature that may be used to defend a variety of acceptable habitat losses. Many citizens and resource managers along the Indian River Lagoon, an estuary of national significance, would suggest that no net loss of habitat would be acceptable. The contractor's position on acceptable habitat loss is a valid one and they should not be required to define acceptable habitat losses as part of this work.

More specific details are included on the attached marked up copy. Some of the more important points, which should be addressed, are also included below. Comments are presented sequentially as they appear in the report, not by priority. Text in quotation marks/italicized are take directly from the report. I've deleted sections where I have no comments. While I was reading the document, I also included a few editorial comments/changes where I noticed them. Two minor (to some) editorial points are the frequency of starting sentences with it is, it was, there is, there are…, and consistency in format. Examples of consistency comments include use of data as singular and plural throughout the report and changing caps vs. no caps (inlet is an interesting example). I've pointed out a few of these in the attached text but you may wish to do some global search and replace on some of these editorial comments. Minor editorial points like this sometimes diminish the overall quality of this otherwise excellent study.

Dr. Windsor provided a copy of the text with revisions. These changes have been incorporated into the report.

Table 4. I know that the Q's are segmented by salinity but the table appears to contain values in ppt rather than % because ppt is placed at the top of each column of data; perhaps add % to each value.

The table will be changed in the report.

Do you really believe that there is a "dissolved" ferric iron problem with lagoon water? Is the problem for the membranes fine particle formation?

Page 77. Many of the applications of RO are for ground water which has relatively high concentrations of dissolved ferrous iron which rapidly is converted to ferric iron. IRL feedwater will not be similar to saline ground water.

The discussion in the text refers to the addition of iron in the pretreatment process. The feedwater discussed is therefore after pretreatment where the iron was added. The discussion does not relate to the potential for iron in the intake water.

Forchammer's Principle aka Marcet's Principle, is for seawater. Most good oceanography books have great sections on exceptions to Marcet's Principle. One of the most notable exceptions to Marcet's Principle is estuaries. I'm not comfortable with the repeating "constant proportions" in the report. Variations in major ion ratios can have some interesting effects on optimum habitats for species also. One assumption of this study is that variations in salinity are reflecting variations in all the major ions. This may or may not be the case so I would always include a waffle word like nearly with any use of constant.

Comment noted. Changes will be made within the text to reflect this comment.

Page 79 I don't see the value of the Venice System discussion here? Maybe the relevance of the bullets needs to be made clearer?

The Venice system discussion here simply provides a breakdown of estuary types based upon salinity. As this project is focused on changes in salinity, providing a reference which categorizes various levels, allows some reference point when discussions of salinity changes is provided.

Page 81 "Saturation decreases as both temperature and salinity increase (Richards, 1957)." I made this comment in earlier draft but it still has not been fixed. If I warm a volume of water of known oxygen concentration the solubility of the oxygen decreases. However, equilibrium is not achieved instantly. So until equilibrium is achieved with the atmosphere or another water body the SATURATION of the oxygen actually increases until equilibrium is achieved. I strongly recommend that you replace increases and decreases in saturation with increases or decreases in solubility. Then you can relate the solubility change to an increase or decrease in saturation. If you don't understand this comment please feel free to call me. Page 81

Change will be made.

Page 130 "After review of the available datasets, it was determined that two of the stations in the FDEP STORET IWR dataset (Figure 7) contained the parameters under evaluation. These two stations are Station 21FLA27010876 to the north of the power plants and Station 21FLA27010581 to the south of the power plants. The data for these two stations are reflected in Table 10. The STORET data available were primarily reported from 1991 to 1998, and samples sizes were relatively small."

These data are flawed and I've made the comments about them in earlier written comments and our phone review of the draft reports. Because the dissolved metal data is far too high then any suggestion of increasing the concentration would prevent this project from going forward. Of course the contractor is "stuck" with these data because they exist in "the" data base. I think that if valid data were used no concerns about increased metal concentrations would arise. My biggest concern at this point is that the statements about poor water quality existing now have been left with the public. The idea that a demineralization project would exacerbate an already unacceptable chemical contamination condition has been left with the public. Now that this bell has been rung (incorrectly) how do we go about unringing the bell? The wrong message has gone out, it means little to this project or report but the District and the contractors bear some responsibility in trying to rectify this situation.

Language has been added to the final report that reflects this concern and brings the data into question.

Page 157 "Assessment of potential concentration of pollutants showed that compared to baseline conditions, for some key parameters, water quality criteria may be violated." This paragraph needs to be revised for the final draft taking into consideration the invalid metal data used for the assessment and the perception left with the public about the contaminated nature of this water body.

Language has been added to the final report that reflects the potential errors in the data, but the statements such as above have not been removed as the data is what is available. This was based upon District recommendation.

Page 159 "The definition of acceptable levels of preferred habitat loss is a multi-agency, high-level policy decision." This seems to be a pretty minimal statement which is made both in the executive summary and the conclusions. Perhaps you should add that this study can tell what level of loss is likely but can not define what is acceptable and what is not acceptable? This will need to be done at a time when there is a utility sponsor who wishes to proceed with a project, and the perceived need for new water supply becomes urgent and widely recognized.

Comment acknowledged. Presently, this language is how the District would like this issue stated.

Comments made about the wide salinity tolerances of organisms are confusing in light of the loss of habitat which results from small salinity changes. These comments were made earlier in the report and should also be addressed here.

It should be noted that the "loss of habitat" referred to in the document is the loss of "preferred habitat". While many of these organisms do tolerate a wide range of salinity conditions, they have preferred ranges of salinity. The losses shown do not reflect where organisms will disappear, but rather where the project moves them out of their preferred range, which may have more long-term consequences. Additionally, the changes due to the plant will be consistent and long-term where the salinity variations are more temporal.