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SUMMARY OF AOML OCEANOGRAPHIC INFORMATION INVENTORY AND LITERATURE REVIEW SUPPORTING A DEMINERALIZATION CONCENTRATE OCEAN OUTFALL FEASIBILITY STUDY

Technical Memorandum

Summary of AOML Oceanographic Information Inventory and Literature Review Supporting a Demineralization Concentrate Ocean Outfall Feasibility Study

Prepared for

St. Johns River Water Management District

Prepared by

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EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) is in the process of guiding long-term water supply planning within its jurisdictional boundaries, and in 2000, completed the District Water Supply Plan (DWSP) addressing alternative approaches to meeting water supply demands projected through the year 2020. The DWSP addresses a number of water supply management strategies, and one of them is support for emerging potable water treatment technologies. Raw water treatment using several alternative membrane technologies is one of the more promising of these options. Demineralization methods produce a wastewater concentrate that bears elevated concentrations of minerals. Identifying an environmentally approvable concentrate disposal method is the primary impediment to gaining necessary regulatory approvals for demineralization treatment plant installation and operation.

Management of concentrate by discharge to surface waters through an ocean outfall is an option, but concerns exist regarding technical, regulatory, and economic feasibility. In the interest of better defining the feasibility of ocean outfall disposal of concentrate from water treatment plants located along the Atlantic Ocean coastline within its jurisdiction, SJRWMD initiated a phased investigation designed to help utilities understand the relevant issues as they prepare and subsequently implement their respective long-term water supply plans.

The subject investigation was designed in collaboration with the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanographic and Atmospheric Administration (NOAA). An interagency agreement detailing the administrative arrangements as well as the scope and budget allocation for this preliminary investigation was executed in early 2004. The information inventory and literature review were performed by AOML from April 2004 to January 2005.

In May 2005, SJRWMD retained CH2M HILL to review the AOML draft deliverable, and prepare a summary document to capture the key findings into a Technical Memorandum geared toward SJRWMD's constituents. This Technical Memorandum presents a summary of key physical oceanographic information presented in

the AOML deliverable relevant to addressing concentrate ocean outfall feasibility.

The AOML information inventory and literature review focused on physical oceanographic characteristics considered relevant to determining how a concentrate discharged through an ocean outfall would be dispersed in the receiving water body. AOML's experience with ocean outfall studies and modeling of effluent plumes led it to focus in on the following types of parameters:

- Bathymetry
- Water column temperature and salinity profiles (for calculation of density profiles)
- Current velocity and direction as a function of depth within the water column
- Effects of inlets or coastline variations impacting nearshore physical conditions (currents and waves)

AOML also sought information regarding sediment characteristics and biological survey records in that they might be relevant to future siting of outfalls. The approach taken to identify sources of relevant information consisted of:

- Internet Searches
- Published Literature Review
- Interagency and Research Institution Contacts

The internet searches identified one set of useful information, a multi-year record of physical oceanographic parameters generated by a data collection program at a site approximately a half-mile offshore of Melbourne Beach. These records were collected by a contractor working on behalf of the Florida Department of Environmental Protection (FDEP) Division of Beaches and Shores, with the intent of supporting future beach re-nourishment projects for Melbourne Beach. A bottom-mounted acoustic Doppler current profiler (ADCP) has produced detailed water column density and current velocity metrics, and wave dynamics information, since its deployment in 2001. These records are representative of the types of key information typically required to support ocean outfall investigations with respect to existing state and/or federal regulations.

Searches of the published literature were not productive in terms of identifying information directly relevant to SJRWMD's study area focus, coastal ocean waters within the 3-mile state of Florida jurisdictional limits. Information retrieved from the literature pertained to more offshore environments that fall within federal jurisdiction, and consequently these were not reviewed in detail but rather were archived for future reference should concerns ultimately shift to these deeper waters further offshore.

Interagency communications and contacts with academic and research institutions were made with only limited success in terms of locating relevant datasets considered as useful reference material relevant to concentrate ocean outfall feasibility evaluations within the study area. AOML had participated in two relevant data gathering activities within the study area: near Cape Canaveral and near the Ft. Pierce Inlet. These AOML data gathering programs included physical oceanographic measurements including water column profiles of ambient current velocity and direction over reasonably extended periods of time supporting statistical characterization of some of the key parameters often used in outfall-related hydrodynamic modeling. Representative data presentations addressing current velocity and direction for these two coastal locations are provided as examples of the types of information that can be gleaned using ADCP units. These types of data are likely the kinds of information that would be needed to support hydrodynamic evaluations using models during the course of future, more detailed outfall feasibility evaluations and/or actual permit applications for outfalls that might be proposed by individual county or municipal utilities. The graphics provided serve as examples of the information that should be produced by future data gathering efforts when and where they are implemented in support of future phases of SJRWMD's outfall feasibility evaluations, or during future site-specific investigations by utilities interested in outfall siting, design, and permitting.

The AOML information inventory and literature review leads to the conclusion that detailed, long-term physical oceanographic datasets focused on ambient current velocity and direction records, and water column profiles of density-related parameters are not available for much, if not most, of the Northeast and Central Florida Atlantic coastal waters. As originally envisioned, Phase 2 of this overall investigation was intended to include

focused field data gathering to supplement the results of this information inventory and literature review. Field investigation concepts are being developed by AOML for SJRWMD's review and approval, and to promote further discussions with FDEP and perhaps other stakeholders regarding how, where, and when to conduct those field investigations.

Activities underway are leading in the direction of development of specific research proposals for up to three candidate sites along the Atlantic coast of SJRWMD, and depending on the interaction of factors including scope, locations, schedule, funding availability, and the interest of prospective stakeholder partners, final decisions regarding those field investigations will be made in the future. In the interim, the following recommendations are offered for SJRWMD's review and consideration:

1. SJRWMD should proceed with further discussions with FDEP regarding policy and rule constraints on the permitability of new ocean outfalls within coastal ocean waters (within 3 miles from shore). A working meeting with FDEP should be conducted to discuss regulatory issues and data gathering priorities as an element of the ongoing assembly of field investigation recommendations (or other analytical suggestions) that should be considered by SJRWMD for implementation in support of outfall feasibility evaluations.

2. SJRWMD should continue dialogue with federal and state agencies, or with academic/research institutions or consulting firms working on behalf of such agencies, to determine the availability of additional physical oceanographic datasets for areas north of Cape Canaveral. These follow-up communications might identify information that was not releasable at the time of original contact by AOML, but that has since been cleared for release.

3. SJRWMD should consider alternative funding mechanisms for prospective modeling or field investigations that are likely to be included in the set of recommendations being developed regarding Phase 2 project activities. On the basis of SJRWMD's preliminary project discussions with AOML, it is clear that these activities likely to be proposed as elements of the Phase 2 investigations are going to require funding allocations well in excess of those envisioned at the onset of Phase 1. Therefore, to enable SJRWMD to make future project

scope and budget allocation decisions, it would be advisable to begin discussions now regarding what potential supplemental funding sources could be appropriate. Candidate concepts include but are not limited to some combination of the following:

- *Ad valorem* tax revenue allocations
- Allocations from Legislative funding for alternative water supply development
- Identification of specific county or municipal utilities interested in co-funding the follow-up investigations SJRWMD ultimately approves and elects to implement
- Pursuit of other potential state or federal grants to at least partially fund these types of water supply development programs
- Partnering agreements with federal or state agencies for collaborative studies through in-kind service support, equipment, research vessel and staff time, or other forms of contributions toward investigation planning, management, and execution.

It seems clear that demineralization processes will likely need to be a part of the long-term water supply strategy for achieving sustainable development within SJRWMD, and perhaps state-wide. Therefore, it is critically important to continue to investigate what engineering and environmental strategies are needed to identify administratively approvable infrastructure that supports achieving this long-term goal. This investigation is a critical element of SJRWMD's technical support services being provided to its constituents that are responsible for long-term water supply planning and implementation. Continued commitment to these project activities is clearly justified.

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ACRONYMS AND ABBREVIATIONS

ADCP	acoustic Doppler current profiler
AOML	Atlantic Oceanographic and Meteorological Laboratory
cm/sec	centimeter(s) per second
DWSP	District Water Supply Plan
EPA	U.S. Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
mm/sec	millimeter(s) per second
NESDIS	National Environment, Satellite, Data and Information Service
NOAA	National Oceanographic and Atmosphere Administration
TBELs	technology-based effluent limits
TM	technical memorandum
USACE	U.S. Army Corps of Engineers
WQBELs	water-quality-based effluent limits
WTP	water treatment plant
WWTP	wastewater treatment plant

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) is in the process of guiding long-term water supply planning by utilities, agricultural interests, and industrial facilities located within its jurisdictional boundaries. SJRWMD completed the District Water Supply Plan (DWSP) in 2000. That document addresses alternative approaches to meeting water supply demands projected through the year 2020. Pursuant to the requirements of Subparagraph 373.536, Florida Statutes, SJRWMD is currently engaged in generating a 5-year update for DWSP.

DWSP addresses a number of water supply management strategies, and one of them is support for emerging potable water treatment technologies. Raw water treatment using several alternative membrane technologies is one of the more promising of these options. A broader range of prospective raw water sources can be considered with these state-of-the-art water treatment methods, and greater assurance is achieved regarding compliance with existing and prospective federal drinking water standards.

These types of water treatment technologies generate potable waters that comply with the primary and secondary drinking water standards through processes that physically separate undesired water quality constituents naturally present in the raw source water from the finished potable water. In the separation process, these demineralization methods produce a wastewater concentrate that bears elevated concentrations of minerals. Identifying an environmentally approvable concentrate disposal method is the primary impediment to gaining necessary regulatory approvals for demineralization treatment plant installation and operation.

Concentrate management options were evaluated in prior phases of SJRWMD's water supply planning process (Reiss Environmental 2003). Management of concentrate by discharge to surface waters through an ocean outfall was identified as a possible option, but concerns existed regarding technical, regulatory, and economic feasibility. In the interest of better defining the feasibility of ocean outfall disposal of concentrate from water treatment plants (WTPs) along the Atlantic Ocean coastline within its jurisdiction, SJRWMD initiated a phased investigation designed to help utilities understand the relevant issues as they

prepare and subsequently implement their respective long-term water supply plans.

SJRWMD designed the subject investigation in collaboration with the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanographic and Atmospheric Administration (NOAA).

An interagency agreement detailing the administrative arrangements as well as the scope and budget allocation for this preliminary investigation was executed in early 2004.

The scope of the AOML investigation included the phases and tasks outlined as follows:

- Phase 1 – Information Development and Planning
  - Task 1 – Project Kickoff Meeting
  - Task 2 – Literature and Data Review
  - Task 3 – Evaluation of Additional Information Needs
- Phase 2 – Initial Data Acquisition and Related Technical Activities
  - Task 4 – Planning and Deployment of Instruments
  - Task 5 – Data Acquisition
  - Task 6 – Phase 2 Report Preparation

Tasks 1 and 2 were performed by AOML from April 2004 to January 2005. The AOML information inventory and literature review focused on physical oceanographic characteristics considered relevant to determining how a concentrate discharged through an ocean outfall would be dispersed in the receiving water body. AOML's experience with ocean outfall studies and modeling of effluent plumes led it to focus in on the following types of parameters:

- Bathymetry
- Water column temperature and salinity profiles (for calculation of density profiles)
- Current velocity and direction as a function of depth within the water column
- Effects of inlets or coastline variations impacting nearshore physical conditions (currents and waves)

AOML also sought information regarding sediment characteristics and biological survey records in that they might be relevant to future siting of outfalls.

The AOML draft Task 2 deliverable provides useful technical reference information, and is provided as Appendix A. In May 2005, SJRWMD retained CH2M HILL to review AOML's draft Task 2 deliverable, and prepare a summary document to capture the key findings into a Technical Memorandum geared toward SJRWMD's constituents.

This CH2M HILL Technical Memorandum is a summary of key findings presented in the AOML deliverable relevant to addressing concentrate ocean outfall feasibility. It provides a brief overview of the process applied by AOML in conducting the information inventory and literature review. It also provides a brief summary of the types of key datasets found by AOML, and presented graphically in the draft Phase I, Task 2 deliverable. All of the graphics contained in this Technical Memorandum were generated by AOML.

CH2M HILL's conclusions and recommendations derived from AOML's data inventory and literature review are also presented, as well as a listing of the published documents AOML cited as references consulted during the course of its Phase 1 work efforts.

On the basis of the information located and reviewed to date, recommendations are in preparation regarding what additional investigations might be warranted under Phase 2 of this feasibility study. SJRWMD has requested that CH2M HILL and AOML work together to assemble recommendations to be compiled as a collaborative project deliverable under the work originally envisioned under Phase 1, Task 3. Generation of that deliverable will be completed by mid September 2005.

PROCESS OVERVIEW

The AOML approach taken to identify sources of relevant information consisted of:

- Internet searches
- Published literature review
- Interagency and research institution contacts

These are described in the following subsections.

Early during the information inventory and literature review process, a distinction was made between oceanographic waters falling into the jurisdiction of the federal government as opposed to those where the State of Florida has primary regulatory authority over designated uses. For the purposes of this investigation, waters located within 3 miles from the shoreline are considered coastal oceanic waters under the jurisdiction of the Florida Department of Environmental Protection (FDEP). Offshore waters beyond the 3-mile boundary are still waters of the United States but under the primary jurisdiction of the U.S. Environmental Protection Agency (EPA). Unless otherwise specified, the remaining portions of this document are focused primarily on information relevant to evaluating the overall feasibility of gaining agency approvals for prospective concentrate outfalls to the nearshore waters within FDEP's jurisdiction.

INTERNET SEARCHES

An initial Internet search was conducted by AOML on Google and Netscape using a selected set of key words in combination. AOML's Internet search was focused on key coastal ocean physical parameters and measurements likely relevant to modeling analyses FDEP typically requires during regulatory review of existing or proposed outfalls to open ocean or coastal environments. Table 1 provides a listing of the key words used singly or in combination by AOML for these internet searches.

Table 1. Examples of Key Words Used by AOML in Internet Searches

Demineralization Concentrate Ocean Outfall Feasibility Study

Key Words Used
Florida coastal ocean
Northeast Florida coastal ocean
Ambient currents
Ambient water column density profiles
Water depth
Prevailing wind speed and direction
Indian River Lagoon
Coastal Ocean

Initial general Internet searches using various combinations of the key search words produced hundreds of sites containing the key search words. However, in nearly all cases, AOML indicated those alternative sites were of limited value in terms of generating actual data deemed important for this investigation.

A single internet site of value was located through AOML's internet searches. The FDEP site displaying the web page of the Bureau of Beaches and Coastal Systems (http://www.dep.state.fl.us/beaches/data/wav-wea.htm) provided data recorded from a wave gauge located in the coastal ocean adjacent to Melbourne Beach.

The wave gauge is an acoustic Doppler current profiler (ADCP) device that was deployed in 2001. The FDEP website indicates the following:

> *Wave and current data [are] collected with an RD Instruments 1200 KHz ADCP located approximately 670 meters offshore of Spessard Holland Park in Melbourne Beach, FL. The water depth at the gauge is approximately 8 meters. The wave sampling period is 20-minutes every 2 hours. Current and tide data are collected continuously.*
>
> *Hs Significant Wave Height = 4*sqrt (area under the power spectrum)*
>
> *Tp Peak period = Wave period associated with the largest peak in the power spectrum*

Dp Peak Direction = peak direction from magnetic north at the peak period.

All Times Eastern Standard Time.

The anemometer accuracy is +/- 0.3 m/s. Directional accuracy is +/- 3 deg. The wind is sampled at 2Hz (twice per second) and recorded as an 8 minute average.

The Gauge is operated and maintained by:

Dr. William Dally
Surfbreak Engineering Sciences Inc.
(321) 733-2296

These data are discussed further in the section titled, "Oceanographic Information Summary" on page 9.

PUBLISHED LITERATURE REVIEW

AOML's review of the published, peer-reviewed scientific literature produced no papers with data directly relevant to the near-shore coastal environments of the study area. However, Taylor and Stewart (1959), and Smith (1983) provided information on documented upwelling events that affected the deeper waters of the continental shelf adjacent to SJRWMD. The significance of the occasional presence of upwelled water is twofold:

- Upwelled water could affect the water column density profile and thus impact concentrate plume dilution if a concentrate outfall were located far enough from shore and in an area influenced by upwelling
- Upwelled water can be rich in nutrients and could affect biological processes in waters adjacent to ocean outfalls located far enough from shore and in an area influenced by upwelling

Additional citations were found addressing offshore Gulf Stream-related ambient current effects. These publications were not all Florida-specific, and generally addressed conditions in habitats that were on the order of at least 10 miles offshore. Lee et al. (1977), Lee et al. (1984), and Smith (1982 and 1987) indicated that the Gulf Stream-related ambient current effects in the near-shore coastal waters are limited. From the perspective of plume dilution prospects, the effect of the Gulf Stream currents appears to be insignificant in coastal waters (within 3 miles from shore) adjacent to SJRWMD.

INTERAGENCY AND RESEARCH INSTITUTION CONTACTS

AOML's efforts toward inventory and retrieval of relevant oceanographic datasets included correspondence and direct personal contacts with interagency representatives and/or individuals affiliated with academic or research institutions. Table 2 provides a listing of the agencies/institutions and individuals contacted in this regard.

Table 2. Interagency and Academic/Research Institution Contacts Made by AOML
Demineralization Concentrate Ocean Outfall Feasibility Study

Agency/Institution	Person(s) Contacted (Name and Title)	Date/Type of Contact	Response/Relevant Findings
U.S. Environmental Protection Agency, Region IV	Dr. Roland Ferry, Biologist	Multiple contacts between January 2004 and June 2005	Only limited EPA-generated data. Confirmed division of regulatory jurisdictional authority with the State of Florida occurs at the 3 miles offshore distance.
U.S. Army Corps of Engineers, Jacksonville District	Mr. Glenn Schuster	Multiple contacts between January 2004 and June 2005	Discussions focused on the limited data gathered and held by the USACE for this study area.
U.S. National Marine Fisheries Service	Dr. Joan Browder, Fisheries Ecologist	Multiple contacts between January 2004 and June 2005	Some fisheries data are available on fish species in coastal lagoons and adjacent coastal ocean. Discussed NMFS interests (regulatory and regulatory review).
Florida Department of Environmental Protection	Mr. Jan Mandrup-Poulson, Environmental Administrator Mr. Richard Drew, Bureau Chief	Multiple contacts between January 2004 and June 2005 Multiple contacts between January 2004 and June 2005	Provided extensive information on the FDEP database incorporating most of the known sources of data in Florida Coastal Waters Provided insight into data relevant to concentrate discharge.
Florida Institute of Technology, Department of Marine Environmental Science (DMES).	Dr George Maul, Department Chair Dr. Lee Harris, Professor	Meeting on May 13, 2004 ---	No relevant datasets. Collecting physical oceanographic data for a site near the Sebastian Inlet.
Harbor Branch Institute of Oceanography	Dr. Ned Smith, Principal Investigator	---	No known long-term physical oceanographic datasets for near shore coastal environments along the Northeast and Central Florida Atlantic coast.
Brevard County, Environmental Section	Mr. John Royal, Section Head	Multiple contacts between January 2004 and June 2005	Indicated little Brevard County data available in the coastal ocean.

Because of the location of Cape Canaveral, Patrick Air Force Base, and two U.S. Navy submarine bases within this area of the SJRWMD, one might think that the National Aeronautics and Space Administration (NASA), U.S. Air Force, and U.S. Navy should have ambient current and other environmental data. So far, however, although AOML inquiries have been made of the above agencies, no replies have been received (as of July 13, 2005).

In addition to the above contacts, it is noted that AOML itself is a key agency source of relevant information, and in fact some of the information most relevant to the topic of this preliminary investigation was retrieved from AOML's own files. The data records considered most relevant to this investigation are described in section titled, "Oceanographic Information Summary" on page 9.

OCEANOGRAPHIC INFORMATION SUMMARY

BACKGROUND

The AOML search targeted physical oceanographic data relevant to SJRWMD's concentrate ocean outfall feasibility study. Information categories sought were known to be closely related to modeling evaluations typically conducted during the course of ocean outfall evaluations and permitting by either FDEP and/or EPA.

Regulatory approvals hinge on either meeting all technology-based effluent limits (TBELs) and the applicable water quality standards at the "end of pipe" compliance monitoring point, or gaining agency authorizations for "water-quality-based effluent limits" (WQBELs). WQBELs provide some measure of relief from end of pipe compliance, but are only granted following agency conclusion that the permit holder has provided reasonable assurance that the receiving water body either has:

- Sufficient wasteload assimilative capacity to receive the effluent without irreparable harm to the environment
- Adequate physical mixing conditions, even under "worst-case" discharge scenarios, to ensure that compliance with the applicable standards is achieved within an administratively defined mixing zone

The vast majority of ocean outfalls in the United States are used for discharge of freshwater effluents from municipal or industrial wastewater treatment plants (WWTPs). The freshwater effluents are typically warmer than the receiving waters, and the net effect of these factors is that most effluent plumes are less dense than the receiving water, and therefore are positively buoyant in coastal ocean waters. Density-related plume rise through the receiving water is a key factor that achieves short-term plume dilution immediately following discharge. Key receiving water factors applied in hydrodynamic modeling of effluent plume behavior within receiving waters, therefore, include:

- Distance from the nearest shoreline-related features influencing local current patterns or wave energy patterns

- Depth
- Water column temperature and salinity conditions (leading to ambient water column density profile)
- Tidal influence
- Prevailing current speed and direction
- Prevailing wind speed and direction

Demineralization treatment processes generate concentrate that is physically divergent from typical WWTP effluents. While temperatures are often still substantively higher than those in the receiving water, the elevated concentration of minerals results in concentrate densities that are greater than many, if not most, coastal receiving waters. Thus, the prospects for having to manage a negatively buoyant (sinking) plume are high. The parameters listed above remain key, but the modeling of discharge scenarios will need to address a range of possible concentrate-to-receiving-water density relationships. Additionally, the design of the high-rate diffusers presumably needed for such outfalls will be key to achieving adequate dilution near the outfall (aka nearfield dilution).

Typically, long-term and continuous receiving water data records are preferred over short-term and sporadic periods of record to address short-term (lunar cycle) as well as seasonal variability in the applicable physical oceanographic parameters. The AOML data inventory and subsequent review was not rigidly limited to any pre-defined minimum period of record, but priority was placed on locating database information with sufficient robustness to allow statistical analysis of these key parameters in terms of defining "worst-case" values that FDEP would typically require to be applied in outfall modeling evaluations supporting formal permit applications.

It is important to acknowledge that SJRWMD's information needs linked to this feasibility study are different from those of a prospective utility applicant for a specific outfall. SJRWMD is engaged in long-range planning evaluations that are to have value to SJRWMD's constituents as they develop their respective capital improvement plans for meeting future water supply demands. This distinction allowed SJRWMD's oceanographic data inventory and review to remain focused on planning-level, rather than permitting-level, detail. Accordingly, AOML's data

and literature review were conducted at this planning level with the intent of gaining a general sense of the range of physical oceanographic parameter values that might occur at differing distances from shore and depths within the water column.

AOML's internet searches, peer-reviewed literature searches, university and research institution contacts, federal government contacts, and state government contacts, revealed the existence of several datasets it considered of value to SJRWMD's study. Criteria applied in making this decision included that data were available for sufficient duration, at an adequate frequency of sampling, at relevant locations, and for appropriate coastal ocean measurement parameters.

One of the key sets of information available for SJRWMD's entire coastal waters is bathymetry. AOML's geographic information system (GIS) contains a comprehensive set of information regarding depth of water from the shoreline to beyond the continental shelf. Figure 1 depicts these composite data drawn from multiple surveys conducted over time for the study area ranging from Nassau County to Indian River County. This figure depicts that in the southern portions of the study area, the shelf is relatively narrow, and there are some locations south of Cape Canaveral where potentially favorable depths occur reasonably close to shore. North of Cape Canaveral, the shelf is much broader and to reach deeper waters, one needs to move much further offshore of Nassau County.

Figure 2 is a more focused depiction of relevant bathymetry data, in this case limited to areas within 10 nautical miles from shore. In this particular exhibit, bottom areas colored in the darker shades of blue identify areas where deeper waters are encountered close to shore. It is likely that these deeper areas near the shore might be among the candidate zones where new ocean outfalls might be constructed more cost-effectively because of the shorter outfall pipe lengths that might be needed. Deeper waters translate to more water volume within which dispersion is possible. Depth is not the only parameter, but it could be a key one.

Figure 1. Bathymetry of Near Shore Waters Off of the St. Johns River Water Management District, Nassau to Indian River Counties, Florida

(Source: Hector Casanova, personal communication, AOML)

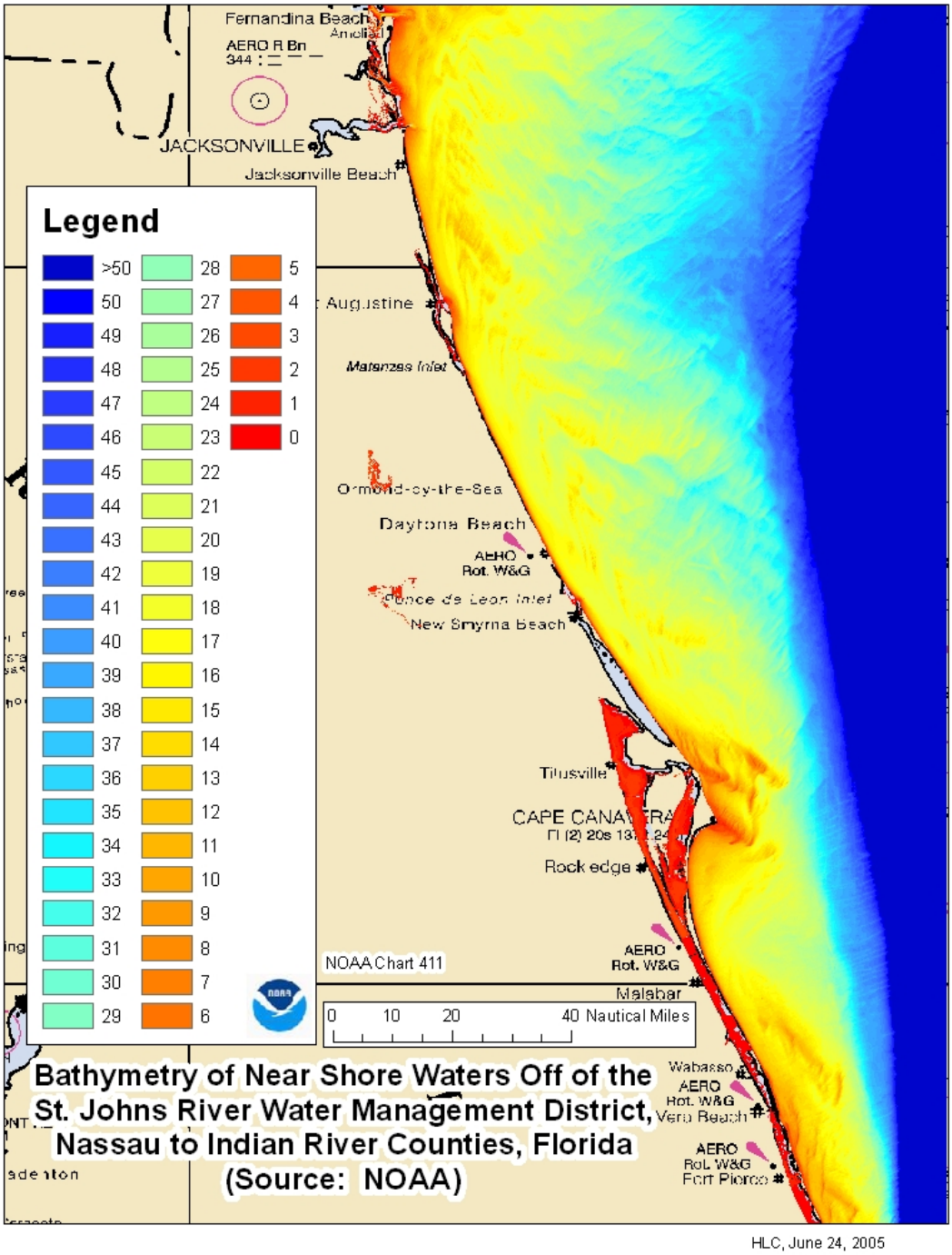
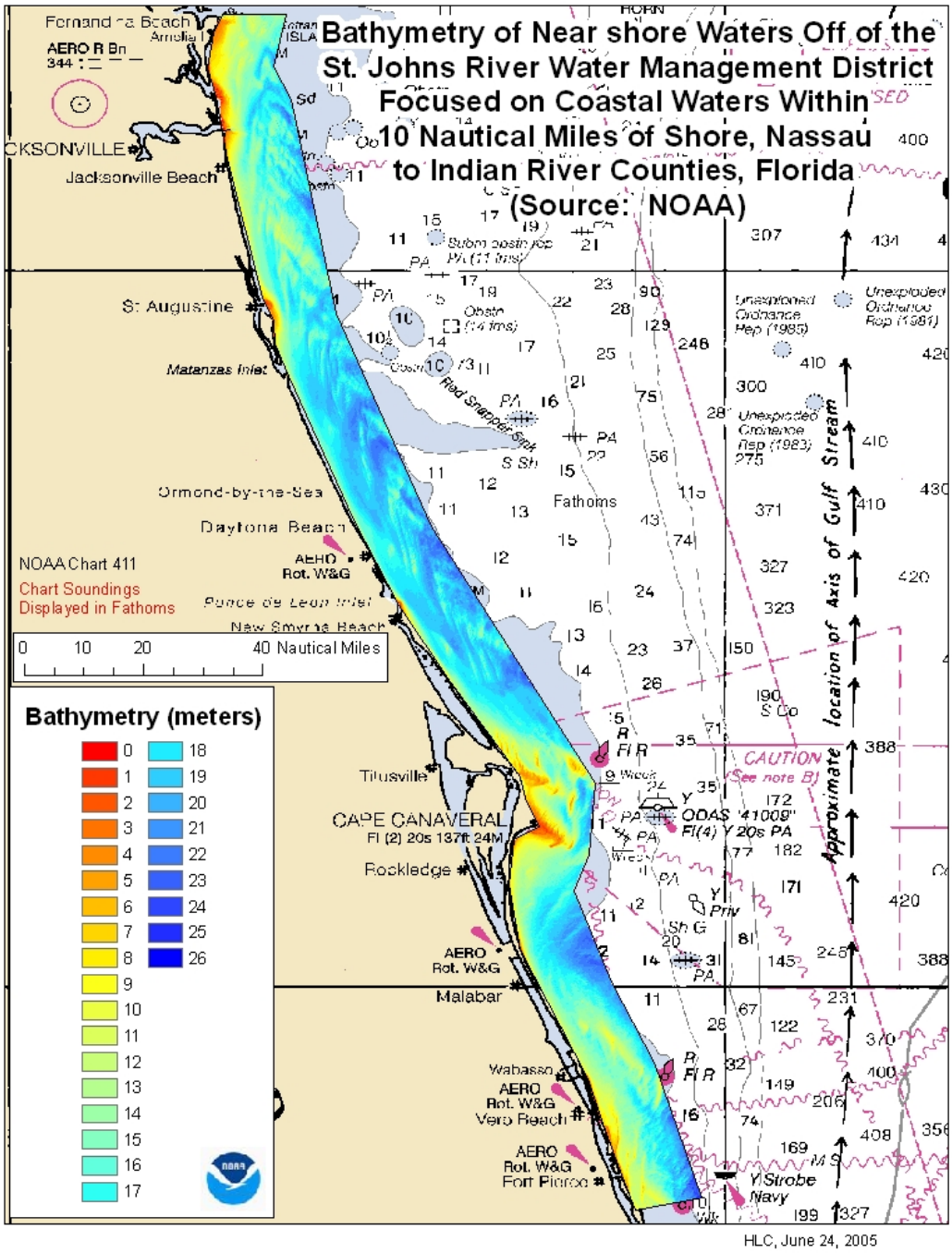


Figure 2. Bathymetry of Near Shore Waters Off of the St. Johns River Water Management District Within 10 Nautical Miles of Shore, Nassau to Indian River Counties, Florida

(Source: Hector Casanova, personal communication, AOML)



On the basis of the AOML information inventory, data regarding all of the key parameters (depth, current velocity and direction, etc.) for substantive time periods were available for only three specific sites within the study area. These data were gathered at the following locations:

- A location 2.6 miles offshore of Cocoa Beach from January 2003 to January 2004. Data are representative of conditions off of Cocoa Beach at a coastal ocean water depth of approximately 15 meters. These records were collected by EPA in support of evaluations of proposed offshore dredged material disposal areas.
- A location approximately 0.5 miles offshore of Melbourne Beach for a 3-year period beginning in 2001. Data were obtained from instrumentation deployed at a depth of approximately 8 meters. These records were collected by a contractor working on behalf of the FDEP Division of Beaches and Shores, with the intent of supporting future beach re-nourishment projects for Melbourne Beach.
- A site located approximately 1 mile from Ft. Pierce inlet for 1-month period in 2000 and for 2 months in 2002. Data were gathered at a water depth of approximately 15 meters. These records were collected by AOML in support of U.S. Army Corps of Engineers (USACE) evaluations of proposed offshore dredged material disposal areas.

These data collection programs generated similar types of data-sets pertaining to physical oceanographic metrics relevant to potential concentrate plume fate and transport.

To illustrate the character of the data typically used to support dilution calculations and for worst-case dilution estimates for FDEP, some data are presented below from the Cape Canaveral study conducted by AOML on behalf of EPA. Figures 3 through 11 were generated by AOML using unpublished data from the Cape Canaveral study, and thus are not peer-reviewed. However, they are instructive in that they help provide useful perspectives on the types of data collection involved in oceanographic studies, and how those support outfall evaluations.

Figure 3 shows a bottom topography map for the coastal ocean in the vicinity of Cape Canaveral. This map was obtained from the AOML National Environmental, Satellite, Data and Information Service (NESDIS 2004). Sub-ocean surface extensions of the Cape

Canaveral topography are clearly seen to be present. The star symbol on the map marks the spot approximately 2.6 miles seaward of Cocoa Beach where a bottom-mounted ADCP was deployed from January 2003 through January 2004. The depth of deployment of the ADCP unit was approximately 15 meters, and the nature of this type of instrumentation allows for collection of extensive time series records of depth, water column profiles of salinity and temperature, and depth-based profiles of ambient current speed and direction. As exemplified in Figure 3, the robust datasets produced by ADCP units of this type allow for detailed dissection of the records that support an extremely detailed understanding of the physical parameter time series over both short- and long-term periods.

In this specific case, these data were gathered south of the areas representing the offshore extension of Cape Canaveral and therefore may or may not be representative of typical ambient conditions elsewhere offshore of SJRWMD. That said, the following figures are provided to illustrate the point that this level of instrumentation deployment supports extensive dataset production.

Figure 3. Side Scan Sonar Records of Cape Canaveral Topography and Depths, With Location of ADCP Deployment Indicated (see Star Symbol)

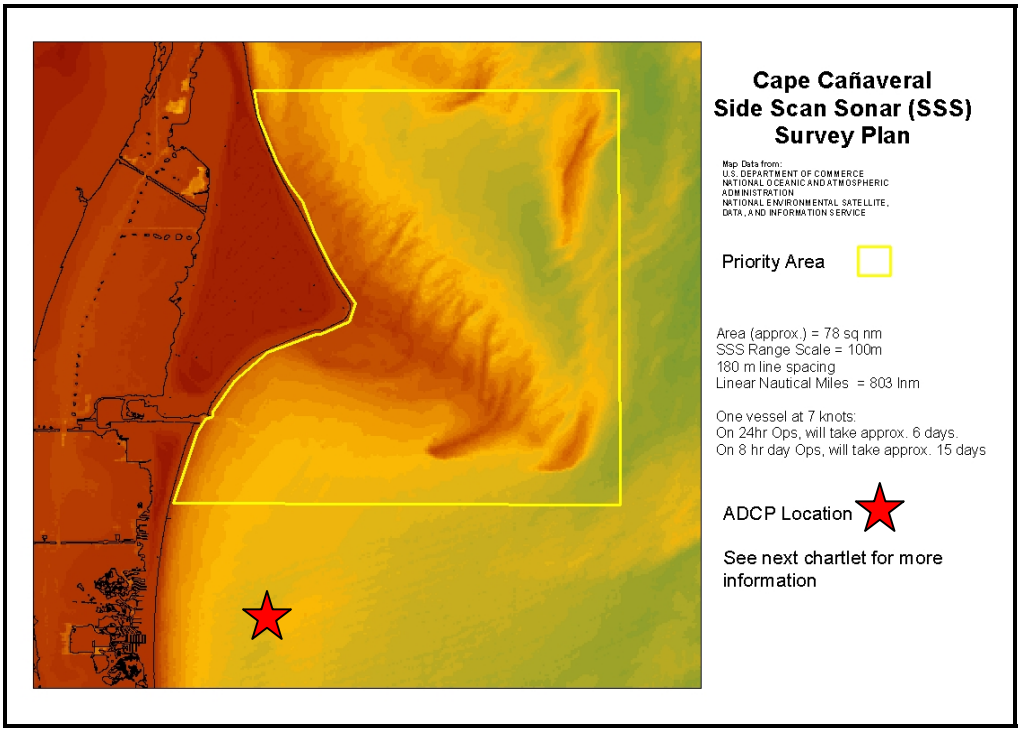


Figure 4 depicts the variations in water depth over the ADCP unit for the example month of April 2003. From this figure, it can be seen that the water column heights over the ADCP ranged from approximately 13.8 meters to 15.4 meters, indicating that there is as much as a 1.6-meter tidal fluctuation in water depth in this vicinity during spring tide conditions. Under neap tide conditions, this tidal influence is on the order of 0.5 meters. In terms of ramifications on ocean outfall feasibility evaluations, FDEP would typically wish to have mixing zone evaluations address scenarios where minimal tidal mixing energy would apply (e.g, neap tide conditions).

Figure 4. Example Summary of Tidal Range during April 2003 at a Coastal Ocean Location Approximately 2.6 Miles Offshore of Cape Canaveral

(note: Z represents depth over the ADCP unit. Data Source: AOML)

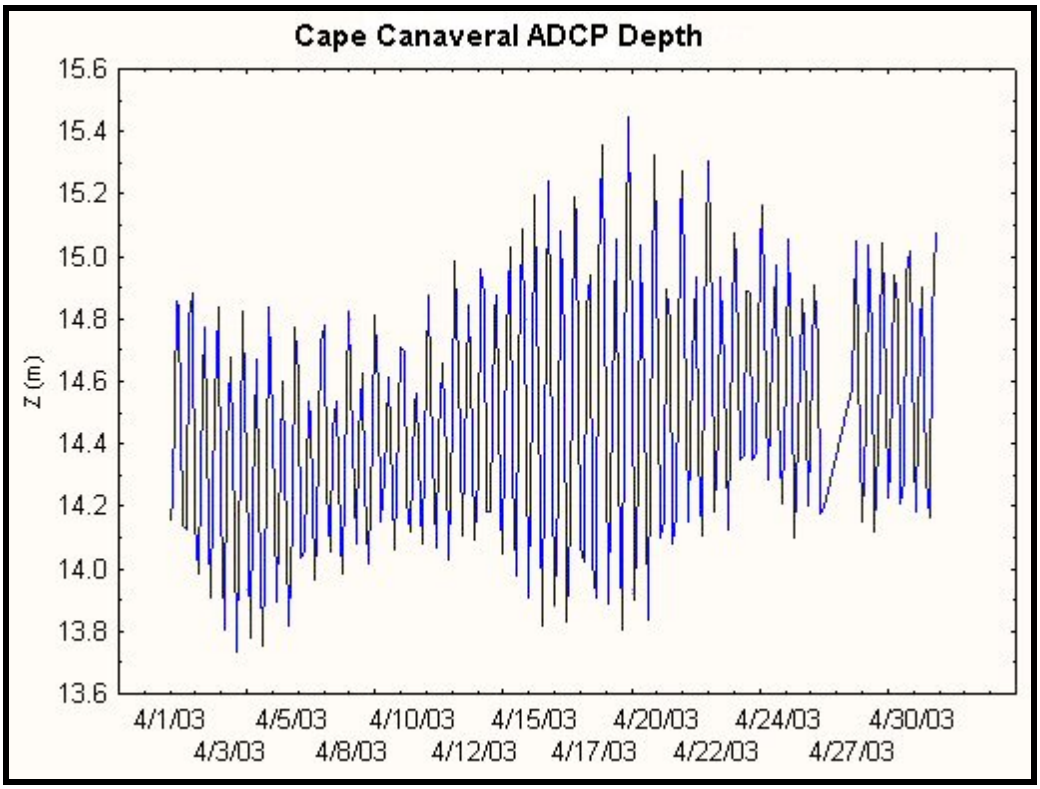
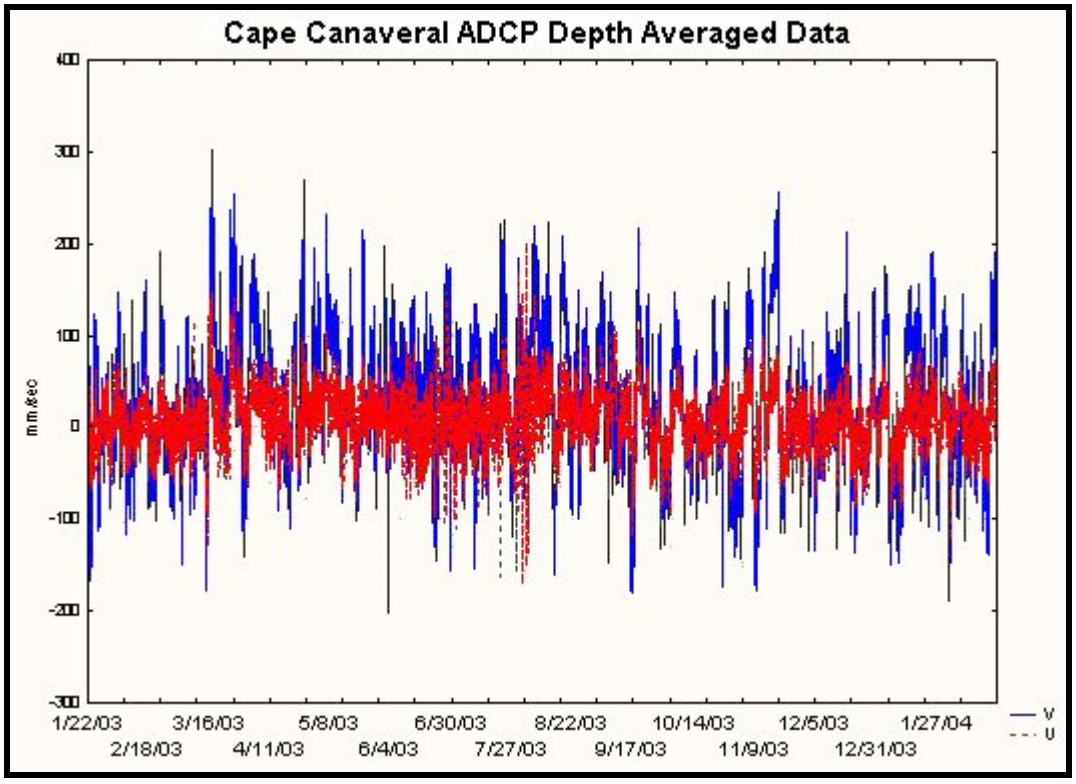


Figure 5 presents a 1-year time series of the V (North-South) and U (East-West) components of the water column averaged ambient current. The V component is blue, and U is red. The time series extends from January 2003 through January 2004 and was obtained using a bottom-mounted ADCP (MacArthur, personal

communication 2004). The speeds are given in millimeters per second (mm/sec), so that the 100 mm/second value is equal to 10 cm/sec. The data were gathered every 15 minutes so that tidal currents are easily resolved. This data summarization is relevant in that it indicates that on a prevailing basis, current direction typically parallels the shoreline with maximum velocities ranging up to 30 cm/sec.

Figure 5. Depth-Averaged Ambient Velocity Time Series Plot Indicating that the North-South Component of Water Movements Typically is Greater Than the East-West Component (Ambient Currents Typically Parallel the Coastline)

(note: graph shows current velocity recorded by the ADCP unit from January 2003 through January 2004, with the North-South velocity component {V} shown in blue and the East-West velocity component {U} shown in red. Data Source: AOML)



The time series data depicted in Figure 5 can be used to depict the velocity-frequency relationships needed to support ocean outfall mixing zone modeling. Histograms of the North-South (V) and East-West (U) current components are presented in Figures 6 and 7, respectively. The mean for the V and U components are approximately 3 cm/sec and 0.8 cm/sec, respectively.

Figure 6. Cape Canaveral North-South Velocity Component Frequency Distribution, January 2003 through January 2004 Reflecting a Mean of 3 cm/sec

(note: Data Source: NOAA)

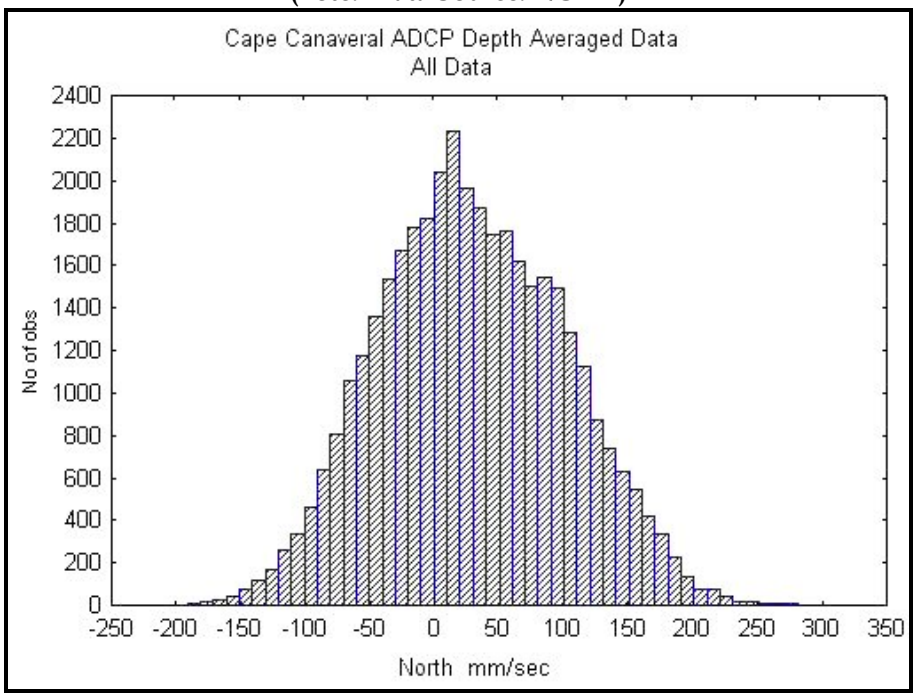


Figure 7. Cape Canaveral East-West Velocity Component Frequency Distribution, January 2003 through January 2004 Reflecting a Mean of 0.8 cm/sec

(note: Data Source: NOAA)

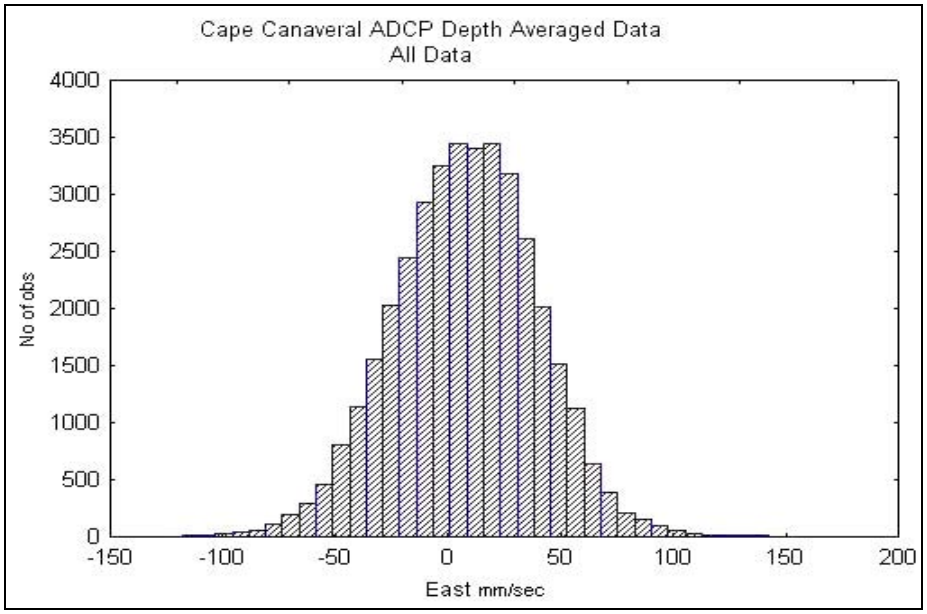


Figure 8 depicts the integrated depth-averaged current magnitude (equal to the square root of the sum of the squares of the V and U components of the ambient current), or speed time series for the entire data period. The peak ambient current velocities on the order of 25 to 30 cm/sec are more clearly depicted in this graphical format.

Figure 8. Depth-Averaged Ambient Current Velocity Time Series for a Site Offshore of Cape Canaveral, January 2003 through January 2004

(note: Data Source: AOML)

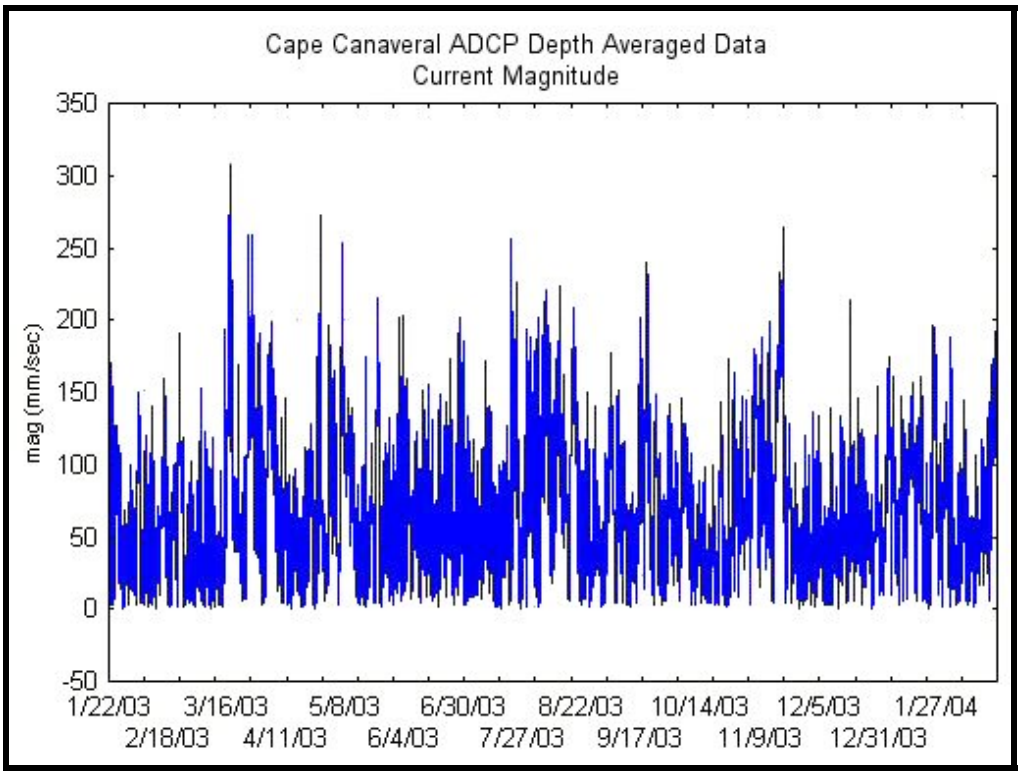


Figure 9 shows a histogram of the ADCP Cape Canaveral/Cocoa Beach data reflecting the distribution of the velocity-frequency records. A mean current speed of 7.2 cm/sec is determined for this particular dataset.

Figure 9. Ambient Current Velocity-Frequency Histogram for a Site Offshore of Cape Canaveral, January 2003 through January 2004

(note: Data Source: AOML)

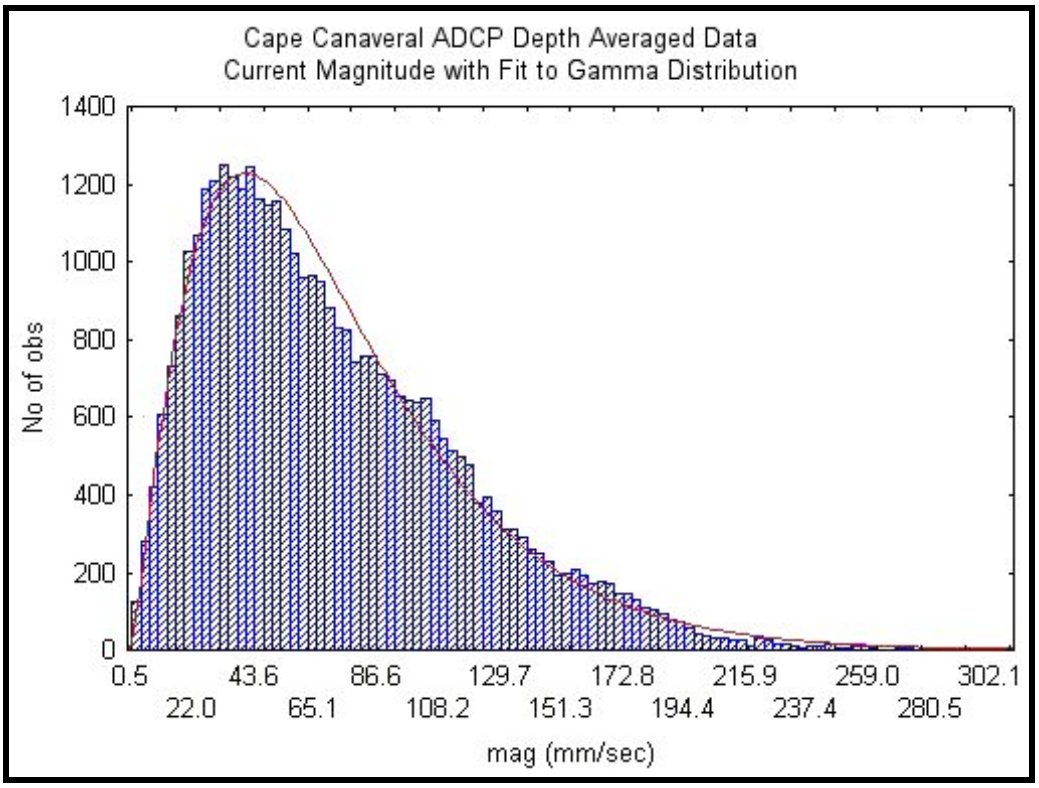


Figure 10 depicts these same velocity records in the format of a cumulative probability distribution of the current speed or magnitude. The cumulative probability plot is of prime interest for regulating and permitting purposes. A worst-case dilution condition is often determined using the 10th percentile current speed for hydrodynamic modeling analyses. In Figure 10, the 10th percentile current speed is seen to be approximately 2 cm/sec.

Figure 10. Cape Canaveral Site Current Velocity – Relative Frequency Plot, January 2003 through January 2004

(note: Data Source: AOML)

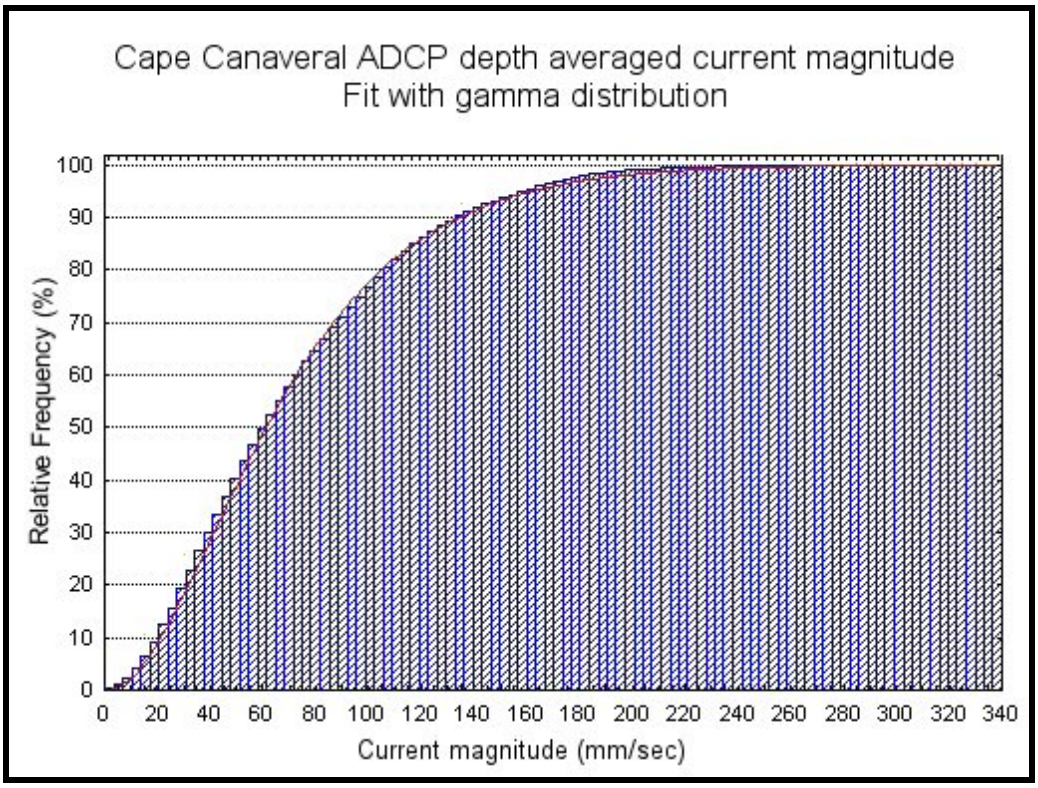
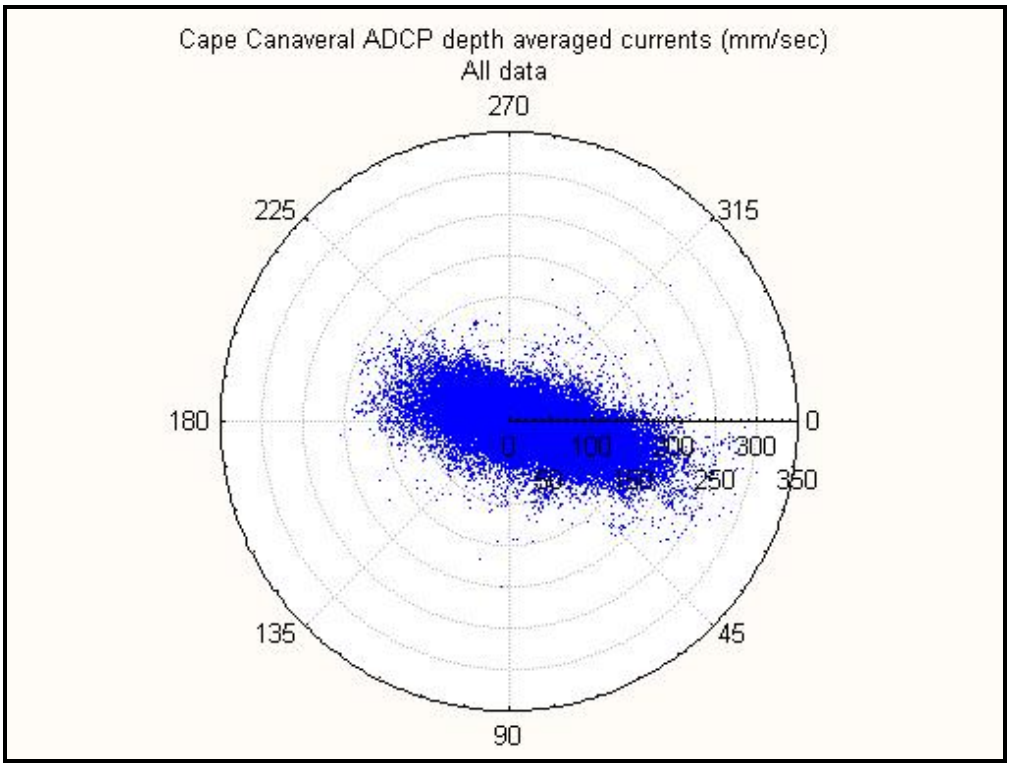


Figure 11 provides an alternative format for depiction of depth-averaged prevailing current speed and direction. In this plot, the direction north is at zero (or 360) degrees. Individual data values are reflected by the individual points on the graphic, and the magnitude of the current velocity increases with distance from the center of the plot. It is seen from this figure that at this coastal ocean site, ambient currents are generally directed around 20° east of north and 20° west of south, approximately paralleling the shore.

Figure 11. Current Velocity and Direction Rose/Scatter Plot for a Location Offshore of Cape Canaveral, January 2003 through January 2004

(note: Current to the North = 0 degrees, Current to the East = 90 degrees, Current to the South = 180 degrees, Current to the West = 270 degrees; Current velocity scale ranges from 0 to 350 mm/sec. Data Source: AOML)

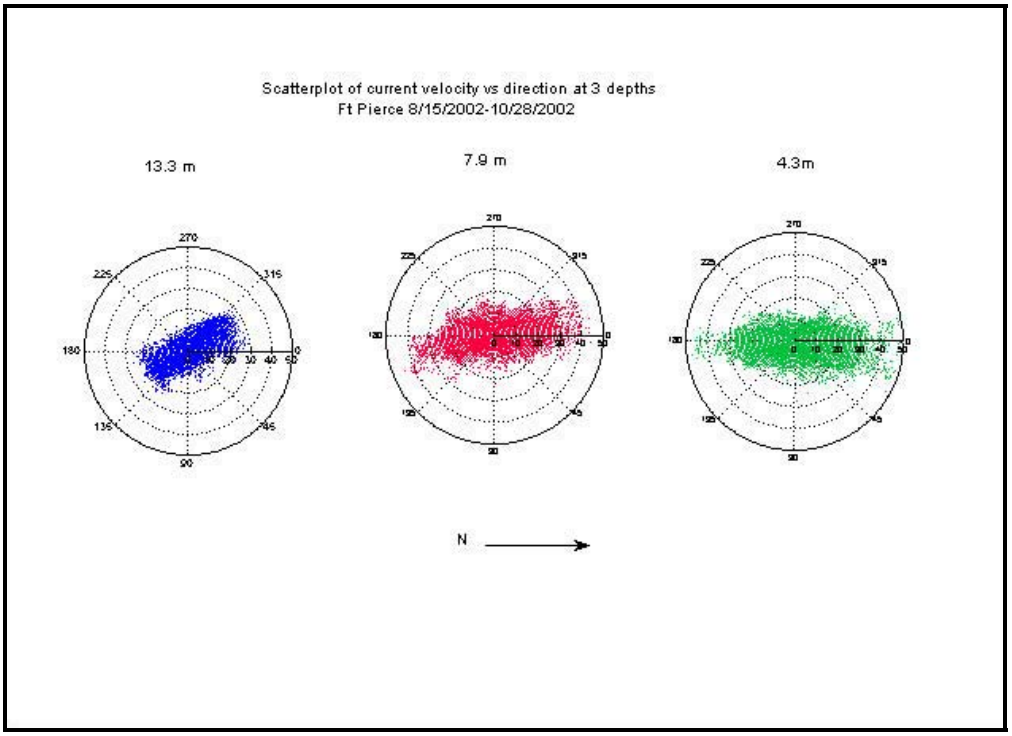


Oceanographic studies have repeatedly demonstrated that physical conditions within any given water column vary with depth. An example of velocity magnitude and direction data plots for three different depths at a given location (in this case, near the Ft. Pierce Inlet) is provided in Figure 12. These data were taken from studies conducted during a 10-week period by the USACE and AOML in the coastal ocean in the vicinity of Ft. Pierce Inlet. Figure 12 shows ambient current magnitude and direction at three depths (4.3 meters or near surface, 7.9 meters or near mid-depth, and 13.3 meters or near bottom). This figure demonstrates that for this site during the period of data gathering, the largest currents were demonstrated at the 4.3-meter depth, and that the ambient current is bi-modal with a slight variation of current direction with depth. Ramifications for a concentrate ocean outfall are substantive. With a positively buoy-

ant plume, dilution occurs rapidly as effluent rises through the water column; and as greater lateral water column velocity is met with the effluent rise toward the surface, substantive potential dilution is achieved. In contrast, with a negatively buoyant plume, mixing will more likely be dependent on initial dilution achieved through diffuser designs to achieve rapid ejection of the effluent into the receiving water body. If lower velocities typically are present at depth, there is less native energy in the water column to promote further mixing–a condition that clearly would be less favorable for a prospective concentrate ocean outfall location.

Figure 12. Current Velocity and Direction Data at Three Depths for a Site Offshore of Ft. Pierce Inlet, August to October 2002

(note: Current to the North = 0 degrees, Current to the East = 90 degrees, Current to the South = 180 degrees, Current to the West = 270 degrees; Current velocity scale ranges from 0 to 350 mm/sec. Data Source: AOML)



OVERVIEW

The bathymetry data available in AOML's GIS system is comprehensive for this study area, and could be key to supporting future evaluations of conceptual ocean outfalls for concentrate discharge off of this District. Future GIS evaluations could use the depth coverage overlaid with other key siting factors as a means of identifying favorable locations within 3 miles from shore that might warrant further study.

On the basis of these examples of physical oceanographic information types that are available for at least some portions of the near-shore coastal waters off of SJRWMD, AOML concluded the following:

1. The bottom topography of the coastal ocean adjacent to SJRWMD generally lacks sharp depth gradients and gently slopes to the east within the 2- to 3-mile range interval from the shore.

2. Typical coastal ocean ambient currents are largely parallel to the coast, generally uniform throughout the coastal ocean water, and have statistically significant 10th percentile current speed values ranging from 2 cm/sec to 5 cm/sec.

The 10th percentile current speeds are typically applied during hydrodynamic modeling analyses and AOML experience suggests that this range of low-flow condition velocities is likely sufficient to support positively buoyant effluent dilution through appropriate outfall and high-rate diffuser design and operations. How these physical conditions would impact a negatively buoyant concentrate plume, however, remains to be demonstrated through future computer modeling of a range of possible concentrate discharge scenarios.

CONCLUSIONS AND RECOMMENDATIONS

This review and summarization of the AOML information inventory and literature review leads to the conclusion that detailed, long-term physical oceanographic datasets focused on ambient current velocity and direction records, and water column profiles of density-related parameters apparently are not available for much if not most of the northeast and central Florida Atlantic coastal waters.

Approximate bathymetric profiles perpendicular to shore within the study area could be generated from data available through AOML's National Environmental, Satellite, Data and Information Service (NESDIS 2004). AOML has provided bathymetry information for the coastal and open ocean environments off of SJRWMD, and these are viewed as very valuable for supporting ocean outfall siting and further investigation planning. However, corresponding records of the other key physical metrics as a function of distance offshore have not yet been found to be available.

The three datasets identified by AOML through this inventory and review provide meaningful and potentially useful information for three specific locations near Ft. Pierce, Melbourne, and Cocoa Beach, but no comparable sets of information were found for areas to the north. These datasets are specific to locations located approximately 1, 0.5, and 3 miles offshore, respectively. Because of their geographic locations, using these data to generally characterize conditions along an increased distance from shore, or an increased depth gradient for the entire study area, should be done with extreme care and only with the appropriate qualifying notes. However, these data provide some potentially useful insights into the range of parameter values that could be used as general guidelines during future analyses related to concentrate ocean outfall feasibility.

The literature search confirmed that the physical oceanographic information retrievable from peer-reviewed journals seems more focused on conditions well offshore of the coastal waters that are the primary focus of this investigation. Literature is available that addresses upwelling events and effects on the outer portion of the continental shelf. If the concentrate ocean outfall investigation ultimately expands its focus to address discharge feasibility at locations well beyond the 3-mile distance offshore, some of

these literature reports may become more elevated in importance. However, with respect to conceptual concentrate ocean outfalls to the coastal oceanic environments within 3 miles from shore, it appears that substantive gaps in the existing information base exist that could best be filled through additional field investigations.

The nature and timing of such field investigations remain under SJRWMD's consideration. As originally envisioned, Phase 2 of this overall investigation is intended to include focused field data gathering to supplement the results of this information inventory and literature review. Under the Phase 1, Task 3 project activity, field investigation concepts are being developed under AOML leadership for SJRWMD's review and approval, and to promote further discussions with FDEP and perhaps other stakeholders regarding how, where, and when to conduct those field investigations. Activities underway are leading in the direction of development of specific research proposals for up to three candidate sites along the Atlantic coast of SJRWMD, and depending on the interaction of factors including scope, locations, schedule, funding availability, and the interest of prospective stakeholder partners, final decisions regarding those field investigations will be made in the future.

In the interim, the following recommendations are offered by CH2M HILL for SJRWMD's review and consideration:

1. SJRWMD should proceed with further discussions with FDEP regarding policy and rule constraints on the permitability of new ocean outfalls within coastal ocean waters (within 3 miles from shore). A working meeting with FDEP should be conducted to discuss regulatory issues and data gathering priorities as an element of the ongoing assembly of field investigation recommendations (or other analytical suggestions) that should be considered by SJRWMD for implementation in support of outfall feasibility evaluations.
2. SJRWMD should continue dialogue with federal and state agencies, or with academic/research institutions or consulting firms working on behalf of such agencies, to determine the availability of additional physical oceanographic datasets for areas north of Cape Canaveral. These follow up communications might identify information that was not releasable at the

time of original contact, but that has since been cleared for release.

3. SJRWMD should consider alternative funding mechanisms for prospective modeling or field investigations that are likely to be included in the Phase 1, Task 3 set of recommendations. On the basis of preliminary project discussions with AOML, it is clear that these activities likely to be proposed as elements of the Phase 2 investigations are going to require funding allocations well in excess of those envisioned at the onset of Phase 1. Therefore, to enable SJRWMD to make future project scope and budget allocation decisions, it would be advisable to begin discussions now regarding what potential supplemental funding sources could be appropriate. Candidate concepts include, but are not limited to, some combination of the following:

    - *Ad valorem* tax revenue allocations.
    - Allocations from legislative funding for alternative water supply development.
    - Identification of specific county or municipal utilities interested in co-funding the follow-up investigations SJRWMD ultimately approves and elects to implement.
    - Pursuit of other potential state or federal grants to at least partially fund these types of water supply development programs
    - Partnering agreements with federal or state agencies for collaborative studies through in-kind service support, equipment, research vessel and staff time, or other forms of contributions toward investigation planning, management, and execution.

It seems clear that demineralization processes will very likely need to be a part of the long-term water supply strategy for achieving sustainable development within SJRWMD, and perhaps statewide. Therefore, it is critically important to continue to investigate what engineering and environmental strategies are needed to identify administratively approvable infrastructure that supports achieving this long-term goal. This investigation is a critical element of SJRWMD's technical support services being provided to its constituents that are responsible for long-term water supply planning and implementation. Continued commitment to these project activities is clearly justified.

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Appendix A

Literature and Data Review for Ambient Coastal Ocean Parameters for Potential Coastal Ocean Concentration Discharges, Phase 1, Task 2 (AOML Draft Deliverable, January 6, 2005)

Literature and Data Review for Ambient Coastal Ocean Parameters for Potential Coastal Ocean Concentrate Discharges
Phase I, Task 2

For a

Preliminary Investigation into the Oceanic Dispersion and Disposal of Desalination/Demineralization Concentrate In Coastal Ocean Waters Adjacent the St Johns River Water Management District

By

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FINAL DRAFT

St Johns River Water Management District
PO Box 1429
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January 6, 2005

EXECUTIVE SUMMARY

This report is written in satisfaction of work requirements specified for Phase I Task 2, 'Literature and Data Review' of the St Johns Water Management District (SJRWMD) and the National Oceanic and Atmospheric Administration (NOAA) agreement, entitled, "A Preliminary Investigation into the Oceanic Dispersion and Disposal of Desalination/Demineralization Concentrate In Coastal Ocean Waters Adjacent the St Johns River Water Management District". The objective of this report is to provide a literature and data review for the ocean environment adjacent to the SJRWMD of those coastal ocean parameters relevant to the prospective discharge of demineralization/desalination concentrate into the coastal ocean.

A National Pollution Discharge Elimination System (NPDES) permit is required to discharge concentrate in the coastal ocean adjacent to SJRWMD. Depending on the specific design of the concentrate discharges, dredge and fill permits may also be required.

The information an applicant must supply when applying for the required permit for coastal ocean discharge of concentrate generally includes:

(a) An analysis of the chemical constituents of any discharge;
(b) Appropriate bioassays necessary to determine the limiting permissible concentrations for the discharge;
(c) An analysis of initial dilution;
(d) Available process modifications which will reduce the quantities of pollutants which will be discharged;
(e) Analysis of the location where pollutants are sought to be discharged, including the biological community and the physical description of the discharge facility;
(f) Evaluation of available alternatives to the discharge of the pollutants including an evaluation of the possibility of land-based disposal or disposal in an approved ocean dumping site.

In a report prepared for SJRWMD (Reiss Environmental, Inc 2002) a review of the permitting process anticipated for the granting of a permit for concentrate discharge to surface waters from the FDEP was presented. In that report, many of the items presented in (a) through (f) preceding also were identified, although somewhat different phraseology was used. In addition it was pointed out that: (1) concentrate discharge-specific conditions can render every concentrate permit effort unique, (2) because of the complexity of issues, eg societal benefit considerations involved in permitting surface water discharges, FDEP officials have some discretion in

permit decisions and (3) that concentrate discharge regulations in the FDEP are currently undergoing modifications and development.

Of the list of parameters indicated to be of importance in (a) through (f) preceding and indicated to be of importance in SJRWMD report mentioned, the present report focuses on item (c), ie, "an analysis of initial dilution", because dilution is a key parameter for both state and federal regulators and has played a key role in other coastal ocean discharge circumstances.

Interest in achievement of adequate dilution in coastal ocean discharges arises because whole (concentrate) effluent toxicity tests (WET) done on demineraliza-tion/desalination concentrate, have demonstrated varying levels of toxicity. There are a number of approaches for relief and for addressing toxicity issues. In order to be able to have the opportunity to have concentrate toxicity tests carried out on less than 100% concentrate, eg 30% concentrate, it must be shown, among other things, that adequate (100:1) dilution can be achieved in coastal ocean

discharges. The relevant Florida Administrative Code Sections are 62-4.244(3)(b) and 62-302.200(i).

To help determine possible dilutions achievable this report identifies the principal coastal ocean parameters that will affect dilution and dispersion in the coastal ocean. Further, this report provides a literature and data review of the identified parameters and provides a sufficient basis for judgment as to whether additional coastal ocean data is needed, beyond that which has been identified in the review. Identification of the principal ocean parameters affecting dilution of coastal ocean concentrate discharge was based upon 1) knowledge of physical processes governing dilution and dispersion in the coastal ocean gained through past field and analytic studies of coastal ocean dilution and dispersion in coastal ocean discharges, and identification of parameters used in models of coastal ocean discharge, 2) recognition of the partition of the coastal ocean adjacent to SJRWMD in terms of regulatory authority, between the State of Florida and the federal government. The State of Florida has regulatory authority over the ocean from the shore seaward up to 3 miles offshore. The federal government has authority from 3 miles and beyond to the limit of the US

territorial waters. While these two authorities have regulations which are derived from the Clean Water Act (1972) and are consistent with each other, specific concerns may be emphasized more by one authority than another and the scope of considerations may vary, thereby affecting the ranges of physical, chemical, biological, and geological parameters of significance, 3) recognition that at the time of writing this report (Summer 2004), decisions regarding potential source waters, and acceptable discharge concentrate characteristics (eg concentrate density) have not been finalized.

At the time of initiation of this literature and data review, there was not a specific geographic focus for the review, so that a broad area of the coastal ocean adjacent to SJRWMD was reviewed. In a meeting held in November 2004 at SJRWMD, it was decided that three geographic locations would be focused upon. These three locations are thought to be generally representative of the areas where demineralization projects are likely to occur. Going forward in this project, the specific features of these locations will be focused upon.

The system comprised of piping for transport of concentrate from the plant to the coastal ocean is called the "outfall". The seaward terminus of the transport pipe, ie, the coastal ocean disposal site, can take many forms including a simple single port pipe, a multi-port diffuser and/or inclined ports.

Since three specific locations for potential concentrate discharges have been identified, this will enable a more specific geographic focus for both reviewing extant environmental data and for gathering additional data in the future. Generally, biological data required for coastal ocean discharge environmental issues are site specific, so that biological data gathered in the near vicinity of the discharge site is of prime importance.

Other types of environmental data are needed, beyond those environmental parameters that play a key role in dilution determination. Class III marine surface water quality criteria provide values for a number of quantities that may appear in the concentrate discharge. Some of these criteria are expressed in terms of environmental (background) values. Thus environmental background data for some of these quantities may be needed.

Biological criteria are also provided in the criteria. For example, biological integrity appears in the criteria. The integrity criteria are expressed in terms of an index for benthic macro-invertebrates and is also expressed in terms of environmental or background data. The site specificity provided by selection of three specific potential discharge coastal locations enables a more focused examination of biological indices.

CONCLUSIONS:

1. A close working cooperation with the Florida Department of Environmental Protection (FDEP) is required to fully define all environmental issues of interest for the issuance of a National Pollution Discharge Elimination System (NPDES) permit. The Federal government (US EPA) has delegated authority to the State of Florida (FDEP) for granting the required NPDES permit for coastal ocean waters adjacent to SJRWMD that are within three miles of the coast. Beyond three miles from the coast, the authority for issuance of NPDES is with the federal government and is administered by the United States Environmental Protection Agency (US EPA). If there is a possibility that SJRWMD will

consider discharge of concentrate beyond the three mile range, then a close working cooperation with the US EPA Region IV, in Atlanta GA is required.

2. The principal coastal ocean parameters affecting coastal ocean concentrate discharge dilution are

a) coastal ocean currents,
b) coastal ocean water column density profiles and
c) depth of the seaward terminus of the outfall pipe.

3. Internet searches, peer reviewed literature searches, university and research institution contacts, federal government contacts, and state government contacts, have so far revealed the existence of three data sets of sufficient duration, frequency of sampling, correctness of location and appropriate coastal ocean measurement parameters to merit in-depth data review. These data were gathered at:

a) 2.6 miles East of Cocoa Beach between January 2003-January 2004 in a coastal ocean water depth of approximately 15 meters,
b) approximately 1 mile from Ft Pierce outlet, for one month in 2000 and for 2 months in 2002, in a water depth of approximately 15 meters and
c) a location in proximity to the Melbourne Beach Inlet for a three year period.

Review of the data indicates that coastal ocean ambient currents are largely parallel to the coast, generally uniform throughout the coastal ocean water and

have statistically significant 10th percentile current speed values ranging from 2 cm/sec to 5 cm/sec.

3. Item (a) in the list of information to be supplied by an NPDES permit application requires a characterization of the concentrate to be discharged. A pilot production of the concentrate will be needed in order to fully determine the toxicity of the concentrate. SJRMD has already performed a first pilot production for concentrate characterization. The source of raw water for this pilot production was taken from the Indian River Lagoon. For dilution estimation purposes, the concentrate density is a key factor to determine. Pilot production concentrate toxicities and dilution requirements are linked, and depend upon the nature and origin of the toxicity. If, for example, the toxicity is shown to be due solely to major ion imbalance, as opposed to a chemical constituent introduced in the processing of the source water, potential relief mechanisms will likely be different (specific rule development is underway within FDEP).

4. The bottom topography of the coastal ocean adjacent to SJRWMD generally lacks sharp depth gradients and is generally gentle in the 2-3 mile range interval from the shore. The bottom topography information

together with the ambient current information gathered in this literature and data review suggest that the construction of diffusers for the terminus of the outfall pipe can be readily accomplished. It appears that the orientation of the diffuser sections should be perpendicular to both the ambient current flows (which generally parallel the coast) and the coastline to obtain maximum dilution. Diffusers will likely be of significant benefit to SJRWMD utilities, in obtaining required concentrate discharges dilutions.

Recommendations:

5. Generally, long term biological data on benthic communities, coastal ocean habitats, and endangered species are lacking for the coastal ocean adjacent to SJRWMD, and are lacking at the three specific locations identified in November 2004. As part of the FDEP anti-degradation policy, attention is now being paid to endangered and threatened species.

NMFS (National Marine Fisheries Service), a component of NOAA, has issued a temporary rule regarding the accidental taking of sea turtles by shrimping vessels operating between 28◦ N latitude and the Florida-Georgia border. In addition to the FDEP and US EPA cooperative, relationships with other agencies

particularly NMFS(NOAA) and the US ACE will likely be required. The US Minerals Management Service (US MMS) has programs underway or in development to examine coastal benthic habitats in Florida and elsewhere.

RECOMMENDATIONS:

A meeting in November 2004 between SJRWMD and NOAA personnel discussed the most significant points in these recommendations.

a. Meet with NOAA personnel to discuss the contents of the present draft literature and data review and discuss options for siting of concentrate discharge locations in the coastal ocean and to discuss the need for additional environmental data. (The meeting in November 2004 between SJRWMD and NOAA personnel discussed the most significant points in these recommendations.)

b. Meet with FDEP, NOAA, and possibly US EPA personnel to discuss requirements for information content for a prospective SJRWMD NPDES permit application and to discuss additional coastal ocean data and measurements needed, if any.

c. Begin a project to characterize concentrate to be discharged for the three specific discharge locations identified in the November 2004 meeting. This

characterization will be a requirement and will be part of the information content of a NPDES permit application. In order to characterize actual concentrate discharge, pilot production of the concentrate is required. Pilot production is needed in order to determine toxicity, or not, of any chemicals added in the desalination/demineralization process as well as of the concentrate itself. From the perspective of the present literature and data review, and additional measurements to be made, characterization of the concentrate must include the expected range of concentrate density determinations.

d. In the meeting between SJRWMD and NOAA three specific locations were suggested. It was also indicated that the SJRWMD would seek to have the concentrate characteristics determined for each of the locations. Based upon the locations selected, it is recommended that studies be done on the local area of environmental impacts, if any, of the concentrate exiting the outfall terminus. Such studies will examine bottom sediments, substrates, benthic communities, local ambient currents, water column stratification and the effects of winds and waves, eg, fronts, storms, on the local environment.

e. Initiation of a program to examine the range of dilutions achievable as plant efficiency, concentrate total dissolved solids, concentrate density and plant production rate are allowed to extend over a range of values. Such programs should also consider dilution achieved as a function of ambient currents, oceanic water columns, density profiles, and outfall terminus design. Other factors that may play a role in dilutions, eg waves, should also be considered.

f. The present effort and discussions with FDEP suggest that concentrate discharge within a distance of three miles of shore is potentially possible.

It is possible that some dredging activity may be carried out in the construction of the outfall piping system running from the demineralization/desalination plant site to the actual concentrate disposal site in the coastal ocean. As part of, or in conjunction with, the environmental data gathering which will occur in the future with regard to the discharge site itself, environmental data could also be obtained that is appropriate for both dredging permitting and actually specifying the route of the discharge pipe.

g. Initiate contact with the NMFS and US EPA Region 4 regarding endangered marine species and dredge

activities. A focus of the contacts will be on the nature of environmental data required, beyond that which is currently available for fisheries and dredging considerations.

h. If coastal ocean water is considered as potential source water for desalination, consideration of environmental data required for the evaluation of effects of intake of significant volumes of seawater should be initiated.

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I. INTRODUCTION

This report provides the results of a literature and data review carried out in conjunction with the joint St Johns Water Management District (SJRWMD) and the National Oceanic and Atmospheric Administration (NOAA) project, for a preliminary investigation into the dispersion of demineralization concentrate released into coastal ocean waters adjacent SJRWMD.

The regulatory authority for both federal and state governments for coastal ocean discharges originates with the Clean Water Act (CWA) of 1972, officially known as the Federal Water Pollution Control Act. Any discharge of a 'pollutant' from a point source, eg an outfall terminus, to the navigable waters of the US or beyond must obtain a National Pollution Discharge Elimination System (NPDES) permit. The permit requires compliance with technology and water quality-based treatment standards. Any discharge must also comply with the Ocean Discharge Criteria established under CWA Section 403. The NPDES program is administered by the US EPA and authorized states.

The State of Florida was delegated authority to administer the NPDES program for coastal ocean water within three miles from shore for waters adjacent to SJRWMD. The

specific information required to be submitted by an applicant may include the following from the *Protection of Environment, Criteria and Standards for the National Pollutant Discharge Elimination System* (Sec 125.124, Title 40) (US EPA, 2004):

> (a) An analysis of the chemical constituents of any discharge;
> (b) Appropriate bioassays necessary to determine the limiting permissible concentrations for the discharge;
> (c) An analysis of initial dilution;
> (d) Available process modifications which will reduce the quantities of pollutants which will be discharged;
> (e) Analysis of the location where pollutants are sought to be discharged, including the biological community and the physical description of the discharge facility;
> (f) Evaluation of available alternatives to the discharge of the pollutants including an evaluation of the possibility of land-based disposal or disposal in an approved ocean dumping site.

The main focus of this report is on item (c) immediately preceding. Dilution is of key importance for both state and federal regulators. Items (a) and (e) are also significant for the choice of environmental quantities to be reviewed, however these items are not discussed asa extensively as item (c) due to the need for more information on concentrate characteristics, eg, density, toxicity, and plant siting. Thus, in addition, there is some subjectivity in specification of the importance of some quantities, which will be resolved in future discussions with FDEP and US EPA personnel. there has been a less in-depth review of environmental quantities related to (a) and (e) preceding.

In a report prepared for SJRWMD (Reiss Environmental, Inc 2002), a review of the permitting process anticipating granting of a permit for concentrate discharge to surface waters was presented by the FDEP. In that report, many of the items presented in (a)-(f) were also identified, although somewhat different phraseology was used.

The coastal ocean has provided significant dilution opportunities for a wide variety of discharge substances including positively buoyant wastewater effluent, negatively buoyant dredged material and many others (see Appendix). At the time this literature and data review was initiated, there were several uncertainties, all having the potential to affect the coastal ocean parameters to be selected for review. Some of those uncertainties concerned regulations regarding acceptable dilutions and parameters needed for accepting dilution estimates by the State of Florida and the federal government. Other uncertainties included prioritization of coastal areas for literature searches and data reviews. Yet other uncertainties concerned discharge concentrate characteristics such as density and source water characteristics. This literature search and data review has been carried out to allow the largest possible latitude for literature search and data review parameters.

To correctly carry out this literature search and data review, a clear understanding of the nature of the data relevant to the demineralization concentrate disposal in the coastal ocean adjacent to SJRWMD is required. As indicated earlier, emphasis will be on dilution related coastal ocean parameters, rather than on other important coastal data such as biological and water quality data. The principal ambient environmental data types of importance are 1) ambient currents, 2) water column density profiles, 3) water depth or height of the water column above discharge at prospective disposal sites 4) local bottom topography, and 5) water mass types occupying prospective disposal sites. Some of the required ambient environmental data types needed for the definition of the present literature and data review can also be seen by consideration of mathematical expressions expected to be generally relevant for the dilution of positively buoyant concentrate and of computer models for concentrate discharge. One of these expressions is presented as an equation in the background section of this report. Also relevant for prospective exposure concerns are local biota and other species of environmental concern. Also of interest are meteorological data since wind driven currents may be of significance. Some references of interest with regard to general disposal issues and concentrate management issues are

Lattemenn and Hopner (Lattemenn and Hopner, 2003), the California Water Desalination Task Force (CWDTF) (CWDTF 2003) and the Texas Water Development Board (TWDB 2004).

One of the most significant factors in choosing the location for discharge of demineralization concentrate in the coastal waters adjacent to SJRWMD is the distance of the discharge (or outfall) from the coast. The distance is critical because of *1) Regulatory authority* - If the distance from the shore to the outfall is more than 3 miles, the Federal government and especially the US EPA, will be the lead regulatory agency. If the distance from the shore to the discharge is less than 3 miles, the State of Florida and especially the FDEP would have regulatory authority. *2) Dilution requirements* – Depending on the results of toxicity tests and the nature of the toxicity determined, dilutions as great as 100:1 may be required for concentrate discharges occurring within 3 miles of the coast. *3) Depth change with distance* – The depth (or height) of the coastal ocean water column above the outfall is an important parameter for dilution. The greater the vertical extent of the water column above the outfall, the greater the dilution. The contribution of surface waves to mixing processes may be a factor in dilution, depending upon the depth of discharge. *4) Cost* – Clearly the cost of piping, its placement, and

monitoring and maintenance of the piping is a significant cost factor. The possibility of locating a discharge site within 3 miles of the coast makes coastal ocean discharge of concentrate attractive. *5) Amenities Impact Reduction* – There are numerous amenities of concern that could potentially exist in coastal ocean waters. However several of theses amenities, eg rock shrimp habitats/fisheries (FMRI, 1977), coral reefs/occulina reefs, right whale habitats, and artificial reefs appear to be generally in deeper water. A key concern at this time is amenities distribution within 3 miles of the coast. Endangered species, such as the Leather back Sea Turtle, and migratory routes of their prey (eg white, pink, and brown shrimp) will also be of concern (NMFS, 2001).

In addition to a clear understanding of the data type requirements, an identification of the coastal ocean areas of interest (prospective outfall discharge areas), and relevance to the project are required. It is currently anticipated (on a cost basis) that the principal coastal areas of interest will be those which are reasonably close to the shoreline, for example within about 5 miles from shore. In November 2004, a meeting was held at SJRWMD in which three sites thought to be representative of the areas where demineralization projects are likely to occur were identified. In addition, SJRWMD will

develop a concentrate characterization work statement and will provide characteristics of the prospective concentrates to be discharged including water chemistry and quantity. Selection of likely prospective sites, as opposed t a broad geographic effort, complements views expressed by FDEP personnel. In addition, subsequent to this meeting, it was determined that FDEP personnel will review portions of the prospective concentrate characterization work statement developed by SJRWMD prior to release (FDEP, 2004). It is anticipated that examination of the effects of a range of values of concentrate characteristics, eg total dissolved solids, volumes of discharge, for open coastal ocean discharge dilution will be carried out by NOAA.

The most useful literature on ambient current data, would be data gathered in the general areas of prospective disposal sites, gathered over sufficient time (1-3 year intervals) for reliable 'worst-case' dilution analysis, sufficiently temporally sampled (able to resolve tidal currents), suitably quality controlled, and in easily usable format.

In this writer's view, the Florida Department of Environmental Protection (FDEP) will require adequate ambient current data so that selected statistical parameters of the data can be determined. One of the key parameters is typically the

10^{th} percentile current speed; the US EPA has used this current speed in worst-case dilution analysis. FDEP will be interested in both the initial dilution and subsequent dilution achieved by the concentrate discharge in the immediate local vicinity of the discharge site. For a positively buoyant discharge, the initial dilution will be achieved in the vertical rise of the concentrate plume to the surface of the ocean. This dilution occurs over a plume travel distance approximately equal to the depth of the discharge site. The dilution that the concentrate discharge plume undergoes over distances on the order of three times the discharge site depth and beyond is considered to be subsequent dilution and is of value in mixing zone determinations.

A. PURPOSE

The principal purpose of the present literature search and data review is to provide SJRWMD and FDEP a basis to determine whether the present coastal ocean data are adequate to meet National Pollution Discharge Elimination System (NPDES) permit application information requirements for environmental data or whether additional data gathering is required. Such data requirements may be specified indirectly such as through

requirements for data on dilution achievable in prospective concentrate discharges.

Identification of types of coastal ocean data needed and measurement requirements for the data were a corollary purpose of the study. Because of ambiguities in discharge concentrate characteristics and potential distances from shore to discharge, it was necessary to list a moderately broad range of coastal ocean quantities, perhaps broader than will ultimately be required.

In addition, depending on specific outfall construction requirements, permits may be needed for dredging activities. As part of consideration for granting such permits, examination of many of the same data types, including biological data, as required for NPDES permits is likely.

B. BACKGROUND

An attractive alternate for the disposal of demineralization concentrate is disposal into 'coastal ocean waters' adjacent to SJRWMD.

Regulating authority for concentrate discharges in the coastal ocean is partitioned according to distance from shore. For concentrate discharges that occur within 3 miles of shore,

the State of Florida has regulatory authority. For concentrate discharges further than 3 miles from shore, the federal government has regulatory authority. Within the State of Florida, FDEP has lead authority and within the federal government, the US EPA has lead authority, although other federal agencies also have input to the regulatory process, eg, NOAA, through the National Marine Fisheries Service (NMFS).

The reason for dilution requirements arises because various studies, including two extensive studies, one by the FDEP (FDEP 1995) and one by the American Water Works Association (AWWA), (AWWA 2000), have shown that concentrate discharges display varying degrees of toxicity. Under existing Florida regulations (EG, FAC 62-4.244(3)(b), (FDEP 2004) if it can be shown that a 100:1 dilution can be achieved, along with some additional conditions, in the coastal ocean (within the 3 mile limit) *under critical conditions,* then the discharge concentrate can be tested at 30% full strength. New language is under development (FDEP 2004) that addresses the circumstance in which concentrate toxicity can be shown to be due only to ion imbalance. In order to determine whether dilution can be achieved, data on the environmental parameters influencing initial and subsequent dilutions are required. Those environmental variables are well known and have been listed in the introduction. The

environmental parameters are not the only parameters affecting dilution; outfall design, eg, diffusers, and concentrate flow rates also play a basic role in dilution.

Of prime importance in the values of the discharge dilution are values of the relevant environmental parameters in the immediate vicinity of the prospective discharge. For concentrate discharges, data of importance include ambient water currents, ambient water column density profiles, water depth, and variations of water depth.

The reasoning for the selection of certain data types from this literature search can be seen from examination of Equation One. This equation expresses the initial dilution seen from a wastewater outfall of about 35 million gallons per day discharge. The main environmental parameters governing the initial dilution of wastewater effluent will also govern the initial dilution of concentrate discharge, although they may appear with different exponents, or constants. The role of each parameter should be roughly the same for both types of discharge. This equation is taken from Proni et al (Proni et al 1994) and is

$$D = 0.3 \left(\frac{H}{l}\right)^{1.85} \frac{ul}{Q} \qquad 1.$$

where D is the dilution, Q is the concentrate discharge rate, u is the depth averaged current speed, H is the water depth above the discharge site and l is equal to the buoyancy flux divided by the cube of u. The buoyancy flux is the product of Q and the reduced gravitational acceleration g defined by

$$g = \frac{(d_w - d_c)}{d_w} \qquad 2.$$

where d_w is the density of the receiving coastal ocean water and d_c is the density of the concentrate discharge. The same environmental variables have been identified and used in a well-known model for oceanic discharge, the CORMIX model by Del Bene et al (Del Bene et al 1994).

Thus the approach to meet FDEP permit and dilution requirements for discharges occurring within 3 miles of shore will be to achieve an optimum mix of coastal ocean parameter

values, and discharge characteristics. Note also the relation between the dilution D, and the water depth, H, applicable for this wastewater effluent discharge. With each doubling of water depth, the dilution increases nearly four fold. Dilution-depth relations will be of value subsequently in a demineralization project when distances from shore (and discharge pipe length) are being examined. From the perspective of the present literature search, the range of variations of H with tides, and possibly other forces, is of interest.

From equations 1 and 2 it can be seen that literature search points of interest, as identified earlier in the introduction, are 1) ambient currents, 2) water column density (d_w), 3) water mass types (which can affect the value of (d_w), 4) water depth (H), and 5) local bottom topography (for negatively buoyant plumes and biological considerations), all of which are required by FDEP in permit dilution language development.

Throughout most of this work effort a broad geographic coastal area was encompassed for both literature searches and data reviews. At a meeting to review the first draft of this report between SJRWMD and NOAA personnel held in November 2004, it was decided to focus upon three prospective coastal locations that are representative of the areas where

demineralization projects are most likely to occur. Going forward in the joint SJRWMD/NOAA demineralization project these three locations will be focused upon. The general conclusions of the current literature and data review report are not affected by the selection of three prospective discharge locations. However, the work effort going forward in Phase 2, Task 3, will greatly benefit from having three prospective concentrate discharge sites upon which to focus.

In addition to examination of the extant literature and data for adequacy for NPDES permit application, the possibility exists that dredge and fill permits may be required. Many of the same data types of interest for NPDES permit application will also be of interest for dredging permit applications.

The selection of three sites of interest also enables a more focused biological literature and data review. Among the biological data of interest will be the benthic influence in the area of the prospective discharges. Biological communities and habitats vary substantially in the coastal ocean, so that biological studies must be site specific. Also of interest are endangered species and fisheries present in the general area of the prospective concentrate discharge. Leatherback Turtles sometimes appear where white, pink or brown shrimp are present in the coastal ocean areas of

interest, so that once again site-specific considerations are required.

II. METHODS

The following is a listing of the main features of the methods used in this literature search.

1. Identification of key coastal ocean parameters and measurements required for prospective coastal ocean concentrate discharge.

2. Validation of the parameters and measurements in discussions with FDEP and US EPA personnel.

3. Establishment of geographic limitations of principal coastal ocean regions of concern for ambient parameter information through consultation with SJRWMD personnel and review of prior siting studies by SJRWMD.

4. Utilization of the Internet for broad category searches to determine sites of informational value and to eliminate sites of no informational value.

5. Sites deemed to be of value in step 4 preceding were evaluated in terms of parameters measured, locations of the parameters measured, duration of the measurement periods, frequency of sampling, quality control of data, etc.

6. Reviewed the peer reviewed scientific literature for relevant information papers.

7. Contacted and visited local (within SJRWMD area) colleges and universities to determine whether any faculty or staff are involved in projects that would have relevant environmental parameter information.

8. Contacted, when appropriate, federal agencies that may have potentially relevant ambient environmental data, particularly those agencies that have a presence within SJRWMD, eg. NASA, US Air Force, US Coast Guard, US Navy, USEPA, US Army Corps of Engineers, and of course, NOAA.

9. Contacted, when appropriate, state agencies that may potentially have relevant ambient environmental data.

10. Contacted, when appropriate, county agencies that may potentially have relevant ambient environmental data.

11. Determined any private corporations that may potentially have relevant ambient environmental data.

12. Contacted SJRWMD personnel for any information on coastal parameters. (It is anticipated that SJRWMD personnel will provide information source suggestions during the 30 day review period of the present draft literature search report.)

DISCUSSION:

The ultimate feasibility of concentrate discharges in coastal ocean waters adjacent to SJRWMD will depend on the data supplied by a water utility or other applicant in its application for an NPDES, and possibly dredge and fill permits. A discussion of the range of data types that may be required has been provided in Section I, *Introduction*, to this report. It is assumed that concentrate dischargers will, on the basis of cost considerations, seek to locate outfall disposal sites within three miles of the coast rather than beyond three miles. The State of Florida, FDEP, will then have regulatory purview over the prospective coastal ocean discharge.

It is possible, based upon the results of toxicity testing of pilot concentrate discharge that certain ocean dilutions, perhaps from 60 to 100:1 will be required. In the event that concentrate discharge occurs beyond three miles from the coast, the US EPA will have regulatory authority over the prospective discharge. It is possible that US EPA will place meeting water quality standards as a key requirement for granting an NPDES permit. US EPA could specify these without consideration for the methods by which the standards are met (dilution, blending, etc.).

A necessary step in defining the proper approach to the literature search was to determine the geographic areas of the coastal ocean adjacent to SJWMD of initial interest. At the time of initiation of the literature search and data review, the broad coastal area extending from the southern to northern limits of SJRWMD was of initial interest. The current report was completed in draft form and reviewed. In a meeting between SJRWMD and NOAA held in November 2004, to review the first draft of this report, three coastal locations thought to be generally representative of the areas where it is believed that demineralization projects are likely to occur. In going forward in this joint project, SJRWMD/NOAA in task 3 of Phase 1, these three locations will be focused upon. Largely however, the general literature search and data review results provided in the initial final draft are not significantly affected.

Beyond dilution related coastal ocean data types, there are other data types that will be relevant in permitting considerations. Florida Administrate Code Chapter 62-302.530 entitled *Criteria for Surface Water Classifications* (FAC 62-302.530, 2004) lists a series of quantities of importance in permit considerations. Some of these quantities are water quality related and with criteria stated in terms of background ambient (environmental) levels. Other quantities

are biological and include, for example, biological integrity, which is stated in terms of and index for benthic macro-invertebrates, which is evaluated against background or ambient environmental values. Identification of three specific prospective discharge locations greatly facilitates future gathering of relevant water quality and biological data.

With the data parameters of interest now defined, a systematic data search began with an Internet search. Using standard search engines such as Google or Netscape, a large number of sites of potential information were discovered. Many of the sites evaluated had no information of relevance, and some were of value because they contained links to other more specific areas of information.

The process of examining websites using key words such as "Florida coastal ocean' or 'Northeast Florida coastal ocean" was carried out numerous times; the results of these searches are presented in Section IV of this report.

From many years of experience, this writer has gained knowledge of the organizations and institutions likely to have ambient environmental data of relevance to this project. Nevertheless, there are always sources of data that may not be anticipated or may be overlooked. It is anticipated that

SJRWMD personnel will suggest any data sources inadvertently omitted from this report.

III. RESULTS AND DISCUSSION

The key coastal ocean ambient parameters for estimation of the dilution of concentrate discharge in the coastal ocean adjacent to SJRWMD are: ambient currents, ambient water columns density profiles, and water depth and its range of variation at a discharge site.

The exact length of time over which additional measurements of the preceding parameters may need to be made will be determined in a future meeting with FDEP personnel. Achievement of 100:1 initial dilution for discharge within the 3-mile limit from the coast, with certain other requirements, would enable testing for concentrate toxicity at a 30% dilution, and still provide a substantial safety factor for the FDEP.

In addition to oceanic ambient parameters, knowledge of the near shore bottom topography, ie, within 5 nautical miles, is required. This information needed is not only for the specification of the vertical extent of the water column above the concentrate discharge, but also for the estimation of bottom-adjacent transport of negatively buoyant plumes.

Initial general Internet searches using key search words as 'ocean currents Northeast Florida' produced hundreds of

sites containing the key search words. Various combinations of the search terms were used, all producing a plethora of sites. It was then necessary to visit each site to determine the usefulness of any items at that site.

Therefore, one might say each visit to any site was useful in that it determined if there were any data of value or not.

As an example, the search site 'ocean portal' was examined. Upon entering this site (which is operated by the International Ocean Data Center, a component of the United Nations), a search opportunity is presented for searching within the ocean portal site. Using the search words 'Florida Coastal Ocean', 9 possible links of value are indicated. Examination of the links showed no data of value, at present, for the coastal ocean waters adjacent to SJRWMD. Another matching site entitled 'Summary of Regional Ocean Observing Systems and Plans' also failed to yield useful data.

The process of querying Internet sources and matching sites was completed many times without significant success. However one site of value was located, namely the Florida Department of Environmental Protection (FDEP) site displaying the web page of the Bureau of Beaches and Coastal Systems (http://www.dep.state.fl.us/beaches/data/wav-wea.htm). At this site is displayed data from a wave gauge located in the

area of the coastal ocean adjacent to Melbourne Beach in a water depth averaging about 8.7 meters. After examination of the data it was clear that the wave gauge was an acoustic Doppler current profiler (ADCP) device so that full water column ambient current data was available. Data have been gathered over a three-year period.

The existence of this measurement site was also disclosed in discussions with Brevard County personnel. Other than this single FDEP website, no other sites were of value in providing relevant data. This negative result does not necessarily mean that no other sites of value exist on the Internet, rather, it means, at least, that those sites were not easily found. Further, and more importantly, the negative result does not mean that relevant coastal ocean parameter data does not exist, it means, at least, that it has not been published on the Internet.

A review of the published, peer-reviewed scientific literature produced no papers with data directly relevant to the geographic search of the present project. However, two papers (Taylor and Stewart 1959 and Smith 1983) contained information on upwelling in the general area of the coastal waters adjacent to SJRWMD. The significance of the occasional presence of upwelled water is twofold: first, upwelled water can effect the water columns density profile

and thus have some (probably) minor effect on dilution and second, the upwelled water can be rich in nutrients and effect biological processes in coastal waters. The most important results in the scientific literature dealt with the effects (or lack thereof) of the Gulf Stream on the near shore coastal ocean (within 10 miles of shore). Lee [(Lee et al 1977), (Lee et al 1984)] and Smith (1982 and 1987) show that the magnitude of the Gulf Stream related ambient current effects in the near shore coastal waters are very limited except possibly in longer-period flow. From the perspective of initial dilution, and local subsequent dilution (distances no more that three times the discharge depth), the effect of the Gulf Stream currents appears to be insignificant.

This writer visited the Florida Institute of Technology (FIT) in Melbourne, FL, on May 13, 2004, and was hosted by Dr George Maul, Chair of the Department of Marine Environmental Science (DMES). Several senior faculty members were present at the meeting. When this writer posed the question, "What data has been obtained on coastal ambient currents and density fields in the coastal areas adjacent to SJRWMD?", the answer was "Very little". When the writer posed the question "Why is there such a lack of data?", the answer was "There has been no interest and consequently there has been no

funding for data gathering". The writer did learn that Dr. Lee Harris was gathering some wave and current data in the vicinity of Sebastian Inlet (on the ocean side of the inlet). In subsequent discussions with Dr. Harris, he indicated that once he received approval from his sponsor, he would share his data with the writer.

The writer contacted Dr. Ned Smith at the Harbor Branch Oceanographic Institute (HBOI) and asked him about coastal ocean environmental data in the coastal area of SJRWMD. He indicated that very little data existed. He subsequently provided the writer copies of the scientific papers he had published. These papers deal mainly with the Gulf Stream flow and upwelling, and very little with near shore coastal ocean currents; these papers are listed in the references.

Contacts were made with the various federal agencies potentially having relevant coastal ocean data. It was know that the US EPA often obtains such data at coastal ocean sites designated for disposal of dredged material. The writer's agency, NOAA, had recently cooperated with those agencies at two designated coastal ocean disposal sites, one off Cape Canaveral and one off the Ft Pierce Inlet. Good quality ambient current data are available from both those sites. Because the Cape Canaveral and Port Canaveral areas are indicated as priority sites in the report by Beck (Beck

2003), and also was identified as a relevant location in the November 2004 meeting, an in-depth review (as is indicated in the work statement for Task 2) of the US EPA/NOAA data is given. To illustrate the character of the data required for dilution calculations and for worst-case dilution estimates for FDEP, some data are presented from the Cape Canaveral US EPA study (Figures 1 through 14). These are unpublished and are not available on the Internet or in scientific peer-reviewed literature.

Figure 1 shows a bottom topography map for the coastal ocean in the vicinity of Cape Canaveral. This map was obtained from the NOAA National Environmental, Satellite, Data and Information Service (NESDIS 2004). Sub-ocean surface extensions of the Cape Canaveral topography are clearly seen to be present. The star on the map, approximately 2.6 miles seaward of Cocoa Beach, marks the spot where a bottom-mounted ADCP was deployed form January 2003-January 2004. The depth of the ADCP unit was approximately 14.5 meters.

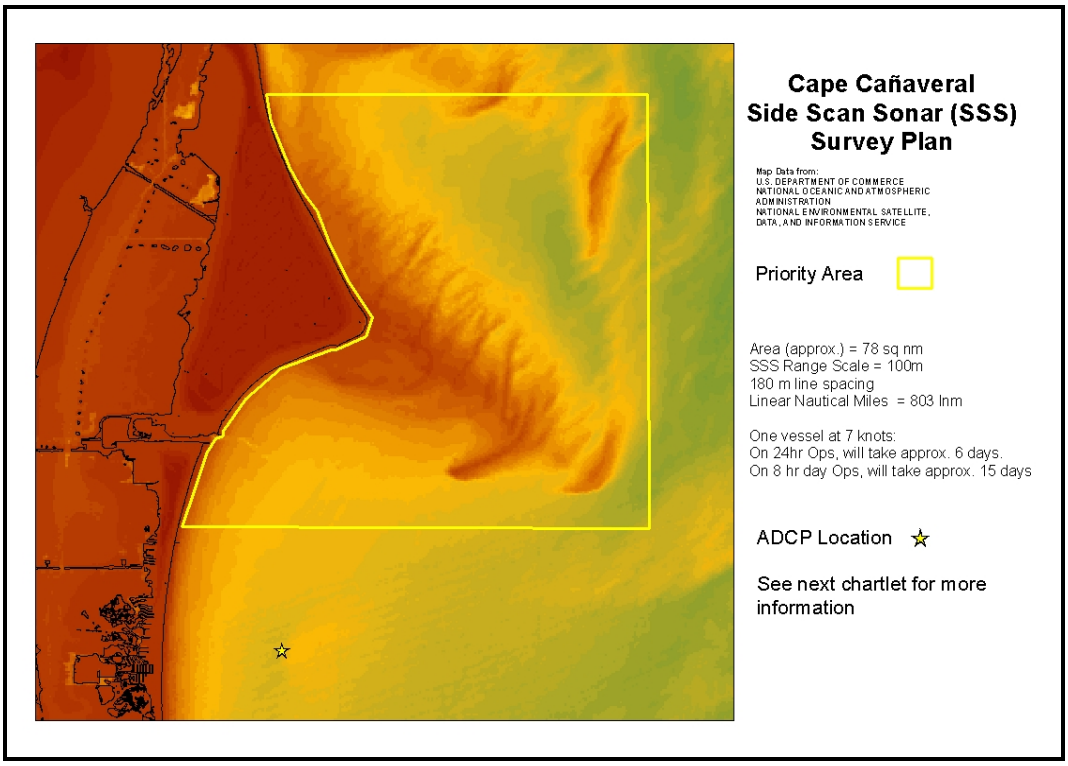


Figure 1

Figure 2 shows the depth variation (height of the water column above the ADCP) for the month of April 2003. From this figure, it can be seen that the water column heights ranged from about 13.8 meters to 15.4 meters.

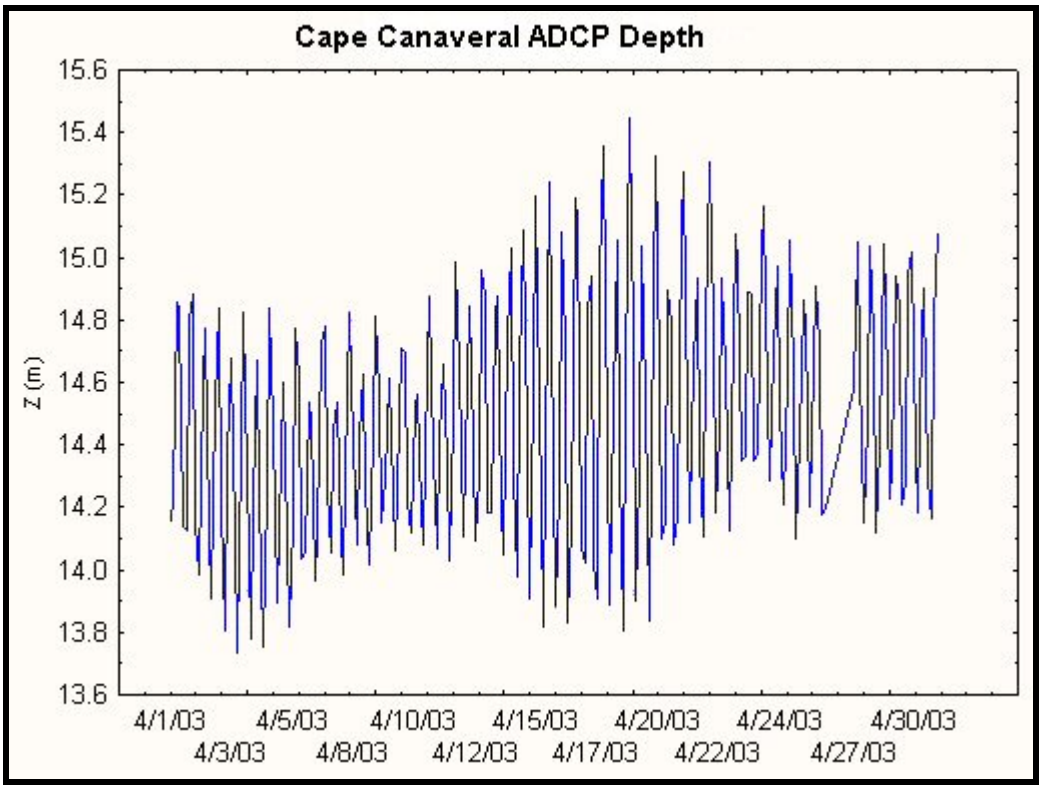


Figure 2

Figure 3 shows a one-year time series of the V (North-South) and U (East-West) components of the water column averaged ambient current. The V component is blue and U is red. The time series extends from January 2003-January 2004 and was obtained using a bottom-mounted ADCP (MacArthur 2004). The speeds are given in millimeters per second, so that the 100mm/second value is equal to 10cm/sec. The data are gathered every 15 minutes so that tidal currents are very easily resolved.

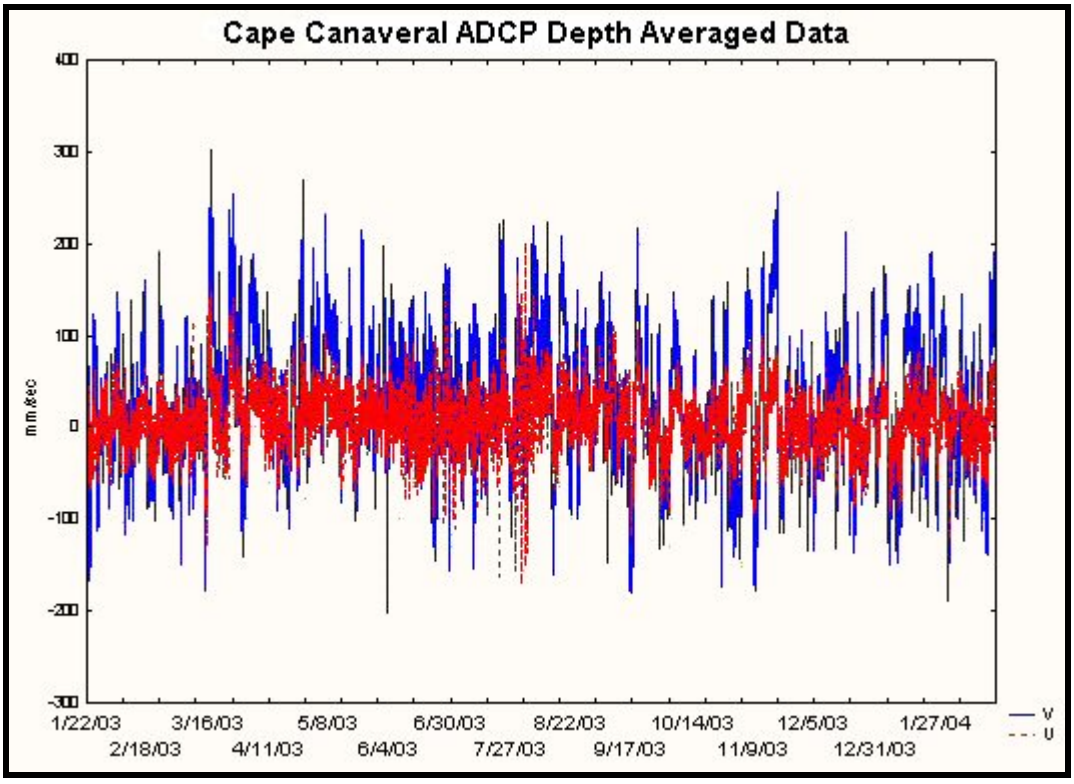


Figure 3

Histograms of the V and U current components are presented in Figure 4 and Figure 5. The mean for the V and U components are approximately 3 cm/sec and 0.8 cm/sec, respectively.

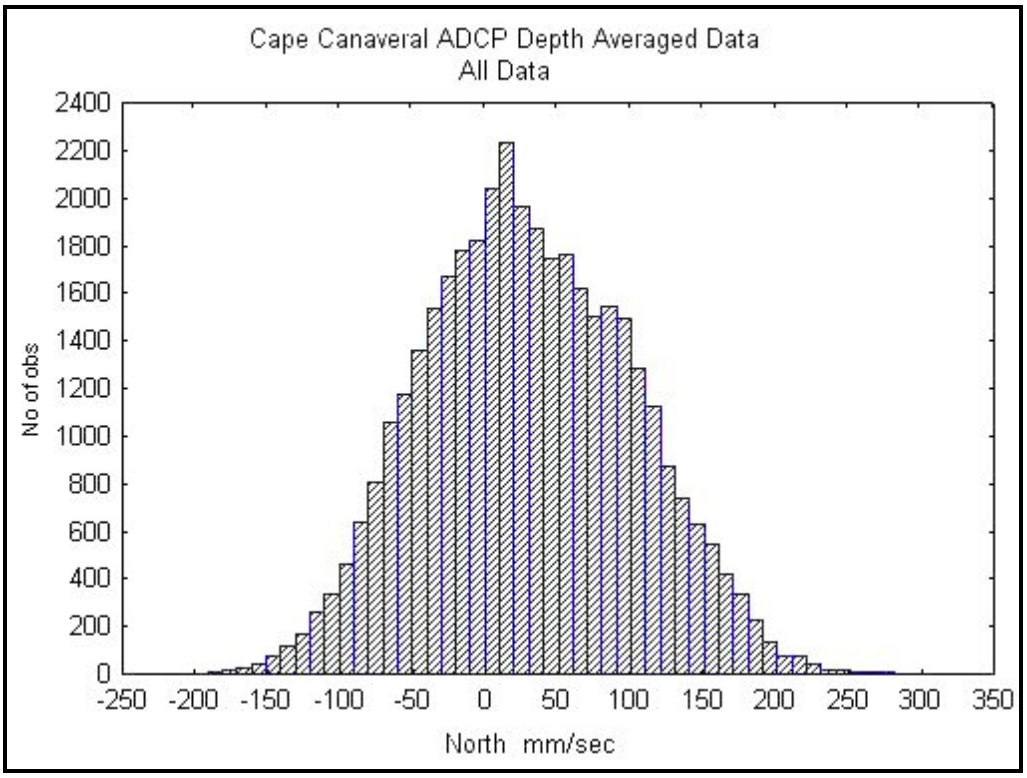


Figure 4

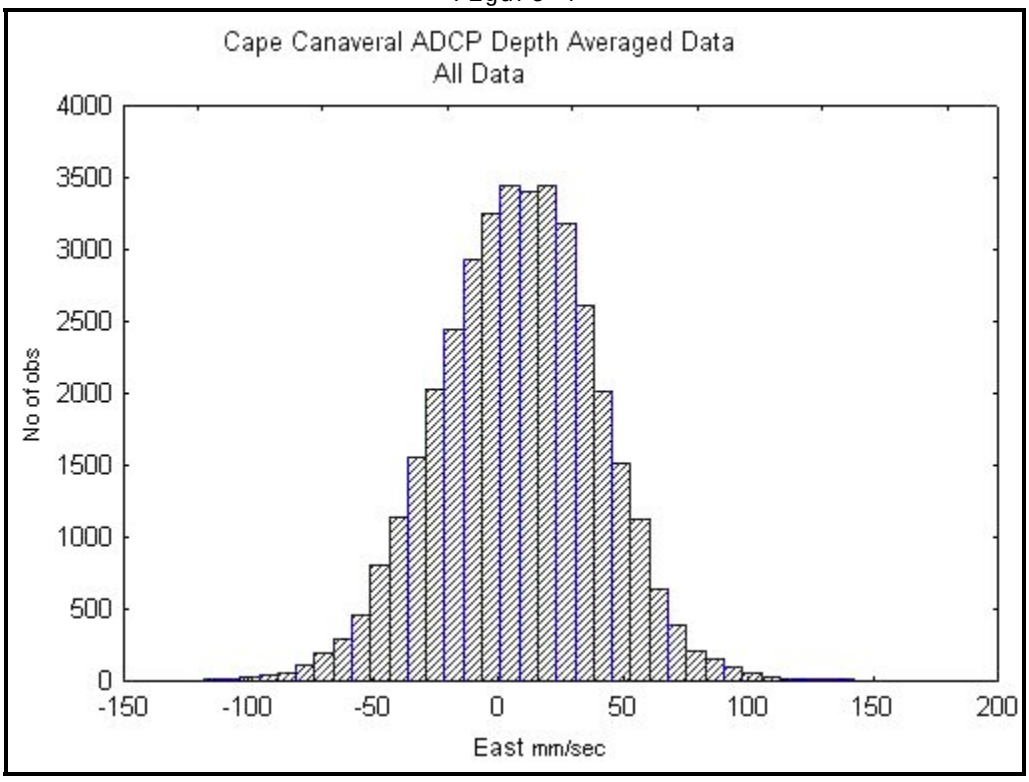


Figure 5

Figure 6 shows the current magnitude (equal to the square root of the sum of the squares of the V and U components of the ambient current), or speed time series for the entire data period. Note that peak speeds on the order of 25-30 cm/sec are seen.

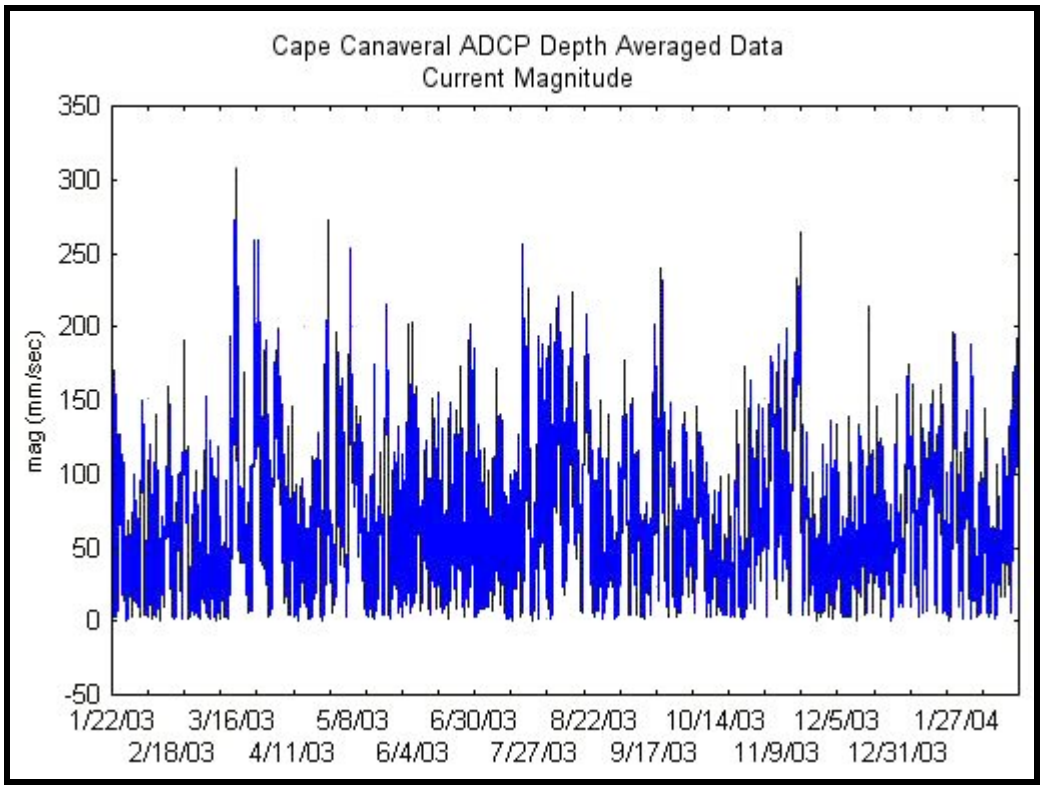


Figure 6

Figure 7 shows a histogram of the ADCP Cape Canaveral/Cocoa Beach data. The data appear to fit a gamma distribution reasonably well. A mean current speed of 7.2 cm/sec is determined.

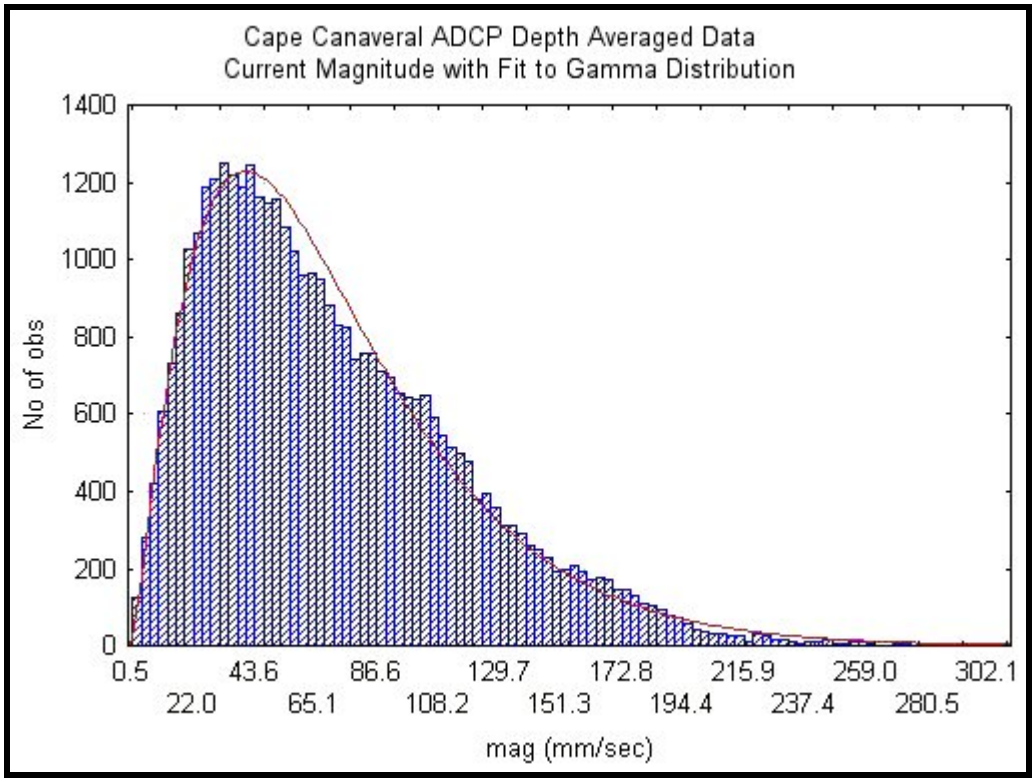


Figure 7

Figure 8 shows the cumulative probability distribution of the current speed or magnitude. Note that the current speed is the square root of the sum of the squares of the U and V current components. The cumulative probability plot is of prime interest for regulating and permitting purposes. A

worst-case dilution condition is often determined using the 10^{th} percentile current speed. One of the reasons for investigating the effects of larger scale current phenomena on local currents is the effect of large-scale currents on the range of values in the coastal ocean waters adjacent to SJRWMD, for the 10^{th} percentile ambient current speeds.

To illustrate the effects of the presence of large-scale ocean current features, Figure 9 presents the probability of current speed off Miami in a water depth of 30 m. Here the effect of large scale eddys on the western boundary of the Gulf Stream, as well as the western boundary of the Gulf Stream itself, results in a 10^{th} percentile speed of approximately 10 cm/sec.

In Figure 8 the 10th percentile current speed is seen to be approximately 2 cm/sec.

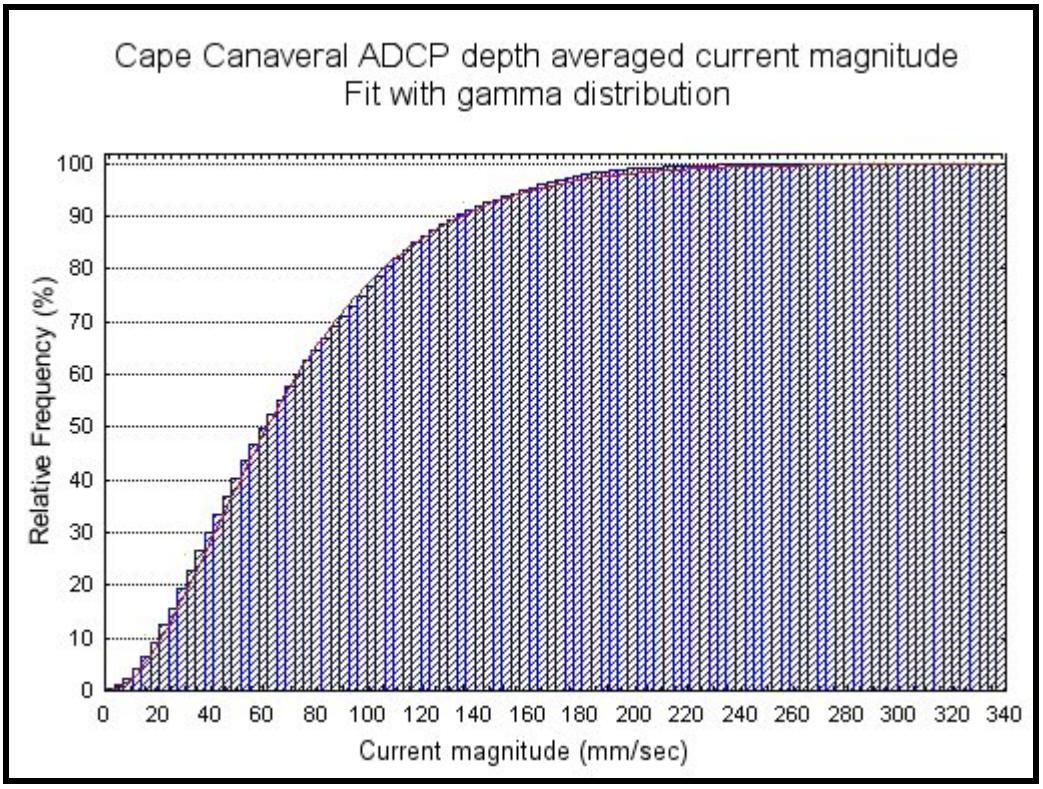
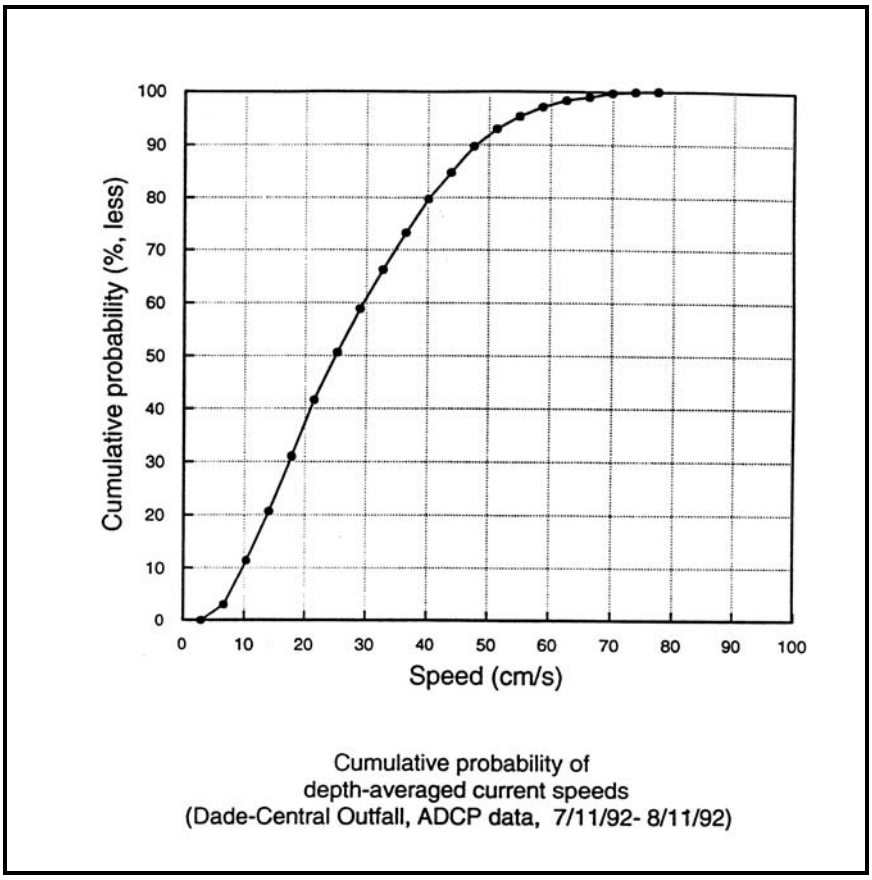


Figure 8



Cumulative probability of
depth-averaged current speeds
(Dade-Central Outfall, ADCP data, 7/11/92- 8/11/92)

Figure 9

Figure 10 shows a plot of current direction and speed. In this plot the direction north is at zero (or 360) degrees. It is seen from this figure that at this coastal ocean site, ambient currents are generally directed around 20° east of north and 20° west of south, roughly paralleling the shore.

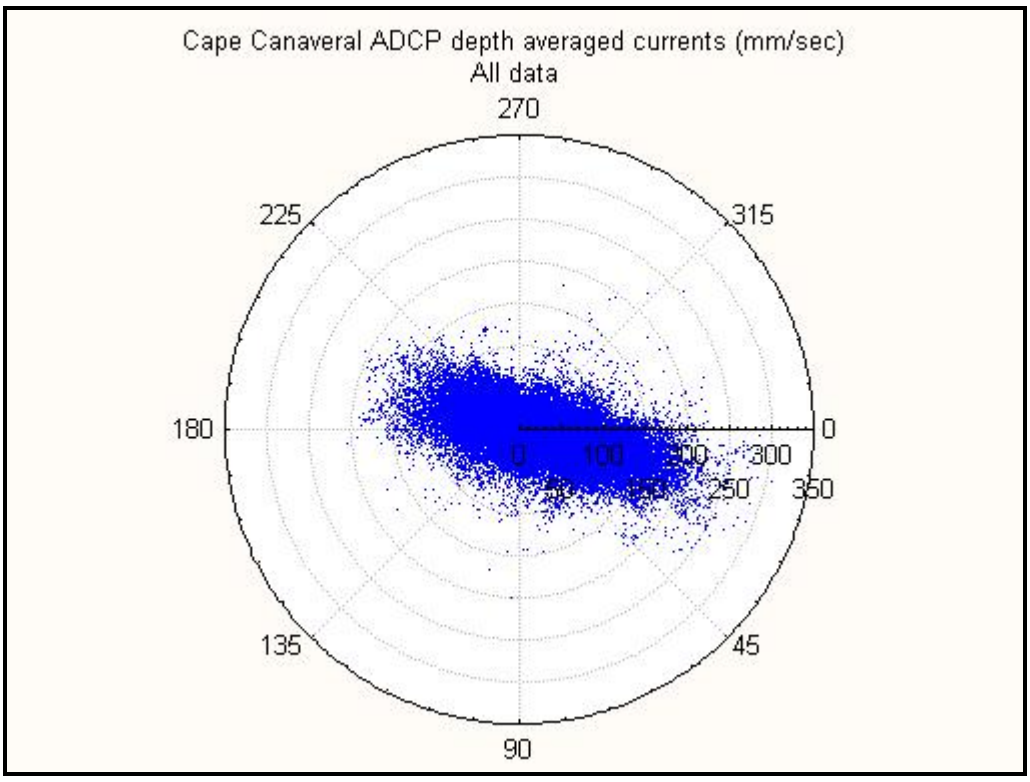


Figure 10

Figure 11 shows additional data of interest, namely bottom sampling sites and results of samples obtained for different bottom types. This data was obtained from the NOAA National Ocean Service (NOS) bottom type database (NOS 2004).

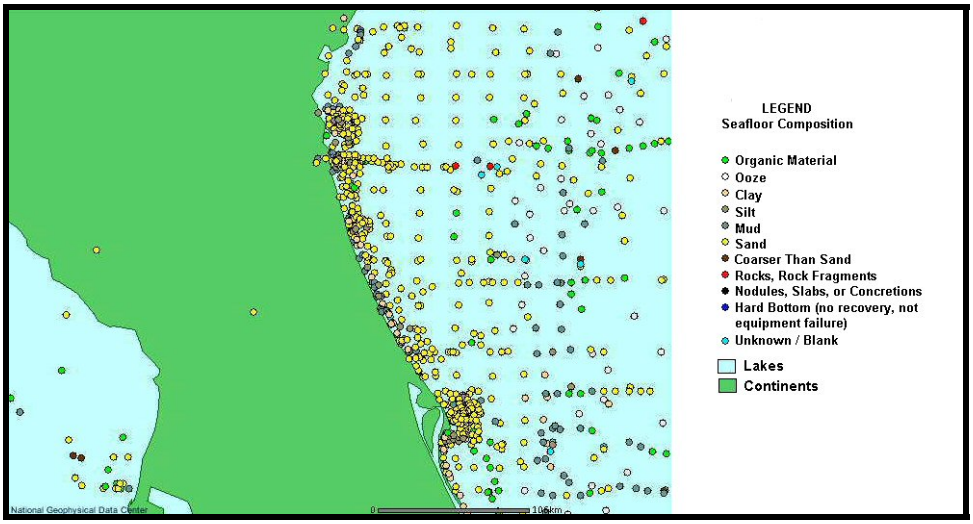


Figure 11

Data of the type shown in Figure 11 are relevant to item 3 specified in the list of information required for a NPDES permit. Bottom substrate, benthic communities, and sediment types are all environmental data of interest both to FDEP and US EPA. One key difference between the FDEP and US EPA is that FDEP may require specific dilution achievement while US EPA may require achievement of applicable water quality

standards without specification of the methods for achieving those standards.

Figure 12, shown for comparison with Cape Canaveral, is a bottom topography map of the Jacksonville area.

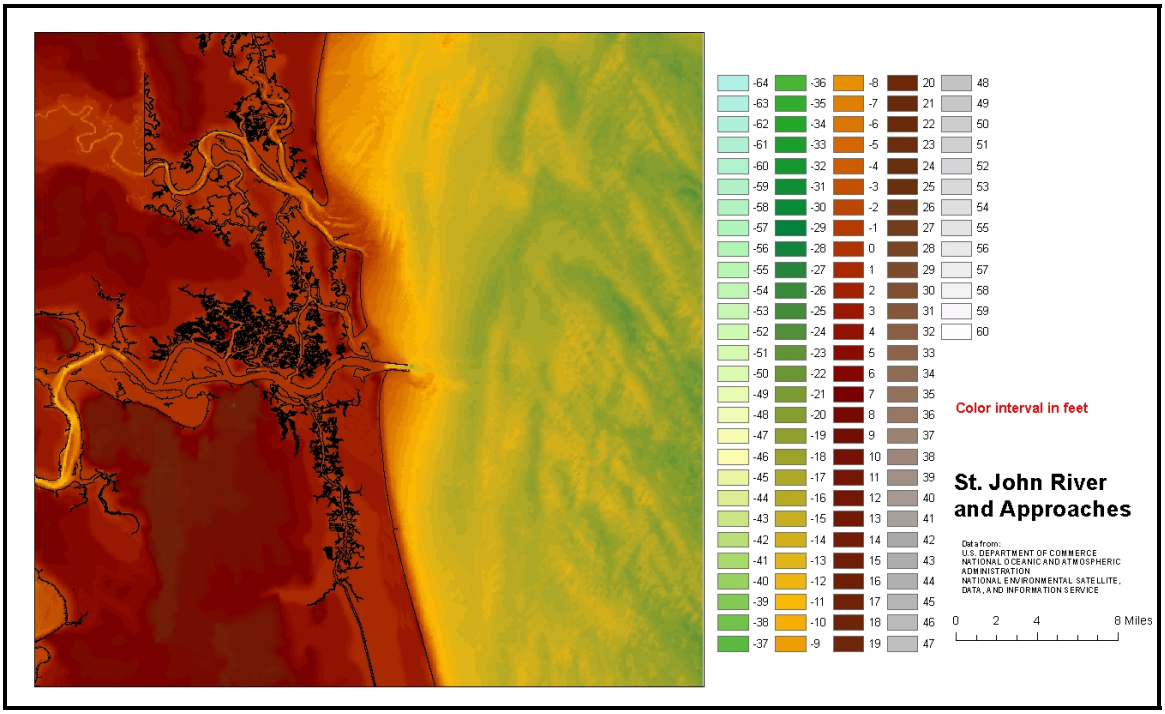


Figure 12

Because of the location of Cape Canaveral, Patrick Air Force Base, and two US Navy submarine bases within the area of SJRWMD, one might think that NASA, US Air Force, and US Navy should have ambient current and other environmental data. So far however, the writer has been unable to establish that this is so. Inquiries have been made of the

above agencies and as the date of this writing (September 3, 2004) no replies have been received.

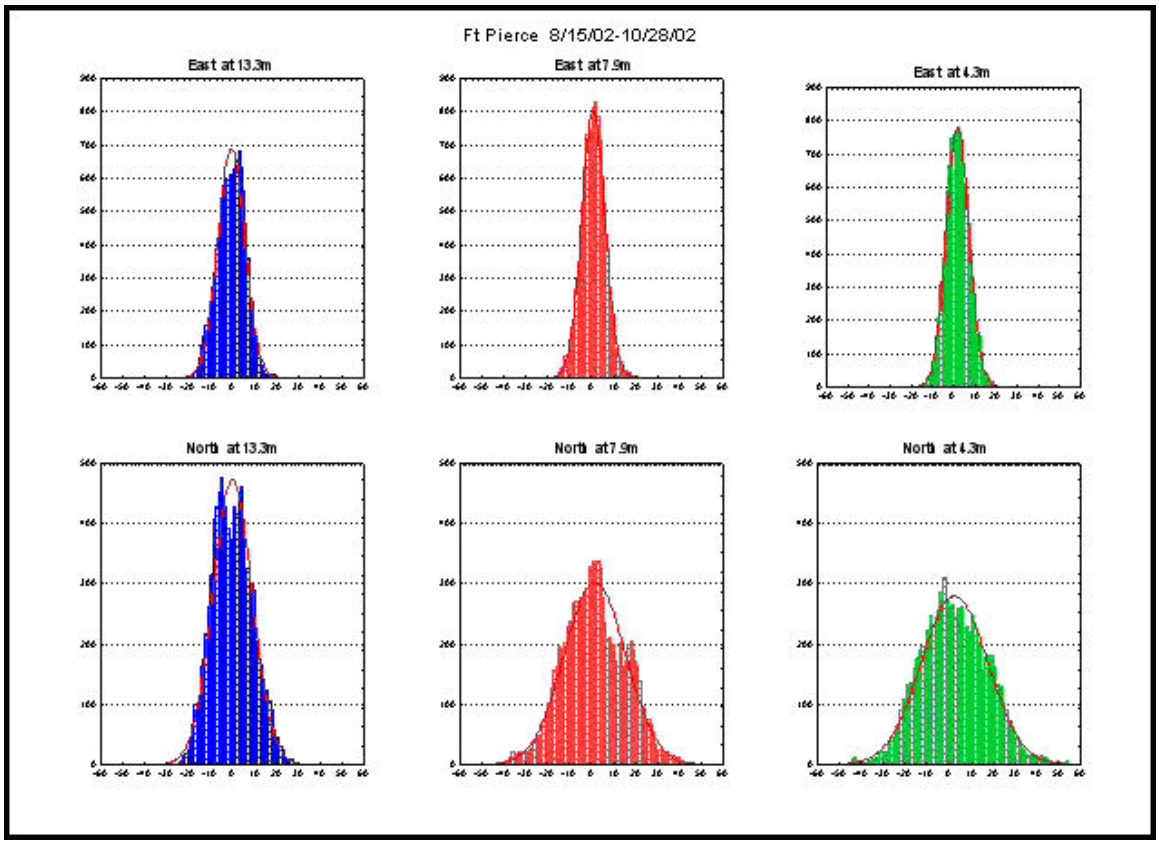


Figure 13

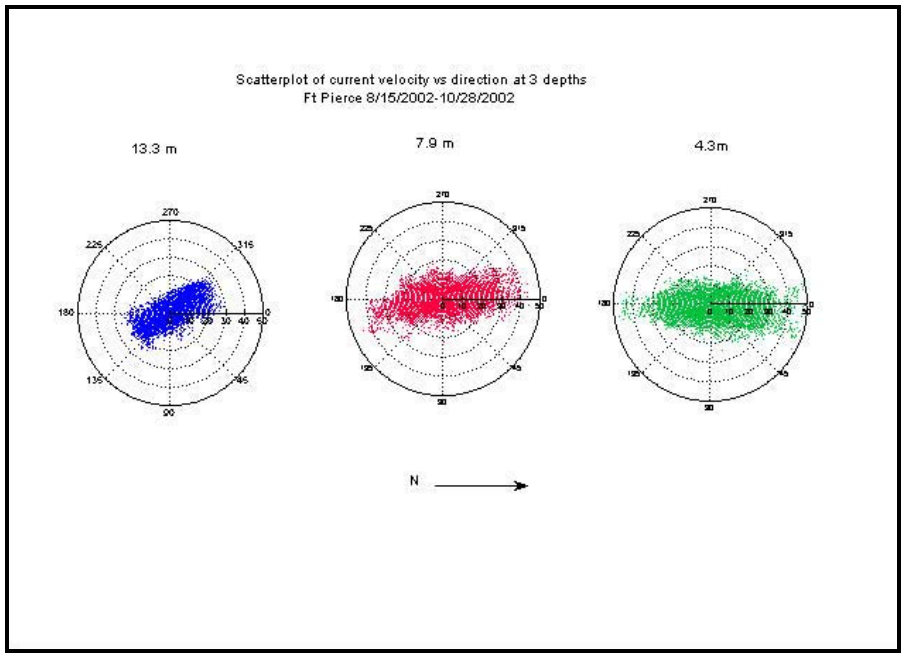


Figure 14

A second data set of relevance was gathered by federal agencies. US ACE and NOAA gathered the data in the coastal ocean in the vicinity of Ft Pierce Inlet in 2002. The present writer served as Chief Scientist for the joint agency project. Project descriptions and results are presented in Elkind et al (Elkind et al 2000), Proni and Nelsen (Proni and Nelsen 2000). Two examples for the data obtained in this project are shown in Figures 13 and 14. Figure 13 shows the histograms of the U and V components at depths of 13.3 meters, 7.9 meters and 4.3 meters. Figure 14 shows ambient current magnitude and direction at depths corresponding to those shown in Figures 13. Note that the largest currents are seen at the 4.3meter depth and that the ambient current

is bi-modal with a slight variation of current direction with depth.

Beyond the US EPA/NOAA Cape Canaveral study and the US ACE/NOAA Ft Pierce study, no other Federal agency studies of environmental parameters that were adequately sampled were found. At a recent (24AUG2004) US EPA convened meeting in Jacksonville, FL, on dredged material discharge, inquiries (NOAA 2004) were made of the attendees regarding the existence of long-term environmental data relevant to the present project. No specific data sets were immediately identified, but further inquiries are being conducted.

Parallel with the literature search for dilution related parameters, an initial search for biological data types of interest was carried out: Prior to specification of three prospective locations for concentrate discharge in the coastal ocean, only general biological information was included (eg shrimp fisheries, occulina reefs). However since specification of the three prospective locations, more focused biological data considerations are possible.

An important listing of biological data types relevant to coastal ocean discharge is provided in the Florida Administrative Code chapter that provides water quality criteria (FAC 64-302.500-530). The section of this chapter likely to be applicable for future concentrate discharge is

that for Class III: Marine surface waters (FDEP personal communications December, 2004). One reason this is appropriate, is that no shellfish habitat is located in sufficient proximity to the prospective discharge location to be affected by the discharge. The presence of shellfish is in the definition of Class II waters in the same Florida Administrative Code Chapter.

The principal sources of biological information arise in conjunction with either beach renourishment or dredge projects. The Marine Minerals Management Service (US MMS), US ACE, US EPA, and NOAA are all active in benthic studies.

IV. CONCLUSIONS AND RECOMMENDATIONS

The present report is for Task 2, Phase I, of a preliminary investigation into the oceanic dispersion and dissposal of desalination/demineralization concentrate in coastal ocean waters adjacent to SJRWMD. While the title of this Task is "Literature and Data Review' the task is in fact broader than a literature and data review, since it is required as part of this task that 'interagency relationships be established to further advance the project'. The project being the preliminary investigation referred to previously, and also the literature and data review which comprises a sub-part of the overall project.

A. CONCLUSIONS

The first conclusion is that the extant literature, as reviewed by the methods specified in Section II of this report, contains three data sets of relevance for the estimation of dilution and dispersion in the coastal ocean environment. These data were obtained in the coastal ocean waters proximal to Cocoa Beach, Cape Canaveral, Ft Pierce, and Melbourne Beach. All three data sets were gathered within three miles of the shore.

The second conclusion is that the data from these three sites have some key features in common: a) the ambient current directions are principally parallel to the coastline, b) ambient currents are largely the result of winds and tides, c) large scale current features, eg eddies, and Gulf Stream meanders are largely absent from the data, but upwelling does occur throughout the year, particularly in the summer, d) tenth percentile current speeds are in the range 2-5 cm/sec, e) maximum currents are less than 50 cm/sec.

The third conclusion is that because regulatory authority for concentrate discharge in the coastal ocean changes at the three-mile point from shore, from state to federal authority, there is an accompanying change in emphasis on environmental characteristics deemed to be of importance to regulatory considerations.

Coastal ocean concentrate discharge outfall sites that are within 3 miles of shore fall under the State of Florida regulations, while those sites more than 3 miles offshore are under federal regulation. The sites under state authority may be required to achieve dilutions as high as 100:1 depending on the results from toxicity tests.

The fourth conclusion is that the coastal ocean depth at 3 miles from shore is usually on the order of 15 meters. This depth, and the gradient from shore, will play a key role in determining dilution values that can be achieved within 3 miles of shore.

The fifth conclusion is that there is little evidence to suggest significant water column density stratification; there is a paucity of water column density profiles. The ambient current data suggest a fairly uniform flow, implying open channel type flows. If later data supports this conclusion, then angled jet discharge can be considered in discharge port and diffuser design, thereby extending the effective length of the water column and increasing the effective dilution.

The sixth conclusion is that permitting for the prospective concentrate discharge in coastal ocean waters adjacent to SJRWMD will likely be affected by the State of Florida's anti-degradation policy (FAC Title 62). In turn,

this implies that the discharge will likely have to meet the Class III Marine surface waters water quality criteria. Some of the referenced criteria involve both chemical and biological measurements and are described in terms of ambient coastal ocean characteristics. If shellfish harvesting were occurring in parts of the coastal waters, then sub-portions of the coastal ocean might be classified as Class II waters. Initial conversations with FDEP have not suggested the presence of significant shellfish harvesting in coastal waters adjacent to SJRWMD (FDEP personal communication, 2005).

The seventh conclusion is that characterization of the prospective concentrate to be discharge is needed for several purposes including: (a) determination of the toxicity or not of the concentrate, (b) determination of concentrate density – a range of densities depending upon source water used and demineralization process efficiency, (c) determination of selected chemical constituents for comparison with receiving water standards, eg Class III marine surface water discharge standards.

B. RECOMMENDATIONS

1. It is recommended that SJRWMD and NOAA personnel meet to discuss the literature and data review. The meeting agenda will include discussion of options for SJRWMD to

consider when choosing sites for concentrate discharge. (The first draft of this memorandum was reviewed in a joint SJRWMD/NOAA meeting held in November, 2004.)

2. It is recommended that after the SJRWMD/NOAA meeting, subsequent meetings should take place between SJRWMD, NOAA, and FDEP personnel. Key subjects of further meetings should include a) review of the current status of the State of Florida regulations governing concentrate discharge in the coastal ocean, and b) a determination of any additional coastal ocean environmental data that may be required.

3. It is recommended that SJRWMD prioritize water sources, bearing in mind the implications of different source waters for concentrate discharges in the coastal waters. A program of concentrate characterization and toxicity evaluation should begin. This program must include pilot production of actual concentrate to be discharged. [An initial pilot production of concentrate showed no toxicity(SJRWMD, 2003)]. The toxicity of the concentrate will largely be governed by the specific source-water origin, any chemicals introduced in processing and processing procedures. There is a distinct difference in the use of groundwater (demineralization) and the use of seawater (desalination) as source water. Groundwater may contain chemicals or substances [see FAC 62-4.244(3)(b) for a list]

that should be tested, and concentrations should not exceed stated values. Those chemicals will not likely be found in concentrations of concern in seawater. If the toxicity arises solely due to ionic imbalance, other considerations apply. There is specific additional language under development within FDEP regarding toxicity arising solely from ionic imbalance.

4. It is recommended that SJRWMD begin examination of coastal ocean outfall siting options using an integrated approach that includes a) recognition and evaluation of the consequences of the partitioning of the coastal ocean into two areas, each under different regulatory bodies (the State of Florida and the federal agencies); the partition point, or boundary, is 3 miles offshore the coastline, b) determining the likely locations of demineraliza-tion/desalination plants and the shore locations that will serve as origins for pipe placement for transport of concentrate discharge to coastal ocean outfall sites, c) evaluation of cost and trade-offs in outfall site locations within and beyond the 3-mile boundary. Outfall locations shoreward of the 3-mile boundary will likely require use of multi-port diffusers. In the November 2004, meeting SJRWMD provided three prospective coastal ocean locations for discharges.

5. It is recommended that as part of source water selection and concentrate characterization, the potential range of discharged concentrate density and concentrate concentrations of quantities of interest indicated in the Class III marine surface water standards be determined. Some environmental factors will receive more emphasis than others, depending upon whether the concentrate is positively or negatively buoyant. The density of the discharge is affected by source, and desalination/demineralization processing efficiency. The specific design of the outfall pipe transport system will be affected by the difference in the density of the concentrate discharge and the density of the receiving waters. It is further recommended that the opinions of both the FDEP and US EPA regarding the discharge of negatively buoyant concentrate be considered.

6. It is recommended that a sampling program should be developed in cooperation with FDEP and US EPA, if it is determined that additional coastal ocean data is required. If additional data is required, it will likely include data on ambient currents as a function of distance from shore, biological communities, long-term transport of discharged concentrate, water column density profiles, and the impact of discharge plumes on the ocean bottom.

Once potential shore locations of pipe transport systems are identified, ambient currents can easily be measured using self-contained acoustic Doppler current profilers (ADCPs). These systems can be deployed for extended periods, up to many months, and at different distances from shore (1, 2, 5 miles) and are relatively inexpensive to purchase, install, maintain, and to retrieve data.

The ADCP measurements are fixed location (Eulerian) current measurements. For subsequent dilution, transport, and exposure determinations, Lagrangian (following the water) current measurements are very useful. These measurements can be accomplished using injected tracers, eg, dye, sulfur hexafluoride, and drogues.

7. It is recommended that at the second meeting, the longer-term subject outfall and concentrate discharge monitoring requirements be raised. This will be of value to utilities that may implement future projects.

8. It is recommended that the subject of 'blended' discharge possibilities should also be raised at the second meeting. Raising this subject would provide an opportunity to obtain FDEP news on blending of concentrate with other fluids, such as cooling water, wastewater effluent, etc. for coastal ocean discharge.

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V. APPENDIX

In this appendix some background information on plume dynamics is presented. Some of the figures show the application of underwater sound to create 'acoustic visualizations' of discharge plumes. The application of underwater sound to make acoustic photographs of coastal ocean plumes has been developed at AOML (Atlantic Oceanographic and Meteorological Laboratory) of NOAA in Miami FL.

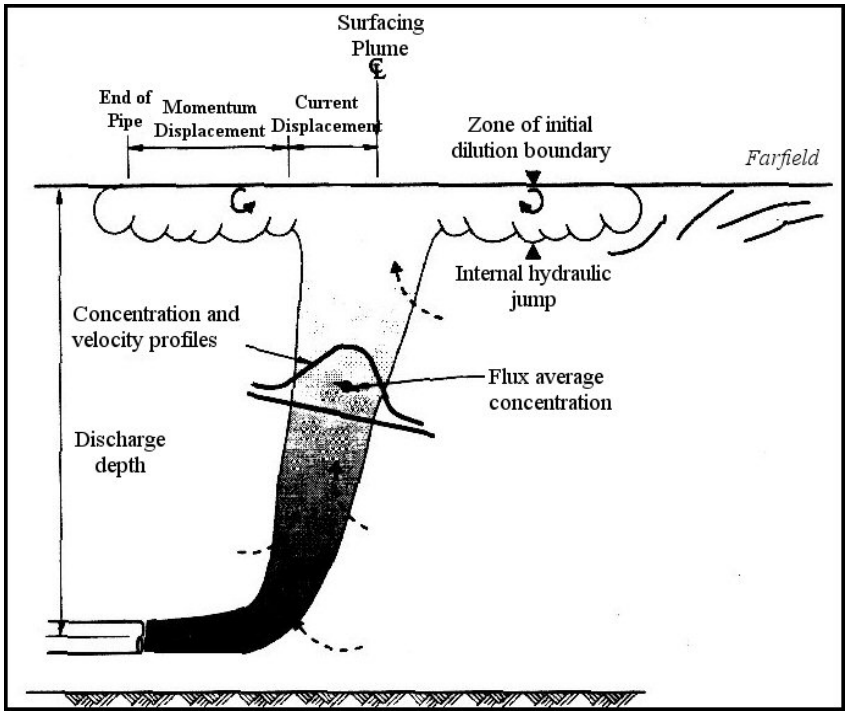

Figure 1

A simplistic concept of a positively buoyant plume is shown in Figure 1. In this figure, which was used for a

specific waste-water effluent discharge, the discharge port releases the discharge at an angle of zero degrees (parallel to bottom) and relies upon the positive buoyancy of the plume to cause it to rise to the ocean surface. In the case of concentrate discharge, many angles of injection of discharge will be considered, e.g., 45° from the bottom.

Figure 2 shows the actual spatial disposition and form of an effluent plume from one of the Miami area wastewater outfalls.

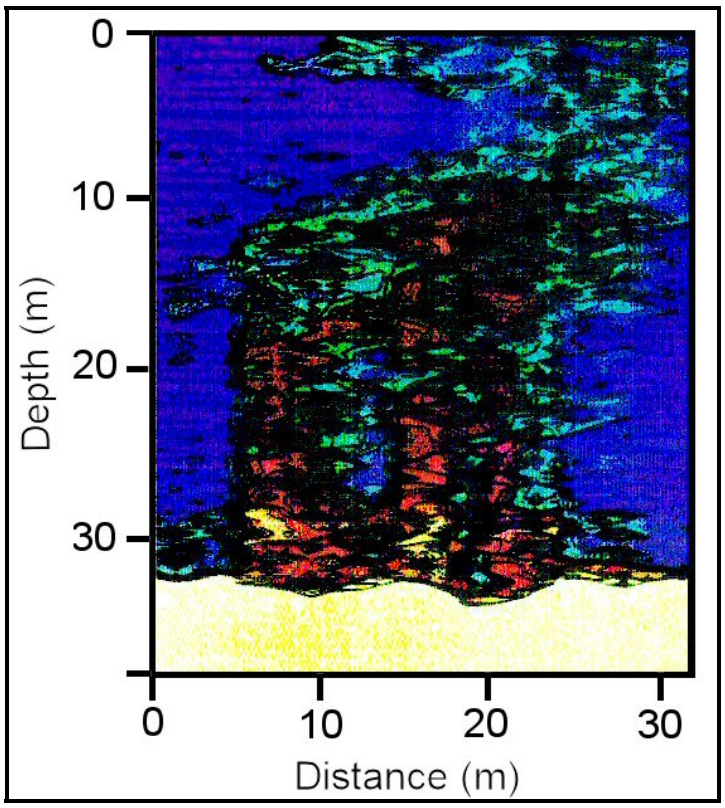

Figure 2

This figure was made using underwater sound, in which pulses of sound from a surface ship are reflected from the effluent plume.

The plume examples In Figures 1 and 2 are for positively buoyant plumes.

A negatively buoyant plume is shown in Figure 3, which shows the plume formed when dredged material is released into the coastal ocean from the surface of the ocean.

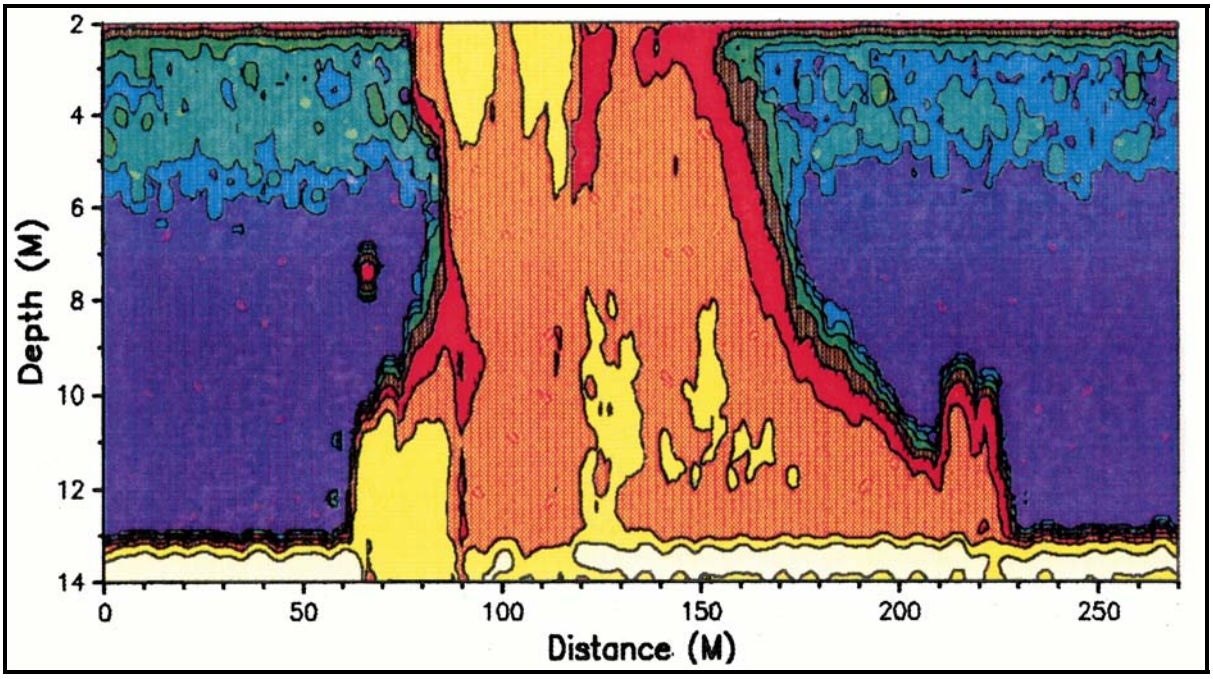

Figure 3

The plume can be seen to expand and dilute with depth. Notable in this discharge are bottom surges that cause the

discharged plume to expand laterally upon impacting the ocean bottom.

Figure 4 shows several model estimated centerline plume trajectories calculated by Del Bene et al (Del Bene et al, 1994) using an adapted form of the CORMIX disposal model.

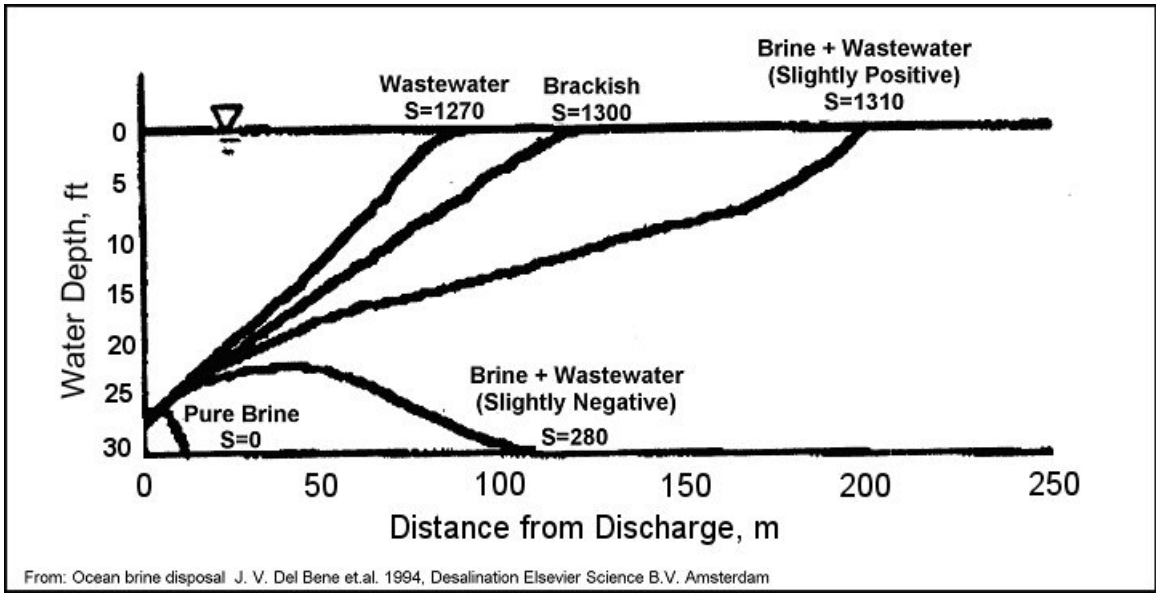

Figure 4

This figure shows centerline plume trajectories for a near bottom-released angle above bottom of 45°) for fine concentrate density possibilities. Also seen are the dilutions calculated by the model for each centerline

trajectory. The concentrate discharged is blended with wastewater effluent to produce the dilutions calculated.

Figure 5 shows ambient water column density profiles at a location about 4 miles from the coast of Miami. Note that the near-surface water column density ranges from approximately 1.0215 gm/cm^3 in September 1991, to approximately 1.0245 gm/cm^3 in January 1992.

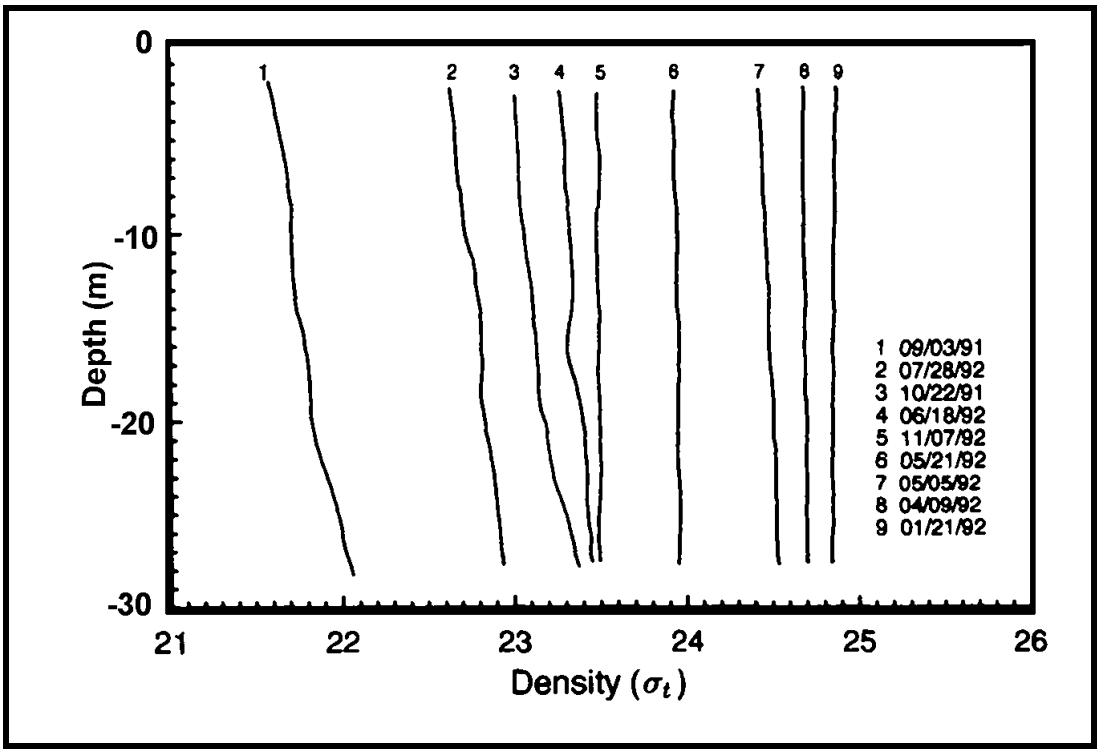

Figure 5