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FEASIBILITY EVALUATIONS FOR ST. JOHNS RIVER MEMBRANE WATER PLANT DEMINERALIZATION CONCENTRATE MANAGEMENT

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CH2MHILL

FINAL REPORT

St. Johns River Water Management District
Palatka, Florida

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EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) is working closely with public water suppliers within its jurisdiction in developing implementable plans for meeting future water supply demands. A central theme is the need to develop alternatives to the historical reliance on the Upper Floridan groundwater aquifer as the primary source of potable water. Investigations on alternative water supply (AWS) strategies for some of the utilities located in east-central Florida along the St. Johns River (SJR) have indicated that the river may be a viable raw water supply; some river withdrawals are believed to be allowable while still meeting minimum flows and levels (MFLs) requirements.

The river tends to be slightly brackish resulting from significant groundwater influence under low river flow conditions. Demineralization treatment technologies are likely needed for producing potable water. These treatment processes generate a wastewater containing concentrated constituents found in the source water called generically *concentrate*. Management of this concentrate is now recognized as the major factor influencing engineering, environmental, and economic feasibility determinations because of the potential environmental challenges to dispose of it.

SJRWMD initiated focused studies on the environmental and regulatory feasibility of returning the concentrate from conceptual AWS demineralization facilities in east-central Florida back to the river through new surface water discharges. A Plan of Study (POS) was developed for an initial planning-level analysis of key environmental and regulatory feasibility criteria that were identified in conjunction with the Florida Department of Environmental Protection (FDEP). This technical report summarizes the key information compiled in FY2006-2007 and FY2007-2008.

The work plan included:

- Review of the literature
- Compilation of key hydrologic, water quality, and biological data

- Preliminary field site reconnaissance focused on characterization of river channel physical conditions (depths and widths and sediment characteristics)
- Mass balance analysis for each of the potential AWS demineralization water treatment plant (WTP) locations
- Evaluation of mixing zone feasibility for the potential outfalls
- Preparation and documentation of a mass balance spreadsheet model to estimate the effects of WTP loading on SJR

These activities were developed 1) to provide the basis for an initial fatal flaws evaluation of a set of candidate AWS project study zones located along this portion of the SJR and 2) to support dilution modeling analyses to directly address the feasibility of gaining regulatory approval of mixing zones that are anticipated to be necessary.

One set of a typical WTP treatment technology was used at each location to estimate the potential water quality of the concentrate. This treatment train was based on the results of a previous treatability study sponsored by SJRWMD at Lake Monroe. Consequently, the range of the differences between WTP locations estimated herein were small, primarily because the plants were of similar size and the maximum concentrations of the river water quality parameters do not differ along the river.

From the mass balance analysis around each WTP, a concentration factor for each water quality constituent was computed as the concentration in the concentrate divided by the concentration of the source water. The same concentration factor was estimated regardless of the location and was primarily a factor of the potable water recovery rate except for parameters that had extra reduction (like phosphorus) or compounds that are added for process optimization (sulfates and sodium from ferric chloride and pH adjustment chemicals).

Mixing zone plume modeling and mass balance analyses were conducted for each potential AWS area. The estimated recovery factors provided in the mass balance analysis were used to evaluate with more specificity potential changes in water quality constituents at different potential WTP locations. However, future WTPs' actual performance will vary from these estimates because many of the assumptions used herein will change (e.g., process selection, flow rates, actual equipment, and so forth).

The following conclusions are based on the results of mixing zone modeling and mass balance analysis:

1. Background information assembly has highlighted the fact that the SJR is a relatively low-energy river (HSW 2004), with a total elevation drop of only approximately 30 feet from its headwaters in Indian River County to the outfall to the Atlantic Ocean. For the portion of the river basin under current consideration (east-central Florida), low-flow conditions routinely occur each year, and under some conditions, transient periods of reverse flow occur in some river reaches as result of a combination of wind driven and tidally influenced currents. Therefore, evaluation of the effects of concentrate discharge scenarios should focus on these low-flow condition periods to conservatively evaluate worst-case conditions with respect to concentrate mixing with the ambient waters.

2. Standard mixing zone evaluations conducted in accordance with the provisions of Rule 62-4.244, *Florida Administrative Code (F.A.C.),* can adequately address the likely localized discharge effects near the prospective outfalls. Results of the preliminary mixing zone modeling of the discharge scenarios that bracket the anticipated concentrate discharge rates, seasonal river temperatures/densities, and limited diffuser design scenarios indicate that compliance with the mixing zone regulations should be achievable with the proper attention to outfall siting and design. The mixing zone modeling performed thus far indicates that mixing zones appear feasible even after applying conservative, "worst-case" assumptions regarding concentrate water quality and ambient river conditions.

   Compliance can be obtained with the estimated mixing zone dilution factors under Class III criteria. If the use classification changes to Class I, then there are compliance issues related to the naturally high ambient chlorides.

3. An initial planning level mass balance model was prepared for analysis of WTP loading effects on the SJR concentrations. Because of the order-of-magnitude mass balance relationships between the subject WTPs and the ambient river conditions, the net effects of these WTP operations on the flow and water quality conditions in the river are predicted to be small. The largest upstream/downstream differences calculated were well within the month to month or

overall wet season/dry season differences seen in the river on a routine basis. These results suggest that the downstream effect of concentrate discharge from each water treatment plant on ambient conditions in the river would be smaller than the normal variability that occurs in the river. Aquatic organisms living downstream of these conceptual water treatment plant discharges are unlikely to experience conditions measurably distinguishable from the normal variations in ambient water quality that occur due to climatic variations. The ecological significance of these small calculated changes will need to be addressed in SJRWMD's ongoing studies of cumulative withdrawals from the river. This model can be used by the District for future evaluation of possible combinations of WTPs, membrane plant operational levels, and varied application of supplemental nutrient removal technologies.

These results support the following recommendations regarding study refinements that might warrant consideration:

1. The findings to date are based on execution of only initial screening-level mixing zone modeling and feasibility investigations. These results should be discussed with the utility stakeholders in the development of improved conceptual designs as applicable and/or as new information is provided regarding AWS projects. WTP and pipeline siting and likely river access and prospective outfall locations need to be better defined to improve on this feasibility study.

2. Interagency review and research regarding the cumulative effects issues should be continued. The "focused" approach of this study was conducted because it pertained to specific stakeholders and their area of interest. The water supply impact study currently underway by SJRWMD will broaden the assessment to technical issues not covered here (trophic states, zooplankton, floodplains, and so forth). These concerns revolve around the water balance as well as these additional ecological relationships of the Middle St. Johns River, Lake George, and Lower St. Johns River Basins to help formulate an acceptable holistic plan to help define the magnitude of these AWS projects.

3. If specific utility proposals exist that would elevate the prioritization of lake-based discharges, mixing zone evaluations for lake environments should be reconsidered for inclusion in future phases of this feasibility evaluation. On the basis of the mixing zone

modeling performed to date, dilution achievable in waters as shallow as 6 feet might be sufficient to achieve compliance with the mixing zone rules. However, it should be understood that water-quality-based constraints could potentially require these AWS project concepts to be designed for achieving lower rather than higher levels of potable water recovery. In this manner, less concentrated constituent presence might make the subsequent surface water discharges relatively more feasible from a regulatory and environmental effects perspective.

The investigations conducted thus far support the continued development of AWS project concepts that include concentrate discharge back to the SJR, assuming appropriately conservative environmental planning and design of these facilities are applied during project development. This study's conclusions and recommendations are offered as a reasonable starting point from which additional interagency suggestions may be developed for future work by the AWS applicants.

As emphasized above, because of the conceptual and preliminary nature of the AWS projects considered in this evaluation, further development is needed preferably with stakeholder input to improve the specificity of the feasibility assessments.

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CONTENTS

APPENDICES

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

AWS	alternative water supply
AWWA	American Water Works Association
°C	Celsius
CF	concentration factor
CFCA	Central Florida Coordination Area
cfs	cubic feet per second
DWSP	District Water Supply Plan
E	Endangered (species list)
ECT	Environmental Consulting and Technology, Inc.
EPA	U.S. Environmental Protection Agency
F.A.C.	*Florida Administrative Code*
FDEP	Florida Department of Environmental Protection
FP&L	Florida Power and Light
fps	feet per second
FS	Florida Statute
g/cm^3	grams per cubic centimeter
GRI-FW-STR	Gas Research Institute-Freshwater-Salinity/Toxicity Relationship
HSW	HSW Engineering, Inc.
I-4	Interstate Highway 4
kg/day	kilograms per day
L_D	discharge length scale, square root of port area
LSJR	Lower St. Johns River
MFLs	minimum flows and levels
mgd	million gallons per day
mg/L	milligrams per liter
MLLW	mean lower low water
MSIIT	Major Seawater Ion Imbalance Toxicity

m^2	square meter
μmhos/cm	micromhos/centimeter
mmhos/cm	millimhos/centimeter
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity unit
OFW	Outstanding Florida Waters
PCU	platinum cobalt unit
POS	Plan of Study
psu	practical salinity unit
ppt	parts per thousand
RO	reverse osmosis
ROSA	Reverse Osmosis System Analysis
S/cm	Siemens/centimeter
SD	standard deviation
SJR	St. Johns River
SJRWMD	St. Johns River Water Management District
SSAC	Site Specific Alternative Criterion
SSC	Species of Special Concern
S.U.	standard unit
SWIM	Surface Water Improvement and Management
SWTD	Surface Water Treatment and Demineralization
T	Threatened (species list)
TCR	Taylor Creek Reservoir
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TM	technical memorandum
TOC	total organic carbon
TSS	total suspended solids

USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VP	VISUAL PLUMES (program)
WET	whole effluent toxicity
WRV	water resource value
WQS	Water Quality Standards
WTP	water treatment plant
WWTP	wastewater treatment plant

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) is working closely with public water suppliers within its jurisdiction in developing implementable plans for meeting future water supply demands. A central theme is the need to develop alternatives to the historically heavy reliance on the Upper Floridan groundwater aquifer as the primary source of potable water. Investigations on alternative water supply (AWS) strategies to date have focused on the engineering, environmental, and economic feasibility of using surface waters, deeper and lower quality groundwaters, or even coastal/marine waters as source waters for new or expanded water treatment plants (WTPs). Each of these alternatives has its own suite of advantages and disadvantages, making water supply planning for the future a complex exercise. Future plans are strongly influenced by geographic location and current and near-term rates of increased water supply demands.

SJRWMD water supply planning activities have identified geographic areas with the greatest population growth over the next several decades, and several of these correspond to the areas where potable water supply demands are expected to outpace sustainable groundwater supplies. East-central Florida is one of those planning areas, and SJRWMD has identified general locations along the St. Johns River (SJR) in this region where river withdrawals are believed to be allowable while still meeting statutory minimum flows and levels (MFLs) requirements. Prospective areas where potential AWS projects have been identified are shown in Figure 1.

SJRWMD and several water supply utilities have developed planning scenarios that use the river as a source to meet at least part of the projected future demand for potable and nonpotable water. In the Upper and Middle St. Johns River Basin, many areas are known to exhibit brackish water tendencies as a result of "…the inflow of brackish water from the Floridan aquifer" (Kroening 2004). Treatment of such brackish waters to potable standards, therefore, will require the use of demineralization treatment technologies for producing finished water. The by-product of these membrane treatment technologies is a wastewater-bearing concentrated natural water quality constituent found in the source water. The management of this concentrate is recognized as a major factor that influences engineering, environmental, and economic feasibility determinations.

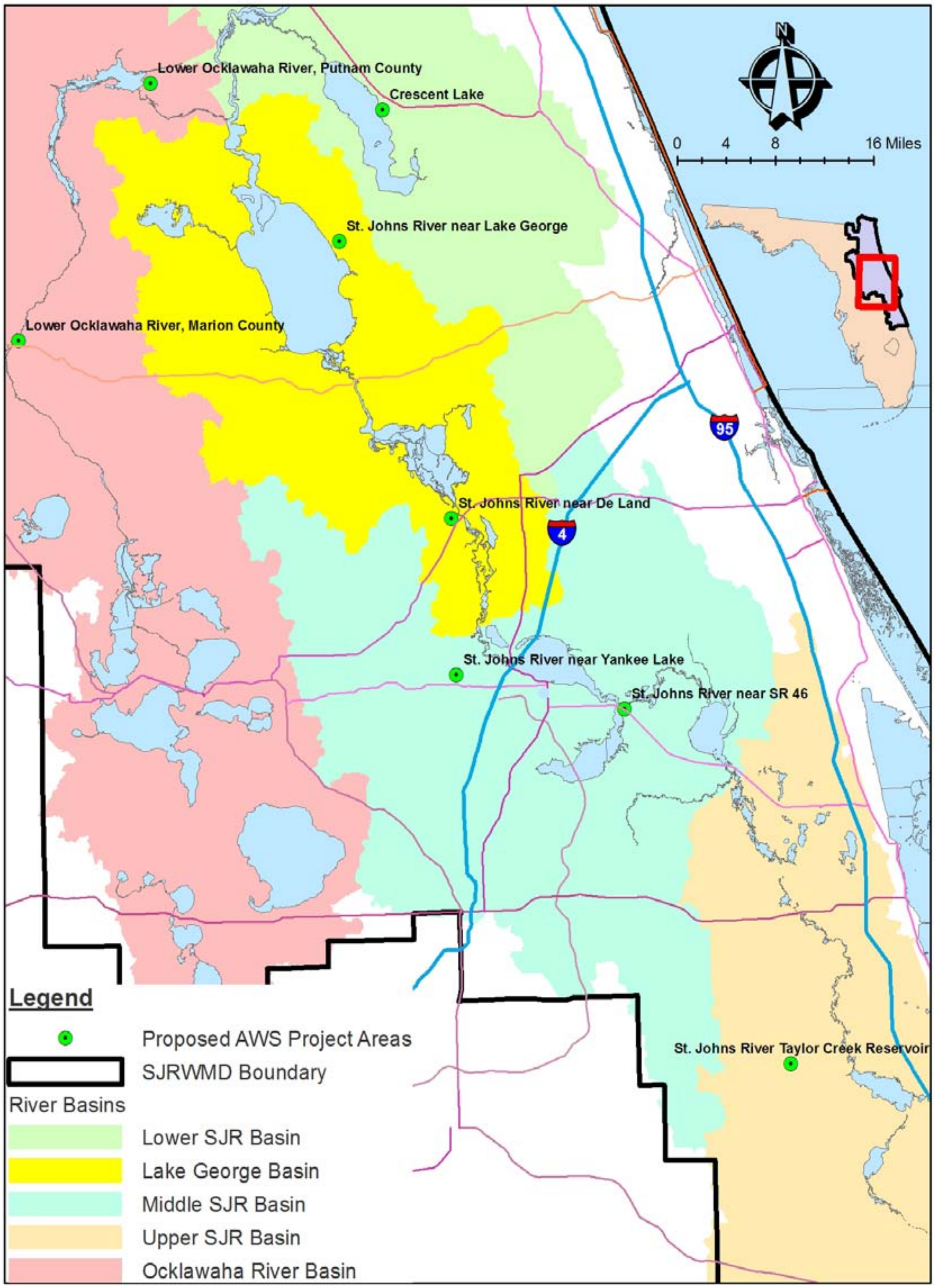

Figure 1. Locations of prospective alternative water supply projects on or near the St. Johns River in east-central Florida

To date, surface water facilities project planning has been based on the assumption that demineralization concentrate generated while producing potable water would be returned to the river. To evaluate the environmental and regulatory feasibility of this concentrate management strategy, SJRWMD initiated planning-level discussions with the Florida Department of Environmental Protection (FDEP) in January 2007. These discussions were focused on identifying the key issues that would impact future permitting decisions. During the first two quarters of 2007, a Plan of Study (POS) was developed by SJRWMD and reviewed by FDEP. Tasks included within the POS are summarized as follows:

- Task 1 – Develop Candidate Discharge Scenarios: Summarize representative concentrate discharge scenarios for a range of locations within SJR, bracketing realistic ranges of concentrate quality and quantity and receiving water physical and chemical characteristics and aquatic community characteristics. Collaborate with FDEP to select three to six representative scenarios and locations for inclusion in the remaining portions of the study.

- Task 2 – Conduct Literature Review and Compile Background Data: Review the scientific literature addressing the themes of surface and groundwater inflows, ionic imbalance toxicity or other associated water quality effects, and aquatic community biological responses within SJR. Assess these potential receiving water effects in terms of localized and cumulative effects within SJR.

- Task 3 – Conduct Fatal Flaw Evaluations of Candidate Discharge Scenario Locations: For the selected three to six demonstration scenarios, evaluate the discharge locations in terms of presence of fatal flaw factors, such as the presence of extensive submerged aquatic vegetation known to function as a nursery area for fish and invertebrates or reliance on the area by threatened or endangered species.

- Task 4 – Conduct Mixing Zone Modeling: For those locations where fatal flaw factors are not present, prepare conceptual designs for concentrate discharge facilities. These planning-level conceptual designs are to be developed to an adequate level of detail needed to support mixing zone analyses and order-of-magnitude cost estimation for facility implementation. Work with FDEP to develop an acceptable mixing zone modeling plan. Conduct instructive, planning-level computer modeling of mixing zone scenarios to provide stakeholders with an understanding of the types of mixing zone demonstrations needed to support potential future permit applications. Demonstrate the ability to achieve permitting of mixing zones for typical concentrate constituents that may exceed freshwater or estuarine water quality standards, as applicable.

- Task 5 – Facilitate Stakeholder Workshop: Work collaboratively with FDEP to prepare examples of acceptable documentation meeting the Department's reasonable assurance guidelines. Facilitate a workshop with interested stakeholders where investigation results can be presented and stakeholder questions and concerns can be discussed.

- Task 6 – Prepare Feasibility Study Report: Synthesize the investigation results and the workshop points of discussion into a special technical publication addressing the feasibility of using the surface discharge of concentrate as an element of long-term water supply planning within the applicable portions of SJRWMD.

During the third quarter of 2007, substantive POS implementation was achieved. The initial elements of the POS (Tasks 1, 2, and 3) were completed by the end of SJRWMD's fiscal year 2007. Additionally, preliminary modeling evaluations were conducted to support the planning-level fatal flaw analyses described under Task 3. These initial mixing zone analyses represented the initial efforts under Task 4. Activities on the remaining portions of the POS (Tasks 4, 5, and 6) were completed in SJRWMD's fiscal year 2008. This technical report presents the cumulative findings of the work conducted from 2007 to 2008.

REGULATORY AND ADMINISTRATIVE CONSTRAINTS

SJRWMD staff and consultants met with FDEP policy, technical, and permitting staff members in January 2007 to initiate interagency coordination efforts regarding the feasibility of permitting AWS facilities that include surface water discharges of demineralization concentrate back to the SJR. The primary emphasis was on identifying key regulatory and administrative constraints that would need to be addressed in FDEP concentrate discharge permit applications from public supply utilities.

Representatives of FDEP and SJRWMD reached consensus that a number of such constraints are directly linked to whether such conceptual concentrate discharges would be consistent with the policies and rules detailed under Chapters 62-302 and 62-4 of the *Florida Administrative Code* (*F.A.C.*). Chapter 62-302, *F.A.C.*, details the policies and rules for protecting Florida surface waters while Chapter 62-4, *F.A.C.*, defines the specific regulations under which the FDEP authorizes activities within these waters through the issuance of permits.

Because the conceptual AWS project outfalls would be new point source discharges, the State's Antidegradation Policy and Rules would be applicable. These provisions are defined under the following portions of the *F.A.C.*:

- Rule 62-302.300, *F.A.C.—Findings, Intent and Antidegradation Policy for Surface Water Quality.*
- Rule 62-4.242, *F.A.C.—Antidegradation Permitting Requirements; Outstanding Florida Waters; Outstanding National Resource Waters; Equitable Abatement.*

These sections essentially require that applications for a new or expanded point source discharge to surface waters provide FDEP with reasonable assurance that the discharge will not cause or contribute to violations of the applicable surface water quality standards and that the project's purpose is clearly in the public interest. The proposed project must also be consistent with the recommendations contained within any applicable Surface Water Improvement and Management (SWIM) plans approved by a water management district governing board.

Many federally or state-protected lands are situated within the SJR and adjacent floodplain, and many of these natural areas are afforded special water quality protection as Outstanding Florida Waters (OFWs), as defined under Rule 62-302.700, *F.A.C.—Special Protection, Outstanding Florida Waters, Outstanding National Resource Waters.* This section states that:

> *"No degradation of water quality, other than that allowed in Rule 62-4.242(2) and (3), F.A.C., is to be permitted in Outstanding Florida Waters and Outstanding National Resource Waters, respectively, notwithstanding any other Department rules that allow water quality lowering. "*

Thus, river reaches that are within these administratively defined areas along the floodplain are afforded an even higher level of protection than other surface waters within the state. FDEP guidance was to avoid siting new discharges in or adjacent to waters designated as OFWs. This administrative constraint was applied during this demineralization concentrate discharge feasibility study.

Because of the nature of demineralization treatment processes, most if not all such concentrates are anticipated to contain several constituents at concentrations above at least some numerical criteria applicable for Class III freshwaters. The provisions of Chapter 62-4, *F.A.C.,* allow for exceedances of such criteria only if the applicant can demonstrate compliance with the mixing zone provisions detailed under Rule 62-4.244, *F.A.C*. Thus, a key regulatory constraint that must be addressed is the specific question of whether the physical conditions at any given prospective outfall would allow for the outfall to be designed to meet the mixing zone demonstration requirements.

In fact, for this preliminary environmental and regulatory feasibility evaluation, the ability to meet mixing zone requirements is a key demonstration required prior to addressing whether the proposed discharges would cause or contribute to more regional- or systemwide cumulative effects associated with violations of water quality standards. Assuming that some of the conceptual outfall scenarios pass this initial fatal flaw analysis, more detailed evaluations of the cumulative effects of complying with MFLs and/or total maximum daily load (TMDL) requirements will be performed in the future.

General Mixing Zone Regulations

Discharges to surface waters in Florida must comply with the applicable water quality standards at the point of discharge. If "end of pipe" exceedances of numerical criteria exist and if the outfall operator can show that source reduction or pollutant control are not technically or economically feasible, FDEP regulations allow the applicant to demonstrate that it qualifies for a zone of mixing in the receiving water around the point of discharge. Based on historically available evaluations of concentrate water quality, mixing zones likely would be needed for the conceptual concentrate outfalls to the SJR.

The rules for mixing zones are listed in Rule 62-4.244, *F.A.C.* Basic provisions are in effect for which all mixing zones must comply and for more categorically focused rules that vary based on the type of receiving water body (freshwater lakes, rivers, and other linear water bodies contrasted with estuaries, coastal waters, and open ocean habitats). Additionally, recent rule modifications created specific provisions for demineralization concentrate discharges. For this feasibility study, the most relevant mixing zone rules are those that apply to demineralization concentrate discharges and generally to outfalls to Class III freshwater lakes, rivers, and other linear water bodies. Class III waters are designated as waters used for fishing, swimming, and propagation of fish and wildlife.

Mixing zones are evaluated on a parameter by parameter basis, and in all cases the mixing zones granted by FDEP may not be any larger than that necessary to comply with the applicable numerical criterion. With regard to mixing zones in freshwater systems, Rule 62-4.244(1)(g), *F.A.C.* specifies that the maximum size of a mixing zone in lakes is 125,600 square meters (m^2). Assuming a circular mixing zone with its center at one discharge location, the allowable mixing zone is limited to a circle with a radius of 200 meters. For long, multi-port diffuser sections, the area around each port is applied cumulatively to address this spatial limit.

In linear water bodies, the maximum size is 800 meters in length but is non-specific regarding width resulting from the variability of this parameter in rivers, streams, and canals. To ensure that the channels of such water bodies remain passable to fish and other aquatic life, the U.S. Environmental Protection Agency (EPA) recommends that mixing zone widths not extend over more than 25 percent of the channel width under low flow conditions (7Q10; the 7-day average low flow occurring at a 10 percent probability for any given year). Rule 62-4.244, *F.A.C.*, also sets the following limits on cumulative areas:

(i) The mixing zones in a given water body shall not cumulatively exceed the limits described below:

1. *In rivers, canals, and streams, and tributaries thereto and other similar water bodies: 10% of the total length;*
2. *In lakes, estuaries, bays, lagoons, bayous and sounds: 10% of the total area.*

PROVISIONS REGARDING TOXICITY

Whole effluent toxicity (WET) tests are conducted by exposing certain test organisms to different dilutions of the concentrate to observe their survival rate over a period of time. This topic needs to be discussed because of its importance in permit compliance and in defining mixing zone requirements. However, WET cannot be adequately addressed for conceptual facilities so further assessment of this issue has been deferred.

Acute toxicity tests use an endpoint based on lethality, and chronic toxicity tests use biomass, growth, or reproductive characteristics of organisms as endpoints (Mickley et al. 1993). Chapter 62-302, *F.A.C.,* defines acute toxicity as the presence of one or more substances, or characteristics or components of substances, in amounts greater than 1/3 of the amount lethal to 50 percent of the test organisms in 96 hours (96-hour LC_{50}), where LC_{50} is the concentration at which survival of the test species is less than 50 percent. Chronic toxicity is defined by Chapter 62-302, *F.A.C.,* as the presence of one or more substances, or characteristics or components of substances, in amounts greater than 1/20 of the amount lethal to 50 percent of the test organisms in 96 hours (96-hour LC_{50}).

The selection of acute toxicity test species for the WET tests is based on the salinity of the effluent and that of the receiving waters. Freshwater test species are used regardless of the salinity of the effluent if the receiving waters are considered as freshwater (total dissolved solids [TDS] less than 1,500 milligrams per liter [mg/L]). Note that most average SJR results were less than 1,500 mg/L TDS. On the other hand, if the receiving waters are considered as saline (TDS greater than

1,500 mg/L) then salinity of the effluent determines the selection of the test species. For cases with saline receiving waters, marine species are used if the effluent salinity is equal to or exceeds 1 part per thousand (ppt), while freshwater species are used for effluent with salinity of less than 1 ppt.

Historical toxicity testing records of demineralization concentrates nationwide have documented a high incidence of apparent acute or chronic toxicity associated with these types of discharges. In some cases, the test organisms used in toxicity tests fail to survive the laboratory tests because of the presence of sufficient concentrations of known toxicants at lethal or sublethal levels. However, in many cases, FDEP has found that the apparent toxicity of concentrates may be attributable to osmotic stress of the test organisms merely due to what has become known as Major Seawater Ion Imbalance Toxicity, or MSIIT.

FDEP guidelines for conducting MSIIT evaluations are published by the agency. Essentially, MSIIT occurs when the test organisms held in the concentrate for the duration of the standard toxicity tests either exhibit impaired growth or sexual maturation (chronic toxicity), or fail to survive short-term exposure (acute toxicity), because the ratios of ions present in the concentrate differ radically from those of normal surface waters. The Florida Statutes (state law) created specific mixing zone provisions that have been incorporated into Rule 62-4.244, *F.A.C.* for demineralization concentrate dischargers. If the concentrate does not exhibit toxicity to test organisms, the normal provisions of the overall mixing zone rule apply. However, if the concentrate does exhibit chronic or acute toxicity, the discharger has the option of conducting MSIIT testing to determine if the toxicity is primarily or wholly attributable to ionic imbalance conditions.

If the applicant can prove through testing that the observed toxicity is attributable to MSIIT, then FDEP may grant a toxicity mixing zone with the following constraint: The size requirement of the mixing zone is limited to a distance no larger than two times the natural depth at the point of discharge. A mixing zone for toxicity can still be pursued if no clear demonstration is made attributing the toxicity to MSIIT, but the criteria for qualifying for such a mixing zone are somewhat more stringent.

Where whole effluent toxicity cannot be demonstrated as primarily attributable to ionic imbalance, the following FDEP criteria would apply to concentrate discharges that are considered acutely toxic (i.e., fail 96-hour LC_{50} tests, as defined by *F.A.C.*). Note that all of these criteria must be satisfied.

- A dilution ratio of 100:1 must be achievable in the receiving body under critical conditions (Rule 62-4.244(3)(b)1., *F.A.C.*).
- A high-rate diffuser must be used (Rule 62-4.244(3)(b)2., *F.A.C.*).
- A dilution of 10:1 is required at a distance of 50 times the discharge length scale (L_D = square root of port area) in any spatial direction (Rule 62-4.244(3)(b)3., *F.A.C.*). For example, a 6-inch-diameter port has a discharge length distance equal to approximately 22 feet.
- Bioassay organisms must survive exposure to a 30 percent concentration of effluent for the duration of the 96-hour test (96-hour LC_{50} > 30%) (Rule 62-4.244(3)(b)4., *F.A.C.*).
- Concentrations of a specific list of water quality constituents of concern must be below the criteria listed in Rule 62-4.244(3)(b)5., *F.A.C.*

The special provisions for concentrate discharge mixing zones are detailed under Rule 62-4.244(3)(d), *F.A.C.* Figure 2 schematically depicts the mixing zone demonstrations required assuming the bioassay organisms fail to survive in the concentrate bioassays. The provisions for concentrate discharges with MSIIT are fewer but can still be restrictive given the receiving water body, especially for shallow water discharges.

EPA has detailed the mixing zone requirements in the *Technical Support Document for Water Quality-based Toxics Control* (EPA 1991). Many provisions are similar to state rules. EPA (1991; Section 4.3.3, alternative two) recommends that the state agency review the most restrictive of the following:

- A high rate diffuser is required. EPA defines this as a diffuser designed to produce port exit velocities equal to or greater than 3 meters per second (approximately 10 feet per second [fps]).

- A dilution of 10:1 is required at a distance of 50 times the discharge length scale (L_D=square root of port area) in any spatial direction.

EPA (1991; Section 4.4.2) also refers to a Section 301(h) guidance, which suggests that a dilution of 100:1 is to occur before the plume begins a predominantly horizontal flow. The EPA document implies that the mixing zone is assumed to be limited to the discharge's near field flow regime, which is not the case in Florida; therefore, this guidance is not applicable.

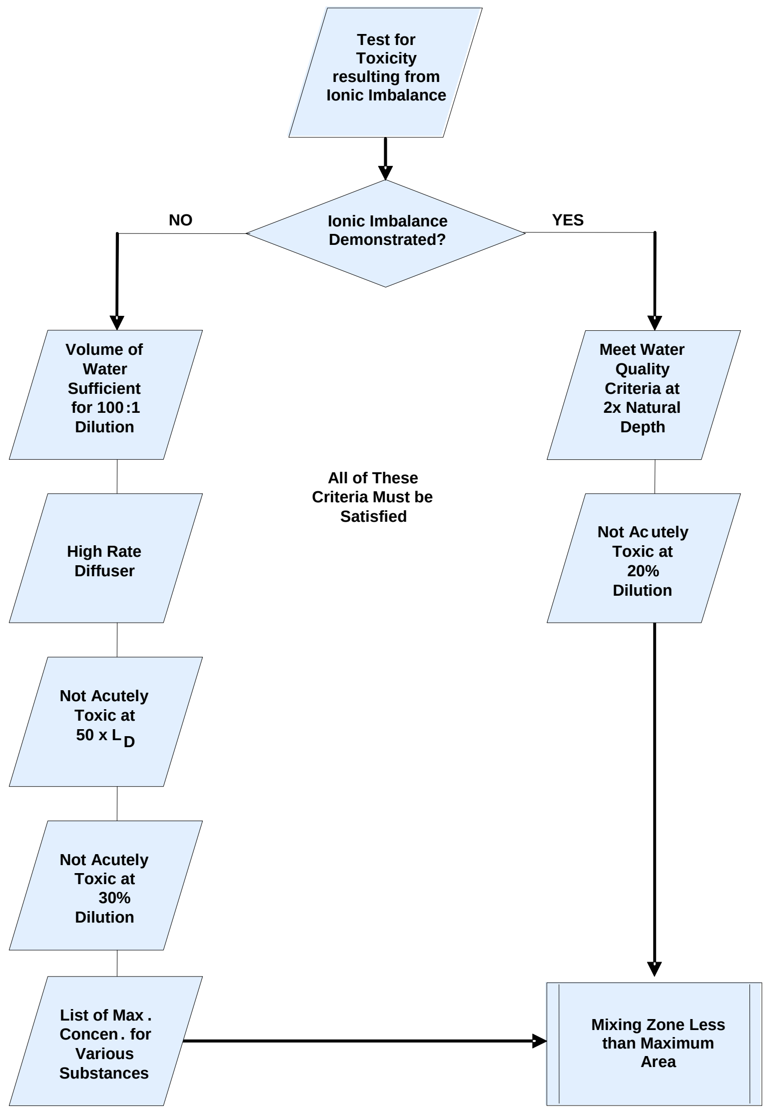

Figure 2. Selected Florida criteria for determining mixing zones when discharge is acutely toxic (Rule 62-4.244, *F.A.C.*)

CANDIDATE AWS PROJECT FOCUS AREAS

BACKGROUND

Water supply planning activities to date by SJRWMD have identified geographic areas within SJRWMD with the greatest projected population growth over the next several decades, and several of these correspond to the areas where potable water supply demands are expected to outpace the sustainable groundwater supplies. East-central Florida is one of those areas, and SJRWMD has identified general locations along the SJR in this region where river withdrawals may be allowable while still meeting applicable MFLs.

The following four conceptual AWS project focus areas are those that involve demineralization treatment technologies and that are generally located along the SJR (listed from north to south, not by priority):

- St. Johns River near DeLand
- St. Johns River near Yankee Lake
- St. Johns River near State Road 46
- St. Johns River near the Taylor Creek Reservoir/Lake Poinsett

Potential surface AWS projects located in these focus areas are among those having the highest priority for meeting central Florida's projected 2025 water supply demands. The areas under consideration are briefly described below along with currently predicted concentrate discharge rate assumptions applied to this feasibility study. For this discussion, a high potable water recovery rate—90 percent—was used to conservatively state the potential return concentrate flow rate. However, as is discussed further in this report, such a high recovery rate is unlikely.

DELAND

The proposed location for the DeLand AWS project has been set at various locations. The conceptual WTP concentrate discharge would likely need to be shifted to a location on the SJR just beyond the reaches designated as OFW (Figure 4). For this preliminary evaluation of feasibility, therefore, it has been assumed that regardless of the specific location of the conceptual demineralization WTP, the concentrate outfall would be located in the non-OFW reach of the river downstream of the SR-44 bridge (Figure 5).

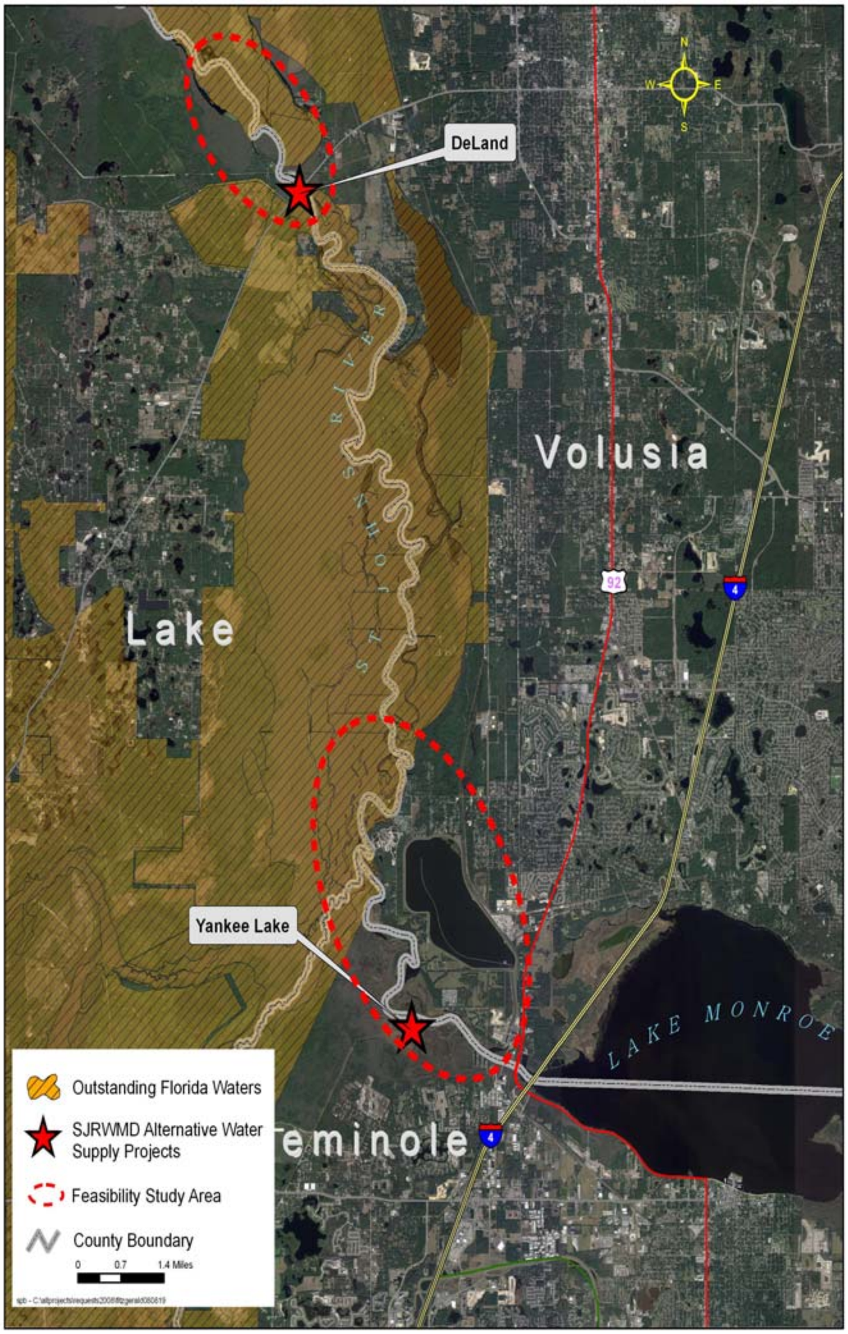

Figure 4. Conceptual DeLand and Yankee Lake AWS project locations

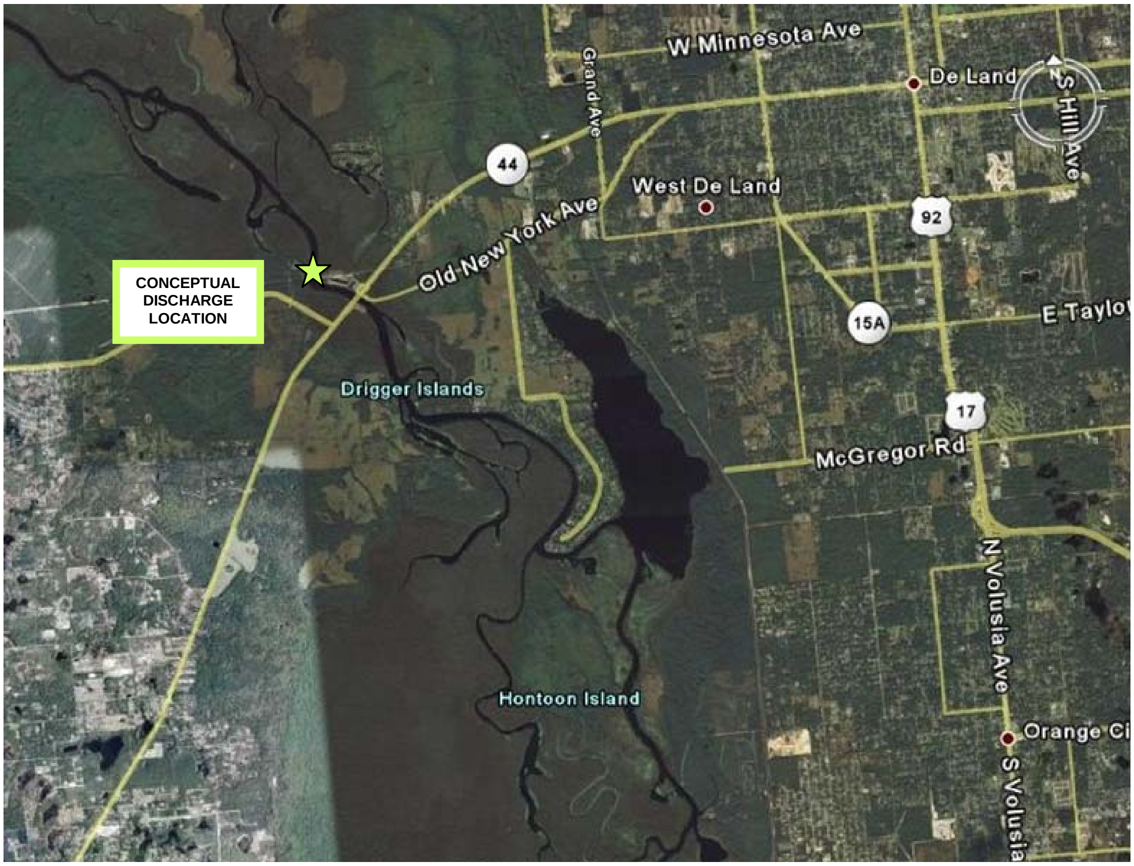

Figure 5. Conceptual DeLand AWS project candidate outfall location

The conceptual WTP project would require approximately 45 mgd of withdrawal from the SJR. With 90 percent recovery from the WTP, approximately 4.5 mgd of concentrate likely would be generated.

YANKEE LAKE

The Yankee Lake WTP project includes both non-potable and potable supply for Seminole County. The initial construction phase is to develop up to 10 mgd capacity of reuse-quality water treated with coagulation (ACTIFLO) and disinfection, with the product water being used for blending to augment the existing wastewater treatment plant (WWTP) reuse program. Further WTP expansion, considered the second phase of the program, would logically be located at the same location and would consist of generating an additional 5 mgd of reuse-quality water to further expand the planned blending with WWTP effluent. Additionally, 25 mgd of potable water would be generated using the membrane treatment. The third phase planned would increase the potable water production to as high as 60 mgd. Assuming 90 percent recovery from the demineralization components of the overall WTP and potable water yield of about 60 mgd, approximately 6 mgd of concentrate would be generated. The total withdrawal from the river to support the third phase of system expansion would be approximately 81 mgd (15 mgd of reuse augmentation water, 60 mgd of potable water, and 6 mgd of concentrate).

Figure 4 depicts the general location of the existing and proposed Yankee Lake treatment facility, and Figure 6 shows the current plans for the location of river water withdrawal and conveyance to the WTP to support the ongoing reuse augmentation project (non-membrane treatment dependent). In this case, if demineralization technologies are ultimately added at this plant, the following are assumed: The resultant concentrate would be piped back to the river following the same intake pipeline corridor, and the discharge infrastructure likely would be sited slightly downstream of the indicated water intake location.

Ideally, the outfall would be sited far enough downstream of the intake so that the mixing zone area could be centered over the outfall ports to maintain compliance with standards during intermittent periods of reverse river flow that are known to occur in this study area zone. This approach to specifying a mixing zone would be analogous to mixing zones in estuarine systems where tidal flow reversal occurs daily. Optimization of the system design, and detailed definition of mixing zone configuration and placement in relation to the conceptual outfall diffuser ports, will be deferred until the time when more specific utility-supported concepts are identified.

This portion of the SJR is bounded on the west by lands that are included within the Wekiva River Aquatic Preserve. However, the river itself *"…between Interstate Highway 4 and the Wekiva River confluence…"* is specifically excluded from OFW designation (Rule 62-302.700(9)(h)(42), *F.A.C.*). Thus, apparently an outfall to this reach of the river may attain permit status from FDEP, assuming that any short-term construction and/or long-term operations impacts can be minimized or mitigated to FDEP's satisfaction.

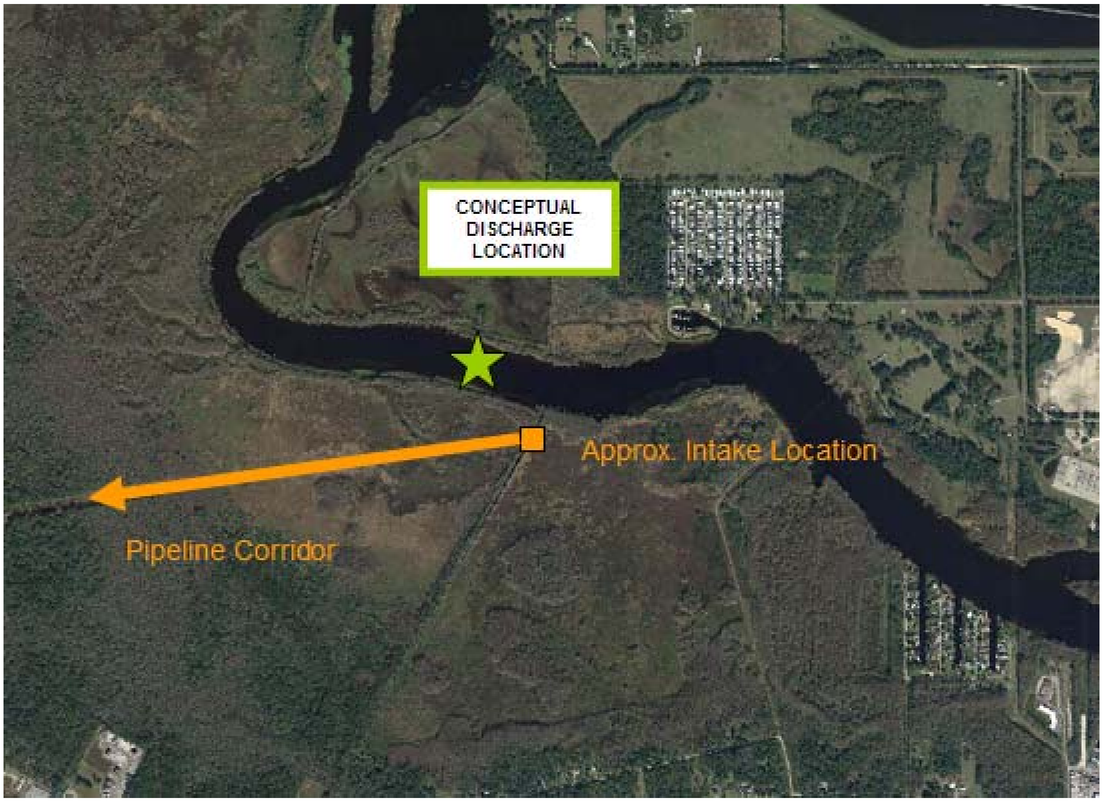

Figure 6. Conceptual Yankee Lake AWS project candidate outfall location

ST. JOHNS RIVER NEAR STATE ROAD 46

On the basis of information provided to date, the expected quantity of raw water withdrawal from the SJR for this proposed AWS project is about 33 mgd. Assuming 90 percent recovery from the WTP, the potable water yield will be 30 mgd. Consequently, about 3 mgd of concentrate will be generated by the WTP.

For this preliminary evaluation, the water withdrawal site likely could be located east of the SR-46 bridge crossing over the outflow from Lake Jesup to the SJR. This scenario assumes that the subject WTP facilities would be located east of this bridge location. For concentrate discharge purposes, two candidate outfall locations were considered during preliminary planning efforts. One site would be located in the SJR very near SR-46, approximately 0.6 mile east of the previously referenced outflow channel from Lake Jesup. An alternative site under investigation would be near the SR-415 crossing of the river, approximately 2 miles upstream of the inflow point into Lake Monroe. This concept would require approximately a 3-mile-long pipeline to convey the concentrate to this river crossing when compared to the SR-46 site. These conceptual locations are depicted in Figures 8 and 9, respectively.

Figure 8. Conceptual AWS outfall focus area in the St. Johns River near State Road 46

Figure 9. Conceptual AWS outfall locations at the St. Johns River near State Road 415 and State Road 46

ST. JOHNS RIVER NEAR TAYLOR CREEK RESERVOIR

The Taylor Creek Reservoir AWS project concept calls for diversion of some SJR waters into the reservoir during times of surplus. This process will result in the reservoir being filled to capacity more frequently, and a net increase in the overall water supply will be available through this reservoir's operations. On the basis of information shared with FDEP in January 2007, the expectation is that 40 mgd would be the incremental increase in potable water produced using membrane technologies, and the associated 4 mgd of concentrate is the volume that was proposed as the new surface discharge to the SJR.

Portions of the river immediately east of the reservoir are all designated as OFW (Figure 10). This designation would make surface discharge to the river downstream of Lake Poinsett unacceptable to FDEP. Alternative discharge locations near the inflows into either Lake Poinsett or Lake Winder could potentially be considered since these locations are well upstream of the OFW designated areas. These alternatives are the areas in this portion of the study area that were included for further evaluation.

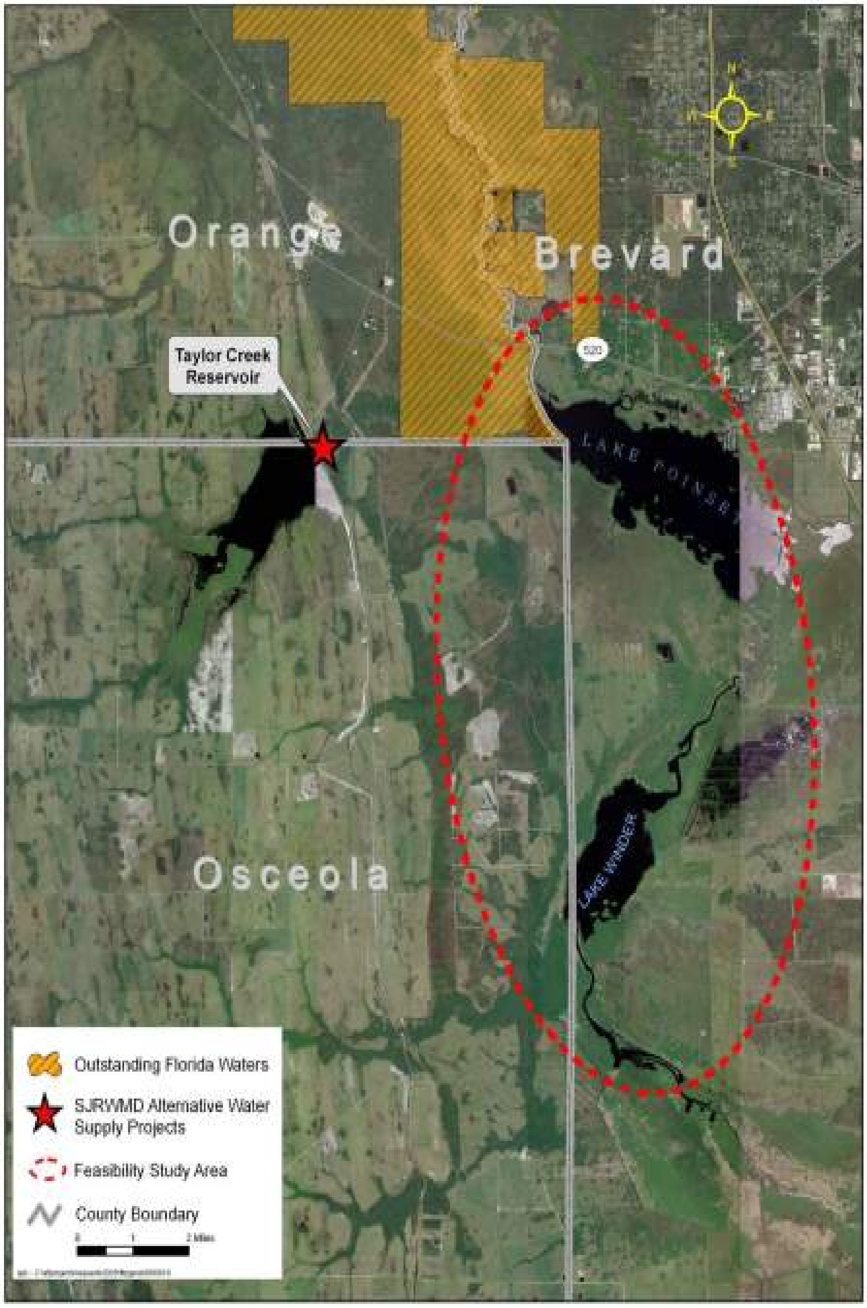

Figure 10. Location of Taylor Creek Reservoir and conceptual AWS outfall focus areas near Lake Poinsett and Lake Winder (Note: The map in this figure was provided by SJRWMD)

CANDIDATE AWS PROJECTS SUMMARY

For the initial concept development activities, the following four focus areas were taken into consideration for preliminary feasibility evaluations:

- St. Johns River at DeLand near SR-44
- St. Johns River – Lake Monroe to Yankee Lake Reach
- St. Johns River near SR-46/415
- St. Johns River near the Taylor Creek Reservoir/Lake Poinsett

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BACKGROUND INFORMATION ASSEMBLY

A review of available literature for the existing MFLs, flow characteristics, and water quality within various reaches of the SJR was conducted to provide background information to support further analyses of the prospective concentrate discharge feasibility. The literature review primarily focused on compiling information on the section of the SJR that lies between SR-40 and SR-50. This section of the river includes the three study areas that remain under consideration for alternative water supply projects and is viewed as representative of the general water quality and aquatic biological conditions in these portions of the river. Additionally, this section of the river includes locations where SJRWMD has conducted detailed evaluations supporting the formal setting of MFLs. The background information collected during this task is described below.

MINIMUM FLOWS AND LEVELS

In accordance with Section 373.042 of the Florida Statutes (F.S.), SJRWMD is in the process of establishing MFLs for the rivers and streams, lakes, wetlands, and groundwater aquifers within its jurisdiction. SJRWMD has developed MFLs for the Upper and Middle SJR reaches and some of its tributaries, such as Wekiva River and Blackwater Creek. MFLs define the minimum flow regime that can maintain the water resource and biological integrity of a water body. The establishment of MFLs serves as a hydrologic constraint to water supply development and helps SJRWMD monitor and protect waterbodies from harm that could potentially be caused by excessive consumptive use of water. Based on the frequency and duration of historically recorded water levels, the MFLs are typically characterized into five subcategories: infrequent high, frequent high, minimum average, frequent low, and infrequent low (Figure 11). As shown in Figure 11, these categories also have a corresponding frequency; for example, the infrequent low corresponds to the 95^{th} percentile low flow.

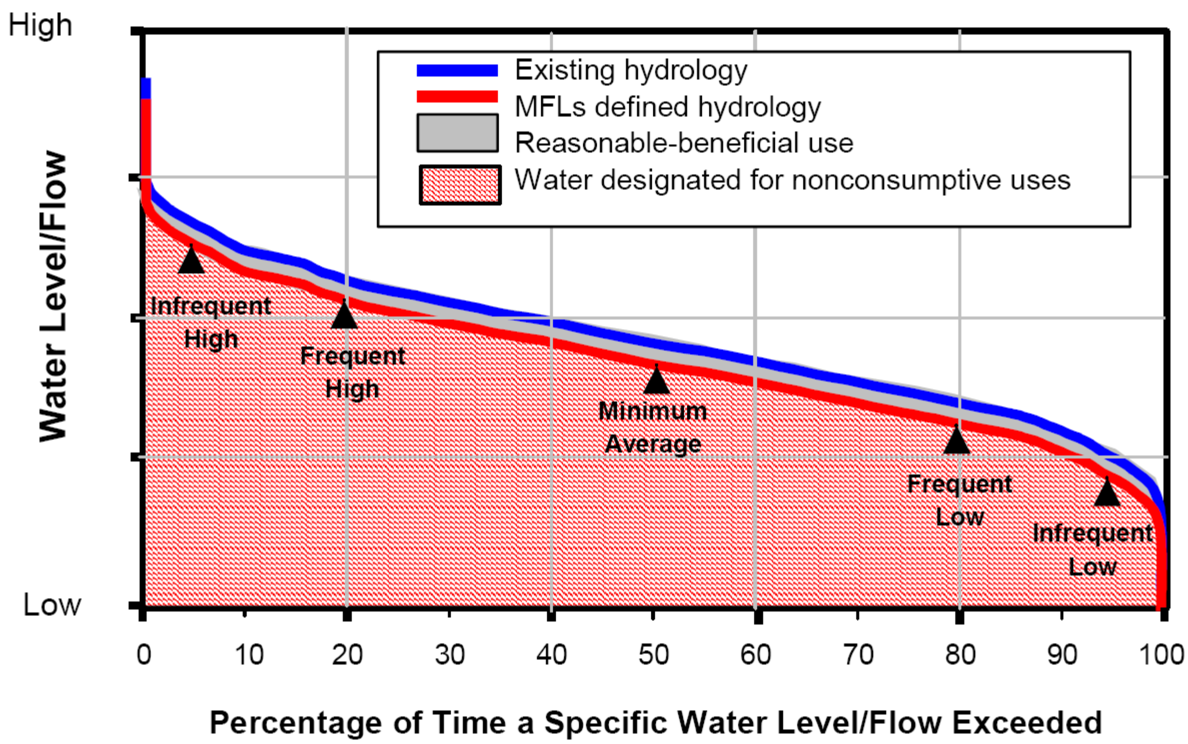

Figure 11. Hypothetical percentage exceedance curves for existing and MFLs-defined hydrologic conditions (Mace 2007a)

The MFLs developed by SJRWMD that are relevant to this feasibility evaluation are located at SR-50 (Mace 2007b), SR-44 (Mace 2006), and Lake Monroe (Mace 2007a). Chapter 62.40, *F.A.C.*, describes 10 natural resource and environmental decision variables, also referred to as water resource values (WRVs), which were examined by SJRWMD when it established MFLs for the SJR. Currently, few substantial withdrawals of surface water occur for consumptive use from the SJR in the study area. Note that when SJRWMD evaluates a proposed withdrawal to determine if it would cause water levels or flows to fall below established MFLs , the evaluation takes into account cumulative withdrawals already permitted upstream of the proposed new withdrawal. For example, at Lake Monroe any withdrawal from upstream projects would be included with the Lake Monroe project such that the total withdrawals do not exceed the limit established by MFLs for the SJR at Lake Monroe.

SJR at SR-50

SJRWMD determined that the proposed MFL for the river at SR-50 could not be met if an additional surface water withdrawal (i.e., more than is currently occurring) over approximately 78 cubic feet per second (cfs), or 50 mgd, upstream from SR-50 (Mace 2007b) were to occur. In another study, HSW Engineering, Inc. (HSW) determined that except for recreation, fish and wildlife habitat, and navigation all other WRVs will be protected under the 50 mgd constant withdrawal scenario (HSW 2004). To protect the three WRVs (recreation, fish and wildlife habitat, and navigation), HSW recommended that no surface water withdrawals from the river should occur if the flow in the river at SR-50 is less than 300 cfs. Based on this recommendation, SJRWMD established an infrequent low flow for the SJR at SR-50.

Lake Monroe in Volusia and Seminole Counties

SJRWMD determined that the proposed minimum water levels for the river at Lake Monroe could not be met if surface water withdrawals exceeding 180 cfs, or 116 mgd, were to occur. In a supporting study, Environmental Consulting and Technology, Inc. (ECT), concluded that the minimum levels recommended at Lake Monroe would protect the 10 WRVs (ECT 2006). In its evaluation of the MFL at Lake Monroe, ECT recommended continued water quality monitoring in and near the lake to establish a sediment budget for Lake Monroe.

SJR at SR-44 near DeLand, Volusia County

SJRWMD determined the minimum frequent low, minimum average, and minimum high flow in the SJR at SR-44 to be 1,100, 2,050, and 4,600 cfs, respectively. ECT concluded that the recommended MFLs would protect the 10 WRVs (ECT 2002).

STREAMFLOW AND WATER QUALITY CHARACTERISTICS

Water quality and streamflows in the SJR were reviewed to provide background information for the discharge evaluation. A USGS report by Kroening (2004) provides further streamflow and water quality information for the river. The study area included a 90-mile stretch of the river ranging from downstream of Lake Poinsett to near DeLand. Kroening (2004) summarized historical flow records and also collected streamflow and water quality data from several sites on the SJR from January 2000 to September 2002. A number of water quality parameters were analyzed during this period of study, including nutrients, major ions, organic constituents, organic carbon, suspended solids, and chlorophyll *a*. Key water quality observations included the following:

- Higher dissolved oxygen concentrations were found at the sites downstream from Lake Poinsett, Lake Harney, and Lake Monroe.
- The TDS in more than 50 percent of the samples collected during the study period was reported to be above the secondary drinking standard of 500 mg/L.
- Chloride and sulfate concentrations were also reported to be above the secondary drinking standards.

The concentration of other parameters was reported to vary with the streamflow. Based on historical USGS flow data from 1985 to 2000, Kroening (2004) reported that the mean annual flow in the river increases from nearly 1,030 cfs downstream of Lake Poinsett to nearly 2,850 cfs near DeLand. Lowest flows in the river in the 90-mile stretch were observed in May while the highest flows were observed in September and October.

To further study the background information, hydrologic data at different locations on the SJR were obtained from the USGS (USGS 2007). The hydrologic data showed that the mean velocity in the river varies from 0.4 to 0.6 fps (Table 1). The average discharge rates in the river increase from about 1,110 cfs near Cocoa to 2,960 cfs near DeLand (Table 1).

Table 1. Summary of St. Johns River surface water flow data

Station	USGS Station Number	Flow (cfs)		Velocity (fps)	
		Mean ± SD	Maximum	Mean ± SD	Maximum
SJR Near Cocoa, FL [1]	USGS 02232400	1,110 ± 1,410	8,880	0.5 ± 0.4	2.3
Lake Jesup Outlet, Near Sanford, FL[2]	USGS 02234435	120 ± 445	1,280	0.2 ± 0.2	0.8
SJR At SR-415, Near Sanford, FL [3]	USGS 02234440	1,980 ± 2,270	9,130	0.6 ± 0.5	2.1
SJR Near Sanford, FL [4]	USGS 02234500	2,030 ± 2,500	9,980	0.4 ± 0.4	1.4
SJR Near DeLand, FL[5]	USGS 02236000	2,960 ± 2,640	12,800	0.5 ± 0.4	1.8

[1-5]Period of Records: 1 - 1954 to 2007; 2 - 1994 to 2007; 3 – 1943 to 2007; 4 – 1987 to 2007; 5 – 1983 to 2007
cfs = cubic feet per second; fps = feet per second
Source: USGS (2007)

CH2M HILL (2004) conducted a water supply treatability pilot study on the SJR to support evaluation of applicability of alternative water treatment processes and the costs involved in producing potable water using raw water from the river. Lake Monroe was used as the raw water source for the pilot study conducted from August to December 2001. The raw water quality for several key parameters during the pilot testing is summarized in Table 2. Additional water quality data from the pilot study is provided in Appendix A. CH2M HILL (2004) concluded from the pilot study that water from Lake Monroe is treatable using membrane technologies and, from a treatability perspective, can be used as a potential source for potable water.

Table 2. Summary of raw water quality for the St. Johns River at Lake Monroe, August to December 2001

Parameter	Unit	Mean ± SD	Maximum	Minimum
Turbidity	NTU	7.5 ± 8.9	58.6	1.5
Specific conductance	S/m	67.3 ± 18.5	92.0	43.8
Total Suspended Solids (TSS)	mg/L	49 ± 48	120	16
Total Dissolved Solids (TDS)	mg/L	631.2 ± 213.7	988	294
pH	S.U.	7.1 ± 0.7	9.2	6.3

NTU = nephelometric turbidity units; S/cm = Siemens per centimeter; mg/L = milligram per liter; S.U. = standard unit; SD = standard deviation
Period of Record = August 2001 to December 2001; Source: CH2M HILL (2004)

CH2M HILL (2002a) conducted a separate study on the SJR between Titusville and DeLand to identify the treatment requirement for the demineralization technologies. In the reach between Titusville and DeLand, the water was found to have low turbidity, high total organic carbon (TOC), high hardness, and high TDS concentrations. Average TOC values ranged from 20 to 25 mg/L. TDS concentration varied between 1,118 and 645 mg/L and hardness between 411 and 233 mg/L. In general, the SJR water in this study area changes from fresh to slightly brackish with TDS ranging from 400 to 1,060 mg/L and chlorides from 139 to 455 mg/L (CH2M HILL 2002a and 2002b).

Further investigation included obtaining water quality data at different locations on the SJR from the USGS (USGS 2007). The USGS data consisted of an array of water quality parameters, including nutrients, metals, and physical characteristics of water such as turbidity and water color. Table 3 provides a summary of the water quality data along with the established Class I and Class III water quality standards.

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Table 3. Summary of water quality at different locations along the St. Johns River

Parameter	Unit	Water Quality Criterion		USGS 02232400 SJR Near Cocoa [a]			USGS 02234500 SJR Near Sanford [b]			USGS 02236000 SJR Near DeLand [c]		
		Class I	Class III	Mean ± SD	Max	95%ile	Mean ± SD	Max	95%ile	Mean ± SD	Max	95%ile
Turbidity[1]	NTU	< 29 above BG		5.3 ± 4.0	20.0	12.45	5.5 ± 6.6	45.0	11.45	3.2 ± 1.6	8.7	6.06
Water Color[2]	PCU[3]			147.8 ± 80.6	400.0	280	118.9 ± 84.0	320.0	258	107.8 ± 91.6	320.0	280
Specific conductance[1]	µS/cm	50 % above BG or 1,275		1,033.6 ± 703.0	2620.0	2,415	1,261.2 ± 487.5	2,380.0	2,065	1,121.1 ± 366.1	2,010.0	1,656
Dissolved oxygen[1]	mg/L	5 (min)		6.7 ± 1.9	0.9/min	9.4	7.4 ± 2.5	1.7/min	10.85	5.3 ± 2.0	0.1/min	7.85
pH[1]		± above Natural Max:8.5; Min:6.0		7.7 ± 0.6	9.1	8.75	7.9 ± 0.7	9.6	9.03	7.4 ± 0.4	8.2	8.1
Ammonia[1]	mg/L	≤ 0.02 (unionized)		0.1 ± 0.1	0.4	0.32	0.1 ± 0.1	0.8	0.28	0.1 ± 0.1	0.5	0.27
Nitrite[1]	mg/L			0.0 ± 0.0	0.1	0.04	0.1 ± 0.1	0.21	0.21	0.0 ± 0.1	0.2	0.16
Ammonia+organic N[1]	mg/L			2.0 ± 0.5	3.9	2.96	1.7 ± 0.4	2.5	2.48	1.2 ± 0.3	1.8	1.8
Nitrite + nitrate[1]	mg/L	≤ 10 (nitrate)		0.2 ± 0.2	0.7	0.50	0.2 ± 0.1	0.3	0.27	0.2 ± 0.1	0.4	0.30
Phosphorus[1]	mg/L			0.1 ± 0.1	0.4	0.24	0.1 ± 0.1	0.4	0.22	0.1 ± 0.0	0.2	0.16
Orthophosphate[2]	mg/L			0.1 ± 0.1	0.4	0.23	0.1 ± 0.1	0.2	0.18	0.1 ± 0.0	0.2	0.15
Organic Carbon[1]	mg/L			25.8 ± 4.3	38.0	32	18.5 ± 5.6	33.0	24.8	13.3 ± 5.8	30	22.8
Sulfide[1]	mg/L			2.0 ± 0.8	4.0	3	1.6 ± 0.6	3.0	2.0	2.0 ± 0.7	4.0	3.05
Calcium[2]	mg/L			90.3 ± 42.7	170.0	160	60.5 ± 13.9	87.0	84.8	60.4 ± 10.2	81.0	72
Magnesium[1]	mg/L			26.8 ± 12.0	48.0	43	26.9 ± 6.2	39.0	39.0	24.5 ± 4.0	36.0	30.2
Sodium[2]	mg/L			117.2 ± 83.0	310.0	260	157.8 ± 70.7	300.0	290	132.6 ± 50.5	260.0	207.5
Potassium[2]	mg/L			5.5 ± 1.7	9.4	8.1	7.1 ± 2.2	12.0	11	6.0 ±1.5	10.0	8.6
Chloride[2]	mg/L	≤ 250		224.2 ± 162.5	647.0	540	284.9 ± 121.5	560.0	482.5	241.8 ± 86.0	459.0	366
Sulfate[2]	mg/L			118.1 ± 101.2	380.0	344	89.8 ± 50.6	200.0	184.5	80.3 ± 38.9	190.0	140
Fluoride[2]	mg/L	≤ 1.5	≤ 10							0.1 ± 0.1	0.2	0.18
Silica[2]	mg/L			5.4 ± 4.3	15.0	11.45	5.0 ± 3.1	12.0	9.34	5.9 ± 2.3	11.0	9.9
Barium[1]	µg/L	≤ 1		64.0 ± 31.4	130.0	118	33.0 ± 9.1	51.0	48.5	25.8 ± 5.5	43.0	34.7
Iron[1]	µg/L	<1000		372.3 ± 178.5	992.0	673.8	306.1 ± 253.9	1,400.0	766	213.2 ± 172.5	644.0	558
Manganese[2]	µg/L									4.7 ± 2.5	7.0	6.8
Strontium[2]	µg/L			3,186.4 ± 1722.0	6,500.0	5,880	1,495.1 ± 444.2	2,300.0	2,272	1,247.8 ± 299.5	2,090.0	1,700
Aluminum[2]	µg/L									33.3 ± 15.3	50.0	48
Chlorophyll-*a*	µg/L						34.6 ± 27.1	120.0	92.15	25.9 ± 24.5	150.0	59.6
Bromide[2]	mg/L			1.0 ± 1.5	12.0	2.03	1.3 ± 1.3	8.3	2.5	1.2 ± 1.4	8.7	2.81
TSS	mg/L						17.4 ± 31.4	152.0	32.85	8.0 ± 6.1	34.0	15.75

[1] Unfiltered
[2] Filtered
[3] PCU is Platinum Cobalt Unit
BG = background
TSS = total suspended solids

Period of Record: [a]- 2000-2005; [b]-2000-2002;[c]-2000-2002

Source: USGS (2007)

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CONCENTRATE CHARACTERISTICS

Developing alternative water supplies that utilize water from the SJR may also involve the return of the concentrate back into the river. The amount of a constituent found in the concentrate from the operation of a typical membrane WTP will depend on the characteristics of the raw water and the effectiveness of the different chemicals added during the treatment process.

Different chemicals, such as coagulants, flocculants, anti-scalants, disinfection chemicals, dechlorination agents, and acids, are added to raw water for pretreatment prior to entering the membrane system. Coagulation and settling pretreatment processes reduce some parameters. Other additives lead to an increase in certain constituents, such as chlorides (Cl^-), sulfates (SO_4) and bicarbonates (HCO_3). Depending upon the membrane system, these chemicals may or may not be completely rejected by the membrane system. For the membrane system with complete rejection, the demineralization concentrate is typically a simple concentration of raw water. For such systems, the concentration factor (CF) can be calculated as:

$$\text{CF} = \frac{1}{1-R}$$

where R is the fractional volume recovery of the membrane system (Mickley et al. 1993).

For systems with partial rejection of different chemical forms of constituents in raw water, the CF can be estimated using the membrane rejection factor (r) as follows:

$$\text{CF} = \frac{1-R\times(1-r)}{1-R}$$

The rejection factor will vary between constituents (Mickley et al. 1993) and perhaps between different membrane manufacturers' products. The overall CF must be determined either by manufacturer literature or more typically by pilot testing.

CH2M HILL (2004) conducted a pilot study of different membrane systems using raw water from the SJR at Lake Monroe. The raw water and concentrate characteristics were monitored during the course of the study from April to June 2002. The system was projected to recover

85 percent of water with 90 percent rejection. However, actual operations reported approximately 75 percent recovery during the pilot study. The CF of the concentrate for most ions was found to be between 3 and 4, based on the membrane rejection of the individual ions. The highest CF of 5.68 was reported for SO_4.

For a typical membrane system designed for 80 percent recovery, the CF may vary from 3.09 to 4.92 based on the rejection of individual ions from 70 percent to 99 percent, respectively. For a reasonably high estimate, a CF of 5 can be expected from a typical system designed for 80 percent recovery and 100 percent membrane rejection (Mickley et al. 1993). Therefore, planning-level estimates of potential concentrate characteristics can be based on the observed source water quality times a CF of 5.

A more detailed mass balance analysis around membrane treatment plants was conducted by CH2M HILL for refining the CF for various parameters. A WTP mass balance analysis was conducted at three out of four AWS project focus areas (DeLand, Yankee Lake, and SR-46/415) to evaluate the expected change in river loadings resulting from potential WTPs at these locations. Mass balances were calculated for each potential site using a recovery of 70 and 85 percent. Multiple scenarios were evaluated to assess the overall effect of the proposed potable water plants and to encompass the ultimate operating conditions of the membrane system. An anticipated CF was calculated by dividing the concentration of a compound in the concentrate by the concentration in the reverse osmosis (RO) feedwater. These factors did not change between locations because of the relative similarity of the water quality of the raw water and similar assumptions about the WTP processes. A detailed discussion of this analysis is presented in a later section.

ASSESSMENT OF POTENTIAL WHOLE EFFLUENT TOXICITY (WET)

Because of the concern that demineralization concentrate can cause stress or mortality in plant and animal species in the receiving water, discharge permits issued by the FDEP typically require acute and/or chronic toxicity testing. Two relevant sources of information in regard to the potential WET tests results on the demineralization concentrate were found, specifically:

- Pilot study conducted by CH2M HILL using raw water from Lake Monroe (CH2M HILL 2004) and
- An independent assessment by FDEP (2007b) using the average water quality data from Lake George.

Both references used the Gas Research Institute-Freshwater-Salinity/ Toxicity Relationship (GRI-FW-STR) model for their evaluations. This model is based on empirical data and allows calculation of the predicted level of toxicity of a water solution to the selected bioassay test species. Because the SJR water is considered freshwater, only freshwater test species (*Ceriodaphnia dubia*, *Daphina magna* and *Pimephales promelas*) were evaluated.

For the modeling of potential concentrate toxicity using a worst case scenario approach, CH2M HILL (2004) used five times the concentration of the raw water from Lake Monroe (assuming 80 percent recovery and 100 percent rejection). CH2M HILL (2004) reported that modeling results indicated that *Daphnia magna* would not be significantly affected by the conceptual concentrate. However, the other, water flea (*C. dubia*), was more sensitive, and the 48-hour LC_{50} for *C. dubia* was predicted to be 60 percent. The 48-hour and 96-hour LC_{50} values predicted for the fathead minnow, *Pimephales promelas,* were 95 percent and 84 percent, respectively. Similar results were estimated by FDEP (2007b), which reported a predicted 96-hour LC_{50} of 86 percent for *Pimephales promelas*. To represent concentrate conditions, FDEP (2007b) used a concentration factor of 4 for the major ion concentrations as a typical scenario using the 16-year maximum ion values from Lake George.

Both of the analyses conducted to date suggest that demineralization concentrate is likely to be acutely toxic to some sensitive fish and invertebrate species as a result of the major ions change. Therefore, the conceptual concentrate discharges should be assumed as not permitted by FDEP unless an applicant could successfully demonstrate that the system design complied with the mixing zone provisions defined in Rule 62-4.244, *F.A.C.*

When ionic imbalance can be demonstrated, the mixing zone rule for membrane concentrate discharge limits the zone of mixing spatially to an area no greater than 2 times the natural water depth at the point of discharge. The rule further defines natural water depth as either the depth at mean lower low water (MLLW) in tidally affected waters, or the depth at the 7-day, 10-year low flow (7Q10) conditions for non-tidal rivers, streams, canals, or ship channels. No modification of the depth is allowed (e.g., dredging). Depending on the demonstrations and the path that the utility may wish to follow to permit a mixing zone, the distance from the ports of the discharge may be limited either to 2 times the depth or to the other maximum areas found in the rule.

KEY AQUATIC BIOLOGICAL RESOURCES

Comprehensive evaluation of the biological communities in and around the SJR that could potentially be affected by the proposed demineralization concentrate discharges will occur in support of project-specific plan development, design, and permitting efforts. However, concerns about ensuring that such prospective impacts are thoroughly understood and avoided to the extent possible and then minimized and/or mitigated as applicable became clear during the course of working meetings held to date with FDEP and other interested parties. A very preliminary evaluation of the types of key aquatic biological resources known to be present in the river was conducted simultaneously with a review of the literature and the background information.

A representative overview of the biological resources found in and along the SJR in the areas under primary focus for this preliminary feasibility study is found in the *Wekiva River Aquatic Preserve Management Plan* (FDEP 1987). This specific aquatic preserve, while focused on the Wekiva River, also includes lands adjacent to the SJR running from Lake Monroe downstream to the SR-44 bridge near DeLand. The management plan indicates that the preserve includes the Lower Wekiva River State Reserve, a 4,500-acre tract that borders approximately 1 mile of the river just downstream from Lake Monroe. The original land areas within the aquatic preserve were expanded in 1985 to include approximately 20 miles of the SJR running from the confluence with the Wekiva River downstream to the SR-44 bridge (FDEP 2007a).

Species of Special Concern

A number of state or federally protected plant and animal species are known or believed present in this portion of the overall SJR Basin. Future, more detailed evaluations regarding the potential effects of outfall and pipeline construction and operation on these protected species likely will be needed if this preliminary feasibility investigation concludes that more specific outfall siting and construction, as well as operational planning, is warranted. The list below was drawn from the FDEP (2007a) website addressing the Wekiva River Aquatic Preserve's key resources in need of particular protection http://www.dep.state.fl.us/coastal/sites/wekiva/.

Fishes
- Bluenose Shiner (*Pteronotropis welaka*) – State Species of Special Concern (SSC)

Reptiles
- American Alligator (*Alligator* mississipiensis) – State SSC, Federal Threatened (T)

Birds
- Limpkin (*Aramus guarauna*) – State SSC
- Little Blue Heron (*Egretta caerulea*) – State SSC
- Snowy Egret (*Egretta thula*) – State SSC
- Tricolor Heron (*Egretta tricolor*) – State SSC
- White Ibis (*Eudocimus albus*) – State SSC
- Southeastern American Kestrel (*Falco sparverius paulus*) – State T
- Florida Sandhill Crane (*Grus canadensis pratensis*) – State T
- Bald Eagle (*Haliaetus leucocephalus*) – State T, Federal Endangered (E)
- Wood Stork (*Mycteria americana*) – State and Federal E
- Least Tern (*Sterna antillarum*) – State T

Mammals
- West Indian Manatee (*Trichechus manatus*) – State and Federal E
- Florida Black Bear (*Ursus americanus floridanus*) – State T

Plants
- Cardinal Flower (*Lobelia cardinalis*) – State T
- Hand Fern (*Ophioglossum palmatum*) – State E

(Note: State listings by the Florida Fish and Wildlife Conservation Commission and Florida Department of Agriculture; Federal listings by the U.S. Fish and Wildlife Service.)

The management plan lists additional plant and animal species that may warrant further consideration, but the above list is believed to be inclusive of those species that are most likely to be at least intermittently present within the SJR corridor near the locations of the candidate AWS project focus areas. In most cases, the prospective effects of the proposed concentrate outfalls on the above species are minimal. Rapid dilution will be required to achieve compliance with water-quality-based regulatory constraints applicable at the edge of the conceptual mixing zones; thus, for any of the above species to be exposed to increased water quality constituent concentrations is very unlikely.

Lastly, in addition to the above plants and vertebrate animal species, Florida has identified selected invertebrates for protection from exploitation. One of these is a mussel species, *Elliptio buckleyi*, that is described as “abundant in the St. Johns River” (Warren 1999). By some accounts, these mussels can occur in large numbers at some locations in the Upper St. Johns River, Ocklawaha River, and Lake Monroe. If the proposed concentrate outfall concepts are carried forward into more detailed planning, design, and permitting efforts in the future, field investigations at the prospective aquatic pipeline and diffuser locations will be needed. Such field studies will be applied to addressing potential construction and/or operational effects on these mussel populations within the mixing zone areas and construction corridors.

Vegetation

Along the river, wetland communities are dominated by pristine hardwood swamps, with herbaceous wetland vegetation commonly present along the shoreline and in patches distributed in the floodplain. Information presented in the management plan (FDEP 1987) lists plant communities commonly found in the basin and representative plant species applicable to this study include:

- Mixed hardwood swamp – tupelo, red maple, water ash, bald cypress, sweet gum, button bush, willow, pond apple, wax myrtle, dahoon holly
- Cypress swamp – predominantly bald cypress with a lesser percentage of hardwoods similar to those found in mixed hardwood swamp
- Hardwood hammock – sweet gum, magnolia, tupelo, live oak, laurel oak, water oak, hickory, wax myrtle, sweet bay, cedar, American holly, red maple

- Pine flatwoods – pond pine, loblolly pine or slash pine, longleaf pine, saw palmetto, wire grass, gallberry
- Scrub – stagger bush, rosemary, silk bay, wild olive, blueberry, gopher apple, prickly pear cactus, wire grass, lichens
- Scrubby flatwoods – slash pine, chapman's oak, myrtle oak, saw palmetto, runner oak, wire grass
- Freshwater marsh – saw grass, arrowhead, pickerelweed, coastal plain willow, button bush, red maple, bald cypress
- Bayhead – loblolly bay, sweet bay, red bay, black tupelo, red maple, loblolly pine, dahoon holly, coastal plain willow, gallberry, wax myrtle

Additional helpful information regarding vegetation commonly encountered along the SJR is provided by the St. Johns Riverkeeper (2007) Web site (http://www.stjohnsriverkeeper.org). The following listing is pertinent regarding such plant community composition; species listed as commonly present in combinations include:

> *"cardinal flowers, pickerelweed, spatterdock, alligator lilies, duck potato, maidencane, giant bulrush, joint weed, eelgrass, coontail, alligator weed, aster, mosquito fern, button bush, musk grass, wild taro, water hyacinth, spikerush, hydrilla, iris, duckweed, water primrose, baby tears, southern naiad, yellow water lily, pond lily, water lettuce, Illinois pondweed, sago pondweed, widgeon grass, marsh pink, dwarf arrowhead, water fern, lizard's tail, cattail, horned pondweed."*

In terms of aquatic vegetation, the FDEP (2007a) Web site indicates that *"Eelgrass is the dominant submerged vegetation."* If concentrate outfall concepts are carried forward into more detailed planning, design, and permitting efforts in the future, field investigations at the prospective outfall locations likely will be needed to confirm the incidence and coverage of eelgrass (*Valisneria* sp.) along the construction corridors and/or within areas under consideration as mixing zones. FDEP would typically interpret the presence of eelgrass beds as indicative of the area functioning significantly as a nursery area for juvenile fish and invertebrates. Additionally, under FDEP's mixing zone rules, the agency could not permit a mixing zone that includes such submerged aquatic vegetative beds.

Benthic Invertebrate and Fish Communities

The aquatic fauna most likely to be affected by the prospective concentrate discharges to the SJR would include the invertebrates living on or in the bottom substrate within mixing zones and the fish communities within the river that rely on those invertebrate communities as their prey. Existing conditions are not always favorable to diverse benthic community composition. Anoxic benthic conditions are known to occur in many of the river's reaches as a minimum during the summer months, and bottom conditions also experience variable ambient concentrations of TDS depending on both seasonal changes in river base flow as well as proximity to springs and groundwater inflow areas that enter the river directly. While the springs are well identified and locations of inflow known and in some cases well quantified, the locations of other, more diffuse groundwater inflows are less well defined.

The USGS (Kroening 2004) specifically noted that elevated conductivity concentrations frequently occur at locations in the river ranging from Lake Harney to SR-415. This USGS report notes that DeMort (1990) *"…reported saline water and the presence of plants more tolerant of saline conditions in the Puzzle Lake and Mullet Lake areas of the St. Johns River,"* and opined that higher conductivities were attributable to the inflow of brackish water from the Floridan aquifer system. Further, it is reported that *"The reach of the St. Johns River from Puzzle Lake to State Road 415 also coincides with areas where faults or subsidence features – which probably extend into the Floridan aquifer system – were reported, and known or suspected springflow from the Floridan aquifer system to the St. Johns River occurs"* (Tibbals 1990).

Thus, the portions of the river that are under current evaluation include areas that have variable TDS. Likely present in these river reaches are benthic invertebrate and fish species, which are expected to be somewhat pre-adapted to variable concentrations of constituents, similar to the vegetative communities present in the river. Species intolerant of such variability are unlikely to be commonly present or numerically dominant. That said, it may be assumed that the invertebrate and fish populations living within the river are seasonally abundant and productive, and therefore, a high level of emphasis on these faunal elements will be needed if the conceptual outfalls move into more detailed planning, design, and permitting phases of evaluation. Intuitively, the operation of the outfalls would be most likely to have the greatest localized effect on invertebrates and fish during the dry or low river base flow season. Therefore, future aquatic ecological investigations should prioritize assessments of community composition and structure likely to exist during the dry season of the year.

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SITE RECONNAISSANCE AND CONCEPTUAL DISCHARGE SCENARIOS

To support development of conceptual discharge scenarios to be carried forward into the preliminary modeling work and outfall feasibility evaluations, limited site reconnaissance surveys were performed to accomplish the following goals:

- Gain familiarity with river channel depths and widths in the general vicinity of prospective AWS project outfall locations

- Qualitatively assess the incidence and abundance/relative coverage of rooted aquatic vegetation across the channel to evaluate whether the AWS project focus areas might overlap with aquatic habitats likely to be used as nursery grounds by ecologically significant fish or invertebrate species

- Observe shoreline conditions near the prospective outfall locations with regard to potential accessibility issues for concentrate pipeline entry into the river

Windshield surveys of four prospective outfall locations along the SJR within Seminole County were conducted on June 8, 2007. One additional prospective outfall location in Volusia County was visited on June 26, 2007. Photographic records of those windshield surveys combined with aerial photographs obtained through Web site sources are found in Appendix B.

Subsequent to those initial site reconnaissance visits, project team consultations led to prioritization of the four AWS project focus areas as defined previously in this report. SJRWMD and CH2M HILL team members conducted field site reconnaissance on August 22 and 23, 2007, to accomplish the following:

- Established temporary transect perpendicular to the river channel axis, with the zero (0) mark set at the left (east) end of the transect looking upstream
- Measured depth from water surface to the bottom substrate using a standard surveyor's rod (depths less than approximately 20 feet) or a calibrated lead line (depths in excess of approximately 20 feet) at five to seven locations across the transect

- Collected bottom sediment samples from three to five locations across the transect using a petite ponar grab to qualitatively assess the presence/absence of rooted aquatic vegetation and keystone macrobenthic invertebrates (bivalve or gastropod mollusks)
- Photographed representative shoreline vegetation and recorded observations regarding existing prospective corridors for pipeline access to the river

These activities were performed at a series of transects located in each of the four AWS project focus areas:

- St. Johns River at DeLand near SR-44
- St. Johns River – Lake Monroe to Yankee Lake Reach
- St. Johns River near SR-46/415
- St. Johns River near the Taylor Creek Reservoir/Lake Poinsett

Field reconnaissance results for each of these sites are summarized below.

ST. JOHNS RIVER AT DELAND NEAR SR-44

The northernmost focus area site reconnaissance location was the reach immediately downstream of the SR-44 bridge. FDEP and SJRWMD staff consultations regarding the spatial limits of OFWs in the area confirmed in early 2007 that all of the portions of the river immediately upstream of this location are designated as OFWs because of natural preserve lands. However, downstream of this roadway intersection with the river, only lands east of the river are designated as preserves. Consequently, this reach downstream of SR-44 was not presumptively excluded by OFWs; field reconnaissance was performed at two transects in this focus area. The approximate transect locations are shown in Figure 12 in relation to land areas that bear the OFW designation. The transect designations were SR44_A and SR44_B moving from upstream to downstream.

Figures 13 and 14 depict the channel profiles documented on August 23, 2007. On the day of these field activities, water levels were at approximately 1 foot National Geodetic Vertical Datum (NGVD). These figures document maximum depths at these transects on this date of approximately 36 and 21 feet, respectively. Accounting for the aforementioned frequent low stage of 0.3-foot NGVD (Mace 2006), the estimated low flow dry season depths under drought conditions this past spring would have been approximately 35 and 20 feet. Figure 15 presents some historical bathymetric information published by National

Oceanic and Atmospheric Administration (NOAA) in its navigation charts for this reach of the river. This image implies that these depths are naturally maintained by river scour at these river bends.

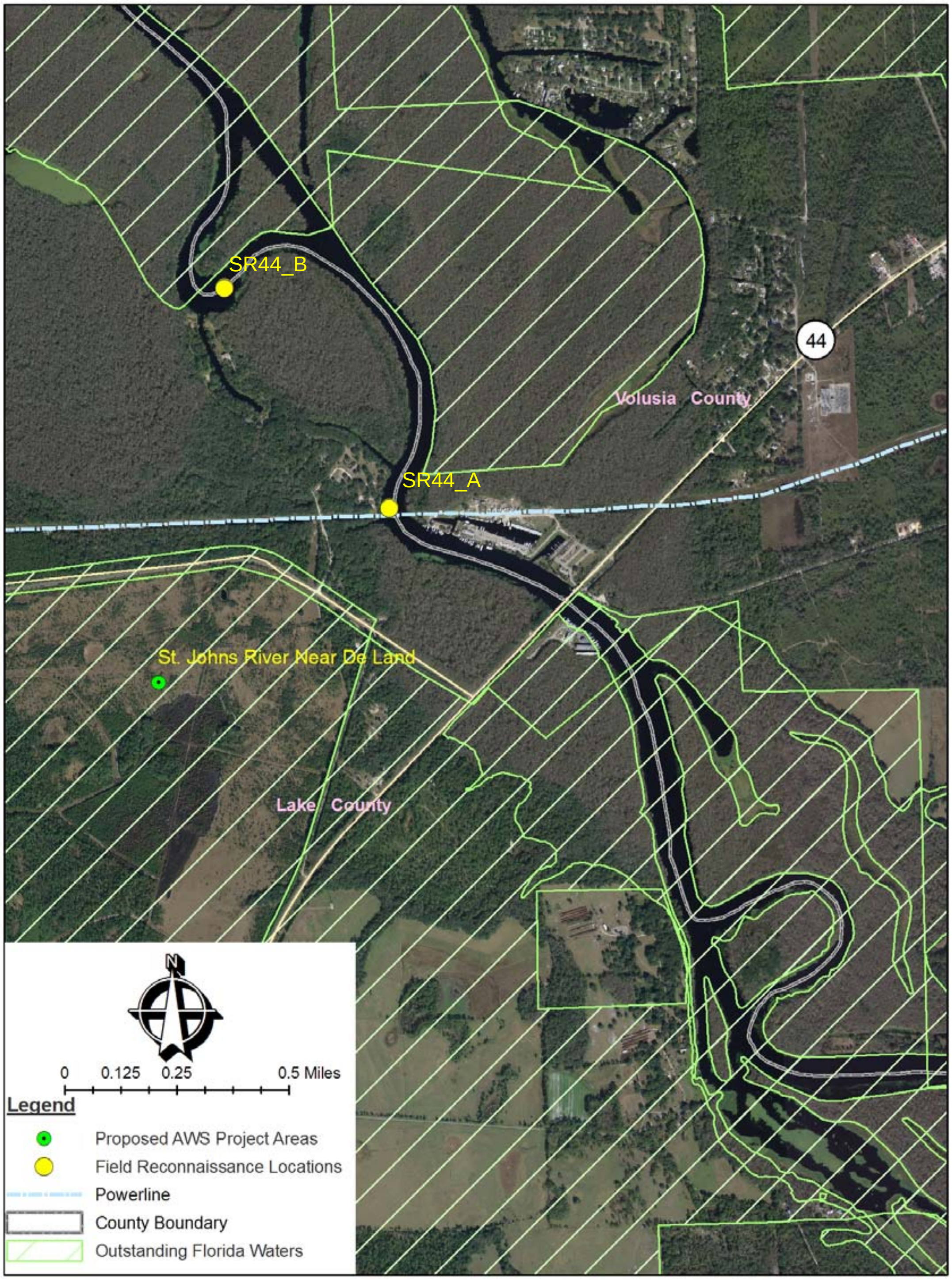

Figure 12. Approximate locations of field site reconnaissance in St. Johns River near the SR-44 bridge

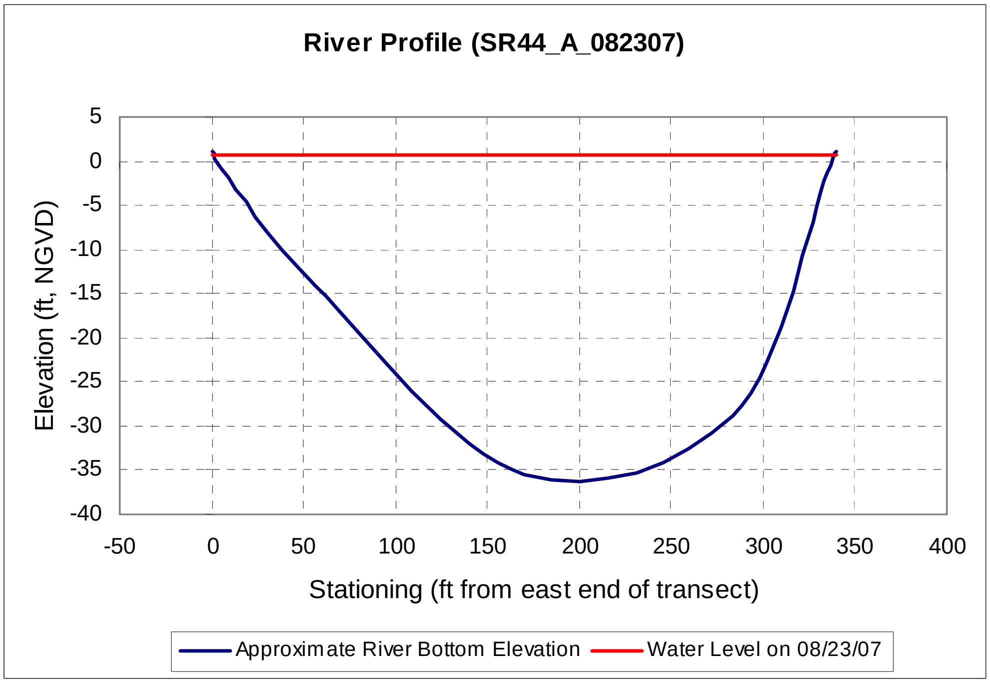

Figure 13. Bottom substrate elevations in relation to water level on August 23, 2007, at transect SR44_A

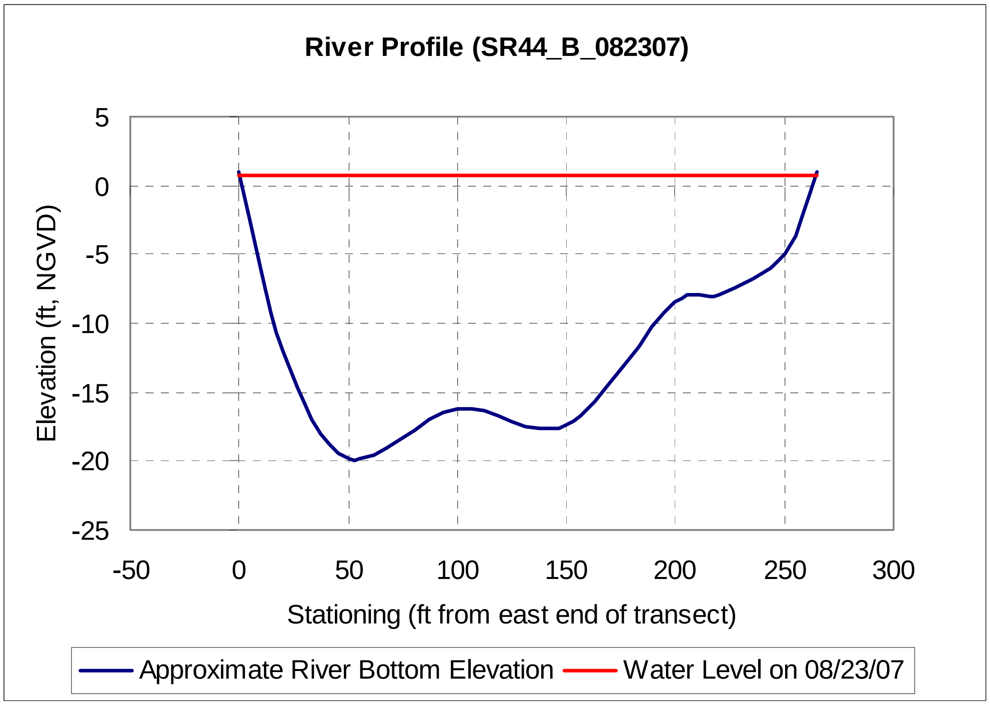

Figure 14. Bottom substrate elevations in relation to water level on August 23, 2007, at transect SR44_B

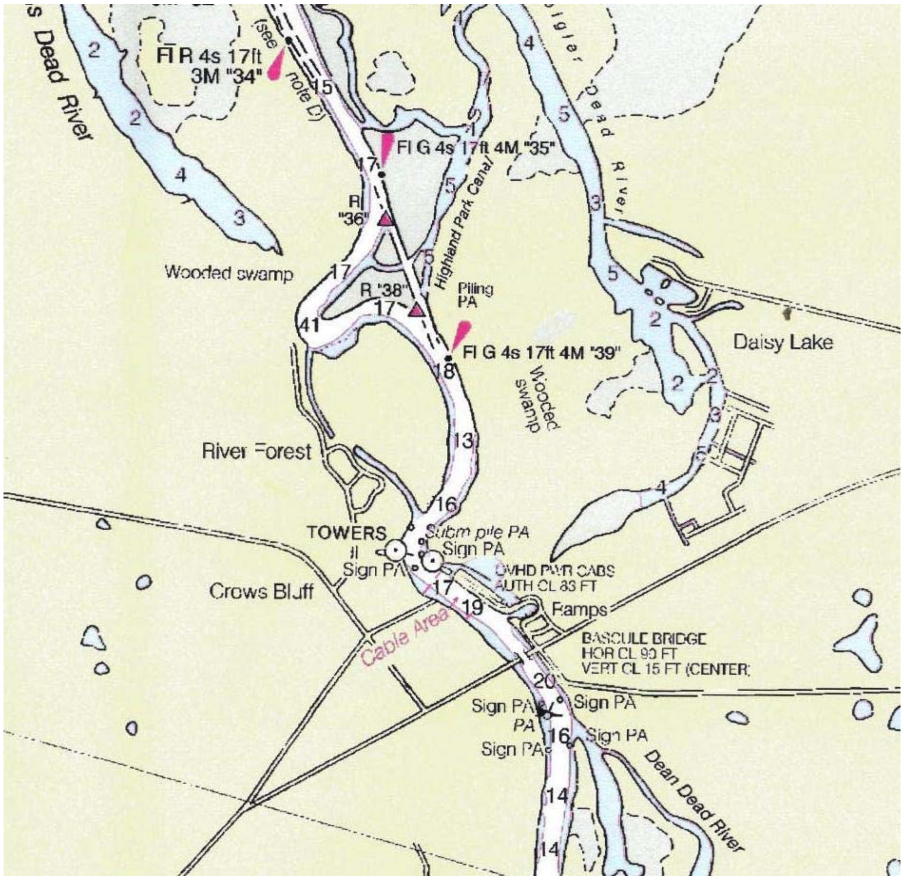

Figure 15. Historical bathymetry in the St. Johns River downstream of the SR-44 bridge at Crows Bluff (Source: NOAA 2007)

Benthic substrate grab samples and visual observations confirmed the presence of spatterdock (*Nuphar* sp.) and/or other mixed aquatic vegetation beds at the ends of both of these transects. Root mats retrieved from some of these beds were inhabited by shrimp and juvenile xanthid crabs (*Xanthidae*) as well as a variety of insect larval forms. Bivalve or gastropod mollusk shell incidence in each sediment sample was documented photographically and later characterized as abundant, moderate, or rare using the following subjective scale:

- Abundant: > 20 paired shells/individuals
- Moderate: 10 to 20 paired shells/individuals
- Rare: < 10 paired shells/individuals

The samples collected from Transect B did not reflect presence of molluscan populations. However, at Transect A, bivalve mollusk shells were moderately to abundantly common and some live specimens were found. The presence of euryhaline and typically estuarine xanthid crabs serves as evidence of the brackish nature of this reach of the river. Tidal introduction of ocean water is not believed present this far upstream, so groundwater input is the likely source of elevated TDS that allows these euryhaline invertebrates to successfully colonize in this river reach.

One complicating factor that may constrain conceptual design options for this area is the fact that the U.S. Army Corps of Engineers (USACE) is responsible for maintaining the navigability of the river from its juncture with the Atlantic Ocean up through Lake Harney. The nominal navigation channel specifications are for a 100-foot-wide channel with depths maintained to 8 feet in this reach of the river. As the NOAA chart indicates, the federally maintained navigation channel runs through this portion of the river although not through the Transect B area. The Transect B reconnaissance site was located in the original river channel on a hairpin turn, which USACE elected to bypass when the navigation channel was installed. Thus, the original flow regime at Transect B is unlikely because of the dredged cut off channel; however, substantive flows may well remain at this location.

The Transect A location may actually represent the most favorable candidate location identified thus far in the river based solely on river morphology characteristics. The deep water appears to be naturally maintained by the river flow at this river bend; the depths are favorable for allowing rapid dilution of the conceptual concentrate discharge from a high rate diffuser system. Dredging in this area to maintain the navigational depth specifications would not occur.

In terms of conceptual pipeline accessibility to the river, uncertainty exists regarding the side of the river on which an AWS project facility might be located. However, a large power line corridor was noted to cross the river overhead very close to the Transect A location. Therefore, a potential route for the concentrate pipeline to approach the river from either direction in a manner that minimizes construction impacts to higher quality wetland systems would seem possible. Short term effects would occur to the rooted aquatic vegetation located along both shorelines, but these would be expected to be transient and mitigation of those effects through active restoration would appear feasible. With these perspectives in mind, the SR44_A location would appear to be the preferred location for further investigation if this focus area is selected for further AWS demineralization project consideration.

ST. JOHNS RIVER – LAKE MONROE TO YANKEE LAKE REACH

Because portions of this reach of the SJR abuts lands included within the Wekiva River Aquatic Preserve, siting of any conceptual water supply infrastructure in the river will need to take special care to address environmental impact avoidance, minimization, and mitigation. The river reach already contains commercial marina facilities as well as cooling water intake and discharge from a major FP&L power plant. The river extending from the I-4 bridge to the downstream confluence with the Wekiva River is not an OFW.

Three transects were evaluated during the field reconnaissance of this focus area conducted on August 23, 2007. The approximate transect locations are shown in Figure 16; each transect was located near existing navigation channel markers for easy reference. Although the locations of these channel markers appear to have shifted slightly from those shown in Figure 17, the indicated historical information on depth provides a helpful regional perspective.

Transect designations, with letter designations running from upstream to downstream, were as follows:

- Transect LM_YL_A: SJR near channel marker 115
- Transect LM_YL_B: SJR near channel marker 113
- Transect LM_YL_C: SJR near channel marker 112

On the date of this reconnaissance, water elevations in the area were approximately 1-foot NGVD. The bottom substrate profiles for the three locations are shown in Figures 18, 19, and 20, respectively. These figures document the river channel in this reach as substantively wider than at the focus areas visited further upstream. On the day of these field activities, maximum water depths at these transects were approximately 22, 16, and 21 feet, respectively.

Again applying the approximate frequent low river stage of about 0.3-foot NGVD for this portion of the river (Mace 2007a), the low stage dry season depth maxima at these locations would be roughly 21, 15, and 20 feet. Note that these depths are consistently greater than those observed at the upstream focus areas; more extensive bathymetric investigation may be warranted to identify the locations where depths are the greatest in this reach of the river so that an outfall could be directed toward deeper zones.

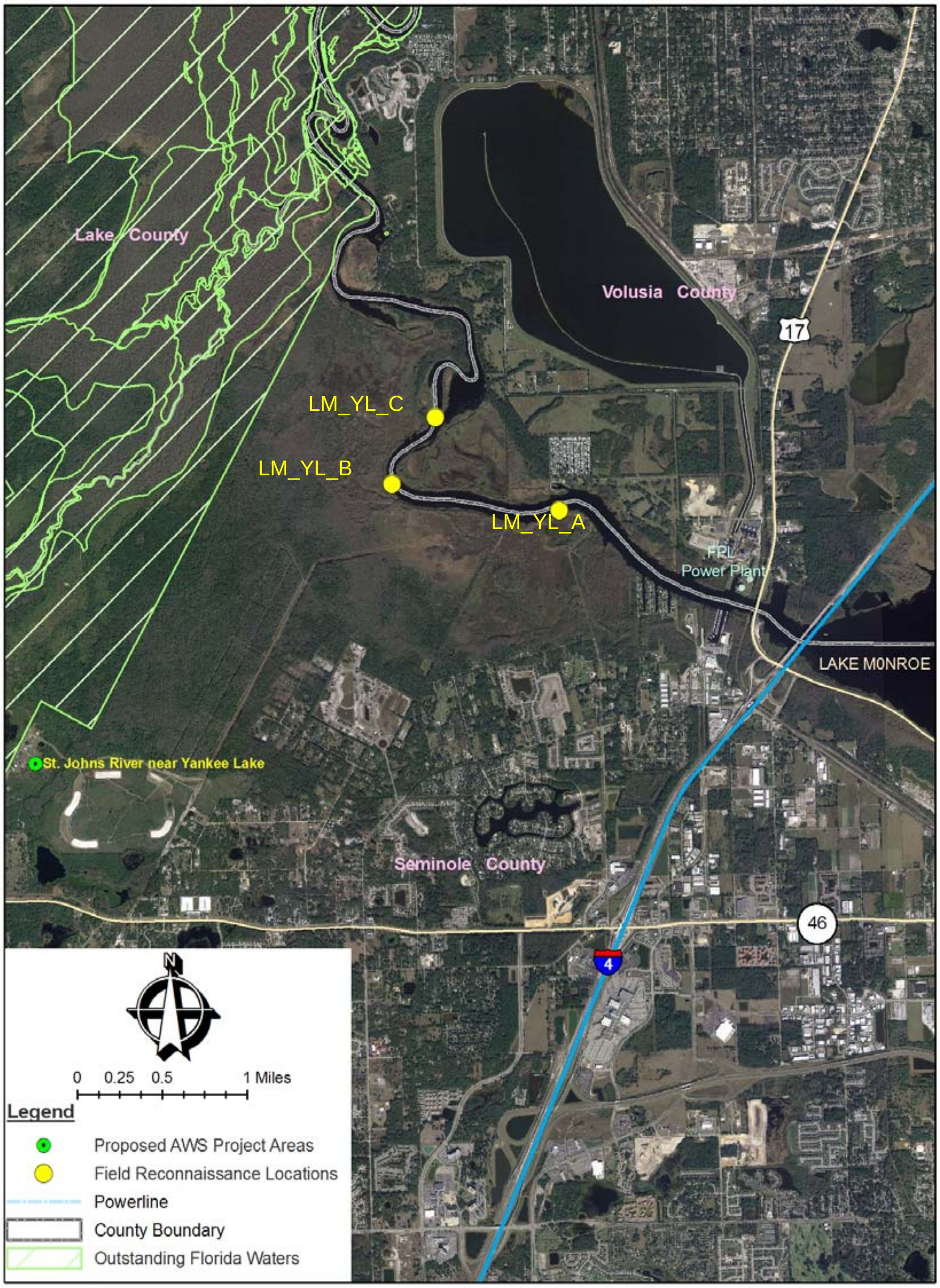

Figure 16. Approximate locations of field site reconnaissance in the St. Johns River near the Yankee Lake area

Benthic substrate grab samples were collected at five sites along each of these transect. Eelgrass was present at the eastern end of Transects A and B in water depths of approximately 2 feet, but was absent in samples collected from approximately 5- to 10-foot depths. The latter depths were encountered at 50 to 80 feet from the shoreline; the channel-ward extent of the eelgrass bed was not clearly delineated through sampling, but from the surface the bed width appeared to be approximately 20 to 30 feet wide. Large beds of spatterdock however were visible along this side of the river out to roughly the 80-foot distance from the shoreline. No rooted aquatic vegetation was detected at locations that were deeper than about 5 feet along these transects.

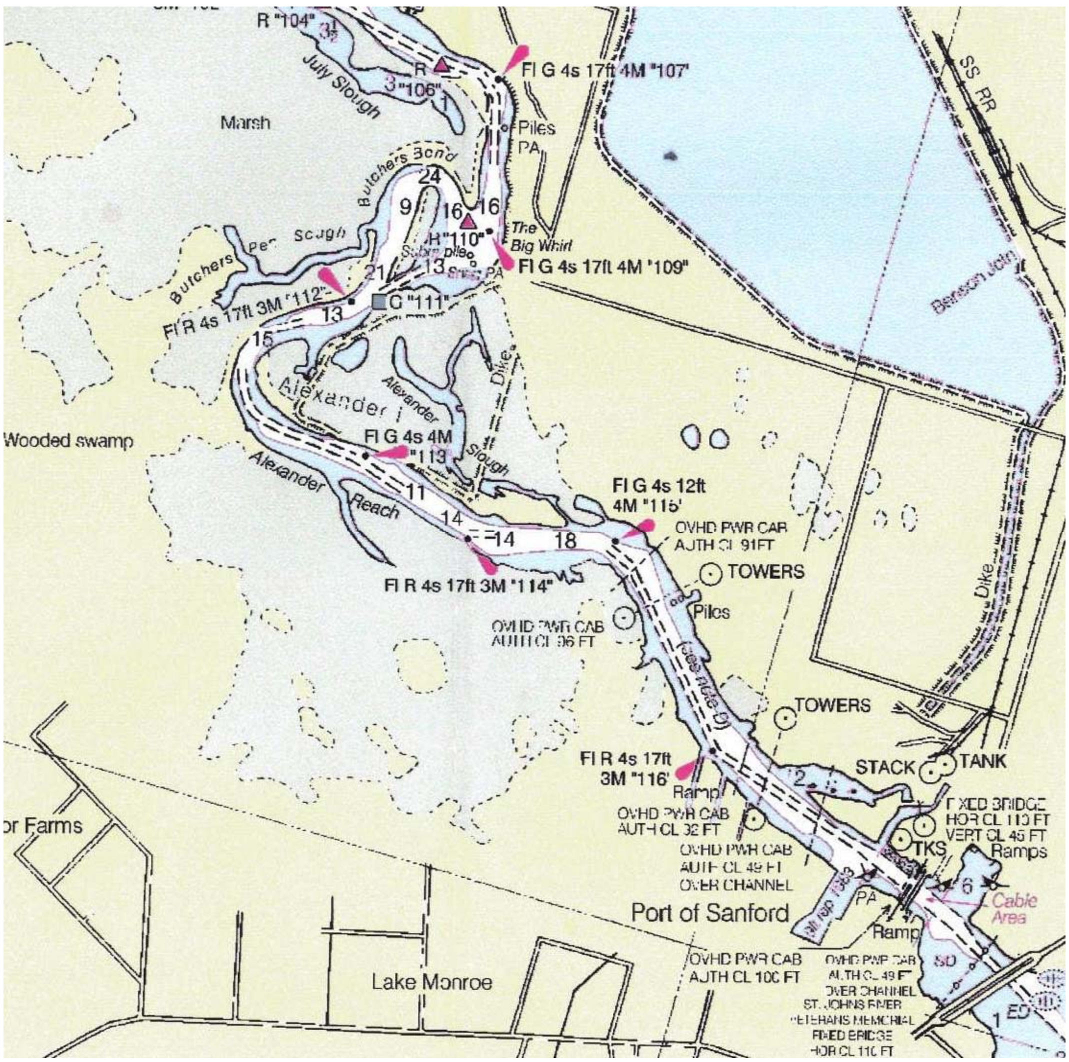

Figure 17. Historical bathymetry in the St. Johns River near the Yankee Lake area (Source: NOAA 2007)

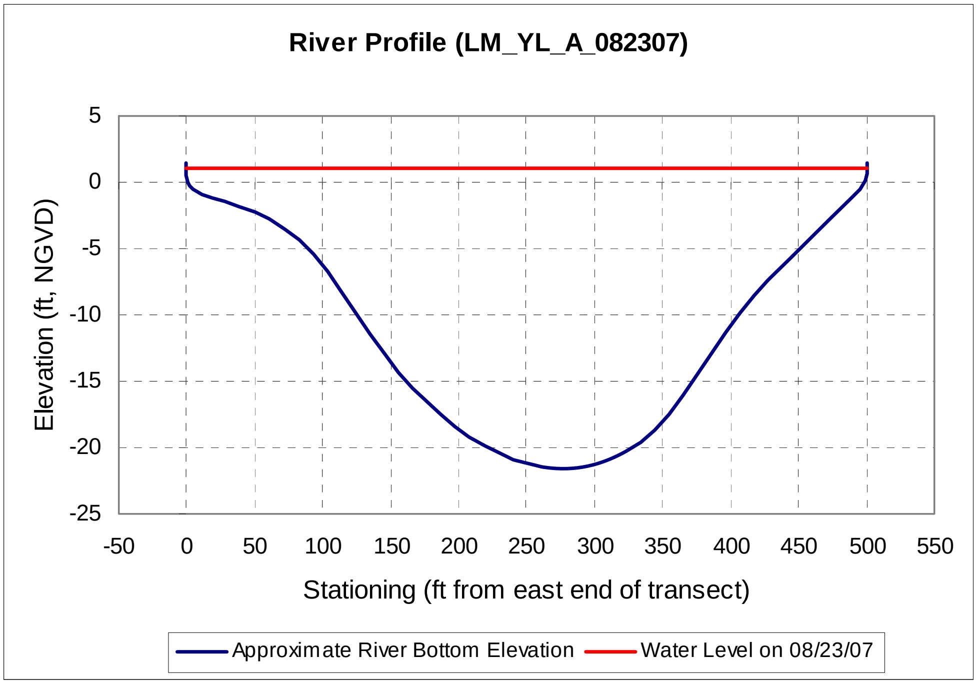

Figure 18. Bottom substrate elevations in relation to water level on August 23, 2007, at transect LM_YL_A

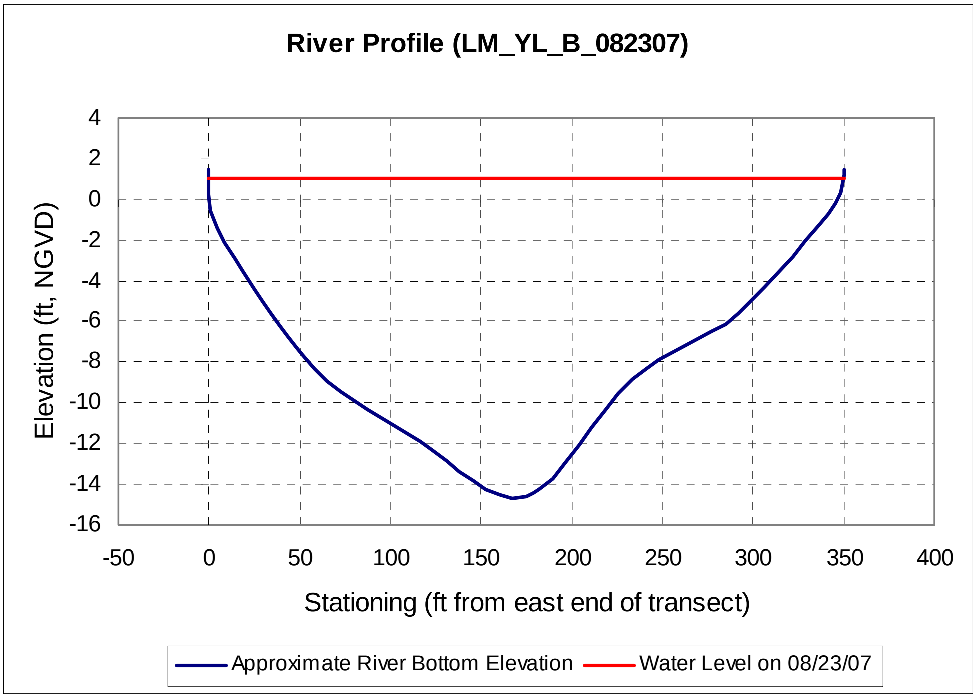

Figure 19. Bottom substrate elevations in relation to water level on August 23, 2007, at transect LM_YL_B

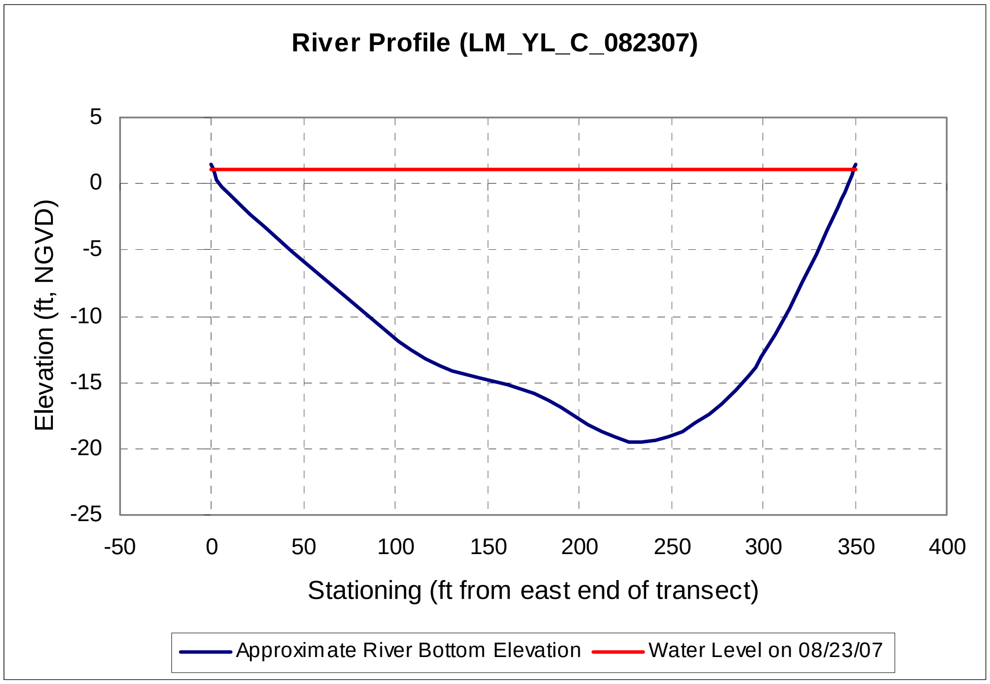

Figure 20. Bottom substrate elevations in relation to water level on August 23, 2007, at transect LM_YL_C

The sediment samples along these three transects were reviewed for mollusk presence and for all three transects, mollusks were either not found or were only present at the lowest semi-qualitative scale (<10). Two exceptions include: 1) corbiculid (*Corbiculidae*) clam shells were abundant at Transects A and C at the deepest locations sampled, but no live specimens were retrieved. The other exception/observation worth noting is: 2) live juvenile xanthid crabs (carapace widths of only a few millimeters) were found living in the root mats of the eelgrass retrieved in the shallows. Their presence in this reach of the river and the range of sizes of the specimens found, serves as indirect confirmation of brackish water conditions, which appear to have been present for a substantive period during the summer of 2007, when field reconnaissance was performed in support of this investigation.

For this AWS project focus area, the navigational channel constraint mentioned previously may also apply. Presuming a maintained channel width of 100 feet roughly centered in the channel, and assuming this portion of the channel would need to be avoided in terms of any prospective outfall installation and operation, the greatest available channel depths might not be available for proposed new outfall infrastructure. Despite this constraint, fairly deep water (10- to 15-ft) appears to be present along the edge of the navigable channel limits and on the Yankee Lake WTP site side of the river. If this focus area is evaluated further in future phases of these investigations, more detailed study for the siting of a conceptual outfall appears warranted.

These siting studies would clearly need to address the presence of the water lily beds along this side of the river channel as well as potential presence of additional areas of eelgrass beds in the shallow/littoral zones along the river. If such are present in the pipeline and outfall diffuser corridor ultimately identified as preferred, impacts should be minimized to the extent possible, and substantive mitigation of unavoidable impacts during construction would need to be integrated into the site planning efforts.

Pipeline accessibility to the river may also be a substantive issue. Hardwood swamp habitats line the edge of the river in much of this river reach, and construction-related impacts to these wooded wetlands need to be minimized. Again, existing powerline routes could be investigated as possible access points. An ongoing water supply project planned for this area appears to include an intake pipeline corridor acceptable to the parties involved in that project planning activity, and the concentrate pipeline possibly may follow the same route to return to the river. This approach may make the most sense; further landside impact avoidance, minimization, or mitigation plan modifications may be needed if this focus area is selected for AWS project implementation.

ST. JOHNS RIVER NEAR SR-46/415

AWS project concept development for this focus area is based on the assumption that the river water withdrawal site would be located east of the SR-46 bridge crossing over the outflow from Lake Jesup to the SJR. Accordingly, two transect locations were evaluated on August 22, 2007, in the SR-46/415 AWS project focus area (Figure 21). Transect locations are described below:

- Transect SR46_A was located just upstream of the SR-415 bridge near an existing USGS water level recording station and approximately 2 miles upstream of the inflow point into Lake Monroe.

- Transect SR46_B was located in the St. Johns River immediately adjacent to SR-46 approximately 0.6 mile east of the outflow channel from Lake Jesup.

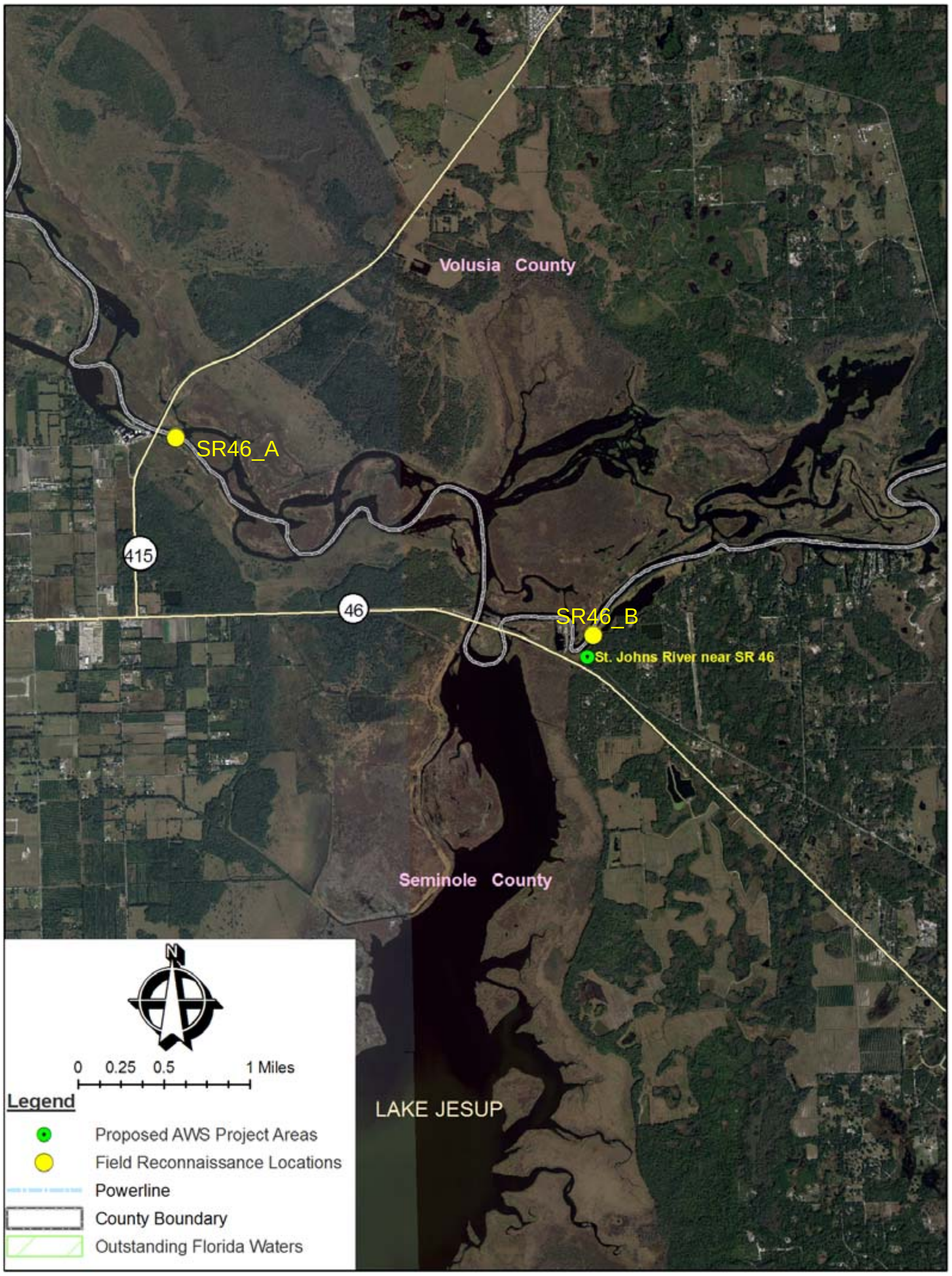

Figure 21. Approximate locations of field site reconnaissance in SJR near SR-415 and the Lake Jesup outlet

The Transect SR46_A site would require a pipeline about 3 miles longer to convey the concentrate to this river crossing in contrast to the Transect SR46_B location. Water elevation for this location on the date of the site reconnaissance was approximately 1-foot NGVD.
The bottom profiles depicted in Figures 22 and 23 were generated using the field depth measurements at these transect locations. Maximum water depths on August 22, 2007, for these two locations were approximately 16 and 9 feet, respectively. The SJRWMD has determined that the frequent low stage elevation in this portion of the river would be 0.3-foot NGVD (Mace 2007a), which means that the depth would be approximately 15 and 8 feet during low flow. Locating outfalls at greater depth allows for a greater potential of more favorable physical mixing conditions, suggesting that the SR-415 bridge location would be a more favorable discharge location over SR-46 despite the longer concentrate discharge pipeline.

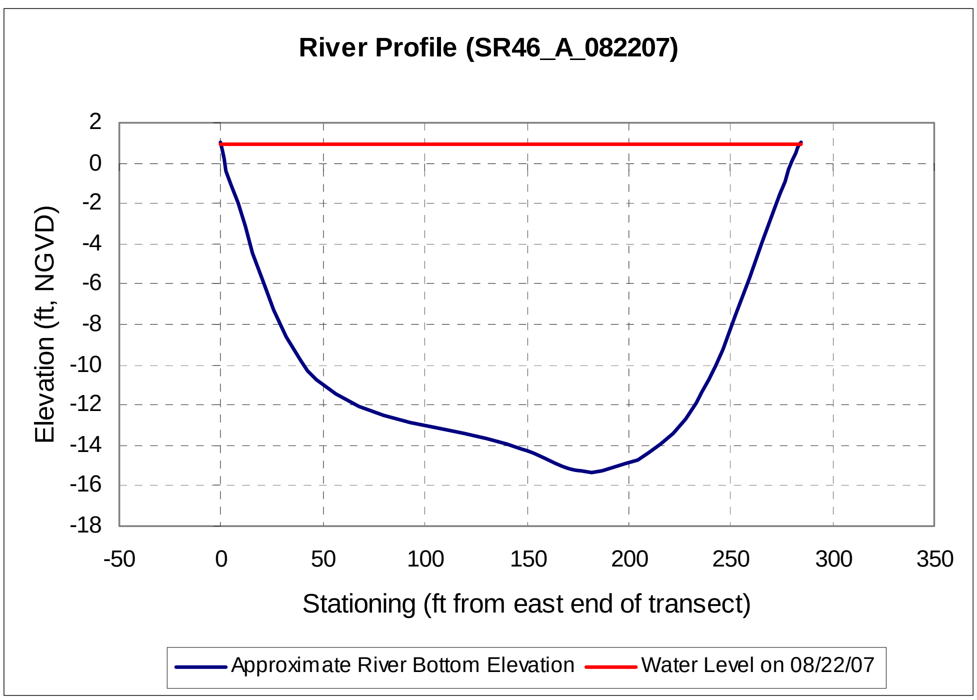

Figure 22. Bottom substrate elevations in relation to water level on August 22, 2007, at transect SR46_A

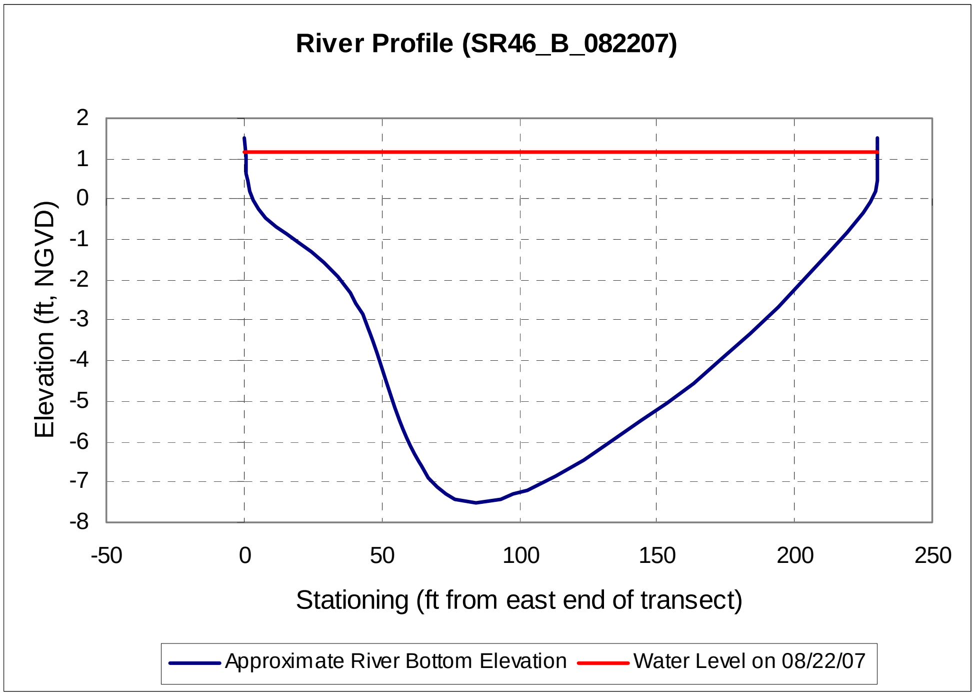

Figure 23. Bottom substrate elevations in relation to water level on August 22, 2007, at transect SR46_B

Sediments retrieved from the SR-46 focus area transects indicated that rooted aquatic vegetation beds were not present in the center half of each channel area surveyed, nor in areas within which the conceptual outfalls would most likely need to be constructed. Both bivalve and gastropod shells were found, but for both transects the incidence was low (rare).

In terms of relative site access, the Transect SR46_B location is clearly favorable because the river bend is directly adjacent to SR-46. A long pipeline run through floodplain wetlands or other sensitive habitats would not be necessary. For this focus area, the alternative location at the SR-415 bridge also offers a potentially favorable river access corridor because the roadways themselves (SR-46 and SR-415) are linear features that potentially could be followed by the pipeline. At least one crossing under these primary roads would be needed, and in the case of the SR-415 location, care would be required to avoid impacting the existing utilities crossings located in the roadway and bridge right of way (existing cable crossing – see Figure 24).

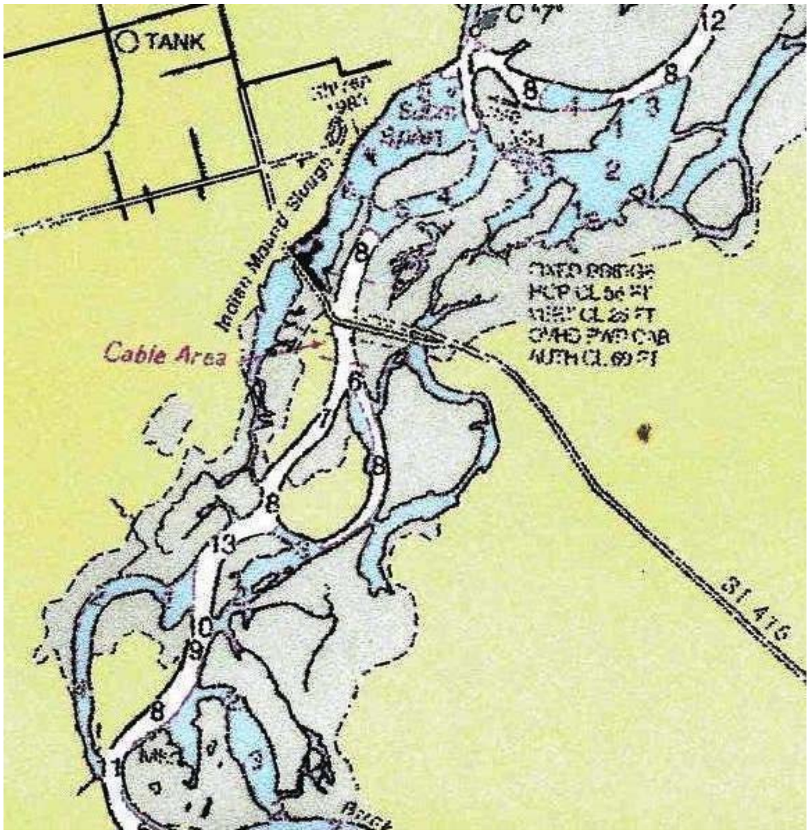

Figure 24. Historical bathymetry in the St. Johns River near transect SR46_A at the SR-415 bridge (Source: NOAA 2007)

On the basis of the field site reconnaissance survey for this focus area, the Transect SR46_A location apparently has the more favorable river channel morphology for a discharge. Frequent low stage depths in the range of 15 feet are present in the area. Additionally, this portion of the river represents a relatively narrow constrained reach in the river – all of the upstream flow must pass through this one channel in the floodplain. The SJR is more braided upstream and near SR-44. Thus, seemingly intuitive is that greater flow volumes are likely to be experienced at this location for longer periods of the year, leading to an overall improvement in dilutions achievable when compared with the other focus areas.

As noted previously, the nominal navigation channel specifications are for a 100-foot-wide channel with depths maintained to 8 feet in this reach of the river. While the depths observed at the SR-415 bridge appear to represent un-dredged conditions, note that if this site is evaluated further as a prospective concentrate outfall location, more detailed evaluations will be needed regarding the ramifications of the federal navigation channel. The channel at this location is narrower than at the other focus areas further downstream rating the navigation channel issues at this location of greater potential importance.

ST. JOHNS RIVER NEAR THE TAYLOR CREEK RESERVOIR/LAKE POINSETT

For the Taylor Creek Reservoir/Lake Poinsett area, transects were evaluated at three sites: the outflow from Lake Poinsett, the inflow channel leading from Lake Winder to Lake Poinsett, and the inflow channel leading into Lake Winder (see Figure 25). These transects were identified as USJR_A, USJR_B, and USJR_C, respectively. These three transects were evaluated on August 22, 2007; water elevation on this date in the Lake Poinsett area was approximately 13-feet NGVD.

The approximate channel profiles as measured in the field and converted to NGVD based on the lake elevation are presented in Figures 26, 27, and 28. On the basis of this information, maximum water depths on August 22, 2007, for each transect were 8, 12, and 7 feet, respectively. Generally, the deepest locations were found near the center of the channel for these three transects. SJRWMD representatives who participated in these field reconnaissance surveys advised that water depths on this date were approximately 4 feet deeper than the lowest stages observed during the spring of 2007, a period of significant regional drought. On the basis of this information, it may be surmised that under low-flow conditions, these specific locations would have held maximum channel depths of only 4, 8, and 3 feet, respectively.

Sediment grab samples retrieved from three locations representative of the central half of each transect confirmed no presence of rooted aquatic vegetation that these locations. . In samples collected at the SJR outflow channel from Lake Poinsett, bivalves were abundant and in one of the samples, 15 live corbiculid clams were retrieved. Gastropods were rare or absent in these particular samples. In contrast, samples retrieved at the location in the channel leading from Lake Winder to Lake Poinsett indicated only rare incidence of both bivalves and gastropods, and at the inflow channel into Lake Winder, no bivalves or gastropods were detected in any of the grab samples.

As noted in a prior report section, siting of a new outfall into waters designated as OFW is not acceptable to FDEP. Therefore, the outflow location from Lake Poinsett is not under consideration as a prospective site. Of the other two transect locations visited; the channel leading from Lake Winder to Lake Poinsett exhibited more favorable channel morphology, with apparent low-stage depths of approximately 8 feet for a channel width in the range of 50 feet near the center of the channel. Sediments were muddy sands, suggesting that seasonal flow scouring of the bottom is unlikely to be significant.

In terms of accessibility, this area is characterized by a very wide floodplain suggesting that unavoidable wetland impacts during construction could be significant. However, note that lands to either side of this general area have historically been used for agricultural purposes, and drainage canals are present both to the east and west (Figure 29). Depending on the location of the conceptual AWS demineralization facility, agricultural travel corridors might represent a means of pipeline installation while minimizing impacts on previously non-impacted wetland habitats. Of the sites visited in this AWS project focus area, Transect USJR_B appears to offer the greatest potential for favorable outfall location and operation.

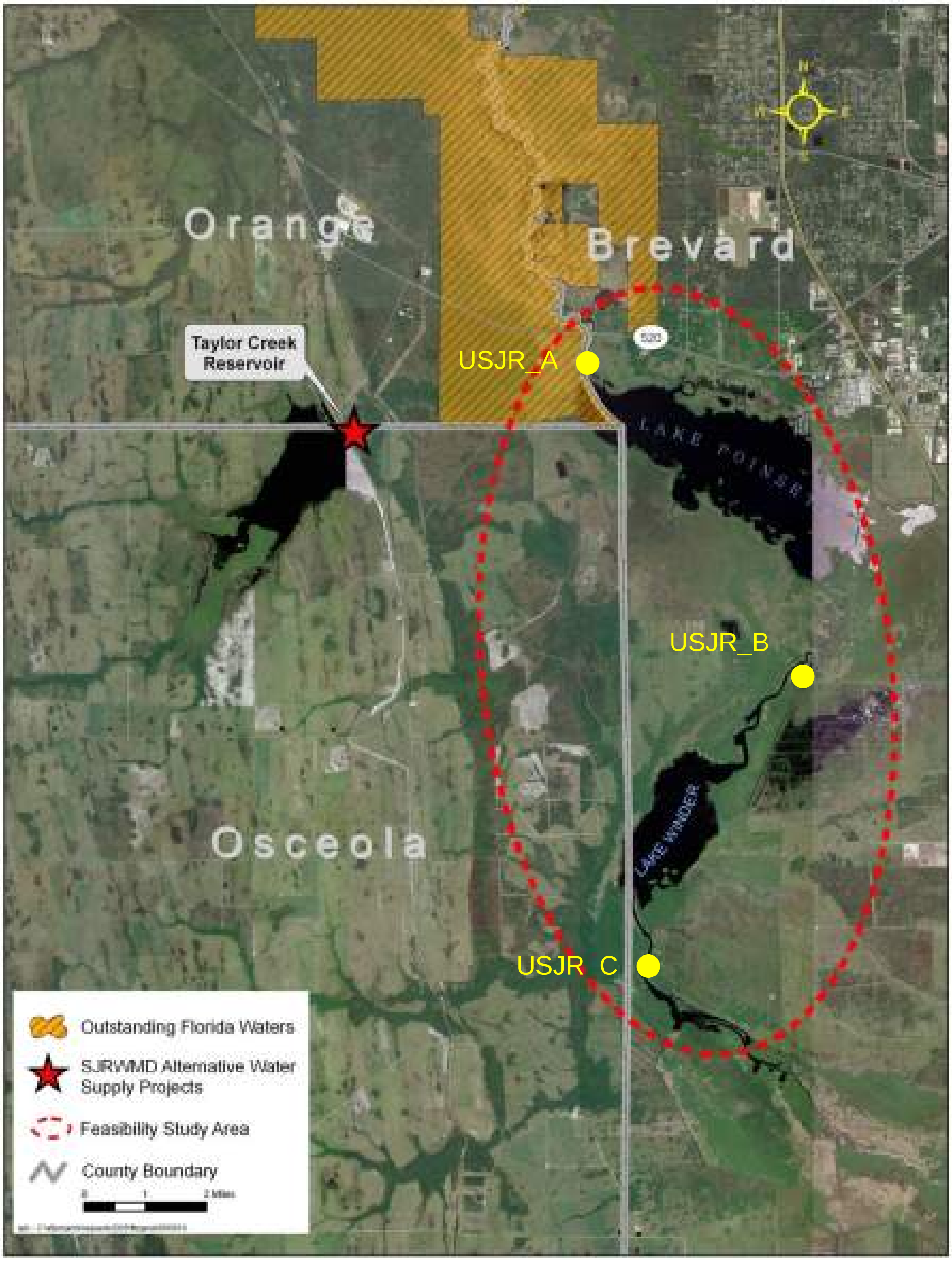

Figure 25. Approximate locations of field site reconnaissance near Lake Poinsett and Lake Winder

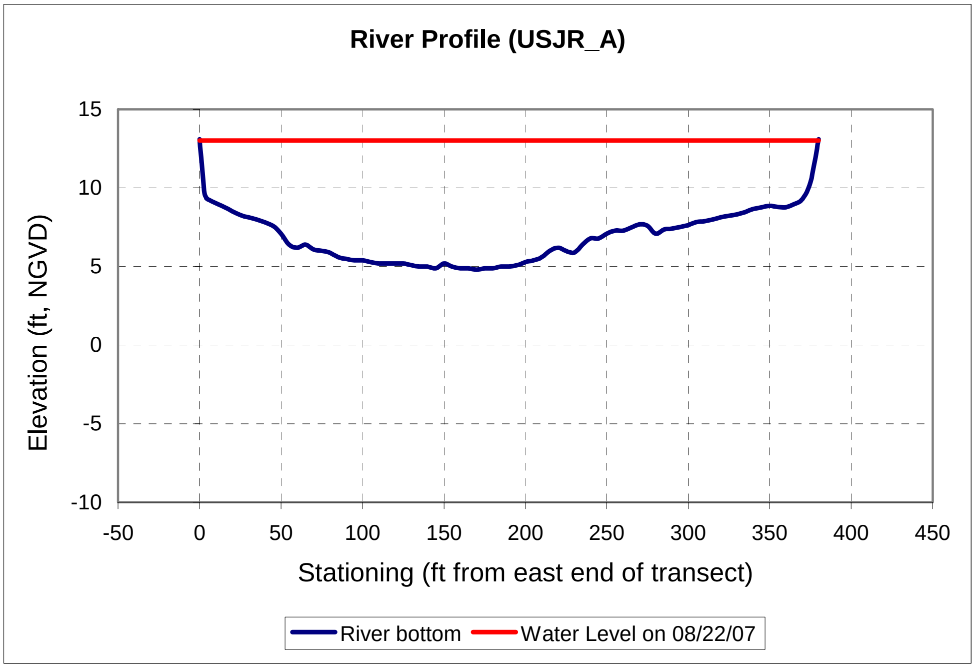

Figure 26. Bottom substrate elevations in relation to water level on August 22, 2007, at transect USJR_A

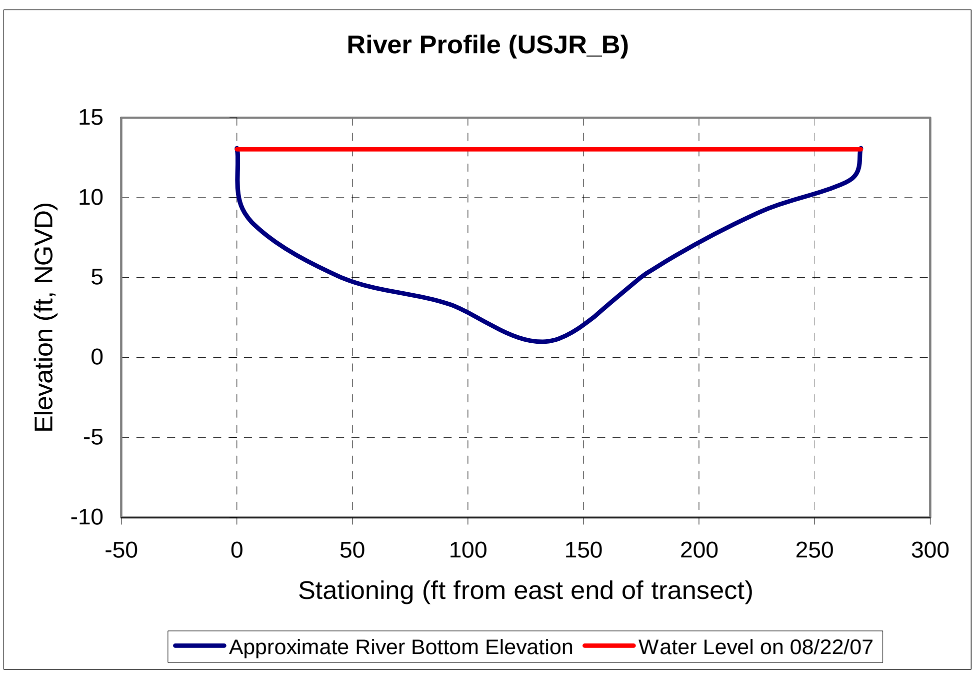

Figure 27. Bottom substrate elevations in relation to water level on August 22, 2007, at transect USJR_B

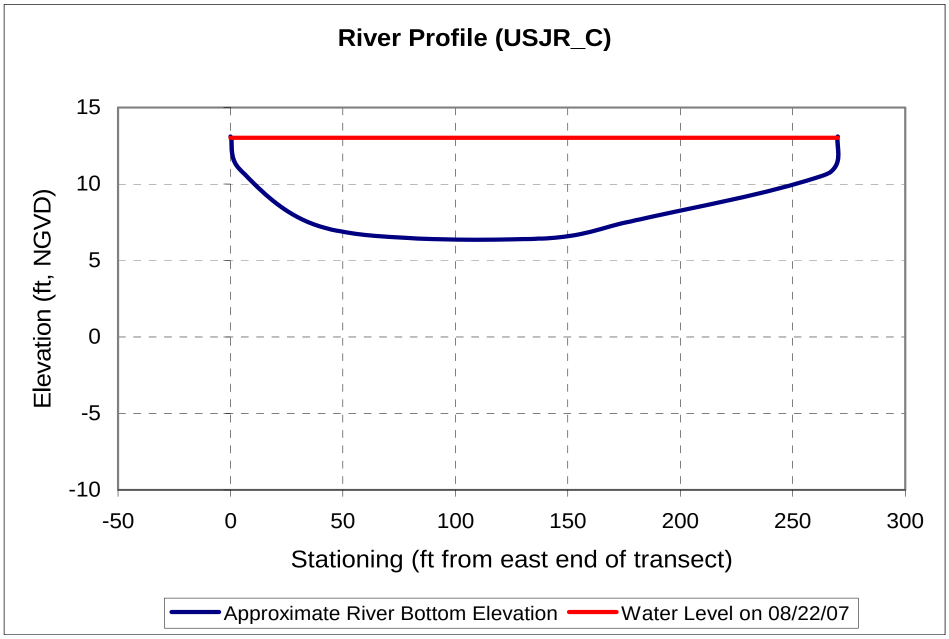

Figure 28. Bottom substrate elevations in relation to water level on August 22, 2007, at transect USJR_C

Figure 29. Historical agricultural land uses bordering the SJR floodplain between Lakes Winder and Poinsett

OVERVIEW

The site reconnaissance effort conducted as an element of the preliminary feasibility evaluation provided useful perspectives regarding each focus area's river channel morphology and apparent flow conditions based qualitatively on the river substrate. It confirmed study areas within which fairly extensive molluscan populations appear likely to be present and also detected the presence of invertebrates generally considered to be tolerant of fluctuations in salinity. Key rooted aquatic vegetation beds were detected along the shallow zones of some of the focus areas, and extensive spatterdock water lily beds were also found, both of which will need to be avoided to the extent possible during future outfall siting efforts. Additionally, observations regarding river accessibility were noted.

Several of the transects that were visited appear to represent naturally maintained deep channel habitats within which conditions conducive to concentrate discharge and mixing would seem most likely to occur for the greatest periods of time over the course of the year. Lastly, these site reconnaissance activities confirmed that some river reaches include depths that would favor outfall site operations even during low stage dry season conditions. The field data gathered regarding river depths provided a basis for setting the range of depth conditions to be evaluated in the preliminary mixing zone modeling. These data also will help guide refinement of the concentrate outfall preliminary conceptual designs that have been proposed thus far during these water supply project planning activities.

PRELIMINARY MIXING ZONE MODELING

This mixing zone assessment was used to examine the range of discharge scenarios analyzed under this phase of the feasibility study and to document the key assumptions applied. Based on the characterization of the literature discussed previously, a new outfall that discharged membrane concentrate was ascertained as likely to require a mixing zone allowance of some distance. These evaluations provide an initial quantification of the magnitude of dilution that could be expected and the distance needed from the discharge ports to achieve compliance with numerical criteria.

MIXING ZONE MODEL

A buoyant outfall plume will rise and mix until it reaches equilibrium with the surrounding waters (at the trapping depth) or reaches the surface. The deeper the water over the outfall, the more likely that the plume will reach density equilibrium prior to reaching the water surface (Figure 30). When the ambient water has uniform density, a buoyant plume may not trap and continue rising until it reaches the surface. However, for the conceptual discharge scenarios analyzed in this report, the maximum depth of water was only 20 feet. Consequently, the buoyant plumes examined here did not get trapped before reaching the surface.

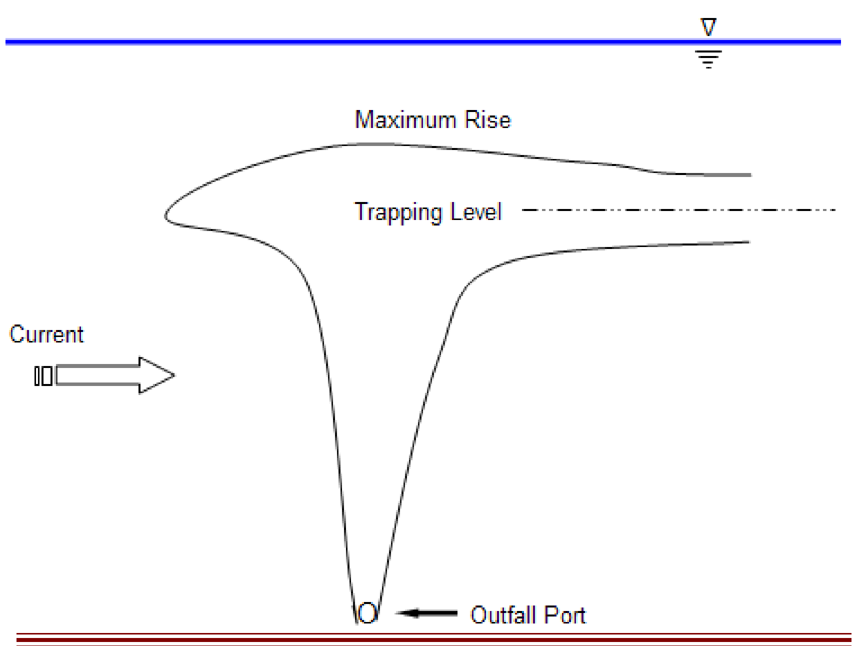

Figure 30. Example of a trapped plume

As a discharge plume rises, it undergoes rapid initial dilution (nearfield mixing) caused by jet momentum or buoyancy-induced turbulent entrainment of ambient water into the plume. After either trapping as a distinct layer beneath the surface or spreading out on the surface, the plume will then undergo dispersion during transport by the ambient currents. This farfield mixing is controlled by passive diffusion and is far less energetic and much slower than the rapid initial dilution.

For a negatively buoyant plume, the vertical angle of discharge becomes more important as a design parameter than for a buoyant plume. Because of the potentially higher salinity and density of membrane concentrate, the discharge may not rise through the water column. If the outfall diffuser is designed to jet the discharge upward into the water column, as is usually the case, the plume may reach an equilibrium depth above the river bottom or could collapse back to the bottom depending on ambient and effluent conditions. The model applied to support the river outfall feasibility study had to be capable of addressing the range of concentrate plume behaviors within the water column.

The VISUAL PLUMES (VP) program, which is supported by EPA for these types of mixing zone analyses, was the model applied for this study. This program has been used previously for establishing zones of mixing in Florida. Specifically, Version 1.0 of VISUAL PLUMES using the UM3 submodel was selected to support the analysis in the current study (Davis 1999; Frick et al. 2001).

The VP models predict the mixing and trajectory of the plume during the initial dilution process until the plume reaches equilibrium or the surface. Beyond this point, the program switches the computational algorithm to a farfield, passive diffusion model (the Brooks Equation), which predicts continued dilution as the plume travels farther downstream. The physical mixing mechanisms involved in farfield dilution are dominated by ambient receiving water conditions. The Brooks Equation accounts for horizontal mixing, but not vertical mixing. It is expected that nearfield mixing will be the most important dilution mechanism because the mixing zone may be limited to no further than 2 times the depth of the receiving waters.

The required dilution to bring a given effluent constituent concentration down to the water quality criterion for that constituent can be computed from the effluent concentration, ambient receiving water concentration, and water quality standard concentrations, as follows:

$$Sa' = (Ce - Ca)/(Cwqc - Ca) = [(Qe+Qa)/Qe] \quad (1)$$

where,

Sa′ = bulk dilution factor at the point where Cwqc is attained
Ce = concentrate concentration
Ca = ambient concentration
Cwqc = target plume concentration that is equal to the water quality criterion
Q = flow volume of the discharge (e) and ambient river (a)

The VP models predict the bulk dilution factor for use in the above equation. The resultant average plume concentration (Cp) at any particular dilution can be estimated by rearranging the above equation as:

$$Cp = [(Ce-Ca)/Sa] + Ca \quad (2)$$

FDEP also reviews the centerline dilution, which is typically Sa/1.4 for a plume (Fischer et al. 1979).

NEARFIELD MODEL SELECTION

VP's current version (1.0) supports a total of four different nearfield plume development models: UM3, DKHW, PDS, and NRFIELD. However, only UM3 and DKHW have the capabilities to perform modeling of three-dimensional plumes from single- and multi-port submerged discharges.

UM3 is a three-dimensional Lagrangian model that uses the projected-area-entrainment hypothesis to predict plume development. The independent variable in this model is time. DKHW is also a three-dimensional model, but it uses an Eulerian integral method to solve the equations of motion for plume trajectory, size, concentration, and temperature. In this model, the independent variable is distance. UM3 was used as the primary mixing zone model for this feasibility study because of the possibility of negatively buoyant plumes that are denser than the receiving waters. DKHW presently does not support modeling of such plumes. Moreover, using UM3 as the primary mixing zone model is consistent with similar analyses conducted previously for SJRWMD (CH2M HILL 2007).

SUMMARY OF PLUMES MODELING INPUTS

The VP model requires definition of the discharge configuration and ambient physical environmental characteristics in the vicinity of the port(s). The field reconnaissance of the potential project sites concluded that locations further downstream, near Sanford and near DeLand, were more favorable for mixing zone permitting because of the relatively deeper water depth. The following key modeling input parameters were applied for the preliminary assessment.

Water Depth

According to Rule 62-4.244, *F.A.C.*, the discharge effluent must meet the specific water quality criterion within a distance to two times the natural water depth at the point of discharge to qualify for a demineralization concentrate zone of mixing The natural water depth is defined as the 7-day, 10-year low flow (7Q10) conditions for non-tidal waters. During the field reconnaissance, the depth of the deepest part of the river channel at different locations was observed to vary between 6 feet and 36 feet. However, the deepest zones are maintained for navigation purposes and that may affect where an outfall could be located. To bracket the range of likely depths of the river at the potential concentrate discharge locations, three depths were evaluated for the mixing zone simulations: 6, 12, and 20 feet.

Physical Characteristics of Ambient Waters

To determine the physical characteristics of the ambient waters of the SJR near the alternative water supply projects, data from three different USGS monitoring stations was used to characterize the ambient SJR conditions (Figure 31). The monitoring station near Sanford is located at the outflow from Lake Monroe, close to the US-17 bridge. Because the station near Sanford was close to the potential discharge location near SR-46/415 and Yankee Lake, the water quality data from the station near Sanford was used as representative for these three locations. The USGS monitoring location near DeLand is situated near the SR-44 bridge (Figure 31) on the river, a potential discharge location. Therefore, the station near DeLand was used as representative of the project location near SR-44.

While the water temperatures did not vary considerably between the three USGS stations, the temperatures were found to fluctuate seasonally from winter to summer. To capture the seasonality of ambient water temperature in the modeling analysis, scenarios with different summer and winter temperatures were evaluated. The average water temperature during the summer months (May to October) was 28.0°C, while it was 20.7°C during the winter months (November to April). The average water temperatures for the summer and winter months was calculated from the water quality data obtained for the three USGS stations. The ambient water temperature is used in the standard equation to compute density by the VP model.

The specific conductance was used to estimate the salinity of the ambient conditions using a standard equation listed below (EPA 1985), which in turn is also used by the VP model to compute ambient density. The maximum observed specific conductivity of the river among the three monitoring locations was highest near Cocoa. Specific conductance of the river decreased moving downstream of Cocoa. For each location, three scenarios of specific conductance were simulated. For the high ambient conductivity (higher density), the 95th percentile of the observed specific conductance data was evaluated. The median value of specific conductance at each location was also evaluated. The third scenario was to evaluate an average specific conductance value between the median and the 95th percentile value at each location.

The SJR is a very slow moving river with the average velocity of about 0.4 to 0.6 fps. The maximum velocity at the three USGS monitoring locations was 2.3 fps, near Cocoa. Because of the slow currents in the river, mixing zones were evaluated for a negligible flow velocity of 0.0001 fps. This scenario is to evaluate the mixing zone in very low flow conditions. A second scenario using the median flow velocity in the river was also evaluated. The median velocity in the river was calculated based on the surface water data obtained from the three USGS monitoring stations.

PHYSICAL CHARACTERISTICS OF CONCENTRATE

The flow rate from a given diffuser port affects the densimetric Froude Number, which in turns provides a measure of the expected entrainment characteristics of the discharge. Higher exit velocities generally tend to improve the mixing and dilution. Based on the conceptual proposals of the WTPs, the concentrate flow rates are expected to range from 1 to 7 mgd. Based on the expected flow rates, three concentrate flow rates were evaluated: 2, 4 and 8 mgd. Modeling of the three concentrate flow rates is discussed further in the Outfall Configuration section of this report.

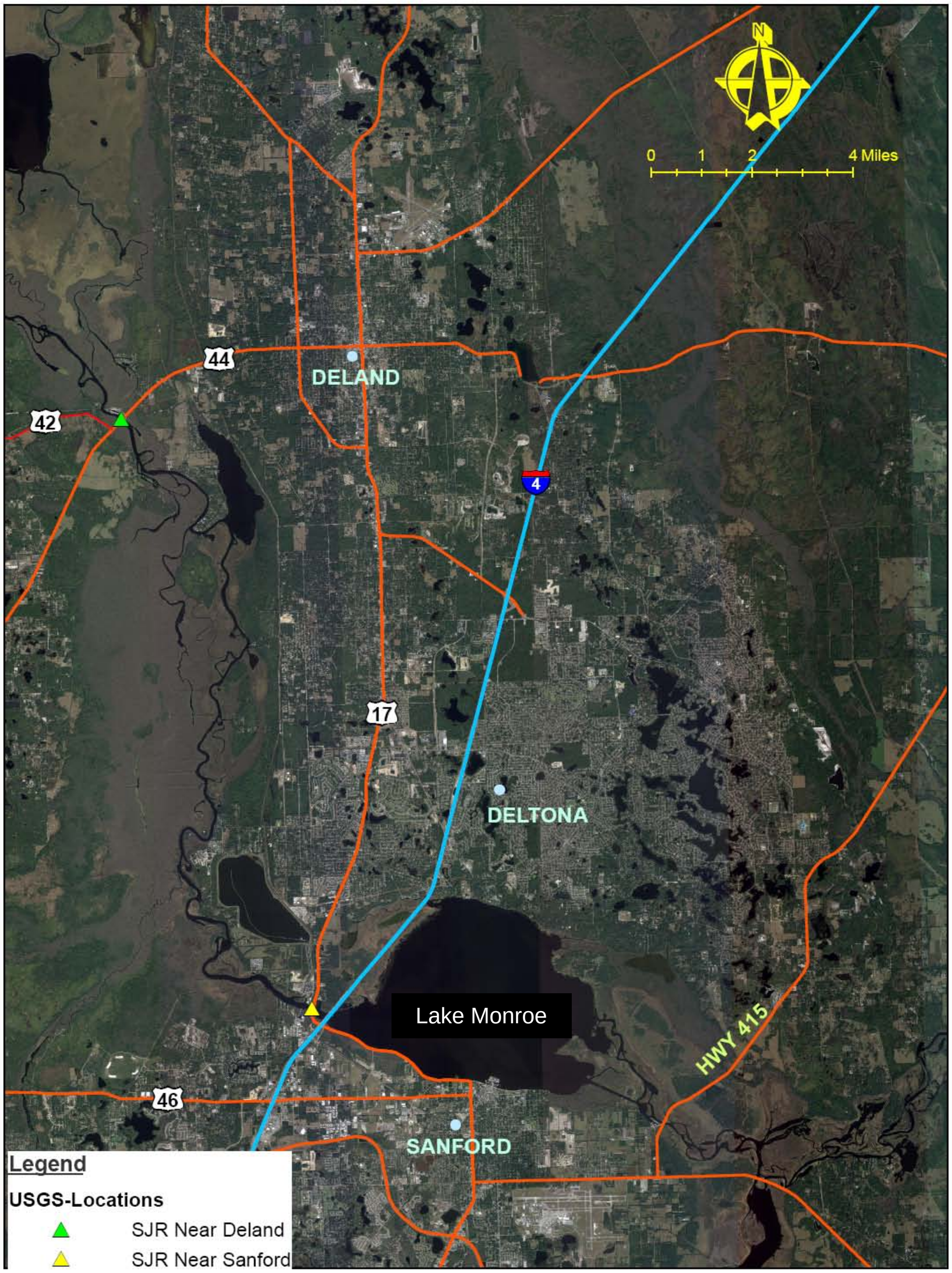

Figure 31. Location of USGS monitoring stations

The density of the plume relative to the ambient water will affect the rise and mixing characteristics. Because water density is a function of salinity and temperature, both of these characteristics were varied within the range of observed data. The range of key physical characteristics of concentrate used as input parameters for the dilution model is summarized in Table 4.

Table 4. Range of discharge concentrate characteristics used in planning-level modeling

Parameter	Unit	Concentrate											
		Sanford						DeLand					
Concentrate Salinity	psu	6.0						4.75					
Concentrate Density	g/cm^3	PLUMES will compute from Temp. and Salinity											
Concentrate Flow	mgd	2		4		8		2		4		8	
Concentrate Temperature	°C	21	28	21	28	21	28	21	28	21	28	21	28

21°C and 28°C represent winter season and summer season temperatures, respectively.
°C = degrees Celsius; g/cm^3 = grams per cubic centimeter; mgd = million gallons per day;
psu = practical salinity unit

For the mixing zone modeling, the ambient salinity was varied and the discharge salinity was held constant. Salinity of the concentrate at each location (near Sanford and near DeLand) was calculated based on the specific conductance of the river water. The 95th percentile ambient specific conductivity at each station was used to estimate the salinity of the concentrate. The salinity of water was then estimated based on the specific conductance using the following equation (EPA 1985):

$$\text{Salinity (psu)} = 5.572 \times 10^{-4} \text{ (SC)} + 2.02 \times 10^{-9} \text{ (SC)}^2$$

Where salinity expressed as a practical salinity unit (psu) is equivalent to parts per thousand, and SC is specific conductance in micromhos per centimeter (μmhos/cm). A typical brackish water membrane system is designed for 80 percent recovery and 100 percent membrane rejection (Mickley et al. 1993). A CF of 5 can be expected from such a system. By using this planning-level approach, a typical discharge salinity of about 6.0 psu was estimated at Sanford, and 4.75 psu was estimated at DeLand using the 95th percentile ambient values times 5.

A range of ambient salinities was simulated: high, medium, and low values as obtained from the observed data. The discharge salinity concentrations assumed for Sanford corresponded to a CF of 5.2 when high observed ambient salinity conditions occur (1.16 psu); moderate ambient salinity conditions (0.94 psu) corresponded to a CF of 6.4; and the median ambient salinity conditions (0.73 psu) corresponded to a CF of 8.2. Similar CFs resulted at DeLand using this approach. The WTP mass balance did not explicitly include salinity, but TDS CFs ranged from 3.8 to 7.6. Therefore, the simulated ambient range included the predicted highest TDS CF from the WTPs.

Water treated by RO remains at the ambient temperature of the source water (Mickley 1995); therefore, the concentrate was modeled at temperatures representing the water source.

OUTFALL CONFIGURATIONS

The potential diffuser configurations could be numerous, as there is no default standard design and many different styles are available to choose from. A diffuser system for a small flow could be much different than for large flows. Two parameters affect the plume mixing from a single port: diameter and vertical discharge angle. An outfall should include a high-rate diffuser to achieve rapid dilution. A high-rate diffuser is generally defined as one that has an exit velocity from the ports of at least 10 fps to generate a high rate of mixing (EPA 1991). Alternately, a dilution of 100:1 is also considered a high-rate diffuser even if the port exit velocity is less than 10 fps. However, a port velocity that is too high generates high energy loss (also called head loss), which will require much larger pumping requirements. Consequently, a range of port velocities between 10 fps and 18 fps was considered reasonable for this analysis.

A minimum port diameter of 2 inches typically is recommended for outfalls to prevent fouling by scaling. For the low-flow range, small ports are appropriate, but for the large flows multiple ports may be required. The sum of the port area needs to be less than the upstream diffuser barrel area (Fischer et al. 1979), therefore, very large-diameter ports are not recommended either. For this feasibility analysis, four different outfall configurations were evaluated (Table 5).

The vertical angle of the port assists in avoiding the buoyant plume from impinging on the river bottom. Experience has shown that a vertical angle of 15 degrees from horizontal is sufficient for rising plumes. For sinking plumes, the angle is probably more important. A vertical angle of approximately 45 degrees maximizes the travel path of a sinking plume before it strikes the floor. Because of the shallow river conditions, only a 15° angle was simulated.

Table 5. Range of outfall port configurations evaluated

Approximate Concentrate Flow	Port Size (in)	Target Velocity (fps)	Max. Flow per Port (mgd)	Number of Ports Required
2	6	18	2.28	1
4	8	18	4.06	1
8	8	18	4.06	2
8	12	18	9.14	1

fps = feet per second; in = inch(es); mgd = million gallons per day

All mixing zone results depend on the specific combination of concentrate flow (velocity) and concentrate versus ambient density differences. For the scenario with an 8-inch port discharging 8 mgd with two ports, the distance between the two ports was maintained at 12 feet. Table 6 presents the parameter values applied.

Table 6. Modeling input parameters used in planning-level modeling

Parameter	Unit	Value*							
		Sanford				DeLand			
Concentrate Conductivity	umhos/cm	10,325				8,280			
Concentrate Temperature	°C	Summer and Winter Distributions*							
Concentrate Flow	mgd	2	4	8		2	4	8	
Port Size	inches	6	8	8	12	6	8	8	12
Number of Ports		1	1	2	1	1	1	2	1
Concentrate Discharge Angle	°	15°							
Ambient Current Speed	fps	0.0001		0.4		0.0001		0.4	
Ambient Current Direction	°	90° to discharge port							
Ambient Temperature	°C	Summer and Winter Distributions*							
Ambient Salinity		1.16	0.94	0.73		0.93	0.79	0.65	

* see text for details

°C = degrees Celsius; fps = feet per second; mgd = million gallons per day; umhos/cm = micromhos/centimeter

PRELIMINARY MODELING RESULTS

The following section presents the graphical and numerical preliminary modeling results generated by VP for conceptual outfall discharges of concentrate in the SJR. This section provides a sensitivity analysis of the predicted dilution factors achieved at varied horizontal and vertical distances from the discharge ports of conceptual high rate diffusers with different flow rates. The UM3 modeling was conducted for two sets of ambient water quality data from the SJR, near Sanford and near DeLand. The Sanford location is considered representative of potential concentrate discharge locations at SR-46, at SR-415, and the Yankee Lake project. The TCR project is not included here because it is not anticipated to utilize membrane treatment.

Results for Sanford Location

A total of 20 scenarios were modeled for the Sanford location; modeling results are documented in Appendix D. Table 7 lists a selected summary of the lowest dilution factors at the water surface for both summer and winter simulations at the Sanford location. Summer conditions consisted of warmer effluent and ambient water temperatures while the winter conditions included colder water temperatures. As demonstrated by the results, for the same background conditions very little difference was evident between the dilutions generated for summer and winter conditions. Therefore, seasonal fluctuations in the ambient and concentrate temperature conclusively had minimal impact on the expected dilution.

Lower concentrate discharge volumes had somewhat higher dilution factors. Furthermore, most plumes reached the surface. Some of the plumes reached a local maximum before intercepting the surface, which is an indicator that the plume started to reach a trapping level. Dilution factors at the local maximum were considered the dilution factors at the time of trapping, which in most cases is a conservative assumption since plumes do dilute further while oscillating (CH2M HILL 2007). The reported dilution and distances are those predicted at the surfacing of the plume or at the first local maximum.

For the 8 mgd case, two scenarios were simulated, two 8-inch ports and one 12-inch port, to illustrate that multiple ports may be used to achieve results similar to those of the smaller ports. The case with 8 mgd using two ports generated similar dilutions as the case with an 8-inch port discharging 4 mgd using one port. Therefore, the results presented below include only the case discharging 8 mgd using one port. Appendix D contains the results for the case with 8 mgd discharge using two ports.

The depth of ports was varied to demonstrate the effect of shallow outfalls. For any set of ambient conditions, the maximum dilution was generated for the deepest channel (20 feet), while the minimum dilution was generated for the shallowest depth of 6 feet. Therefore, depth of water column above the diffuser port had considerable effect on the dilutions achieved. Figure 32 shows that the maximum dilution achieved with the 6-foot deep channel was about 16.1, while it increased to 24.8 and 29.6 for the 12- and the 20-foot deep channels, respectively. A similar trend was observed with other modeling scenarios of median velocity and different salinities. As expected, the greater the depth of the water column (and port), the greater the dilution that can be achieved.

Table 7. Selected summary of summer and winter season results at Sanford location

Case	Season	Ambient Salinity (psu)	Ambient Velocity (fps)	Water Depth (ft)	Concentrate Flow (mgd)	Mixing Zone	
						Dilution	Horizontal Distance (ft)
1	Summer	1.16	0.0001	6	2	16.1	18.1
2	Summer	1.16	0.0001	6	4	11.9	17.5
3	Summer	1.16	0.0001	6	8	8.2	17.3
4	Summer	1.16	0.0001	12	8	11.9	26.4
5	Summer	1.16	0.0001	20	8	21.1	49.2
6	Summer	1.16	0.4	6	2	23.9	14.1
7	Summer	1.16	0.4	6	4	15.7	15.0
8	Summer	1.16	0.4	6	8	10.2	15.4
9	Summer	1.16	0.4	12	8	14.8	20.7
10	Summer	1.16	0.4	20	8	29.9	32.1
11	Winter	1.16	0.0001	6	2	16.1	18.1
12	Winter	1.16	0.0001	6	4	11.9	17.5
13	Winter	1.16	0.0001	6	8	8.2	17.2
14	Winter	1.16	0.0001	12	8	11.9	26.4
15	Winter	1.16	0.0001	20	8	24.3	57.2
16	Winter	1.16	0.4	6	2	23.9	14.1
17	Winter	1.16	0.4	6	4	15.7	15.0
18	Winter	1.16	0.4	6	8	10.2	15.4
19	Winter	1.16	0.4	12	8	14.8	20.7
20	Winter	1.16	0.4	20	8	29.9	32.1

fps = feet per second; ft = feet; mgd = million gallons per day; psu = practical salinity unit

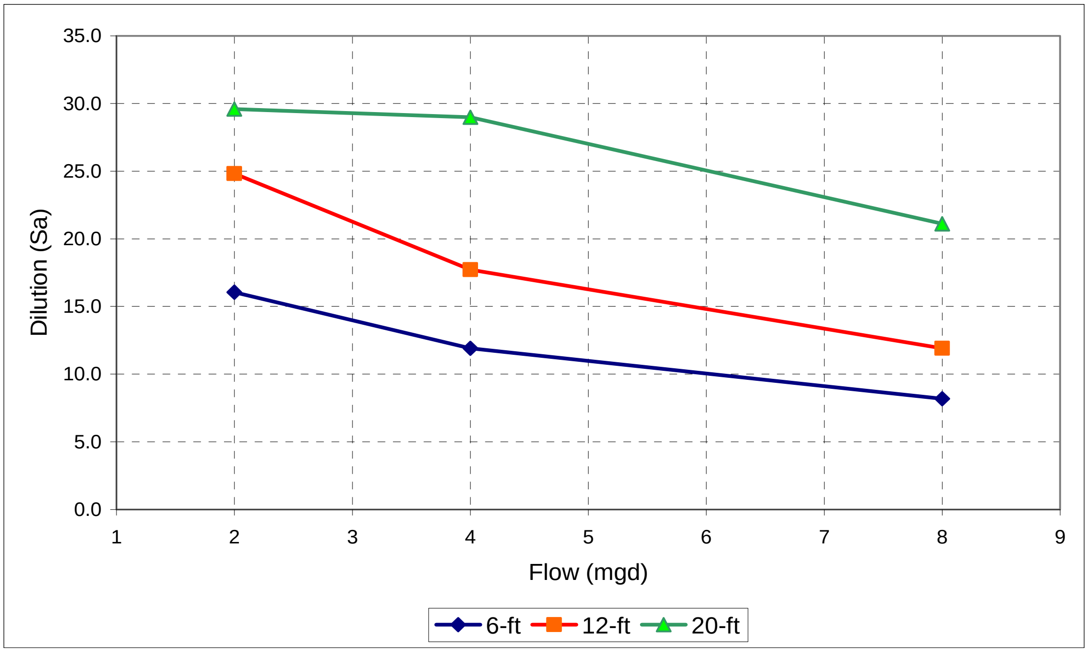

Figure 32. Dilution at the water surface for a low velocity and 95 percentile ambient salinity case at Sanford location (summer conditions)

The background salinity of the receiving waters did not seem to have much effect on the dilutions within the range of salinities found in the river at these locations. With other inputs remaining the same, similar dilutions were generated as the background salinity of the receiving water was varied from 1.16 to 0.73 psu (Appendix D).

For any set of ambient conditions but different ambient velocity, the case with the higher median velocity generated a higher dilution factor. The reasoning is that with higher river current more ambient water is available for entrapment in the plume. Figure 33 shows the case with median velocity and high ambient salinity during the summer conditions. When compared to the dilutions generated for the equivalent ambient conditions except with low velocity (Figure 32), higher dilutions were generated for the case with median velocity. A maximum dilution of 69 was generated for the case discharging 2 mgd in a 20-foot channel with ambient salinity of 1.16 psu and median velocity of 0.4 fps. The comparable low ambient velocity conditions with the same discharge generated a dilution of about 29.6. Thus, dilution is sensitive to the ambient velocity.

The case with low velocity shown in Figure 32 is a conservative permitting scenario with near stagnant flow conditions and is expected to occur very infrequently. In general, the velocity in the river can be expected to be in the range of the median velocity most of the time, and the higher dilutions as shown in Figure 33 would be more representative of typical conditions.

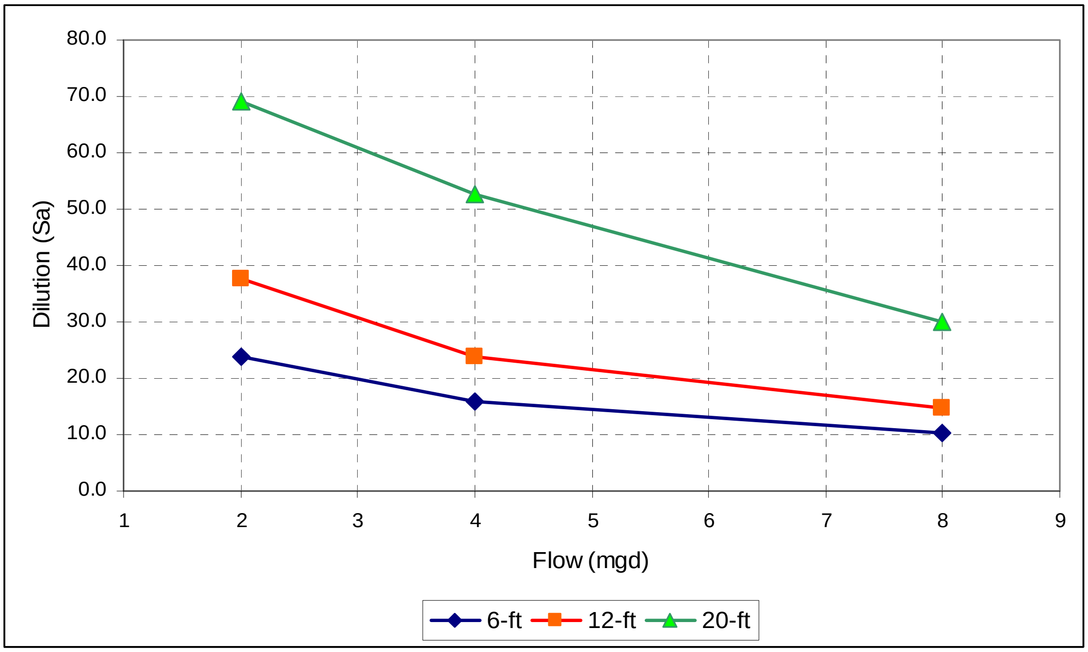

Figure 33. Dilution at the water surface for a median velocity and 95 percentile salinity case at Sanford location (summer conditions)

The travel time taken by the plumes to reach the surface in both low and median velocity conditions was similar because of similar exit velocities of concentrate from the diffuser port. Port sizes were selected to produce similar exit velocities (approximately 18 fps) between the scenarios. Some variations may occur with different outfall designs, but these flows and port sizes would be typical and results representative of a high rate diffuser.

Apart from different dilutions generated under different ambient velocities, another difference between the results was the horizontal distance traveled by the plume before it emerged on the surface. As shown in Figure 34, the low ambient velocity plume traveled a longer distance before it reached the surface as compared to the median velocity plume. Consequently, the size of a regulatory zone of mixing would be larger also for the low ambient velocity case. However, if the MSIIT provision of the mixing zone rule is applied, the maximum mixing zone size of 2 times the natural depth likely will be the limiting factor prior to the plume reaching the surface. The needed dilution for compliance is discussed further in the Feasibility Analysis section of this report.

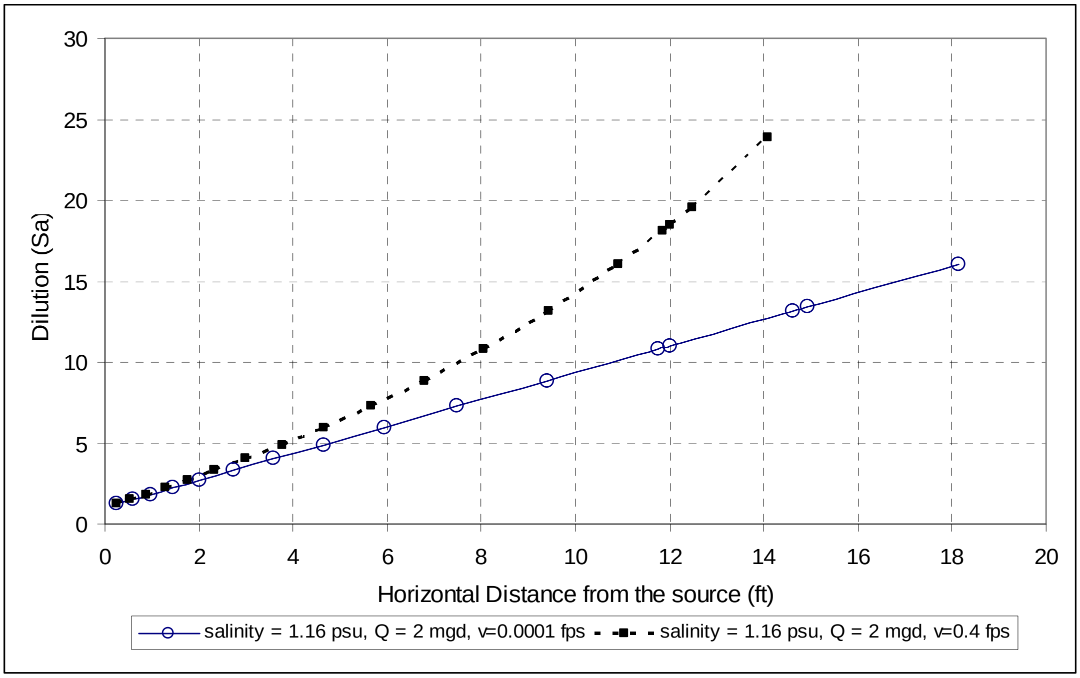

Figure 34. Dilution versus distance for high salinity at Sanford location

Flow volume also affected the predicted dilution. Results showed that the greater the flow the less dilution was generated for any set of ambient conditions (Figures 33 and 34). Because the flow velocity in all the cases was maintained around 18 fps, the higher discharge flow volume reduced the proportion of ambient water entrained into the plumes.

Overall, the lowest dilutions were generated for the shallow 6-foot channel for the highest discharge condition (8 mgd). The lowest dilution generated for the 6-foot deep channel was about 8 for the worst-case scenario of near stagnant flow conditions during winter season. For the worst case, the lowest dilution generated for the 12- and the 20-foot deep channels was about 12 and 21, respectively, for summer conditions. These dilution values may be reduced slightly because of the horizontal distance limit.

Results for DeLand Location

A total of 20 scenarios were modeled for the DeLand location; modeling results are documented in detail in Appendix E. Table 8 lists a selected summary of the dilution factors at the water surface for both summer and winter simulations for the DeLand location. These results are very similar to those predicted for the Sanford location, with little difference between the summer and winter dilutions for any set of ambient conditions. The maximum dilution was generated for the deepest channel (20 feet), while the minimum dilution was generated for the shallowest depth of 6 feet.

Compared to the dilutions generated for the Sanford location, the dilutions generated for DeLand location were similar for different cases for the 6- and 12-foot deep channels. However, the dilutions generated for the DeLand locations were higher than those generated for Sanford for the remaining cases of deeper channels (12 feet and 20 feet). The main reasons for a higher dilution generated for the DeLand location is that the ambient water quality in the river is slightly fresher near DeLand as compared to the SJR near Sanford. Because of the comparatively fresher river water, the specific conductance of the concentrate generated at the DeLand location was less than that generated at the Sanford location, and the combination of comparatively fresher ambient water and less saline concentrate produced slightly higher dilution factors.

Similar trends in the dilutions changing as a result of change in velocity and flow were seen at the DeLand location as compared to those seen at the Sanford location and are not discussed further in this report. Appendix E contains the simulation results. Overall, the lowest dilutions were generated for the shallow 6-foot channel for the highest discharge condition (8 mgd). For the 6-foot channel, the lowest dilution generated was about 8 for the worst-case scenario of near stagnant flow conditions during winter season. For the worst case, the lowest dilution generated for the 12-foot and the 20-foot channels was about 12 and 23, respectively, for summer conditions. Again, the horizontal distance limit of 2 times the natural depth would reduce the permittable dilution somewhat below those values listed above if this portion of the mixing zone rule is applied.

Table 8. Selected summary of summer and winter season results at DeLand location

Case	Season	Ambient Salinity (psu)	Ambient Velocity (fps)	Water Depth (ft)	Concentrate Flow (mgd)	Mixing Zone	
						Dilution	Horizontal Distance (ft)
1	Summer	1.16	0.0001	6	2	15.7	17.7
2	Summer	1.16	0.0001	6	4	11.9	17.5
3	Summer	1.16	0.0001	6	8	8.2	17.2
4	Summer	1.16	0.0001	12	8	11.9	26.3
5	Summer	1.16	0.0001	20	8	23.3	54.7
6	Summer	1.16	0.4	6	2	23.4	13.9
7	Summer	1.16	0.4	6	4	15.7	15.0
8	Summer	1.16	0.4	6	8	10.2	15.4
9	Summer	1.16	0.4	12	8	14.8	20.7
10	Summer	1.16	0.4	20	8	46.2	39.5
11	Winter	1.16	0.0001	6	2	15.7	17.7
12	Winter	1.16	0.0001	6	4	11.9	17.5
13	Winter	1.16	0.0001	6	8	8.2	17.2
14	Winter	1.16	0.0001	12	8	17.0	38.9
15	Winter	1.16	0.0001	20	8	23.8	55.7
16	Winter	1.16	0.4	6	2	23.4	13.9
17	Winter	1.16	0.4	6	4	15.7	15.0
18	Winter	1.16	0.4	6	8	10.2	15.4
19	Winter	1.16	0.4	12	8	24.8	28.9
20	Winter	1.16	0.4	20	8	47.0	39.8

fps = feet per second; ft = feet; mgd = million gallons per day; psu = practical salinity unit

WTP Mass Balance

To determine the expected change in river loadings resulting from the potential demineralization plant(s), hypothetical membrane WTPs were evaluated using the information gathered from a treatability study (CH2M HILL 2004) and the assembled SJR water quality data. The calculated mass balances around each WTP estimated the concentration and mass removed from the SJR to supply feedwater to the treatment plant and the mass being returned to the SJR in the demineralization concentrate stream. Of the four potential AWS locations, no site was excluded from consideration as a potential AWS project. However, the Taylor Creek Reservoir WTP is currently expected to use more traditional treatment technology, while the other three locations (SR 46/415, Yankee Lake, and DeLand) will require membrane technologies to meet potable standards.

Proposed Water Quality Constituent Mass Balance Scenarios

Multiple scenarios were evaluated to determine the overall affect of the proposed potable water plants and to encompass the probable operating conditions of the demineralization system. Mass balances were calculated at each potential site using a recovery of 70 and 85 percent, where recovery is the percentage of the feedwater that is available for use as potable water. Table 9 shows scenarios for membrane WTPs at three locations (SR 46/415, Yankee Lake, and DeLand) at 70 and 85 percent recovery rates and supplemented phosphorus removal of 0 and 65 percent.

Because the Lower St. Johns River (LSJR [and the whole river in general]) is impaired from excess nutrients, SJRWMD wanted to evaluate the potential changes to nutrients if the WTPs treatment processes were modified slightly to improve the removal of nitrogen (N) and/or phosphorus (P). The actual scenarios performed did not include additional nitrogen reduction inside the WTP. A separate post-treatment phase would be needed to remove dissolved nitrogen (that is, separate from the WTP). From a mass balance computational standpoint, this extra step could be applied directly to the results. The additional phosphorus treatments included in the mass balances calculated, reflect a higher phosphorus removal percentage during the pretreatment system before the membranes.

Table 9. Scenarios for WTP mass balance scenarios

Scenario	Location	WTP Recovery (%)	Nitrogen Reduction	Phosphorus Treatment
1	SR-46/415	70	No extra	No extra*
2		85	No extra	No extra*
3		70	Additional	Additional**
4		85	Additional	Additional**
5	Yankee Lake	70	No extra	No extra*
6		85	No extra	No extra*
7		70	Additional	Additional**
8		85	Additional	Additional**
9	DeLand	70	No extra	No extra*
10		85	No extra	No extra*
11		70	Additional	Additional**
12		85	Additional	Additional**

* These scenarios assume a phosphorus removal of 0.0% in the pretreatment system. See the Pretreatment Section below for Details

** These scenarios assume a phosphorus removal of 65% in the pretreatment system. See the Pretreatment Section below for Details

Potable WTP Flow Rates

The desired potable water flow rates for the various WTP projects are still under refinement. The current estimates, as provided by SJRWMD, are summarized as the rectified values in Table 10. The MFL at SR-44 (DeLand) allows for a cumulative total of up to 155 mgd being withdrawn from the main stem of the SJR. For future modeling purposes, the flows may need to be further adjusted downward because consumptive use permits will not be allowed to exceed this value. The "Adjusted Main Stem Values" in the table identifies the flows that were used in this assessment.

Table 10. Assumed potable water demands per potential WTP (finished water, mgd)

Data Source	TCR	YL	SR-46	DeLand	Total
Best Estimate of Project Demands	50	30	50	40	170
Adjusted Main Stem Values	***50***	***30***	***35***	***40***	***155***

All values are average annual daily flow in mgd.
TCR = Taylor Creek Reservoir Project (under development)
YL = Yankee Lake WTP Project (under development)
SR-46 = Potential NE Orange County project location near SR-46/415
DeLand = Potential project near SR-44

The demand values represent the net water removed, so each membrane project will withdraw more water than that listed and then return the remainder to the river as concentrate. The flows in this evaluation were estimated as:

Withdrawal Rate = Potable Demand / WTP Membrane Recovery

Concentrate Discharge Rate = Withdrawal Rate – Potable Demand

Thus the potable demand flows and WTP recovery rates are particularly relevant to the water balance evaluations (net withdrawals) and to influencing the concentrate constituent mass balance analyses. Because the Taylor Creek Reservoir project does not currently plan to use membranes, its flow and constituent masses will be 100 percent removed from the river and no recovery estimate is needed. The applicable feed, concentrate, and permeate (that is, potable water) flow rates are calculated for each mass balance.

Pretreatment

Figure 35 is a schematic of a typical pretreatment system (high-rate clarification with media filtration), RO system, and optional post-WTP concentrate nitrogen treatment. The goal of the pretreatment system is to produce pretreated water to the membranes to improve the performance and service life of the RO system. A pretreatment system is optimized to maximize the removal of organics and particulate matter as measured by turbidity. The Surface Water Treatment and Demineralization (SWTD) study (CH2M HILL 2004) evaluated several pretreatment technologies at the conceptual and pilot plant scales. The SWTD study found that several suitable pretreatment technologies are feasible for the water quality characteristics found in the SJR at Lake Monroe. Pretreatment technologies included high-rate clarification followed by filtration with either granular media or membrane filtration. Direct filtration consisting of the addition of a coagulant, followed by cartridge filters, with a microfiltration system also is a feasible pretreatment option.

Pretreatment systems require the addition of pH adjusting chemicals, ferric salt-based coagulant, and chloramines, which are produced by the addition of chlorine and ammonia. Other chemicals that may be required, such as a coagulant aid, membrane-scale inhibitor, and powdered activated carbon, depend on the final design. However, these additional chemicals should not add significant levels of concentrations to the WTP mass balance computations.

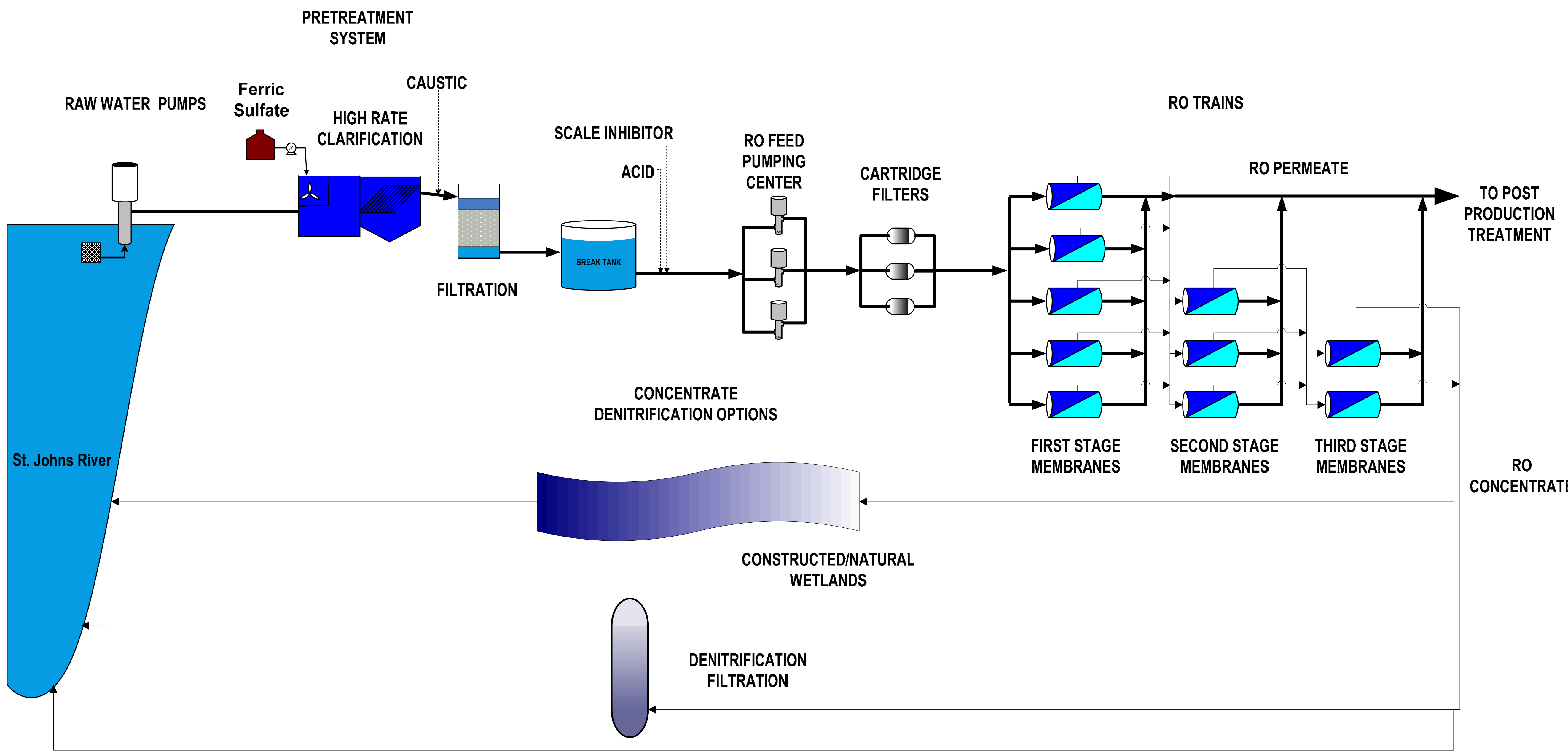

Figure 35. Process schematic for high-rate clarification, reverse osmosis, and optional concentrate treatment processes

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Providing the worst-case scenario from a concentrate mass loading perspective, the maximum dose of ferric sulfate recommended in the SWTD study (CH2M HILL 2004) was used to calculate the mass balances. The maximum dose required to meet the treatment goals would correlate with the maximum concentrations found in the raw water quality used in the mass balances. To estimate the RO system feedwater characteristics, the water treatment software Water!Pro™[1] was used to determine the pH and alkalinity after the addition of coagulation and pH adjustment chemicals. Chemical additions and the targeted pH values used as input into Water!Pro™ are shown in Table 11 and were based on the results of the SWTD study (CH2M HILL 2004). Pre-coagulation pH adjustment is made to optimize the coagulation process. Iron is less soluble when the pH is between 6.5 and 8.5, so adjusting the pre-filtration pH to ~7 will augment the removal of iron during filtration.

Table 11. Pretreatment chemical addition and targeted pH characteristics

Parameter/Chemical Addition	Value
Ferric Sulfate Added (mg/L)	289
Pre-coagulation pH Adjustment (sodium hydroxide addition) (mg/L)	90 to 110
Coagulation Target pH	~4.7
Pre-filtration pH Adjustment (sodium hydroxide addition) (mg/L)	48 to 60
Pre-filtration Target pH	~7.0

mg/L = milligrams per liter

The coagulation process in drinking water treatment is focused on the removal of organic compounds and pathogens; however, it also has the potential to reduce phosphorus concentration in the treated water. At phosphorus concentrations exceeding about 1 mg/L the stoichiometric molar ratio for the removal of phosphorus using a ferric coagulant is 1:1. Because of competing interactions, though, excess iron is needed to achieve higher phosphorus removal percentages.

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Phosphorus removal during the treatment of drinking water typically is not monitored. The removal percentages for phosphorus in metal salt coagulation of treated wastewater are often reported in publications; however, these removal percentages may not be generally applicable to conventional drinking water treatment. This is due primarily to the wastewater phosphorus concentrations generally being 1 to 2 orders of magnitude higher than most drinking WTP source waters. The raw water quality data used to calculate the mass balances presented in this report range from 0.03 to 0.38 mg/L of phosphorus (unfiltered sample) where treated wastewater phosphorus concentrations reportedly can range from 7 to 20 mg/L (EPA 1976). Also, at lower phosphorus concentrations, the reduction tends to be controlled by the equilibrium chemistry associated with the phosphorus, iron, and hydroxyl compounds. The solution pH also plays an important role in phosphorus solubility. When treating wastewater, the pH is relatively neutral and tends to be the optimal pH for the removal of phosphorus from most wastewaters. Other factors, such as calcium and alkalinity concentrations, may also affect the chemical precipitation of phosphorus.

As previously stated, the pretreatment for RO is optimized for the removal of organic carbon from the source water and results in a higher dose (relative to the stoichiometric molar ratio of Fe:P) of ferric sulfate and a lower coagulation pH (4.5 to 5.0) relative to typical wastewater treatment. Phosphorus likely will always be removed during the pretreatment; however, to ensure analysis of the worst-case scenario, removal of phosphorus during pretreatment was assumed to be negligible (0 percent) in the "no extra" scenarios shown in Table 12. For the mass balance scenarios designated as "additional treatment," a removal percentage of 65 percent was used for orthophosphorus removal in the pretreatment system. This removal percentage resulted in an RO feed concentration of 0.07 to 0.08 mg/L orthophosphorus. CH2M HILL (2004) experience when treating wastewaters with low initial phosphorus concentrations indicates that lower orthophosphorus values can be achieved using pretreatment. Therefore, a removal of 65 percent will likely still result in a conservative high return mass balance estimate for orthophosphorus in the RO concentrate.

Dissolved inorganic nitrogen species generally are not reduced during coagulation, flocculation, sedimentation, and filtration. Organic and particulate nitrogen species were not evaluated in the mass balances presented in the mass balance evaluation because these species are not typically included in RO evaluations or software. However, much of the particulate nitrogen likely would be removed in the pretreatment system. Some non-particulate organic nitrogen would also be reduced during the pretreatment processes. Limited information is available concerning the removal of dissolved organic nitrogen (Westerhoff and Mash 2002). The characteristics of dissolved organic nitrogen vary significantly between source waters, effecting generalized estimates of nitrogen removal difficult. However, the limited research results on organic nitrogen removal during coagulation indicate that 25 to 40 percent of the organic nitrogen could be removed during pretreatment (Esparza-sota et al. 2001; Lee and Westerhoff 2006). Note: Non-purgeable dissolved organic carbon, turbidity, and color reduction in the pretreatment process were estimated in accordance with the SWTD study (CH2M HILL 2004).

Chlorine and ammonia are added during pretreatment to minimize biofouling development on the membranes. The chlorine added will react with the ammonia in the raw water to form chloramines. The RO membranes can be damaged by free chlorine in the RO feedwater. For this reason, excess ammonia is added to develop a 0.1 mg/L (NH_3-N) concentration of free ammonia, ensuring that all of the chlorine added has either reacted with other constituents in the RO feedwater or combined with the ammonia. The concentrate and permeate mass balance calculations are based on an RO feed concentration of 0.1 mg/L of ammonia.

Reverse Osmosis Treatment

The RO system treatment projections used to develop the WTP mass balances presented herein were based on a three stage reverse osmosis system. Mass balance projections were produced using the FilmTec™ Reverse Osmosis System Analysis (ROSA) design software[2], version 6.1.5. A three-stage RO system was modeled for the calculations of the mass balances. In a three-stage RO train, the concentrate from the first stage acts as feedwater to the second stage, with the second stage concentrate feeding the third stage. Because a reduction in flow rate input occurs between each stage, fewer membrane elements are evident in each stage. The membrane system modeled had a ratio of first:second:third stage of 5:3:2, which is referred to as a 5:3:2 array. The

[2] **Copyright © The Dow Chemical Company (2007), 5/23/2007.**

projections used FilmTec™ membrane model BW30-400FR, which was consistent with the SWTD study (CH2M HILL 2004) recommendations. This conceptual WTP design and the flows presented in Table 13 (adjusted main stem values plus the extra water to account for recovery) were used as input to evaluate the ROSA projections for the RO system. The ROSA software calculated projections for all of the parameters shown in the mass balance with the exception of bromide and orthophosphorus concentrations. Orthophosphorus and bromide mass balances were calculated based on the pilot test results of the SWTD study (CH2M HILL 2004) and other membrane manufacturers' projection software.

The addition of anti-scaling compounds will be required to prevent the formation of mineral compounds on the membrane. As reported in the SWTD study (CH2M HILL 2004), "There are a variety of these weak acid compounds available for use and, at this time, these are not used in doses sufficient to warrant further investigation with respect to environmental risk. All anti-scalant products are NSF/ANSI 60, NSF/ANSI 61 approved for potable water production processes." For the development of the mass balances it was assumed that the anti-scalant used would not contain phosphorus.

Post-Treatment

Post-treatment would be needed to improve nitrogen removal as the WTP would not normally reduce nitrogen by a large amount. As is shown in Figure 35 some form of denitrification process would be added, either denitrification filters or maybe even a treatment wetland. For purposes of this feasibility study, this process was simply represented as a percent removal of all nitrogen species.

WTP Mass Balance Results

The WTP mass balance results for the 12 scenarios listed in Table 9 are included as Appendix C. Table 12 provides a summary of the change in loadings of primary nutrients and TDS in the receiving water in the vicinity of each WTP discharge for the scenarios. The daily mass loading in the concentrate being returned to the SJR is increased only for sulfate and TDS. This increase is a result of the addition of pretreatment chemicals, including ferric sulfate coagulant, sodium hydroxide, and sodium hypochlorite, and that, in addition to the other salts in the source water that is rejected, raises the mass loading for these two parameters downstream the WTPs.

Table 12. Estimated changes in loadings for various constituents for potential WTP along the SJR

Scenario		1	2	3	4	5	6	7	8	9	10	11	12		
Location		SR-46/415				Yankee Lake				DeLand				Max	Min
Water Treatment Plant Production	**(mgd)**	35	35	35	35	30	30	30	30	40	40	40	40	40	30
RO system recovery		70%	85%	70%	85%	70%	85%	70%	85%	70%	85%	70%	85%	85%	70%
Pretreatment P Removal		0%	0%	65%	65%	0%	0%	65%	65%	0%	0%	65%	65%	65%	0%
Raw water flow	**(mgd)**	50	41	50	41	43	35	43	35	57	47	57	47	57	35
Orthophosphorus	**(kg/day)**	42	34	42	34	36	29	36	29	45	37	45	37	45	29
Nitrate	**(kg/day)**	53	44	53	44	45	37	45	37	95	78	95	78	95	37
TDS	**(kg/day)**	264,917	218,184	264,917	218,184	227,071	187,015	227,071	187,015	268,217	220,865	268,217	220,865	268,217	187,015
Ammonia	**(kg/day)**	62.4	51.4	62.4	51.4	53.5	44.1	53.5	44.1	69.2	57.0	69.2	57.0	69	44
Concentrate flow	**(mgd)**	15	6	15	6	13	5	13	5	17	7	17	7	17	5
Orthophosphorus	**(kg/day)**	40	33	14	12	34	28	12	10	44	36	15	13	44	10
Nitrate	**(kg/day)**	50	39	50	39	43	33	43	33	88	69	88	69	88	33
TDS	**(kg/day)**	303,199	248,907	303,199	248,907	259,885	213,349	259,885	213,349	303,279	248,891	303,279	248,891	303,279	213,349
Ammonia	**(kg/day)**	17.2	13.1	17.2	13.1	14.8	11.2	14.8	11.2	19.2	14.5	19.2	14.5	19	11
Change in Orthophosphorus	**(kg/day)**	-2	-1	-28	-23	-1	-1	-24	-20	-2	-1	-30	-25	-1	-30
Change in Nitrate	**(kg/day)**	-3	-5	-3	-5	-3	-4	-3	-4	-7	-9	-7	-9	-3	-9
Change in TDS	**(kg/day)**	38,283	30,723	38,283	30,723	32,814	26,334	32,814	26,334	35,062	28,027	35,062	28,027	38,283	26,334
Change in Ammonia	**(kg/day)**	-45	-38	-45	-38	-39	-33	-39	-33	-50	-42	-50	-42	-33	-50

Negative change means that less load is returned to the SJR.

kg/day = kilograms per day; mgd = million gallons per day; RO = reverse osmosis; TDS = total dissolved solids

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ESTIMATED WTP CONCENTRATION FACTORS

The CF was calculated by dividing the concentration of a compound in the concentrate by the concentration in the RO feedwater. These factors did not change between locations because of the relative similarity of the water quality of the raw water and the use of similar assumptions about the WTP processes. Table 13 lists the resulting CFs applied to estimate concentrate concentrations. This analysis provided a better estimate of potential concentrations and changes to the concentrate than is often conducted for preliminary planning or screening purposes.

The range of CF by constituent varied from 0.9 to 6.8 for 70 percent recovery and from 1.7 to 13.6 for 85 percent recovery. Ammonia and bromide had lower CFs, indicating that these constituents either are not highly rejected or are consumed (by the free chlorine for ammonia) in the WTP process. For planning purposes, if one assumed 100 percent rejection by the membranes, a value of 3.3 would be estimated for 70 percent recovery (1/(1-0.70), and 6.6 would be estimated for 85 percent recovery (1/(1-0.85). These default factors were used if no better data were available from the membrane treatment software. As discussed previously, typically observed CF range between 3 and 5 (Mickely et al. 1993), so the range of CFs listed in Table 16 bracket the expected performance.

Table 13. Estimated concentration factors for modeled water quality parameters

Scenarios		1, 5, 9	2, 6, 10	3, 7, 11	4, 8, 12
RO system recovery		70%	85%	70%	85%
Pretreatment P Removal		0%	0%	65%	65%
TDS	**(mg/L)**	3.8	7.6	3.8	7.6
Nitrate	**(mg/L)**	3.1	6.0	3.1	6.0
Orthophosphorus	**(mg/L)**	3.2	6.4	1.1	2.2
Ammonia	**(mg/L)**	0.9	1.7	0.9	1.7
Chlorides	**(mg/L)**	3.3	6.6	3.3	6.6
Sodium	**(mg/L)**	4.5	8.9	4.5	8.9
Barium	**(mg/L)**	3.8	7.3	3.8	7.3
Bromide	**(mg/L)**	2.3	4.7	2.3	4.7
Calcium	**(mg/L)**	3.3	6.6	3.3	6.6

Table 13. Estimated concentration factors for modeled water quality parameters

Scenarios		1, 5, 9	2, 6, 10	3, 7, 11	4, 8, 12
RO system recovery		70%	85%	70%	85%
Pretreatment P Removal		0%	0%	65%	65%
Magnesium	**(mg/L)**	3.3	6.6	3.3	6.6
Potassium	**(mg/L)**	3.3	6.6	3.3	6.6
Silica	**(mg/L)**	3.3	6.6	3.3	6.6
Sulfate	**(mg/L)**	6.8	13.6	6.8	13.6
Strontium	**(mg/L)**	3.3	6.6	3.3	6.6
Maximum		6.8	13.6	6.8	13.6
Minimum		0.9	1.7	0.9	1.7

mgd = million gallons per day

RO = reverse osmosis

TDS = total dissolved solids

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SJR MASS BALANCE

Results of the WTP-based mass balance analyses provided an overview of the ambient water quality information available as well as the prediction of concentrate water quality characteristics. An initial planning-level mass balance spreadsheet model for the SJR was developed using the results from the WTP mass balance analysis. The SJR mass balance model addressed the potential effects of the four conceptual WTPs on ambient water quality in the river and on cumulative water and constituent loadings downstream to the boundary condition for input into the LSJR Basin models. For purposes of the feasibility study, an average monthly time step was evaluated with this SJR mass balance spreadsheet model.

The spreadsheet model calculated the water and key constituent mass balance at the four potential WTP locations along the SJR. For each location, the upstream concentrations of each constituent analyzed and the associated flow records for the nearest reference location were used to calculate in-stream loads. Surface water withdrawals of water and constituent loads and subsequent concentrate water and constituent loads returned to the river were calculated along with the resultant water and constituent loads passed downstream. A simple mass balance approach was followed for calculating the load at each plant location as shown in Figure 36.

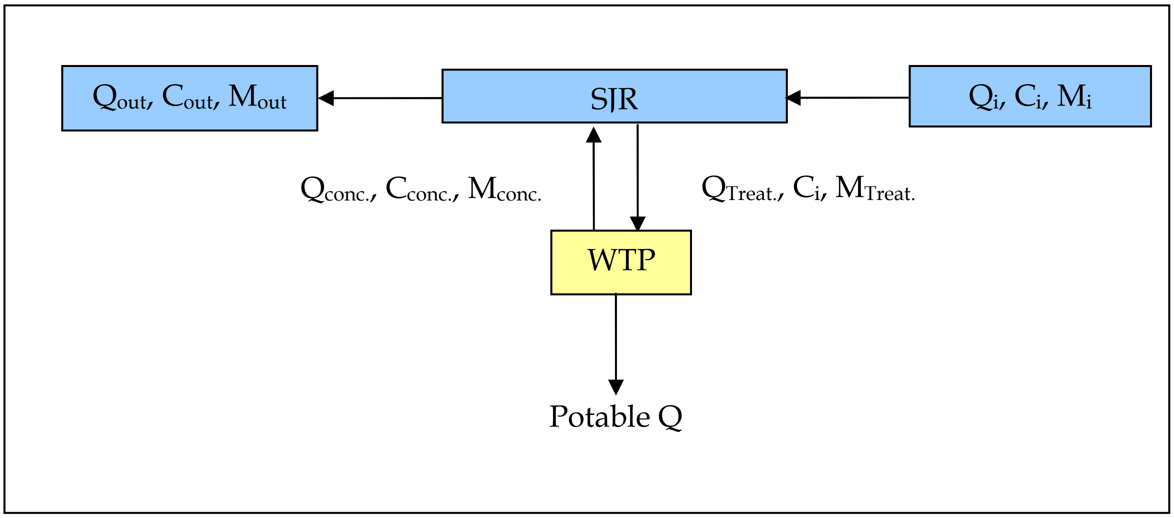

Figure 36. Schematics of mass balance approach

For each subsequent candidate WTP location downstream, this process was repeated. Ambient concentration and flow monitoring records were used to calculate mass loadings upstream, and these were adjusted to account for the anticipated influence of the upstream WTP operations. Thus, the model was constructed to account for all four WTPs operating at the maximum anticipated allowable river withdrawal of 155 mgd. Key information used in constructing the mass balance model includes the following.

- Water quality and flow data
- Potable WTP flow rates
- WTP mass balance scenarios
- Concentration factors
- Monthly withdrawal rates

These inputs are already discussed in previous sections but some additions/changes made to these items for modeling purpose are discussed below.

INPUT DATA AND MODEL DEVELOPMENT

Water Quality and Flow Data

Not all water quality parameters are conservative and will travel unchanged through the SJR. The purpose of this model was to provide a planning-level feasibility assessment tool, not a fate and transport model. Between each location various inputs and losses cannot be accounted for by a simple spreadsheet model. To account for these potential changes, the observed water quality and flow data from each location were applied to show the change around each WTP using the CFs estimated previously.

Historical water quality and quantity data derived from monitoring studies by the USGS at three locations along SJR were key inputs to the mass balance model. For the potential DeLand WTP location, river water quality records used were compiled from USGS records for its monitoring Station 02236000, located near DeLand. Water quality data collected between January 1995 and October 1995 and from January 2000 to October 2002 were used for this mass balance model construction. Long-term flow records for the river collected between January 1980 and September 2007 at this USGS gauge were used to support the mass balance evaluations at this location.

For the Yankee Lake and SR-46/415 WTPs, flow data were compiled from USGS Station 02234500, located near Sanford. Long-term flow data were available at this station; data collected between April 1995 and September 2007 were used for the mass balance analyses for these two WTP locations. River water quality data for the mass balance evaluations for these two WTP locations were compiled from the SWTD study (CH2M HILL 2004) and from USGS station 02234500, located near Sanford. River water quality data collected between January 2000 and October 2002 were used for these two locations.

Raw water characteristics for the Taylor Creek Reservoir (TCR) treatment plant location were compiled using data collected from USGS Station 02232400, located on the SJR near Cocoa. River water quality data collected from January 2000 to October 2002 were used for this station. Long-term flow data were also available at this station; data collected between January 1980 and September 2007 were used.

Potable WTP Flow Rates

For the purpose of setting up the model, the potable flow or production rates at the potential WTPs summarized in Table 13 were used. These potable flow rates are an input into the model so that values can be changed later should SJRWMD or other model users wish to evaluate different combinations of the WTPs and/or different WTP design capacities. The current model structure and scenarios present the worst-case projections (all plants operating at their full average annual daily flow rate capacities).

Application of Concentration Factors

The estimated CF did not change between the locations because of the relative similarity of the water quality of the raw water and the use of similar assumptions about the WTP processes. Values of the concentration factors for water quality parameters included in the model are listed in Table 16.

These concentration factors were based on 70 and 85 percent potable water recovery and 0 and 65 percent phosphorus removal in the pretreatment. For this model, a non-linear interpolation was conducted using these concentration factors to provide the model user the flexibility to increase or decrease the percent recovery and phosphorus removal percent. An option for additional phosphorus and nitrogen removal was also included in the model. This reduction in nutrients is applied equally to all species of phosphorus or nitrogen.

Potable Water Recovery Rates

The WTP mass balance analysis calculated the change in the river's mass at each potential WTP (SR-46/415, Yankee Lake, and DeLand), under two different levels of WTP potable water recovery rates (70 percent and 85 percent), and under two different phosphorus pretreatment levels (0 and 65 percent). This range in the model input provided results for each of the 12 scenarios defined through the combinations of these factors. The SJR model was constructed to provide the flexibility to choose the recovery rate from a range of possible recovery rates (70, 75, 80, 85, 90, and 100 percent). Recovery rate is a user-defined input to the model and can be varied at each WTP location.

The model is also constructed to allow the user to modify the level of nutrient removal included in the scenarios analyzed. For phosphorus removal, the model can be run using the following settings: 0, 35, 65, and 75 percent removal. For nitrogen, the model can be run using the following settings: 0, 30, 45, and 60 percent removal. These nutrient removal rates can be varied by WTP location.

Currently, the Taylor Creek Reservoir WTP is not proposed as a membrane treatment plant, and the modeled scenarios described below presume 100 percent removal of both water and constituents at TCR for every scenario. With this flexibility in the model construction, however, scenario evaluations in the future also can address the use of membrane treatment at the TCR location, if desired.

Variable Monthly Withdrawal

The model was constructed to allow the user to simulate WTP operational levels that might vary during the course of the year. Monthly withdrawal rates can be varied for each WTP location by applying a fraction to the plant capacity, defined as the total average annual daily flow. For a WTP withdrawing constantly at the plant capacity, the factor applied would be 1.0 for all months. For the demonstration scenarios, monthly withdrawal factors for all the months and plants have been set to 1 to represent the operational scenario in terms of having the greatest possible effect on ambient river water and constituent mass balance.

MODEL SETUP

The monthly mass balance spreadsheet model was created to allow future users to evaluate the net effects of varying combinations of key factors affecting the water and constituent mass balances at these four potential WTP locations along the SJR. This section describes general setup of the sheets and how to input data and read results from the model.

The model has six different sections, each of which consists of one or more sheets.

- The first section is the "Summary" sheet, which contains a list of instructions, assumptions, and limitations in the current model.
- The second section is the "Input&Output" work sheet where all the input data are entered and the output is summarized.
- The third section comprises four work sheets, one per WTP (TCR, SR 415, Yankee Lake, and DeLand), wherein the key calculations occur.
- The fourth section includes the concentration factors work sheet that has the original matrix and the extrapolated values.
- The fifth section comprises the summarized monthly flow and concentration data from different USGS stations (Data Cocoa (Taylor Creek Reservoir), Data Sanford (YL & SR-46/415), and Data DeLand).
- The sixth section has all the raw data from the USGS stations used in model development; this section includes six work sheets.

Input settings for the scenario to be analyzed are entered into the model in the "Input&Output" sheet. The model was set up for a monthly temporal scale. A set of instructions is provided at the top of the sheet to guide entering the settings for the scenario evaluation. All of the user input cells are shaded in yellow, while all of the calculated cells are shaded in blue. Values based on analysis of historical monitoring records at the USGS gauging stations are shaded in purple.

For the mass balance in the river at each plant location, a net change in load and flow is computed by taking the difference between the downstream and upstream values. This change in the load and flow is accounted for in the subsequent WTP location's upstream values, which helps in setting the cumulative loading at the upstream location. Appendix F details the general set up and structure of the model and provides guidance on how the user can modify settings and generate predicted results for a wide range of WTP combinations and operational levels.

EXAMPLE SCENARIO RUNS

Selected examples of the predicted mass balance evaluations focused on water quality constituent loads are provided in Appendix F for the following:

- Ammonia: membrane treatment WTP recoveries at 70 percent, with no supplemental nitrogen removal
- Ammonia: membrane treatment WTP recoveries at 70 percent, with supplemental nitrogen removal set at 30 percent
- Orthophosphorus: membrane treatment WTP recoveries at 70 percent, with no supplemental phosphorus removal
- Orthophosphorus: membrane treatment WTP recoveries at 70 percent, with supplemental phosphorus removal set at 65 percent
- Chlorides: membrane treatment WTP recoveries at 70 percent
- Chlorides: membrane treatment WTP recoveries at 85 percent
- Total Dissolved Solids: membrane treatment WTP recoveries at 70 percent
- Total Dissolved Solids: membrane treatment WTP recoveries at 85 percent

These loading calculations indicate that the greatest order of magnitude effect for these parameters is associated with the presumed 100 percent removal of loads at the Taylor Creek Reservoir location where conventional rather than membrane treatment has been assumed.

In terms of aquatic biological community response to the WTP operational effects on the river, greater focus is likely to be placed on concentration changes that organisms might experience resulting from these conceptual water supply withdrawals and concentrate discharges. Appendix G summarizes the concentration-based results of the example model analyses reflected for the following water quality constituents: ammonia, barium, bromide, calcium, chloride, magnesium, nitrate, orthophosphorus, potassium, silica, strontium, sulfate, and TDS. For these particular demonstration scenarios (Scenarios 2, 6, and 10), the following settings have been applied to conservatively predict high expected concentrate effects on the ambient conditions in the SJR:

- Membrane WTPs at the three locations along the river are operating at an 85 percent recovery rate (a high level of net water withdrawal and similarly high constituent concentrations in the discharged concentrate)
- No nutrient removal applied (highest nitrogen and phosphorus concentrations in the concentrate discharged back to the river)
- All four WTPs operating continuously at maximum capacity; no seasonal constraints on operations levels

The results of the SJR mass balance spreadsheet model application are presented and discussed further in the following section.

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PRELIMINARY FEASIBILITY EVALUATION

The investigations documented in the preceding sections of this report represent a compilation of the key findings generated by the execution of an overall plan of study developed by SJRWMD in conjunction with FDEP to address the feasibility of these conceptual concentrate outfalls to the SJR. To evaluate the surface discharge of demineralization concentrate obtained from raw water drawn from the river, as a prospective element of future water supply plans, key issues that must be addressed include:

- Regulatory or administrative constraints that are applicable to the proposed surface discharges to the river
- Preferred locations where utilities or groups of utilities may wish to locate new intake and discharge infrastructure in the SJR
- Possibility of “fatal flaws” with candidate AWS project focus areas resulting in the inability of these conceptual facilities to obtain FDEP permitting

Addressing these issues through a screening analysis was the primary focus of the preliminary feasibility investigations conducted to date by SJRWMD. Future study phases would address issues identified during the course of the preliminary investigations. On the basis of the work conducted to date, these “deferred issues” will include but not necessarily be limited to the following:

- Candidate river discharge location accessibility and linkage to the prospective WTP sites
- Potential cumulative effects of river water, associated water quality constituent withdrawals, and subsequent concentrate discharges on MFL evaluations
- Potential downstream effects (either positive or negative) on the TMDL program’s pollutant load reduction goals established for the Lower St. Johns River Basin
- Feasibility of mixing zones for concentrate discharges directly to in-stream lake systems along the SJR
- Treatment technologies that may improve concentrations of concentrate constituents thereby effecting surface discharge as

obviously permitable/acceptable from a regulatory as well as an environmental resource management perspective

- Definition of specific concentrate conveyance and outfall system designs and detailed definition of mixing zone configuration and placement in relation to the conceptual outfall diffuser ports

Some of these future assessments likely would be undertaken by stakeholders to further specific WTP proposals.

KEY REGULATORY DEMONSTRATIONS AND RELATED WATER QUALITY ISSUES

Regardless of the raw water source, because of the nature of demineralization treatment processes, demineralization concentrates typically contain several constituents at concentrations above at least some numerical criteria applicable for Class I or III freshwaters. On the basis of the review of ambient river water quality alone, the concentrations of the following parameters are naturally present in the river at high enough concentrations such that the river water may exceed the applicable Class III surface water quality criteria at times (Appendix H):

- Specific Conductance
- Iron
- Turbidity
- pH

If the river is used as a potable water source, it could be reclassified from a Class III to a Class I use in the future. If that occurs, Class I surface water criteria for chloride and possibly barium and fluoride may also be of concern.

As detailed in this report, the provisions of Chapter 62-4, *F.A.C.*, allow for exceedances of such criteria only if the applicant can demonstrate compliance with the mixing zone provisions detailed under Rule 62-4.244, *F.A.C.* Thus, the key regulatory constraint that must be addressed is the specific question of whether the physical conditions at any given prospective outfall location allow for a design to meet the mixing zone demonstration requirements. This preliminary investigation addressed this over-arching regulatory feasibility issue by first reviewing the likely concentrations of these parameters of concern in the concentrate by using CFs derived during the WTP mass balance (Appendix H). By applying the CF to the maximum value, a potential worst case discharge value was obtained. This value was then used to estimate the required dilution factor (Equation 1). The dilution factor needed for compliance will depend on the ambient concentration, numeric criterion, as well as the discharge concentration.

Each of the constituents identified above are discussed below in greater detail.

SPECIFIC CONDUCTANCE

Specific conductance, or conductivity, is a physical measure of the collective ionic strength of an aqueous solution and is generally considered a surrogate reflection of the overall TDS present. The conductivity of surface waters within the SJR is extremely variable depending on proximity to river reaches affected by significant inputs of groundwater. Historical monitoring records document that ambient conductivity levels frequently approach or exceed the numerical criterion of 1,275 µmhos/cm (maximum level), and most knowledgeable accounts relate this to natural conditions resulting from the input of Floridan aquifer water that often bears higher TDS levels. Consequently, one must rely on the relative criterion of 50 percent above background levels. Compliance will depend on how the background level is derived for use in the permit process. If one assumes that the river concentration at the time of the WTP intake and discharge is equivalent to the background at that moment, then the required dilution can be computed directly from Equation 1 as follows:

$$Sa = (Ce - Ca) / (1.5Ca - Ca) = 2(CF - 1)$$

For a 70 percent recovery, CF is 3.3 so the required dilution factor is 4.6; and for 85 percent recovery factor with CF = 6.6, the dilution factor is 11.2.

IRON AND TURBIDITY

The CF reported for iron and turbidity were the standard volumetric values of 3.3 and 6.6 for 70 and 85 percent recovery, respectively. These CF values were chosen because there was no better information from the manufacturer's software, which focuses on ionic constituents. However, as part of the pre-treatment process, iron and turbidity are reduced to low levels to keep the membranes from fouling. The enhanced coagulation pretreatment and cartridge filters are included to specifically reduce these and other solid constituents. Therefore, it is unlikely that the discharge will have concentrations as high as indicated by the default CFs. However, it should be pointed out that the river has maximum iron concentrations that exceed the numeric criterion at the Sanford gauge.

The maximum turbidity is high too. However, these high ambient values are likely inversely related to flow so there may be opportunity for utilities to evaluate these maximum values in light of the likelihood of low flow and high ambient concentrations.

pH and Chlorides

Similar to iron, pH maximum values in the river can be higher than the numeric criterion of a maximum of 8.5 units. While there is no Class III criterion for chlorides, the river water values are often naturally above the Class I criterion of 250 mg/L. These high values are directly attributable to groundwater influences. Exceedances of the standard by natural ambient levels for any constituent present a particular challenge for mixing zone evaluations in that mixing zones are intended to allow relief only from the standard for the minimum spatial area required to re-establish compliance with the criterion in question. High ambient levels reduce the available dilution within a given spatial extent.

A potential solution to compliance lies within the existing provisions of Rule 62-302.800, *F.A.C.*, which provides the administrative process for establishing a Site Specific Alternative Criterion (SSAC) for any water quality parameter in a specific water body reach where it can be demonstrated that the ambient condition exceeds the criterion because of natural causes and/or unabatable influences of man. For some constituents found in the SJR, formal administrative demonstrations may be required before FDEP could take action and establish a technically based SSAC for this parameter.

This is a major topic for future interagency research and discussion by the utilities as they move forward. However, for the purposes of this preliminary mixing zone evaluation, it has been presumed that a SSAC will ultimately be approvable by FDEP and that this numerical value will be based on the historical monitoring records generated by SJRWMD, USGS, and other credible researchers who may have established long-term water quality databases for the river.

FLUORIDE AND OTHER CONSTITUENTS

Fluoride and barium were listed as constituents of possible concern because the maximum value times the CF was just under the Class I numeric criterion for the higher recovery rate. However, only a limited amount of Fluoride data is available and only near DeLand. Barium levels are very low most of the time. These constituents may warrant further monitoring.

Unionized ammonia and dissolved oxygen compliance issues are also considered as unknown, but not likely to be problematic. Because of the high pH values, the percent of ammonia that may become unionized is higher than for low pH. While ammonia is reduced in the WTP, this issue needs to be reviewed during pilot testing. Dissolved oxygen levels can be low in the concentrate after membrane treatment. Mixing zones are to have dissolved oxygen above 1.5 mg/L, but a mixing zone may be required to obtain compliance to the ambient criterion of 5 mg/L. Compressed air may be included as part of the WTP post-processing to help achieve compliance for dissolved oxygen. Just like toxicity issues, these other constituent considerations need to be deferred until the design process has proceeded.

SCREENING-LEVEL MODELING RESULTS

As discussed in the mixing zone modeling section of this report, the modeling was conducted using UM3, a program routinely applied in Florida for permit-specific mixing zone demonstrations on behalf of public- and private-sector clients. Assumptions applied were generally conservative, as are commonly practiced, and focused on ensuring that the modeled scenarios bracketed extreme variability in ambient conditions. In this way, the receiving water density and the resulting potential physical dilution of the concentrate within the conceptual mixing zone was estimated.

The preliminary modeling picked a range of scenarios defined through the combination of input factors affecting the calculated levels of dilution achieved at varying distances from the conceptual outfall diffuser. Understanding that these analyses generally addressed the dilution achieved through a single diffuser port is important. This conservative approach was applied to numerically address dilution achieved using a simple conceptual outfall design. Increasing the complexity of the diffuser port system is possible toward improving the mixing achieved and toward altering the shape and sizing of the mixing zone required for each AWS project focus area. As noted above, that final detailed outfall evaluation is deferred until such time as greater definition of any given AWS project is available. However, an example evaluation was conducted utilizing the results of the CF factors applied at each candidate focus area.

Modeling confirmed that ambient current velocity is a key factor affecting the size of the mixing zones needed to re-achieve compliance with the numerical criteria for the parameters of concern. Because the river base flows can be very low in some portions of the river during dry season conditions, the worst-case scenarios that were modeled used near zero river velocities and the highest ambient concentrations of the parameters of concern. For the dilution simulations, the density of the plume was affected by the salinity (affected by CF for TDS), so a combination of high and low river velocities and the 70 and 85 percent WTP recoveries were simulated. For each recovery, the discharge was through either four or two 8-inch diameter ports (higher flow for lower recovery), spaced apart enough to discourage overlap of plumes. The results of the dilution factor when the plume either hit the surface or bottom of the water column is shown in Table 14.

Table 14. Estimated dilution of concentrate for modeled candidate focus areas

70% Recovery						
Location	**Low Ambient Velocity (fps)**	**Dilution Low Velocity (Sa)**	**Distance Low Velocity (ft)**	**Mean Ambient Velocity (fps)**	**Dilution Mean Velocity (Sa)**	**Distance Mean Velocity (ft)**
SR-46	0.0001	**17.4**	**26.3**	0.4	23.8	19.8
Yankee Lake	0.0001	**25.3**	**39.5**	0.4	39.6	24.9
DeLand	0.0001	**38.3**	**60.7**	0.4	60.8	39.3
85% Recovery						
Location	**Low Ambient Velocity (fps)**	**Dilution Low Velocity (Sa)**	**Distance Low Velocity (ft)**	**Mean Ambient Velocity (fps)**	**Dilution Mean Velocity (Sa)**	**Distance Mean Velocity (ft)**
SR-46	0.0001	29.9	46.7	0.4	**28.0**	**20.1**
Yankee Lake	0.0001	**25.0**	**39.0**	0.4	50.5	28.0
DeLand	0.0001	**37.3**	**58.9**	0.4	71.8	39.7

Bold means lowest dilution factor for location.

Sa is the bulk dilution factor, defined as the total plume volume divided by the effluent volume.

Even under these least-favorable conditions, the modeling results indicate that mixing zone sizes would be small, with the mixing zones restricted to areas immediately adjacent to the conceptual outfall ports. Under the worst-case modeled scenarios for conditions considered representative of the Yankee Lake to Lake Monroe reach, and for the SR-46/415 area, these mixing zones were predicted to be no greater than approximately 40 feet in diameter around the diffuser port. When viewed in the context of the river cross sections at the candidate AWS project focus areas, these spatial zones of mixing are small. Similar results were obtained for the conditions representative of the DeLand area near SR-44 but the dilution factor and distance to reach the surface was a little larger. With the required dilution factors to achieve compliance for specific conductivity being between 4.6 and 11.2, the plumes easily exceeded these dilution rates in the near field.

One of the existing mixing zone rule provisions allows mixing zones for concentrate to be sized at twice the natural depth at the point of discharge if the concentrate is shown to be toxic due to ionic imbalance issues. Whether this portion of the rule can be applied to these conceptual surface water discharges to the SJR remains unclear since the proposed scenarios call for return of the raw water constituents back to the original source water, the river itself. Ionic imbalance in the concentrate may still occur because of differential recovery of some water quality constituents by the membrane and/or pretreatment systems; and, if so, the use of the MSIIT or of a modified, analysis approach may well be considered appropriate. For discussion purposes regarding the scenarios modeled to date, many of the projected mixing zone sizes are slightly in excess of twice the natural depth metric, but again optimization of the diffuser design and siting is expected to produce mixing zones that would comply with this conceptual size constraint, assuming it is applicable.

MASS BALANCE MODELING RESULTS

As detailed in the WTP mass balance modeling sections of this report, the modeling was conducted using a simple mass balance approach around each conceptual WTP. Manufacturer's proprietary software was applied, and the treatability results from SJRWMD's studies conducted at Lake Monroe were applied to estimate the expected WTP performance. Using these results, another simple mass balance model of the SJR was developed for average monthly conditions. The assumptions applied were conservative and focused on confirming the potential effects of the four conceptual WTPs on ambient water quality in the river and on cumulative water and constituent loadings downstream.

Selected model scenarios as described in the SJR Mass Balance section of this report were analyzed and are presented as Appendix F in the report. Appendix G details the SJR model run for ammonia, barium, bromide, calcium, chloride, magnesium, nitrate, orthophosphorus, potassium, silica, strontium, sulfate, and TDS. For these model runs, conceptual membrane WTPs at three potential locations were assumed to be operating at 85 percent recovery rate, no nutrient removal was applied, and all four WTPs were operating continuously at maximum capacity with no seasonal constraints on operations levels.

With these conservative assumptions applied, these results indicate that these four WTPs, individually as well as collectively, are unlikely to have a net effect on ambient concentrations in the SJR that are likely to cause or contribute to compliance issues in downstream river reaches. For those parameters where the downstream concentrations for a given parameter is predicted to reflect some change, the order of magnitude of these predicted differences is very small, often within the range of standard analytical accuracy, and generally within the range indicated in descriptive statistical summaries of historical water quality monitoring records. The ecological significance of these small calculated changes will need to be addressed in SJRWMD's ongoing studies of cumulative withdrawals from the river.

FEASIBILITY OVERVIEW

On the basis of the screening level analyses conducted to date, the AWS project focus areas under consideration are located within river reaches that contain adequate depth options and velocity conditions to potentially achieve mixing conditions conducive to gaining mixing zone approvals through the regulatory process. The transects established during the site reconnaissance surveys confirmed that some of the river cross sections were unfavorably shallow, with the prediction that installation and operation of the outfall infrastructure would not be recommended because of the seasonal low water depths. Water availability for withdrawal would in theory potentially be a real-time limitation under those dry season conditions and an investment toward finding a way to make this infrastructure work seems ill advised if any other alternative can be identified.

For the three membrane WTP AWS project focus areas visited, at least one prospective channel cross section was identified that seemed likely to be adequate to support outfall operations within the rules controlling discharge permit review and approval. Even in areas where the USACE is charged with maintaining the federal navigation channel, adequate depths appear to be present along the edge of the channel to allow consideration of outfall siting and operation, with the appropriate mixing zones defined in the permits. That said, on the basis of these preliminary feasibility evaluations, more favorable discharge locations appear to be associated with the AWS project focus areas downstream of Lake Harney, near SR-46/415, Yankee Lake, and SR-44.

The small size of the projected mixing zones likely needed suggests that judicious site selection can be used to avoid most major construction or operational impacts. At this point, no fatal flaws were identified for the AWS project focus areas downstream of Lake Harney. However, further dialogue and demonstrations with FDEP are needed prior to making any final conclusions. These discussions should be undertaken by the utilities when specific projects are moved forward in the planning process. At this point, the locations and projects are too conceptual to be more specific.

For addressing the concentration issues, the SJR mass balance analysis was conducted for the potential AWS project focus areas. The reverse osmosis system treatment projections were used to develop the WTP mass balances for the water quality constituents. The calculated WTP mass balances estimated the concentration and mass removed from the SJR to supply feedwater to the treatment plant and the mass to be returned to the SJR in the demineralization concentrate stream.

The SJR mass balance spreadsheet model developed for the four potential WTP locations is a planning-level analysis tool to track the mass balance of selected constituents in the SJR in the study area. This model provides flexibility to the user to apply different combinations of WTPs, membrane plant operational levels, and varied application of supplemental nutrient removal technologies to acquire the net change in water quality. This model was applied to evaluate potential changes to the observed water quality concentrations to demonstrate that after complete mixing, negligible changes in concentration are expected even with all four of these potential projects in place.

CONCLUSIONS AND RECOMMENDATIONS

The SJRWMD initiated planning-level discussions with FDEP in January 2007, to identify the key issues that would influence future permitting decisions regarding the prospective concentrate outfalls to the SJR. This report summarizes the findings of the elements of the investigations that were completed by the end of SJRWMD's fiscal year 2008. Preliminary conclusions based on this feasibility analysis of conceptual membrane WTPs and their apparent implications are summarized below along with recommendations regarding further investigations.

CONCLUSIONS FROM PRELIMINARY FEASIBILITY ASSESSMENTS

Preliminary conclusions formulated from the findings of this study include the following:

1. Standard mixing zone evaluations in accordance with the provisions of Rule 62-4.244, *F.A.C.,* can adequately address the likely discharge effects near the prospective outfalls. Demonstration of rapid compliance with the applicable water quality criteria within the allowable spatial limits for such mixing zones may be taken as documentation of low potential for significant harm to aquatic flora and fauna near the outfalls. The estimated dilution rates were significant (17 to 38), when compared to the expected concentration factors of typically 3.3 to 6.6, with sulfate as the highest at 13.6. These high dilution rates were obtained within a short distance from ports, on the order of 20 to 60 feet depending on discharge rates. The results of the preliminary mixing zone modeling of discharge scenarios bracketing the anticipated range of concentrate discharge rates, seasonal river temperatures/densities, and limited diffuser design scenarios indicate that compliance with the mixing zone regulations should be readily achievable with the proper attention to outfall siting and design. The preliminary mixing zone modeling performed thus far indicates that mixing zones appear feasible even after applying conservative, “worst-case” assumptions regarding concentrate water quality and ambient river conditions.
2. An important regulatory issue pertaining to high chlorides and pH in the river water was identified as in need of interagency review and research. Ambient levels of total dissolved solids naturally present in the river due to the cumulative effects of groundwater inflows to the river are high enough to drive the chloride levels above the Class I

freshwater standard 250 mg/L. Under Class III criteria, chlorides do not have a numeric limit. As long as the river remains a Class III waterbody, then this should not be considered a major constraint. However, membrane treatment systems will concentrate the dissolved solids from the background levels upward by a factor estimated from 3 to 8 times, raising the question of how procedurally to conduct mixing zone analyses focused on achieving compliance with potential numeric criterion. Also, pH is naturally high in the river at times resulting from the groundwater input. Administratively, a site-specific alternative criterion for this portion of the SJR for groundwater influenced constituents (chloride and pH) may need to be established following the protocols defined in Rule 62-302.800, *F.A.C.* This step would provide a revised water-body-specific regulatory metric to use in future, formal mixing zone evaluations regarding these types of constituents.

3. WTP mass balance analyses were conducted for each potential AWS focus area. The estimated recovery factors provided in the mass balance analysis can be used to more accurately assess potential changes in water quality constituents at different potential WTP locations. However, a WTP's actual performance will vary from these estimates because many factors will not remain the same (for example, process selection, flow rates, actual equipment, and so forth). In this analysis, the range of daily loading changes between the raw water intake and concentrate discharge is small between locations, and the difference in results also are small primarily because the plant sizes and maximum concentrations for the water quality did not differ greatly along the river.

4. Without any phosphorus removal through pretreatment prior to the membrane system, the reduction in loads by the WTP would be small. However, a moderate to high reduction (like 65 percent) could be expected as normal operation of an appropriate pretreatment system. Nitrogen reduction could also be realized, but that would require an additional post-WTP treatment process to be added.

5. An initial planning-level SJR mass balance model was prepared for analysis of WTP loading effects on the river. Because of the order-of-magnitude mass balance relationships between the subject WTPs and the ambient river conditions, the net effects of these WTP operations on the flow and water quality conditions in the river are predicted to be very small. The ecological significance of these small calculated changes will need to be addressed in additional studies of the effects

of cumulative withdrawals from the river. This planning-level model can be used for future evaluation of possible combinations of WTPs, membrane plant operational levels, and varied application of supplemental nutrient removal technologies. These predicted values are needed to conduct refined assessments of the proposed concentrate discharges from the conceptual WTPs.

CONSTRAINTS AND ISSUES

The site reconnaissance work conducted under this investigation was limited to data gathered over a 2-day period. These field investigations provided critically needed confirmation of SJR channel depths and widths in the AWS project focus areas. Results of the investigation gave credence to setting the values of some key parameters for the preliminary mixing zone analyses. Because the field investigations were necessarily cursory, they should not be viewed as adequate to fully assess site-specific conditions regarding the aquatic and wetland biological communities present in these study areas.

Much more intensive ecological review of proposed outfall locations will be needed as candidate AWS projects become better defined. The locations of proposed WTPs need to be better defined. Alternative concentrate conveyance pipeline corridors were generally considered in this report, but these locations are likely to vary depending the specific project. Finally, the intake and outfall facilities must be designed and permitted with proper emphasis on construction as well as operational effects minimization andor mitigation. Environmental and regulatory reviewers must be assured that these facilities will be implemented with the highest regard for regional environmental and water resource protection. Future SJRWMD evaluations will address cumulative effects on MFLs and Total Maximum Daily Load (TMDL) programs, as well as on potential effects on federally or state-protected fauna and flora.

The approach taken during these preliminary investigations was focused on addressing the overall feasibility of mixing zone permitting in the river at the AWS project areas. All of the conditions addressed were river channel habitats because of the presumed need for the deepest water possible near each prospective AWS area. These evaluations should not be extrapolated to projections about the relative feasibility of successful permitting of mixing zones in any lakes in and around the SJR since most lakes are very shallow systems when compared with the river channel locations. Prospective lake discharges remain a topic for potential consideration under future phases of the feasibility study.

RECOMMENDATIONS FOR FURTHER STUDY

On the basis of the key findings to date, certain supplemental studies may be warranted. The following recommendations are offered in the interest of addressing some of the key technical and regulatory issues identified to date. These are as follows:

1. Background information assembly has highlighted the fact that for the portion of the river basin under current consideration (east-central Florida), low flow conditions routinely occur each year, and under some conditions, transient periods of reverse flow occur due to wind-driven currents. Therefore, evaluation of the effects of concentrate discharge scenarios should focus on these low-flow condition periods to conservatively evaluate worst-case conditions with respect to concentrate mixing with the ambient waters. In addition, additional evaluation of the frequency and duration of those worst-case conditions should be undertaken to provide a real-life perspective on both the magnitude and duration of concentrate-related effects on the river directly adjacent to the prospective outfall locations.
2. As new information is provided regarding specific AWS projects, including more specific WTP and pipeline siting, likely river access and prospective outfall locations, pilot testing of membranes and pretreatment, mixing zone modeling, and site-specific ecological investigations; more definitive conclusions will be possible. FDEP has been briefed about these feasibility results and will likely formulate further opinions about how to proceed in demonstrating compliance. Future coordination with FDEP by the utilities is recommended.
3. Interagency review and research regarding the ambient levels of pH and chlorides in these portions of the SJR should be initiated as soon as possible to address the potential need for undertaking a formal site-specific alternative criterion study. If so, the administrative and technical steps required should be mapped out by FDEP, SJRWMD, and stakeholder representatives, and the respective roles should be discussed to resolve if and how this process should be executed.

4. Interagency review and research regarding the cumulative effects issues is under way. These concerns revolve around both the water balance and the constituent mass balance relationships for the Middle St. Johns River, Lake George, and Lower St. Johns River Basins. The impacts of cumulative water withdrawals and constituent load changes on existing or proposed MFLs and TMDLs may require more detailed assessment — or modifications to those that were provided in this feasibility analysis — to help formulate a defensible and holistic plan for which AWS projects should be implemented and to what magnitude these might be allowed.
5. On the basis of the mixing zone modeling performed to date, some level of dilution appears to be achievable in waters as shallow as 6 feet and might be sufficient to achieve compliance with the mixing zone rules. However, note that water-quality-based constraints could potentially require these AWS project concepts to be designed to achieve lower rather than higher levels of potable water recovery. In this manner, less concentrated constituent presence might render the subsequent surface water discharges relatively more feasible from a regulatory and environmental effects perspective.

The above recommendations are offered as a reasonable starting point from which a collective set of suggestions for further action may be developed in the future. The investigations conducted thus far support the continued development of AWS project concepts that include concentrate discharge back to the SJR, assuming appropriately conservative environmental planning and design of these facilities are applied during project development.

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