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EVALUATION OF THE EFFECTS OF THE PROPOSED MINIMUM FLOWS AND LEVELS REGIME ON WATER RESOURCE VALUES ON THE ST. JOHNS RIVER BETWEEN SR 528 AND SR 46 (UPDATE)

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

EVALUATION OF THE EFFECTS OF THE PROPOSED MINIMUM FLOWS AND LEVELS REGIME ON WATER RESOURCE VALUES ON THE ST. JOHNS RIVER BETWEEN SR 528 AND SR 46 (UPDATE)

October 2006

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EXECUTIVE SUMMARY

In 1999, the portion of the St. Johns River bounded by SR 528 and SR 46 was placed on the MFLs Priority Water Body List of the St. Johns River Water Management District (the District) (Figures 1-1 and 1-2). In May 2004, recommended MFLs were developed by the District for the St. Johns River at SR 50, in the approximate middle of this portion of the river (Mace 2004). With a comprehensive regional watershed model (HSPF), along with historic flow and stage records for the period of record (1959-2000), a “baseline” model of current conditions was developed (CDM 2004). Following multiple model runs with different withdrawal scenarios, the District determined that 50 million gallons per day (mgd) could be withdrawn upstream of SR 50 without exceeding the MFLs, recognizing that withdrawing 50 mgd during periods of low flow would represent a “worst case” scenario (CDM 2004). Since 2004, the Mace (2004) report has been updated (Mace 2005). The Mace (2005) report has been further updated and includes the addition of an infrequent low flow and level for the St. Johns River at SR 50 that has been added to the MFL criteria (personal communication with SJRWMD on September 22, 2006). This new information is not included or discussed further in this report. In addition, peer review comments were received on the Mace (2005) and HSW (2004) reports. Also, important new literature regarding the St. Johns River has been published that directly relates to the MFL work. This report provides an update based on this new information, literature sources and peer review comments.

The State of Florida Minimum Flows and Levels (MFLs) Program is based on Chapter 373.042, *Florida Statutes*, which requires, in part, the establishment of minimum flows and levels for surface waters. The statutory description of a minimum flow is “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (Ch. 373.042 (1)(a), *FS*). The statutory description of a minimum level is “the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area” (Ch. 373.042 (1)(b), *FS*). Once developed, consideration should be given to whether or not the MFLs are protective of ten natural resources and environmental values (62-40.473, *Florida Administrative Code).*

The specific approach requested of HSW Engineering, Inc. (HSW) by the District comes under the general heading of frequency analysis, in which the magnitude, duration, and return intervals (or frequency of occurrence) of one or more key events under long-term existing (i.e., baseline or current) conditions were compared with the magnitude, duration, and return intervals of these same events under the MFLs regime (i.e., a 50 million gallon per day [mgd] withdrawal scenario) at various transects or locations along this stretch of the river. Shifts in the duration curve that would occur under the 50 mgd withdrawal scenario also were examined. The ten water resource values (WRVs) are considered protected if the frequency of occurrence of these key events do not differ unacceptably (as determined by professional judgment) from their frequency of occurrence under long-term existing conditions (Figure 1 and Table 1).

The estuarine resources evaluation (WRV 3) was completed by others (ECT 2006) on a section of the river down stream from the section covered by this report, and this evaluation is directly applicable the SR 50 section. The appropriate section of the ECT report is included as Attachment F. ECT found that withdrawals of 240 cfs would protect estuarine resources. It also was determined that WRV-5 (maintenance of freshwater storage and supply) would not be affected by the change in hydrologic regime, and so no frequency analysis was performed for this WRV.

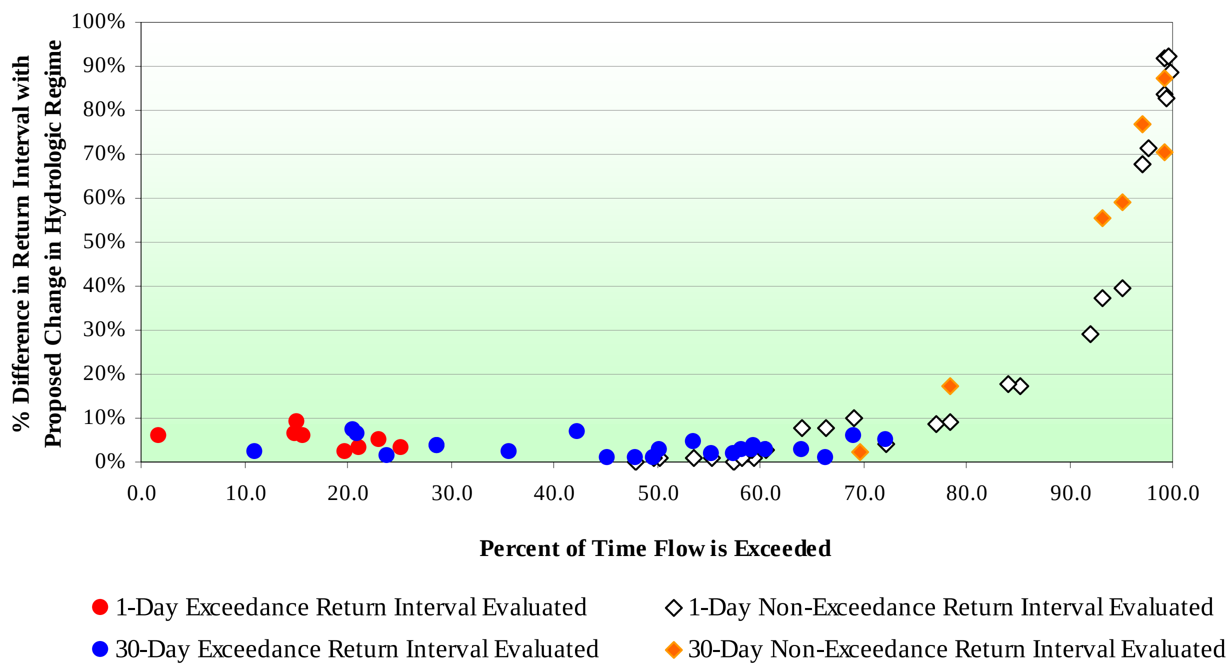


Figure 1. Percent difference in return interval of baseline conditions vs. 50 mgd withdrawal scenario as a function of percent of time flow is exceeded.

Because only river hydrology is changed under the proposed MFLs regime, frequency analysis is ideal for evaluating WRVs that are clearly and directly impacted by changes in river hydrology. This common quantitative approach, along with supporting literature reviews and discussion, allows an assessment of the impact of withdrawals on the health of the river at various river stages to be obtained.

Collectively, the difference of the return interval between existing hydrologic conditions and the MFLs hydrologic regime is small until the river is below the level that historically has been exceeded 80-85% of the time (Figure 1). Below this flow, return intervals under the 50 mgd withdrawal scenario differ substantially from baseline conditions. The 80-85% exceedance value represents a historic river discharge of about 300 cubic feet per second (cfs), or about 195 mgd, at SR 50.

A 50 mgd withdrawal constitutes more than 25% of the discharge during low flow periods and would substantially change the frequency of events that could affect some of the WRVs (Table 1). WRVs affected are those impacted by low flow conditions, such as recreation in and on the water (WRV-1), fish and wildlife habitats at higher elevations (WRV-2), and navigation (WRV-10). For example, for safe boating access to the river, flows of less than 157 cfs at SR 50 may become problematic, as water depths in the access channels would be less than the safe depth criterion of two feet. Flows of less than 21 cfs upstream of SR 50 may become problematic by precluding the passage of some species of fish. For two-way navigation in the main channel, flows of less than 179 cfs at SR 50 may become problematic, as the channel width would be less than the safe boating width criterion of 30 feet. WRVs affected by medium or high flow events, such as transfer of detrital material (WRV-4) or filtration and absorption of nutrients and other pollutants (WRV-7), would be much less impacted by a 50 mgd withdrawal.

Based on this evaluation, it is HSW's opinion that the proposed MFLs would be protective of the ten WRVs under medium or high flow events; however, three WRVs would not be protected under low flow conditions. HSW recommends a withdrawal scenario that results in no withdrawal when the river discharge at SR 50 is below the 80-85% exceedance value of about 300 cfs. This operational approach will serve to protect those WRVs that are most vulnerable at low flows.

Table 1. Water resource values and assessment of protection under the proposed MFLs regime (50 mgd withdrawal scenario)

Water Resource Value (WRV)	Flow Condition Evaluated to Determine if WRV Protected	MFLs Regime Protective/Not Protective
1. Recreation In and On the Water	Low flow	Not Protective
2. Fish and Wildlife Habitats and the Passage of Fish	High flow (elevated habitats) Low flow (fish passage; all other fish and wildlife habitats)	Protective (elevated habitats) Not protective (fish passage and all other habitats)
3. Estuarine Resources	Reference ECT 2006	Protective
4. Transfer of Detrital Material	High flow	Protective
5. Maintenance of Freshwater Storage and Supply	(None required)	Protective
6. Aesthetic and Scenic Attributes	Low flow	Protective
7. Filtration and Absorption of Nutrients and Other Pollutants	High flow	Protective
8. Sediment Loads	High flow	Protective
9. Water Quality	Low flow	Protective
10. Navigation	Low flow	Not Protective

1.0 INTRODUCTION

HSW Engineering, Inc., (HSW) was contracted by St. Johns River Water Management District (SJRWMD, or the District) to evaluate whether or not the hydrologic regime defined by the recommended minimum flows and levels (MFLs) for the St. Johns River at State Road (SR) 50 will protect the ten water resource values (WRVs) described in Section 62-40.473, *Florida Administrative Code (F.A.C.)*. HSW completed and submitted an evaluation report to the District in November 2004 (HSW 2004). This report drew substantially on the work of the District (Mace 2004). Since that time, the Mace (2004) report has been updated (Mace 2005). In addition, peer review comments were received on the Mace (2005) and HSW (2004) reports. Also, important new literature on the St. Johns River has been published that directly relates to the MFL work. This report provides an update based on this new information, literature and peer review comments. The Mace (2005) report has been further updated and includes the addition of a recommended infrequent low flow and level for the St. Johns River at SR 50 that has been added to the MFL criteria (personal communication with SJRWMD on September 22, 2006). This new information is not included or discussed further in this report.

The MFL Program is based on Chapter 373.042, *Florida Statutes (F.S.)*, which requires that either a water management district (WMD) or the Florida Department of Environmental Protection (FDEP) establish minimum flows for surface watercourses and minimum levels for groundwaters and surface waters. The statutory description of a minimum flow is “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (Ch. 373.042 (1)(a), *F.S.*). The statutory description of a minimum level, as applies to Florida’s surface water bodies, is “the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area” (Ch. 373.042 (1) (b), *F.S.*).

The statute provides additional guidance to the WMDs and FDEP on how to establish such MFLs. The MFLs are to be established using the “best information available” and may be calculated to reflect “seasonal variations,” if appropriate. Protecting non-consumptive uses also is to be considered as part of the process. The decision on whether to provide for protection of non-consumptive uses is to be made by the Governing Board of the appropriate WMD or the FDEP (. Subsection 373.042 (1) (b), *F.S.*).

Each WMD is required to develop a priority list of water courses and water bodies for the establishment of MFLs and the proposed schedules to do so. This list is to be updated yearly and sent to the FDEP for review and approval. In developing these lists, the WMD is to examine the importance of the watercourse or water body to the State or region and the potential for significant harm to the water resources or ecology. In 1999, the portion of the St. Johns River bounded by SR 528 and SR 46 was placed on the St. Johns River Water Management District's MFLs Priority Water Body List (Figures 1-1 and 1-2). SR 50 crosses the river in the approximate middle of this river reach.

Based on the provisions of Section 62-40.473, *F.A.C.*, once developed, consideration should be given to whether or not the MFLs are protective of ten natural resources and environmental values. These water resource values (WRVs) are as follows:

1. Recreation in and on the water
2. Fish and wildlife habitats and the passage of fish
3. Estuarine resources
4. Transfer of detrital material
5. Maintenance of freshwater storage and supply
6. Aesthetic and scenic attributes
7. Filtration and absorption of nutrients and other pollutants
8. Sediment loads
9. Water quality
10. Navigation

The SJRWMD has developed and implemented a multiple MFLs method that uses three to five MFLs to define a minimum hydrologic regime. The MFLs are represented by hydrologic statistics composed of three components: magnitude, duration, and return interval. The MFLs are primarily ecologically based and are used with hydrologic water budget models to determine *a priori* the quantities of water than can be withdrawn without causing flows and levels to fall below adopted MFLs (Robison 2004). The approach used by the District forms the basis of this evaluation of the potential effects of the proposed MFLs regime on the ten WRVs; i.e., comparison of magnitude, duration, and return intervals of long-term existing conditions with magnitude, duration, and return intervals under MFLs conditions.

References:

Title XXVIII, Ch. 373.042 (1) (a) and (b), *Florida Statutes.* http://www.flsenate.gov/Statutes/index.cfm?App_mode=Display_Statute&Search_String =&URL=Ch0373/Sec042.HTM.

62-40.473, *Florida Administrative Code.* http://fac.dos.state.fl.us/

HSW,2004. (HSW Engineering, Inc). Evaluation of the Effects of the Proposed Minimum Flows and Levels Regime on the Water Resource Values on the St. Johns River Between SR 528 and SR 46. Prepared for the St. Johns River Water Management District.

Mace, J. 2005. *Draft Preliminary Levels Determination: St. John River at State Road 50, Orange and Brevard Counties*. Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

Mace, J. 2004. *Draft Preliminary Levels Determination: St. John River at State Road 50, Orange and Brevard Counties*. Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

Robison, C. Price. 2004. Middle St. Johns River Minimum Flows and Levels Hydrological Methods Report. SJRWMD Technical Publication SJ2004-2, 2004.

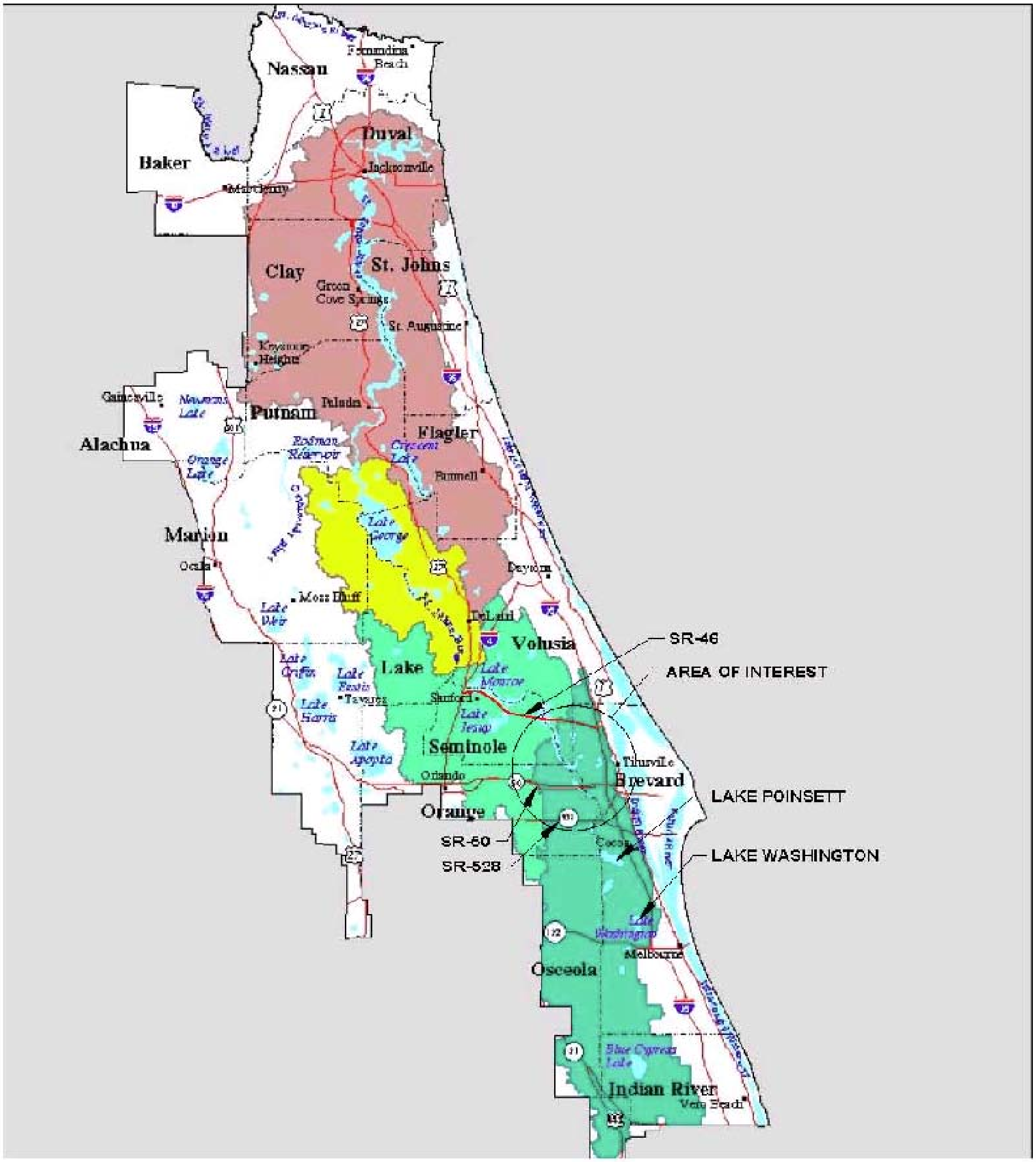
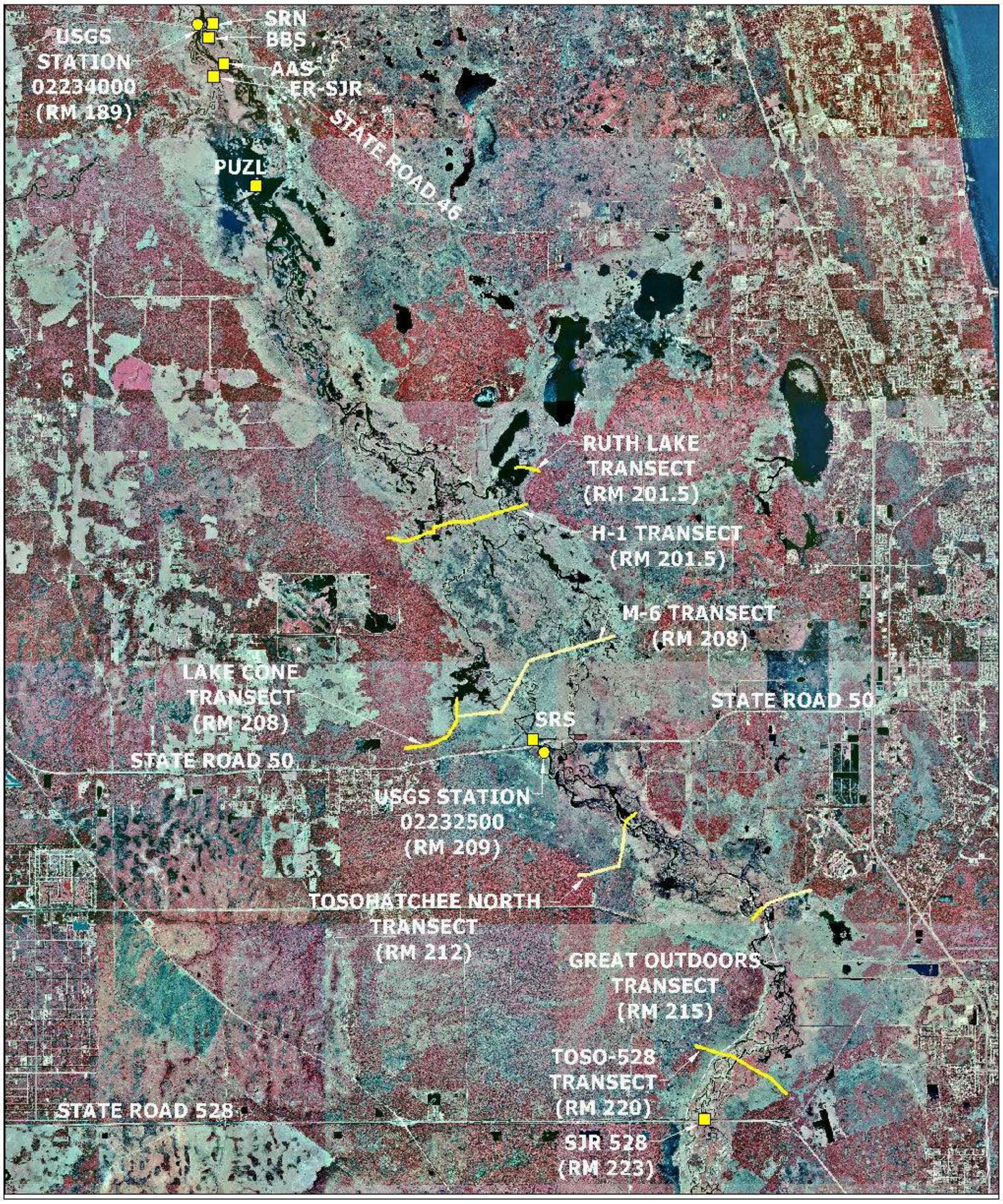


FIGURE 1-1
LOCATIONS OF SJRWMD MAJOR SURFACE WATER BASINS AND AREA OF INTEREST BETWEEN SR 528 AND SR 46 ALONG THE ST. JOHNS RIVER

SOURCE: PRELIMINARY MINIMUM LEVELS DETERMINATION
ST. JOHNS RIVER AT STATE ROAD 50, ORANGE
AND BREVARD COUNTIES.
(MACE 2006)

HSW



EXPLANATION

- USGS GAGING STATION
- SJRWMD WATER QUALITY STATION

RM RIVER MILE DESIGNATION

SOURCE: SJRWMD

0 2.32 MI.
1 INCH = 12,240 FT.

FIGURE 1-2
LOCATIONS OF GAGES, STATIONS, AND TRANSECTS BETWEEN SR 528 AND SR 46 ALONG THE ST. JOHNS RIVER

HSW

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2.0 CHARACTERISTICS OF THIS RIVER SECTION

The section of the St. Johns River bounded by SR 528 and SR 46 is within the Upper St Johns River hydrologic basin (Figure 1-1) and consists of multiple, extensive public land parcels with high quality, environmentally sensitive, natural ecosystems (Mace 2005). Several of these public land parcels border the river between SR 528 and SR 46, including the Tosohatchee State Reserve, Canaveral Marshes Conservation Area, St. Johns National Wildlife Refuge, Seminole Ranch Conservation Area, the Yarborough Conservation Easement, and the Little Big Econ State Forest (Mace 2005).

Figure 2-1. The St. Johns River between SR 528 and SR 46.
Photo courtesy of Central Florida Airboat Tours.

Various wetland communities are present along the St. Johns River, primarily wet prairie and shallow marsh, which comprise approximately three-fourths of the vegetated area within a one-mile buffer of the river channel (Mace 2005). The marshes provide habitat for a diverse population of fish and wildlife, including numerous migratory and resident wading birds and waterfowl and alligators (Figure 2-1). Naturally salty water flows from small springs near Harney and Puzzle lakes. The salinity of small lakes in the area approaches one-third that of seawater. Many salt-tolerant and marine-dwelling organisms present here are not found anywhere else in the St. Johns River (SJRWMD Seminole Ranch Conservation Area Quick Guide).

This stretch of river is about 30 miles in length (from river mile 190 at SR 46 to river mile 220 at SR 528). The watershed area contributing to this stretch of river is estimated at 608 square miles (USGS drainage area data). Long-term mean annual rainfall over the watershed is about 52-56 inches (SJRWMD Hydrologic Conditions Report December 2003). The driest year on record was 2000, with only 32.7 inches of rain, while the wettest year on record was 1953, with 81.7 inches of rain.

References:

Mace, J. 2005. *Draft Preliminary Levels Determination: St. Johns River at State Road 50, Orange and Brevard Counties*. Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL. March 17, 2005.

SJRWMD Hydrologic Conditions Report, December 2003.

3.0 HOW THE PROPOSED MFLS WERE DEVELOPED

The District used soils, vegetation, topographic, water flow and water level data to develop a set of proposed MFLs for this portion of the St. Johns River, and the District recommended three minimum surface water flows and levels for this section of the river (Table 3-1): a minimum frequent high flow and level, a minimum average flow and level, and a minimum frequent low flow and level (Mace 2005).

Table 3-1. Preliminary minimum surface water levels and flows for the St. Johns River at SR 50

	Minimum Frequent High	Minimum Average	Minimum Frequent Low
Stage (feet [ft] NGVD 1929 datum)	8.1	5.9	4.2
Flow (cubic feet per second [cfs])	1,950	580	140
Hydroperiod Category	Seasonally flooded	Typically saturated	Semipermanently flooded
Return Interval	2 years or less	1.5 years or greater	5 years or greater
Duration	30 days or more	180 days or less	120 days or less

The proposed MFLs were established to protect existing ecological structure and functions of the aquatic wetland system and were supported by observed conditions at several transects along this section of river (Mace 2005). HSW used the work conducted by Mace (2005) extensively in the analyses of the WRVs, particularly the cross-sectional diagrams of each of the seven transects (Appendix E) and for evaluating WRV-2 (Fish and wildlife habitat and the passage of fish). The stage values at the transects were translated and converted to stage values at the SR 50 bridge with a water surface profile model (HEC-RAS) developed by the District. With a comprehensive watershed model (HSPF) that encompassed this section of the river (draft model results, CDM 2004), along with historic flow and stage records for the period of record 1959-2000 (41 years), a “baseline” model was developed. Different water withdrawal scenarios were then input into the HSPF model and the resultant flows and levels were compared to the proposed minimum levels at the transects. SJRWMD staff determined, following multiple model runs, that a withdrawal of 50 million gallons per day (mgd) from this stretch of river could be accomplished without exceeding any of the above MFLs. The proposed withdrawal includes 25 mgd from Lake Poinsett and 25 mgd from Lake Washington (Figure 1-1). Both of these withdrawal points are upstream of SR 528.

Flows within this stretch of river have varied from as high as 11,600 cubic feet per second (cfs) at the USGS gage located at SR 50 near Christmas (Gage 02232500), or 7.5 billion gallons in a day, to as low as -137 cfs (negative value indicates water was flowing upstream). Under extreme high flow conditions, a withdrawal of 50 mgd would not have a measurable effect on the river stage or the river flow. Based on modeled data, interquartile (25-75%) river flows at SR 50 have ranged from 369-1,520 cfs (Table B.1 of Appendix B).

References:

CDM. 2004. St. Johns River Water Management District: Hydrologic Model Development for MFL Evaluation of the Upper St. Johns River Basin, Florida. Technical Memorandum. November 2004.

Mace, J. 2005. *Draft Preliminary Levels Determination: St. Johns River at State Road 50, Orange and Brevard Counties*. Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

Mace, J. 2004. *Draft Preliminary Levels Determination: St. Johns River at State Road 50, Orange and Brevard Counties*. Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

4.0 PROCEDURE FOR EVALUATING WATER RESOURCE VALUES

HSW was contracted by the District to evaluate whether or not the hydrologic regime defined by the proposed MFLs will protect the ten WRVs described in Section 62-40.473, *FAC*, for the St. Johns River between SR 528 and SR 46. The specific approach requested by the District comes under the general heading of frequency analysis and parallels the method used by the District to develop the MFLs (i.e., by identifying and evaluating magnitude, duration, and return interval components that are biologically meaningful). The details of this approach are explained in this section.

Working definitions of protection of WRVs that were used for this project are as follows.

> High flow (flood) -related WRVs are considered to be protected if, under the proposed MFLs regime, the high flow event of a specified magnitude and duration does not occur too infrequently when compared to the high flow event frequency under long-term existing conditions.

> Low flow (drought or drawdown) -related WRVs are considered to be protected if, under the proposed MFLs regime, the low flow event of a specified magnitude and duration does not occur too frequently when compared to the low flow event frequency under existing conditions.

Each WRV may represent a broad class of functions, processes and/or activities that require consideration of protection. To facilitate the process of determining if recommended MFLs are protective of these classes of functions/processes/activities, a four-level hierarchical approach to the assessment was implemented. This approach, described below, moves from broad, general definitions to more specific criteria of protection, then to general indicators of protection and, finally, to specific indicators of protection that can be measured and assessed. This approach is similar to that used for wetland delineation (National Research Council 1995).

Level 1. Restate the WRV in terms of **criteria** that are specific to the water body being evaluated. Include the definition of the WRV as provided by the District.

Level 2. Identify a **representative function, process,** or **activity** of that specific WRV. This criterion should be very sensitive or possibly the most sensitive to changes in the return interval of high or low water events (defined by magnitude and duration components).

Level 3. Identify a **general indicator** parameter for the protection of that function/process/activity, such as river flow and/or depth. This criterion might include the appropriate definition of protection for either high or low water events from the contract that are directly related to each WRV.

Level 4. Identify **specific indicator** parameter(s) for the protection of the river specific WRV in terms of magnitude (flow and or water level), duration (number of days), and return interval. This criterion will include an assessment of the change in the number of events per 100 years under existing long-term hydrologic conditions and MFLs hydrologic conditions.

The following example using WRV 1 Recreation in and on the water will help illustrate this approach:

Level 1. Recreation in and on the water is defined as the active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.

Level 2. The most sensitive criteria to hydrologic alteration along this stretch of the river is recreational boating. Explain why high or low water events were chosen for the WRV assessment.

Level 3. This WRV will be protected if, under the recommended MFLs, the low flow event of the specific magnitude and specific duration does not occur too frequently when compared to the same low flow event frequency under the long-term existing conditions regime.

Level 4. Include a minimum water depth and channel width with a duration that is measurable and can be used with the frequency analysis of the existing long-term conditions and MFLs conditions hydrologic regimes.

By using this approach, it is assumed that if the recommended MFLs do not result in an unacceptable change at the most specific indicator (i.e., Level 4), then the broader, more general function/process/activity is protected. This hierarchical approach was applied to each relevant WRV (Table 4-1).

One of the most common methods used in hydrology to indicate the probability of an event is to evaluate the return period or recurrence interval of an event (Bedient and Huber 1988). An annual event (e.g., flow maximum) has a return period of T years if its magnitude is equaled or exceeded once, on the average, every T years. The reciprocal of T is the exceedance probability of the event, or the probability that the event is equaled or exceeded in any one year. Thus, a 25-year, 24-hour storm event has a probability of 0.04, or 4%, of being equaled or exceeded in any single year. Expressed another way, four such 24-hour storm events are expected to occur in a 100 year time period.

In the "boat passage" and storm event examples above, three parameters are described or implied: the magnitude of the event (e.g., maximum value that is equaled or exceeded or minimum value that is not equaled or exceeded), duration of 24 hours, and return interval of 25 years. These concepts are used extensively in flood frequency analysis but can also be applied to other aspects of river hydrology. In this example, the WRV "recreation in and on the water" is protected if it is demonstrated, for instance, that the river depth (at key locations) is not less than 2 feet (ft) for more than one week at an acceptable frequency (i.e., probability). The acceptable frequency for this "event" will be a frequency that does not differ unacceptably from the long-term existing conditions frequency.

Frequency analysis as it is applied to evaluating protection of the WRVs involves the following four steps:

1. Generate synthetic hydrographs for various sections of the river based on existing hydrologic (baseline) conditions. This was accomplished using regional hydrologic data and watershed (HSPF) and hydraulic models (HEC-RAS).
2. Generate synthetic hydrographs for various portions of the river based on the same conditions above but including simulated water withdrawal from the

river, without exceeding the MFLs conditions provided in Table 1-1 (recommended MFLs).

3. For each WRV, select a key river characteristic (e.g., flow, depth, stage, velocity, or width) that is most critical to the protection of that specific WRV.

4 Develop appropriate frequency curves from hydrographs developed in steps 1 and 2 above that are relevant to the WRV considered for protection, and compare the return intervals of a specific event for a specific duration under the two scenarios. For example, is the return interval of an annual minimum low water level of 4.1 ft for duration of 1 day under an MFLs water withdrawal scenario substantially different from what occurred for the same level (4.1 ft NGVD0 and duration (1 day) under the existing water flow (baseline) conditions?

The rationale used to determine this prioritization is explained within the detailed write-up for each WRV. The frequency curves used in Step 4 are developed for extreme (i.e., minimum and maximum) annual values (e.g., annual minimum flow not exceeded for 14 consecutive days). The guiding premise is that hydrologic processes that may impact the ten WRVs are event-driven (e.g., flood impacts on sediment transport) or can best be characterized by extreme events (e.g., minimum annual stage impacts on navigation). These concepts will become clearer in Section 5 when each of the WRVs is evaluated.

For each WRV, the difference in the frequencies of the selected WRV event associated with the baseline and MFLs scenarios are evaluated. Analysis of the period of record duration curve also is included. Because only the river hydrology is being altered under the MFLs scenario, this approach clearly is ideal for WRVs assessments that are directly impacted by river hydrology, such as navigation and fish passage. It is posited that each of the WRVs can be evaluated by identifying key hydrologic conditions that are relevant to that WRV. Through analyses of all of the WRVs using a common quantitative approach, including WRVs that involved more complex processes (e.g., fish and wildlife and the passage of fish), along with supporting literature and discussion, an assessment of the impact of withdrawals on the health of the river at various river stages will be obtained.

Table 4-1. WRV hierarchy for MFLs evaluation for the St. Johns River between SR 528 and SR 46

WRV		Criteria	Function	General Indicator	Specific Indicator
1.	Recreation In and On the Water	Legal water sports and activities	Recreational boat passage	Water depth and width in channel	Stage associated with minimum channel width and depth to allow two-way boat passage at a safe water depth
2.	Fish and Wildlife Habitat and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife	Fish passage for a large game species (e.g., bass)	Water depth in channel and floodplain	Stage associated with river channel and floodplain to allow passage of fish and preservation of habitat
3.	Estuarine Resources	Coastal systems and associated natural resources	Salinity fluctuations in the estuary	Discharge	Identify relationship between toe of wedge and discharge and identify discharge value of importance
4.	Transfer of Detrital Material	The movement of loose organic material and debris and associated decomposing biota	Water depth and floodplain inundation	Depth of water in floodplain	Stage associated with depth and area of inundation for transfer of detrital material into suspension
5.	Maintenance of Freshwater Storage and Supply	Current permitted users	The maintenance of adequate surface water levels and aquifer levels in the area adjacent to the water withdrawals	Stage that protects aquifer levels that do not result in adverse impacts	Examine existing groundwater withdrawals and groundwater/surface water interaction change associated with MFLs
6.	Aesthetics and Scenic Attributes	Passive recreation	Visual setting at selected points	Stage	Stage associated with optimal scenic and wildlife viewing
7.	Filtration and Absorption of Nutrients and Other Pollutants	The process of absorption and filtration	Concentration and load of nutrients	Depth of water in floodplain	Stage associated with inundation of floodplain
8.	Sediment Loads	The process of sediment movement and deposition	Water velocities and flow	Velocity for sediment transport	Discharge associated with velocity necessary for sediment transport
9.	Water Quality	Chemical and physical properties of the water	Concentration of chemical parameters	Discharge	Discharge associated with mixing and maintenance of healthy temperature, oxygen and turbidity levels
10.	Navigation	Legal operation of eco-tourism and commercial fishing vessels	Area access	Water depth	Stage associated with minimum channel depth for representative commercial vessel operation

A condition specified in Section 373.042, F.S., is that best available information shall be used to determine MFLs. HSW researched available information to support the selection of the specific indicator parameter(s) and duration(s) for the protection of each WRV. The HSW team's senior professionals have in-depth knowledge of biology, ecology, hydrology, and cultural practices, such that our selection of key characteristics and events (Level 3 and 4) can be defended. It must be continually emphasized that the conditions associated with the critical indicator parameters (and durations) will still occur, more or less frequently depending upon the MFL. Also, while Section 62-40.473, F.A.C., requires considering each WRV, certain WRVs may be more or less relevant based on the nature and the location of the water body.

References:

National Research Council. 1995. *Wetlands Characteristics and Boundaries*. National Academic Press, Washington, D.C.

Bedient, B.B. and W. C. Huber. 1988. Hydrology and Floodplain Analysis. Addison-Wesley Publishing Company.

5.0 EVALUATION OF WATER RESOURCE VALUES

5.1 WRV-1: Recreation In and On the Water

Florida and water-based recreation are synonymous around much of the world, and a major portion of the State's economy depends on water-based recreational activities (Marine Industries Association of Florida 2004; American Sports Fishing Association 2004). To evaluate the impacts of water withdrawals on recreational activities associated with the portion of the St. Johns River from SR 528 to SR 46, recreation in and on the water is **defined** as the active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities include but are not limited to swimming, scuba diving, water skiing, boating, fishing, and hunting. Activities of a more passive nature, such as viewing wildlife from boats, are discussed in Section 5.6 (WRV-6, aesthetic and scenic attributes).

The **criteria** for protection of this WRV are "legal water sports and activities." The analyses focus on the applicability of various legal forms of recreational water sports and water activities. The two main recreational activities documented for this stretch of the St. Johns River are boating (including jet skiing) and fishing from boats. Therefore, recreational boat passage is the **representative function** used to assess protection of this WRV. The **general indicator** of protection is the depth of water needed to allow for safe recreational boat passage. The **specific indicator** is the return interval of the stage associated with a one-day minimum channel width that allows two-way boat passage at a safe water depth at a specific hydraulic control point on the river near SR 50. Consequently, minimum water depths and channel widths for safe boating for craft used for these activities are parameters of interest.

In general, this stretch of river is characterized by shallow, braided, serpentine channels within a wide, flat floodplain (Mace 2004; refer also to cross-sectional topographic diagrams of transects from Mace 2004 included in Appendix E). It is not conducive to primary contact recreation such as swimming. Water depths are not great in the main channels when river flows are not sufficient to inundate the floodplain. Along five of the seven transects evaluated by Mace (H-1, Lake Cone, M-6, TOSO North, and TOSO-528 transects), the vertical distance from channel bottom to top of bank appears to range from 6 to 7 ft (Appendix E). Only at the Great Outdoors transect is the vertical channel depth greater than 10 ft (Appendix E). Water clarity is poor under the majority of flow conditions (HSW 2004a: field observations at moderately high water, low water and extreme low water conditions).

When the floodplain is inundated, currents within the channels would make swimming difficult. In addition, this stretch of river is undeveloped and rich in wildlife, including a significant population of alligators. Therefore, swimming, scuba diving, water skiing and other primary contact forms of recreational activities generally do not occur.

Figure 5.1-1. Boaters launching recreational craft along the St. Johns River near SR 46 under unusually low flow conditions (HSW, May 2004)

5.1.1 Field Surveys and User Survey

HSW undertook a wet season and a dry season survey of boats on the stretch of river from the SR 528 Bridge to north of Hatbill Park (Figure 1-2) (HSW 2004a). HSW also conducted a user survey at two of the more heavily used boating ramps (at SR 50 and at SR 46) on one of the most popular boating days of the year, Memorial Day May 31, 2004 (HSW 2004b). The water level at the SR 50 Bridge on May 31, 2004, was calculated to be about 2.8 ft NGVD

(Jane Mace, personal communication, June 8, 2004). At this elevation, only airboats can access the main channel of the river from the SR 50 launch area, and the water is too shallow for all but the most shallow draft boats launched at SR 46. According to District personnel (Jane Mace, personal communication, June 28, 2004), the water elevation on May 31, 2004, at the SR 46 Bridge was -0.2 ft NGVD.

From these efforts, the following picture of recreational boating use emerged.

1. Airboats are common and are able to use most of the main channels of the entire stretch of river from SR 528 to SR 46 under high and low flow conditions.
2. According to several airboat captains using this portion of the river on Memorial Day (May 31, 2004), the water levels on that day were almost too low for the airboats to navigate safely.
3. The stretch of river from SR 50 upstream to SR 528 contained few boats other than airboats. Virtually all the boats able to use the SR 50 boat ramp on Memorial Day were airboats. One or two jon-boats attempted to launch at the SR 50 ramp but were unable to avoid running hard aground in the shallow water leading to the main channel. The water depth appeared to be only about 0.5 ft or less at that point.
4. The stretch of river from SR 46 to SR 50 is used by a wider array of watercraft. The largest non-airboat launched from the SR 46 ramp on Memorial Day was a 16.5 ft bass boat. The most common style of boat launched from that ramp was the flat-bottomed jon boat of 16 ft length or less. A fewer number of 16 ft-length or less vessels with modified "V" hull also were launched. Several of these ran aground in one of the main access channels roughly 300 yards upstream of the launch area, where water depths were estimated as less than 0.5 ft.
5. Jet skis are used in the portion of the river from the SR 46 launch area. Fishermen indicated that these recreational watercrafts were becoming more popular along this stretch of river.
6. Pontoon boats start out from the SR 46 launch area but move downstream (north) under low water level conditions such as were experienced on Memorial Day.

7. All fishermen interviewed agreed that the water levels in the river on May 31, 2004, were not optimal. The levels were too low to allow any vessel other than airboats to access the better fishing areas.
8. Several boaters complained of a water odor problem at the confluence of the Econlockhatchee River and the St. Johns River at the low flow condition.
9. Several airboat operators made special mention of safety concerns at low water level conditions. They related recent serious accidents involving jet skis and airboats or other boats, when the high-speed craft are unable to see each other as they round the many curves and blind corners. At low flow conditions, boaters and jet skiers cannot see over the floodplain banks and vegetation. At low flows, channels are relatively narrow and very serpentine, with limited sight distances.

On May 5, 2004, several of HSW's team members used airboats from the District to conduct a survey of approximately 80% of the river length from SR 528 to SR 46 (HSW 2004a; Figure 1-2). On that date, the water elevation at the SR 50 Bridge was reported to be 4.5 ft NGVD (1.7 ft above the level on May 31, 2004). On May 5, 2004, only the main channels of the river were navigable. The shallowest and most narrow location within the main river channel on May 5, 2004, appeared to be at the TOSO-528 transect location, with a water elevation of 6.3 ft NGVD (SJRWMD survey crew, on-site May 5, 2004) and maximum water depth of 2.8 ft (from data in Mace 2004). Near the SR 528 Bridge, the east channel was impassable, even for airboats. A water elevation of 6.3 NGVD is associated with a flow of about 56 cfs (value obtained from rating curve data for the TOSO-528 transect in Table B.3 of Appendix B; rating curve displayed in Figure A.4a of Appendix A), a flow that historically has an annual one-day non-exceedance minimum of 1:6.95 years, or about 14% (from frequency data provided in Table B.2-1 of Appendix B; frequency curve displayed in Figure A.1-3a of Appendix A).

5.1.2 Safe Boating Information

Yingling (1997) compiled information on boating safety and recreational use that indicated 3 to 4 ft of water at the toe of a boat ramp is the minimum recommended for boat launching. Wagner (1991) indicated that for boats with outboard motors, a minimum of 3 ft of water is usually recommended for safe operation. However, this general recommendation needs to be studied in light of the fact that the largest motorized boats observed on this stretch of river are relatively small (about 16 ft). The boats operating on this section of river are specially designed for shallow water boating.

Reported drafts for flat bottomed jon boats of 16 ft-length or less are usually a little less than 1 ft. The draft of a 16 ft length vessel with a modified “V’ hull is about 1.5 ft. Consequently, the typical boats with outboard motors using this section of river would be able to navigate in water depths of about 2 ft.

Jet skis require less than 1 ft of water to float. However, for safe use of jet skis, different state organizations recommend the water should be a minimum of 2 ft deep (see, for example, State of Georgia Safe Boating Course web site – official on-line course, and Wisconsin Department of Natural Resources boating safety Web site). The Wisconsin Department of Natural Resources states that such craft can operate safely in as little as 2 ft of water, but deeper water is recommended. At water depths less than 2 ft, the jet skis can damage aquatic vegetation and can be damaged by the water pump taking in bottom sediment and aquatic vegetation.

Information pertaining to safe channel widths for two-way boat passage is not available (see also Section 5.10, Navigation). Visual evidence from the river survey conducted on May 5, 2004, (low water conditions, 4.5 ft NGVD at the SR 50 bridge) indicated that the main channel appeared to have a minimum width of about 30 ft at the narrowest point (near the TOSO-528 transect). This width is more than twice the width of the wider beamed watercraft documented as using this portion of the river (8 ft-beam airboats seating six people and 10 ft-beam airboats seating a dozen people; from interviews with Central Florida Airboat Tours Captain Bruce Fryer on June 1 and August 27, 2004). In these interviews, the captain indicated that a minimum channel width of 30 ft would be barely adequate (although less than optimal) to allow for two-way boat passage. Consequently, it is concluded that channel widths within the main channel of the river at a water level elevation of 4.5 ft NGVD at SR 50 are adequate to allow for two-way boat passage.

5.1.3 Baseline and MFLs Conditions

From the interviews with boaters, and from the visual evidence of the problems being experienced by the non-airboats in navigating on May 31, 2004, water levels of about 2.8 ft NGVD at the SR 50 bridge and -0.2 ft NGVD at the SR 46 bridge translate to very shallow water depths in access channels at both the SR 46 and SR 50 boat ramps. These depths are below levels that would be considered passable for even extremely shallow draft vessels.

A water level of 4.5 ft NGVD at the SR 50 Bridge (as experienced by HSW on May 5, 2004) would provide approximately 2.2 ft of water depth at the shallow spot in the access channel leading from the SR 50 boat ramp to the main water channel. This water level would be barely adequate for the safe operation of most types of vessels using this portion of the river. A water level of 4.3 ft NGVD at the SR 50 Bridge would allow for 2.0 ft of water depth in the shallow spot of the access channel.

The parameter of concern is a minimum depth, and the duration of interest for safe boating depth is one day. Using the proposed channel depths and associated stage and discharge at SR 46 and SR 50, the frequency of the annual one-day non-exceedance minimum is increased from 73% (1:1.34 years) to 85% (1:1.17 years) at SR 46 and from 43% (1:2.35 years) to 60% (1:1.68 years) at SR 50 (Table 5.1-1). The frequency of the 30-day non-exceedance minimum event also was evaluated, which may be more appropriate for long-term economic considerations.

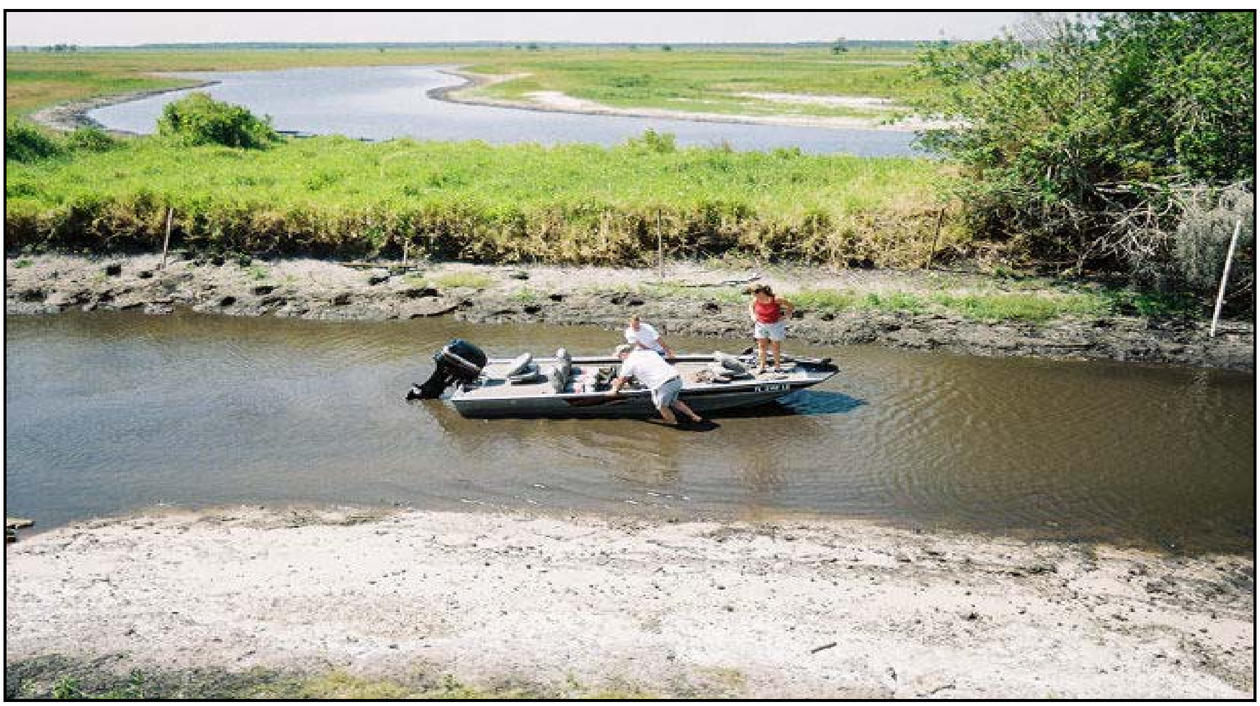

Figure 5.1-2. Recreational boaters negotiating unusually low water conditions within an access channel to the St. Johns River at SR 50 (HSW, May 2004)

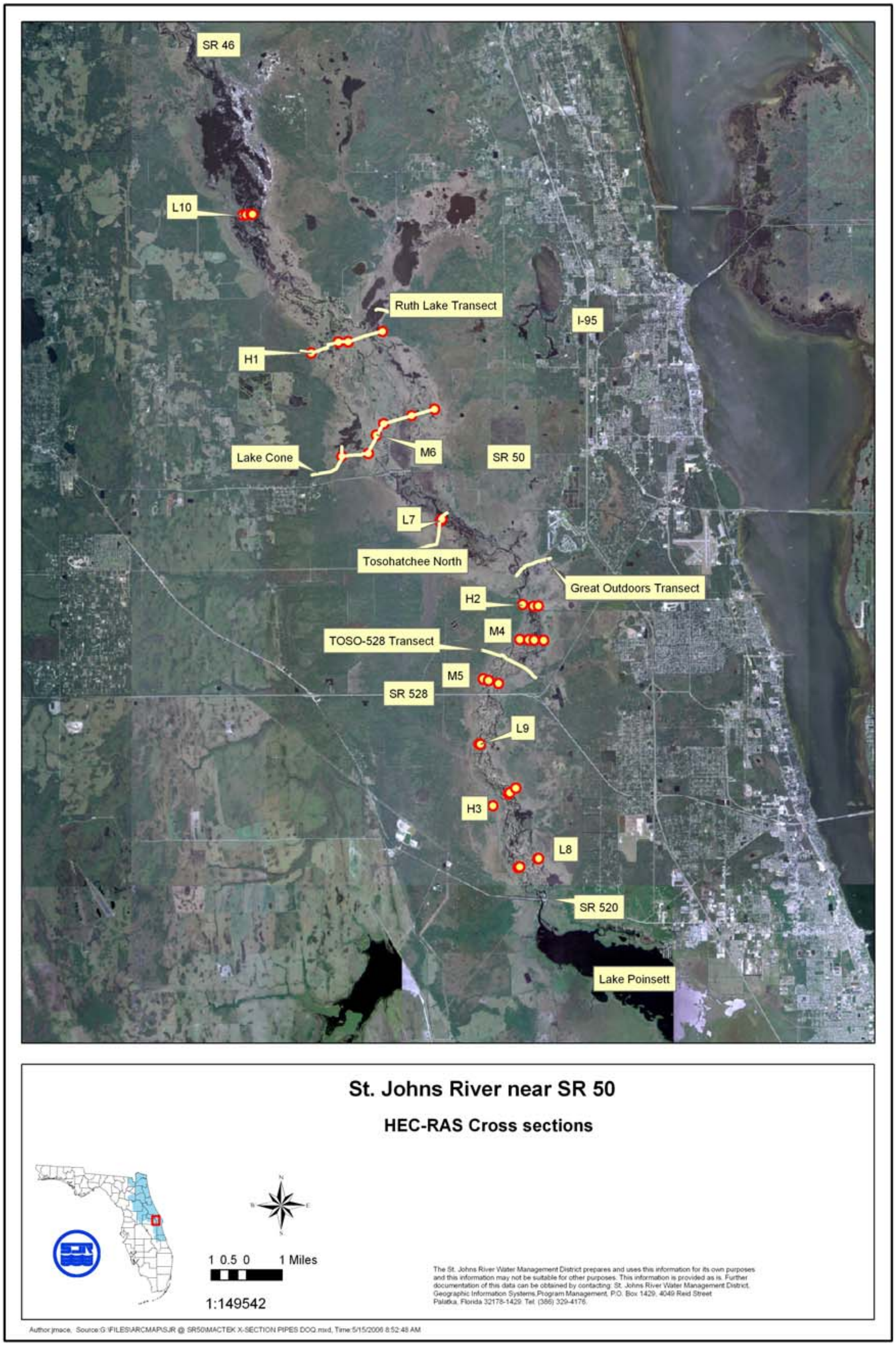

Figure 5.1-3 Locations of shallowest points (red/yellow circles) surveyed in May 2006 (Jane Mace, personal communication, July 5, 2006)

Table 5.1-1. Frequency and duration parameters for WRV-1 for a depth of 2.0 ft: recreation in and on the water

Location	River Mile	Stage (Depth)	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD (ft)	cfs	Days	Current	MFLs	Current	MFLs
Access channel at State Road 50	209	4.3 (2.0)	157	1	2.77	1.68	95.1	89.0
Access channel at State Road 50	209	4.3 (2.0)	157	30	5.77	2.35	95.1	89.0
Access channel at State Road 46	190	1.3 (2.0)	337	1	1.29	1.17	78.4	72.7
Access channel at State Road 46	190	1.3 (2.0)	337	30	1.62	1.34	78.4	72.7
Main channel at TOSO-528	220	5.5 (2.0)	21	1	31.7	2.62	99.3	95.2
Main channel at TOSO-528	220	5.5 (2.0)	21	30	34.1	4.41	99.3	95.2
Bathymetry data 2006 [c/]	220	6.5 (3.0)	68	1	5.81	1.87	97.1	90.1
Bathymetry data 2006 [c/]	220	6.5 (3.0)	68	30	9.53	2.19	97.1	90.1

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 of Appendix B).

c/ Bathymetry data collected in 2006 were referenced to stage at TOSO-528 to calculate frequency values.

These analyses are based on the access channel depths at the SR 46 and SR 50 boat launch areas. The main river channel at both these locations would have more than 2 ft of water depth when the water level at the SR 50 Bridge is at 4.3 ft NGVD. Jet skis were able to (at slow speeds) navigate from the SR 46 launch area north (downstream) on Memorial Day 2004, when the water levels were unusually low. No jet skier was observed attempting to navigate the access channel from the SR 46 launch area south toward the main river channel (within the study area) on Memorial Day 2004.

Because river flows under baseline conditions will, on occasion, naturally fall below those required to maintain a 2ft depth in both access channels and in portions of the main river channel, emphasis was placed on how the annual frequency of occurrence of these low flow conditions would be altered under a 50 mgd withdrawal scenario. Transect information from Mace 2004 (Appendix E) was evaluated to determine the depth of the main river channel at different locations. The river channel was shallowest at the TOSO-528 transect. A depth of 2 ft within the main channel at TOSO-528 is associated with a flow of about 21 cfs (Table B.3 and Figure A.4a). Under baseline conditions, the annual one-day non-exceedance minimum has a frequency of occurrence of about 3%, or 1:31.7 years (Table 5.1-1). Under the proposed 50 mgd withdrawal scenario, the annual one-day non-exceedance minimum has a frequency of occurrence of about 38%, or 1:2.62 years (Table 5.1-1). The frequency of the 30-day non-exceedance minimum event also was evaluated, which may be more appropriate for long-term economic considerations.

Such a low water condition could impact the safe use of this portion of the river by jet skiers and operators of vessels using outboard motors during those periods. However, even at an elevation of 4.3 ft NGVD (at the SR 50 Bridge), the main channel of the river would have in excess of 2 ft of water near both the SR 46 and SR 50 bridges. For water depth in the main river channel to fall below the 2.0 ft safe boating depth, the river flows would need to be unusually low (Table 5.1-1).

Table 5.1-2. River reaches and location of shallowest points survey in May 2006

Reach	River Reach Description	Latitude and Longitude of shallowest points
1	State Road 46 to L10	No extremely shallow areas
2 [a/]	L10 to H1	28 36 12; 80 58 12
3 [a/]	H1 to M6	28 33 29; 80 57 40
4	M6 to State Road 50	No extremely shallow areas
5 [a/]	State Road 50 to L7	28 31 47; 80 55 17
6 [a/]	L7 to Great Outdoors Transect	28 31 10; 80 54 25 28 30 38; 80 54 04 28 30 40; 80 53 18
7	Great Outdoors Transect to H2	No extremely shallow areas
8 [a/]	H2 to M4	28 29 18; 80 52 34 28 28 59; 80 52 29 28 28 29; 80 52 24
9 [a/]	M4 to TOSO-528 Transect	28 28 12; 80 52 24 28 28 10; 80 52 42 28 27 56; 80 53 24
10	TOSO-528 Transect to M5	No extremely shallow areas

a/ River reaches with very shallow areas. Shallow areas were 0.6 to 1.0 ft deep and were the deepest area of the channel when the SJR stage at State Road 50 equaled 2.6 ft NGVD.

To locate additional shallow cross-sections, bathymetry data were collected by SJRWMD from February 27 to April 4, 2006, along the stretch of river between SR 46 and Lake Poinsett

(Jane Mace, personal communication, July 5, 2006). Additional data were collected in May 2006 when the river stage at State Road 50 equaled 2.6 ft NGVD. Twelve locations were identified (when the SJR stage at SR 50 equaled 2.6 ft NGVD) as potential hydraulic control points, where the maximum water depth within the narrower channel ranged consistently between 0.6 and 1.0 ft (Table 5.1-2 and Figure 5.1-3). Using the surveyed data, a water depth of approximately 1.6 ft at TOSO-528 was obtained, or a depth that was about 1 ft greater than other hydraulic control locations. This is equivalent to a critical stage of about 6.5 ft NGVD referenced to TOSO-528.

Both one-day and 30-day non-exceedance events (depth of 3.0 feet) were evaluated at the TOSO-528 transect (i.e., Lake Poinsett frequency data) to represent the other hydraulic control locations (Table 5.1-2). For both 1 and 30 day events, the frequency of occurrence increases by about 35 events per 100 years.

Based on this analysis, withdrawals of 50 mgd when the river is at or above 4.3 ft NGVD at the SR 50 Bridge would be protective of recreational activities in and on the water in access channels and in the main river channel. Continuing to withdraw 50 mgd when water levels fall below 4.3 ft NGVD would create about 35 additional 1-day and 30-day low water events within the access channels when compared with baseline conditions.

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5.2 WRV-2: Fish and Wildlife Habitats and the Passage of Fish

For this report, fish and wildlife habitats are **defined** as those aquatic and wetland environments required by fish and wildlife – including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species – to live, grow and migrate. These environments include hydrologic conditions (i.e., inundation magnitudes, frequencies, and durations) that support the life cycles of wetland and wetland dependent species, including the passage of fish. Several aspects of fish and wildlife as they pertain to human recreation and aesthetics are examined under WRVs 1 and 6 (Sections 5.1 and 5.6). Water quality parameters, such as dissolved oxygen and temperature, which affect fish passage under low flow conditions, are addressed under the WRV 9 (Section 5.9). Due to the abundant information available and the complexity of this WRV, additional information is provided in Appendix C.

The District conducted the habitat analyses considered in HSW's evaluation (Mace 2004), and set the MFLs based on their extensive field studies and professional judgments. No additional field research on fish passage was conducted as part of HSW's work effort. The vegetative data collected by the District were checked in a qualitative manner during field trips on the section of river under study. HSW used the best information available and note that additional research may be necessary to establish life history requirements for some species considered in the analysis.

The **criteria** for the assessment of the protection of this WRV are "aquatic and wetland environments required by fish and wildlife." The **representative function** used to assess protection is fish passage for a large fish species such as a largemouth bass, bowfin, gar, or sunfish, plus fish habitat requirements. The **general indicator** of protection is floodplain access and fish passage in the main channel as defined by water level. The **specific indicator** is water depth sufficient to allow passage of the larger-bodied fish species within the channel at a selected hydraulic control point(s), for a representative duration, and for water inundation of the floodplain for sufficient durations to allow for recruitment. The St. Johns River is a complex and diverse ecosystem supporting a broad variety of flora and fauna that could potentially be impacted by surface water withdrawals. The floodplain is contiguous with the river and partially isolated by natural levees. The seasonal variability of water levels within the river basin creates cyclical inundation over much of the floodplain, although permanent water typically persists within the main river channels and in the deeper depressions of the floodplain even under low flow conditions.

Native and non-native invertebrate and vertebrate wildlife species occur in this stretch of the St. Johns River basin. Wildlife occupies niches and unique habitats or combinations of habitats, to provide food, cover, and space, including suitable home ranges and territories. Species are expected to occur based on their statewide distribution and dependence on the habitats in the study area (Florida Natural Areas Inventory 2001, FFWCC undated, USFWS 2004a, b).

Interactions of water quality, temperature, and salinity affect the distribution of fish species, depending on their life history. River levels fluctuate seasonally depending largely on precipitation. Some species spawn so that the fry and juveniles hatch and grow out in the marshes and swamps of the floodplain; others respond inversely (Graff and Middleton 2002). Populations of some small fishes increase dramatically during high flows, then decrease just as dramatically during low or drought flows. As water levels drop during the dry season, floodplain fish populations retreat to the main steam channel or become concentrated in shrinking floodplain pools. To maintain this diverse fish assemblage, water level regimes should regularly satisfy temporal and spatial reproductive requirements for channel-dependent species and for species dependent on shallow and deep marshes and wet prairies (Hill and Cichra 2002a, b).

Wetland plants, particularly aquatic macrophytes, vary in sensitivity to inundation or soil water table. Reductions in wetland hydroperiods can result in changes to species composition and structure of wetland communities, particularly during the dry season. Floating leaved aquatic plants recede with the water or are left stranded on the substrate. Submerged aquatic vegetation and emergent vegetation typically have rhizomatous or tuberous roots and can withstand periodic low flows. Generally, facultative wet and obligate wetland tree species will not be affected by temporary, small-scale declines of the water level. Seedlings of some ecotonal species may sprout during the dry period, but these are likely to succumb to saturation when water levels rise. The abundance of mesic or xeric species may also increase in wetland communities and persist after the water elevation rises (Ann Hodgson, personal observation, Lake Tsalapopka, August 23, 2004); the St. Johns River basin currently experiences great variability (Mace 2004). Several invasive native and non-native species occur within the basin and may proliferate further during longer duration high water events, particularly in herbaceous wetland systems (FLEPPC 2003).

Long-term variations in the distribution and extent of each community could affect some terrestrial and aquatic invertebrate production, thus affecting available system energetics and fishery production (Hill and Cichra 2002a, b). Soil oxidation or subsidence in organic soils during low flows could occur, but do not frequently appear to occur under baseline conditions.

5.2.1 Assessment of WRV Protection at the Top of Bank and Higher

The proposed 50 mgd withdrawal scenario would change the recurrence interval of flow stages through the system but would have minimal impact to the vegetative communities and hydric soils existing beyond the top of the banks of the main channels of the river. Near Lake Cone, a hardwood swamp community occurs with a maximum elevation of 8.3 ft NGVD (Mace 2004). Under baseline conditions, the annual 30-day exceedance maximum has a frequency of occurrence of 40%, or 1:2.49 years (Table 5.2-1). The frequency of this flooding event would decrease to about 39% (1:2.55 years), or about 1 less flood event every 100 years under the 50 mgd withdrawal scenario. River floodplain swamps typically experience short hydroperiods while maintaining community integrity (Myers and Ewel 1990).

Also near Lake Cone, a wet prairie occurs up to a maximum elevation of 7.2 ft NGVD (Mace 2004). Under baseline conditions, the annual 30-day exceedance maximum has a frequency of occurrence of about 76%, or 1:1.31 years (Table 5.2-1). The frequency of this flooding event would decrease to about 75%, or 1:1.34 years, under the 50 mgd withdrawal scenario, or one less event per 100 years.

Few studies have been published concerning the effects of water flows and levels on fishes in Florida. The recent literature survey commissioned by the St. Johns River Water Management District to evaluate the importance of water depth and frequency of water levels and flows on fish population dynamics included a review of about 300 relevant studies (Hill and Cichra 2002b). General ecological principles relating water level to fish response are reasonably well known, however few studies link mechanisms with fish population responses relative to water levels. These authors concluded that the FFWCC should continue monitoring fish populations to research effects of flow on fish and evaluate relationships among river levels and habitat availability. Given the lack of studies specifically related to the St. Johns River or other

Florida rivers with similar fish assemblages, some reasonable conclusions were extrapolated from literature.

Fish use of habitats adjacent to the main river channel and movement onto the floodplain during periods of high water vary inter-specifically (Toth 1991, 1993). Several alternative ecological paradigms have been developed to describe the response of fish assemblages to water level. The flood-pulse and river continuum concepts emphasize the importance of floodplains to river productivity and fish population maintenance. The riverine productivity model suggests that within-channel productivity is more important than allochthonous inputs where floodplain inundation is unsynchronized with spawning or nutrient cycling.

High flows have been correlated with fish abundance, particularly small-bodied species, in Florida marshes (Toth 1991, 1993; DeAngelis et al. 1997; Jordan et al. 1998); however, seasonally flooded marshes may retain stranded fishes and produce a net negative demographic balance (Poizat and Crivelli 1997). Conversely, low water levels (associated with drought or drought simulating conditions) often decrease fish populations (DeAngelis et al. 1997; Jordan 1998). During a six-year study in the Escambia River, fish assemblages were stable and persistent regardless of large natural fluctuations of stream flows and salinity (Bass 1985). Maintenance of floodplain fisheries and water bird forage availability may be dependent on the drawdown rate across the floodplain (Lorenz 2000; Lorenz et al. 2002). Several authors have shown that fish assemblage structure was largely determined by the extent of connectivity among floodplain wetlands and the primary channel (Halyk and Balon 1983; Dunson et al. 1997; Galat et al. 1998; Pezold 1998). Broad marshes of the upper St. Johns River show extensive changes in fish populations associated with flood/drought cycles, and numbers, often dominated by cyprinodontiform fishes, dramatically increase then decrease, respectively, with rising and falling water levels (DeAngelis et al. 1997).

As water levels recede, species-specific behavior causes some fishes to move into remaining deeper channels or remain in isolated pools within the floodplain. Physical changes occur with rising and falling water levels; water temperatures typically increase in shallower water, detrital material decomposes at an accelerated rate, and night-time dissolved oxygen levels decrease. Some disjunct ponds, isolated from the primary and secondary river channels, may be formed. Fish population within-channel and in pools may be population sources in succeeding flood cycles.

Table 5.2-1. Frequency and duration parameters for WRV-2: Fish and wildlife habitats and the passage of fish at top of bank and higher

Location	River Mile	Stage	Flow [a/]	Duration	Maximum Annual Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	cfs	days	Current	MFLs	Current	MFLs
Maximum elevation of hardwood swamp								
Lake Cone	208	8.3	2,408	30	2.49	2.55	11.1	10.3
Maximum elevation of wet prairie								
Lake Cone	208	7.2	1,166	30	1.31	1.34	35.7	32.5
Top of bank plus 0.5 feet								
TOSO 528	220	9.0	602	30	1.10	1.13	50.3	46.4
Great Outdoors	215	8.0	473	30	1.06	1.09	59.2	53.4
TOSO North	212	6.8	522	30	1.08	1.10	55.4	50.8
Lake Cone	208	6.5	725	30	1.09	1.14	53.6	49.7
M6	208	6.3	633	30	1.07	1.10	58.3	54.5
H-1	201	5.0	799	30	1.14	1.15	49.7	46.6
Ruth Lake	201	5.1	836	30	1.14	1.15	48.0	45.1
Top of bank								
TOSO 528	220	8.5	454	30	1.06	1.09	60.6	54.7
Great Outdoors	215	7.5	337	30	~1.00	1.06	69.2	63.0
TOSO North	212	6.3	408	30	1.05	1.08	64.1	58.0
Lake Cone	208	6.0	494	30	1.06	1.07	66.5	61.4
M6	208	5.8	402	30	~1.00	1.05	72.2	67.3
H-1	201	4.5	613	30	1.06	1.10	59.4	55.5
Ruth Lake	201	4.6	650	30	1.08	1.10	57.5	53.6

a/ From HEC-RAS rating curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 in Appendix B).

Most species of wading birds are able to forage for fish and invertebrates in up to 6-10 inches (0.5-0.8 ft) of water, depending on bird size. Those smaller fish species that comprise a large part of the diet of these birds, and which reproduce within the floodplain, could swim in water depths of 0.5 ft.

For the transect with the largest change in return interval (Lake Cone), the annual 30-day exceedance maximum has a frequency of occurrence of about 92% (1:1.09 years) under current conditions and a frequency of occurrence of about 88% (1:1.14 years) under the proposed conditions, or a reduction of about 4 flooding events per 100 years (Table 5.2-1). The percent of time flow is exceeded, on average, also is presented for each of the scenarios.

When water levels reach an elevation that approximates the top of the riverbank, the associated flow ranges from 337-650 cfs (Table 5.2-1). At this water level, a 50 mgd (77 cfs) withdrawal scenario represents about 12-23% of the total flow. Habitats at elevations around the top of the riverbank would experience a greater decrease in inundation duration and return frequencies than would those habitats at the higher elevations above the top of the bank, where the floodplain is very broad and flat, with less topographic change. Under baseline conditions, the top of bank elevation is reached 58-72% of the time. Under the 50 mgd withdrawal scenario, the top of bank elevation would be reached 54-67% of the time (Table 5.2-1). Some variability in the structure and species composition of existing wetland systems might be expected; however, dramatic changes in floodplain hydrology currently occur, and the wetland communities described above are not expected to be affected more significantly than they are under baseline conditions.

The top of bank elevations along the transects are similar to the water level component of the minimum average level at each transect (Mace 2004). A 50 mgd withdrawal scenario still results in inundations at these elevations more than 50% of the time (Table 5.2-1). Consequently, floodplain habitats required by fish and wildlife would be protected under the 50 mgd withdrawal scenario. Because the vegetative communities/habitats and soils at and above the top of bank are expected to be protected under the 50 mgd withdrawal scenario, the use of these habitats by fish and wildlife is also expected to be protected. This includes the protection of those endangered, threatened, and sensitive species that use these specific habitats.

Thus, assuming that the current landscape level distribution of habitats within the floodplain remains static within the study area, the 50 mgd withdrawal scenario when river elevations are at or above the top of bank is not expected to influence the population of any bird species nor impact the ability of the fish fauna to continue to move within the system and reproduce successfully.

5.2.2 Assessment of WRV Protection at Elevations Below the Top of Bank

As water levels drop below the top of bank, open water areas within deep marshes will be reduced, open water areas within shallow marshes will dry out, and many secondary channels may become disconnected from the main channel and will have reduced water depths or be dry. Those fish and wildlife species that depend upon the open water main channel habitat are, therefore, those species most at risk from the withdrawal scenario. Once water levels in the river fall to where flow is limited to the main river channels, the effects of a 50 mgd withdrawal scenario may restrict the ability of certain fish species to move from location to location, forage, and survive to reproduce once conditions become favorable to do so.

Colonial nesting water bird breeding success appears to be correlated to low water levels during nesting, when forage availability increases as fish become concentrated in small areas. It is advantageous for wading birds to obtain fishes in temporarily concentrated marshes and sloughs, and, to the extent that declining levels in the main river channel will tend to make foraging easier, wading birds would not be impacted from lowered levels within the channels, as long as these lowered levels do not adversely impact the recruitment of those fish species that rely upon the channels for that function. The net drawdown was not modeled at colonial water bird colonies because water depth data were not available. Future research could confirm deviations from present scenario inundation regimes at known colonies.

The “storage effect” is defined as the ability of populations to “store” production of strong year classes until environmental conditions are favorable. The storage effect is likely most beneficial to highly fecund species that are long-lived or have multiple spawning events during the year (Warner and Chesson 1985). Because fish populations are generally resilient to short periods of poor spawning conditions, populations of such species can survive occasionally adverse water level conditions. Rogers and Allen (2004) have suggested that criteria to help ensure the continued viability of fish populations under MFLs scenarios should focus on the periodicity and duration of low flow events, and that special attention should be given to limiting the frequency low flow events in order to prevent sequential years of adverse effects on fish populations. Low river levels negatively affect fish communities by reducing fish abundance. The threshold used to set withdrawal limits should consider life history attributes and not allow durations greater than the generation time for most species (Hill and Cichra 2002a). Unfortunately, much of these data are insufficiently known for species using the river. Further research would be extremely useful.

Fish population data obtained in 2001-2003 (Appendix C) were used to estimate body sizes for those species expected to be most impacted by very low water levels in the river channels. The most sensitive species of animals to lowered water conditions within the channels of the river are certain species of fish that are limited to the main channels and that require the deepest amount of water to pass from one place to another. The largest bodied fishes, based on FWC electro shocking data, were selected as the surrogates for the fish passage analysis under the assumption that if deep-bodied fishes could swim freely up and down the river channel, smaller fishes could, also. Fish passage for larger bodied fishes therefore is the representative function for this WRV for water levels below the top of bank.

Thompson (1972) developed minimum depth criteria for the passage of fish in typically high gradient streams, based on the body dimensions of large salmonids (such as Chinook salmon), and recommended depths of 0.6-0.8 ft over at least 25% of the stream width. The depth was determined based on migratory behavior of some salmonid species in cold, well-oxygenated water, and these fishes are physiologically dissimilar from Southeastern warm water fishes (Table C.5). Although this fish passage criterion has been recommended in other MFL studies (Southwest Florida Water Management District 2002; Water Resource Associates, Inc. 2004), the emerging concern of fishery resource managers in the state of Florida (Gary Warren, FWC, personal communications, 2004) is that Thompson's criteria should be qualified in transferring them to Southeastern fishes and complemented by recognition of habitat and fish life history requirements in setting Florida MFL fish passage depths. Some physico-chemical parameters and habitat requirements of fish life stages, including ranges of depth, velocity, substrate type and cover type, or reduced forage availability, may not be met temporarily for various species using 0.6 ft (Freeman et al. 1997; Travnichek and Maceina 1994; Travnichek et al. 1995).

Given the concerns of the various fisheries resource managers within Florida about the use of the single fish passage criteria, we chose to examine each channel transect described in Mace (2004) individually to attempt to determine critical stages for each. Transect data (Mace 2004) were examined to estimate water elevations within the larger channels of the river that would represent approximately a 50% reduction in the area of inundation of the channel when compared with areas inundated when the channels were full of water. It was determined that the average within–channel elevation was a good approximation of the level at which half the channel was inundated. Therefore, the mean within-channel elevation for each channel was used as the stage to be modeled for that transect. In places with several large channels along the same transect, the mean elevation representing the shallowest channel depth was utilized. For two of the transects, the mean channel depth represented a depth of slightly less than one foot, which closely approximates Thompson's (1972) depth of 0.8 ft. The stages identified in Table 5.2-2 represent reasonable minimum stages necessary to allow for the passage of a larger fish (such as an adult largemouth bass, gar, tilapia, bullhead or catfishes) through at least a portion of the main channel. The main channels of the river are shallow and constricted during low flows, and water withdrawals are expected to decrease further the amount of lateral habitat available in the channels. Water depths within the channel may not occur uniformly or continuously within the channel, and portions of the channel may not meet this criterion, while it may be met in other channel reaches. Similarly, the criterion may be exceeded in some areas, thus providing additional habitat, but these areas may be isolated or disconnected from other portions of the river.

Given the concerns expressed by representatives of resource agencies over the adequacy of the 0.8 ft channel depth to protect fish passage, HSW also modeled within-channel depths for the same four transects, employing a safety factor of about two (1.6-1.8 ft channel depth) (Table 5.2-3).

Table 5.2-2. Frequency and duration parameters for WRV-2: fish and wildlife habitats and the passage of fish at deepest points at selected transects

Location	Depth at Deepest Point	River Mile	Stage	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
	ft		ft NGVD	cfs	Days	Current	MFLs	Current	MFLs
TOSO 528	1.3	220	4.8	13	1	35.5	2.78	99.6	95.8
Great Outdoors	8.8	215	0.5	0	1	41.7	4.67	99.9	98.0
TOSO North [c/]	0.8	212	4.8	178	1	1.64	1.36	85.3	77.6
M-6	3.4	208	2.6	44	1	28.8	4.95	99.4	98.0
H-1	0.9	201	2.6	193	1	2.21	1.57	92.1	86.3

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 in Appendix B).

c/ Open water sub channel data used in this table (Mace 2004).

At mean channel depths, river flows are extremely low (ranging from 0-193 cfs; Table 5.2-2). A withdrawal of 50 mgd under such circumstances would take all the available flow at some channel locations. At the M-6 transect, the annual one-day non-exceedance minimum of the mean channel depth condition would occur almost six times more frequently, increasing from 3.5% (1:28.8 years) to 20% (1:4.95 years). At the most upstream transect site (TOSO-528), the low water condition would occur more than 12 times more frequently, increasing from 2.8% (1:35.5 years) to 36% (1:2.78 years) (Table 5.2-2), or about 33 additional events per 100 years.

Table 5.2-3. Frequency and duration parameters for WRV-2: fish and wildlife habitats and the passage of fish at depths of twice the deepest points at selected transects

Location	Depth at Deepest Point × 2	River Mile	Stage	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
	Ft		Ft NGVD	cfs	Days	Current	MFLs	Current	MFLs
TOSO North [c/]	1.6	212	5.6	251	1	1.37	1.25	77.0	70.4
H-1	1.8	201	3.5	284	1	1.57	1.29	84.0	78.1
Bathymetry data 2006 [d/]	1.8	220	6.3	56	1	6.95	2.00	97.7	91.8

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).
b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 in Appendix B).
c/ Open water sub channel data used in this table (Mace 2004).
d/ Bathymetry data collected in 2006 were referenced to stage at TOSO-528 to calculate frequency values.

At channel depths of 1.6-1.8 ft, river flows range from 56 cfs at TOSO-528 (for hydraulic control points surveyed in 2006 by Mace) to 284 cfs at the H-1 transect (Table 5.2-3). At the Tosohatchee North transect, the annual one-day non-exceedance minimum depth of 1.6 ft has a frequency of occurrence of about 73%, or 1:1.37 years, which would increase to 80%, or 1:1.25 years, under the 50 mgd withdrawal scenario (Table 5.2-3). At the H-1 transect, the annual one-day non-exceedance minimum under baseline conditions has a frequency of occurrence of about 64%, or 1:1.57 years, which would increase to 78%, or 1:1.29 years, under the 50 mgd withdrawal scenario. The increase in the number of one-day events ranges from about 7 to 36 per 100 years. The percent of time flow is exceeded, on average, also is presented for each of the scenarios.

Fish and wildlife habitats and fish passage would be adequately protected under a 50 mgd withdrawal scenario at levels at or above the top of the channel banks. Differences in return intervals between the baseline and withdrawal scenarios are not large when river levels and flows are sufficient to fill the channels. Based on the available data, however, it is highly likely that at very low flow conditions the recommended withdrawal scenario would have unacceptable impacts to species of fish with respect to their ability to move among locations (Table 5.2-2).

HSW also examined flows relative to known life history requirements and determined that information on microhabitat conditions for various fish species is not available nor mapped at a level of resolution that is possible to assess. Future work could include modeling inundation of submerged and emergent vegetation at various flows below the top of bank.

Several species of fish that utilize the upper portions of the St. Johns River exhibit specialized life history strategies that deserve to be discussed within the realm of MFLs. One of these is the American shad (*Alosa sapidissima*). The landings data suggest that this is not the largest bodied fish species found in the river around SR 50. Hence, this species was not used in the estimates of minimal channel depths. However, the anadromous behavior of this species may make it uniquely sensitive to changes in flows.

American shad and hickory shad (*A. mediocris*) are commercially and recreationally valuable species in the western Atlantic Ocean and a diadromous shad species that occur in rivers of northeast Florida. The historic shad population was reduced by over fishing, and shad stocks were depleted by the 1990s. Landings declined over the last century due to over fishing (Williams and Bruger 1972), declining markets for shad, and netting regulations within the state. Recreational fishing landings and effort have also been declining within Florida, both historically and within the last decade. In addition, it is plausible and increasingly likely that environmental degradation within the St. Johns River or other natural perturbations have impacted Florida’s shad populations. American shad and hickory shad in Florida’s St. Johns River are at historically depressed levels, and at best, can be described as at low but currently stable population sizes (Harris and McBride 2004).

The Atlantic population is now being managed to restore its abundance by inter-organizational commissions (i.e., Atlantic States Marine Fisheries Commission, South Atlantic Fisheries Management Council). American shad are anadromous with moderate fidelity to their natal river, so each river’s population of American shad may be considered a separate management unit (McBride 2000). Tagging evidence indicates that all American shad migrate to Canada before returning to their natal river to spawn again (McBride 2000). For the purpose of this report, the St. Johns River is defined as a separate management unit of American shad, because the St. Johns River is the only river in Florida with sufficient data regarding an American shad spawning population. The St. Johns River shad population migrates to Nova Scotia, and returns after four years to spawn in the river during winter. American shad tagged within the St. Johns River were not recaptured outside the river, supporting a semelparous life history (McBride 2000). Adults occur in the St Johns River during winter-spring (November-May), and juveniles occur during spring-autumn and during winter in some years (Harris and McBride 2004).

Florida's American shad today are smaller on average than historic estimates of mean length, and the proportions of female American and hickory shad are markedly lower than historic estimates. Biological studies and descriptions of Florida's *Alosa* fisheries are also reported in Williams and Bruger (1972) and McBride (2000). These studies provide habitat-based management recommendations, particularly with regard to proposed alterations of river flow and channelization in Alosa spawning areas. Harris and McBride (2004) recently completed a review of habitat requirements, specifically in relation to river water levels and flows.

In the St. Johns River, few shad enter the river until river water temperatures fall below 20˚C, generally in November, and peak shad numbers occur when water temperatures are their lowest (15˚C); and spawning adult American shad were reported in the river from November to May (McBride 2000). A dam at the downstream end of Lake Washington, at rkm 415, has in some years set the upper limit of spawning. This dam was installed sometime early in the last century (McBride 2000). It has a low flow discharge design, and fish are not impeded in high water level years.

A unique, reproductively isolated population spawns in the freshwater St. Johns River between Lakes Monroe and Poinsett, centered around SR 50 (McBride 2000). Shad spawn in the winter (December-April, mostly February-March). Williams and Bruger (1972) identified spawning substrates as sandy or a mix of sand and mud. Moreover, they concluded that, within the river, "current, depth, and bottom contour and type apparently determined spawning locations, with most spawning occurring in currents of 1-1.5 ft/sec (0.3-0.45 m/sec) where there is a clean sand bottom less than 4 m in depth" (Williams and Bruger 1972). Spawning may occur over a broader current velocity of 20.5 to 91.4 cm/sec (Harris and McBride 2004), and from depths of 1.2 to 7.0 m. Harris and McBride (2004) reviewed the literature for habitat requirements of American shad and hickory shad, in relation to the low flow conditions that are typical of the St. Johns River.

Temperature, photoperiod, current velocity, turbidity, depth, bottom type and bottom contour appear influential to the onset of spawning and spawning location (Harris and McBride 2004; Williams and Bruger 1972). They are reported to need dissolved oxygen at 5 mg/L (Harris and McBride 2004). Spawning locations are variable inter-annually within the river depending on current velocity and temperature, and the extent of the spawning ground is probably not known. The importance of the area between Lakes Harney and Poinsett increased in low flow years when there was little current above Lake Harney (Williams and Bruger 1972). Literature suggests the elevation gradient between Lakes Harney and Poinsett is apparently great enough to produce a sufficient current in the upper river and support shad spawning even during low water conditions (McBride 2000; Williams and Bruger 1972). Williams and Bruger (1972) suggested that American shad require a minimum current of 1 ft/sec upstream from Lake Harney to prevent siltation and ensure successful egg incubation. However, actual current measurements in this stretch of river do not appear to reach 1 ft/sec on a frequent basis at lower flows. Survival and larval growth were greatest when flow volumes were low (50-100 m^3/sec) and temperatures were high (10-14 °C) (McBride 2000). Survival might decrease with increased flow because increased flow is correlated with increased turbidity, which might harm larvae (McBride 2000). Shad fry moved downstream in the spring as water temperatures increased and emigrated when water temperatures in November and December dropped to 14.9 °C. Under low flows, shad may not exit the river.

American eels (*Anguilla rostrata*) also utilize the river. Harris and McBride (2004) reviewed the present status of American eels in Florida. Eels are catadromous and, hence, may be sensitive to flow reductions. Eels are distributed throughout most Atlantic coastal rivers. Commercial landings of eels have declined through the 1990s, and eels are used recreationally generally as bait. Mature eels migrate from rivers when temperatures drop below 17-20 °C. After offshore spawning elvers arrive generally in the spring in estuaries, then migrate upstream when temperatures reach 10-12 °C continuing to 19 °C. Current velocity did not appear to affect upstream migration. American eels are ecological generalists and use clear streams to turbid rivers. Eels were found in rivers between 13-27 °C, salinities ≤12 ppt, and D.O. 5-9 mg/L. Basic life history and population dynamics research is needed, but the relatively wide ecological niche for this species would indicate it to be less sensitive to flow reductions than the American shad.

HEC-RAS analysis of flow velocities in this river reach showed that 1 ft/sec is seldom achieved under existing conditions at SR 50, especially during the shad spawning season of November-May. Existing velocity conditions are approximately 0.7 ft/sec mean channel average and rarely achieve the 1 ft/sec criterion, based on the nearest USGS gauging stations. Nonetheless, shad populations clearly utilize this stretch of river successfully. American and hickory shad populations are apparently protected under existing discharge conditions and are reproductively successful despite conditions where the current velocity is usually below 1 ft/sec and may reverse intermittently under existing discharge volumes. In the absence of site-specific information related to minimum currents required by the local shad populations in the area around SR 50, we relied upon the predicted percentage of changes from baseline to the MFL conditions, assuming that baseline conditions were protective of the shad. With respect to the less-than-1 ft/sec velocity that will occur less often under the proposed MFL conditions in this stretch of river, it is reasonable to assume that shad will be little impacted at SR 50 by a withdrawal of 50 mgd since this 1 ft/sec velocity occurs at flow rates on the order of 7,000 to 10,000 cfs. The shad is recognized as a very important species in the St. Johns River and additional research is needed on critical metrics for shad habitat, reproduction, and movement in the river. American eels, which have wider tolerance of ecological conditions, also should also be protected under the proposed MFL scenario.

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5.3 WRV-3: Estuarine Resources

For this report, the evaluation of the estuarine resource is based entirely on recent work completed by others (ECT 2006), which is included by reference and as Appendix F. The evaluation was based on simulations provided by SJRWMD using the EFDC model. The model was used to project changes in the salinity regime of the lower Saint Johns River (LSJR) as a result of increased cumulative surface water withdrawals from the St. Johns River near DeLand (SJRND). An assessment of the effect the projected salinity changes would have on aquatic life in the LSJR was also performed.

The EFDC model was run for the baseline flow conditions and for three other flow scenarios, which reflect the withdrawal of surface water from the SJRND at the maximum rate of 120, 240, and 360 cfs. Statistical analyses for the four simulated scenarios were performed and comparisons were made to quantify the changes in average salinity regime. Summary results are as follows:

- The projected increase in average salinity in the LSJR over the 5-year simulation period due to a maximum withdrawal of 240 cfs from the SJRND is small when compared with the daily variability in salinity currently observed in the LSJR caused by tidal transport.
- The projected average increase in salinity as a result of the surface water withdrawals may have a minor effect on the distribution of some aquatic species. The average 5-ppt isohaline of the average daily maximum salinity during the dry season is estimated to move upstream about 0.6 miles, and may impose slight stress on freshwater plant habitat. The species composition of the river is not expected to change.
- The increase in daily maximum salinity due to a maximum 240-cfs withdrawal from the SJRND will be quite small. For example, the increase in daily maximum salinity will be about 0.4 ppt in the 5-ppt average salinity zone under a 240-cfs withdrawal from the SJRND. A maximum withdrawal of 240 cfs from the SJRND will not greatly change the absolute maximum salinity in the LSJR.
- The potential DO decrease under the preliminary MFLs regime is determined to be negligible.

Based on the results of the salinity assessment in the LSJR, ECT concluded that a maximum withdrawal of 240 cfs from the SJRND, as limited by the preliminary MFLs regime, will protect the estuarine resources.

References:

Environmental Consulting & Technology, Inc. (ECT). 2006. Water Resources and Human-Use Values Assessment: Lake Monroe, Volusia and Seminole Counties, Florida. Prepared for the SJRWMD, Division of Water Supply management, Palatka, FL.

5.4 WRV-4: Transfer of Detrital Material

The term "detritus" has different meanings, depending on the field of study. For this WRV analysis, the transport of detritus is **defined** as the movement by water of loose organic material and debris and associated decomposing biota. The organic particles consist of microbially altered vegetation, including leaves and wood, and the particles are consumed as high quality food by organisms living in the stream. In other contexts, detritus may refer to either inorganic or organic disintegrated matter. Inorganic constituents are discussed separately, under WRV-8 (sediment loads).

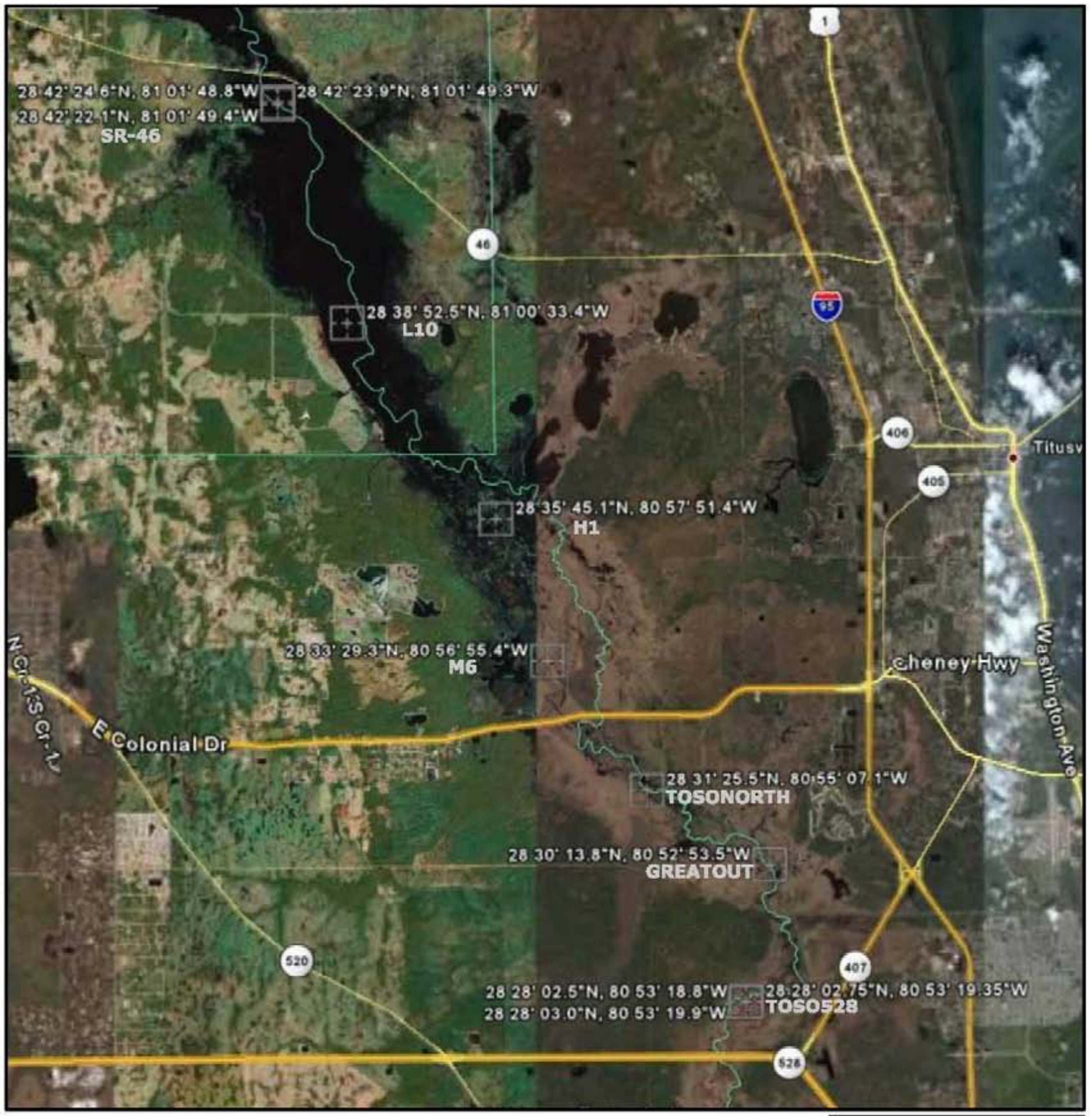
The **criterion** for protection is "the transfer of loose organic materials." The **representative functions** used to assess protection are water depth and inundation of the flood plain. The **general indicators** of protection for high water conditions are depths of water in the floodplains. **Specific indicators** of protection are the return interval of a stage associated with depth and area of inundation necessary for adequate detrital transfer to the water column, which does not differ unacceptably from baseline conditions.

Detritus can be transferred into a stream from the floodplain during both low and high water events. Therefore, detrital transfer with respect to protecting this WRV is event-driven, as is sediment transport. However, total detrital transfer to the stream itself also depends on the seasonal and vegetative growths, the effects of which are difficult to quantify and would require additional study beyond the scope of assessing protection of this WRV.

As an example of seasonal effects, Mehta et al. (2004) presents data from a study by Kroening (2004) that compares total suspended solids (TSS) and streamflow with time in the St. Johns River near Deland and near Christmas. Kroening found a reciprocal relationship between flow data and TSS. TSS was high in spring/early summer, whereas current velocities peak in autumn/winter. This is rationalized as the TSS not being detrital, but rather authigenic. The reason for the reciprocal relationship between flow and TSS can be explained by the peak in primary production, as measured by chlorophyll-*a*, which occurs in spring/early summer. Mehta et al. (2004) further indicates that herbicidal spraying adds organic rich black mud throughout the SJRWMD and "possibly overwhelms other sediment sources such as detrital transfer by natural means." Detrital transfer of organic materials from the floodplain also depends on vegetative supply, which is seasonal. The stretch of river for this study is in a rural area composed of protected lands (Mace 2004). Vegetation is thick in most of the floodplain, providing a rich source of detritus. However, Mace (2004) notes that the vegetation composition and dominance in the adjacent floodplain changes dramatically throughout the year because of cattle grazing, seasonal weather patterns, fire, and inundation. For example, significant shifts in frequency of inundation would affect the vegetative communities, but assessing the detrital production rates associated with those communities is too complicated an endeavor to adequately address here, nor is it specifically relevant to protecting this WRV. In addition, if the frequency of inundation is not significantly changed, then this becomes less of an issue. Finally, Mace (2004) states that habitat will be preserved by the MFL, so a reduction in vegetation is not expected.

Detrital transfer and transport is difficult to predict because it is site-specific, and limited data exist. To address data limitations and to obtain a better understanding of the system, HSW collected bed sediment samples from the deepest point (the thalweg) at seven locations in this reach of the river (Figure 5.4-1). At the two locations that bound this reach (SR 46 and SR 528), samples also were collected near the left and right banks. These samples were collected on May 10, 2006, during very low water level conditions, and the analytical results compared with three samples collected by Battelle for the District (Durell et al. 1998) nearly a decade ago (Table 5.4-1). One of these three comparison samples, labeled SRS (SR 50), was collected at SR 50, and the other two were collected from locations immediately downstream of our project reach.

The total organic carbon for this section of river is very low, less than 1% at all locations except two (M6 and TOSONORTH). At M6 and TOSONORTH, which are located on either side of SR 50, total organic carbon was 1.1% and 1.9%, respectively. Samples from these two locations had a higher percentage of fine cohesive material (silt and clay) than samples collected from the other locations. These results are very similar to the results reported by Durell et al. (1998). The bed sediments at the remaining locations are classified as silty sand and have very little organic material. This information indicates that there is little organic matter present in the bed sediments during low flow events in late spring. Samples did not provide any indication of the organic rich black mud that may occasionally occur in the river (Mehta 2004).



0 1.5 3
MILES

	Sample Depth (ft)		
Transect	West Bank	Thalweg	East Bank
SR-46	1.3	3.9	0.8
L10	NS	1.5	NS
H1	NS	3	NS
M6	NS	9	NS
TOSONORTH	NS	3	NS
GREATOUT	NS	6	NS
TOSO 528	0.8	2	1.2

Legend

28 28' 02.5"N	Latitude Coordinate
80 53' 18.8"W	Longitude Coordinate
	Sediment Sampling Location
TOSO528	Sediment Sampling Transect
NS	Not Sampled

Note: aerial photograph adapted from Google Earth

SJRWMD
SR 50 Reach MFL
Sediment Sampling Locations
May 8, 2006

HSW

Figure 5.4-1. Sediment sampling locations in May 2006

Table 5.4-1. Bed sediment composition in percent along the St. Johns River near SR 50

Sample ID [a/]	Moisture	TS [a/] (wet wt)	TOC [a/]	TVS [a/] (dry wt)	Gravel	Sand	Silt	Clay	Mud [a/]	Sample Depths (ft)
SR46-EB	29.2	70.8	0.33	No [b/]	2.1	82.8	13	2.1	15.1	0.8
SR46-WB	29.8	70.2	0.24	No	8.7	79.0	10.2	2.1	12.3	1.3
SR46-TH	22.7	77.3	0.26	No	14.5	82.0	2.6	0.9	3.5	3.9
L10-TH	36.3	63.7	0.84	No	4.4	80.7	10.2	4.7	14.9	1.5
H1-TH	35	65	0.46	No	2.1	87.3	6.4	4.2	10.6	3.0
M6-TH	49.3	50.7	1.1	No	8.5	74.4	10.8	6.3	17.1	9.0
TOSONORTH-TH	48.6	51.4	1.9	No	0.8	62.4	28.3	8.5	36.8	3.0
GREATOUT-TH	34	66	0.72	No	3.5	88.2	5	3.3	8.8	6.0
TOSO528-EB	32.2	67.8	0.4	No	3.3	90.1	6.6	0	6.6	1.2
TOSO528-WB	35.7	64.3	0.89	No	4.7	84.2	9.2	1.9	11.1	0.8
TOSO528-TH	28.3	71.7	0.37	No	0	96.5	3.5	0	3.5	2.0
02236000 [c/]	61.6	38.4	2.35	7.2	NR [a/]	64.5	32.9	2.6	35.5	NR
20010003 [d/]	59.6	40.4	2.03	4.3	NR	62.7	34.5	2.7	37.2	NR
SRS (SR50) [e/]	45.9	54.1	1.33	3.7	NR	63.0	28.7	8.3	37.0	NR

a/ EB = east bank; WB = west bank; TH = thalweg; TS = Total Solids; TOC = Total Organic Carbon; TVS = Total Volatile Solids; Mud = silt and clay; NR = Not Reported
b/ Not detected above the minimum detectable limit (MDL) of 10%
c/ St Johns River near Deland (Durell et al. 1998)
d/ St Johns River near US Highway 17 & 92 (Durell et al. 1998)
e/ St Johns River near SR 50 (Durell et al. 1998)

Organic detritus tends to adhere to surfaces and to flocculate, making its behavior difficult to predict (see Section 5.8, WRV-8). However, some broad conclusions may be drawn. The protection of detrital transfer and transport during high water and low water conditions is related to the changes in current velocities between the baseline and MFLs conditions for each case. Protection also depends on maintaining the hydroperiod characteristics of the floodplain, especially high-flow conditions (ECT 2003). The velocities found in the river at the USGS gage near Christmas, at SR 50, are well under 1.0 ft/sec for the entire year (Figure 5.4-2). The higher flows are associated with a velocity of approximately 0.50 ft/sec and higher. Although detritus particles range in size, their cohesive nature may be more similar to silts and clays than to heavier particles like sand. The District's HEC-RAS model could be used to predict decreases in velocity for the MFLs conditions. If the change in velocity and in inundated floodplain width is negligible, then the vegetative supply from the banks and the transport of detritus downstream should remain unaffected.

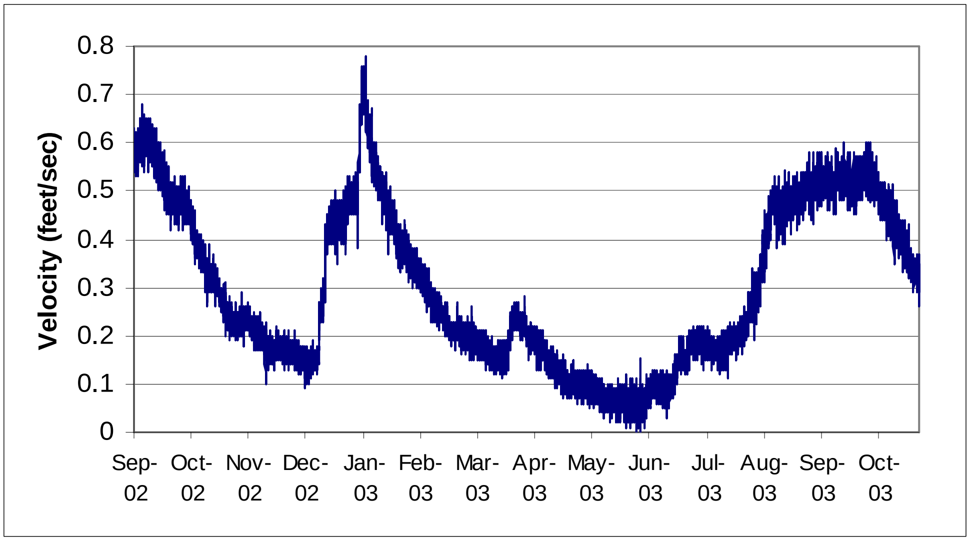


Figure 5.4-2. U.S. Geological Survey velocity data for St. Johns River near Christmas, Florida, depicting a representative range of water velocities for this stretch of river

The District's HEC-RAS results consistently predict depth-averaged longitudinal velocities in the floodplains to be less than 0.2 ft/sec (and less than 0.1 ft/sec for many cross sections). In broad floodplains such as these, it is easy to envision the transverse velocities being even lower, especially in regions of excessive vegetation, where cattle grazing is limited. Under these conditions, the transverse movement of detritus will be limited and the transfer of detrital material into the channel from the floodplain will largely occur in the zones immediately adjacent to the channel. Therefore, the key parameter is bank-full stage. If the water rises above bank-full and inundates the zone immediately adjacent to the channel, then the transfer of detrital material to the channel will be preserved.

As a graphical representation of this process, Mehta et al. (2004) present a model to predict the transfer of detrital material from a floodplain to the channel (see Figure 5.4-3). The lateral mass load (i.e., the detrital mass transfer per unit length of river), g_{sL}, can be represented mathematically as

$$g_{sL} = \frac{K}{L}\left(A_o - A_N\right)^m$$

where A_o, A_N, and L are defined in Figure 5.4-3 and K and m are site specific constants (ECT 2003).

However, for MFL analysis, the magnitude and duration of the water level is held constant such that $A_o = A_N$. In addition, for this stretch of river, it is hypothesized that a majority of detrital transfer will occur in the zone adjacent to the channel (comparable to area A_N in the figure). As such, the important factor with regards to protecting this WRV is not the overall lateral mass load, which is highly site-specific (ECT 2003), or the reduction of area (as implied by the figure), but rather that the relative frequency of occurrence of A_N is not significantly impacted under the proposed MFL. To be conservative in our analysis, the average floodplain inundation was set to be 1.0 ft of water. This ensures that A_N will be of sufficient size and that the transfer of detrital material does occur.

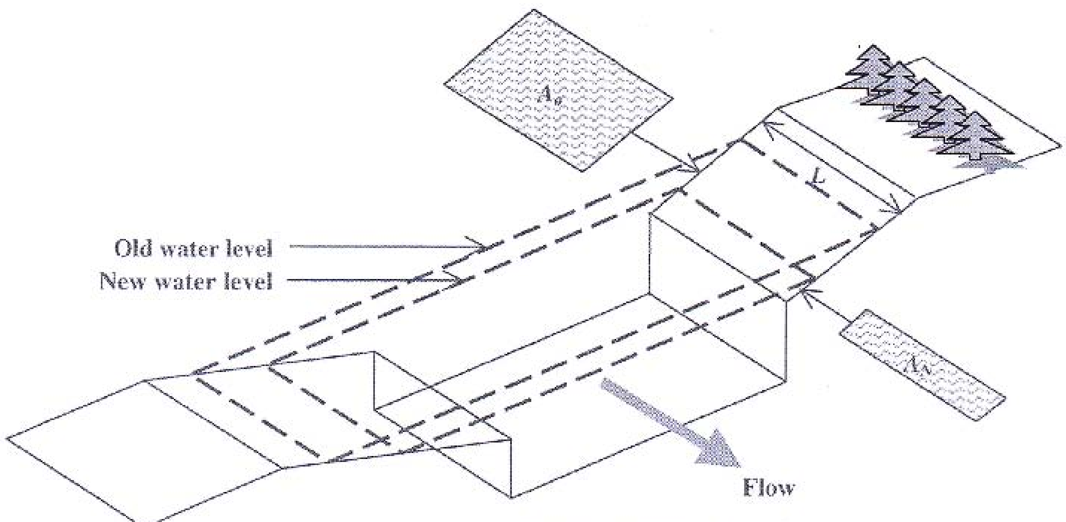


Figure 5.4-3. Detrital transfer loss due to water level decrease (Mehta et al. 2004)

Using the ground surface elevations in the floodplains of the seven transects evaluated by Mace (2004), an approximate stage that preserves the historic transport of detritus can be estimated. Because the area of inundated floodplain is critical, the protection of stream stage and its associated area of coverage is the end goal. If, for example, 1.0 ft of depth over the floodplain surface is needed to protect detritus, then adding one foot to the average ground elevation along each transect would provide an estimate of stage. Approximate stages for the seven transects (Appendix E) based on a 1.0-ft depth are provided in Table 5.4-2. The average floodplain elevation was determined by first excluding any open channels, sloughs, and lake bottoms from the transects and then using the average elevation of the larger vegetative communities to calculate an overall average floodplain ground surface elevation. The water ward edge of hydric hammocks was considered the edge of the floodplain, so the ground elevations in the hammocks were not included in the averaging.

Table 5.4-2. Approximate stage required for a one-foot depth over the average floodplain elevation of seven transects along the St. Johns River near SR 50

Transect Name	River Mile	Average Ground Elevation (ft NGVD)	Approximate Detrital Transfer Stage (ft NGVD)
TOSO 528	220	9.4	10.4
Great Outdoors	215	8.3	9.3
Tosohatchee North	212	7.6	8.6
M-6	208	6.5	7.5
Lake Cone	208	7.0	8.0 [a/]
H-1	201.5	5.4	6.4
Ruth Lake	201.5	5.5	6.5 [a/]

a/ Not including the lake. The values shown consider the floodplain elevations only.

Table 5.4-3. Frequency and duration parameters for WRV-4: transfer of detrital material

Location	River Mile	Stage	Flow [a/]	Duration	Maximum Annual Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	cfs	days	Current	MFLs	Current	MFLs
TOSO-528	220	10.4	1,625	1	1.40	1.48	15.8	14.4
Great Outdoors	215	9.3	1,281	1	1.19	1.25	23.2	21.2
TOSO North	212	8.6	1,657	1	1.42	1.55	15.2	13.9
M-6	208	7.5	1,509	1	1.23	1.27	25.3	23.2
Lake Cone	208	8.0	2,079	1	1.44	1.53	14.9	13.6
H-1	201.5	6.4	1,697	1	1.30	1.34	21.1	19.7
Ruth Lake	201.5	6.5	1,774	1	1.32	1.35	19.8	18.3

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 of Appendix B).

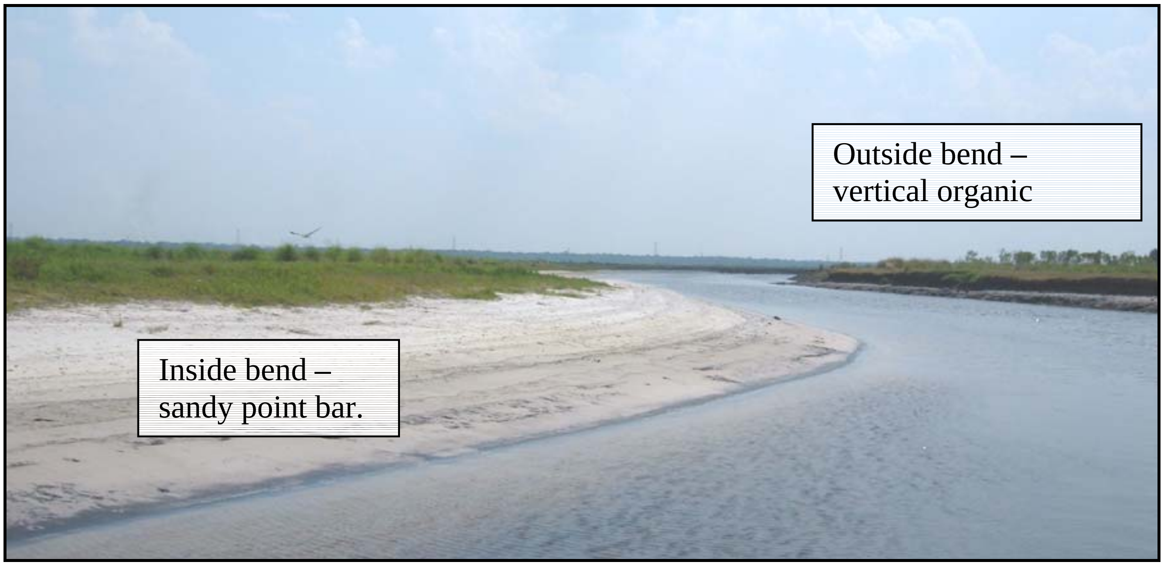


Figure 5.4-4. St. Johns River near SR 528

Figure 5.4-5. Three-foot organic layer on top of sand layer

Because the process of transfer of detrital material occurs at high flows, it is presumed to be short-term event-driven, and the return interval of a one-day maximum stage (or associated flow) is an appropriate measure of the effect of surface water withdrawal. Under baseline conditions, the annual one-day exceedance maximum of levels that inundate a substantial portion of the floodplain to a depth of 1.0 ft has a frequency of occurrence of 69-84% (or 1:1.44 years to 1:1.19 years) at the seven transects. Under the proposed 50 mgd withdrawal scenario, the annual one-day exceedance maximum would have a frequency of occurrence of about 65-80%, or 1:1.55 to 1:1.25 years (Table 5.4-3), or a decrease of about 4 events per 100 years. The percent of time flow is exceeded, on average, also is presented for each of the scenarios. While a majority of the focus belongs on high water events, there is also transfer of detrital material into the channel that occurs during low flow events. The main channel of this section of river has a gentle meander pattern in which sandy point bars alternate with vertical organic banks (Figure 5.4-4). It was observed by the team that, during extreme low-flow events such as those present during May of 2006, boat wakes from airboats cause significant erosion of organic bank material from the outside of bends. Near SR 528, a 3+-ft layer of organic-rich deposits was observed resting on top of a layer of sand, which is also several feet thick (Figure 5.4-5). This is an obvious example of transfer of organic material to the channel that occurs even during low flow periods.

Based on the results of the frequency and duration evaluation discussed above, the shift in frequency will not appreciably affect the transfer of detritus within this segment of the river. HSW concludes that this water resource value will be protected under the proposed MFLs regime.

References:

Durell, G., Seavery, J.A., and Hunt, C.D. 1998. Sediment quality in the St. Johns River Water Management District: Physical and Chemical Characteristics – Revised. Special Publication SJ 98J169 prepared for the St. Johns River Water Management District by Battelle Duxbury Operations.

Environmental Consulting & Technology, Inc. 2003. *Environmental Evaluations for the Development of Minimum Flows and Levels for the St. Johns River near Deland at State Road 44, Volusia County*. Prepared for the St. Johns River Water Management District.

Kroening, S. 2004. Streamflow and water quality characteristics at selected sites of the St. Johns River in central Florida, 1993 to 2002. U.S.G.S., Altamonte Springs, FL.

Mace, J. 2004. *Draft Preliminary Levels Determination: St. Johns River at State Road 50, Orange and Brevard Counties.* Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

Mehta, A.J., Hayter, E.J., and R. Kirby. 2004. *Sediment Transport and Detrital Transfer Changes Related to Minimum Flows and Levels*. Special Publication SJ2004-SP31 prepared for the St. Johns River Water Management District by the University of Florida.

5.5 WRV-5: Maintenance of Freshwater Storage and Supply

For this analysis, maintenance of freshwater storage and supply is **defined** as the protection of an existing amount of freshwater for existing permitted users. The **criterion** for protection is the amount(s) of surface water and groundwater that are currently permitted to be withdrawn. Our analyses focus on the effect that additional permitted surface water withdrawal may have on existing permitted surface water and groundwater users. The **representative function** used to assess protection is the maintenance of adequate surface water levels and aquifer levels in the area adjacent to the water withdrawals. The **general indicators** of protection are aquifer levels that do not result in adverse impacts. The **specific indicators** of protection examined include the types of existing groundwater withdrawal, the historical aquifer levels, and an evaluation as to whether the groundwater-surface water interactions will change as a result of the MFLs to the extent that existing, permitted groundwater withdrawals will result in new low pressure levels in the aquifer.

Maintenance of adequate aquifer levels is assessed by evaluating both surface and groundwater withdrawals and also by examining the aquifer recharge characteristics within the study area. Water withdrawal and storage relationships can be complex with respect to how they affect water bodies. Groundwater withdrawals can indirectly reduce river flows by increasing the amount of induced groundwater recharge over a given stretch of river, and by decreasing base flows to the river. The District's evaluation of consumptive use permits (CUPs) involves a cumulative impact analysis whereby existing CUPs are taken into account in the evaluation of a new CUP. Consequently, all significant withdrawals within this portion of the river and upstream would be accounted for in models used by the District.

The District CUP database was searched to determine if any groundwater and/or surface water withdrawals are taking place in the vicinity of the St. Johns River within the study area that may impact flows and levels within the river (Table 5.5-1, Figure 5.5-1). The District's Palatka office also was contacted and inquiries made regarding CUPs within the study area. According to the District, no significant permitted water users located near the SR 50 reach of the St. Johns River are withdrawing water from either the Floridan or surficial aquifers. There are three permitted groundwater users along this entire reach, with a permitted allocation totaling 283.48 million gallons per year (MGY). The largest of these is Lee Ranch in Oviedo, Florida, with a permitted allocation rate of 139.6 MGY (less than 0.4 million gallons per day [MGD]). The only permitted surface water user near the SR 50 reach of the River (Great Outdoors RV/Golf Resort), as well as the other permitted surface water users, are included in the basin water budget model and the cumulative consumptive use approach that was utilized for the MFL model scenario. Therefore, the MFLs protect existing permitted users from the impacts associated with the development of new water uses.

Table 5.5-1. CUP allocations near the SR 50 reach of the river

Permit ID	Issue Date	Expire Date	Permit Status	Project Acreage	Total Number of Wells	Total Number of Pumps	Current Year Water Allocation (MGY)	Allocation Source
8305	4/99	4/19	Active	160	1	0	23.8	Ground
8833	12/01	12/21	Active	141	1	0	120.08	Ground
10914	6/96	6/11	Active	460	8	5	0	Surface
10914	6/96	6/11	Active	460	8	5	139.6	Ground
1818	1299	12/19	Active	1069	0	3	600	Surface
7612	7/86	7/87	Expired	1680	--	--	0	None

The maintenance of freshwater storage could be adversely affected if the study area is a recharge area, particularly to the Lower Floridan aquifer, which is typically used for production well purposes. The top of the Upper Floridan aquifer in the study area is generally less than 100 ft below land surface (bls) and the top of the Lower Floridan aquifer is 400-500 ft bls (Tibbals 1990), with a 300-to-400 foot thick semi-confining unit separating the two zones. Boniol et al. (1993) developed a recharge map that includes the study area, and Tibbals (1990) derived rates of recharge and aerial discharge as diffuse upward leakage from a computer model of the Floridan aquifer system. These studies, along with others, both regional and local (Phelps 1984, 1990; Vecchhioli et al. 1990), indicate that recharge to the Floridan aquifer, both Upper and Lower, is unlikely within the study area, and, therefore, the proposed 50 MGD withdrawal scenario should not impact groundwater recharge.

There are no frequency or duration parameters to evaluate for this WRV. The absence of groundwater withdrawal wells within the study area, along with the aquifer characteristics (non-recharge area), indicate that the proposed surface water pumping will be protective of WRV-5.

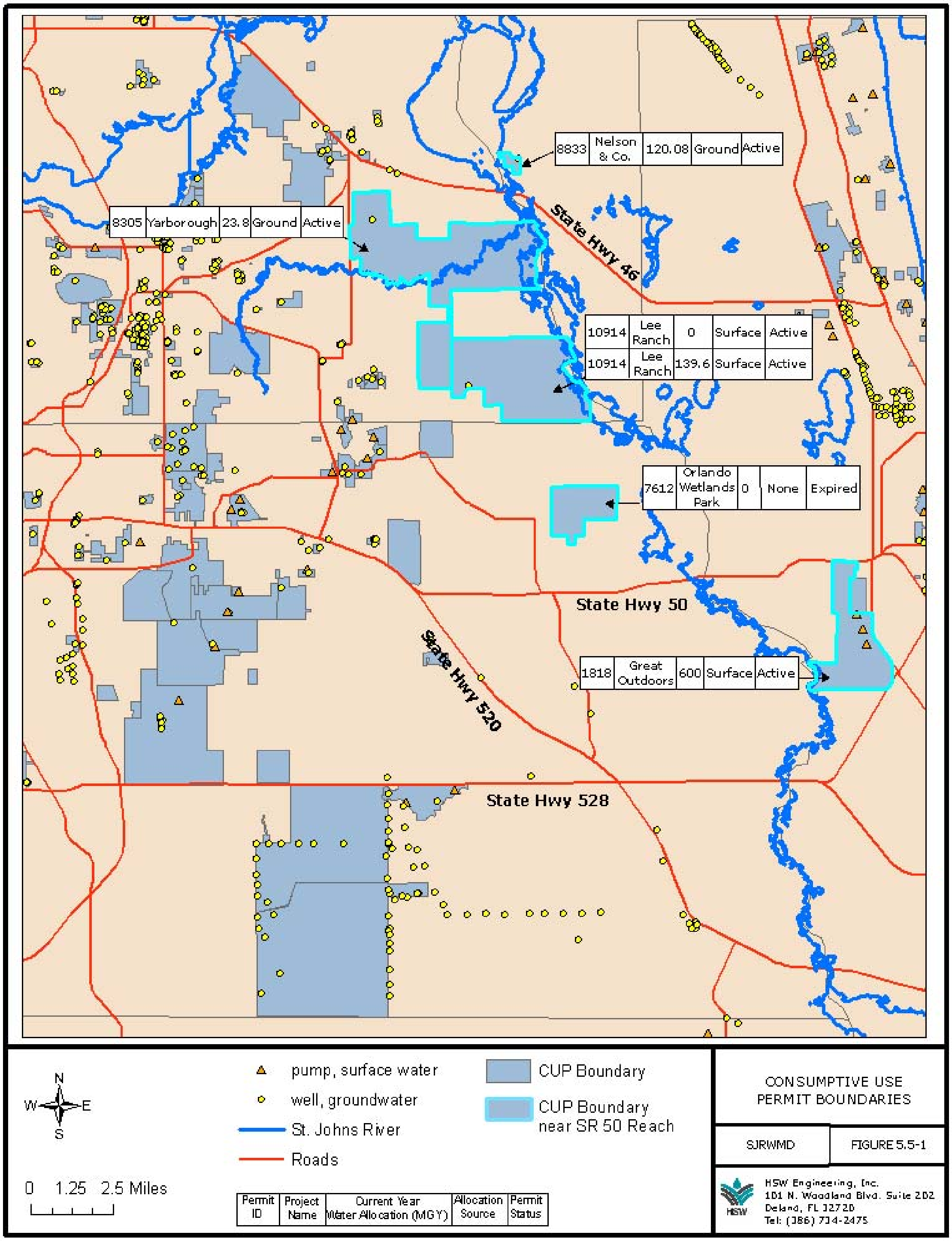


Figure 5.5-1. Location map showing CUP allocations near the SR 50 reach of the river

References:

Boniol, D., Williams, M and Munch, D. 1993. *Mapping recharge to the Floridan aquifer using a geographic information system.* St Johns River Water Management District Technical Publication SJ93-5

Phelps, G.G. 1984. *Recharge and Discharge Areas of the Floridan Aquifer in the St. Johns River Water Management District*. U.S. Geological Survey Water Resources Investigation Report 82-4058.

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Tibbals, C.H. 1990. *Hydrology of the Floridan aquifer system in east-central Florida.* U.S. Geological Survey Professional Paper 1403-E.

Vecchioli, J., Tibbals, C.H., Duerr, A.D., and Hutchinson, C.B. 1990. *Ground-water recharge in Florida – a pilot study in Okaloosa, Pasco, and Volusia counties*. U.S. Geological Survey Water Resources Investigation Report 90-4195.

5.6 WRV-6: Aesthetic and Scenic Attributes

For this analysis, aesthetic and scenic attributes are **defined** as those features of a waterscape usually associated with passive uses such as bird watching, sight seeing, hiking, photography, contemplation, painting, and other forms of relaxation that usually result in human emotional responses of well-being and contentment. Taken together, these may be considered as “passive” recreation. “Active” recreation activities have been examined under WRV-1 (Section 5.1).

For WRV-6, aesthetic and scenic attributes, the **criteria** for protection will be passive recreation. The majority of forms of passive recreation primarily involve the visual sense. Therefore, the **representative function** used to assess protection of this water resource value is the visual setting at select points. The **general indicator** of protection is the stage of the river. The **specific indicator** of protection is the return interval of the stage of the river associated with optimal scenic and wildlife viewing that does not differ unacceptably from baseline conditions.

In contrast to portions of the St. Johns River downstream from SR 46, where there are lakes with homes, parks, marinas, etc., the portion upstream from SR 46 to SR 528 is largely undeveloped. Over the entire 30 miles of river, only three river crossings exist: one at the southern end - SR 528; one in the approximate middle – SR 50; and one at the northern end – SR 46. Public views of this stretch of river from these crossings can be accomplished by pulling off the road (in the case of SR 528), pulling into a boat launch area (in the case of SR 50), or pulling into a boat launch area/marina (in the case of SR 46). Public opportunities to photograph the river or capture the river from the shore in a painting would be largely limited to these few locations. Public views of this section of river are most productive when conducted from a watercraft.

The floodplain over this entire stretch is very wide (up to four miles at some locations). Anyone walking along the upland edge of the floodplain would be a considerable distance from the main river channel. Views of the main channel from the upland floodplain edges would be few. There are not many hikers in this area (Peter Henn, personal communication, June 25, 2004). Few trails and public access points exist. The trails that do exist for public use are located within the Tosohatchee State Reserve (Tom O’Neill, personal communication, July 8, 2004), Seminole Ranch Wildlife Management Area, and Canaveral Marshes Conservation Area (Peter Henn, personal communication, June 25, 2004). Based on the field survey conducted along the main channel of the river on May 5, 2004 (HSW 2004a), public hiking trails were not noted close to the main channel of the river. The existing public trails are, for the most part, a considerable distance from the main channel of the river, so there are very few views of the main river channel. These trails are more likely to be negatively impacted by unusually high water conditions (flooding) than they are by low water conditions. Much of the time the river marsh is too wet to be used by the casual hiker (Tom O'Neill, personal communication, July 8, 2004). Lower water conditions would tend to be more conducive to hiking activity (Tom O'Neill, personal communication, July 8, 2004). Visually, walkers along the public trails cannot determine what the water levels are in the main channels. Walkers along the trails are able to visually determine only whether the floodplain is inundated or not. Due to the floodplain vegetation, walkers along the trails cannot visually determine whether the floodplain contains one inch or several inches of water. Consequently, small changes in water levels within the channels or within the floodplain itself cannot be determined visually from the majority of public access points.

Even from the boat launch areas close to the main river channel, it would be difficult to visually distinguish a water level variation of only a few inches. During periods of high-flow, a withdrawal of 50 mgd would represent a very small portion of the flow, with water level reductions on the order of a few inches compared with baseline conditions. For people viewing this portion of the river from trails along the upland edges of the floodplain, such small changes will be protective of the scenic and aesthetic attributes of this portion of the St. Johns River. What would be modified slightly is the amount of time the floodplain would be inundated at a given elevation. Visually, viewers from the trails would be noting the vegetation within the habitats close to where they would be walking.

According to the graphical representations and detailed descriptions of vegetation found in Mace (2004), the botanical communities located at the higher elevations (i.e., in the areas most likely to be viewed by persons on the trails) include the following.

> <u>Wet prairie and palm hydric hammock communities at higher elevations at TOSO-528, Great Outdoors, and TOSO North transects (River Miles 220, 215, and 212; Figure 1-2)</u>: Both communities have historically been inundated by unusually (infrequent) high water levels. Both these systems will still receive

inundation under the 50 mgd withdrawal scenario to an extent that the community plant composition will not be altered. The palm hydric hammock will continue to have as co-dominants cabbage palm and live oak in the overstory. The upper portion of the wet prairie will continue to be dominated by sand cordgrass. Consequently, without changes in species composition, the aesthetic/scenic visual component will not be altered.

Figure 5.6-1. Boat launch/access canal to the St. Johns River at the SR 50 Bridge under unusually low-flow conditions (HSW May 2004)

Hardwood swamp community at Lake Cone transect (River Miles 206 through 208; Figure 1-2): This community consists of a variety of deciduous hardwood species of trees in the overstory (such as red maple and pop ash). This community type is frequently associated with riverine systems that flood on a seasonal basis. This hardwood swamp will continue to be flooded seasonally under the proposed 50 mgd withdrawal. There would be no changes in species composition that would adversely impact the visual characteristics of this area.

Wet prairie and hydric hammock communities at Lake Ruth transect (River Mile 201; Figure 1-2): Both communities exist at higher elevations and have historically been inundated by unusually (infrequent) high water levels. Both these systems will still receive inundation under the proposed 50 mgd withdrawal to an extent that the community plant composition will not be altered (per analyses in Mace 2004). The hydric hammock will continue to have a mix of shrubs and overstory tree species such as cabbage palm and live oak. The upper portion of the wet prairie will continue to be dominated by sand cordgrass. Consequently, without changes in species composition, the aesthetic/scenic visual component will not be altered.

The annual one-day exceedance maximum has a frequency of occurrence of about 73% (1:1.37 years) under current conditions and a frequency of occurrence of about 70% (1:1.42 years) under the proposed 50 mgd withdrawal scenario (Table 5.2-1). The percent of time flow is exceeded, on average, also is presented for each of the scenarios. Slight changes in river elevation due to the proposed MFLs regime would not be visually obvious to shoreline hikers, nor would they impact the aesthetic view at the boat launch facilities as the water would still be covering the banks and much of the launch ramp ruderal areas adjacent to the ramps themselves.

Most passive recreation for the general public on this portion of the river comes from being on the river itself. The eco-tourism industry provides its services primarily to people seeking passive recreation in the form of alligator watching and bird watching (Captain Bruce Fryer, personal communications, June 1 and August 27, 2004). The most active times of the year for customers for eco-tourism are from November to about mid-April. The optimal water levels for alligator viewing occur when the water is just below the banks. Under such conditions, alligators find it easy to crawl onto the bank area to sun themselves, making them visually evident to the eco-tourists (Figure 5.6-2). Optimal water levels for birding are more varied but appear to be best at times when the floodplain is slightly inundated, to allow long-legged wading birds ample foraging areas and allow eco-tourists access to viewing them by airboat. From an aesthetic and scenic viewpoint, the eco-tourism aspect is the most sensitive to changes in water levels and flows.

Figure 5.6-2. Alligator along the banks of the St. Johns River under optimal water level conditions for eco-tourism *(Photo courtesy of Central Florida Airboat Tours)*

Mace (2004) provides detailed bathymetric information for multiple transects along this stretch of the river. Water elevations for top of bank along the main channel of the river have been estimated based on Mace's analysis (Table 5.6-1). At all transects, the associated water level component of the proposed minimum average level is within a few inches of the top of bank elevation along the edges of the main channels.

Table 5.6-1. Estimations of water level elevations for the top of bank along the main channel of the St. Johns River

Transect Name	Approximate Top of Bank (ft NGVD)	Water Level Component of Proposed Minimum Average Level (ft)
TOSO-528	8.5	8.4
Great Outdoors	7.5	7.5
Tosohatchee North	6.3	6.4
Lake Cone	6.0	5.8
M-6	5.8	5.8
H-1 [a/]	4.5	4.5
Ruth Lake [a/]	4.6	4.5

a/ Minimum average level estimated for H-1 and Ruth Lake transects, based on Hatbill Park.

From the top of bank elevation down perhaps one-half foot, alligator viewing would be expected to be optimal. Under baseline conditions, the annual one-day non-exceedance minimum for these optimal elevations has a frequency of occurrence of about 82% (1:1.22 years, at Great Outdoors) to 96% (1:1.04 years, at Ruth Lake Park) (Table 5.6-2). Under the proposed

50 mgd withdrawal scenario, the annual one-day non-exceedance minimum has a frequency of occurrence of about 89-96% (1:1.13 to 1:1.04 years).

Table 5.6-2. Frequency and duration parameters for WRV-6: aesthetic and scenic attributes – alligator viewing

Location	River Mile	Stage	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	cfs	Days	Current	MFL	Current	MFL
TOSO 528	220	8.5	454	1	1.08	1.05	60.6	54.7
Great Outdoors	215	7.5	337	1	1.22	1.10	69.2	63.0
TOSO North	212	6.3	408	1	1.14	1.05	64.1	58.0
Lake Cone	208	6.0	494	1	1.14	1.05	66.5	61.4
M6	208	5.8	402	1	1.18	1.13	72.2	67.3
H-1	201	4.5	613	1	1.05	1.04	59.4	55.5
Ruth Lake	201	4.6	650	1	1.04	1.04	57.5	53.6

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (Appendix A).
b/ From Scenarios A and D (Appendix A).

Because bird-viewing activities are more varied and are based on multiple factors (habitat, time of year, temperatures, wind conditions, as well as water levels), optimal conditions for birding are less easily quantified. Wading birds (a group that represents the most visible group of birds for eco-tourists) are abundant within this area of the river (Figure 5.6-3; see also Section 5-2, WRV-2, for detailed description). For scenic and aesthetic considerations, the two factors of importance are: (1) that the floodplain is inundated at least to a level where the wading birds can stand and hunt; and (2) that there is sufficient water within the floodplain system so that the eco-tourism airboats can access the congregation spots for the birds.

Wading birds find abundant food sources along the floodplain when the floodplain is inundated at relatively shallow depths (less than six inches for all but the largest wading bird species). Also, at these shallow floodplain inundation depths, food resources would tend to be concentrated in pool areas, making foraging more efficient. Such shallow water depths are adequate for the eco-tourism airboats to access the foraging sites where the wading birds would congregate.

Figure 5.6-3. Wading birds along the shallows of the St. Johns River under optimal water level conditions for eco-tourism
(*Photo courtesy of Central Florida Airboat Tours)*

Table 5.6-3. Frequency and duration parameters for WRV-6: aesthetic and scenic attributes – bird viewing

Location	River Mile	Stage	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	cfs	Days	Current	MFLs	Current	MFLs
TOSO 528	220	9.0	602	1	1.04	1.03	50.3	46.4
Great Outdoors	215	8.0	473	1	1.07	1.04	59.2	53.4
TOSO North	212	6.8	522	1	1.05	1.04	55.4	50.8
Lake Cone	208	6.5	725	1	1.04	1.03	53.6	49.7
M6	208	6.3	633	1	1.05	1.04	58.3	54.5
H-1	201	5.0	799	1	1.04	1.03	49.7	46.6
Ruth Lake	201	5.1	836	1	1.03	1.03	48.0	45.1

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).
b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 of Appendix B).

At 0.5 ft above the top of bank elevations, the portion of the floodplain easily accessible to eco-tourists would have water inundation depths that approximate an optimal viewing condition for wading birds. Under baseline conditions, the annual one-day non-exceedance minimum has a frequency of occurrence of about 96% (average of all transects), or about 1:1.04 years, under baseline conditions; under the 50 mgd withdrawal scenario, the frequency of occurrence of this low flow condition is about 97%, or about 1:1.03 years (Table 5.6-3).

The proposed 50 mgd withdrawal scenario would not result in adverse impacts to the scenic viewing of alligators from eco-tourism. The reduction in number of days of inundated floodplain will not affect the ability of eco-tourists to view a wide variety of bird species along the river channels and within the floodplain. However, under very low river flow conditions, a proposed withdrawal scenario of 50 mgd could hinder boat access to certain wildlife viewing areas more frequently than under baseline conditions (see also Section 5-10, WRV-10, Navigation).

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5.7 WRV-7: Filtration and Absorption of Nutrients and Other Pollutants

This WRV is **defined** as the reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., the removal of suspended and dissolved materials as these substances move through the water column, soil, or substrate and associated organisms). In evaluating this WRV, HSW examined whether or not there is an association between flow and nutrient levels measured either as concentrations in the water column or as loading rates. Increases in nutrient loading that might occur during periods of high flow resulting from increased surface water runoff, as well as reductions resulting from physical, chemical, and biological processes that take place when the floodplain is inundated, are examined. The **criteria** for protection are "the processes of filtration and absorption." The **representative function** used to assess protection is the concentration or load of key nutrients in the river. The **general indicators** of protection are the maintenance of depth of water and inundation of the floodplain. The **specific indicator** of protection is the return interval of depth of water and floodplain inundation that does not differ unacceptably from baseline conditions.

The biogeochemical processing of dissolved constituents is controlled by complex interactions between the rate at which water flows through surface and subsurface flow paths and the rate at which dissolved constituents are processed by methods such as adsorption to sediments or uptake by microorganisms and vegetation (Phillips et al. 1993; Hamilton and Helsel 1995). Floodplain soils and sediments that comprise the boundaries of streams support abundant microorganisms and vegetation, as well as low redox environments and/or steep redox gradients that are essential for numerous biogeochemical processes (Ponnamperuma 1972). Consequently, floodplain soils and sediments that comprise the boundaries of streams are areas in which a large proportion of the biogeochemical processing of dissolved constituents occurs (Peterjohn and Correl 1984; Munn and Meyer 1990; Vervier et al. 1993; Dahm et al. 1998; Hill et al. 1998; Hill and Lymburner 1998; Alexander et al. 2000). Therefore, the conceptual model relevant to the WRV assessment is that filtration and absorption occur in the pervious soils adjacent to the river channel and in the floodplain; hence, the frequency, duration, and return period of overbank flooding are the defining characteristics (Battelle 2004). With respect to low current velocities and water levels, data from Section 5.4 (Transfer of Detrital Material), Section 5.8 (Sediment Loads), and Section 5.9 (Water Quality) can be used to infer protection at low flows and water levels via determinations of the degree to which biological activities and physical transport activities are maintained under the recommended MFLs. It is recognized that the processes associated with filtration and absorption of nutrients will affect the condition of water quality in the river. However, “water quality” is explicitly defined as the chemical and physical properties of the aqueous phase not included in WRV-7 (filtration and absorption of nutrients).

Nitrogen- and phosphorus-containing compounds are naturally occurring and essential to life but in excess can quickly result in a proliferation of undesirable vegetative and microbial organisms, a lowering of dissolved oxygen levels, and depression of desirable species (Maher 1997). Once started, this process of eutrophication can be difficult to reverse, particularly in shallow, low-flow conditions, which typify portions of the St. Johns River (Cadenhead 1997). Riparian wetlands serve important functions by filtering and absorbing nutrients from runoff (which typically contains nutrients at concentrations greater than the parent soil), serving as sinks for nutrients deposited from the river during periods of inundation, and allowing long-term nutrient removal through microbial action (Adams 1997; Boudreau et al. 2004; Labaree 1992). The ability of wetlands to perform these functions depends on cycles of flooding and drying as both anaerobic and aerobic processes are involved (Boudreau et al. 2004). Recognition of the importance of wetlands to the aquatic health of neighboring bodies of water has resulted in the creation or restoration of wetland areas throughout the country. However, there is debate about whether or not wetlands adapted to low nutrient loading, such as the wetlands associated with the St Johns River, are effective at filtration and absorption. Even so, the key issue for this MFL analysis is whether or not specified events (overbank flooding) occur substantially less frequently under an MFL scenario than occurred historically.

Excessive nutrient loading can occur naturally by the decomposition of vegetative and animal matter but is more often caused by agricultural or anthropogenic activities (Banks 1997; Follett 1995; USGS 1993) (Figure 5.7-1). The reach of the St. Johns River that extends from SR 528 to SR 46 is surrounded primarily by cattle farms or undeveloped land, much of it owned by the District or by the State of Florida and is likely to remain undeveloped (Mace 2004). The City of Orlando discharges treated wastewater from its Iron Bridge Regional Water Reclamation Facility in Oviedo, Florida, directly into the Little Econlockhatchee River (about 8-9 million gallons per day [mgd]) and into the St. Johns River from an unnamed ditch that passes through Seminole Ranch (about 18 mgd) after first passing through approximately 2000 acres of manmade wetlands; there are no other known or permitted point sources along this reach of the river (Brian Smith, personal communications, August 2004). Therefore, attention is focused on the extent to which nutrient loading along this reach of the river occurs from non-point sources such as wildlife or cattle, historical concentrations or loads of nutrients and related water quality parameters and their correlation, if any, with streamflow and stage, and the potential effects of the projected MFLs conditions on the river's ability to maintain historical biological and physical transport activities.

Figure 5.7-1. Cows along and in the St. Johns River; nutrient source (Mace 2004)

Much of the physical transport of the nutrient load introduced into rivers is the result of natural and anthropogenic atmospheric deposition (Graham and Duce 1979; Logan 1983; Lyons et al. 1990; Penner et al. 1991; Kasibhahatla et al. 1993), erosion of soils and sediments (ammonium or phosphorus bound to negatively-charged soil or clay particulates), erosion of organic material (ammonium, nitrogen, or phosphorus chemically bound or physically sorbed to organic matter), surface water runoff (mainly water-soluble, highly-mobile nitrate ions but also dissolved phosphorus), and baseflow (also mainly water-soluble, highly-mobile nitrate ions but also dissolved phosphorus) (Griffith et al. 1977; Schlesinger and Hartley 1992; Follett 1995; Howarth et al. 1995; Prather et al. 1995). Ammonium, nitrate, and phosphorus are readily transformed or taken up by microorganisms and plant life, with woody, well-established vegetation more effective at uptake than new growth (Labaree 1992). Phosphorus sorbed to particulates or chemically bound in iron or aluminum complexes can serve as a long-term source of phosphorus, with bioavailability enhanced by selective transport of fine-grained particles (which have a greater percentage of phosphorus than larger-grained particulate) with changes in streamflow (Sharpley 1995). Soils rich in organic matter also enhance the bioavailability and permanent loss of nutrients by serving as reductants for bacterial denitrification (under anaerobic conditions) and by influencing the solubility of some phosphorus complexes.

Consistent nutrient uptake and removal depends on maintenance of streamflow and regular cycles of inundation of the floodplain. To determine whether there has historically been an association between changing flow conditions and nutrient levels, concentrations of ammonia, nitrate-nitrite, organic plus ammonia nitrogen, orthophosphorus, and total phosphorus reported for U.S. Geological Survey (USGS) gage near Christmas, Florida (gage no. 02232500) for the period of record were plotted as functions of daily streamflow measurements taken at this gage (Figures A.6-1 and -2, Appendix A). Dissolved oxygen concentrations also have been plotted as a function of streamflow at this location (second graph in Figure A.7, Appendix A).

Historically, there has been virtually no correlation between streamflow and concentrations of nutrients for which data are available, while dissolved oxygen data suggests concentrations may actually decrease slightly during periods of high flow. The USGS reported a discordant association between total nitrogen, ammonia nitrogen, organic plus ammonia nitrogen, and flow for 1991-1999 and 2000-2002 data for the Christmas site with the nonparametric Kendal's tau (τ) statistic (Kroening 2004). Explanations of this inverse relationship included influx of groundwater and increased decomposition at low flows. Total phosphorous concentrations were not consistently associated with flow, but increasing total phosphorous was observed during extreme events. These results are consistent with results elsewhere in the U.S. Nutrient concentrations are largely controlled by loading rates rather than by in-stream processing rates. Therefore, nutrient concentration data are complicated by hysteresis effects within rising and falling stages of single-peaked runoff events and by variable depletion of suspended sediment sources through multiple-peaked runoff events and years (e.g., Holloway and Dahlgren 2001; Rains et al. 2006).

A direct comparison of nutrient levels under historical flow conditions and nutrient levels under projected MFLs conditions is not appropriate, as the planned withdrawals do not affect inputs from atmospheric deposition, erosion of soils and sediments, erosion of organic matter, surface water runoff, or baseflow but may affect the river's assimilative capacity. However, dilution of these various inputs will occur inversely proportional to the withdrawal amount.

The key issue for this MFL analysis is whether or not a specified event (overbank flooding) occurs substantially less frequently under an MFL scenario than occurred historically. According to preliminary determinations by the District (Mace 2004), the average elevations of shallow marshes, hardwood swamps, and wet prairies – which occupy over 65% of the one-mile buffer zone of the river channel between SR 528 and SR 46 – range from 4.5 ft NGVD (all shallow marshes at transect H-1) to 10.1 ft NGVD (wet prairie and upper wet prairie at transect TOSO-528) (Table 5.7-1).

Table 5.7-1. Summary of elevations of marshes, swamps, and wet prairies within a one-mile buffer along the St. Johns River from SR 528 to SR 46 (Mace 2004)

Transect	Location	Minimum Elevation (ft NGVD)	Mean Elevation (ft NGVD)
Ruth Lake	Wet Prairie	4.6	**5.5**
H-1	Shallow Marshes (all)	3.6	4.5
H-1	Wet Prairie (all)	4.4	**6.0**
Lake Cone	Wet Prairie	5.5	6.6
Lake Cone	Hardwood Swamp	6.4	**7.4**
M-6	Shallow Marshes (1-3)	4.0	5.8
M-6	Wet Prairie 3	5.9	6.1
M-6	Wet Prairies 1-2	6.4	**6.9**
TOSO North	Shallow Marsh	5.5	6.4
TOSO North	Wet Prairie	6.4	6.9
TOSO North	Hardwood Swamp	7.5	**8.1**
Great Outdoors	Wet Prairie 1	7.4	7.5
Great Outdoors	Shallow Marsh	6.6	7.5
Great Outdoors	Wet Prairie 2	7.6	8.1
Great Outdoors	Upper Wet Prairie	8.4	**9.4**
TOSO-528	Shallow Marshes (1-3)	6.9	8.4
TOSO-528	Wet Prairie and Upper Wet Prairie	8.6	**10.1**

Each of these values was evaluated at the appropriate transect, assuming that the processes of filtration and absorption take place over some extended period (e.g., 30 days) (Table 5.7-2). When two or more of these vegetative communities were identified at a given transect, the higher (or highest) mean value was evaluated (indicated in bold in Table 5.7-1).

Table 5.7-2. Frequency and duration parameters for WRV-7: filtration and absorption of nutrients

Location	River Mile	Stage	Flow [a/]	Duration	Maximum Annual Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	cfs	Days	Current	MFLs	Current	MFLs
TOSO 528	220	10.1	1,391	30	1.40	1.50	20.6	18.9
Great Outdoors	215	9.4	1,376	30	1.40	1.49	20.9	19.1
TOSO North	212	8.1	1,257	30	1.38	1.40	23.8	21.7
Lake Cone	208	7.4	1,394	30	1.37	1.42	28.7	26.2
M-6	208	6.9	910	30	1.15	1.16	45.3	41.8
H-1	201	6.0	1,388	30	1.36	1.41	28.8	26.3
Ruth Lake	201	5.5	1,002	30	1.16	1.24	42.3	38.6

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1, B.2-1, and B.2-2 of Appendix B).

Because the process of filtration and absorption requires cycles of wet and dry periods, the return interval of a 30-day maximum stage (or associated flow) is an appropriate measure of the effect of surface water withdrawal. Under baseline conditions, the annual 30-day exceedance maximum has a frequency of occurrence of about 72% (1:1.38 years) at five of the seven transects and about 87% (1:1.16 years) at the other two transects (M-6 and Ruth Lake) (Table 5.7-2). Under the proposed 50 mgd withdrawal scenario, the annual 30-day exceedance maximum would have a frequency of occurrence of 67-86% (1:1.50 to 1:1.16 years), or a decrease of 1 to 5 30-day events per 100 years. The percent of time flow is exceeded, on average, also is presented for each of the scenarios.

The Upper St. Johns River basin is part of the Group 3 basin group established by the Florida Department of Environmental Protection (FDEP) for the development of total maximum daily loads (TMDLs) for nutrients and other pollutants required under the Clean Water Act. Within this basin group, the only water segment between SR 528 and SR 46 that has been identified for TMDL development (WBID 2893I, the Upper St. Johns River above Puzzle Lake) is given a priority of "low," with submittal of TMDLs for nutrients not anticipated until the end of 2008. Given this fact and the results of the frequency and duration evaluation, the shift in frequency will not appreciably affect the filtration and absorption of nutrients within this segment of the river, and this water resource value will be protected under the proposed MFLs regime. Ongoing monitoring of nutrient concentrations, as well as dissolved oxygen levels, should continue to ensure that there are no adverse trends resulting from the recommended MFLs that were not suggested by this evaluation.

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5.8 WRV 8: Sediment Loads

For purposes of this analysis, sediment transport is **defined** as the transport of inorganic materials, suspended in water, which may settle or rise, often depending on the volume and velocity of water. Sediment transported as bed material also will be considered. Organic constituents are discussed separately, under WRV-4 (Transfer of Detrital Material). The **criterion** for protection that will be the focus of the analyses is the “transport of inorganic materials.” HSW’s analyses focus on the effect of change in flow and stage on transport, erosion, and deposition of sediment. The **representative function** used to assess the protection of the transport of fine sediment will be stage, water current velocity, and bed shear stress and associated volumes of water in this portion of the St. Johns River. The **general indicators** of protection for high water and low water conditions will be changes in stage, velocity, and bed shear stress between the baseline and MFLs conditions for each situation. The **specific indicators** of protection will be minimal current velocity and duration, and bed shear stress required for adequate sediment transport derived from the literature, and the extent to which the return intervals of these low velocities will change under the proposed 50 mgd withdrawal scenario.

The transport of sand, silt, and clay within a river depends on hydraulic properties of the channel, as well as fluid and sediment properties. Major hydraulic properties include stage, water current velocity, bed shear stress, and turbulence. Fluid properties include specific weight and viscosity. Sediment properties of interest are particle size, shape, specific gravity, and location in the bed with respect to other surrounding particles. A common definition of sediment transport is the sub-aqueous movement of particles (Vanoni 1977; Mehta 2004). The movement of particles, or transport, is a function of flow condition, material composition, and supply (i.e., source of particulate matter). Sediment transport amount, or “sediment load,” is conveyed as a mass or weight per unit time (e.g. tons/day or kg/sec).

The total amount of sediment moved by the system, or total load, can be divided into two categories: the bed material load and the wash load (Figure 5.8-1). The bed material load is the portion of the sediment transport that can be found in the bed in appreciable quantities. The wash load is the portion of the total load that is always in suspension for a given flow condition and would not typically be found in the bed. The bed material load can further be differentiated as bed load and suspended bed material load. The bed load is the portion of sediment transport occurring near the fluidized bed surface. In bed load transport, the particles are rolling, sliding, or saltating along the bed. In suspended bed material load transport, the bed material particles are supported in the water column by the upward components of turbulent eddies and stay in suspension for an appreciable length of time. Using this categorization, the bed load and the suspended load both consist of similar particles with a continuous exchange between the suspended load and bed load such that a particle in suspension may at a later time be a component of bed load and *vice versa*. An alternative representation of sediment load categories is a classification system based on either transport mechanism or particle size (Figure 5.8-2).

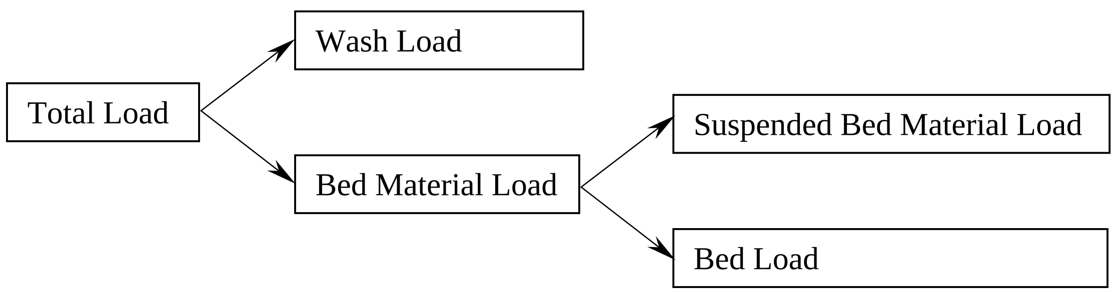

Figure 5.8-1. Schematic of sediment load categories

In many systems the wash load is negligible and "total load" and "bed material load" are used interchangeably. This is not the case for the St. Johns River. In low gradient river systems, the wash load is by far the largest fraction of total load, where turbulent eddying sufficient to suspend bed material load occurs only during high-flow events (Knighton 1998). The wash load is largely controlled by supply from the watershed rather than by river hydraulics. Once in suspension, the wash load remains in suspension and moves at the speed of the water. As such, in low gradient river systems, measurements of total suspended solids (TSS) will include wash load as well as suspended bed material load. Therefore, to protect WRV-8 within this portion of the St. Johns River, consideration must be given to the effect of water withdrawals on wash load and TSS, in addition to bed material load.

Based on a review of existing literature, information and data on sediment transport for Florida streams and the St. Johns River are limited (Mehta 2004). However, research conducted on sediment transport in general allows scientific comparisons between existing and recommended MFLs conditions.

USDA-NRCS soil survey information was used in conjunction with detailed soil sampling at seven transects along the river (Mace 2004) to determine floodplain sediment information in the assigned portion of the St. Johns River. The soil survey indicates that the floodplain surrounding the main channel in this portion of the river consists of Floridiana and Chobee soils which are frequently flooded. The floodplain is broad and very likely contributes large amounts of this type of soil to the main channel. Tomoka muck is also found in portions of the floodplain in Brevard County. Floridiana soil consists of a sand layer of 14 inches that is comprised of about 10% coarse sand (0.5 – 1.0 mm), 50% medium sand (0.25 – 0.50 mm), and 30% fine sand (0.10 – 0.25 mm) with silt and clay making up the final 10% (Carlisle et al. 1989). Chobee soil consists of fine sandy loam in the top 12 inches. In fine sandy loam, the soil survey indicates there are less than 52% fine sand particles (0.10 – 0.25 mm), with silt usually being the next biggest fraction, and clay making up the rest of the sample.

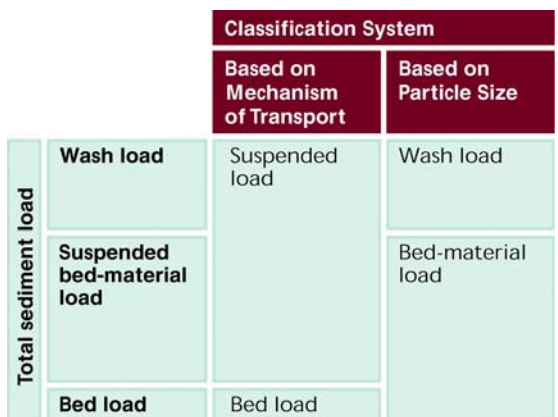

Figure 5.8-2. Sediment load classification categories (FISRWG 1998)

The District mapped hydric soils for transects of interest along the river near SR 50 (Mace 2004), and differences were found between the field soil sampling and the NRCS soil surveys. The H-1 transect south of Ruth Lake contained the Bradenton and Bluff soil series near the main channel. The M-6 and Tosohatchee North transects have Bluff soil near the main channel. There is more muck and loam described in the District field sample results than would be expected from examining the NRCS surveys.

To more clearly determine bed sediment composition, bed material samples were collected by HSW personnel, accompanied by SJRWMD staff, at seven locations in this section of the river on May 8, 2006 (Figure 5.4-1). Samples were taken at the deepest point at each cross section (defined as the “thalweg” of the channel) and, at the two locations that bound this reach (SR 46 and TOSO528), also collected near both banks to help determine the transverse variability. This sampling was conducted during very low water level conditions. An Eckmann sediment grab sampler was utilized at all locations except two (SR 46 and SR 528), where the presence of mussels necessitated the use of a hand auger to obtain a core sample of the top 30 mm of bed material.

Table 5.8-1. Bed sediment composition based on samples collected on May 8, 2006

Sample ID Location	D_{10} [a] (mm)	D_{50} [b] (mm)	NVR [c] (%)	USCS [d] Class.	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mud [e] (%)
SR46-EB	0.0572	0.110	99	SM	2.1	82.8	13.0	2.1	15.1
SR46-WB	0.0644	0.112	99	SM	8.7	79.0	10.2	2.1	12.3
SR46-TH	0.108	0.202	98	SP	14.5	82.0	2.6	0.9	3.5
L10-TH	0.0463	0.120	98	SM	4.4	80.7	10.2	4.7	14.9
H1-TH	0.0712	0.145	99	SP-SM	2.1	87.3	6.4	4.2	10.6
M6-TH	0.0430	0.173	95	SM	8.5	74.4	10.8	6.3	17.1
TOSONORTH-TH	0.0095	0.0919	94	SM	0.8	62.4	28.3	8.5	36.8
GREATOUT-TH	0.0773	0.123	98	SP-SM	3.5	88.2	5.0	3.3	8.3
TOSO528-EB	0.0950	0.185	98	SP-SM	3.3	90.1	6.6	0.0	6.6
TOSO528-WB	0.0687	0.116	97	SP-SM	4.7	84.2	9.2	1.9	11.1
TOSO528-TH	0.150	0.229	99	SP	0	96.5	3.5	0.0	3.5

a/ D10 = grain size in mm, relative to which 10% of the sample are finer
b/ D50 = grain size in mm, relative to which 50 % of the sample are finer
c/ NVR = Non-Volatile Residue (ash content)
d/ USCS = Unified Soil Classification System (SM = silty sand; SP = well graded sand)
e/ Mud = silt and clay

Table 5.8-2. Classification of particles by size (Graf 1971)

Classification	Particle Size (mm)	Designation
Gravel	2 to 52	Coarse
Sand	0.063 to 2	
Silt	0.002 to 0.063	Fine
Clay	<0.002	

Overall, the bed material in this reach is very consistent with limited longitudinal variability in D_{50} or ash content (Table 5.8-1), in which particle distribution by size is defined by Graf (1971) (Table 5.8-2). At SR 46 and TOSO528, the thalweg samples provided the largest D_{50} fraction and smallest percentage of fine sediments, but, overall, transverse variability is small. In addition, every sample is classified according to the NRCS as either silty sand or well-graded sand; in only one location (TOSONORTH) is the percentage of fine sediments (silt and clay) high enough that the bed material may behave in a cohesive fashion. Thus, for sediment transport purposes, the bed material can be analyzed as non-cohesive inorganic fine sediment.

From the bed material sampling, as well as the floodplain analysis, it is evident that sediment loads within this portion of the St. Johns River are dominated by fine sand and silt. The initiation of motion of these particles is primarily a function of bed shear stress and particle size (Vanoni 1977; Yang 1996). Bed shear stress (τ) is computed as:

$$\tau = \gamma R S$$

where γ is the specific weight of water, R is the hydraulic radius (cross-sectional flow area over wetted perimeter), and S is the slope of the energy grade line (which can be approximated by the bottom slope of the channel for uniform or gradually varied flow conditions).

Table 5.8-3. Determination of motion or no motion of sediment using HEC-RAS river station 208.94 near SR 50 and shields curve

Particle Size (mm)	Flow (cfs)	Velocity (ft/s)	Bed Shear Stress [a/] (lb/ft^2)	Motion? [b/]
0.10	969	0.59	0.01	Yes
0.10	5,290	1.04	0.03	Yes
0.25	969	0.59	0.01	Yes
0.25	5,290	1.04	0.03	Yes

a/ From SJRWMD HEC-RAS output table.
b/ From incipient motion criteria based on Shields curve.

A commonly accepted measure of initiation of motion for uniform, non-cohesive sediments can be determined using the Shields curve, which divides a region of motion from a region of no motion (Shields 1936). By determining the dimensionless Shields parameter and dimensionless grain Reynolds number, a prediction of sediment motion may be obtained. For D_{50} sediment grain sizes of between 0.1 mm and 0.25 mm (the range of sediment sizes in this reach of the St. Johns River), the critical shear for motion is approximately 0.004 lb/ft^2. By using the District’s HEC-RAS model results, the bed shear stress was taken from a user-defined output table at a cross section for varying conditions (both low and high flow conditions). According to the Shields diagram, for the cross section near the USGS gage at SR 50, motion occurs for fine-grained sand under both low and high flow conditions (Table 5.8-3).

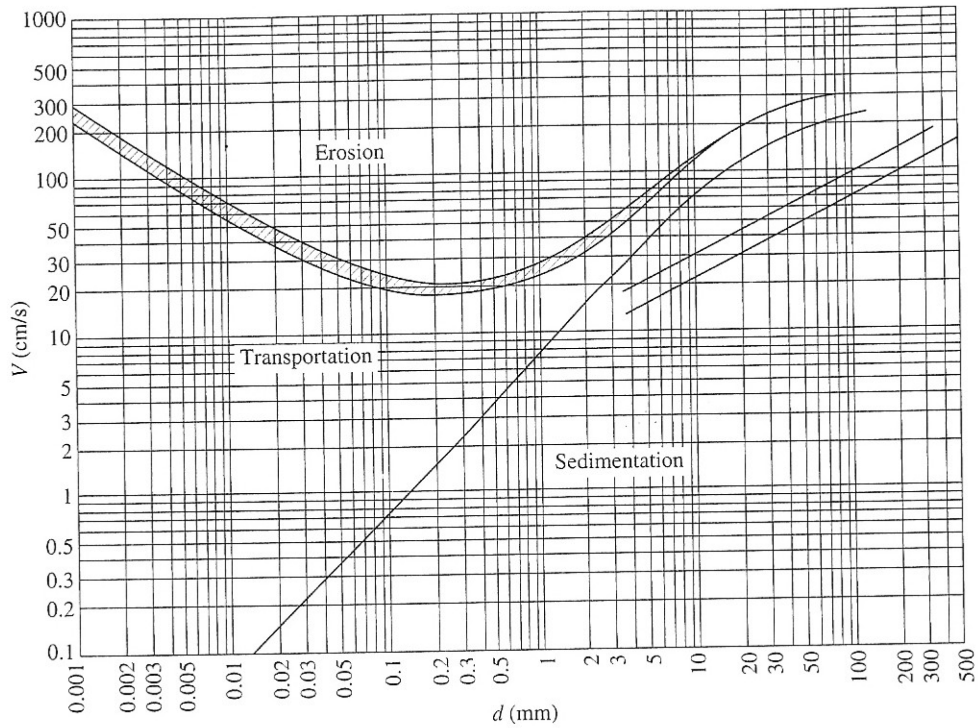

Figure 5.8-3. Hjulstrom's chart of sediment zones (Yang 1996)

While protecting the initiation of sediment motion is an important initial step, it is also important to consider the overall transport of sediment to determine if the water withdrawals will significantly affect erosion or deposition of sediment in the channel. A simplistic approach is to consider the work of Hjulstrom. Hjulstrom (1935) considered a wide range of uniform sediment size and flow conditions and developed a chart that indicates the regions of erosion, transport, and deposition (or sedimentation) (Figure 5.8-3). The sediment sampled in the St. Johns River is not uniform, but the gradation curves are fairly steep, and a majority of the samples consists of fine-grained sand; therefore, approximating the bed material as uniform sediment with a D_{50} particle diameter is appropriate. Under such an assumption, a sediment diameter of 0.2 mm would remain transported between 1.5 cm/sec and 18 cm/sec. Based on the data presented in Table 5.8-3, under the 969 cfs condition, velocity is 0.59 ft/sec, or 18 cm/sec (transport region), and under the 5,290 cfs condition, velocity is 1.04 ft/sec, or 32 cm/sec (erosion region).

Regarding the MFL analysis, the important consideration is not necessarily the condition (erosion vs. transport), but rather that the water withdrawals do not cause a significant shift in occurrence of those conditions. For example, if under current water levels, the flow condition is erosive, then it should remain erosive under the MFL conditions to maintain the morphology of the river. Thus, for the ranges of bed material sediment size present in this stretch of river, the key velocity is approximately 20 cm/sec, or about 0.6 ft/sec. A significant shift in the occurrence of this velocity could cause morphological changes in the river.

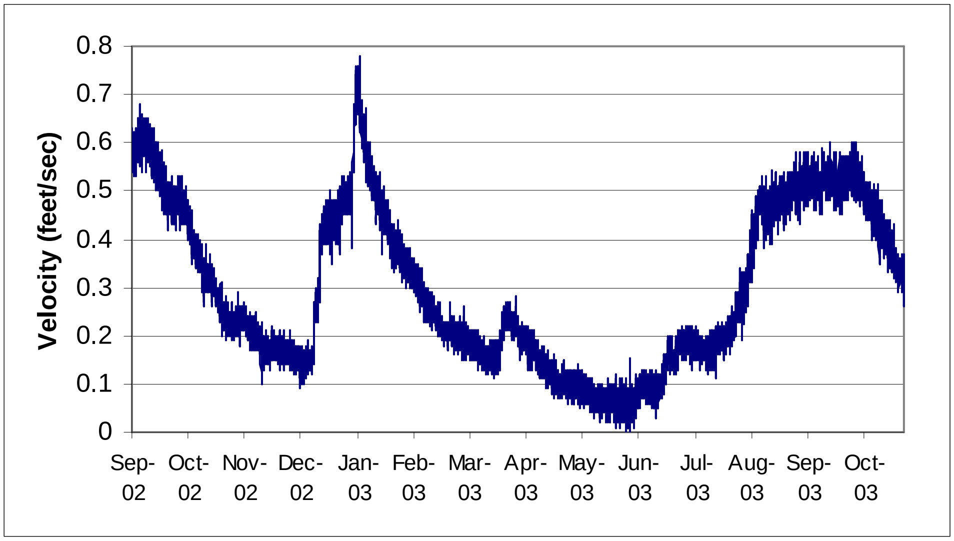

Figure 5.8-4. U.S. Geological survey velocity data for St. Johns River near Christmas, Florida

A more sophisticated approach would be to consider total sediment load. One option would be to calculate (or measure) sediment load for current conditions and verify that the overall sediment load would not be significantly altered under MFL conditions. Numerous sediment load equations have been developed for the prediction of bed load transport, suspended load transport, and total load transport (U.S. Army Corps of Engineers 1995; Yang 1996). These equations are used to predict sediment load based on variables such as mean flow velocity, discharge, stream power, shear stress, particle size, water depth, and water temperature. The Engelund-Hansen method (Engelund and Hansen 1972), which predicts total sediment load, is one methodology that is well suited for Florida streams (Reid and Dunne 1996). The Engelund-Hansen method is based on a stream power approach where stream power is the product of shear stress and mean flow velocity (τ V). Shear stress is the product of the specific weight of water, hydraulic radius (cross-sectional area over wetted perimeter), and channel bottom slope. When considering total sediment load, the emphasis is on high flow conditions during which a majority of the sediment will be moved. For high flow events in low gradient, wide rivers such as the St.

Johns, none of these variables (specific weight of water, hydraulic radius, and bottom slope) will change significantly with 50 mgd water withdrawals. Therefore, when considering total sediment load under high flow conditions, if the mean flow velocity is protected, then the sediment load is subsequently protected.

The final concern when considering the effect of water withdrawals is the protection of total suspended solids (TSS). The key variable with regard to TSS is mean flow velocity, which transports the suspended particles (both organic and inorganic). If mean flow velocity is not significantly changed under MFL conditions, it can be inferred that TSS will be protected (refer also to Section 5.4, WRV 4).

As a final consideration, actual data collected at the USGS gage near Christmas (Figure 5.8-4) were evaluated. The velocities measured in the river are under 1.0 ft/sec. However, hydraulic conditions can be such that sediment is still moving at lower velocities (Table 5.8-4 and Figure 5.8-3). The acoustic velocity meter at the USGS gage near Christmas records every 30 minutes and demonstrates fluctuations over the day for the same stage. The fluctuations are due to backwater effects from wind, which can affect the entire St. Johns River. The river is shallow and has very little slope, making it susceptible to wind effects, and thus it is difficult to determine the relationship between depth and velocity. Another factor to consider is the high level of boat traffic, with its potential for the re-suspension and re-entrainment of sediments. Even if a velocity could be determined that would maintain the “normal” sediment transport rate, boats disrupt the natural erosion and deposition processes, and the resulting suspended load may be higher than expected. The relationship between boat traffic, water level, and re-suspension and re-entrainment of sediments would be difficult to quantify, but it could be expected to be greater at low water levels when the bottom and banks are greater impacted by boat waves.

The low-energy condition in the St. Johns River seems to be more conducive to the transport of the smallest particles, such as silts and clays. Only very large storm events are likely to flush coarser sediment through the river. Since silt and clay have cohesive properties, their movement is difficult to predict because physiochemical forces are often more important to the erosion process than fluid forces. No general relationship is known that defines the incipient motion of cohesive material. However, some broad conclusions may be drawn. Based on the Christmas gage data, the average velocity for water year 2003 was 0.30 ft/s. The maximum was 0.78 ft/s. The higher flow events could therefore be associated with a velocity of approximately

0.50 ft/s. A HEC-RAS simulation, reported by ECT (2003) for a portion of the river further downstream from the reach of interest, showed that a 320-cfs withdrawal at higher flows (10% exceedance condition) reduces the channel velocity by 0.05-0.1 ft/s. ECT concluded that there would not be an increase in net sediment loads due to the withdrawal, which is consistent with the analysis presented here. When water is withdrawn from surface water during times of high flows, there is little change in flow and velocity.

Table 5.8-4. Frequency and duration parameters for WRV-8: sediment loads

Location	River Mile	Stage [a]	Flow	Duration	Maximum Annual Exceedance Return Interval (year) [b]		Percent of Time Flow is Exceeded [b]	
		ft NGVD	cfs	days	Current	MFLs	Current	MFLs
State Road 50	209	10.3	4,847	1	3.48	3.68	1.81	1.57

a/ From HEC-RAS Rating Curve at Near SR 50 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1 and B.2-2 of Appendix B).

Given the sediment regime of the St. Johns River, the parameter of concern is high flow and the duration of interest is one day. The specific indicators are mean flow velocity and bed shear stress. The critical value of mean flow velocity is 0.6 ft/sec and the critical value of shear stress is 0.004 lb/ft^2. The proposed mean flow velocity of 0.6 ft/sec corresponds to a flow of 4,847 cfs at SR 50. The annual one-day exceedance maximum has a frequency of occurrence of about 28.7%, or 1:3.48 years, under the baseline conditions and a frequency of occurrence of about 27.2%, or 1:3.68 years, under the 50 mgd withdrawal scenario (Table 5.8-4) (i.e., about 2 less events per 100 years).

HSW’s quantitative analysis indicates that the recommended MFLs protect the water resource value for sediment loads inasmuch as the slight reduction in average high flow will not result in noticeable changes to the depositional regime of this reach of the river system.

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5.9 WRV-9: Water Quality

For purposes of this analysis, water quality is **defined** as the chemical and physical properties of the aqueous phase within this stretch of river. The **criteria** for protection are "the chemical and physical properties of the water" that affect the aquatic community. The **representative function** used to assess protection of the flows in the river is the concentrations of key chemicals/indicators in the river. The **general indicators** of protection are the maintenance of flow for adequate mixing/dilution (avoid stagnant water conditions) and the maintenance of adequate temperatures, dissolved oxygen (DO), and turbidity levels to continue to support a healthy aquatic community. The **specific indicator** is the return interval of specified discharge necessary to maintain adequate mixing/dilution that does not differ unacceptably from baseline conditions.

Nutrient concentrations in rivers are largely controlled by loading rather than by in-stream processing. Loading is largely due to runoff from point and non-point sources in adjacent uplands, with loading from both natural areas (e.g., recently-burned areas) and developed areas (e.g., agricultural, urban, or industrial areas). This segment of the river is surrounded mostly by publicly-owned land that is unlikely to be developed (Mace 2004); therefore, nutrient loading from human activity is not expected to increase. Proposed withdrawals from the river are unlikely to have any significant effect on concentrations of nitrogen- or phosphorus-containing compounds unless withdrawals occur in areas of lower concentrations (potentially resulting in higher nutrient loading) or in areas of higher concentrations (potentially resulting in lower nutrient loading). However, lower flow rates will increase the residence times of these nutrients. Regardless, nutrient loading is complicated by hysteresis effects within rising and falling stages of single-peaked runoff events and by variable depletion of sources through multiple-peaked runoff events and years. Therefore, determining process-driven relationships between nutrient loading, nutrient concentrations, and flows is difficult. For these reasons, nutrient concentrations are not used to address this WRV.

This WRV is instead addressed by concentrating on those physical and chemical parameters most likely to negatively impact the ecological structure and function of the river because of the altered hydrologic regime. Low flow conditions are the focus of this examination. Low flows promote stagnant conditions and increased residence times that in turn promote high water temperatures, algal growth, and large diurnal swings in DO concentrations. DO is perhaps the most frequently used indicator for assessing the fitness of a body of water to support aquatic life (Maher and James 1997).

Low flows affect DO concentrations through several mechanisms. As flows decrease, water temperatures tend to rise, which reduces DO saturation levels. Therefore, DO concentrations are inversely a function of water temperatures. DO concentrations also are a function of biological oxygen production and demand within the water body. As flows decrease, algal production may increase. During the day, algae photosynthesize and produce abundant oxygen; at night, algae cease to photosynthesize but continue to respire and consume abundant oxygen. The result can be large diurnal swings in DO concentrations that can result in nighttime fish kills. Low flows can also affect turbidity. As flows decrease, turbidity may increase, possibly due to the presence of unmoving, suspended particulates, but more likely due to the growth of microorganisms that attach to undissolved organic and inorganic matter. Nutrient loading and greater residence times can exacerbate such growth.

Table 5.9-1. Identifications of stations used for water quality evaluation

Station	River Mile	Station Location
ER-SJR [a/]	190	Econlockhatchee River before confluence with St. Johns River
SJR528 [a/]	223	St. Johns River on north side of 528 bridge
SRN [a/]	189	Lake Harney inflow - St. Johns River at SR 46 bridge
SRS [a/]	209	Seminole Ranch south boundary at SR 50 in St. Johns River
02232400	232	St. Johns River near Cocoa, Florida
02232500	209	St. Johns River near Christmas, Florida
02234000	189	St. Johns River above Harney Lake near Geneva, Florida

a/ River miles for ER-SJR, SJR528, SRN, and SRS are approximate.

Four SJRWMD water quality sampling stations and two USGS water quality sampling stations located along the stretch of the river from SR 528 to SR 46, and a third USGS station located south of SR 528, were identified for evaluating historical water quality data (Table 5.9-1). Summary statistics were generated for key parameters and historical averages compared with Class III surface water standards, when applicable (Appendix D). Dissolved oxygen concentrations, which are expected to fluctuate daily and with changes in streamflow, ranged from a low of 0.1 mg/L to a high of 13.4 mg/L. Although the St. Johns River is more turbid than many Florida rivers that are more spring-fed (Maher 1997), turbidity measurements were below the Class III surface water maximum ($\leq$ 29 N.T.U. above background) in all instances. Turbidity increases above this maximum are likely to have adverse effects on existing aquatic life.

Scatter plots of streamflow versus water temperature, DO concentrations, and turbidity as measured at the U.S. Geological Survey (USGS) gage near Christmas, Florida (gage no. 02232500), were generated (graphs shown in Figure A.7, Appendix A). In general, none of the above parameters was strongly correlated with flow, although weak correlations emerged as flow rates and/or the number of data points increased.

Water temperature essentially remained unchanged with changes in streamflow (Figure A.7, Appendix A), while a slight negative association was noted between DO concentrations and increased streamflow. The lower DO concentrations associated with higher flows may be because the increased flow takes place during the hot, rainy season when biotic activity and associated biological oxygen demand are higher (Figure A.7, Appendix A). As long as there is measurable flow in the river, the data indicate that the proposed withdrawals from this segment of the river are unlikely to adversely affect water temperatures or DO concentrations.

Flow data since 1933, and water quality data since 1991, were examined by Kroening (2004) in the context of developing MFLs for the St. Johns River. Data for a 90-mile stretch of the river from just south of Lake Poinsett to near Deland, which encompasses the subject area of this MFL report, were examined. The inferences made in the referenced report were predominantly based on the Kendal-tau (τ) statistic. DO concentrations and pH values in the St. Johns River were significantly lower during high-flow conditions than low-flow conditions. Low DO concentrations may have resulted from input from marsh areas during high-flow conditions or from decomposition of organic matter transported during high flow. Conversely, low DO concentrations may result from smaller water volumes relative to rates of respiration and poor vertical and horizontal exchange of water and diffusion of oxygen (Battelle 2004). Low pH values may have resulted from the increase in dissolved organic carbon (DOC) concentrations in the river during high flows. Water-color values and DOC concentrations were generally significantly greater during high-flow conditions than low-flow conditions.

Chlorophyll-a and total suspended solids generally were greatest under low-flow conditions during May and June. A decrease in chlorophyll-a during high-flow events is attributed to light limitations of phytoplankton growth during high flows, but may also be related to decreased nutrient residence times (Battelle 2004) or, to some extent, simply the result of dilution. Turbidity was inversely related to flow, which suggests that turbidity is related to resuspension of bottom sediments, increased water column stratification due to decreased turbulence, and/or algal production and not soil erosion (Battelle 2004). High flows can be associated with increased suspension of sediment and organic matter, but these are typically episodic events not impacted greatly (but positively) by relatively small water withdrawals.

Table 5.9-2. Frequency and duration parameters for WRV-9: water quality

Location	River Mile	Stage	Flow [a/]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b/]		Percent of Time Flow is Exceeded [b/]	
		ft NGVD	Cfs	days	Current	MFLs	Current	MFLs
SJR at SR 50	209	5.93	440	30	1.24	1.21	69.8	64.6

a/ From HEC-RAS Rating Curve at or near SR 50 or SR 520 (linear interpolation of data provided in Table B.3 of Appendix B).
b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1 and B.2-2 of Appendix B).

Based on these observations and assertions, turbidity was used to model the potential effects of the low-flow regime on water quality (Table 5.9-2). Monthly averages obtained for daily turbidity readings for the period of record at the USGS Christmas gage (02232500) indicated that the highest monthly turbidity readings occurred during the month of June (average of 8.5 N.T.U.). Turbidity measurements of about 8.5 N.T.U. or higher were measured when streamflow was 440 cfs or less (third graph of Figure A.7, Appendix A). Assuming a streamflow of less than or equal to 440 cfs for a 30-day duration (i.e., with the potential for turbidity at this low level to be no higher than naturally occurs for one month during any given year), the return frequency under current conditions is about 81% (1:1.24 years) and under the proposed low-flow regime would be about 83% (1:1.21 years), or an increase in the number of 30-day low-flow events of 2 per 100 years. The percent of time flow is exceeded would decrease from about 70% to about 65%.

At this water level, there would be adequate flow to maintain water temperatures, dissolved oxygen, and turbidity at levels that support the existing aquatic community. The frequency of occurrence of the annual 30-day non-exceedance minimum would be essentially unchanged under the 50 mgd withdrawal scenario (i.e., would increase by only about 2%), and a flow of 440 cfs would be reduced by about 19 days per year, on average (Table 5.9-2). Based on this analysis, HSW concludes that withdrawals of 50 mgd when the river is at 5.93 ft NGVD at SR 50 would be protective of water quality.

References:

Battelle. 2004. Minimum Flows and Levels in the St. Johns River Water Management District. Sensitivities of “filtration and absorption of nutrients and other pollutants” and “water quality” to alterations in hydrologic regimes. Special Publication SJ2004-SP37.

Kroening, S.E. 2004. Steamflow and Water-Quality Characteristics at Selected Sites of the St. Johns River in Central Florida, 1933 to 2002: U.S. Geological Survey Scientific Investigations Report 2004-5177, 102p.

Mace, J. 2004. *Draft Preliminary Levels Determination: St. John River at State Road 50, Orange and Brevard Counties.* Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

Maher, P.E. and James R. 1997. “Water Quality & the St. Johns River.” Florida Department of Environmental Protection, Northeast District Office. Water Quality and the St. Johns River.

5.10 WRV-10: Navigation

For this analysis, navigation is **defined** as the safe passage of commercial watercraft (e.g., boats and ships) that is dependent on sufficient water depth, sufficient channel width, and appropriate water velocities. Based on the survey of this part of the river, the **criterion** for the protection of this WRV is “legal operation of eco-tourism activities involving large airboats and related water craft (e.g., pontoon boats).” The navigational activities of fish netters and frog hunters are addressed as part of the analysis conducted for WRV-1 (recreation in and on the water, Section 5.1). The **general indicator** will be the depth of water necessary for safe boat passage of the largest beam and draft commercial vessel being utilized by the eco-tourism industry. The **specific indicator** of protection will be a frequency of occurrence of the minimum depth of water needed to allow access to eco-tourism locations and the minimum width of channel required for safe two-way passage of the largest beamed vessels under the proposed hydrologic regime that do not differ unacceptably from baseline conditions.

This examination of eco-tourism navigation centers on the protection of commercial navigation related to airboat and pontoon boat eco-tourism. For airboat tours, the entire floodplain as well as the main and side channels of the river is considered. For pontoon boats, the emphasis is on maintaining adequate water depths and channel widths within the main channels.

In contrast to conditions on the lower St. Johns River, commercial watercrafts are extremely limited within the stretch of river from SR 528 to SR 46. There are no maintained channel markers within this stretch of river. Based on surveys of boaters (HSW 2004b) and discussions with resource officers from different agencies, there are three types of commercial watercraft operations on this portion of the river: eco-tourism, netting of armored catfish, and commercial frog hunting. The most common watercraft on this section of the river is the airboat.

Several companies provide eco-tours of this portion of the river in large airboats. These vessels can be launched from shore and draw very little water. They can be navigated in the main river channels and in the floodplain at water depths of less than 0.5 ft. The larger commercial airboats observed operating along this stretch of river can accommodate more than a dozen people. The largest airboats observed being trailered and launched accommodate up to six people and have beams of about 8 ft (Captain Bruce Fryer, personal communication, August 27, 2004).

Netting of the armored catfish is a relatively recent commercial enterprise. Netting activities have increased as this introduced species of catfish has become more prevalent. The most commonly used vessel for the netting activities is the flat-bottomed jon-boat. All boats noted during the survey were 16 ft or less in length, with small outboard engines. Netting takes place largely within the main channels of the river.

Figure 5.10-1. Airboat used on St. Johns River at SR 46 (HSW May 2004)

Commercial frog hunting typically does not begin until after sunset and so was not observed when the survey was conducted. Most commercial frog hunters use small, flat-bottomed skiff-style boats or air boats.

Pontoon boats are available for rent at the Jolly Gator Restaurant at the SR 46 Bridge (downstream endpoint of the study area). These are aluminum pontoon deck boats with small outboard engines.

Catfish netters and frog hunters use the same types of vessels that were evaluated as part of the analysis of WRV-1 (Section 5.1). These vessels can operate in shallow waters of 2 ft in depth. Pontoon boats draw slightly more water than smaller, flat-bottomed boats and usually remain within the main channels of the river. These boats can be navigated in less than 3 ft of water.

Figure 5.10-2. Pontoon boats used on the St. Johns River (HSW May 2004)

5.10.1 Field Surveys and User Survey

Surveys of boats on the stretch of river from the SR 528 Bridge north past Hatbill Park were undertaken during the wet season and the dry season (HSW 2004a). A boat and user survey (of 60 watercraft and discussions with more than 30 people) also was conducted at two of the more heavily used boating ramps (at SR 50 and at SR 46) on May 31, 2004 (Memorial Day), typically one of the most popular boating days of the year (HSW 2004b; see Section 5.1).

On Memorial Day (May 31, 2004), the water elevations at the SR 50 Bridge and the SR 46 Bridge were 2.8 and -0.2 ft NGVD, respectively (Jane Mace, personal communication, June 8, 2004). At these levels, only airboats can access the main channel of the river from the SR 50 launch area, and only the most shallow-draft boats can be launched at SR 46. On May 5, 2004, the water elevation at the SR 50 Bridge was 4.5 ft NGVD, and only the main channels of the river were navigable (see also Section 5.1). From these visual observations, it is concluded that a water level of 2.8 ft NGVD at the SR 50 Bridge is below a level that would be considered safe for the types of pontoon boats that use this portion of the river, and that a water level of 4.5 ft NGVD at the SR 50 Bridge would be barely adequate (Table 5.10-1).

5.10.2 Safe Boating Information

Airboats are not limited by these minimum water depths but are limited by channel width. Specific published safety criteria regarding minimum channel widths required for safe two-way boat traffic were not available. Safety-related guidance information from the U.S. Coast Guard (Joe Estes, personal communication, July 23, 2004) is available regarding boat traffic in narrow channels (Rule 9) and head-on situations (Rule 14) (U.S. Coast Guard Navigation Rules – online, accessed July 2004). While this information provides detailed rules on proper boating behaviors, there are no data or formulas to calculate a minimum safe channel width(s).

The question of a minimum channel width for two-way airboat passage was asked of Captain Bruce Fryer on August 27, 2004. Captain Fryer estimated that a minimum width of 30 ft is needed to allow for two 8 ft-beam airboats to pass in relative safety but that this width is less than optimal due the many curves in the river where vessel operators cannot see over the shoreline vegetation to detect one another (Captain Bruce Fryer, personal communications, May 31 and August 27, 2004).

The May 5, 2004, airboat-based survey of most of the main channel of the river included periodic estimates of channel widths. The narrowest part of the main channel was noted as being close to the TOSO 528 transect (the farthest upstream transect location). The width of the main channel at this transect was about 30 ft on a day when the water elevation at the TOSO-528 transect was 6.3 ft NGVD and the elevation at the SR 50 bridge was 4.5 ft NGVD.

5.10.3 Baseline versus MFLs Conditions

Under baseline conditions, the annual one-day non-exceedance minimum observed on May 31, 2004, has a frequency of occurrence of about 3.8%, or 1:25.9 years. Under the proposed 50 mgd withdrawal scenario, the frequency of occurrence increases to about 24%, or 1:4.21 years (Table 5.10-1). Under the proposed 50 mgd withdrawal scenario, the annual one-day non-exceedance minimum observed on May 5, 2004, increases to 63% (1:1.59 years) from 40% (1:2.53 years). The number of one-day events increases from about 20 to 36 per 100 years and 30-day events increase from about 7 to 35 event per 100 years. The percent of time flow is exceeded, on average, also is presented for each of the scenarios. Based on observations of water depths and channel widths, a reasonable value for safe navigation is a channel width of 30 ft, a width that corresponds to a water elevation at SR 50 of 4.5 ft NGVD. Many of the narrow channels will remain narrow at much higher flow rates until the banks overflow.

Table 5.10-1. Frequency and duration parameters for WRV-10: navigation

Location	River Mile	Stage	Flow [a]	Duration	Minimum Annual Non-Exceedance Return Interval (year) [b]		Percent of Time Flow is Exceeded [b]	
		ft NGVD	cfs	Days	Current	MFLs	Current	MFLs
State Road 50 (May 31, 2004)	209	2.8	54	1	25.9	4.21	99.3	97.4
State Road 50 (May 31, 2004)	209	2.8	54	30	33.7	9.92	99.3	97.4
State Road 50 (May 5, 2004)	209	4.5	179	1	2.53	1.59	93.3	87.3
State Road 50 (May 5, 2004)	209	4.5	179	30	4.67	2.09	93.3	87.3
Bathymetry data 2006 [c]	220	6.5 (3.0)	68	1	5.81	1.87	97.1	90.1
Bathymetry data 2006 [c]	220	6.5 (3.0)	68	30	9.53	2.19	97.1	90.1

a/ From HEC-RAS rating curve at SR 50 (linear interpolation of data provided in Table B.3 of Appendix B).

b/ From Scenarios A and D (linear interpolation of data provided in Tables B.1 and B.2-2 of Appendix B).

c/ Bathymetry data collected in 2006 were referenced to stage at TOSO-528 to calculate frequency values.

Additional bathymetry data were collected in 2006 to help define additional hydraulic control locations (see Section 5.1, Table 5.1-2 and Figure 5.1-3). Based on these data, additional hydraulic control points are identified that correspond to a stage of up to 6.5 ft NGVD at TOSO-528 when the depth is 2.0 ft. Approximately 35 additional one-day and 30-day events occur that are associated with this stage.

The withdrawal of 50 mgd from the river when water levels are above 4.5 ft NGVD at SR 50 would be protective of this WRV. Continuing to withdraw 50 mgd of water when the level in the river falls below 4.5 ft NGVD at SR 50 would increase the frequency of 1-day and 30-day events to as much as 36 per 100 years.

References:

HSW Engineering, Inc. 2004a. Summary Notes of May 5 Field Survey of St. Johns River between SR 528 Bridge and north of Hatbill Park.

HSW Engineering, Inc. 2004b. Summary Results of Memorial Day (May 31) River Use Survey at SR 46 and SR 50 Launch Areas.

Mace, J. 2004. *Draft Preliminary Levels Determination: St. John River at State Road 50, Orange and Brevard Counties.* Minimum Flows and Levels Section, Division of Water Supply Management, Department of Resource Management, St. Johns River Water Management District, Palatka, FL.

U.S. Coast Guard. 2004. Safe Boating "Rules of the Road". www.navcen.uscg.gov/mwr/navrules/navrules.htm.

6.0 SUMMARY AND CONCLUSIONS

The District contracted with HSW to evaluate whether a 50-mgd withdrawal upstream of SR 528, regardless of flow conditions, would be protective of the ten WRVs defined in Section 62-40.473, *F.A.C.* It is HSW's opinion that the recommended MFLs for the section of the St. Johns River between SR 46 and SR 528 are protective of the ten water resource values under medium and high flow conditions. However, three WRVs may not be protected under low-flow conditions. The exact value of the low flow at which a particular WRV might no longer be protected varies. For safe boating access to the river, flows less than 157 cfs at SR 50 may become problematic, as water depths in the access channels would fall below the 2-ft safe-depth criterion. For safe boating on the main river channels, a flow less than 21 cfs at TOSO-528 may become problematic for the same reason. For fish passage within the main channel, flows less than 193 cfs at H-1 may become problematic with respect to passage of some fish species. For two-way navigation in the main channel, flows less than 179 cfs at SR 50 may become problematic, inasmuch as the width of the main channel would be less than the 30 ft safe boating width criterion.

The District proposed three minimum surface water flows and levels: minimum frequent high, minimum average, and minimum frequent low. The proposed stages were based on detailed observed conditions at multiple transects along this section of river. By means of a comprehensive watershed model (HSPF), a conveyance model (HEC-RAS), and site-specific hydrologic data, a baseline model was developed. Different water withdrawal scenarios were then developed with HSPF and the resultant flows and levels compared to the preliminary MFLs at the transects. The District technical staff determined that a withdrawal of 50 mgd above this section of river could be accomplished without exceeding the preliminary MFLs, recognizing that withdrawing 50 mgd under low-flow conditions would represent a "worst-case" scenario.

HSW's task was to use frequency information developed by CDM (2004) to determine if the ten WRVs would be protected under the proposed MFLs regime. More specifically, the return intervals (frequency of occurrence) of hydrologic conditions from which one may infer protection of the WRVs were evaluated under baseline conditions (i.e., historic flow conditions) and under a 50 mgd withdrawal scenario (Table 6-1). The water resource value was considered to be protected if the frequency of occurrence and duration of the hydrologic condition under the

50 mgd withdrawal scenario did not differ unacceptably from the baseline condition. The term "unacceptably" implies a subjective evaluation.

Collectively, the percent difference of the return interval for a hydrologic condition varies less than 10% until the flow in the river is below the 15-20% exceedance percentage (i.e., the flow value that historically has been exceeded 80-85% of the time) (Figure 6-1). Below this flow, return intervals under the 50 mgd withdrawal scenario differ substantially from the baseline scenario.

Under some circumstances, the percent difference method of analysis can lead to erroneous assessments. For example, if a low water event that occurs with a 100-year return interval under the existing long-term hydrologic regime is then projected to occur twice in 100 years (i.e., a 50 year return interval), the percent difference of [(100 - 50) / 100] years x 100 = 50% might be unacceptable. However, it might be concluded that the low water event that occurs twice in 100 years vs. once in 100 years is still protective of the WRV. Events of extremely low frequency are better evaluated by absolute differences; i.e., is a frequency change of one event in 100 years acceptable? In this report, the WRV parameters that were evaluated occurred with much greater frequency (on the order of years or tens of years, rather than a hundred years) and the shifts in frequency in some instances striking (e.g., an annual one-day non-exceedance minimum for fish passage at TOSO-528 shifting from a frequency of occurrence of 36 years to three years).

The 80-85% exceedance value represents a historic river discharge of about 300 cfs (195 mgd) at SR 50. A 50-mgd withdrawal constitutes more than 25% of the discharge in the river and would substantially change the frequency of events that could affect some of the WRVs. The values affected are those impacted by low flow conditions, including recreation, fish passage, and navigation. WRVs affected by medium or high flow events, such as fish and wildlife habitats at higher elevations, transfer of detrital material, sediment loads, and filtration and absorption of nutrients, are much less impacted by the 50-mgd withdrawal scenario. It was concluded that maintenance of freshwater storage and supply (WRV-5) would not be affected by the proposed change in hydrologic regime; thus, no frequency analysis was performed for these two WRVs.

Table 6-1. Summary of frequency and duration parameters used to evaluate water resource values

Water Resource Value (WRV)	Section 5 Frequency and Duration Table	Location on River	River Mile	Stage	Flow	Duration	Analysis	Return Interval			Percent of Time Flow is Exceeded
				ft NGVD	cfs	days		Current	MFLs	%D	Current
WRV-1: Recreation In and On the Water	5.1-1	Access Channel at State Road 50	209	4.3	157	1	Annual Non-Exceedance Minimum	2.77	1.68	39%	95.1
		Access Channel at State Road 46	190	1.3	337			1.29	1.17	9%	78.4
		Main Channel at TOSO-528	220	5.5	21			31.7	2.62	92%	99.3
		Bathymetry data 2006[a]	220	6.5	68			5.81	1.87	68%	97.1
		Access Channel at State Road 50	209	4.3	157	30		5.77	2.35	59%	95.1
		Access Channel at State Road 46	190	1.3	337			1.62	1.34	17%	78.4
		Main Channel at TOSO-528	220	5.5	21			34.1	4.40	87%	99.3
		Bathymetry data 2006[a]	220	6.5	68			9.53	2.19	77%	97.1
WRV-2: Fish and Wildlife Habitats and the Passage of Fish	5.2-1	Lake Cone (hardwood swamp)	208	8.3	2,408	30	Annual Exceedance Maximum	2.49	2.55	2.4%	11.1
		Lake Cone (wet prairie)	208	7.2	1,166			1.31	1.34	2.3%	35.7
		TOSO-528	220	9.0	602			1.10	1.13	2.7%	50.3
		Great Outdoors	215	8.0	473			1.06	1.09	2.8%	59.2
		TOSO North	212	6.8	522			1.08	1.10	1.9%	55.4
		Lake Cone	208	6.5	725			1.09	1.14	4.6%	53.6
		M-6	208	6.3	633			1.07	1.10	2.8%	58.3
		H-1 Park	201	5.0	799			1.14	1.15	0.9%	49.7
		Ruth Lake Park	201	5.1	836			1.14	1.15	0.9%	48.0
		TOSO-528	220	8.5	454			1.06	1.09	2.8%	60.6
		Great Outdoors	215	7.5	337			~1.00	1.06	6.0%	69.2
		TOSO North	212	6.3	408			1.05	1.08	2.9%	64.1
		Lake Cone	208	6.0	494			1.06	1.07	0.9%	66.5
		M-6	208	5.8	402			~1.00	1.05	5.0%	72.2
		H-1 Park	201	4.5	613			1.06	1.10	3.8%	59.4
		Ruth Lake Park	201	4.6	650			1.08	1.10	1.9%	57.5
	5.2-2	TOSO 528	220	4.8	13	1	Annual Non-Exceedance Minimum	35.5	2.78	92%	99.6
		Great Outdoors	215	0.5	0			41.7	4.67	89%	99.9
		TOSO North	212	4.8	178			1.64	1.36	17%	85.3
		M-6	208	2.6	44			28.8	4.95	83%	99.4
		H-1 Park	201	2.6	193			2.21	1.57	29%	92.1
	5.2-3	TOSO North	212	5.6	251	1	Annual Non-Exceedance Minimum	1.37	1.25	9%	77.0
		H-1 Park	201	3.5	284			1.57	1.29	18%	84.0
		Bathymetry data 2006[a]	220	6.3	56			6.95	2.00	71%	97.7
WRV-3: Estuarine Resources	N/A	--	--	--	--	--	--	--	--	--	--
WRV-4: Transfer of Detrital Material	5.4-3	TOSO-528	220	10.4	1,625	1	Annual Exceedance Maximum	1.40	1.48	5.7%	15.8
		Great Outdoors	215	9.3	1,281			1.19	1.25	5.0%	23.2
		TOSO North	212	8.6	1,657			1.42	1.55	9%	15.2
		M-6	208	7.5	1,509			1.23	1.27	3.3%	25.3
		Lake Cone	208	8.0	2,079			1.44	1.53	6.3%	14.9
		H-1 Park	201.5	6.4	1,697			1.30	1.34	3.1%	21.1
		Ruth Lake	201.5	6.5	1,774			1.32	1.35	2.3%	19.8

Table 6-1. Summary of frequency and duration parameters used to evaluate water resource values (cont'd)

Water Resource Value (WRV)	Section 5 Frequency and Duration Table	Location on River	River Mile	Stage	Flow	Duration	Analysis	Return Interval			Percent of Time Flow is Exceeded
				ft NGVD	cfs	days		Current	MFLs	%D	Current
WRV-5: Maintenance of Freshwater Storage and Supply	N/A	--	--	--	--	--	--	--	--	--	--
WRV-6: Aesthetic and Scenic Attributes	5.6-2	TOSO 528	220	8.5	454	1	Annual Non-Exceedance Minimum	1.08	1.05	2.8%	60.6
		Great Outdoors	215	7.5	337			1.22	1.10	9.8%	69.2
		TOSO North	212	6.3	408			1.14	1.05	7.9%	64.1
		Lake Cone	208	6.0	494			1.14	1.05	7.9%	66.5
		M6	208	5.8	402			1.18	1.13	4.2%	72.2
		H-1 Park	201	4.5	613			1.05	1.04	1.0%	59.4
		Ruth Lake Park	201	4.6	650			1.04	1.04	0.0%	57.5
	5.6-3	TOSO 528	220	9.0	602	1	Annual Non-Exceedance Minimum	1.04	1.03	1.0%	50.3
		Great Outdoors	215	8.0	473			1.07	1.04	2.8%	59.2
		TOSO North	212	6.8	522			1.05	1.04	1.0%	55.4
		Lake Cone	208	6.5	725			1.04	1.03	1.0%	53.6
		M6	208	6.3	633			1.05	1.04	1.0%	58.3
		H-1 Park	201	5.0	799			1.04	1.03	1.0%	49.7
		Ruth Lake Park	201	5.1	836			1.03	1.03	0.0%	48.0
WRV-7: Filtration and Absorption of Nutrients and Other Pollutants	5.7-2	TOSO 528	220	10.1	1,391	30	Annual Exceedance Maximum	1.40	1.50	7.1%	20.6
		Great Outdoors	215	9.4	1,376			1.40	1.49	6.4%	20.9
		TOSO North	212	8.1	1,257			1.38	1.40	1.4%	23.8
		Lake Cone	208	7.4	1,394			1.37	1.42	3.6%	28.7
		M-6	208	6.9	910			1.15	1.16	0.9%	45.3
		H-1 Park	201	6.0	1,388			1.36	1.41	3.7%	28.8
		Ruth Lake Park	201	5.5	1,002			1.16	1.24	6.9%	42.3
WRV-8: Sediment Loads	5.8-4	State Road 50	209	10.3	4,847	1	Annual Exceedance Maximum	3.48	3.68	5.7%	1.81
WRV-9: Water Quality	5.9-2	SJR at SR 50	209	5.93	440	30	Annual Non-Exceedance Minimum	1.24	1.21	2.4%	69.8
WRV-10: Navigation	5.10-1	State Road 50 (May 31, 2004)	209	2.8	54	1	Annual Non-Exceedance Minimum	25.9	4.21	84%	99.3
		State Road 50 (May 5, 2004)	209	4.5	179			2.53	1.59	37%	93.3
		Bathymetry data 2006[a]	220	6.5	68			5.81	1.87	68%	97.1
		State Road 50 (May 31, 2004)	209	2.8	54	30		33.7	9.92	71%	99.3
		State Road 50 (May 5, 2004)	209	4.5	179			4.67	2.09	55%	93.3
		Bathymetry data 2006[a]	220	6.5	68			9.53	2.19	77%	97.1

N/A Not applicable. No frequency analysis performed as part of this WRV evaluation.

/a Referenced to TOSO-528

HSW recommends a withdrawal scenario that results in no withdrawal when the river discharge is below the 80-85% exceedance value of about 300 cfs. Such an operational approach would serve to protect those WRVs that are most vulnerable at low flows (Table 6-2).

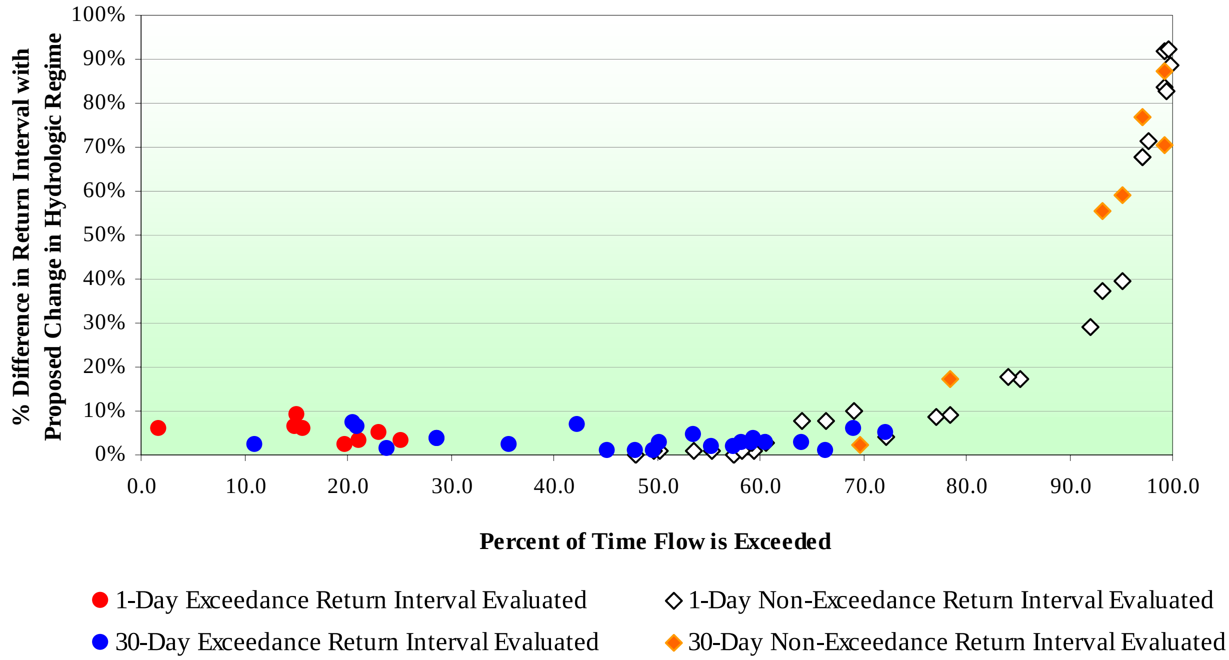


Figure 6-1. Percent difference in return interval of baseline conditions vs. 50 mgd withdrawal scenario as a function of percent of time flow is exceeded

Another important observation is that the withdrawals are cumulative down river of the withdrawal. For example, a withdrawal of 77 cfs (50 mgd) above this section of river and a withdrawal of 320 cfs down river of this section will have the cumulative effect of a withdrawal of about 400 cfs down stream of the most downstream withdrawal point.

Table 6-2. Water resource values and conclusions regarding protection under the recommended MFLs (50 mgd withdrawal scenario)

Water Resource Value (WRV)	Flow Condition Evaluated to Determine if WRV Protected	MFLs Regime Protective/Not Protective
1. Recreation In and On the Water	Low flow	Not Protective
2. Fish and Wildlife Habitats and the Passage of Fish	High flow (elevated habitats) Low flow (fish passage; all other fish and wildlife habitats)	Protective (elevated habitats) Not protective (fish passage and all other habitats)
3. Estuarine Resources	(None required)	Protective
4. Transfer of Detrital Material	High flow	Protective
5. Maintenance of Freshwater Storage and Supply	(None required)	Protective
6. Aesthetic and Scenic Attributes	Low flow	Protective
7. Filtration and Absorption of Nutrients and Other Pollutants	High flow	Protective
8. Sediment Loads	High flow	Protective
9. Water Quality	Low flow	Protective
10. Navigation	Low flow	Not Protective

References:

CDM. 2004. St. Johns River Water Management District: Hydrologic Model Development for MFL Evaluation of the Upper St. Johns River Basin, Florida. Technical Memorandum. November 2004.

APPENDIX A

FIGURES

Figure A.1-1
SJRWMD - USJRB Minimum Flows and Levels
Exceedance Curves 1959-2000 (HSPF)
Lake Poinsett Outlet
(River Mile 232)

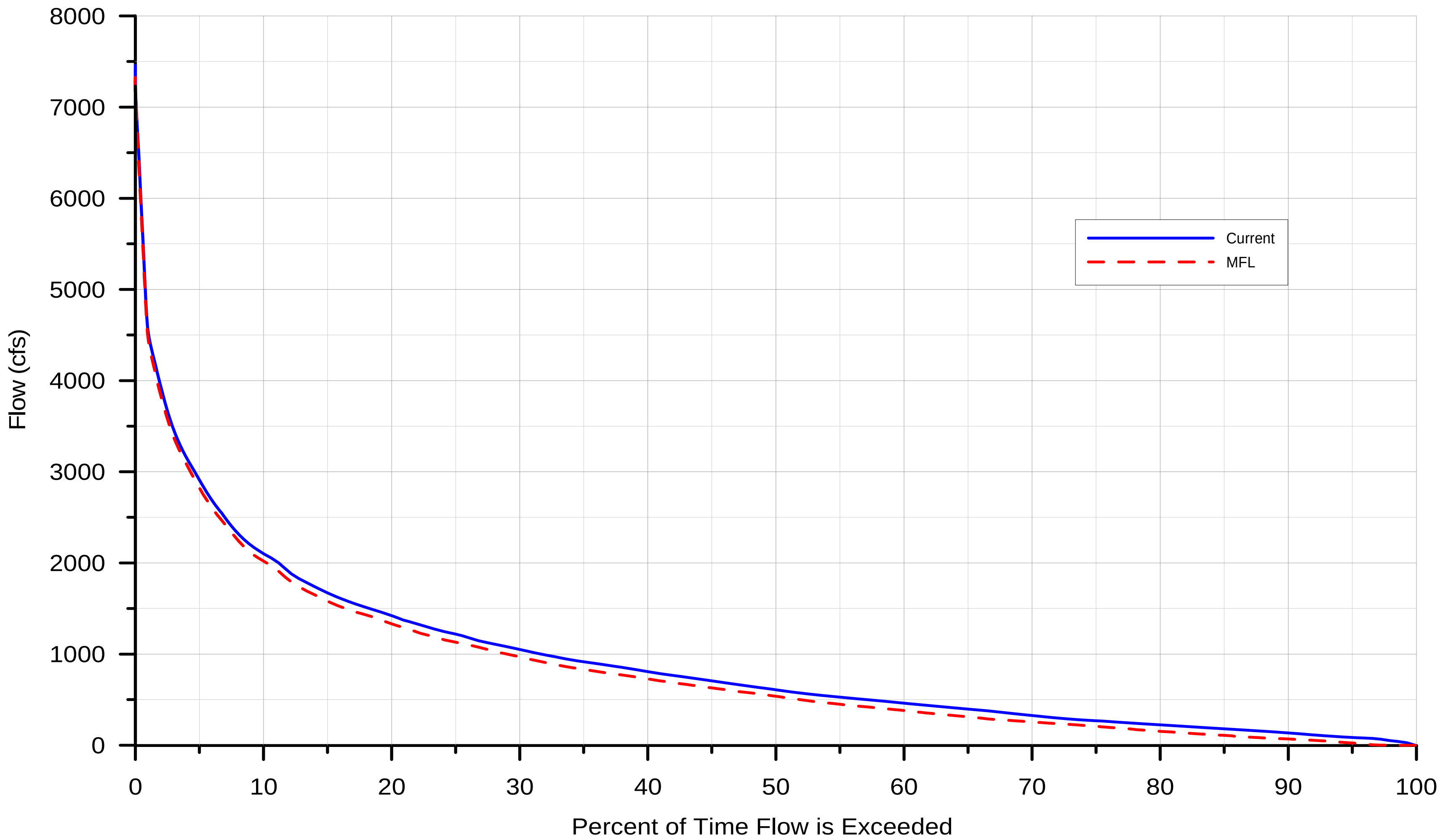


Figure A.1-2a
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Lake Poinsett Outlet - 1 Day Duration
(River Mile 232)

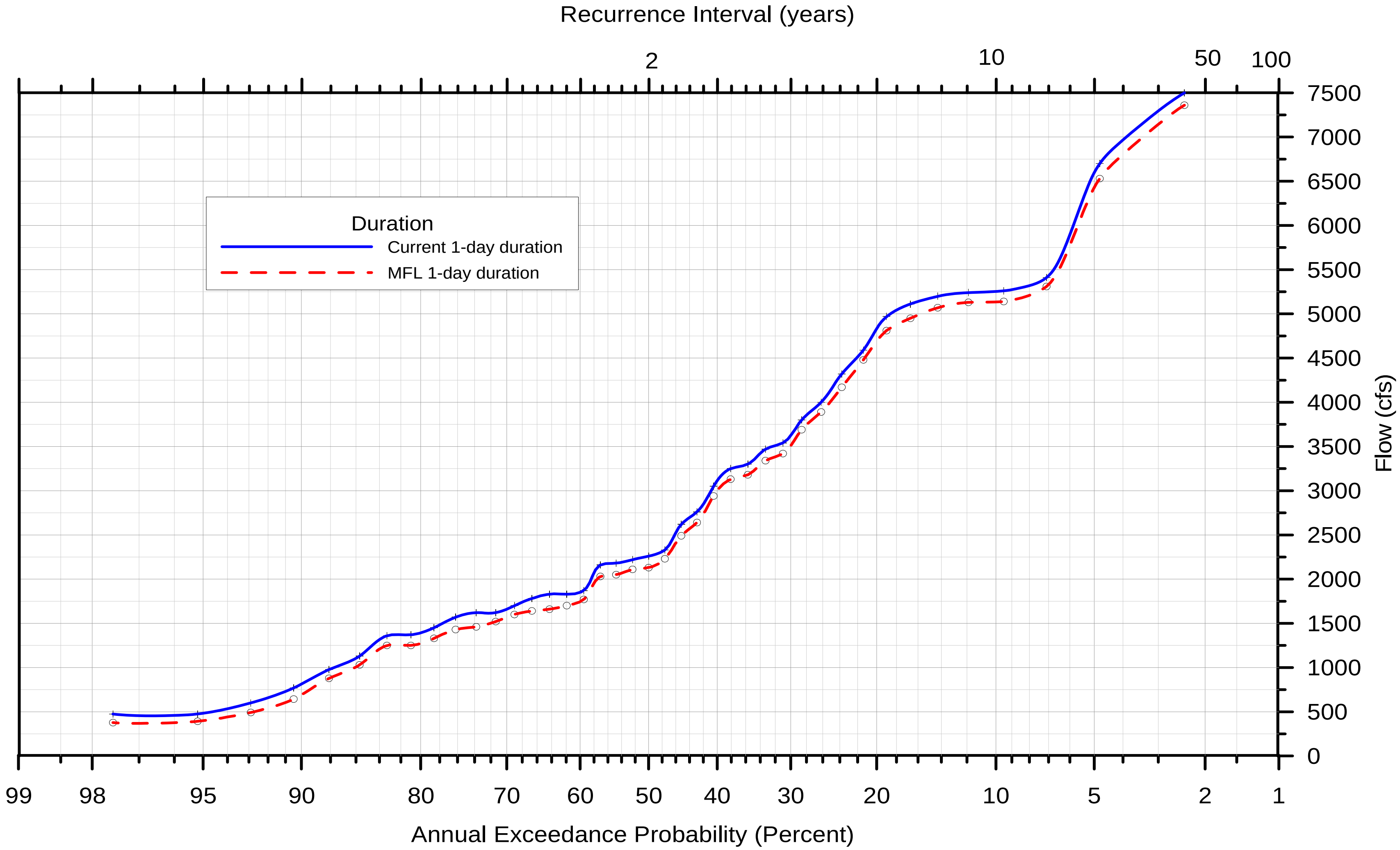


Figure A.1-2b
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Lake Poinsett Outlet - 14 Day Duration
(River Mile 232)

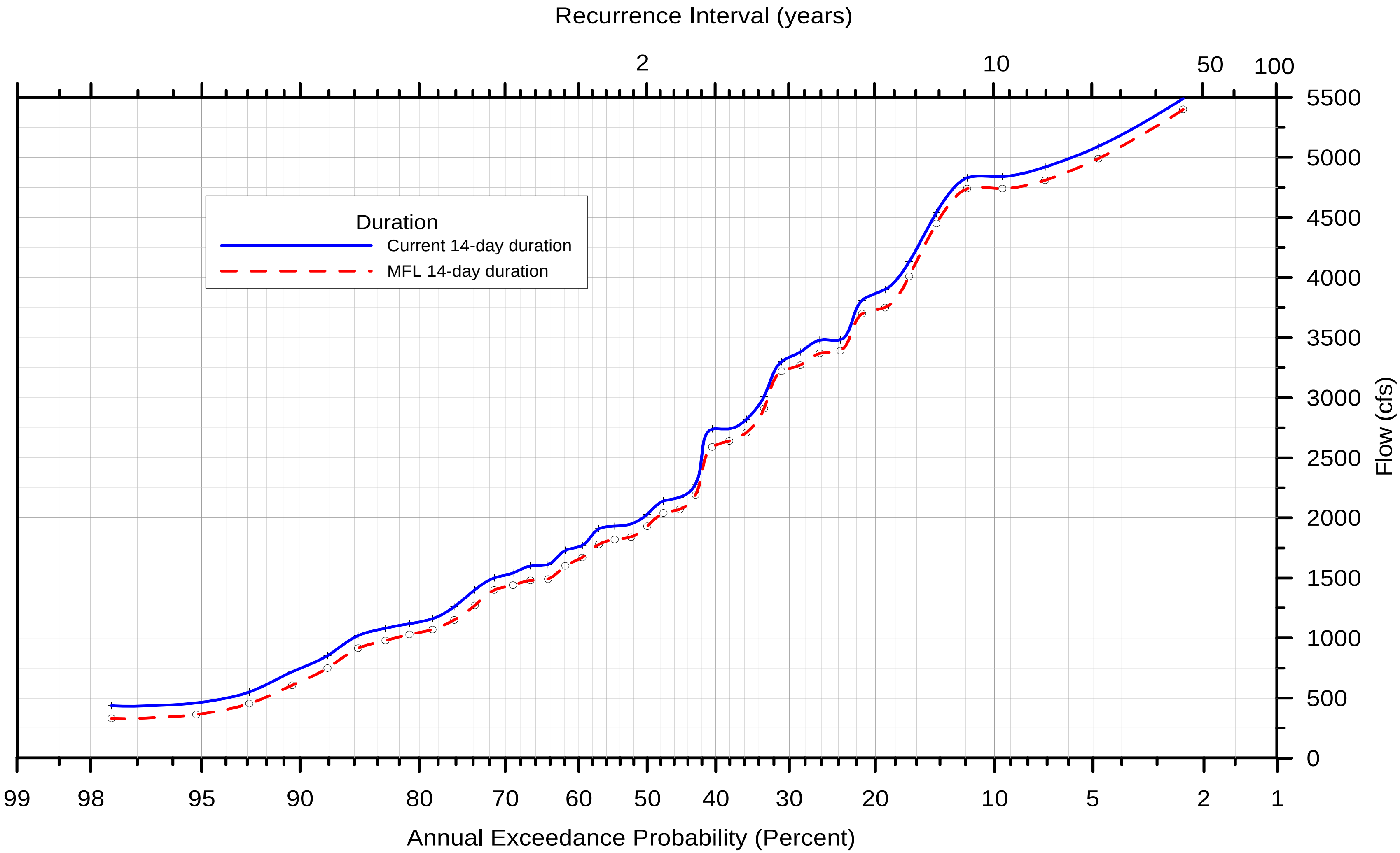


Figure A.1-2c
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Lake Poinsett Outlet - 30 Day Duration
(River Mile 232)

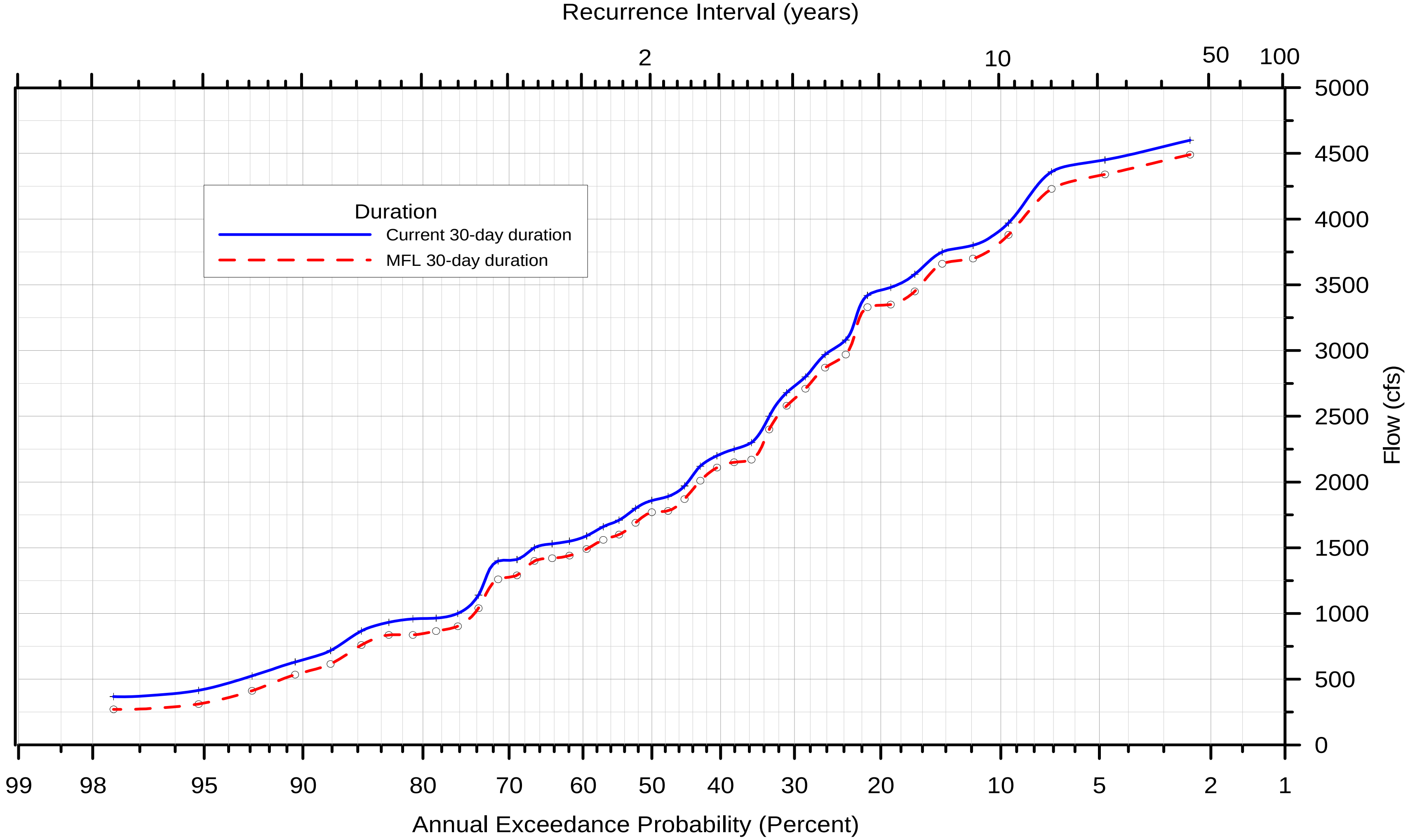


Figure A.1-3a
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Lake Poinsett Outlet - 1 Day Duration
(River Mile 232)

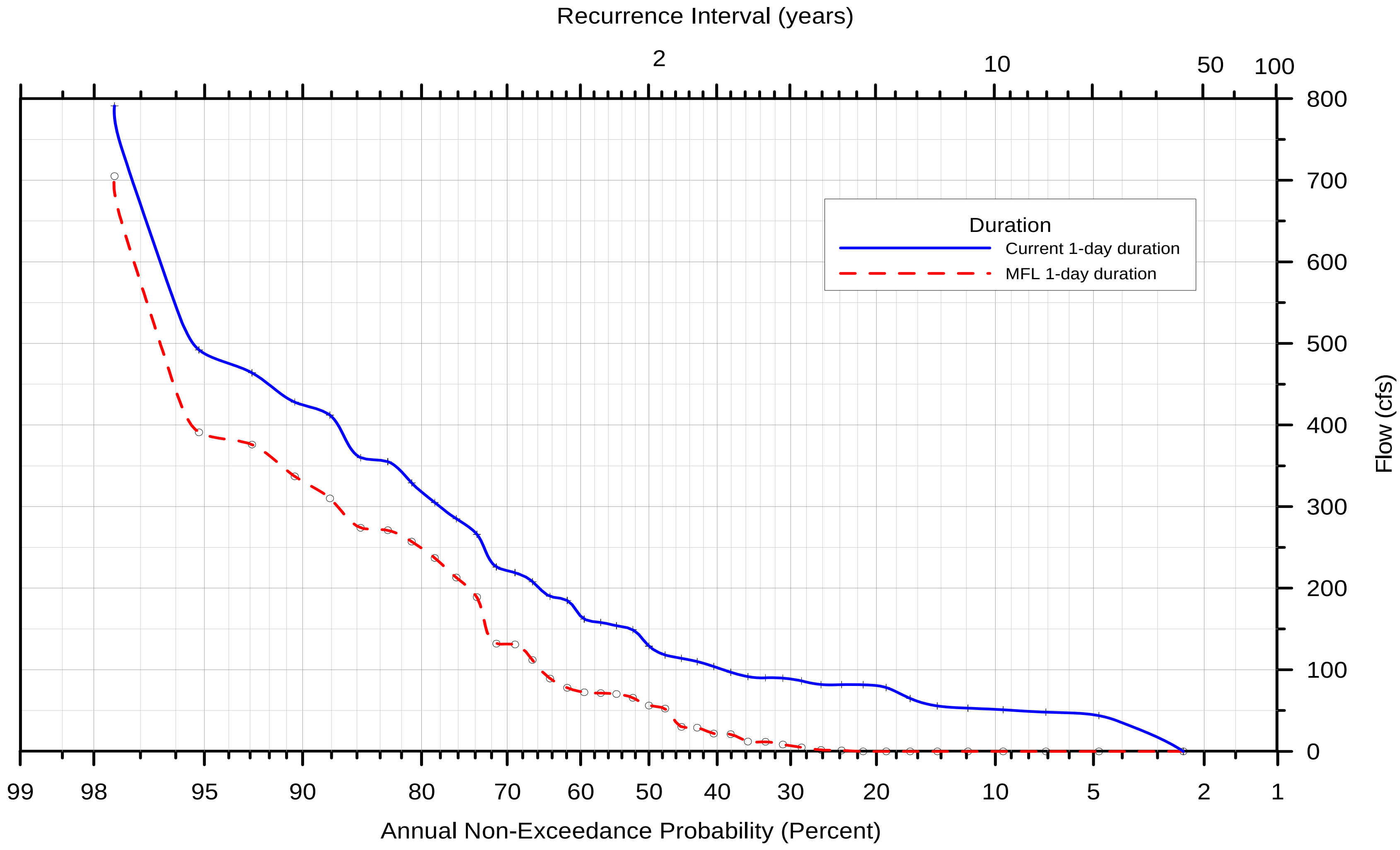


Figure A.1-3b
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Lake Poinsett Outlet - 14 Day Duration
(River Mile 232)

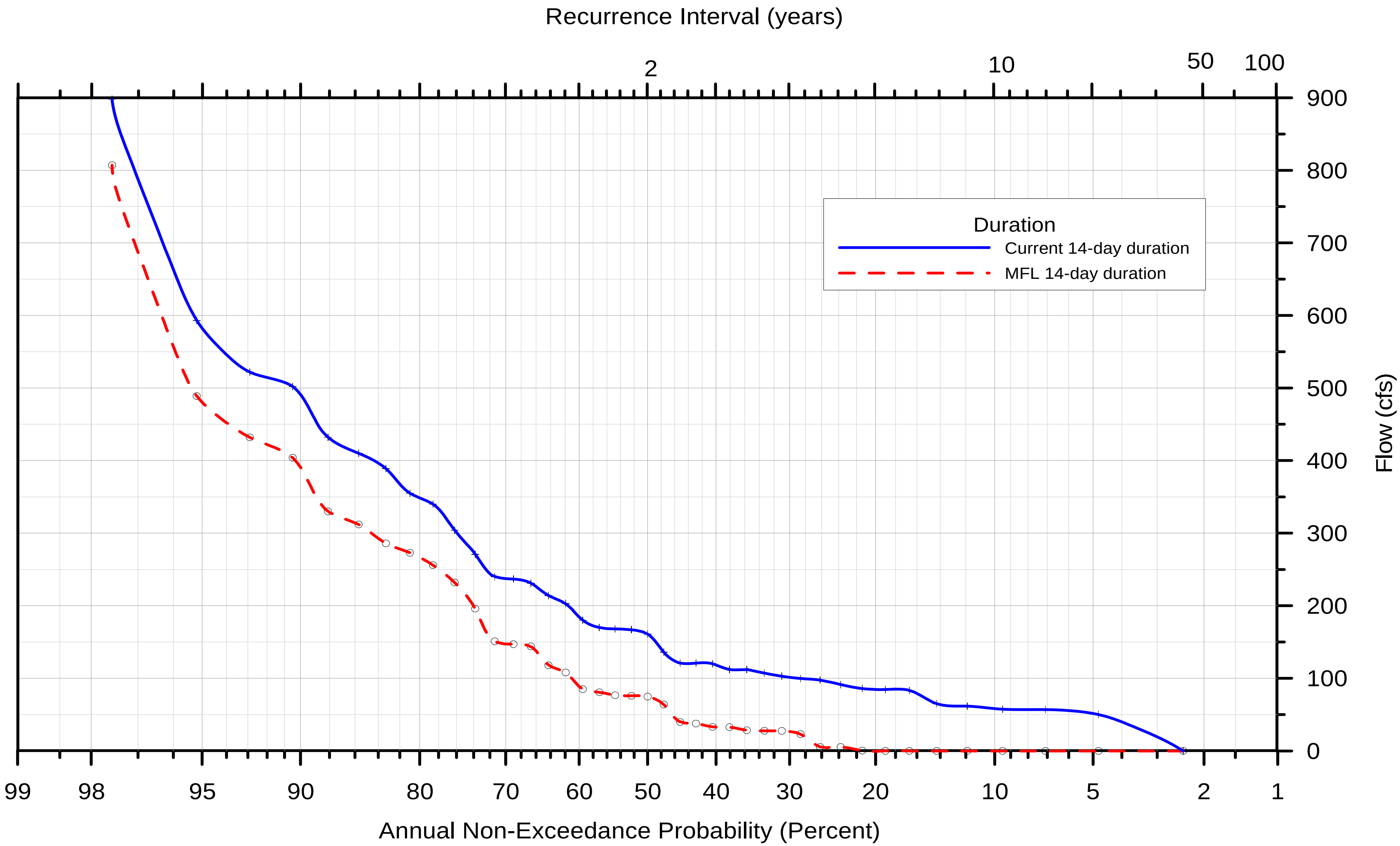


Figure A.1-3c
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Lake Poinsett Outlet - 30 Day Duration
(River Mile 232)

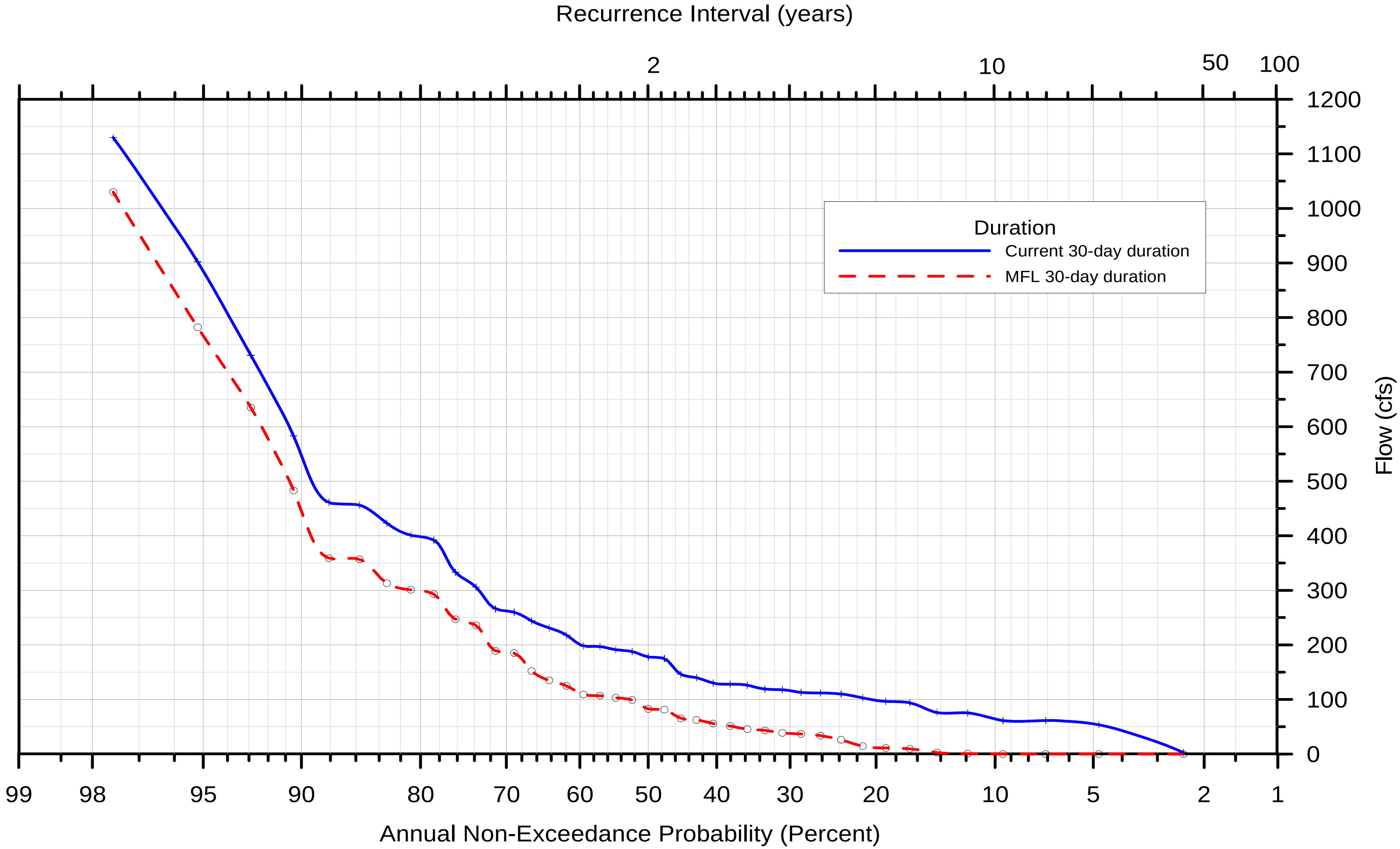


Figure A.2-1
SJRWMD - USJRB Minimum Flows and Levels
Exceedance Curves 1959-2000 (HSPF)
SJR at SR50
(River Mile 209)

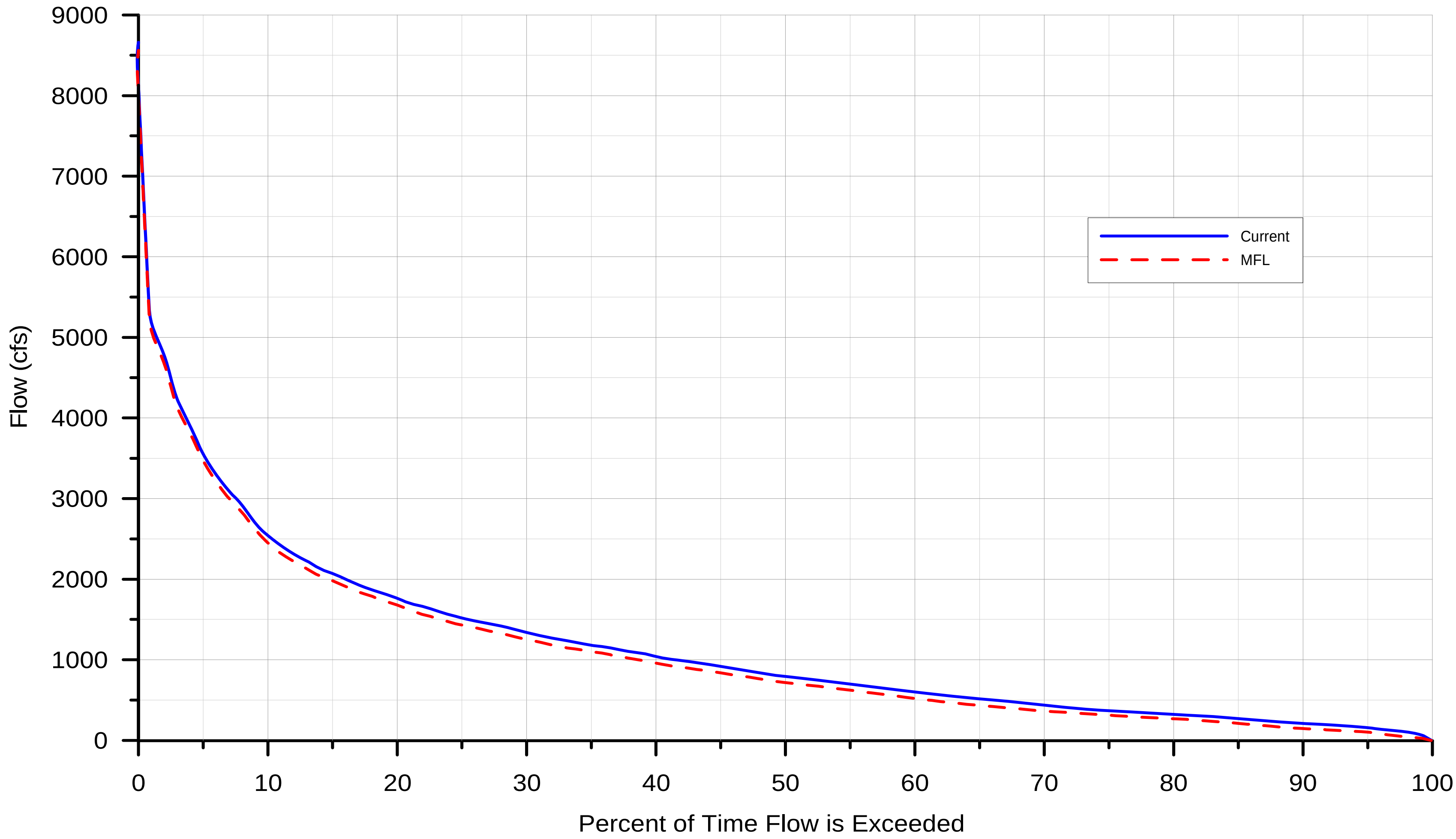


Figure A.2-2a
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
SJR at SR50 - 1 Day Duration
(River Mile 209)

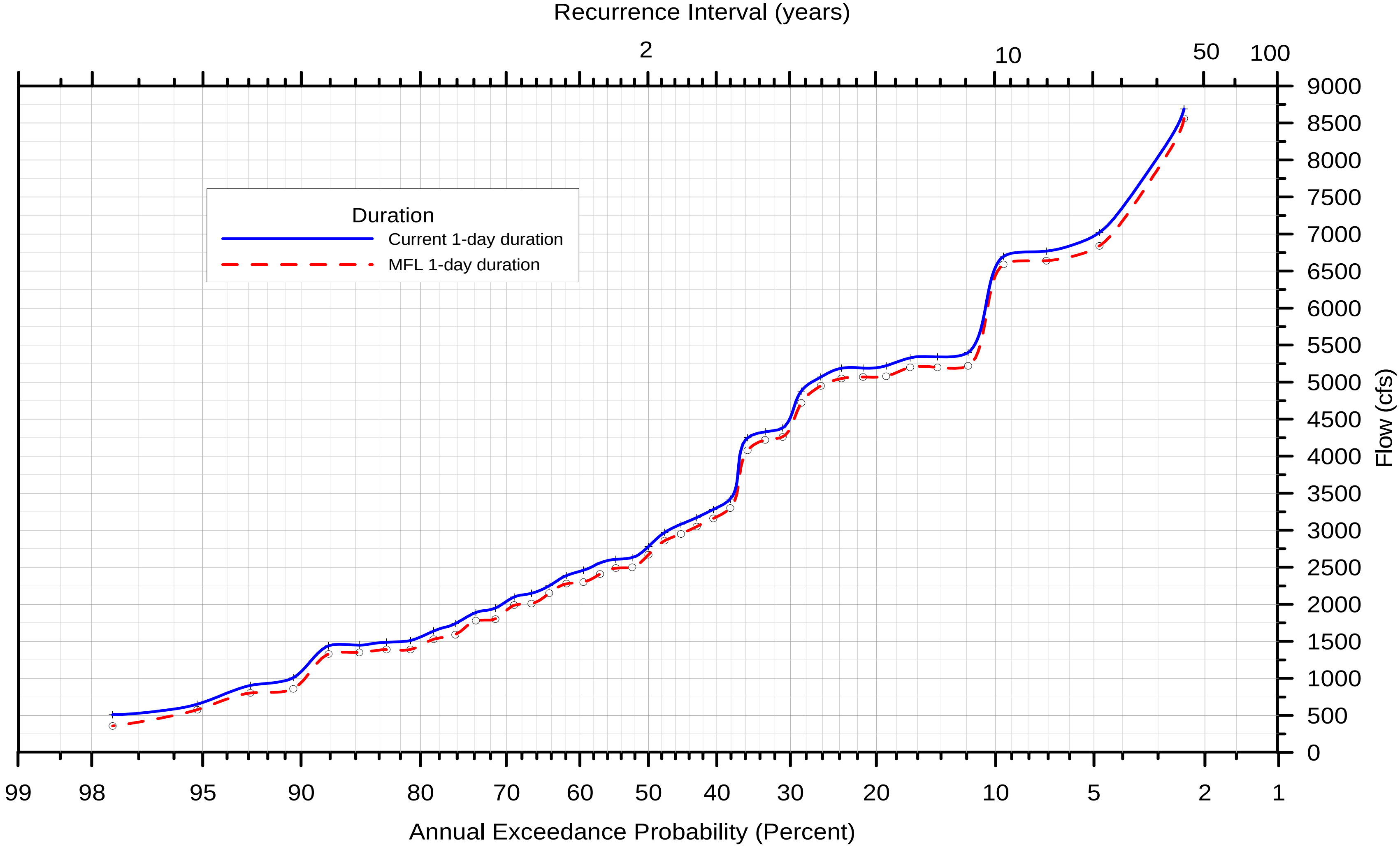


Figure A.2-2b
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
SJR at SR50 - 14 Day Duration
(River Mile 209)

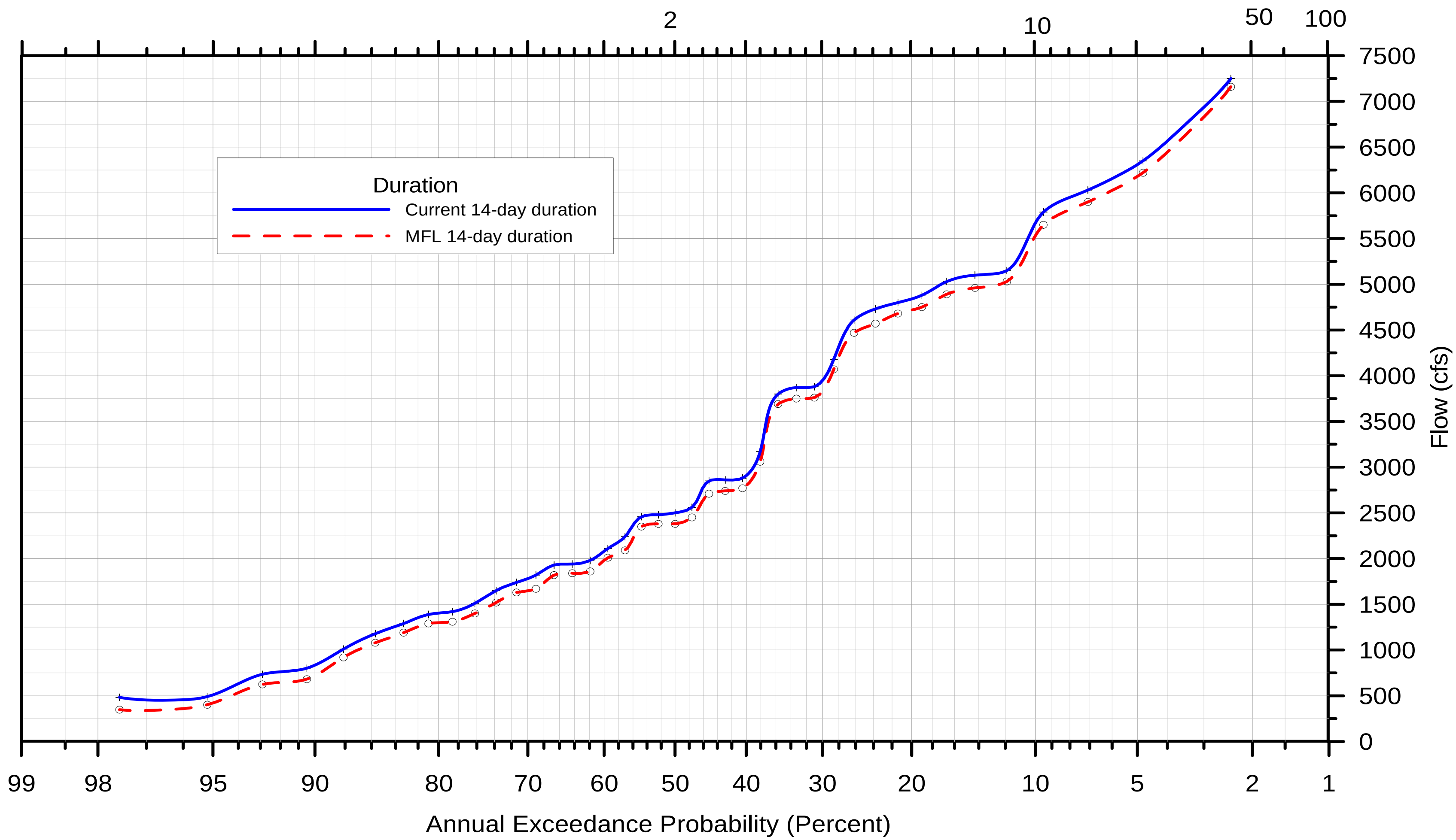


Figure A.2-2c
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
SJR at SR50 - 30 Day Duration
(River Mile 209)

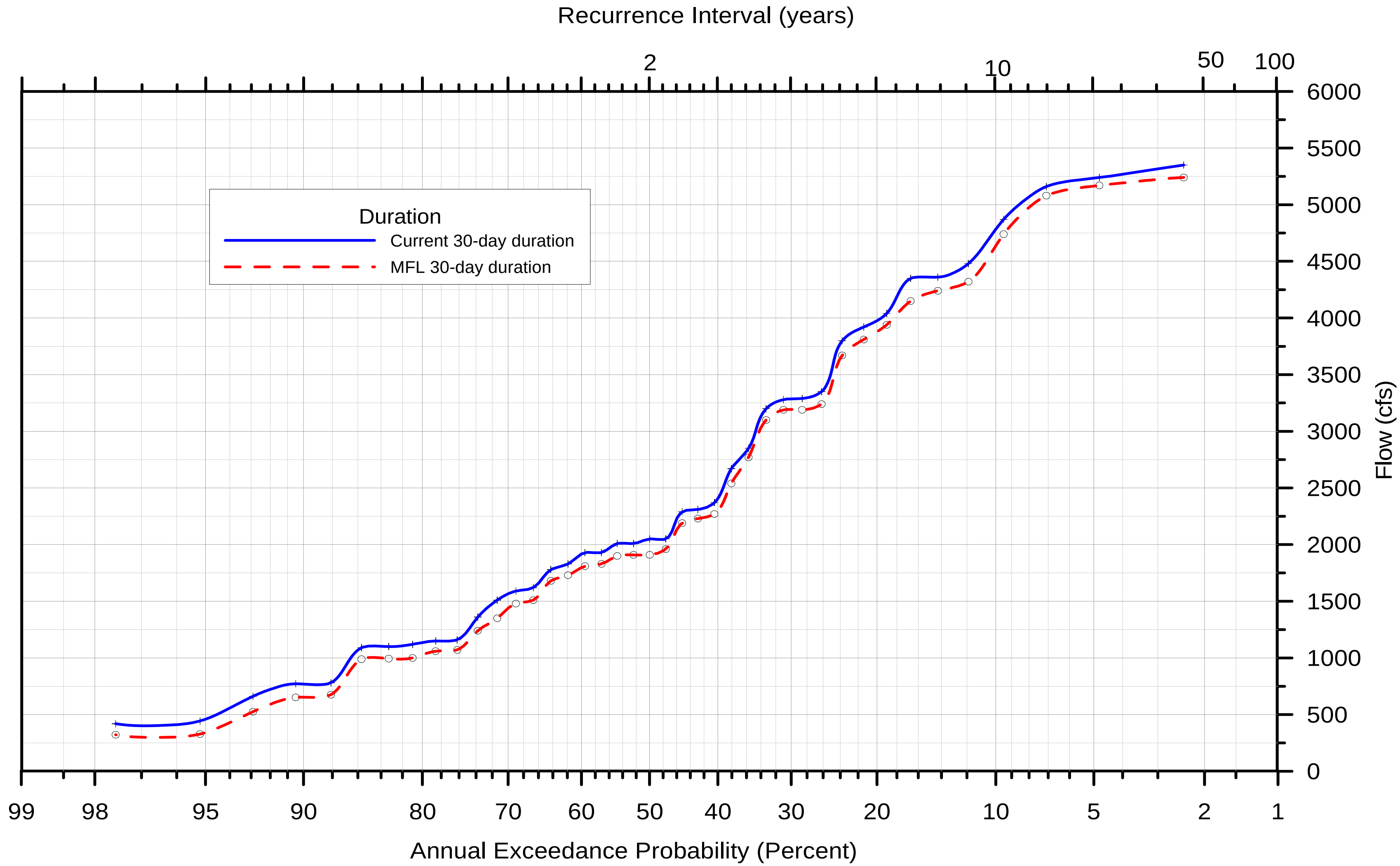


Figure A.2-3a
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
SJR at SR50 - 1 Day Duration
(River Mile 209)

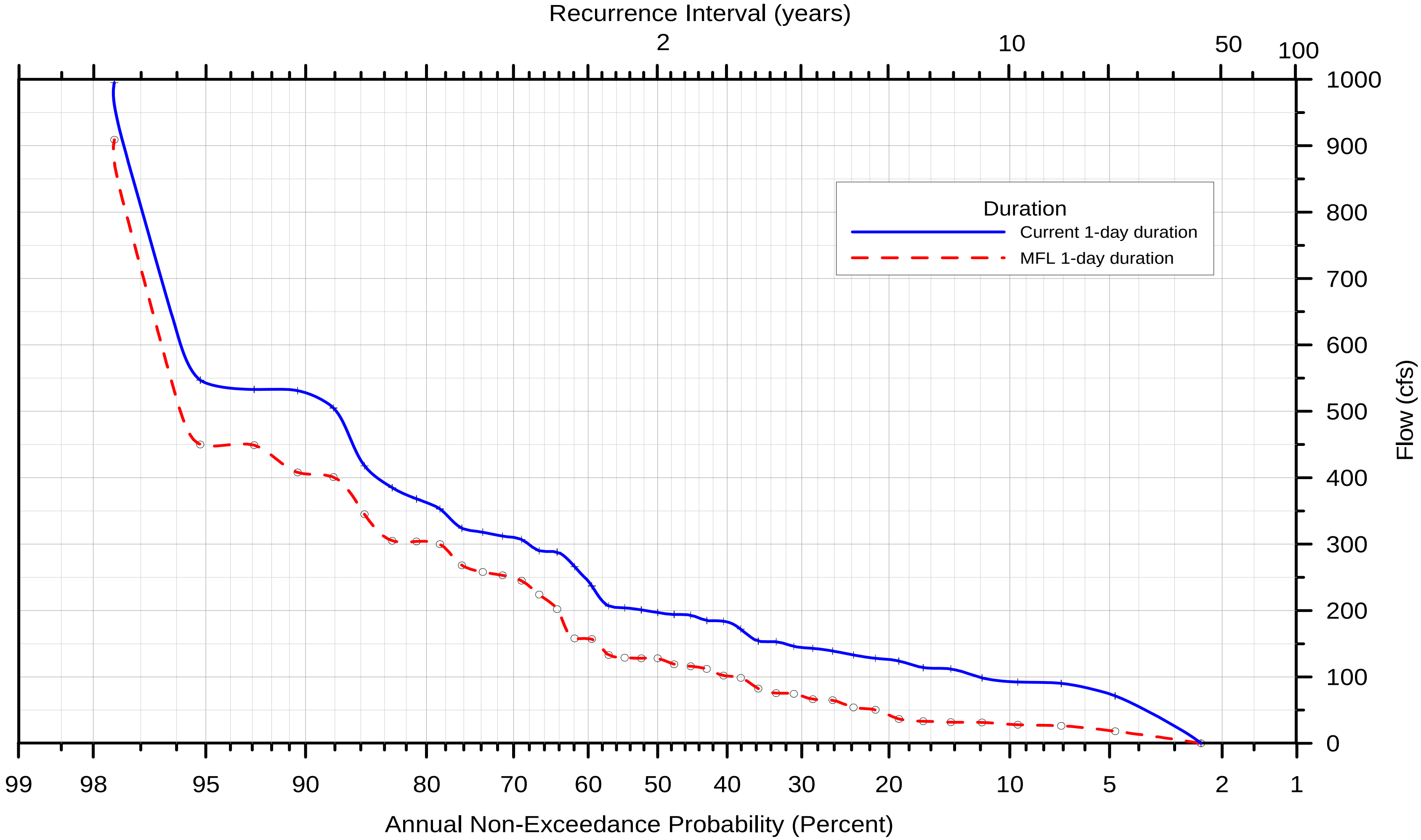


Figure A.2-3b
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
SJR at SR50 - 14 Day Duration
(River Mile 209)

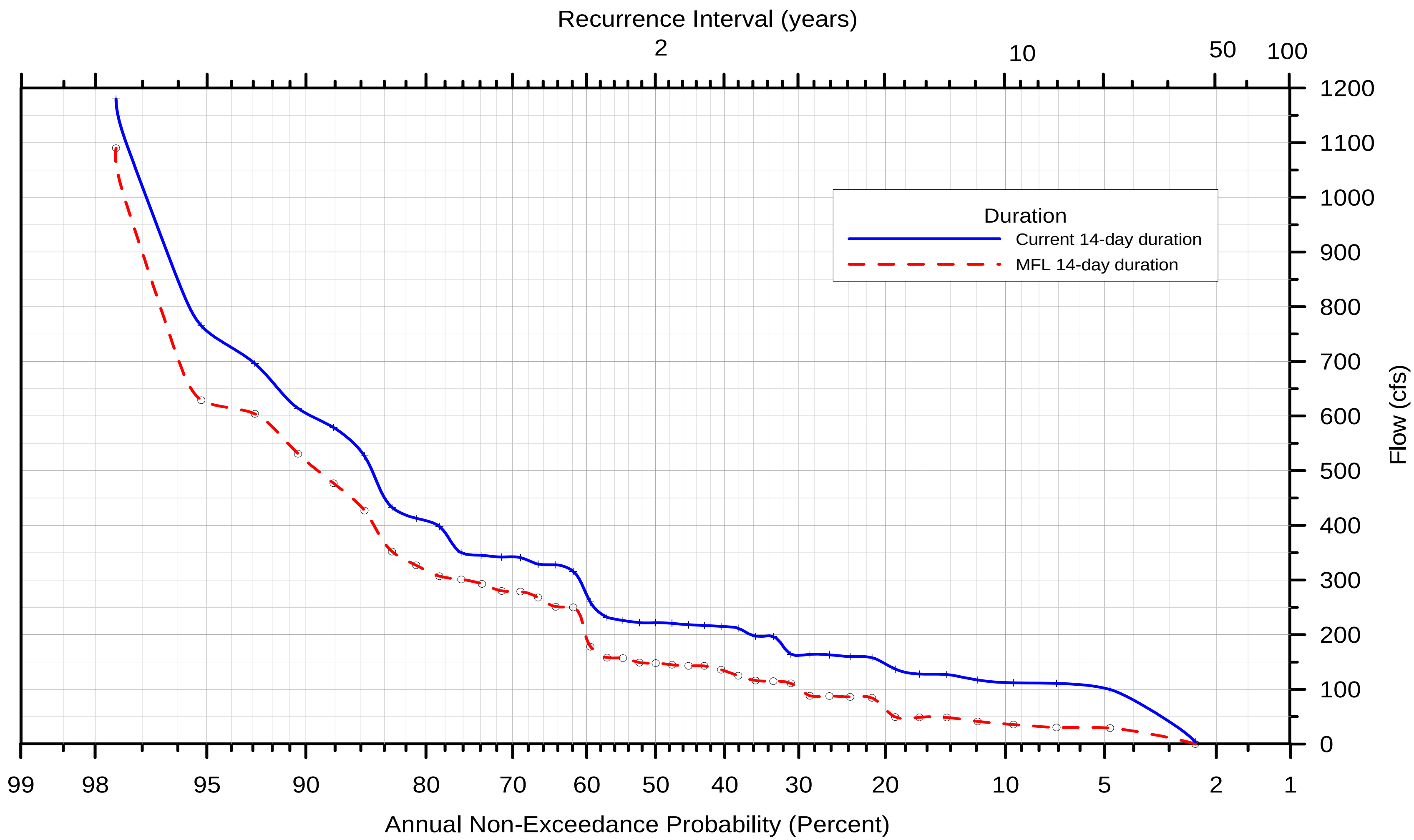


Figure A.2-3c
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
SJR at SR50 - 30 Day Duration
(River Mile 209)

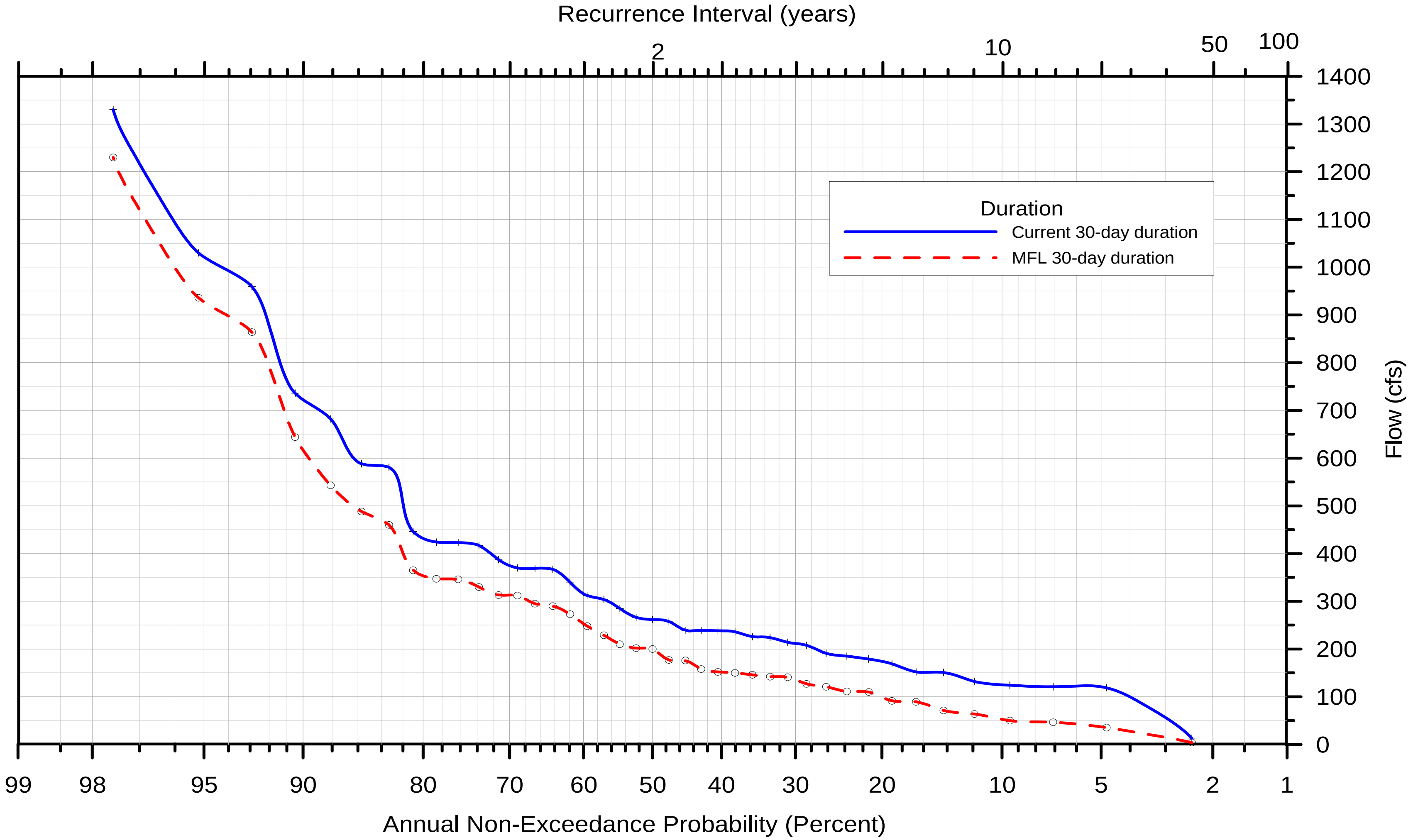


Figure A.3-1
SJRWMD - USJRB Minimum Flows and Levels
Exceedance Curves 1959-2000 (HSPF)
Puzzle Lake Outlet
(River Mile189)

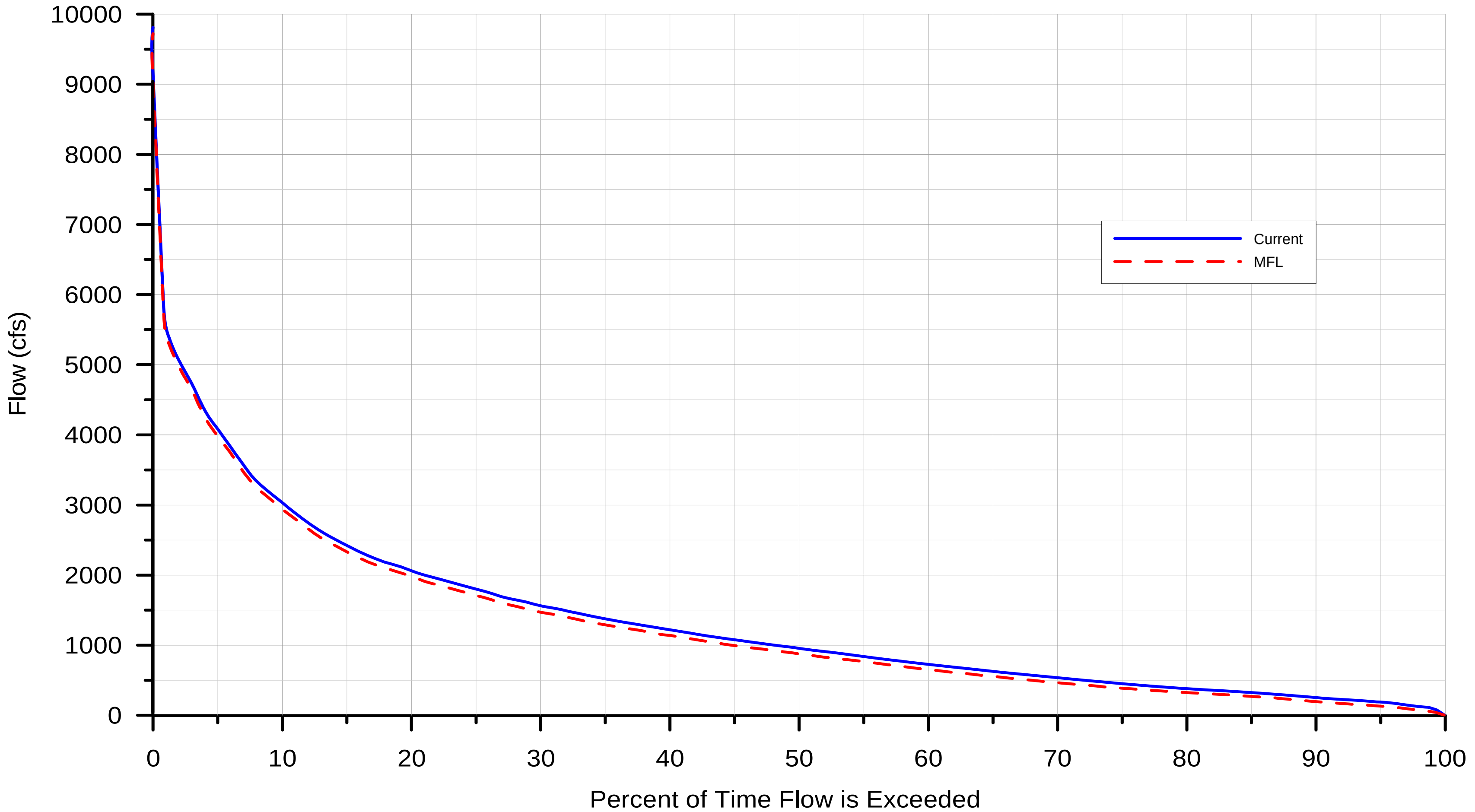


Figure A.3-2a
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Puzzle Lake Outlet - 1 Day Duration
(River Mile 189)

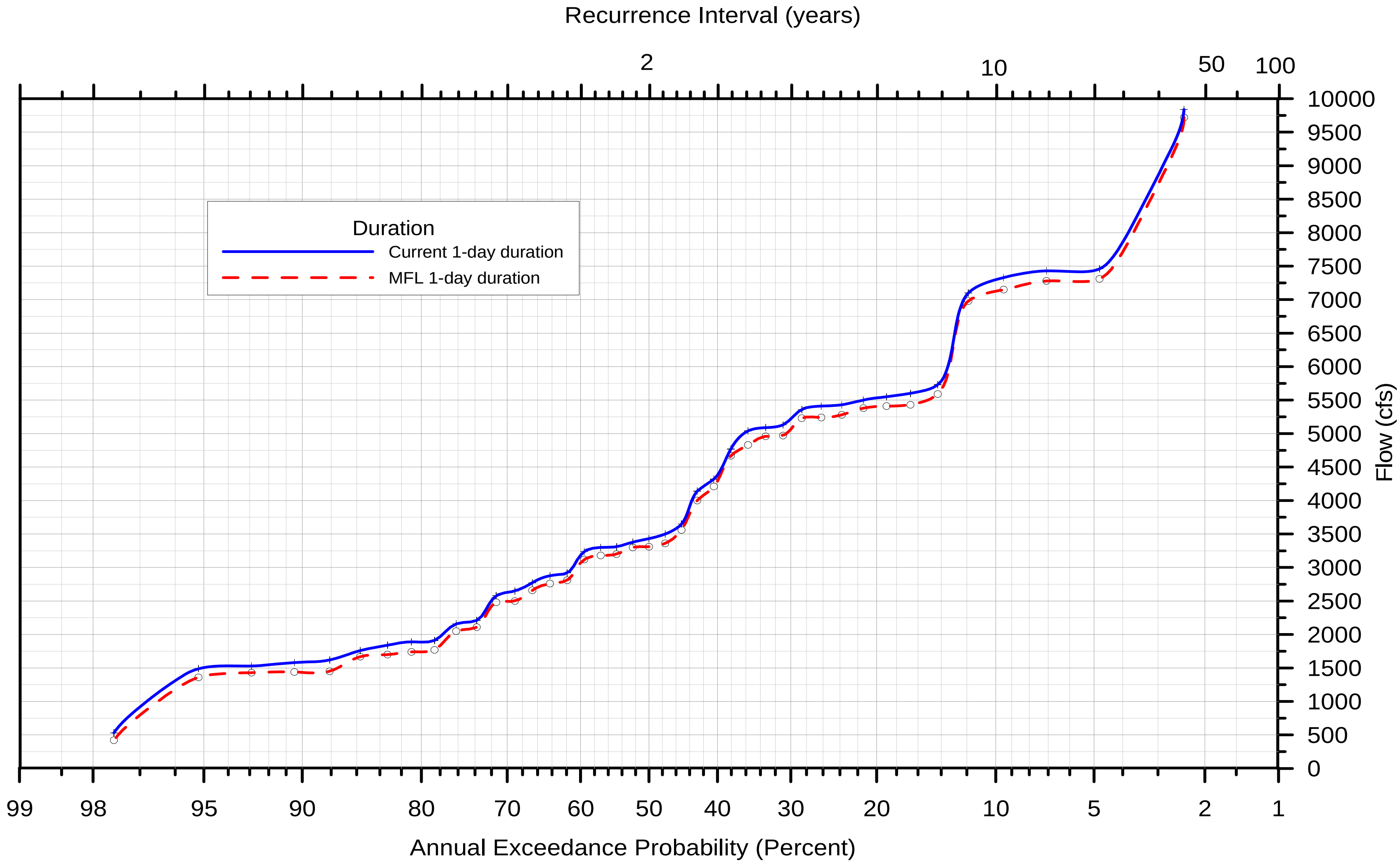


Figure A.3-2b
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Puzzle Lake Outlet - 14 Day Duration
(River Mile 189)

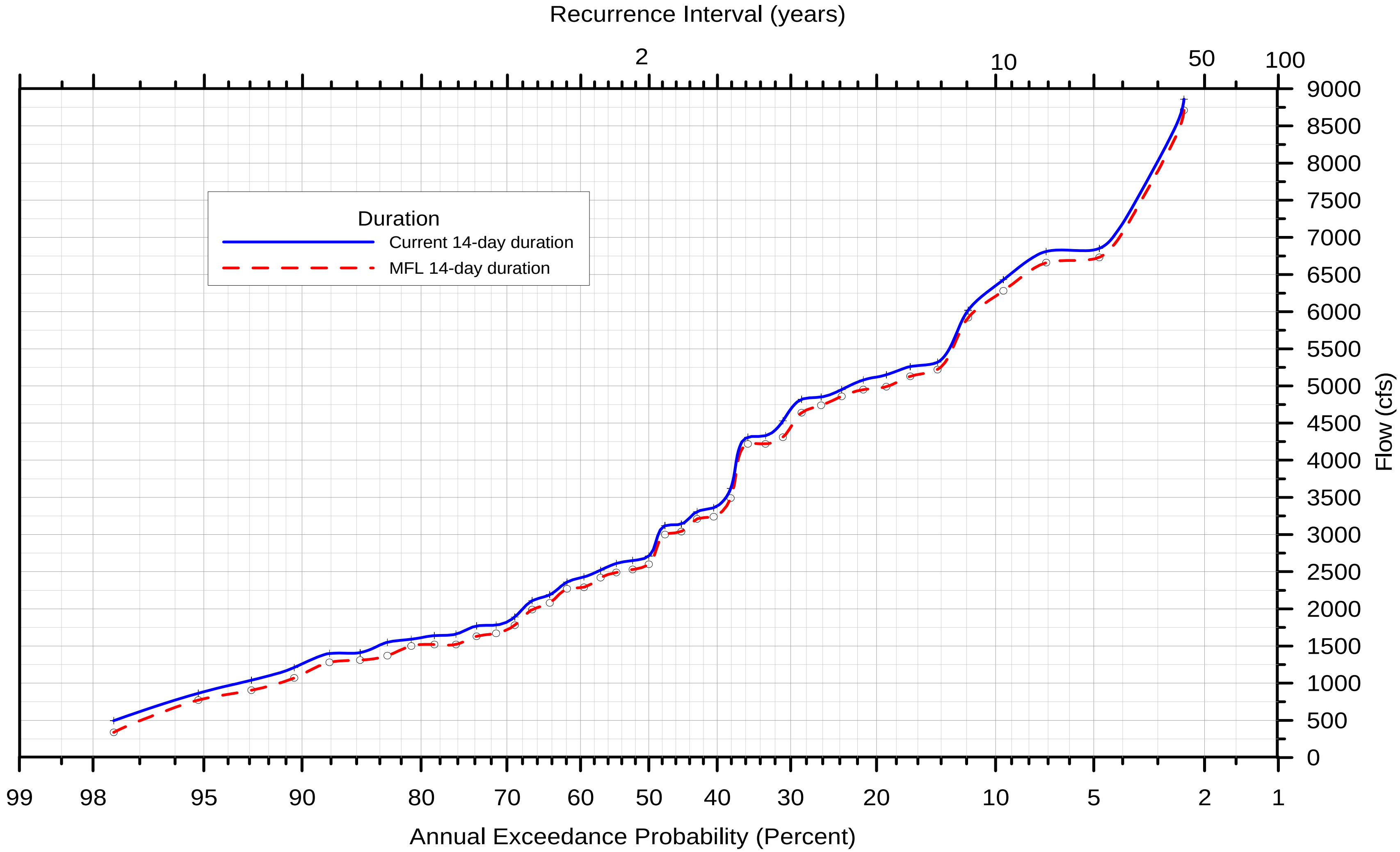


Figure A.3-2c
SJRWMD - USJRB Minimum Flows and Levels
High Frequency Continuously Exceeded
Puzzle Lake Outlet - 30 Day Duration
(River Mile 189)

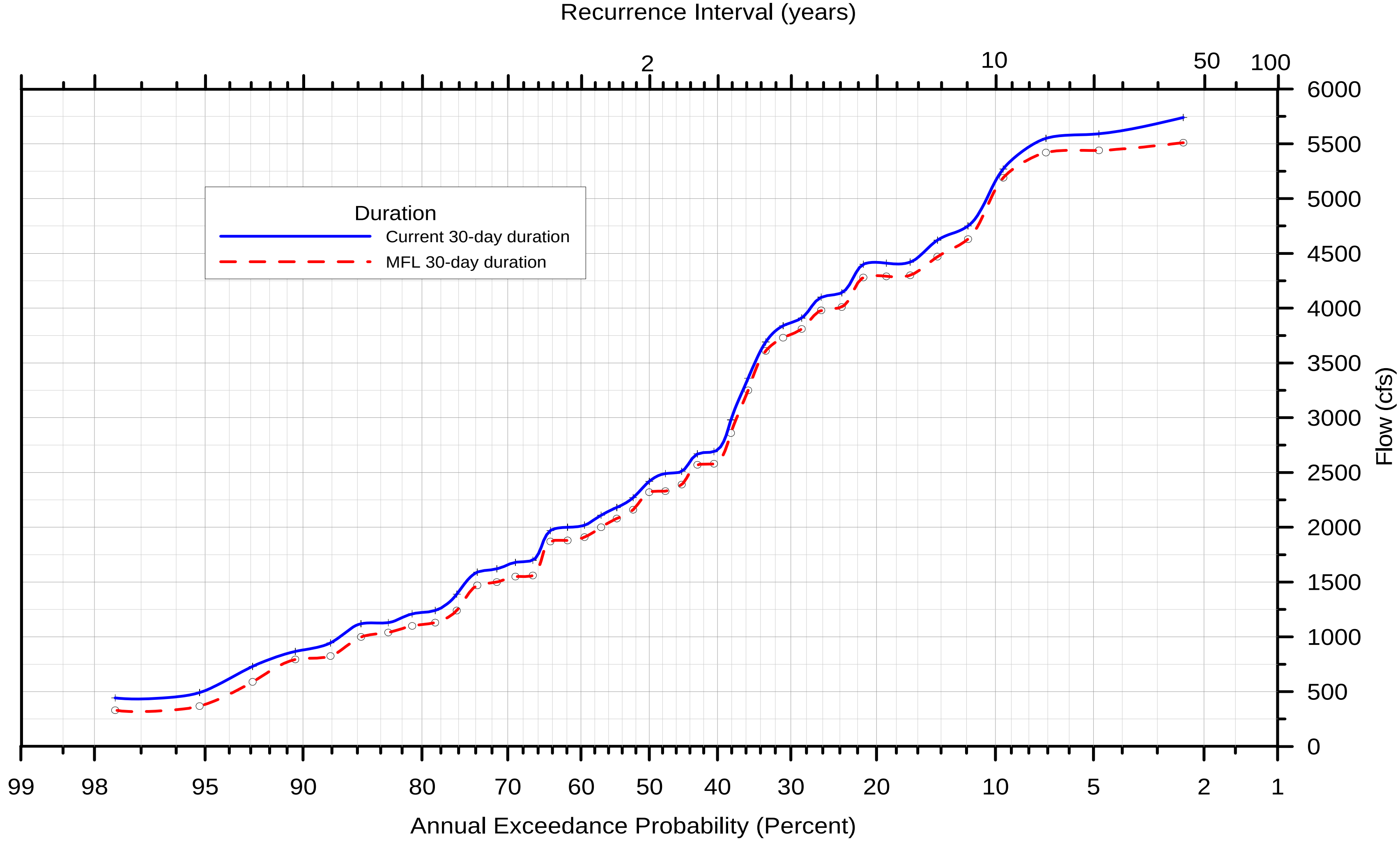


Figure A.3-3a
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Puzzle Lake Outlet - 1 Day Duration
(River Mile 189)

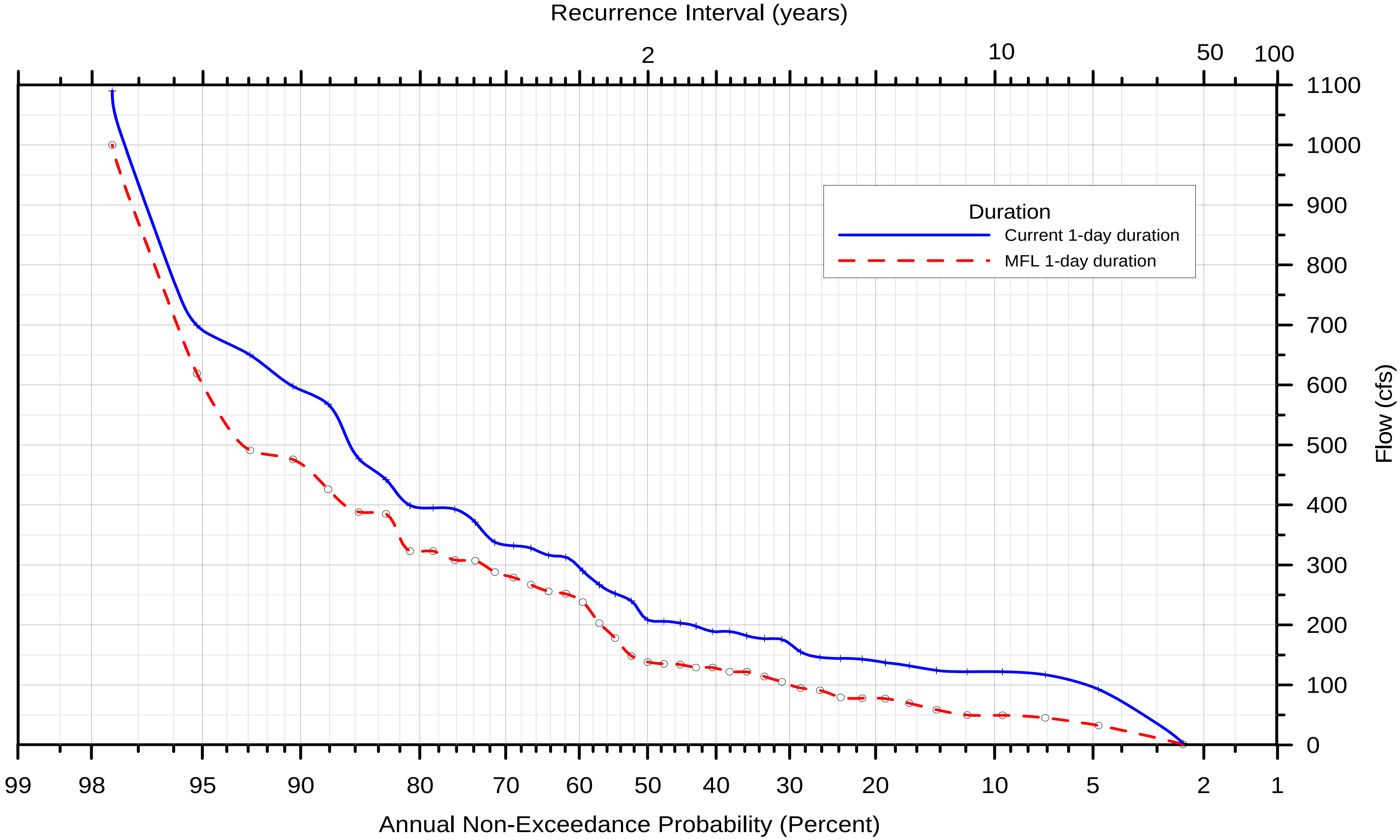


Figure A.3-3b
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Puzzle Lake Outlet - 14 Day Duration
(River Mile 189)

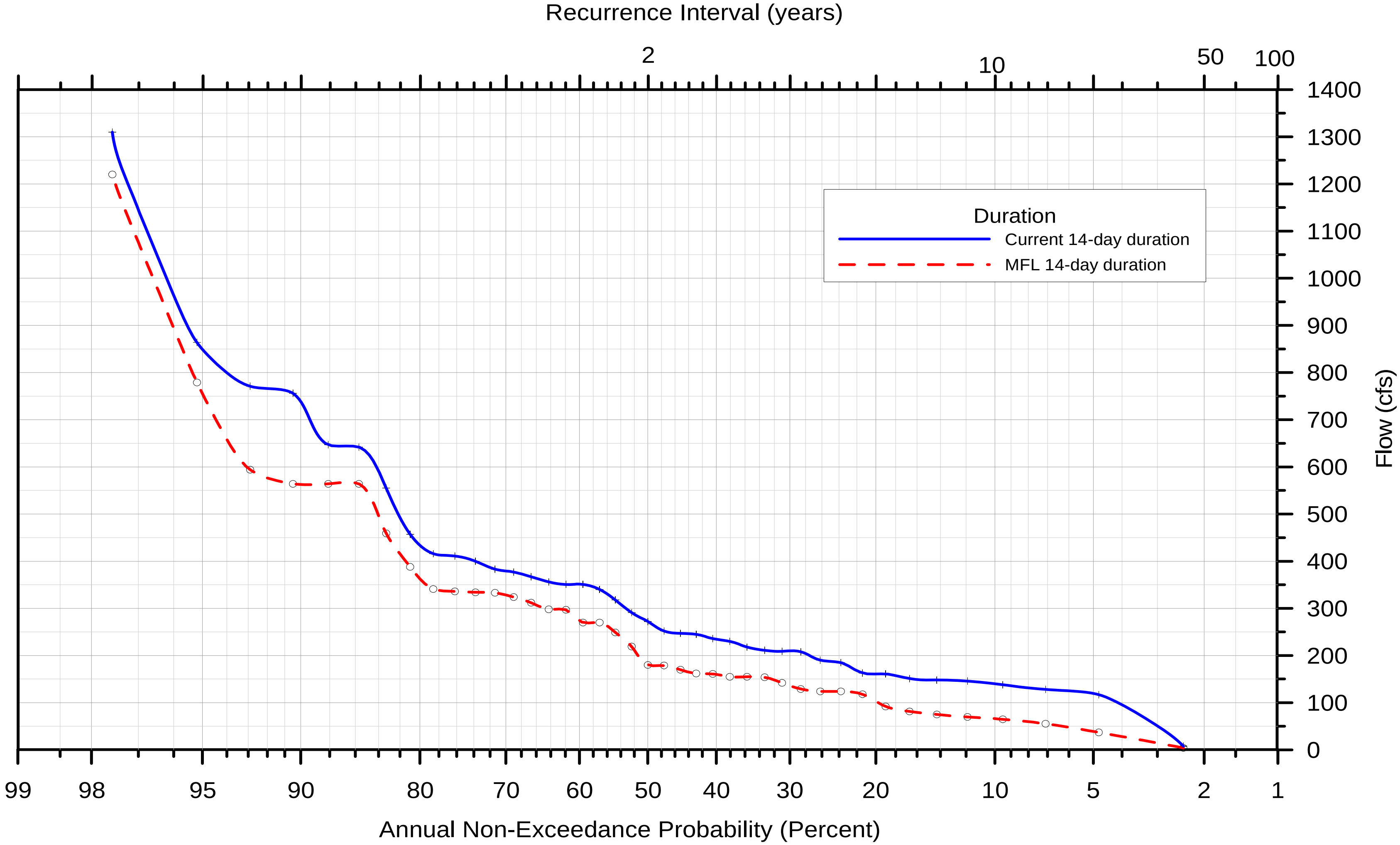


Figure A.3-3c
SJRWMD - USJRB Minimum Flows and Levels
Low Frequency Continuously Not Exceeded
Puzzle Lake Outlet - 30 Day Duration
(River Mile 189)

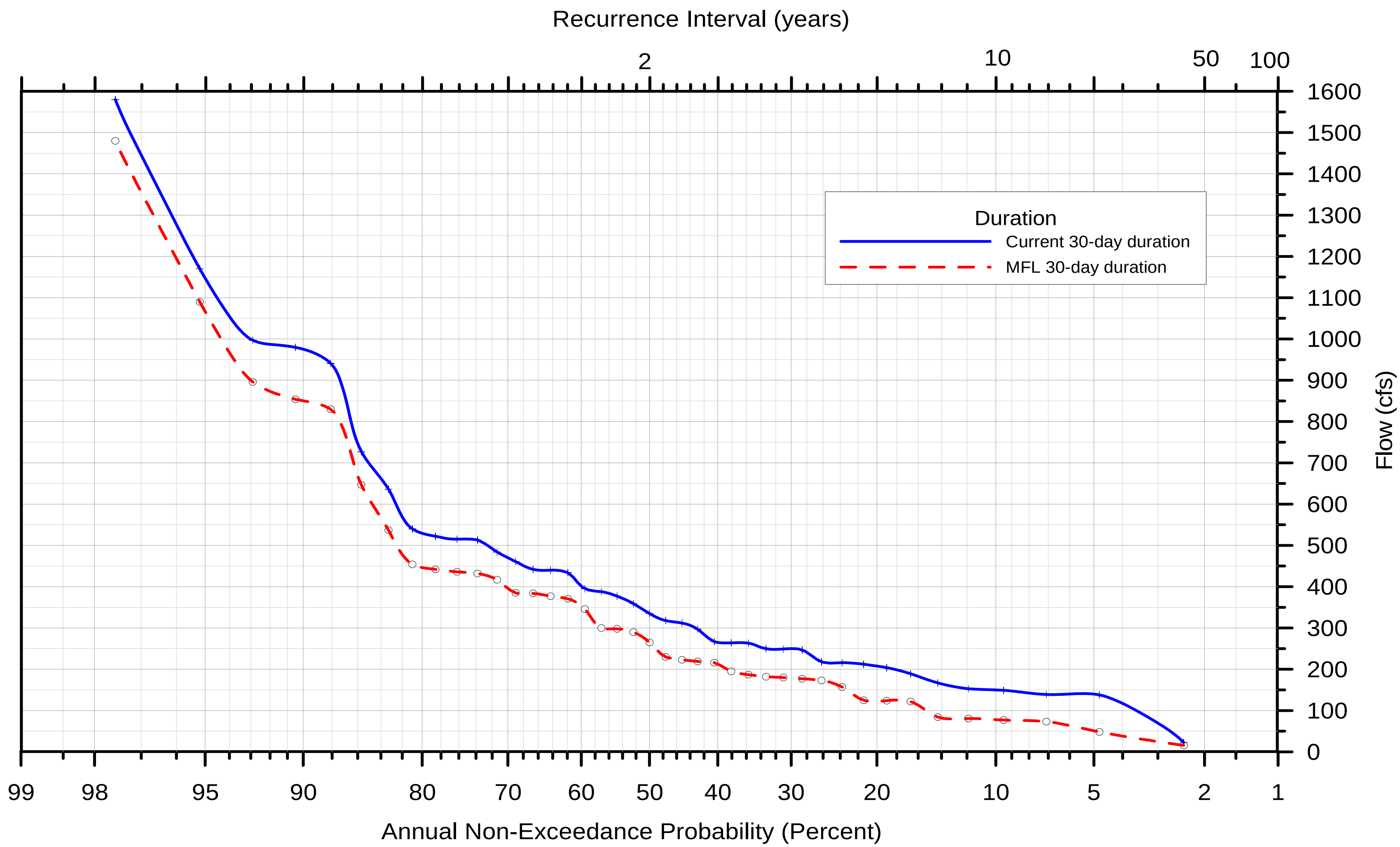
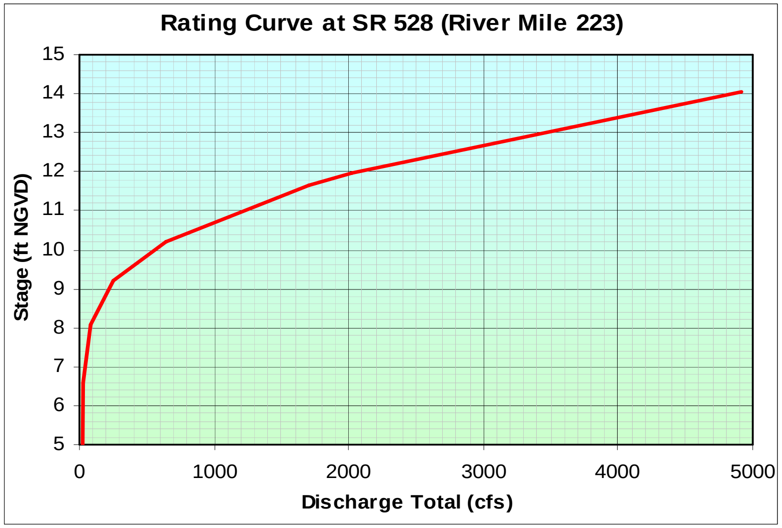
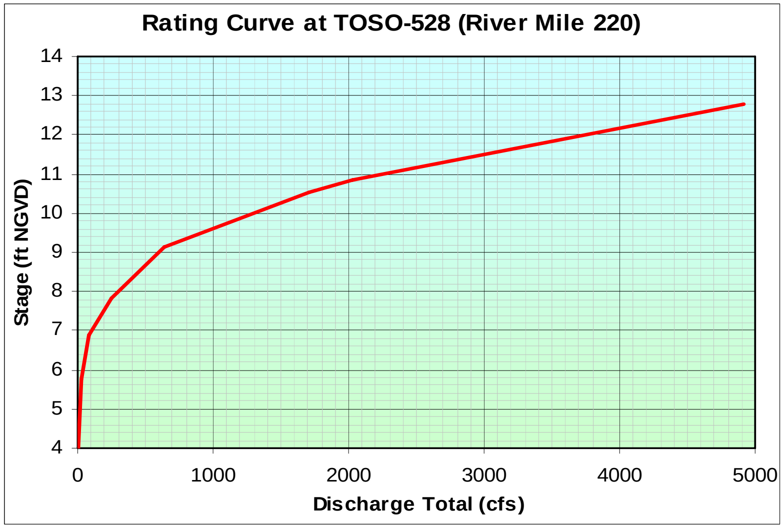
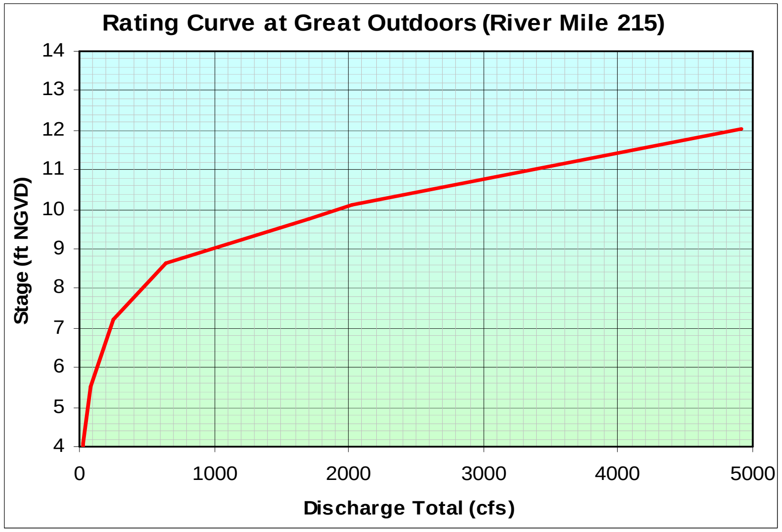


Figure A.4a Rating curves for bridges and transects located along the St. Johns River between SR 46 and SR 528 (from HEC-RAS)







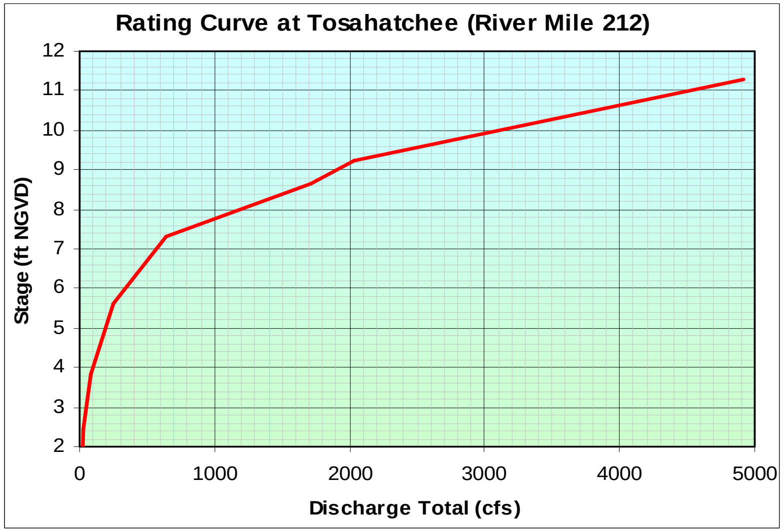
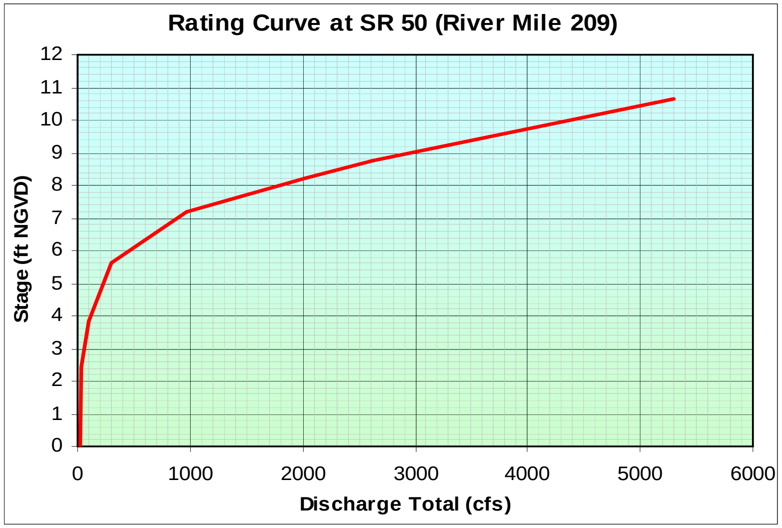
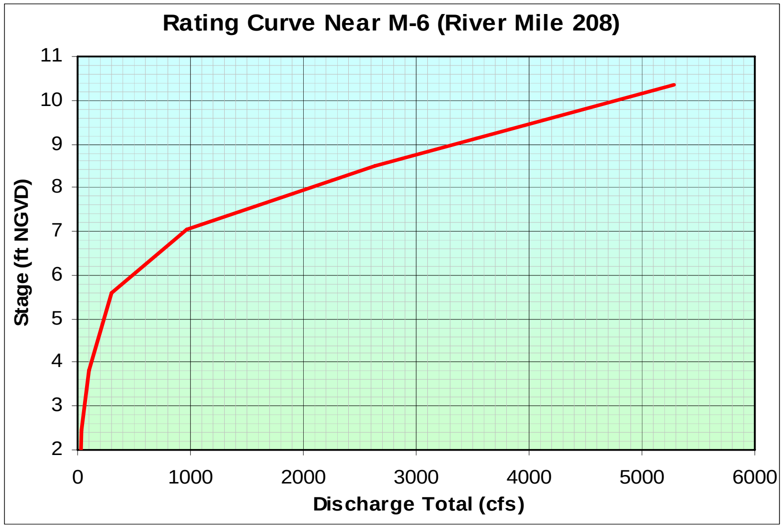
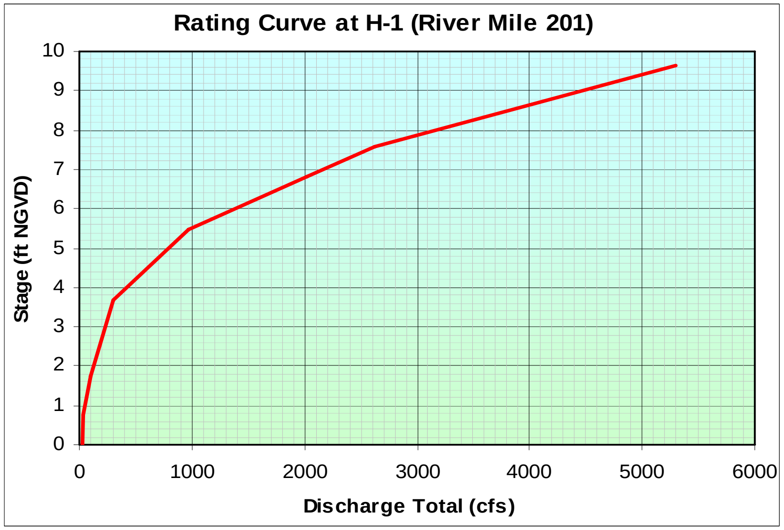


Figure A.4b Rating curves for bridges and transects located along the St. Johns River between SR 46 and SR 528 (from HEC-RAS)







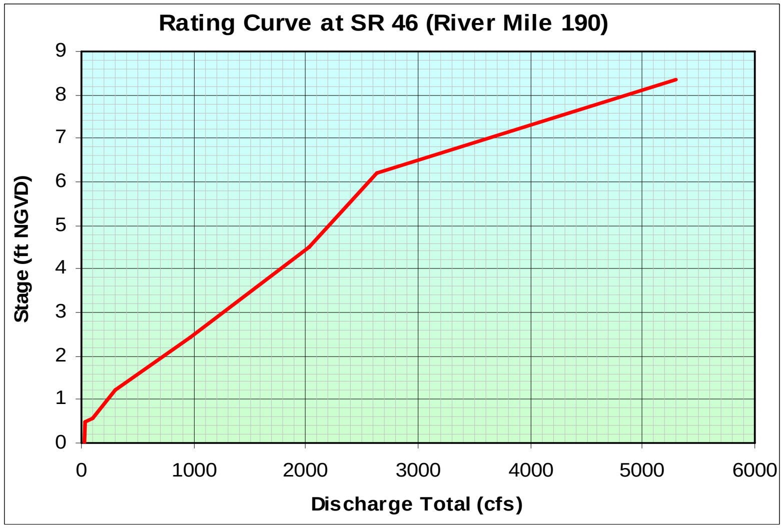


Figure A.5 Channel velocity versus discharge at SR 50 (River Mile 209)
(From HEC-RAS)

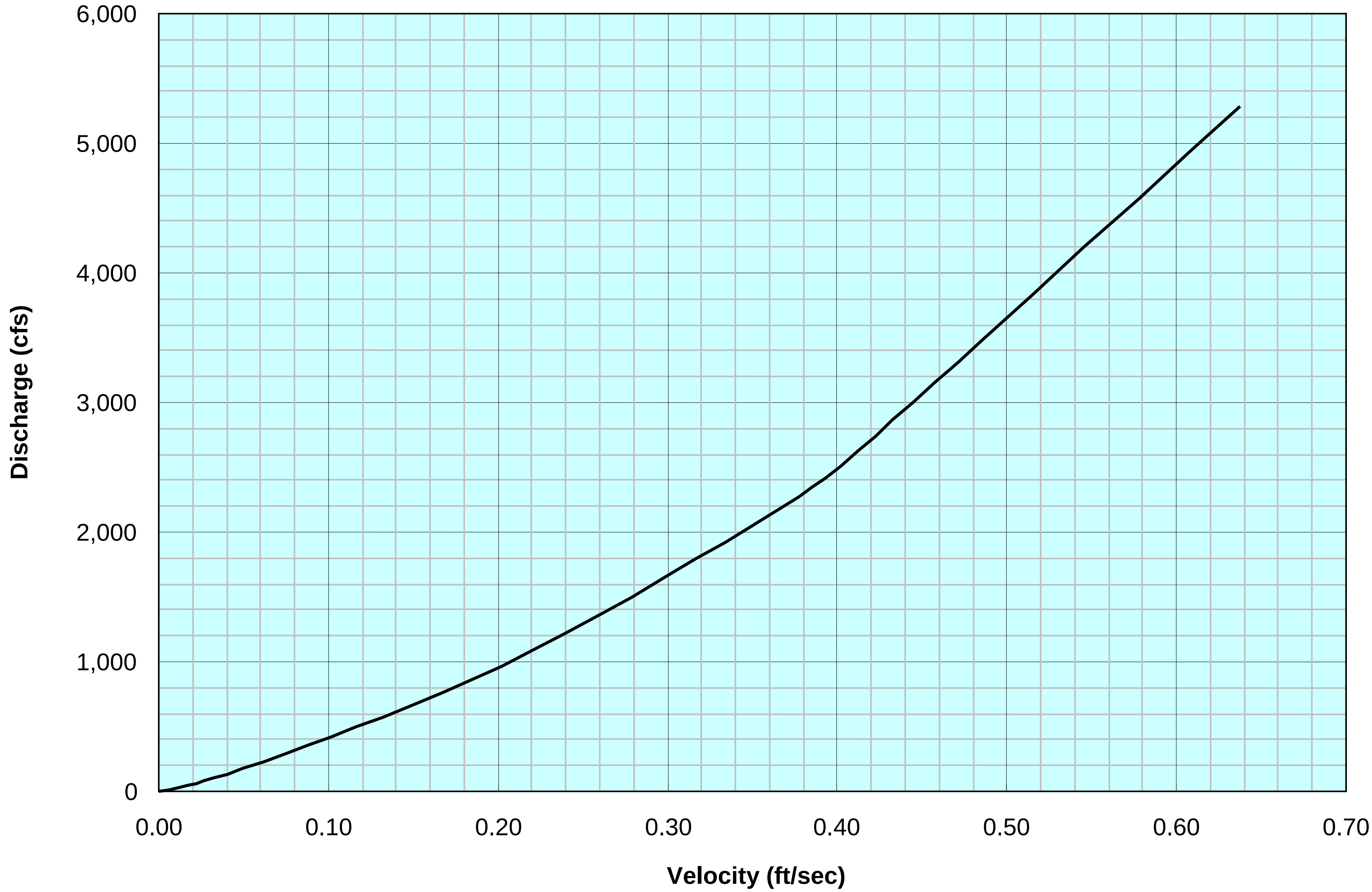


Figure A.6-1 Nutrients vs. streamflow at USGS 02232500
St. Johns River between SR 46 and SR 528

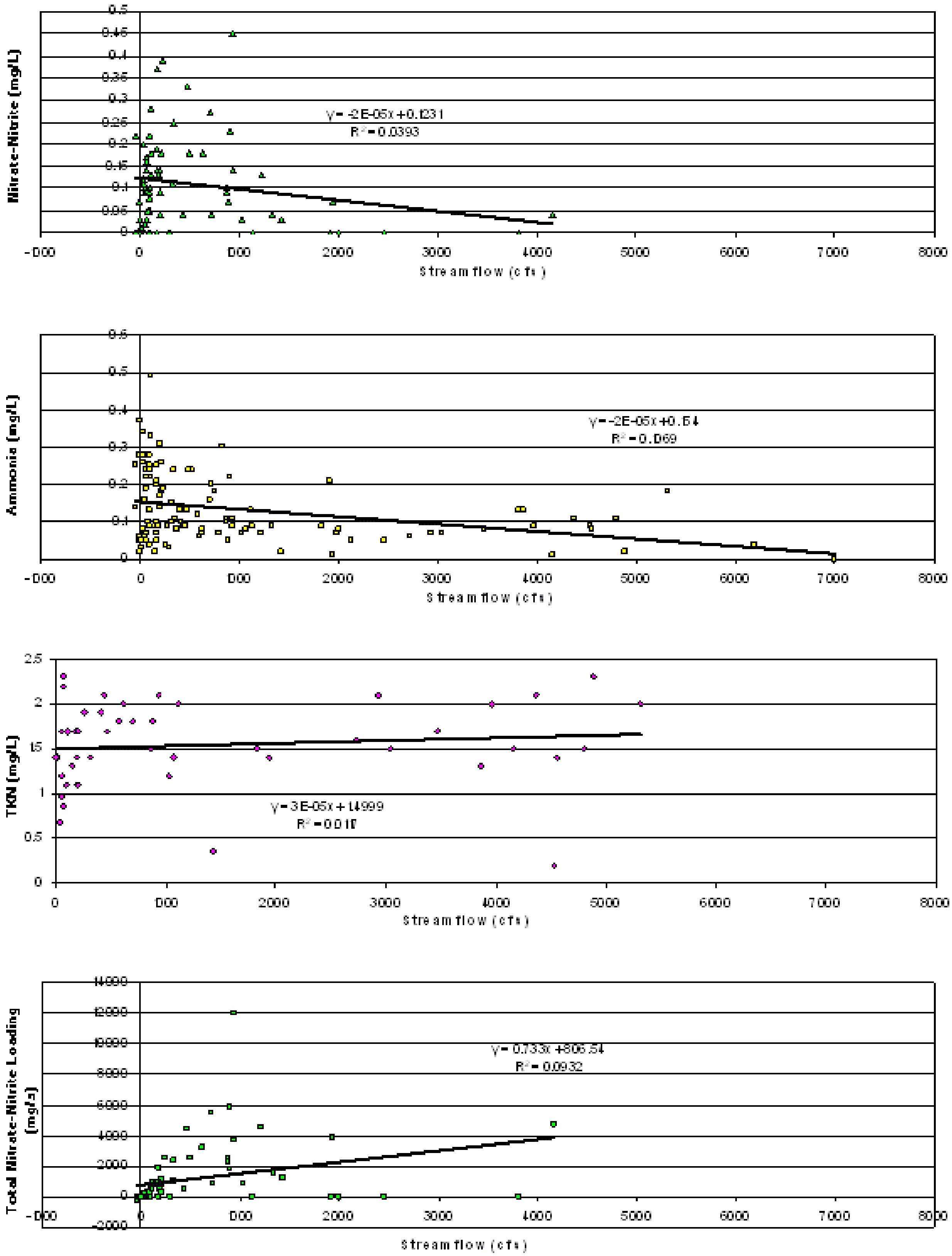


Figure A.6-2 Nutrients vs. streamflow at USGS 02232500
St. Johns River between SR 46 and SR 528

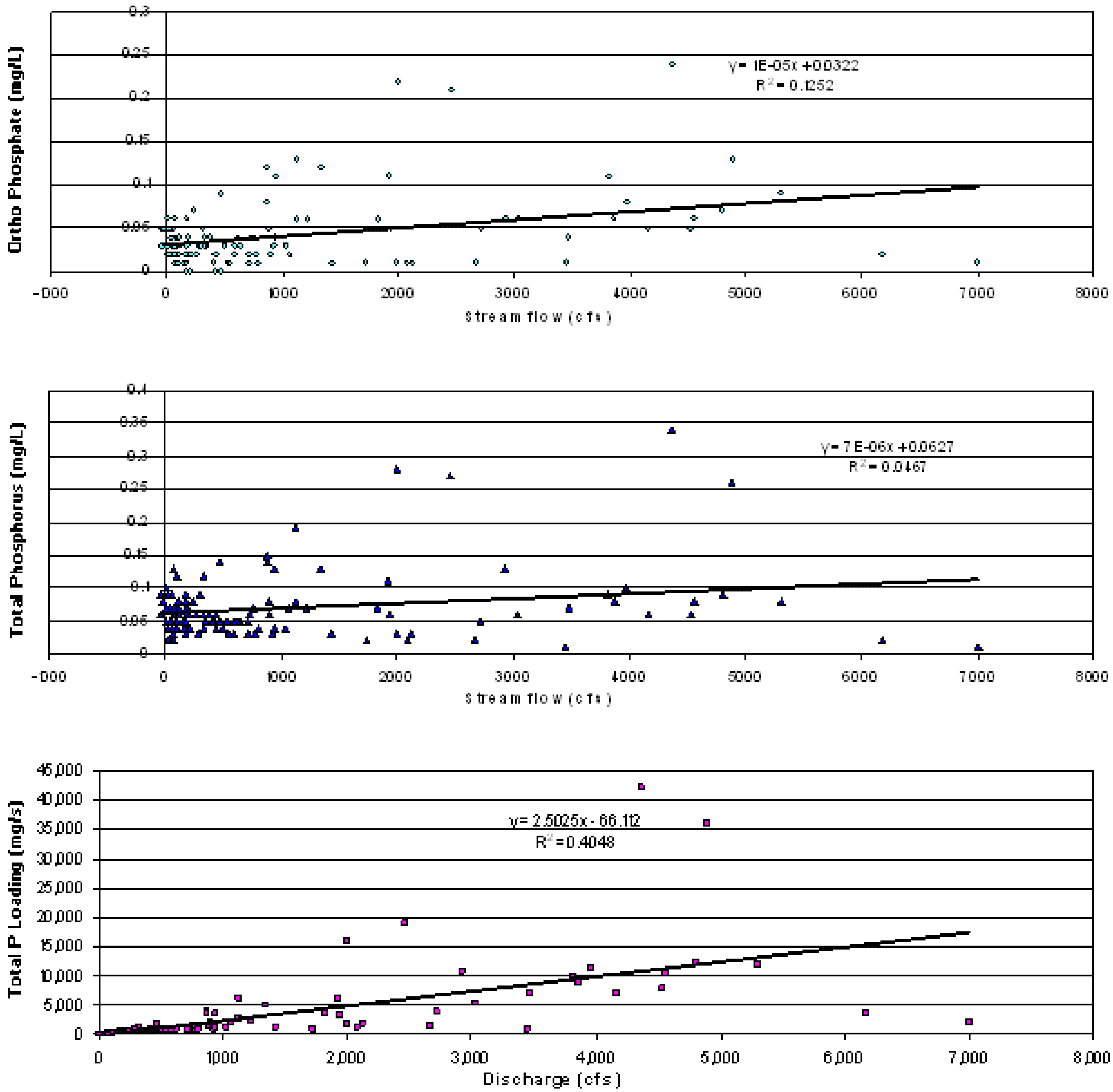
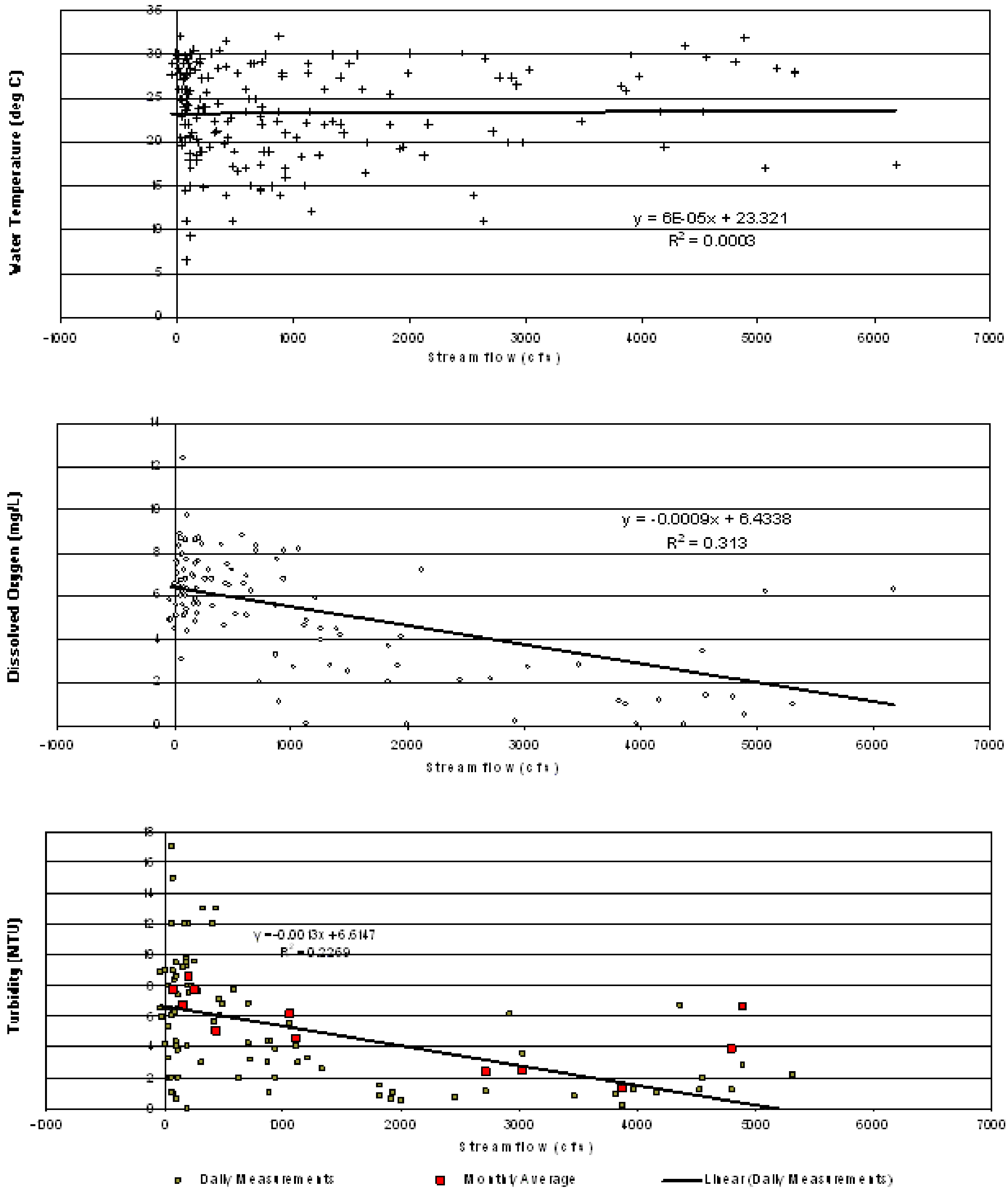


Figure A.7 Water quality parameters vs. streamflow at USGS 02232500 St. Johns River between SR 46 and SR 528



APPENDIX B

TABLES

Table B.1 Selected duration data from HSPF model Lake Poinsett, SJR at SR 50, and Puzzle Lake

Percentile		PU 6G - Lake Poinsett RM 232		PU 6H - SJR at SR50 RM 209		PU 6I - Puzzle Lake RM 189	
Non-Occurrence	Occurrence	Scenario A Current Conditions	Scenario D Minimum Flow Conditions	Scenario A Current Conditions	Scenario D Minimum Flow Conditions	Scenario A Current Conditions	Scenario D Minimum Flow Conditions
0.001	99.90	0	0	2.902	0.134	7.836	4.468
0.01	99.00	34.32	0	76.72	30.02	103	51.22
0.02	98.00	49.68	0	104	43.8	125	73.3
0.03	97.00	69.32	2.66	121	61.32	146	95.04
0.04	96.00	78.4	10.86	140	80.86	173	117
0.05	95.00	85.4	24	158	102	189	130
0.06	94.00	93.62	33.4	171	112	201	144
0.07	93.00	103	45.46	182	122	216	156
0.08	92.00	112.2	54.2	194	130	226	168
0.09	91.00	123	61.56	202	138	238	181
0.10	90.00	136	68.4	211	147	253	195
0.11	89.00	146	74.4	221	156.4	270	210.4
0.12	88.00	154	81.3	231	169	283	227
0.13	87.00	163	88.22	243	183	297	244
0.14	86.00	172	98	257	197	310	258.6
0.15	85.00	181	108	271	212	325	270
0.16	84.00	189	116	284	224	337	283
0.17	83.00	197	125	296	237	348	293
0.18	82.00	206	135	306	248	360	304.2
0.19	81.00	215	144	314	260	370	314
0.20	80.00	223	152	323	268	380	325
0.21	79.00	232	162	332	277	391.4	336
0.22	78.00	241	174	341	285	405	347
0.23	77.00	251	185	350	293	419	359
0.24	76.00	260	196	360	302	435	373
0.25	75.00	269	208	369	312	452	387
0.26	74.00	277	218	377	323	467	400
0.27	73.00	285	227	389	333.8	485	416
0.28	72.00	300	236	405	345	503	434
0.29	71.00	312	246	421	354	518	449
0.30	70.00	325	255	437	365	536	465
0.31	69.00	340	265	454	376.4	554.4	481
0.32	68.00	356	275	471	392	572	500
0.33	67.00	370.2	284	487	406	588	518
0.34	66.00	386	297	502	420	607	536
0.35	65.00	397	312	517	434	627	555
0.36	64.00	409	325	530	449	646	573
0.37	63.00	421	337	546.8	465	667	593
0.38	62.00	434	351	564	481.2	687	610.2
0.39	61.00	448	366	581.6	501.6	706	631
0.40	60.00	462	381	602	520	724	653
0.41	59.00	476	395	619	541	747.4	672
0.42	58.00	489	408	639	561	769	697
0.43	57.00	501	422	659	581	791	718
0.44	56.00	514	435	677.6	602.6	815	743
0.45	55.00	527	449	699	623	838	766
0.46	54.00	541	464	717	642	863	788
0.47	53.00	556	479.8	738	663	887	809
0.48	52.00	571	498	758	681	908	828
0.49	51.00	588	517	776	697.6	931	853
0.50	50.00	608	537	793	718	956	878
0.51	49.00	627	556.4	812	738	981	900

Table B.2-1 Selected results from HSPF model 1959 - 2000
Planning unit 6G - Lake Poinsett outlet
River Mile 232

River Mile 232

Annual Exceedance or Non-Exceedance Probability (%)	Return Interval (Years)	Continuously not Exceeded - Low Flow						Continuously Exceeded - High Flow					
		Scenario A Current Conditions			Scenario D Minimum Flow Conditions			Scenario A Current Conditions			Scenario D Minimum Flow Conditions		
		1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day
2.40	41.67	0	0	2.5	0	0	0	7500	5490	4600	7360	5400	4490
4.80	20.83	43.8	50.2	53.7	0	0	0	6700	5090	4450	6530	4990	4340
7.10	14.08	48	56.9	61.4	0	0	0	5410	4920	4360	5310	4810	4230
9.50	10.53	50.9	57.4	61.5	0	0	0	5260	4840	3970	5140	4740	3880
11.90	8.40	53	61.6	75.4	0	0	0.8	5240	4830	3800	5130	4740	3700
14.30	6.99	55.6	65	76.1	0	0	2.6	5200	4540	3750	5070	4450	3660
16.70	5.99	64.7	83.5	93.9	0	0	9.6	5110	4130	3580	4950	4010	3450
19.00	5.26	78.2	84.6	96.5	0	0	11	4970	3900	3480	4810	3750	3350
21.40	4.67	81.6	86.1	103	0	0.4	14.4	4590	3810	3420	4480	3700	3330
23.80	4.20	81.7	91.2	110	1.1	5.4	26.1	4320	3480	3080	4170	3390	2970
26.20	3.82	81.8	97.8	112	1.7	5.5	33.7	4000	3480	2970	3890	3370	2870
28.60	3.50	86.3	99.7	113	4.8	23.2	36.8	3800	3380	2800	3690	3270	2710
31.00	3.23	89.7	103	118	8.4	27.6	38.7	3540	3300	2680	3420	3220	2580
33.30	3.00	90.2	107	119	11.7	27.8	43.3	3470	3010	2500	3340	2910	2400
35.70	2.80	91.5	112	126	12	28.4	45.6	3300	2820	2300	3180	2710	2170
38.10	2.62	97	112	128	21	32.7	51.2	3250	2740	2250	3130	2640	2150
40.50	2.47	104	120	130	21.8	33.1	55.9	3050	2740	2200	2940	2590	2110
42.90	2.33	110	121	140	29	37.6	62.4	2760	2280	2120	2640	2190	2010
45.20	2.21	114	121	146	30	39.8	65.3	2620	2170	1970	2490	2070	1870
47.60	2.10	118	136	175	52.4	64	81.3	2330	2140	1890	2230	2040	1780
50.00	2.00	129	161	178	56.1	74.8	82.6	2260	2030	1860	2130	1930	1770
52.40	1.91	149	167	188	65.7	75.9	99.1	2220	1950	1800	2110	1840	1690
54.80	1.82	154	168	191	70.3	76.7	103	2180	1930	1710	2050	1820	1600
57.10	1.75	158	170	197	71.4	80.8	107	2160	1910	1660	2030	1780	1560
59.50	1.68	162	180	198	72.4	85	109	1870	1770	1590	1770	1670	1490
61.90	1.62	185	203	218	77.9	108	125	1830	1730	1550	1700	1600	1440
64.30	1.56	190	214	231	89.2	118	135	1830	1610	1530	1660	1490	1420
66.70	1.50	208	231	244	112	144	152	1780	1600	1500	1640	1480	1400
69.00	1.45	219	237	260	131	147	185	1700	1540	1410	1600	1440	1290
71.40	1.40	226	240	266	132	151	189	1620	1500	1400	1520	1400	1260
73.80	1.36	266	271	306	189	196	236	1620	1400	1140	1460	1270	1040
76.20	1.31	285	304	333	213	232	247	1570	1260	1000	1430	1150	903
78.60	1.27	305	340	392	237	256	293	1450	1160	965	1330	1070	866
81.00	1.23	329	355	401	257	273	301	1370	1120	959	1250	1030	837
83.30	1.20	355	389	423	271	286	313	1360	1080	933	1250	978	837
85.70	1.17	360	410	456	274	312	357	1130	1020	867	1030	915	760
88.10	1.14	412	432	461	310	330	359	976	853	718	878	749	616
90.50	1.10	428	502	583	337	404	483	769	718	631	643	606	535
92.90	1.08	464	522	731	376	432	635	599	550	525	492	454	412

Table B.2-2 Selected results from HSPF Model 1959 - 2000 Planning unit 6H – SJR at SR 50 outlet River Mile 209

Annual Exceedance or Non-Exceedance Probability (%)	Return Interval (Years)	Continuously not Exceeded - Low Flow						Continuously Exceeded - High Flow					
		Scenario A Current Conditions			Scenario D Minimum Flow Conditions			Scenario A Current Conditions			Scenario D Minimum Flow Conditions		
		1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day
2.40	41.67	0	3.9	13.4	0	0	4.1	8690	7250	5350	8560	7160	5240
4.80	20.83	71.4	99.6	119	18.2	29.2	35.3	7020	6350	5240	6840	6220	5170
7.10	14.08	90.2	111	121	26.3	30.4	46.7	6770	6030	5160	6640	5900	5080
9.50	10.53	92.3	112	124	28	35.7	50	6700	5790	4870	6590	5650	4740
11.90	8.40	98.6	117	132	31.4	41.3	63.9	5400	5150	4480	5220	5030	4320
14.30	6.99	112	127	151	31.8	48.6	71.2	5340	5100	4360	5200	4960	4240
16.70	5.99	114	128	152	33.3	48.9	89.4	5330	5030	4350	5200	4890	4150
19.00	5.26	124	137	169	36.6	49.3	91.3	5220	4880	4040	5080	4750	3940
21.40	4.67	128	158	179	50.5	84.7	110	5190	4800	3920	5070	4680	3810
23.80	4.20	133	160	185	54.1	86.1	111	5190	4730	3800	5050	4570	3670
26.20	3.82	139	163	191	65	87.8	121	5070	4610	3350	4950	4470	3240
28.60	3.50	143	164	208	66.4	88.2	127	4880	4180	3290	4720	4070	3190
31.00	3.23	146	164	214	74.6	111	141	4380	3880	3280	4260	3760	3190
33.30	3.00	153	197	224	75.5	115	142	4330	3870	3200	4220	3750	3100
35.70	2.80	154	197	226	82.4	116	146	4250	3800	2850	4080	3690	2770
38.10	2.62	172	212	236	98.6	125	150	3420	3170	2670	3300	3060	2540
40.50	2.47	184	215	238	102	136	152	3280	2880	2370	3160	2770	2270
42.90	2.33	185	217	239	112	143	158	3170	2860	2310	3050	2740	2230
45.20	2.21	193	218	239	116	143	176	3080	2850	2290	2950	2710	2190
47.60	2.10	194	221	258	119	145	177	2970	2560	2050	2860	2450	1960
50.00	2.00	197	222	262	128	148	200	2780	2500	2050	2670	2380	1910
52.40	1.91	201	222	266	128	149	202	2630	2480	2010	2500	2380	1910
54.80	1.82	204	226	285	129	157	210	2610	2460	2010	2490	2350	1900
57.10	1.75	207	232	304	133	158	229	2560	2240	1930	2410	2090	1830
59.50	1.68	237	260	312	157	178	248	2460	2110	1930	2300	2010	1810
61.90	1.62	266	316	340	158	250	273	2390	1980	1830	2280	1860	1730
64.30	1.56	288	328	367	202	251	290	2250	1940	1780	2150	1840	1680
66.70	1.50	290	329	369	224	268	295	2150	1930	1620	2010	1820	1510
69.00	1.45	307	341	370	245	279	312	2100	1820	1590	1990	1670	1480
71.40	1.40	312	342	387	253	280	313	1950	1740	1510	1800	1630	1350
73.80	1.36	318	345	417	258	293	330	1890	1650	1360	1780	1520	1240
76.20	1.31	324	350	423	268	301	346	1740	1510	1160	1590	1400	1070
78.60	1.27	353	398	424	300	307	347	1640	1420	1150	1530	1310	1060
81.00	1.23	368	413	446	304	327	365	1510	1390	1120	1390	1290	1000
83.30	1.20	385	433	581	305	352	460	1490	1290	1100	1390	1190	994
85.70	1.17	418	527	588	345	427	488	1450	1180	1090	1350	1080	989
88.10	1.14	505	579	682	401	477	543	1440	1010	780	1330	920	675
90.50	1.10	531	614	736	408	531	644	1010	802	772	859	681	652
92.90	1.08	533	696	959	449	604	864	905	735	661	804	625	526
95.20	1.05	547	765	1030	450	629	936	651	490	443	577	402	328
97.60	1.02	995	1180	1330	909	1090	1230	510	483	419	357	348	322

Table B.2-3 Selected results from HSPF model 1959 - 2000
Planning unit 6I – Puzzle Lake outlet
River Mile 189

Annual Exceedance or Non-Exceedance Probability (%)	Return Interval (Years)	Continuously not Exceeded - Low Flow						Continuously Exceeded - High Flow					
		Scenario A Current Conditions			Scenario D Minimum Flow Conditions			Scenario A Current Conditions			Scenario D Minimum Flow Conditions		
		1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day	1-day	14-day	30-day
2.40	41.67	3	7.9	22.7	0.9	4.1	15.5	9840	8860	5740	9720	8710	5510
4.80	20.83	92.8	117	138	32.3	37	48.3	7460	6850	5590	7310	6730	5440
7.10	14.08	117	128	139	45.1	55.4	73.3	7430	6810	5550	7280	6660	5420
9.50	10.53	122	138	149	49.4	64.9	77	7330	6430	5270	7150	6280	5190
11.90	8.40	122	146	153	49.8	69.8	80.8	7100	6020	4750	6980	5920	4630
14.30	6.99	124	148	167	58.5	75	84.2	5730	5320	4620	5590	5220	4470
16.70	5.99	132	151	189	69.4	81.4	122	5600	5260	4420	5430	5130	4300
19.00	5.26	137	161	204	77.1	92	124	5550	5150	4410	5410	4990	4290
21.40	4.67	143	163	212	77.7	118	125	5500	5080	4400	5380	4950	4280
23.80	4.20	144	185	216	79.2	124	157	5430	4950	4140	5280	4860	4010
26.20	3.82	146	190	218	91	124	173	5410	4850	4100	5240	4740	3980
28.60	3.50	155	208	247	94.9	129	177	5360	4820	3910	5230	4640	3810
31.00	3.23	176	209	249	105	142	180	5130	4530	3840	4970	4310	3730
33.30	3.00	177	211	250	114	154	182	5090	4330	3690	4960	4220	3610
35.70	2.80	182	218	263	122	155	187	5040	4310	3360	4830	4220	3250
38.10	2.62	189	230	264	122	155	195	4770	3620	2980	4670	3490	2860
40.50	2.47	189	236	267	129	161	216	4320	3360	2690	4210	3240	2580
42.90	2.33	198	245	297	129	162	219	4140	3310	2670	4000	3210	2570
45.20	2.21	203	247	312	134	170	223	3650	3140	2510	3560	3040	2390
47.60	2.10	206	252	318	135	179	230	3500	3120	2490	3360	3000	2330
50.00	2.00	208	272	335	138	180	265	3430	2710	2420	3310	2600	2320
52.40	1.91	240	291	359	148	219	290	3380	2650	2270	3300	2530	2160
54.80	1.82	252	318	377	178	249	298	3310	2610	2180	3200	2490	2080
57.10	1.75	267	340	388	203	270	300	3300	2520	2110	3180	2420	2000
59.50	1.68	290	351	395	238	270	346	3240	2430	2020	3120	2290	1910
61.90	1.62	313	351	434	252	297	371	2920	2360	2000	2810	2270	1880
64.30	1.56	316	356	440	256	298	377	2880	2190	1970	2760	2080	1870
66.70	1.50	328	367	442	267	312	384	2770	2110	1700	2660	1990	1560
69.00	1.45	332	377	461	279	324	385	2650	1890	1680	2500	1780	1550
71.40	1.40	338	383	484	288	333	417	2580	1780	1620	2480	1670	1500
73.80	1.36	371	400	513	307	334	432	2210	1770	1590	2110	1630	1470
76.20	1.31	393	411	515	308	336	436	2160	1660	1390	2050	1520	1240
78.60	1.27	395	416	522	323	341	442	1910	1640	1240	1770	1520	1130
81.00	1.23	399	457	540	323	388	454	1890	1590	1210	1740	1500	1100
83.30	1.20	442	555	636	385	459	537	1840	1550	1130	1700	1370	1040
85.70	1.17	477	642	727	388	564	647	1760	1410	1120	1670	1310	999
88.10	1.14	568	647	941	426	564	830	1620	1400	944	1450	1280	825
90.50	1.10	598	756	980	476	564	854	1580	1210	867	1440	1070	794
92.90	1.08	650	771	997	491	594	896	1530	1040	730	1430	905	589
95.20	1.05	699	864	1170	619	779	1090	1490	865	491	1360	772	368
97.60	1.02	1090	1310	1580	1000	1220	1480	532	495	443	421	338	330

Table B.3 Rating curve data from HEC-RAS model 1959-2000 for transects and bridges between SR 528 and SR 46

SR 528		TOSO-528 Transect		Near Great Outdoors Transect		Near Tosahatchee Transect		SR 50		Near M-6 Transect		H-1 Transect		SR 46	
RM 223.3		RM 219.976		RM 215		RM 212.33		RM 209		RM 207.97		RM 201		RM 189.995	
Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)	Flow (cfs)	Stage (ft NGVD)
0	-6	0	3.62	0	1.313	0	-1.04	0	-6	0	-1.03	0	-3.14	0	-2
24	6.568983	24	5.748932	24	4.092908	24	2.449559	36	2.448486	36	2.445793	36	0.74503	36	0.503499
90	8.074986	90	6.873055	90	5.518021	90	3.833348	105	3.827533	105	3.819937	105	1.734943	105	0.574268
253	9.191784	253	7.817132	253	7.193341	253	5.621385	300	5.599927	300	5.579105	300	3.657574	300	1.232046
644	10.18409	644	9.142013	644	8.628212	644	7.333804	969	7.176154	969	7.028111	969	5.457548	969	2.444822
1710	11.63508	1710	10.50928	1710	9.751875	1710	8.666153	2030	8.239359	2030	7.955698	2030	6.830772	2030	4.480513
2030	11.96895	2030	10.85879	2030	10.11849	2030	9.237014	2630	8.78074	2630	8.502394	2630	7.598989	2630	6.191404
4910	14.03031	4910	12.77513	4910	12.03685	4910	11.29549	5290	10.62505	5290	10.36048	5290	9.650982	5290	8.352307

APPENDIX C

SUPPLEMENTAL INFORMATION FOR WRV-2

Appendix C

Supplemental Information regarding WRV-2: Fish and wildlife habitats and the passage of fish

The ten dominant plant communities within 2 miles of the river channels (in decreasing order of coverage) are wet prairie, shallow marsh, water, hydric hammock, transitional shrub, free floating, upland, hardwood swamp, cabbage palm – hydric hammock, and deep marsh, based on vegetation maps produced by the SJRWMD GIS department (Mace 2005, p. 9). Of these, nine are wetland communities and one is ‘upland’, which borders wetland communities and is not considered a wetland community. Upland plant communities occur interspersed at the periphery of the floodplain in the landscape mosaic of the mapped plant communities (Mace 2005, Figure 3), and provide life history requirements for many of the terrestrial insects, reptiles, birds, and mammals in the study area (Table C.1). Uplands are an alternate habitat and refugium for species that use both upland and wetland habitats. These areas generally begin above the frequent high elevation (Table 3-1), which varies from 6.9 ft NGVD at Hatbill Park to 10.8 ft NGVD for TOSO-528 (Mace 2005, p. 22, Tables 7a-7e).

Juxtaposition to the upland areas, moving downward in elevation, at the Hatbill Park, Tosohatchee North, Great Outdoors, and TOSO-528 transects, the frequent high elevation represents the average elevation of the upper wet prairie, while at the Lake Cone transect it is the average elevation of the hardwood swamp. Other wetland habitats, including the ten most common wetland habitats (Mace 2005, Table 3), occur transitionally across the floodplain to the main channel of the river.

Four communities – hydric hammock, transitional shrub, hardwood swamp, and cabbage palm hydric hammock – are important for aquatic and terrestrial invertebrate production and for amphibian, reptile, mammal and bird populations but generally occur at higher elevations in the floodplain, have variable and more restricted inundation patterns, and provide limited support for fish reproduction. These areas, however, provide the substrate for many corollary ecological functions that contribute to robust fishery production within the main river. Five of the wetland communities: wet prairie, shallow marsh, water, free floating, and deep marsh, have a larger role in fishery production.

Several other habitats occur within this river reach in limited distribution (Mace 2005, Figure 3). These habitats have not been analyzed in detail. Most wetlands in central Florida have adapted to a late fall, winter, and spring dry season and an approximately four month long rainy season. However, as water elevations and soil moisture depths vary spatially and temporally across a floodplain, the vigor and distribution of some of the plant communities vary in response.

One federally-listed plant species has been reported occurring in Brevard County, Carter's mustard (*Warea carteri*), and seven federally-listed plant species occur in Orange County, Britton's beargrass (*Nolina brittoniana*), Florida bonamia (*Bonamia grandiflora*), scrub lupine (*Lupinus aridorum*), beautiful pawpaw (*Deeringothamnus pulchellus*), sandlace (*Polygonella myriophylla*), papery whitlow-wort (*Paronychia chartacea = Nyachia pulvinata*), scrub wild buckwheat (*Eriogonum longifolium* var. *gnaphalifolium*) (USFWS 2004a, b). Four of these species are restricted to sand pine (*Pinus clausa*) and evergreen oak scrub vegetation (referred to as Florida scrub), and occur in upland habitats on the Lake Wales Ridge, and three are mesic species. These species should not be expected to be affected by varying water levels within the floodplain. A number of sensitive plants occur within the SJRWMD but species distribution has not been completely confirmed (FNAI 2001).

Listed species can be indicators of the fragility of natural systems and are integral components of the ecological integrity of Florida ecosystems. Invertebrates, fish, amphibians, reptiles, birds, mammals, and plants exhibiting significant declines from historic population levels have been placed into specific categories of protection by both federal and state agencies.

The Endangered Species Act of 1973 (7 U.S.C. 136; 16 U.S.C., 460 *et seq.*) provides for a program for the conservation of threatened and endangered plants and animals and the habitats in which these species are found. The U.S. Fish and Wildlife Service (USFWS) administers these federally listed plants and animals and provides protection of these species. The State of Florida has similarly listed endangered, threatened, or species of special concern animal species that are protected by the Florida Fish and Wildlife Conservation Commission (FFWCC or FWC) in Sections 39-27.003, 39-27.004 and 39-27.005, F.A.C., respectively. The state lists of plants are categorized into endangered, threatened, and commercially exploited, and are administered and maintained by the Florida Department of Agriculture and Consumer Services in Chapter 5B-40, F.A.C.

Based on historical records and their potential occurrence in the study area, 17 federally listed endangered, threatened, or species of special concern and 30 state listed species could occur within portions of the St. Johns River and associated floodplain within Brevard and Orange Counties (Table C-2).

<u>Invertebrate (Mollusks, Crustaceans, and Aquatic and Terrestrial Insects) Populations</u>
There are no federally-listed invertebrate (mollusks, crustaceans, and aquatic and terrestrial insects) species in Brevard and Orange Counties (USFWS 2004a, b). The occurrence of state-listed species is not defined (FNAI 2001, FWC 2004). Few studies of invertebrates of the St. Johns River have been conducted (Heard 1979, Water & Air Research, Inc. 2000, Franz 1982), and specific population information for benthic invertebrates was not available for the study area. Agency databases and literature were searched; however, quantitative data were not obtained for populations of invertebrates (mollusks, crustaceans, and aquatic and terrestrial insects), amphibians, reptiles, or mammals in and around the river reach study area.

Aquatic invertebrates provide detrital decomposition of organic material, releasing nutrients for plant and animal metabolism, and are forage for larger predators (fish, mammals and birds) (Merritt and Cummins 1984, Redmer 2000). Data from other habitats have shown that a small percentage of loss in fish habitat may result in a two- or three-fold loss in invertebrates (Gore 1989). Such changes in the abundance or composition of the benthic invertebrate community may have adverse cascading effects on many taxa, including commercial or recreationally important fish species.

Aquatic habitat utilization may vary temporally, depending on the life stage, so that taxon response to water quality, flow, and substrate is variable. Aquatic invertebrates include larvae and adults of numerous taxa (orders Insecta, Arthropoda, Crustacea, Gastropoda, Annelidae, etc.) that live on or in the substrates of springs, rivers, and other waterbodies and occur across a range of habitat conditions. Many forms of aquatic insects typically inhabit aquatic habitats as larvae; the adults reproduce terrestrially, laying eggs on emergent vegetation. Other species survive in marshes, tributaries, or in the main channel of the river, and disperse as water levels increase. Many benthic invertebrates, particularly larval instars, are relatively sessile and are vulnerable to fluctuations in habitat, while planktonic forms may be carried along with receding or rising water levels (Layzer and Madison 1995). The distribution of Asiatic clams (*Corbicula fluminea*) in the upper St. Johns River is correlated with sand sediment types and fast, but not scouring flow rate (Belanger, Annis, et al. 1990). Within floodplain ponds, invertebrate populations have been correlated with inaccessibility by fish and intermediate hydroperiods (Corti, Kohler et al. 1997), and the flood pulse hypothesis where densities increased dramatically on a rising flood in a midwestern floodplain, then fell equally rapidly on receding water, and invertebrate densities were highest (in decreasing abundance) in inundated grasses, flooded trees, floating macrophytes and open water (Theiling and Tucker 1999).

Aquatic invertebrates have various adaptations to enable them to survive drying of their environment. Many species, such as clams and crayfish, burrow into the substrate to maintain contact with water (Graff and Middleton 2002). Crayfish (*Procambarus* spp.), are an indicator taxon of wetland ecosystem integrity (Momot 1978, Yoon 2001), and crayfish burrows may be refugia during dry periods for a number of invertebrate and vertebrate species (Creaser 1931, Momot 1978, Neill 1951, Redmer 2000).

<u>Fish</u>

There are no federally-listed fish species in Brevard and Orange Counties (FWS 2004a, b). The SJRWMD includes the entire range of the Lake Eustis pupfish, and the peninsular range of the bluenose shiner; three or four other state-listed fishes may possibly occur (FNAI 2001); however, many of the small fishes have not been systematically surveyed recently, so their possible distribution is not known.

The composition of the fish fauna of the St. Johns River is known from historical studies and approximately 85 species probably occur in this river reach (McLane 1955, Tagatz 1967, FWC undated, FFWRI 2004) (see Table C.3). Fish populations have been surveyed more recently by FWC regional fisheries biologists using main channel electro shocking runs. While electro shocking does not capture many of the fish species that occur in the river, the method provides an indication of species present in the deeper portions of the main channel (Bob Eisenhauer, personal communication, August 2004).

Thirty-four fish species (n = 1277) were captured in electrofishing runs in the main channel in the study area from 2002 – 2004 (Table 5-5, 5-6). Numerically dominant fish species (n = 10 or more) caught during electro shocking were American shad, armored catfish, bluegill, channel catfish, Florida gar, golden shiner, largemouth bass, redbreast sunfish, redear sunfish, sailfin catfish, spotted sunfish, threadfin shad, warmouth, white catfish, and yellow bullhead, while body mass (length = 300 mm or greater, weight = 500 gms or greater) dominant fish species caught during electrofishing were: American eel, American shad, Atlantic needlefish, bowfin, channel catfish, Florida gar, gizzard shad, largemouth bass, sailfin catfish, striped mullet, suckermouth catfish, white catfish and yellow bullhead (Figure C-1, C-2, C-3, C-4). These data present an interesting contrast between the larger-bodied fishes in the system, some of which are introduced to the endemic fish fauna, and the great variety of native, small bodied cyprinodontiforms, which contribute significantly the diversity of the fish assemblage, secondary productivity, and angler satisfaction. Interactions of water quality, temperature variation, and salinity affect the distribution of fish species depending on their life history. River levels fluctuate seasonally depending largely on precipitation. Some species spawn so that the fry and juveniles hatch and grow out in the marshes and swamps of the floodplain (Graff and Middleton 2002). Populations of some small cyprinodontiform fishes increase dramatically during high flows, then decrease just as dramatically during low or drought flows. As water levels drop during the dry season, floodplain fish populations seek refuge in the main stem channel or become concentrated in shrinking floodplain pools.

Detailed life history studies for each fish have not been conducted, although requirements for some of the important 'game fish' are well studied. To maintain this diverse fish assemblage, water level regimes should regularly satisfy temporal and spatial reproductive requirements for channel-dependent and shallow and deep marsh and wet prairie dependent species.

The fishes of the upper St. Johns River can be divided into groups based on their preferred habitats (Table C-4) and expected responses to potential impacts from water withdrawals. One approach is to use a combination of habitat and behavior, which produces groups including marine and estuarine species, anadromous species, main channel species, and floodplain species. An alternate approach to assessing the effects of streamflow regulation on fish species is a habitat-based method for describing how fish assemblages use microhabitat. Using this approach, five habitat-use assemblages can be defined: shallow-fast habitat, slow-cover habitat, deep-fast habitat, shallow-slow habitat, and shallow-coarse habitat (Knight, Bain et al. 1991). These authors suggest that in stream flow recommendations should include the shallow-slow (vegetated margins of the main channel, backwaters and oxbows, secondary channels, shallow and deep marsh, and wet prairies) and shallow-coarse habitats because these contain the highest species richness and fish densities, and are most sensitive to reductions in flow. General groups of fishes grouped by habitat use are discussed in the following paragraphs.

Atlantic stingray, gafftopsail catfish, Atlantic needlefish, Atlantic silverside, Atlantic croaker, striped mullet, white mullet, and naked goby are primarily marine and estuarine species which are resident and occur apparently as far upstream as the St. Johns River at Highway 50 (Bob Eisenhauer, personal communication, August 2004).

Blueback herring, hickory shad, American shad, and striped bass are anadromous species present in this river reach, possibly because of salinity introduced further upstream. These species use the main channel, and spawn in suitable habitat in or off-channel, and it is assumed these fishes will remain a component of the fish assemblage if adequate flows are available.

Longnose gar, gizzard shad, threadfin shad, golden shiner, ironcolor shiner, redeye chub, coastal shiner, pugnose minnow, lake chubsucker, snail bullhead, white catfish, channel catfish, brook silverside, redbreast sunfish, largemouth bass, black crappie, and blue tilapia utilize the main channel of the river, floodplain and backwater pools and oxbows. Juvenile fishes of many of these species utilize the flooded swamps and marshes as nursery habitat during high flows (Graff and Middleton 2002). It is assumed these fish species will remain a component of the fish assemblage if adequate flows are available.

Bowfin, American eel, redfin pickerel, chain pickerel, eastern mudminnow, common carp, hybrid grass carp, bluenose shiner, yellow bullhead, brown bullhead, tadpole madtom, pirate perch, golden topminnow, marsh killifish, flagfish, pygmy killifish, bluefin killifish, mosquitofish, least killifish, sailfin molly, mud sunfish, everglades pygmy sunfish, bluespotted sunfish, warmouth, dollar sunfish, spotted sunfish, and swamp darter occupy backwaters and streams where remnant populations survive the dry season in deeper holes, if available. Populations of some small cyprinodontiform fishes increase dramatically during high flows and then decrease just as dramatically during low or drought flows. Many of these species (e.g., killifish, sunfish) reproduce during high water levels, spawning in the marshes and swamps of the floodplain, and mature rapidly (Graff and Middleton 2002).

The largest bodied fishes expected to routinely inhabit this stretch of river in the main channels would include the following:

1. Bowfin prefer slower water in rivers and streams, backwaters, ponds and lakes and channel currents. Juvenile bowfin forage on insects and crustaceans, adult bowfin are opportunistic predators that eat fish, insects, crayfish, amphibians. They average 25" long and five pounds, but can become very large (three feet and over 20 pounds). Bowfin can tolerate poorly oxygenated water and drying habitat by breathing air and estivating in mud for extended periods.

2. Longnose and Florida gar inhabit sluggish, sometimes poorly oxygenated water, backwaters and oxbows of medium-to-large rivers and lakes, medium-to-large lowland streams, canals and lakes with mud or sand bottoms near underwater vegetation, occasionally in brackish waters, and are able to tolerate poor water quality by breathing air through their air bladder. Spawning occurs between December and March in Florida. Adhesive eggs are scattered in shallow water over vegetation or other structure and hatch between six and eight days later. The larvae are sessile as they develop, attached to the substrate with a prognathous sucker. Sessile larvae are vulnerable to flow variability.

3. Catfish in the upper St. Johns River include endemic (channel catfish, white catfish, snail bullhead, yellow bullhead, brown bullhead, sailfin catfish, and gafftopsail catfish). Channel and white catfishes are most common in big rivers, slow-moving streams, and river backwaters, and prefer some current and deep water with sand, gravel, or rubble bottoms. They also inhabit lakes, reservoirs, and ponds. Spawning occurs mostly in rivers and streams in the spring and early summer when waters warm to 70 to 85 degrees. Eggs are deposited in nests secluded under banks or logs or over open bottom, and eggs hatch in six to 10 days depending on water temperature. White catfish tolerate a siltier bottom and higher salinity, and prefer water temperatures of 80 to 85 degrees. Yellow and brown bullhead use variable habitat including mud or deep muck as well as sand or gravel bottoms, and vegetated areas of clear, shallow lakes, reservoirs, ponds, and slow-flowing streams. They prefer water temperatures of 78 to 82

degrees, but can survive in warmer waters, and are more tolerant of polluted environments than most other members of the catfish family.

4. Brown hoplo or ‘armored catfish’ are nonindigenous fish from tropical America discovered in ditches of the Indian River lagoon system of Florida in late 1995, and found in the St. Johns and Kissimmee River drainages recently. They are small (20-25 cm) fish that prefer moving water, can tolerate low dissolved oxygen similarly to gar or bowfin, and are able to motivate over land as habitat availability varies. The female deposits as many as 250 eggs on a stone where they adhere, and hatch in one week. In several Florida water bodies this species is locally abundant; because it feeds heavily on benthic invertebrates and detritus, the species may be causing significant changes in food web structure, negatively impacting native invertebrates, and competing with native fishes for food (Nico 2004). This species can breathe air and can tolerate a wide range of environmental conditions (e.g., fresh and brackish waters). Fishery biologists are concerned that it will eventually invade many natural freshwater wetlands, and coastal marshes in Florida (Nico et al. 1996). A fishery has developed in the upper St. Johns River in the past few years and many fish biologists statewide are concerned that the endemic fish assemblage may be deleteriously affected.

5. Several sunfish (redbreast sunfish, bluegill, longear sunfish, redear sunfish, and spotted sunfish) are listed by the FWC as recreationally important. Sunfish occupy dense aquatic vegetation and soft bottoms in sluggish water, and are often associated with a particular submerged tree, rock, or overhanging bank. Spawning occurs over sandy or gravel bottoms in lakes, ponds, streams, and rivers. Many *Lepomis* species (not redbreast sunfish) have community nests, which consist of a circular depression on the bottom that is lined with pebbles. Often, nests are associated with some type of cover and in the main channel of the stream. Forage species preferred by sunfish vary (aquatic and terrestrial invertebrates, mollusks, small crustaceans, and fish). An abundance of snag habitats that provide a constant source of aquatic insects in a system is an important factor in regulating the population.

6. Largemouth bass were not recorded at large body sizes by the fisheries survey. However, they are a highly sought-after species by recreational anglers (see Section 5.1) and do grow to large size. The largemouth bass is the largest member of the sunfish family and prefers clear, nonflowing waters with aquatic vegetation where food and cover are available. They occupy brackish to freshwater habitats, including upper estuaries, rivers, lakes, reservoirs and ponds. Bass can tolerate a wide range of water clarities and bottom types but prefer water temperatures from 65 to 85 degrees and are usually found at depths less than 20 feet. Spawning occurs from December through May but usually begins in February and March in most of Florida, when water temperatures reach 58 to 65 degrees, and continues as temperatures rise into the 70s. The male builds saucer-shaped nests 20 to 30 inches in diameter, typically in hard-bottom areas along shallow shorelines or in protected areas such as canals and coves. Growth rates are highly variable with differences attributed mainly to their food supply and length of growing season. Males seldom exceed 16 inches, while females frequently surpass 22 inches. Generally, trophy bass (10 pounds and larger) are about 10 years old.

<u>Reptiles and Amphibians</u>

There are no amphibians listed and six federally listed reptile species in Brevard County, of which four, the sea turtles, would not be expected to occur in the study area. There are no amphibians listed, and two federally listed reptile species – sand skink and eastern indigo snake – in Orange County (USFWS 2004a). These are associated with upland areas, and the eastern indigo snake also uses hammock areas, depressional wetlands, and marsh edges, although neither species should be affected by the potential MFL. The SJRWMD includes the partial range of the gopher frog, and the peninsular range of the striped newt; and is an important part of the Florida range of the carpenter frog, many-lined salamander, and timber rattlesnake; other state-listed amphibians and reptiles may possibly occur, even transitorily, in the two county area (FNAI 2001, Appendix 4, FWC 2004). Alligators, a state species of special concern, are an important component of marshes and swamps since they excavate *gator holes*, which usually retain water during the dry season (FWC 2004, Kushlan 1974).

Bird Populations

Bird populations are diverse and potentially numerous within the study area based on the Florida Breeding Bird Atlas (FWC 1990) and water bird colony data (FWC 1990) as well as from surveys made by HSW biologists during 2004. Bird populations vary seasonally due to migration and breeding dynamics, and annual climatic events.

There are five federally listed bird species (bald eagle, piping plover, Florida scrub jay, wood stork, red-cockaded woodpecker) in Brevard County which could be expected to occur, even transitorily, in the study area, and six federally-listed bird species (Audubon's crested caracara, bald eagle, Everglade snail kite, Florida scrub jay, wood stork, red-cockaded woodpecker) in Orange County (USFWS 2004a, b). There are other bird species which could occur, even transitorily, in the two county areas. These species and black rail, limpkin and swallow-tailed kite, plus other state-listed birds, may possibly occur, even transitorily, in the two county area (FNAI 2001).

Wading bird species include great egret, little blue heron, reddish egret, roseate spoonbill, snowy egret, tricolored heron, white ibis, and wood stork (all state species of special concern). Wading birds typically forage in relatively shallow water, and periodic shallow ponding in isolated sloughs throughout the shallow marshes concentrates numerous small fish, amphibians, and small reptiles in these aquatic refugia. Great egrets prefer water depths of less than 10 inches and the small herons prefer depths of less than 6 inches. Birds effectively exploit these concentrations (Bancroft et. al. 1990). District research indicates that high water levels directly under colonial nest sites are significantly directly correlated with nesting success of many colonial waterbirds. Total calendar year precipitation during 1993-1995, 1999-2000, and 2003-2004 was significantly correlated with nesting success. The colonies that were studied are extremely difficult to access and water levels have not been measured, only observed during aerial surveys.

Mammals

There are two federally listed mammal species in Brevard County, the West Indian manatee and southeastern beach mouse; neither would be expected to occur in the study area (USFWS 2004a, b). There are approximately twelve mammal species which could occur, even transitorily, in the two county area (FNAI 2001).

Table C.1 Summary of existing and potential aquatic plant and wildlife uses for the St Johns River at State Road 50, Brevard County and Orange County, Florida. The study area is 209 miles upstream from the mouth within the northern portion of the Upper basin.

Water Resource Value	Subcategory	Basis for Confirmation of Use	Number of species potentially occurring in study area
Fish and Wildlife Habitat, Passage of Fish	Plants	Airboat field trip; literature	See Mace 2005
	Invertebrates	Terrestrial and aquatic invertebrates - literature	Unknown
	Mollusks	Literature	Unknown
	Crustaceans	Literature	Unknown
	Insects	Literature	Unknown
	Fish	Airboat field trip; literature, fish are well distributed throughout the river, and have variable, species-specific populations. distribution is related to variable dissolved oxygen concentrations, temperature and flow.	Estimated 94
	Reptiles	Various reptile species are commonly reported in wildlife inventories of the river; alligators are numerous	Estimated 30
	Amphibians	No amphibians were observed during the brief site visit by airboat; various amphibian species are commonly reported in wildlife inventories of the river.	Estimated 20
	Birds	Various species observed including piscivorous birds (anhinga, cormorant, egrets, etc.) during airboat field trip. Many other wetland-dependent birds have been reported in breeding bird atlas records; other literature.	Brevard County 127 species, Orange County 111 species (FWC Breeding Bird Atlas)
	Water bird colonies	Water bird colonies are distributed throughout Brevard and Orange Counties (literature).	Brevard County: 8; Orange County: 10 potentially active colonies (FWC 1990, Bryan et al. 2003)
	Mammals	Numerous wetland-dependent mammals, including otters, have been reported in inventories, literature.	Estimated 40

Table C.2 Taxonomic groups of federally and state-listed species potentially occurring in the study area within Brevard and Orange Counties.

Subcategory	Federally listed species		State listed species	
	Brevard	Orange	Brevard	Orange
Plants	1	7	0	0
Invertebrates	0	0	0	0
Mollusks	0	0	0	0
Crustaceans	0	0	0	0
Insects	no data	no data	0	0
Fish	0	0	2	2
Reptiles [a]	2	2	3	3
Amphibians	0	0	3	3
Birds [b]	5	6	10	10
Water bird colonies	no data	no data	10	10
Mammals [c]	1	0	5	5

[a] Marine reptiles (marine turtles) excluded from summary.
[b] All species included due to possible vagrancy.
[c] Marine mammal (manatee) excluded from summary.

Table C.3 Fish species probably occurring in the upper St. Johns River in the Highway 50 river reach (sources: Adapted from Tagatz 1967, Burgess et al. 1977, Trexler 1995, FFWCC, FWC electro shocking data, Bob Eisenhauer, FWC, personal communication, August 2004; Jim Estes, FWC, personal communication, August 2004).

Species, Common Name	Species, Common Name
Dasyatis sabina, Atlantic stingray	Lepisosteus platyrhincus, Florida gar
Lepisosteus osseus, Longnose gar	Anguilla rostrata, American eel
Amia calva, Bowfin	Alosa mediocris, Hickory shad
Alosa aestivalis, Blueback herring	Brevoortia tyrannus, Atlantic menhaden
Alosa sapidissima, American shad	Dorosoma petenense, Threadfin shad
Dorosoma cepedianum, Gizzard shad	Esox americanus, Redfin pickerel
Esox niger, Chain pickerel	Umbra pygmaea, Eastern mudminnow
Cyprinus carpio, Common carp	Notemigonus crysoleucas, Golden shiner
Notropis chalybaeus, Ironcolor shiner	Notropis cummingsae, Dusky shiner
Notropis harperi, Redeye chub	Notropis maculatus, Taillight shiner
Notropis petersoni, Coastal shiner	Opsopoeodus emillae, Pugnose minnow
Pteronotropis hypselopterus, Sailfin shiner	Pteronotropis welaka, Bluenose shiner
Erimyzon sucetta, Lake chubsucker	Ameiurus brunneus, Snail bullhead
Ameiurus catus, White catfish	Ameiurus natalis, Yellow bullhead
Ameiurus nebulosus, Brown bullhead	Ictalurus punctatus, Channel catfish
Pterygoplicthys gibbiceps, sailfin catfish	Hoplosternum littorale, armored catfish
Noturus gyrinus, Tadpole madtom	Noturus leptacanthus, Speckled madtom
Bagre marinus, Gafftopsail catfish	Hypostomus plecostomus, Suckermouth catfish
Aphredoderus sayanus, Pirate perch	Strongulura marina, Atlantic needlefish
Cyprinodon variegatus, Sheepshead minnow	Fundulus chrysotus, Golden topminnow
Fundulus confluentus, Marsh killifish	Fundulus escambiae, Eastern starhead minnow
Fundulus lineolatus, Lined topminnow	Fundulus rubifrons, Redface topminnow
Fundulus seminolis, Seminole killifish	Jordanella floridae, Flagfish
Leptolucania ommata, Pygmy killifish	Lucania goodei, Bluefin killifish
Lucania parva, Rainwater killifish	Belonesox belizanus, Pike killifish
Gambusia holbrooki, Mosquitofish	Heterandria formosa, Least killifish
Poecilia latipinna, Sailfin molly	Labidesthes sicculus, Brook silverside
Menidia beryllina, Inland silverside	Menidia menidia, Atlantic silverside
M. saxatilis x M. chrysops, Striped bass hybrid	Morone saxatilis, Striped bass
Acantharchus pomotis, Mud sunfish	Centrarchus macropterus, Flier
Elassoma evergladei, Everglades pygmy sunfish	Elassoma okefenokee, Okefenokee pygmy sunfish
Elassoma zonatum, Banded pygmy sunfish	Enneachanthus gloriosus, Bluespotted sunfish
Enneachanthus obesus, Banded sunfish	Lepomis auritus, Redbreast sunfish
Lepomis gulosus, Warmouth	Lepomis macrochirus, Bluegill
Lepomis marginatus, Dollar sunfish	Lepomis microlophus, Redear sunfish
Lepomis punctatus, Spotted sunfish	Micropterus salmoides, Largemouth bass
Pomoxis nigromarginatus, Black crappie	Etheostoma edwini, Brown darter
Etheostoma fusiforme, Swamp darter	Etheostoma olmstedi, Tessellated darter
Percina nigrofasciata, Blackbanded darter	Mugil cephalus, Striped mullet
Micropogonias undulatus, Atlantic croaker	Dormitator maculatus, Fat sleeper
Oreochromis aurea, Blue tilapia	Microgobius gulosus, Clown goby
Mugil curema, White mullet	Trinectes maculatus, Hogchoker
Gobiosoma bosci, Naked goby	Cyprinus carpio, koi
Paralichthys lethostigma, Southern flounder	
Ctenopharyngodon idella, Hybrid grass carp	

Table C.4 Habitat preferences and/or salinity ranges at time of capture for selected fish species occurring in the St. Johns River near Highway 50, between S R 548 and S R 46 (Source: ECT 2002, FWC undated, Bob Eisenhauer, FWC, personal communication, August 2004).

Scientific Name	Common Name	Salinity Range (ppt)	Habitat	References
Dasyatis sabina	Atlantic stingray	0.09 – 41	Marine and high salinity inland, close to shore	Bigelow and Schroeder 1953, Gunter and Hall 1965, Mountain 1972, Snelson and Williams 1981
Lepisosteus osseus	Longnose gar	1.2 – 26.9	Adults in large rivers, juveniles in small streams, fresh and brackish water	Springer and Woodburn 1960, Suttkus 1963, Swingle and Bland 1974
Lepisosteus platyrhincus	Florida gar	0 – 26.0	Main river channels, pools in small creeks, lakes and ponds, fresh and brackish water	Barnett 1972, Gunter and Hall 1965, Mountain 1972, Suttkus 1963; Tabb and Manning 1962
Amia calva	Bowfin	—	Sluggish, weedy water	Barnett 1972
Anguilla rostrata	American eel	0.3 – 29.9	Catadromous, adults in fresh water, undercut banks of rivers, ponds; spawn in Sargasso Sea	Smith 1968; Springer and Woodburn 1960; Swingle and Bland 1974; Graff and Middleton 2002
Alosa sapidissima	American shad	—	Anadromous, present in St. Johns River when temperature falls below 20ºC	Leggett 1973
Dorosoma cepedianum	Gizzard shad	0.0 - 24.7	Large, mud bottom, highly eutrophic lakes	Barnett 1972; Swingle and Bland 1974
Dorosoma petenense	Threadfin shad	0.0 - 21.7	Open water in lakes	Barnett 1972; Gunter and Hall 1965; Swingle and Bland 1974
Notemigonus crysoleucas	Golden shiner	1.3 - 10.7	Permanent open water with a depth of 0.5m or more, most common along outer edge of vegetation; fry and juveniles in shallow weedy areas	Barnett 1972; Swingle and Bland 1974
Notropis chalybaeus	Ironcolor shiner	—	Swamp streams, spring runs, rivers and bayou ponds in moving water	Barnett 1972; Marshall 1946
Notropis maculatus	Taillight shiner	0.09 - 1.0	Ponds and lakes on or near the bottom at a depth of 2-3 m	Barnett 1972; Beach 1974; Gunter and Hall 1965
Notropis petersoni	Coastal shiner	0.12 - 0.65	Found in nearly all flowing water and occasionally in stagnant pools.	Barnett 1972; Cowell and Resico 1975; Gunter and Hall 1965
Pteronotropis hypselopterus	Sailfin shiner	—	Streams of moderate to swift currents with a sand or gravel bottom	Barnett 1972
Pteronotropis welaka	Bluenose shiner	—	Deeper holes and quiet, weedy water	Gilbert 1978
Centrarchus macropterus	Flier	--	Swamps; prefer acidic water	
Erimyzon sucetta	Lake chubsucker	0.6 - 14.4	Nearly every available aquatic habitat; young school in moderate current but adults prefer quiet, vegetated backwaters	Barnett 1972; Swingle and Bland 1974
Ameiurus brunneus	Snail bullhead	—	Streams with rock bottoms and moderate to swift current; restricted range in nw FL	Gilbert 1978
Ameiurus catus	White catfish	0.09 - 0.26	Deep portions of rivers and large connecting lakes	Barnett 1972; Gunter and Hall 1965
Ameiurus natalis	Yellow	0 - 12	Quiet heavily vegetated areas in	Barnett 1972; Tabb and Manning

Scientific Name	Common Name	Salinity Range (ppt)	Habitat	References
	bullhead		streams and ponds	1962
Ameiurus nebulosus	Brown bullhead	0.4 - 3.5	Common in ponds, less common in flowing water	Barnett 1972; Swingle and Bland 1974
Ictalurus punctatus	Channel catfish	0 - 12.6	Deep portions of river channel and in large connecting lakes	Barnett 1972; Gunter and Hall 1965; McMahon and Terrell 1982; Swingle and Bland 1974
	Sailfin catfish			
Hoplosternum littorale	Armored catfish		Nonindigenous, tropical America; discovered in ditches of the Indian River lagoon system 1995; found in the St. Johns and Kissimmee River drainages recently; 20-25 cm l.	Nico et al. 1996, Nico 2004
	hybrid grasscarp Koi			
Sarotherodon spp., *Oreochromis* spp., *Tilapia* spp.	tilapia	--	Prohibited east African lakes fishes, primarily lakes, but also rivers and estuaries; substrate spawner; ominvorous	Bars, Shafland and Wattendorf 1990
Noturus gyrinus	Tadpole madtom	—	Sand or silt bottom eddies near vegetation or under leaves and other rubble	Barnett 1972
Noturus leptacanthus	Speckled madtom	0.22		Gunter and Hall 1965
Bagre marinus	Gafftopsail catfish	0.17 - 35	--	Gunter and Hall, 1965; Mountain, 1972;Springer and Woodburn, 1960; Swingle and Bland, 1974; Tabb and Manning, 1962
Esox americanus	Redfin pickerel	—	Quiet, weedy areas of rivers, sluggish swamp streams, and pond margins	Barnett 1972; Graff and Middleton 2002
Esox niger	Chain pickerel	0 – 7.5	Common in rivers and large lakes in heavily vegetated areas or where fallen logs are present	Barnett 1972; Swingle and Bland 1974;Graff and Middleton 2002
Aphredoderus sayanus	Pirate perch	0.6 - 19.7	Sluggish fish which swim infrequently, occupy dense vegetation	Parker and Simpco 1975; Swingle and Bland 1974; Graff and Middleton 2002
Strongulura marina	Atlantic needlefish	0 - 23.0	—	Mountain 1972; Swingle and Bland 1974
Cyprinodon variegatus	Sheepshead minnow	0 - 31.8	Shallow areas next to shoreline which are without vegetation	Gunter and Hall,1965; Mountain 1972; Springer and Woodburn 1960; Swingle and Bland 1974; Tabb and Manning 1962
Fundulus chrysotus	Golden topminnow	0 - 5	Common in shallow, current-free areas with dense vegetation	Barnett 1972; Gunter and Hall 1965;Swingle and Bland 1974; Tabb and Manning 1962
Fundulus confluentus	Marsh killifish	0.0 - 20.4	—	Gunter and Hall 1965; Springer and Woodburn 1960; Swingle and Bland 1974;Tabb and Manning 1962; Burgess et al. 1977
Fundulus lineolatus	Lined topminnow	—	Vegetated margins of lakes, ponds, and swamp stream pools, at outer edge of vegetation	Barnett 1972
Fundulus seminolis	Seminole killifish	0 - 7.3	On bottom of lakes from near shore to depths of 2 meters	Barnett 1972; Gunter and Hall 1965; Tabb and Manning 1962
Jordanella floridae	Flagfish	0 - 9	Shallow areas of ponds and streams, usually near vegetation	Barnett 1972; Gunter and Hall 1965; Tabb and Manning 1962
Lucania goodei	Bluefin	0 - 12	Vegetated areas in springs,	Barnett 1972; Gunter and Hall

Scientific Name	Common Name	Salinity Range (ppt)	Habitat	References
	killifish		swamp streams, rivers, ponds and lakes, usually in dense vegetation	1965; Tabb and Manning 1962
Lucania parva	Rainwater killifish	0 - 28	Heavily vegetated areas, usually at salinity greater than 25 ppt	Gunter and Hall 1965; Mountain 1972; Springer and Woodburn 1960; Swingle and Bland 1974; Tabb and Manning 1962
Gambusia holbrooki	Mosquitofish	0 - 30	Almost any fresh water body, usually in shallow water near vegetation	Barnett 1972; Gunter and Hall 1965; Swingle and Bland 1974; Tabb and Manning 1962
Heterandria formosa	Least killifish	0 - 30.2	Usually near surface in heavy vegetation	Barnett 1972; Gunter and Hall 1965; Tabb and Manning 1962
Poecilia latipinna	Sailfin molly	0 - 33	Shallow, densely vegetated shorelines	Barnett 1972; Gunter and Hall 1965; Mountain 1972; Swingle and Bland 1974; Tabb and Manning 1962
Labidesthes sicculus	Brook silverside	0.12	Open water of lakes, streams, river channels	Barnett 1972; Gunter and Hall 1965
Menidia beryllina	Inland silverside	0 - 33	—	Gallaway and Strawn 1974; Gunter and Hall 1965; Mountain 1972; Swingle and Bland 1974; Tabb and Manning 1962
Centropomus undecimalis	Common snook	0 - 35	—	Gunter and Hall 1965; Tabb and Manning 1962
Morone saxatilis	Striped bass	—	Inshore coastal waters, ascending rivers; some populations landlocked; spawns in fresh or nearly freshwater at head of estuaries or in rivers.	Fischer 1978
Acantharchus pomotis	Mud sunfish	—	Low gradient streams and ponds with dense vegetation	Gilbert 1978
Elassoma evergladei	Everglades pygmysunfish	0 - 14.4	Shallow margins of ponds, streams, and rivers; as water rises in spring, moves into extremely shallow areas with or without cover	Barnett 1972; Swingle and Bland 1974; Rubenstein 1981; Tabb and Manning 1962
Elassoma okefenokee	Okefenokee pygmysunfish	—	Margins of rivers	Barnett, 1972
Enneachanthus gloriosus	Bluespotted sunfish	0 – 3.8	Lakes and rivers wherever dense vegetation in present	Barnett 1972; Gunter and Hall 1965; Swingle and Bland, 1974
Lepomis auritus	Redbreast sunfish	≤ 8 ≥	Flowing water and connecting lakes	Barnett 1972; Tabb and Manning 1962
Lepomis gulosus	Warmouth	0.5 - 14.4	Sluggish swamp streams and ponds in dense cover	Barnett 1972; Swingle and Bland 1974; Graff and Middleton 2002
Lepomis macrochirus	Bluegill	0 - 13.8	Ponds, lakes, low velocity streams; prefers velocity <10 cm/sec	Barnett 1972; Gunter and Hall 1965; Stuber et al. 1982a; Swingle and Bland 1974; Graff and Middleton 2002; Cox 1970
Lepomis marginatus	Dollar sunfish	5	Pond margins, eddies along margins of swift streams; rarely numerous	Barnett 1972; Swingle and Bland 1974
Lepomis microlophus	Redear sunfish	0 - 14.4	Lakes and sluggish currents in streams, usually in deep areas	Barnett 1972; Gunter and Hall 1965; Swingle and Bland 1974; Tabb and Manning 1962
Lepomis punctatus	Spotted sunfish	0 - 17.5	Common in streams, usually in areas less than 1 m deep with dense cover	Barnett 1972; Swingle and Bland 1974; Tabb and Manning 1962
Micropterus salmoides	Largemouth bass	0 - 17.5	All permanent bodies of water; adults near cover; fry and	Barnett 1972; Chew 1974; Stuber et al.1982b; Swingle and Bland

Scientific Name	Common Name	Salinity Range (ppt)	Habitat	References
			fingerlings in shallow, current-free, vegetated areas	1974; Tabb and Manning 1962
Pomoxis nigromarginatus	Black crappie	0 - 2.4	Open water of lakes and ponds; prefers clear water	Barnett, 1972; Edwards et al., 1982; Swingle and Bland 1974
Etheostoma fusiforme	Swamp darter	—	Sand and mud bottomed lakes, swamp stream, and rivers	Barnett 1972
Etheostoma olmstedi	Tessellated darter	2.23	Small to medium-sized streams, out of main current	Gilbert 1978
Micropogonias undulatus	Atlantic croaker	0 - 29.8	Primarily marine and estuarine	Gallaway and Strawn 1974; Gunter and Hall 1965; Mountain 1972; Springer and Woodburn 1960; Swingle and Bland 1974
Mugil cephalus	Striped mullet	0 - 39.0	Primarily marine and estuarine, often entering freshwater to the heads of streams	Fischer, 1978; Futch and Dwinell 1977; Gunter and Hall 1965; Moore 1974; Mountain 1972; Springer and Woodburn1960; Swingle and Bland 1974; Tabb and Manning 1962
Mugil curema	White mullet	11.0 - 37.5	Primarily marine and estuarine	Futch and Dwinell 1977; Gunter and Hall 1965; Moore 1974; Mountain 1972; Springer and Woodburn 1960
Dormitator maculatus	Fat sleeper	0.1 - 3.4	Low salinity streams	Springer and Woodburn, 1960; Swingle and Bland 1974
Gobiosoma bosci	Naked goby	0 - 33.0	—	Gunter and Hall 1965; Springer and Woodburn 1960; Swingle and Bland 1974
Microgobius gulosus	Clown goby	0.18 - 33.0	Primarily marine and estuarine	Gunter and Hall 1965; Mountain 1972; Swingle and Bland 1974; Tabb and Manning, 1962
Paralichthys lethostigma	Southern flounder	0 - 30.8	Primarily marine and estuarine	Gunter and Hall 1965; Swingle and Bland 1974
Trinectes maculatus	Hogchoker	0 - 35	—	Gunter and Hall 1965; Mountain 1972; Swingle and Bland 1974; Tabb and Manning 1962

Table C.5 Results of electroshocking runs in the main channel of the SJR 2002, 2003, 2004 (Bob Eisenhauer, FWC, personal communication, August 2004; FWC unpublished data).

Species	Year		N	Range	Minimum	Maximum	Mean	Std. Deviation
$ unknown	2003	LENGTH TL (mm)	12	85	4	89	14.75	23.75
		WEIGHT weight (gms)	12	92	4	96	44.08	35.91
		Valid N (listwise)	12					
American eel	2002	LENGTH TL (mm)	3	145	375	520	461.67	76.54
		WEIGHT weight (gms)	3	0	0	0	0.00	0.00
		Valid N (listwise)	3					
American shad	2002	LENGTH TL (mm)	5	39	386	425	400.80	15.39
		WEIGHT weight (gms)	5	0	0	0	0.00	0.00
		Valid N (listwise)	5					
	2003	LENGTH TL (mm)	16	96	355	451	403.00	21.40
		WEIGHT weight (gms)	16	249	330	579	392.88	60.51
		Valid N (listwise)	16					
	2004	LENGTH TL (mm)	4	18	417	435	426.50	8.43
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
Armored catfish	2002	LENGTH TL (mm)	3	61	150	211	172.00	33.87
		WEIGHT weight (gms)	3	0	0	0	0.00	0.00
		Valid N (listwise)	3					
	2003	LENGTH TL (mm)	15	105	145	250	201.87	35.14
		WEIGHT weight (gms)	15	268	40	308	166.00	81.81
		Valid N (listwise)	15					
Atlantic croaker	2002	LENGTH TL (mm)	1	0	198	198	198.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Atlantic needlefish	2004	LENGTH TL (mm)	2	25	485	510	497.50	17.68
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
Black crappie	2002	LENGTH TL (mm)	2	144	64	208	136.00	101.82
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
	2003	LENGTH TL (mm)	8	188	11	199	156.75	63.01
		WEIGHT weight (gms)	8	98	18	116	76.25	38.80
		Valid N (listwise)	8					
	2004	LENGTH TL (mm)	4	38	152	190	163.50	17.79
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
Bluefin killifish	2003	LENGTH TL (mm)	2	1	2	3	2.50	0.71
		WEIGHT weight (gms)	0					
		Valid N (listwise)	0					
Bluegill	2002	LENGTH TL (mm)	119	149	60	209	108.50	34.99
		WEIGHT weight (gms)	119	0	0	0	0.00	0.00
		Valid N (listwise)	119					
	2003	LENGTH TL (mm)	73	221	4	225	84.42	67.96
		WEIGHT weight (gms)	73	480	4	484	99.70	108.45
		Valid N (listwise)	73					

Species	Year		N	Range	Minimum	Maximum	Mean	Std. Deviation
	2004	LENGTH TL (mm)	50	215	7	222	125.14	45.60
		WEIGHT weight (gms)	50	0	0	0	0.00	0.00
		Valid N (listwise)	50					
Bowfin	2002	LENGTH TL (mm)	2	88	532	620	576.00	62.23
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
	2003	LENGTH TL (mm)	2	25	560	585	572.50	17.68
		WEIGHT weight (gms)	2	2000	0	2000	1000.00	1414.21
		Valid N (listwise)	2					
Brook silverside	2003	LENGTH TL (mm)	2	2	5	7	6.00	1.41
		WEIGHT weight (gms)	1	0	4	4	4.00	.
		Valid N (listwise)	1					
	2004	LENGTH TL (mm)	1	0	67	67	67.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Brown bullhead	2004	LENGTH TL (mm)	1	0	205	205	205.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Channel catfish	2002	LENGTH TL (mm)	11	465	365	830	518.27	151.49
		WEIGHT weight (gms)	11	0	0	0	0.00	0.00
		Valid N (listwise)	11					
	2003	LENGTH TL (mm)	1	0	498	498	498.00	.
		WEIGHT weight (gms)	1	0	1400	1400	1400.00	.
		Valid N (listwise)	1					
	2004	LENGTH TL (mm)	2	65	287	352	319.50	45.96
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
Coastal shiner	2004	LENGTH TL (mm)	5	24	33	57	47.20	11.10
		WEIGHT weight (gms)	5	0	0	0	0.00	0.00
		Valid N (listwise)	5					
Dollar sunfish	2002	LENGTH TL (mm)	1	0	72	72	72.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
	2004	LENGTH TL (mm)	2	27	53	80	66.50	19.09
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
Florida gar	2002	LENGTH TL (mm)	15	371	132	503	321.07	121.63
		WEIGHT weight (gms)	15	0	0	0	0.00	0.00
		Valid N (listwise)	15					
	2003	LENGTH TL (mm)	33	382	153	535	398.18	88.02
		WEIGHT weight (gms)	33	676	44	720	311.85	173.94
		Valid N (listwise)	33					
	2004	LENGTH TL (mm)	16	442	261	703	460.88	115.72
		WEIGHT weight (gms)	16	0	0	0	0.00	0.00
		Valid N (listwise)	16					
Gizzard shad	2002	LENGTH TL (mm)	4	68	337	405	365.00	28.62
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
	2003	LENGTH TL (mm)	8	106	322	428	366.13	33.18

Species	Year		N	Range	Minimum	Maximum	Mean	Std. Deviation
		WEIGHT weight (gms)	8	350	322	672	444.00	107.90
		Valid N (listwise)	8					
	2004	LENGTH TL (mm)	1	0	387	387	387.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Golden shiner	2002	LENGTH TL (mm)	19	69	108	177	139.53	19.34
		WEIGHT weight (gms)	19	0	0	0	0.00	0.00
		Valid N (listwise)	19					
	2003	LENGTH TL (mm)	1	0	177	177	177.00	.
		WEIGHT weight (gms)	1	0	52	52	52.00	.
		Valid N (listwise)	1					
	2004	LENGTH TL (mm)	1	0	143	143	143.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Lake chubsucker	2002	LENGTH TL (mm)	3	25	72	97	83.33	12.66
		WEIGHT weight (gms)	3	0	0	0	0.00	0.00
		Valid N (listwise)	3					
	2003	LENGTH TL (mm)	1	0	221	221	221.00	.
		WEIGHT weight (gms)	1	0	150	150	150.00	.
		Valid N (listwise)	1					
Largemouth bass	2002	LENGTH TL (mm)	57	353	217	570	307.23	87.60
		WEIGHT weight (gms)	57	0	0	0	0.00	0.00
		Valid N (listwise)	57					
	2003	LENGTH TL (mm)	16	557	3	560	321.44	154.10
		WEIGHT weight (gms)	15	2094	6	2100	733.60	594.81
		Valid N (listwise)	15					
	2004	LENGTH TL (mm)	68	240	185	425	249.40	49.65
		WEIGHT weight (gms)	68	0	0	0	0.00	0.00
		Valid N (listwise)	68					
Needlefish	2003	LENGTH TL (mm)	3	153	8	161	60.00	87.48
		WEIGHT weight (gms)	2	6	2	8	5.00	4.24
		Valid N (listwise)	2					
Pirate perch	2003	LENGTH TL (mm)	1	0	4	4	4.00	.
		WEIGHT weight (gms)	1	0	2	2	2.00	.
		Valid N (listwise)	1					
Redbreasted sunfish	2002	LENGTH TL (mm)	36	116	87	203	135.31	32.87
		WEIGHT weight (gms)	36	0	0	0	0.00	0.00
		Valid N (listwise)	36					
	2003	LENGTH TL (mm)	73	226	5	231	125.15	55.93
		WEIGHT weight (gms)	72	196	4	200	62.92	44.51
		Valid N (listwise)	72					
	2004	LENGTH TL (mm)	47	204	7	211	114.06	46.13
		WEIGHT weight (gms)	47	0	0	0	0.00	0.00
		Valid N (listwise)	47					
Redear sunfish	2002	LENGTH TL (mm)	29	105	65	170	93.24	29.00
		WEIGHT weight (gms)	29	0	0	0	0.00	0.00
		Valid N (listwise)	29					
	2003	LENGTH TL (mm)	61	206	5	211	128.79	60.03
		WEIGHT weight (gms)	61	202	2	204	73.67	38.82

Species	Year		N	Range	Minimum	Maximum	Mean	Std. Deviation
		Valid N (listwise)	61					
	2004	LENGTH TL (mm)	10	156	11	167	114.80	48.70
		WEIGHT weight (gms)	10	0	0	0	0.00	0.00
		Valid N (listwise)	10					
Sailfin catfish	2002	LENGTH TL (mm)	49	444	120	564	177.33	87.74
		WEIGHT weight (gms)	49	0	0	0	0.00	0.00
		Valid N (listwise)	49					
	2004	LENGTH TL (mm)	4	44	117	161	136.25	18.28
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
Seminole killifish	2002	LENGTH TL (mm)	4	2	113	115	114.25	0.96
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
	2003	LENGTH TL (mm)	4	7	4	11	8.00	2.94
		WEIGHT weight (gms)	4	16	2	18	11.00	6.83
		Valid N (listwise)	4					
Spotted sunfish	2002	LENGTH TL (mm)	14	91	82	173	111.50	23.22
		WEIGHT weight (gms)	14	0	0	0	0.00	0.00
		Valid N (listwise)	14					
	2003	LENGTH TL (mm)	51	170	4	174	89.41	64.98
		WEIGHT weight (gms)	51	148	2	150	60.12	41.42
		Valid N (listwise)	51					
	2004	LENGTH TL (mm)	17	152	9	161	120.82	37.57
		WEIGHT weight (gms)	17	0	0	0	0.00	0.00
		Valid N (listwise)	17					
Striped mullet	2002	LENGTH TL (mm)	7	115	242	357	291.14	49.42
		WEIGHT weight (gms)	7	0	0	0	0.00	0.00
		Valid N (listwise)	7					
	2004	LENGTH TL (mm)	4	60	267	327	298.50	24.68
		WEIGHT weight (gms)	4	0	0	0	0.00	0.00
		Valid N (listwise)	4					
Suckermouth catfish	2003	LENGTH TL (mm)	9	180	350	530	426.22	74.30
		WEIGHT weight (gms)	9	951	424	1375	791.22	390.36
		Valid N (listwise)	9					
Swamp darter	2003	LENGTH TL (mm)	2	0	3	3	3.00	0.00
		WEIGHT weight (gms)	0					
		Valid N (listwise)	0					
Taillight shiner	2002	LENGTH TL (mm)	1	0	61	61	61.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
	2003	LENGTH TL (mm)	6	42	3	45	10.83	16.75
		WEIGHT weight (gms)	1	0	2	2	2.00	.
		Valid N (listwise)	1					
	2004	LENGTH TL (mm)	1	0	5	5	5.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					
Threadfin shad	2002	LENGTH TL (mm)	76	48	83	131	106.04	8.21
		WEIGHT weight (gms)	76	0	0	0	0.00	0.00
		Valid N (listwise)	76					

Species	Year		N	Range	Minimum	Maximum	Mean	Std. Deviation
	2003	LENGTH TL (mm)	16	129	9	138	109.56	39.67
		WEIGHT weight (gms)	16	10	0	10	1.13	3.10
		Valid N (listwise)	16					
	2004	LENGTH TL (mm)	6	114	7	121	29.00	45.13
		WEIGHT weight (gms)	6	0	0	0	0.00	0.00
		Valid N (listwise)	6					
Warmouth	2002	LENGTH TL (mm)	16	80	70	150	110.31	23.82
		WEIGHT weight (gms)	16	0	0	0	0.00	0.00
		Valid N (listwise)	16					
	2003	LENGTH TL (mm)	77	186	4	190	90.23	62.38
		WEIGHT weight (gms)	76	164	0	164	50.13	41.76
		Valid N (listwise)	76					
	2004	LENGTH TL (mm)	12	166	9	175	123.25	56.37
		WEIGHT weight (gms)	12	0	0	0	0.00	0.00
		Valid N (listwise)	12					
White catfish	2002	LENGTH TL (mm)	9	276	166	442	283.78	108.49
		WEIGHT weight (gms)	9	0	0	0	0.00	0.00
		Valid N (listwise)	9					
	2003	LENGTH TL (mm)	26	390	9	399	214.12	107.73
		WEIGHT weight (gms)	26	900	0	900	177.35	231.94
		Valid N (listwise)	26					
	2004	LENGTH TL (mm)	2	65	299	364	331.50	45.96
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
Yellow bullhead	2002	LENGTH TL (mm)	2	56	207	263	235.00	39.60
		WEIGHT weight (gms)	2	0	0	0	0.00	0.00
		Valid N (listwise)	2					
	2003	LENGTH TL (mm)	23	303	9	312	203.39	83.71
		WEIGHT weight (gms)	23	510	0	510	153.26	134.48
		Valid N (listwise)	23					
	2004	LENGTH TL (mm)	1	0	177	177	177.00	.
		WEIGHT weight (gms)	1	0	0	0	0.00	.
		Valid N (listwise)	1					

Table C.6 Composite mean, minimum and maximum fish lengths and weights from electroshocking runs in the upper St. Johns River during 2002, 2003, 2004 (Bob Eisenhauer, FWC, personal communication, August 2004; FWC unpublished data).

	LENGTH TL (mm)	WEIGHT weight (gms)	Valid N (listwise)
N	1291	1277	1277
Range	828.00	2100.00	
Minimum	2.00	.00	
Maximum	830.00	2100.00	
Mean	168.5871	60.2028	
Std. Deviation	123.8586	168.6922	

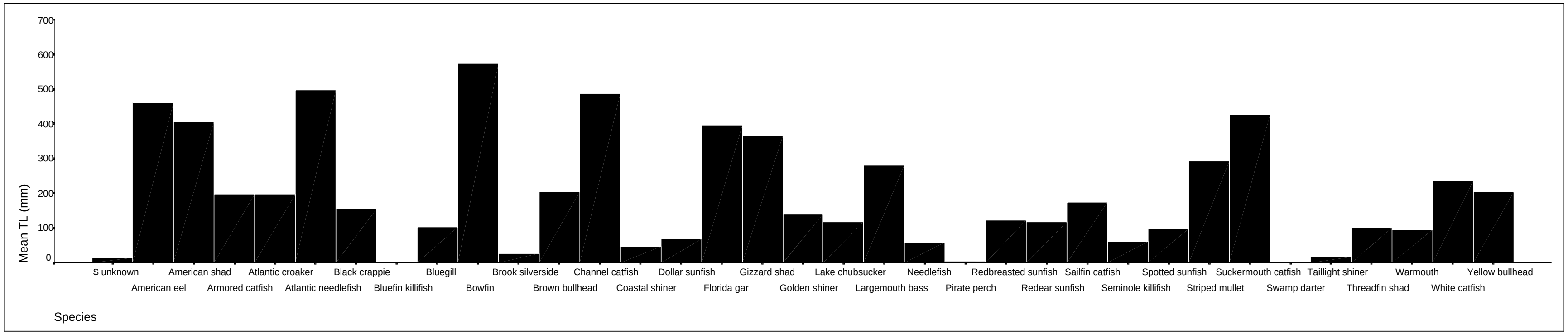


Figure C.1 Composite mean fish lengths by species from electroshocking runs in the upper St. Johns River during 2002, 2003, 2004 (Bob Eisenhauer, FWC, personal communication, August 2004; FWC unpublished data).

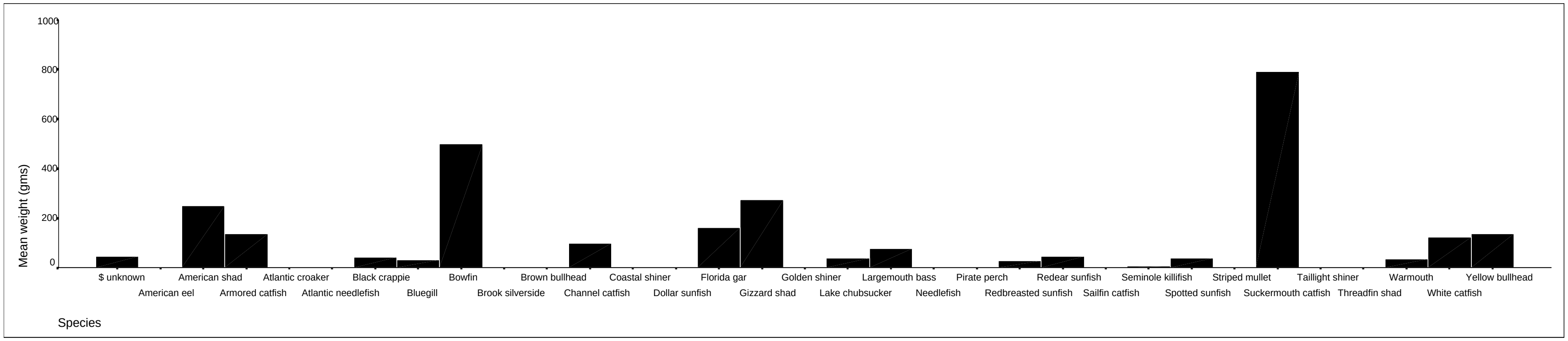


Figure C.2 Composite mean fish weights by species from electroshocking runs in the upper St. Johns River during 2003 (Bob Eisenhauer, FWC, personal communication, August 2004; FWC unpublished data).

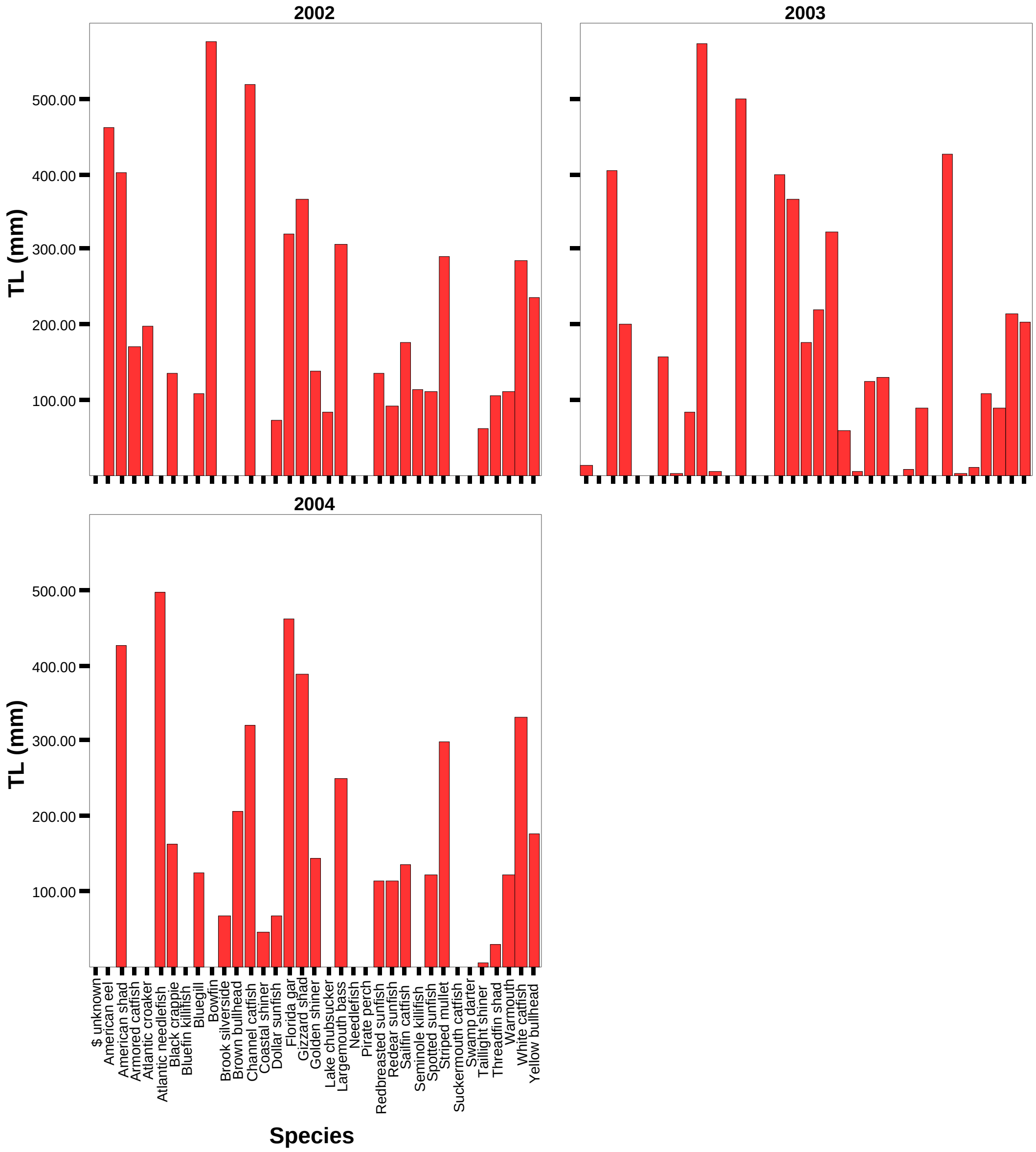


Figure C.3 Mean fish lengths by species from electroshocking runs in the upper St. Johns River during 2002, 2003, 2004 (Bob Eisenhauer, FWC personal communication, August 2004; FWC unpublished data).

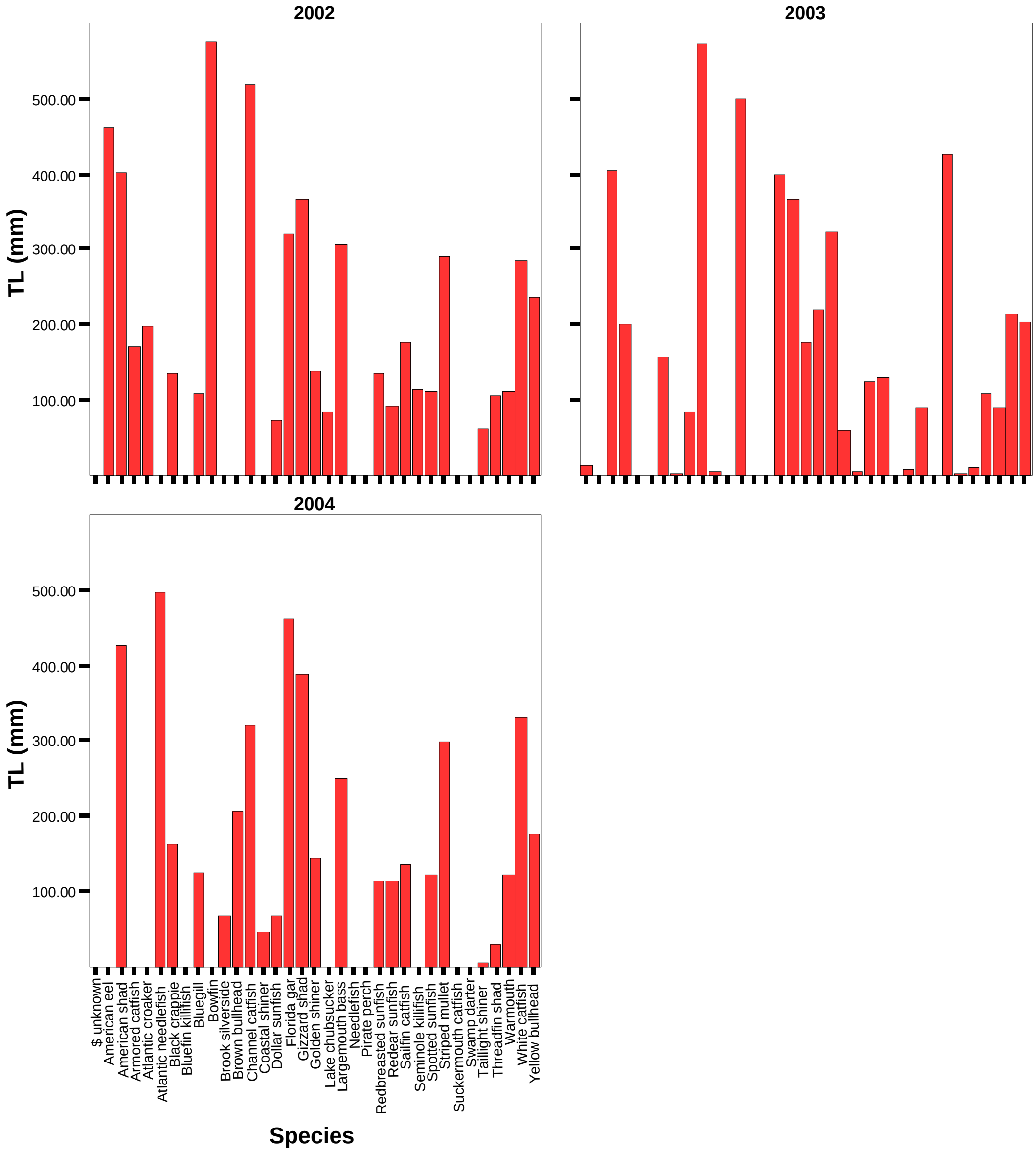


Figure C.4 Composite fish weights by species from electroshocking runs in the upper St. Johns River during 2003 (Bob Eisenhauer, FWC, personal communication, August 2004; FWC unpublished data).

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APPENDIX D

WATER QUALITY SUMMARY STATISTICS

Table D.1a Summary statistics for water quality parameters collected at station ER-SJR Econlockhatchee River before confluence with St. Johns River Period of record: 2002 – 2004

Analyte Name	Units of Measure	Class III Standard	Average	Standard Deviation	Maximum	Minimum	Count
Alkalinity	mg/L	$\geq$ 20 as $CaCO_3$	41	11.0	56	20	14
Aluminum	ug/L	--	575	--	575	575	1
Ammonium (dissolved)	mg/L	--	0.041	0.018	0.079	0.017	14
Ammonium	mg/L	< 0.02 as NH_3	0.041	0.016	0.068	0.011	14
Antimony	ug/L	--	0.7	--	0.7	0.7	1
Arsenic	ug/L	$\leq$ 50	0.8	--	0.8	0.8	1
Barium	ug/L	--	11.4	--	11.4	11.4	1
Beryllium	ug/L	$\leq$ 0.13 annual avg	0.5	--	0.5	0.5	1
Calcium	mg/L	--	20.5	5.80	31.7	9.94	14
Cadmium	ug/L	$\leq e^{(0.7852[\ln H]-3.49}$	0.2	--	0.2	0.2	1
Chloride	mg/L	--	68.6	34.3	137	16.8	14
Color	C.P.U.	--	233	126	500	70	14
Conductivity-Field	umhos/cm	--	333	158	651.1	86.6	14
Chromium	ug/L	$\leq$ 11	0.8	--	0.8	0.8	1
Copper	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	2.1	--	2.1	2.1	1
Depth Collection	m	--	0.5	0	0.5	0.5	14
Depth Stream	m	--	1.67	0.643	2.98	1.08	14
Dissolved Oxygen (DO)	mg/L	> 5	6.20	1.24	8.99	4.44	14
Dissolved Organic Carbon (DOC)	mg/L	--	21.6	4.15	30.2	15.6	14
Hardness (calculated)	mg/L	--	72.8	24.4	123	32	14
Iron	ug/L	--	626	136	883	424	14
Mercury	ug/L	--	-0.04	--	-0.04	-0.04	1
Magnesium	mg/L	--	5.28	2.43	10.7	1.74	14
Manganese	ug/L	--	5.7	--	5.7	5.7	1
Nickel	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	1.1	--	1.1	1.1	1
Nitrate-Nitrite	mg/L	--	0.10	0.055	0.227	0.032	14
Lead	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	1.9	--	1.9	1.9	1
pH-Field	S.U.	6 - 8.5	6.92	0.234	7.26	6.54	14
Phosphate (dissolved)	mg/L	--	0.047	0.019	0.066	-0.002	14
Phosphate	mg/L	--	0.055	0.020	0.075	-0.002	14
Potassium	mg/L	--	1.84	--	1.84	1.84	1
Secchi	m	--	0.72	0.139	0.96	0.46	14
Selenium	ug/L	$\leq$ 5	1.5	--	1.5	1.5	1
Silicon Dioxide	mg/L	--	6.6	1.84	8.7	3.3	14
Silver	ug/L	$\leq$ 0.07	0.09	--	0.09	0.09	1
Sulfate	mg/L	--	19.3	8.48	34.3	1.84	14
Strontium	ug/L	--	63.5	--	63.5	63.5	1
Temperature	deg C	--	21.8	5.364	28.22	11.61	13
Tin	ug/L	--	-1.28	--	-1.28	-1.28	1
Total Dissolved Solids (TDS)	mg/L	--	226	64.5	349	110	14
Total Kjeldahl Nitrogen (dissolved)	mg/L	--	0.71	0.12	0.96	0.57	14
Total Kjeldahl Nitrogen	mg/L	--	0.75	0.13	0.96	0.51	14
Total Organic Carbon (TOC)	mg/L	--	23.0	5.33	34.6	15.1	14
Total Phosphorus (dissolved)	mg/L	--	0.072	0.011	0.088	0.045	14
Total Phosphorus	mg/L	--	0.093	0.016	0.116	0.062	14
Total Suspended Solids (TSS)	mg/L	--	3.93	2.4	7	0	14
Turbidity	N.T.U.	$\leq$ 29 above background	4.16	1.4	6.6	1.3	14
Vanadium	ug/L	--	1.9	--	1.9	1.9	1
Zinc	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	3.4	--	3.4	3.4	1

Table D.1b Summary Statistics for water quality parameters collected at station SJR528
St. Johns River along north side of 528 bridge
Period of record: 1996 – 2002

Analyte Name	Units of Measure	Class III Standard	Average	Standard Deviation	Maximum	Minimum	Count
Alkalinity	mg/L	$\geq$ 20 as $CaCO_3$	61.8	14.5	103	34	77
Aluminum	ug/L	--	201	310	2248	0.01	67
Ammonium	mg/L	< 0.02	0.092	0.071	0.431	0.014	77
Calcium	mg/L	--	55.7	34.3	164	19.8	77
Cadmium	ug/L	$\leq e^{(0.7852[\ln H]-3.49}$	0.18	0.32	1.08	-0.012	12
Chlorophyll a	mg/m3	--	6.0	3.3	10.7	0.01	10
Chlorophyll a_Corr	mg/m3	--	4.0	3.1	8.38	0.01	10
Chlorophyll b	mg/m3	--	1.7	2.0	5.07	-0.4	10
Chlorophyll c	mg/m3	--	3.2	3.3	8.79	-0.2	10
Chloride	mg/L	--	196	138	595	28.8	77
Color	C.P.U.	--	184	99	400	50	72
Conductivity-Field	umhos/cm	--	884	544	2320	264	77
Chromium	ug/L	$\leq$ 11	1.1	1.6	5.49	-0.005	12
Copper	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	1.17	0.88	2.99	0.184	12
Depth Collection	m	--	0.5	0.0	0.5	0.5	75
Depth Stream	m	--	2.1	1.2	5	0.8	10
Dissolved Oxygen (DO)	mg/L	> 5	4.9	2.8	11.3	0.14	76
Iron	ug/L	--	365	266	1246	17	77
Hardness (calculated)	mg/L	--	203	129	612	71	77
Lead	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	0.71	0.72	1.95	-0.17	12
Magnesium	mg/L	--	15.63	10.57	48.8	4.735	77
Nickel	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	4.1	8.3	29	-0.09	12
Nitrate-Nitrite	mg/L	--	0.059	0.069	0.311	-0.001	77
Pheophytin_Corr	mg/m3	--	8.4	13.5	35.5	0.01	10
pH-Field	S.U.	6 - 8.5	7.02	0.51	8.24	5.75	77
Phosphate (dissolved)	mg/L	--	0.083	0.044	0.15	0.038	10
Phosphate	mg/L	--	0.060	0.039	0.2	0.017	68
Potassium	mg/L	--	4.92	1.97	9.89	1.309	76
Silicon Dioxide (dissolved)	mg/L	--	5.2	4.7	14	0.425	10
Silicon Dioxide	mg/L	--	2.9	1.9	7.92	0.13	77
Sodium	mg/L	--	94.4	66.0	303	23.8	77
Sulfate	mg/L	--	74	84	394	8.3	77
Temperature	deg C	--	24	5	32.6	14	77
Total Dissolved Solids (TDS)	mg/L	--	565	348	1641	193	77
Total Kjeldahl Nitrogen (dissolved)	mg/L	--	1.29	0.18	1.54	1.05	10
Total Kjeldahl Nitrogen	mg/L	--	1.8	0.5	3.53	1.1	77
Total Organic Carbon (TOC)	mg/L	--	25.4	4.5	36.4	16.96	77
Total Phosphorus (dissolved)	mg/L	--	0.11	0.05	0.181	0.045	10
Total Phosphorus	mg/L	--	0.11	0.06	0.352	0.035	77
Total Suspended Solids (TSS)	mg/L	--	11	14	73	-1	77
Turbidity	N.T.U.	$\leq$ 29 above background	5.5	5.4	24.9	0.4	72
Zinc	ug/L	--	4.44	4.11	15.5	0.419	12

Table D.1c Summary statistics for water quality parameters collected at station SRN Lake Harney inflow - St. Johns River at SR 46 bridge Period of record: 1982 – 2004

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Alkalinity	mg/L	$\geq$ 20 as $CaCO_3$	51.1	17.1	89.245	0.5	183
Aluminum	ug/L	--	248	173	905	40.3	86
Ammonium (dissolved)	mg/L	--	0.048	0.026	0.169	0.001	59
Ammonium	mg/L	< 0.02	0.062	0.043	0.246	0.001	178
Antimony	ug/L	--	-0.15	0.4	0.1	-0.4	2
Arsenic (dissolved)	ug/L	--	1.7	0.8	3	1	7
Arsenic	ug/L	--	0.69	1.3	2.4	-2	11
Barium (dissolved)	ug/L	--	39	32	100	2	7
Barium	ug/L	--	37	18	64	16.5	5
Beryllium	ug/L	--	0.25	0.07	0.3	0.2	2
Biochemical Oxygen Demand (BOD)	mg/L	--	1.5	0.9	4	0.1	33
Calcium (dissolved)	mg/L	--	43	12	62	15	14
Calcium	mg/L	$\leq e^{(0.7852[\ln H]-3.49}$	46	28	139.076	8.4	144
Cadmium (dissolved)	ug/L	--	1.1	1.4	3.9	0.2	8
Cadmium	ug/L	--	0.098	1.1	2.3	-5.5	42
Chlorophyll a	mg/m3	--	4.6	4.6	24.6	0	99
Chlorophyll a_Corr	mg/m3	--	3.0	3.6	24	0	96
Chlorophyll b	mg/m3	--	0.81	3.3	32.6	-0.6	99
Chlorophyll c	mg/m3	--	1.35	5.0	49.5	-1	99
Chloride	mg/L	--	264	172	865.571	0.431	185
Color	C.P.U.	--	207	129	700	50	179
Conductivity	umhos/cm	--	1790	--	1790	1790	1
Conductivity-Field	umhos/cm	--	1005	634	3250	163	185
Chromium (dissolved)	ug/L	--	1.8	1.2	5	1	10
Chromium	ug/L	$\leq$ 11	2.5	8.4	54.6	-1.9	42
Copper (dissolved)	ug/L	--	2.3	2	8	1	11
Copper	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	2.2	2.7	15.3	0	42
Depth Collection	m	--	0.51	0.15	1.8	0.2	183
Depth Stream	m	--	1.8	0.90	3.86	0.5	67
Dissolved Oxygen (DO)	mg/L	> 5	5.8	2.2	11.8	0.66	183
Dissolved Organic Carbon (DOC)	mg/L	--	26.0	3.45	34.8	21.4	14
Fecal Coliform	#/100mL	--	46	38.2	127	3	7
Hardness (as CaCO3)	mg/L	--	148	35.1	228	100	10
Hardness (calculated)	mg/L	--	203	130	622	27	127
Iron (dissolved)	ug/L	--	309	239	1000	92	14
Iron	ug/L	--	480	251	1740	42	146
Lead (dissolved)	ug/L	--	8.3	9.9	30	2	9
Lead	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	1.5	2.5	14	-0.05	41
Mercury	ug/L	--	-0.03	0	-0.03	-0.03	2
Magnesium (dissolved)	mg/L	--	18	6.8	32	5.5	15
Magnesium	mg/L	--	19.4	13.66	66.637	1.422	144
Manganese (dissolved)	ug/L	--	15.7	15	46	1	9
Manganese	ug/L	--	18.5	9.8	42.3	7.5	19
Nickel (dissolved)	ug/L	--	5.3	6.6	22	1	9
Nickel	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	6.2	16	95.1	-1	41
Nitrate-Nitrite (dissolved)	mg/L	--	0.081	0.053	0.29	0.013	31
Nitrate-Nitrite	mg/L	--	0.092	0.10	0.946	0.007	183
Pheophytin_Corr	mg/m3	--	3.2	6.7	54.6	-1.7	98
pH-Field	S.U.	6 - 8.5	6.93	0.502	8.23	4.599999	183

Table D.1c Summary statistics for water quality parameters collected at station SRN Lake Harney inflow - St. Johns River at SR46 bridge Period of record: 1982 – 2004

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Phosphate (dissolved)	mg/L	--	0.034	0.014	0.084	0.003	52
Phosphate	mg/L	--	0.043	0.022	0.129	-0.003	180
Potassium (dissolved)	mg/L	--	5.6	2.1	10	2.8	14
Potassium	mg/L	--	6.93	3.83	17.801	1.737	131
Salinity	ppth	--	0.1	0	0.1	0.1	2
Secchi	m	--	0.70	0.21	1.2	0.3	54
Secchi	in	--	27	10.3	42	16	5
Selenium	ug/L	--	1.9	0.70	2.6	1.2	3
Silicon Dioxide (dissolved)	mg/L	--	4.4	2.7	11	0.925	49
Silicon Dioxide	mg/L	--	2.4	1.21	6	0.442	120
Silver (dissolved)	ug/L	--	0.7	0.42	1	0.4	2
Silver	ug/L	--	0.12	0.45	1.5	-0.5	13
Sodium (dissolved)	mg/L	--	137	59	271	35	14
Sodium	mg/L	--	147	101	476.259	6.177	130
Sulfate	mg/L	--	83	77	439.902	3	186
Strontium (dissolved)	ug/L	--	2195	346	2440	1950	2
Strontium	ug/L	--	806	557	1200	412	2
Temperature	deg C	--	23.54	4.77	31.09	11.51	185
Tin	ug/L	--	-3.045	1.72	-1.83	-4.26	2
Total Dissolved Solids (TDS)	mg/L	--	654	420	3460	65	186
Total Kjeldahl Nitrogen (dissolved)	mg/L	--	1.1	0.28	2.21	0.5	67
Total Kjeldahl Nitrogen	mg/L	--	1.4	0.33	2.83	0.76	177
Total Organic Carbon (TOC)	mg/L	--	22.6	6.14	63.8	6.37	160
Total Phosphorus (dissolved)	mg/L	--	0.056	0.023	0.132	0.000057	68
Total Phosphorus	mg/L	--	0.095	0.084	1.13	0.005	185
Total Suspended Solids (TSS)	mg/L	--	6.6	5.5	35	-1	186
Turbidity	N.T.U.	$\leq$ 29 above background	4.5	3.0	20.4	0	179
Vanadium	ug/L	--	1.5	0.49	1.8	1.1	2
Zinc (dissolved)	ug/L	--	68	88	268	3	12
Zinc	ug/L	--	14.5	15	76	-0.273	42

Table D.1d Summary statistics for water quality parameters measured at station SRS Period of record: 1982 – 2004

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Alkalinity	mg/L	$\geq$ 20 as $CaCO_3$	62	18	118	1	208
Aluminum	ug/L	--	272	313	1540	0	69
Ammonium (dissolved)	mg/L	--	0.060	0.042	0.196	0.016	22
Ammonium	mg/L	< 0.02	0.11	0.11	0.871	0.001	202
Arsenic	ug/L	--	0.99	1.19	2.82	-1	10
Barium	ug/L	--	38	47	92	9.8	3
Biochemical Oxygen Demand	mg/L	--	1.97	1.41	4.8	0.6	9
Calcium (dissolved)	mg/L	$\leq e^{(0.7852[lnH]-3.49}$	36	6.4	45	30	4
Calcium	mg/L	$\leq e^{(0.7852[lnH]-3.49}$	65.2	67.0	637	17.7	185
Cadmium	ug/L	--	0.065	1.012	2.28	-4.4	34
Chlorophyll a	mg/m3	--	13.3	33.1	244	0	74
Chlorophyll-a_Corr	mg/m3	--	9.48	24.7	230	0	137
Chlorophyll b	mg/m3	--	1.24	5.78	47.2	-12.0957	74
Chlorophyll c	mg/m3	--	2.84	10.0	85.1	-1.2	74
Chloride	mg/L	--	326	487	3750	12	210
Color	C.P.U.	--	175	97	500	10	185
Apparent Color-Unfiltered	C.P.U.	--	195	47	250	100	19
Conductivity	umhos/cm	--	1255	791	3800	300	67
Conductivity-Field	umhos/cm	--	1261	1549	13652	102	259
Chromium	ug/L	$\leq$ 11	3.01	9.52	56.3	-1.7	34
Copper	ug/L	$\leq e^{(0.8545[lnH]-1.702}$	1.69	2.05	8.35	-1	45
Depth Collection	m	--	0.80	0.68	3.8	0.1	258
Depth Stream	m	--	2.7	1.7	20	0.3	171
Dissolved Oxygen (DO)	mg/L	> 5	5.4	2.6	12.2	0.18	258
E. Coli MTEC-MF	#/100mL	--	48	47.0	150	2	20
Enterococci ME-MF	#/100mL	--	126	178	800	1	50
Fluoride	mg/L	--	0.16	0.05	0.29	0.086	66
Fecal Coliform-STORET 31615	L	--	30	14.1	40	20	2
Fecal Coliform-STORET 31616	#/100mL	--	75	138	1000	1	76
Iron (dissolved)	ug/L	--	393	475	1100	102	4
Iron	ug/L	--	394	257	1449	26	119
Hardness (calculated)	mg/L	--	314	433	3070	39	139
Potassium (dissolved)	mg/L	--	3.27	0.86	4.3	2.2	4
Potassium	mg/L	--	6.68	7.31	61.5	1.25	184
Lead	ug/L	$\leq e^{(1.273[lnH]-4.705}$	1.51	2.7	17	-1	45
Magnesium (dissolved)	mg/L	--	11.3	3.7	16	8.199999	4
Magnesium	mg/L	--	24.6	39.1	359	4.153	185
Manganese	ug/L	--	24.4	29.0	99.3	3	14
Nickel	ug/L	$\leq e^{(0.846[lnH]-0.0584}$	7.6	22.1	128	-2	34
Nitrate-Nitrite (dissolved)	mg/L	--	0.038	0.054	0.209	0.002	23
Nitrate-Nitrite	mg/L	--	0.078	0.104	0.714	-0.006	210
Pheophytin_Corr	mg/m3	--	3.1	7.5	75.3	-2.3	139
pH-Field	S.U.	6 - 8.5	6.99	0.51	8.46	4.04	258
Phosphate (dissolved)	mg/L	--	0.042	0.037	0.215	0.003	94
Phosphate	mg/L	--	0.047	0.049	0.502	0.005	141
Salinity	ppth	--	0.61	0.59	4.6	0	114
Secchi	m	--	0.58	0.31	1.6764	0.2	46

Table D.1d Summary Statistics for water quality parameters measured at station SRS
Period of record: 1982 – 2004

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Secchi	in	--	38	18.6	66	18	6
Selenium	ug/L	--	5.4	7.6	10.8	0.01	2
Silicon Dioxide (dissolved)	mg/L	--	4.7	4.0	13	0	27
Silicon Dioxide	mg/L	--	3.1	1.9	8.24	0	96
Silver	ug/L	--	0.04	0.07	0.2	0	9
Sodium (dissolved)	mg/L	--	79	12	89	63	4
Sodium	mg/L	--	163	262	2260	8.370001	185
Sulfate	mg/L	--	127	225	1948.74	2	210
Temperature	deg C	--	23.41	4.88	32.28	11.93	259
Total Dissolved Solids (TDS)	mg/L	--	770	983	8680	170	201
Total Kjeldahl Nitrogen (dissolved)	mg/L	--	1.33	0.32	2.04	0.29	28
Total Kjeldahl Nitrogen	mg/L	--	1.86	0.54	5.04	0.34	201
Total Organic Carbon (TOC)	mg/L	--	25.1	4.9	46.6	11.1	191
Total Coliform-STORET 31501	#/100mL	--	423	508	2200	20	36
Total Coliform-STORET 31505	L	--	2200	2235	5000	300	4
Total Hardness (as CaCO3)	mg/L	--	137	21.0	156	92	10
Total Phosphorus (dissolved)	mg/L	--	0.060	0.051	0.262	0.001	32
Total Phosphorus	mg/L	--	0.097	0.078	0.924	0.013	208
Total Suspended Solids (TSS)	mg/L	--	9.7	10.0	64	-1	210
Turbidity	N.T.U.	$\leq$ 29 above background	5.8	6.4	40	0.2	185
Turbidity	F.T.U.	--	6.8	4.7	17	1.4	19
Zinc	ug/L	--	14	17	84	-12	45

Table D.1e Summary statistics for water quality parameters measured at station 02232400 St. Johns River near Cocoa, Florida

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Aluminum, water, unfiltered, recoverable	ug/L	--	77.5	73.1	200	0.0	12
Ammonia plus organic nitrogen, water, filtered	mg/L	--	0.070		0.070	0.070	1
Ammonia plus organic nitrogen, water, unfiltered	mg/L	--	1.58	0.506	3.90	0.190	67
Ammonia, water, filtered	mg/L	< 0.02	0.088	0.082	0.380	0.0	127
Ammonia, water, unfiltered	mg/L	< 0.02	0.089	0.074	0.400	0.0	152
Biochemical oxygen demand, water, unfiltered, 5-day	mg/L	--	1.24	0.96	6.10	0.100	48
Calcium, water, filtered	mg/L	$\leq e^{(0.7852[lnH]-3.49}$	38.1	31.0	170	6.40	423
Calcium, water, unfiltered, recoverable	mg/L	$\leq e^{(0.7852[lnH]-3.49}$	90.3	42.7	170	31.0	45
Chlorophyll a, phytoplankton, chromatographic-fluo	mg/m^3	--	20.6	23.3	110	0.100	72
Chlorophyll a, phytoplankton, spectrophotometric m	mg/m^3	--	4.3	13.6	53.1	0	15
Chlorophyll b, phytoplankton, spectrophotometric m	mg/m^3	--	1.42	3.45	9.20	0	13
Chlorophyll c, phytoplankton, spectrophotometric m	mg/m^3	--	12.0	13.9	24.0	0.001	4
Chlorophyll, total, phytoplankton, spectrophotomet	mg/m^3	--	19.0	21.9	38.0	0.002	4
Chromium, water, unfiltered, recoverable	ug/L	≤ 11	4.00	8.94	20.0	0.000	5
Color, water, filtered	C.P.U.	--	116	57.2	420.0	3.000	439
Copper, water, filtered	ug/L	$\leq e^{(0.8545[lnH]-1.702}$	7.08	8.43	20.0	0.000	13
Copper, water, unfiltered, recoverable	ug/L	--	1.67	4.08	10.0	0.000	6
Cyanide, water, unfiltered	mg/L	--	0.00		0	0.000	1
Discharge	cfs	--	1253	1420	9850	-55.0	402
Discharge, instantaneous	cfs	--	951	1222	5970	-346	143
Dissolved oxygen, water, unfiltered	mg/L	> 5	6.99	1.86	13.4	0.200	347
Dissolved oxygen, water, unfiltered	% sat	--	81.5	15.0	123	15.0	200
Fluoride, water, filtered	mg/L	--	0.192	0.119	0.700	0	335
Gage height	ft	--	11.6	1.99	16.4	7.97	233
Hardness, water, unfiltered	mg/L	--	114	94.6	650	16.0	344
Iron, suspended sediment, recoverable	ug/L	--	99.0	50.9	210	40.0	10
Iron, water, filtered	ug/L	--	118	110	635	0	342
Iron, water, unfiltered, recoverable	ug/L	--	349	172	992	116	105
Lead, suspended sediment, recoverable	ug/L	$\leq e^{(1.273[lnH]-4.705}$	2.85	3.54	12.0	0.0	20
Lead, water, filtered	ug/L	$\leq e^{(1.273[lnH]-4.705}$	0.375	0.744	2.00	0.0	8
Lead, water, unfiltered, recoverable	ug/L	$\leq e^{(1.273[lnH]-4.705}$	0.75	1.50	3.00	0.0	4
Lithium, water, filtered	ug/L	--	0.00		0.0	0.0	1
Magnesium, water, filtered	mg/L	--	10.7	10.7	70.0	0.0	417
Magnesium, water, unfiltered, recoverable	mg/L	--	26.8	12.0	48.0	6.60	39
Manganese, water, filtered	ug/L	--	11.0	6.1	20.0	0	36
Manganese, water, unfiltered, recoverable	ug/L	--	15.3	7.2	30.0	0	32
Mercury, water, unfiltered, recoverable	ug/L	--	0.338	0.212	0.600	0	26
Methylene blue active substances, water, unfiltered	mg/L	--	0.030		0.030	0.030	1
Nickel, water, unfiltered, recoverable	ug/L	$\leq e^{(0.846[lnH]-0.0584}$	1.00		1.000	1.000	1
Nitrate, water, filtered	mg/L	--	0.321	0.676	5.60	0.0	344
Nitrate, water, filtered	mg/L	--	0.053	0.172	1.20	0.0	53
Nitrate, water, unfiltered	mg/L	--	0.058	0.166	1.40	0.0	76
Nitrite plus nitrate, water, filtered	mg/L	--	0.065	0.089	0.410	0.010	73
Nitrite plus nitrate, water, unfiltered	mg/L	--	0.095	0.180	1.41	0	85
Nitrite, water, filtered	mg/L	--	0.028	0.029	0.20	0	45
Nitrite, water, filtered	mg/L	--	0.024	0.149	1.60	0	114
Nitrite, water, unfiltered	mg/L	--	0.011	0.006	0.060	0	125
Noncarbonate hardness, water, unfiltered, field	mg/L	--	77.9	80.4	570	8.0	341
Number of tentatively identified compounds (TICS)	--	--	1.00	0.00	1.00	1.00	8
Organic carbon, water, filtered	mg/L	--	25.7	5.2	42.0	2.20	73
Organic carbon, water, unfiltered	mg/L	--	24.7	7.12	49.0	0.100	108
Organic nitrogen, water, filtered	mg/L	--	1.19	0.296	1.50	0.620	7
Organic nitrogen, water, unfiltered	mg/L	--	1.32	0.504	3.30	0.060	79
Orthophosphate, water, filtered	mg/L	--	0.057	0.070	0.370	0.000	109
Orthophosphate, water, unfiltered	mg/L	--	0.045	0.056	0.390	0.010	151

Table D.1e Summary statistics for water quality parameters measured at station 02232400 St. Johns River near Cocoa, Florida

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
pH, water, unfiltered, field	S.U.	6 - 8.5	7.25	0.482	9.20	5.10	490
pH, water, unfiltered, laboratory	S.U.	6 - 8.5	7.44	0.299	8.00	6.50	79
Phosphate, water, unfiltered	mg/L	--	0.131	0.081	0.390	0.040	28
Phosphorus, water, filtered	mg/L	--	0.071	0.033	0.120	0.020	13
Phosphorus, water, unfiltered	mg/L	--	0.079	0.062	0.420	0.010	158
Potassium, water, filtered	mg/L	--	2.46	2.34	14.0	0.0	399
Residue on evaporation, dried at 180 degrees C	mg/L	--	429	359	2320	68	397
Residue, total nonfilterable	mg/L	--	14.6	16.9	130	1.00	72
Residue, water, filtered, sum of constituents	mg/L	--	457	392	1980	81.0	76
Residue, water, filtered	tons/acre-ft	--	0.535	0.447	3.16	0.14	294
Residue, water, filtered	tons/day	--	721	633	5800	36.2	272
Sampling depth	ft	--	5.38	3.97	16.5	0.0	177
Silica, water, filtered	mg/L	--	4.41	3.12	16.0	0.0	454
Silvex, water, unfiltered, recoverable	ug/L	--	0.081	0.100	0.350	0.0	14
Sodium, water, filtered	mg/L	--	71.3	72.1	500	10.0	403
Sodium, water	% equiv.	--	51.7	3.97	63.0	40.0	291
Specific conductance, water, unfiltered	umhos/cm	--	1063	664	2560	336	79
Specific conductance, water, unfiltered	umhos/cm	--	705	615	6500	31.0	580
Strontium, water, filtered	ug/L	--	2473	1811	8300	420	111
Strontium, water, unfiltered, recoverable	ug/L	--	3186	1722	6500	800	45
Sulfate, water, filtered	mg/L	--	46.0	61.3	380	0.400	412
Sulfide, water, unfiltered	mg/L	--	1.55	0.77	4.00	1.00	49
Surface area	sq mi	--	1331	0.00	1331	1331	44
Suspended sediment concentration	mg/L	--	7.24	5.33	25.0	0.0	46
Suspended solids, dried at 110 degrees Celsius	mg/L	--	6.92	2.94	11.0	3.00	12
Tannin and lignin, water, unfiltered, recoverable	mg/L	--	2.56	0.78	3.70	1.90	5
Temperature, water	deg C	--	23.7	5.76	80.0	8.50	414
Total coliform, M-Endo MF method, immediate	count	--	1250		1250	1250	1
Total nitrogen, water, unfiltered	mg/L	--	3.14	2.61	14.0	0.270	108
Transparency, water, unfiltered, Secchi disc	inches	--	31.1	12.5	72.0	12.0	43
Turbidity, water, unfiltered	J.T.U.	--	4.99	3.12	20.0	1.00	70
Turbidity, water, unfiltered	N.T.U.	$\leq$ 29 above background	5.24	4.00	20.0	0.270	77
Zinc, water, filtered	ug/L	--	22.6	12.5	60.0	4.00	23
Zinc, water, unfiltered, recoverable	ug/L	--	16.0	8.94	30.0	10.0	5

Table D.1f Summary statistics for water quality parameters measured at station USGS 02232500 St. Johns River near Christmas, Florida

Analyte Name, Units of Measure	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
2,4,5-T, water, unfiltered, recoverable	ug/L	--	0.0	0.0	0.0	0.0	6
2,4-D, water, unfiltered, recoverable	ug/L	--	0.125	0.128	0.350	0.0	6
Acid neutralizing capacity, water, unfiltered		--	53.2	22.4	137	17.0	176
Alpha radioactivity, water, unfiltered	pCi/L	--	2.00	0.00	2.00	2.00	2
Altitude of land surface	ft	--	1.60	0.00	1.60	1.60	32
Aluminum, water, unfiltered, recoverable	ug/L	--	50.0	70.7	100	0.00	2
Ammonia plus organic nitrogen, water, filtered	mg/L	< 0.02	1.30		1.30	1.30	1
Ammonia plus organic nitrogen, water	mg/L	< 0.02	1.54	0.46	2.30	0.200	50
Ammonia, water, filtered	mg/L	--	0.176	0.287	2.00	0.010	105
Ammonia, water, unfiltered	mg/L	--	0.160	0.220	1.70	0.0	114
Arsenic, water, filtered	ug/L	--	10.0		10.0	10.0	1
Arsenic, water, unfiltered	ug/L	--	1.00		1.00	1.00	1
Barium, water, filtered	ug/L	--	49.7	25.7	120	20.0	72
Barium, water, unfiltered, recoverable	ug/L	--	60.7	26.9	120	22.0	45
Barometric pressure	mm/Hg	--	766	2.64	769	760	12
Beta radioactivity, water, unfiltered	pCi/L	--	7.55	4.76	12.0	2.00	4
Bicarbonate, water, unfiltered, fixed endpoint	pH	--	54.6	26.9	146	21.0	101
Biochemical oxygen demand, water, unfiltered, 5 day	mg/L	--	0.750	0.342	1.10	0.30	4
Boron, water, filtered	ug/L	--	0.0		0.0	0.0	1
Bromide, water, filtered	mg/L	--	1.41	1.28	6.60	0.300	72
Cadmium, water, filtered	ug/L	--	5.00	7.07	10.0	0.0	2
Cadmium, water, unfiltered	ug/L	--					0
Calcium, water, filtered	mg/L	$\leq e^{(0.7852[\ln H]-3.49)}$	60.5	41.0	180	13.0	173
Calcium, water, unfiltered, recoverable	mg/L	$\leq e^{(0.7852[\ln H]-3.49)}$	95.4	44.5	180	30.0	45
Carbon dioxide, water, unfiltered	mg/L	--	14.4	31.9	157	1.90	24
Carbonate, water, unfiltered, fixed endpoint	pH	--	0.0	0.0	0.0	0.0	37
Chemical oxygen demand, high level, water, unfiltered	mg/L	--	68.4	17.7	110	40.0	19
Chloride, water, filtered	mg/L	--	300	247	1150	37.0	174
Chlorophyll a, phytoplankton, chromatographic-fluo	mg/m^3	--	12.7	16.1	71.0	0.100	72
Chlorophyll a, phytoplankton, spectrophotometric m	mg/m^3	--	5.00	7.07	10.0	0.0030	2
Chlorophyll b, phytoplankton, spectrophotometric m	mg/m^3	--	2.50	3.53	5.00	0.0020	2
Chlorophyll c, phytoplankton, spectrophotometric m	mg/m^3	--	7.50	10.6	15.0	0.0080	2
Chlorophyll, total, phytoplankton, spectrophotomet	mg/m^3	--	30.0		30.0	30.0	1
Chromium, water, unfiltered, recoverable	ug/L	≤ 11	0.0	0.0	0.0	0.0	3
Color, water, filtered	C.P.U.	--	131	76.9	700	35.0	174
Copper, water, filtered	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	0.0	0.0	0.0	0.0	3
Copper, water, unfiltered, recoverable	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$					0
Cyanide, water, unfiltered	mg/L	--	0.0	0.0	0.020	0.000	18
Discharge	cfs	--	1224	1372	5800	-42.0	159
Discharge, instantaneous	cfs	--	1134	1480	5390	-85.0	96
Dissolved oxygen, water, unfiltered	mg/L	> 5	5.44	2.46	12.4	0.100	116
Dissolved oxygen, water, unfiltered	% sat	--	61.5	30.1	114	1.00	71
Fecal coliform, M-FC MF (0.7 micron) method, water	count	--	21.6	11.7	42.0	11.0	9
Fluoride, water, filtered	mg/L	--	0.303	0.121	0.60	0.00	68
Gage height	ft	--	6.68	32.2	418	0.350	166
Hardness, water, unfiltered	mg/L	--	196	151	720	44.0	98
Iron, suspended sediment, recoverable	ug/L	--	70.0		70.0	70.0	1
Iron, water, filtered	ug/L	--	185	183	992	0.0	153
Iron, water, unfiltered, recoverable	ug/L	--	594	300	1860	190	73
Lead, suspended sediment, recoverable	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	2.0		2.00	2.00	1
Lead, water, filtered	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	0.0		0.0	0.0	1
Lead, water, unfiltered, recoverable	ug/L	$\leq e^{(1.273[\ln H]-4.705}$					0
Lithium, water, filtered	ug/L	--	0.0		0.0	0.0	1
Magnesium, water, filtered	mg/L	--	22.2	17.8	90.0	2.20	167
Magnesium, water, unfiltered, recoverable	mg/L	--	36.7	19.9	90.0	7.10	39
Manganese, water, filtered	ug/L	--	8.89	10.5	30.0	0	9
Manganese, water, unfiltered, recoverable	ug/L	--	10.0		10.0	10.0	1
Mercury, water, unfiltered, recoverable	ug/L	--	0.100		0.100	0.100	1
Methylene blue active substances, water, unfiltered	mg/L	--	0.170		0.170	0.170	1
Nickel, water, unfiltered, recoverable	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	0.0	0.0	0.0	0.0	5
Nitrate, water, filtered	mg/L	--	0.498	0.810	6.40	0.0	110
Nitrate, water, filtered	mg/L	--	0.030	0.044	0.18	0.0	30
Nitrate, water, unfiltered	mg/L	--	0.200		0.200	0.200	1
Nitrate, water, unfiltered	mg/L	--	0.097	0.271	1.80	0.0	51

Table D.1f Summary statistics for water quality parameters measured at station USGS 02232500 St. Johns River near Christmas, Florida

Analyte Name, Units of Measure	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Nitrite plus nitrate, water, filtered	mg/L	--	0.099	0.093	0.400	0.020	73
Nitrite plus nitrate, water, unfiltered	mg/L	--	0.148	0.247	1.87	0.0	68
Nitrite, water, filtered	mg/L	--	0.450	2.22	12.0	0.010	29
Nitrite, water, filtered	mg/L	--	0.013	0.010	0.088	0.0030	99
Nitrite, water, unfiltered	mg/L	--	0.200		0.200	0.200	1
Nitrite, water, unfiltered	mg/L	--	0.015	0.013	0.090	0.0	96
Noncarbonate hardness, water, unfiltered, field	mg/L	--	150	133	670	21.0	96
Number of tentatively identified compounds (TICS)		--	1.00	0.0	1.00	1.00	8
Organic carbon, water, filtered	mg/L	--	24.9	4.3	34.0	2.10	73
Organic carbon, water, unfiltered	mg/L	--	24.2	3.5	33.0	12.0	52
Organic nitrogen, water, filtered	mg/L	--	0.83	0.00	0.830	0.830	2
Organic nitrogen, water, unfiltered	mg/L	--	1.21	0.615	3.90	0.120	38
Orthophosphate, water, filtered	mg/L	--	0.051	0.050	0.270	0.0	104
Orthophosphate, water, unfiltered	mg/L	--	0.052	0.087	0.820	0.010	119
pH, water, unfiltered, field	S.U.	6 - 8.5	7.11	0.419	8.80	5.80	203
pH, water, unfiltered, laboratory	S.U.	6 - 8.5	7.34	0.317	7.90	6.40	75
Phenolic compounds, water, unfiltered, recoverable	mg/L	--	0.0		0.0	0.0	1
Phosphate, water, unfiltered	mg/L	--	1.71	7.73	38.0	0.0400	24
Phosphorus, water, filtered	mg/L	--	0.074	0.034	0.140	0.050	7
Phosphorus, water, unfiltered	mg/L	--	0.084	0.095	0.860	0.010	124
Potassium, water, filtered	mg/L	--	6.20	3.98	23.0	0.600	124
Radium-226, water, filtered, radon method	pCi/L	--	0.175	0.096	0.300	0.100	4
Residue on evaporation, dried at 180 degrees C	mg/L	--	897	612	2830	189	120
Residue, total nonfilterable	mg/L	--	11.6	7.1	30.0	1.00	81
Residue, water, filtered, sum of constituents	mg/L	--	503	351	1580	97.0	87
Residue, water, filtered	tons/acre-ft	--	0.872	0.723	3.85	0.130	97
Residue, water, filtered	tons/day	--	1195	1023	6220	2.44	93
Sampling depth	ft	--	3.64	3.92	10.0	1.00	13
Silica, water, filtered	mg/L	--	4.06	3.02	14.0	0.0	175
Silver, water, unfiltered, recoverable	ug/L	--	0.059	0.243	1.0	0.0	17
Silvex, water, unfiltered, recoverable	ug/L	--	0.065	0.018	0.090	0.040	6
Sodium adsorption ratio, water		--	3.94	1.81	10.0	1.00	94
Sodium plus potassium, water, filtered	mg/L	--	91.3	61.3	290	18.0	28
Sodium, water, filtered	mg/L	--	167	139	620	23.0	130
Sodium, water	% equiv	--	58.8	3.1	65.0	49.0	60
Specific conductance, water	umhos/cm	--	1463	985	4430	336	75
Specific conductance, water, unfiltered	umhos/cm	--	1270	937	4060	190	224
Strontium, water, filtered	ug/L	--	2625	1706	8000	580	88
Strontium, water, unfiltered, recoverable	ug/L	--	3223	1665	6300	800	45
Sulfate, water, filtered	mg/L	--	103	105	530	2.00	173
Sulfide, water, unfiltered	mg/L	--	1.67	1.0	6.00	1.00	49
Surface area	sq mi	--	1539	0.0	1539	1539	32
Suspended sediment concentration	mg/L	--	12.2	7.0	28.0	3.00	22
Suspended solids, dried at 110 degrees Celsius	mg/L	--	7.60	5.74	24.0	0.0	20
Tannin and lignin, water, unfiltered, recoverable	mg/L	--	2.52	0.90	3.80	1.70	5
Temperature, air	deg C	--	22.3	8.08	27.0	13.0	3
Temperature, water	deg C	--	23.7	6.74	79.0	6.50	190
Total coliform, M-Endo MF method, immediate, water		--	550		550	550	1
Total nitrogen, water, unfiltered	mg/L	--	3.95	3.09	11.0	0.820	47
Transparency, water, unfiltered, Secchi disc	inches	--	46.0		46.0	46.0	1
Turbidity, water, unfiltered	J.T.U.	$\leq$ 29 above background	6.4	4.0	12.0	1.00	14
Turbidity, water, unfiltered	N.T.U.	--	5.30	3.89	17.0	0.0	89
Uranium, water, filtered, extraction fluorometric	ug/L	--	0.28	0.29	0.700	0.100	4
Zinc, water, filtered	ug/L	--	32.0	19.2	60.0	10.0	5
Zinc, water, unfiltered, recoverable	ug/L	--	22.8	25.9	110	0.0	18

Table D.1g Summary statistics for water quality parameters measured at station USGS 02234000 St. Johns River above Lake Harney near Geneva, Florida

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
2,4,5-T, water, unfiltered, recoverable	ug/L	--	0.0	0.0	0.0	0.0	6
2,4-D, water, unfiltered, recoverable	ug/L	--	0.332	0.495	1.30	0.0	6
Acid neutralizing capacity, water, unfiltered, fix		--	43.6	18.8	108	10.0	109
Aluminum, water, unfiltered, recoverable	ug/L	--	135	102	320	0.0	12
Ammonia plus organic nitrogen, water, filtered	mg/L	--	1.20		1.20	1.20	1
Ammonia plus organic nitrogen, water, unfiltered	mg/L	--	1.40	0.463	3.50	0.740	47
Ammonia, water, filtered	mg/L	< 0.02	0.190	0.254	1.20	0.0200	39
Ammonia, water, unfiltered	mg/L	< 0.02	0.147	0.202	1.10	0.0	77
Arsenic, water, filtered	ug/L	--	15.7	7.87	30.0	10.0	7
Arsenic, water, unfiltered	ug/L	--	3.28	4.86	20.0	1.00	18
Bicarbonate, water, unfiltered, fixed endpoint	pH	--	53.0	23.1	132	12.0	98
Biochemical oxygen demand, water, unfiltered, 5 day	mg/L	--	1.45	1.15	7.30	0.100	49
Boron, water, filtered	ug/L	--	70.0	47.6	100	0.0	4
Cadmium, water, filtered	ug/L	--	0.0	0.0	0.0	0.0	8
Cadmium, water, unfiltered	ug/L	--	1.00	0.816	2.00	0.0	4
Calcium, water, filtered	mg/L	$\leq e^{(0.7852[\ln H]-3.49}$	48.0	26.9	126	12.0	81
Carbon dioxide, water, unfiltered	mg/L	--	7.81	9.30	63.0	0.400	58
Carbonate, water, unfiltered, fixed endpoint	pH	--	0.0	0.0	0.0	0.0	48
Chemical oxygen demand, high level, water, unfiltered	mg/L	--	57.8	17.6	90.0	17.0	18
Chloride, water, filtered	mg/L	--	357	241	1210	8.00	83
Chlorophyll a, phytoplankton, spectrophotometric m	mg/m^3	--	6.96	10.8	39.7	0.0	16
Chlorophyll b, phytoplankton, spectrophotometric m	mg/m^3	--	2.68	5.46	18.5	0.0	16
Chlorophyll c, phytoplankton, spectrophotometric m	mg/m^3	--	8.67	15.0	26.0	0.011	3
Chlorophyll, total, phytoplankton, spectrophotomet	mg/m^3	--	37.0		37.0	37.0	1
Chromium, water, unfiltered, recoverable	ug/L	≤ 11	2.50	5.00	10.0	0.0	4
Color, water, filtered	C.P.U.	--	126	72.8	420	5.0	98
Copper, water, filtered	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	5.36	7.85	20.0	0.0	11
Copper, water, unfiltered, recoverable	ug/L	$\leq e^{(0.8545[\ln H]-1.702}$	0.0	0.0	0.0	0.0	2
Cyanide, water, unfiltered	mg/L	--	0.00842	0.00688	0.020	0.0	19
Discharge	cfs	--	1385	1540	6900	142	36
Discharge, instantaneous	cfs	--	1900	2489	13800	50.0	119
Dissolved oxygen, water, unfiltered	mg/L	> 5	6.79	1.64	10.9	1.9	179
Dissolved oxygen, water, unfiltered	% sat	--	79.6	17.8	137	20.0	151
Fecal coliform, M-FC MF (0.7 micron) method, water		--	135	120	220	50.0	2
Fluoride, water, filtered	mg/L	--	0.287	0.125	0.700	0.100	52
Gage height	ft	--	2.45	2.24	13.2	0.0	193
Hardness, water, unfiltered	mg/L	--	223	131	640	36.0	76
Iron, suspended sediment, recoverable	ug/L	--	192	237	760	0.0	9
Iron, water, filtered	ug/L	--	152	128	640	0.0	68
Iron, water, unfiltered, recoverable	ug/L	--	408	296	1400	110	18
Lead, suspended sediment, recoverable	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	2.77	4.02	15.0	0.0	13
Lead, water, filtered	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	0.700	1.34	4.00	0.0	10
Lead, water, unfiltered, recoverable	ug/L	$\leq e^{(1.273[\ln H]-4.705}$	4.00		4.00	4.00	1
Lithium, water, filtered	ug/L	--	0.0	0.0	0.0	0.0	2
Magnesium, water, filtered	mg/L	--	23.6	15.4	78.0	1.5	81
Manganese, water, filtered	ug/L	--	14.8	8.23	30.0	0.0	25
Manganese, water, unfiltered, recoverable	ug/L	--	18.1	9.81	40.0	10.0	21
Mercury, water, unfiltered, recoverable	ug/L	--	0.310	0.220	0.600	0.0	20
Methylene blue active substances, water, unfiltered	mg/L	--	0.0750	0.0778	0.130	0.0200	2
Nickel, water, unfiltered, recoverable	ug/L	$\leq e^{(0.846[\ln H]-0.0584}$	1.20	1.79	4.00	0.0	5
Nitrate, water, filtered	mg/L	--	0.838	1.25	5.60	0.0	64
Nitrate, water, filtered	mg/L	--	0.184	0.208	0.770	0.0	27
Nitrate, water, unfiltered	mg/L	--	0.441	0.431	1.70	0.0	79
Nitrite plus nitrate, water, filtered	mg/L	--	0.290		0.290	0.290	1
Nitrite plus nitrate, water, unfiltered	mg/L	--	0.610	0.494	1.72	0.0300	47
Nitrite, water, filtered	mg/L	--	0.0990	0.0987	0.390	0.0100	20
Nitrite, water, filtered	mg/L	--	0.0296	0.0296	0.120	0.00300	21
Nitrite, water, unfiltered	mg/L	--	0.0395	0.0447	0.270	0.0	81
Noncarbonate hardness, water, unfiltered, field	mg/L	--	180	121	540	10.0	71

Table D.1g Summary statistics for water quality parameters measured at station USGS 02234000 St. Johns River above Lake Harney near Geneva, Florida

Analyte Name	Units of Measure	Class III Std	Average	Standard Deviation	Maximum	Minimum	Count
Organic carbon, water, filtered	mg/L	--	25.0		25.0	25.0	1
Organic carbon, water, unfiltered	mg/L	--	20.7	7.35	46.0	5.00	52
Organic nitrogen, water, filtered	mg/L	--	1.09	0.289	1.40	0.770	6
Organic nitrogen, water, unfiltered	mg/L	--	1.31	0.521	3.70	0.120	76
Orthophosphate, water, filtered	mg/L	--	0.993	1.13	4.20	0.0400	25
Orthophosphate, water, unfiltered	mg/L	--	0.267	0.275	1.20	0.0200	77
pH, water, unfiltered, field	S.U.	6 - 8.5	7.08	0.460	8.50	5.50	155
pH, water, unfiltered, laboratory	S.U.	6 - 8.5	7.12	0.524	7.70	6.30	9
Phenolic compounds, water, unfiltered, recoverable	mg/L	--	0.0	0.0	0.0	0.0	2
Phosphate, water, unfiltered	mg/L	--	0.962	1.12	4.1	0.0900	13
Phosphorus, water, filtered	mg/L	--	0.277	0.215	0.73	0.0600	11
Phosphorus, water, unfiltered	mg/L	--	0.368	0.444	2.90	0.0300	85
Potassium, water, filtered	mg/L	--	7.36	5.40	24.0	0.700	47
Residue on evaporation, dried at 180 degrees C	mg/L	--	909	592	2950	66.0	41
Residue, total nonfilterable	mg/L	--	9.88	7.62	23.0	2.00	8
Residue, water, filtered, sum of constituents	mg/L	--	726	436	1980	51.0	72
Residue, water, filtered	tons/acre-ft	--	1.12	0.732	4.01	0.0900	77
Residue, water, filtered	tons/day	--	2048	1428	7060	166	32
Sampling depth	ft	--	4.35	3.20	12.0	0.0	76
Silica, water, filtered	mg/L	--	4.00	3.31	30.0	0.400	105
Silver, water, unfiltered, recoverable	ug/L	--	0.0526	0.229	1.00	0.0	19
Silvex, water, unfiltered, recoverable	ug/L	--	0.0133	0.0151	0.030	0.0	6
Sodium adsorption ratio, water		--	5.30	1.95	11.0	0.400	72
Sodium plus potassium, water, filtered	mg/L	--	165	101	420	53.0	24
Sodium, water, filtered	mg/L	--	196	130	644	5.00	53
Sodium, water, percent in equivalents of major cation	% equiv	--	62.9	6.89	70.0	23.0	42
Specific conductance, water, unfiltered, laboratory	umhos/cm	--	1162	619	2100	308	9
Specific conductance, water, unfiltered	umhos/cm	--	1425	804	4230	102	171
Strontium, water, filtered	ug/L	--	1721	1239	6000	140	33
Sulfate, water, filtered	mg/L	--	88.4	63.4	270	6.80	82
Surface area	sq mi	--	2043	0.0	2043	2043	54
Suspended sediment concentration	mg/L	--	5.00		5.00	5.00	1
Suspended solids, dried at 110 degrees Celsius	mg/L	--	7.21	5.10	23.0	0.0	28
Tannin and lignin, water, unfiltered, recoverable	mg/L	--	2.16	0.832	3.60	1.60	7
Temperature, air	deg C	--	16.4	5.28	24.0	12.0	4
Temperature, water	deg C	--	24.4	8.64	87.0	6.00	223
Total coliform, M-Endo MF method, immediate, water		--	1012	1555	4400	180	7
Total nitrogen, water, unfiltered	mg/L	--	4.69	3.99	18.0	0.850	115
Transparency, water, unfiltered, Secchi disc	inches	--	26.0	7.02	38.0	11.0	30
Turbidity, water, unfiltered	J.T.U.	--	6.04	3.20	15.0	1.00	48
Turbidity, water, unfiltered	N.T.U.	$\leq$ 29 above background	3.53	4.82	22.0	0.0	19
Zinc, water, filtered	ug/L	--	29.5	25.3	120	0.0	19
Zinc, water, unfiltered, recoverable	ug/L	--	17.0	13.0	60.0	0.0	20

APPENDIX E

CROSS-SECTIONAL TRANSECT TOPOGRAPHY DIAGRAMS FORM MACE 2004

Figure 7. Ruth Lake Transect topography with ecological communities

*At Hatbill Park / Ruth Lake the Minimum Frequent High (MFH) equals 6.9 ft. NGVD, the Minimum Average (MA) equals 4.5 ft. NGVD, and the Minimum Frequent Low (MFL) equals 3.8 ft. NGVD

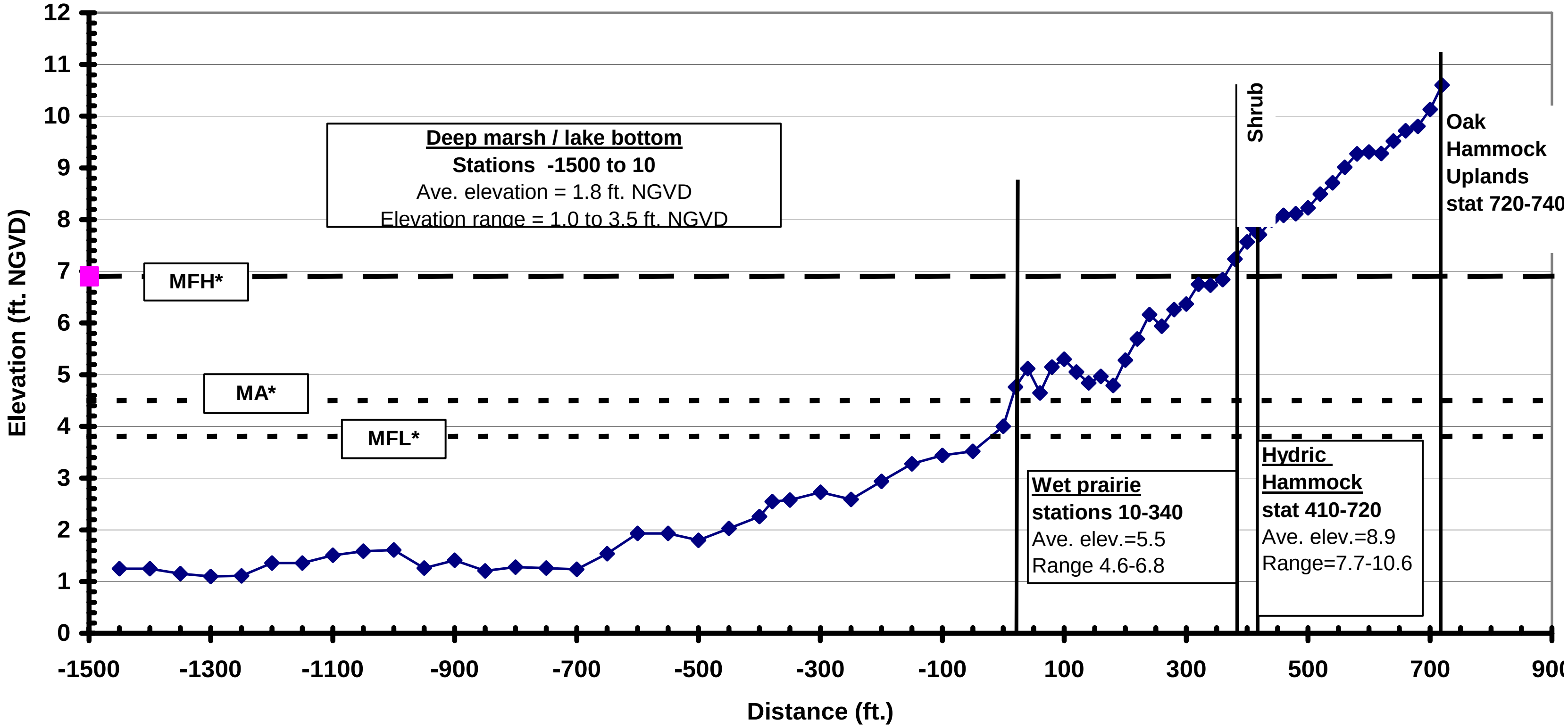


Figure 9. H-1 Transect topography with ecological communities

***At Hatbill Park / H-1 the Minimum Frequent High (MFH) equals 6.9 ft. NGVD, the Minimum Average (MA) equals 4.5 ft. NGVD, and t Minimum Frequent Low (MFL) equals 3.8 ft. NGVD**

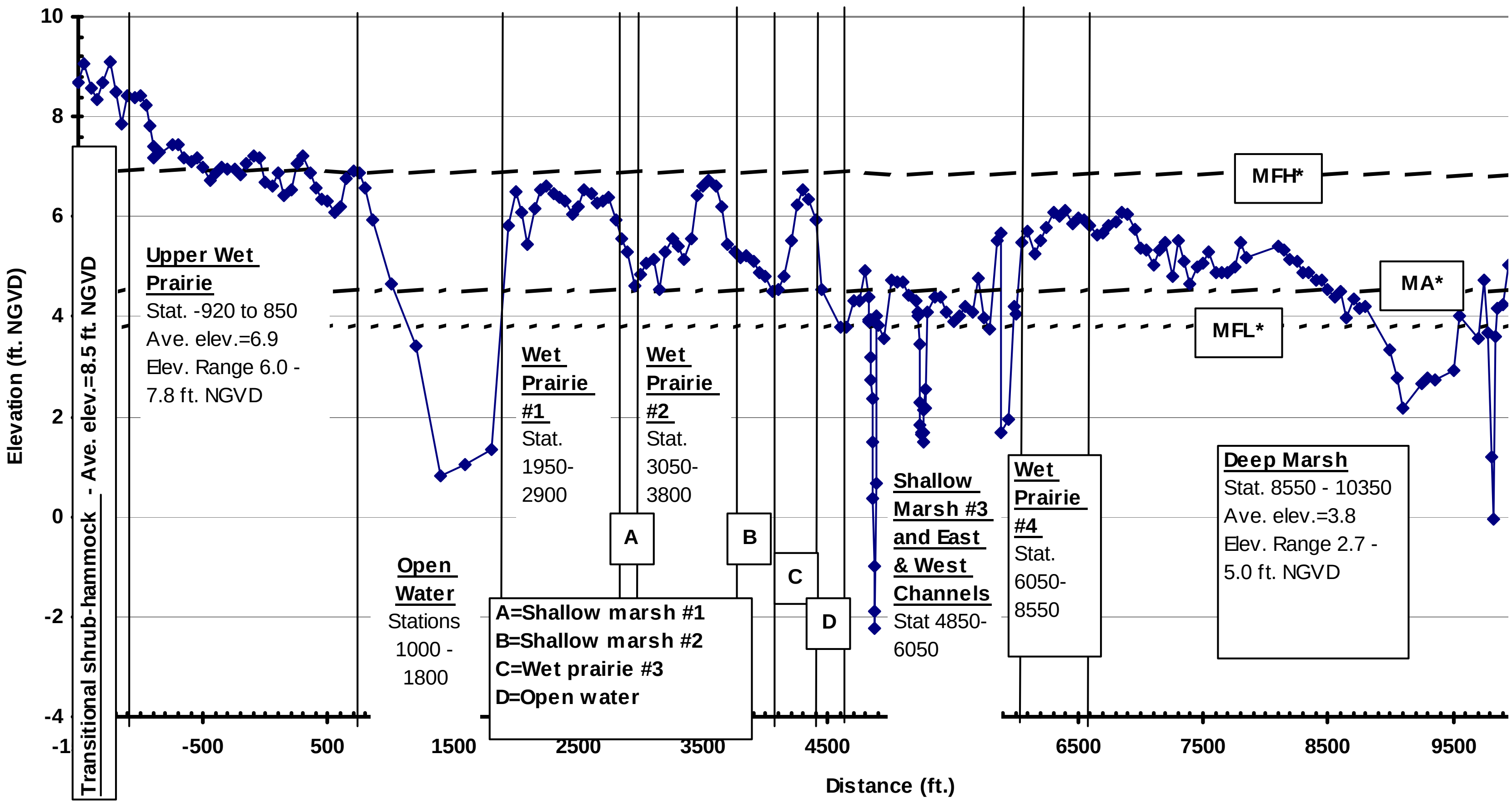


Figure 12. Lake Cone Transect topography with ecological communities

*At Lake Cone the Minimum Frequent High (MFH) equals 7.7 ft. NGVD, the Minimum Average (MA) equals 5.8 ft. NGVD and the Minimum (MFL) equals 5.0 ft. NGVD

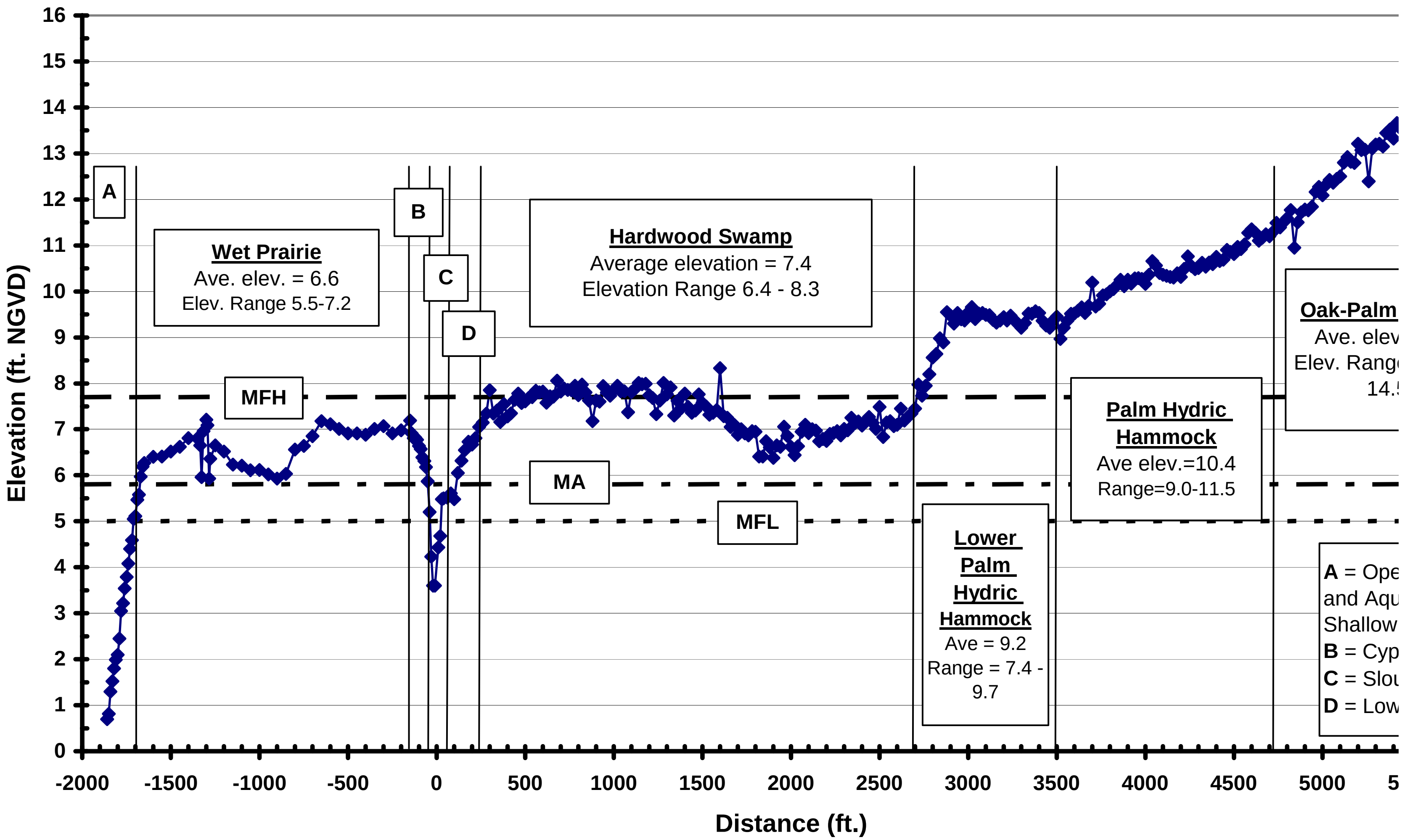


Figure 14. M-6 Transect topography with ecological communities

***At Lake Cone and M-6 the Minimum Frequent High (MFH) equals 7.7 ft. NGVD, the Minimum Average (MA) equals 5.8 ft. NGVD and the Minimum Frequent Low (MFL) equals 5.0 ft. NGVD**

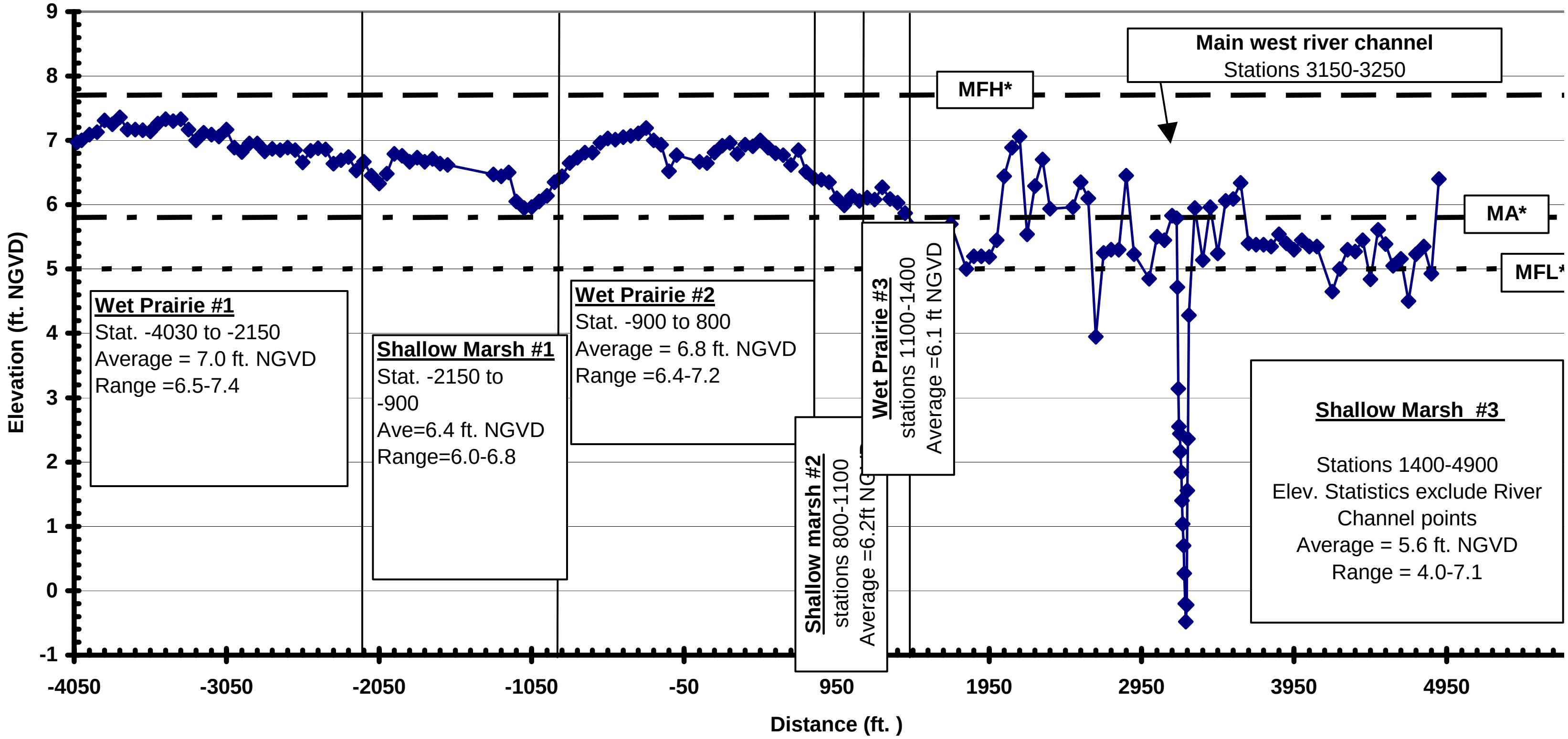


Figure 16. Tosohatchee North Transect topography with ecological communities

*At the Tosohatchee North Transect the Minimum Frequent High (MFH) equals 9.0 ft. NGVD, the Minimum Average (MA) equals 6.4 ft. NGVD, Minimum Frequent Low (MFL) equals 5.6 ft. NGVD

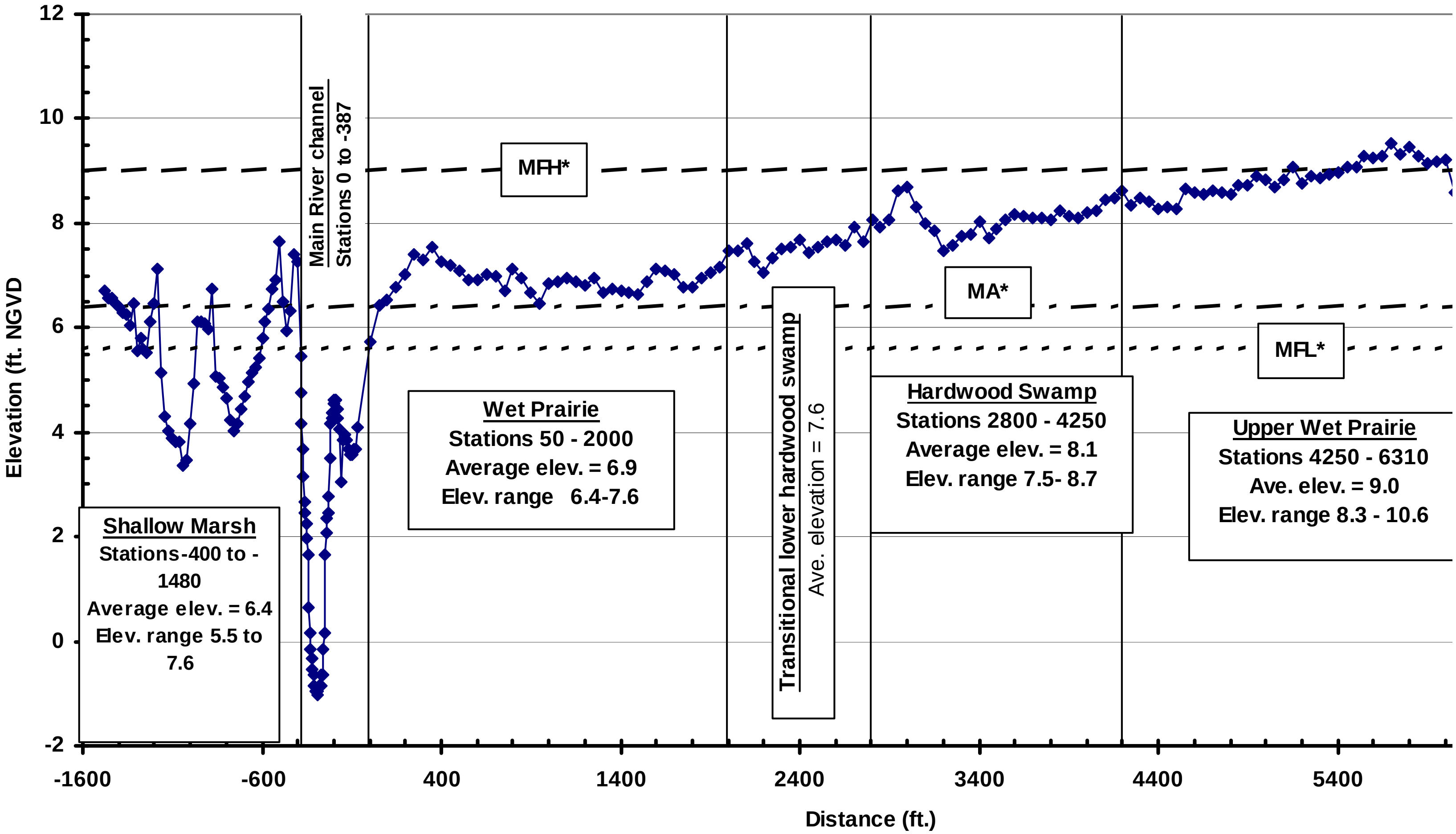


Figure 18. Great Outdoors Transect topography with ecological communities

***At the Great Outdoors the Minimum Frequent High (MFH) equals 9.4 ft. NGVD, the Minimum Average (MA) equals 7.5 ft. NGVD and the Minimum Frequent Low (MFL) equals 6.6 ft. NGVD**

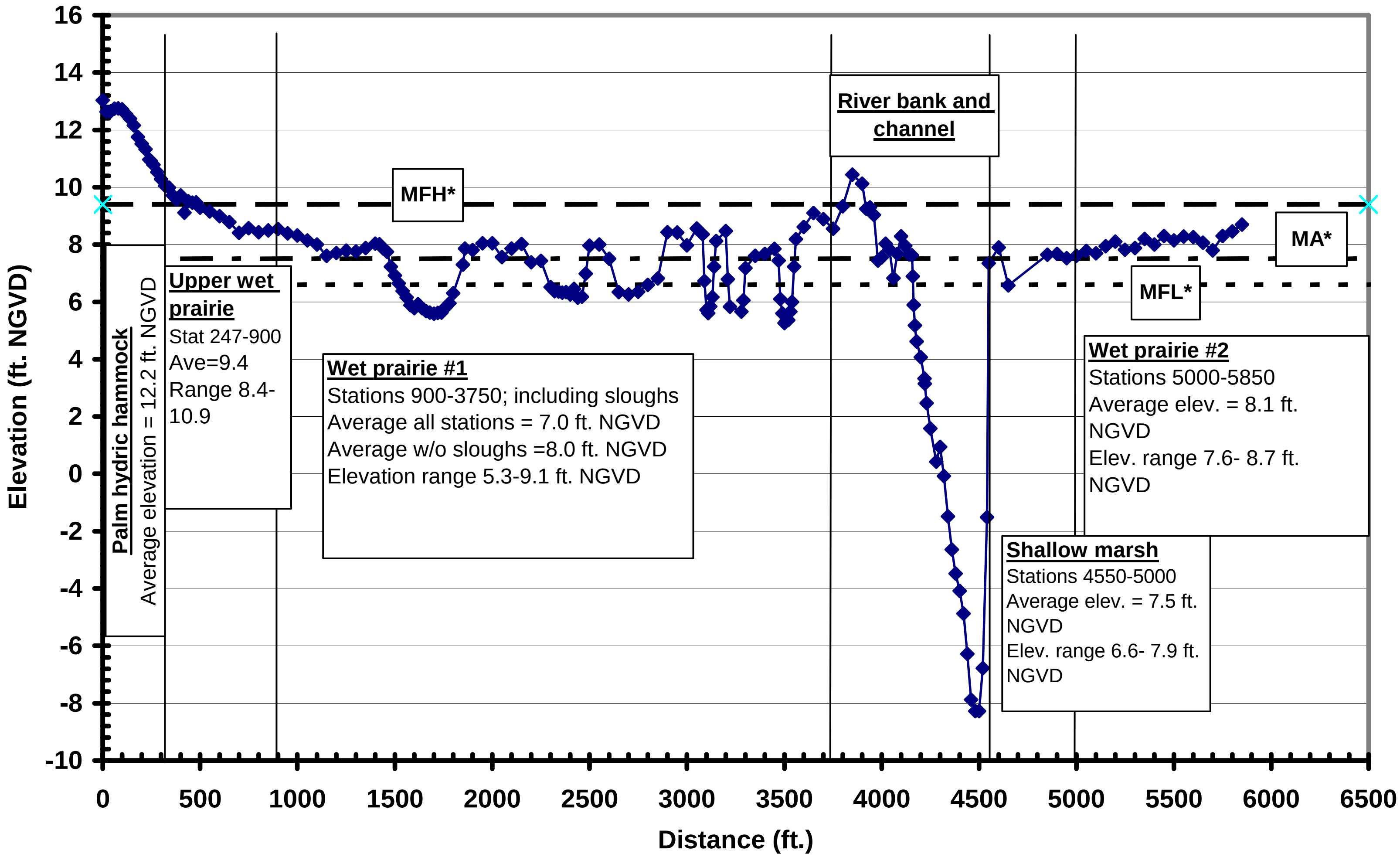
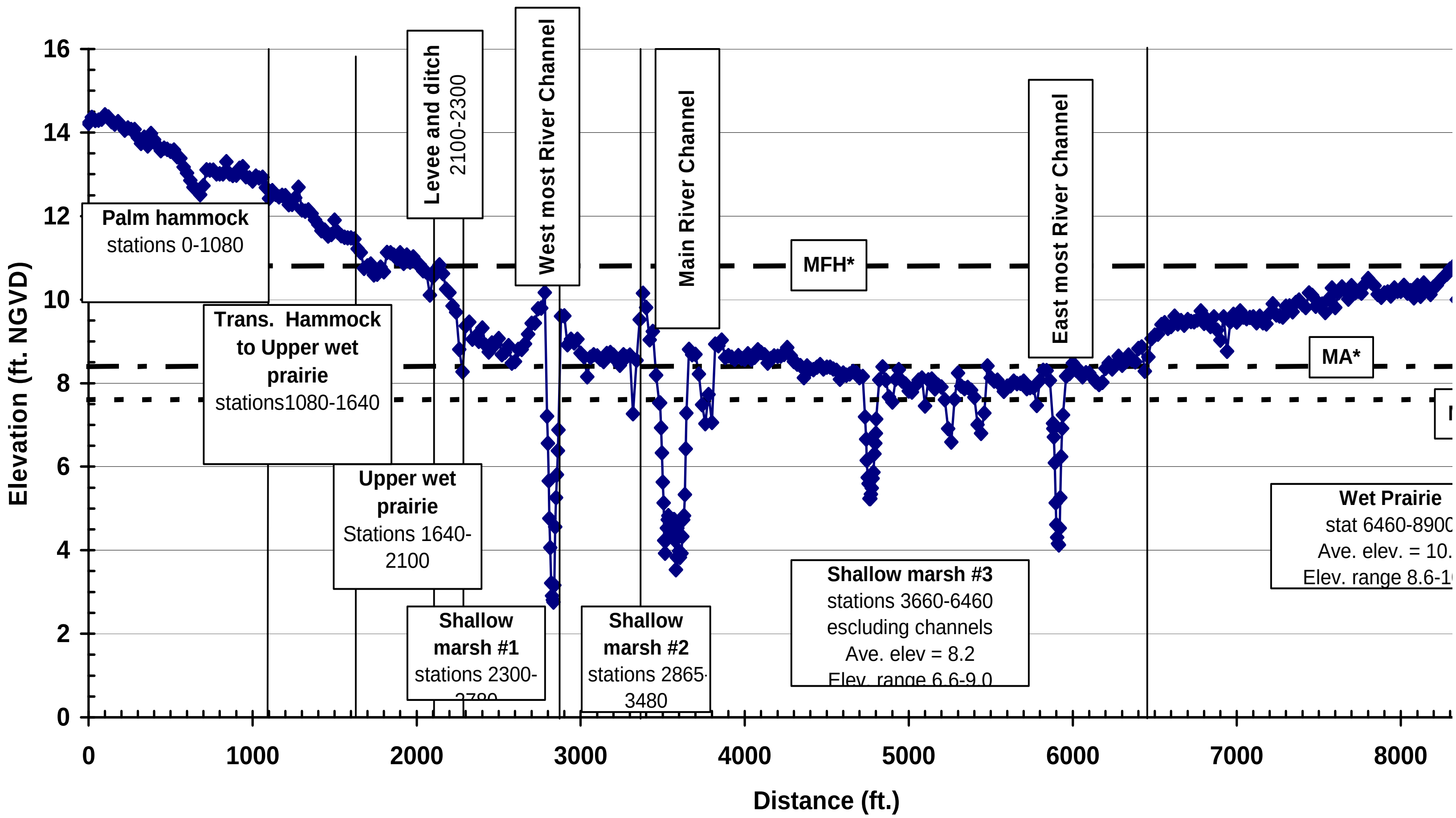


Figure 20. TOSO-528 Transect topography with ecological communities

***At the TOSO-528 Transect the Minimum Frequent High (MFH) is 10.8 ft. NGVD, the Minimum Average (MA) is 8.4 ft. NGVD, and the Minimum Frequent Low (MFL) is 7.6 ft. NGVD**



APPENDIX F

ECT RESPORT SECTION 5.2 ON ESTUARINE RESOURCES