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# LOWER ST. JOHNS RIVER SALINITY REGIME ASSESSMENT: EFFECTS OF UPSTREAM FLOW REDUCTION NEAR DELAND

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# LOWER ST. JOHNS RIVER SALINITY REGIME ASSESSMENT: EFFECTS OF UPSTREAM FLOW REDUCTION NEAR DELAND

**Prepared for:**

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

**Palatka, Florida**

**Prepared by:**


Environmental Consulting & Technology, Inc.

*3701 Northwest 98th Street*
*Gainesville, Florida 32606*



**ECT No. 020229-0100**

**July 2002**

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# Revisions

The following are the revisions to the July 2002 report:

| Page No. | Line No. | Was | Changed to |
|---|---|---|---|
| 4-1 | 20 | RM 14.8 | RM 14.3 |
| 4-1 | 20 | 11.0 | 11.1 |
| 4-1 | 20 | RM 19.8 | RM 19.2 |
| 4-1 | 20 | 6.7 | 7.2 |
| 4-1 | 21 | RM 24.9 | RM 23.7 |
| 4-1 | 21 | 2.8 | 2.7 |
| 4-1 | 21 | RM 34.1 | RM 33.9 |
| 4-1 | 21 | 1.0 | 0.9 |
| 4-1 | 22 | RM 48.4 | RM 47.9 |
| 4-1 | 28 | RM 9.0 | RM 8.8 |
| 4-5 | 1 | 5.0 | 5.5 |
| 4-5 | 1 | RM 31.6 | RM 30.8 |
| 4-5 | 1 | 1.2 | 1.1 |
| 4-5 | 2 | RM 34.1 | RM 33.9 |
| 4-5 | 13 | 3-year salinity | 3-year average salinity |
| 4-5 | 13-14 | 0.21 0.33 0.52 | 0.20 0.33 0.51 |
| 4-5 | 15 | no measurable changes | less than 0.01 ppt change |
| 4-5 | 16 | RM 67.8 | RM 67.1 |
| 4-8 | 5 | RM 19.8 | RM 19.2 |
| 4-8 | 10 | 34.4 | 32 |
| 4-8 | 10 | RM 24.9 | RM 23.7 |
| 4-8 | 11 | 5.0 | 5.5 |
| 4-8 | 12 | 0.46 | 0.47 |
| 4-8 | 13 | 27.5 | 26 |
| 4-8 | 13 | RM 34.1 | RM 33.9 |
| 4-8 | 15 | RM 50.3 | RM 49.9 |
| 4-8 | 24-25 | about 1 to 2 miles downstream from JU | between JU and Trout River |

| Page No. | Line No. | Was | Changed to |
|---|---|---|---|
| 4-27 | 3 | RM 45.6 | RM 45.2 |
| 4-27 | 10 | 0.97 | 0.98 |
| 4-27 | 10 | Piney Point (RM 31.6) | Venetia (RM 27.8) |
| 4-27 | 11-12 | near RM 22.7 between JU and Acosta Bridge | between JU and Piney Point |
| 4-27 | 13 | 1.49 | 1.5 |
| 4-30 | 14 | 2.4 | 2.5 |
| 4-30 | 15 | 0.8 | 0.3 |
| 4-30 | 16 | 3,880 2,230 1,130 | 4,188 2,161 430 |
| 4-31 | | Replace Figure 4-24 | |
| 4-32 | 4 | 46.50 33.54 28.39 | 46.0 32.7 27.4 |
| 4-32 | 5 | 48.02 34.27 28.89 | 47.5 33.4 27.6 |
| 4-32 | 6 | 48.94 37.70 29.15 | 48.6 33.9 27.7 |
| 4-32 | 7 | 50.08 35.28 29.59 | 49.6 34.5 28.1 |
| 4-32 | 12 | 1.52 0.73 0.50 2,720 1,260 740 | 1.5 0.7 0.2 2,617 1,277 282 |
| 4-32 | 13 | 2.44 1.16 0.76 3,880 2,230 1,130 | 2.5 1.2 0.3 4,188 2,161 430 |
| 4-32 | 14 | 3.58 1.74 1.20 5,140 3,310 1,760 | 3.6 1.8 0.7 5,831 3,321 1,041 |
| 4-34 | 6 | 9.0 | 8.8 |
| 4-34 | 7 | 19.8 | 19.2 |
| 4-34 | 8 | 34.1 | 33.9 |
| 4-34 | 8 | 3.01 | 3.00 |
| 4-34 | 9 | 50.3 | 49.9 |
| 4-36 | 7 | 9.0 | 8.8 |
| 4-36 | 8 | 11.0 20.37 12.20 0.22 0.35 0.53 | 10.6 21.52 12.22 0.22 0.32 0.49 |
| 4-36 | 9 | 14.8 | 14.3 |
| 4-36 | 10 | 19.8 | 19.2 |
| 4-36 | 11 | 24.9 6.74 5.00 0.31 0.46 0.70 | 23.7 7.15 5.52 0.32 0.47 0.71 |
| 4-36 | 12 | 34.1 | 33.9 |
| 4-36 | 13 | 42.9 | 42.3 |
| 4-36 | 14 | 48.4 | 47.9 |
| 4-36 | 15 | 50.3 | 49.9 |
| 4-36 | 16 | 60.9 | 60.2 |

| Page No. | Line No. | Was | Changed to |
|---|---|---|---|
| 4-36 | 17 | 67.8 0.49 0.02 0.00 0.00 | 67.1 0.49 0.02 <0.01 <0.01 |

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# EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) is currently establishing minimum flows and levels (MFL) as mandated by state water policy (Section 373.042, Florida Statutes). The purpose of this report is to evaluate whether the preliminary MFL established by SJRWMD for the St. Johns River near DeLand will provide protection to the estuarine resources, as required by Rule 62-40.471(1)(c), Florida Administrative Code.

SJRWMD used the EFDC model to project the salinity distribution in the Lower St. Johns River (LSJR) for the baseline (or existing) condition, the recommended maximum withdrawal rate as defined by the MFL regime (320-cubic feet per second [cfs]) and two alternative withdrawal schemes (160 and 480 cfs withdrawal limits).

Statistical analyses for the four simulated scenarios were performed and comparisons were made to quantify the changes in average salinity regime. For the withdrawal limit of 320 cfs, the results show that the projected increase in salinity in the LSJR over the 3-year simulation period is small when compared with the daily variability in salinity presently observed in the LSJR caused by tidal transport. The greatest increase of average salinity within the LSJR under the recommended MFL regime is 0.49 parts per thousand (ppt) near Jacksonville University, while the seasonal and daily variation of salinity is more than one order of magnitude higher.

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 in the LSJR. The salinity simulation results indicate the average 5-ppt isohaline will be shifted upstream by 0.8 mile. This upstream translation of the saline water may impose stress or impacts to freshwater plant habitat in a 1,130-acre area. Although the 5-ppt isohaline may be shifted upstream by 0.8 mile at 320-cfs withdrawal limit, the absolute change in mean salinity within the impacted area is only about 0.4 ppt. The species composition of the river, however, is not expected to change.

Based on the results of the salinity assessment in the LSJR, it is ECT's opinion that the MFL regime recommended by SJRWMD will provide protection of the estuarine resources. However, this conclusion should be re-evaluated when the ongoing *Vallisneria americana* (eel grass) study results by SJRWMD and the U.S. Geological Survey become available.

# 1.0 INTRODUCTION

The St. Johns River near DeLand, Volusia County, has been identified as a potential alternative surface water supply source for east-central Florida (Vergara, 2000). Development of alternative water supply sources is required to avoid projected environmental impacts to regional water resource features, such as springs, isolated wetlands, and lakes, resulting from increased ground water withdrawals. To protect water resource values and quantify safe water yields from this reach of the St. Johns River, the St. Johns River Water Management District (SJRWMD) is currently establishing minimum flows and levels (MFL), as mandated by state water policy (Section373.042, Florida Statutes). The MFL designates the minimum hydrologic/hydraulic conditions that must be maintained in the river to prevent significant harm to the ecology or water resources of the area resulting from permitted water withdrawals (Chapter 40C, Part 8.011(3), Florida Administrative Code [F.A.C.]). According to Rule 62-40.473, F.A.C., the MFL should be evaluated to ensure the protection of the following natural resources and environmental values:

a. Recreation in and on the water (Rule 62-40.473[1][a], F.A.C.).
b. Fish and wildlife habitats and the passage of fish (Rule 62-40.473[1][b], F.A.C.).
c. Estuarine resources (Rule 62-40.473[1][c], F.A.C.).
d. Transfer of detrital material (Rule 62-40.473[1][d], F.A.C.).
e. Maintenance of freshwater storage and supply (Rule 62-40.473[1][e], F.A.C.).
f. Aesthetic and scenic attributes (Rule 62-40.473[1][f], F.A.C.).
g. Filtration and absorption of nutrients and other pollutants (Rule 62-40.473[1][g], F.A.C.).
h. Sediment loads (Rule 62-40.473[1][h], F.A.C.).
i. Water quality (Rule 62-40.473[1][i], F.A.C.).
j. Navigation (Rule 62-40.473[1][j], F.A.C.).

The focus of this study is Item c., estuarine resources, and to determine whether the recommended MFL hydrologic regime protects the Lower St. Johns River (LSJR) estuarine resources from significant ecological harm, as measured by changes in salinity regimes.

## 1.1 BACKGROUND

SJRWMD's MFL determination included a detailed evaluation of topographic, soil, and vegetation data collected within the plant communities associated with the river (Mace, 2002), in conjunction with an intensive hydrologic modeling effort (Robison, 2001). An extensive field investigation was conducted along the main-stem of the St. Johns River, the Lower Wekiva River, and the Lake Woodruff Preserve (Figure 1-1).

Based on these studies, SJRWMD recommended three preliminary minimum surface water flows and levels for the St. Johns River at State Road (SR) 44 near DeLand: minimum frequent high, minimum average, and minimum frequent low flows and levels. The recommended MFL and their associated stages, flows, hydroperiod categories, approximate frequencies, and approximate durations at SR 44 are listed in Table 1-1.

**Table 1-1. Preliminary MFL for the St. Johns River near DeLand (SR44)**

| | Minimum Frequent High Level | Minimum Average Level | Minimum Frequent Low Level |
|---|---|---|---|
| Elevation (ft-NGVD) | 1.9 | 0.8 | 0.3 |
| Flow (cfs) | 4,600 | 2,000 | 1,100 |
| Hydroperiod category | Seasonally flooded | Typically saturated | Semipermanently flooded |
| Frequency | Once every 2-year high | Once every 2-year low | Once every 5- to 10-year low |
| Duration | 30 days or more | ~ 6 Months | Several Months |

Source: Mace (2002).

Robison (2001) used an interactive hydrologic modeling approach and found that the MFL may be exceeded (violated) when a maximum surface water withdrawal of 320 cubic feet per second (cfs) occurs from the river. The following withdrawal rule was applied to regulate the amount of water withdrawn from the river.

- Existing flow condition subject to a withdrawal limit of 320 cfs.

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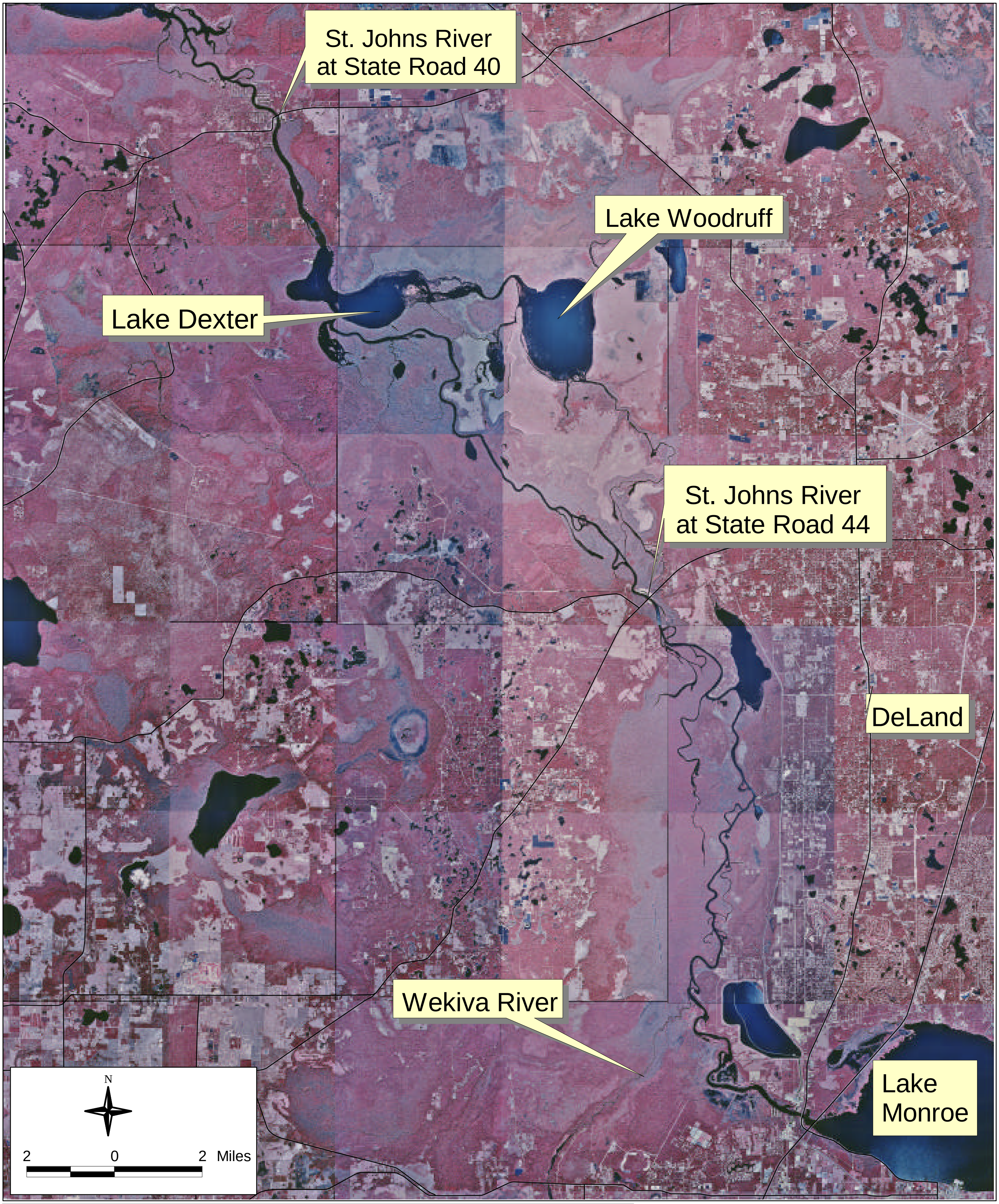


FIGURE 1-1.

STUDY AREA OF THE MFL DETERMINATION

Sources: SJRWMD, 2000; ECT, 2002.

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- Water withdrawal may occur only when the water level at DeLand is above 0.1 foot National Geodetic Vertical Datum (ft-NGVD; 1929 datum).
- The amount of allowable water withdrawal will gradually increase to the maximum amount (320 cfs) when the water level at DeLand reaches 0.25 ft NGVD (Figure 1-2).

This withdrawal rule is just one of many possibilities. Depending on the stage parameters used to regulate withdrawals, the maximum withdrawal limit might change.

## 1.2 APPROACH

An estuary is a dynamic ecoregion where saltwater from the ocean meets the freshwater from the watershed. The mixing/transport of the estuarine water is driven by the forces of tides, freshwater flows, and meteorologic phenomena. The LSJR receives approximately 60 percent of its total freshwater flow from sources upstream of Buffalo Bluff (Upper and Middle St. Johns River basins and the Lake George basin). Therefore, the salinity distribution in the LSJR may be significantly influenced by the freshwater inflow from the Lake George and Middle St. Johns River basins.

The estuarine resources such as fish and wildlife, aquatic vegetation, and water quality are significantly influenced by instream salinity concentrations. It is important to ensure that the MFL regime in the study area will protect the salinity regime of any part of the LSJR from significant alteration.

Environmental Consulting & Technology, Inc. (ECT), previously conducted continuous simulations of circulation and salinity distribution in the LSJR for the period January 1, 1995 through June 30, 1997, using the three-dimensional LSJR Environmental Fluid Dynamic Code (EFDC) model developed by SJRWMD. A hydrodynamic simulation for 1999 was also conducted. ECT attempted to use these data to establish a correlation between the freshwater flow and the salinity at various locations in the LSJR to quantifying the potential alterations of the salinity regime due to flow reductions. However, it was found that a simple correlation could not be established between stream flow and salinity

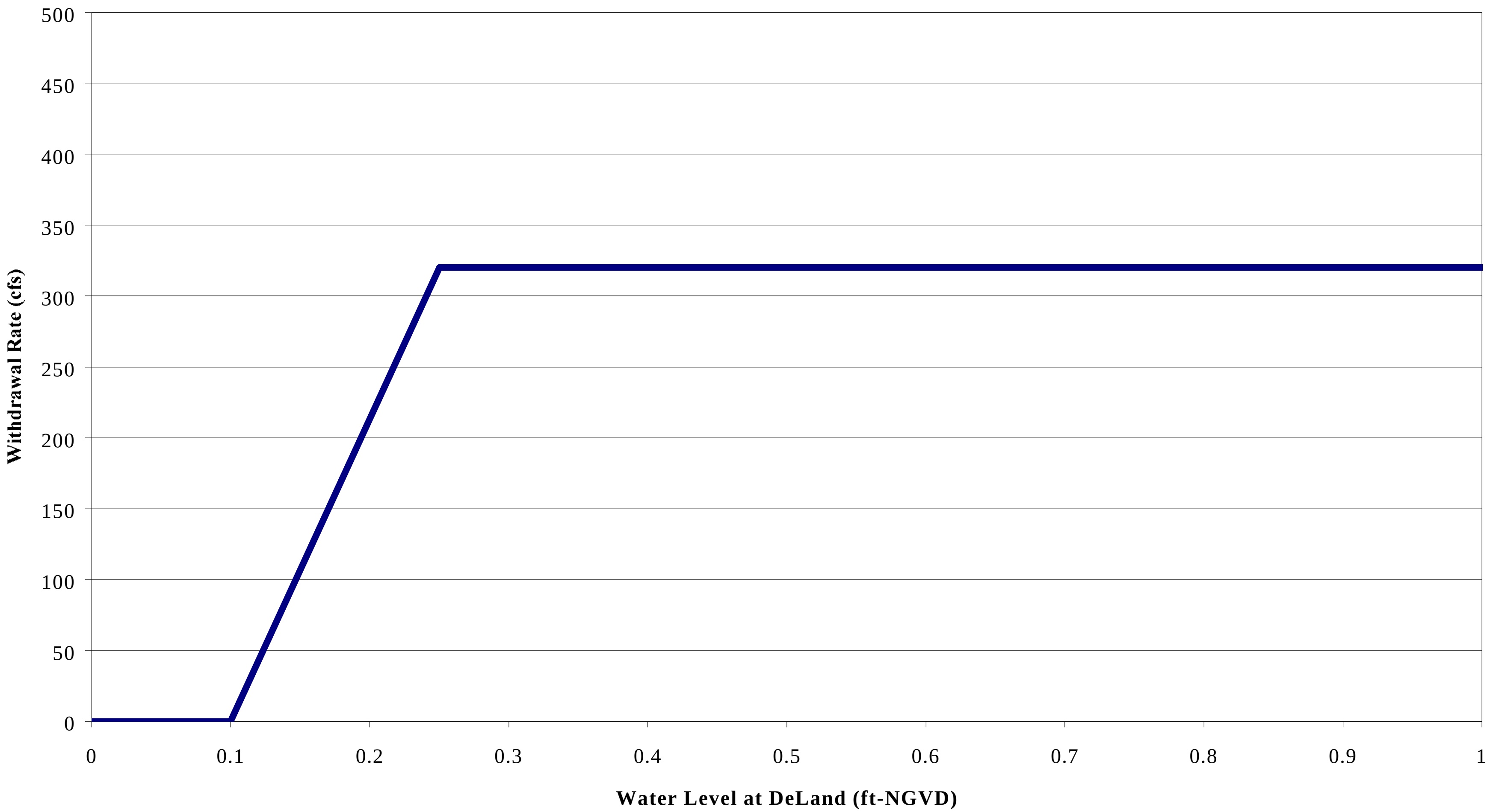


FIGURE 1-2.

SURFACE WATER WITHDRAWAL SCHEDULE FOR THE MAXIMUM WITHDRAWAL RATE OF 320 cfs

Source: Robison, 2001.

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time series, because the effects of other important factors, such as tides and weather, masked the flow/salinity relationship.

Therefore, the approach to the salinity assessment was to conduct salinity simulations with various freshwater flow regimes using the EFDC model. To isolate the effects of the freshwater flow regimes alone, the model simulations for the various flow scenarios use the same tidal and meteorological conditions, while varying only freshwater flow rates. The change of salinity regimes can then be quantified by comparing the statistical parameters between different cases. Dr. Pete Sucsy of SJRWMD conducted hydrodynamic modeling using the coarse-grid version of the LSJR EFDC model for the following four scenarios:

- Existing condition.
- Recommended surface water withdrawal limit for the minimum flow regime described in Section 1.1 (320 cfs maximum withdrawal limit).
- Alternate maximum withdrawal limits:
  - 160 cfs (50 percent less than the MFL regime withdrawal limit).
  - 480 cfs (50 percent more than the MFL regime withdrawal limit).

Continuous hydrologic and meteorologic data from 1997 through 1999 were used as the boundary conditions for the existing (baseline) condition because it included a wet El Ninõ period in 1998 and a very dry period in 1999. Simulated salinity time-series at 60 locations along the main channel centerline of the LSJR and major tributaries were provided by SJRWMD for each surface water withdrawal scenario. Salinity time-series analyses to determine frequency distributions of salinity changes were conducted at 15 of the 60 sites that were considered to be representative of the LSJR condition. These time-series analyses were used to quantify the statistical variances between existing condition and the minimum flow regimes and to assess potential changes in ecological habitats.

According to the withdrawal schedule described in Section 1.1 and the historic water level data at DeLand (1934-2002), the long-term average withdrawal rate would have been 297 cfs under the recommended MFL regime (320 cfs maximum withdrawal), which represents approximately 9.8 percent of the long-term average flow at DeLand (3,041 cfs).

## 2.0 DESCRIPTION OF THE LOWER ST. JOHNS RIVER

St. Johns River is the longest river originating in the state of Florida (about 310 miles long). Blue Cypress Lake (headwaters) is less than 25 feet above mean sea level (ft-msl). The average bottom slope of the main river channel is about 0.1 foot (ft) per mile. The total drainage area of the St. Johns River is about 9,430 square miles ($mi^2$). The average river discharge is approximately 6,500 cfs at the river mouth (Morris, 1995) .

The LSJR (Figure 2-1) is defined as the 101-mile river segment from the confluence of the Oklawaha River and the St. Johns River to the river mouth at the Atlantic Ocean. The watershed is fed by 12 major tributaries. The drainage area of each major tributary, including the area which directly drains into the main stem of the St. Johns River is summarized in Table 2-1.

**Table 2-1. Summary of Drainage Area of Major Tributaries of the LSJR Basin**

| Drainage Basin | Drainage Area ($mi^2$) |
|---|---|
| Crescent Lake | 605.0 |
| Black Creek | 496.5 |
| Rice Creek | 355.0 |
| Six-Mile Creek | 121.8 |
| Julington Creek | 104.3 |
| Ortega River | 99.2 |
| Trout River | 94.0 |
| Deep Creek | 76.0 |
| McCullough Creek | 61.8 |
| Arlington River | 32.4 |
| Broward River | 26.8 |
| Dunns Creek | 23.3 |
| St. Johns River | 210.0 |
| **Total LSJR Basin** | **2,306.1** |

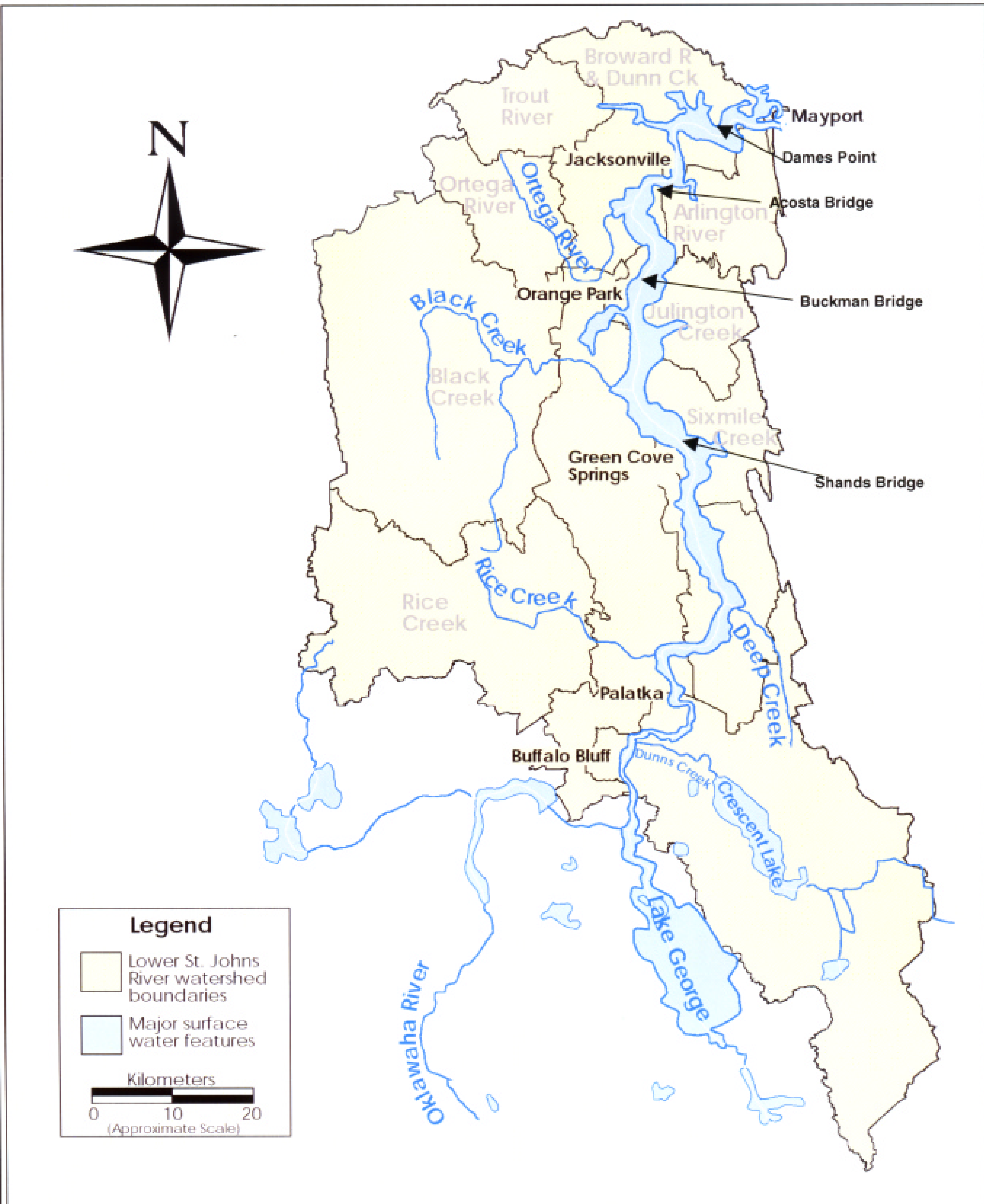


FIGURE 2-1.

LOWER ST. JOHNS RIVER AND MAJOR DRAINAGE BASINS

Source: SJRWMD, 2002.

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The total LSJR Basin drainage area of 2,306 $mi^2$ is about 27 percent of the entire watershed of the St. Johns River, and it receives about 60 percent of its total freshwater flow from sources upstream of Buffalo Bluff.

Prominent features in the LSJR and river mile designations are presented in Figures 2-2 through 2-4. The major water bodies/courses in the upstream vicinity of Buffalo Bluff include the Ocklawaha River, Rodman Reservoir, Dunns Creek, Crescent Lake, Little Lake George, and Lake George. Lake George, with an area of 68 $mi^2$, is the second largest lake in Florida. Due to the mild bottom slope of the LSJR, tidal fluctuation can propagate into Lake George. Small long-period fluctuations (more than 30 hours) of the ocean water surface may have significant influence on the river hydraulics in the LSJR because it can influence the water level in Lake George, which may provide a large tidal prism and subsequently induce significant tidal flows. Tidal prism is the volume of water between high tide and low tide, or the tidal flow volume coming in and out of the estuary within a tidal cycle.

## 2.1 TIDES

Ocean tides, meteorological conditions, and freshwater inflow to the LSJR are the most important factors that determine the hydrodynamics of this complex riverine and estuarine system.

According to the National Oceanic and Atmospheric Administration (NOAA) (1993), the mean tide range of the Atlantic Ocean at Little Talbot Island near Mayport is about 5.49 ft. When tide propagates into the St. Johns River, the resistance and shoaling effects of the channel bottom reduces the tide range to its minimum (0.71 ft) near Julington Creek. When a tidal wave continues to travel upstream toward the end of the estuary, a portion of the wave energy is reflected by either a solid boundary or a constricted pathway. The reflected wave energy is then combined with the incoming wave energy and tends to amplify the tide range. The standing wave, or the effect of wave reflection, causes the tidal range to increase from Julington Creek confluence to Palatka. The mean tidal range at Palatka is 1.09 ft. Further upstream from Palatka, the tidal range is again decreased by damping mechanisms to 0.93 ft at Buffalo Bluff.

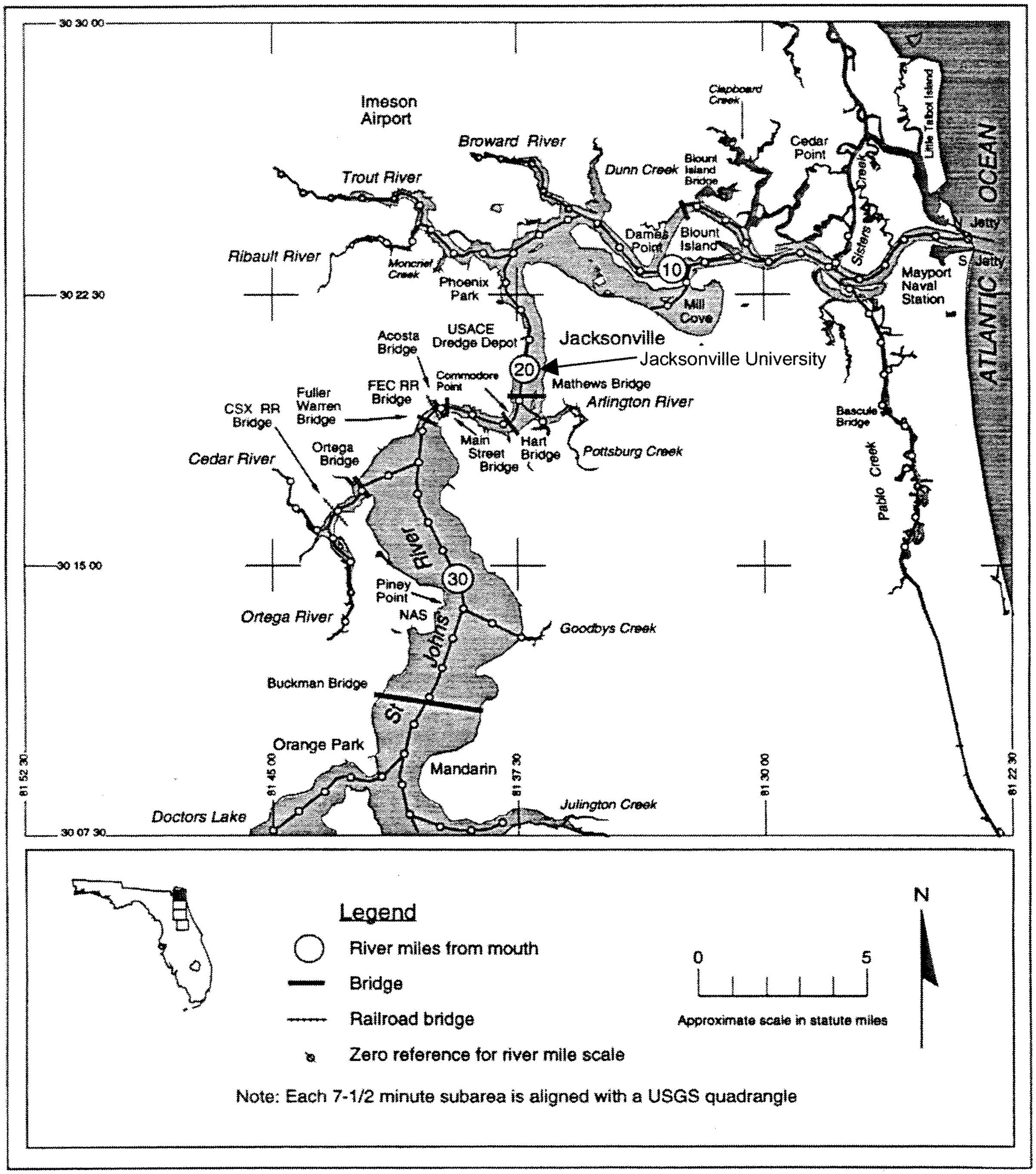


FIGURE 2-2.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN THE RIVER MOUTH AND JULINGTON CREEK

Source: Morris, 1995.

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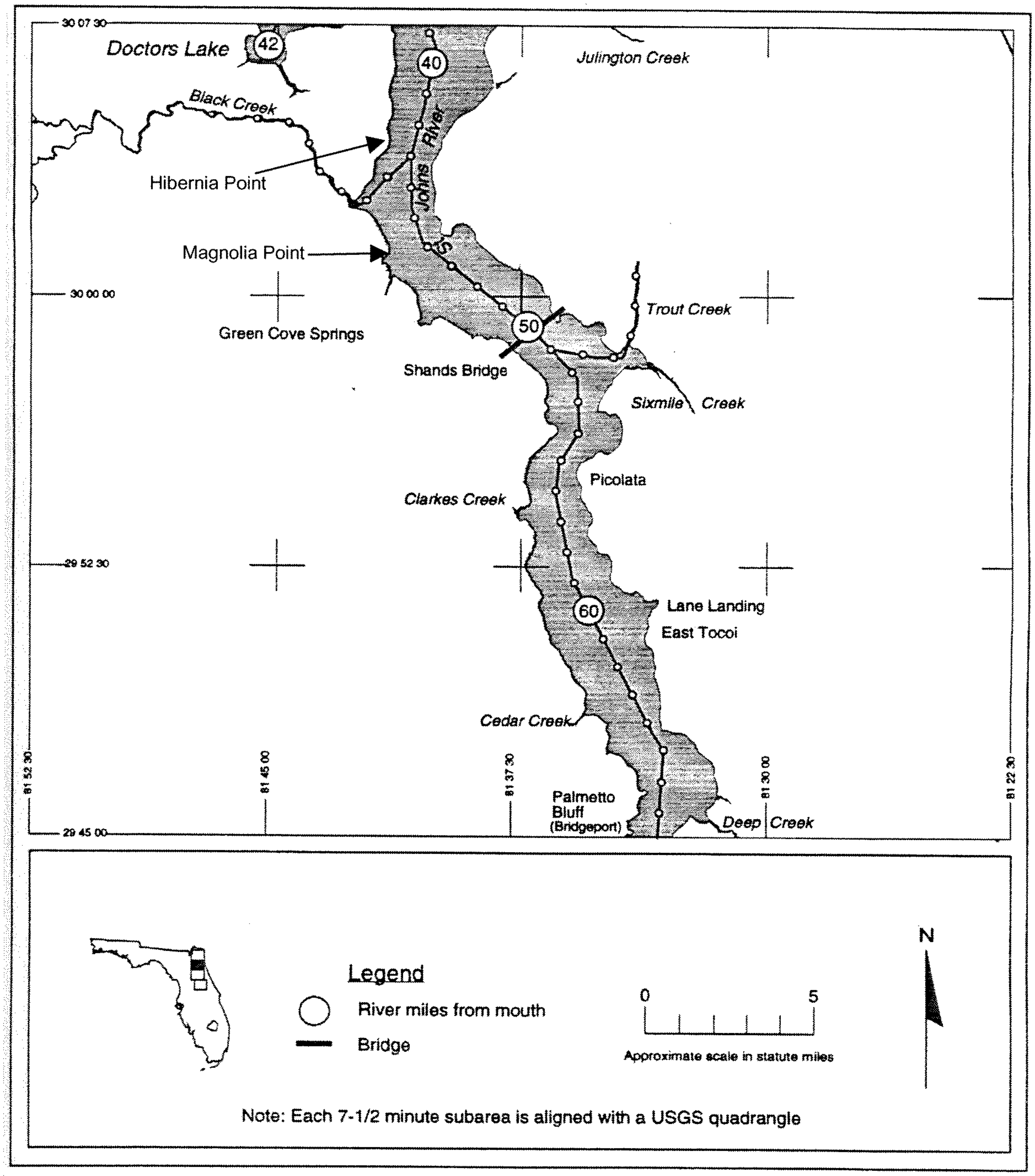


FIGURE 2-3.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN JULINGTON CREEK AND DEEP CREEK

Source: Morris, 1995.

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Environmental Consulting & Technology, Inc.

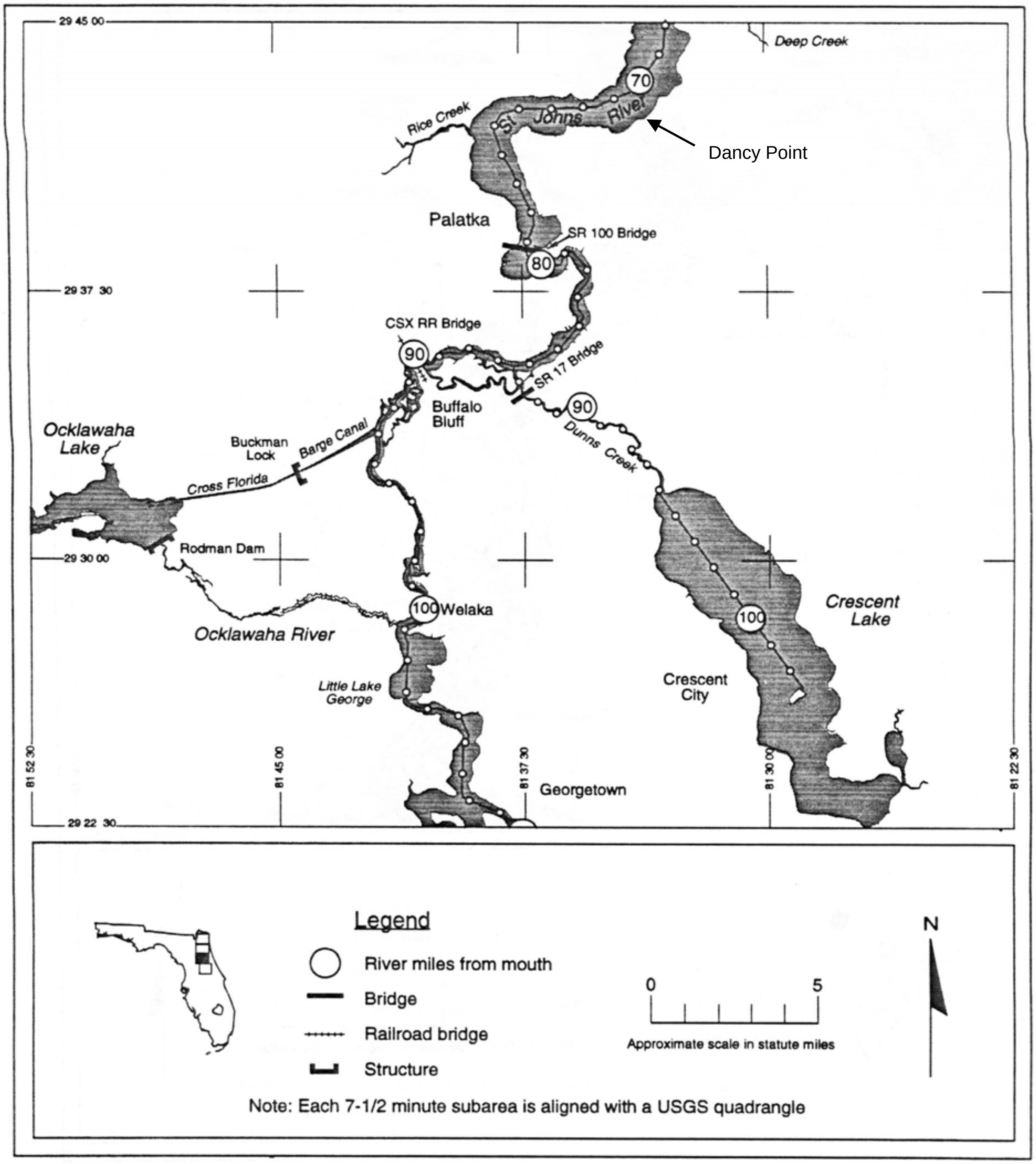


FIGURE 2-4.
LOCATION MAP, BY RIVER MILE, FOR SIGNIFICANT LOCATIONS ON THE ST. JOHNS RIVER BETWEEN A LOCATION NORTH OF RICE CREEK AND GEORGETOWN

Source: Morris, 1995.

Environmental Consulting & Technology, Inc.

The phase lag of high slack water between Little Talbot Island and Buffalo Bluff is almost 8 hours. Because of this significant phase difference, high tide and low tide can occur at different locations in the LSJR at the same time, which makes the LSJR a complex hydrodynamic system.

Table 2-2 shows the average tide range and phase lag at 21 stations in the LSJR from the river mouth to its upstream boundary. According to NOAA (1993), ocean tide can propagate to Welaka (about 9 miles upstream from Buffalo Bluff) with a mean tide range of 0.35 ft.

**Table 2-2. Summary of Tidal Characteristics of the LSJR**

| Station | Mean Range (ft) | High Water Phase Lag (hours) |
|---|---|---|
| Little Talbot Island | 5.49 | 0.00 |
| Mayport | 4.51 | 0.39 |
| Pablo Creek Entrance | 3.89 | 0.87 |
| Fulton | 3.66 | 0.80 |
| Clapboard Creek | 3.64 | 0.93 |
| Blount Island Bridge | 3.51 | 1.10 |
| Dame Point | 3.19 | 1.10 |
| Navy Fuel Depot | 2.63 | 1.59 |
| Phoenix Park | 2.54 | 1.42 |
| Long Branch | 2.08 | 1.61 |
| Little Pottsburg Creek | 2.05 | 1.90 |
| Acosta Bridge | 1.51 | 2.14 |
| Ortega River Entrance | 1.11 | 2.54 |
| Piney Point | 0.88 | 3.03 |
| Orange Park | 0.74 | 3.79 |
| Julington Creek | 0.71 | 4.36 |
| Green Cove Spring | 0.74 | 5.45 |
| East Tocoi | 0.97 | 6.51 |
| Palmetto Bluff | 1.04 | 6.98 |
| Palatka | 1.09 | 7.57 |
| Buffalo Bluff | 0.93 | 7.85 |
| Welaka | 0.35 | 8.04 |

Source: NOAA, 1993.

Figure 2-5 shows the average tide range along the river and Figure 2-6 shows the high slack water phase lag along the river.

Water level in a tidal estuary can be divided into two components: tidal and nontidal (or subtidal) fluctuation. Tidal fluctuation is induced by astronomic effects of planetary attraction. The nontidal fluctuation may be caused by meteorological effects such as wind, atmospheric pressure, and weather systems. The nontidal component can be approximately isolated from the water level data by numerically filtering out the harmonic constituents having periods less than 30 hours using a Fast Fourier Transform algorithm. As an example, Figure 2-7 shows the ocean tide at the Atlantic Ocean near Mayport in 1995 through 1997, along with the nontidal component of the water surface displacement. It is evident that the nontidal, or long-period, fluctuation of the water level can, at times, be significant compared to the tidal component.

Figure 2-8 shows the nontidal water level fluctuations at Mayport and at Buffalo Bluff from 1997 through 1998, and indicates that the long-period rise and fall of the water levels at these two stations can be quite synchronized, even though they are 88 miles apart. The nontidal component showed the Buffalo Bluff water level rose by 2.28 ft from December 9 to 12, 1997, a 4-day period. The subtidal rise of water level may push river water back into Lake George, causing significant flow reversal, or upstream backward flow, at Buffalo Bluff. Recent flow measurements by the U.S. Geological Survey (USGS) also showed that significant flow reversal could be observed at the Main Street Bridge in Jacksonville, which is a river segment highly dominated by tides. Main Street Bridge is about 0.5 mile downstream of the Acosta Bridge.

## 2.2 <u>FRESHWATER INFLOWS</u>

USGS maintains a flow gauging station in the St. Johns River at Buffalo Bluff (Station 02244040). The drainage area upstream of Buffalo Bluff contributes approximately 60 percent of the total freshwater inflow of the St. Johns River system. Figure 2-9 presents the daily average flow rate at Buffalo Bluff from October 1992 through April 2002.

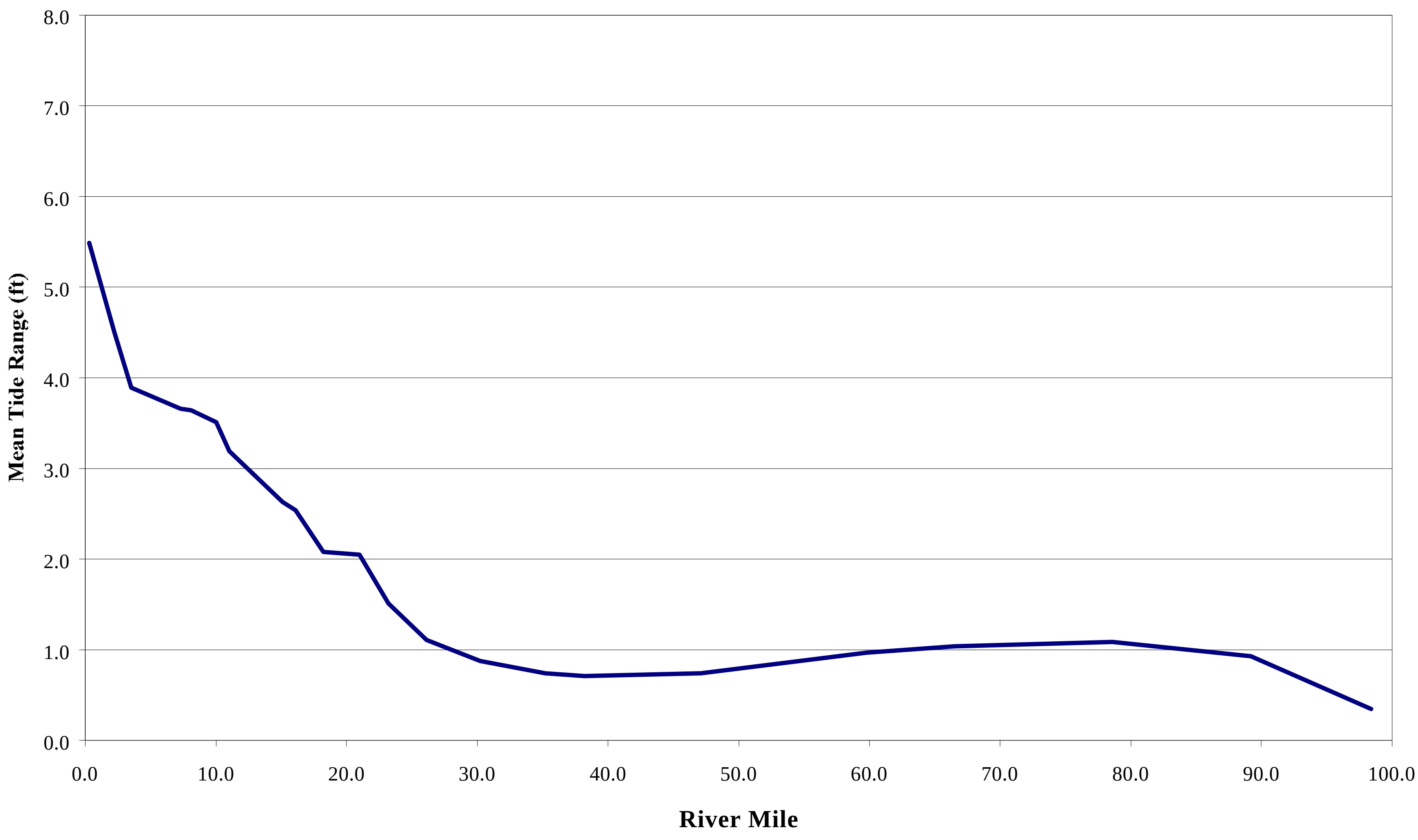


FIGURE 2-5.

MEAN TIDAL RANGES IN ST. JOHNS RIVER

Source: ECT, 2001.

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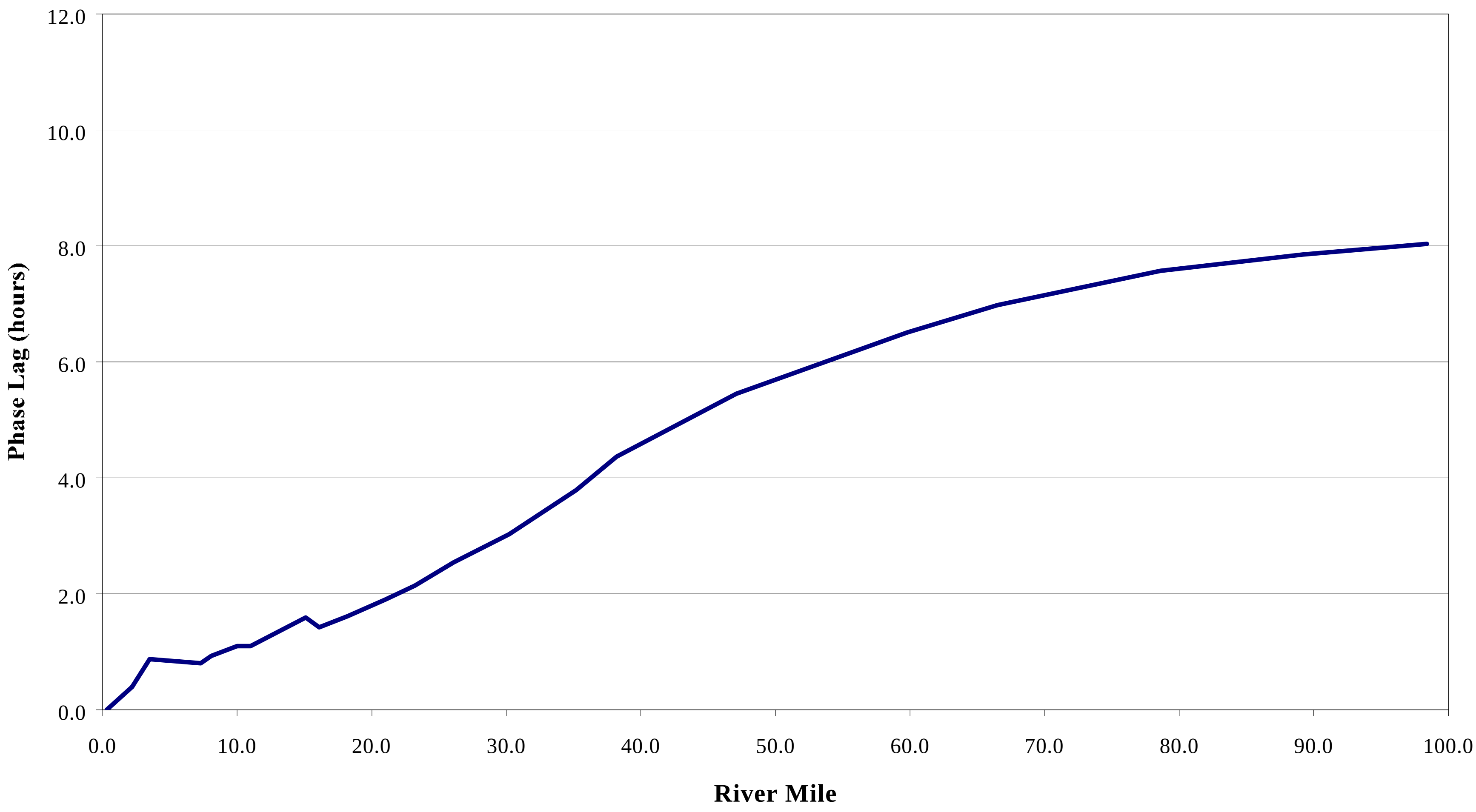


FIGURE 2-6.

HIGH TIDE PHASE DIFFERENCES IN ST. JOHNS RIVER

Source: ECT, 2001.

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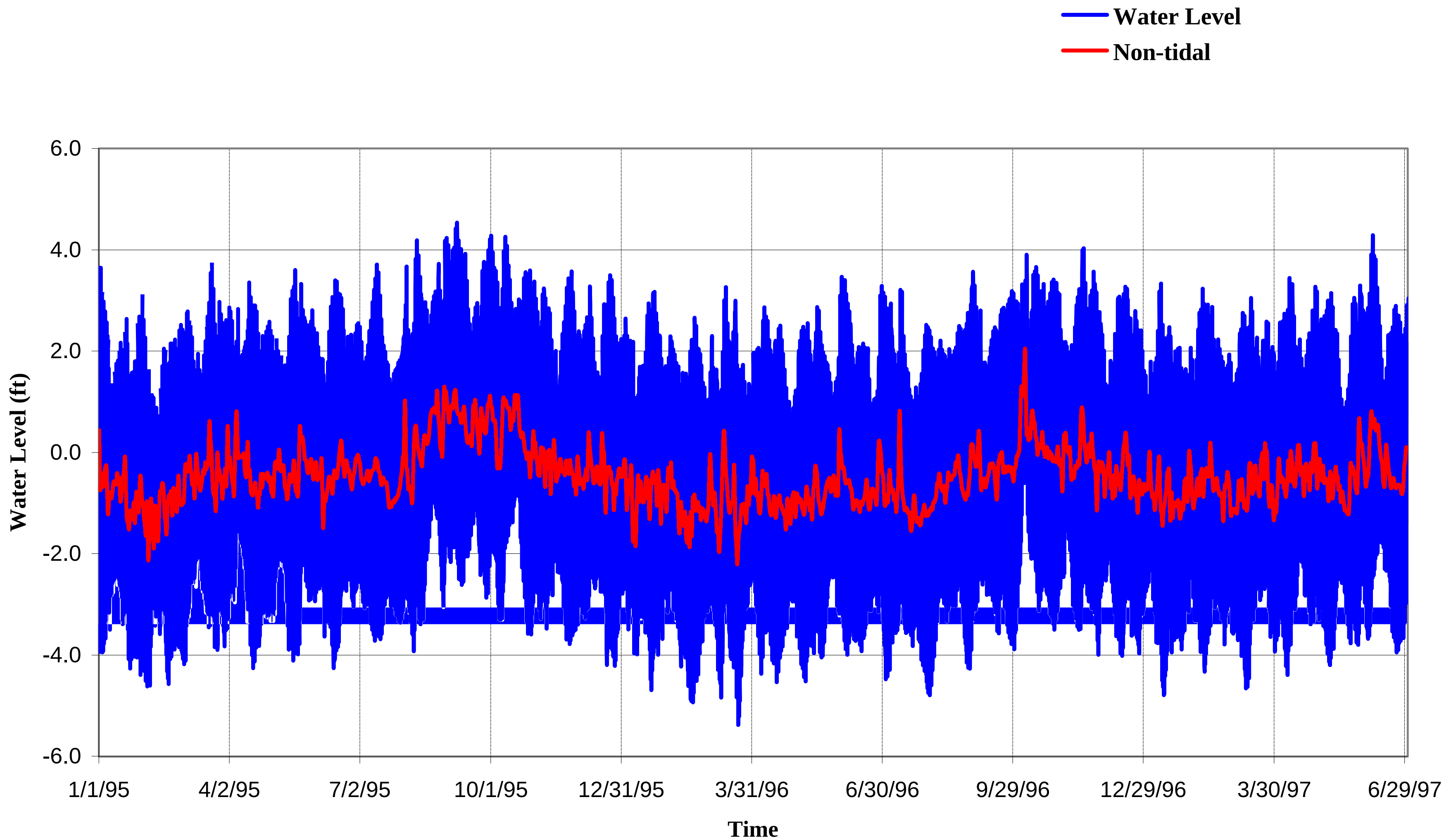


Sources: St. Johns River Water Management District, 2000; ECT2001

FIGURE 2-7.

OCEAN TIDE (1995-1997)

Sources: SJRWMD, 2000; ECT, 2001.

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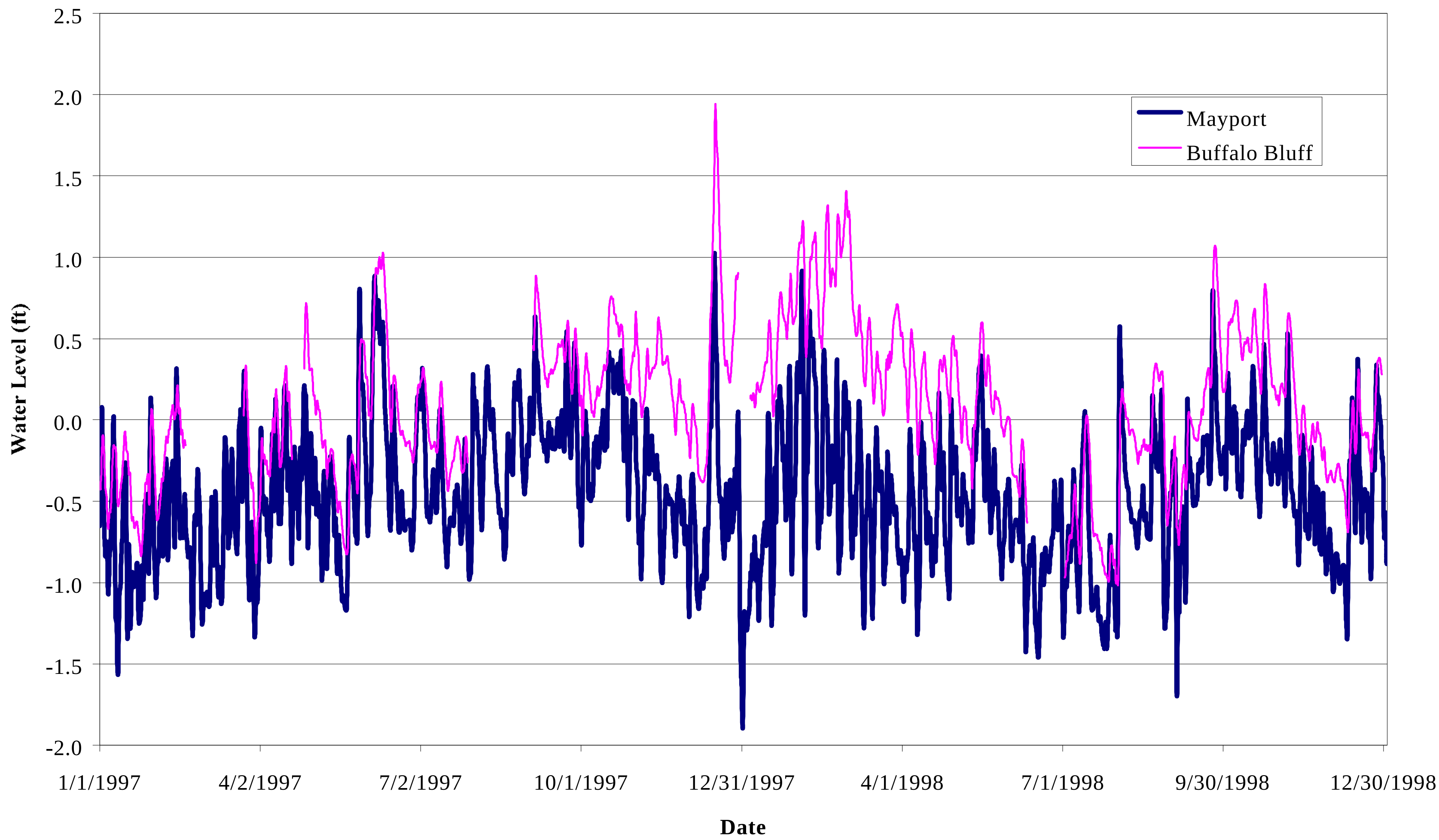


FIGURE 2-8.

ST. JOHNS RIVER WATER LEVEL—NONTIDAL COMPONENT (1997-1998)

Sources: SJRWMD, 2000; ECT, 2001.

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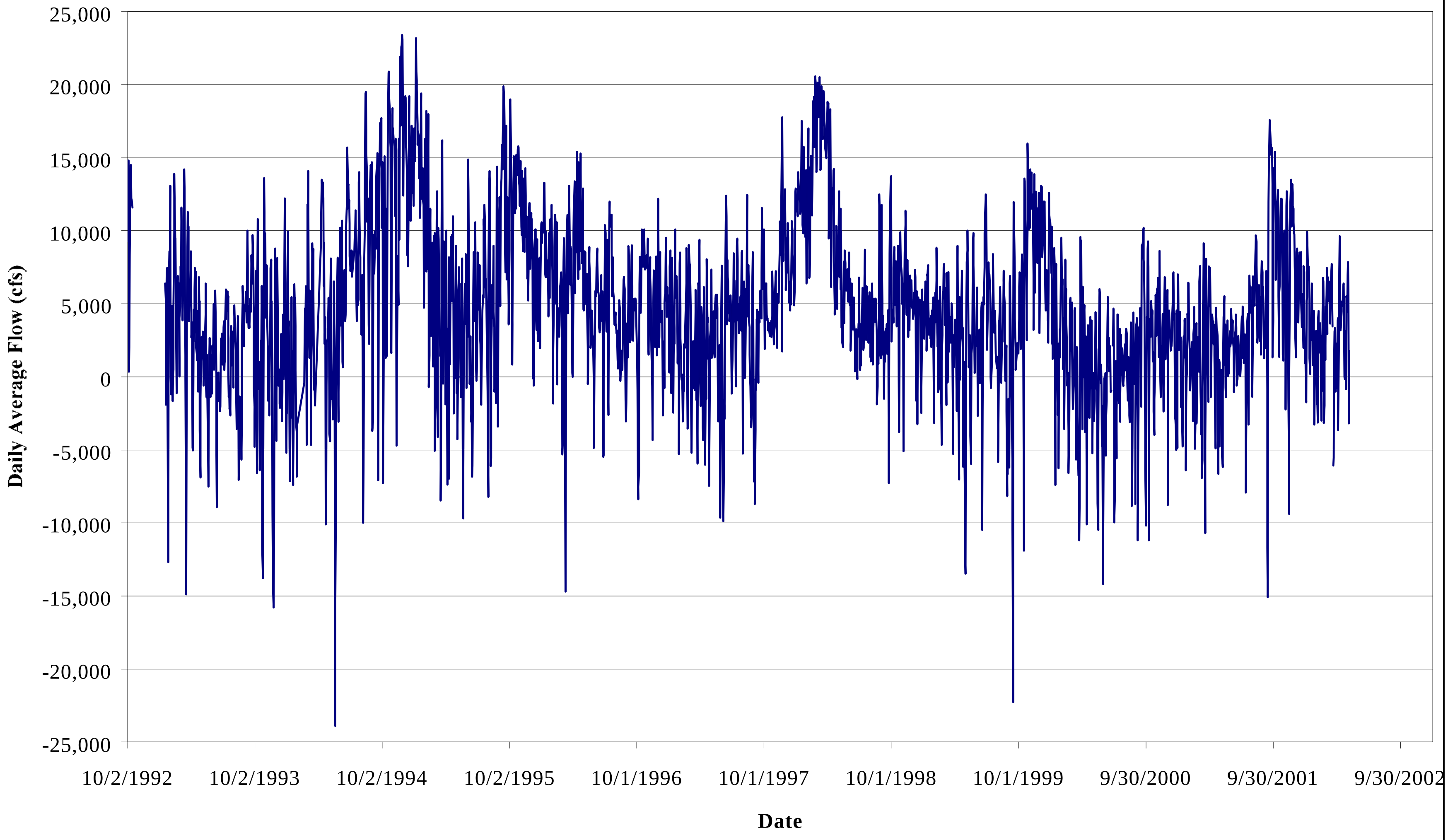


FIGURE 2-9.

DAILY AVERAGE FLOW OF ST. JOHNS RIVER AT BUFFALO BLUFF (1992-2002)

Sources: SJRWMD, 2000; ECT, 2001.

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Environmental Consulting & Technology, Inc.

The average flow rate in the period of record was 4,726 cfs and the maximum daily flow was 23,400 cfs on November 28, 1994.

ECT (2001) conducted a frequency analysis of the St. Johns River flows at Buffalo Bluff for the period of 1993 through 1999. The analysis showed that 16.2 percent of the time the daily average flows were negative, or flowing upstream, which verified the hypothesis that the subtidal rise of the water level in the estuary system will cause sustained flow reversal. The highest flow reversal was –23,900 cfs on May 20, 1994, more than 3.5 times the absolute magnitude of the average flow at the river mouth.

The 15-day running average of the river flow (Figure 2-10) at Buffalo Bluff indicates that 5 percent of the time the net river flow is negative averaged in a 15-day period.

Figure 2-11 shows the cumulative frequencies of daily, 7-day, and 30-day average flows at Buffalo Bluff. The analysis indicates that long lasting flow reversal of the St. Johns River occurs quite frequently. This flow reversal phenomenon in the LSJR has been demonstrated and verified by various modeling studies conducted by SJRWMD and ECT (ECT, 2001), and it may have significant effects on pollutant transport, water quality, and salinity intrusion (Sucsy and Morris, 2001).

## 2.3 TIDAL FLOWS

USGS maintains a flow monitoring station at the Main Street Bridge. Figure 2-12 is an illustration of the instantaneous tidal flow at the Main Street Bridge in April 1997. The daily average flow data, which may represent the daily net flow at the bridge, are also shown in Figure 2-12. Similarly, the tidal flow and the daily average net flow in the year 1997 are shown in Figure 2-13. The tidal flow data at the Main Street Bridge in the period of 1996 through 2000 showed that the instantaneous tidal flows ranged from -208,996 to 184,090 cfs and the average net flow was 7,710 cfs. Therefore, the peak ebb and flood flows were more than an order of magnitude greater than the average net flow in the river. Figure 2-14 shows the cumulative frequency of the instantaneous tidal flow at the Main Street Bridge. The flow frequency analysis indicates that 82 percent of

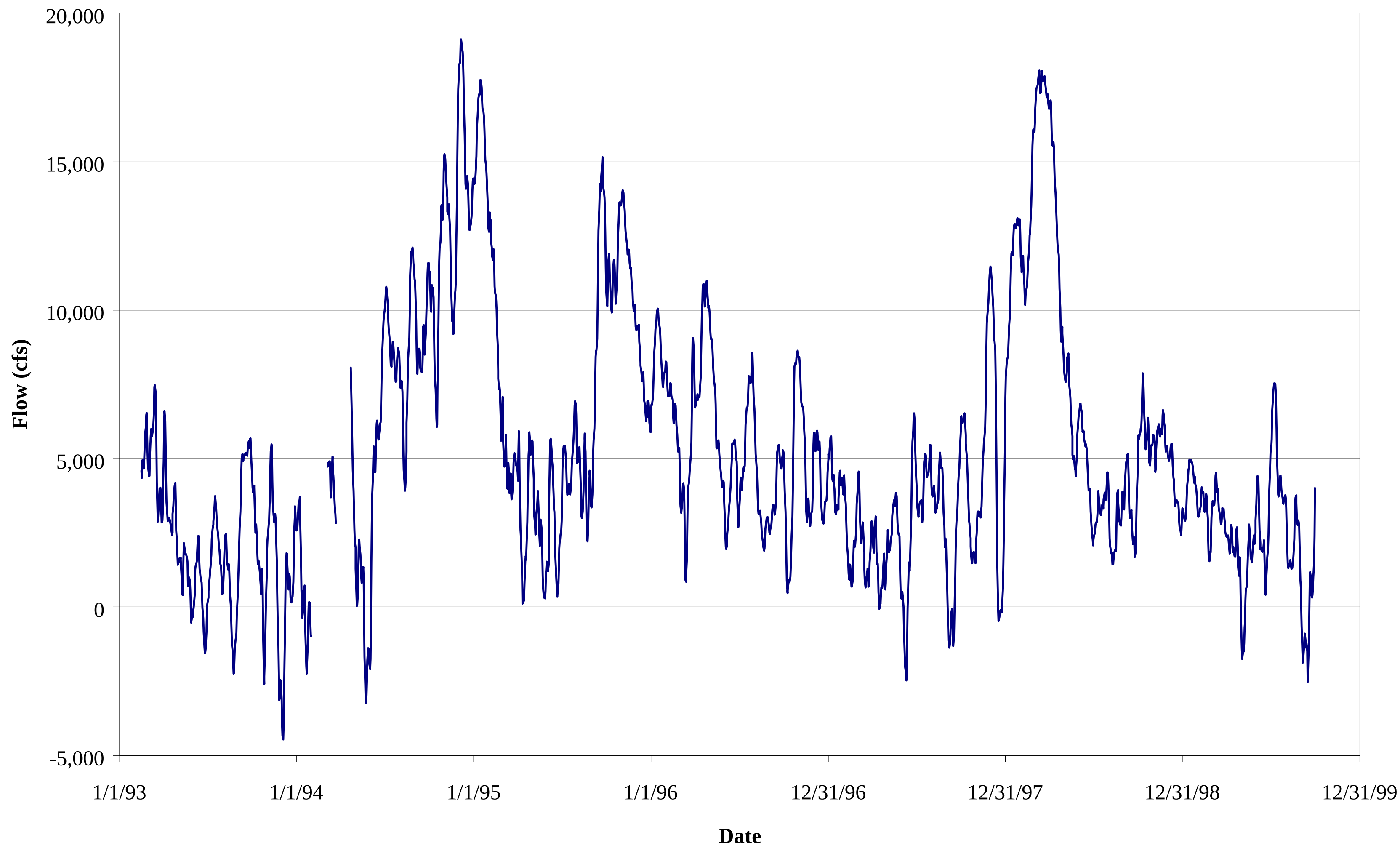


FIGURE 2-10.

ST. JOHNS RIVER FLOW AT BUFFALO BLUFF (15-DAY AVERAGE)

Sources: SJRWMD, 2000; ECT, 2001.

ECT
Environmental Consulting & Technology, Inc.

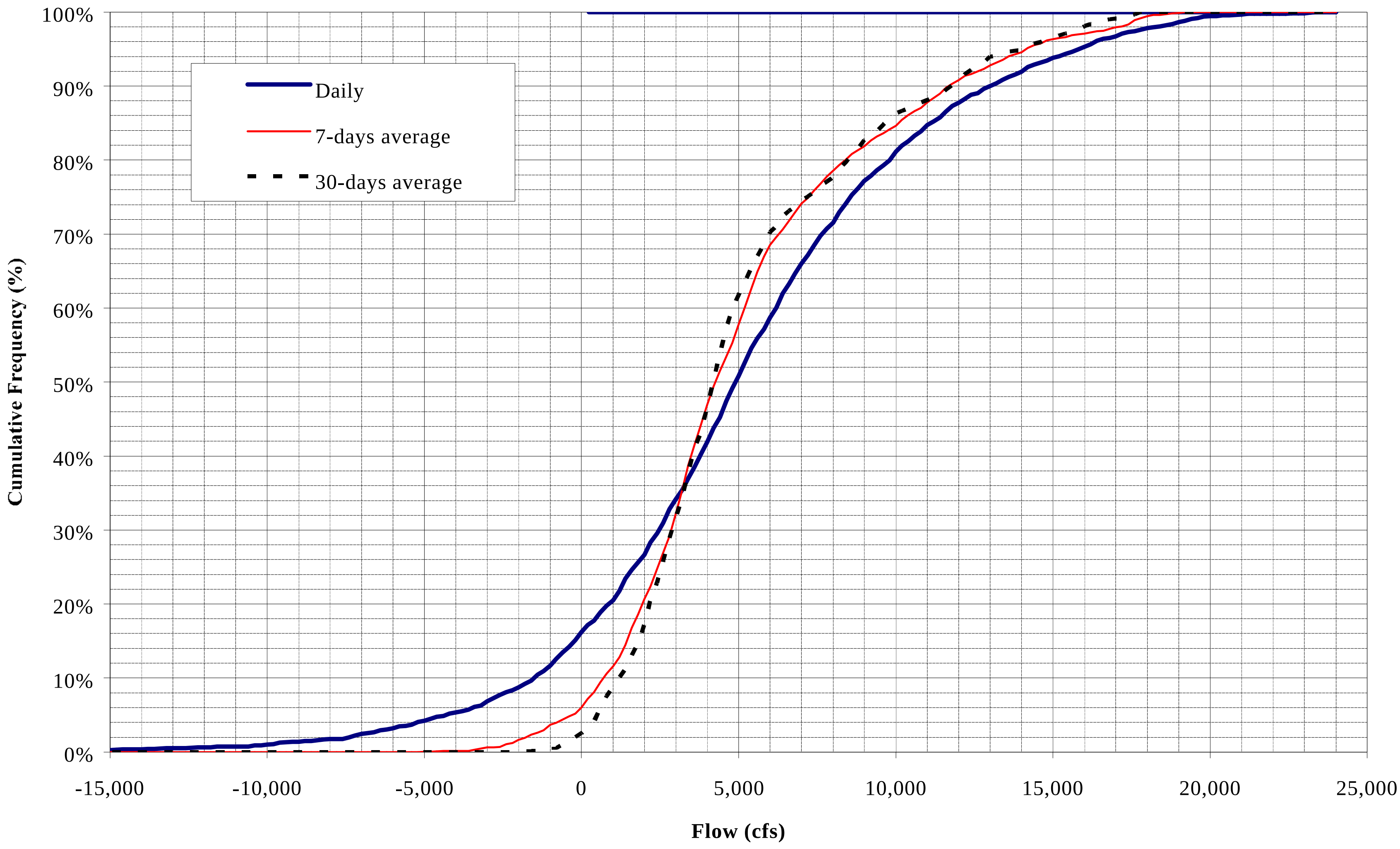


FIGURE 2-11.

FREQUENCY ANALYSIS OF ST. JOHNS RIVER FLOW
AT BUFFALO BLUFF

Sources: SJRWMD, 2000; ECT, 2001.

ECT
Environmental Consulting & Technology, Inc.

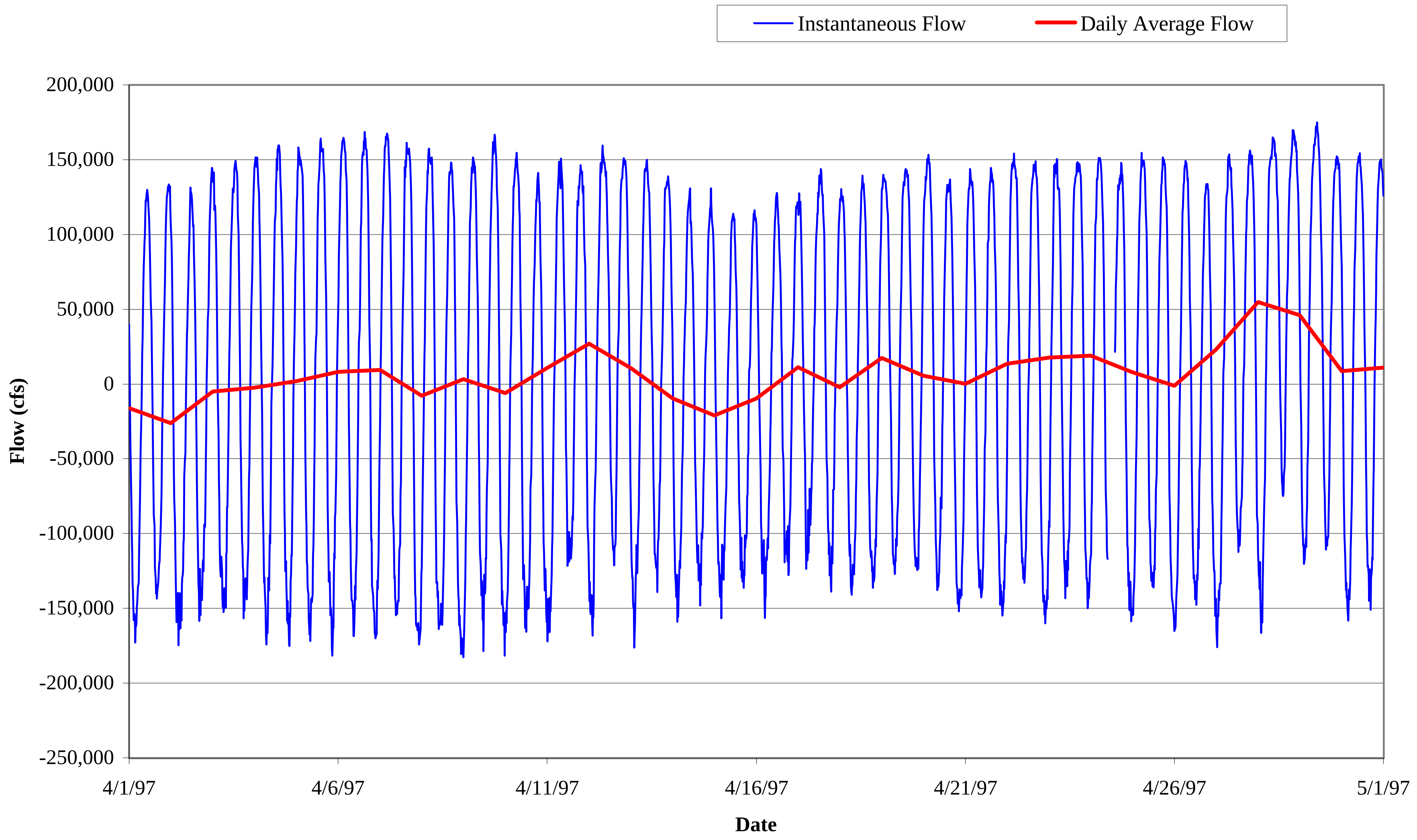


FIGURE 2-12.

ST. JOHNS RIVER FLOW AT MAIN STREET BRIDGE (APRIL 1997)

Sources: SJRWMD, 2002. ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

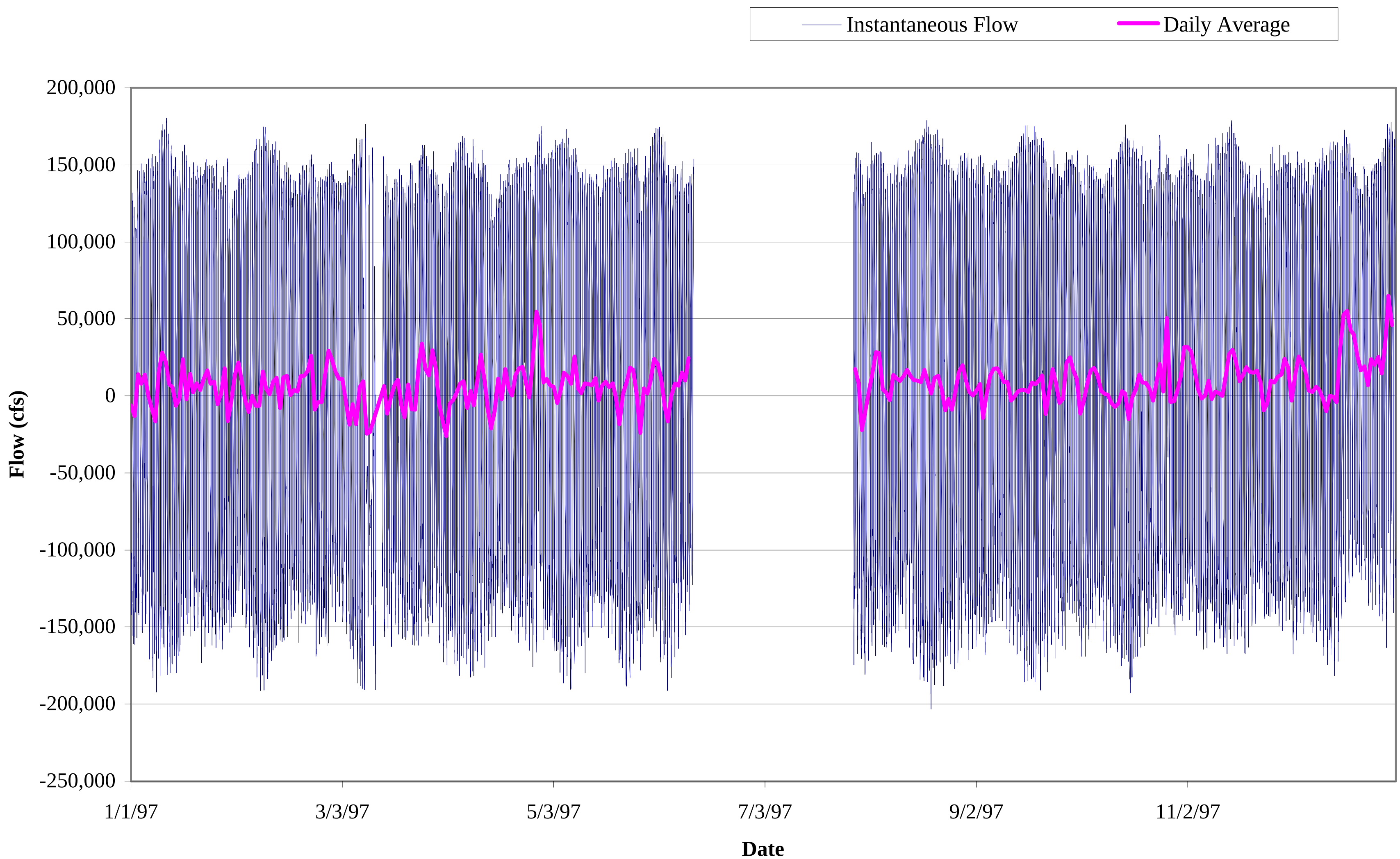


FIGURE 2-13.

ST. JOHNS RIVER TIDAL FLOW AT MAIN STREET BRIDGE (JANUARY 1 THROUGH DECEMBER 31, 1997)

Sources: SJRWMD, 2002. ECT, 2002.

Environmental Consulting & Technology, Inc.

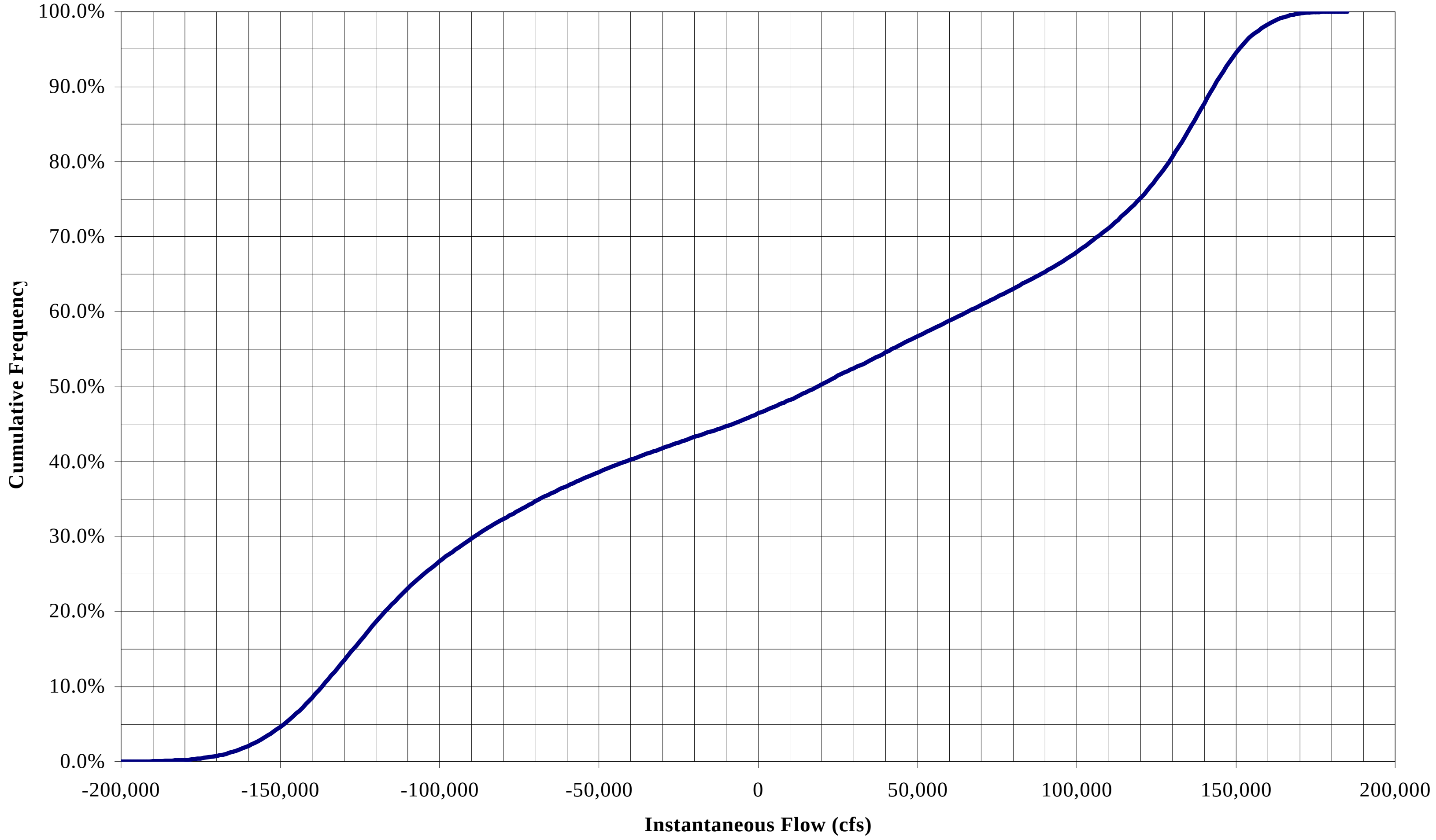


FIGURE 2-14.

FREQUENCY ANALYSIS OF TIDAL FLOW AT MAIN STREET BRIDGE
(8/1/96 THROUGH 10/1/00)
Sources: SJRWMD, 2002. ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

the time the magnitude of the tidal flow is greater than 50,000 cfs at the Main Street Bridge.

## 2.4 SALINITY

USGS has maintained continuous recording salinity gauges at six stations in the LSJR since 1995: Dames Point, Acosta Bridge, Buckman Bridge, Shands Bridge, Dancy Point, and Buffalo Bluff. Figures 2-15 and 2-16 show the mid-depth salinity at the Acosta Bridge in 1995-1998 and 1999-2001, respectively. Figures 2-17 and 2-18 show the mid-depth salinity at the Buckman Bridge. Figures 2-19 and 2-20 show the mid-depth salinity at the Shands Bridge. These graphs were separated to facilitate viewing. The data indicate that it has been extremely dry since 1999, and unusually high salinity values were observed as far upstream as the Shands Bridge. The data also show that the salinity in St. Johns River estuary is highly variable and can have large salinity changes in a short period of time. The salinity at the Acosta Bridge ranges from 0.1 to 34.5 ppt; the salinity at the Buckman Bridge ranges from 0.1 to 27.6 ppt; and the salinity at the Shands Bridge ranges from 0.1 to 9.7 ppt.

According to Sucsy and Morris (2001), the salinity intrusion in the LSJR is determined by four factors: subtidal water level at the river mouth, maximum daily tidal range at the mouth, total freshwater discharge, and surface wind stress. They found that the salinity in the St. Johns River estuary would take 12 to 30 days to respond to the changes in freshwater inflows. In contrast, the subtidal water level changes, or long-period water level fluctuation at the ocean boundary, could cause rapid changes of the salinity (as quick as 2 days), especially during significant pulses of flow reversal. This subtidal water level-induced salinity intrusion may overpower the effects of spring/neap tide or the freshwater flows.

The average river flow of the St. Johns River at Buffalo Bluff during 1995-1998 was 6,041 cfs, almost twice the average flow rate in 1999-2001 (3,039 cfs). The dramatic salinity increases at the Buckman Bridge and the Shands Bridge due to 50 percent flow reduction in a 3-year period are clearly shown in Figures 2-17 through 2-20.

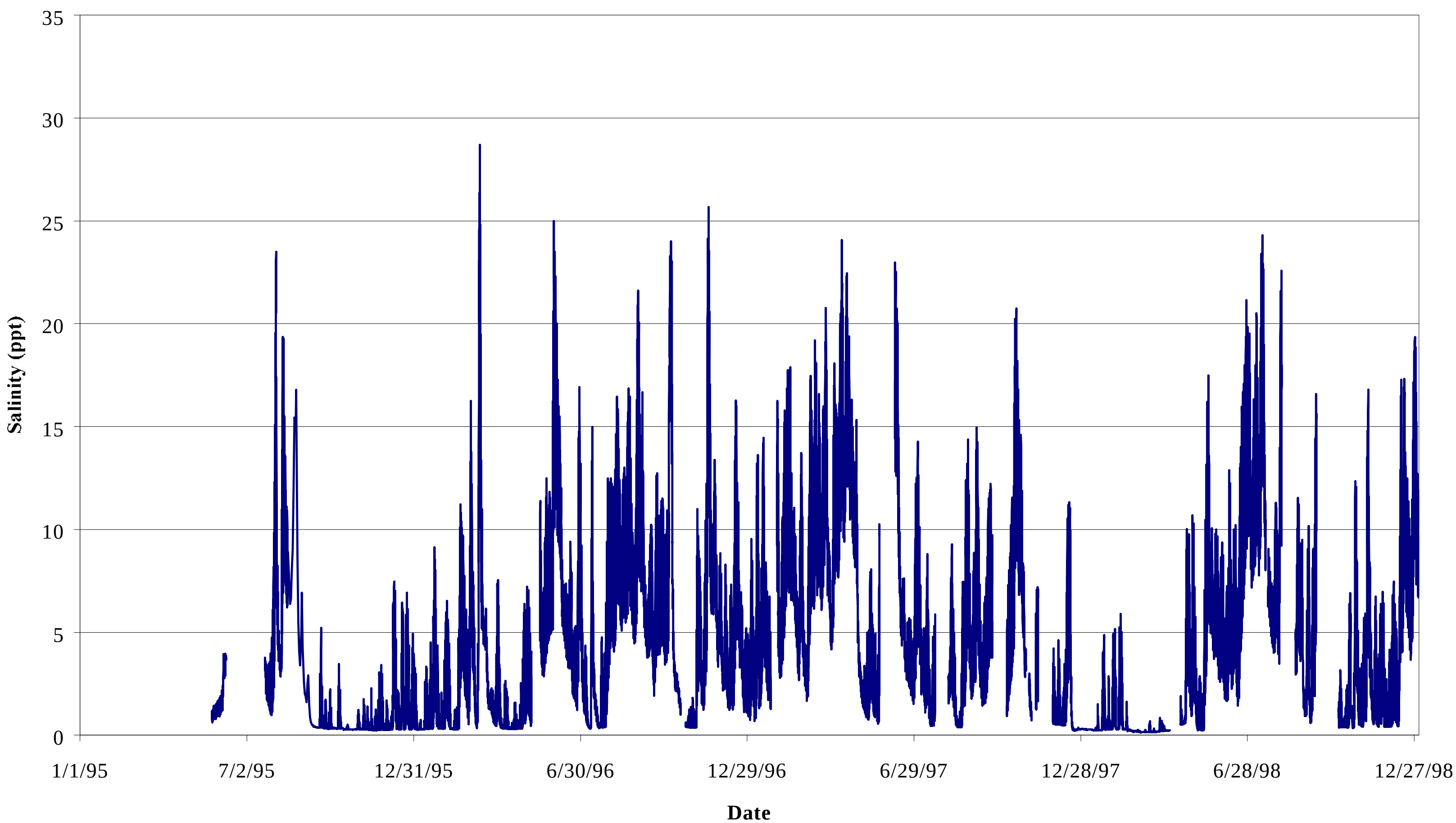


FIGURE 2-15.

MID-DEPTH SALINITY AT ACOSTA BRIDGE (1995-1998)

Sources: USGS, 2002; ECT, 2002.

ECT

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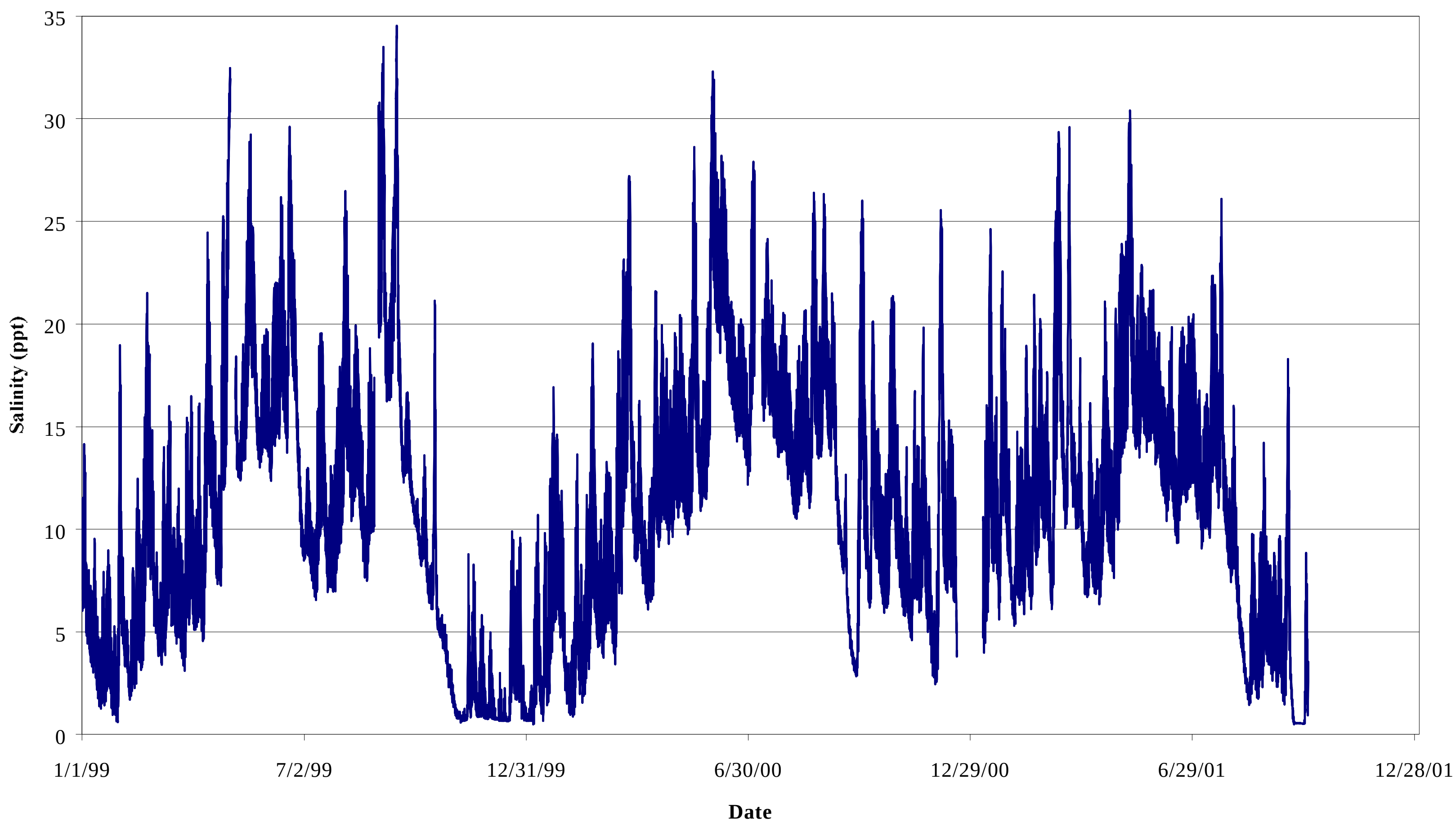


FIGURE 2-16.

MID-DEPTH SALINITY AT ACOSTA BRIDGE (1999-2001)

Sources: USGS, 2002; ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

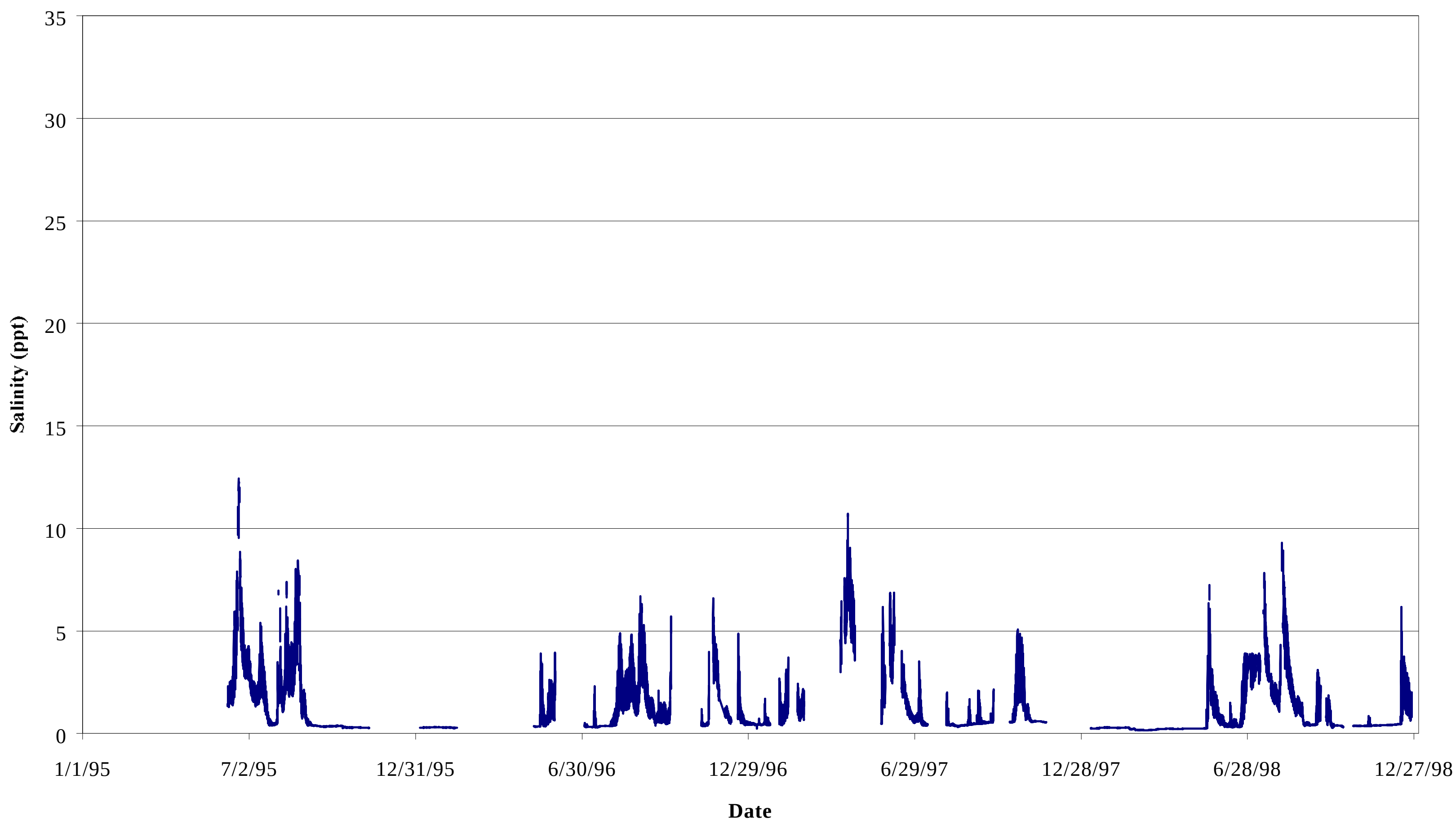


FIGURE 2-17.

MID-DEPTH SALINITY AT BUCKMAN BRIDGE (1995-1998)

Sources: USGS, 2002; ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

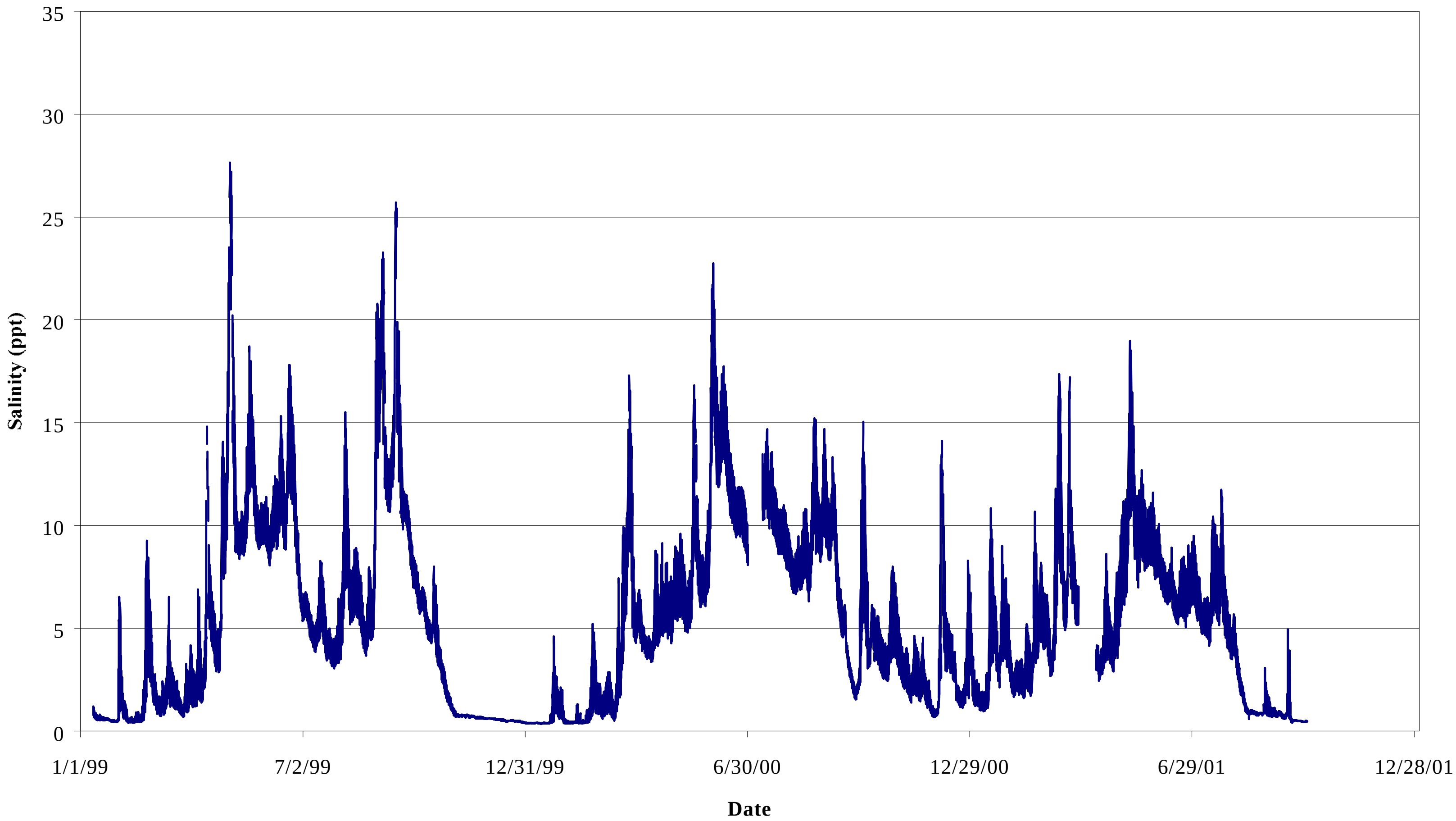


FIGURE 2-18.

MID-DEPTH SALINITY AT BUCKMAN BRIDGE (1999-2001)

Sources: USGS, 2002; ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

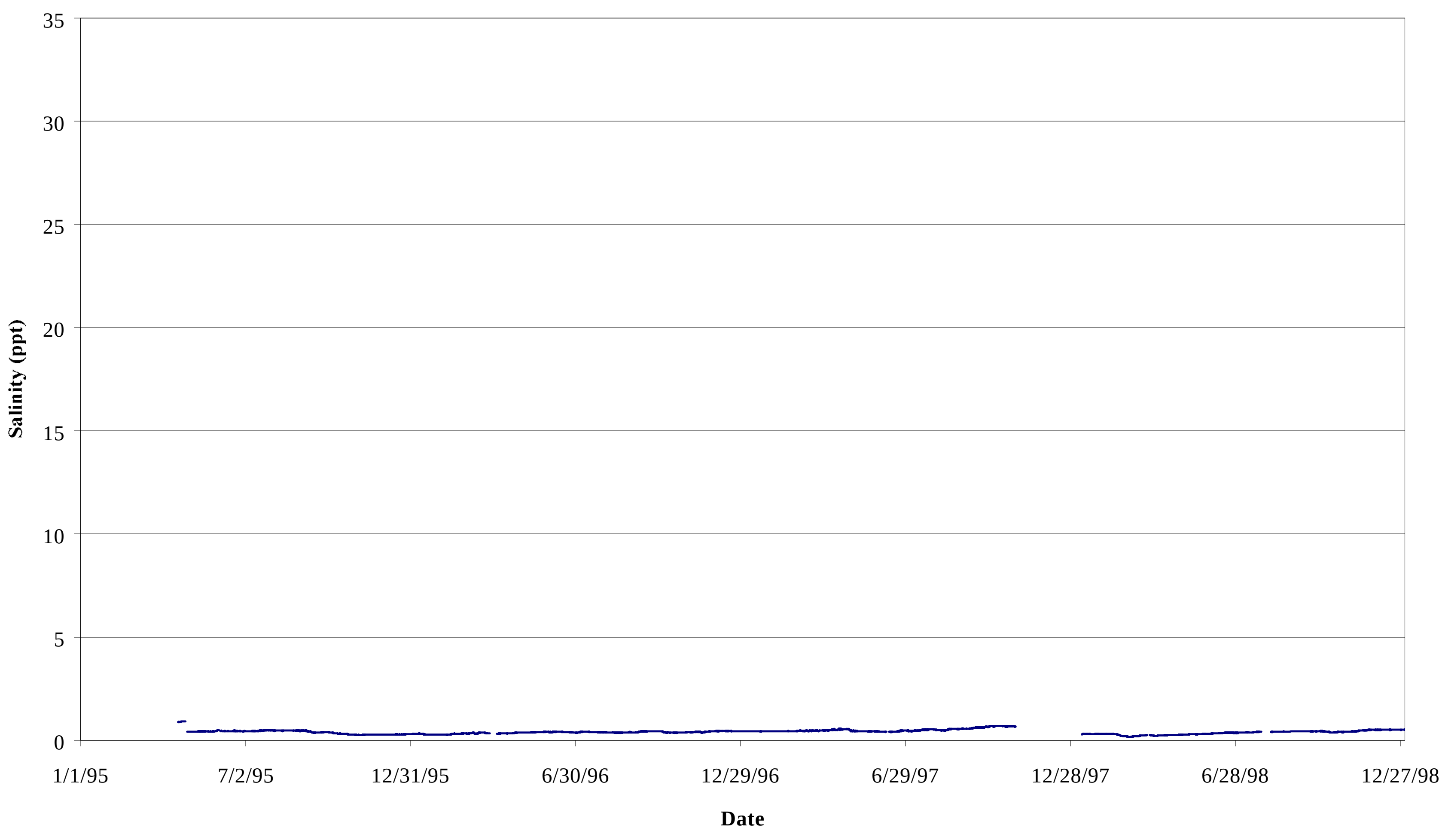


FIGURE 2-19.

MID-DEPTH SALINITY AT SHANDS BRIDGE (1995-1998)

Sources: USGS, 2002; ECT, 2002.

Environmental Consulting & Technology, Inc.

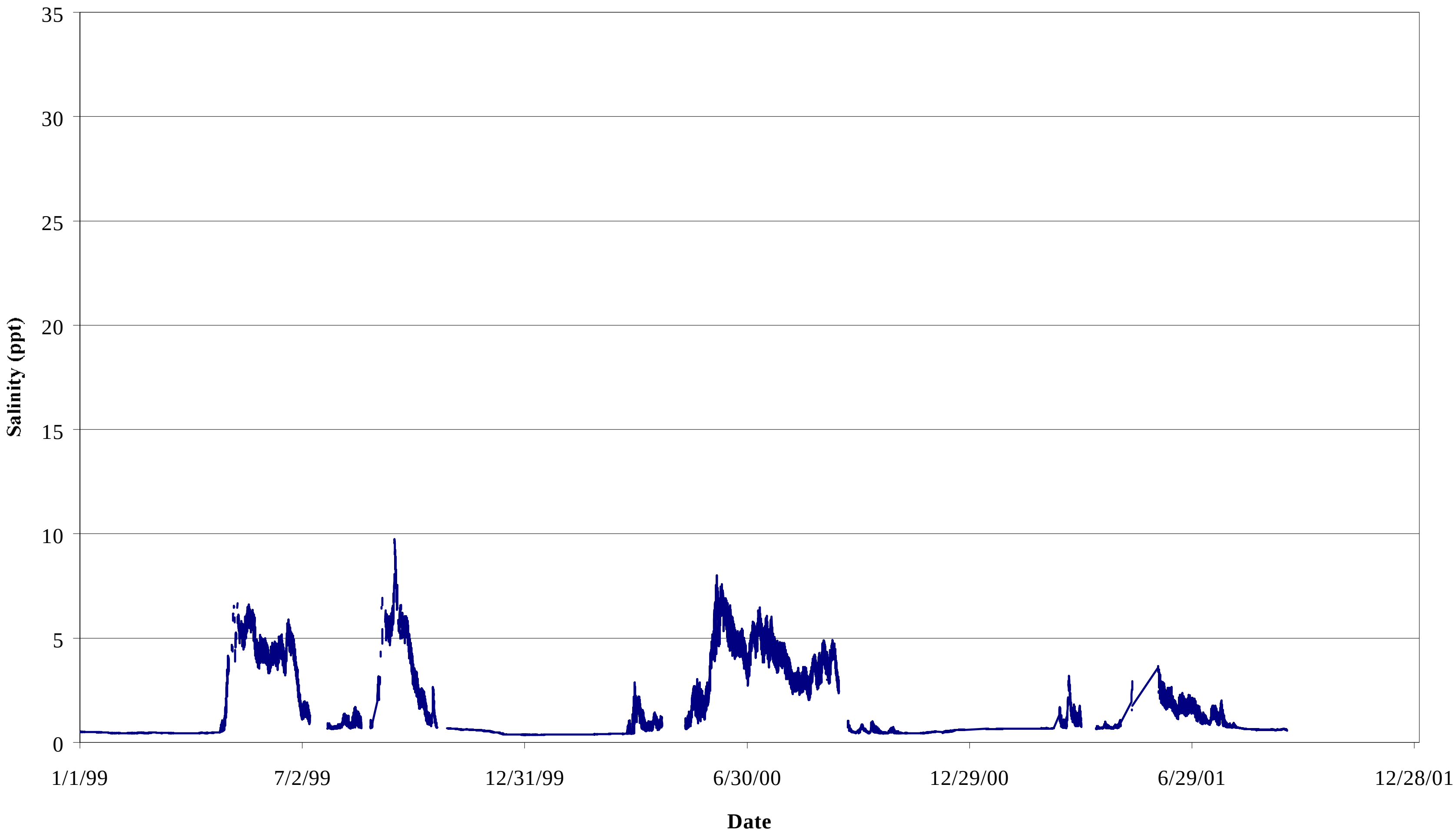


FIGURE 2-20.

MID-DEPTH SALINITY AT SHANDS BRIDGE (1999-2001)

Sources: USGS, 2002; ECT, 2002.

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# 3.0 SALINITY ASSESSMENT METHODOLOGY

The three-dimensional EFDC hydrodynamic and water quality model was used to simulate salinity distribution in the LSJR.

## 3.1 MODEL DESCRIPTION

The EFDC model was developed by Dr. John Hamrick (Hamrick, 1992a; 1992b). It is a three-dimensional finite difference model using orthogonal curvilinear grid in the horizontal dimension. It uses a stretched sigma grid in the vertical dimension. The model solves the momentum equation, continuity equation, equation of state, and turbulent kinetic energy.

The model inputs include ocean boundary tide, ocean boundary salinity, bathymetry, freshwater inflows, rainfall, evaporation, windspeed, and wind direction. The model outputs include water level, flow velocity in three components, salinity, and water quality within each model cell.

SJRWMD has previously applied the EFDC model in the LSJR basin for the purpose of establishing total maximum daily load (TMDL) of nutrients and other pollutants in the watershed. The model was calibrated by SJRWMD (Sucsy and Morris, 1999 and 2002) using tide and salinity data collected in the river. Model calibration was further verified by ECT using dye study data collected in 1999 and the USGS 1999 salinity data as part of a study to simulate the effluent plume from JEA's Buckman Water Reclamation Facility (ECT, 2001).

## 3.2 MODEL CONFIGURATION

Initially, Dr. Peter Sucsy of the SJRWMD constructed the EFDC model for the LSJR in 1998. The model consisted of 5,229 horizontal grid cells and 6 layers. The model was calibrated in 1999 with tide, flow, and salinity data from January 1, 1995, through June 30, 1997 (Sucsy and Morris, 1999).

SJRWMD later modified the model grid to include a lesser number of cells (2,210) to improve the runtime speed. The coarse-grid model, calibrated by SJRWMD (Sucsy and Morris, 2002), runs about six times faster than the fine-grid model. Dr. Peter Sucsy of SJRWMD used the coarse-grid version of the LSJR EFDC model to produce the results for the salinity assessment.

Figure 3-1 shows the EFDC model grid configuration of the LSJR. As shown in the figure, a 13-$mi^2$ grid area is created at the upstream boundary of the model near Buffalo Bluff. These so-called *sponge cells* are a means to limit the model domain to the LSJR without simulating the Middle St. Johns River, which will significantly increase the complexity and runtime of the model.

For numerical stability, the model simulations were conducted with a 30-second time step.

## 3.3 BOUNDARY CONDITIONS

### 3.3.1 OCEAN AND UPSTREAM BOUNDARY

The LSJR model grid configurations contain an open ocean boundary area near the river mouth and a *sponge* area upstream of Buffalo Bluff. The open ocean boundary consisted of 173 grid cells covering 72.6 $mi^2$ coastal ocean area east of the river mouth. The purpose of the open ocean boundary grids is to allow a realistic exchange of river flow with the ocean waters outside of the river mouth. It also places the model boundary at a location where the salinity is relatively constant (34 to 36.5 parts per thousand [ppt]). The purpose of the sponge cells is to dampen the standing tidal waves reflected from the model boundary. Without these sponge cells, the model would have predicted higher tide range in the upstream segment than actual conditions.

Temporally constant salinity values are applied at the ocean boundary (36 ppt at the bottom and linearly increased to 35 ppt at the surface).

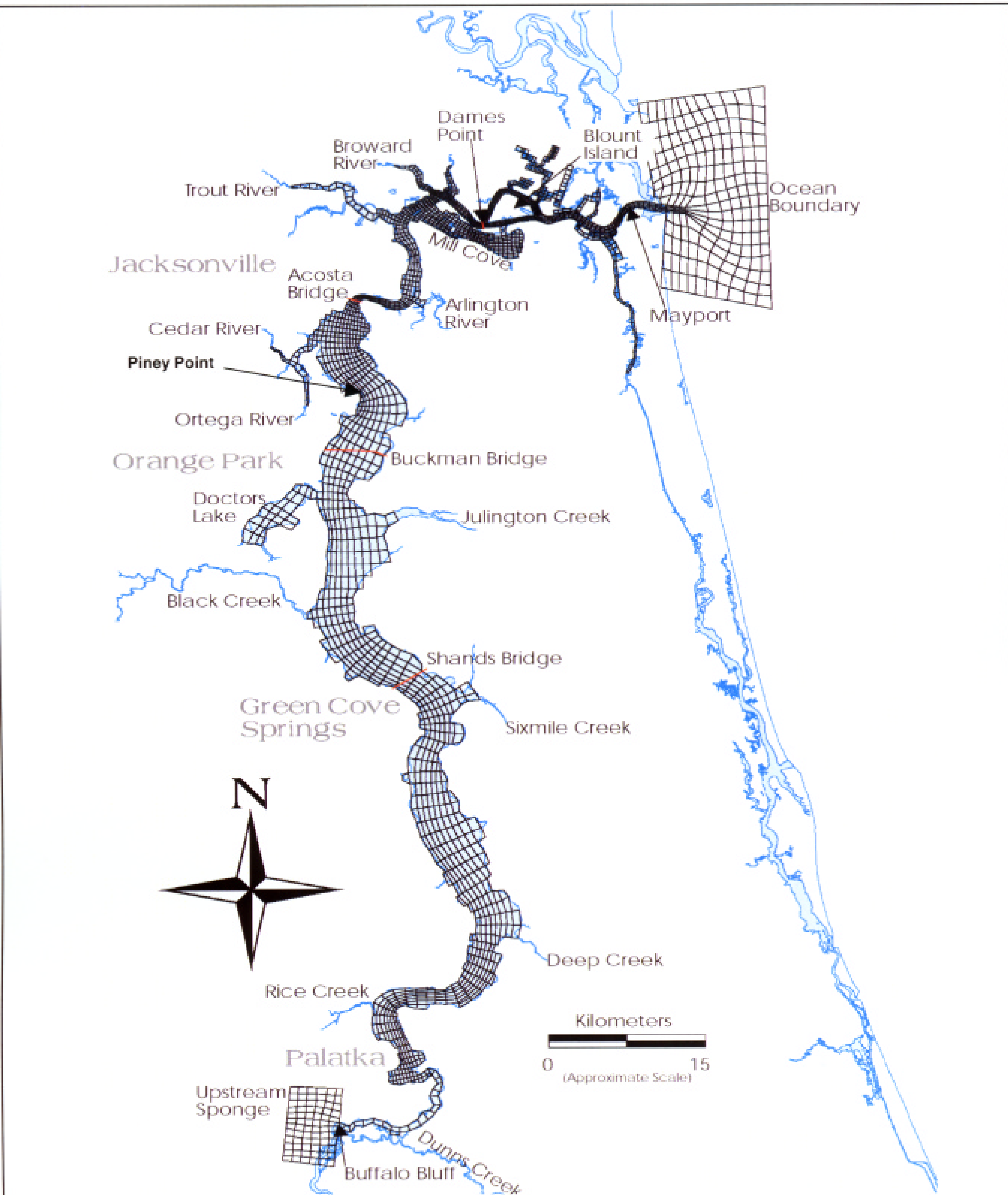


FIGURE 3-1.

BOUNDARY-FITTED MODEL GRID OF THE LOWER ST. JOHNS RIVER

Source: SJRWMD, 2002.

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### 3.3.2 TRIBUTARY INFLOWS

The LSJR EFDC model has 62 freshwater tributary inflow points. Eleven of the 62 points are USGS gauging stations which represent about 89 percent of the total freshwater flow volume. The freshwater discharges at the remaining 51 ungauged inflow points were calculated by SJRWMD using a GIS-based screening level hydrologic model, the Pollutant Loading Screening Model (PLSM) (Adamus and Bergman, 1993; Hendrickson and Konwinski, 1998), that computes seasonal runoff according to rainfall and land use.

### 3.3.3 METEOROLOGICAL CONDITIONS

A spatially constant, time-varying wind field was applied to the model using hourly wind data at Jacksonville Naval Air Station. Spatially uniform rainfall was applied to the model based on the composite of eight rainfall stations located throughout the LSJR basin. Daily total evaporation data collected at Gainesville, Florida, by NOAA were used for the model input. A pan coefficient of 0.78 (Kohler *et al.*, 1959) was applied to the pan evaporation data to estimate lake/open water evaporation.

## 3.4 MODEL CALIBRATION

As mentioned previously, hydrodynamic calibrations were conducted for both the fine- and coarse-grid versions of the LSJR EFDC model. The calibration results indicated that the model is capable of simulating water surface elevation, tidal flows, and salinity with reasonable accuracy. ECT also conducted model verification for the fine-grid model using dye study and salinity data collected in 1999, a very dry year. Figure 3-2 shows the simulated salinity versus the observed values at the Buckman Bridge, and Figure 3-3 shows the simulated salinity versus the observed values at the Shands Bridge. The verification results indicate that the EFDC model can provide an accurate representation of salinity intrusion patterns even under unusually dry conditions.

## 3.5 MODEL SCENARIOS

A total of four freshwater-flow scenarios were evaluated using the EFDC model as part of the salinity assessment in the LSJR:

- Baseline (existing) freshwater flow conditions.

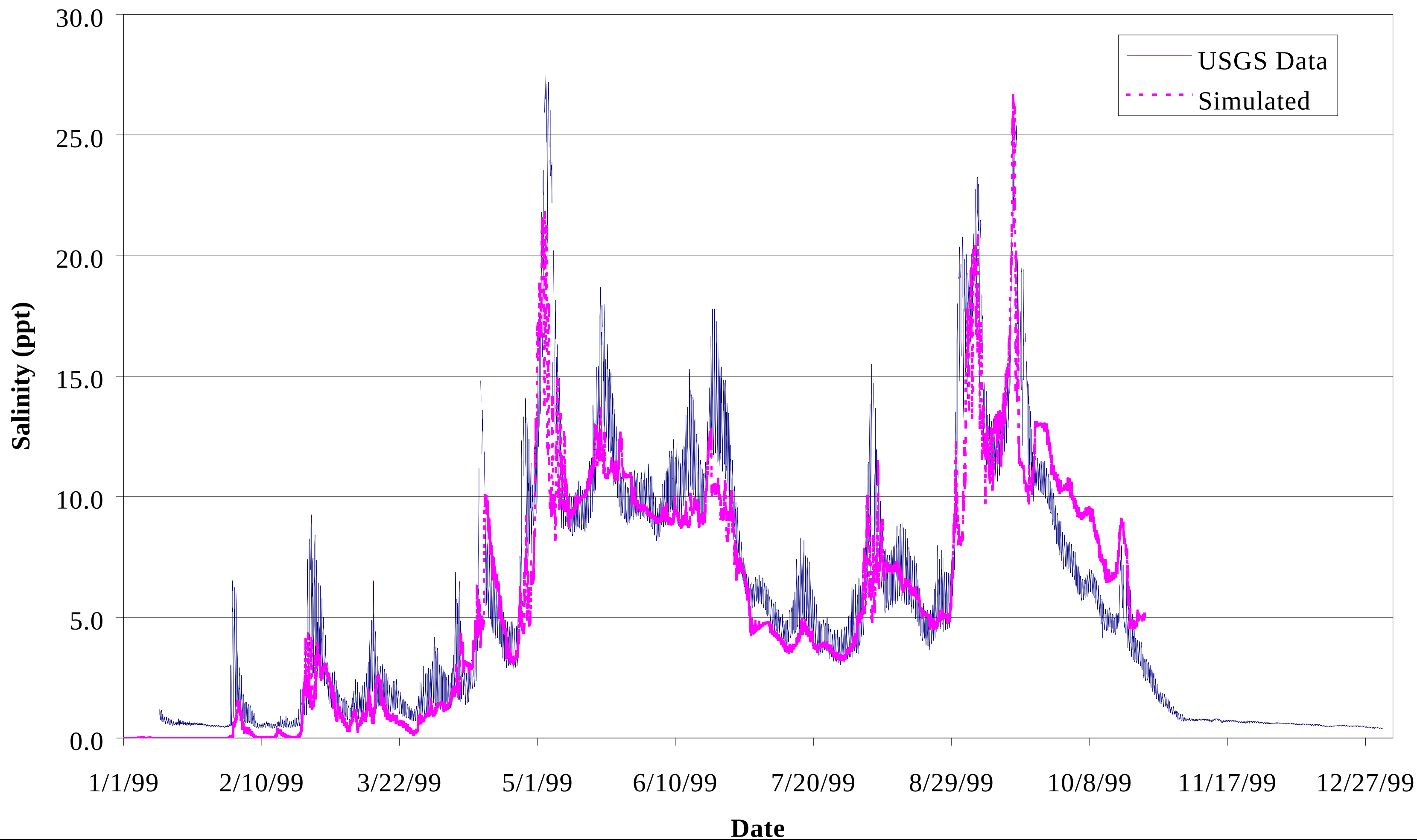


FIGURE 3-2.

MODEL VERIFICATION RESULT—SALINITY AT BUCKMAN BRIDGE

Source: USGS, 2001; ECT, 2001.

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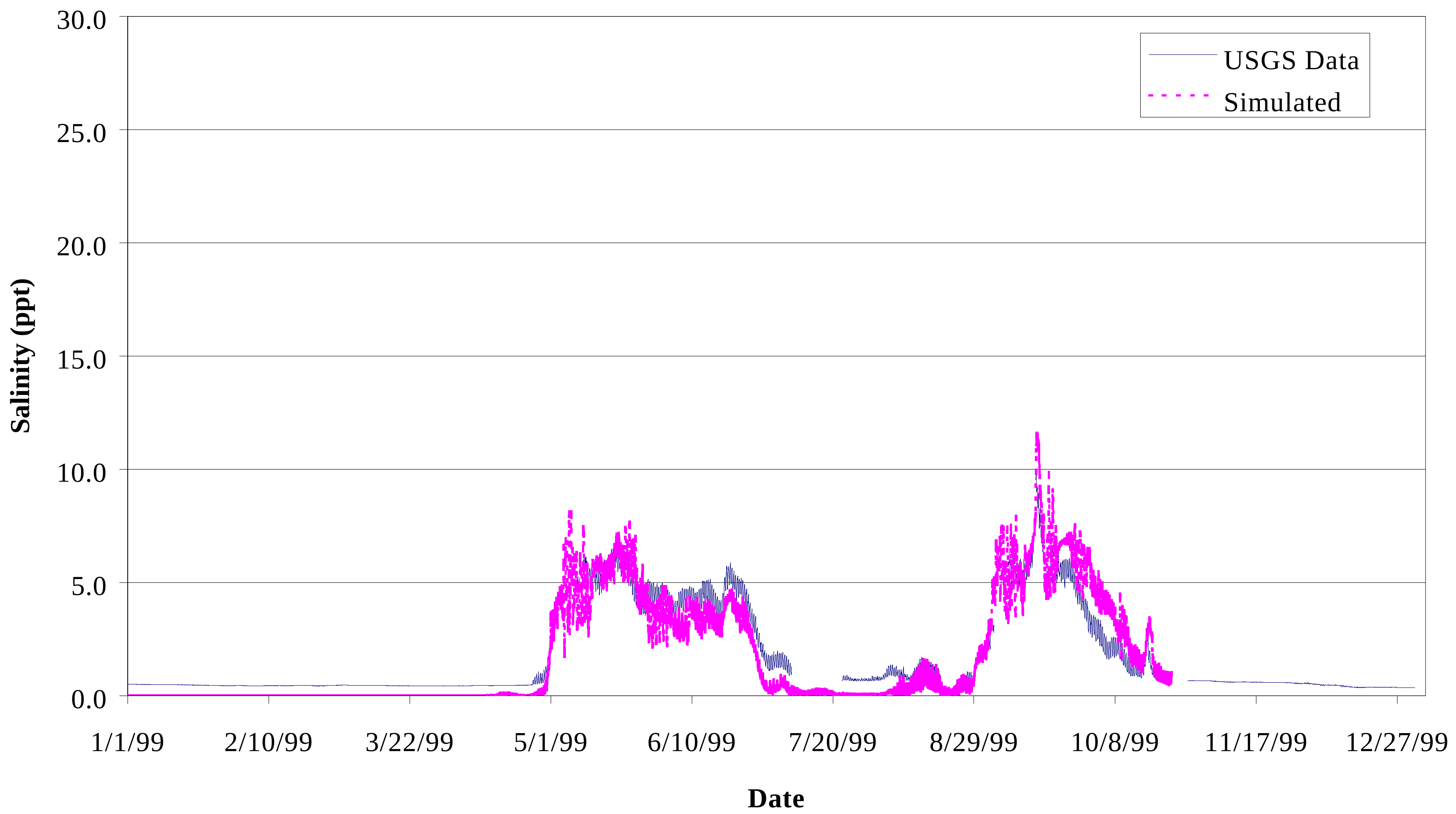


FIGURE 3-3.

MODEL VERIFICATION RESULT—SALINITY AT SHANDS BRIDGE

Source: USGS, 2001; ECT, 2001.

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- Maximum withdrawal limit of 320 cfs (as limited by the MFL regime).
- Withdrawal limit of 160 cfs (50 percent less than the maximum withdrawal rate defined by the MFL regime).
- Withdrawal limit of 480 cfs (50 percent more than the maximum withdrawal rate defined by the MFL regime).

Hydrological and meteorological data in 1997 through 1999 were used as the boundary input conditions for the model to include both a wet El Ninõ period in 1997-98 and an extreme dry year in 1999. Figure 3-4 shows the upstream freshwater inflow at Buffalo Bluff for the baseline condition. The upstream inflows to the LSJR are computed based on the withdrawal schedules defined in Sections 1.1 and 1.2 and depending on the St. Johns River water level near DeLand. Figure 3-5 shows the water level at the St. Johns River near DeLand for the period of model simulation (1997-1999). Figure 3-6 shows the tide data at Mayport near the ocean boundary for the period of model simulation.

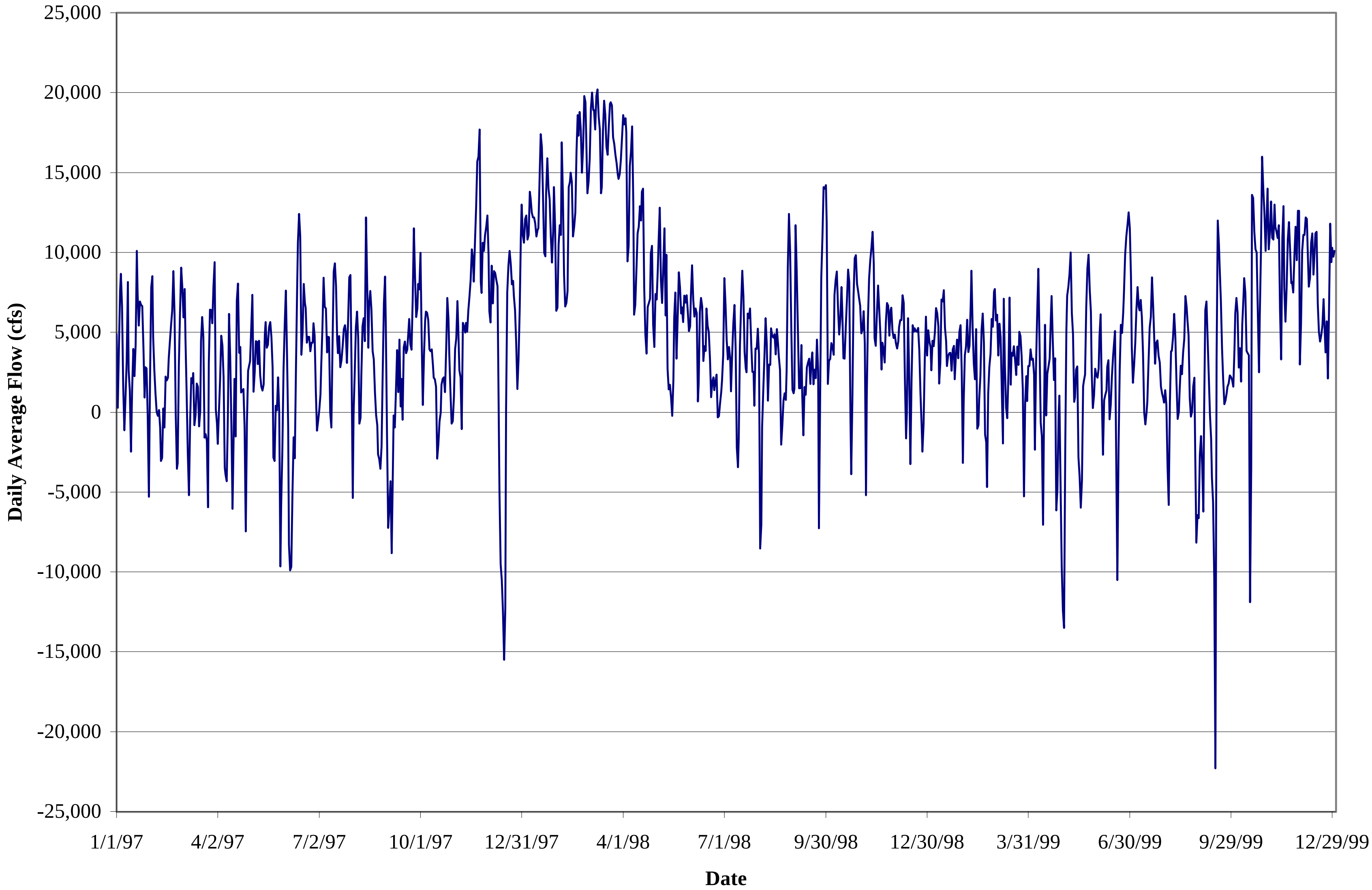


FIGURE 3-4.

DAILY AVERAGE FLOW DATA AT BUFFALO BLUFF (1997-1999)

Source: USGS, 2002.

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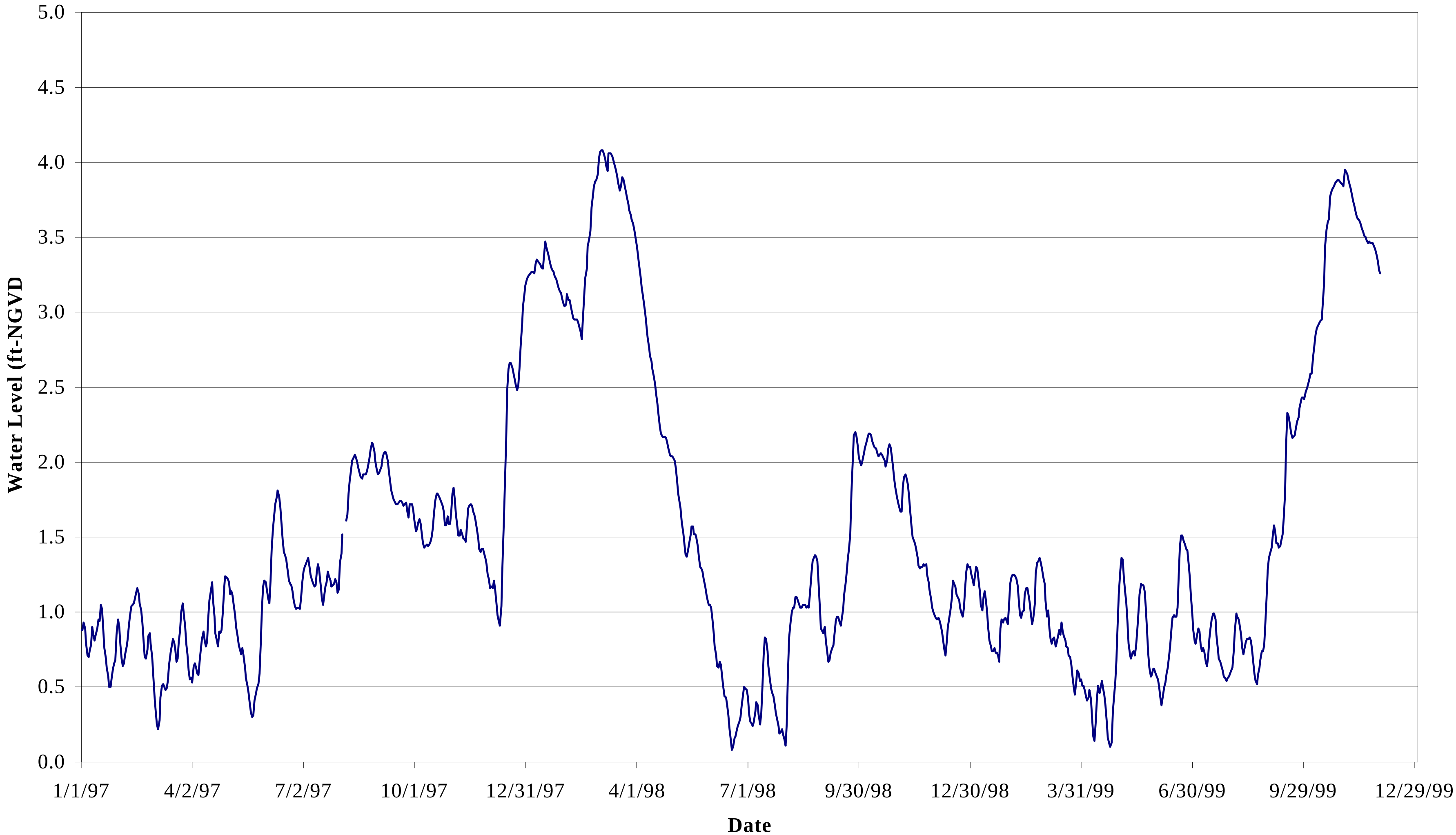


FIGURE 3-5.

DAILY AVERAGE WATER LEVEL IN THE ST. JOHNS RIVER NEAR DELAND (1997-1999)

Source: USGS, 2002.

Environmental Consulting & Technology, Inc.

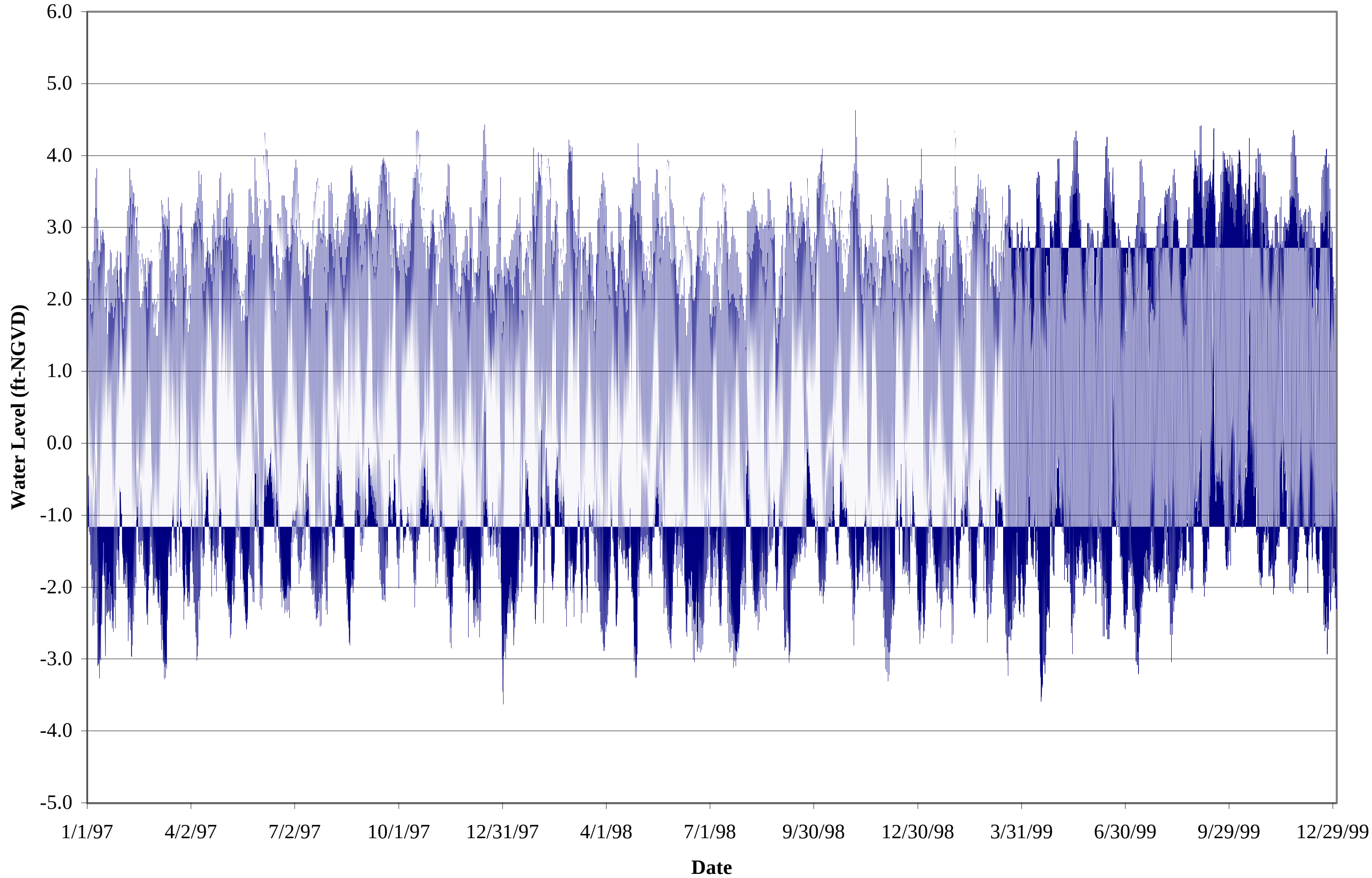


FIGURE 3-6.

TIDE DATA AT MAYPORT (1997-1999)

Source: NOAA, 2002.

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# 4.0 RESULTS

The following sections present the EFDC model simulation results of the salinity projections for the baseline flow conditions and the three alternative flow regimes described in Section 1.2. Statistical analyses of the model results were conducted to quantify the effects of freshwater flow reduction on the salinity regime in the LSJR. The EFDC model produced salinity time-series at 1-hour intervals for the 3-year period (1997-1999) at 60 locations in six vertical layers for four flow scenarios. The total information provided by the model was quite massive. For conciseness, all data presentations and analyses in this section represent vertically averaged salinity values. Also, frequency analyses of the simulated salinity results were presented at 15 selected locations shown in Figure 4-1; 11 locations in the main river and 4 locations in tributaries. Federal Point was selected to be the most upstream location for frequency analysis because of the insignificant salinity intrusion there (mean salinity is less than 0.5 ppt).

## 4.1 BASELINE SALINITY CHARACTERIZATION

Maximum, average, and minimum salinities for each day within the 3-year simulation period were computed at all 60 time-series output locations. Averages of the daily maximum, daily average, and daily minimum salinities for the 3-year simulation period were computed and are presented in Figure 4-2. The results indicate that the average salinity near the river mouth is about 32.1 ppt, and is reduced to 14.8 ppt at Drummond Point river mile (RM) 14.3, 11.1 ppt at the Jacksonville University (JU) (RM 19.2), 7.2 ppt at the Acosta Bridge (RM 23.7), 2.7 ppt at the Buckman Bridge (RM 33.9), and 0.9 ppt at Green Cove Springs (RM 47.9). The daily salinity fluctuations were computed at each location by taking the difference between daily maximum and daily minimum salinity. The 3-year average of the daily salinity fluctuations was then computed for each location. Figure 4-3 shows the averages of daily salinity fluctuations at various locations along the main stem of the river. The results show that the average daily salinity fluctuation is about 8.1 ppt near the river entrance, and the greatest salinity fluctuation occurs near Blount Island (RM 8.8) with an average daily fluctuation range of 14.1 ppt. Further upstream from this point, the diminishing salt exchange with the ocean gradually reduces

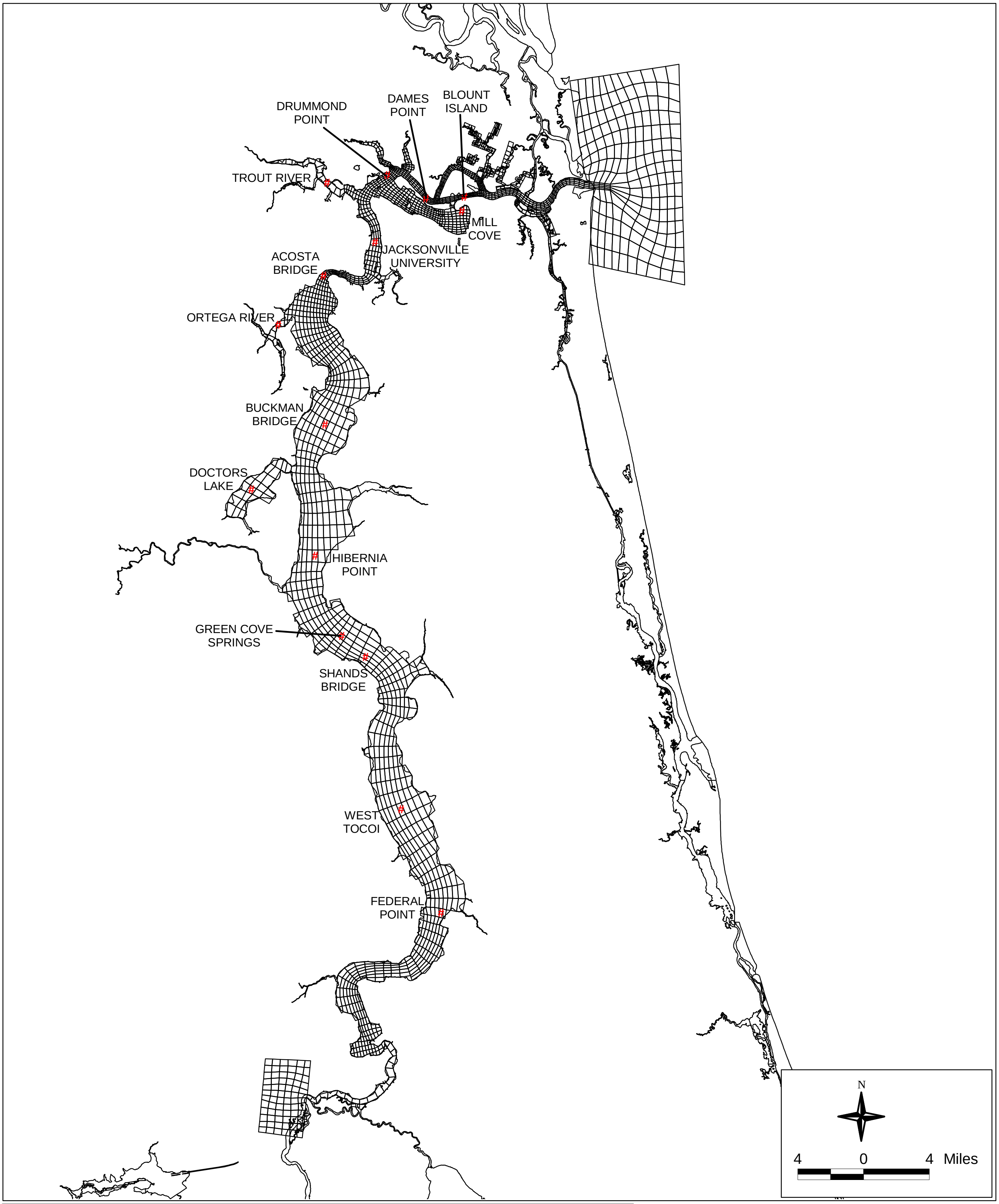


FIGURE 4-1.

SELECTED LOCATIONS FOR FREQUENCY ANALYSES

Sources: SJRWMD, 2000; ECT, 2002.

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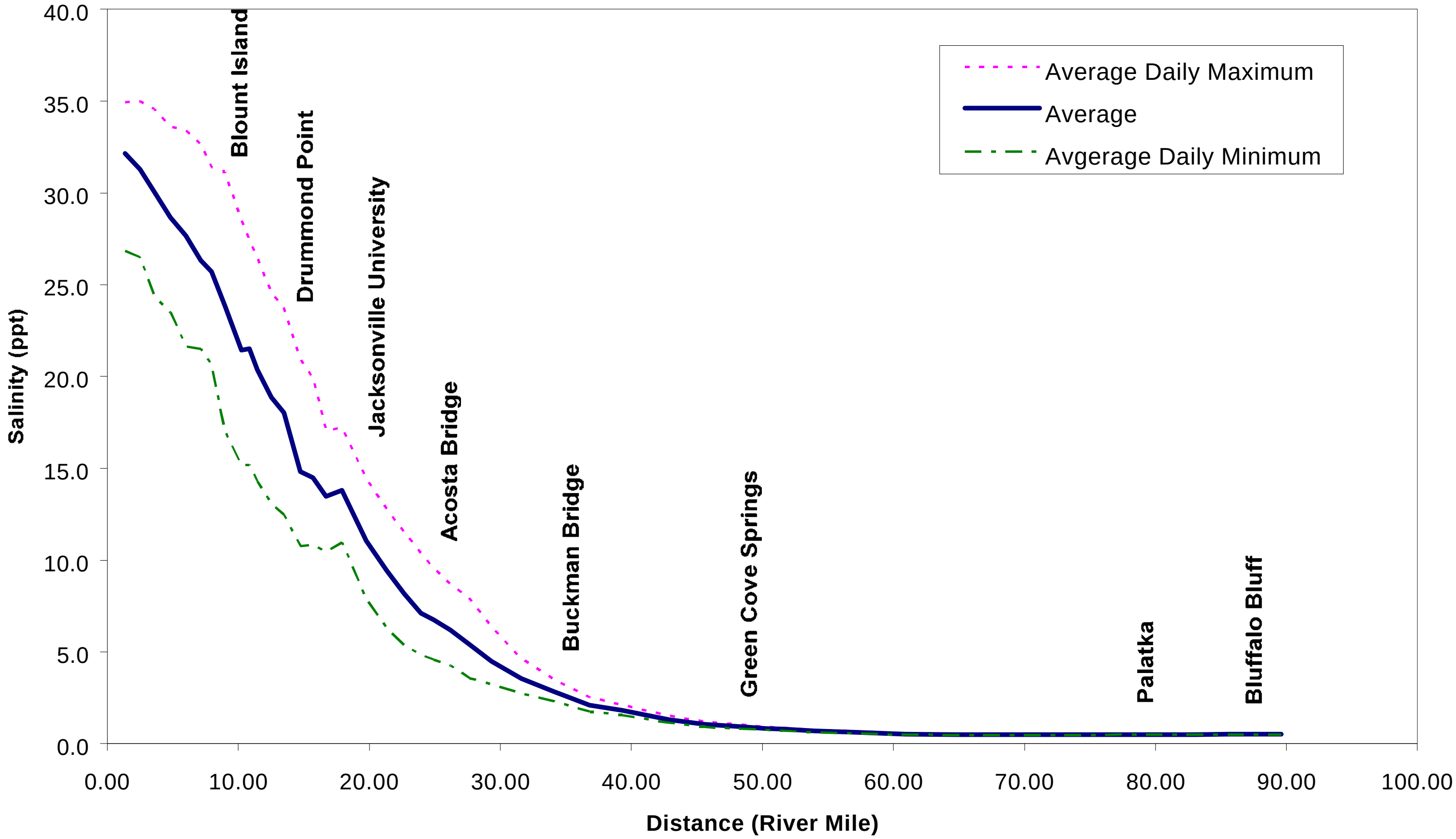



Note: All salinity values are vertically averaged.

FIGURE 4-2.

MODEL-SIMULATED LONGITUDINAL SALINITY PROFILES IN THE ST. JOHNS RIVER—BASELINE CONDITIONS (1997-1999)

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

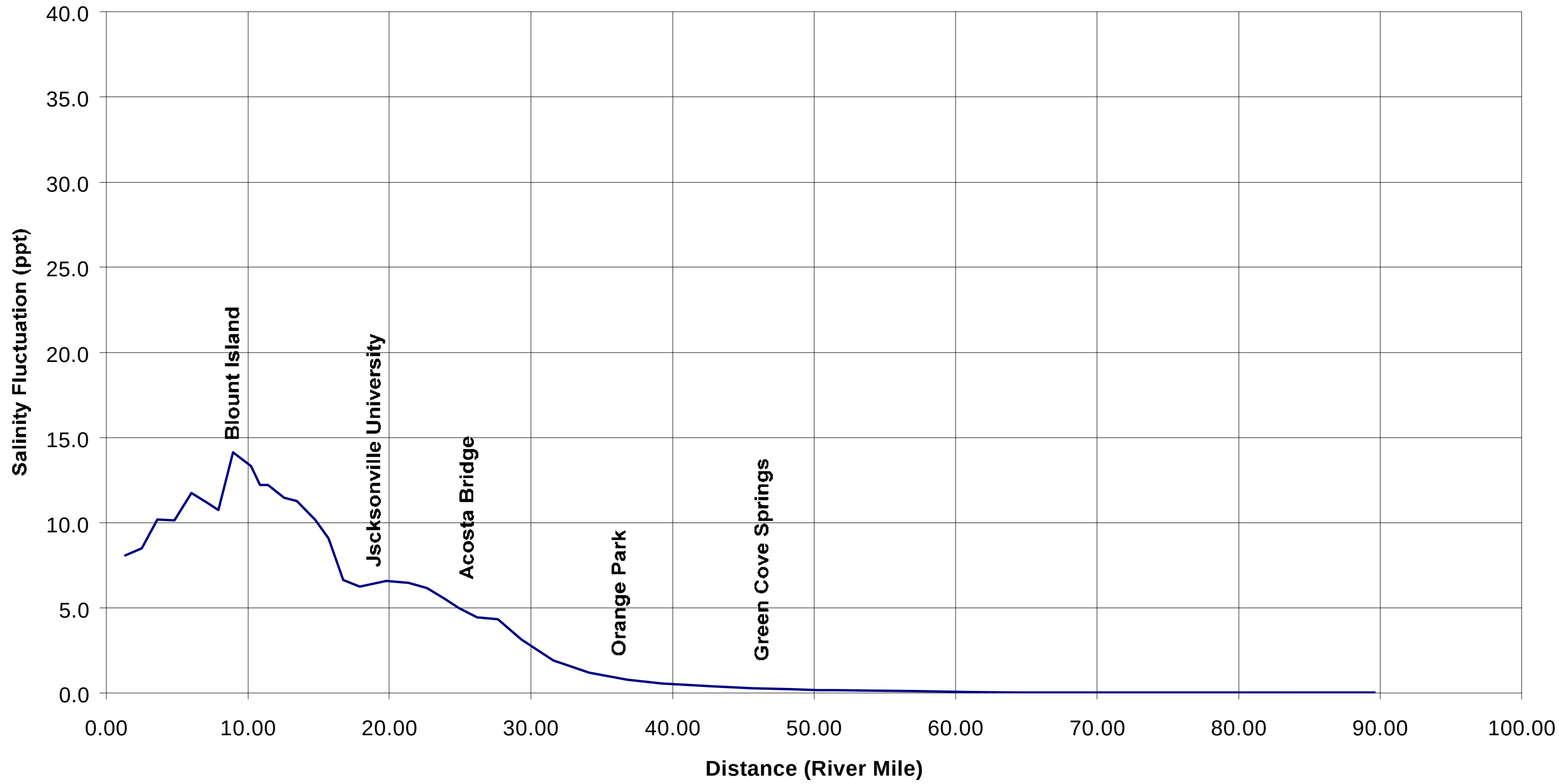



FIGURE 4-3.

AVERAGE DAILY FLUCTUATIONS OF SALINITY IN THE ST. JOHNS RIVER

Source: ECT, 2002.

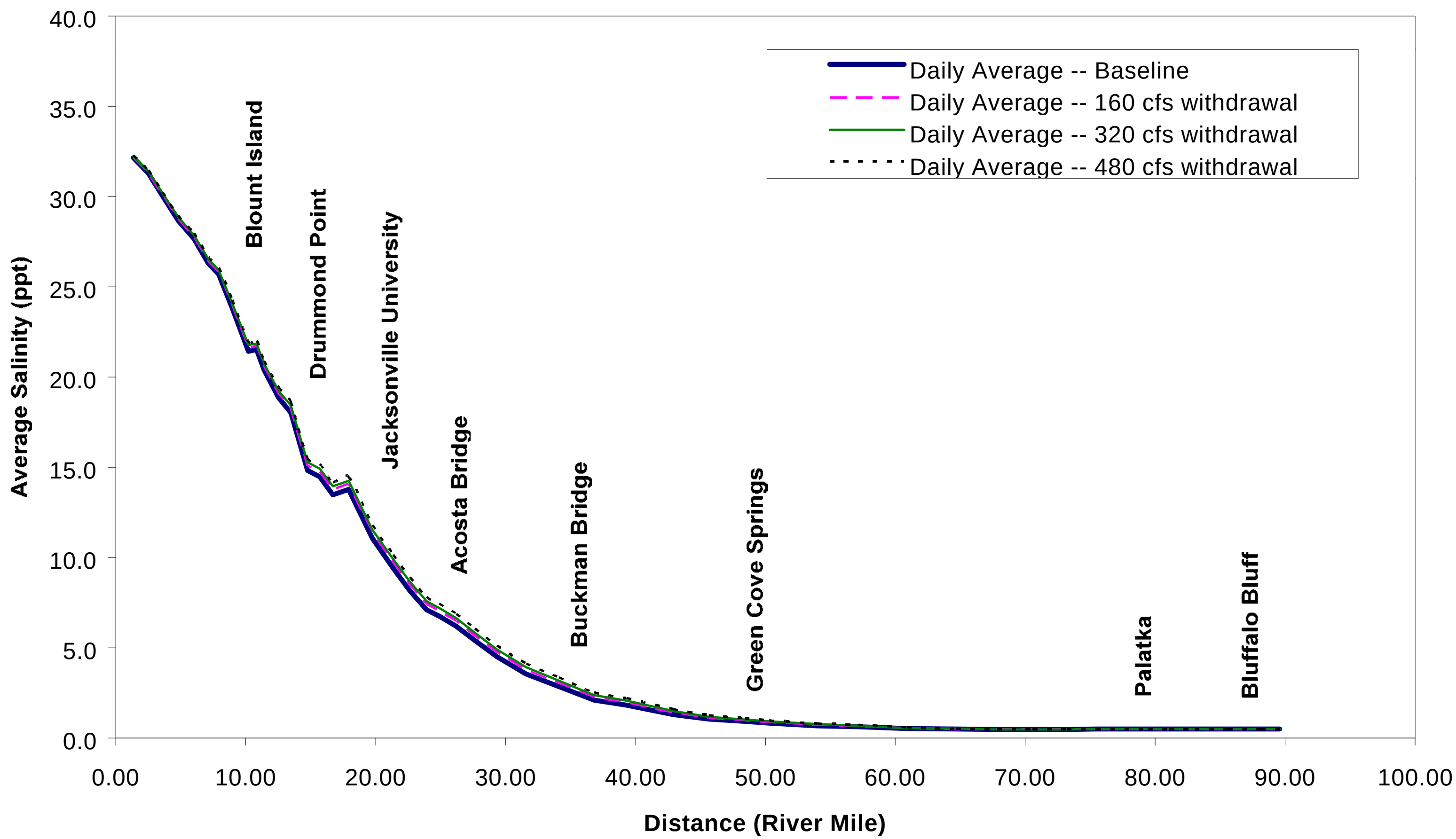
Environmental Consulting & Technology, Inc.

salinity fluctuation to 6.6 ppt at JU, 5.5 ppt at Acosta Bridge, 1.9 ppt at Piney Point (RM 30.8), and 1.1 ppt at Buckman Bridge (RM 33.9).

## 4.2 SALINITY INCREASE DUE TO FRESHWATER FLOW REDUCTION

Similar to the baseline case, the 3-year average salinity was computed at various locations along the river for each surface water withdrawal scenario and was compared to the baseline case. Figure 4-4 presents the longitudinal profiles of the 3-year average simulated salinity for the baseline and 160-, 320-, and 480-cfs withdrawal scenarios. The results show that the average salinity increase caused by the withdrawal scenarios will not be significant (less than 0.5 ppt at 320-cfs withdrawal limit). Figure 4-5 presents the 3-year average salinity increase along the river for each withdrawal scenario. The results indicate that the greatest average salinity increase occurs near JU. The 3-year average increases of salinity at JU are 0.33, 0.49, and 0.74 ppt for the withdrawal limits of 160, 320, and 480 cfs, respectively. The 3-year average salinity increases at the Buckman Bridge are 0.20, 0.33, and 0.51 ppt for 160, 320, and 480 cfs withdrawal limits, respectively. There will be less than 0.01 ppt change in average salinity in the river upstream from the Federal Point (RM 67.1) at the given withdrawal rates.

The salinity distribution in an estuary is influenced primarily by the freshwater inflows from upstream and tributaries and by the ocean saltwater transported upstream by tidal currents. At one extreme, the salinity near the mouth of the river is dominated by the ocean background salinity and it is not likely to increase appreciably by a moderate freshwater reduction. At the other extreme, the upstream end of a river is dominated by the freshwater inflow and its salinity is near zero and it is not subject to appreciable salinity increase due to moderate freshwater reduction. The river segments between these two extremes will exhibit varying degrees of salinity increases according to bathymetry, tributaries, and width of the river. The model projection shows a maximum salinity impact near JU due to flow reduction ranging from 160 to 480 cfs. It could be an indication that the relative influences from the ocean and freshwater inflow may reach a balance in this stretch of the river.




Note: All salinity values are vertically averaged.

FIGURE 4-4.

MODEL SIMULATED LONGITUDINAL AVERAGE SALINITY PROFILES (1997-1999)

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

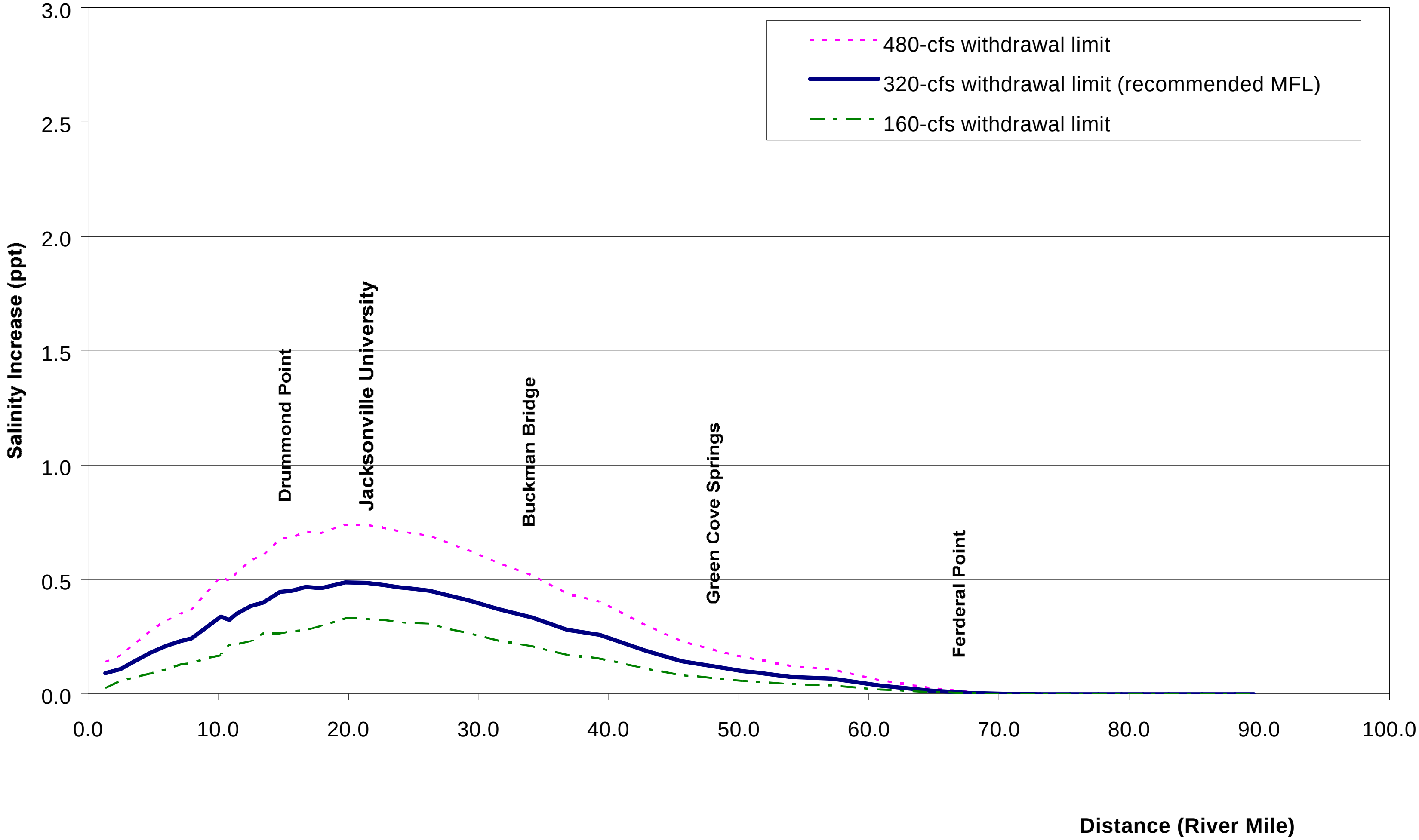



FIGURE 4-5.

AVERAGE SALINITY INCREASE DUE TO FRESHWATER WITHDRAWAL

Source: ECT, 2002.

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Figure 4-6 presents the average salinity increase resulting from the withdrawal limit of 320 cfs MFL, compared with the average salinity in the river and the naturally-occurring daily salinity fluctuations. It shows that the average salinity increase caused by the 320 cfs withdrawal limit is quite small compared to the daily variability of the salinity caused by tidal transport. For example, the average salinity increase at JU (RM 19.2) is 0.49 ppt, while the average salinity is 11.1 ppt and the average daily salinity fluctuation is 6.6 ppt.

In addition to daily tidal variation in salinity, the salinity in LSJR is subject to large seasonal changes as described in Section 2.4. For example, the seasonal salinity changes can be as high as 32 ppt at the Acosta Bridge (RM 23.7) where the projected average daily salinity variation is 5.5 ppt and the projected average salinity increase due to 320-cfs withdrawal limit is only 0.47 ppt. Similarly, the seasonal salinity changes is up to 26 ppt at the Buckman Bridge (RM 33.9) where the average daily salinity variation is 1.09 ppt and the average salinity increase due to 320-cfs withdrawal is 0.33 ppt. The maximum seasonal salinity change is 9.6 ppt at the Shands Bridge (RM 49.9) where the daily salinity variation is 0.16 ppt and the salinity increase due to 320-cfs withdrawal is only 0.10 ppt.

Similarly, Figure 4-7 presents the longitudinal profiles of the 3-year average of the daily maximum salinity for various flow scenarios. Figure 4-8 presents the 3-year average of the daily minimum salinities. The results also indicate that the changes of the daily maximum and minimum salinities will be relatively small at the given withdrawal scenarios. The greatest change of average daily maximum salinity occurs near the Acosta Bridge. It is increased by 0.35, 0.49, and 0.75 ppt for 160, 320, and 480 cfs withdrawal limits, respectively. The greatest change of average daily minimum salinity occurs between JU and Trout River. It is increased by 0.33, 0.49, and 0.75 ppt for 160, 320, and 480 cfs withdrawal limits, respectively.

To quantify the short-term salinity increase due to freshwater withdrawals near DeLand, frequency analyses were conducted for the daily salinity time-series. Figures 4-9 through 4-23 present the cumulative frequency analyses results for the daily average salinity at 15

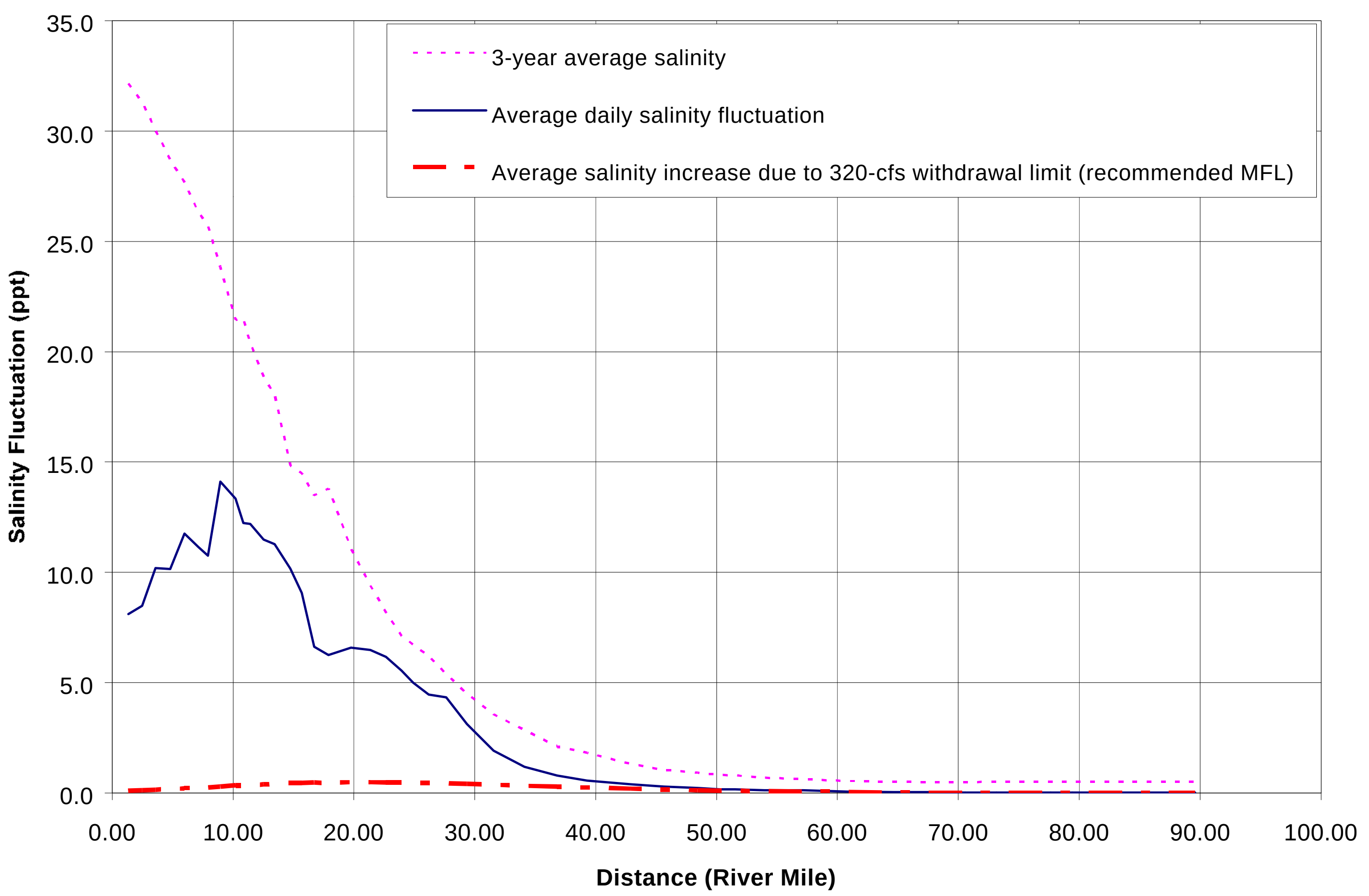
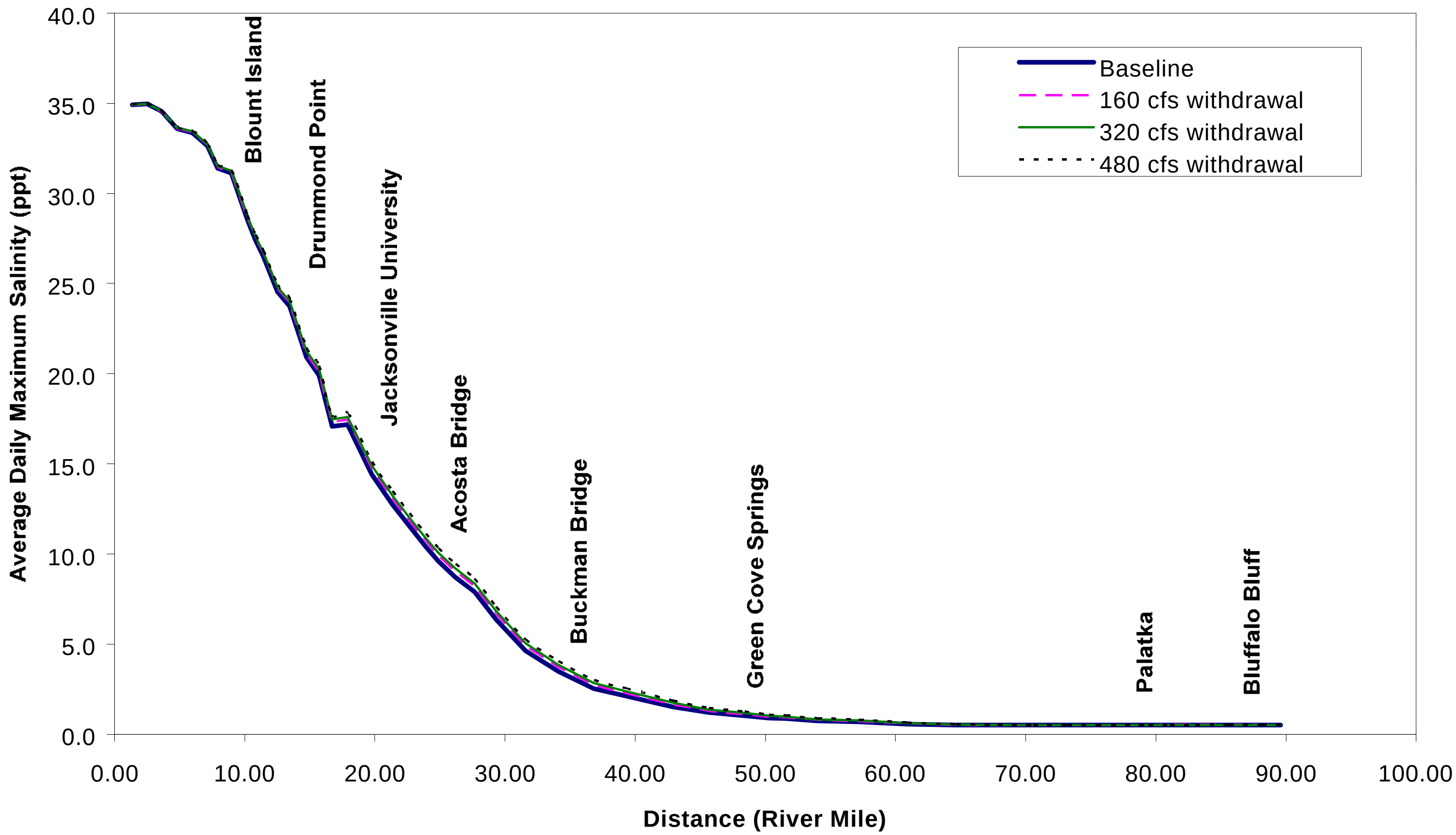



FIGURE 4-6.

AVERAGE SALINITY CHANGES RELATIVE TO DAILY FLUCTUATIONS
IN THE ST. JOHNS RIVER

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.



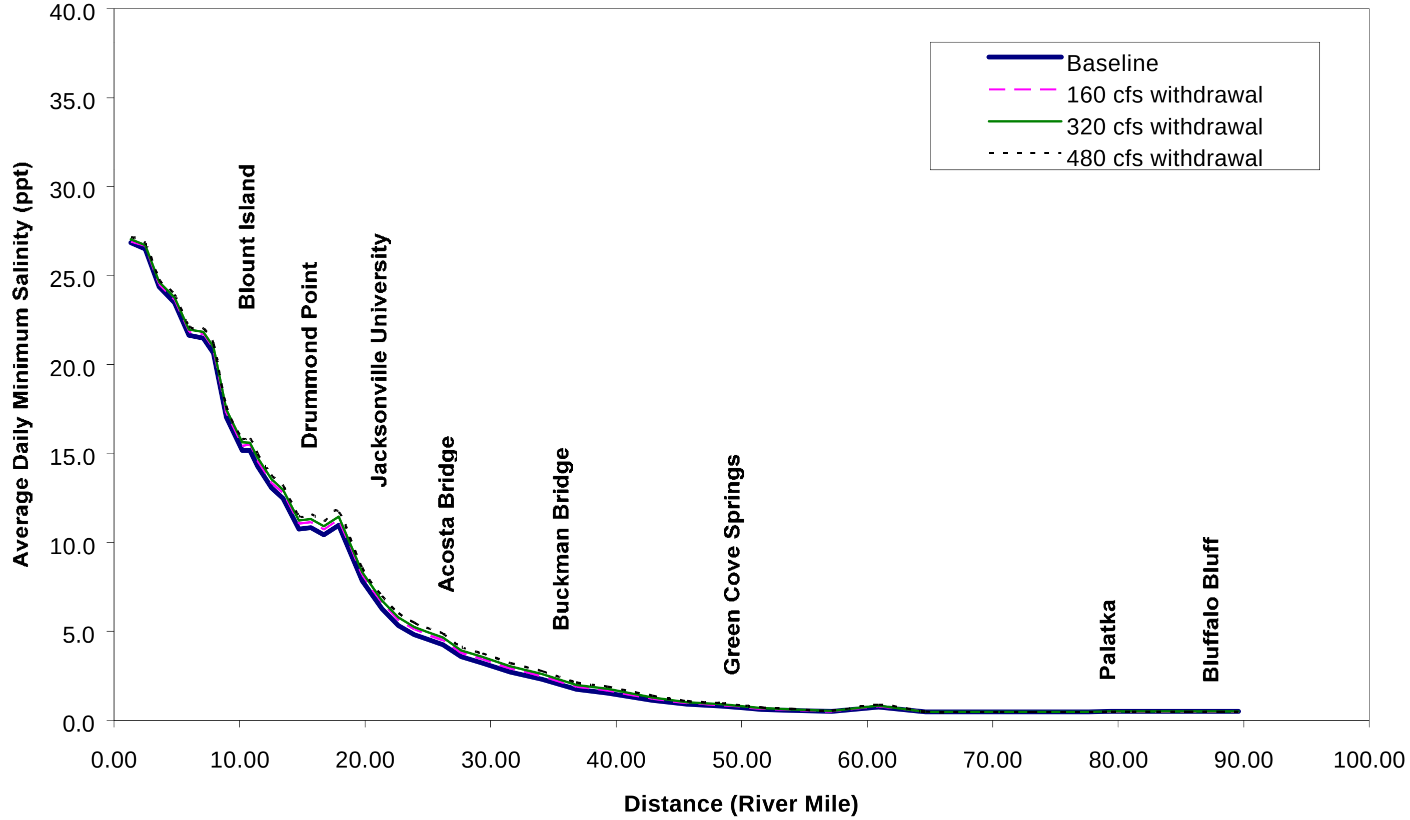

Note: All salinity values are vertically averaged.

FIGURE 4-7.

MODEL SIMULATED LONGITUDINAL AVERAGE DAILY MAXIMUM SALINITY PROFILES (1997-1999)

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.




Note: All salinity values are vertically averaged.

FIGURE 4-8.

MODEL SIMULATED LONGITUDINAL AVERAGE DAILY MINIMUM SALINITY PROFILES (1997-1999)

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

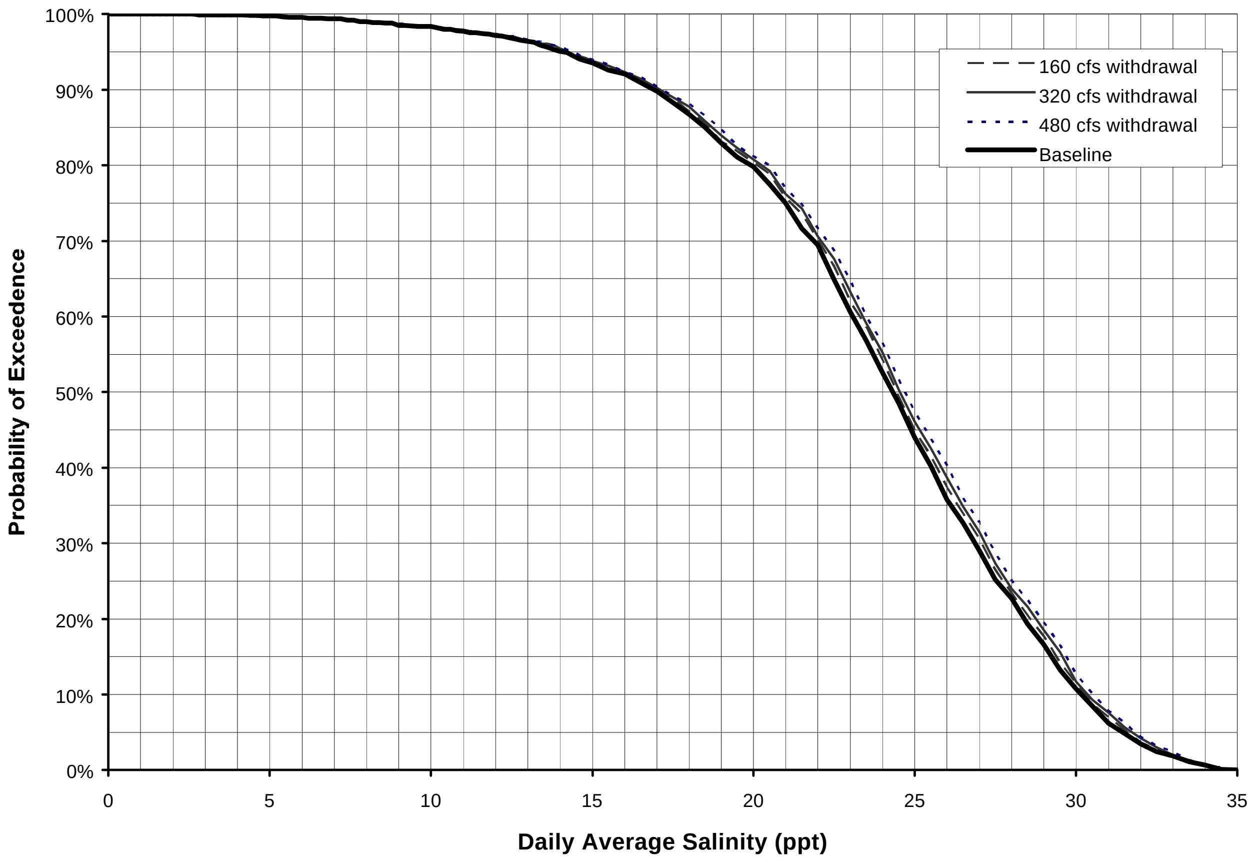



FIGURE 4-9.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR BLOUNT ISLAND

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

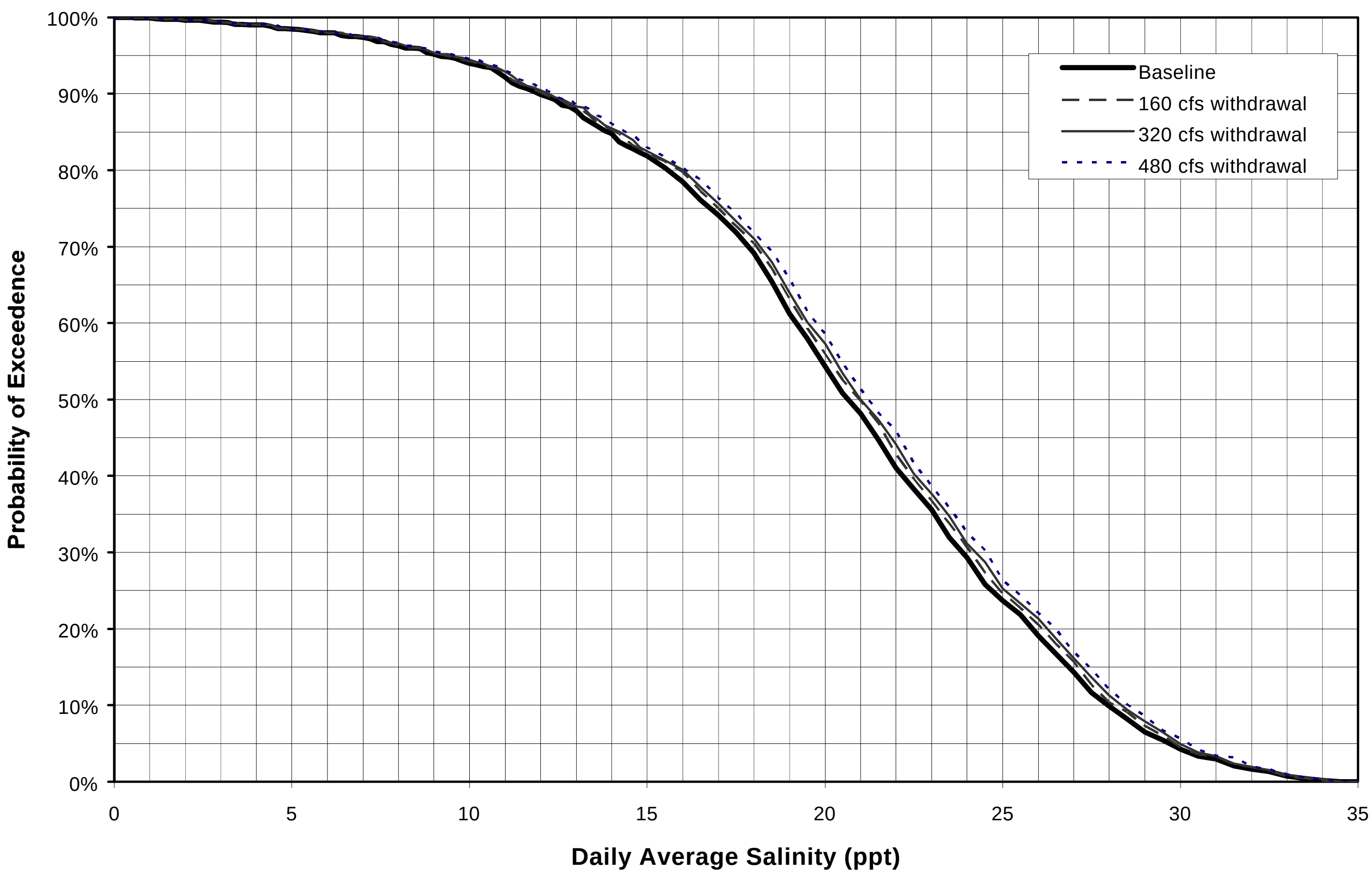



FIGURE 4-10.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY NEAR DAMES POINT

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

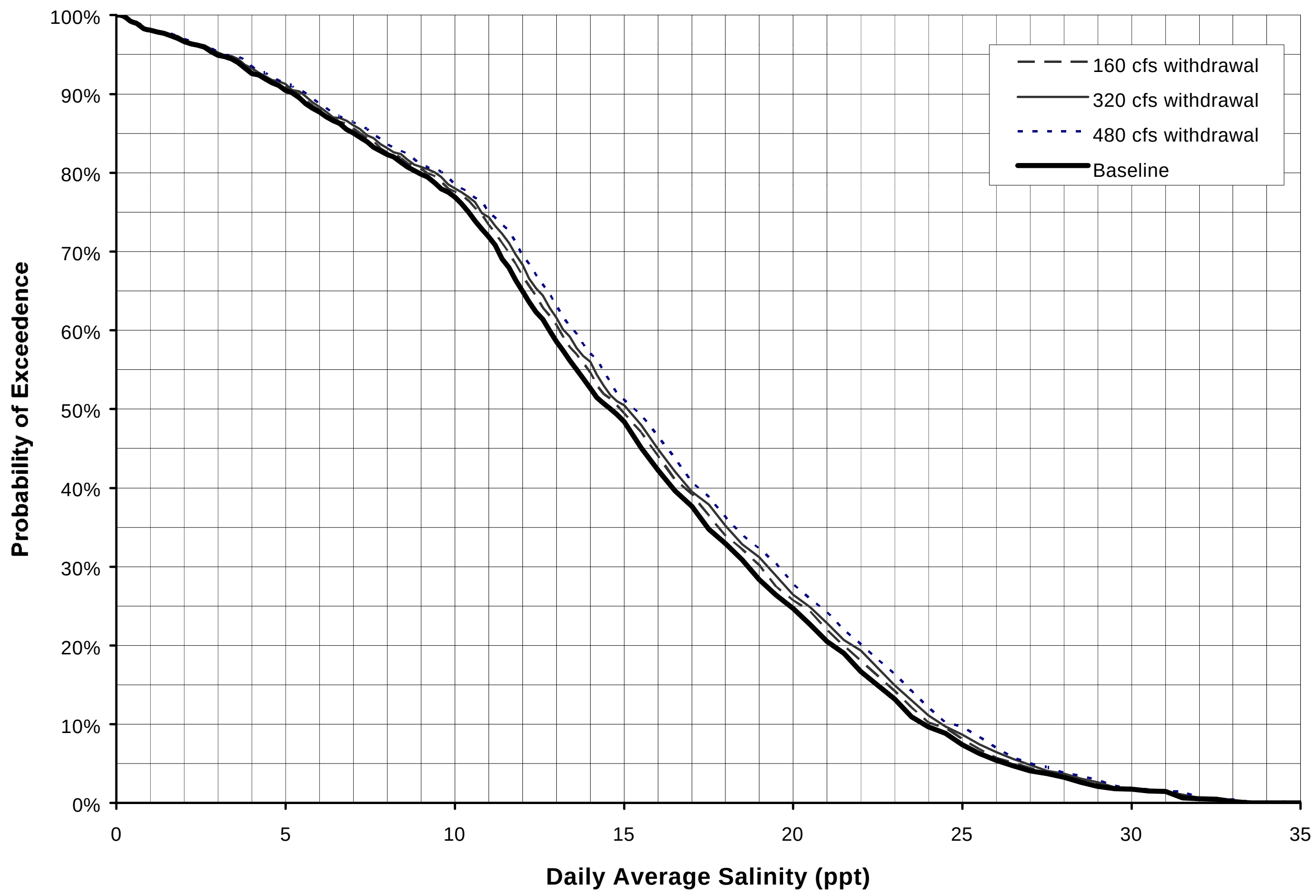



FIGURE 4-11.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR DRUMMOND POINT

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

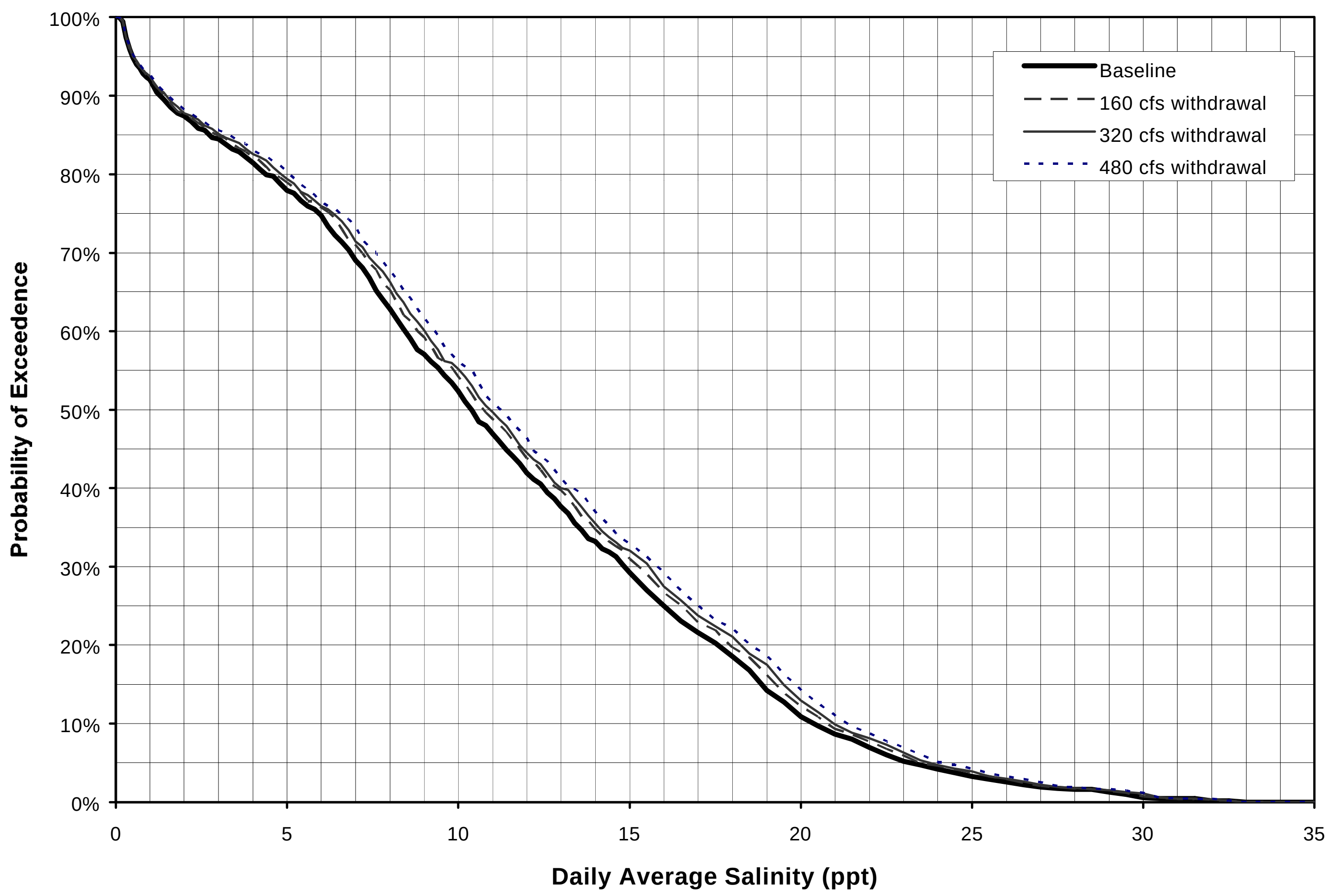



FIGURE 4-12.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR JACKSONVILLE UNIVERSITY

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

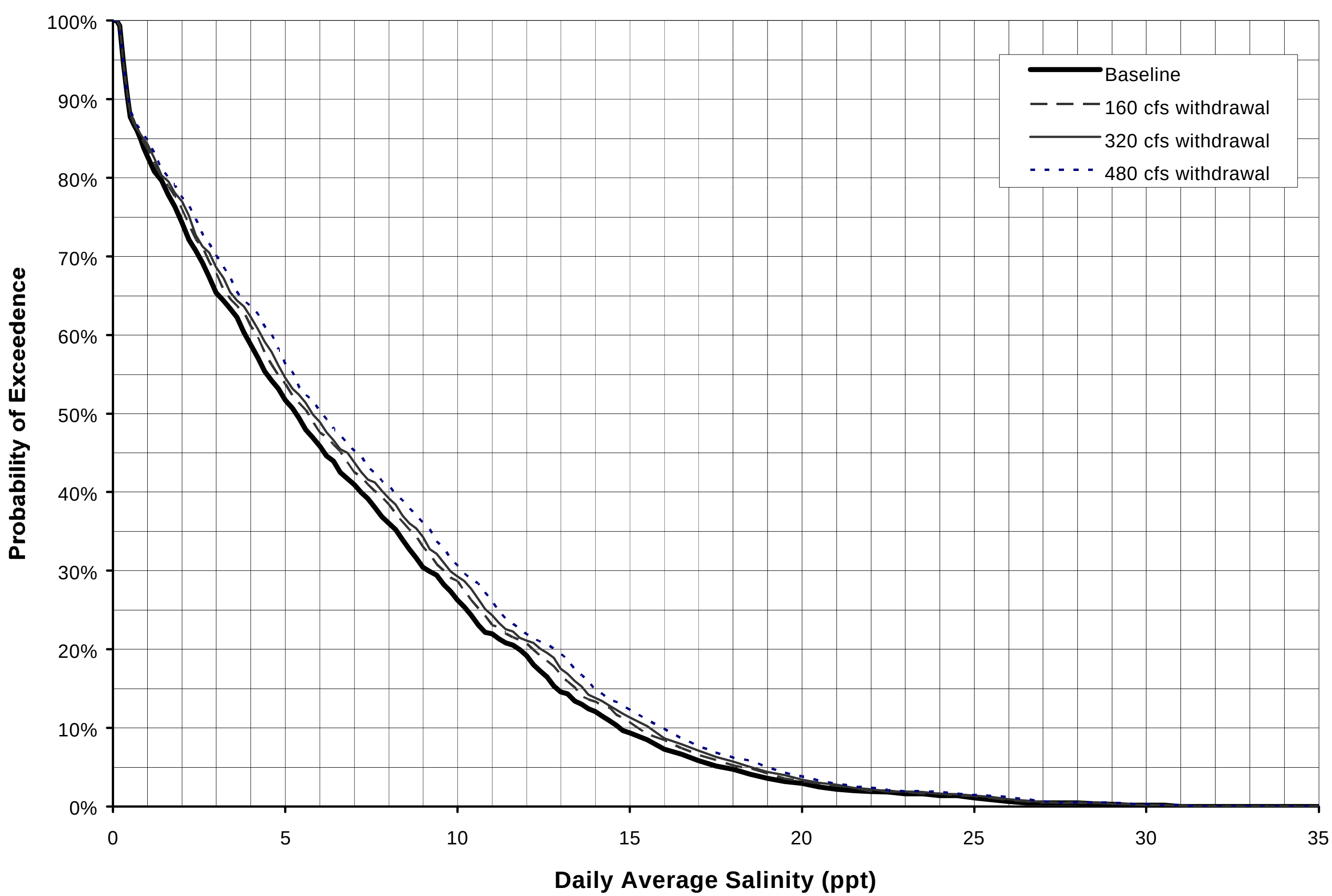



FIGURE 4-13.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT ACOSTA BRIDGE

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

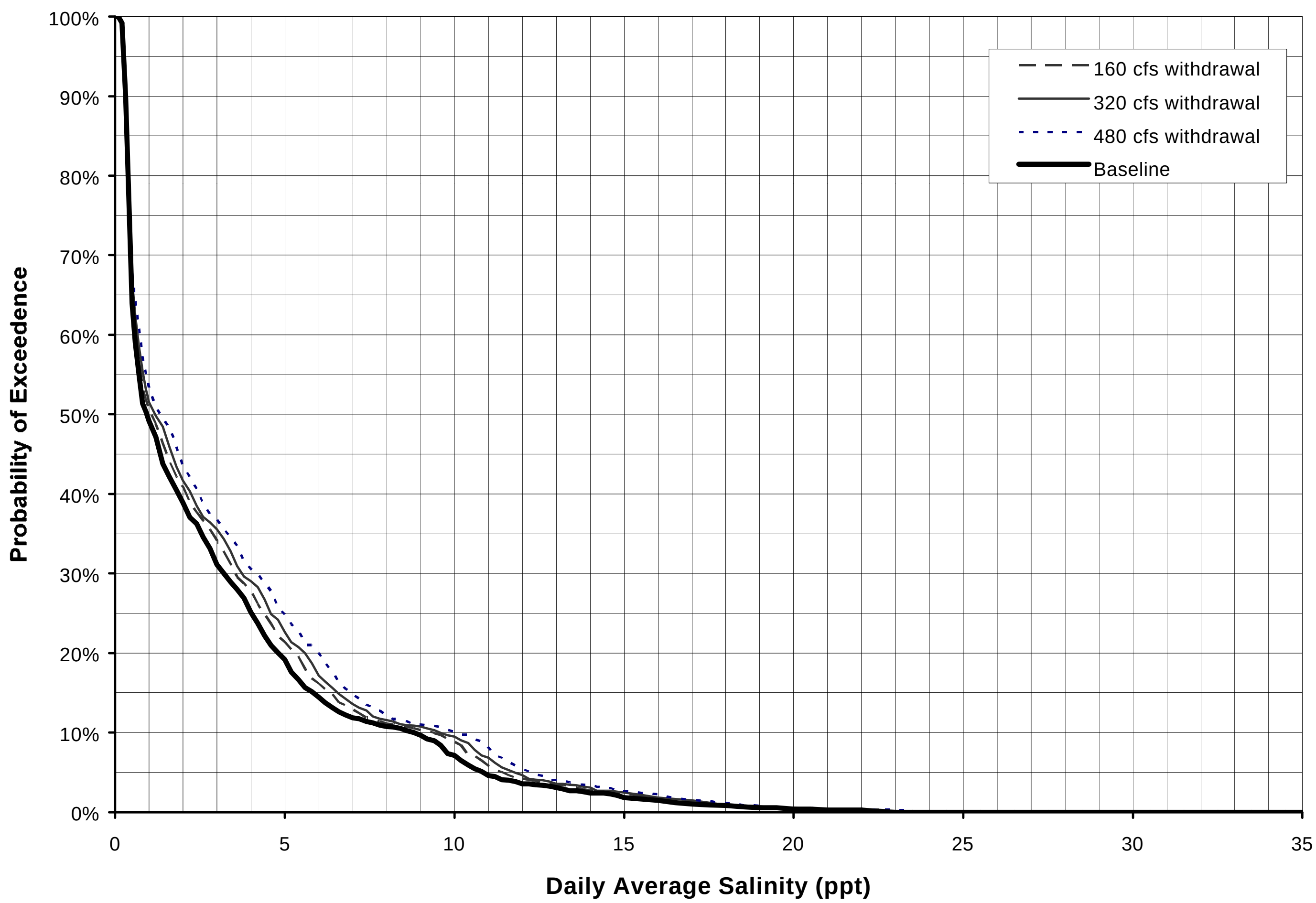



FIGURE 4-14.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT BUCKMAN BRIDGE

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

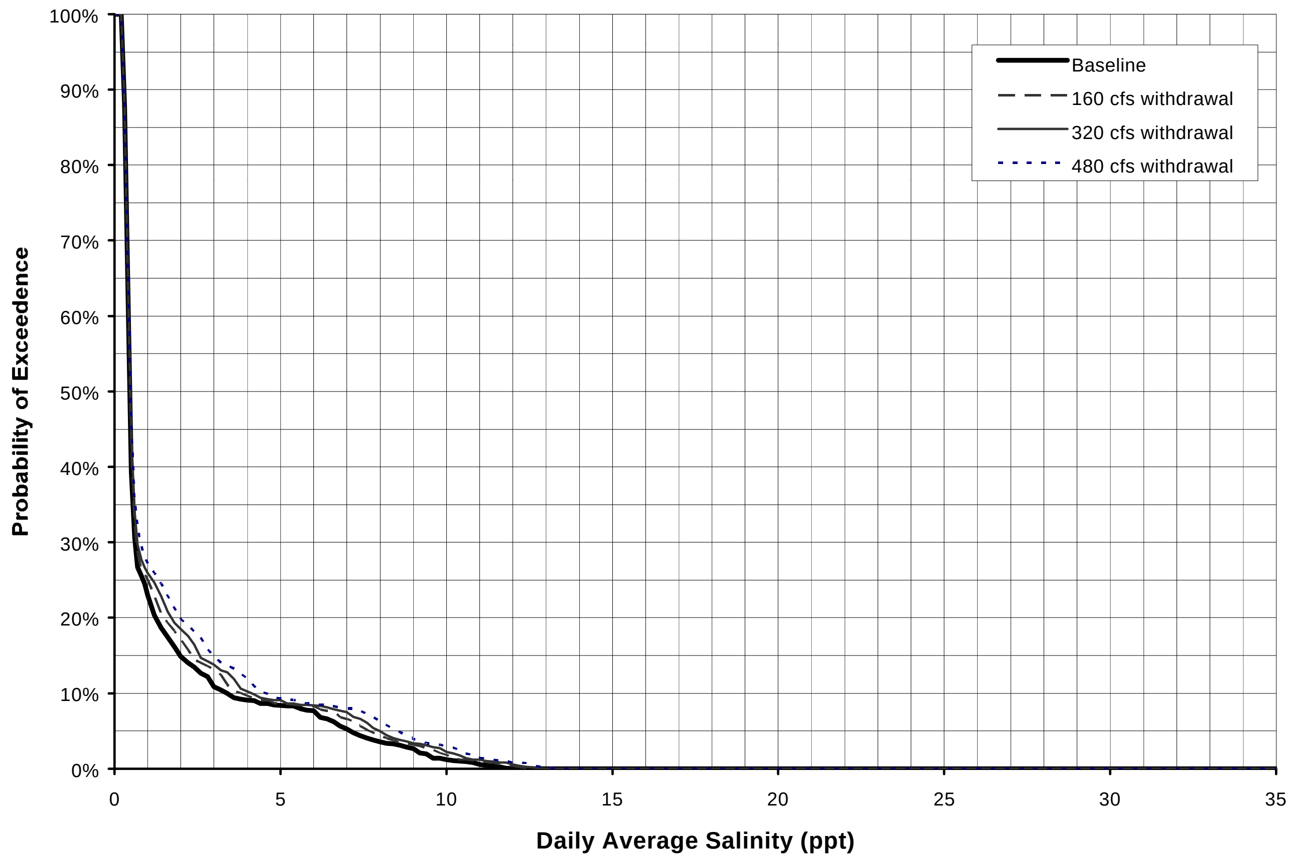



FIGURE 4-15.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY AT HIBERNIA POINT

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

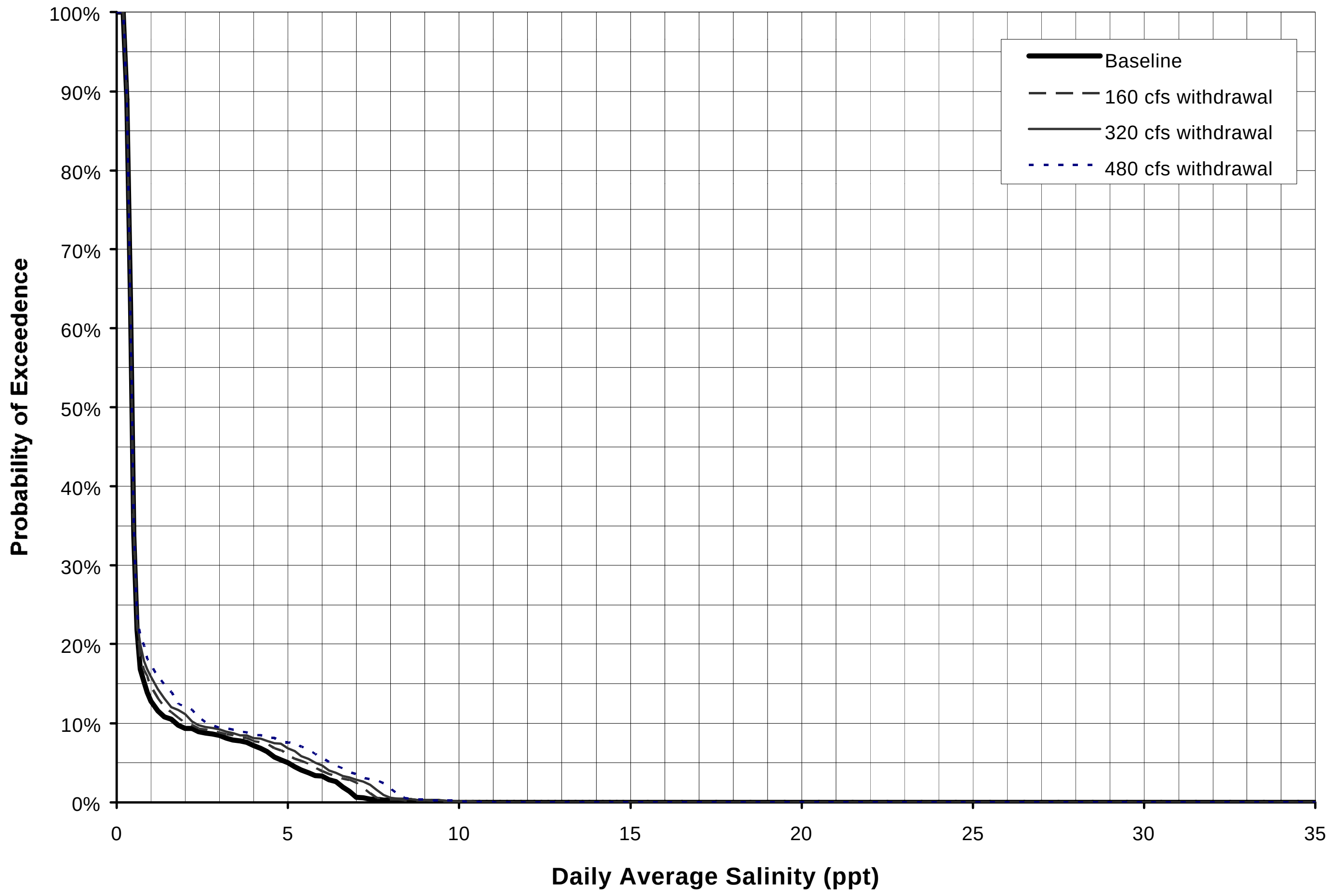



FIGURE 4-16.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR GREEN COVE SPRINGS
Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

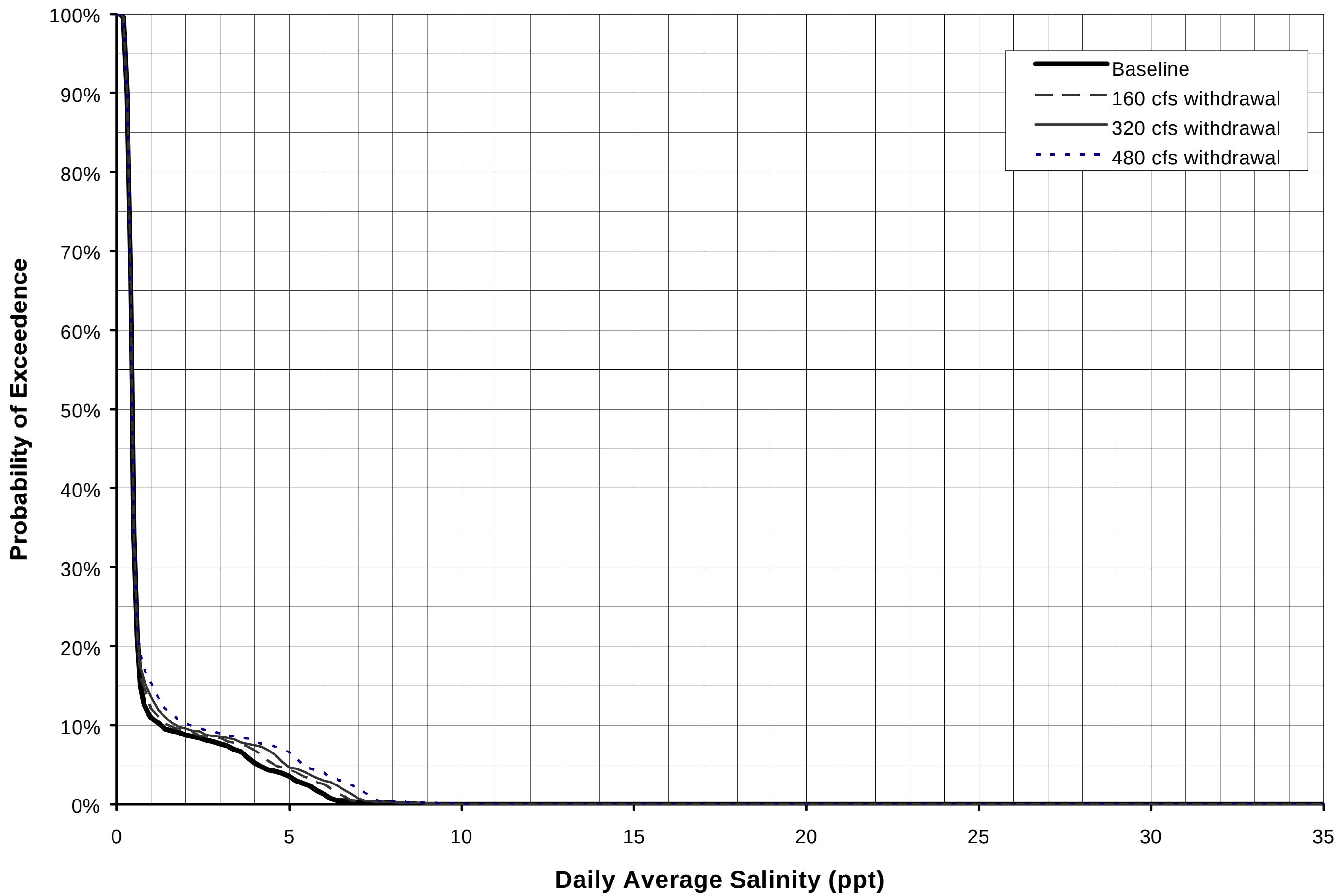



FIGURE 4-17.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT SHANDS BRIDGE

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

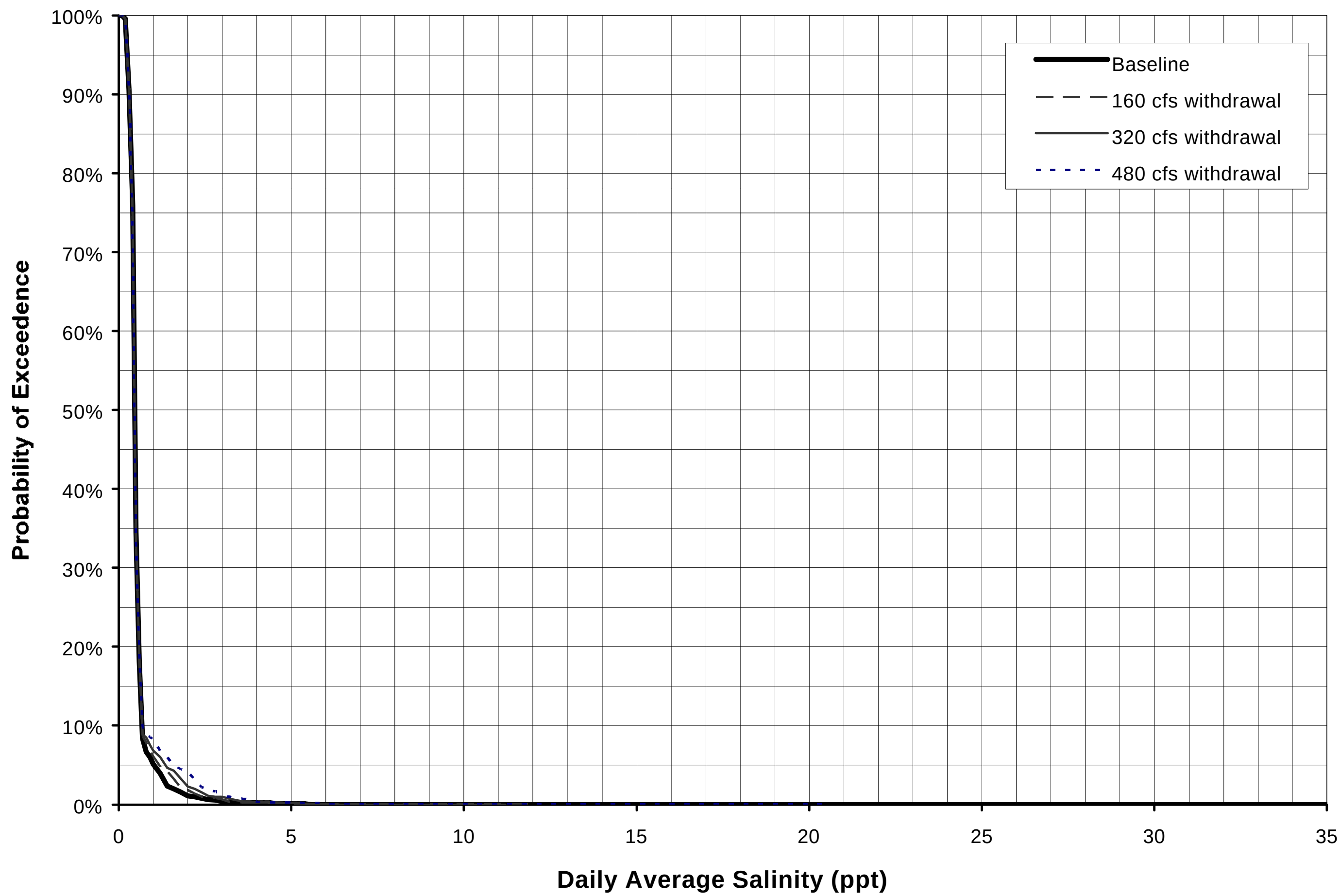



FIGURE 4-18.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR WEST TOCOI

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

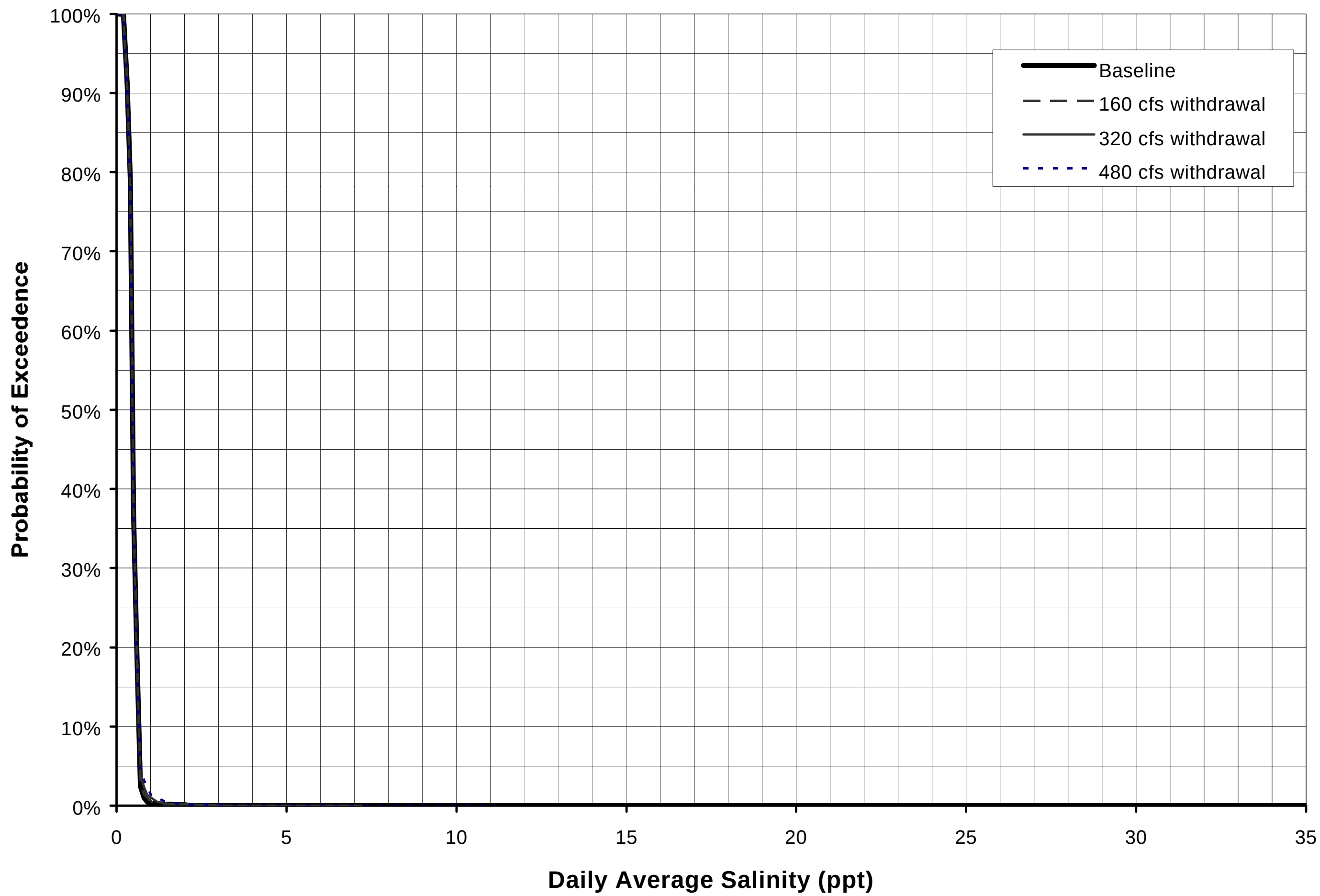



FIGURE 4-19.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
NEAR FEDERAL POINT

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

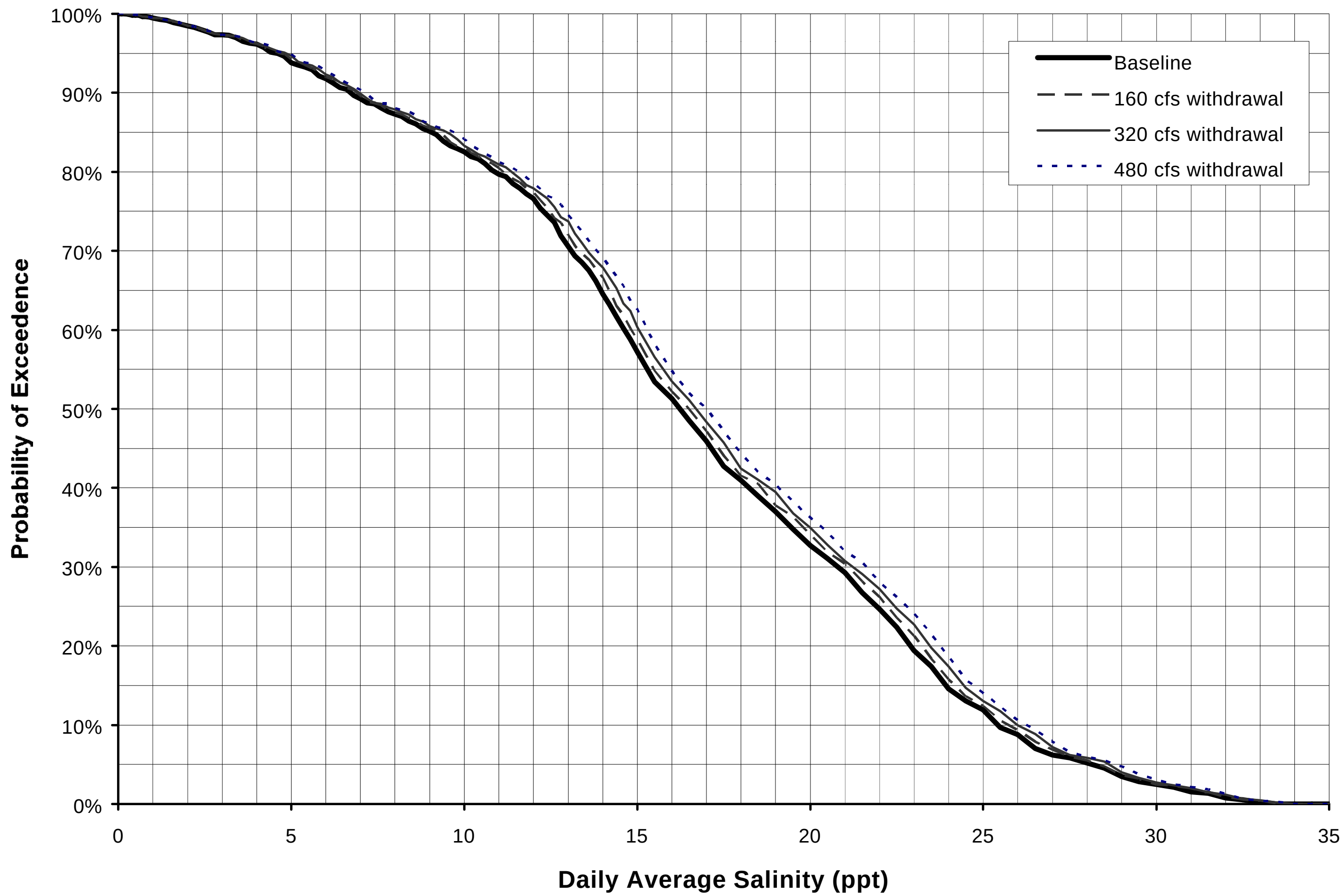



FIGURE 4-20.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT MILL COVE

Source: ECT, 2002.

Environmental Consulting & Technology, Inc.

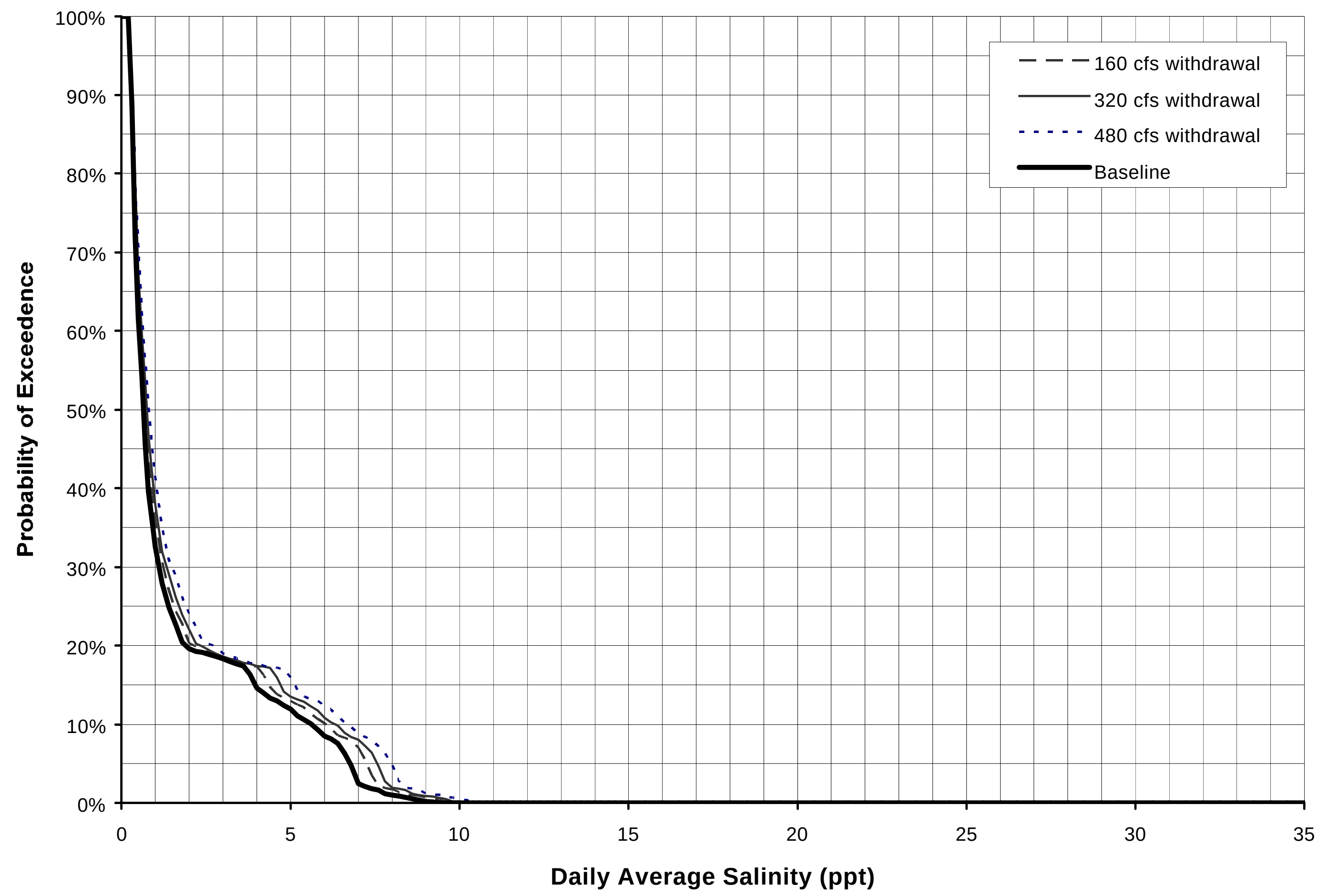



FIGURE 4-21.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT DOCTORS LAKE
Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

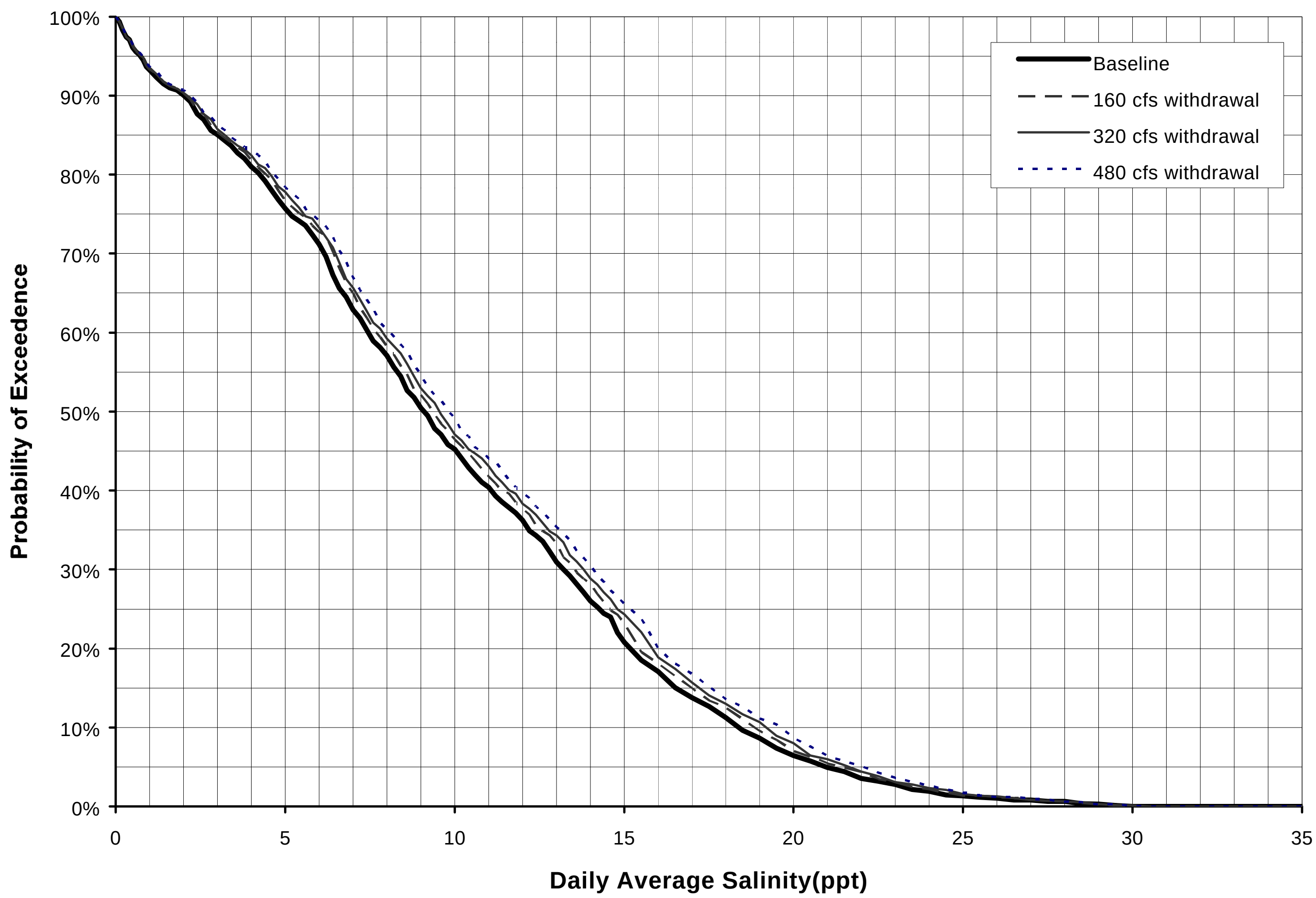



FIGURE 4-22.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT TROUT RIVER

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

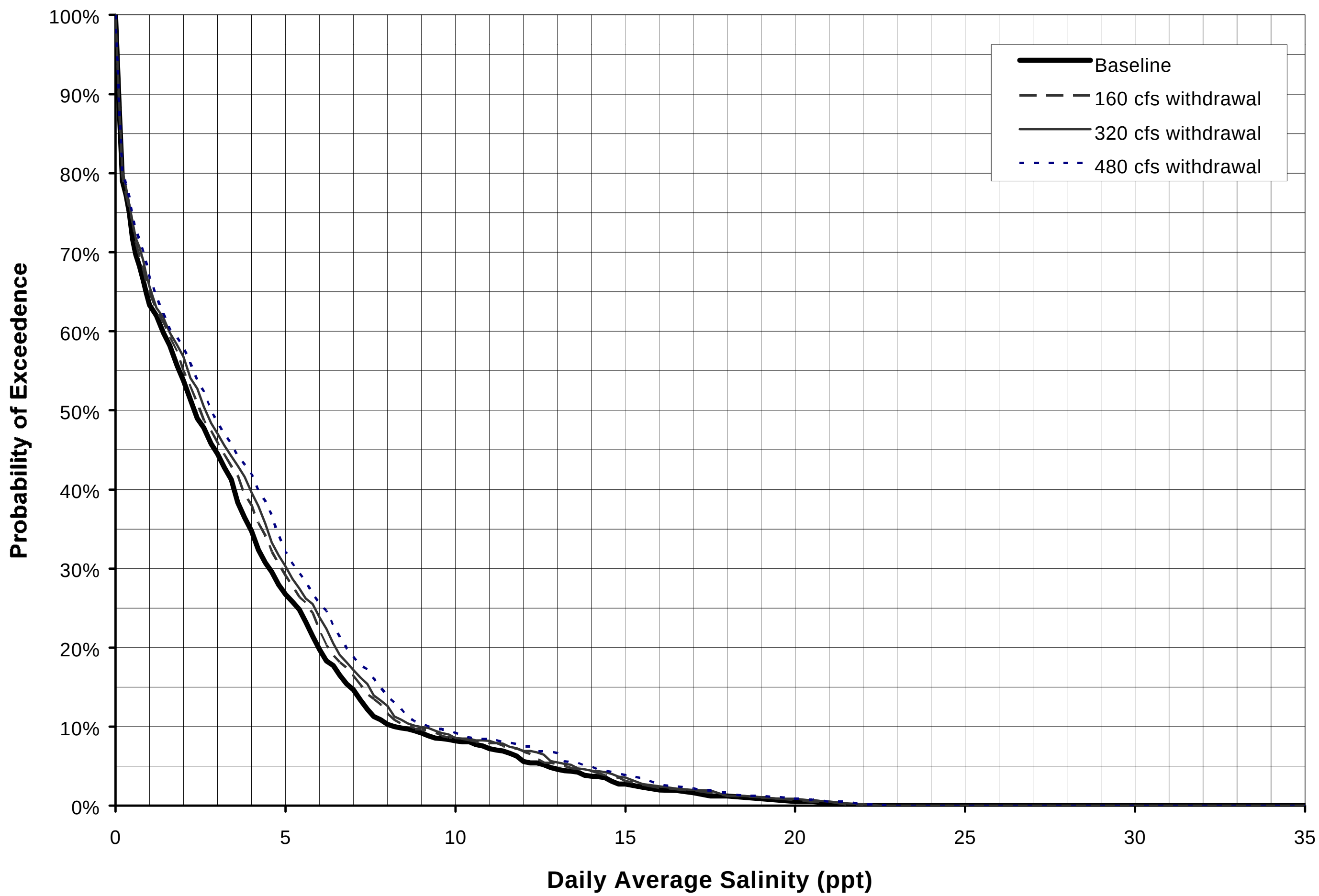



FIGURE 4-23.

CUMULATIVE FREQUENCY OF DAILY AVERAGE SALINITY
AT ORTEGA RIVER

Source: ECT, 2002.

ECT
Environmental Consulting & Technology, Inc.

selected locations for various flow scenarios. The analyses indicate the maximum increase of daily salinity due to 320 cfs withdrawal is about 1.2 ppt between JU and Magnolia Point (RM 45.2). This short-term increase near JU represents about an 8 percent increase of the daily average salinity, and is about 19 percent of the average daily salinity fluctuation due to tidal transport.

The maximum daily salinity increase by 160 cfs withdrawal is 0.9 ppt, occurring between JU and Piney Point. The maximum daily salinity increase by 480 cfs withdrawal limit is about 1.8 ppt, occurring between JU and Hibernia Point. According to the frequency analysis, the greatest 95$^{th}$ percentile daily salinity increase by 320 cfs withdrawal limit is 0.98 ppt, occurring near Venetia (RM 27.8). The greatest 95$^{th}$ percentile salinity increase by 160 cfs withdrawal limit is 0.70 ppt, occurring between JU and Piney Point. The greatest 95$^{th}$ percentile salinity increase by 480 cfs withdrawal limit is 1.5 ppt, occurring near Piney Point.

## 4.3 POTENTIAL EFFECTS OF PREDICTED SALINITY CHANGE ON AQUATIC LIFE

Salinity changes due to the withdrawal of freshwater from the St. Johns River near DeLand can result in changes in the distribution of fishes and invertebrates. Table 4-1 lists the observed salinity ranges at which selected species have been collected.

As described in the fisheries and wildlife section of the MFL report (ECT, 2002), many of the species inhabiting the LSJR are of marine or estuarine origin. These species are euyhaline, that is they are adapted to a wide range of salinities. For these species, the increase in salinity may result in changes in the areas or the upstream/downstream limits of where they can survive, although many of these species already occur throughout the river. On the other hand, the primary freshwater species (for example, fishes of the families Cyprinidae, Ictaluridae, and Centrarchidae, as well as most insect larvae) are restricted to narrower ranges of salinities (stenohaline), often less than 3 to 5 ppt (although different species may be able to tolerate higher salinity for varying periods of time). In addition, salinity at any point in the river is subject to seasonal changes due to variation

**Table 4-1. Salinity Ranges for Selected Species**

| Scientific name | Common name | Salinity Range (ppt) | References |
|---|---|---|---|
| *Dasyatis sabina* | Atlantic stingray | 0.09 - 41 | 4, 6, 8 |
| *Lepisosteus osseus* | Longnose gar | 1.2 - 26.9 | 9, 10 |
| *Lepisosteus platyrhincus* | Florida gar | 0 - 26.0 | 4, 6, 11 |
| *Elops saurus* | Ladyfish | 0 - 35 | 4, 10, 11 |
| *Megalops atlanticus* | Tarpon | 0 - 35 | 11 |
| *Anguilla rostrata* | American eel | 0.3 - 29.9 | 9, 10 |
| *Brevoortia tyrannus* | Atlantic menhaden | 36 | 1 |
| *Dorosoma cepedianum* | Gizzard shad | 0.0 - 24.7 | 10 |
| *Dorosoma petenense* | Threadfin shad | 0.0 - 21.7 | 4, 10 |
| *Anchoa mitchilli* | Bay anchovy | 0 - 36 | 1, 2, 4, 6, 9, 10, 11 |
| *Esox niger* | Chain pickerel | 0 - 7.5 | 10 |
| *Notemigonus crysoleucas* | Golden shiner | 1.3 - 10.7 | 10 |
| *Notropis maculatus* | Taillight shiner | 0.09 - 1.0 | 4 |
| *Notropis petersoni* | Coastal shiner | 0.12 - 0.65 | 4 |
| *Erimyzon sucetta* | Lake chubsucker | 0.6 - 14.4 | 10 |
| *Ameiurus catus* | White catfish | 0.09 - 0.26 | 4 |
| *Ameiurus natalis* | Yellow bullhead | 0 - 12 | 11 |
| *Ameiurus nebulosus* | Brown bullhead | 0.4 - 3.5 | 10 |
| *Ictalurus punctatus* | Channel catfish | 0 - 12.6 | 4, 10 |
| *Noturus leptacanthus* | Speckled madtom | 0.22 | 4 |
| *Bagre marinus* | Gafftopsail catfish | 0.17 - 35 | 4, 6, 9, 10, 11 |
| *Aphredoderus sayanus* | Pirate perch | 0.6 - 19.7 | 10 |
| *Strongulura marina* | Atlantic needlefish | 0 - 23.0 | 6, 10 |
| *Cyprinodon variegatus* | Sheepshead minnow | 0 - 31.8 | 4, 6, 10, 11 |
| *Fundulus chrysotus* | Golden topminnow | 0 - 5 | 4, 10, 11 |
| *Fundulus confluentus* | Marsh killifish | 0.0 - 20.4 | 4, 9, 10, 11 |
| *Fundulus seminolis* | Seminole killifish | 0 - 7.3 | 4, 11 |
| *Jordanella floridae* | Flagfish | 0 - 9 | 4, 11 |
| *Lucania goodei* | Bluefin killifish | 0 - 12 | 4, 11 |
| *Lucania parva* | Rainwater killifish | 0 - 28 | 4, 6, 10, 11 |
| *Gambusia holbrooki* | Mosquitofish | 0 - 30 | 4, 10, 11 |
| *Heterandria formosa* | Least killifish | 0 - 30.2 | 4, 11 |
| *Poecilia latipinna* | Sailfin molly | 0 - 33 | 4, 6, 10, 11 |
| *Labidesthes sicculus* | Brook silverside | 0.12 | 4 |
| *Menidia beryllina* | Inland silverside | 0 - 33 | 2, 4, 6, 10, 11 |
| *Syngnathus scovelli* | Gulf pipefish | 0 - 35 | 4, 9, 10, 11 |
| *Centropomus undecimalis* | Snook | 0 - 35 | 4, 11 |
| *Elassoma evergladei* | Everglades pygmy sunfish | 0 - 14.4 | 10, 11 |
| *Enneachanthus gloriosus* | Bluespotted sunfish | 0 - 3.8 | 4, 10 |
| *Lepomis auritus* | Redbreast sunfish | 0 | 11 |
| *Lepomis gulosus* | Warmouth | 0.5 - 14.4 | 10 |

**Table 4-1. Salinity Ranges for Selected Species**

| Scientific name | Common name | Salinity Range (ppt) | References |
|---|---|---|---|
| *Lepomis macrochirus* | Bluegill | 0 - 13.8 | 4, 10 |
| *Lepomis marginatus* | Dollar sunfish | 5 | 10 |
| *Lepomis microlophus* | Redear sunfish | 0 - 14.4 | 4, 10, 11 |
| *Lepomis punctatus* | Spotted sunfish | 0 - 17.5 | 10, 11 |
| *Micropterus salmoides* | Largemouth bass | 0 - 17.5 | 10, 11 |
| *Pomoxis nigromarginatus* | Black crappie | 0 - 2.4 | 10 |
| *Etheostoma olmstedi* | Tessellated darter | 2.23 | 3 |
| *Lutjanus griseus* | Gray snapper | 0 - 37 | 4, 9, 10, 11 |
| *Eucinostomus argenteus* | Spotfin mojarra | 0 - 35 | 1, 4, 6, 9, 10 |
| *Gerres cinereus* | Yellowfin mojarra | 12 - 35 | 11 |
| *Micropogonias undulatus* | Atlantic croaker | 0 - 29.8 | 2, 4, 6, 9, 10 |
| *Sciaenops ocellatus* | Red drum | 0.14 - 34.5 | 4, 6, 9, 11 |
| *Mugil cephalus* | Striped mullet | 0 - 39.0 | 1, 4, 5, 6, 9, 10, 11 |
| *Mugil curema* | White mullet | 11.0 - 37.5 | 1, 4, 5, 6, 9 |
| *Dormitator maculatus* | Fat sleeper | 0.1 - 3.4 | 10 |
| *Gobiosoma bosci* | Naked goby | 0 - 33.0 | 4, 9, 10 |
| *Microgobius gulosus* | Clown goby | 0.18 - 33.0 | 4, 6, 10, 11 |
| *Paralichthys lethostigma* | Southern flounder | 0 - 30.8 | 4, 10 |
| *Trinectes maculatus* | Hogchoker | 0 - 35 | 4, 6, 10, 11 |
| *Rhithropanopeus harrisii* | Mud crab | <1 - 27.5 | 7 |
| *Vallisneria americana* | Eel grass | 0 - 7 | 12 |

1 Futch and Dwinell, 1977.
2 Gallaway and Strawn, 1974.
3 Gilbert, 1978.
4 Gunter and Hall, 1965.
5 Moore, 1974.
6 Mountain, 1972.
7 Odum, 1971.
8 Snelson and Williams, 1981.
9 Springer and Woodburn, 1960.
10 Swingle and Bland, 1974.
11 Tabb and Manning, 1962.
12 Korschgen and Green. 1988.

in rainfall, and daily/hourly changes due to tidal transport. These natural salinity variations can be seen in Figures 2-15 through 2-20. Most animals are able to move in response to preferred salinity. Plants, however, are fixed in position and must endure ambient conditions.

To quantify the spatial shifts of the fish habitats and the potential impacts of freshwater plant habitat due to freshwater withdrawal, the 1-, 3-, and 5- ppt isohalines positions were determined for various flow scenarios based on the model simulation results and are shown in Figure 4-24. Table 4-2 presents the average salinity isohaline positions for 1, 3, and 5 ppt under the baseline condition as well as the 160-, 320-, and 480- cfs withdrawal limit scenarios. Table 4-3 presents the longitudinal translation of the 1-, 3-, and 5-ppt isohaline due to freshwater withdrawals. The results show that the 1-ppt isohalines occur near Green Cove Springs, the 3-ppt isohalines occur near the Buckman Bridge, and the 5-ppt isohalines occur between Piney Point and the Ortega River mouth. The 320-cfs freshwater withdrawal scheme will shift the 1-, 3-, and 5-ppt isohalines upstream by 2.5, 1.2, and 0.3 mile, respectively. The potential impacted area of freshwater habitats due to 320-cfs withdrawal for 1-, 3-, and 5-ppt area are 4,188; 2,161; and 430 acres, respectively. Assuming the 5-ppt isohaline being the upper salinity boundary for freshwater species, the withdrawal of water at the rate of 320 cfs would shift the 5-ppt isohaline 0.8 mile upstream. This isohaline shift may result in some impacts to approximately 1,130 acres of habitat for freshwater plants such as *Vallisneria americana* (eel grass). Eel grass is a predominant submerged aquatic vegetation (SAV) species in the LSJR and makes up about 40 to 60 percent of the SAV in the river (Dobberfuhl, pers. comm., 2002). Currently, Dr. Dean Dobberfuhl of the SJRWMD is conducting field experiments in conjunction with USGS to determine the response of SAV to salinity changes. The study is expected to be complete in 2003. According to preliminary information from Dobberfuhl, the SAV responds to salinity changes in a rather complex manner. The SAV does not just perish when salinity exceeds a certain threshold value. Instead, it may tolerate a salinity level of varying ranges depending on many factors, including the toxicity level and the duration of exposure (Dobberfuhl, pers. comm., 2002). It should be pointed out that the isohaline shifts and acreage changes presented in this section are based on certain

M:\acad\080425\Salinity Levels Freshwater CSF 531.dwg8 mile

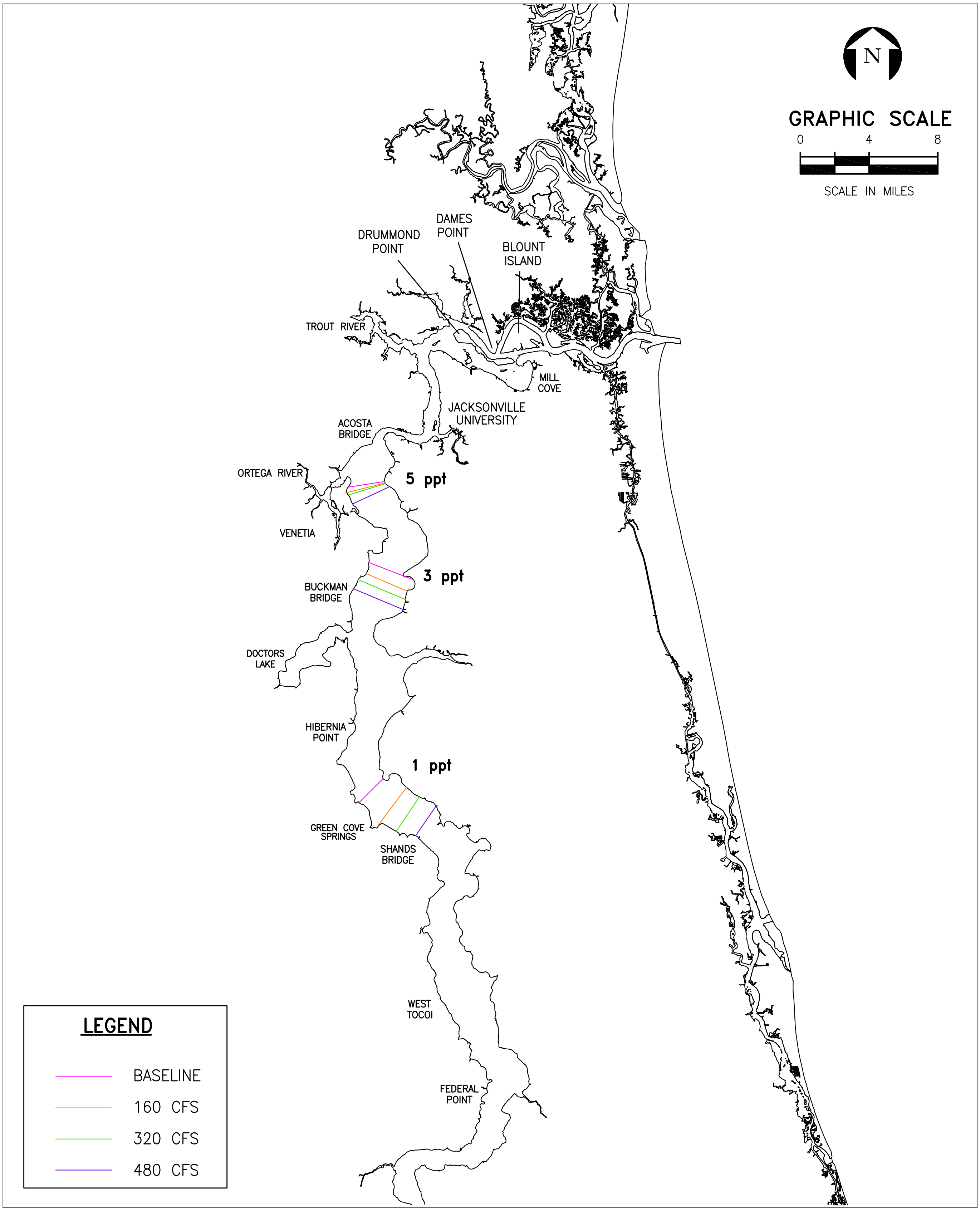



FIGURE 4-24.

AVERAGE SALINITY ISOHALINE SHIFTS DUE TO FRESHWATER WITHDRAWAL

Source: ECT, 2008.

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Environmental Consulting & Technology, Inc.

**Table 4-2. Isohaline Positions for Various Flow Scenarios**

| Flow Scenarios | Isohaline Position (RM) | | |
|---|---|---|---|
| | 1 ppt | 3 ppt | 5 ppt |
| Baseline | 46.0 | 32.7 | 27.4 |
| 160-cfs withdrawal | 47.5 | 33.4 | 27.6 |
| 320-cfs withdrawal | 48.6 | 33.9 | 27.7 |
| 480-cfs withdrawal | 49.6 | 34.5 | 28.1 |

Source: ECT, 2008.

**Table 4-3. Isohaline Shifts and Change of Freshwater Habitat Areas**

| Withdrawal Scenario | Isohaline Shift (miles) | | | Area Changes (acres) | | |
|---|---|---|---|---|---|---|
| | 1 ppt | 3 ppt | 5 ppt | 1 ppt | 3 ppt | 5 ppt |
| 160 cfs | 1.5 | 0.7 | 0.2 | 2,617 | 1,277 | 282 |
| 320 cfs | 2.5 | 1.2 | 0.3 | 4,188 | 2,161 | 430 |
| 480 cfs | 3.6 | 1.8 | 0.7 | 5,831 | 3,321 | 1,041 |

Source: ECT, 2008.

assumed fixed thresholds. Although the 5-ppt isohaline may be shifted upstream by 0.8 mile at 320-cfs withdrawal limit, the absolute change in mean salinity within the impacted area is only about 0.4 ppt.

Due to the minor changes in salinity level in the LSJR resulting from the 320-cfs withdrawal, the overall composition of plant and animal species inhabiting the river should not change. The only changes that may occur are minor shifts in the boundary between fresh water and estuarine habitats and their associated faunas. Although it is possible that the minor salinity increases due to surface water withdrawals from the river near DeLand could affect distribution of some aquatic species, the effect would be minor.

## 4.4 EFFECTS OF SALINITY CHANGES ON DISSOLVED OXYGEN

When salinity is increased in the water column, the dissolved oxygen (DO) may decrease because the DO saturation level decreases with increasing salinity. To quantify the changes in DO saturation concentration due to salinity increase resulting from freshwater withdrawal, the saturation DO concentrations at several locations are computed for the baseline and 320-cfs withdrawal condition at average salinity. The saturation DO was computed by a computer program developed by Ivan B. Chou (Chou, 1982), based on the data presented in Clark *et al*. (1971). A water temperature of 30 degrees Celsius (ºC) (86 degrees Fahrenheit [ºF]) is used for the calculations. Table 4-4 shows the baseline average saturation DO concentration at Blount Island, JU, Buckman Bridge, and Shands Bridge. The average saturation DO concentrations for the 320 cfs withdrawal limit are also presented in Table 4-4. The results show that the change in saturation DO concentration is less than or equal to 0.02 mg/L at all locations. Therefore, it is concluded that the DO decrease due to freshwater water withdrawal will be negligible.

## 4.5 SUMMARY

Simulations were provided by SJRWMD using the EFDC model to project changes in the salinity regime of the LSJR which may occur as a result of increased surface water withdrawals in the St. Johns River near DeLand. An assessment of the effect the projected salinity changes would have on aquatic life in the LSJR was also performed.

Table 4-4. Dissolved Oxygen Impact Due to Freshwater Withdrawal (at 30ºC)

| Location | River Miles | Baseline Conditions Average Salinity (ppt) | Baseline Conditions Saturation DO (mg/L) | 320 cfs Withdrawal Average Salinity (ppt) | 320 cfs Withdrawal Saturation DO (mg/L) | 320 cfs Withdrawal Saturation DO Reduction (mg/L) |
|---|---|---|---|---|---|---|
| Blount Island | 8.8 | 23.83 | 6.63 | 24.12 | 6.61 | 0.02 |
| Jacksonville University | 19.2 | 11.05 | 7.17 | 11.54 | 7.15 | 0.02 |
| Buckman Bridge | 33.9 | 2.68 | 7.53 | 3.00 | 7.52 | 0.01 |
| Shands Bridge | 49.9 | 0.83 | 7.61 | 0.93 | 7.61 | <0.01 |

Source: ECT, 2008.

The EFDC model was run for the baseline, or existing, flow conditions and for three other flow regimes. These three flow regimes reflect the withdrawal of surface water from the St. Johns River near DeLand at the maximum rate of 160, 320, and 480 cfs, respectively. Statistical analyses for the four simulated scenarios were performed and comparisons were made to quantify the changes in average salinity regime. The results of these analyses are summarized in Table 4-5. For the withdrawal limit of 320 cfs, the results show that the projected increase in salinity in the LSJR over the 3-year period is small when compared with the daily variability in salinity presently observed in the LSJR caused by tidal transport.

With respect to aquatic life in the LSJR, 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 salinity simulation results indicate the average 5-ppt isohaline will be shifted upstream by 0.8 mile. This upstream translation of the saline water may impose stress or cause impact on freshwater plants habitat in a 1,130-acre area. Although the 5-ppt isohaline may be shifted upstream by 0.8 mile at 320-cfs withdrawal limit, the absolute change in mean salinity within the impacted area is only 0.4 ppt. The species composition of the river, however, is not expected to change.

The potential DO decrease due to 320 cfs withdrawal is determined to be insignificant.

Based on the results of the salinity assessment in the LSJR, it is ECT's opinion that the MFL regime recommended by SJRWMD will provide protection of the estuarine resources. However, this conclusion should be re-evaluated when the results of the ongoing eel grass study by SJRWMD and USGS become available.

Table 4-5. Summary of Salinity Changes in the LSJR Due to Freshwater Withdrawal

| Location | River Miles | Baseline Conditions: Average Salinity (ppt) | Baseline Conditions: Average Daily Fluctuations (ppt) | Daily Average Salinity Increase: 160 cfs withdrawal (ppt) | Daily Average Salinity Increase: 320 withdrawal (ppt) | Daily Average Salinity Increase: 480 withdrawal (ppt) |
|---|---|---|---|---|---|---|
| Blount Island | 8.8 | 23.83 | 14.11 | 0.15 | 0.29 | 0.43 |
| Dames Point | 10.6 | 21.52 | 12.22 | 0.22 | 0.32 | 0.49 |
| Drummond Pt. | 14.3 | 14.83 | 10.16 | 0.26 | 0.45 | 0.68 |
| Jacksonville University | 19.2 | 11.05 | 6.58 | 0.33 | 0.49 | 0.74 |
| Acosta Bridge | 23.7 | 7.15 | 5.52 | 0.32 | 0.47 | 0.71 |
| Buckman Bridge | 33.9 | 2.68 | 1.09 | 0.20 | 0.33 | 0.51 |
| Hibernia Point | 42.3 | 1.31 | 0.39 | 0.11 | 0.19 | 0.30 |
| Green Cove Springs | 47.9 | 0.91 | 0.22 | 0.07 | 0.12 | 0.19 |
| Shands Bridge | 49.9 | 0.83 | 0.16 | 0.06 | 0.10 | 0.16 |
| West Tocoi | 60.2 | 0.53 | 0.06 | 0.02 | 0.03 | 0.06 |
| Federal Point | 67.1 | 0.49 | 0.02 | <0.01 | <0.01 | 0.01 |
| Mill Cove | | 16.56 | 2.01 | 0.22 | 0.44 | 0.67 |
| Doctors Lake | | 1.59 | 0.06 | 0.13 | 0.22 | 0.35 |
| Trout River | | 9.90 | 1.37 | 0.26 | 0.44 | 0.66 |
| Ortega River | | 3.58 | 0.83 | 0.20 | 0.32 | 0.50 |

Source: ECT, 2008.

Y:\GDP-08\SJRWMD\SALHTB45.xls—9/24/2008

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