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St. Johns River Water Supply Project
Surface Water Treatment and Demineralization Study

Preliminary Raw Water Characterization

TECHNICAL MEMORANDUM
PRELIMINARY RAW WATER CHARACTERIZATION

ST. JOHNS RIVER WATER SUPPLY PROJECT
SURFACE WATER TREATABILITY AND DEMINERALIZATION STUDY

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CONTENTS

FIGURES

TABLE

INTRODUCTION

The purpose of this technical memorandum (TM) is to provide the preliminary raw water characterization for the St. Johns River Water Supply Project Surface Water Treatability and Demineralization Study. This study is being conducted to identify the treatment requirements for the St. Johns River water for a potential treatment facility to be located in the reach between Titusville and De Land.

This TM was developed to review the raw water characteristics of the St. Johns River. These data are being summarized for use in the evaluation and selection of appropriate treatment processes for the pilot program. More detailed discussions on water treatment regulations, treatment levels, and appropriate treatment technologies will be the subject of later TMs for this project.

In order to quantify the different treatment requirements between Titusville and De Land, raw water characteristics and quality must be identified. Currently, the United States Geological Survey (USGS) is conducting biweekly sampling at four points along this reach of the river. The U.S. Geological Survey (USGS) began sampling at these locations in January 2000. This initial raw water characterization will summarize the first 10 months of data collected. During the 2-year duration of this pilot study, additional raw water data will be collected and summarized in the final report. The initial water quality characterization presented in this TM will define the expected range of raw water quality parameters sufficiently to assist in the selection of appropriate water treatment process for testing. Subsequently, additional analysis will be performed as additional data are collected and become available.

USGS WATER QUALITY DATA SUMMARY

The following text summarizes the data obtained from the USGS and identifies raw water quality trends and correlations.

The USGS data were collected at established USGS sampling locations that ranged from Cocoa, Florida, to De Land, Florida.

SAMPLING LOCATIONS

USGS sampling locations included four points along the St. Johns River, as well as a point on the Wekiva River and a point along Blackwater Creek. The St. Johns River was sampled near Cocoa, Christmas, Sanford, and De Land. The sampling station on the Wekiva River is near Sanford, and the station along Blackwater Creek is near Cassia. All USGS sampling locations are illustrated in Figure 1.

STREAMFLOW CHARACTERISTICS AND DROUGHT EFFECTS

The primary source for the St. Johns River is groundwater inflow and surface water inflow. The Floridan aquifer contains brackish water beneath the River, and because the potentiometric head of the aquifer (pressure within the aquifer) is higher than the downward force exerted by the River, there is a continuous discharge of this brackish groundwater into the river. During low flow conditions, groundwater inflow makes up a significant portion of total river flow. The influence of groundwater inflow on in-stream quality will vary with location as well as with river basin inflow tributary area and springflow influences.

During wet weather, low TDS surface water inflow dominates and TDS concentrations will be relatively low. Also, at the De Land monitoring station, the brackish groundwater effect is partially offset by the significant inflow of non-brackish groundwater from freshwater springs and tributaries, including the Wekiva River and Blue Springs.

Total tributary area also plays a significant role in expected TDS concentration and other in-stream water quality parameters. As tributary area increases both surface water inflow and groundwater inflow will increase. It is the relative contribution of each of these major sources that will define water quality at any point and time. Tributary area increases from 1,331 square miles at Cocoa, to 3,066 square miles at

De Land. The tributary areas at the intermediate sampling stations are 1,539 square miles at Christmas and 2,582 square miles at Sanford.

As illustrated in Figure 1, the Sanford sampling station is located at the north end of Lake Monroe just upstream of the confluence with the Wekiva River. As mentioned earlier, under normal and high flow conditions, the effects of the fresh water from the Wekiva on the St. Johns River water quality are generally seen downstream of the Wekiva confluence in the De Land area. However, during the current drought conditions under which these samples have been taken, the St. Johns River may experience reverse flow, and fresh water from the Wekiva may influence the Sanford sampling station at the outlet of the lake.

WATER QUALITY DATA SUMMARY

Data were collected biweekly by the USGS along the St. Johns River (quarterly on the Wekiva River and Blackwater Creek). Table 1 summarizes the results of the first 10 months of USGS data collected from January 2000 to October 2000.

Table 1 is divided into four sections — general water quality parameters, nutrients, organics, and inorganics. The general water quality section summarizes commonly monitored parameters such as temperature and pH. The nutrients section contains information on parameters that primarily support biological activity (e.g., nitrogen, phosphorus, oxygen). Organic parameters include organic carbon concentration, as well as organic carbon surrogates including color and UV 254. Inorganic parameters include metals, silica, and sulfur-derived compounds.

The averages and standard deviations for all monitored parameters are reported in Table 1 for the initial 10-month sampling period.

General Water Quality Parameters

The general water quality parameters summarized in Table 1 include alkalinity, pH, conductivity, temperature, total hardness, and turbidity.

In Table 1, the monitoring stations from Cocoa to De Land indicate that the St. Johns River has low to moderate alkalinity ranging from 71 milligrams per liter (mg/L) in Cocoa to 90 milligrams per liter (mg/L) in De Land. The slightly higher alkalinity levels in De Land can be attributed to the influence of the Wekiva, which had an average alkalinity of 115 mg/L.

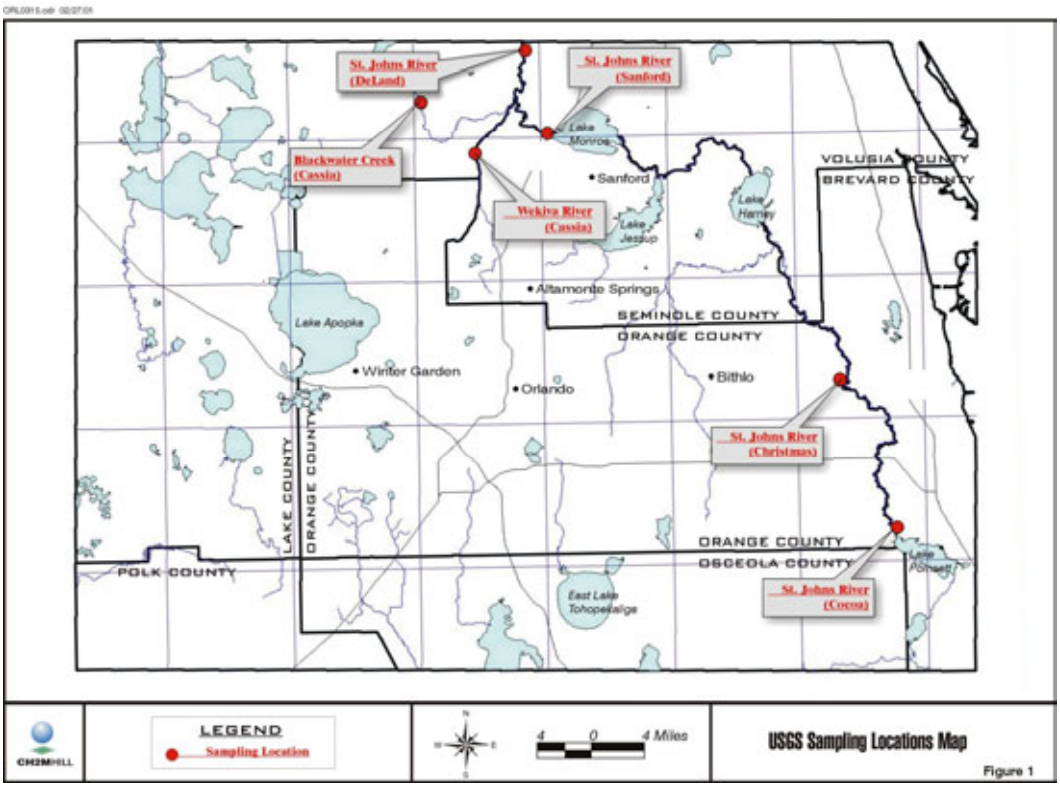

Figure 1. USGS Sampling Locations Map

Table 1. Summary of USGS WQ Data for the St. Johns River

Parameter	St. Johns River, Cocoa	St. Johns River, Christmas	St. Johns River, Sanford	St. Johns River, De Land	Wekiva River	Blackwater Creek
General Water Quality						
Alkalinity (mg/L as $CaCO_3$)						
Average	71	66	72	90	115	58
Standard Deviation	13	19	17	16	2	16
pH						
Average	8.00	7.39	8.10	7.62	7.63	7.06
Standard Deviation	0.57	0.28	0.57	0.36	0.43	0.62
Specific Conductance (mS/cm)						
Average	1380	1745	1283	1125	513	379
Standard Deviation	713	944	306	194	10	123
Temperature (^oC)						
Average	25.5	24.6	26.1	24.9	24.2	23.0
Standard Deviation	5.3	5.2	5.6	5.1	2.4	3.3
Total Hardness (mg/L as $CaCO_3$)						
Average	357	411	237	233	173	187
Standard Deviation	88	173	20	17	6	51
Turbidity (NTU)						
Average	7.2	7.3	4.3	3.4	0.81	1.3
Standard Deviation	4.6	3.3	2.3	1.1	0.49	0.6
Nutrients						
Ammonia (mg/L as N)						
Average	0.065	0.255	0.028	0.047	0.013	0.014
Standard Deviation	0.078	0.342	0.021	0.044	0.009	0.011
Chlorophyll a (mg/L)						
Average	32.2	15.3	23.6	20.9	4.9	< 0.1
Standard Deviation	31.1	18.2	14.3	16.0	8.7	N/A
Nitrate Total (mg/L as N)						
Average	0.15	0.13	0.15	0.17	0.56	0.17
Standard Deviation	0.03	0.07	0.03	0.06	N/A	N/A
Nitrite (mg/L as N)						
Average	< 0.01	0.0148	< 0.01	< 0.01	< 0.01	< 0.01
Standard Deviation	N/A	0.0122	N/A	N/A	N/A	N/A
NO_2^- + NO_3^- Dissolved (mg/L as N)						
Average	0.053	0.115	0.046	0.092	0.483	0.490
Standard Deviation	0.076	0.086	0.069	0.091	0.063	0.324

Table 1. Summary of USGS WQ Data for the St. Johns River (Continued)

Parameter	St. Johns River, Cocoa	St. Johns River, Christmas	St. Johns River, Sanford	St. Johns River, De Land	Wekiva River	Blackwater Creek
NO_2^- + NO_3^- Total (mg/L as N)						
Average	0.047	0.106	0.046	0.091	0.500	0.475
Standard Deviation	0.072	0.094	0.070	0.096	0.082	0.299
Orthophosphorus (mg/L as P)						
Average	0.016	0.029	0.017	0.025	0.103	0.040
Standard Deviation	0.013	0.021	0.013	0.021	0.005	0.008
Oxygen (mg/L)						
Average	7.286	5.767	8.186	6.097	7.575	4.675
Standard Deviation	1.582	1.504	2.104	1.079	2.170	1.063
Phosphorus Total (mg/L)						
Average	0.088	0.071	0.080	0.065	0.103	0.038
Standard Deviation	0.057	0.025	0.073	0.014	0.017	0.021
Organic						
Color (cu)						
Average	109	124	80	65	9	160
Standard Deviation	43	58	64	64	3	143
Dissolved Organic Carbon (mg/L)						
Average	25.8	24.2	16.9	11.8	2.3	19.5
Standard Deviation	3.9	1.9	5.5	5.5	0.3	12.0
Total Organic Carbon (mg/L)						
Average	26.3	25.0	17.5	12.1	2.4	20.1
Standard Deviation	4.0	2.1	5.6	5.8	0.3	12.1
UV_{254} (abs/cm)						
Average	0.90	0.91	0.56	0.38	0.28	0.98
Standard Deviation	0.10	0.20	0.23	0.20	0.42	0.61
Inorganic						
Barium (mg/L)						
Average	58	58	28	21	9	15
Standard Deviation	25	28	7	3	1	4
Bromide (mg/L)						
Average	1.00	1.31	0.93	0.79	0.20	< 0.05
Standard Deviation	0.63	0.90	0.27	0.16	0.00	N/A
Calcium (mg/L)						
Average	79	85	51	53	47	49
Standard Deviation	32	39	9	9	2	18

Table 1. Summary of USGS WQ Data for the St. Johns River (Continued)

Parameter	St. Johns River, Cocoa	St. Johns River, Christmas	St. Johns River, Sanford	St. Johns River, De Land	Wekiva River	Blackwater Creek
Chloride (mg/L)						
Average	311	420	287	241	59	13
Standard Deviation	188	285	87	47	2	2
Iron Dissolved (mg/L)						
Average	0.067	0.203	0.067	0.058	0.006	0.287
Standard Deviation	0.052	0.187	0.091	0.072	0.002	0.189
Iron Total (mg/L)						
Average	0.257	0.523	0.179	0.140	0.027	0.451
Standard Deviation	0.098	0.222	0.113	0.101	0.011	0.257
Magnesium (mg/L)						
Average	28	38	23	21	13	12
Standard Deviation	8	20	3	2	1	3
Potassium (mg/L)						
Average	7.4	10.1	7.3	5.7	2.2	1.3
Standard Deviation	1.2	4.2	1.8	0.7	0.1	0.1
Silica (mg/L)						
Average	6.0	4.7	4.0	4.6	8.1	11.4
Standard Deviation	4.6	3.5	2.7	1.7	1.0	1.3
Sodium (mg/L)						
Average	215	296	186	143	33	7
Standard Deviation	82	180	44	18	0	2
Strontium (mg/L)						
Average	2.889	2.918	1.156	0.992	0.498	0.825
Standard Deviation	1.461	1.559	0.273	0.154	0.063	0.387
Sulfate (mg/L)						
Average	111	167	78	76	45	101
Standard Deviation	55	123	28	26	2	51
Sulfide (mg/L as S)						
Average	< 1	< 1	< 1	< 1	< 1	< 1
Standard Deviation	N/A	N/A	N/A	N/A	N/A	N/A
Total Dissolved Solids (mg/L)						
Average	893	1118	735	645	287	285
Standard Deviation	448	630	180	105	8	65

Samples were taken biweekly except for Wekiva River and Blackwater Creek which were taken quarterly
All parameters are dissolved unless otherwise noted.
A less than symbol (<) preceeding a number indicates that the compound was present but was less than the detection limit.
A N/A in a standard deviation entry indicates that a standard deviation could not be calculated, due to lack of sufficient data points or the parameter average being below the detection limit.
UV_{254} -- Ultraviolet Absorbance @ 254 nm (abs/cm)

The pH and temperature values for the St. Johns River are considered normal compared to other central Florida surface waters. The average pH values ranged from 7.4 to 8.1 with temperature averaging from 24.6 to 26.1 degrees Centigrade (^{o}C). Both pH and temperature had relatively low standard deviations, which indicate that they remain relatively constant.

The data in Table 1 also suggest that that St. Johns River between Cocoa and De Land is a relatively high hardness water. The hardness reported is the sum of the calcium and magnesium hardness expressed as calcium carbonate. The highest hardness levels were observed in the Cocoa and Christmas sites with average values of 357 and 411 mg/L, respectively. Lower average hardness levels between 233 and 237 mg/L were reported for the Sanford and De Land sites. The lower hardness for the De Land site can be attributed to the confluence of the Wekiva River (average hardness 173 mg/L) with the St. Johns. The explanation for the relatively low hardness at the Sanford site is not obvious but may be due to possible reverse flow conditions associated with drought conditions during the sampling period. During higher river flows (non-drought conditions), higher hardness levels may be possible for the Sanford area at Lake Monroe. Additional data collected during normal river flow conditions will be needed to fully define water quality characteristics at Sanford.

Average alkalinity for these sampling locations averaged below 100 mg/L. With the hardness values well in excess of the alkalinity values, much of the hardness is in the noncarbonate form.

The turbidity levels for these sites along the St. Johns River are also summarized in Table 1. The turbidity varies from 7.2 nephelometric turbidity units (NTUs) at Cocoa to 3.4 NTUs at De Land. As with the hardness, the lower turbidity values for the Sanford and De Land sites can be attributed to the influence of the Wekiva River with an average turbidity of less than 1 NTU.

Nutrients

The following text quantifies the primary nutrient concentrations at the USGS monitoring points. The primary nutrients summarized include phosphorus, ammonia, nitrate, and nitrite.

The data summaries in Table 1 indicate that the average ammonia concentration on the St. Johns River ranged from 0.255 mg/L (as nitrogen) at Christmas to 0.028 mg/L as N at Sanford.

The sum of dissolved nitrate and nitrite is summarized in Table 1. The highest dissolved nitrate and nitrite concentration was 0.115 mg/L as N at Christmas. The lowest concentration was determined to be 0.046 mg/L as N at Sanford. Both the Wekiva River and Blackwater Creek had total nitrate and nitrate concentrations near 0.5 mg/L as N.

Table 1 indicates that phosphorus concentrations ranged from 0.088 mg/L at Cocoa to 0.065 mg/L at De Land.

Organics

The primary organic parameters quantified in Table 1 include total organic carbon (TOC) and color.

Table 1 illustrates that average TOC concentrations at Cocoa and Christmas were 26.3 mg/L and 25.0 mg/L, respectively. This would indicate that there is little change in TOC concentration from Christmas to Cocoa. Also, TOC concentrations at Sanford and De Land were 17.5 mg/L and 12.1 mg/L, respectively. There is a significant decrease in TOC concentration between Sanford and De Land due to the confluence of the Wekiva River before De Land discussed earlier. Further, there appears to be a significant decrease in TOC from Christmas to Sanford. This is likely due to the reverse flow conditions discussed previously. Again, this may be due in part to the drought conditions prevalent during this sampling period. Additional sampling data for normal flow conditions will be needed to determine if the relatively low TOC observed at Sanford is truly representative.

The color in the St. Johns River is reported in Table 1. Average color ranged from 124 color units (cu) at Christmas to 65 cu at De Land. Further, the color at Sanford is 80 cu, which is a decrease of 44 cu from the Christmas monitoring location.

All sampling locations had a high variability in color as illustrated in Table 1. For example, there was a standard deviation of 64 cu, a minimum color of 10 cu, and a maximum color 200 cu for the Sanford monitoring, illustrating the wide range of color levels experienced in the St. Johns River at Sanford.

Inorganics

The inorganic parameters monitored by the USGS on the St. Johns River are summarized in Table 1. The inorganics of concern include bromide, chloride, and TDS.

As indicated in from Table 1, average TDS concentrations ranged from 1,118 mg/L at Christmas to 645 mg/L at De Land. The average TDS concentration at Sanford was 735 mg/L.

The USGS TDS data from previous years are sparse and were only collected during the months of April to August. The average historical USGS TDS for these months indicate an average TDS of 1,155 mg/L for the Sanford monitoring station. For the same months in the current data (year 2000), the TDS concentration was approximately 800 mg/L. This would indicate that the recent TDS data at Sanford may under-represent long-term conditions by approximately 30 percent. Again, additional monitoring data representing normal flow conditions are required to fully define expected TDS at Sanford.

Average chloride concentrations, reported in Table 1, ranged from 420 mg/L to 241 mg/L. Again the highest chloride concentrations were observed at Christmas, and the lowest chloride concentration occurred at De Land.

According to Table 1, average bromide levels at Cocoa and Christmas were 1.00 mg/L and 1.31 mg/L, respectively, both of which had a high variability. Bromide levels at Sanford and De Land were 0.93 mg/L and 0.79 mg/L, respectively, with a much lower variability.

WATER QUALITY TRENDS AND CORRELATIONS

Organics

Figure 2 illustrates the sampling period trend for TOC along the St. Johns River. Fluctuations in TOC concentration in the raw water are likely due to surface runoff events. During the summer months, TOC concentrations at Cocoa and Christmas were much more variable when compared to data collected from January to May. A decrease in TOC was observed at Sanford and De Land throughout the sampling period, again with higher variability in TOC occurring during the summer months.

UV254 is the absorbance of light at an ultraviolet light wavelength of 254 nanometers (nm) and is a surrogate measure of TOC. To quantify the correlation between TOC and UV 254 in the St. Johns River, TOC and UV 254 data were plotted in Figure 3. Linear regression analysis was used to establish the TOC/UV 254 relationship for the data set, resulting in the following equation.

$$TOC = (23.9 * UV254) + 3.4 \qquad \text{Equation 1}$$

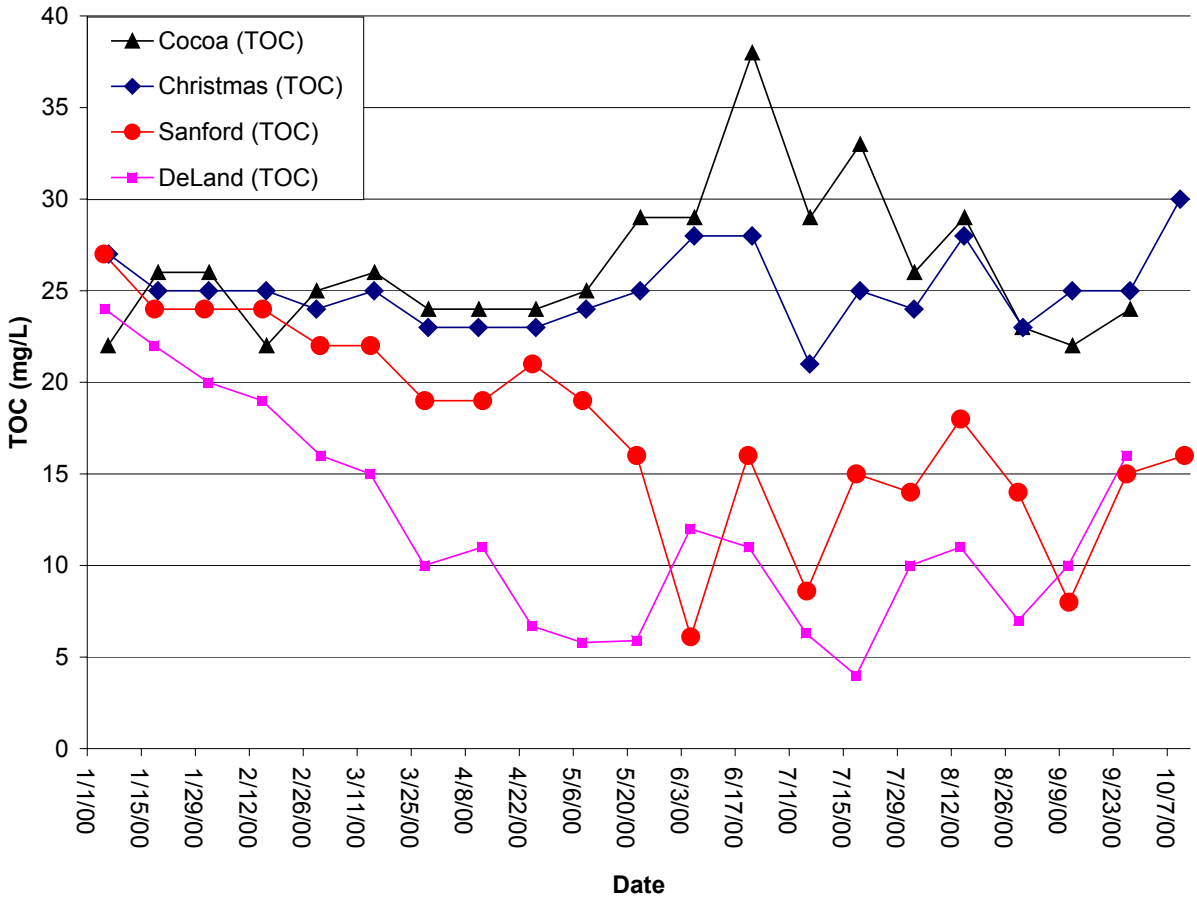

Figure 2. Historical TOC for the St. Johns River

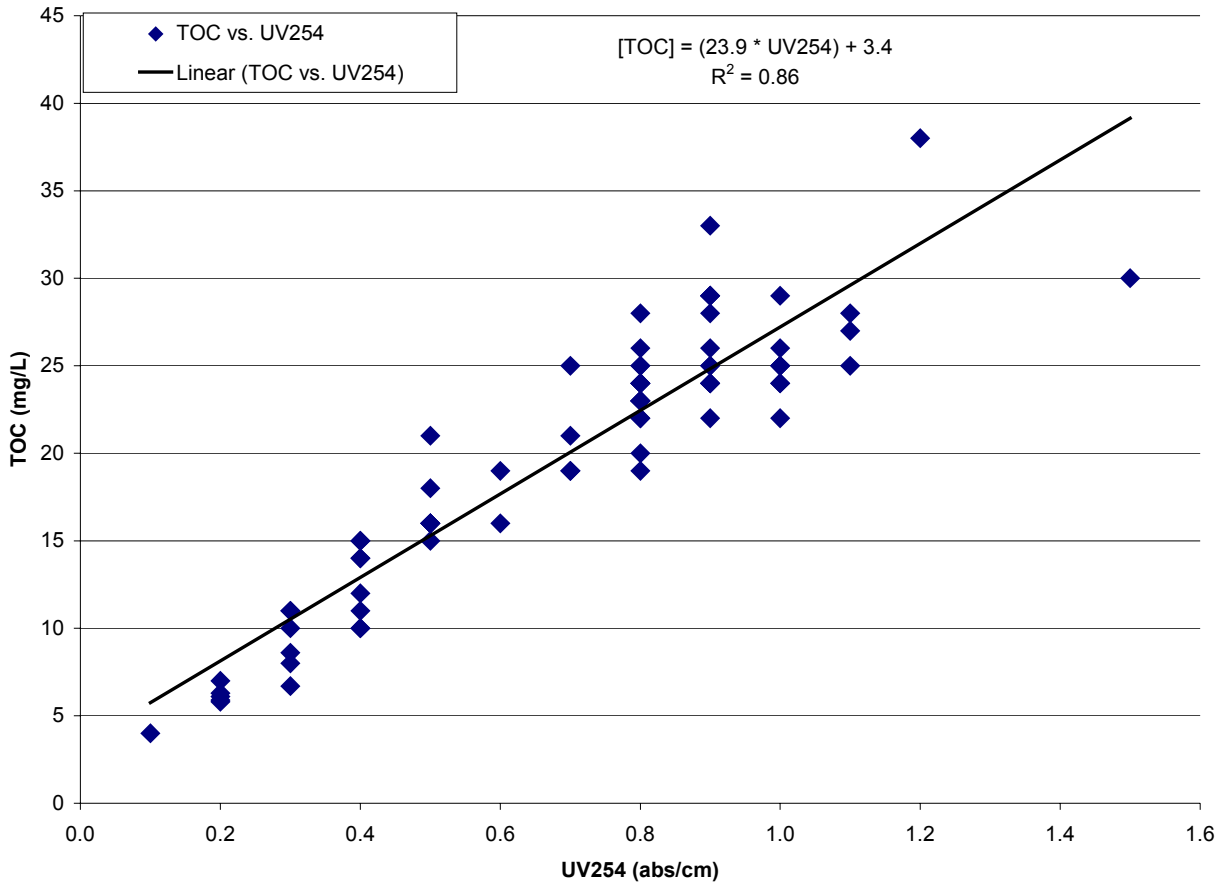

Figure 3. Approximate TOC/UV 254 Relationship for the St. Johns River

where TOC is in units of mg/L and UV 254 is in units of absorbance per centimeter (abs/cm). With this equation, TOC can be estimated if UV 254 is known. This is significant because TOC analyses are often more expensive than UV 254 analyses.

The correlation coefficient is .086 for the TOC vs. UV 254 data.

Inorganics

In water treatment, inorganics are generally considered to be salts and metals. They include hardness-causing species as well as other metals such as iron, aluminum, and sodium. TDS is determined by evaporating a water sample and weighing the mass of solids remaining. Inorganics are often the primary contributor to the mass of TDS.

Figure 4 illustrates the TDS concentration of the St. Johns River as the river flows from south to north. The squares in the graph represent the average TDS concentration at the respective location. The vertical lines represent the maximum and minimum TDS for the data set. The small horizontal tick marks are the standard deviations of the data set. Figure 4 illustrates the highest TDS variability occurs at Christmas, as does the highest TDS concentration. The samples taken at the De Land station are much lower in TDS concentration due to the confluence of the Wekiva River prior to the monitoring station.

An inorganic of concern with respect to this study is chloride. Figures 5 and 6 illustrate the sampling period TDS and chloride concentrations for the monitoring stations at Cocoa/Christmas and Sanford/De Land, respectively.

In Figure 5, the highest chloride and TDS concentrations for Christmas and Cocoa occurred during July.

In Figure 6 there is only a slight increase in TDS and chloride concentration during the summer months observed at Sanford and De Land. Figures 5 and 6 illustrate that the chloride concentration at each station correlates well with the TDS concentration. The correlation between chloride and TDS is quantified in Figure 7. The figure presents a linear relationship (correlation coefficient (R^2) of 0.97) between TDS and chloride, as follows:

$$TDS = (2.3 * Cl^{-}) + 129.6 \qquad \text{Equation 2}$$

where TDS and chloride (Cl-) are in units of mg/L.

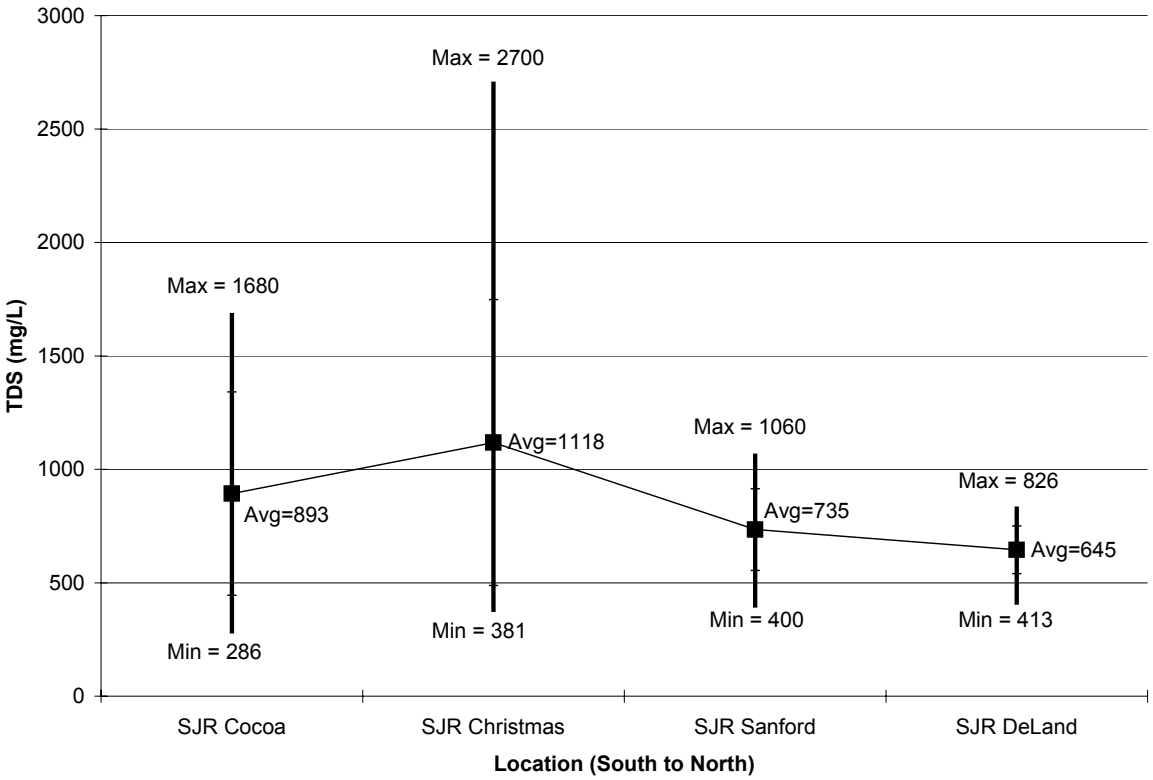

Figure 4. TDS Concentration along the St. Johns River (from furthest point south to furthest point north)

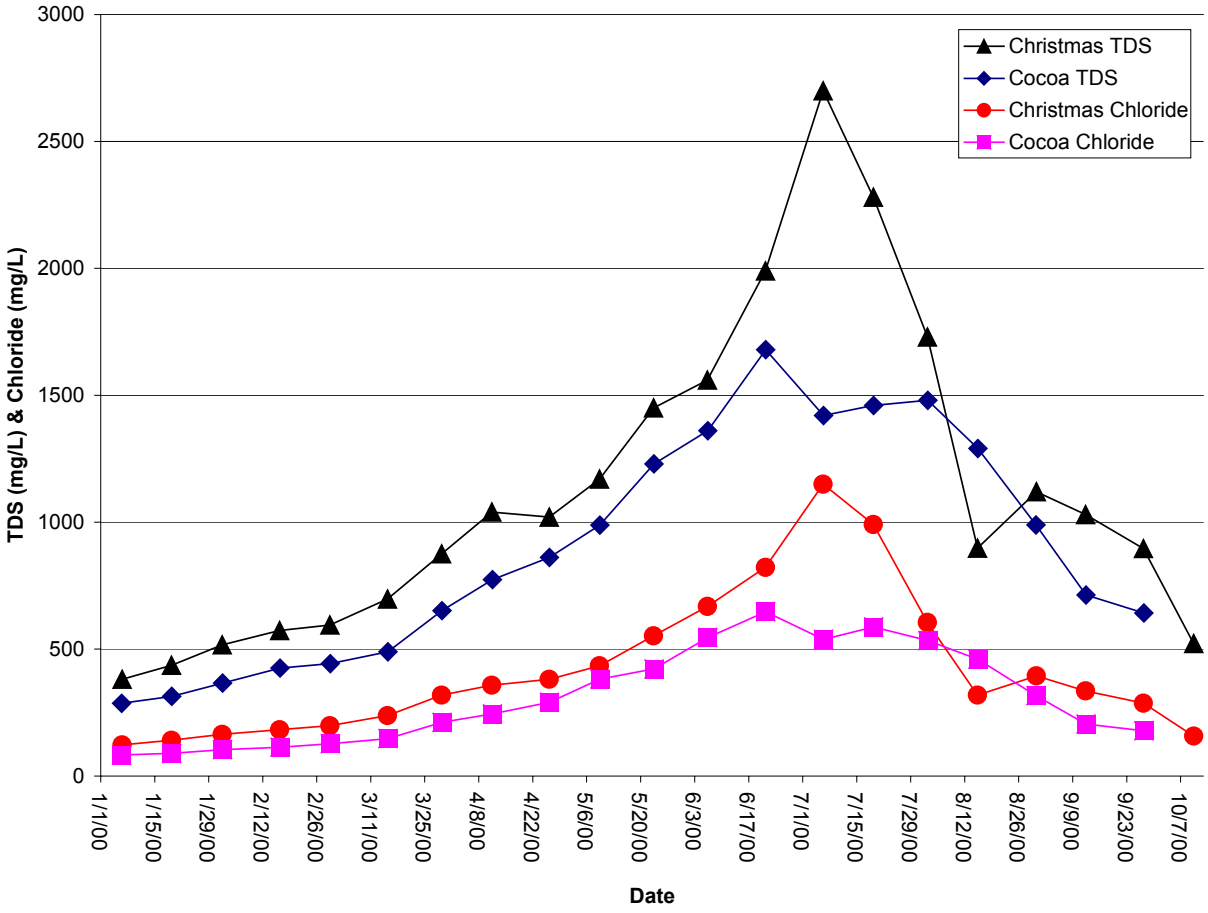

Figure 5. Historical TDS/Cl^- for Cocoa and Christmas Monitoring Sites on the St. Johns River

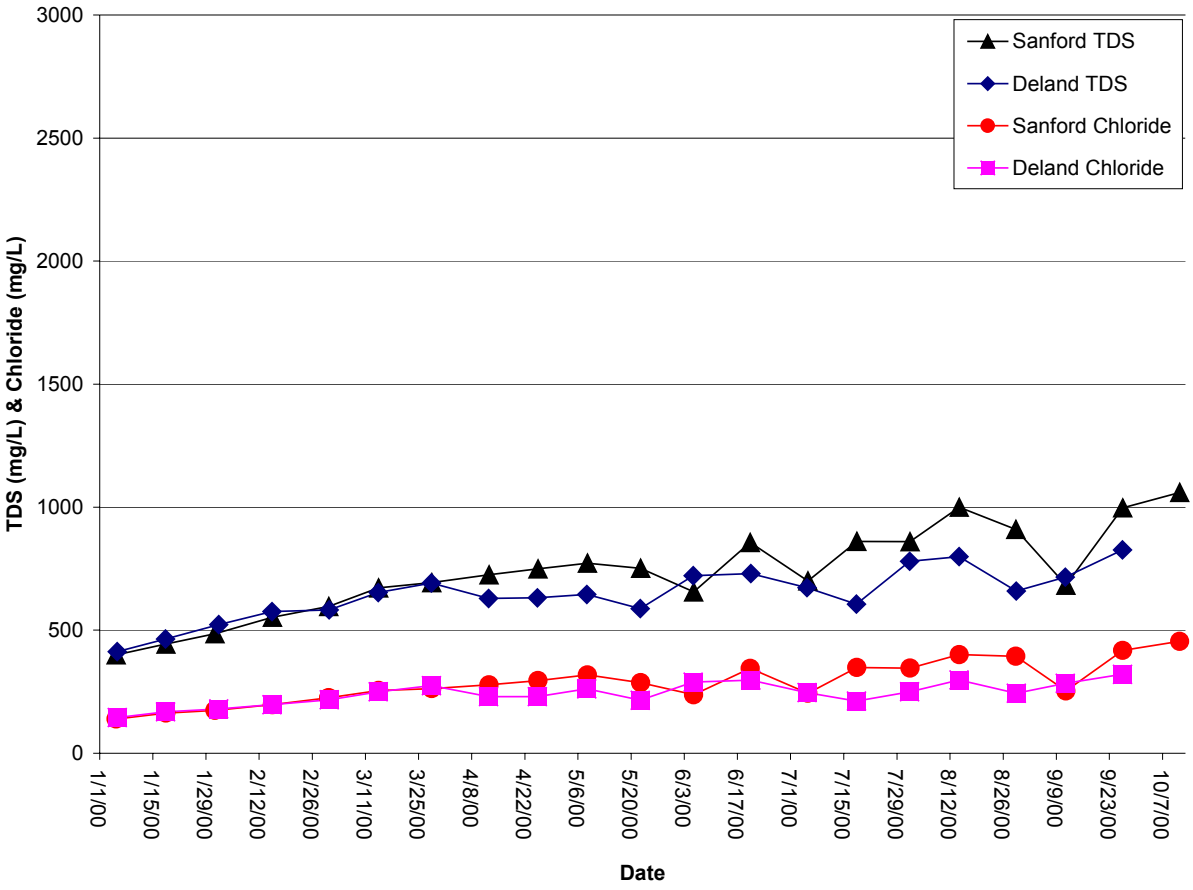

Figure 6. Historical TDS/Cl^- for Sanford and De Land Monitoring Sites on the St. Johns River

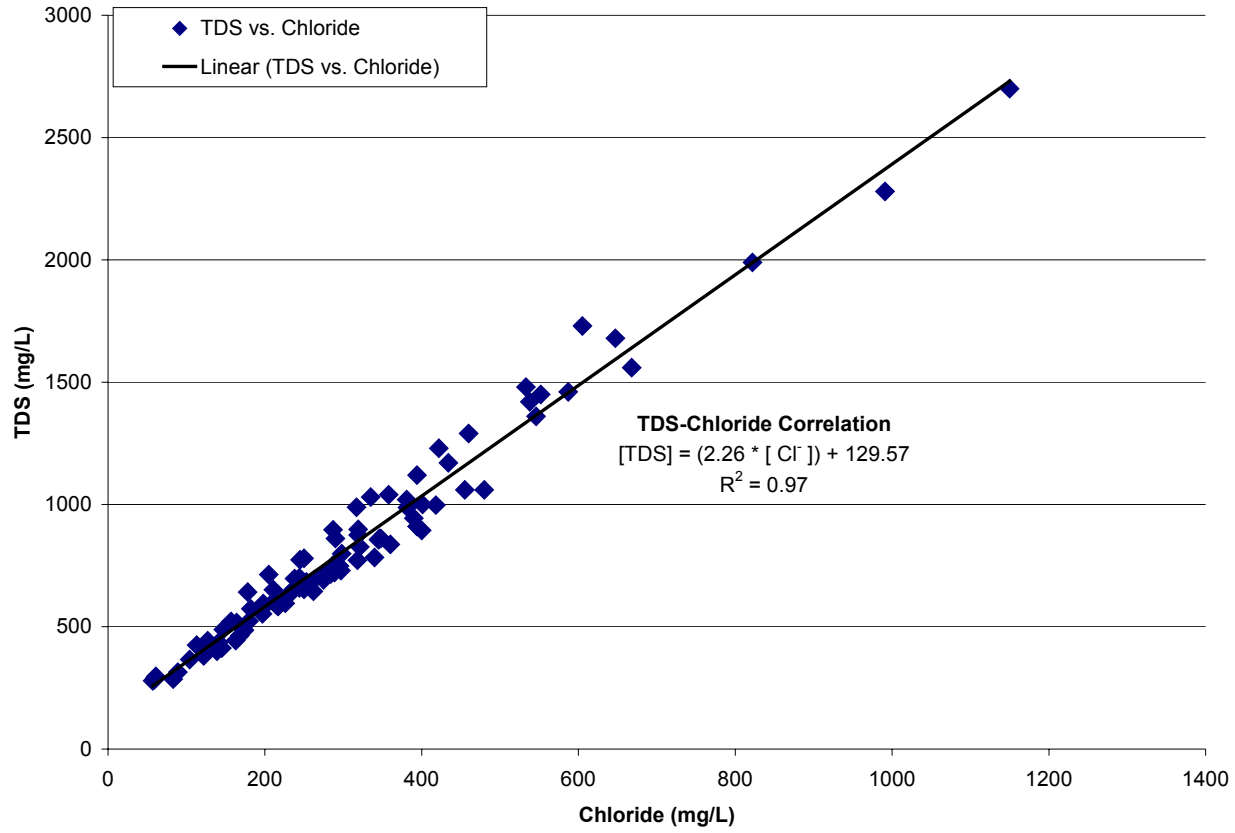

Figure 7. Approximate TDS/Chloride Relationship for the St. Johns River

Bromide is another inorganic of concern in this study. The linear correlations between bromide and chloride as well as between bromide and TDS are presented in Figure 8. Correlation coefficients of 0.95 and 0.98 were determined for the TDS/bromide relationship and chloride/bromide relationship, respectively. The correlations suggest that TDS or chloride could be used as a surrogate for bromide. Equations 3 and 4 represent the TDS/bromide relationship and chloride/bromide relationships, respectively:

$$TDS = (712.6 * Br^{-}) + 131.0 \qquad \text{Equation 3}$$

$$Cl^{-} = (313.0 * Br^{-}) + 0.08 \qquad \text{Equation 4}$$

where TDS, chloride (Cl^-) and bromide (Br^-) are reported in units of mg/L.

CONCLUSIONS

The St. Johns River water is a slightly brackish surface water. The water has a low turbidity, high TOC, high hardness, and high TDS. As discussed, TDS concentrations range from 1,118 mg/L to 645 mg/L. Hardness in the river ranges from 411 mg/L to 233 mg/L and is primarily noncarbonate hardness due to the low alkalinity levels in the St. Johns River. Average TOC values range from approximately 25 mg/L at the southern monitoring stations to less than 20 mg/L at the northern monitoring stations. This initial water quality characterization summary will help facilitate the selection of pilot treatment technologies to be tested.

Throughout the course of this study, additional data will be collected and summarized for inclusion in the final report. After the pilot study, these raw water data will be used to quantify any differences in treatment levels that may be necessary due to changes in raw water quality along the river between Cocoa and De Land.

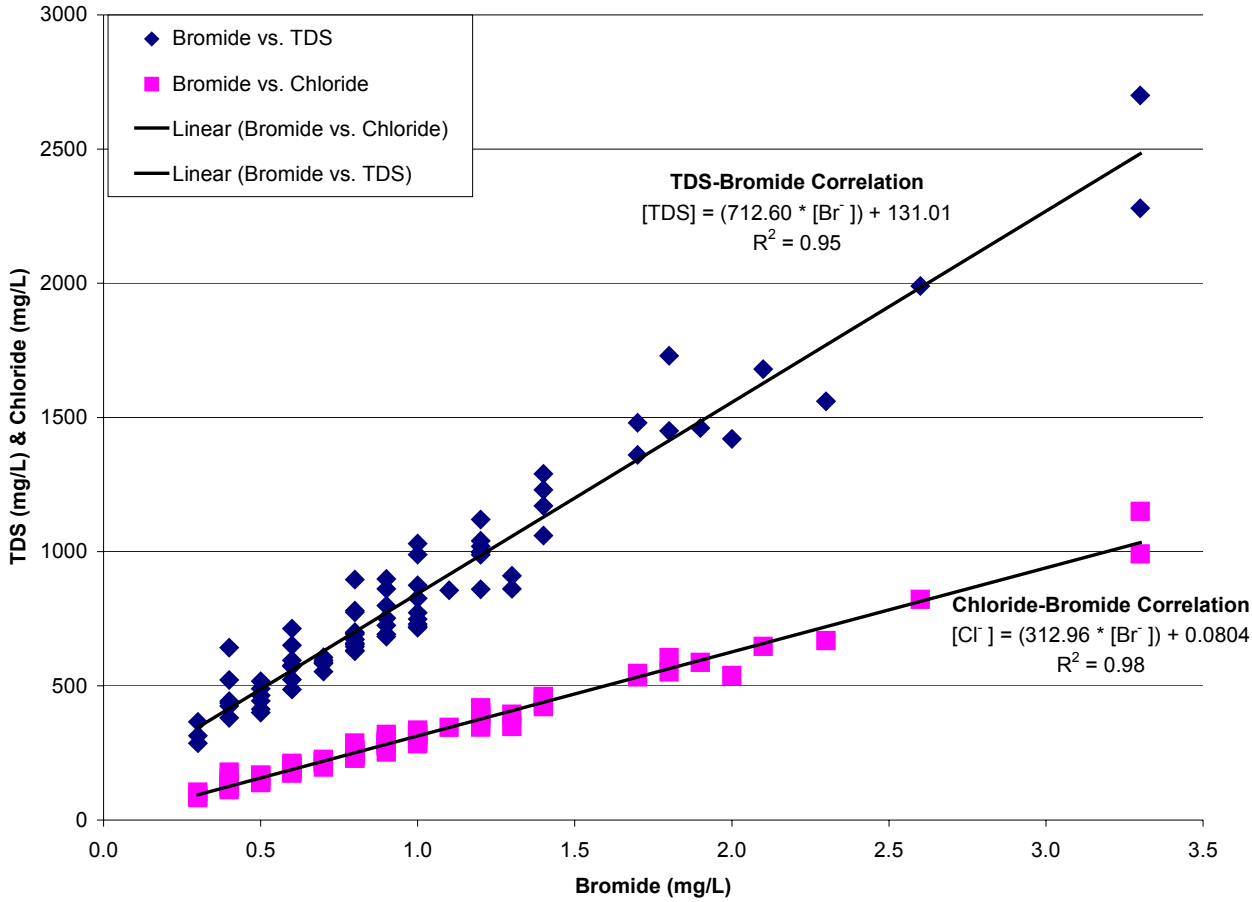

Figure 8. Approximate TDS/Bromide and Chloride/Bromide Relationship for the St. Johns River