FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration

NORTHEAST DISTRICT • LOWER ST. JOHNS BASIN

# Final TMDL Report

# Nutrient TMDL for Arlington River (WBID 2265A)

**Wayne Magley, Ph.D., P.E.**

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# Acknowledgments

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## Websites

### *Florida Department of Environmental Protection, Bureau of Watershed Management*

**TMDL Program**

**http://www.dep.state.fl.us/water/tmdl/index.htm**

**Identification of Impaired Surface Waters Rule**

**http://www.dep.state.fl.us/legal/Rules/shared/62-303/62-303.pdf**

**STORET Program**

**http://www.dep.state.fl.us/water/storet/index.htm**

**2008 305(b) Report**

**http://www.dep.state.fl.us/water/docs/2008_Integrated_Report.pdf**

**Criteria for Surface Water Quality Classifications**

**http://www.dep.state.fl.us/water/wqssp/classes.htm**

**Basin Status Report for the Lower St. Johns Basin**

**http://www.dep.state.fl.us/water/basin411/sj_lower/status.htm**

**Water Quality Assessment Report for the Lower St. Johns Basin**

**http://www.dep.state.fl.us/water/basin411/sj_lower/assessment.htm**

### *U.S. Environmental Protection Agency, National STORET Program*

**Region 4: Total Maximum Daily Loads in Florida**

**http://www.epa.gov/region4/water/tmdl/florida/**

**National STORET Program**

**http://www.epa.gov/storet/**

# Chapter 1: INTRODUCTION

## 1.1 Purpose of Report

This report presents the Total Maximum Daily Load (TMDL) for nutrients for the Arlington River in the North Mainstem Planning Unit of the Lower St. Johns Basin. The river was verified as impaired for nutrients during the Cycle 1 assessment and was included on the Verified List of impaired waters for the Lower St. Johns Basin that was adopted by Secretarial Order in May 2004. Based on a total nitrogen (TN)/total phosphorus (TP) median ratio of 8.8 during the Cycle 1 verified period (January 1, 1996–June 30, 2003), nitrogen was identified as the limiting nutrient. Since there were insufficient chlorophyll (chl*a*) data to demonstrate whether the nutrient criterion was being met during the Cycle 2 assessment period, the Arlington River remained on the Verified List for nutrients. This TMDL establishes the allowable loadings to the Arlington River that would restore the waterbody so that it meets its applicable water quality criterion for nutrients.

## 1.2 Identification of Waterbody

The Arlington River, located in Duval County near downtown Jacksonville (**Figure 1.1**), is a tidally influenced estuarine water that flows into the Lower St. Johns River north of the Hart Bridge. The Arlington River watershed covers 1.58 square miles but receives drainage from a much larger area, including the Pottsburg Creek, Little Pottsburg Creek, Strawberry Creek, and Silversmith Creek sub-basins (**Figure 1.2**).

For assessment purposes, the Florida Department of Environmental Protection (Department) has divided the Lower St. Johns Basin into water assessment polygons with a unique waterbody identification (WBID) number for each watershed or stream reach. This TMDL addresses the Arlington River, WBID 2265A, for nutrients.

The Arlington River is part of the North Mainstem Planning Unit. Planning units are groups of smaller watersheds (WBIDs) that are part of a larger basin unit, in this case the Lower St. Johns Basin. The North Mainstem Planning Unit consists of 49 WBIDs. **Figure 1.3** shows the locations of these WBIDs and the location of the Arlington River watershed in the planning unit.

## 1.3 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida).

Figure 1.1. Location of the Arlington River Watershed (WBID 2265A) in the Lower St. Johns Basin

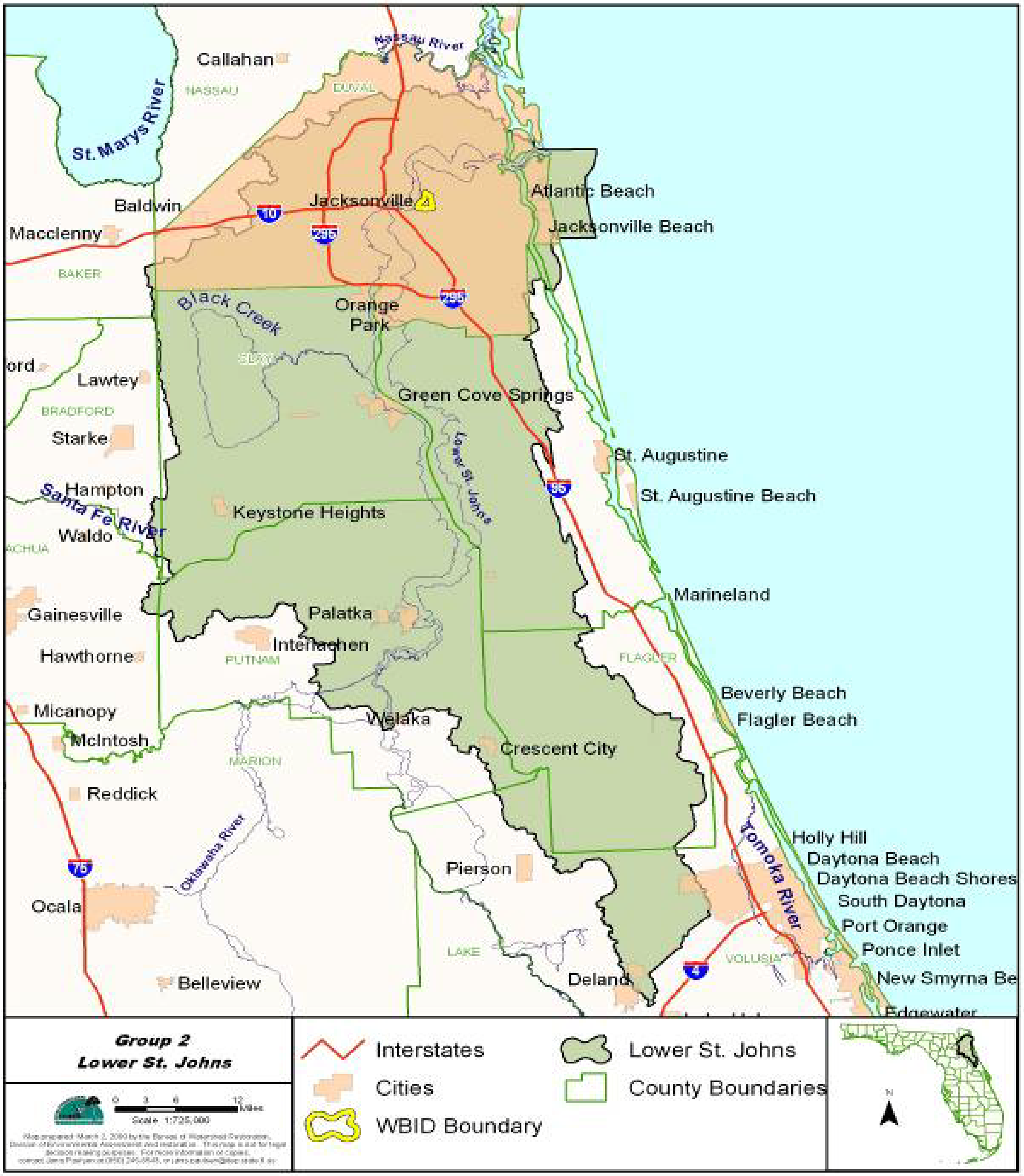
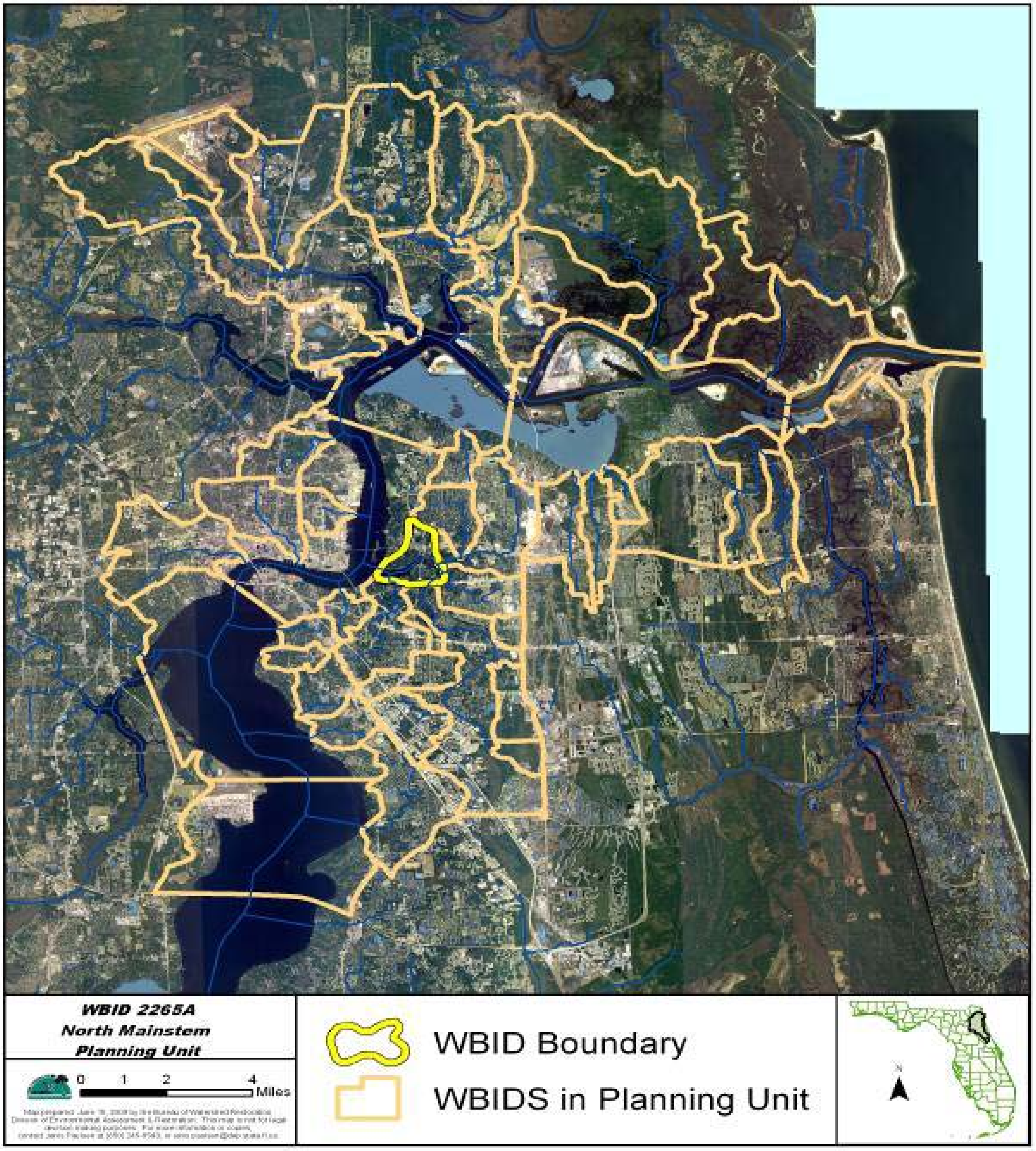


Figure 1.2. Location of the Arlington River Watershed (WBID 2265A) in Duval County and Major Hydrologic Features in the Area

## Figure 1.3. WBIDs in the North Mainstem Planning Unit



A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards. They provide important water quality restoration goals that will guide restoration activities.

A nutrient TMDL, adopted in April 2008 for the mainstem of the Lower St. Johns River, required a 30 to 50 percent reduction in anthropogenic loadings of nitrogen to the marine portion of the Lower St. Johns. A Basin Management Action Plan, or BMAP, adopted in October 2008 outlined a number of activities designed to reduce the amount of TN to the marine portion of the Lower St. Johns River. These activities will depend heavily on the active participation of the St. Johns River Water Management District (SJRWMD), local governments, businesses, and other stakeholders. The Department will work with these organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the established TMDLs for impaired waterbodies, including tributaries to the Lower St. Johns such as the Arlington River.

# Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

## 2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency (EPA) lists of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. The Department has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], Florida Statutes [F.S.]); the state's 303(d) list is amended annually to include basin updates.

Florida's 1998 303(d) list included 55 waterbodies in the Lower St. Johns Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001; the rule was modified in 2006 and 2007.

## 2.2 Information on Verified Impairment

The Department used the IWR to assess water quality impairments in the Arlington River watershed and has verified that this waterbody segment is impaired for nutrients, based on data in the Department's IWR database. **Tables 2.1** and **2.2** summarize the chl*a* data for the Cycle 1 verified period, which for Group 2 waters was January 1, 1996, through June 30, 2003.

The IWR listing threshold for nutrients in estuaries is based on an annual average chl*a* concentration. Annual average chl*a* in 2002 exceeded the threshold of 11 micrograms per liter (μg/L). Note that the original calculation of 83.8 μg/L included a nondetect value that had the incorrect reporting units. The error was subsequently corrected, and the corrected annual average was 13.2 μg/L. During the Cycle 2 assessment period, an annual average of 6.5 μg/L was calculated for 2007.

Possible relationships between chl*a* and other water quality parameters are further assessed in Chapter 5, using the complete historical dataset.

## Table 2.1. Summary of Corrected Chlorophyll *a* (CHLAC) Monitoring Data for the Arlington River (WBID 2265A) During the Cycle 1 Verified Period (January 1, 1996–June 30, 2003)

- = Empty cell

| Waterbody (WBID) | Parameter | CHLAC (µg/L) |
|---|---|---|
| Arlington River (2265A) | Total number of samples | 9 |
| Arlington River (2265A) | IWR-annual average threshold for the Verified List | 11 |
| Arlington River (2265A) | Number of observed exceedances | 1 |
| Arlington River (2265A) | Number of observed nonexceedances | 0 |
| Arlington River (2265A) | Number of seasons during which samples were collected | 4 |
| Arlington River (2265A) | Annual average resulting in listing (µg/L) | 83.8 (corrected to 13.2) |
| Arlington River (2265A) | Lowest individual observation (µg/L) | 0 |
| Arlington River (2265A) | Highest individual observation (µg/L) | 850 (corrected to 44) |
| Arlington River (2265A) | Median TN/TP ratio for 9 observations | 9.3 |
| Arlington River (2265A) | Possible causative pollutant by IWR | TN |
| **-** | **FINAL ASSESSMENT:** | **Impaired** |

## Table 2.2. Summary of Annual Average CHLAC by Year for the Cycle 1 Verified Period (January 1, 1991–June 30, 2003)

CHLAC is in µg/L.

| Year | Number of Samples | Minimum | Maximum | Annual Mean | Number of Exceedances | Mean Precipitation |
|---|---|---|---|---|---|---|
| 2002 | 8 | 0.85 | 850 (corrected to 44) | 83.8 (corrected to 13.2) | 1 | 54.72 |

# Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

## 3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

| | |
|---|---|
| **Class I** | **Potable water supplies** |
| **Class II** | **Shellfish propagation or harvesting** |
| **Class III** | **Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife** |
| **Class IV** | **Agricultural water supplies** |
| **Class V** | **Navigation, utility, and industrial use (there are no state waters currently in this class)** |

The Arlington River (WBID 2265A) is a Class III marine waterbody, with a designated use of recreation, propagation, and the maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the impairment addressed by this TMDL is for nutrients.

## 3.2 Applicable Water Quality Standards and Numeric Water Quality Target

The nutrient criterion in Rule 62-302, F.A.C., is expressed as a narrative:

***Nutrients:***

*In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna [Note: For Class III waters in the Everglades Protection Area, this criterion has been numerically interpreted for phosphorus in Section 62-302.540, F.A.C.].*

To assess whether this narrative criterion was being exceeded, the IWR provides thresholds for nutrient impairment in estuaries based on annual average chl*a* levels. The following language is found in Rule 62-303, F.A.C.:

***62-303.353 Nutrients in Estuaries and Open Coastal Waters.***
*Estuaries, estuary segments, or open coastal waters shall be included on the planning list for nutrients if their annual mean chlorophyll a for any year is greater than 11 ug/l or if data indicate annual mean chlorophyll a values have increased by more than 50% over historical values for at least two consecutive years.*

***62-303.450 Interpretation of Narrative Nutrient Criteria.***

*(1) A water shall be placed on the verified list for impairment due to nutrients if there are sufficient data from the last five years preceding the planning list*

> *assessment, combined with historical data (if needed to establish historical chlorophyll a levels or historical TSIs), to meet the data sufficiency requirements of subsection 62-303.350(2), FA.C. If there are insufficient data, additional data shall be collected as needed to meet the requirements. Once these additional data are collected, the Department shall determine if there is sufficient information to develop a site-specific threshold that better reflects conditions beyond which an imbalance in flora or fauna occurs in the water segment. If there is sufficient information, the Department shall re-evaluate the data using the site-specific thresholds. If there is insufficient information, the Department shall re-evaluate the data using the thresholds provided in Rules 62-303.351-.353, F.A.C., for streams, lakes, and estuaries, respectively. In any case, the Department shall limit its analysis to the use of data collected during the five years preceding the planning list assessment and the additional data collected in the second phase. If alternative thresholds are used for the analysis, the Department shall provide the thresholds for the record and document how the alternative threshold better represents conditions beyond which an imbalance in flora or fauna is expected to occur.*

The annual average chl*a* concentration in 2002 exceeded the IWR estuarine threshold of 11 μg/L in 2002, and, based on the TN/TP ratio, nitrogen was identified as the limiting nutrient. The only additional year during the Cycle 2 verified period with sufficient data to calculate annual average chl*a* was 2007, and chl*a* was below the threshold for impairment.

# Chapter 4: ASSESSMENT OF SOURCES

## 4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of pollutants in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, agriculture, silviculture, and mining; discharges from failing septic systems; and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) **AND** stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

## 4.2 Potential Sources of Nutrients in the Arlington River Watershed

### *4.2.1 Point Sources*

There are no NPDES wastewater facilities located in the Arlington River WBID.

#### Municipal Separate Storm Sewer System Permittees

The city of Jacksonville and Florida Department of Transportation (FDOT) District 2 are co-permittees for a Phase I NPDES municipal separate storm sewer system (MS4) permit (FLS000012) that includes all of the Arlington River watershed.

### *4.2.2 Land Uses and Nonpoint Sources*

Nutrient loadings to the Arlington River are generated from nonpoint sources in the watershed. These potential sources include loadings from surface runoff, ground water inflow, and septic tanks.

## Land Uses

The spatial distribution and acreage of different land use categories were identified using the SJRWMD's year 2004 land use coverage (scale 1:51,000) contained in the Department's geographic information system (GIS) library. Land use categories in the watershed were aggregated using Level 2 land use codes and tabulated in **Table 4.1**. **Figure 4.1** shows the acreage of the principal Level 1 land uses in the watershed.

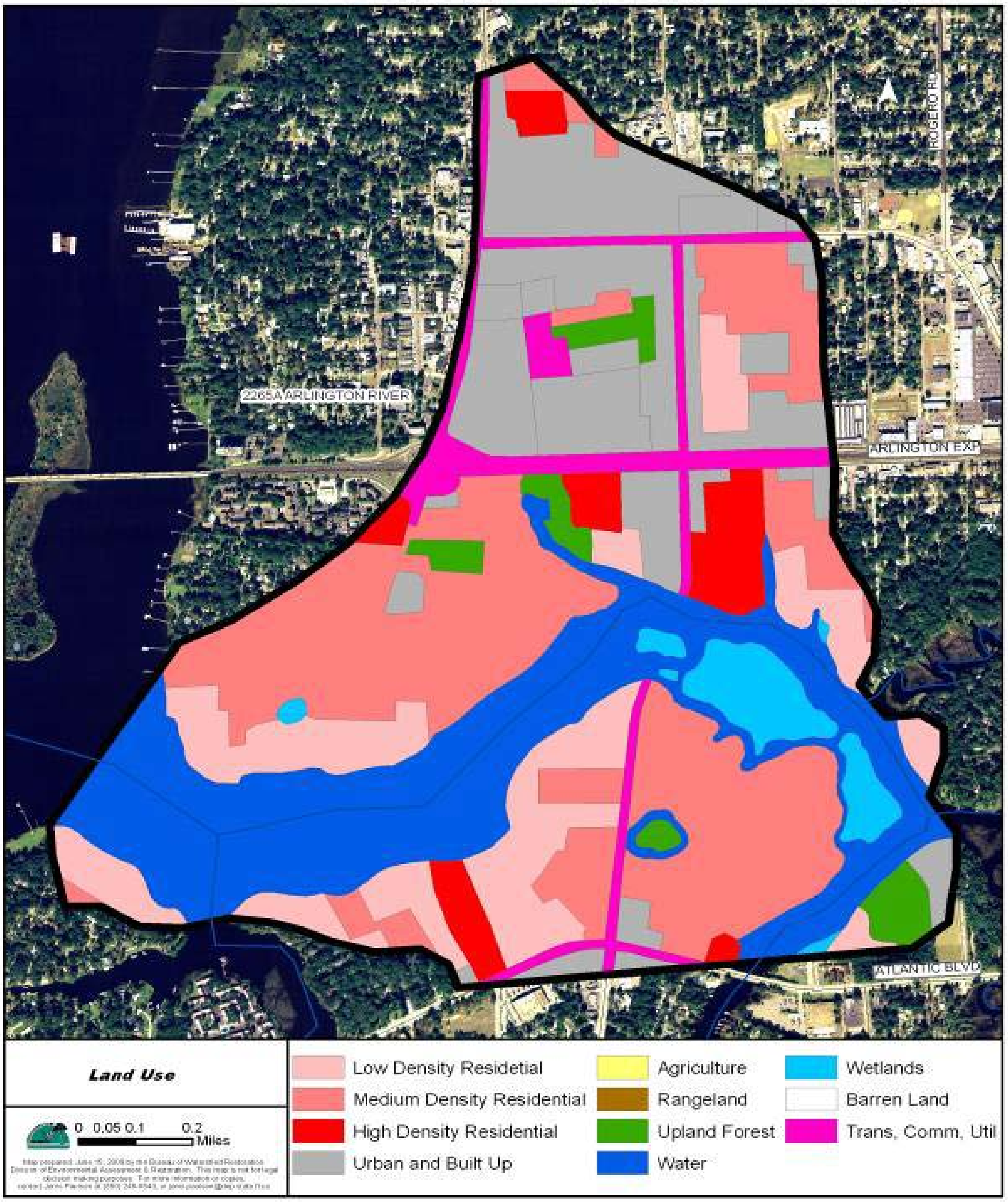
As shown in **Table 4.1**, the total area of the Arlington River watershed is about 1,011 acres. The dominant land use is urban and built-up, which accounts for about 65.8 percent of the total watershed area. Within this category, low- and medium-density residential along with commercial land use dominate and occupy 56.4 percent of the total watershed area. Of the 981 acres of urban lands, residential land use occupies about 507 acres, or about 6.9 percent of the total watershed area. Natural land uses, including water/wetlands, and upland forest, occupy about 285.7 acres, accounting for about 28.2 percent of the total watershed area.

### Table 4.1. Classification of Land Use Categories in the Arlington River Watershed (WBID 2265A) in 2004

- = Empty cell

| Level 2 Land Use Code | Attribute | Acres | % of Total |
|---|---|---|---|
| 1100 | Residential, low density – less than 2 dwelling units/acre | 140.25 | 13.86% |
| 1200 | Residential, medium density – 2-5 dwelling units/acre | 283.8 | 28.05% |
| 1300 | Residential, high density – 6 or more dwelling units/acre | 46.71 | 4.62% |
| 1400 | Commercial and services | 147.08 | 14.54% |
| 1700 | Institutional | 45.08 | 4.46% |
| 1800 | Recreational | 2.46 | 0.24% |
| 4100 | Upland coniferous forests | 9.81 | 0.97% |
| 4300 | Upland hardwood forests cont. | 18.62 | 1.84% |
| 5100 | Streams and waterways | 219.9 | 21.74% |
| 5300 | Reservoirs – pits, retention ponds, dams | 2.87 | 0.28% |
| 6400 | Vegetated nonforested wetlands | 34.47 | 3.41% |
| 8100 | Transportation | 55.62 | 5.50% |
| 8300 | Utilities | 4.97 | 0.49% |
| **-** | **SUM:** | **1,011.64** | **100.00%** |

Figure 4.1. Principal Land Uses in the Arlington River Watershed (WBID 2265A) in 2004



### Soil Characteristics

The Soil Survey Geographic Database (SSURGO) in the Department's GIS database from the SJRWMD was accessed to provide coverage of hydrologic soil groups in the Arlington River watershed (**Figure 4.2**). **Table 4.2** briefly describes the major hydrology soil classes. Soil groups B/D (40.6 percent) and C/D (29.6 percent) are the most common in the watershed, with Type D (28.8 percent) found in the lower portion of the watershed and along its eastern boundaries.

Table 4.2. Description of Hydrologic Soil Classes from the SSURGO Database

| Hydrology Class | Description |
|---|---|
| A | High infiltration rates. Soils are deep, well-drained to excessively drained sands and gravels. |
| A/D | Drained/undrained hydrology class of soils that can be drained and are classified. |
| B | Moderate infiltration rates. Deep and moderately deep, moderately well- and well-drained soils that have moderately coarse textures. |
| B/D | Drained/undrained hydrology class of soils that have moderately coarse textures. |
| C | Slow infiltration rates. Soils with layers impeding downward movement of water, or soils that have moderately fine or fine textures. |
| C/D | Drained/undrained hydrology class of soils that can be drained and classified. |
| D | Very slow infiltration rates. Soils are clayey, have a high water table, or are shallow to an impervious layer. |

### Population

Population and housing unit information from the 2000 census at the block level were obtained from the U.S Census Bureau. GIS was used to estimate the fraction of each block in the Arlington River watershed and then applied to the block information to estimate the population and number of housing units. Based on **Table 4.3**, the population in the watershed is estimated at 3,657 people living in 1,604 households. Based on 2008 Florida Department of Health (FDOH) onsite sewage GIS coverage (available: http://www.doh.state.fl.us/environment/programs/EhGis/EhGisDownload.htm), about 300 housing units *(N)* were identified as being on septic tanks in the Arlington River watershed (**Figure 4.3**).

## Figure 4.2. Distribution of Hydrologic Soil Groups in the Arlington River Watershed (WBID 2265A)

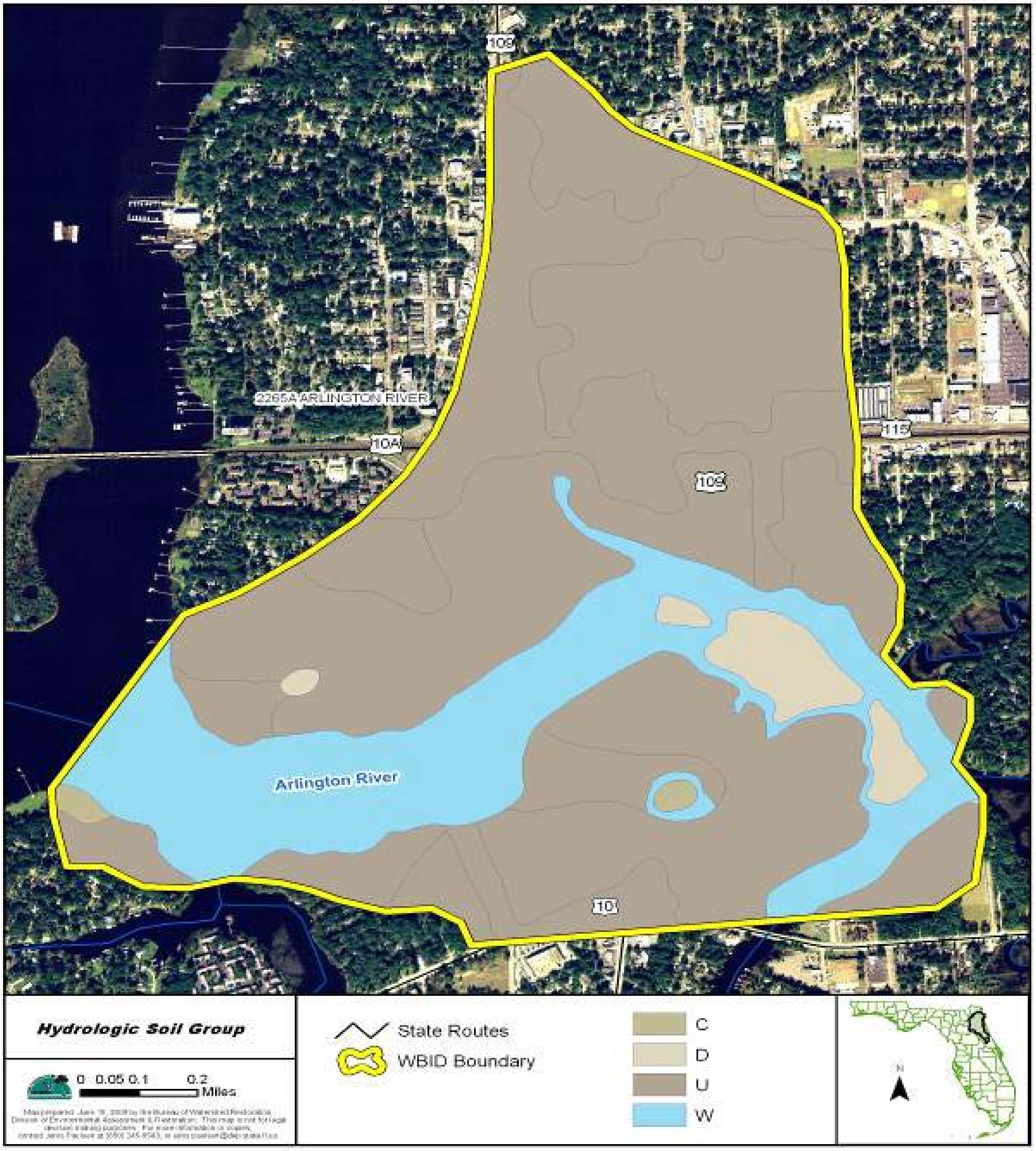
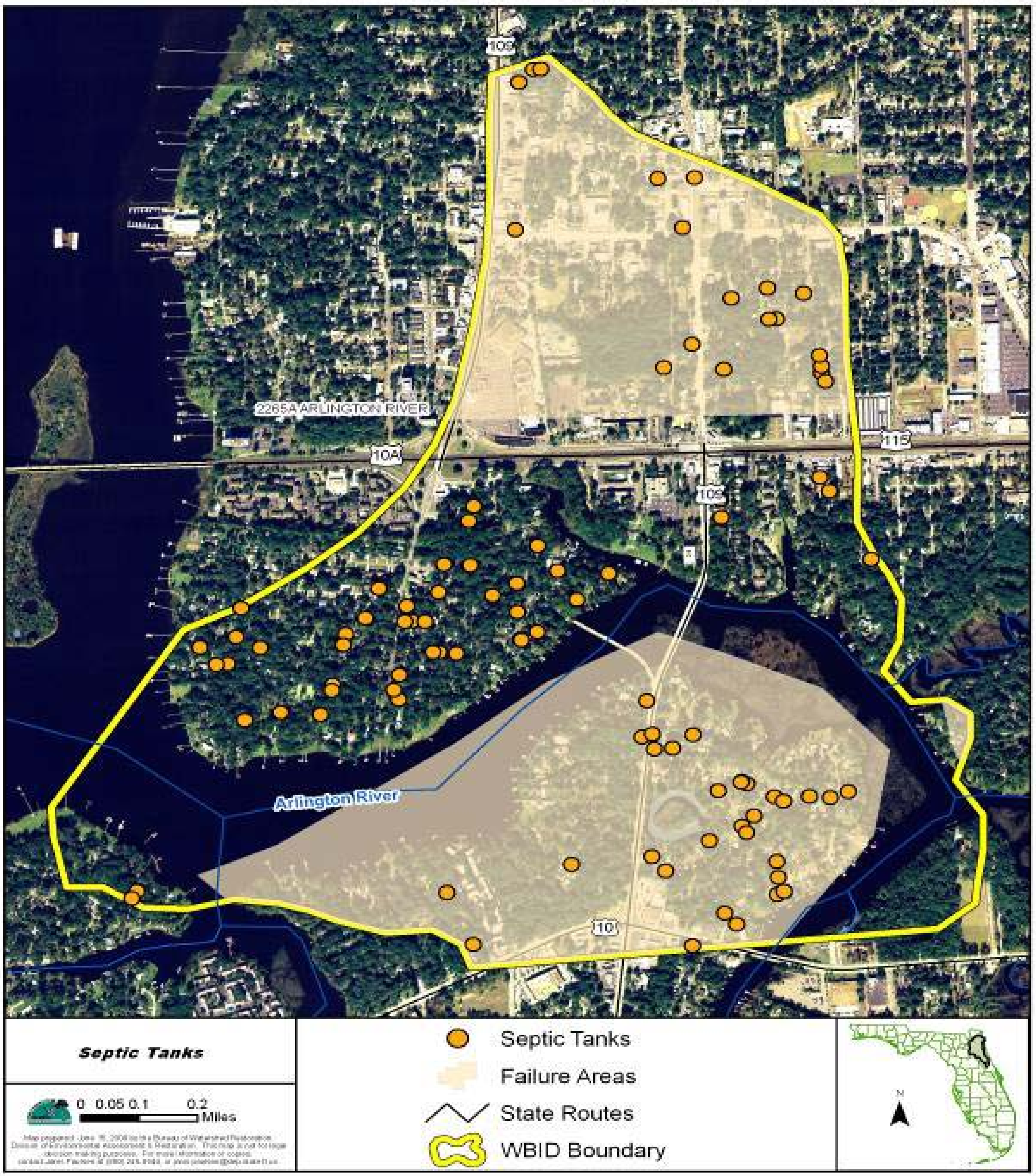


Figure 4.3. Distribution of Onsite Sewage Disposal Systems (Septic Tanks) in the Arlington River Watershed (WBID 2265A)



## Table 4.3. Estimated Average Household Size in the Arlington River Watershed (WBID 2265A)

\- = Empty cell
Data from U.S. Census Bureau Website, 2000, based Duval County blocks present in the Arlington River watershed.

| Tract | Block Group | Population | Housing Units |
|---|---|---|---|
| 153 | 1 | 15 | 6 |
| 153 | 2 | 105 | 69 |
| 154 | 1 | 3 | 3 |
| 154 | 2 | 430 | 181 |
| 154 | 3 | 91 | 55 |
| 155 | 3 | 814 | 337 |
| 156 | 1 | 1,017 | 408 |
| 156 | 2 | 1,059 | 477 |
| 156 | 3 | 107 | 60 |
| 157 | 1 | 8 | 5 |
| 157 | 2 | 9 | 4 |
| | **Total:** | **3,657** | **1,604** |
| **-** | **-** | **AVERAGE HOUSEHOLD SIZE:** | **2.28** |

### Septic Tanks

Approximately 78 percent of Duval County residences are connected to a wastewater treatment plant, while the rest are using septic tanks (PBS&J, 2007; FDOH Website, 2008). Based on the 2000 census estimates of 1,604 households in the Arlington River WBID, this corresponds to about 352 residences on septic tanks. This estimate is very similar to the 300 residences identified from the 2008 FDOH coverage. Assuming that 300 residences in the Arlington River watershed are using septic tanks, and using an estimate of 70 gallons/day/person (EPA, 1999), and drainfield TN and TP concentrations of 36 and 15 milligrams per liter (mg/L), respectively, potential annual ground water loads of TN and TP were calculated. This is a screening level calculation, and soil types, the age of the system, vegetation, proximity to a receiving water, and other factors will influence the degree of attenuation of this load (**Table 4.4**).

## Table 4.4. Estimated Nitrogen and Phosphorus Annual Loading from Septic Tanks in the Arlington River Watershed (WBID 2265A)

[1] U.S. Census Bureau; see **Table 4.3** for more information on this estimate.
[2] EPA, 1999

| Estimated Number of Households on Septic | Estimated Number of People per Household[1] | Gallons/ Person/ Day[2] | TN in Drainfield (mg/L) | TP in Drainfield (mg/L) | Estimated Annual TN Load (lbs/yr) | Estimated Annual TP Load (lbs/yr) |
|---|---|---|---|---|---|---|
| 300 | 2.28 | 70 | 36 | 15 | 5,251 | 2,188 |

### *4.3.1 Summary of Nutrient Loadings to the Arlington River from Various Sources*

Screening level estimates of annual nitrogen and phosphorus loadings to the watershed were developed based on 2004 land use and hydrologic soil groups. GIS shapefiles of land use and hydrologic soil groups were used to determine the acreage associated with various Level 2 land uses and soils. Estimates for annual runoff coefficients and event mean concentrations (EMCs) were based on Harper and Baker (2007) and Gao (2006). A screening level estimate of annual runoff was calculated by multiplying the long-term annual average rainfall of 52.44 inches (Jacksonville International Airport [JIA], 1955–2007) by the respective runoff coefficient and area. Estimates of annual nitrogen and phosphorus loading were obtained by multiplying the annual runoff by the corresponding EMC. A more detailed loading analysis could be performed based on the development of site-specific runoff coefficients, EMCs, and knowledge of best management practices (BMPs) that have been implemented in the watershed.

#### Agriculture

At the Level 3 land use category, no agricultural areas or rangeland were identified in the Arlington River watershed.

#### Urban Areas

There are 665 acres in the Level 1 category of urban and built-up in the watershed and 60 acres in transportation, communication, and utilities. Low- and medium-density residential represent approximately 21 and 43 percent, respectively, of the total acreage in the urban and built-up category. **Table 4.5** summarizes the screening level estimates for nitrogen and phosphorus loads from urban and built-up land uses in the watershed.

#### Forest/Wetland/Water/Open Lands

**Table 4.6** summarizes the estimates for nitrogen and phosphorus loadings from the Level 2 land use classifications for forest, wetland, and water. Wetlands and upland forests represent 3.4 and 2.8 percent, respectively, of the acreage in the watershed.

## Table 4.5. Estimated Urban and Built-up Annual Nitrogen and Phosphorus Loading in the Arlington River Watershed (WBID 2265A)

- = Empty cell/no data

| Land Use Classification | Soil Group | Acres | Annual Runoff Coefficient | Gross Runoff (acre-feet) | Estimated TN Load (lbs) | Estimated TP Load (lbs) |
|---|---|---|---|---|---|---|
| Residential, low density – less than 2 dwelling units/acre | D | 0.3 | 0.226 | 0.30 | 1.30 | 0.15 |
| - | U | 131.83 | 0.435 | 250.60 | 1,097.84 | 130.24 |
| - | C | 2.4 | 0.166 | 1.74 | 7.63 | 0.90 |
| - | W | 5.73 | 0.435 | 10.89 | 47.72 | 5.66 |
| Residential, medium density – 2-5 dwelling units/acre | D | 0.24 | 0.252 | 0.26 | 1.49 | 0.24 |
| - | U | 281.02 | 0.435 | 534.20 | 3,008.89 | 475.32 |
| - | W | 2.52 | 0.435 | 4.79 | 26.98 | 4.26 |
| Residential, high density – 6 or more dwelling units/acre | U | 46.12 | 0.435 | 87.67 | 553.45 | 62.50 |
| - | W | 0.6 | 0.435 | 1.14 | 7.20 | 0.81 |
| Commercial and services | U | 146.79 | 0.435 | 279.04 | 1,359.09 | 198.93 |
| - | W | 0.29 | 0.435 | 0.55 | 2.69 | 0.39 |
| Institutional | U | 44.89 | 0.435 | 85.33 | 278.63 | 60.37 |
| - | D | 0.05 | 0.35 | 0.08 | 0.25 | 0.05 |
| - | W | 0.14 | 0.435 | 0.27 | 0.87 | 0.19 |
| Recreational | U | 2.46 | 0.435 | 4.68 | 14.63 | 0.70 |
| Transportation | U | 55.48 | 0.435 | 105.46 | 470.63 | 63.13 |
| - | W | 0.17 | 0.435 | 0.32 | 1.44 | 0.19 |
| - | U | 4.97 | 0.435 | 9.45 | 42.16 | 5.66 |
| **-** | **SUM:** | **726** | **-** | **1,376.78** | **6,922.89** | **1,009.71** |

## Table 4.6. Estimated Forest/Wetland/Water/Open Lands Annual Nitrogen and Phosphorus Loading in the Arlington River Watershed (WBID 2265A)

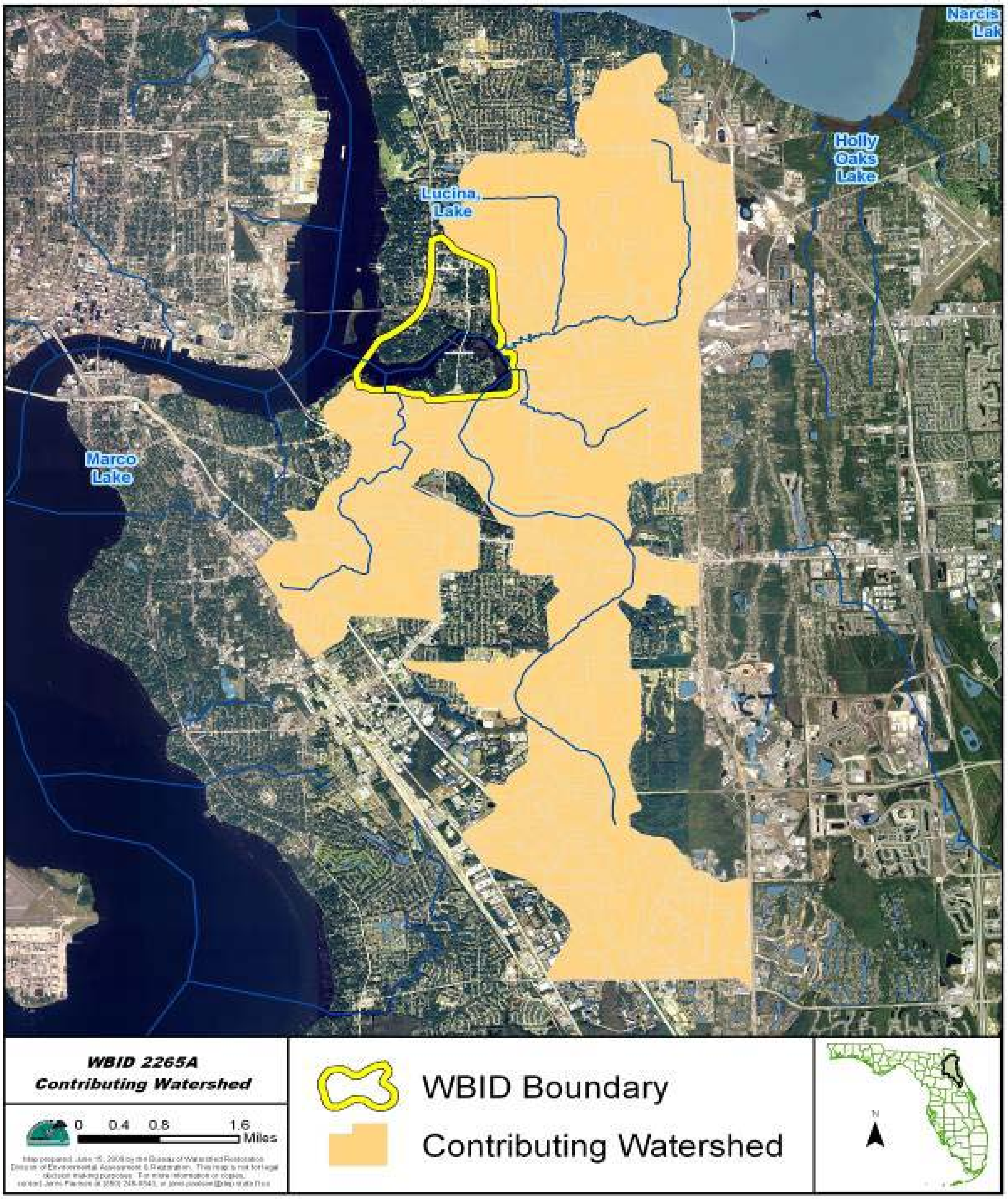
- = Empty cell/no data

| Land Use Classification | Soil Group | Acres | Annual Runoff Coefficient | Gross Runoff (acre-feet) | Estimated TN Load (lbs) | Estimated TP Load (lbs) |
|---|---|---|---|---|---|---|
| Upland coniferous forests | W | 0.3 | 0.435 | 0.57 | 1.78 | 1.78 |
| - | U | 8.78 | 0.435 | 16.69 | 52.23 | 52.23 |
| - | C | 0.73 | 0.166 | 0.53 | 1.66 | 1.66 |
| Upland hardwood forests | U | 16.29 | 0.435 | 30.97 | 96.90 | 96.90 |
| - | W | 1.17 | 0.435 | 2.22 | 6.96 | 6.96 |
| - | C | 1.15 | 0.166 | 0.83 | 2.61 | 2.61 |
| Streams and waterways | C | 0.79 | 0.435 | 1.50 | 5.11 | 0.45 |
| - | U | 9.44 | 0.435 | 17.94 | 61.04 | 5.37 |
| - | D | 3.57 | 0.435 | 6.79 | 23.08 | 2.03 |
| - | W | 206.1 | 0.435 | 391.79 | 1,332.56 | 117.27 |
| Reservoirs – pits, retention ponds, dams | W | 2.04 | 0.435 | 3.88 | 13.19 | 1.16 |
| - | U | 0.33 | 0.435 | 0.63 | 2.13 | 0.19 |
| - | C | 0.5 | 0.435 | 0.95 | 3.23 | 0.28 |
| Vegetated nonforested wetlands | D | 30.64 | 0.435 | 58.25 | 253.58 | 9.51 |
| - | U | 1.37 | 0.435 | 2.60 | 11.34 | 0.43 |
| - | W | 2.45 | 0.435 | 4.66 | 20.28 | 0.76 |
| **-** | **SUM:** | **285.65** | **-** | **540.80** | **1,887.67** | **299.58** |

### Upstream Areas Draining to the Arlington River Watershed

The Red Bay Branch, Silversmith Creek, Strawberry Creek, Pottsburg Creek, and Little Pottsburg Creek sub-basins contribute to the water quality observed in the Arlington River (**Figure 4.4**). The same procedure used for the Arlington River WBID was used to estimate annual TN and TP loading from these contributing watersheds (**Table 4.7**).

## Figure 4.4. Upstream Areas Draining to the Arlington River Watershed (WBID 2265A)



## Table 4.7. Estimated Annual Nitrogen and Phosphorus Loading to the Arlington River Watershed (WBID 2265A) from Upstream Drainage Areas

| Land Use Category | Acres | Gross Runoff (acre-feet) | Estimated TN Load (lbs) | Estimated TP Load (lbs) |
|---|---|---|---|---|
| Urban | 11,036.55 | 18,199.62 | 95,337.89 | 15,680.86 |
| Agriculture | 205.55 | 144.39 | 532.79 | 40.17 |
| Forest/Wetland/ Water | 2,500.1 | 4,064.65 | 16,265.91 | 792.61 |
| **TOTAL:** | **13,742.2** | **22,408.67** | **112,136.60** | **16,513.65** |

**Table 4.8** summarizes the estimates from various land uses in the watershed. It is important to note that this is not a complete list and represents estimates of potential loadings. In addition, proximity to the waterbody, site-specific soil characteristics, and rainfall frequency and magnitude are just a few of the factors that could influence and determine the actual loadings from these sources that reach Arlington River. The types of BMPs, both structural and nonstructural, implemented for specific land uses in the watershed could reduce the actual nutrient loads delivered to the Arlington River. Finally, the age and condition of the septic systems and drainage characteristics in the watershed compared with the county overall could affect assumptions about the assimilation and/or retention of nutrients.

## Table 4.8. Summary of Estimated Potential Annual Nitrogen and Phosphorus Loading from Various Sources in the Arlington River Watershed (WBID 2265A)

[1] Potential contribution to ground water

| Source | TN (lbs/yr) | TP (lbs/yr) |
|---|---|---|
| Septic Tanks[1] | 5,251 | 2,188 |
| Urban and Built-up | 6,922.89 | 1,009.71 |
| Forest/Wetland/Water/ Open Lands | 1,887.67 | 299.58 |
| Upstream Drainage Area | 112,136.60 | 16,513.65 |

The screening model estimated an annual surface runoff of 24,326.2 acre-feet, or 19.8 inches per year, based on the combined Arlington River watershed and contributing watershed area. Dividing the estimated TN load by the surface runoff volume yielded an average TN concentration of 1.83 mg/L. The average and median TN concentrations from the available data were 1.15 and 1.14 mg/L, respectively. Dividing the estimated TP load by the surface runoff volume yielded an average TP concentration of 0.269 mg/L. The average and median TP concentrations from the available data were 0.176 and 0.140 mg/L, respectively. Flow and nutrient contributions from ground water inputs to the Arlington River were not included in this screening level calculation and would likely influence instream concentrations. Tidal exchange with the St. Johns River was also not considered in the calculation.

Camp Dresser & McKee, Inc. is currently working with the city of Jacksonville on an update to the Master Stormwater Management Plan, using the Watershed Management Model (WMM) to develop nutrient loads for sub-basins. The Arlington River watershed is one of the watersheds in which the WMM is being applied.

# Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

## 5.1 Determination of Loading Capacity

### *5.1.1 Data Used in the Determination of the TMDL*

Twelve sampling stations on the Arlington River have historical observations (**Figure 5.1**). Six of those stations have CHLAC measurements. **Table 5.1** contains summary information on each of the stations (N represents the number of CHLAC observations). **Table 5.2** provides a statistical summary of CHLAC observations at each station, and **Appendix B** contains CHLAC, temperature (TEMP), TN, and TP observations from sampling sites in WBID 2265A from 1992 to 2008. **Figure 5.2** displays the historical CHLAC observations over time. The simple linear regression of CHLAC versus sampling date was significant at an α level of 0.05. **Appendix E** contains plots of CHLAC by season, station, and year.

**Figures 5.3** and **5.4** present historical TN and TP observations, respectively. Linear regressions of each parameter versus sampling date indicate that regressions for TN and TP were significant at an α level of 0.05. **Appendix E** contains additional plots by season, station, and year. **Tables 5.3** and **5.4** provide statistical summaries of TN and TP, respectively, by station. **Table 5.5** presents a statistical summary of major water quality parameters from the available data.

Table 5.1. Sampling Station Summary for the Arlington River (WBID 2265A)

| Station | STORET ID | Station Owner | Years With Data | N |
|---|---|---|---|---|
| Arlington River at the St. Johns River | 11NPSWRDTIMU_DER_SJR-11 | Department | 1982–83 | 0 |
| Arlington R Cesery Blvd | 21FLA 20030073 | Department | 1968–2008 | 17 |
| Arlington River Near Mouth Below Pottsburg Ck | 21FLJXWQARLRM | City of Jacksonville | 1994–95 | 0 |
| Arlington R. Near Confl. With L. Pottsburg Cr. | 21FLJXWQJAXSJR20A | City of Jacksonville | 1999–2001 | 0 |
| Arlington River at Cesery Blvd | 21FLJXWQRR0005 | City of Jacksonville | 1983–91 | 0 |
| Arlington River at University Blvd | 21FLSJWMLSJ090 | SJRWMD | 1992–93 | 4 |
| Arlington River Near Mouth Below Pottsburg Ck | 21FLSJWMARLRM | SJRWMD | 1993–94 | 2 |
| Arlington R Nr Mouth Bel Pottsburg Ck Stormflow | 21FLSJWMARLRM.S | SJRWMD | 1993–94 | 0 |
| Arlington River Bridge | 21FLVOL ARL010 | Volunteer | 1996 | 0 |
| Arlington R Nr Conf w/ Little Pottsburg | 21FLA 20030811 | Department | 2007–08 | 5 |
| Arlington R 500M SW University Blvd | 21FLA 20030812 | Department | 2007 | 5 |
| Arlington R Btwn Conf W Strawberry Cr & Silversmith Cr | 21FLA 20030813 | Department | 2007 | 5 |

## Table 5.2. Statistical Summary of Historical CHLAC Data for the Arlington River (WBID 2265A)

CHLAC data are µg/L.

| Station | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| Arlington R Cesery Blvd | 17 | 1.0 | 44.0 | 9.2 | 1.0 |
| Arlington River at University Blvd | 4 | 1.9 | 71.6 | 28.2 | 19.6 |
| Arlington River Near Mouth Below Pottsburg Ck | 2 | 4.8 | 19.2 | 12.0 | 12.0 |
| Arlington R Nr Conf w/ Little Pottsburg | 5 | 1.0 | 16.0 | 6.2 | 5.1 |
| Arlington R 500M SW University Blvd | 5 | 1.0 | 12.0 | 6.5 | 8.7 |
| Arlington R Btwn Conf W Strawberry Cr & Silversmith Cr | 5 | 1.0 | 16.0 | 10.8 | 12.0 |

## Table 5.3. Statistical Summary of Historical TN Data for the Arlington River (WBID 2265A)

TN data are mg/L.

| Station | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| Arlington R Cesery Blvd | 54 | 0.17 | 3.09 | 1.33 | 1.31 |
| Arlington River at Cesery Blvd | 14 | 0.27 | 1.62 | 1.04 | 1.07 |
| Arlington River at University Blvd | 4 | 0.62 | 1.19 | 1.00 | 1.10 |
| Arlington River Near Mouth Below Pottsburg Ck | 8 | 0.18 | 1.44 | 0.87 | 0.96 |
| Arlington River Near Mouth Below Pottsburg Ck | 4 | 1.08 | 1.71 | 1.38 | 1.36 |
| Arlington River Near Mouth Below Pottsburg Ck (Jax) | 6 | 0.60 | 0.97 | 0.78 | 0.77 |
| Arlington R. Near Confl. With L. Pottsburg Cr. | 32 | 0.31 | 2.53 | 1.03 | 0.94 |
| Arlington R Nr Conf w/ Little Pottsburg | 5 | 0.63 | 1.74 | 1.20 | 1.25 |
| Arlington R 500M SW University Blvd | 5 | 0.66 | 1.57 | 1.14 | 1.17 |
| Arlington R Btwn Conf W Strawberry Cr & Silversmith Cr | 5 | 0.69 | 1.70 | 1.19 | 1.19 |

## Table 5.4. Statistical Summary of Historical TP Data for the Arlington River (WBID 2265A)

TP data are mg/L.

| Station | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| Arlington R Cesery Blvd | 50 | 0.027 | 0.850 | 0.210 | 0.135 |
| Arlington River at Cesery Blvd | 34 | 0.030 | 0.351 | 0.165 | 0.152 |
| Arlington River at University Blvd | 4 | 0.130 | 0.190 | 0.150 | 0.140 |
| Arlington River Near Mouth Below Pottsburg Ck | 9 | 0.110 | 0.180 | 0.131 | 0.120 |
| Arlington River Near Mouth Below Pottsburg Ck | 5 | 0.147 | 0.327 | 0.209 | 0.187 |
| Arlington River Near Mouth Below Pottsburg Ck (Jax) | 6 | 0.091 | 0.248 | 0.137 | 0.111 |
| Arlington R Nr Conf w/ Little Pottsburg | 5 | 0.082 | 0.210 | 0.146 | 0.150 |
| Arlington R 500M SW University Blvd | 5 | 0.091 | 0.210 | 0.136 | 0.140 |
| Arlington R Btwn Conf W Strawberry Cr & Silversmith Cr | 5 | 0.110 | 0.200 | 0.148 | 0.150 |

## Table 5.5. Summary Statistics for Major Water Quality Parameters Measured in the Arlington River (WBID 2265A)

| PARM | N | MIN | 25% | MEDIAN | MEAN | 75% | MAX |
|---|---|---|---|---|---|---|---|
| BOD (mg/L) | 137 | 0.0 | 1.1 | 2.0 | 1.8 | 2.0 | 7.8 |
| CHLAC (ug/L) | 38 | 1.0 | 1.0 | 7.4 | 10.8 | 15.0 | 71.6 |
| CHLORIDE (mg/L) | 176 | 4 | 1000 | 2687 | 3581 | 5484 | 17994 |
| COLOR (PCU) | 110 | 30 | 50 | 60 | 83 | 100 | 225 |
| COND (uS/cm) | 164 | 14 | 4527 | 9630 | 11514 | 17850 | 45350 |
| DO (mg/L) | 256 | 1.50 | 5.86 | 6.90 | 7.01 | 8.20 | 19.50 |
| DOSAT (%) | 240 | 31.77 | 69.37 | 83.17 | 82.93 | 93.52 | 229.41 |
| NH4 (mg/L) | 169 | 0.00 | 0.01 | 0.03 | 0.08 | 0.08 | 1.13 |
| NO3O2 (mg/L) | 124 | 0.00 | 0.04 | 0.16 | 0.17 | 0.28 | 0.53 |
| PH (su) | 248 | 5.10 | 7.11 | 7.48 | 7.40 | 7.70 | 8.83 |
| SO4 (mg/L) | 38 | 24.00 | 230.00 | 510.00 | 589.76 | 916.00 | 1400.00 |
| TEMP (C) | 249 | 7.00 | 19.15 | 24.00 | 23.34 | 27.85 | 33.50 |
| TKN (mg/L) | 102 | 0.13 | 0.63 | 0.87 | 0.88 | 1.07 | 2.37 |
| TN (mg/L) | 137 | 0.17 | 0.75 | 1.14 | 1.15 | 1.44 | 3.09 |
| TOC (mg/L) | 54 | 5.00 | 10.00 | 13.00 | 15.46 | 18.00 | 60.00 |
| TORTHO (MG/L) | 59 | 0.040 | 0.060 | 0.089 | 0.122 | 0.104 | 1.030 |
| TP (mg/L) | 123 | 0.027 | 0.110 | 0.140 | 0.178 | 0.204 | 0.850 |
| TSS (mg/L) | 152 | 4 | 15 | 19 | 23 | 29 | 161 |
| TURB (NTU) | 119 | 1 | 4 | 6 | 8 | 10 | 70 |

## Figure 5.1. Historical Sampling Sites in the Arlington River (WBID 2265A)

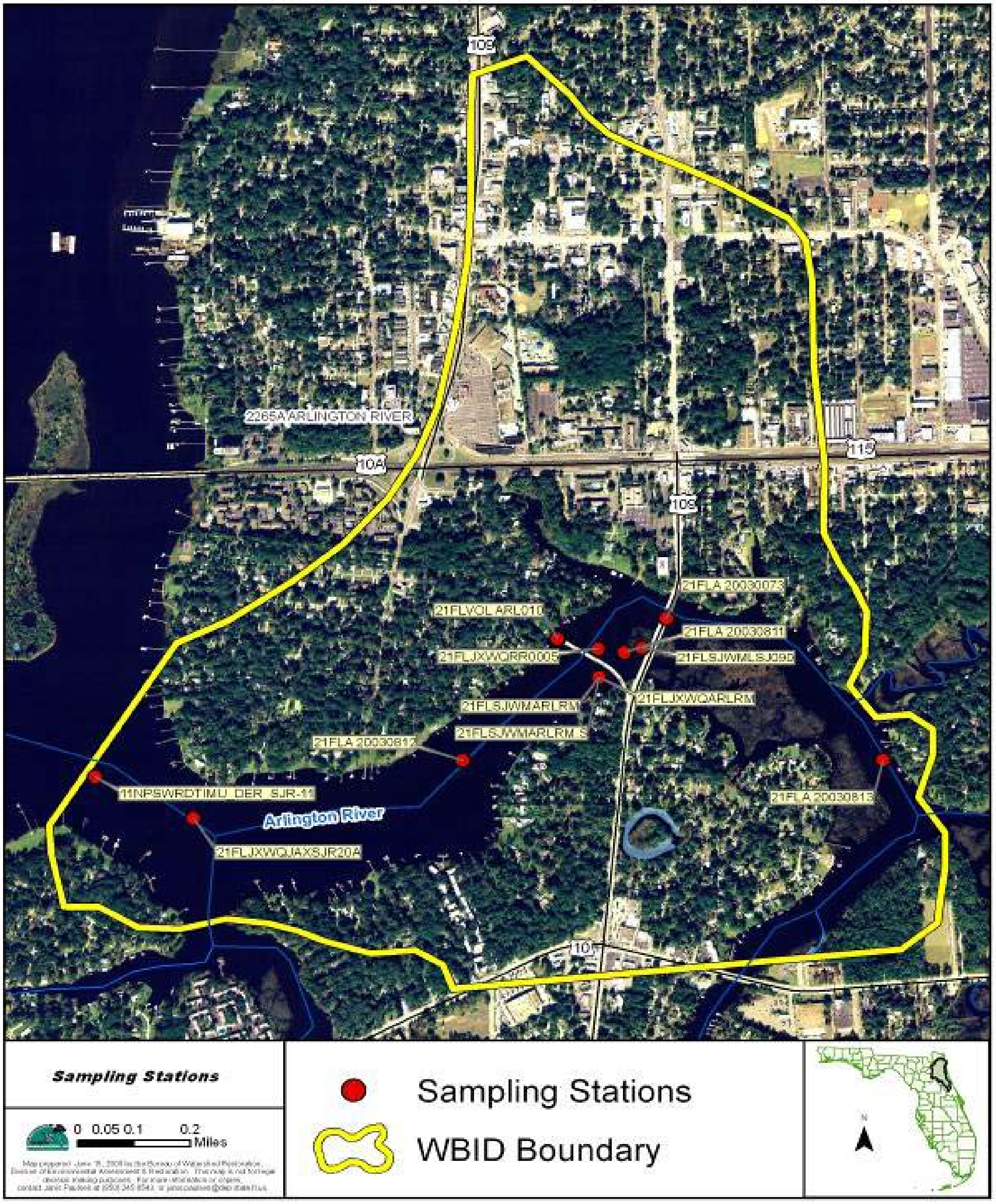


Figure 5.2. Historical CHLAC Observations for the Arlington River (WBID 2265A)

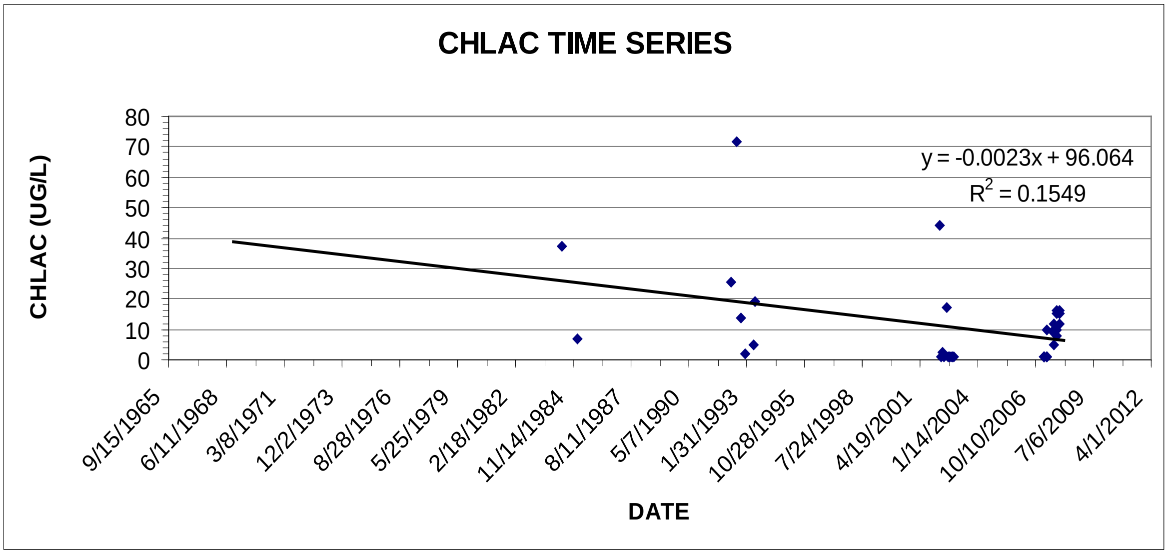
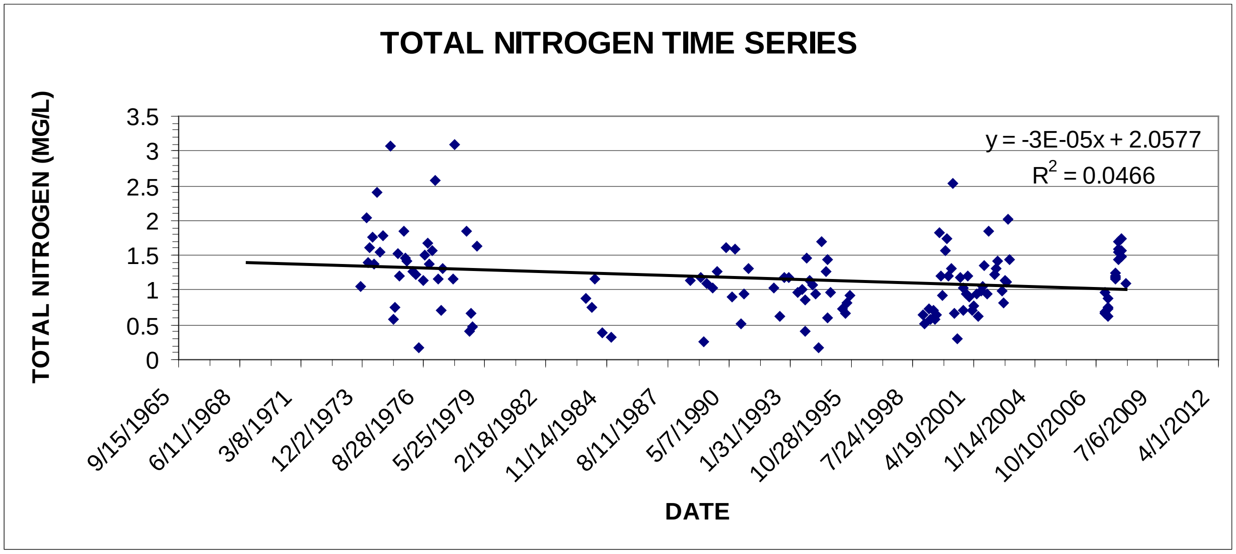
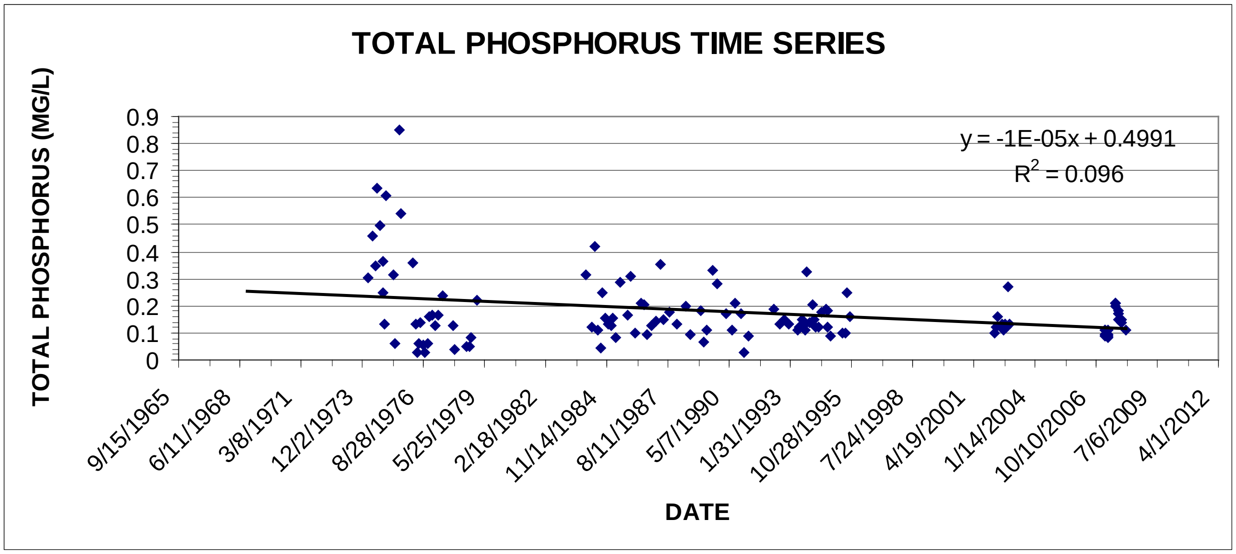



Figure 5.3. Historical TN Observations for the Arlington River (WBID 2265A)



## Figure 5.4. Historical TP Observations for the Arlington River (WBID 2265A)




Available CHLAC, TN, and TP measurements were also summarized by year (**Tables 5.6, 5.7,** and **5.8**). A nonparametric test (Kruskal-Wallis) was applied to the CHLAC, TN, and TP datasets to determine whether there were significant difference among seasons (**Appendix C**). At an α level of 0.05, differences were significant among seasons for TN. A similar test for differences among months was not significant at an α level of 0.05 (**Appendix D**). Time series plots of TN (**Figure 5.3**) and TP (**Figure 5.4**) suggested a decline in concentrations, particularly when compared with levels observed during the mid-1970s.

## Table 5.6. Statistical Summary of Historical CHLAC Data by Year for the Arlington River (WBID 2265A)

CHLAC concentrations are μg/L.

| Year | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| 1984 | 1 | 37.3 | 37.3 | 37.3 | 37.3 |
| 1985 | 1 | 7.0 | 7.0 | 7.0 | 7.0 |
| 1992 | 3 | 13.9 | 71.6 | 37.0 | 25.4 |
| 1993 | 3 | 1.9 | 19.2 | 8.6 | 4.8 |
| 2002 | 10 | 1.0 | 44.0 | 7.1 | 1.0 |
| 2007 | 20 | 1.0 | 16.0 | 8.0 | 9.3 |

## Table 5.7. Statistical Summary of Historical TN Data by Year for the Arlington River (WBID 2265A)

TN concentrations are mg/L.

| Year | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| 1973 | 1 | 1.05 | 1.05 | 1.05 | 1.05 |
| 1974 | 8 | 1.38 | 2.40 | 1.74 | 1.69 |
| 1975 | 8 | 0.59 | 3.08 | 1.48 | 1.43 |
| 1976 | 7 | 0.17 | 1.67 | 1.19 | 1.28 |
| 1977 | 6 | 0.71 | 2.57 | 1.41 | 1.23 |
| 1978 | 5 | 0.41 | 3.09 | 1.29 | 0.67 |
| 1979 | 1 | 1.62 | 1.62 | 1.62 | 1.62 |
| 1983 | 1 | 0.88 | 0.88 | 0.88 | 0.88 |
| 1984 | 3 | 0.39 | 1.15 | 0.77 | 0.75 |
| 1985 | 1 | 0.32 | 0.32 | 0.32 | 0.32 |
| 1988 | 1 | 1.15 | 1.15 | 1.15 | 1.15 |
| 1989 | 5 | 0.27 | 1.27 | 0.97 | 1.10 |
| 1990 | 4 | 0.51 | 1.62 | 1.16 | 1.25 |
| 1991 | 2 | 0.95 | 1.32 | 1.14 | 1.14 |
| 1992 | 3 | 0.62 | 1.18 | 0.94 | 1.02 |
| 1993 | 7 | 0.41 | 1.46 | 1.00 | 1.01 |
| 1994 | 8 | 0.18 | 1.71 | 1.02 | 1.03 |
| 1995 | 4 | 0.67 | 0.92 | 0.78 | 0.77 |
| 1999 | 10 | 0.51 | 1.83 | 0.83 | 0.68 |
| 2000 | 11 | 0.31 | 2.53 | 1.20 | 1.18 |
| 2001 | 11 | 0.62 | 1.84 | 1.03 | 0.95 |
| 2002 | 9 | 0.82 | 2.02 | 1.27 | 1.22 |
| 2007 | 20 | 0.63 | 1.74 | 1.17 | 1.20 |
| 2008 | 1 | 1.09 | 1.09 | 1.09 | 1.09 |

## Table 5.8. Statistical Summary of Historical TP Data by Year for the Arlington River (WBID 2265A)

TP concentrations are mg/L.

| Year | N | Minimum | Maximum | Mean | Median |
|---|---|---|---|---|---|
| 1974 | 8 | 0.133 | 0.636 | 0.374 | 0.357 |
| 1975 | 5 | 0.059 | 0.850 | 0.474 | 0.540 |
| 1976 | 9 | 0.027 | 0.357 | 0.113 | 0.062 |
| 1977 | 5 | 0.127 | 0.238 | 0.165 | 0.164 |
| 1978 | 4 | 0.041 | 0.081 | 0.055 | 0.049 |
| 1979 | 1 | 0.220 | 0.220 | 0.220 | 0.220 |
| 1983 | 1 | 0.316 | 0.316 | 0.316 | 0.316 |
| 1984 | 7 | 0.043 | 0.419 | 0.175 | 0.131 |
| 1985 | 6 | 0.085 | 0.309 | 0.188 | 0.162 |
| 1986 | 5 | 0.094 | 0.209 | 0.147 | 0.128 |
| 1987 | 4 | 0.141 | 0.351 | 0.205 | 0.165 |
| 1988 | 3 | 0.096 | 0.201 | 0.143 | 0.132 |
| 1989 | 5 | 0.068 | 0.330 | 0.194 | 0.182 |
| 1990 | 4 | 0.110 | 0.210 | 0.165 | 0.170 |
| 1991 | 2 | 0.030 | 0.090 | 0.060 | 0.060 |
| 1992 | 3 | 0.130 | 0.190 | 0.157 | 0.150 |
| 1993 | 8 | 0.110 | 0.327 | 0.152 | 0.130 |
| 1994 | 9 | 0.091 | 0.205 | 0.150 | 0.147 |
| 1995 | 4 | 0.102 | 0.248 | 0.153 | 0.131 |
| 2002 | 9 | 0.099 | 0.270 | 0.141 | 0.130 |
| 2007 | 20 | 0.082 | 0.210 | 0.143 | 0.145 |
| 2008 | 1 | 0.110 | 0.110 | 0.110 | 0.110 |

### *5.1.2 TMDL Development Process*

A Spearman correlation matrix was used to assess the potential relationships between CHLAC and other water quality parameters (**Appendix G**). At an alpha (α) level of 0.05, correlations between CHLAC and the water quality parameters BOD5, conductance, pH, and salinity were significant. The simple linear regression equations suggested that increased conductance, salinity, or pH resulted in lower CHLAC concentrations (**Appendix H**).

Rainfall records for JIA (**Appendix F** illustrates rainfall from 1955 to 2008) were used to determine the rainfall amounts associated with individual sampling dates. Rainfall recorded on the day of sampling (1D), the cumulative total for the day of and the previous 2 days (3D), the cumulative total for the day of and the previous 6 days (7D), and the cumulative total for the day of sampling and 13 days prior (14D) were all paired with the respective water quality observation based on date. Simple linear regressions of CHLAC versus precip, precip3day, precip7day, and precip14day were all significant at an α level of 0.05. Among the four variables, the precip3day explained the most variance in CHLAC (33 percent). The expression suggested a positive relationship between the cumulative rainfall total and CHLAC. This could represent a lag in the delivery of algal biomass from the upstream drainage area and/or a lag in the response of algae to an increase in available nutrients.

The general linear model (GLM) was used to evaluate possible relationships between nutrients that included the interaction with TEMP. None of the expressions involving TEMP, TN, or TP separately or in combination was significant at an α level of 0.05.

The Arlington River is tidally influenced, and there is a 3- to 4-foot tidal variation in the Jacksonville area. Previous dye studies conducted for the Buckman WWTF discharge to the St. Johns River north of the Hart Bridge demonstrated the exchange between the St. Johns and the Arlington River. Historical CHLAC, TN, and TP measurements from the St. Johns River (WBID 2213D) near the Arlington River were compared with measurements from the Arlington River (**Figures 5.5** through **5.7**, respectively). Fluctuations in CHLAC, TN, and TP concentrations in the St. Johns River are reflected in the Arlington River.

## Figure 5.5. Comparison of Historical CHLAC Measurements from the St. Johns River (WBID 2213D) and the Arlington River (WBID 2265A)

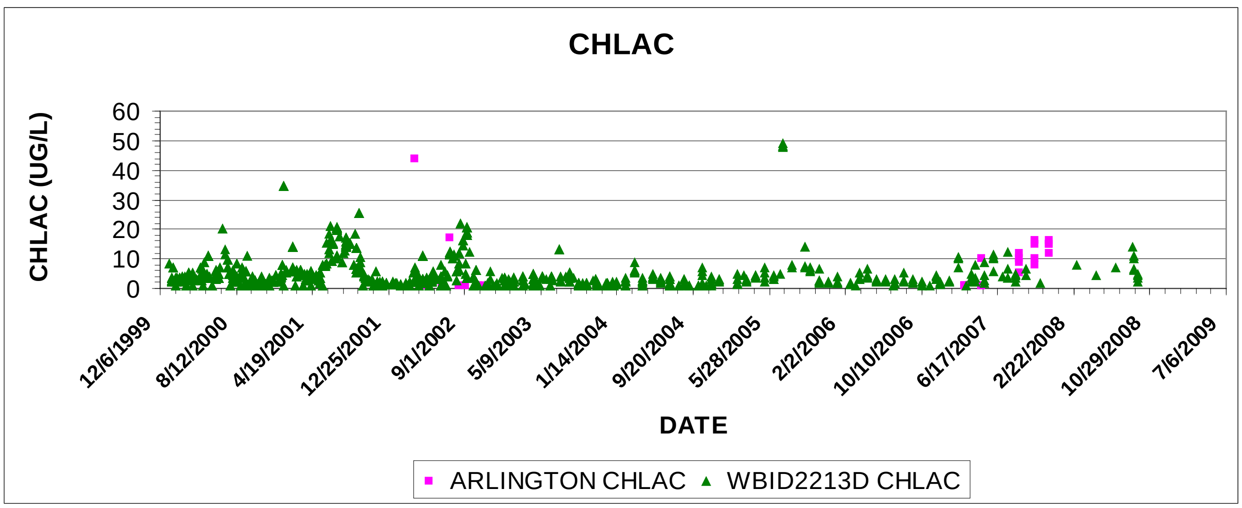


Figure 5.6. Comparison of Historical TN Measurements from the St. Johns River (WBID 2213D) and the Arlington River (WBID 2265A)

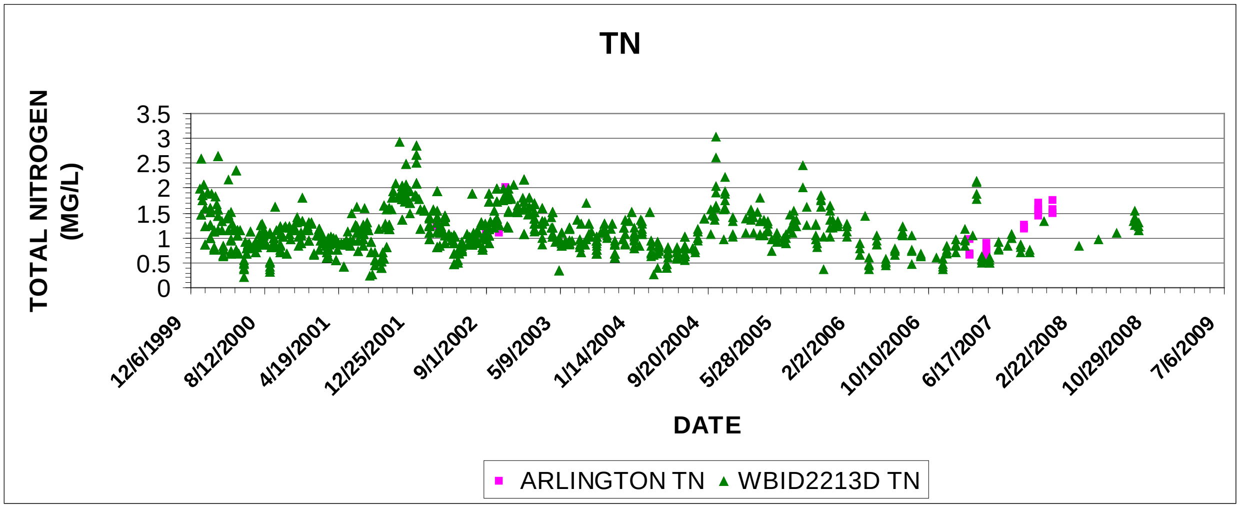
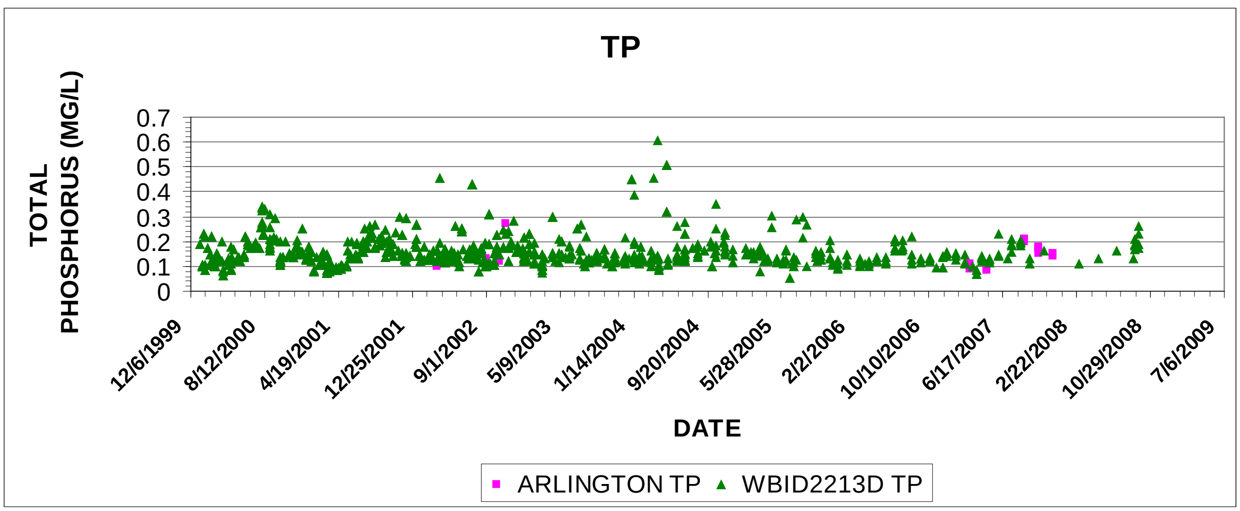



Figure 5.7. Comparison of Historical TP Measurements from the St. Johns River (WBID 2213D) and the Arlington River (WBID 2265A)




Plots of CHLAC, TN, and TP versus sample date in the Arlington River indicated a pattern of decreasing concentrations. A cumulative frequency plot of historical CHLAC concentrations (**Appendix E**) demonstrated that 30 percent of the observations were 1 μg/L or less. Over 60 percent of the observations were below 11 μg/L. The Arlington River was verified impaired based on exceeding the estuarine annual average chl*a* threshold of 11 μg/L in one year (13.2 μg/L in 2002). The next year with sufficient data to calculate an annual average per the IWR was well below the threshold (6.6 μg/L in 2007).

The adopted nutrient TMDL for the Lower St. Johns River requires a 30 to 50 percent reduction in anthropogenic nitrogen loads to the marine portion of the river. This requirement will influence nitrogen, phosphorus, and CHLAC contributions to the Arlington River from both the contributing watersheds as well as the direct tidal exchange with the St. Johns River. These reductions, in conjunction with the existing trend of declining CHLAC, TN, and TP concentrations in the Arlington River, are expected to restore the river such that designated uses are restored and maintained.

### *5.1.3 Critical Conditions/Seasonality*

A nonparametric test (Kruskal-Wallis) was applied to the CHLAC, TN, and TP datasets to determine whether there were significant differences among months or seasons. At an alpha (α) level of 0.05, there were no significant differences among seasons or months for either CHLAC or TP. The only significant difference found was between TN and season (**Appendices C** and **D**). **Tables 5.9a, 5.9b,** and **5.9c** provide seasonal summary statistics for CHLAC, TN, and TP, respectively. Mean and median CHLAC levels were elevated during the summer and fall seasons (**Table 5.9a**). In comparison, mean and median TN concentrations in the fall and winter seasons were elevated relative to other seasons (**Table 5.9b**). Mean, median, and maximum TP concentrations were elevated during the summer season relative to other seasons. **Table 5.9c** provides seasonal summary statistics for TP.

Table 5.9a. Seasonal Summary Statistics for CHLAC for the Arlington River (WBID 2265A)

CHLAC concentrations are μg/L.

| Season | N | Minimum | 5% | 25% | Mean | Median | 75% | Maximum |
|---|---|---|---|---|---|---|---|---|
| Winter | 7 | 1.0 | 1.0 | 1.0 | 8.1 | 1.0 | 5.7 | 44.0 |
| Spring | 10 | 1.0 | 1.0 | 1.0 | 8.5 | 1.8 | 10.0 | 37.3 |
| Summer | 9 | 1.0 | 1.0 | 4.1 | 16.2 | 10.0 | 17.6 | 71.6 |
| Fall | 12 | 1.0 | 1.0 | 4.5 | 10.3 | 13.0 | 15.0 | 16.0 |

Table 5.9b. Seasonal Summary Statistics for TN for the Arlington River (WBID 2265A)

TN concentrations are mg/L.

| Season | N | Minimum | 5% | 25% | Mean | Median | 75% | Maximum |
|---|---|---|---|---|---|---|---|---|
| Winter | 32 | 0.27 | 0.34 | 0.73 | 1.25 | 1.18 | 1.56 | 3.09 |
| Spring | 30 | 0.17 | 0.18 | 0.71 | 0.98 | 0.90 | 1.22 | 2.53 |
| Summer | 34 | 0.31 | 0.40 | 0.67 | 1.08 | 1.13 | 1.26 | 2.40 |
| Fall | 41 | 0.47 | 0.56 | 0.95 | 1.27 | 1.35 | 1.56 | 2.02 |

## Table 5.9c. Seasonal Summary Statistics for TP for the Arlington River (WBID 2265A)

TP concentrations are mg/L.

| Season | N | Minimum | 5% | 25% | Mean | Median | 75% | Maximum |
|---|---|---|---|---|---|---|---|---|
| Winter | 29 | 0.030 | 0.040 | 0.101 | 0.162 | 0.127 | 0.173 | 0.608 |
| Spring | 26 | 0.027 | 0.053 | 0.094 | 0.157 | 0.115 | 0.190 | 0.459 |
| Summer | 34 | 0.029 | 0.044 | 0.110 | 0.213 | 0.179 | 0.238 | 0.850 |
| Fall | 34 | 0.062 | 0.083 | 0.130 | 0.173 | 0.150 | 0.180 | 0.363 |

# Chapter 6: DETERMINATION OF THE TMDL

## 6.1 Expression and Allocation of the TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\mathbf{TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (b) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of BMPs.

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. The TMDL for the Arlington River is expressed in terms of a percent reduction in TN and TP, to meet both the DO and nutrient criteria (**Table 6.1**).

### Table 6.1. TMDL Components for the Arlington River (WBID 2265A)

- = Empty cell/no data
[1] As the TMDL represents a percent reduction, it also complies with EPA requirements to express the TMDL on a daily basis.

| WBID | Parameter | TMDL (mg/L) | WLA for Wastewater (mg/L) | WLA for NPDES Stormwater (% reduction)[1] | LA (% Reduction)[1] | MOS |
|---|---|---|---|---|---|---|
| 2265A | TN | - | N/A | 30% | 30% | Implicit |

## 6.2 Load Allocation

TN reductions of 30 percent are required from nonpoint sources. It should be noted that the load allocation includes loading from stormwater discharges that are not part of the NPDES Stormwater Program.

## 6.3 Wasteload Allocation

### *6.3.1 NPDES Wastewater Discharges*

There are currently no permitted NPDES discharges in the Arlington River watershed; however, any future discharge permits issued in the watershed will also be required to contain appropriate discharge limitations on nitrogen that will comply with the TMDL.

### *6.3.2 NPDES Stormwater Discharges*

The city of Jacksonville and FDOT District 2 are co-permittees for a Phase I NPDES MS4 permit (FLS000012) that includes all of the Arlington River watershed.

## 6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department, 2001), an implicit MOS was used in the development of this TMDL by considering all available historical CHLAC, TN, and TP data, and the existing mainstem nutrient TMDL that requires a 30 to 50 percent reduction in anthropogenic nitrogen loading.

# Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

## 7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending on the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. BMAPs are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies.

If the Department determines that a BMAP is needed to support the implementation of this TMDL, a BMAP will be developed through a transparent, stakeholder-driven process intended to result in a plan that is cost-effective, technically feasible, and meets the restoration needs of the applicable waterbodies. Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals (based directly on the TMDL);*
- *Refined source identification;*
- *Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible);*
- *A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach;*
- *A description of further research, data collection, or source identification needed in order to achieve the TMDL;*
- *Timetables for implementation;*
- *Implementation funding mechanisms;*
- *An evaluation of future increases in pollutant loading due to population growth;*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures; and*
- *Stakeholder statements of commitment (typically a local government resolution).*

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies; improved internal communication within local governments;

applied high-quality science and local information in managing water resources; clarified the obligations of wastewater point source, MS4, and non-MS4 stakeholders in TMDL implementation; enhanced transparency in the Department's decision making; and built strong relationships between the Department and local stakeholders that have benefited other program areas.

## 7.2 Other TMDL Implementation Tools

However, in some basins, and for some parameters, particularly those with fecal coliform impairments, the development of a BMAP using the process described above will not be the most efficient way to restore a waterbody, such that it meets its designated uses. This is because fecal coliform impairments result from the cumulative effects of a multitude of potential sources, both natural and anthropogenic. Addressing these problems requires good old-fashioned detective work that is best done by those in the area.

A multitude of assessment tools is available to assist local governments and interested stakeholders in this detective work. The tools range from the simple (such as Walk the WBIDs and GIS mapping) to the complex (such as bacteria source tracking). Department staff will provide technical assistance, guidance, and oversight of local efforts to identify and minimize fecal coliform sources of pollution. Based on work in the Lower St Johns River Tributaries and the Hillsborough Basin, the Department and local stakeholders have developed a logical process and tools to serve as a foundation for this detective work. In the near future, the Department will be releasing these tools to assist local stakeholders with the development of local implementation plans to address fecal coliform impairments. In such cases, the Department will **rely on these local initiatives** as a more cost-effective and simplified approach to identify the actions needed to put in place a road map for restoration activities, while still meeting the requirements of Subsection 403.067(7), F.S.

Earlier in the document, reference was made to the BMAP adopted in October 2008 that outlined implementation activities in the marine portion of the Lower St. Johns River to achieve the nutrient TMDL. Since the Arlington River represents a contributing watershed to the Lower St. Johns River, applicable activities undertaken in the Arlington River watershed as part of the Lower St. Johns River BMAP should be sufficient to address the nutrient impairment in the Arlington River.

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# Appendices

## Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit regulations.

Rule 62-40 also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES Stormwater Program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the FDOT throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES Stormwater Program in 2000.

An important difference between the federal NPDES and the state's stormwater/environmental resource permitting programs is that the NPDES Program covers both new and existing discharges, while the state's program focus on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

## Appendix B: CHLAC, TEMP, TN, and TP Observations in the Arlington River (WBID 2265A), 1992–2008

- = Empty cell/no data

| Station | Sample Date | CHLAC (µg/L)) | TEMP (°C) | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| FLA20030073 | 11/7/1973 | - | 21.5 | 1.05 | - |
| FLA20030073 | 1/7/1974 | - | 20 | - | - |
| FLA20030073 | 2/25/1974 | - | - | 2.05 | - |
| FLA20030073 | 3/19/1974 | - | 19 | 1.39 | 0.304 |
| FLA20030073 | 4/15/1974 | - | - | 1.60 | - |
| FLA20030073 | 5/13/1974 | - | 24 | 1.77 | 0.459 |
| FLA20030073 | 6/12/1974 | - | 29.5 | 1.38 | - |
| FLA20030073 | 7/15/1974 | - | 28.3 | - | - |
| FLA20030073 | 7/15/1974 | - | - | - | 0.350 |
| FLA20030073 | 8/12/1974 | - | - | 2.40 | 0.636 |
| FLA20030073 | 9/9/1974 | - | - | - | - |
| FLA20030073 | 9/16/1974 | - | 30 | 1.55 | 0.496 |
| FLA20030073 | 10/29/1974 | - | 24 | 1.79 | 0.363 |
| FLA20030073 | 11/18/1974 | - | 20 | - | 0.248 |
| FLA20030073 | 12/10/1974 | - | 18 | - | 0.133 |
| FLA20030073 | 1/6/1975 | - | 16 | - | 0.608 |
| FLA20030073 | 2/24/1975 | - | 19.5 | - | - |
| FLA20030073 | 3/3/1975 | - | 13.5 | - | - |
| FLA20030073 | 3/10/1975 | - | 17 | 3.08 | - |
| FLA20030073 | 3/24/1975 | - | 22 | - | - |
| FLA20030073 | 3/31/1975 | - | 21.5 | - | - |
| FLA20030073 | 4/21/1975 | - | 23.8 | 0.59 | 0.313 |
| FLA20030073 | 4/28/1975 | - | 26 | - | - |
| FLA20030073 | 5/5/1975 | - | 24.5 | - | - |
| FLA20030073 | 6/2/1975 | - | 26 | 0.76 | 0.059 |
| FLA20030073 | 6/30/1975 | - | - | - | - |
| FLA20030073 | 7/21/1975 | - | - | 1.52 | - |
| FLA20030073 | 8/4/1975 | - | 28 | 1.20 | 0.850 |
| FLA20030073 | 9/8/1975 | - | 29 | - | 0.540 |
| FLA20030073 | 10/13/1975 | - | 27 | 1.84 | - |
| FLA20030073 | 11/3/1975 | - | - | 1.45 | - |
| FLA20030073 | 12/15/1975 | - | 22 | 1.41 | - |
| FLA20030073 | 3/22/1976 | - | 20.5 | 1.28 | 0.357 |
| FLA20030073 | 4/19/1976 | - | 23 | 1.22 | 0.130 |
| FLA20030073 | 5/17/1976 | - | 23 | - | 0.027 |

| Station | Sample Date | CHLAC (µg/L)) | TEMP ($^{o}$C) | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| FLA20030073 | 6/21/1976 | - | 23.5 | - | 0.059 |
| FLA20030073 | 7/19/1976 | - | 24 | - | 0.136 |
| FLA20030073 | 8/30/1976 | - | 28.5 | - | 0.053 |
| FLA20030073 | 9/20/1976 | - | 27.5 | - | 0.029 |
| FLA20030073 | 11/1/1976 | - | - | 1.67 | 0.062 |
| FLA20030073 | 12/15/1976 | - | 17 | 1.38 | 0.161 |
| FLA20030073 | 1/17/1977 | - | - | 1.56 | 0.167 |
| FLA20030073 | 3/14/1977 | - | 22 | 2.57 | 0.127 |
| FLA20030073 | 5/2/1977 | - | 27 | 1.15 | 0.164 |
| FLA20030073 | 6/2/1977 | - | - | - | - |
| FLA20030073 | 6/13/1977 | - | 20.5 | 0.71 | - |
| FLA20030073 | 7/13/1977 | - | 33.5 | 1.31 | 0.238 |
| FLA20030073 | 12/19/1977 | - | 18 | 1.15 | 0.127 |
| FLA20030073 | 1/31/1978 | - | 8 | 3.09 | 0.041 |
| FLA20030073 | 8/8/1978 | - | 30 | 1.84 | 0.050 |
| FLA20030073 | 9/19/1978 | - | 29.8 | 0.41 | 0.049 |
| FLA20030073 | 10/18/1978 | - | 22 | 0.67 | 0.081 |
| FLA20030073 | 11/14/1978 | - | 22 | 0.47 | - |
| FLA20030073 | 12/19/1978 | - | 15 | - | - |
| FLA20030073 | 1/11/1979 | - | 12.5 | 1.62 | 0.220 |
| 11NPSWRDTIMUDER_SJR-11 | 4/19/1982 | - | 23.9 | - | - |
| 11NPSWRDTIMUDER_SJR-11 | 8/9/1982 | - | 30.1 | - | - |
| FLJXWQRR0005 | 10/5/1983 | - | 28.5 | - | - |
| FLJXWQRR0005 | 12/14/1983 | - | 16.5 | 0.88 | 0.316 |
| FLJXWQRR0005 | 3/14/1984 | - | 18.5 | 0.75 | 0.122 |
| FLA20030073 | 4/24/1984 | 37.295 | 23 | 1.15 | 0.419 |
| FLJXWQRR0005 | 6/26/1984 | - | 29 | - | 0.110 |
| FLJXWQRR0005 | 8/14/1984 | - | 31.2 | - | 0.043 |
| FLA20030073 | 8/27/1984 | - | 28 | 0.39 | 0.247 |
| FLJXWQRR0005 | 10/23/1984 | - | 26 | - | 0.154 |
| FLJXWQRR0005 | 12/5/1984 | - | 16.8 | - | 0.131 |
| FLA20030073 | 1/14/1985 | 6.98 | 13.5 | 0.32 | 0.125 |
| FLJXWQRR0005 | 2/19/1985 | - | 14 | - | 0.157 |
| FLJXWQRR0005 | 4/10/1985 | - | 20.9 | - | 0.085 |
| FLJXWQRR0005 | 6/11/1985 | - | 30.6 | - | 0.287 |
| FLJXWQRR0005 | 10/15/1985 | - | 25.6 | - | 0.167 |
| FLJXWQRR0005 | 12/3/1985 | - | 20.8 | - | 0.309 |
| FLJXWQRR0005 | 2/26/1986 | - | 14 | - | 0.101 |
| FLJXWQRR0005 | 5/21/1986 | - | 24 | - | 0.209 |

| Station | Sample Date | CHLAC (μg/L)) | TEMP (°C) | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| FLJXWQRR0005 | 7/8/1986 | - | 30 | - | 0.202 |
| FLJXWQRR0005 | 9/9/1986 | - | 28.5 | - | 0.094 |
| FLJXWQRR0005 | 11/4/1986 | - | 22 | - | 0.128 |
| FLJXWQRR0005 | 2/4/1987 | - | - | - | 0.141 |
| FLJXWQRR0005 | 3/31/1987 | - | 16.5 | - | 0.351 |
| FLJXWQRR0005 | 6/2/1987 | - | 28.5 | - | 0.150 |
| FLJXWQRR0005 | 9/15/1987 | - | 30.5 | - | 0.179 |
| FLJXWQRR0005 | 1/12/1988 | - | 11 | - | 0.132 |
| FLJXWQRR0005 | 5/24/1988 | - | 27 | - | 0.201 |
| FLJXWQRR0005 | 8/9/1988 | - | 30.5 | 1.15 | 0.096 |
| FLJXWQRR0005 | 1/25/1989 | - | 15.07 | 1.17 | 0.182 |
| FLJXWQRR0005 | 3/14/1989 | - | 18 | 0.27 | 0.068 |
| FLJXWQRR0005 | 5/17/1989 | - | 26.51 | 1.10 | 0.110 |
| FLJXWQRR0005 | 8/16/1989 | - | 25.5 | 1.04 | 0.330 |
| FLJXWQRR0005 | 10/25/1989 | - | 20.54 | 1.27 | 0.280 |
| FLJXWQRR0005 | 3/26/1990 | - | 23.56 | 1.62 | 0.170 |
| FLJXWQRR0005 | 6/19/1990 | - | 25.9 | 0.91 | 0.110 |
| FLJXWQRR0005 | 8/22/1990 | - | 30.62 | 1.58 | 0.210 |
| FLJXWQRR0005 | 11/6/1990 | - | 22.58 | 0.51 | 0.170 |
| FLJXWQRR0005 | 1/15/1991 | - | 16.77 | 0.95 | 0.030 |
| FLJXWQRR0005 | 3/26/1991 | - | 24.18 | 1.32 | 0.090 |
| FLSJWMLSJ090 | 5/13/1992 | 25.39 | 24.1 | 1.02 | 0.190 |
| FLSJWMLSJ090 | 8/6/1992 | 71.63 | 29.1 | 0.62 | 0.130 |
| FLSJWMLSJ090 | 11/4/1992 | 13.9 | 23.1 | 1.18 | 0.150 |
| FLSJWMLSJ090 | 1/12/1993 | 1.87 | 17.7 | 1.19 | 0.130 |
| FLSJWMARLRM.S | 6/9/1993 | 4.81 | 29.7 | 0.97 | 0.110 |
| FLSJWMARLRM.S | 7/8/1993 | 19.2 | 30.5 | - | 0.120 |
| FLSJWMARLRM.S | 8/24/1993 | - | 30.2 | 1.01 | 0.150 |
| FLSJWMARLRM.S | 9/21/1993 | - | 29.2 | 0.41 | 0.110 |
| FLSJWMARLRM.S | 10/7/1993 | - | 25.3 | 0.85 | 0.130 |
| FLSJWMARLRM | 10/31/1993 | - | 19.2 | 1.46 | 0.327 |
| FLSJWMARLRM.S | 12/21/1993 | - | 14.08 | 1.13 | 0.140 |
| FLSJWMARLRM | 1/31/1994 | - | 14.34 | 1.08 | 0.205 |
| FLSJWMARLRM | 3/2/1994 | - | 18.91 | - | 0.147 |
| FLSJWMARLRM.S | 3/29/1994 | - | 22.36 | 0.95 | 0.120 |
| FLSJWMARLRM.S | 5/4/1994 | - | 25.69 | 0.18 | 0.120 |
| FLSJWMARLRM | 7/1/1994 | - | 29.47 | 1.71 | 0.178 |
| FLSJWMARLRM | 9/12/1994 | - | 25.53 | 1.26 | 0.187 |
| FLSJWMARLRM.S | 10/3/1994 | - | 25.61 | 1.44 | 0.180 |

| Station | Sample Date | CHLAC (µg/L)) | TEMP ($^{o}$C) | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| FLJXWQARLRM | 10/11/1994 | - | 23.41 | 0.60 | 0.120 |
| FLJXWQARLRM | 11/16/1994 | - | 21.85 | 0.97 | 0.091 |
| FLJXWQARLRM | 4/6/1995 | - | 19.75 | - | - |
| FLJXWQARLRM | 6/5/1995 | - | 27.13 | 0.73 | 0.102 |
| FLJXWQARLRM | 7/18/1995 | - | 26.96 | 0.67 | 0.102 |
| FLJXWQARLRM | 8/25/1995 | - | 26.51 | 0.81 | 0.248 |
| FLJXWQARLRM | 10/10/1995 | - | 25.56 | 0.92 | 0.160 |
| FLJXWQJAXSJR20A | 1/12/1999 | - | 17 | 0.64 | - |
| FLJXWQJAXSJR20A | 2/10/1999 | - | 23 | 0.51 | - |
| FLJXWQJAXSJR20A | 3/10/1999 | - | 17.32 | - | - |
| FLJXWQJAXSJR20A | 4/20/1999 | - | 23.5 | 0.73 | - |
| FLJXWQJAXSJR20A | 5/12/1999 | - | 25.84 | 0.59 | - |
| FLJXWQJAXSJR20A | 6/30/1999 | - | 31.5 | 0.71 | - |
| FLJXWQJAXSJR20A | 7/14/1999 | - | 31.25 | 0.57 | - |
| FLJXWQJAXSJR20A | 8/17/1999 | - | 32.08 | 0.64 | - |
| FLJXWQJAXSJR20A | 10/13/1999 | - | 28.1 | 1.83 | - |
| FLJXWQJAXSJR20A | 11/8/1999 | - | 27 | 1.20 | - |
| FLJXWQJAXSJR20A | 12/1/1999 | - | 11.8 | 0.92 | - |
| FLJXWQJAXSJR20A | 1/12/2000 | - | 26.4 | 1.56 | - |
| FLJXWQJAXSJR20A | 2/9/2000 | - | 23.6 | 1.73 | - |
| FLJXWQJAXSJR20A | 3/8/2000 | - | 27.8 | 1.21 | - |
| FLJXWQJAXSJR20A | 4/12/2000 | - | 23.5 | 1.31 | - |
| FLJXWQJAXSJR20A | 5/9/2000 | - | 24.44 | 2.53 | - |
| FLJXWQJAXSJR20A | 6/13/2000 | - | 28.97 | 0.67 | - |
| FLJXWQJAXSJR20A | 7/19/2000 | - | 29.48 | 0.31 | - |
| FLJXWQJAXSJR20A | 8/15/2000 | - | 31 | - | - |
| FLJXWQJAXSJR20A | 9/13/2000 | - | 32 | 1.18 | - |
| FLJXWQJAXSJR20A | 10/24/2000 | - | 22 | 0.71 | - |
| FLJXWQJAXSJR20A | 11/8/2000 | - | 26 | 1.04 | - |
| FLJXWQJAXSJR20A | 12/12/2000 | - | 21 | 0.95 | - |
| FLJXWQJAXSJR20A | 1/9/2001 | - | 7 | 1.21 | - |
| FLJXWQJAXSJR20A | 2/14/2001 | - | 21 | 0.91 | - |
| FLJXWQJAXSJR20A | 3/14/2001 | - | 20 | 0.70 | - |
| FLJXWQJAXSJR20A | 4/11/2001 | - | 24.92 | 0.77 | - |
| FLJXWQJAXSJR20A | 5/9/2001 | - | 24.07 | - | - |
| FLJXWQJAXSJR20A | 6/6/2001 | - | 30.84 | 0.95 | - |
| FLJXWQJAXSJR20A | 7/10/2001 | - | 31.99 | 0.62 | - |
| FLJXWQJAXSJR20A | 8/8/2001 | - | 19.21 | 0.98 | - |
| FLJXWQJAXSJR20A | 9/19/2001 | - | 24.18 | 1.06 | - |

| Station | Sample Date | CHLAC (µg/L)) | TEMP ($^{o}$C) | TN (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| FLJXWQJAXSJR20A | 10/9/2001 | - | 23.54 | 1.35 | - |
| FLJXWQJAXSJR20A | 11/19/2001 | - | 20.68 | 0.94 | - |
| FLJXWQJAXSJR20A | 12/18/2001 | - | 21.68 | 1.84 | - |
| FLA20030073 | 3/21/2002 | 44 | 24.1 | 1.22 | 0.099 |
| FLA20030073 | 4/17/2002 | 1 | 26.9 | 1.32 | 0.120 |
| FLA20030073 | 5/6/2002 | 2.6 | 28.2 | 1.41 | 0.160 |
| FLA20030073 | 6/19/2002 | 1 | 27.8 | - | - |
| FLA20030073 | 7/15/2002 | 17 | 30.1 | 0.98 | 0.130 |
| FLA20030073 | 8/12/2002 | 1 | 28.3 | 0.82 | 0.110 |
| FLA20030073 | 9/4/2002 | 1 | 28.6 | 1.14 | 0.130 |
| FLA20030073 | 10/16/2002 | 1 | 24.7 | 1.11 | 0.120 |
| FLA20030073 | 11/6/2002 | 1 | 22.8 | 2.02 | 0.270 |
| FLA20030073 | 12/3/2002 | 1 | 15.2 | 1.43 | 0.130 |
| FLA20030073 | 2/27/2007 | 1 | 18.8 | 0.66 | 0.096 |
| FLA20030811 | 2/27/2007 | 1 | 17.8 | 0.96 | 0.110 |
| FLA20030812 | 2/27/2007 | 1 | 18.3 | 0.66 | 0.091 |
| FLA20030813 | 2/27/2007 | 1 | 18.8 | 0.69 | 0.110 |
| FLA20030073 | 4/25/2007 | 1 | 25.1 | 0.75 | 0.094 |
| FLA20030811 | 4/25/2007 | 1 | 23 | 0.63 | 0.082 |
| FLA20030812 | 4/25/2007 | 1 | 23.8 | 0.74 | 0.091 |
| FLA20030813 | 4/25/2007 | 10 | 23.6 | 0.89 | 0.110 |
| FLA20030073 | 8/28/2007 | 10 | 30.9 | 1.21 | 0.210 |
| FLA20030811 | 8/28/2007 | 5.1 | 31.5 | 1.25 | 0.210 |
| FLA20030812 | 8/28/2007 | 8.7 | 31.3 | 1.17 | 0.210 |
| FLA20030813 | 8/28/2007 | 12 | 30.9 | 1.19 | 0.200 |
| FLA20030073 | 10/17/2007 | 15 | 25.6 | 1.58 | 0.170 |
| FLA20030811 | 10/17/2007 | 7.9 | 25.4 | 1.44 | 0.180 |
| FLA20030812 | 10/17/2007 | 9.9 | 25.5 | 1.55 | 0.150 |
| FLA20030813 | 10/17/2007 | 16 | 25.4 | 1.70 | 0.170 |
| FLA20030073 | 12/4/2007 | 15 | 17.5 | 1.49 | 0.140 |
| FLA20030811 | 12/4/2007 | 16 | 17.6 | 1.74 | 0.150 |
| FLA20030812 | 12/4/2007 | 12 | 17.2 | 1.57 | 0.140 |
| FLA20030813 | 12/4/2007 | 15 | 17.7 | 1.49 | 0.150 |
| FLA20030073 | 2/14/2008 | - | 16.9 | 1.09 | 0.110 |

## Appendix C: Kruskal–Wallis Analysis of CHLAC, TN, TP, Conductance, and Chloride Observations versus Season in the Arlington River (WBID 2265A)

Kruskal-Wallis One-Way Analysis of Variance for 38 cases
Dependent variable is VCHLAC
Grouping variable is SEASON$

| Group | Count | Rank Sum |
|---|---|---|
| FALL | 12 | 267.000 |
| SPRING | 10 | 165.000 |
| SUMMER | 9 | 208.000 |
| WINTER | 7 | 101.000 |

Kruskal-Wallis Test Statistic = 4.078
Probability is 0.253 assuming Chi-square distribution with 3 df

Kruskal-Wallis One-Way Analysis of Variance for 137 cases
Dependent variable is VTN
Grouping variable is SEASON$

| Group | Count | Rank Sum |
|---|---|---|
| FALL | 41 | 3346.500 |
| SPRING | 30 | 1631.500 |
| SUMMER | 34 | 2171.000 |
| WINTER | 32 | 2304.000 |

Kruskal-Wallis Test Statistic = 8.969
Probability is 0.030 assuming Chi-square distribution with 3 df

Kruskal-Wallis One-Way Analysis of Variance for 123 cases
Dependent variable is VTP
Grouping variable is SEASON$

| Group | Count | Rank Sum |
|---|---|---|
| FALL | 34 | 2353.000 |
| SPRING | 26 | 1353.500 |
| SUMMER | 34 | 2319.500 |
| WINTER | 29 | 1600.000 |

Kruskal-Wallis Test Statistic = 5.515
Probability is 0.138 assuming Chi-square distribution with 3 df
Kruskal-Wallis One-Way Analysis of Variance for 164 cases

Dependent variable is VCONDUCTANCE
Grouping variable is SEASON$

| Group | Count | Rank Sum |
|---|---|---|
| FALL | 48 | 2880.500 |
| SPRING | 37 | 4127.000 |
| SUMMER | 39 | 3344.000 |
| WINTER | 40 | 3178.500 |

Kruskal-Wallis Test Statistic = 24.951
Probability is 0.000 assuming Chi-square distribution with 3 df

Kruskal-Wallis One-Way Analysis of Variance for 176 cases
Dependent variable is VCHLORIDE
Grouping variable is SEASON$

| Group | Count | Rank Sum |
|---|---|---|
| FALL | 55 | 3602.000 |
| SPRING | 45 | 4811.000 |
| SUMMER | 36 | 3522.000 |
| WINTER | 40 | 3641.000 |

Kruskal-Wallis Test Statistic = 18.400
Probability is 0.000 assuming Chi-square distribution with 3 df

## Appendix D: Kruskal–Wallis Analysis of CHLAC, TN, TP, Conductance, and Chloride Observations versus Month in the Arlington River (WBID 2265A)

Kruskal-Wallis One-Way Analysis of Variance for 38 cases
Dependent variable is VCHLAC
Grouping variable is MONTH

| Group | Count | Rank Sum |
|---|---|---|
| 1 | 2 | 34.000 |
| 2 | 4 | 30.000 |
| 3 | 1 | 37.000 |
| 4 | 6 | 89.500 |
| 5 | 2 | 51.000 |
| 6 | 2 | 24.500 |
| 7 | 2 | 67.000 |
| 8 | 6 | 133.500 |
| 9 | 1 | 7.500 |
| 10 | 5 | 110.000 |
| 11 | 2 | 34.500 |
| 12 | 5 | 122.500 |

Kruskal-Wallis Test Statistic = 16.593
Probability is 0.120 assuming Chi-square distribution with 11 df

Kruskal-Wallis One-Way Analysis of Variance for 137 cases
Dependent variable is VTN
Grouping variable is MONTH

| Group | Count | Rank Sum |
|---|---|---|
| 1 | 11 | 857.000 |
| 2 | 9 | 493.500 |
| 3 | 12 | 953.500 |
| 4 | 12 | 670.000 |
| 5 | 8 | 568.500 |
| 6 | 10 | 393.000 |
| 7 | 8 | 436.000 |
| 8 | 18 | 1205.500 |
| 9 | 8 | 529.500 |
| 10 | 17 | 1440.500 |
| 11 | 11 | 753.500 |
| 12 | 13 | 1152.500 |

Kruskal-Wallis Test Statistic = 16.491
Probability is 0.124 assuming Chi-square distribution with 11 df

Kruskal-Wallis One-Way Analysis of Variance for 123 cases
Dependent variable is VTP
Grouping variable is MONTH

| Group | Count | Rank Sum |
|---|---|---|
| 1 | 10 | 638.500 |
| 2 | 8 | 298.000 |
| 3 | 11 | 663.500 |
| 4 | 9 | 421.500 |
| 5 | 9 | 615.500 |
| 6 | 8 | 316.500 |
| 7 | 8 | 565.500 |
| 8 | 17 | 1230.500 |
| 9 | 9 | 523.500 |
| 10 | 15 | 1098.500 |
| 11 | 7 | 431.500 |
| 12 | 12 | 823.000 |

Kruskal-Wallis Test Statistic = 12.926
Probability is 0.298 assuming Chi-square distribution with 11 df

Kruskal-Wallis One-Way Analysis of Variance for 164 cases
Dependent variable is VCONDUCTANCE
Grouping variable is MONTH

| Group | Count | Rank Sum |
|---|---|---|
| 1 | 12 | 856.500 |
| 2 | 15 | 1271.000 |
| 3 | 13 | 1051.000 |
| 4 | 13 | 1361.500 |
| 5 | 12 | 1272.000 |
| 6 | 12 | 1493.500 |
| 7 | 12 | 990.000 |
| 8 | 18 | 1742.000 |
| 9 | 9 | 612.000 |
| 10 | 20 | 1158.500 |
| 11 | 12 | 804.500 |
| 12 | 16 | 917.500 |

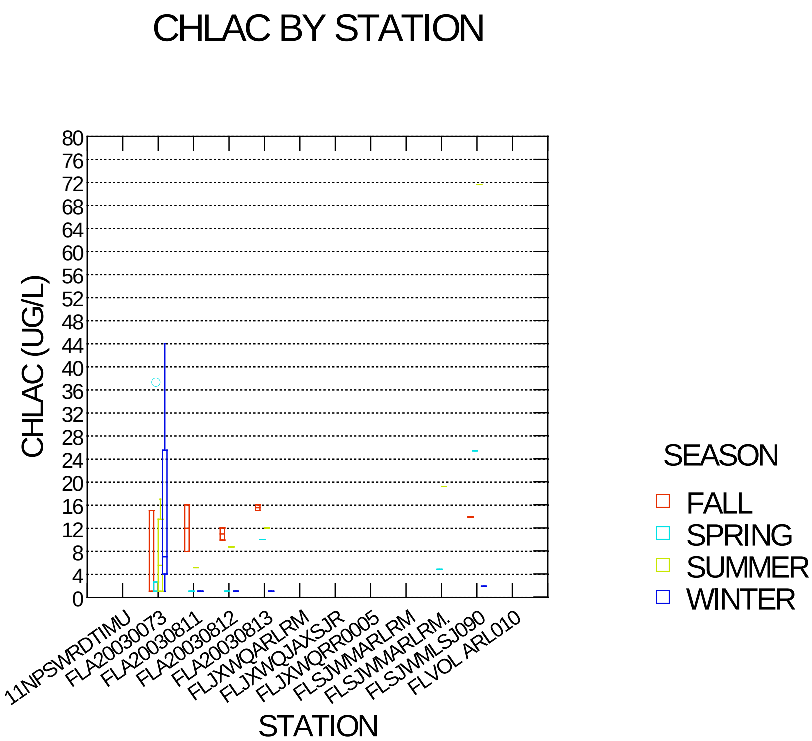
Kruskal-Wallis Test Statistic = 29.450
Probability is 0.002 assuming Chi-square distribution with 11 df

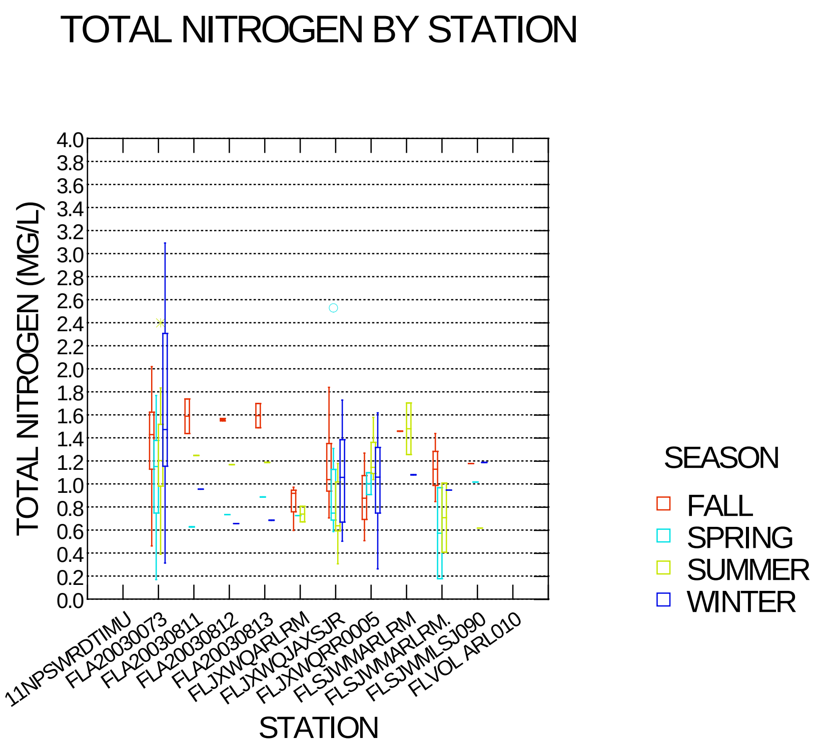
Kruskal-Wallis One-Way Analysis of Variance for 176 cases
Dependent variable is VCHLORIDE
Grouping variable is MONTH

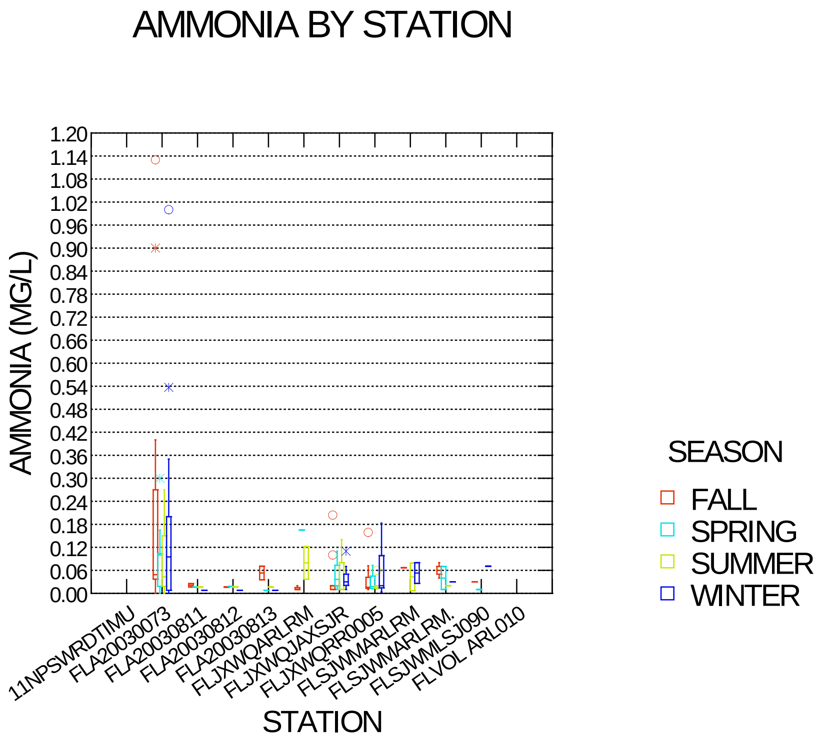
| Group | Count | Rank Sum |
|---|---|---|
| 1 | 10 | 838.000 |
| 2 | 20 | 1865.500 |
| 3 | 10 | 937.500 |
| 4 | 18 | 1646.000 |
| 5 | 8 | 974.000 |
| 6 | 19 | 2191.000 |
| 7 | 7 | 721.000 |
| 8 | 21 | 2174.500 |
| 9 | 8 | 626.500 |
| 10 | 26 | 1957.000 |
| 11 | 9 | 707.000 |
| 12 | 20 | 938.000 |

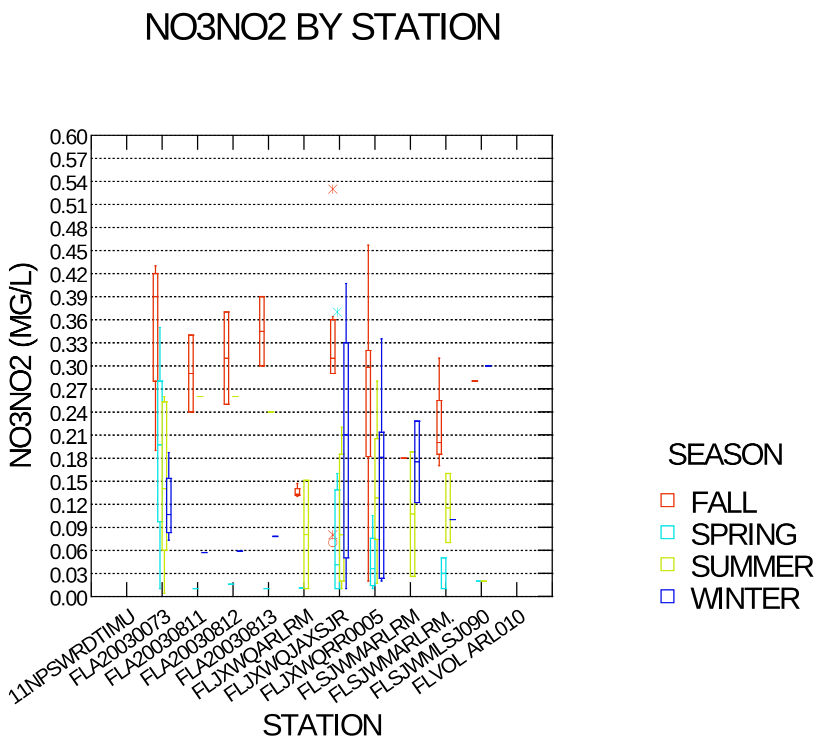
Kruskal-Wallis Test Statistic = 27.246
Probability is 0.004 assuming Chi-square distribution with 11 df

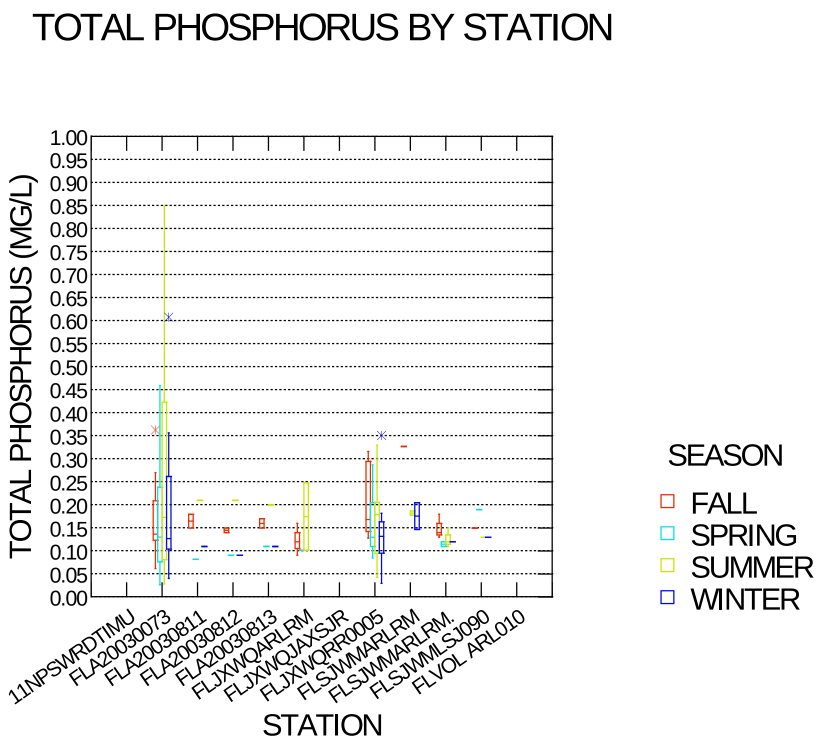
## Appendix E: Chart of CHLAC, TN, Nitrogen Ammonia (NH4), Nitrate Nitrite (NO3O2), and TP Observations by Season, Station, and Year in the Arlington River (WBID 2265A)

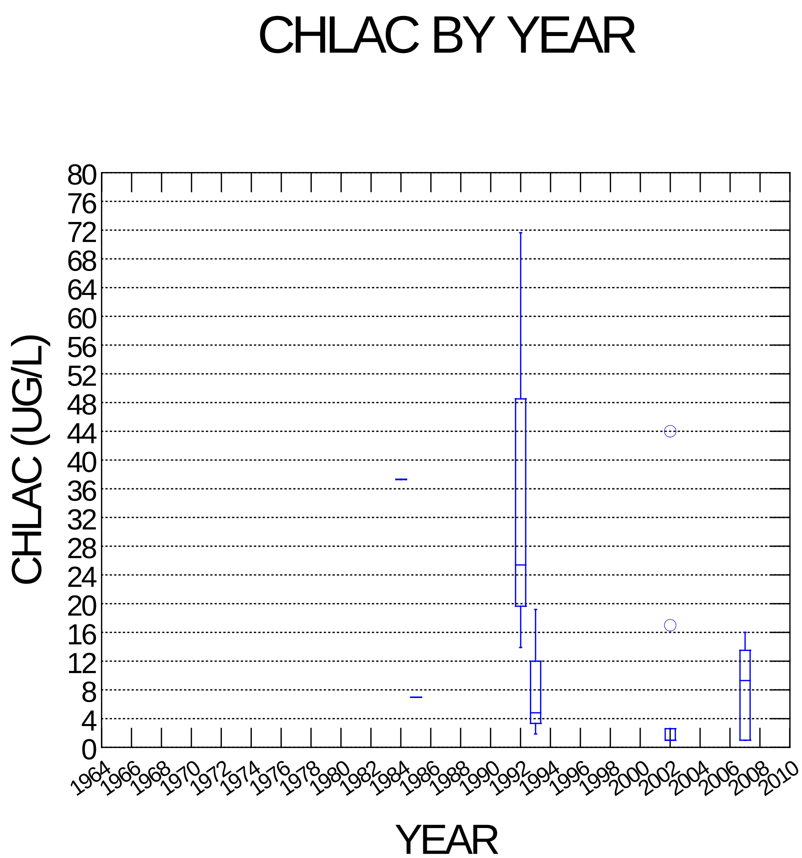


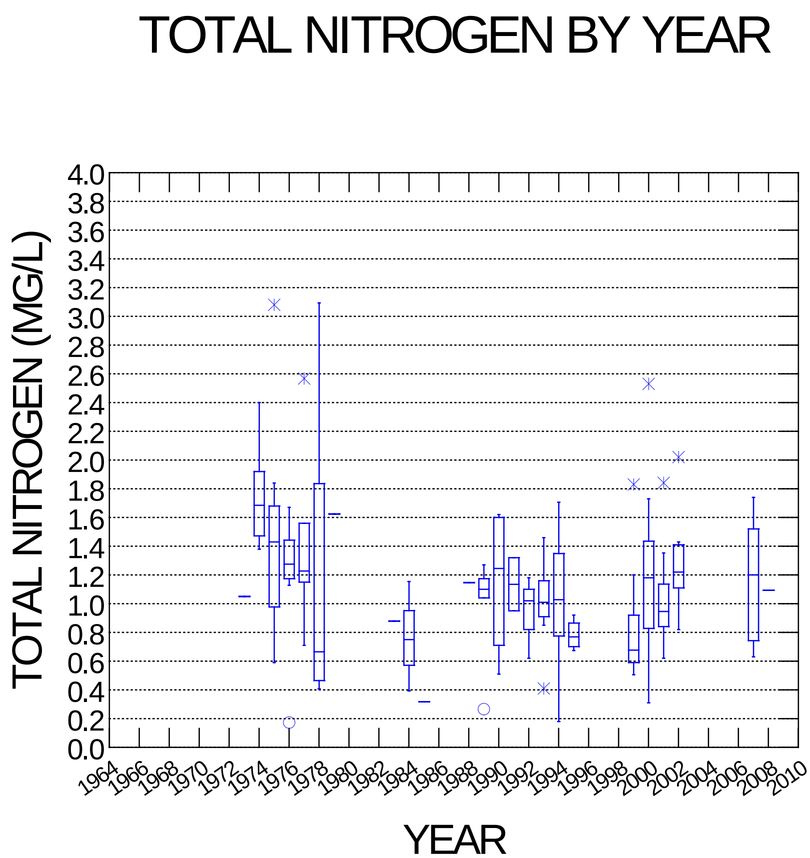

TOTAL NITROGEN BY STATION
TOTAL NITROGEN (MG/L)
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
11NPSWRDTIMU
FLA20030073
FLA20030811
FLA20030812
FLA20030813
FLJXWQARLRM
FLJXWQJAXSJR
FLJXWQRR0005
FLSJWMARLRM
FLSJWMARLRM.
FLSJWMLSJ090
FLVOL ARL010
STATION
SEASON
FALL
SPRING
SUMMER
WINTER

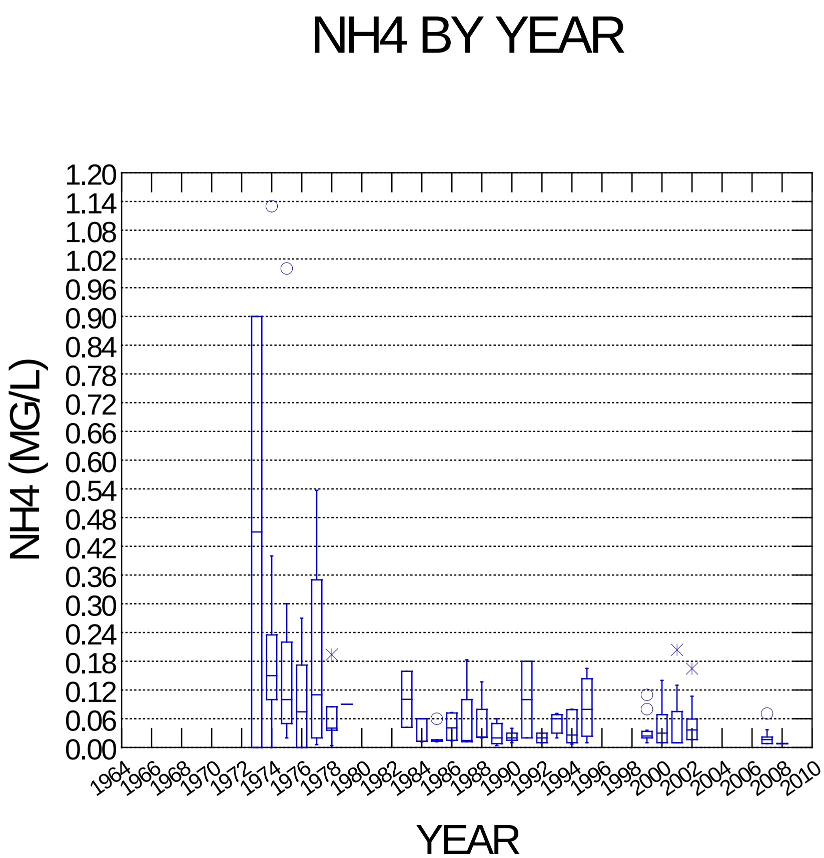

AMMONIA BY STATION
AMMONIA (MG/L)
1.20
1.14
1.08
1.02
0.96
0.90
0.84
0.78
0.72
0.66
0.60
0.54
0.48
0.42
0.36
0.30
0.24
0.18
0.12
0.06
0.00
11NPSWRDTIMU
FLA20030073
FLA20030811
FLA20030812
FLA20030813
FLJXWQARLRM
FLJXWQJAXSJR
FLJXWQRR0005
FLSJWMARLRM
FLSJWMARLRM.
FLSJWMLSJ090
FLVOL ARL010
STATION
SEASON
FALL
SPRING
SUMMER
WINTER

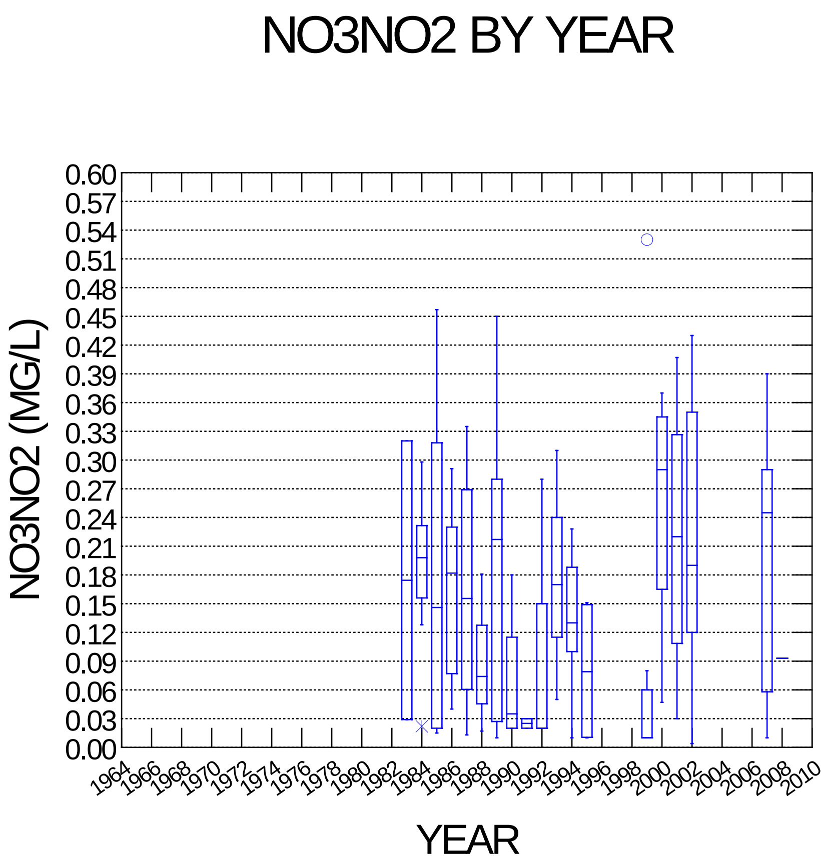

NO3NO2 BY STATION
NO3NO2 (MG/L)
0.60
0.57
0.54
0.51
0.48
0.45
0.42
0.39
0.36
0.33
0.30
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0.00
11NPSWRDTIMU
FLA20030073
FLA20030811
FLA20030812
FLA20030813
FLJXWQARLRM
FLJXWQJAXSJR
FLJXWQRR0005
FLSJWMARLRM
FLSJWMARLRM.
FLSJWMLSJ090
FLVOL ARL010
STATION
SEASON
FALL
SPRING
SUMMER
WINTER

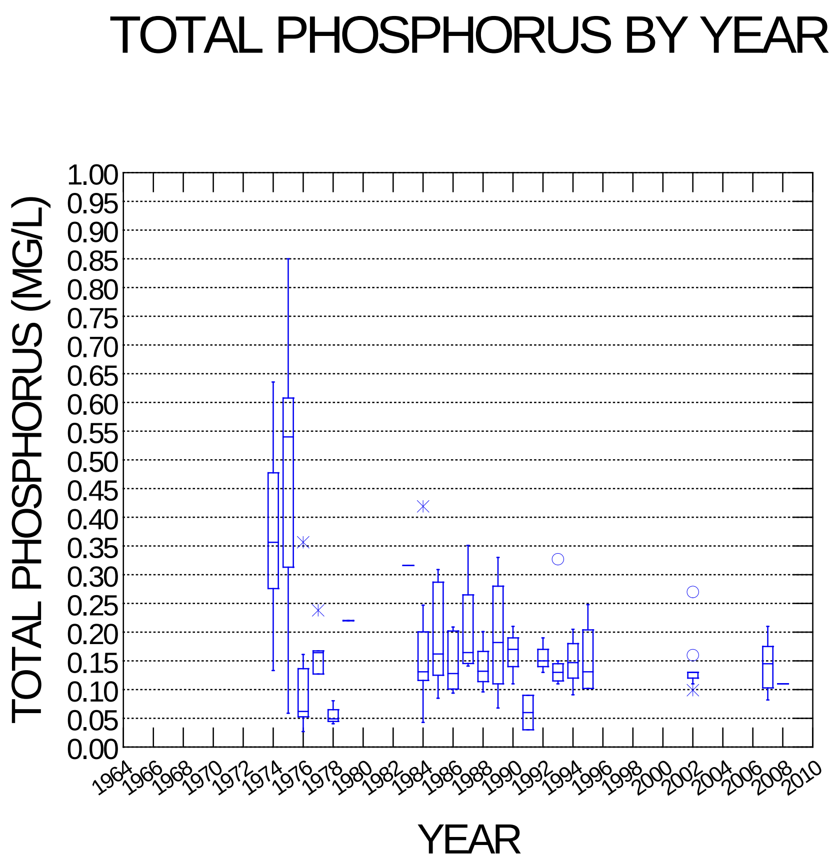

TOTAL PHOSPHORUS BY STATION
TOTAL PHOSPHORUS (MG/L)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
11NPSWRDTIMU
FLA20030073
FLA20030811
FLA20030812
FLA20030813
FLJXWQARLRM
FLJXWQJAXSJR
FLJXWQRR0005
FLSJWMARLRM
FLSJWMARLRM.
FLSJWMLSJ090
FLVOL ARL010
STATION
SEASON
FALL
SPRING
SUMMER
WINTER

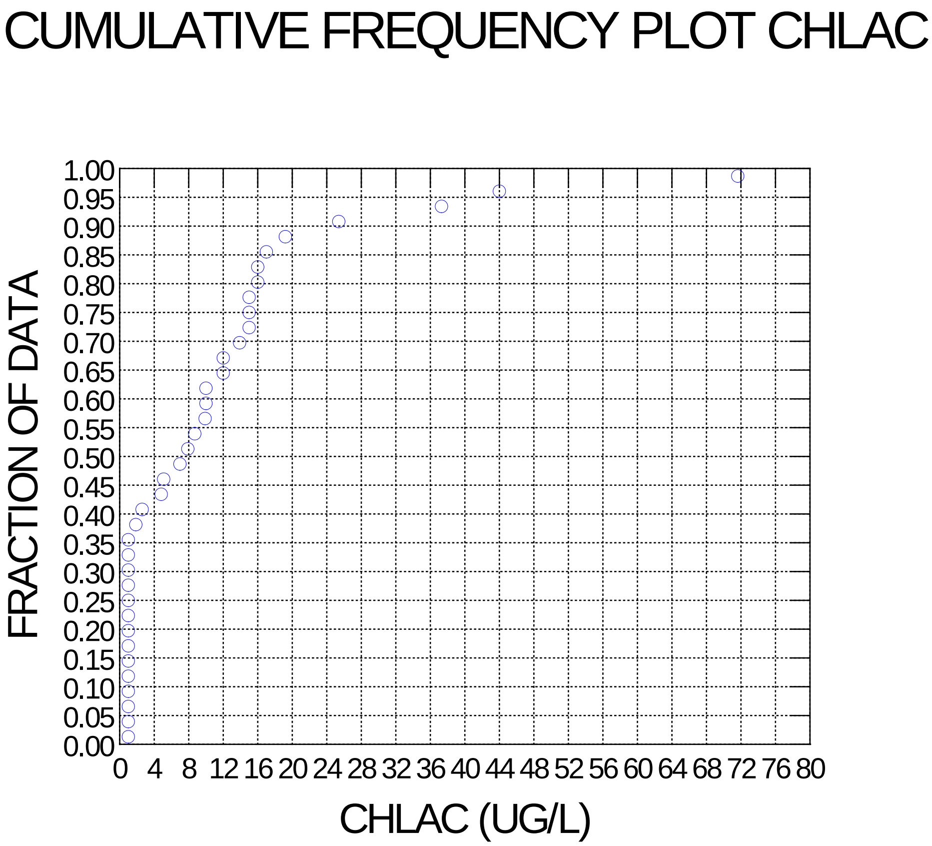

CHLAC BY YEAR
CHLAC (UG/L)
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
YEAR

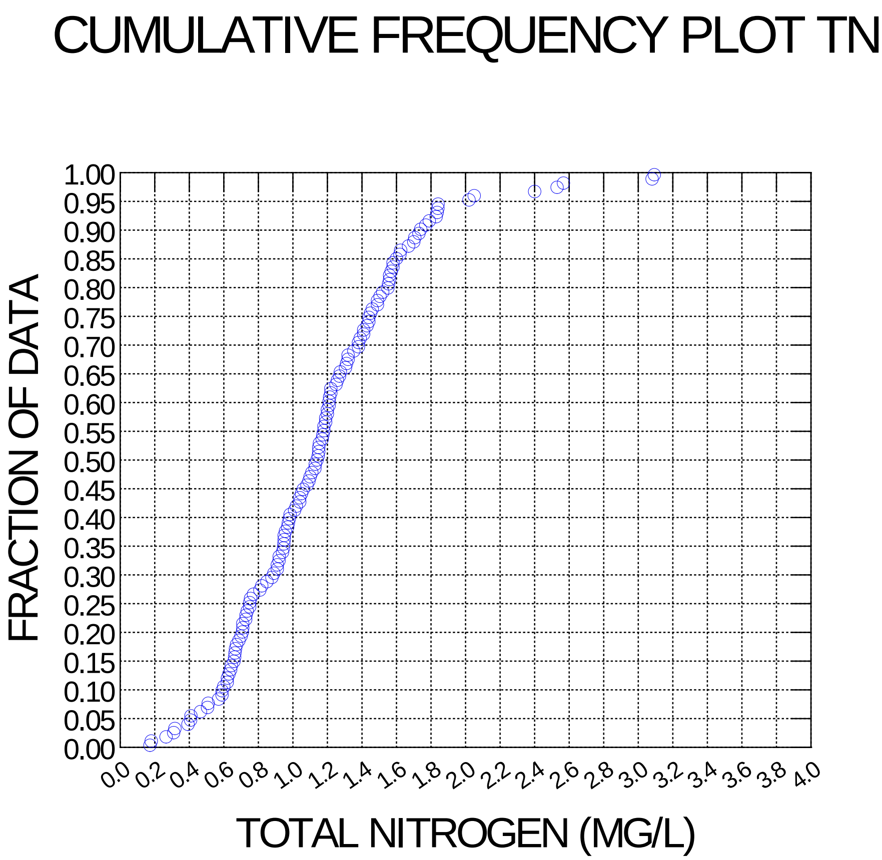

TOTAL NITROGEN BY YEAR
TOTAL NITROGEN (MG/L)
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
YEAR

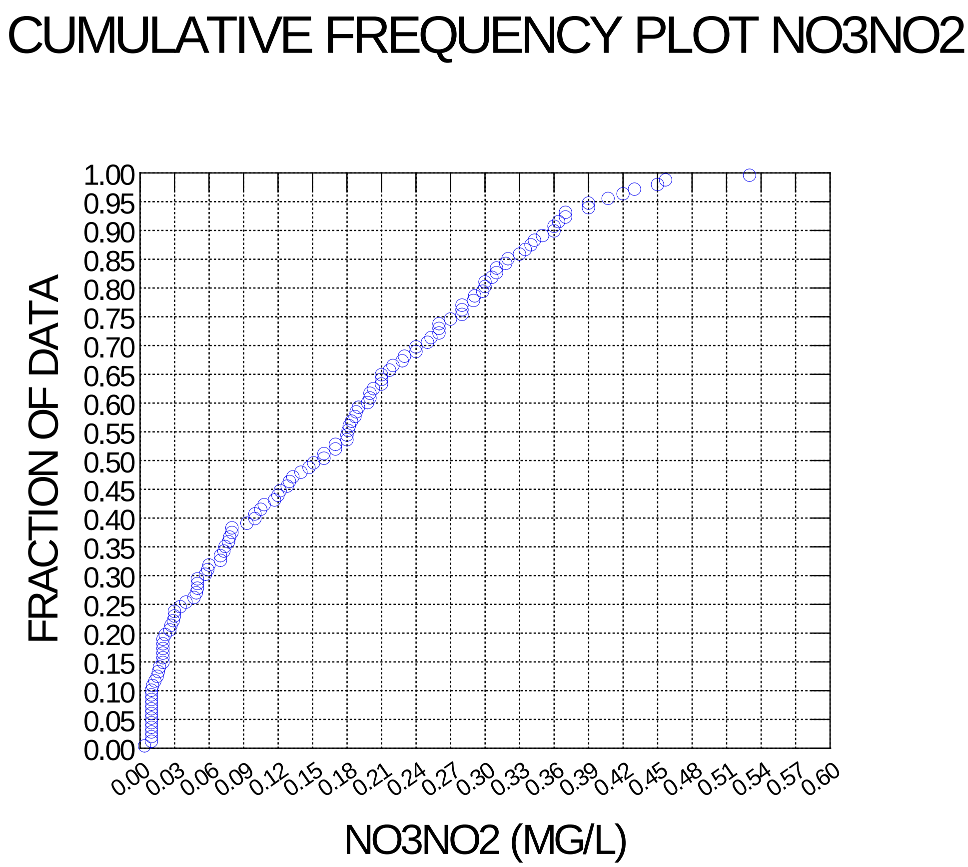

NH4 BY YEAR
NH4 (MG/L)
1.20
1.14
1.08
1.02
0.96
0.90
0.84
0.78
0.72
0.66
0.60
0.54
0.48
0.42
0.36
0.30
0.24
0.18
0.12
0.06
0.00
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
YEAR

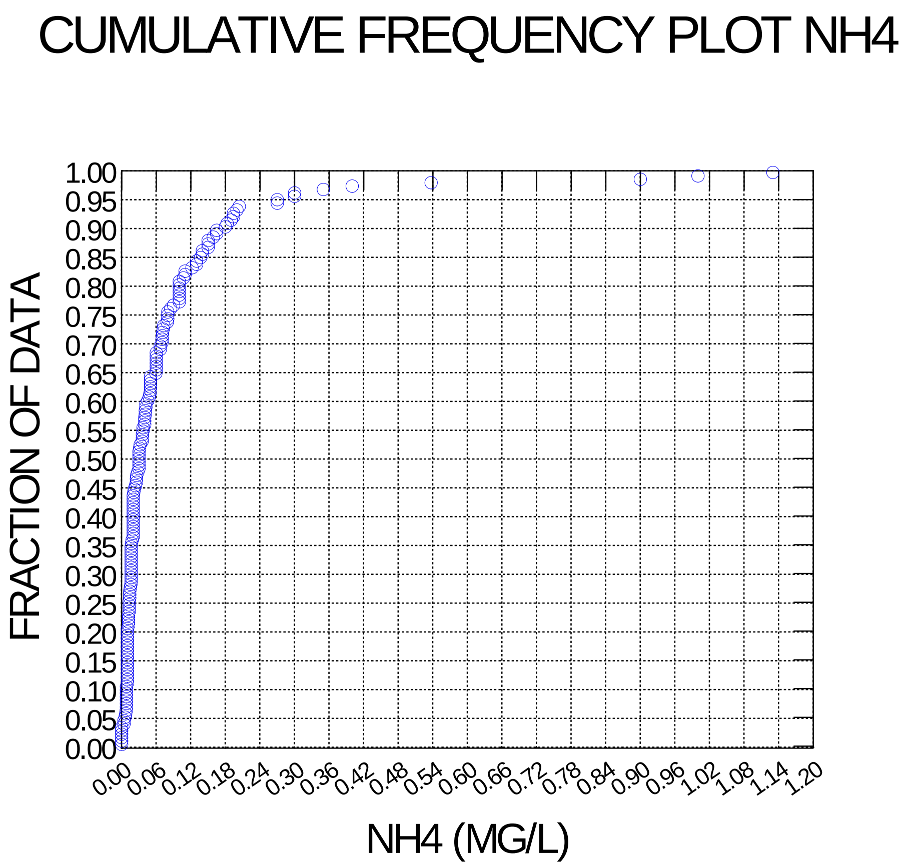

NO3NO2 BY YEAR
NO3NO2 (MG/L)
0.60
0.57
0.54
0.51
0.48
0.45
0.42
0.39
0.36
0.33
0.30
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0.00
1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
YEAR

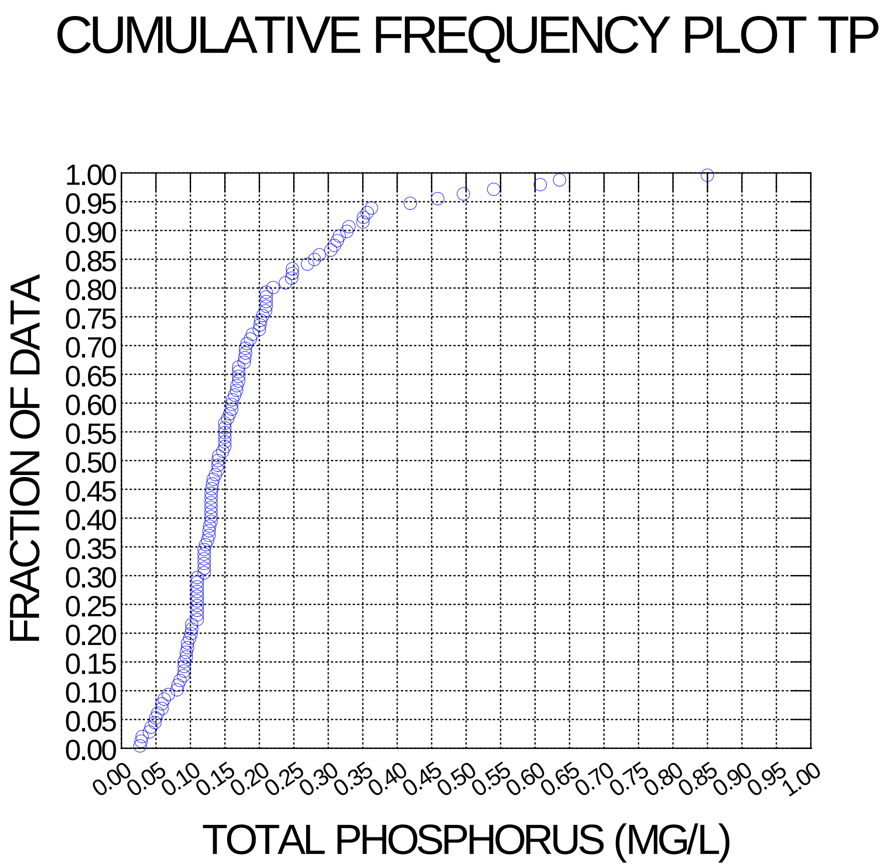

TOTAL PHOSPHORUS BY YEAR
TOTAL PHOSPHORUS (MG/L)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
YEAR


CUMULATIVE FREQUENCY PLOT CHLAC
FRACTION OF DATA
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80
CHLAC (UG/L)

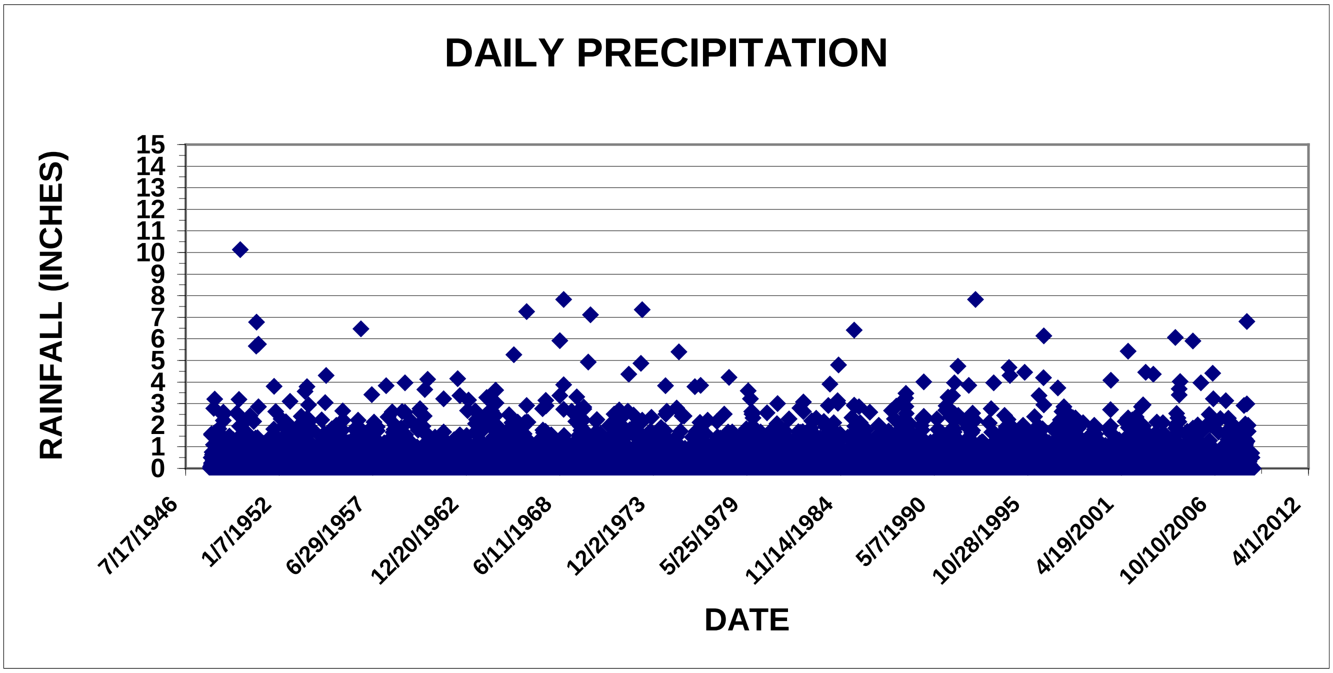

CUMULATIVE FREQUENCY PLOT TN
FRACTION OF DATA
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0
TOTAL NITROGEN (MG/L)


CUMULATIVE FREQUENCY PLOT NO3NO2
FRACTION OF DATA
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.30
0.33
0.36
0.39
0.42
0.45
0.48
0.51
0.54
0.57
0.60
NO3NO2 (MG/L)


CUMULATIVE FREQUENCY PLOT NH4
FRACTION OF DATA
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
0.00 0.06 0.12 0.18 0.24 0.30 0.36 0.42 0.48 0.54 0.60 0.66 0.72 0.78 0.84 0.90 0.96 1.02 1.08 1.14 1.20
NH4 (MG/L)


CUMULATIVE FREQUENCY PLOT TP
FRACTION OF DATA
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00
TOTAL PHOSPHORUS (MG/L)

## Appendix F: Chart of Rainfall for JIA, 1948–2008



## Appendix G: Spearman Correlation Matrix Analysis for Water Quality Parameters in the Arlington River (WBID 2265A)

### Spearman correlation matrix

| | PRECIP | PRECIP3D | PRECIP7D | PRECIP14 | JULIANDATE | VBOD | VCHLAC |
|---|---|---|---|---|---|---|---|
| PRECIP | 1 | | | | | | |
| PRECIP3DAY | 0.555 | 1 | | | | | |
| PRECIP7DAY | 0.443 | 0.673 | 1 | | | | |
| PRECIP14DAY | 0.347 | 0.441 | 0.662 | 1 | | | |
| JULIANDATE | 0.004 | -0.112 | -0.189 | -0.233 | 1 | | |
| VBOD | 0.02 | 0 | -0.131 | -0.145 | 0.429 | 1 | |
| VCHLAC | 0 | 0.325 | 0.177 | 0.233 | -0.005 | 0.281 | 1 |
| VCHLOR | -0.094 | -0.194 | -0.121 | -0.294 | 0.306 | 0.248 | -0.442 |
| VCOLOR | 0.017 | -0.06 | -0.02 | 0.15 | -0.3 | -0.156 | 0.439 |
| VCOND | -0.138 | -0.182 | -0.169 | -0.307 | 0.148 | 0.258 | -0.352 |
| VDO | -0.11 | -0.231 | -0.238 | -0.238 | 0.216 | 0.122 | -0.08 |
| VDOSAT | -0.093 | -0.22 | -0.219 | -0.194 | 0.316 | 0.312 | -0.049 |
| VNH4 | 0.016 | 0.098 | 0.142 | 0.226 | -0.323 | -0.236 | 0.091 |
| VNO3O2 | -0.088 | -0.067 | -0.082 | -0.09 | 0.154 | -0.061 | 0.117 |
| VPH | -0.145 | -0.187 | -0.334 | -0.283 | 0.183 | 0.149 | -0.058 |
| VSD | -0.088 | -0.167 | -0.085 | -0.211 | 0.045 | -0.007 | -0.33 |
| VSALIN | -0.193 | -0.17 | -0.238 | -0.383 | -0.017 | 0.205 | -0.304 |
| VSO4 | -0.175 | -0.143 | -0.196 | -0.337 | 0.063 | 0.196 | -0.403 |
| VTEMP | 0.124 | 0.103 | 0.116 | 0.162 | 0.109 | 0.158 | 0.134 |
| VTKN | -0.062 | -0.141 | -0.187 | -0.001 | 0.218 | 0.268 | 0.327 |
| VTN | -0.081 | -0.145 | -0.18 | 0.015 | -0.121 | 0.155 | 0.326 |
| VTOC | 0 | -0.004 | 0.091 | 0.213 | -0.422 | -0.671 | 0.265 |
| VTORTH | -0.023 | 0.02 | 0.053 | 0.083 | -0.175 | -0.211 | 1 |
| VTP | 0.095 | 0.199 | 0.052 | 0.037 | -0.173 | 0.101 | 0.46 |
| VTSS | -0.069 | -0.024 | -0.044 | 0.007 | -0.315 | 0.154 | 0.225 |
| VTURB | 0.149 | 0.144 | 0.071 | 0.176 | 0.121 | -0.084 | 0.455 |

**Spearman correlation matrix (cont.)**

| | VCHLOR | VCOLOR | VCOND | VDO | VDOSAT | VNH4 | VNO3O2 |
|---|---|---|---|---|---|---|---|
| VCHLOR | 1 | | | | | | |
| VCOLOR | -0.564 | 1 | | | | | |
| VCOND | 0.887 | -0.701 | 1 | | | | |
| VDO | 0.141 | 0.036 | -0.039 | 1 | | | |
| VDOSAT | 0.359 | -0.164 | 0.146 | 0.877 | 1 | | |
| VNH4 | -0.25 | 0.498 | -0.203 | -0.286 | -0.413 | 1 | |
| VNO3O2 | -0.341 | 0.491 | -0.253 | -0.106 | -0.373 | 0.199 | 1 |
| VPH | 0.383 | -0.332 | 0.338 | 0.274 | 0.319 | -0.183 | -0.252 |
| VSD | 0.524 | -0.651 | 0.469 | -0.251 | -0.171 | -0.187 | -0.266 |
| VSALIN | 0.945 | -0.821 | 0.974 | -0.102 | 0.075 | -0.159 | -0.277 |
| VSO4 | 0.962 | -0.887 | 0.826 | 0.099 | 0.226 | -0.501 | -0.412 |
| VTEMP | 0.289 | -0.269 | 0.233 | -0.437 | -0.033 | -0.046 | -0.299 |
| VTKN | -0.334 | 0.482 | -0.338 | -0.013 | -0.083 | 0.128 | 0.346 |
| VTN | -0.381 | 0.515 | -0.367 | -0.066 | -0.213 | 0.249 | 0.591 |
| VTOC | -0.431 | 0.702 | -0.381 | 0.008 | -0.178 | 0.289 | 0.352 |
| VTORTH | -0.189 | 0.103 | -0.131 | -0.257 | -0.277 | 0.135 | 0.26 |
| VTP | -0.186 | 0.374 | -0.046 | -0.159 | -0.23 | 0.244 | 0.385 |
| VTSS | 0.135 | 0.088 | 0.093 | 0.174 | 0.212 | -0.074 | -0.04 |
| VTURB | -0.501 | 0.717 | -0.453 | 0.065 | 0.046 | 0.14 | 0.112 |

| | VPH | VSD | VSALIN | VSO4 | VTEMP | VTKN | VTN |
|---|---|---|---|---|---|---|---|
| VPH | 1 | | | | | | |
| VSD | 0.094 | 1 | | | | | |
| VSALIN | 0.289 | 0.534 | 1 | | | | |
| VSO4 | 0.541 | 0.465 | 0.988 | 1 | | | |
| VTEMP | -0.018 | 0.148 | 0.256 | 0.374 | 1 | | |
| VTKN | -0.017 | -0.372 | -0.382 | -0.574 | 0.03 | 1 | |
| VTN | -0.069 | -0.381 | -0.379 | -0.573 | -0.049 | 0.943 | 1 |
| VTOC | -0.258 | -0.421 | -0.629 | -0.572 | -0.137 | 0.518 | 0.576 |
| VTORTH | -0.031 | -0.049 | 0.103 | -0.527 | 0.04 | 0.07 | 0.275 |
| VTP | -0.13 | -0.167 | -0.015 | -0.319 | 0.034 | 0.375 | 0.391 |
| VTSS | -0.033 | -0.465 | 0.097 | 0.119 | 0.053 | 0.371 | 0.326 |
| VTURB | -0.116 | -0.696 | -0.534 | -0.76 | -0.047 | 0.375 | 0.352 |

| | VTOC | VTORTH | VTP | VTSS | VTURB |
|---|---|---|---|---|---|
| VTOC | 1 | | | | |
| VTORTH | 0 | 1 | | | |
| VTP | 0.159 | 0.488 | 1 | | |
| VTSS | 0.129 | 0.139 | 0.177 | 1 | |
| VTURB | 0.529 | 0.097 | 0.274 | 0.32 | 1 |

**Pairwise frequency table**

| | PRECIP | PRECIP3D | PRECIP7D | PRECIP14 | JULIANDATE | VBOD | VCHLAC |
|---|---|---|---|---|---|---|---|
| PRECIP | 271 | | | | | | |
| PRECIP3DAY | 271 | 271 | | | | | |
| PRECIP7DAY | 271 | 271 | 271 | | | | |
| PRECIP14DAY | 271 | 271 | 271 | 271 | | | |
| JULIANDATE | 271 | 271 | 271 | 271 | 271 | | |
| VBOD | 137 | 137 | 137 | 137 | 137 | 137 | |
| VCHLAC | 38 | 38 | 38 | 38 | 38 | 22 | 38 |
| VCHLOR | 176 | 176 | 176 | 176 | 176 | 118 | 25 |
| VCOLOR | 110 | 110 | 110 | 110 | 110 | 96 | 28 |
| VCOND | 164 | 164 | 164 | 164 | 164 | 71 | 38 |
| VDO | 256 | 256 | 256 | 256 | 256 | 133 | 38 |
| VDOSAT | 240 | 240 | 240 | 240 | 240 | 126 | 38 |
| VNH4 | 169 | 169 | 169 | 169 | 169 | 74 | 37 |
| VNO3O2 | 124 | 124 | 124 | 124 | 124 | 66 | 36 |
| VPH | 248 | 248 | 248 | 248 | 248 | 125 | 37 |
| VSD | 81 | 81 | 81 | 81 | 81 | 49 | 38 |
| VSALIN | 108 | 108 | 108 | 108 | 108 | 55 | 32 |
| VSO4 | 38 | 38 | 38 | 38 | 38 | 27 | 24 |
| VTEMP | 249 | 249 | 249 | 249 | 249 | 131 | 38 |
| VTKN | 102 | 102 | 102 | 102 | 102 | 64 | 37 |
| VTN | 137 | 137 | 137 | 137 | 137 | 72 | 36 |
| VTOC | 54 | 54 | 54 | 54 | 54 | 28 | 32 |
| VTORTH | 59 | 59 | 59 | 59 | 59 | 42 | 2 |
| VTP | 123 | 123 | 123 | 123 | 123 | 43 | 37 |
| VTSS | 152 | 152 | 152 | 152 | 152 | 73 | 27 |
| VTURB | 119 | 119 | 119 | 119 | 119 | 70 | 28 |

**Pairwise frequency table (cont.)**

| | VCHLOR | VCOLOR | VCOND | VDO | VDOSAT | VNH4 | VNO3O2 |
|---|---|---|---|---|---|---|---|
| VCHLOR | 176 | | | | | | |
| VCOLOR | 103 | 110 | | | | | |
| VCOND | 106 | 57 | 164 | | | | |
| VDO | 172 | 107 | 162 | 256 | | | |
| VDOSAT | 162 | 98 | 152 | 240 | 240 | | |
| VNH4 | 119 | 59 | 150 | 162 | 151 | 169 | |
| VNO3O2 | 106 | 60 | 111 | 120 | 115 | 122 | 124 |
| VPH | 167 | 104 | 158 | 243 | 228 | 159 | 114 |
| VSD | 55 | 46 | 78 | 78 | 78 | 72 | 70 |
| VSALIN | 65 | 42 | 87 | 108 | 108 | 82 | 81 |
| VSO4 | 38 | 36 | 35 | 38 | 33 | 37 | 35 |
| VTEMP | 169 | 106 | 157 | 244 | 239 | 160 | 123 |
| VTKN | 84 | 59 | 94 | 99 | 95 | 99 | 100 |
| VTN | 92 | 58 | 123 | 131 | 122 | 135 | 101 |
| VTOC | 39 | 32 | 51 | 53 | 47 | 52 | 41 |
| VTORTH | 52 | 33 | 53 | 56 | 50 | 57 | 50 |
| VTP | 83 | 41 | 107 | 119 | 112 | 117 | 90 |
| VTSS | 117 | 58 | 135 | 145 | 134 | 149 | 111 |
| VTURB | 110 | 60 | 106 | 115 | 110 | 116 | 113 |

| | VPH | VSD | VSALIN | VSO4 | VTEMP | VTKN | VTN |
|---|---|---|---|---|---|---|---|
| VPH | 248 | | | | | | |
| VSD | 74 | 81 | | | | | |
| VSALIN | 105 | 65 | 108 | | | | |
| VSO4 | 37 | 25 | 22 | 38 | | | |
| VTEMP | 234 | 81 | 108 | 38 | 249 | | |
| VTKN | 93 | 72 | 80 | 35 | 102 | 102 | |
| VTN | 128 | 72 | 79 | 35 | 130 | 100 | 137 |
| VTOC | 52 | 34 | 29 | 31 | 51 | 40 | 50 |
| VTORTH | 51 | 32 | 35 | 16 | 58 | 51 | 54 |
| VTP | 119 | 44 | 53 | 36 | 118 | 69 | 94 |
| VTSS | 143 | 61 | 70 | 36 | 143 | 90 | 118 |
| VTURB | 110 | 62 | 71 | 36 | 118 | 92 | 94 |

| | VTOC | VTORTH | VTP | VTSS | VTURB |
|---|---|---|---|---|---|
| VTOC | 54 | | | | |
| VTORTH | 9 | 59 | | | |
| VTP | 48 | 21 | 123 | | |
| VTSS | 41 | 56 | 104 | 152 | |
| VTURB | 34 | 54 | 84 | 117 | 119 |

## Appendix H: Linear Regression Analysis of CHLAC Observations versus Nutrients and Rainfall in the Arlington River (WBID 2265A)

Dep Var: VCHLAC N: 38 Multiple R: 0.157 Squared multiple R: 0.025

Adjusted squared multiple R: 0.000 Standard error of estimate: 14.288

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | 0.250 | 11.325 | 0.000 | . | 0.022 | 0.982 |
| VTEMP | 0.440 | 0.461 | 0.157 | 1.000 | 0.954 | 0.347 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 185.716 | 1 | 185.716 | 0.910 | 0.347 |
| Residual | 7349.553 | 36 | 204.154 | | |

*** WARNING ***
Case 110 has large leverage (Leverage = 0.294)
Case 159 is an outlier (Studentized Residual = 5.834)
Case 226 has large leverage (Leverage = 0.329)

Durbin-Watson D Statistic 1.312
First Order Autocorrelation 0.292

Dep Var: VCHLAC N: 36 Multiple R: 0.341 Squared multiple R: 0.117

Adjusted squared multiple R: 0.034 Standard error of estimate: 14.263

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | -56.222 | 34.047 | 0.000 | . | -1.651 | 0.108 |
| VTEMP | 3.160 | 1.562 | 1.105 | 0.093 | 2.024 | 0.051 |
| VTN | 51.930 | 29.508 | 1.353 | 0.047 | 1.760 | 0.088 |
| VTEMP*VTN | -2.473 | 1.358 | -1.719 | 0.031 | -1.821 | 0.078 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 858.456 | 3 | 286.152 | 1.407 | 0.259 |
| Residual | 6510.090 | 32 | 203.440 | | |

*** WARNING ***
Case 80 has large leverage (Leverage = 1.506)
Case 104 has large leverage (Leverage = 0.447)
Case 110 has large leverage (Leverage = 7.509)
Case 111 has large leverage (Leverage = 0.523)
Case 112 has large leverage (Leverage = 0.520)
Case 116 has large leverage (Leverage = 0.430)
Case 126 has large leverage (Leverage = 0.389)
Case 129 has large leverage (Leverage = 0.578)
Case 159 is an outlier (Studentized Residual = 5.393)
Case 165 has large leverage (Leverage = 0.466)

Case 172 has large leverage (Leverage = 0.388)
Case 209 has large leverage (Leverage = 0.433)
Case 210 has large leverage (Leverage = 0.401)
Case 218 has large leverage (Leverage = 0.589)
Case 220 has large leverage (Leverage = 0.616)
Case 226 has large leverage (Leverage = 0.374)
Case 232 has large leverage (Leverage = 0.419)

Durbin-Watson D Statistic 1.282
First Order Autocorrelation 0.304

Dep Var: VCHLAC N: 37 Multiple R: 0.389 Squared multiple R: 0.152

Adjusted squared multiple R: 0.074 Standard error of estimate: 13.827

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | -74.599 | 44.197 | 0.000 | . | -1.688 | 0.101 |
| VTEMP | 3.292 | 1.874 | 1.173 | 0.058 | 1.757 | 0.088 |
| VTP | 536.955 | 300.905 | 2.306 | 0.015 | 1.784 | 0.084 |
| VTEMP*VTP | -20.169 | 12.501 | -2.501 | 0.011 | -1.613 | 0.116 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 1127.094 | 3 | 375.698 | 1.965 | 0.138 |
| Residual | 6309.075 | 33 | 191.184 | | |

*** WARNING ***
Case 61 has large leverage (Leverage = 0.827)
Case 63 has large leverage (Leverage = 0.753)
Case 70 has large leverage (Leverage = 4.470)
Case 73 has large leverage (Leverage = 0.373)
Case 76 has large leverage (Leverage = 13.004)
Case 89 has large leverage (Leverage = 10.284)
Case 90 has large leverage (Leverage = 4.293)
Case 94 has large leverage (Leverage = 0.878)
Case 108 has large leverage (Leverage = 0.726)
Case 110 has large leverage (Leverage = 2.439)
Case 111 has large leverage (Leverage = 0.503)
Case 112 has large leverage (Leverage = 0.487)
Case 116 has large leverage (Leverage = 0.911)
Case 121 has large leverage (Leverage = 1.761)
Case 123 has large leverage (Leverage = 0.662)
Case 125 has large leverage (Leverage = 0.730)
Case 132 has large leverage (Leverage = 0.841)
Case 134 has large leverage (Leverage = 0.507)
Case 141 has large leverage (Leverage = 2.478)
Case 151 has large leverage (Leverage = 0.396)
Case 156 has large leverage (Leverage = 0.635)
Case 159 is an outlier (Studentized Residual = 6.345)
Case 167 has large leverage (Leverage = 0.995)
Case 169 has large leverage (Leverage = 0.492)

Durbin-Watson D Statistic 1.537

First Order Autocorrelation 0.228

Dep Var: VCHLAC N: 36 Multiple R: 0.552 Squared multiple R: 0.304

Adjusted squared multiple R: 0.160 Standard error of estimate: 13.295

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | -126.785 | 49.848 | 0.000 | . | -2.543 | 0.017 |
| VTEMP | 4.692 | 2.022 | 1.640 | 0.048 | 2.321 | 0.028 |
| VTP | 654.909 | 379.198 | 2.817 | 0.009 | 1.727 | 0.095 |
| VTN | 62.910 | 32.252 | 1.639 | 0.034 | 1.951 | 0.061 |
| VTEMP*VTP | -14.986 | 13.732 | -1.867 | 0.008 | -1.091 | 0.284 |
| VTEMP*VTN | -2.124 | 1.445 | -1.476 | 0.024 | -1.470 | 0.152 |
| VTP*VTN | 174.752 | 121.019 | -1.340 | 0.028 | -1.444 | 0.159 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 2242.816 | 6 | 373.803 | 2.115 | 0.082 |
| Residual | 5125.730 | 29 | 176.749 | | |

*** WARNING ***

Case 61 has large leverage (Leverage = 0.903)
Case 63 has large leverage (Leverage = 3.193)
Case 70 has large leverage (Leverage = 7.052)
Case 73 has large leverage (Leverage = 1.535)
Case 83 has large leverage (Leverage = 1.466)
Case 89 has large leverage (Leverage = 13.774)
Case 94 has large leverage (Leverage = 1.006)
Case 97 has large leverage (Leverage = 0.840)
Case 100 has large leverage (Leverage = 1.090)
Case 104 has large leverage (Leverage = 0.725)
Case 108 has large leverage (Leverage = 0.775)
Case 110 has large leverage (Leverage = 16.919)
Case 111 has large leverage (Leverage = 2.598)
Case 112 has large leverage (Leverage = 1.169)
Case 116 has large leverage (Leverage = 0.979)
Case 121 has large leverage (Leverage = 3.000)
Case 123 has large leverage (Leverage = 0.859)
Case 126 has large leverage (Leverage = 1.331)
Case 129 has large leverage (Leverage = 0.603)
Case 148 has large leverage (Leverage = 0.631)
Case 150 has large leverage (Leverage = 0.519)
Case 156 has large leverage (Leverage = 0.776)
Case 159 is an outlier (Studentized Residual = 6.358)
Case 165 has large leverage (Leverage = 0.560)
Case 167 has large leverage (Leverage = 1.124)
Case 169 has large leverage (Leverage = 0.649)
Case 238 is an outlier (Studentized Residual = 3.199)
Case 246 has large leverage (Leverage = 0.893)

Durbin-Watson D Statistic 1.913
First Order Autocorrelation 0.040

Dep Var: VCHLAC N: 38 Multiple R: 0.578 Squared multiple R: 0.334

Adjusted squared multiple R: 0.316 Standard error of estimate: 11.803

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | 7.529 | 2.065 | 0.000 | . | 3.646 | 0.001 |
| PRECIP3DAY | 11.125 | 2.616 | 0.578 | 1.000 | 4.253 | 0.000 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 2520.148 | 1 | 2520.148 | 18.090 | 0.000 |
| Residual | 5015.122 | 36 | 139.309 | | |

*** WARNING ***
Case 32 has large leverage (Leverage = 0.559)
Case 69 has large leverage (Leverage = 0.298)
Case 89 has large leverage (Leverage = 0.261)
Case 158 has large leverage (Leverage = 0.647)
Case 158 is an outlier (Studentized Residual = -4.359)
Case 158 has large influence (Cook distance = 11.587)
Case 159 has large leverage (Leverage = 0.285)
Case 159 is an outlier (Studentized Residual = 4.314)
Case 167 has large leverage (Leverage = 0.718)
Case 175 has large leverage (Leverage = 0.285)
Case 176 has large leverage (Leverage = 1.803)
Case 180 has large leverage (Leverage = 0.521)
Case 181 has large leverage (Leverage = 1.336)
Case 196 has large leverage (Leverage = 0.744)

Durbin-Watson D Statistic 1.743
First Order Autocorrelation 0.055

Dep Var: VCHLAC N: 38 Multiple R: 0.565 Squared multiple R: 0.319

Adjusted squared multiple R: 0.300 Standard error of estimate: 11.939

| Effect | Coefficient | Std Error | Std Coef | Tolerance | t | P(2 Tail) |
|---|---|---|---|---|---|---|
| CONSTANT | 7.179 | 2.130 | 0.000 | . | 3.370 | 0.002 |
| PRECIP7DAY | 6.762 | 1.647 | 0.565 | 1.000 | 4.107 | 0.000 |

Analysis of Variance

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 2403.922 | 1 | 2403.922 | 16.865 | 0.000 |
| Residual | 5131.347 | 36 | 142.537 | | |

*** WARNING ***

Case 14 has large leverage (Leverage = 0.429)
Case 15 has large leverage (Leverage = 0.429)
Case 20 has large leverage (Leverage = 0.388)
Case 21 has large leverage (Leverage = 0.388)
Case 51 has large leverage (Leverage = 1.324)
Case 52 has large leverage (Leverage = 1.324)
Case 69 has large leverage (Leverage = 0.349)
Case 86 has large leverage (Leverage = 0.481)
Case 158 has large leverage (Leverage = 0.303)
Case 159 has large leverage (Leverage = 0.478)
Case 159 is an outlier (Studentized Residual = 3.779)
Case 167 has large leverage (Leverage = 0.310)
Case 176 has large leverage (Leverage = 0.689)
Case 181 has large leverage (Leverage = 0.850)
Case 194 has large leverage (Leverage = 0.316)
Case 196 has large leverage (Leverage = 0.335)
Case 234 has large leverage (Leverage = 0.427)
Case 238 is an outlier (Studentized Residual = 3.087)

Durbin-Watson D Statistic 1.383
First Order Autocorrelation 0.227

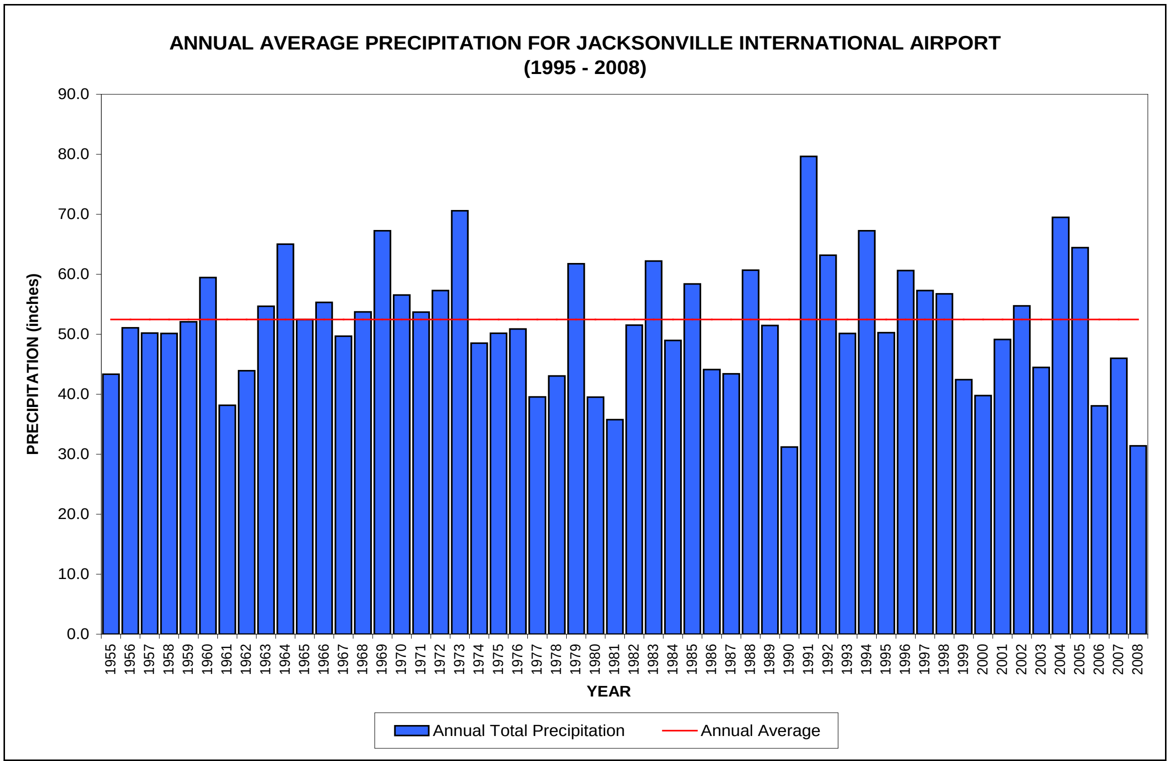
## Appendix I: Monthly and Annual Precipitation at JIA, 1955–2008

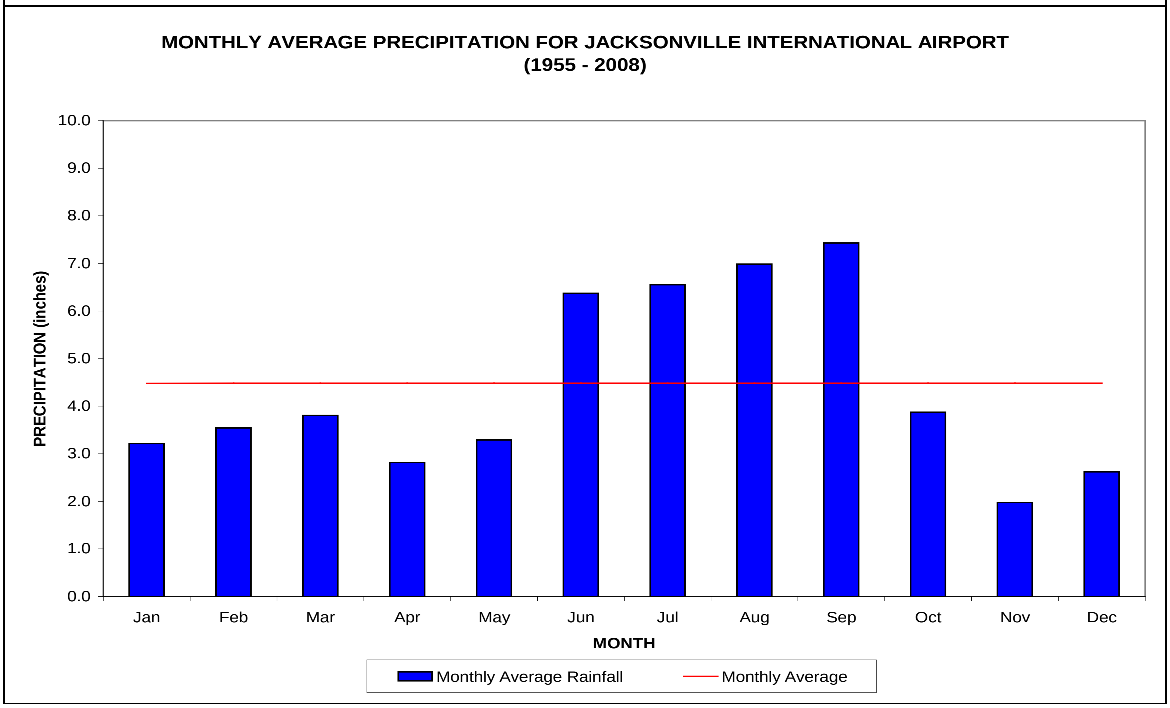
Rainfall is in inches, and represents data from JIA.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1955 | 3.1 | 2.46 | 1.66 | 1.5 | 4.51 | 2.7 | 5.53 | 3.85 | 10.6 | 5.36 | 1.9 | 0.2 | **43.33** |
| 1956 | 2.9 | 2.94 | 0.81 | 2.33 | 3.98 | 7.87 | 8.25 | 5.24 | 2.89 | 13.4 | 0.4 | 0 | **51.08** |
| 1957 | 0.3 | 1.69 | 3.87 | 1.61 | 5.25 | 7.1 | 12.3 | 3.3 | 8.33 | 3.5 | 1.6 | 1.3 | **50.18** |
| 1958 | 3.4 | 3.74 | 3.38 | 8.24 | 3.79 | 3.96 | 4.37 | 4.67 | 4.75 | 5.07 | 2 | 2.8 | **50.14** |
| 1959 | 3 | 5.22 | 9.75 | 2.65 | 9.2 | 2.94 | 4.51 | 2.86 | 5.67 | 3.12 | 2.2 | 1 | **52.08** |
| 1960 | 2.1 | 5.17 | 6.94 | 3.54 | 1.18 | 4.7 | 16.2 | 6.5 | 8.57 | 2.95 | 0.1 | 1.5 | **59.45** |
| 1961 | 2.9 | 4.85 | 1.17 | 4.16 | 3.06 | 5.27 | 3.48 | 10.6 | 1.02 | 0.27 | 0.9 | 0.5 | **38.15** |
| 1962 | 2.2 | 0.52 | 3.1 | 2.36 | 1.12 | 8.22 | 6.31 | 10.1 | 4.37 | 1.13 | 2.1 | 2.5 | **43.9** |
| 1963 | 5.4 | 6.93 | 2.23 | 1.75 | 1.74 | 12.5 | 6.47 | 4.95 | 4.88 | 1.53 | 2.7 | 3.6 | **54.66** |
| 1964 | 7.3 | 6.55 | 1.76 | 4.65 | 4.8 | 4.67 | 6.12 | 5.63 | 10.3 | 5.09 | 3.3 | 4.8 | **65.03** |
| 1965 | 0.7 | 5.5 | 3.91 | 0.95 | 0.94 | 9.79 | 2.71 | 9.58 | 11 | 1.75 | 1.9 | 3.8 | **52.47** |
| 1966 | 4.6 | 5.97 | 0.71 | 2.25 | 10.4 | 7.74 | 11.1 | 3.88 | 5.94 | 1.38 | 0.2 | 1.1 | **55.3** |
| 1967 | 3.1 | 4.35 | 0.81 | 2 | 1.18 | 12.9 | 5.22 | 12.3 | 1.8 | 1.13 | 0.2 | 4.7 | **49.68** |
| 1968 | 0.8 | 3.05 | 1.2 | 0.99 | 2.17 | 12.3 | 6.84 | 16.2 | 2.68 | 5.09 | 1.3 | 1.1 | **53.72** |
| 1969 | 0.8 | 3.39 | 4.23 | 0.34 | 3.78 | 5.12 | 5.89 | 15.1 | 10.3 | 9.81 | 4.6 | 3.9 | **67.26** |
| 1970 | 4.2 | 8.85 | 9.98 | 1.77 | 1.84 | 2.65 | 7.6 | 11 | 3.2 | 3.95 | 0 | 1.6 | **56.55** |
| 1971 | 2 | 2.55 | 2.41 | 4.07 | 1.9 | 5.52 | 5.07 | 12.8 | 4.17 | 6.46 | 0.8 | 5.9 | **53.69** |
| 1972 | 5.8 | 3.48 | 4.43 | 2.98 | 8.26 | 6.75 | 3.15 | 9.76 | 2.6 | 4.46 | 4.2 | 1.4 | **57.29** |
| 1973 | 4.6 | 5.07 | 10.2 | 11.6 | 5.33 | 4.1 | 5.45 | 7.49 | 7.86 | 4.08 | 0.4 | 4.3 | **70.57** |
| 1974 | 0.3 | 1.28 | 3.47 | 1.53 | 4.14 | 5.53 | 9.83 | 11.2 | 8.13 | 0.34 | 1 | 1.7 | **48.52** |
| 1975 | 3.5 | 2.58 | 2.46 | 5.78 | 7 | 5.21 | 6.36 | 6.23 | 5.24 | 3.63 | 0.4 | 1.8 | **50.15** |
| 1976 | 2.3 | 1.05 | 3.41 | 0.63 | 10 | 4.26 | 5.41 | 6.37 | 8.56 | 1.63 | 2.4 | 4.8 | **50.87** |
| 1977 | 3 | 3.24 | 1.03 | 1.76 | 3.07 | 2.65 | 1.97 | 7.26 | 7.45 | 1.68 | 3.1 | 3.4 | **39.56** |
| 1978 | 4.6 | 4.17 | 2.83 | 2.24 | 9.18 | 2.62 | 6.67 | 2.39 | 4.4 | 1.26 | 0.8 | 1.8 | **43.04** |
| 1979 | 6.3 | 3.75 | 1 | 4.18 | 7.54 | 5.91 | 4.67 | 4.78 | 17.8 | 0.25 | 3.6 | 2 | **61.76** |
| 1980 | 2.6 | 1.06 | 6.83 | 3.91 | 3.02 | 4.59 | 5.29 | 3.97 | 3.03 | 2.69 | 2.3 | 0.2 | **39.53** |
| 1981 | 0.9 | 4.53 | 5.41 | 0.32 | 1.48 | 3.31 | 2.46 | 6.47 | 1.22 | 1.35 | 4.9 | 3.4 | **35.77** |
| 1982 | 3 | 1.67 | 4.26 | 3.6 | 3.55 | 8.06 | 3.81 | 6.93 | 9.32 | 3.37 | 1.9 | 2 | **51.52** |
| 1983 | 7.2 | 4.27 | 8.46 | 4.65 | 1.38 | 6.86 | 6.11 | 4.63 | 4.61 | 4.29 | 3.3 | 6.4 | **62.19** |
| 1984 | 2.1 | 4.67 | 5.77 | 3.14 | 1.46 | 4.76 | 6.01 | 3.78 | 12.3 | 1.53 | 3.3 | 0.1 | **48.96** |
| 1985 | 1.1 | 1.45 | 1.26 | 2.76 | 2.08 | 3.71 | 6.33 | 8.93 | 16.8 | 8.34 | 2.1 | 3.6 | **58.39** |
| 1986 | 4.2 | 4.72 | 5.44 | 0.93 | 2.13 | 2.53 | 3.27 | 9.6 | 1.99 | 1.8 | 2.9 | 4.7 | **44.1** |
| 1987 | 4.1 | 6.47 | 6.27 | 0.14 | 0.75 | 4.18 | 4.4 | 4.48 | 7.13 | 0.3 | 5 | 0.2 | **43.39** |
| 1988 | 6.4 | 6.08 | 2.65 | 3.44 | 1.35 | 3.71 | 4.5 | 8.48 | 16.4 | 2.35 | 4.3 | 1.1 | **60.68** |
| 1989 | 1.7 | 1.77 | 2.14 | 2.79 | 1.55 | 3.66 | 8.98 | 9.16 | 14.4 | 1.39 | 0.5 | 3.4 | **51.45** |
| 1990 | 1.8 | 4.07 | 1.59 | 1.34 | 0.18 | 1.59 | 6.53 | 3.81 | 2.6 | 4.54 | 1.2 | 1.9 | **31.2** |
| 1991 | 10 | 1.52 | 7.33 | 6.31 | 9.35 | 11.7 | 15.9 | 3.48 | 6.2 | 6.36 | 0.7 | 0.6 | **79.63** |
| 1992 | 5.8 | 2.64 | 4.09 | 5.33 | 5.97 | 7.04 | 3.32 | 10.8 | 7.33 | 8.34 | 1.9 | 0.7 | **63.18** |
| 1993 | 3.9 | 2.89 | 5.98 | 0.85 | 1.6 | 2.52 | 7.54 | 2.96 | 7.6 | 8.84 | 3.6 | 1.9 | **50.12** |
| 1994 | 6.6 | 0.92 | 2.14 | 1.51 | 3.15 | 14 | 8.26 | 3.29 | 9.79 | 10.2 | 3.5 | 3.9 | **67.26** |
| 1995 | 1.9 | 2.07 | 3.67 | 1.77 | 1.77 | 5.35 | 9.45 | 9.93 | 5.41 | 3.53 | 3.2 | 2.2 | **50.25** |

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1.1 | 1.11 | 6.83 | 2.85 | 0.72 | 11.4 | 4.2 | 7.83 | 8.49 | 11.5 | 1.4 | 3.2 | **60.63** |
| 1997 | 2.9 | 1.28 | 1.84 | 4.56 | 3.43 | 6.33 | 7.69 | 8.24 | 3.97 | 4.84 | 2.4 | 9.8 | **57.27** |
| 1998 | 3.5 | 11.1 | 2.64 | 4.71 | 0.96 | 2.95 | 7.29 | 10.1 | 7.65 | 3.01 | 2.4 | 0.4 | **56.72** |
| 1999 | 4.6 | 1.7 | 0.4 | 1.92 | 1.02 | 7.75 | 3.56 | 3.51 | 13 | 3.24 | 0.8 | 0.9 | **42.44** |
| 2000 | 2.8 | 1.17 | 1.79 | 2.6 | 1.15 | 2.43 | 5.69 | 7.38 | 11.6 | 0.23 | 1.6 | 1.4 | **39.77** |
| 2001 | 0.9 | 0.68 | 5.48 | 0.62 | 2.56 | 5.59 | 8.31 | 3.58 | 16 | 0.81 | 1.4 | 3.1 | **49.14** |
| 2002 | 4.5 | 0.82 | 4.38 | 2.41 | 0.47 | 6.24 | 7.8 | 8.14 | 9.31 | 2.58 | 2.7 | 5.4 | **54.72** |
| 2003 | 0.1 | 4.66 | 10.7 | 2.63 | 2.54 | 6.75 | 7.33 | 1.83 | 3.04 | 2.98 | 0.7 | 1.2 | **44.47** |
| 2004 | 1.6 | 4.47 | 1.36 | 2.02 | 1.24 | 17.2 | 8.6 | 9.85 | 16.3 | 1.32 | 2.9 | 2.7 | **69.47** |
| 2005 | 1.9 | 3.56 | 3.67 | 4.53 | 3.51 | 14.8 | 7.37 | 4.43 | 5.76 | 6.49 | 1.1 | 7.4 | **64.44** |
| 2006 | 2.30 | 3.91 | 0.68 | 1.22 | 2.01 | 7.25 | 3.97 | 7.08 | 4.55 | 1.81 | 0.39 | 2.90 | **38.07** |
| 2007 | 2.29 | 2.40 | 2.22 | 1.02 | 1.12 | 6.68 | 9.48 | 3.57 | 5.44 | 8.85 | 0.17 | 2.74 | **45.98** |
| 2008 | 2.63 | 5.22 | 3.50 | 2.34 | 0.66 | 8.21 | 8.73 | 16.83 | 5.84 | 1.62 | 1.01 | 0.59 | **46.01** |
| **AVG** | **3.21** | **3.54** | **3.81** | **2.82** | **3.29** | **6.37** | **6.55** | **6.99** | **7.43** | **3.87** | **1.98** | **2.62** | **52.32** |

## Appendix J: Annual and Monthly Average Precipitation at JIA



## Appendix K: Response to Comments

August 4, 2009

John P. Pappas, P.E.
Deputy Director Public Works
City of Jacksonville
214 N. Hogan Street, Suite 1079
Jacksonville, FL 32202

Subject: Draft Total Maximum Daily Loads for the Ortega (WBID 2213P), Trout (WBID 2203), and Arlington (WBID 2265A) Rivers

Dear Mr. Pappas:

Thank you for providing comments on several of our draft Total Maximum Daily Load reports in your letter of July 15th. We appreciate you and your staff taking the time to help us improve the clarity of these reports and have incorporated your suggested changes wherever possible. As you will see below, your comments are reproduced in the order in which they were presented and then our responses are provided.

1) Explain why upstream tributary areas to the WBIDs appear to exclude some areas7 (see Figure 4.4 for Arlington River, Figure 4.6 for Ortega River, Figure 4.5 for Trout River). These figures exclude large sections of upstream tributary area.

**Department Response:** The intent of these figures and load estimates was to provide an overview of relative contributions of nitrogen and phosphorus from various sources to the impaired WBID from upstream areas, but were not used to establish the Total Maximum Daily Load reductions. If the City could provide a GIS coverage of the upstream tributary drainage area for these WBIDs, the analysis could be revised. As noted in the documents, it was our understanding that the City has contracted with Camp Dresser & McKee, Inc. to model these sub-basins with the Watershed Management Model to develop discharge and pollutant load information as part of an update to the Master Stormwater Management Plan. Determination of the assimilative capacity described in Chapter 5 was based upon observed relationships between multiple water quality parameters in the impaired waterbody. While the source assessments described in Chapter 4 were not a factor in the development of nutrient reductions, they were included to aid in the development of the Basin Management Action Plan (reduction implementation) process.

2) The measured TN and TP concentrations for the Trout River appear to be higher than would be expected for a relatively undeveloped basin. The higher measured concentrations suggest that there is some load in the watershed that is not accounted for, and/ or the station is affected by high downstream TN and TP concentrations migrating upstream. A portion of this inconsistency could be due to tidal influences from the St Johns River.

John P. Pappas, P.E.
Deputy Director Public Works
City of Jacksonville
August 4, 2009
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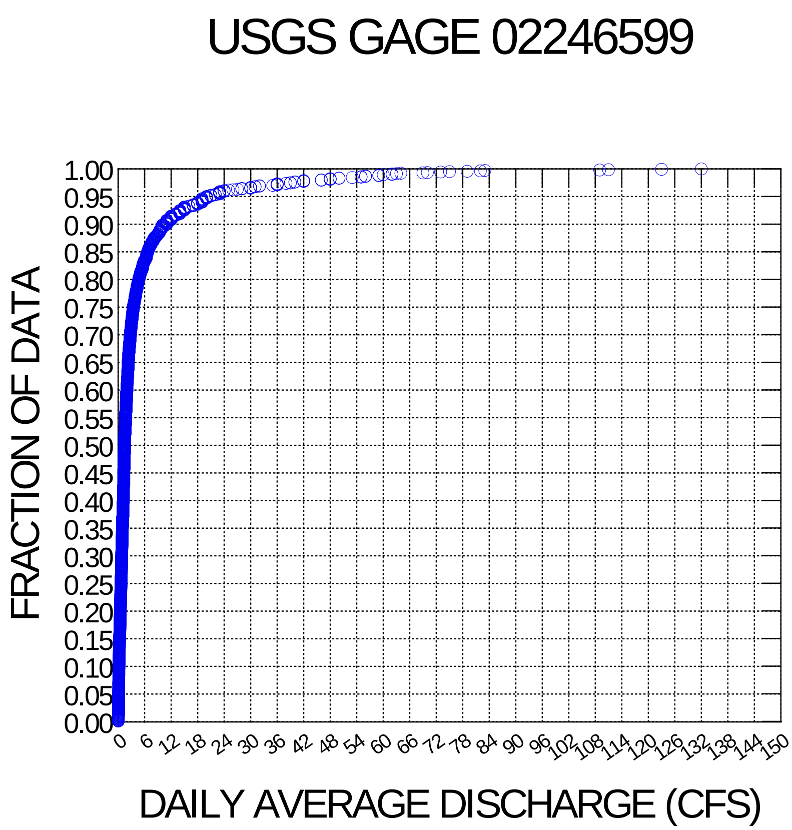
**Department Response:** As noted in the document, there was a considerable increase in the median TN and TP medians in the Middle Trout River WBID (2203) compared to the upstream segment, i.e., the upper Trout River (WBID 2223). Based on data from the Impaired Waters Rule Run 35 database, the median TN and TP concentrations for WBID 2203 were 1.43 mg/L and 0.296 mg/L respectively, versus medians of 0.55 mg/L and 0.068 mg/L, respectively, in WBID 2223 over the same period. Over the same period, median TN and TP concentrations in the downstream Trout River WBID (2203A) were 0.93 mg/L and 0.13 mg/L, respectively. Regarding your concern over the possible effects of high downstream TN and TP concentrations migrating upstream, flow records from the USGS site (02246599) located near the bottom of the middle Trout River WBID did not reflect any negative flows over the period of record (10/1/2002 – 8/10/2006). Daily flows ranged between 0.04 and 130 cubic feet per second (CFS), with a mean flow of 4.9 CFS. A cumulative frequency plot of flow is presented below. As part of the county stormwater program and Phase 1 MS4 monitoring, has the City identified any possible sources that could help explain the elevated TN and TP levels in this WBID?



John P. Pappas, P.E.
Deputy Director Public Works
City of Jacksonville
August 4, 2009
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3) For the Trout River, the relatively low estimated TP loads/ concentrations and the high measured TP concentrations indicate an inconsistency between the modeling and observed conditions. The TMDL for the Trout River should be revisited to account for the additional nutrient source.

**Department Response:** As noted in our response to Item #1, the load/concentration estimates described in Chapter 4 were provided to indicate the relative importance of various sources of nutrients in the watershed. It is our understanding that the City has contracted with Camp Dresser & McKee, Inc. to model the Trout River sub-basin using the Watershed Management Model to develop discharge and pollutant load information as part of an update to your local Master Stormwater Management Plan. The TMDL reductions were not based on model estimated loads and/or concentrations. As discussed in Chapter 5, the assimilative capacity was based upon relationships developed between water quality measurements taken in the middle Trout River WBID.

4) In general, the draft TMDLs for the Arlington, Ortega, and Trout Rivers apply to WBIDs that border the LSJR and are highly tidally influenced. Measured water quality values within these tidally influenced WBIDs are most likely reflective of water quality within the LSJR itself. The reductions needed to protect these WBIDs from impairment will be addressed through the LSJR Mainstem Basin Management Action Plan (BMAP). The projects identified in the Mainstem BMAP will be protective of water quality in these WBIDs and will achieve the specific load reductions.

**Department Response:** Once statistical relationships between dissolved oxygen, chlorophyll, and nutrients were developed for these impaired waters, the percent reduction in nitrogen required under the Mainstem nutrient TMDL was the starting point to assess whether designated uses would be restored within these tributaries with implementation of nitrogen reductions. In the case of the middle Trout River WBID, the TMDL also requires reduction in the total phosphorus. We concur that implementation of projects that improve water quality in the mainstem of the St. Johns River should also benefit the Arlington and portions of the Ortega and Trout Rivers due to tidal exchange. In recognition of this, the TMDL rule language has been written to allow for recognition of projects that provide co-benefits to the mainstem and each individual tributary.

Please contact Dr. Wayne Magley, at 850/245-8463, if you have any further questions.

Sincerely,

Jan Mandrup-Poulsen, Administrator
Watershed Evaluation and TMDL Section

ec: Wayne Magley, DEP
Lisa Sterling, CDM
Jeff Martin, DEP

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