South Florida Water Management District Written Comments for the EPA's Scientific Advisory Board

Carter, Kevin to: Stephanie Sanzone 12/06/2010 06:09 PM

Dear Ms. Sanzone:

The South Florida Water Management District (the District) respectfully submits the following documents for distribution to the United States Environmental Protection Agency's (EPA) Scientific Advisory Board (SAB) who will meet on December 13 – 14 to discuss EPA's Methods and Approaches for Deriving Numeric Criteria for Nitrogen/Phosphorus Pollution in Florida's Estuaries, Coastal Waters, and Southern Inland Flowing Waters:

- Canals in South Florida: A Technical Support Document (South Florida Water Management District, April 28, 2010, 86 pp.);

- The District's cover letter and "Comments (April 28, 2010) on the Proposed 40 CFR Part 131 Water Quality Standards for the State of Florida's Lakes and Flowing Waters";

- The South Florida Environmental Report 2010 (http://my.sfwmd.gov/portal/page/portal/xweb%20about%20us/agency%20reports);

- The District's Facilities and Major Canals Map (http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/facility_map_overview.pdf).

The District is providing you with electronic copies or links (because of file size) in this communication and we are also forwarding 20 hard copies of these documents to your office for distribution to the SAB. The District extends our thanks to the SAB panel members and the EPA, in advance, for your time and efforts on this important endeavor for the State of Florida. As the SAB process continues, please do not hesitate to contact me at 561-682-6949 or kecarter@sfwmd.gov.

Sincerely,

Kevin Carter
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Canals in South Florida:

A Technical Support Document

(April 28, 2010)

Prepared by

South Florida Water Management District

West Palm Beach, Florida

ACKNOWLEDGEMENTS

This report was prepared by the Canal Science Inventory Workgroup led by Kevin Carter. Garth Redfield provided overall science direction. Scott Huebner compiled and summarized the water quality data with support from Lucia Baldwin, Steve Hill, and Nenad Iricanin. Lawrence Glenn, Scot Hagerthey, Brad Jones, Mac Kobza, and Sue Newman compiled information on fish and wildlife including fish, alligators, and birds. John Maxted compiled data on macroinvertebrate communities in canals and prepared summaries and a reanalysis of key data. Matahel Ansar, Lucine Dadrian, Sally Kennedy, Adnan Mirza, and Cled Weldon provided information on the operation, management design, and construction of canals. Christopher Pettit provided legal guidance. Joel VanArman compiled historic information on canals and provided technical support in the preparation of this report under contract with the SFWMD.

EXECUTIVE SUMMARY
SOUTH FLORIDA CANALS IN A NUTSHELL

Background

This report was prepared to support a variety of activities related to the management of South Florida Water Management District (SFWMD or District) canals. Canals are engineered waterways designed to convey water to meet water supply and flood control objectives. Water delivered by canals also supports aquatic habitat for fish and wildlife. The report compiles and summarizes available information on the history, physical characteristics, biology, and water quality of District canals. The information included comes from published literature, reports, and original data derived from searches of resources from the District, cities, counties, municipalities, and universities. No new data were collected for this report; however, additional analyses of existing macroinvertebrate data were conducted to address our specific questions related to conditions in canals. The information is presented at three levels of detail to promote communications to a wide audience of managers, scientists, and the public: executive summary, summary report, and appendices.

Canals of the South Florida Water Management System

Developed over the past hundred years, the canal-based water management system in South Florida is one of the world's largest and most complex civil works projects. Over 1300 water control structures, 64 pump stations, and 2600 miles of canals are used by the SFWMD to provide flood control, water supply, navigation, water quality improvements, and environmental management over its 16-county, 17,000-square mile region.[1]

Canals were built to meet human needs by controlling the water levels and the movement of water from one place to another for water supply, flood control, drainage, and navigation, as well as to provide water needed to sustain natural communities in lakes, rivers, wetlands and estuaries. Ecological functions in canals can be valuable for recreation and aesthetics, but are secondary and largely incidental to their use for conveyance.

A primary function of a canal is to control water levels in order to maintain groundwater control in dry conditions. This can be particularly important for water supply needs such as preventing salt water intrusion. Canals also provide the conduit to remove excess water from drainage basins in wet periods to prevent flooding.

District canals differ greatly in their design, construction, and operation, depending primarily on their geography, intended function, adjacent land use, and development within the basin. Canals exist in the full range of land uses in South Florida including areas that are completely surrounded by natural wetlands, such as those within the Water Conservation Areas or the Kissimmee River Floodplain; areas that are surrounded by intensive urban development, such as coastal canals in Miami-Dade and Broward counties; and areas that are completely surrounded by agriculture, such as the Everglades Agricultural Area.

[1] Data from http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_whatwedo/pg_sfwmd_whatwedo_canalstructureops.

Canal diversity is reflected in many observations:

- Water quality in canals is affected by tributary sources, surrounding soil types, topography, groundwater interaction, and adjacent land uses. In some areas, notably eastern Miami-Dade and Broward counties, water quality in the canals is strongly influenced by groundwater seepage.
- Soil types surrounding canals range from sandy upland soils of the Atlantic Coastal Ridge to hydric sands, marls, and peats of the Everglades.
- Topography differs across the SFWMD, resulting in differences in canal depths, water levels, and flow rates. Water level elevations in canals range from 20 to 60 feet above sea level in the Kissimmee and Istokpoga basins to less than 10 feet above sea level throughout most of Miami-Dade, Broward, and Monroe counties.

Water Quality and System Ecology in South Florida Canals

A survey of existing data for the primary canal system indicates that water quality varies greatly among regions of the SFWMD, individual canals within regions, and sections of the same canal. Some canals convey water that has been treated in one of the Stormwater Treatment Areas, the goal of which is to reduce total phosphorus concentrations to levels necessary to achieve compliance with the phosphorus criterion in the Everglades. A net increase in nutrient concentrations tends to occur in canals adjacent to urban and agricultural land uses and a net decrease occurs in canals surrounded by wetlands or areas where canal water interacts strongly with groundwater. Little is known about the natural chemical and biological assimilation processes that occur in canals and more information is necessary.

Some preliminary findings on canal water quality include the following:

- Canal phosphorus concentrations span an order of magnitude and appear to demonstrate a clear spatial pattern that follows the intensity of land use and the inflow sources (such as Stormwater Treatment Area discharges). The variability of phosphorus concentrations tends to be much higher than that for nitrogen and the two constituents do not correspond closely.
- Within canals, phosphorus concentrations tend to change more than nitrogen as water moves downstream. Nutrient levels tend to be higher at inland and upstream sites, but there also is considerable variation in nutrient concentrations over space and time.
- Primary production, as measured by chlorophyll *a*, is higher in canals compared to natural streams but not particularly elevated compared to other open bodies of water such as ponds and lakes. A frequent concentration for chlorophyll *a* in canals is about 10 mg/m^3 (equivalent to 10 µg/L), which is well below the State of Florida's nutrient impairment threshold of 20 mg/m^3 for lakes. Based only upon chlorophyll *a* measurements, canal primary production does not appear to be sensitive to nutrient concentrations.
- Despite large uncertainty and lack of information, many District canals are currently listed as impaired and are included in the Florida Department of Environmental Protection's Total Maximum Daily Loads and Basin Management Action Plan process.

Natural systems are periodically disturbed through natural processes (i.e., droughts, fires, floods, hurricanes) and biological communities in a particular ecosystem reflect such disturbances over time. By contrast, canals are disturbed almost continually by human interventions for maintenance including herbicide application, mowing, dredging, removing obstructions, and mechanical harvesting. As artificial conveyances with large variations in flow, stage, and water turnover, canals provide less stable and predictable environments than other flowing waters. South Florida canals are part of a large water management system and must convey large volumes of water during storm events. (They do not have the floodplains that natural streams have to reduce the velocity of high flow events, and instead have levees that keep flows in the channel.) While water is retained in the drainage basins during major storms, canals are designed to move high flows accompanied with relatively high velocities. They are more susceptible to channel erosion and the delivery of larger volumes of water and contaminant loads downstream than natural streams and wetlands. At the other extreme, during droughts and dry season operations, canals may be stagnant for long periods and a small number may have little or no water.

Scientific studies (especially in ecology) of canals are a tiny fraction of those found for other South Florida ecosystems. The Everglades marsh numeric criterion for phosphorus was based on literally hundreds of scientific articles spanning more than a decade. Similarly, the Total Maximum Daily Load for Lake Okeechobee was supported by dozens of research publications quantifying algal dynamics in relation to nutrient levels. The limited information available on canal ecology provides some general concepts:

- Canals provide marginal/stressed habitat for many aquatic species in South Florida. Canals tend to have lower species diversity and richness than streams and those species that are present tend to be indicative of stressed or structurally unstable conditions, including many exotic and nuisance species such as hydrilla, cattails, and cichlid fishes.
- Canals contain a diverse community of macroinvertebrates (e.g., larval stages of insects), and the quality of macroinvertebrate assemblages is associated primarily with canal physical features including habitat quality (particularly channel banks and aquatic vegetation), adjacent land uses, and connectivity to wetlands. However, evidence suggests that canals would fail the Stream Condition Index used by the Florida Department of Environmental Protection for assessing impairment. The highly variable nutrients levels in canals show no apparent relationship to macroinvertebrates.
- Fish communities in canals are dominated by large predatory and exotic species. Canals provide a pathway for the spread of exotic species, provide refugia for many species during dry periods and thermal refugia for exotic species during cold events, and are a source for recolonizing wetlands when wet conditions return.
- Large alligators tend to live in canals, although survival of young alligators is greater in marshes. Also, alligators in canals tend to be isolated from marsh alligators.

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INTRODUCTION

This document provides a review, summary, and analysis of historical and scientific information related to the development, physical structure, uses, water quality, and ecology of primary canals within the South Florida Water Management District's (District or SFWMD) borders. The main report is written for a broad audience with extensive technical supporting documentation provided as appendices.

The primary water conveyance system in South Florida consists of the network of canals and associated features that are managed by the District and U.S. Army Corps of Engineers (shown in **Figure 1**) for regional flood protection, water supply, navigation, drainage, and environmental benefits.

The SFWMD has particular interest in the methods used to define how canals are designated and how the development and application of numeric water quality criteria, especially nutrient concentrations, will be developed and applied to the diversity of freshwater canal systems within its jurisdiction. The District has compiled and summarized information on its canal system to support these efforts. Emphasis has been placed on providing information concerning biological communities, physical parameters, water quality conditions, and nutrient concentrations that may be useful for setting criteria and designating appropriate use classifications.

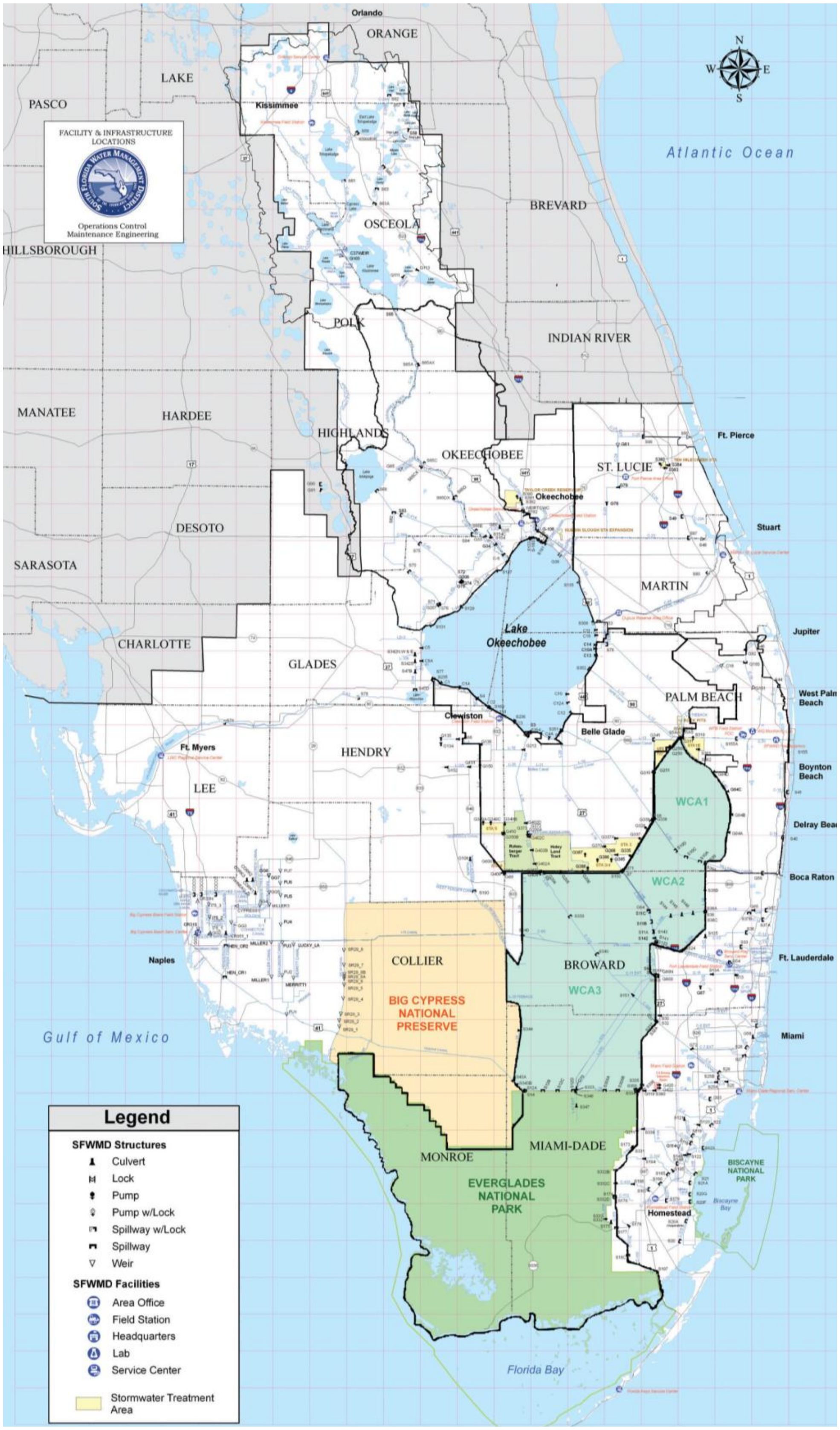

Figure 1. Primary SFWMD canals, structures, and major features of the hydrologic system.

1. THE SOUTH FLORIDA CANAL SYSTEM

The SFWMD region is divided into seven study areas for the purposes of this report:

- Upper Kissimmee
- Lower Kissimmee River/Lake Istokpoga
- Everglades Agricultural Area
- Water Conservation Areas and Everglades National Park
- Lower East Coast – Eastern Palm Beach, Broward, and Miami-Dade counties
- Upper East Coast – Martin, St. Lucie, and part of Okeechobee Counties
- Lower West Coast – Caloosahatchee River basin (Glades, Hendry, and Lee counties) and Big Cypress basin in Collier County

These areas are based on pragmatic divisions of canals by basin, water supply and water management. They may not be suitable for future water quality investigations to support rulemaking. Information about the canals within each of these areas is summarized and analyzed to characterize the canals' physical features, watersheds, water quality, and biological condition. The analysis focuses on information, especially biological communities and water quality criteria, that may be useful to develop general and specific descriptions of SFWMD canals, to support "Designated Use" classification of canals, and to support any associated rule development. In some cases, effects of these canals on adjacent or downstream water management areas, detention/retention areas, treatment areas, lakes, tributary creeks, rivers and streams, and estuaries are discussed. This study also identifies significant gaps in our understanding of canals that may require additional studies.

Some technical terms and concepts related to hydrology, ecology, and water quality are used, as well as abbreviations and designations for water management features (e.g., canals, levees, pumps, structures). A glossary of terms and a list of abbreviations are included in **Appendix A**.

Background on the Canal Report

The need to develop water quality criteria is based on requirements of the Clean Water Act, 33 U.S.C. § 1251, which provides the regulatory foundation for numerous water quality management activities in the United States. The SFWMD and a diverse group of stakeholders are participating in a rulemaking process initiated by the U.S. Environmental Protection Agency (USEPA) and the Florida Department of Environmental Protection (FDEP) to designate uses of water bodies and establish nutrient criteria for Florida waters, including canals.

The SFWMD will be directly affected by any actions that change designated uses or criteria in the water quality standards because the District has jurisdiction over, and management responsibilities for a wide variety and large number of water bodies in South Florida. These water bodies range from natural lakes, rivers, and wetlands to artificially managed reservoirs, retention and detention systems, treatment areas, and canals.

The FDEP plays a primary role in the rulemaking process through developing, monitoring, and enforcing surface water quality standards at the state level. The standards specify the designated and potential uses of water bodies and set scientifically established physical, chemical, and biological thresholds (criteria) to protect those uses. The standards also contain policies to protect high quality waters. Taken together these standards ensure that a water body is suitable for both human and aquatic life uses.

Classification and Designated Uses

Florida's surface water quality standards include a classification system to describe the uses of a water body including drinking water supply, shellfish harvesting, swimming and recreation, aquatic habitat for fish and wildlife, and agricultural uses. FDEP is presently considering a plan to update this 30-year-old classification system based on new information. FDEP also plans to improve surface water quality standards and develop more effective programs to protect and restore Florida's water resources. The new system will be more specific and based on scientific advances concerning water quality, hydrology, habitat availability, and the needs of people and biological resources. The expanded classification system will allow FDEP to better protect existing uses and enhance and restore uses currently not attained (FDEP 2009).

The primary designated uses for the SFWMD canal system, as described by the U.S. Army Corps of Engineers (USACE) and authorized by the U.S. Congress, were to provide water supply and flood protection for the people of South Florida (USACE and SFWMD 2010). However, within the current classification system, canals are considered Class III water bodies, which was the class assigned to surface waters in Florida that were not specifically placed in another class. Fla. Admin. Code R. 62-302.400.. A Class III water body is designated for recreation (i.e., swimmable, fishable) and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The daily operation of the canal system by the USACE and SFWMD attempts to balance the original intended function of the canals with the functions associated with their classification.

Change of Classification or Designated Use

Proposals are being reviewed that would refine the use classification system. All waters will retain their current designated use, and any future change of use for an individual water body will require separate rulemaking and additional approval from the state's Environmental Regulatory Commission and USEPA. If the designated use of a water body is not being attained, the cause of the impairment must be identified and corrected. The primary programs established to identify problems and restore water quality are Total Maximum Daily Loads and Basin Management Action Plans. Changes to the classification system will better align water quality requirements with appropriate ecological and human uses.

Designated use changes occur as a result of informative and compelling demonstrations provided by a Use Attainability Analysis. Such analyses may range from a scientific investigation to a more cursory review of physical characteristics of a water body, such as through the use of photographs (USEPA 2009). This document compiles and summarizes existing data and information on South Florida canals that could be used to support proposed changes to their designated use.

A number of factors or conditions may exist within a canal or surrounding areas that will prevent it from ever achieving a higher or better designated use than currently exists (USEPA 2009). These may include:

- Naturally occurring pollutant concentrations
- Natural, ephemeral, intermittent, or low flow conditions or water levels, unless these conditions may be compensated for by the discharge of sufficient volume of effluent without violating state water conservation requirements
- Human-caused conditions or sources of pollution cannot be remedied or would cause more environmental damage to correct than to leave in place
- Dams, diversions, or other types of hydrologic modifications, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use
- Physical conditions related to natural features of the water body, such as lack of a proper substrate, shade and cover, flow, depth, and the like, unrelated to water quality
- Controls more stringent than those required by sections 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact
- Canals intercept the water table, which is naturally low in dissolved oxygen and high in iron and sulfates

Historical Overview of the SFWMD Canal System

From its inception until about the 1970s, the South Florida canal system served four primary functions: drainage, navigation, flood control, and water supply. Ecological functions and recreational uses have developed as incidental benefits.

Origins

Construction of what is today the primary canal system in South Florida began about 1880 in the Kissimmee River Valley. In 1881, Hamilton Disston purchased four million acres of swampland from the state and initiated efforts to drain this land. He channelized the Kissimmee River during 1881 and 1882 to connect Lake Kissimmee with Lake Okeechobee and then proceeded to connect Lake Okeechobee westward to the Caloosahatchee River with the intent to create a navigable route to Fort Myers. Disston continued channelization of the upper Kissimmee lakes and constructed a number of the canals that connected the lakes together in what is today known as the Kissimmee Chain of Lakes.

The first canals were dug to drain swamps and marshes to promote cultivation and provide navigable links between agricultural communities in the interior of the state and markets in the coastal cities. These canals drained the land but the effects often did not extend far from the waterway and the initial system was overwhelmed by normal wet season rainfall. To be effective over a larger area, the central canals were eventually enlarged and extensive networks of smaller secondary and tertiary drainage systems were built. A timeline for these activities north of Lake Okeechobee is provided in **Appendix B**.

The second phase of early canal construction was conducted south of Lake Okeechobee in the Everglades. Although Hamilton Disston constructed a partial canal in the 1880s, serious dredging did not begin until the early 1900s and continued until 1949. A timeline of activities south of Lake Okeechobee is presented in **Appendix B**.

The inability to handle water effectively during wet periods led to a number of changes designed to provide flood control. They included redesign and enlargement of the canals, construction of additional canals to the south of the lake, and construction of the St. Lucie Canal to provide an outlet to the Atlantic Ocean. Completion of the St. Lucie Canal also provided a major navigational benefit. Many of these changes improved drainage, but did not prevent major damage and loss of life due to flooding during the 1926 and 1928 hurricanes. Following the hurricanes, the major focus of construction was to rebuild and enlarge the Lake Okeechobee dike.

By the 1930s, drainage through the canal system was having recognizable negative effects on the Everglades. Lower water tables allowed soils to oxidize and subside. The highly organic muck and peat soils dried out and caught fire, due either to human carelessness or lightning strikes. The muck burned both above and below ground, accelerating subsidence and destroying wildlife and plant communities. Accelerated drainage and increased water use resulted in a precipitous decline in groundwater levels near the coast and rapid and extensive intrusion of saltwater into the aquifer.

The final events that forced redesign and reconstruction of the South Florida canal system were the hurricanes of 1948. These storms resulted in massive flooding from the Kissimmee Valley to Miami. The following year, the Central and Southern Florida Flood Control Project (C&SF Project)(U.S. House of Representatives 1949) was created. The USACE was assigned the task of redesigning the water management system. The Central and Southern Florida Flood Control District was created by the State of Florida to act as local sponsor of the federal project.

The USACE reevaluated all aspects of the water management system and developed a comprehensive plan to upgrade existing facilities and add new features. Major emphasis was placed on improving navigation and flood control capacity in the Upper Kissimmee and Kissimmee River, enhancing navigation flood control and water supply capabilities of Lake Okeechobee, and improving flood control and water supply for the Everglades Agricultural Area and coastal cities of southeast Florida. A major feature of the 1949 plan was the creation of three Water Conservation Areas (WCAs) to provide storage capacity for flood waters, reservoirs to provide water during dry periods, and areas where natural wetlands and wildlife would be protected from development.

Environmental Resource Management

By the 1970s, criticism was building against the USACE and the Central and Southern Florida Flood Control District concerning adverse environmental effects of the C&SF Project. It was thought that these effects occurred because the C&SF Project goals had focused primarily on addressing flood control and water supply problems while environmental consequences were downplayed. Up until then, management of the system for environmental protection or enhancement was an afterthought. The following issues were major concerns:

- Destruction of the natural Kissimmee River channel and floodplain
- Water quality degradation, massive algal blooms, and destruction of the littoral zone in Lake Okeechobee
- Extreme salinity changes, sedimentation, and poor water quality in the Caloosahatchee and St. Lucie estuaries due to regulatory discharges

- Eutrophication and poor water quality in Lake Okeechobee due to channelization in the basin and backpumping from the Everglades Agricultural Area
- Damage to fish populations and deer herds in the WCAs
- Loss of tree islands and degradation of the ridge and slough landscape in the Everglades
- Inappropriate distribution of flows (i.e., too little during dry periods, too much during wet periods) and poor water quality delivered to Everglades National Park
- Seagrass die-offs and algal blooms in Florida Bay

The Florida legislature responded with the 1972 Water Resources Act, which renamed the Central and Southern Florida Flood Control District to the South Florida Water Management District, spelled out environmental management responsibilities for the agency, and formally established the Florida Department of Environmental Regulation (now the FDEP) as the agency with authority to oversee SFWMD management of environmental aspects of the C&SF Project. Chapter 373, Fla. Stat. (2009).

Features and Functions of South Florida Canals

Canals in South Florida: A Practical Definition

In Florida state statutes, a canal is defined as “a man-made trench, the bottom of which is normally covered by water with the upper edges of its sides normally above water.” 403.803(2), Fla. Stat. However, this definition is not functionally descriptive for the diverse system of canals in South Florida. The following definition of canals in South Florida is consistent with other common definitions2 and is more complete and useful for the purposes of this technical support document:

A canal within the South Florida Water Management District is a man-made waterway dug as an open trapezoidal channel for navigation or conveyance of water. Canals in South Florida are designed to provide flood control, drainage, navigation, and water supply for agriculture, human consumption, or the environment; canals can provide coincidental ecological, aesthetic, and recreational values. Some regional canals have been created where no water course existed before, while many others have been created by channelizing and connecting natural streams, rivers or wetlands.

SFWMD Canals as Water Bodies

More than 1800 miles of such canals currently exist as part of the SFWMD primary water management system. Canals serve an especially important role because they provide the primary means by which water is moved in southern Florida. Without the canals, and their associated pumps and control structures, water could not be effectively managed in the region and the modern landscape of agricultural and urban development would not exist.

[2] See the definitions of “canal” at Your Dictionary.com (http://www.yourdictionary.com/canal) and Merriam-Webster.com (http://www.merriam-webster.com/dictionary/canal).

Much of the South Florida canal system originated as a legacy of channels constructed between 1880 and 1950 by various interests and for various purposes. As a result, there were not uniform specifications. Beginning with the initiation of the C&SF Project in the 1950s, responsibility for this network was adopted by USACE and the predecessor of the SFWMD. The design, flow capacity, and associated structures and pumps of these canals have been extensively modified or redesigned to meet modern engineering standards. These changes were based on a qualitative and quantitative assessment of the present and anticipated future needs for water supply and flood control within their drainage basins.

Canals are substantially different from most natural water bodies. Various features of their design, construction, operation, and maintenance make them marginal habitats for most aquatic life. Water levels and flow rates are subject to extreme fluctuations; depending on operational needs, water may flow through a canal as if in a stream or sit as if in a reservoir. The sides of canals are generally very steep and do not feature shallow areas that would support fish or aquatic plant communities. Unlike natural river or stream systems, canals typically lack mature vegetation communities (e.g., trees and shrubs) that stabilize channel banks, provide a diversity of aquatic habitats, and shade the channel to reduce primary production and minimize swings in dissolved oxygen, temperature, and pH. In general, the lack of suitable water depths, areas, flow regimes, or substrate in canals prevents development of stable littoral, shoreline, and benthic communities.

The surface water that enters canals often consists of runoff from urban and agricultural lands. It may contain chemical fertilizers, pesticides, and other pollutants. The runoff also may carry large amounts of suspended solids and is often highly colored from the presence of organic materials. For this reason, light penetration is very low, which further inhibits growth of aquatic plants and contributes to low oxygen concentrations.

Many of the canals are deep enough to penetrate the surficial aquifer, which contributes to elevated nutrient and dissolved ion concentrations and low concentrations of dissolved oxygen in the canal. Groundwater can also introduce contaminants from septic tanks and landfills. Many of the aquifers in South Florida contain extremely high natural iron concentrations and surface water bodies are often listed as impaired for iron. As iron oxidizes in the surface water body, physical (increased color and turbidity) and chemical (decreased dissolved oxygen) processes can further degrade water quality (Alleman et al. 1995, Brown 2003).

Despite the physical drawbacks, canals can provide incidental habitat for a wide variety of plants and animals. Many organisms migrate into canals and become established over time. Canals are often conducive to exotic species that may be better suited for such a habitat if it is more like their natural environment or lacks predators.

Types and Uses of Canals

The primary canal system in South Florida consists of channels and associated features that are managed by the SFWMD and USACE. Secondary systems consist of canals and features that are managed by designated drainage districts or private entities, which may discharge to the coast or receiving lakes, or into the primary system. Such secondary systems operate under permits issued by the SFWMD. Tertiary systems consist of canals and features generally located on private lands that provide localized drainage, such as for farms or residential developments, and discharge into retention/detention areas or into secondary systems. Such systems generally operate and are regulated under a permit issued by the SFWMD.

The South Florida canal system is now managed for a much wider array of objectives than what was originally intended. Uses of canals are summarized as follows:

- Provide routes for waterborne transportation
- Provide conveyance
  - Drain surface water and groundwater over time to transform wetlands into dry land suitable for human use
  - Remove surface runoff rapidly from critical areas to minimize or avoid loss of life or damage to crops or human structures
  - Move excess water to tide
  - Move water for human consumption or irrigation
  - Move water to maintain appropriate flows in rivers and streams and maintain salinity conditions in estuaries
- Regulate water levels
  - Move water seasonally or prior to a storm event to lower surface and groundwater levels and enhance local basin storage
  - Move water to maintain water levels below ground to enhance seepage and crop production
  - Move water to maintain groundwater levels that recharge wellfields and protect aquifers from saltwater intrusion
  - Move water to maintain appropriate water levels in lakes or wetlands
- Storage
  - Provide means to enhance local storage in groundwater or surface reservoirs
  - Provide means to move water into and out of regional storage areas
- Control seepage
  - Enhance storage capabilities in reservoirs and conservation areas
  - Protect adjacent areas from flooding
- Support ecological systems
  - Maintain appropriate water levels to minimize excessive drying or flooding
  - Provide deep water habitat as refuge during droughts
  - Limit the amount of exchange between contaminated or polluted water being conveyed and less contaminated or uncontaminated water in the adjacent wetlands

Besides being built for their obvious benefits and primary uses, canals have also been created as artifacts of the construction of levees or roadways. Such “borrow canals” represent the area where dirt and rock were removed to construct the levee or roadway. These channels may subsequently become major conduits within a basin for drainage, flood control, water supply, or conveyance.

Canals themselves also provide some limited environmental benefits. In some instances, canals within shallow wetlands provide areas where larger fish and alligators prefer to live, and where fish and wildlife can congregate during droughts. Without the canals, these animals may not move into these areas. The associated levees and roadways provide upland areas where wildlife can find dry land during floods. Levees and canals also facilitate public access to remote areas for fishing, hunting, wildlife viewing, and other forms of recreation. Canals throughout the District are also used extensively for recreational fishing (Florida Fish and Wildlife Conservation Commission 2009).

In addition to their beneficial uses, canals may have harmful consequences. Canals receive runoff from adjacent lands and roadways that may create water quality problems in the canals themselves, adjacent wetlands, or the underlying aquifer system. They may also intercept or divert overland flow, affecting hydrologic conditions and vegetation patterns. Canals also provide conduits for transport of nutrients and pollutants over long distances and facilitate the dispersal of exotic aquatic plants and animals. Over long periods, canals can result in chronic overdrainage and soil subsidence, especially in areas such as the Everglades Agricultural Area and the Everglades that have muck soils with high concentrations of organic material that become oxidized.

Design and Construction of Canals

Canals throughout the SFWMD vary greatly. The overall width and depth of the canal is determined by the amount of water that needs to be conveyed, the change in topography over the length of the canal, the size and nature of water control structures, and local recreational needs. The design of the side slopes considers local substrate, water velocities, and operational discharges to prevent failure of the canal banks. In very solid substrate materials, where water velocities are relatively low and there is little wave action, the sides may be quite steep. In sandy soils or areas with higher water velocities and/or wave action from boats, the banks of the canal may have a shallower slope. **Figure 2a** shows some examples of the design characteristics of typical SFWMD canals. As shown in **Figure 2b**, the design may differ within a canal, depending on the needs and circumstances in different sections.

In some instances, the sides of canals may be specially designed. Large reaches of the perimeter canals in WCA-1 and bisecting canals in WCA-2 and WCA-3 directly interact with the adjacent marsh. This interaction can influence wildlife and recreational usage among other things.

The canal construction process depends on local conditions. Typically a drag line is used to dig the basic structure of the canal. This method is suitable for sandy or rocky soils. In soft soil or muck, a floating dredge may be used to pump sand or mud to a confined disposal area for dewatering. In cases where the underlying material is hard rock, blasting may be required to create small enough pieces to remove with a dragline.

The removed substrate (spoil) is typically placed on the canal banks with a dragline and then bulldozers shape, level, and compact the material to provide a stable surface to allow vehicle traffic on top or along the side for maintenance or public access. If there is a need for the spoil elsewhere, it may be removed. If creation of an embankment may cause drainage or other problems, the spoil may be spread over adjacent land.

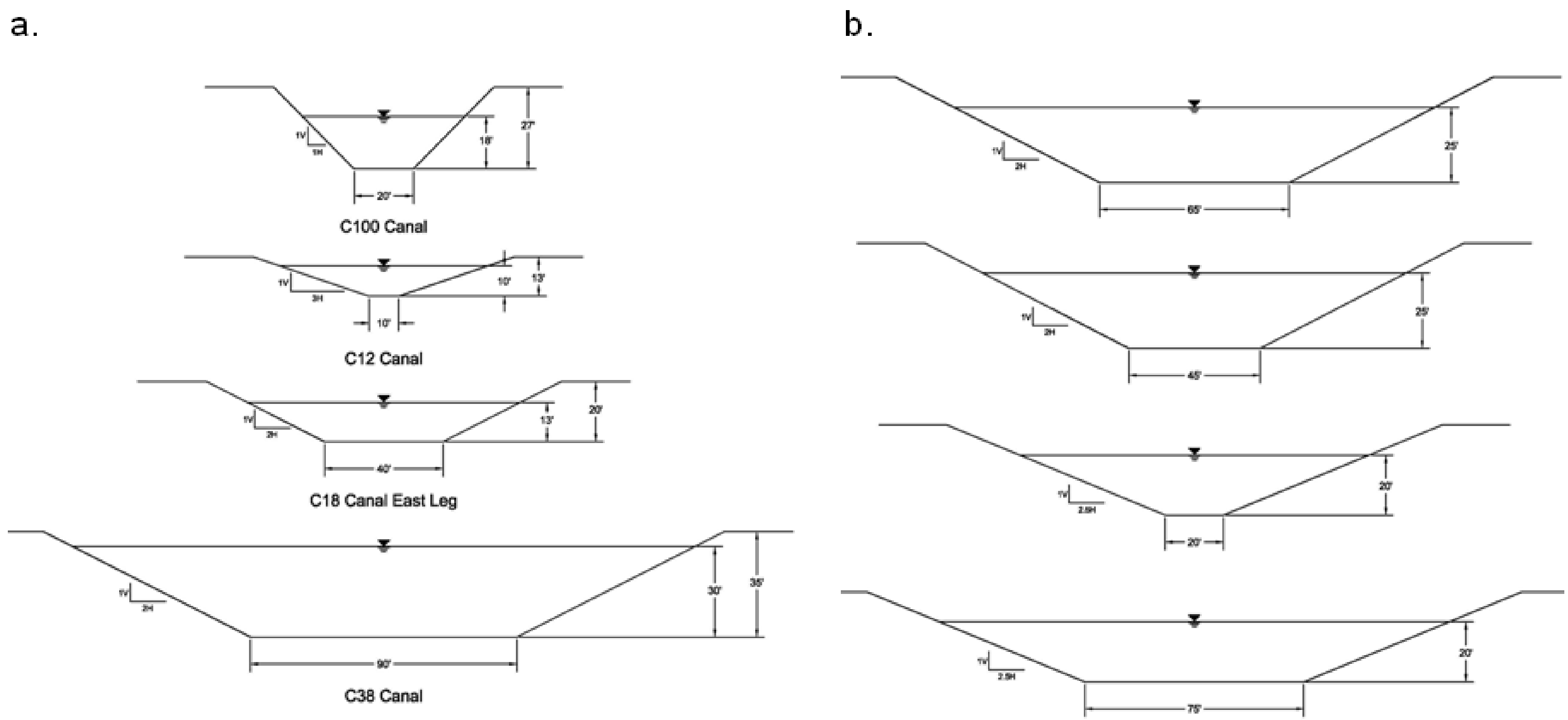

Figure 2. Cross-sections of representative canals within **(a)** Miami-Dade (C-100), Broward (C-12) and Palm Beach (C-18) counties and Kissimmee River Channel (C-38) and **(b)** selected locations within the West Palm Beach Canal (C-51).

Operation of Canals

The primary water management system operated by the SFWMD (not including the Naples/Big Cypress area, which is managed separately from the rest of the District) consists of more than 140 named canals or canal segments. These canals and canal segments are used for flood control, water supply, irrigation, environmental restoration, navigation, or a combination of these. All canal segments either contain a water control structure within them or are directly influenced by the operation of an upstream or downstream control structure. As such, water levels in all canal segments are effectively controlled through the operation of water control structures. Most control structures, along with the upstream and downstream water levels, are monitored electronically on a continuous basis.

Each control structure is operated according to normal operational criteria or based on a normal lake or water conservation area regulation schedule. During unusual meteorological conditions such as droughts or water shortages, it may not be possible to maintain water levels in the canals as stated in the operational criteria or lake regulation schedules. In anticipation of large storm events, water levels may be lowered preemptively to increase storage and reduce the risk to human health and property from flooding.

The continuous monitoring and operation of the water management system is complicated by the various competing interests for the water, and is further complicated by the physical limitations of the canals and water control structures. Some of these include, but are not limited to, the following:

- Agricultural water demands
- Recharge of groundwater
- Prevention of saltwater intrusion
- Water supply for utilities
- Water supply for environmental purposes
- Maintaining water level regulation schedules for various lakes
- Maintaining water levels for navigation
- Legal obligations (e.g., Everglades water quality requirements)
- Water reservations
- Local and regional flood control
- Drought and water shortage operations
- Maintenance of the canals and water control structures
- Design and/or operational limitations of the canals and water control structures
- Instrumentation and/or mechanical failures at water control structures

Maintenance Requirements

The South Florida primary canal network, being an entirely engineered system, requires considerable effort to maintain its function. Structures have to be opened, closed, and maintained. Pumps have to be placed in operation, fueled, maintained, shut off when not needed, and replaced when they become obsolete or worn out. Canals have to be cleaned of plants, debris, and sediments, and erosion needs to be controlled or repaired. These activities are performed routinely throughout the year and often continuously during peak performance periods or emergencies. Canal right-of-ways need to be maintained to ensure access, protect stability of the banks, and allow maximum flow of water through canals during storm events.

Canal maintenance activities are summarized as follows:

- **Herbicide applications** using ground, water, or aerial applications for the treatment of exotic vegetation within its boundaries. Targeted vegetation includes aquatic, terrestrial, and wetland species.
- **Aquatic mechanical harvesting** removes excessive and obstructive aquatic vegetation from District water bodies. Similar equipment is often used to remove floating debris from urban canals.
- **Tree management and removal** from canals, levees, and right-of-ways is essential to ensure water conveyance and equipment access to District canals. Types of trees targeted for removal include dead, dying, leaning, unhealthy, invasive/exotic species, or those that fall within the District canals' right-of-way.
- **Weed barrier cleaning** is necessary on a regular basis to remove trash, weeds, and debris so the canal can convey design water flows.
- **Grading levee berms and roads** to maintain a reasonably smooth and drivable surface.
- **Boat ramp installation and maintenance** is necessary to provide access for District boats and water-based equipment launched into canals.
- **Erosion repairs** are needed due to wave action, pump station or structure discharges, secondary discharges, surface water flows, and animal burrows.
- **Berm culverts** are installed on canal right-of-ways, access roads, and maintenance berms to divert water from swales and to prevent canal bank erosion.
- **Flat mowing** helps to delineate the District right-of-way and to keep the area free from undesirable vegetation.
- **Side slope mowing** keeps canal banks free from unwanted vegetation and provides staff with the ability to perform visual inspections of side slopes to find undermining and erosion.
- **Shoal removal** is performed when sediment accumulates within the canal and reduces the ability to convey design water flows.

Description of Primary Water Management Features by Region

The following sections provide an overview of the primary water management system within the SFWMD. For the purposes of this document, the District is divided into seven study regions, based primarily on hydrology. Each region has a distinct history, operational constraints, soil, land use, and topographic conditions that affect canals. Information about the canals within each area has been compiled, summarized, and analyzed in an attempt to characterize the unique features of each of these water regions. Water quality and biological conditions in canals within each region are presented and summarized in subsequent parts of this report. More detailed consideration of individual canals, basins, sub-basins, and water control features is provided in **Appendix C**.

Upper Kissimmee River Watershed

<u>Introduction</u>

The Upper Kissimmee River watershed covers an area of 1596 square miles in Osceola, Polk, Orange, and Lake counties. The SFWMD and USACE have authority over the primary water management system. Several local drainage districts have local water management responsibilities within this area. The watershed includes 18 major sub-basins, 15 SFWMD primary canals, and 9 structures. Of the sub-basins, six (Boggy Creek, Shingle Creek, Reedy Creek, Horse Creek, Lake Pierce, and Lake Weohyakapka) do not have any SFWMD canals or structures.

Much of this watershed consists of open water (lakes, rivers, and canals) and wetlands. The remaining uplands are primarily used for agricultural crops and pasture. Urban areas include Kissimmee and St. Cloud. Kissimmee in the Lake Tohopekaliga basin is the hub of the cattle industry in Central Florida. St. Cloud is in the East Lake Tohopekaliga basin, just south of East Lake Tohopekaliga.

Many of the lakes in this region are connected by depressional features and wetlands. Historical records confirm that before canals were dug, much of this area flooded frequently and was not suitable for habitation or agricultural use. The original canals connecting the lakes in this region were constructed through low-lying depressions, wetlands, and hydric soils. Canal construction in the Upper Kissimmee River watershed lowered water levels considerably and made the adjacent lands suitable for development.

Lakes are important features of the Upper Kissimmee River watershed. The major lakes have been linked by canals to form a chain. Depending on local conditions, water may flow south from one lake to another following a storm event or during periods of high water use. During other periods, water may flow from south to north as conditions change. Thus water may flow either north from Alligator Lake to Lake Mary Jane or south from Alligator Lake to Lake Gentry. The western chain begins with Lake Hart, continues through Ajay Lake, East Lake Tohopekaliga and Lake Tohopekaliga, and discharges into Cypress Lake. From Cypress Lake the chain continues with Lake Hatchineha and finally, Lake Kissimmee. All major lakes in this basin are shallow; mean depths vary from 6 to 13 feet. Lake water surface elevations vary with topography of the area, ranging from 65 feet in Alligator Lake to 52 feet in Lake Kissimmee (see **Appendix C**).

The primary canals and water control structures allow management and diversion of water within this network to support navigation and to enhance irrigation, water supply, and flood control capabilities in response to local conditions. Since 1971, extreme drawdowns have been used in Lake Tohopekaliga, East Lake Tohopekaliga, and Lake Kissimmee to improve aquatic habitat, water quality, and biological resources. Such reductions in water levels can only occur because of the canal system that allows diversion of surface water flows.

The surface water management basins of the Upper Kissimmee River watershed were first delineated in the mid-1950s by the USACE in their General Design Memoranda for the C&SF Project. The canals and control structures were further modified based on a series of Detailed Design Memoranda, primarily for flood control. Most of the hydraulic works constructed under the C&SF Project are now managed by the SFWMD. Their use has since evolved to meet demands caused by population growth, land use development, and increased water use.

The Primary Water Management System – Canals, Structures and Operations

The primary canal system in the Upper Kissimmee River Watershed consists of a network of 15 canals that range from 0.2 to 4.5 miles in length with a total length of 31.1 miles (see **Appendix C**). The canals generally link one lake to another. The drainage area for each canal ranges from 21 to 60 square miles. Water levels, flows, or both in eight of these canals are controlled by water management structures. Two of the structures (S-61 and S-65) include navigational locks.

Water levels in seven of the eight canals with water control structures are also constrained by regulation schedules in one or both of the connected lakes. Operation of the canals and structures are based both on local and regional water levels and weather conditions. When water levels are above prescribed elevations, flood operation protocols and criteria are followed; low-water or drought management operations are followed if water levels fall below prescribed depths. Operations also depend on hydraulic and physical limitations of the structures. Additional details concerning the canals, structures, and operational procedures are provided in **Appendix C**.

Lower Kissimmee – Kissimmee River and Lake Istokpoga

Introduction

The Lower Kissimmee River basin covers 727 square miles from Lake Kissimmee to Lake Okeechobee, and includes 20 basins in parts of Osceola, Polk, Highlands, Okeechobee, and Glades counties. These basins were first delineated in the 1950s by the USACE in their General Design Memorandum for the C&SF Project. Discharge from all of these basins eventually reaches Lake Okeechobee. The basin boundaries of the Lower Kissimmee River and Lake Istokpoga areas, canals, levees, and control structures relative to roads, local landmarks, and county lines are shown in **Figure 3**.

Nutrient concentrations in the Kissimmee River increase downstream due, in part, to increased agricultural activity in the lower basins. Best Management Practices are being implemented to various degrees to reduce nutrient loads from agriculture.

The vegetation in the Lower Kissimmee River basins changes with surface water depth, elevation, type of soil, and extent of agricultural activity. The terrestrial forested areas are covered with oak, cabbage palm, wax myrtle, and woody shrub. The wetland forests contain willows, hardwood, and cypress. The marshy areas are covered with maidencane, aquatic grasses, buttonbush, switchgrass, sawgrass, and various other plants.

The Lower Kissimmee-Lake Istokpoga area is not significantly developed. Land use patterns reflect large areas of open land, rangeland, and agricultural use. The agricultural land consists of intensively managed beef pasture, semi-improved beef pasture, improved dairy pasture, and citrus groves. Winter truck crops and ornamental plant production are also important to the area.

Soils generally consist of high permeability sands. Along the floodplain of the Kissimmee River, the soil type is sand and shell overlain by a variable layer of muck, peat, and unrecompensed organic matter. The general soil classifications within the watershed indicate the relative extent of hydric and poorly drained soils. Much of the area is prone to flooding and most of the canals were constructed in these types of soils, which contributes to their construction and management characteristics.

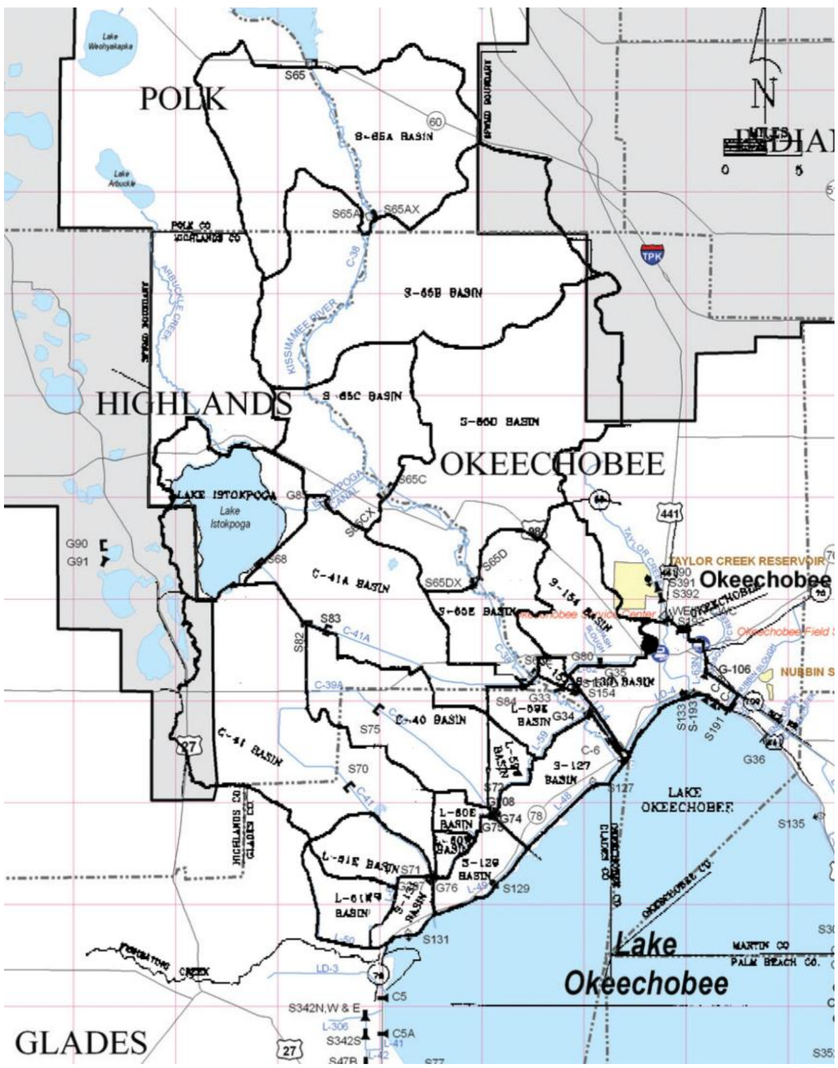

Figure 3. Sub-basins and general features of the Lower Kissimmee River and Lake Istokpoga.

The Primary Water Management System

Canals, Structures and Operations

The primary water management system in the Lower Kissimmee River/Lake Istokpoga Basin consists of 11 canals and 40 water control structures. District canals and structures play an important role in distributing water as needed to protect adjacent land uses, natural areas, and biological communities in the river and lake. Additional details concerning the canals and their operations are provided in **Appendix C**.

The C-38 Canal is the channel that was constructed by the USACE through the Kissimmee River floodplain. This canal ranges from 90 to 340 feet wide and from 18 to 24 feet deep. Water levels and flows in portions of the C-38 Canal are currently managed as part of the Kissimmee River restoration. Sections of the canal have been filled, the S-65B locks and associated water control structures were removed, and flow restored to oxbows. The primary canals (C-40, C-41, and C-41A) and structures south of Lake Istokpoga provide drainage and flood control to adjacent lands, convey excess flood waters from the Lake Istokpoga into regional storage in Lake Okeechobee, and distribute water from the lakes to agricultural lands during drought. These four primary canals and eight additional smaller canals and levee borrow canals (C-39A, L-48, L-49, L-59, L-60, L-61, L-62, and L-63) comprise the primary water conveyance channels in the Lower Kissimmee River basin. Most of these canals were designed for water conveyance purposes. The various borrow canals were built in conjunction with construction of basin divide levees and to help remove runoff and floodwaters from basin lands

The C-38 Canal extends 69 miles from Lake Kissimmee to Lake Okeechobee and consists of five sub-basins. Four other basins (C-41A, L-59E, S-154, and S-154C) discharge into the section of the C-38 Canal located between S-65E and Lake Okeechobee. Two of the primary canals south of Lake Istokpoga (C-40 and C-41) ultimately discharge to Lake Okeechobee. Four basins (L-59W, L-60E, L-60W, and L-61E) discharge into these canals. The remaining sub-basins in this area discharge directly to Lake Okeechobee.

Kissimmee River Restoration Efforts

The Kissimmee River once meandered for 103 miles through Central Florida. Its floodplain, reaching up to 3 miles wide, was inundated for long periods by heavy seasonal rains. Wetland plants, wading birds, and fish thrived there. Prolonged flooding affected the local population, which led to engineering changes to deepen, straighten, and widen the waterway. In the 1960s, the Kissimmee River was cut and dredged to create the C-38 Canal. Before channelization was complete, biologists suspected the project would have devastating ecological consequences. While the project provided flood protection, it also destroyed a floodplain-dependent ecosystem that nurtured threatened and endangered species, as well as hundreds of other animals.

Channelization of the Kissimmee River dramatically altered the system’s hydrology and resulted in drainage or obliteration of almost 35,000 acres of floodplain wetlands, elimination of in-stream and overbank flow, and isolation of the river from its floodplain (Koebel 1995). These hydrologic alterations propagated changes in physical, chemical, and biological aspects of the ecosystem, reduced diversity, and diminished biotic integrity (Dahm et al. 1995). Reduced dissolved oxygen levels, increased biological oxygen demand, and subsequent restructuring of the food web contributed to these declines. These changes led to decreased fish density within the river channel and restricted use of floodplain habitats by small-bodied forage fishes.

The effort to return flow to 43 miles of the Kissimmee River's historic channel and restore about 40 square miles of river/floodplain ecosystem began in 1999. After extensive planning, restoration began with backfilling 7.5 miles of the C-38 Canal and removal of the S-65B structure. Three construction phases are now complete and continuous water flow was reestablished to 27 miles of the meandering Kissimmee River. Seasonal rains and flows now inundate the floodplain in the restored area.

Since restoration began, the river and its floodplain have improved in remarkable ways, surpassing at times the anticipated environmental response. Comprehensive monitoring for the past 10 years has documented the following improvements relative to pre-restoration conditions:

- The aquatic wading bird population in the restored river and floodplain region is more than five times greater. The number of aquatic wading birds, including white ibis, great egret, snowy egret, and little blue heron, has increased significantly; in some years they are more than double the restoration target.
- Duck species including fulvous whistling duck, northern pintail, northern shoveler, American wigeon, and ring-necked duck have returned to the floodplain.
- Several shorebird species including American avocet, black-necked stilt, dowitcher, greater yellowlegs, semipalmated plover, least sandpiper, spotted sandpiper, and western sandpiper have returned to the river and floodplain.
- Organic deposits on the river bottom decreased by 71 percent, reestablishing sand bars and providing new habitat for shorebirds and invertebrates, including native clams.
- Dissolved oxygen levels have increased to a range normally observed in minimally impacted Florida streams.
- Largemouth bass and sunfishes now comprise 64 percent of the fish community, up from 38 percent.

Everglades Agricultural Area

<u>Introduction</u>

The Everglades Agricultural Area comprises those lands south and southeast of Lake Okeechobee in Palm Beach, Martin, Hendry, and Glades counties. These lands were originally part of the natural Everglades system, but were deemed well-suited for agricultural use. The area was drained and used for agricultural production beginning in the early 1900s.

The primary water management system in the Everglades Agricultural Area consists of a network of levees, canals, and water control structures. The canals were originally constructed to provide drainage and to transport agricultural products to urban markets. Later, they were enlarged and pumps and structures added to enhance water supply deliveries to agricultural and urban areas during dry periods and provide additional drainage and flood protection during wet periods. Coastal structures were added and water levels were raised to control soil subsidence and saltwater intrusion. Most recently, canals in the area are used to convey stormwater flows into and out of the Stormwater Treatment Areas for treatment prior to delivery to the WCAs.

Nine water management basins within the Everglades Agricultural Area have a combined area of 1181 square miles and are served by 15 primary canals and 25 water control structures (**Figure 4**). The L-8, S-4, and S-236 basins are not strictly part of the Everglades Agricultural Area legal boundary, but are presently included because they are closely tied to the agricultural area, Lake Okeechobee, or the WCAs by hydrology and water management. In general they are used to discharge excess water from the basins during flooding and to maintain minimum water levels in the canals during periods of low natural flow.

Extensive networks of secondary and tertiary canal systems are operated by landowners within the Everglades Agricultural Area that periodically remove water from, and discharge to, the primary water canals. Although these systems operate under permits from the SFWMD, they are largely managed to meet the needs of individual farms and crops. These activities by private interests can have significant impacts on the overall timing and volume of flow through and water levels within the canal system at any given time.

Soils

Most soils in the Everglades Agricultural Area are muck or peat with a high content of organic material. Flatwoods soils are used for sugarcane and citrus production and cattle ranching. The L-8 basin contains depressional muck, sand, and peat intermixed with sandy soils. The watershed largely consists of public lands that are protected in preserves and wildlife management areas.

The bedrock underlying the area has very low permeability and transmissivity, so there is less exchange with the surficial aquifer than occurs in other parts of the District. The shallow aquifer is not used as a significant source of irrigation water due to generally low yields and the presence of connate (trapped) seawater in many areas. Crops are irrigated with water taken directly from the canals and excess water from the fields flows or is pumped back into the canals. Water in the Everglades Agricultural Area canals is dark due to the presence of tannins from the organic soils, has high levels of organic materials, and occasionally has low concentrations of dissolved oxygen. Nitrogen concentrations in the canals can be elevated due to decomposition of organic material in soil. Phosphorus concentrations, as well as those of pesticides and metals, may become elevated due to discharge from Lake Okeechobee and runoff from agricultural activities in the watershed (Bottcher and Izuno 1992).

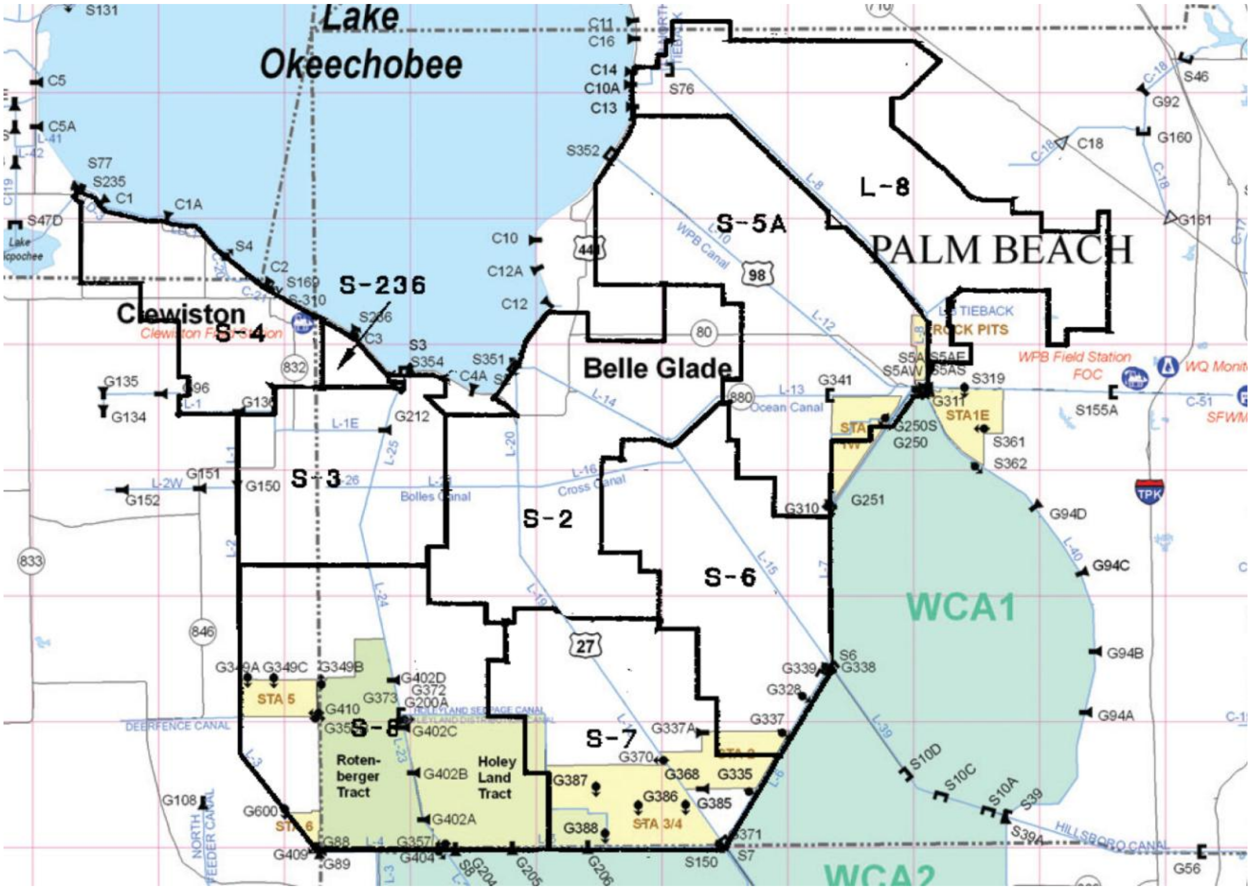

Figure 4. Everglades Agricultural Area drainage basins.

Canal Design

The original canals and water control structures in the basins were designed for flood control and water supply. Water supply in the region was intended for irrigation and to maintain water levels in the basin as high as possible to minimize soil subsidence and oxidation.

Lake Okeechobee Regulatory Releases

Although lake water level regulation was not a factor in the original design, it was anticipated that regulatory releases could be as large as the capacity of the downstream receiving canals in the Everglades Agricultural Area. The levees and discharge structures for Lake Okeechobee were designed assuming releases would be made by way of the St. Lucie Canal, Caloosahatchee River, and the four primary canal outlets through the agricultural area during a major storm event, in accordance with the Lake Okeechobee regulation schedule. Although the St. Lucie Canal and the Caloosahatchee River can pass the largest discharges by the USACE, they are not the preferred outlets since these releases are lost to the ocean and can damage downstream estuaries. To the maximum extent possible, regulatory releases are made south to the agricultural canals and stored in the WCAs. This affords additional opportunity for using the water and reduces the amount of fresh water that enters the estuaries of the Caloosahatchee and St. Lucie rivers. When large quantities of water must be discharged, however, the Caloosahatchee and St. Lucie rivers must be utilized.

S-2, S-3, S-5A, S-6, S-7 and S-8 Basin Boundaries

The primary canals and water control structures in the Everglades Agricultural Area have four functions: (1) remove excess water from the basin to storage in Lake Okeechobee or the WCAs, (2) prevent overdrainage of their respective basins, (3) supply water from Lake Okeechobee to downstream basins as needed for irrigation, and (4) provide conveyance for regulatory releases from Lake Okeechobee to the WCAs or to eastern Palm Beach, Broward and Miami-Dade counties and Everglades National Park.

Holey Land Wetland Restoration

A wetlands restoration project is currently under way in the Holey Land area in the southeastern quarter of the S-8 basin (see **Figure 4**). The Holey Land is a 35,336-acre impoundment that was used was used as a bombing range during World War II and the Korean War, hence the name "Holey." While no physical evidence remains of this disturbance, the area was degraded by decades (1940s to 1980s) of overdrainage and invasion by upland plant species, oxidation and the resulting subsidence of organic peat soils, and muck fires that caused localized areas of even lower elevation.

The Florida Fish and Wildlife Conservation Commission is primarily responsible for managing the flora and fauna of the area and works closely with the District, whose responsibilities include overall hydrological operations, and construction and maintenance of inflow and outflow structures. The goal for management of the Holey Land is to promote historical vegetation communities. Important components of this goal are to create conditions that support the functional integrity of tree islands, maintain or reduce extent of cattail coverage, increase potential for wading bird, snail kite and alligator usage, and maintain the terrestrial wildlife populations near or at high-water carrying capacity.

Levees were constructed around the northern perimeter of the Holey Land to isolate the area hydrologically from the surrounding basins. Water from the Miami Canal can be pumped into the Holey Land at its northwestern corner and distributed along the north perimeter by a spreader canal. Water moves south by sheet flow and is discharged to WCA-3A by way of three gaps cut in L-5.

Primary Canals

The primary canals that convey water from Lake Okeechobee south and east to coastal basins are the L-8, West Palm Beach, Hillsboro, North New River, and Miami canals (**Figure 4**, **Appendix C**). Water enters these canals from Lake Okeechobee at the north end. In the EAA basin these canals are primarily bordered by agricultural lands. When the water leaves the EAA, it is first treated in the Stormwater Treatment Areas to reduce phosphorus levels, and then passes into the WCAs where the canals are bordered by and interact with adjacent natural wetlands.

Other major canals in the Everglades Agricultural Area provide cross-connections between the primary canals or consist of borrow canals associated with the levees that surround the WCAs and Lake Okeechobee. Additional information concerning canals and structures of the water management system within the Everglades Agricultural Area is provided in **Appendix C**.

Water Conservation Areas and Everglades National Park

Introduction

The Everglades includes six basins: five Water Conservation Areas (WCA-1, WCA-2A, WCA-2B, WCA-3A, and WCA-3B) and Everglades National Park (**Figure 5**). The basins have a combined area of 3060 square miles and are served by 18 levees, 5 primary canals, and 60 water control structures. The canals and water control structures in each basin are described and are discussed with regard to their operation and management in **Appendix C**.

The land use consists mostly of natural landscapes including a predominance of wetlands with a few isolated upland areas of hammocks, tree islands, and pine flatwoods. Although the soils of these areas have not been surveyed, they consist primarily of hydric peats, mucks, marls, and sands with occasional rock outcroppings.

The WCAs were designed to provide viable wetland habitat, to receive excess water from the Everglades Agricultural Area, to receive regulatory releases from Lake Okeechobee, to prevent water accumulating in the Everglades from flooding urban and agricultural lands in eastern coastal areas, to recharge regional groundwater, and to store water for dry season deliveries to eastern Miami-Dade, Broward and Palm Beach counties. The WCAs are impounded by levees, with inflows and outflows regulated by control structures. The Everglades National Park basin is a natural basin set aside to preserve portions of the original Everglades. Surface water flows into the park are through District canals and structures.

Canals and structures in the Everglades provide the means by which water is conveyed from one place to another for purposes of flood control, drainage, agricultural and municipal water supply, and regulatory releases from Lake Okeechobee. In general, the canals and structures are used to discharge excess water from the WCAs during flooding and to maintain minimum water levels during dry periods. Some structures are used to supply water from one WCA to another, or to neighboring basins in Palm Beach, Broward, and Miami-Dade counties.

Lake Okeechobee Regulatory Discharges

The WCAs are the preferred receiving bodies for regulatory releases from Lake Okeechobee by way of the primary canals that pass through the Everglades Agricultural Area – the Miami Canal and North New River Canal, after first passing through Stormwater Treatment Area 3/4 for treatment. However, during a major storm event, the USACE discharges water through structures they operate, primarily to the Caloosahatchee River (C-43) and the St. Lucie Canal (C-44). This is a result of localized drainage entering the Everglades Agricultural Area canals and reducing their ability to receive regulatory discharges from the lake. These factors can combine to make regulatory releases by way of the North New River and Miami canals rare events.

Everglades Agricultural Area Discharges

The original drainage design for the Everglades Agricultural Area called for moving excess water to both Lake Okeechobee and the WCAs. Because of environmental problems in the lake resulting from inflows of nutrient-rich water, the current SFWMD water management plan for the agricultural area discourages discharge of water to Lake Okeechobee. Consequently, almost all water pumped from the Everglades Agricultural Area passes through a Stormwater Treatment Area for phosphorus removal before discharge to the WCAs.

Canals

The primary water management system in the Everglades National Park and WCA area includes four primary canals that deliver water from Lake Okeechobee south and east toward the coast – West Palm Beach, Hillsboro, North New River, and Miami canals - and numerous smaller canals (see **Appendix C**). Primary canals provide outlets for excess water from Lake Okeechobee when the lake is above its regulation schedule. They also deliver water from the lake during dry periods to maintain water levels in the WCAs and to meet water supply needs in the Everglades Agricultural Area and coastal basins. The remaining primary canals are peripheral to the WCAs and the park and provide the means to manage the distribution of flows into the basin.

South Miami-Dade Conveyance System

Water deliveries to the southeastern section of Everglades National Park are provided by the South Miami-Dade Conveyance System, which is described in the section of this report dealing with canals in eastern Palm Beach, Broward, and Miami-Dade counties.

Figure 5. WCA and Everglades National Park Drainage Basins.

Upper East Coast - Martin and St. Lucie Counties

Introduction

Nine basins make up the Upper East Coast area: C-23, C-59, S-153, S-135, C-44, Tidal St. Lucie River, North Fork St. Lucie River, C-25, and C-24. These basins cover 853 square miles of Martin and St. Lucie counties (**Figure 6**) and are served by 12 canals and 15 water control structures with the principal function of providing flood protection. Secondary uses include land drainage for agriculture and urban or residential development and regulation of groundwater levels to prevent saltwater intrusion. Most canals supply water for irrigation during periods of low natural flow. The coastal structures have the additional function of preventing salt water from a tidal or storm surge from entering those canals that discharge to tide.

Land use in this area is primarily agricultural – citrus, crops, and cattle. Some urban development is present in areas surrounding Stuart, Port St. Lucie, Fort Pierce, Indiantown, and Okeechobee. Large areas remain undeveloped with natural pine forested uplands, oak hammocks, swamps and marshes, rangeland, and unimproved pasture. Soils are generally sandy flatwoods with occasional hydric depressional features

North Fork St. Lucie Basin Flood Protection and Water Supply

With District approval, two areas in the North Fork St. Lucie basin can be pumped to the C-25 Canal to mitigate flooding in the basin: (1) an 18-square mile parcel in the northwest corner of the basin that normally drains to Ten Mile Creek by gravity flow, and (2) a 3-square mile parcel in the northeast corner of the North Fork St. Lucie basin that normally drains to Five Mile Creek by gravity flow. Water can be diverted from C-25 to the Fort Pierce Farms Drainage District for irrigation during the dry season. Fort Pierce Farms Drainage District drains by gravity flow to C-25 below S-50 (i.e., to tidewater).

A large number of citrus growers are in the Upper East Coast basin and the demand for water is high. Currently, the only source of water is local rainfall and artesian well water from the Floridan Aquifer. This well water has a high mineral content and is generally mixed with surface water before it is used for irrigation. To distribute the available surface water supply equitably, the inverts of irrigation supply culverts and irrigation pump intakes have been limited to a minimum elevation of 14.0 ft NGVD.

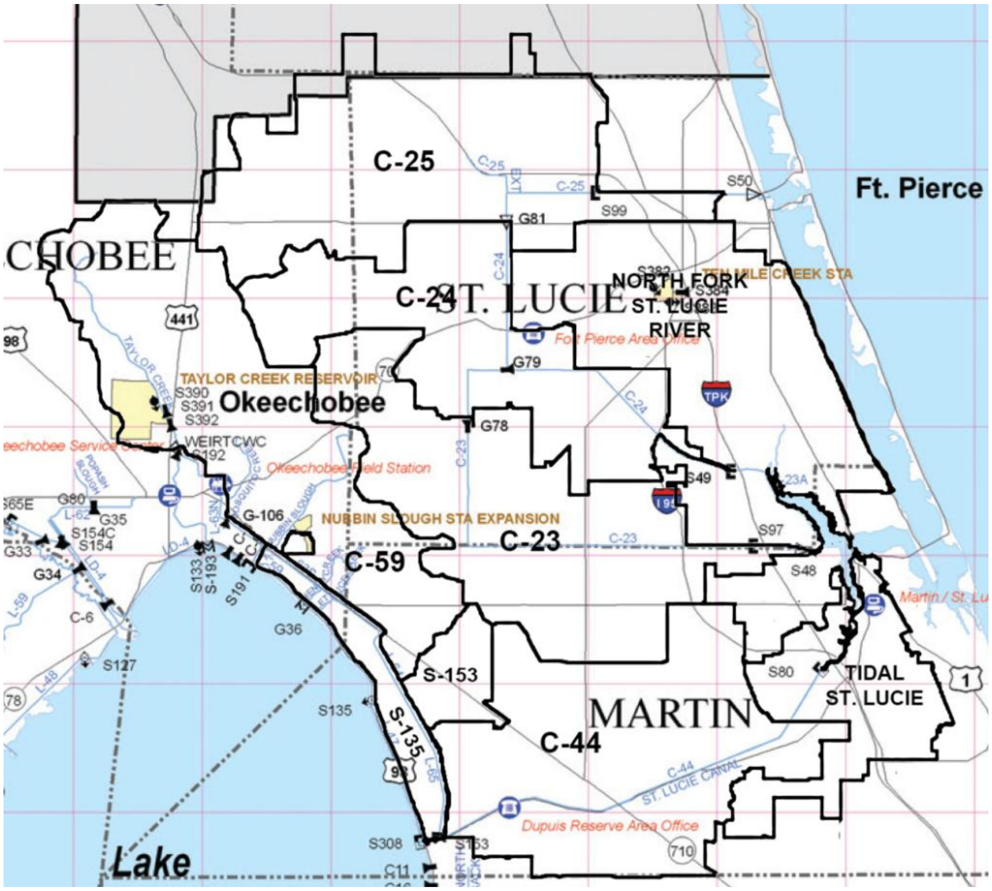

Figure 6. Sub-basins and District facilities in Martin and St. Lucie counties.

History of the St. Lucie Canal

It was realized early in the settlement of South Florida that Lake Okeechobee's water level would have to be substantially lowered to drain and control flooding in the Everglades. The easiest way to control water levels in the lake was by way of canals connecting the lake to the St. Lucie and the Caloosahatchee rivers.

Work on the St. Lucie Canal began in 1915. The primary purpose of the canal was to divert the entire flow from Lake Okeechobee to the ocean. Secondarily, it was expected to provide a navigable waterway from Lake Okeechobee to the ocean and to provide hydroelectric power at the eastern end of the canal. Because of difficulties in financing, the canal was not completed until 1917 and was only half as large as the original design (i.e., 200 feet wide and 12 feet deep). Flow regulation was provided by a dam and lock at the eastern end (at the present site of S-80). A hydroelectric plant was installed at the control structure, but later proved to be impractical.

Lack of money prevented further work on the St. Lucie Canal until the 1930s when the USACE built the Hoover Dike. As part of the legislation authorizing the dike, money was also authorized for deepening the canal and constructing a new lock structure. In 1948, the St. Lucie Canal was deepened again. When the C&SF Project was authorized in 1949, the canal was placed under its management. As part of the project, a spillway and lock (S-308) were completed in 1977 at the outlet from Lake Okeechobee to the St Lucie Canal.

Florida Power and Light Company Reservoir

An area of 6600 acres between the S-153 basin and C-44 that originally drained to the L-65 borrow canal and to S-153 is now the cooling reservoir for a Florida Power and Light power plant. Since the reservoir is hydraulically connected to C-44, the land it occupies is now considered part of the C-44 basin. Excess water in the S-153 basin is discharged to C-44 by way of the L-65 borrow canal and S-153.

Primary Canals that Discharge to Coastal Waters

Four primary canals (C-23, C-44, C-25, and C-24) discharge directly to coastal waters. The C-23 Canal basin measures approximately 167.7 square miles and is located in southwest St. Lucie County, eastern Okeechobee County, and northern Martin County (**Figure 6**). The C-44 basin is approximately 189.8 square miles. The C-44 Canal is a component of the Lake Okeechobee waterway and provides a navigable link from Lake Okeechobee to the lntracoastal Waterway near Stuart. It runs parallel to state road 76 from S-308 at Port Mayaca on Lake Okeechobee to S-80. The C-25 Canal basin is approximately 164.8 square miles and the canal discharges to the lntracoastal Waterway (Indian River) west of the Fort Pierce Inlet. The C-24 basin is approximately 166.6 square miles in area. In general, the only water supply to the C-24 basin is from local rainfall and pumping of groundwater from the Floridan Aquifer; however, water can be supplied from the C-23 basin when necessary.

Basins that Discharge to Lake Okeechobee

The S-135 basin is approximately 28.3 square miles in area. The basin is impounded by levees: on the west by L-47, on the north by L-63S, on the south by L-65, and on the east by L-63S, L-64, and L-65. The C-59 drainage basin is approximately 187.9 square miles in area and is located in portions of Okeechobee, St. Lucie, and Martin counties.

Lower East Coast – Palm Beach, Broward and Miami-Dade Counties

Introduction

The coastal areas of Palm Beach, Broward, and Miami-Dade counties have a number of features in common. The canals and structures were designed primarily to provide flood protection, deliver water needed for urban and agricultural use, and prevent saltwater intrusion.

Most of the land surface in the eastern sections of Miami-Dade and Broward counties, as well as Southern portion of Palm Beach County is underlain by the Biscayne Aquifer, which is directly linked to surface water. The Biscayne Aquifer is highly permeable, transmissive, and extensively used as a source of drinking water by utilities and homeowners. Wells developed in this aquifer yield extremely large amounts of water. Because the aquifer is closely connected to surface water bodies, such as lakes, rock pits, and canals, any contamination derived from these sources spreads rapidly.

The canals are cut through the surface soils and into the rock of the underlying aquifer, providing for a direct exchange of surface and groundwater. Canal water quality is thus continually influenced by exchange with groundwater, which typically contains elevated concentrations of dissolved nutrients and low concentrations of dissolved oxygen. Canals can also transfer contaminants from surface sources to groundwater, including treated or untreated wastewater, urban and agricultural runoff, seepage from septic tanks and landfills, and salt water from canals that connect to tide (Alleman et al. 1995, Brown 2003).

Figure 7 shows the distribution of canals and water control structures in the drainage basins of eastern Palm Beach, Broward, and Miami-Dade counties. In addition to providing water supply and flood control, the primary canals are also an outlet for excess water from the Everglades and Lake Okeechobee during wet periods. During dry periods, stored water can be delivered to eastern Palm Beach, Broward, and Miami-Dade counties to help meet local urban and agricultural needs and prevent saltwater intrusion.

The topography of these counties is very flat. The elevation of most the sub-basins is less than 20 feet above sea level, and many areas have an elevation of 5 feet or less. Historically, much of the area was under water or had fully saturated soils for most of the year.

Most of the area is covered with hydric (wetland) soils, except for areas near the coast that are underlain by an extensive limestone rock ridge (see **Appendix C**). Historically, this ridge had rocky to sandy soils and was covered with upland vegetation consisting of pine flatwoods and oak hammocks. Today, soil patterns show the predominance of urban and man-made lands in eastern Miami-Dade, Broward, and Palm Beach counties. In northern Miami-Dade and southern Broward counties, urban lands extend westward into areas that were historically Everglades peat, muck, sand, and marl wetland soils. Western areas of Miami-Dade and Broward counties east of the WCAs still have Everglades sand, marl, or peat soils in undeveloped areas. In Palm Beach County, lands west of the coastal ridge have higher elevations and contained pine flatwoods vegetation (sandy soils) with intermittent depressional features. This area was largely used for farming in the early to mid-twentieth century but is increasingly transitioning to urban and residential community development. In northern Palm Beach County, large areas east of Lake Okeechobee that have hydric peat and depressional soils are protected from development within various local, state and regional parks, preserves, and management areas.

Structures in the area regulate the flow and level of water in the canals. In general, they are used to discharge excess water from the basins during flooding and maintain minimum water levels in the canals during dry periods. The coastal structures also prevent salt water from a tidal or storm surge from entering canals that discharge to tide. Tables summarizing features of these structures are provided in **Appendix C**. Water levels in the coastal and regional canals are carefully managed to be: (1) high enough, especially during the dry season, to prevent saltwater intrusion and recharge the aquifer; and (2) low enough during the wet season and agricultural growing season to provide drainage and flood control.

Primary Regional Canals

The primary canals in Miami-Dade, Broward, and Palm Beach counties are the coastal extensions of the West Palm Beach Canal, Hillsboro Canal, North New River Canal, and Miami Canal, which originate in at Lake Okeechobee, pass through the Everglades Agricultural Area Everglades and Water Conservation Areas, and end at the estuaries. These primary canals provide region-wide management capabilities. They are used as outlets for regulatory releases from Lake Okeechobee and the WCAs, excess floodwaters from the Everglades Agricultural Area lands, and runoff from the coastal basins. They also convey water releases from Lake Okeechobee or the WCAs to recharge local wellfields and protect the surficial aquifer against saltwater intrusion. Details of canal features and operations are provided in **Appendix C**.

The section of the West Palm Canal located east of WCA-1 is in the C-51 basin. This basin has an area of 164.3 square miles in eastern Palm Beach County. The canal runs parallel to and south of State Road 80, from L-40 to Congress Avenue. East of Congress Avenue, the canal extends to the south and then to the east, connecting to the Intracoastal Waterway at S-155 east of Lake Clarke.

The Hillsboro Canal connects Lake Okeechobee to the Intracoastal Waterway. The canal basin in eastern Palm Beach and Broward counties has an area of 102.5 square miles. Excess water in WCA-1 is discharged to the Hillsboro Canal by way of S-39 at the western edge of the basin.

The North New River Canal basin measures approximately 30 square miles in eastern Broward County. The basin is divided into an eastern basin (7 square miles) and a western basin (23 square miles). The North New River was excavated and extended to drain the Everglades, and to serve as a transportation route between Lake Okeechobee and the coast.

The section of the Miami Canal East of the WCAs is also known as C-6. The C-6 basin has an area of approximately 69 square miles in eastern Miami-Dade County (**Figure 7**). Flow in the C-6 Canal is to the southeast with discharge via S-26 into Biscayne Bay.

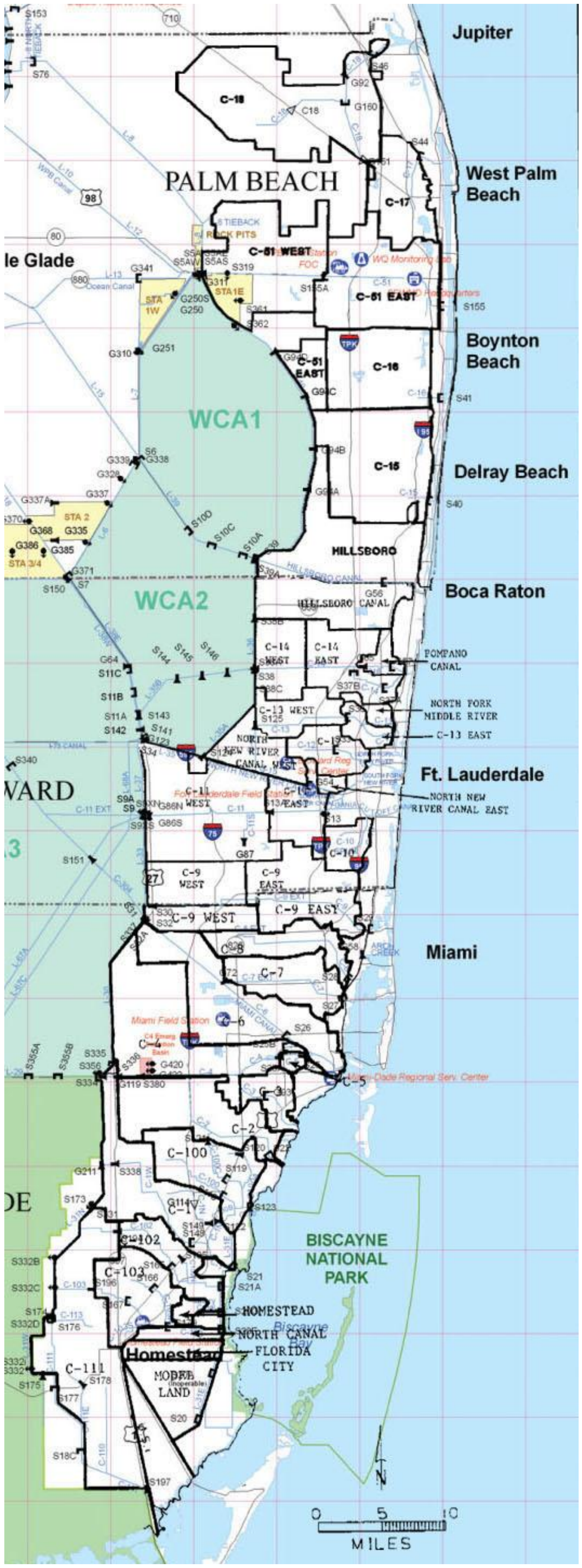

Figure 7. SFWMD canals and structures in coastal sub-basins of Miami-Dade, Broward, and Palm Beach counties.

Coastal Basin Canals

Coastal basin canals originate at or east of the Everglades and discharge to the Intracoastal Waterway or an estuary. These canals were designed primarily to provide flood protection and drainage for coastal development. Some of the canals are linked directly or indirectly to other canals and provide a means to regulate surface and groundwater levels and to recharge the surficial aquifer. Most of these canals have a downstream coastal outfall water control structure to prevent upstream migration of salt water and contamination of groundwater. Some of the coastal canal basins have an eastern and western sub-basin. The western basins tend to be more flood-prone, and hence have more stringent construction criteria, lower densities of development, and more agricultural use.

South Miami-Dade Conveyance System

The South Miami-Dade Conveyance System interconnects several of the basins in southern Miami-Dade County. The system was developed during the 1970s was after a Congressional mandate with the primary purpose of supplying water to Everglades National Park and to canals in southern Miami-Dade County for irrigation, wellfield recharge, and control of saltwater intrusion. The system was also built largely around existing structures. For example, S-151 was enlarged and S-335 was changed to a gated spillway. Three new structures (S-336, S-337, and S-338) were built for the system.

Lower West Coast Watersheds

Caloosahatchee River

Features of the Current System

Three structures and 41 miles of the C-43 Canal provide the primary water management system within the Caloosahatchee basin. The canal was dug to connect Lake Okeechobee to the Gulf of Mexico through the Caloosahatchee River. The resulting channel is 160 to 430 feet wide and 20 to 30 feet deep. The three structures are S-77 at Moore Haven, S-78 at Ortona (15 miles west of S-77), and S-79 (also known as the W.P. Franklin Lock and Dam) near Ft. Myers (40 miles west of S-77). Each of these structures includes water control facilities and navigational locks (**Figure 8**). The structures and canal improvements were authorized not only for navigation and flood protection, but also to manipulate water flow for eliminating undesirable salinity in the lower Caloosahatchee River, raise dry-weather water table levels, and provide water for agricultural irrigation.

The freshwater portion of the Caloosahatchee River watershed includes two primary basins. The upstream section of the river between S-78 and S-77 drains approximately 338 square miles. The water level in this part of the river is maintained at approximately 11 feet above mean sea level. Downstream, between S-78 and S-79, the water level in the river is maintained at 3 feet above mean sea level. The drainage basin for this lower pool is 497 square miles. Land use in the Caloosahatchee basins is mostly agriculture, with some low density residential communities and a small urban area near Labelle. The river, throughout its length, is used as a source of water for agricultural irrigation, including citrus, pasture, vegetables, and flowers.

In the lower section of the Caloosahatchee River, especially areas west of Labelle, many oxbows of the original meandering river remain as shallow diversions from the main canal. Areas where the canal has been channelized are deep, have steep sides, and provide rather limited habitat for most fishes, benthic invertebrates, and shoreline vegetation. By contrast, the remaining oxbows provide sheltered areas and a diversity of littoral habitats.

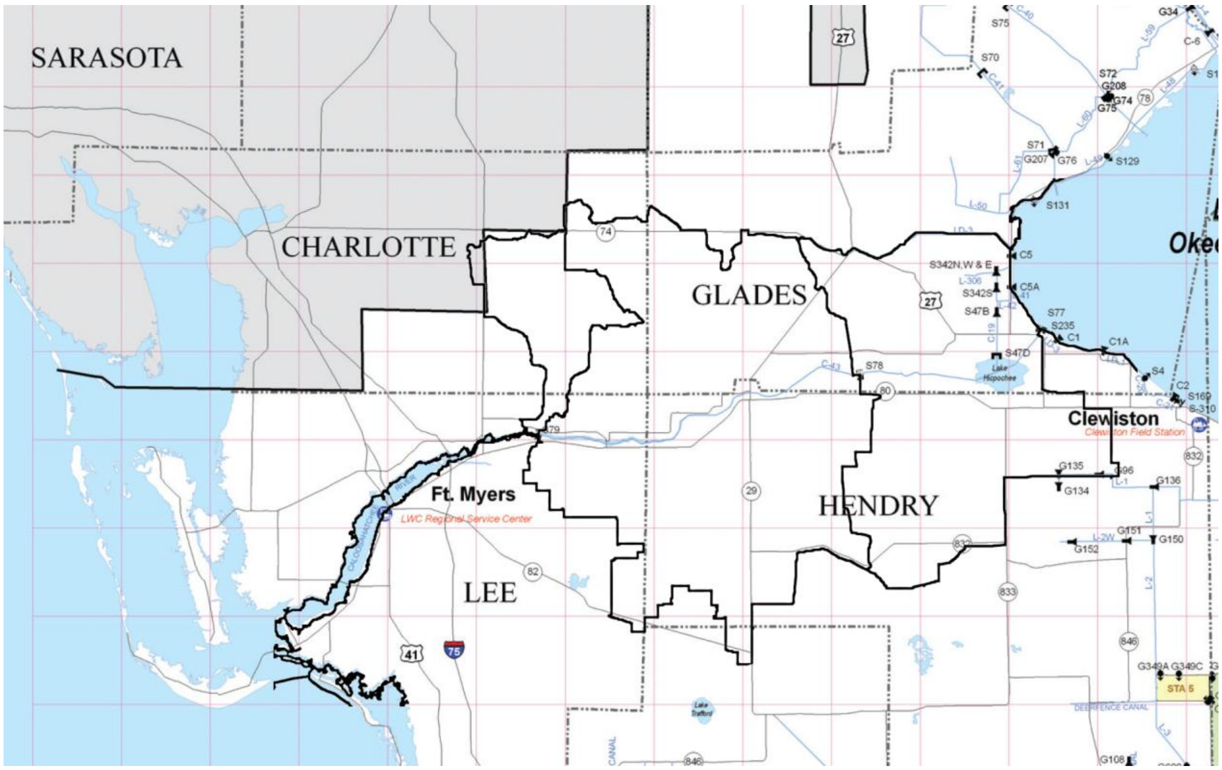

Figure 8. Major features of the Caloosahatchee River watershed.

Water Management Issues

The Caloosahatchee River (C-43) basin represents a complex management situation for the SFWMD. The District is responsibile for water allocations and withdrawals from the river and from Lake Okeechobee, while the USACE is responsibile for operation, maintenance, navigation, and flood control. With this division of responsibilities, there is need for coordination and cooperation, not only between the SFWMD and USACE, but also with the U.S. Geological Survey, U.S. Weather Bureau, various state, county and local authorities, and local landowners.

Need for Additional Water Storage

The Comprehensive Everglades Restoration Plan (CERP), a framework to restore the water resources of central and southern Florida to update the C&SF Project, determined that this area could greatly benefit from construction of additional water storage facilities. The original design of the water management system recognized that the watershed could not meet all of the existing and future water demands within its boundaries and that additional water releases from Lake Okeechobee would be required during the dry season (Mierau et al. 1974). Studies conducted as part of CERP indicated that the inability to meet irrigation needs during dry periods could be largely offset by capturing basin runoff during the wet season, placing this water in storage, and later releasing the water back to the river. The CERP proposed construction of a large reservoir in the watershed to address this need and it is currently being designed.

Regulatory Releases from Lake Okeechobee

One of the primary issues with management of the Caloosahatchee River is the need to periodically regulate water stages in Lake Okeechobee. When the lake is above its regulated water stage, the USACE discharges excess water through structures they operate, primarily through the Caloosahatchee and St. Lucie rivers. During such discharges, river flow rates can exceed 10,000 cubic feet per second. These discharges have significant adverse effects on plants and animals in the estuary and adjacent coastal waters due to rapid changes in salinity and water quality.

Controlling Saltwater Intrusion and Algal Blooms

A major problem with operation of the Caloosahatchee River is the control of saltwater intrusion into the basin during dry periods. Before construction of the S-79 structure, tidal fluctuations and varying amounts of runoff from the basin occasionally resulted in transfer of salt water as far upstream as LaBelle, which contaminated shallow wells adjacent to the river. With the construction of S-79, less salt water is getting upstream, but there continue to be occasional exceedances of the Class I water designation standards that apply to that section of the river.

In conjunction with recurring salinity problems, periods of low river flow are often associated with algal blooms, especially cyanobacteria (blue-green algae) that affect water taste and color. These problems affect the Lee County water supply facility and the Ft. Myers wellfield. Therefore, additional water is discharged from Lake Okeechobee to “flush” the system during periods of high salinity or algal blooms (Boggess 1972, Mierau 1974).

Minimum Flows and Levels

A further issue of concern is the need to prevent significant harm from occurring to the water resources in the Caloosahatchee Estuary. The SFWMD established minimum flow criteria for the Caloosahatchee River based on maintenance of suitable salinity conditions in the downstream estuary (SFWMD 2000, SFWMD 2003). These criteria recommend that additional water be provided from the Caloosahatchee River (and hence from Lake Okeechobee) as needed to protect submerged aquatic vegetation in the section of the estuary adjacent to Fort Myers.

Collier County

Collier County may be roughly divided into the Big Cypress Region, the Western Flatlands, and the Ten Thousand Islands. The area along the coast, west and north of the Big Cypress, and as far south as Gordon’s Pass, is part of the western flatlands. The flatlands are characterized by marshes, swamps, and open water depressions, including Lake Trafford, the Corkscrew Marsh, and the Okaloacoochee Slough.

The first canals in Collier County were dug to provide fill for the roads used to promote harvesting of cypress timber. The combined canals and roads greatly altered the historical surface water movements. In 1928, the Atlantic Coastline Railroad extended their service into the Everglades. This railroad extension prepared a roadbed for a new highway and created sizeable drainage canals that effectively divided the Big Cypress wetlands into east and west portions.

South Florida Water Management District – Big Cypress Basin

The Big Cypress Basin (BCB) was established as a subdivision of the SFWMD by the Florida legislature in 1976. One of the first actions of the BCB Governing Board was to begin efforts to define and take management responsibility for the primary water management system in Collier County. The "primary canals" in this system are the canals that are maintained by BCB; "secondary canals" are all other types of canals not maintained by BCB. The SFWMD through the BCB presently operates and maintains a network of 162 miles of primary canals and 46 water control structures (**Figure 9**) in western Collier County. These facilities provide flood control during the wet season and prevent over-drainage during the dry season to protect the vulnerable water supplies and environmental resources of a rapidly urbanizing region.

Surface Hydrology and Hydraulic Systems

The surface hydrology of the Big Cypress basin is dictated by an extensive system of drainage canals and structures. This system of canals separates the contributory drainage areas of the primary outfalls into the following eight major basins: Golden Gate Canal, Corkscrew-Cocohatchee, District VI, Henderson Creek, Collier-Seminole, Faka Union Canal, Fakahatchee Strand, and Okaloacoochee Slough-Barron River.

With the evolution of urban and agricultural development, the traditional surface water flow patterns in the Big Cypress region have undergone drastic changes. As land areas were developed, "ditch and drain" construction practices resulted in a series of canals and numerous roads that tended to overdrain the water table and drastically altered flow patterns of natural drainage basins. Such combinations of development events greatly reduced the extent of functional wetlands, lowered groundwater levels, reduced aquifer recharge, and contributed to concentrating runoff flow rather than preserving sheet flow across the land. The change in flow characteristics resulted in a significant shift in watershed boundaries.

Of the eight basins, three (Collier-Seminole, Fakahatchee Strand, and District VI) do not contain primary water management canals or control structures. The surface hydrology and primary drainage works of the remaining basins are described in **Appendix C**.

Figure 9. Major drainage basins and water management features within the Big Cypress basin.

2. ANALYSIS OF BIOLOGICAL DATA FROM SFWMD CANALS

Introduction

A review of available literature was conducted by SFWMD staff to identify scientific studies of animals that live in South Florida canals. Relatively few studies have been conducted in recent years, and almost none of these have included synoptic water quality data that met the District staff's evaluation criteria with respect to sampling period, methods, or proximity of water quality sampling to biological sampling times or locations. Primary emphasis was placed on studies of macroinvertebrates (e.g., larval stages of insects) because there is an extensive database of Florida invertebrates available. These communities are widely accepted as indicators of biological conditions by FDEP and the USEPA, and standardized procedures for collecting and processing macroinvertebrate samples have been used in Florida since about 1992. These procedures have been applied to canals by FDEP and private consultants. These macroinvertebrate studies are summarized below and additional details, and in some cases re-analyses of the data by SFWMD staff, are included in **Appendix D**.

A number of studies of other organisms, notably fish and alligators, in and adjacent to District canals are also summarized, with additional information provided in **Appendix E**. While research concerning ecological relationships among these higher organisms is highly developed within some South Florida ecosystems, especially the Everglades and estuaries, canals have not been systematically studied. Furthermore, when compared to macroinvertebrates, methods for collecting and interpreting vertebrate data are more variable and less quantitatively linked to other variables such as habitat quality, surrounding land uses, and water quality.

Macroinvertebrate Communities

Studies of Canals using FDEP methods

The Florida Department of Environmental Protection established the Bioassessment Program for stream macroinvertebrates in 1992 (FDEP 2010). This program provides standard protocols for sample collection, processing, and reporting macroinvertebrate data. The data have been used to develop the Stream Condition Index (SCI), which is a numeric index of biological condition using 10 macroinvertebrate metrics. The database includes a total of 2313 unique sites sampled since 1992, with some sites sampled annually for trends. There are 53 minimally disturbed reference stream sites covering most of the state north of Lake Okeechobee, and these sites were used by FDEP to set quality thresholds (e.g., good, fair, poor) for the SCI. The data were also used to divide Florida into bioregions, two of which include parts of the District. The peninsula bioregion includes most of the Florida peninsula south to Lake Okeechobee; lands south of the lake are in the Everglades bioregion. While SCI scoring has changed over the years, the methods and metrics have not been substantially altered, providing a consistent and semi-quantitative long-term database on Florida streams and canals.

From the Bioassessment Program, FDEP provided data on 156 canal sites south of Orlando and 14 stream reference sites in the southern portion of the peninsula bioregion that includes the District north of Lake Okeechobee (**Figure 10a**). While not all of these canals are under the jurisdiction of the SFWMD, they are all within District boundaries and meet the physical requirement of canals. There are no reference stream sites south of the lake. The 14 reference sites selected for analyses have been sampled annually for 14 or more years and provided information on interannual variability. They were also analyzed to assess the application of the SCI thresholds to South Florida canals. Four consultant reports were found that used FDEP methods to assess the macroinvertebrate communities in canals within the District. More detailed summaries and analyses of these five studies are provided in **Appendix D**.

FDEP Methods – State Bioassessment Database

Of the 156 canal sites sampled in the southern part of the state by FDEP since 1992, 140 were in the southern portion of the peninsula bioregion (including about 60 stations within the SFWMD) and 16 were in the Everglades bioregion (**Figure 10a** and **Table 1**). Although there are no SCI thresholds for the Everglades bioregion, the data are useful for quantifying living resource conditions in canals within this area.

Macroinvertebrate metrics included 10 used to calculate the Stream Condition Index, 3 additional metrics, and the name of the dominant taxon. Habitat and water quality measures were also taken at a subset of these 156 sites (**Table 1**). Water quality parameters included physicochemical, nutrients, and primary production measures at most sites; other measures (e.g., metals, coliforms, sulfate, turbidity, color, TSS, salinity, hardness) were taken at a small number of sites. The data on canals were analyzed in two ways. First comparisons were between canals in the peninsula and Everglades bioregions using mean values (± 1 standard deviation) for three taxonomic richness metrics (total, chironomidae, and EPT richness[3]). The results were used to identify differences in species richness across bioregions. Second, SCI scores and richness measures were regressed against habitat quality scores to assess whether habitat quality was a likely stressor in canals.

[3] EPT richness refers to the total number of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) taxa in a sample.

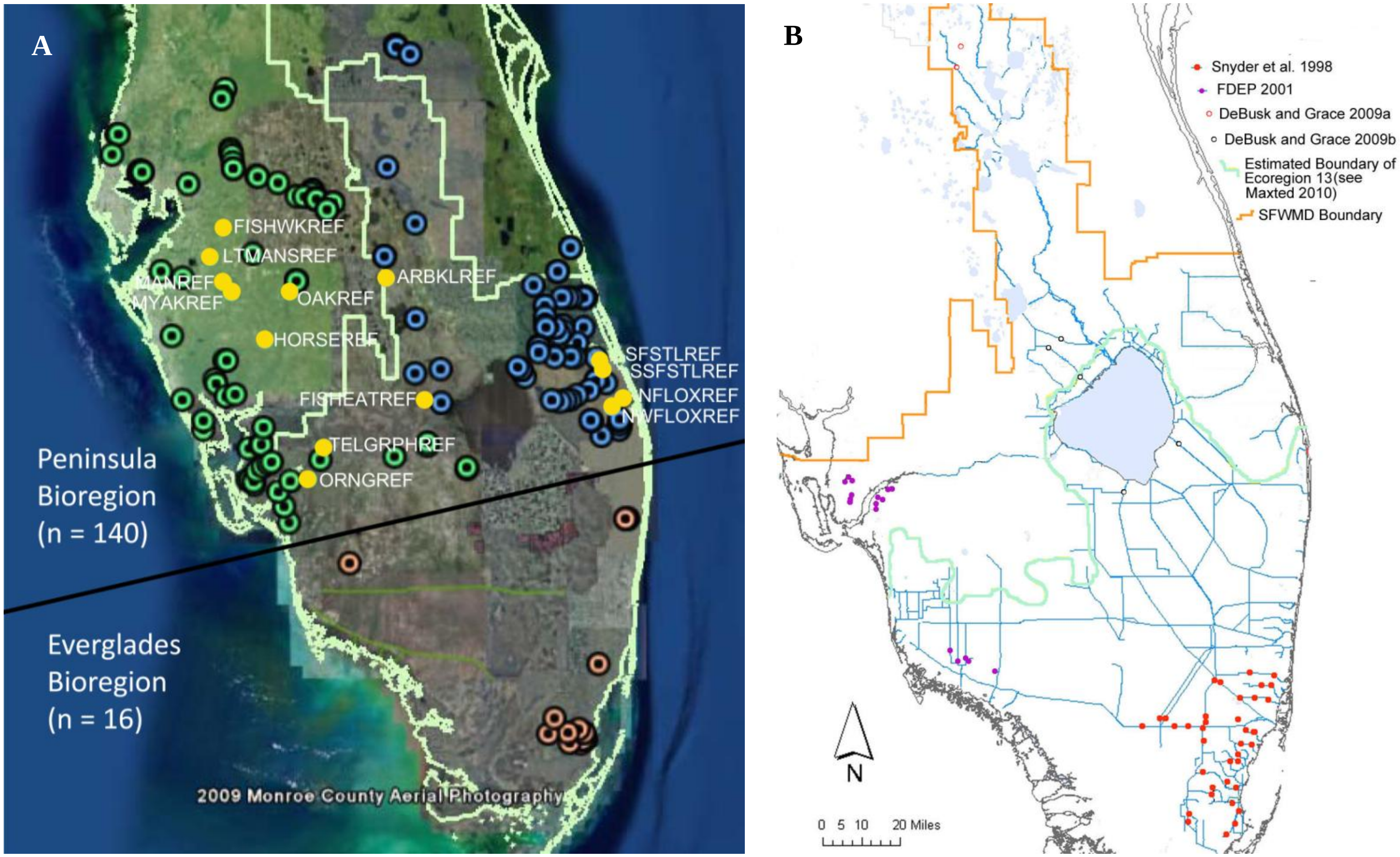

Figure 10. Macroinvertebrate sites within the District boundary sampled using FDEP methods. **A)** Locations of 156 canal sites sampled in two bioregions for macroinvertebrates by FDEP. Blue sites represent Zone 1 (east) and green sites represent zone 2 (west) of the peninsula bioregion (see text). Brown sites represent the Everglades bioregion. Labeled gold sites are reference stream sites (see Maxted 2010 in **Appendix D**). **B)** Locations of sites sampled by consultants using FDEP methods discussed in this report. The light blue line is the FDEP bioregion boundary.

Table 1. Number of sites and metrics where macroinvertebrate, habitat, and water quality data have been collected by FDEP in canals in South Florida (**Figure 10a**).

Measure	# of Metrics	# of Canal Sites by Bioregion	
		Peninsula	**Everglades**
Macroinvertebrate	14	140	16
Habitat	14	95	2
Macroinvertebrate + Habitat	28	93	2
Water Quality*	60	40	2

* not all WQ parameters reported at all sites

The 14 reference stream sites in the southern portion of the peninsula bioregion were also evaluated to understand differences in the invertebrate communities in minimally disturbed streams. The results provide insights into the spatial and temporal variability inherent in natural streams in central Florida and the variability that might also affect more disturbed systems such as canals. Comparisons were made in mean richness (total and EPT richness ± 1 standard deviation) between sites in the eastern and western zones of the bioregion to assess differences that might be due to broad geographic variables such as geology and climate. The data were also plotted over time to understand temporal variations over a 14-year or longer period of record. The following conclusions were drawn from the data (details appear in **Appendix D**):

- Canals had a diverse community of macroinvertebrates based upon three richness metrics – total richness, Chironomidae richness, and EPT richness.
- The macroinvertebrate community in canals was typical of lotic (flowing water) systems with lower topographic gradients, deeper channels, and lower velocities compared to natural streams.
- For canal sites, there were no differences in mean richness metrics between the Everglades and peninsula bioregions, indicating that canal biota were similar across this large geographic area and the two bioregions.
- Habitat quality appeared to be an important stressor in canals although high variability caused weak statistical relationships.
- There were inadequate data to assess effects of water quality, including nutrients, on macroinvertebrate communities in canals because only grab water samples were taken on the day of macroinvertebrate sampling. Macroinvertebrate communities reflect water quality conditions over long periods and water quality parameters, particularly nutrients, are highly variable due to changes in rainfall and flow. Therefore, single water quality values do not accurately reflect water quality conditions needed to assess relationships between water quality (i.e., nutrients) and biology (i.e., invertebrates).
- For reference stream sites, there were no differences in total richness between sites in the eastern and western zones of the peninsula bioregion. There were substantial differences

in EPT richness between the two zones, and this should be investigated further before applying the SCI metrics and thresholds to canals. The differences may be due to differences in gradient, depth, and velocity.

- There was a downward trend in metric values at most reference stream sites over a 14-year period (1992-2006), indicating that changes in macroinvertebrate communities may be due to events that exerted effects over a large geographic area. The variability in macroinvertebrate metric values at reference sites helps to explain the variability observed at all stream and canal sites in southern Florida.
- Metric and SCI scores were lower in canal sites compared to reference stream sites indicating that canals do not achieve the same level of biological quality compared to natural streams. Of the 52 canal sites, 44 (85%) with recent SCI scores (2004 to present) were classified in the lowest ("impaired") assessment category (SCI score < 35 points), and only one site (SCI score = 59) was classified in the middle category (SCI score 35-70 points). No canal sites were classified in the highest category (SCI score > 70 points). This may be due to physical differences related to channelization including riparian habitat quality, depth, and velocity. These SCI results should be viewed with caution because the SCI is not directly applicable to canals and streams in South Florida. Additional research is needed to select sensitive metrics and a quality threshold applicable to low gradient streams and canals within the peninsula and Everglades bioregions.

FDEP Methods – Miami-Dade County

Snyder et al. (1998) collected macroinvertebrate and habitat quality data at 32 sites in Miami-Dade County during February (winter, dry season) 1996 (see **Figure 10b** and **Appendix D**). The sites were selected in four land use categories (wetlands, agriculture, suburban, and urban/industrial) to provide a disturbance gradient for these engineered waterways. Twenty sites were resampled in July (summer, wet season) 1996 to determine seasonal differences. Snyder et al. (1998) concluded that surrounding land use and habitat quality were key drivers of invertebrate community condition.

Several invertebrate metrics (total richness, Florida index, % dominant taxon, % midge) and the SCI followed a pattern of increasing disturbance from wetlands → agricultural → suburban → urban/industrial. This pattern was also identified from analysis of the raw taxonomic data. The highest quality sites were those with wetlands as the predominant surrounding land use, but had lower metric and SCI scores than FDEP reference stream sites in peninsular Florida. Biological condition as measured by the SCI was weakly correlated with habitat quality ($r^2 = 0.35$). Highest quality canal sites were dominated by long-lived taxa, indicating that impacts were related to periodic stressors. These results suggest that canals (1) have lower quality conditions than natural streams and (2) are affected by land use and habitat quality.

FDEP Methods – Ft. Myers, Cape Coral, Golden Gate, Picayune Strand, Fakahatchee Strand

A study by FDEP (2001) provides an assessment of the biological conditions in urban canals across a range of development intensity and habitat conditions. In the fall of 1999 and spring of 2000, habitat, invertebrate, physico-chemical (temperature, DO, pH, conductivity, turbidity), and water quality (NH_3, NO_3/NO_2, TKN, TP, algal growth potential) data were collected at 13 sites in residential canals in and around Ft. Myers and Cape Coral, 3 sites in Southern Golden Gate Estates in an area that had canals and roads but no houses, and 2 sites in natural sloughs (moving water channels) within Picayune Strand and Fakahatchee Strand State Preserve (**Figure 10b**). The sites were selected to represent a disturbance gradient based upon the degree of local development, water quality, and habitat quality. The data were insufficient to assess water quality conditions in canals or to statistically correlate biology to water and habitat quality.

Results indicated that invertebrate communities were quite resilient to this type of physical alteration. Variability was high within each site category – the canals with the highest degree of water quality and habitat disturbances had both high and low invertebrate metric values. Biological quality was generally related to habitat quality but variability was high making for poor correlations. Three major conclusions of the study (FDEP 2001) were as follows:

- “Based on their artificial construction, canals cannot be expected to span the full range of scores found in the stream habitat assessment procedures, even in expected ‘reference canal’ habitat conditions.”
- “ . . . our a priori approach to classifying least disturbed canals (which are all artificially created systems) was not successful. Until additional 20 dip net sweep data is collected from an assortment of canals subject to varying degrees of human disturbance (habitat removal, water quality problems), we cannot fully establish reasonable expectations for these artificial systems.”
- “If additional canals sampling is done (sufficient to bring the total number of sites up to approximately 50) it is possible that a Canal Condition Index (CCI) could be formulated for future use. This CCI would need to consider supplementary factors, such as ecoregion and flow conditions (flowing vs. stagnant) during the calibration process.”

FDEP Methods – Reedy Creek

DeBusk and Grace (2009a) examined the effects of improved water quality on the macroinvertebrate community at a single site (RC-14) on Reedy Creek in the upper Kissimmee Lakes region, south of Orlando (**Figure 10b**). Water quality, habitat, and macroinvertebrate data collected over a 26-year period (1980-2006) were used to assess the effects of sewage treatment plant improvements in 1990. The mean annual TP concentration before 1990 was 266 µg/L compared to 75 µg/L after the improvements; mean annual TN concentrations were 1.92 µg/L and 1.41 µg/L, respectively. The macroinvertebrate community showed little or no response to improved water quality: five macroinvertebrate metrics did not change, two showed some improved response, and six, including the Florida Biotic Index, declined in biological condition with improved water quality. The site maintained “optimal” habitat conditions over the study period, including a natural meandering channel, diverse in-stream habitat, and good riparian vegetation.

Samples also were also collected in a tributary of Reedy Creek (Bonnet Creek) upstream of site RC-14. This site (C-12) was a channelized stream with poor habitat quality, providing a framework for looking at the effects of habitat quality on the macroinvertebrate community. The macroinvertebrate communities were compared between these two sites for the years that had comparable water quality conditions.

Most metrics showed significant reductions in biological condition at site C-12 compared to site RC-14, indicating that habitat quality was a key stressor. The finding of this study should be viewed with caution due to the limited number of sites and the lack of replication. However, the findings are similar to those of the FDEP (2001) and Snyder et al. (1998), which showed that biological communities in channelized South Florida streams and wetlands are influenced by surrounding land use and physical alterations of the channel and riparian habitat.

FDEP Methods – Canals near Lake Okeechobee

DeBusk and Grace (2009b) examined the water quality, physical habitat, and macroinvertebrate communities in five canals near Lake Okeechobee; three sites were north of the lake (and south of Lake Istokpoga) and two sites were in the Everglades Agricultural Area (**Figure 10b**). All sites were engineered canals with poor habitat quality. The investigators compared their results to macroinvertebrate data collected by FDEP as part of their SCI network that included 12 canals and 53 reference streams throughout Florida.

Comparison of scores for total richness, EPT richness, and SCI scores for the five canal sites indicated: (1) lower quality conditions in canals compared to natural streams, and (2) high variability in all metrics. SCI scores were similar to FDEP canal sites and lower than all but one of the FDEP reference stream sites. The metric and SCI values were also similar to other studies of canals in South Florida (Snyder et al. 1998, FDEP 2001, DeBusk and Grace 2009a). The metric and SCI data indicate that canals provide a diverse community of macroinvertebrates (20 to 30 taxa) typical of lotic environments with low velocities, high primary production, and depositional substrata.

Other Macroinvertebrate Studies in South Florida Canals

Ross and Jones (1979) provide one of the earliest investigations of macroinvertebrate communities in South Florida canals. This report included 32 stations throughout the region, including 12 in freshwater canals of the SFWMD.

Rudolph (1985) examined the macroinvertebrate community structure at three canal sites west of the urban areas and four canal sites impacted by urban development in eastern Miami-Dade County. This study was conducted in conjunction with a chemical water quality assessment as a part of the then Florida Department of Environmental Regulation's (now FDEP) statewide basin assessment survey. The author concluded that all of the sites showed some degree of stress, most likely due to effects of nutrient and organic input from the Everglades Water Conservation Areas, the Everglades Agricultural Area, and runoff from urban canal systems. The natural flora and fauna were also impacted by competitive interactions with exotic aquatic plants, invertebrates, and fish. Results of this study are not directly comparable to more recent studies because different methods for collection and processing of samples were used.

Rutchey (1992) monitored littoral shelf communities for three years in the West Palm Beach Canal (C-51) to test whether shallow water habitat could be created and maintained in a canal environment. Both bermed and unbermed littoral shelves quickly became dominated by exotic species of floating vegetation, which limited plant community structure and caused reductions in the number and diversity of benthic macroinvertebrates. The effects of the artificial structure and management of canals were apparent both in the colonization by floating exotic species and by a significant problem with floating debris that collected in the littoral area. Without continuous control of invasive species, debris removal, and stabilization of bank areas, it was concluded that canals were not a suitable setting for creating littoral shelves.

Macroinvertebrate Studies in Canals in Other States

Maxted et al. (2000) conducted a collaborative study among six states along the mid-Atlantic seaboard of the United States to develop a consistent approach for collecting and interpreting macroinvertebrate data for low gradient streams of the coastal plain. Macroinvertebrate, habitat quality, physico-chemical (DO, conductivity, TSS, pH), and water nutrient (TP, NO_3/NO_2) samples were collected in the fall of 1995 for three types of sites: (1) reference sites consisting of natural streams, (2) habitat impaired sites (canals located primarily in agricultural areas), and (3) water quality impaired sites (streams with flow dominated by a municipal wastewater discharge and good habitat quality). Data were reanalyzed to compare macroinvertebrate metrics among reference sites, habitat impaired sites, and water quality impaired sites separately (**Appendix D**).

Results indicated that separation from reference sites was greater for habitat impaired sites than for water quality impaired stream sites, indicating that habitat quality was a primary driver of biological conditions in low gradient streams. Although the results are not directly applicable to the aquatic fauna in Florida streams and canals, three conclusions can be drawn from the data that may also apply to canals in South Florida:

- The removal of riparian vegetation from canal banks makes it difficult for canals to achieve a high degree of biological quality in canals
- A high degree of biological quality can be achieved, despite poor water quality, if natural channels and riparian vegetation are maintained
- Reference sites were similar to each other from one state to the next, despite large differences in land use and percentages of forested lands in their respective catchments

Assuming that water quality is proportional to the degree of development in the catchment, the high degree of urban and agricultural land uses at many reference sites did not affect the biology of streams with natural channels and good riparian vegetation. Taken together, these results provide further indication that water quality is less important than habitat quality in determining the biological condition of canals.

Fish

SFWMD staff conducted a literature review of fish studies from South Florida canals. Results of this review are summarized here and in **Appendix E** along with information provided on the use of fish in aquatic weed maintenance.

Canals Located in Undeveloped or Natural Areas of South Florida

Trexler et al. (2000) concluded, based on results from studies conducted over several years at eight sites in the Florida Everglades, that canals held the largest introduced fish populations in the study area. Exotic species were more abundant in canals within disturbed or developed areas, whereas canals in natural areas and natural habitats distant from canals held fewer introduced fishes. Canals are a permanent aquatic refuge unlike any native Everglades habitat and are sites where introduced species of fish often become established. Canals provide refuge from drought for fish, which move into the marsh during the wet season. Urban and Everglades canals differ in composition and proportion of native to exotic species – principally due to marsh-requirements of native fishes (Trexler et al. 2000).

Jordan (1996) concluded that apparent changes in the occurrence and density of shrimp and crayfish associated with proximity to canals may be due to top-down consumption by fishes and lack of nutritive value of cyanobacteria to crayfish and shrimp in enriched zones. Fish had much higher abundance within enriched areas bordering canals and this region may serve as a littoral zone for fish production. Similarly, Turner et al. (1999) found that sharp nutrient gradients in Everglades marshes along canals resulted in greater fish biomass at enriched sites than reference sites. No such differences were apparent for invertebrates, suggesting that fish are consuming the invertebrate production. Results of the study indicated standing stocks in the Everglades are unusual, and are possibly similar to seasonal-tropical wetlands with limited deep-water refugia for large-sized fish; in other words canals create excessive and artificial refugia for fish.

Rehage and Trexler (2006) found that density of fish and macroinvertebrates changed within 16 feet of canals with little change in community species composition, but showing a pattern, most pronounced in the dry season, suggesting that canals act as refugia. The most apparent effect of canals was that they act as conduits for nutrients that stimulated local productivity in adjacent marshes. There was no evidence that canals were sources of predators into the marsh, but more study is needed, particularly on how fish disperse from canals.

Within the Big Cypress National Preserve, canals supported the greatest diversity of fish species. Most of these were saltwater-adapted or large freshwater predator species. As in other parts of Florida, canals in the preserve also provide aquatic refuge during the dry season. Some species of exotic fish captured on the marsh were exclusively taken at sites adjacent to canals (Ellis et al. 2004).

While canals clearly can act as refugia, the importance of this function depends on the size of the fish (Howard et al. 1995). In the Arthur R. Marshall Loxahatchee National Wildlife Refuge, large fish are uncommon in the marsh, but accumulate in large populations in canals and may affect marsh fish densities within 1.5 miles of the canals (Trexler et al. 2004). Similarly, preliminary results of studies conducted in coastal areas of Miami-Dade and Broward counties indicated that small-bodied fishes were most common in shallow marsh habitats and larger-bodied fishes were more common in canals (Nico et al. 2001).

In non-urbanized canals, particularly those through marshes, exotic fish are less numerous than native fish (Hogg 1976). Many exotic species are less tolerant of low temperature conditions than native species. During cold periods, water temperatures in the marshes tend to be significantly lower than in the canals. This may explain why exotic species are less abundant in the marshes. Canals and deep solution holes provide warm water refugia for exotic fish species during cold weather conditions (Schofield et al. 2009). Other exotic species, such as the brown hoplo, tolerate low temperature exposure and have expanded rapidly across many Everglades habitats and into northern Florida following its introduction (Schofield and Huge 2009).

Langston and Schofield (2009) examined the spawning interaction between exotic Mayan cichlid and native Everglades spotted sunfish to determine how an exotic fish can influence the reproductive success and behavior of a native species. Mayans did not breed when native spotted sunfish were present and did not appear to interfere with the native sunfish breeding success.

Kissimmee River/C-38 Canal Studies

In the Kissimmee River system, Perrin et al. (1982) found Florida gar was the dominant species by weight in trawl samples of the C-38 Canal and the remnant river channels. Florida gar also dominated gill net samples of C-38, while gizzard shad dominated samples from remnant river runs (Perrin et al. 1982). Three species, the blackbanded darter, coastal shiner, and tidewater silverside, have not been collected since channelization and may have been extirpated from the system.

Furse et al. (1996) documented the presence and distribution of largemouth bass in the C-38 Canal and adjacent oxbows and marshes and concluded that large bass preferred to live in the canals but tended to migrate toward shallower water in response to oxygen stress.

A creel survey conducted between September 1978 and August 1980 indicated that the percentage of total fishing effort directed toward largemouth bass declined to 45 percent (Perrin et al. 1982), a decrease of more than 30 percent since channelization. This indicates fishermen began targeting other species, perhaps because fishing success for largemouth bass had diminished. Mean catch rate for largemouth bass during the survey period was 0.25 fish/hour, which was similar to the catch rate during historic conditions. Angler catch rates for bream have increased by 32 percent (1.04 fish/hour), whereas catch rates for black crappie have declined by 29 percent (0.67 fish/hour).

Canals in Developed Areas

Canals in developed areas differ substantially with respect to their fish populations. Some support healthy populations of native species, while others are dominated by exotics. Many exotic fish historically existed only in canals after their initial introduction, and subsequently became widespread and variably established in some Everglades marshes and peripheral habitats. Some exotic species tolerate estuarine salinity conditions and low oxygen concentrations that enhance their ability to survive in coastal canals and rock pits (Schofield et al. 2007). Poor water quality and steep sides may make urban canals less than optimal for native fishes. These adverse conditions allow invaders to more easily establish. Highly urban canals also receive little predation pressure by wading birds or native fish due to low visitation or occurrence and may allow exotics to flourish (Loftus and Kushlan 1987).

Studies by Loftus and Kushlan (1987) indicated that some canals remained free of exotics. Their collections suggested that exotic species were not abundant in canals with healthy native fish populations. Characteristics of canal size and shape, marginal and submerged vegetation, and water quality permit native fishes to maintain their populations and perhaps prevent or delay a large-scale takeover by exotics (Loftus and Kushlan 1987).

The presence of exotic species does not necessarily have adverse effect on native species. Shafland et al. (1985) observed that an excellent largemouth bass fishery existed in Black Creek Canal (C-1) despite the presence of large number of tilapia. Most native canal fishes are primarily carnivorous, whereas most exotic fishes are herbivorous or detritivorous (Courtenay and Hensley 1979), thus exotics can consume the large quantities of algae, macrophytes, and detritus in canal system that are not exploited by native fishes (unpublished data, Loftus and Kushlan 1987). Native and exotic species may therefore be able to coexist over long periods since they are not necessarily competing for the same resources (see also Langston and Schofield 2009).

Fish Studies in Canals in Other Areas

Similar effects of channelization on fish assemblages have been documented in other systems. Tarplee et al. (1971) found channelized Coastal Plain streams in North Carolina had reduced biomass, diversity, carrying capacity, and number of harvestable sized game fishes. They also noted channelization adversely affected game fish to a greater degree than nongame fish. Hortle and Lake (1983) attributed decreased abundance and species richness of fishes in Australian streams after channelization to loss of suitable habitat (i.e., area of snags, area of slack water, length of bank fringed with vegetation). Other studies attribute reduced standing crop, density, and diversity of stream fish to decreased habitat, as well as decreased cover and shelter, food, and available spawning areas (Guillory 1979, Welcomme 1985, Sheaffer and Nickum 1986, Copp 1989, Junk et al. 1989). Karr and Schlosser (1978) suggested that as much as 98 percent of the standing crop of fishes in a river may be lost when the flood regime is altered by channelization. Jurajda (1995) concluded that reduced reproduction and recruitment of age-0+ fish following channelization was primarily due to the isolation of inundated floodplain from the main channel, resulting in loss of spawning habitat and refugia.

Birds

Dalrymple and Dalrymple (1996) found that canals served as focal point for some species, especially wading birds and other wildlife. For other bird species, such as least bitterns, they provide unfavorable habitat (Frederick et al. 1990).

Alligators

Reproduction and Development

Chopp et al. (2000) determined that hatching success and young survivorship is lower in canals. Further studies by Chopp et al. (2001, 2002a) concluded that canals were harsh environments for alligator reproduction compared to interior sites due to flooding and predation of canal nests. However, Chopp et al. (2000) suggest that canal alligators benefit from warmer canal water and better digestion rates and are therefore larger and healthier than marsh alligators. Chopp et al. (2002b) determined that alligators in the Loxahatchee National Wildlife refuge produce relatively small egg clutches compared to North Florida and Louisiana and therefore have comparatively lower annual reproduction rates. Egg position in the clutch significantly affects the probability of eggs being flooded and surviving and even small changes of nest elevation affect survivorship along canals (Chopp, unpublished data). During 2000, all canal nests flooded, while no interior marsh nests flooded.

Diet

Fogarty and Albury (1967) studied juvenile alligators from the L-38 Canal and observed that apple snails and crayfish made up the vast majority of the diet. In contrast, Barr (1997) conducted studies of alligator diets within the Everglades, primarily within Shark River Slough, and found that snakes were dominant prey of adult alligators, snails for sub-adults, and insects for juveniles. Fish were consumed far less than snakes and birds were rare in stomachs. The author suggested that canals have a different prey base and thermal gradient than sawgrass marshes. Urban canals and their alligators have a very different ecology than those associated with the Everglades.

Hydrology

Studies by Fujisaki et al. (2009) suggest that alligators are very sensitive to hydrologic conditions, even on short time scales (days). In areas that have become overdrained, alligators only occur in permanent water bodies such as canals or ponds, or during periods of extremely high water. Alligators, initially displaced by development or drainage, have ended up in canals (Meshaka and Babbitt 2005).

Migration and Distribution

Kushlan (1974) concluded that canals are the primary refugia for alligators in many areas and that many large alligators reside in canals. Studies by Mazzotti and Brandt (1994) and Chopp et al. (2000) indicated that adult alligator density was high in canals due to immigration and high adult survival rates. Canals influence alligator populations 0.6 miles into adjacent Everglades marshes. Chopp et al. (2000) suggest that canal alligators move over larger distances and have larger home ranges than alligators that reside primarily in the marshes. By contrast, Morea et al. (2000) determined that alligators in the Water Conservation Areas and Everglades National Park do not differ in home range; males moved longer distances and had wider home ranges than females and canal alligators had linearly shaped home ranges as opposed to marsh alligator home range size. Large alligators moved less and their movements increased as water levels increased. Adult alligator density is higher in canals than in the marsh and alligators living in canals preferred to stay there. Barr (personal communication) feels that alligators use canals as refugia and conduits for long-distance movements, but often forage in the adjacent marsh.

More recently, Phillips et al. (2003) monitored alligator movements with telemetry. They observed that canal alligators strongly selected canals over all other cover types. Canal alligators spend most of their time in canals and move greater distances (i.e., have larger, more linear home ranges) than alligators in the WCA or Everglades National Park marshes.

Crocodiles

Saltwater crocodiles generally prefer saline or brackish water and only occasionally occur in the freshwater canals of South Florida. Populations in Biscayne Bay and Florida Bay have been studied to some extent. Reported canal-dependant crocodiles range as far north as southern Biscayne Bay/Turkey Point. The easternmost observations of crocodiles are on northern Key Largo in old canals. The only permanent northern population is located in the warm canals in a Fort Lauderdale power plant. Crocodiles have been reported to move 6 miles inland using canals (Kushlan and Mazzotti 1989).

3. SURVEY OF SFWMD CANAL WATER QUALITY AND SEDIMENTS

Introduction

A survey of canal water quality was undertaken to accurately characterize conditions in District canals (primary canals) with respect to key water quality constituents. Water quality monitoring locations were grouped by canal into one of eight regions:

- Caloosahatchee River Basin (CAL)
- Everglades Agricultural Area (EAA)
- Lower East Coast (LEC)
- Lower Kissimmee River Basin (KIS)
- Lower West Coast (LWC)
- Upper East Coast (UEC)
- Upper Kissimmee Basin, Chain of Lakes (UKB)
- Water Conservation Areas (WCA)

These groups allowed a comparison of basic water quality within and between regions, and to illustrate variability within and between canals.

Methods

Identification of Canal Water Quality Monitoring Stations

In all, 208 canal water quality monitoring stations were identified using Google Earth EC and the ArcHydro layers identifying the SFWMD's primary canal system and active water quality monitoring stations (**Figure 11**). At these locations, samples were collected using grab samples, an autosampler, or both. The station had to meet the following criteria:

- Currently active sampling location
- Have at least one sample during the period of analysis (1999 to 2009)
- Be located directly in a primary canal

After the initial screening using Google Earth EC, a list of selected stations and associated maps were circulated among the SFWMD's Water Quality Monitoring staff, who are responsible for all District water quality compliance-related monitoring, to ensure that (1) the stations selected met the first and third conditions above and (2) that no stations that would meet the selection criteria had been omitted. The list was modified based on this review. Eight research canal stations used by the SFWMD's Everglades Division were also added to the list. It should also be noted that the District's primary canal system does not include canals in the urban areas of the Lower East Coast that are part of those areas' secondary and tertiary canal systems.

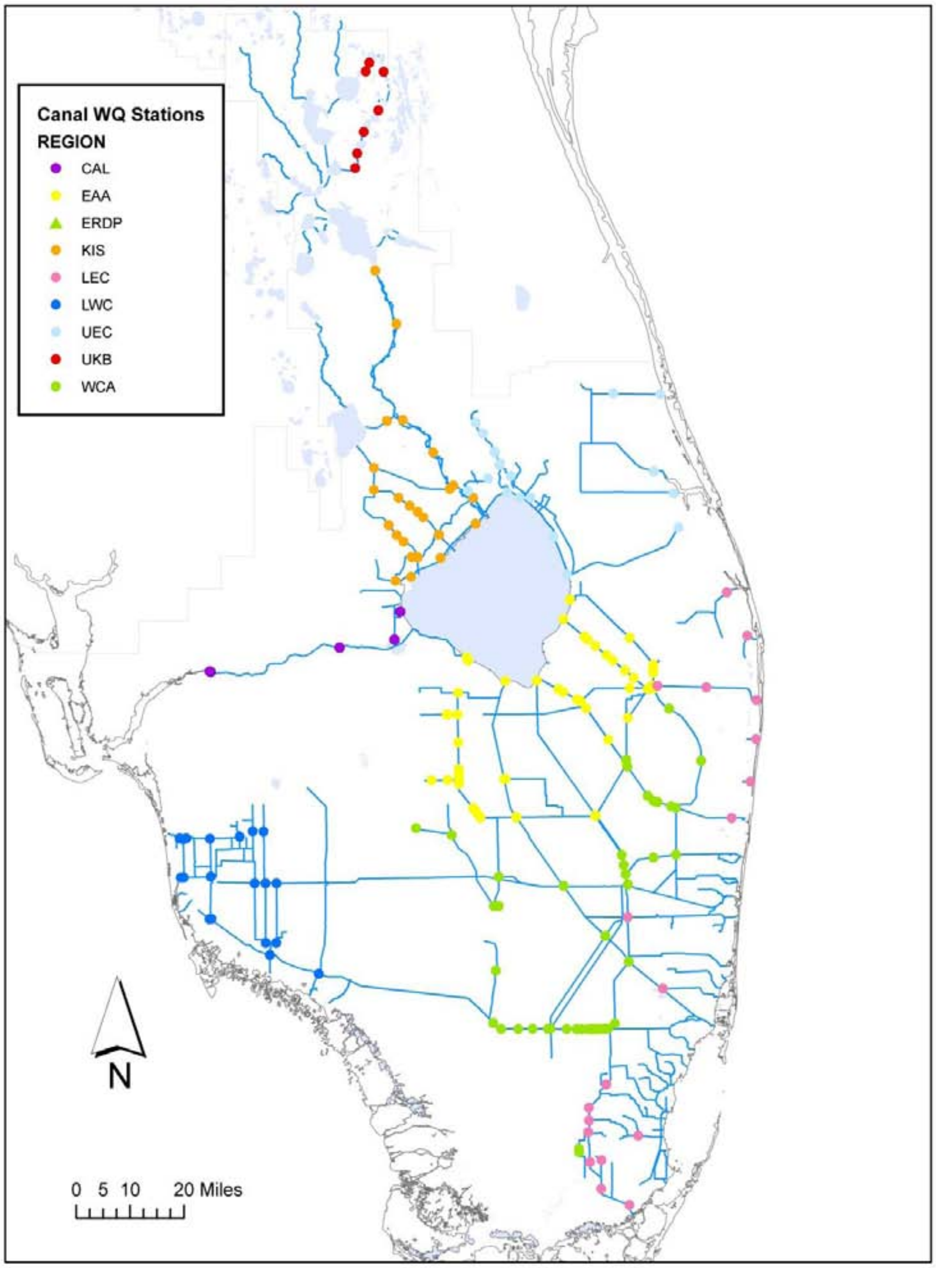

Figure 11. SFWMD monitoring locations used in this survey of water quality and the eight regional groups of stations.

Identification of Key Water Quality Constituents

SFWMD scientists and engineers participating in the Canal Science Team proposed four key water quality constituents for this analysis (**Table 2**).

Table 2. Key canal water quality constituents.

Parameter	Units	Abbreviation
Total Phosphorus	mg/L	TPO4
Total Nitrogen	mg/L	TOTN
Specific Conductance	µS/cm	COND
Chlorophyll *a* (corrected)	mg/m^3	CHLA

Period of Analysis

The period of analysis was January 1, 1999, to April 30, 2009. This period was selected to emphasize more recent water quality conditions in canals based on consistent sampling and quality assurance protocols, as opposed to examining the entire period of record for the identified stations.

Data Management and QA/QC

Water quality data for the identified canal stations and parameters were extracted from the DBHYDRO database. Concentrations that were below detection limits were assigned a value of half of the detection limit. The data were placed in an MS Access 2007 database for further review and QA/QC. The database contained 359,369 records prior to QA/QC. The database was then screened using the following QA/QC processes:

- Data that were qualified as having failed laboratory or field QA/QC tests were removed
- Data with comments indicating that the data should not be used for analysis were deleted
- Duplicate results were removed
- The minimum and maximum values of each parameter were examined for outliers to be further investigated using the SFWMD's established QA/QC procedures
- Data that showed reversals in nutrient concentration (e.g., where dissolved PO4 was greater than total TPO4) were removed

Following screening and review, 337,915 records remained. Some of those records were multiple readings on the same day at the same location. These were collapsed into a mean daily value at the location. Ultimately 331,733 records were used in this survey of canal water quality.

Summary Statistics

SYSTAT 12[4] software was used to produce summary statics to analyze the water quality data and the resulting figures follow. Corresponding tables of all summary statistics produced are provided in **Appendix F**, shown by region, canal, and station.

Water quality data can be highly variable and often skewed (non-normal distribution). Therefore, the median and geometric mean values are probably more reliable indicators of long-typical water quality conditions within the canals. The 25th and 75th percentile values are provided to indicate variability about the median and the range within which 50 percent of the observed values fell.

Results and Discussion

Regional Comparisons and Spatial Patterns

Figures 12 through **15** show the variation in the summary statistics for the key water quality parameters (**Table 2**) among the eight regions (**Figure 11**). The canal monitoring locations in the Upper Kissimmee Basin only had total TPO4 analyses, so subsequent parameter graphs only show the other seven regions.

These figures illustrate the large variation by region and unique patterns between parameters. Results for median TPO4 vary by an order of magnitude among sites and appear to related to the intensity of agricultural land use for the central and northern portions of the District (**Figure 12**). Median values of TOTN and conductivity show less variation. Most water conveyed through the canals has a specific conductance of 500 µS/cm or more (**Figure 15**), which is not surprising in part because many canals were cut through surficial soils high in limestone content. Chlorophyll *a* values are not particularly elevated in canals; all median values are about 10 mg/m^3 or less (**Figure 14**), well below the state's nutrient impairment threshold of 20 mg/m^3. In the context of high nutrient levels in the Caloosahatchee River Basin, Everglades Agricultural Area, Lower Kissimmee River Basin, and the Upper East Coast, it appears that canals are not very sensitive to nutrient concentrations.

The data show a distinct spatial pattern for both TPO4 (**Figure 16**) and TOTN (**Figure 17**). The highest values are near Lake Okeechobee and the Everglades Agricultural Area and lowest values furthest away from this central area.

Temporal Variability and Wet Season Effects

The data provide a relative comparison of data variability across the eight regions and between stations within each region. Temporal variability was high for many stations and several parameters. The interquartile ranges (size of the probability boxes) often exceeded median values indicating high variability. Variations in TPO4 were highest in the Everglades Agricultural Area and lowest in the Lower East Coast, Lower West Coast, Upper Kissimmee Basin, and Water Conservation Areas. Variations in TOTN were highest in the Everglades Agricultural Area and lowest in the Caloosahatchee River Basin. Variation associated with wet seasons was also

[4] SYSTAT Software, Inc., Chicago, IL

examined for TPO4. **Figure 18** shows the impact by region of season by comparing the wet season (June to October) TPO4 concentration summary statistics and annual summary statistics (also shown in **Figure 12**). Wet season (June to October) summary statistics for TPO4 are higher in each region and the range is higher and greater (**Figure 18**). The most obvious example of this is the wet season and annual statistics for the Upper East Coast region.

There also is considerable variation in concentration over time at each station. For example, **Figure 19** shows that variation at S8, a major pump station on the Miami Canal in the Everglades Agricultural Area. The variation and average values of TPO4 have been decreasing at this station in association with the implementation of agricultural best management practices in the mid-1990s and the completion of Stormwater Treatment Area 3/4 in 2005.

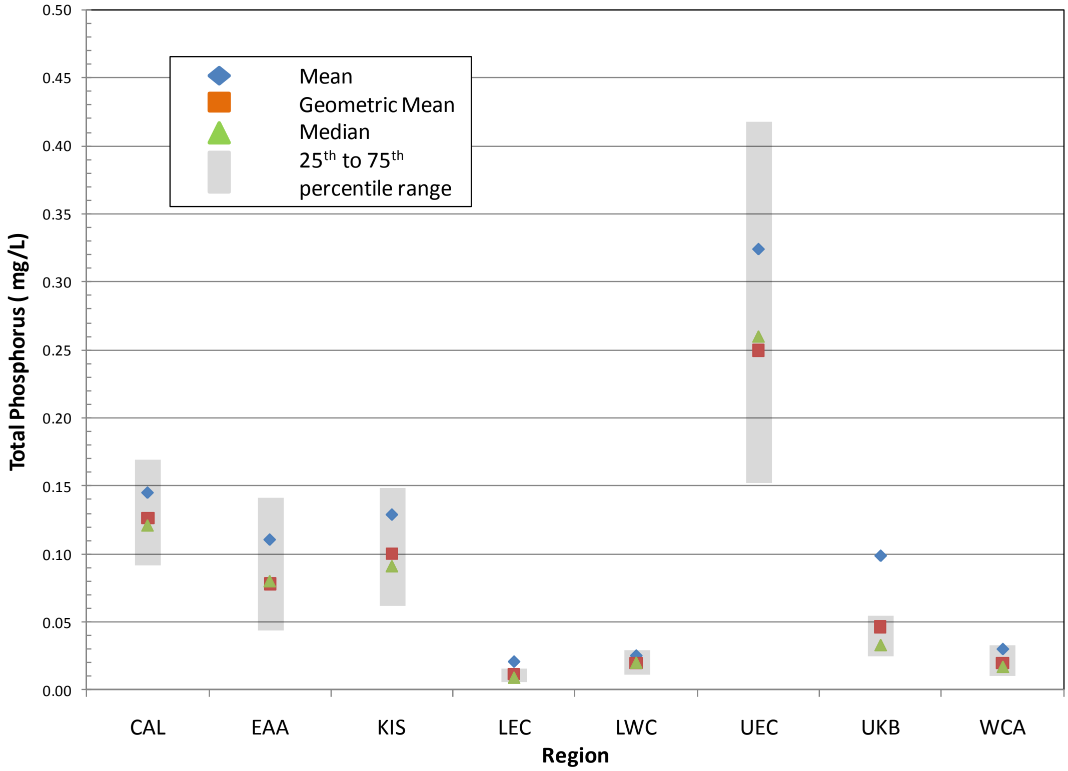

Figure 12. Total phosphorus concentration summary statistics by region.

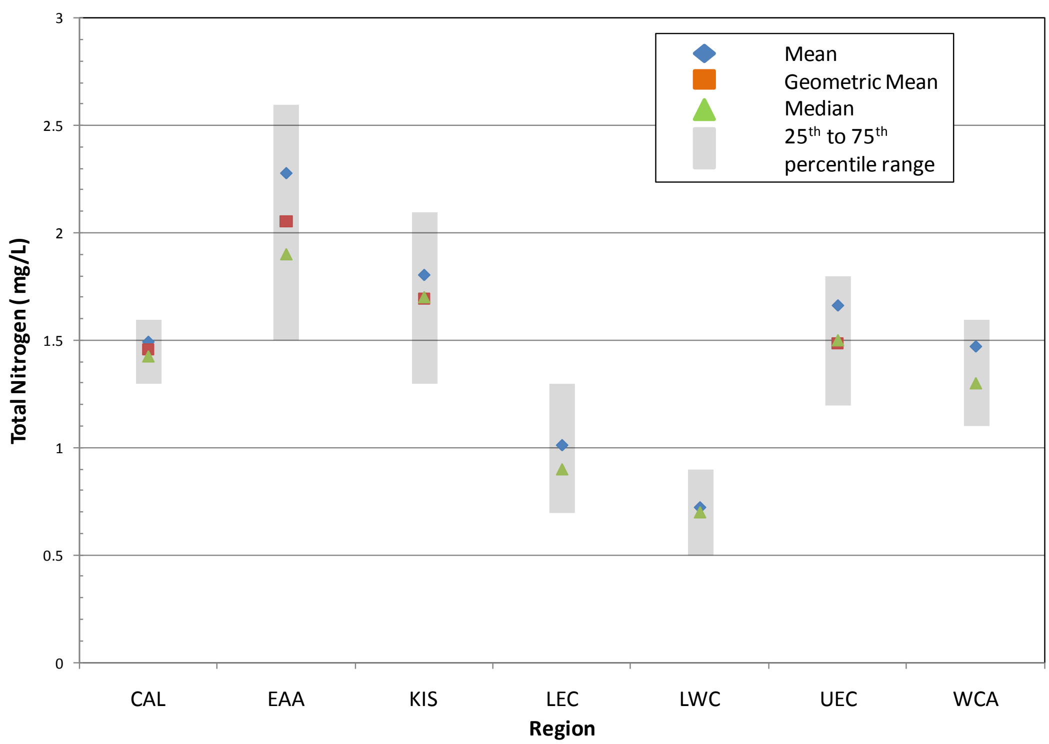

Figure 13. Total nitrogen concentration summary statistics by region.

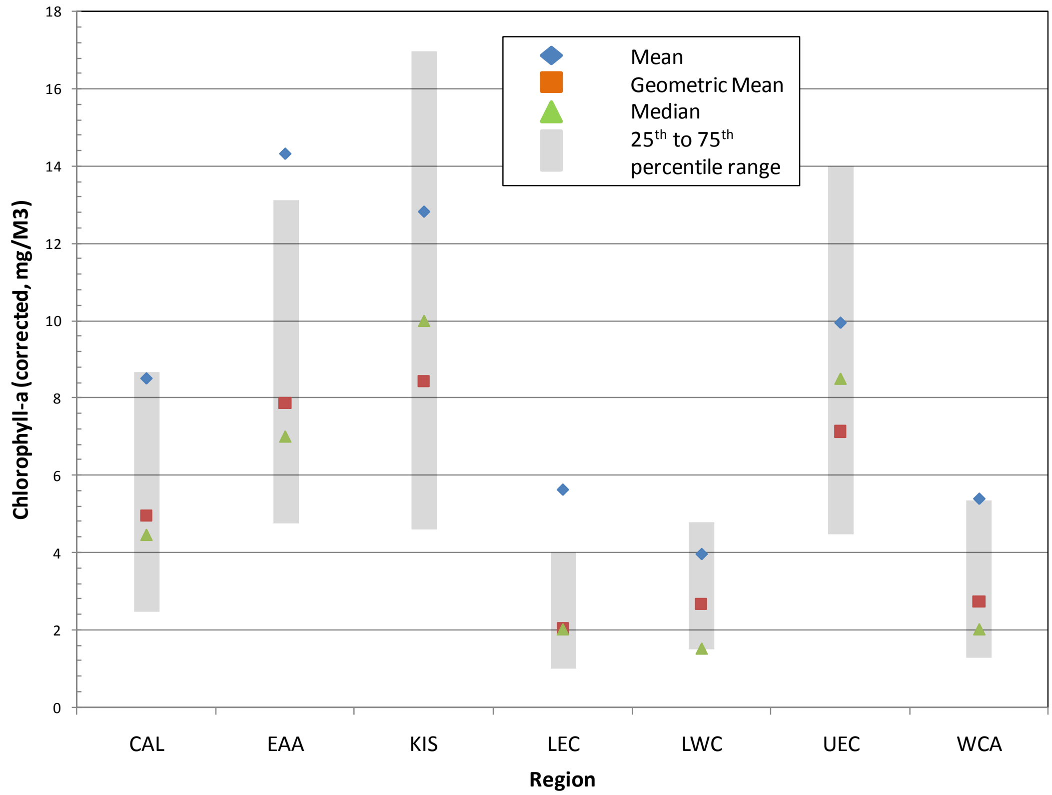

Figure 14. Corrected chlorophyll *a* concentration summary statistics by region.

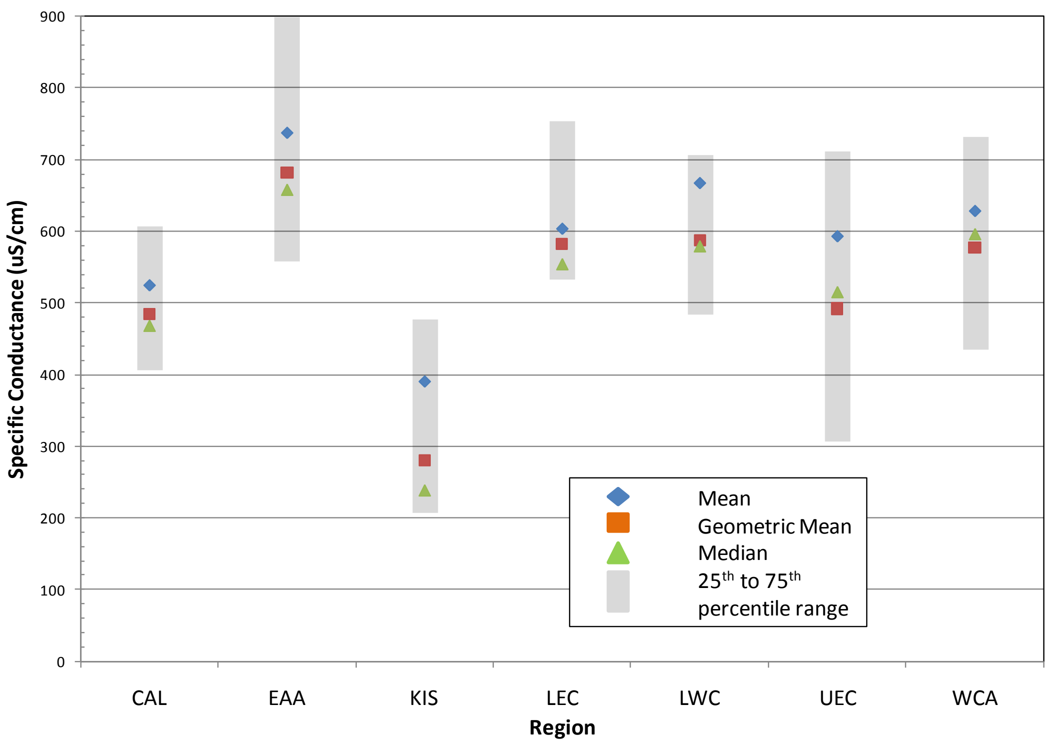

Figure 15. Specific conductance summary statistics by region.

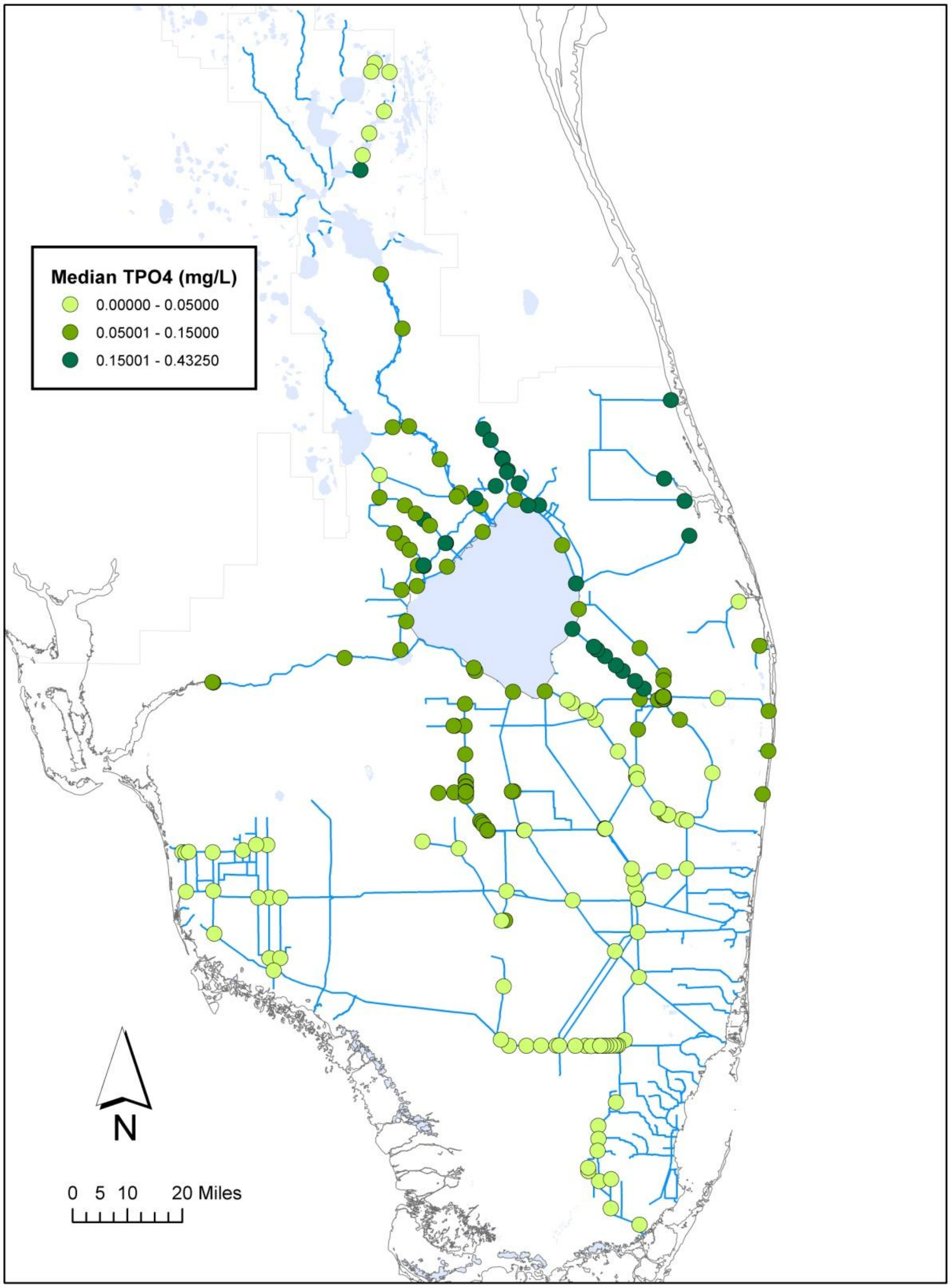

Figure 16. Total phosphorus median values.

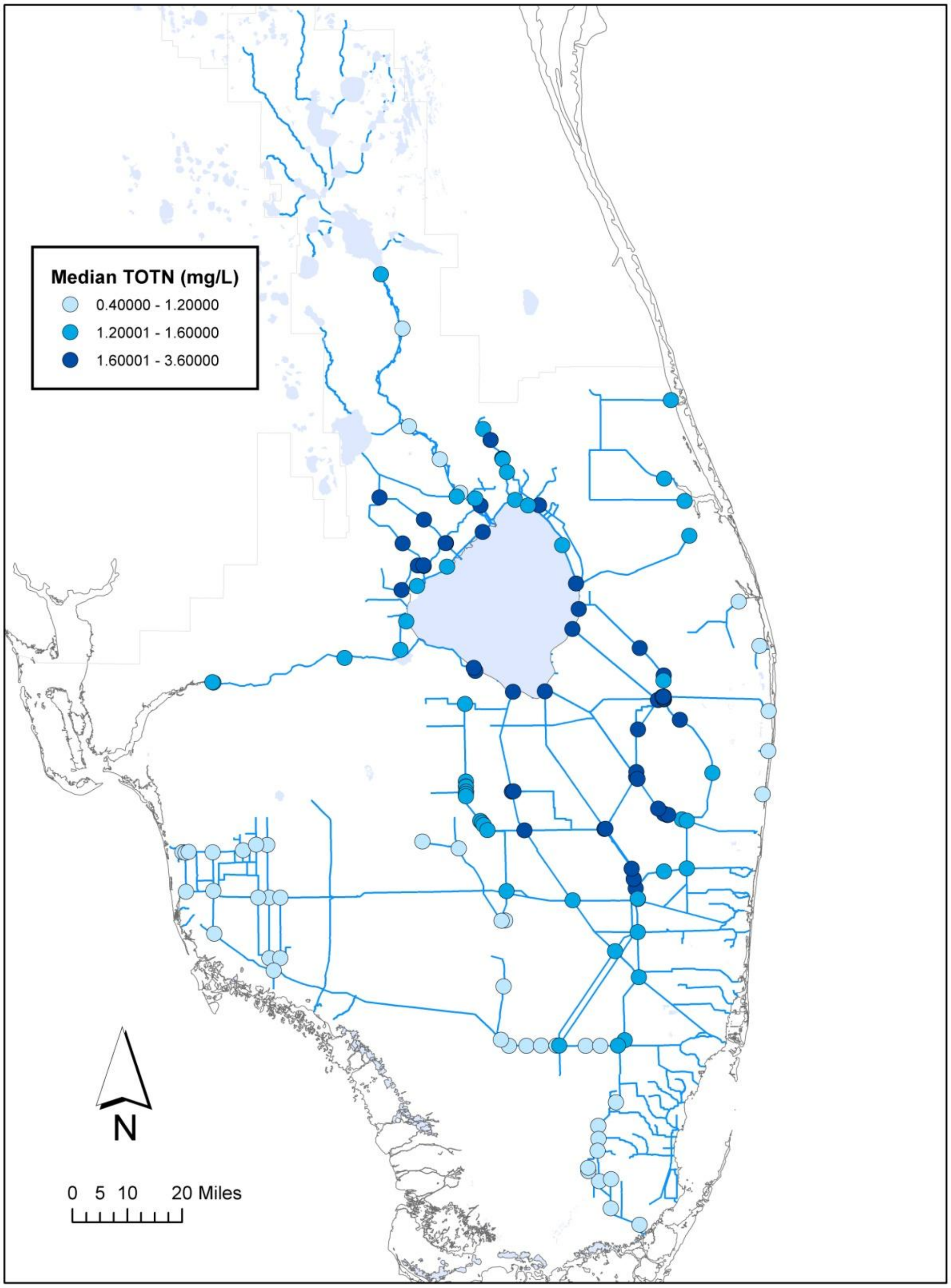

Figure 17. Total nitrogen median values.

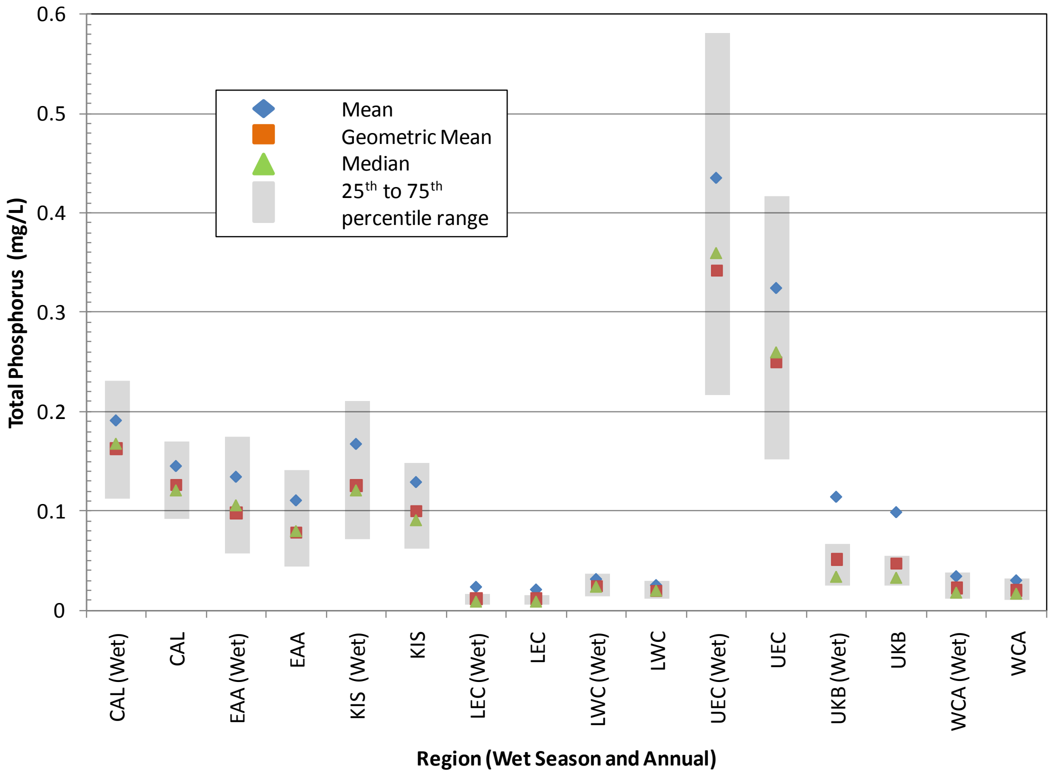

Figure 18. Total phosphorus concentration by region – wet season and annual.

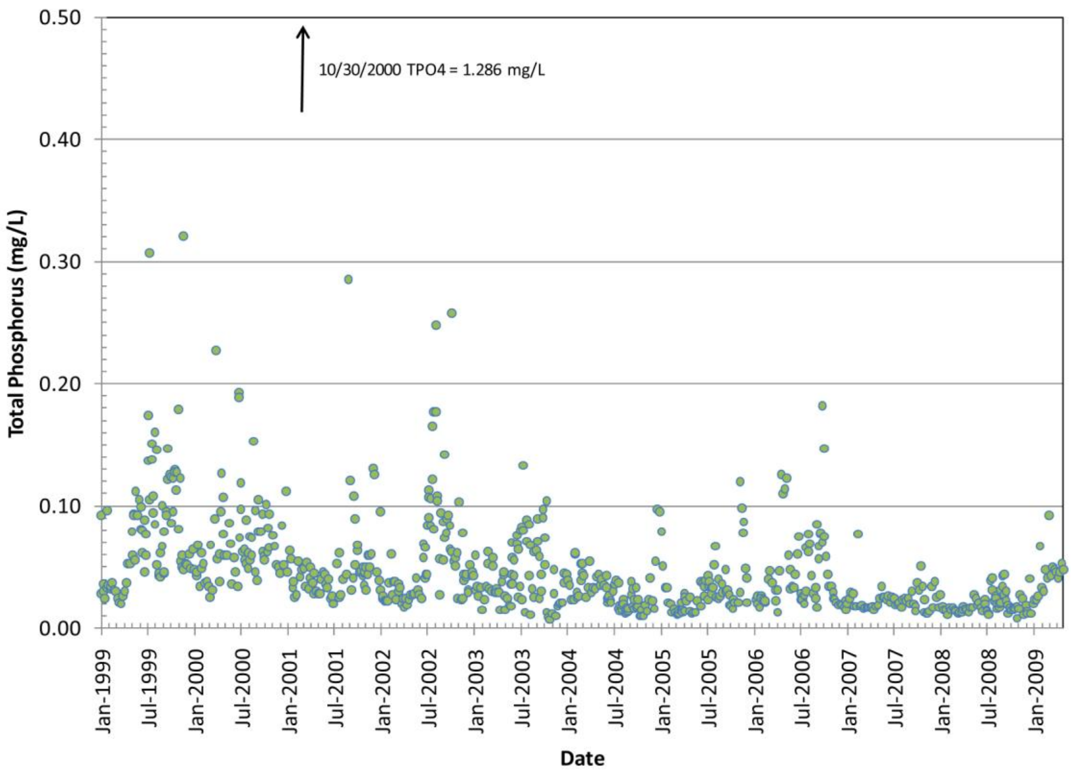

Figure 19. Total phosphorus concentrations over time at S8.

Regional Canals

Variation in summary statistics among canals within a region was also examined. Statistics for TPO4 and TOTN for canals in the Upper East Coast (**Figure 20**) and the Lower East Coast (**Figure 23**) were compared (**Figures 12 to 13** and **24 to 25**). In general, canal locations are ordered from north to south (left to right) on the plot. As noted earlier in regional comparisons, the variation of TPO4 in these regional canals (**Figures 21 and 24**) tends to be much higher than that for TOTN (**Figures 22 and 25**) and the two constituents do not correspond closely.

Canal Stations

The West Palm Beach Canal (**Figure 26**) and the Miami Canal (**Figure 29**) were used to show variation in summary statistics for nutrient (TPO4 and TOTN) concentrations at stations within each canal. These are shown in **Figures 27** to **28** and **30** to **31**. Stations are ordered from upstream to downstream (left to right). Within these canals, TPO4 (**Figures 27 and 30**) tends to change more than TN (**Figures 28 and 31**) as water moves downstream and nutrient levels tend to be higher at the more inland, upstream sites.

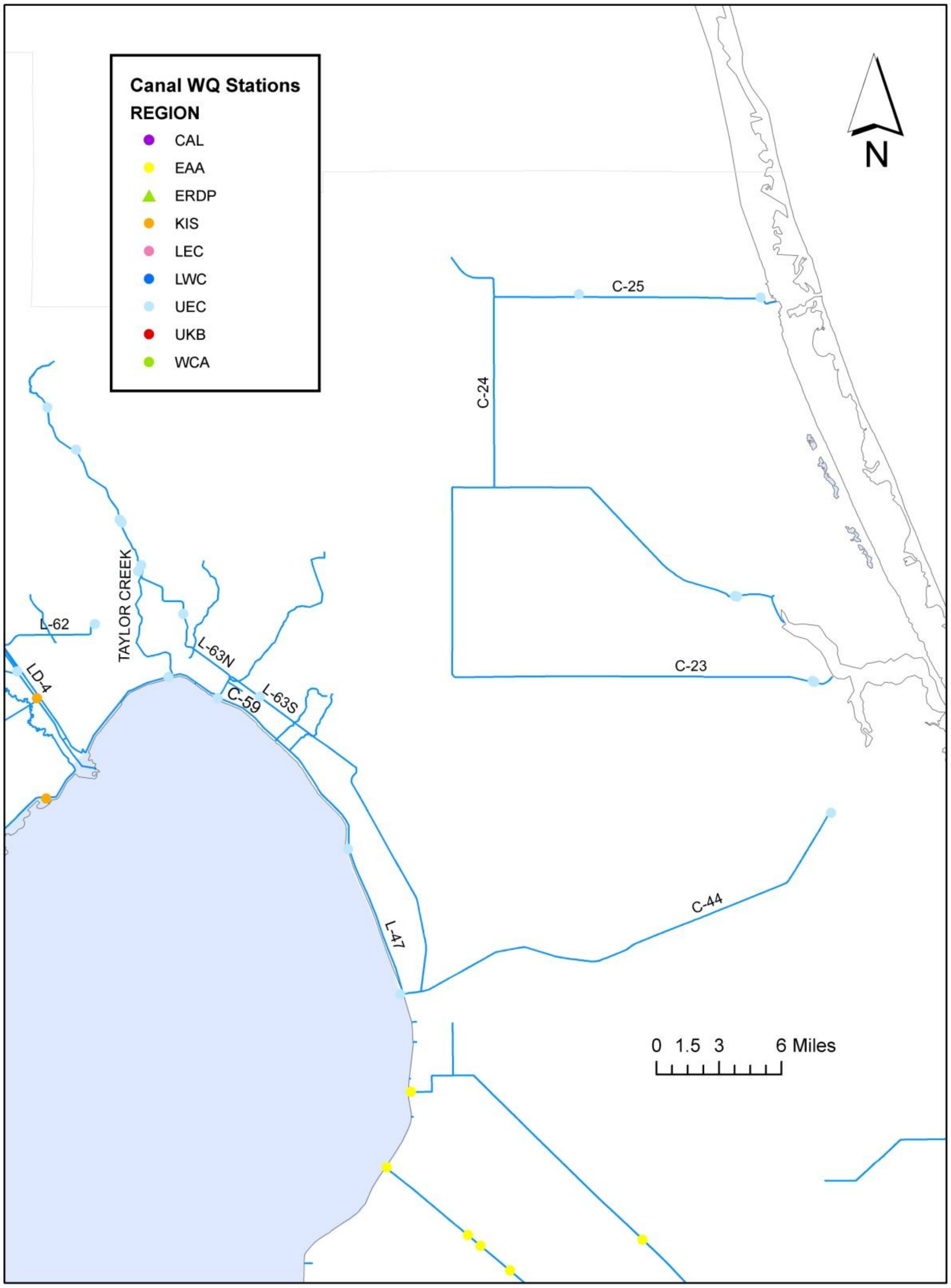

Figure 20. Upper East Coast canals surveyed in this report.

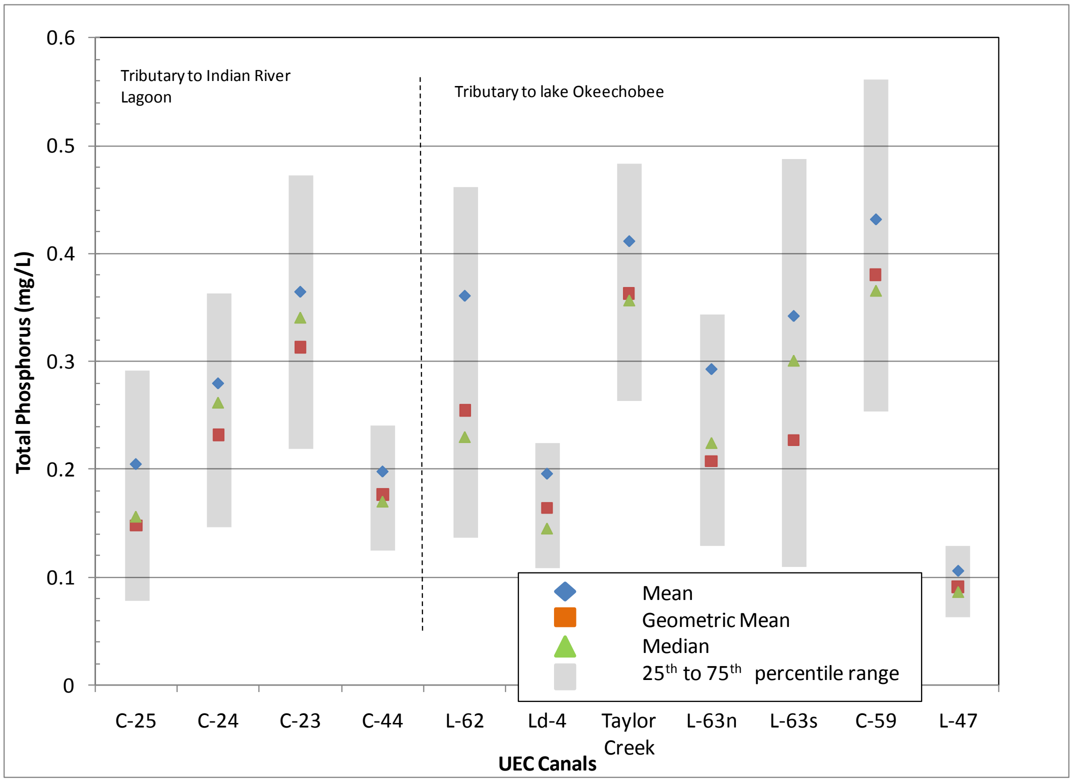

Figure 21. Total phosphorus concentration summary statistics for canals in the Upper East Coast region.

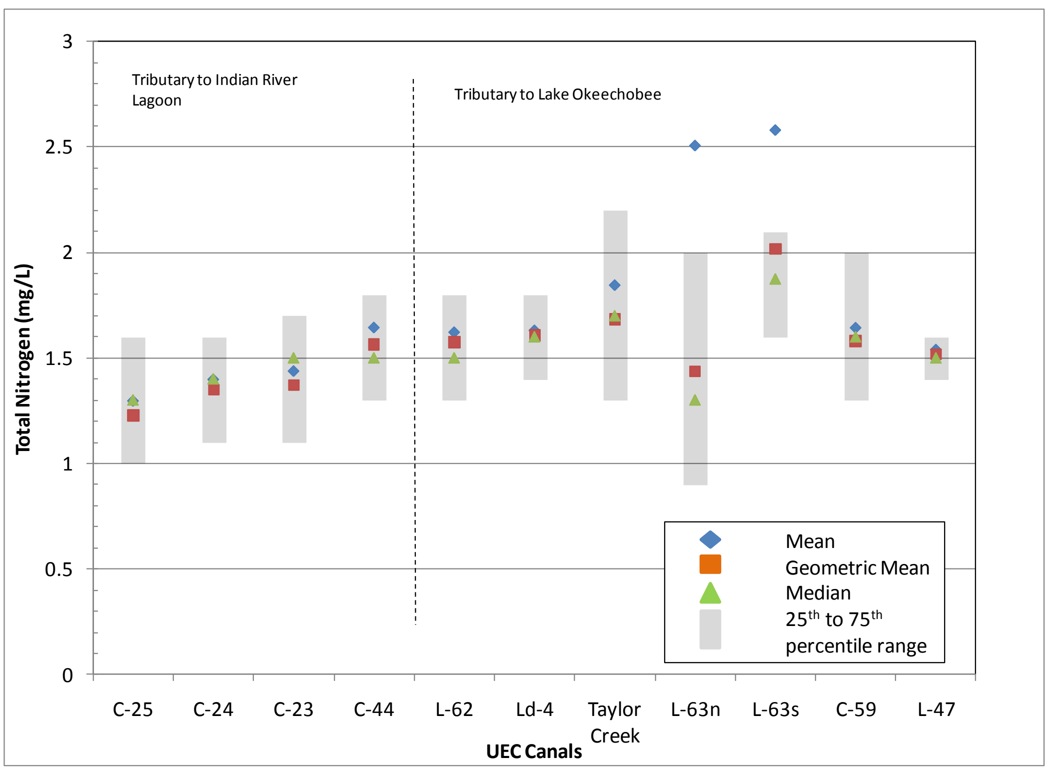

Figure 22. Total nitrogen concentration summary statistics for canals in the Upper East Coast region.

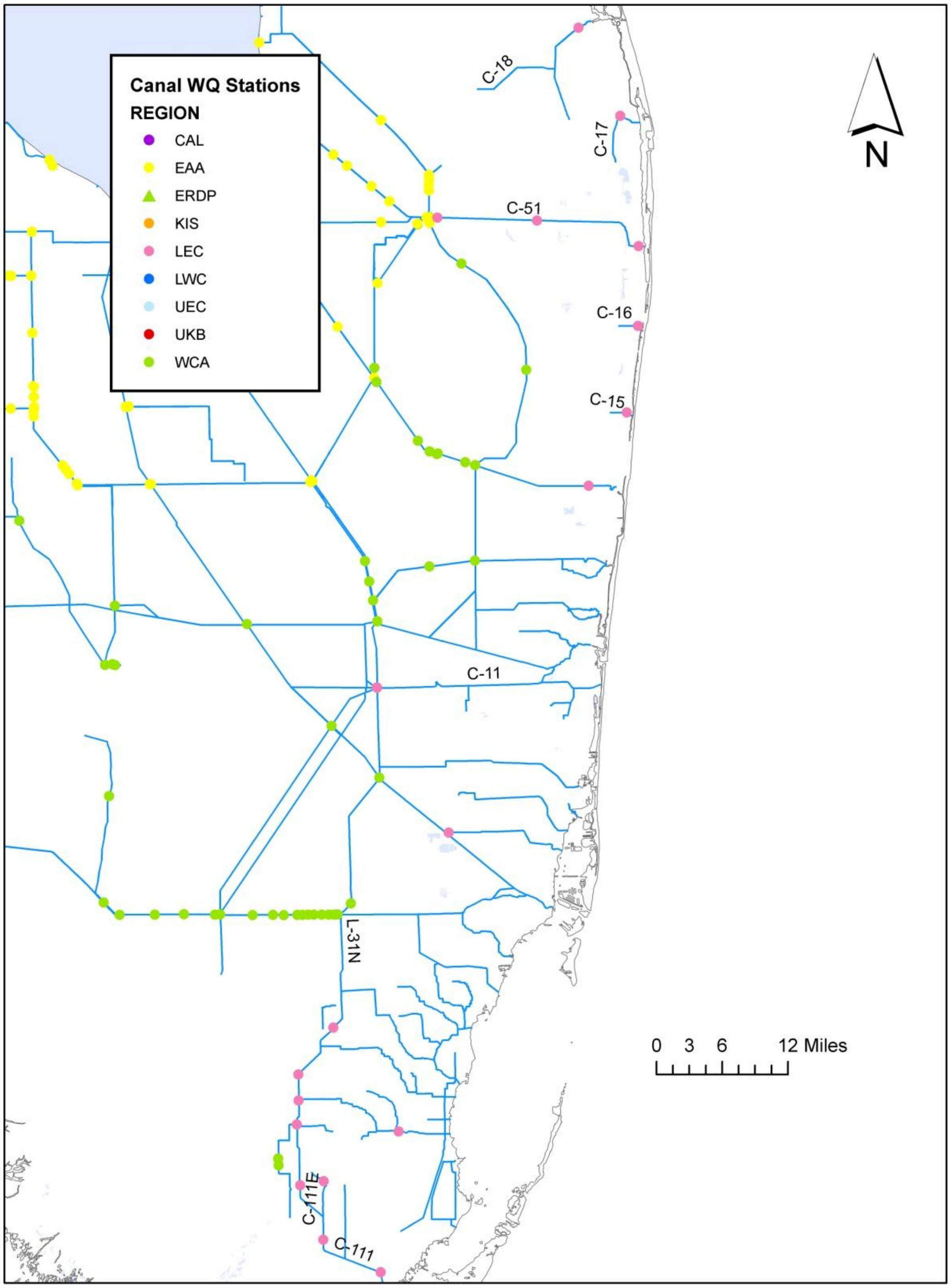

Figure 23. Lower East Coast canals surveyed in this report

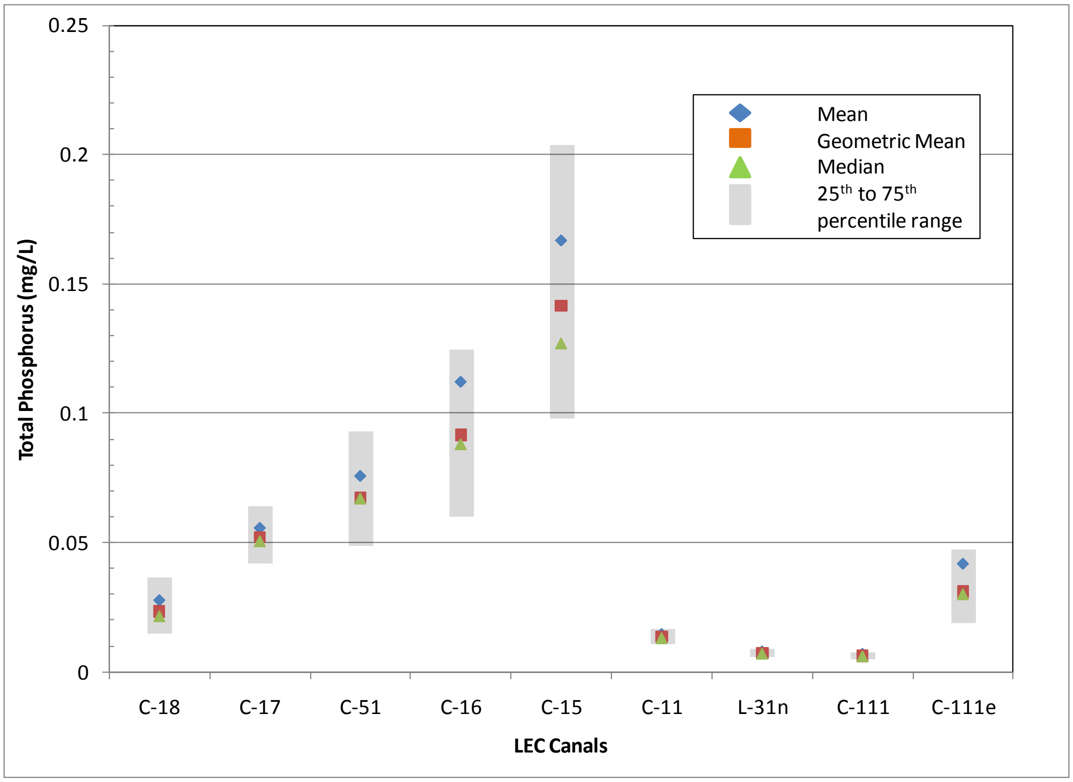

Figure 24. Total phosphorus concentration summary statistics for canals in the Lower East Coast region.

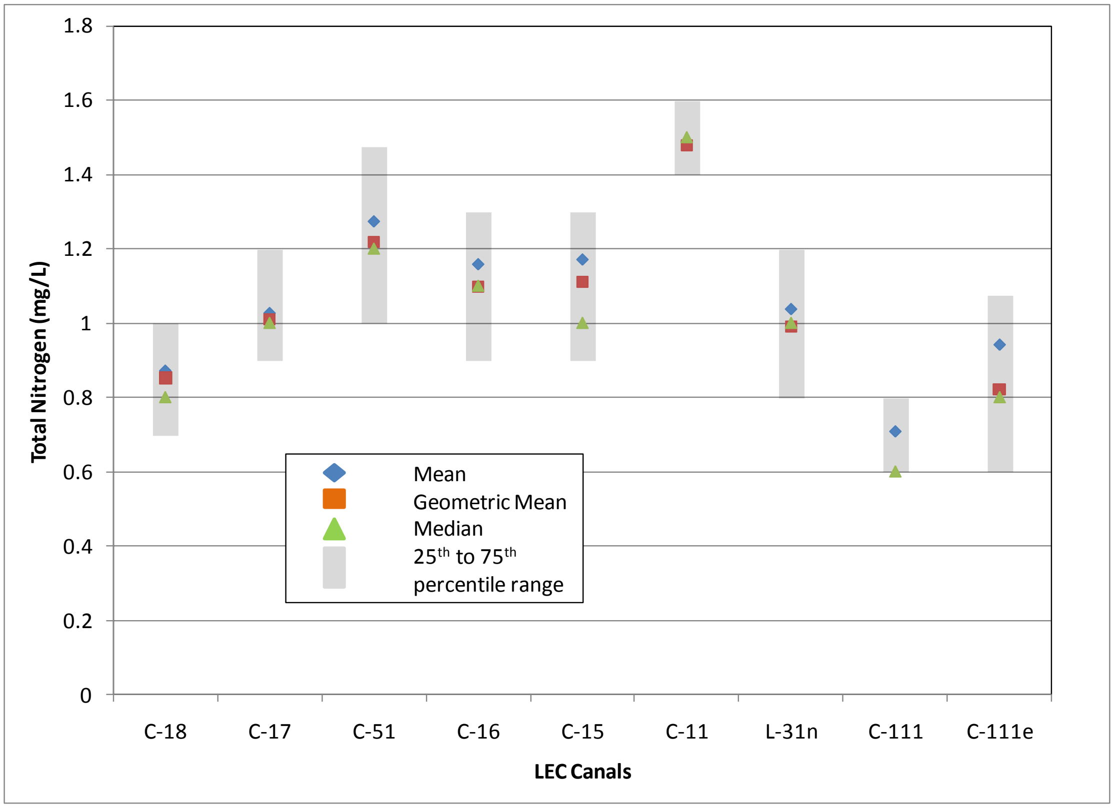

Figure 25. Total nitrogen concentration summary statistics for canals in the Lower East Coast region.

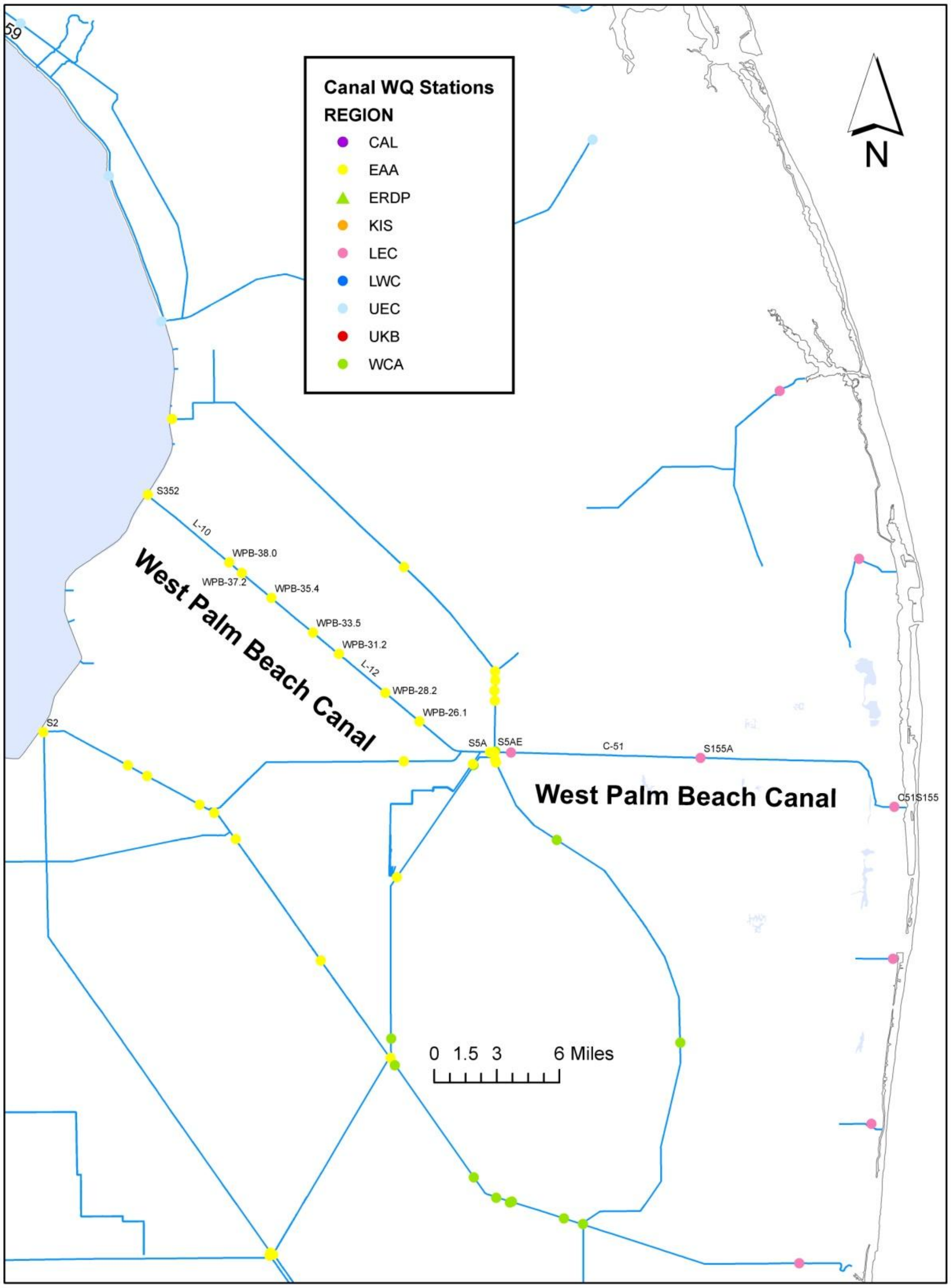

Figure 26. West Palm Beach canal stations.

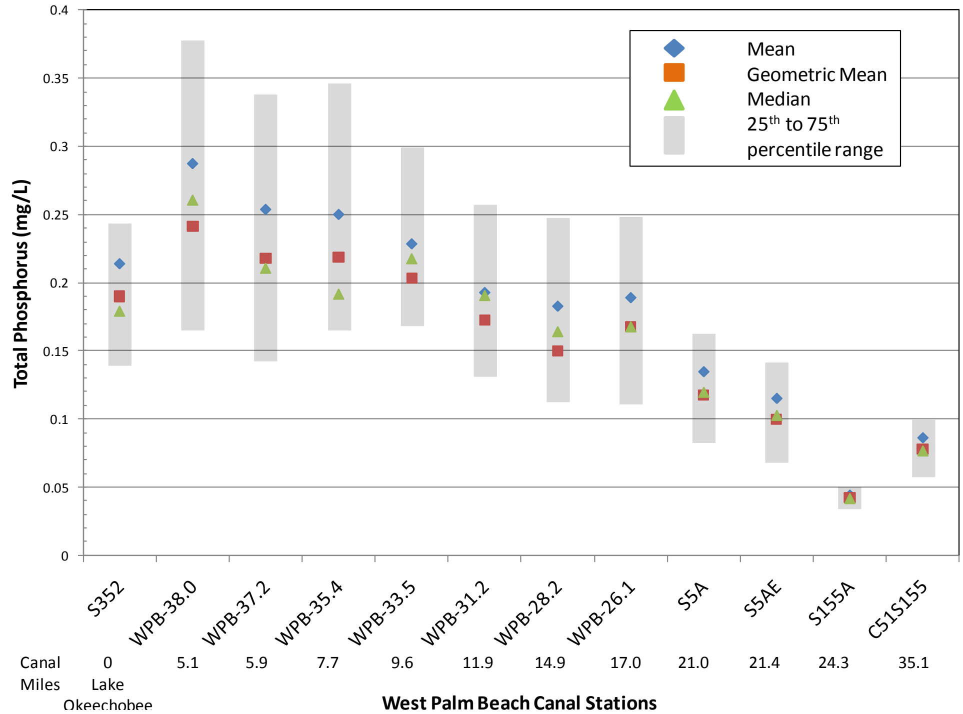

Figure 27. Total phosphorus concentration summary statistics for stations in the West Palm Beach Canal.

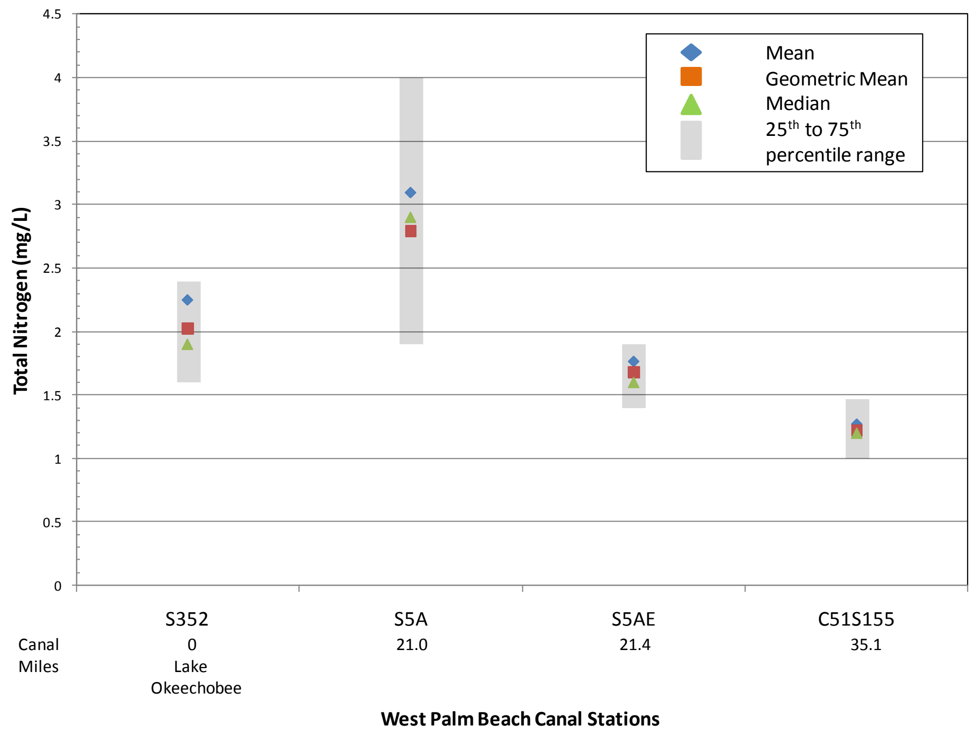

Figure 28. Total nitrogen concentration summary statistics for stations in the West Palm Beach Canal.

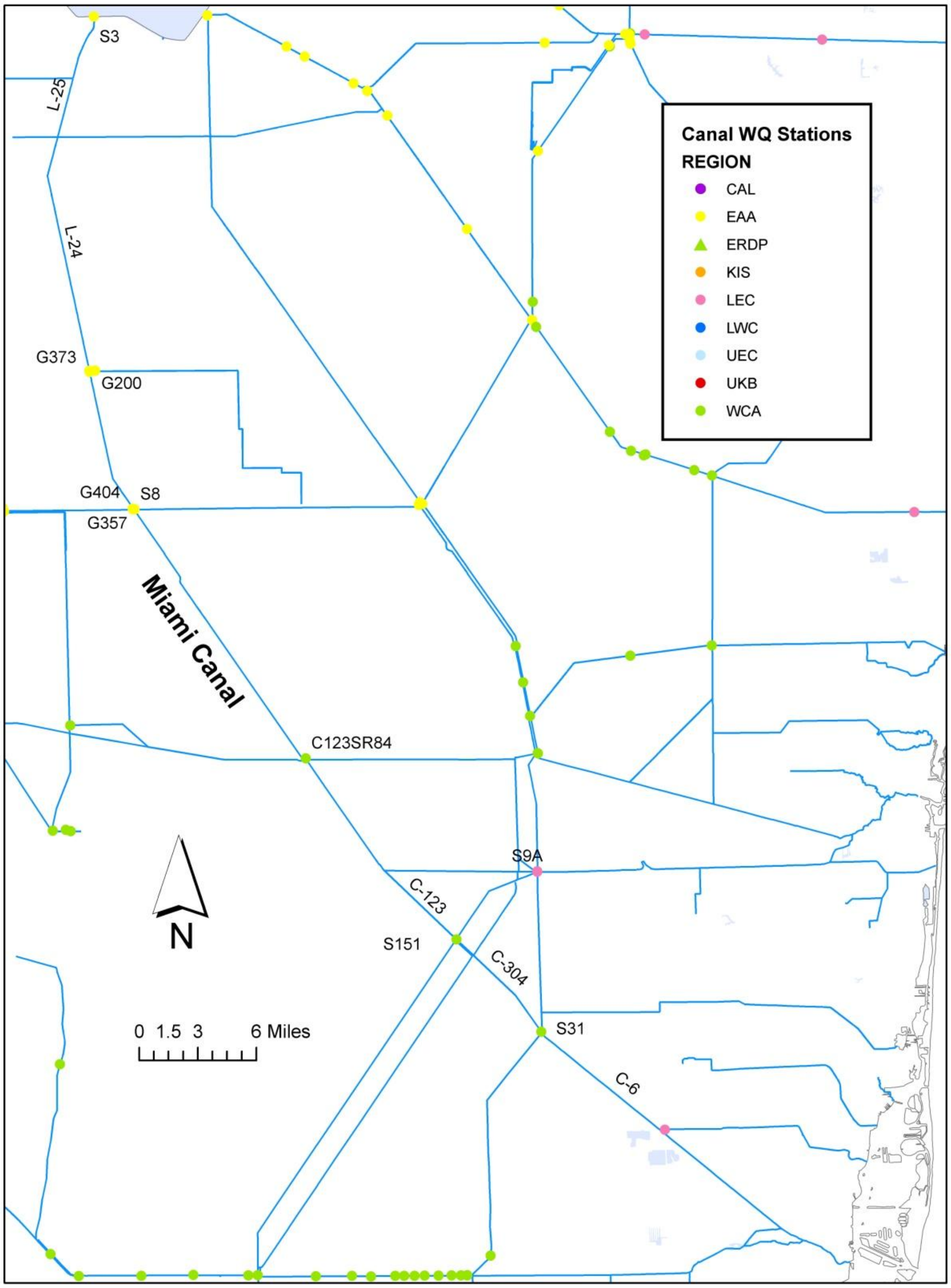

Figure 29. Miami Canal stations.

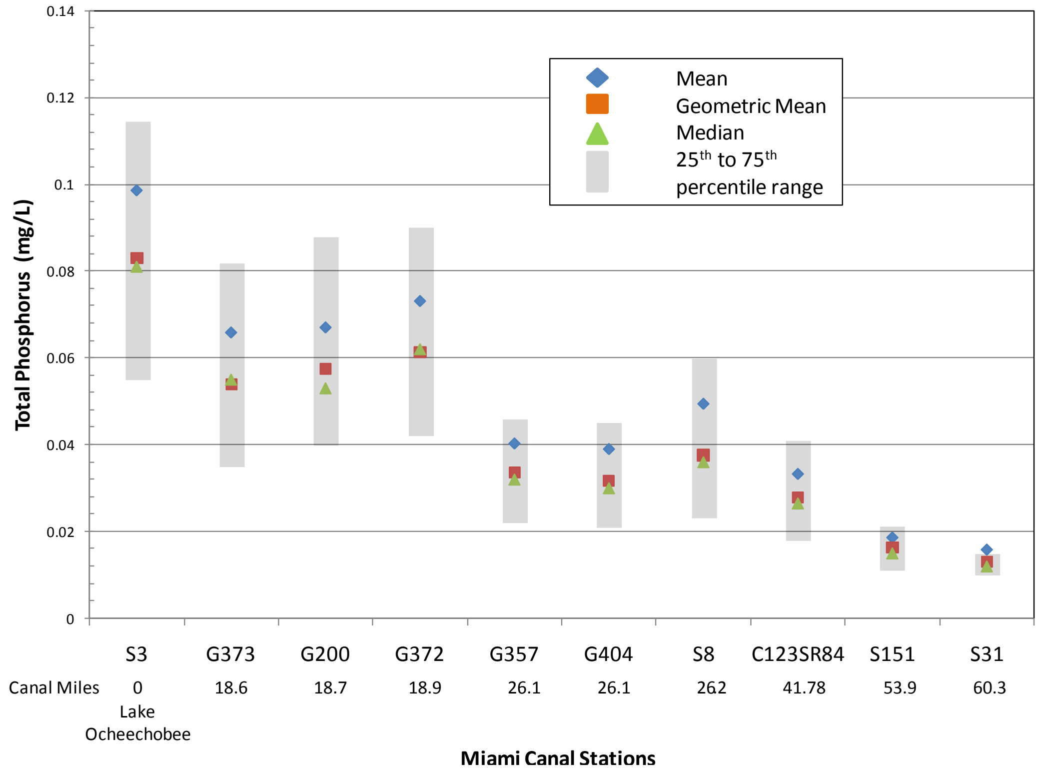

Figure 30. Total phosphorus concentration summary statistics for stations in the Miami Canal.

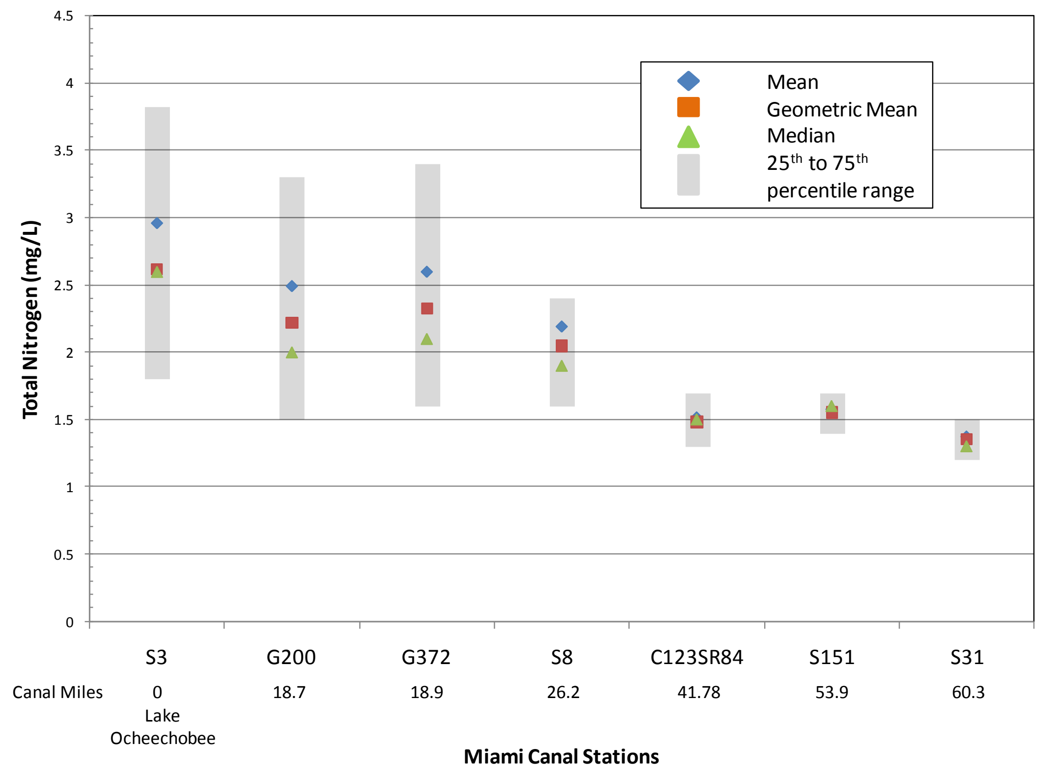

Figure 31. Total nitrogen concentration summary statistics for stations in the Miami Canal.

Summary

Water quality summary statistics for 208 stations in the District’s primary canal system were generated to examine regional, seasonal and intra-regional differences for several key water quality constituents, including TPO4, TOTN, and CHLA. Stations in secondary and tertiary canal systems were not examined since those canals are owned and operated by other entities.

Figures 12 to **15** demonstrate variation of water quality summary statistics among regions. The differences in the statistics for TPO4 (**Figure 12**) are the most obvious and fell into three broad categories determined by values of the geometric mean and median:

TPO4 $<$ 0.05 mg/L	LEC, LWC, UKB, WCA
0.05 mg/L $\leq$ TPO4 $\leq$ 0.15 mg/L	CAL, EAA, KIS
0.15 mg/L $<$ TPO4	UEC

The differences among TOTN concentration summary statistics for the seven regions (**Figure 22**) were less discernable than for TPO4. They also may not be indicative of any practical differences but can be grouped as follows:

TOTN $<$ 1.2 mg/L	LEC, LWC
1.2 mg/L $\leq$ TOTN $\leq$ 1.6 mg/L	CAL, UEC, WCA
1.6 mg/L $<$ TOTN	EAA, KIS

The affect of nutrients and other environmental variables can be seen in the chlorophyll *a* concentration summary statistics shown in **Figure 14**. These statistics were grouped as follows:

CHLA $<$ 4 mg/m^3	LEC, LWC, WCA
4 mg/m^3 $<$ CHLA	CAL, EAA, KIS, UEC

The values of all regional geometric means for chlorophyll *a* were less than 10 mg/m^3.

There appeared to be no clear grouping of summary statistics for specific conductance by region (**Figure 15**). The Lower Kissimmee River Basin had the lowest geometric mean and median values; the Everglades Agricultural Area had the highest.

Variation in the range of TPO4 values between the 25^{th} and 75^{th} percentile values increased when only wet season observations were considered in all regions (**Figure 18**). The groupings remained as described above for **Figure 12**. The mean, geometric mean, and median values for each region increased as a result of selecting only wet season values in the analysis of summary statistics.

Differences among canals within the Upper East Coast and Lower East Coast are apparent for TPO4 but less so for TOTN, although differences can be observed in the corresponding summary statistics (**Figures 21** to **22** and **24** to **25**).

Along canal reaches, there is a downward trend in the summary statistics for TPO4 and TOTN as water moved downstream in the Miami and West Palm Beach canals (**Figures 24 to 25** and **27 to 28**). Although not examined in this analysis, nutrient summary statistics are tied to land use. This is most obvious in **Figures 24 to 25** and **27 to 28**. These figures show the change in statistics from agricultural or urban areas through Stormwater Treatment Areas and WCAs to coastal ridge land uses (primarily urban and agricultural) and ultimately to tide.

Sediments

The SFWMD recognizes that sediment characteristics in canals, lakes, and wetlands are an important factor in determining the chemistry of overlying water. Numerous studies of sediments have been conducted in lakes and wetlands of South Florida. Although fewer such studies have been conducted in canals, information is available. Due to time and manpower constraints, investigations on canal sediments were not extensively searched or reviewed for this report. Two studies are included as representative of the types of additional data that are likely available. Further information concerning these studies is provided in **Appendix G**.

Trefry et al. (2009) provide one of the only detailed studies of the chemistry of canal sediments in South Florida. Bottom sediments in the West Palm Beach (C-51) Canal were analyzed in 33 locations. The average depth of sediments was about 20 inches with 5 of 33 samples in the canal having sediment depths greater than 3 feet. Water depths at these locations averaged 14 feet with shallower depths being seen upstream. No upstream/downstream pattern was evident in sediment depth. Using a suite of chemical ratios for sediments from the C-51 Canal and from Lake Worth Lagoon, Trefry et al. (2009) provided substantial evidence that downstream sediments in the lagoon within 1.2 miles of the canal terminus are derived largely from canal sediments and that canal sediments in turn, are sourced primarily from the western, agricultural portion of the canal. Terrestrial inputs upstream are an important source of organic matter in the canal and downstream in the lagoon. This observation is important as it suggests that the canal is subsidized heavily from external particulate inputs, as opposed to generating organic matter primarily within the canal food web.

A survey of canal sediments, characterizing approximately 122 miles of canals in the Water Conservation Areas was conducted by the University of Florida Institute of Food and Agricultural Sciences in 2001 (Daroub et al. 2003, Diaz et al. 2006). Canals were grouped by location into eastern (L7, L39, and L40), central (L5, L6, and L38), and western (Miami Canal North and Miami Canal South areas. Sediment samples and sediment depths were collected along transects every 1 mile down the length of the canal. Average TPO4 concentrations from surface sediments ranged from 258 mg/kg in sediment samples from the L6 Canal to 1700 mg/kg in samples from the Miami Canal South. The results of this study indicated the following:

- Sediment depths were highly variable, both across a given transect and longitudinally down any given canal. Canal average sediment depth ranged from 1.8 feet in the L6 Canal to 8 feet in the L7N Canal with a volume totaling almost 2 million cubic yards.

- Low sediment accumulation in some canals was suggested to be a result of higher flow velocities due to the canals' small cross-sectional areas, increasing the likelihood of sediment resuspension and transport during strong drainage events.
- The total sediment volume calculated for the entire 122 miles of canal reaches was almost 9 million cubic yards, with 71 percent stored in the canals from the eastern side (L7, L39, and L40) of the WCAs.
- The total phosphorus mass calculated for the entire sediment profile of all canal reaches in the WCAs was estimated to be approximately 2000 tons.
- Phosphorus fractionation results indicated that more than 80 percent of the TPO4 mass in the surface 4-inch sediment layer of all canals in the WCAs is fairly stable and may be a long-term sink for phosphorus.
- Canal sediments from the eastern side of the WCAs were low in bulk density, highly organic, and more susceptible to resuspension and transport during strong drainage events. These sediments showed higher iron- and aluminum-bound phosphorus and organic-bound phosphorus fractions, making them more susceptible to changes in redox potential of the sediments that could result in long-term release of iron-bound phosphorus to the overlying water column.

4. SUMMARY, CONCLUSIONS AND SYNTHESIS

This technical support document is intended to convey existing information on the nature and ecology of canals in South Florida. This information can facilitate prudent management of these unique resources while it supports FDEP's and USEPA's efforts to develop water quality criteria for canals and FDEP's efforts to revise the existing designated use classifications of Florida waters. The document summarizes a preliminary survey of information available on the water quality and ecology of the primary water canal system in southern Florida. The compilation encompasses published literature, agency reports and original data derived from searches of information from cities, counties, municipalities, and universities. The document was assembled and edited by a team of scientists and engineers at South Florida Water Management District, West Palm Beach and this team intends to continue adding information on canals for future versions of the report.

The South Florida Canal System: History, Function and Diversity

History

- The primary water management system in South Florida consists of the canals and management features operated by the SFWMD and the USACE, as opposed to secondary and tertiary systems that are managed by local governments, special districts, or private landowners.
- Initial canal construction focused on needs for navigation, drainage, and flood control. Construction of canals in South Florida began in the Kissimmee River watershed in the late 1800s with the digging of channels to connect lakes in the upper Kissimmee basin, channelization of the Kissimmee River from Lake Kissimmee to Lake Okeechobee, and construction of a channel to connect Lake Okeechobee to the headwaters of the Caloosahatchee River.
- Construction of canals south of Lake Okeechobee began in the early twentieth century. Initial efforts focused on drainage of lands for agricultural development. The key primary canals were complete by 1917.
- Improvements were added from the 1920s to the 1950s to provide services to urban areas along the coast, increase flood protection, and reduce the potential for damage from hurricanes. Water supply became a major issue in the mid-twentieth century.
- Beginning in the 1970s and continuing through the end of the twentieth century, additional emphasis was placed on improved management of environmental resources and ecosystem restoration across the region.

Design and Function

- Canals are designed and managed to meet human and natural system needs. Canals primarily maintain appropriate water levels and convey water from areas that have too much water and toward areas that have too little and move water for discharge to tide or into areas where it can be conserved.

- Most canals provide limited habitat for aquatic plants and animals. In some locations, canals serve an important ecological function by providing deepwater refugia during dry periods and some canals provide highly productive recreational fisheries.
- Primary canals in South Florida were constructed to collect water from secondary systems, convey water over long distances, provide interconnections among storage areas, and in the process, provide regional drainage, flood control, and water delivery.
- Storage areas and flood prone lands are often surrounded by protective levees. “Borrow” canals are constructed adjacent to the levees to provide the necessary fill and often serve as components of the primary water management system.
- Canals that were constructed for one purpose have been subsequently modified and improved to meet other needs. For example, the original regional canals extending south of Lake Okeechobee were intended to provide drainage for adjacent lands and for transport of agricultural products to the coast. Later they were enlarged to improve flood protection and subsequently further modified with the placement of control structures to enhance water supply capabilities for man and the environment.
- Efforts to restore degraded environmental resources, notably in the Kissimmee River, Lake Okeechobee, and the Everglades, are underway and will result in further refinements to the primary canal system.

Diversity of Canals in the South Florida Water Management System

Developed over the past hundred years, the canal-based water management system in South Florida is one of the world’s largest and most complex civil works projects. Over 1300 water control structures, 64 pump stations, and 2600 miles of canals have allowed the South Florida Water Management District to provide flood control, water supply, navigation, and environmental management over its 16 county, 17,000 square mile watershed.

Canals of the SFWMD differ greatly in their design and operation, depending primarily on the land use and development within the basin. Land uses range from areas that are completely surrounded by natural wetlands, such as those within the Water Conservation Areas or the Kissimmee River Floodplain, to areas that are surrounded by intensive urban development, such as coastal canals in Miami-Dade and Broward counties.

The diversity of our canals is reflected in many observations documented in this report:

- Water quality conditions in canals are affected by surrounding soil conditions, topography, groundwater interaction, and land uses. In some areas, notably eastern Miami-Dade and Broward counties, water quality in the canals is strongly influenced by direct interactions with groundwater.
- Soil types surrounding canals range from sandy upland soils of the Atlantic Coastal Ridge to hydric sands, marls, and peats of the Everglades.
- Topography differs across the District, resulting in differences in canal depths, water levels and flow rates. Water level elevations in canals range from 20 to 60 feet above sea level in the Kissimmee and Istokpoga basins to less than 10 feet above sea level throughout most of Miami-Dade, Broward, and Monroe counties.

Upper and Lower Kissimmee Basins

- Canals in the Kissimmee Basin were initially constructed to provide drainage and navigational access between lakes in the region and the Kissimmee River. They also lowered water levels, drained wetlands, and made the adjacent lands suitable for agriculture and development.
- Today, the primary water management system in the Upper Kissimmee River Watershed consists of a network of 15 canals that range from 0.2 to 4.5 miles in length for a total length of over 30 miles. Water levels and flows in some of these canals are controlled by nine primary water control structures that allow for the transfer of water in response to local needs and regulation schedules.
- The Lower Kissimmee and Lake Istokpoga Watershed includes 20 basins that reflect large areas of open land, rangeland, citrus groves, and cropland. These basins eventually discharge to Lake Okeechobee, either directly or via the primary canal system.
- The C-38 Canal was constructed by the USACE through the Kissimmee River floodplain to alleviate flood conditions and improve navigation. In recent years, sections of the C-38 Canal have been filled, structures removed, and water levels and flows managed as part of the Kissimmee River Restoration Project. Restoration has resulted in significant improvements to biological resources throughout the region.
- Three major canals and structures south of Lake Istokpoga provide drainage and flood control, convey excess water to Lake Okeechobee, and distribute water to agricultural lands during drought.

Everglades Agricultural Area

- The area within the Everglades Agricultural Area, directly south of Lake Okeechobee has been drained, developed, and managed mainly for agricultural and urban use since the early 1900s.
- Nine water management basins within the area have a total area of 1181 square miles and are served by 15 primary canals and 25 water control structures. This infrastructure provides drainage, flood control, and water supply for croplands, local communities, and Stormwater Treatment Areas, as well as conveys water supply and regulatory releases to the south.

Water Conservation Areas and Everglades National Park

- The WCAs and Everglades National Park basin is predominately wetlands with peat or marl soils and isolated upland areas. The 3060 square mile area is served by 18 levees, 5 primary canals, and 60 water control structures.
- The major regional canals that originate in Lake Okeechobee and pass through the WCAs distribute water to balance the water management needs of the WCA marshes, Everglades National Park, Lake Okeechobee, and adjacent watersheds.
- Peripheral canals in this broad area are often associated with levees that define the edges of storage areas. Delivery of water to the WCAs and Everglades National Park is

constrained by multiple management considerations in the upstream watersheds and subject to balancing demand and supply.

Upper East Coast

- The Upper East Coast includes seven canal drainage basins, the Tidal St. Lucie River, and the North Fork of the St. Lucie River. The primary water management system consists of 12 canals and 15 structures that control water distribution, level, and flows for 853 square miles of Martin, St. Lucie, and Okeechobee counties.
- Land use in this area is primarily agricultural, consisting of citrus, crops, and cattle. Urban development includes the cities and areas surrounding Stuart, Fort Pierce, Indiantown, and Okeechobee. Large areas remain undeveloped natural pine forested uplands, oak hammocks, wetlands, rangeland, or unimproved pasture.
- The primary canals in this basin (C-44, C-23, C-24, and C-25) have a total length of about 104 miles. They also provide drainage for agriculture, urban or residential development, and regulation of groundwater levels. Most of the canals supply water for irrigation during periods of low natural flow.
- The C-44 Canal connects to the St. Lucie River and serves as an outlet for excess water from Lake Okeechobee and is the eastern leg of the Okeechobee Waterway. Excess flows from the enlarged watershed as well as periodic releases from Lake Okeechobee have resulted in extensive erosion of the canal banks and significant stress to the St. Lucie Estuary.

Lower East Coast

- Canals in the coastal areas of Palm Beach, Broward, and Miami-Dade counties were designed to provide flood protection, deliver water needed for urban and agricultural use, and prevent saltwater intrusion.
- Most of the area is covered with hydric soils, except for areas near the coast that are underlain by a limestone rock ridge. These counties are very flat and most of the sub-basins are less than 20 feet above sea level and many areas are five feet or less.
- The eastern sections of these counties are underlain by the important Biscayne Aquifer, which is closely linked to surface water and is extensively used as a source of drinking water by utilities and homeowners. Many of the canals are cut into the rock of the underlying aquifer, providing for a direct and continuous exchange of surface and groundwater.
- The four primary regional canals that transect this basin are connected to the Everglades and Lake Okeechobee and provide an outlet to remove excess water from the Everglades and the lake during wet periods.
- The South Dade Conveyance System is a sub-regional network of canals and control structures that connects several basins in southern Miami-Dade County and is used to provide flood protection and supply water for urban and agricultural use and for delivery to Biscayne Bay and Everglades National Park.

Caloosahatchee River Basin and Collier County

- The original, natural Caloosahatchee River system has been significantly modified by channelization, connection to Lake Okeechobee, and construction of navigational locks. Three structures and 41 miles of the C-43 Canal now provide the primary water management for the basin.
- A number of water quality, water quantity and environmental issues within the river and its watershed influence how water releases from Lake Okeechobee are managed and downstream structures are operated.
- Outside of the City of Naples and Golden Gate Estates, most of western Collier County is developed for agricultural use. Most of eastern Collier County is undeveloped and large areas are preserved under jurisdictions of state and federal government agencies.
- The primary canals are managed by the SFWMD/Big Cypress Basin Board. The primary water management system consists of 20 canals spanning 162 miles with 46 water control structures.

Analysis of Biological Data from South Florida Canals

The Ecology of South Florida Canals Is Complex and Dominated by Physical Processes

Natural systems are periodically disturbed through natural processes (i.e., droughts, fires, floods, hurricanes, etc.) and biological communities in a particular ecosystem reflect such disturbances. By contrast, canals are disturbed almost continually by human interventions for maintenance including herbicide application, mowing, dredging, removing obstructions, and mechanical harvesting. As a result, plant and animal communities in canals are often dominated by stress tolerant and pioneer species, although such information is very limited compared to natural streams.

As artificial conveyances with large variations in flow and water turnover, canals provide a less stable and predictable environment than other flowing waters. Canals are part of a large water management system, and must convey large quantities of water during storm events. They do not have the floodplains that natural streams have to reduce the energy (e.g., flow and velocity) of high flow events, and instead have levees that keep flows in the channel. They are susceptible to channel erosion and the delivery of larger volumes of water and contaminant loads downstream than natural streams and wetlands. At the other extreme, during droughts and dry season operations, canals may have little or no water movement for long periods, acting somewhat like reservoirs or slow moving rivers. Taken together, these observations paint a picture of complex dynamics and constant change for canals. Plants and animals in canals must cope with the characteristics of rivers at times, those more akin to reservoirs at other times, and occasionally, those associated with fast, deep lowland rivers during runoff events.

An initial review of key studies of animals that live in South Florida canals was conducted. Primary emphasis was placed on studies of macroinvertebrates, primarily insects that used standardized FDEP methods developed in the 1990s. A number of studies of other organisms, notably fish and alligators, in and adjacent to District canals were also summarized.

Macroinvertebrate Communities in Canals

Information was gathered from FDEP data on 156 canal sites south of Orlando, collected as part of a bioassessment program established in 1992. Of the 156 sites, 60 were located in the southern portion of the peninsula bioregion within the SFWMD, and 16 were in the Everglades bioregion. Fourteen stream reference sites are within the southern peninsula bioregion, but there are none south of the lake. A summary of data on these South Florida sites reveals:

- Canals have diverse communities of macroinvertebrates that were typical of flowing water systems with lower topographic gradients, deeper channels, and lower velocities compared to natural streams. For canal sites, there were no obvious differences between the Everglades and peninsula bioregions.
- There is inadequate data available to assess effects of water quality, including nutrients, on macroinvertebrate communities in canals. Habitat quality appeared to be an important factor that influences the quality of macroinvertebrate communities in canals.
- Among the 14 stream reference sites in South Florida, there were differences in some condition metrics but not in others. Differences between sites in the eastern and western zones were seen and may be due to zonal differences in gradient, depth, and velocity.
- Canals do not achieve the same level of biological quality as natural streams, due perhaps to channelization effects on habitat quality, depth, and temporal dynamics in velocity.
- Additional information will be needed if we are to define sensitive measurements and a quality threshold applicable to low gradient streams and canals in the peninsula and Everglades bioregions.

Other studies conducted in South Florida – in Miami-Dade County, Lee and Collier counties, Reedy and Bonnet creeks near Orlando, and agricultural canals surrounding lake Okeechobee – tend to confirm these findings:

- Invertebrate communities in canals were of lower quality than natural streams, but had similar species composition.
- Surrounding land use and habitat quality were key drivers of invertebrate community condition. Sites followed a pattern of increasing disturbance from wetlands → agricultural → suburban →urban/industrial.
- By their physical nature, canal systems are significantly different from streams. Canals cannot be expected to span the full range of scores found in streams, even in expected ‘reference canal’ habitat conditions.
- There are insufficient data to establish ecological expectations for canal systems. Additional sampling may eventually provide a basis to formulate a Canal Condition Index, and consider factors such as ecoregion and unique flow conditions.
- Improvements in water quality (decreases in phosphorus and nitrogen concentrations over time) do not necessarily affect the quality of macroinvertebrate communities. Habitat quality is more important than water quality.

- Macroinvertebrate communities in canals were diverse and were typical of communities found in lotic (flowing-water) environments with low velocities, high primary production, and depositional substrata.

A collaborative study among six states along the mid-Atlantic seaboard of the United States determined that reference sites from all states were similar despite large differences in land use and percentages of forested lands in their respective catchments. A high degree of biological quality can be achieved in canals despite poor water quality if natural channels and riparian vegetation are maintained. Water quality is therefore considered less important than habitat quality in determining the biological condition of canals.

Fish Assemblages in Canals

- Canals provide unique habitat for aquatic life since they have characteristics of both streams and lakes. Because they are man-made water bodies and often highly managed, they tend to provide marginally suitable habitat. Some fish survive quite well and may thrive under these conditions – including both native and exotic species.
- Many exotic fishes are less tolerant of low temperature conditions than native species. During cold periods, water temperatures in the marshes tend to be significantly lower than in the canals. Some exotic species, such as the brown hoplo, tolerate low temperature exposure and have expanded rapidly across many natural habitats.
- Canals in natural areas provide refuge from drought for fish. Larger predatory fish are generally the dominant species. Canals in natural areas tend to have more native and fewer exotic fishes, principally due to lack of adequate marsh habitat.
- Canals act as conduits for nutrients, creating sharp local gradients that stimulate productivity in adjacent marshes. Fish are larger and more abundant in these enriched areas, indicating the canals may serve as a littoral zone for fish production.
- Macroinvertebrate (especially shrimp and crayfish) abundance near canals may be reduced due to predation by fishes and poor quality food sources (an abundance of cyanobacteria) in highly enriched zones.
- Within the Big Cypress National Preserve, canals supported the greatest diversity of fish species. Most of these were saltwater-adapted or large freshwater predator species.
- Channelization of the Kissimmee River resulted in significant changes to fish populations. After channelization, Florida gar and gizzard shad were the dominant species captured in trawls and gill-nets. Three species, the blackbanded darter, coastal shiner, and tidewater silverside, may have been extirpated from the system.
- In areas where lands adjacent to canals have been developed for agricultural or urban uses, larger bodied fishes were more common. Such canals may also receive less predation pressure by wading birds. Exotic species tend to be more abundant than native species, probably due to poor water quality and lack of shoreline habitat.
- Some exotic species tolerate estuarine salinity conditions and low oxygen concentrations and thus survive well in coastal canals and rock pits. Exotic fish historically existed only in canals after their initial introduction, and subsequently spread into marshes and peripheral habitats.

- Despite the pressure from exotic species, some canals in disturbed areas support healthy populations of native species. Characteristics of canal size and shape, shoreline and submerged vegetation, and water quality may allow native fishes to maintain their populations.
- The presence of exotic species does not necessarily inhibit reproduction, growth, or health of native fish populations. Native and exotic species may coexist over long periods because most native canal fishes are primarily carnivorous, whereas the exotic fishes are herbivorous or detritivorous and hence are not necessarily competing for the same resources.
- Similar effects of channelization on fish assemblages have been documented in other systems in the United States and other parts of the world, and are attributed to loss of suitable habitat for feeding, shelter, and spawning, as well as altered hydrologic patterns of seasonal floodplain inundation.

Alligators and Crocodiles in Canals

- Alligators seem to be very sensitive to hydrologic conditions, even on short time scales (days). In areas that have become overdrained, alligators only occur in permanent water bodies such as canals or ponds, although they may move to other areas during periods of extremely high water.
- Larger alligators prefer to live in canals, where they probably benefit from warmer canal water and better digestion rates and are therefore larger and healthier than marsh alligators. Alligators in urban canals have a very different ecology than those associated with the Everglades.
- Hatching success and young survivorship of alligators is lower in canals. Canals were harsh environments for alligator reproduction and early development compared to interior sites due to flooding and predation of canal nests.
- Saltwater crocodiles generally prefer saline or brackish water and only occasionally occur in the freshwater canals Crocodiles have been reported to move 6 miles inland using canals.

Regional Trends in Canal Water Quality

A survey of existing SFWMD water quality data for the primary canal system indicates that there are large variations in water quality conditions between regions of the District, between individual canals within regions, and even between sections of the same canal. A net increase in canal nutrient concentrations tends to occur in areas that have adjacent urban and agricultural land uses and a net decrease in concentration occurs in canals that are surrounded by wetlands or areas where water in the canals interacts strongly with groundwater. Little is known about the natural chemical and biological assimilation processes that occur in canals and, in addition to providing support for the current USEPA water quality criteria, more information on assimilation is important to the Total Maximum Daily Load modeling process.

Water quality summary statistics for more than 200 stations in the District's primary canal system were examined to identify regional, seasonal, and intra-regional differences for key water quality constituents, including total phosphorus, total nitrogen, and chlorophyll *a*. Results were analyzed independently for the seven basins or subregions.

Phosphorus

Analysis of total phosphorus data indicated three broad categories of stations as determined by values of the geometric mean and median: 1) Stations that showed phosphorus concentrations less than 50 ppb, which primarily represented the Lower East Coast, Lower West Coast, Upper Kissimmee Basin, and the Everglades Water Conservation Areas; 2) Stations that had phosphorus concentrations from 50 to 150 ppb are located primarily in the Caloosahatchee, Everglades Agricultural Area, and Kissimmee River basins; and 3) Stations with the highest concentrations, above 150 ppb, are located in the Upper East Coast Basin. These differences tend to be associated with the degree of agricultural development within the watershed and proximity to Lake Okeechobee.

Nitrogen

Analysis of data for total nitrogen for the seven regions indicated a somewhat different distribution than was seen for phosphorus, and the pattern was not clearly related to geography or land use. The lowest concentrations of total nitrogen, less than 1.2 ppm, occurred in the Lower West and Lower East Coast watersheds. Concentrations from 1.2 to 1.6 ppb occurred in the Caloosahatchee and Upper East Coast watersheds and the Water Conservation Areas. The highest concentrations (above 1.6 ppm) occurred in the Everglades Agricultural Area and Kissimmee River watersheds.

Chlorophyll *a*

The USEPA has suggested that nutrients (in conjunction with other environmental variables) can impair the designated use of canals by causing an increase in the concentration of chlorophyll *a*. Paradoxically, no chlorophyll criterion was proposed for streams by USEPA. Grouping of chlorophyll *a* concentrations indicated that the lowest concentrations (less than 4 mg/m^3) occurred in the Lower East Coast and Lower West Coast basins and the Water Conservation Areas. Chlorophyll *a* concentrations greater than 4 mg/m^3 occurred in the Caloosahatchee, Everglades Agricultural Area, Kissimmee River, and Upper East Coast basins. The values of all regional geometric means for chlorophyll *a* were less than 10 mg/m^3, about one-half of the 20 mg/m^3 threshold of impairment for the statewide Total Maximum Daily Load process.

Conductance

There appeared to be no clear grouping of summary statistics for specific conductance by region. The Lower Kissimmee River Basin had the lowest geometric mean and median values and the Everglades Agricultural Area had the highest.

Local Variability

- Total phosphorus concentrations were more variable and somewhat higher during the wet season. Variation in the range of total phosphorus values between the 25^{th} and 75^{th} percentile values increased when only wet season observations were considered in all regions.

- Differences among canals within the Upper East Coast and Lower East Coast are apparent for total phosphorus, but less so for total nitrogen, although differences can be observed in the corresponding summary statistics.
- Along canal reaches, there is a downward trend in the summary statistics for total phosphorus and total nitrogen as water moved downstream in the Miami and West Palm Beach canals.
- Although not examined in this analysis, nutrient summary statistics are tied to land use, as reflected in the change in concentrations of nutrients that occur as water moves from south of Lake Okeechobee (agricultural or urban land uses) through Stormwater Treatment Areas and WCAs (wetland marshes and tree islands) to the coastal ridge (primarily urban and agricultural land uses) and ultimately to tide.

Canal Sediments

- Examination of a very limited amount of sediment data, based on studies conducted in regional canals of the Water Conservation Areas, indicated sediment depths were highly variable, both across a given transect and longitudinally down any given canal. Canal average sediment depth ranged from 1.8 feet to 8 feet with a volume totaling almost 2 million cubic yards.
- Low sediment accumulation in some canals was suggested to be a result of higher flow velocities due to the canals' small cross-sectional areas, increasing the likelihood of sediment resuspension and transport during strong drainage events.
- The total sediment volume calculated for the entire 122 miles of canal reaches was almost 9 million cubic yards, with a total phosphorus mass of 2000 tons.
- More than 80 percent of the total phosphorus mass in the surface 4-inch sediment layer of all canals in the WCAs is fairly stable and may be a long-term sink for phosphorus.
- Canal sediments from the eastern side of the WCAs appear to be more susceptible to resuspension and transport during strong drainage events and, due to their chemical composition, they may be more susceptible to long-term release of iron-bound phosphorus to the overlying water column.

A Context for Water Quality Management in South Florida Canals

The information compiled in this technical support document, albeit limited, provides an initial conceptual framework for the ecology of these artificial systems and for the constraints to applying Clear Water Act standards across the diverse South Florida landscape. No quantified linkage between nutrients and impaired biology in South Florida canals was found during this investigation, nor was evidence found that most canal ecosystems are even sensitive to total nitrogen or total phosphorus. As a result of this limited information, there is no scientific basis to conclude that instream nutrients adversely affect the designated uses of canals in South Florida.

To function as conveyance systems, canals must be maintained by removing or limiting vegetation, creating immediate imbalances in canal flora and potentially fauna. The information compiled in this document on the history and purposes of the complex South Florida canal system demonstrates universally that the canal system is primarily used for flood control and water supply. The designated uses derived under the Clean Water Act for maintenance of healthy, well-balanced flora and fauna are not juxtaposed easily into this context. With the available information reflected in this document, there is not a valid means of determining biological 'normalcy' in canals, and therefore, no rational basis upon which to demonstrate impairment under the Clean Water Act.

Even describing water quality in canals is a challenge. They are highly modified physical systems that behave in unnatural patterns, sometimes acting like reservoirs, other times flowing more like streams, and other times flowing more like slow moving rivers. Compilations of data in this report are only a starting point in describing such complexity. More refined ways of evaluating data in canals must be developed in light of their runoff driven and seasonal complexity. Analysis within years or across years should be done separately for flowing and not flowing regimes. Flow-weighted means rather than annual geometric mean chlorophyll *a*, total nitrogen, and total phosphorus concentrations might be more appropriate for analysis. Furthermore, some primary canals in South Florida can cut across different geologic or ecological regions. Pooling data over the entire water body masks regional differences and provides statistics reflecting none of the actual environments being considered.

Natural systems are periodically disturbed through natural processes (i.e., droughts, fires, floods, hurricanes) and biological communities in a particular ecosystem reflect such disturbances. By contrast, canals are disturbed almost continually by human interventions for maintenance, including herbicide application, mowing, dredging, removing obstructions, and mechanical harvesting. As artificial conveyances with large variations in stage, flow and water turnover, canals provide a less stable and predictable environment than other flowing waters. They do not have the floodplains that natural streams have to reduce the energy of high flow events, and instead have levees that keep flows in the channel. At the other extreme, during droughts and dry season operations, canals may have little or no water movement for long periods. Taken together, these observations paint a picture of complex dynamics and constant change for canals. Based on the limited information summarized in this report on canal biology, the biological communities in canals are strongly influenced by the physical aspects of canals and the availability of quality habitat.

Scientific studies (especially in ecology) of canals are a tiny fraction of those found for other South Florida ecosystems. The Everglades marsh numeric criterion for phosphorus was based on literally hundreds of scientific articles spanning more than a decade. Similarly, the Total Maximum Daily Load for Lake Okeechobee was supported by dozens of research publications quantifying algal dynamics in relation to nutrient levels. Many more examples of technical information available for potential use in nutrient criteria can be seen in the pages of the *South Florida Environmental Report*. Selecting a protective numeric nutrient criteria is premature since there is little information on what comprises the ecological communities which are being protected. This technical support document has clearly shown the lack of canal ecological studies as compared to other systems in Florida (e.g., the Everglades, Chapter 6, *2010 South Florida Environmental Report*). Even FDEP's own Technical Advisory Committee consistently struggled with the lack of available information on the ecological components of canals and how nutrients may or may not have an impact.

The application of Clear Water Act water quality standards directly to such a massive canal system must be done with sound information applied rationally to these artificial water bodies and interpreted in light of their nature and actual uses. Canals were built to meet human needs by controlling the movement of water from one place to another for water supply, flood control, drainage, and navigation, as well as to provide water needed to sustain natural communities in lakes, rivers, wetlands, and estuaries. Ecological functions in canals themselves can be valuable for recreation and aesthetics, but are secondary and largely incidental compared to their uses for conveyance.

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SOUTH FLORIDA WATER MANAGEMENT DISTRICT

April 28, 2010

Water Docket
United States Environmental Protection Agency
Mail Code: 2822T
1200 Pennsylvania Ave. NW
Washington, D.C. 20460

SUBJECT: Docket ID No. EPA-HQ-OW-2009-0596

The South Florida Water Management District (District) appreciates the opportunity to provide feedback and technical comments to the U.S. Environmental Protection Agency (EPA) on its Proposed 40 CFR Part 131—Water Quality Standards for the State of Florida's Lakes and Flowing Waters, published on January 26, 2010. The District offers these written comments on the proposed rule in addition to the input provided at EPA's public hearings on this topic.

As a regional governmental agency, the South Florida Water Management District has a 60-year history in managing and protecting the water resources and ecosystems of South Florida. The agency's multi-faceted mission is to balance and improve water quality, flood control, natural systems and water supply. Originally formed as a flood control agency, the District manages more than 2,600 miles of canals and levees, 64 pump stations and about 1,300 water control structures that were constructed under the federal Central and Southern Florida (C&SF) project to provide conveyance and flood control. Today, a key agency priority is also the restoration of America's Everglades—the largest environmental restoration project in the nation's history. In addition, the District is actively improving the Kissimmee River and its floodplain, Lake Okeechobee and its watershed and South Florida's coastal estuaries.

The District's technical expertise has been invaluable in developing the sound science needed for effective numeric nutrient criteria in the State of Florida. District scientists were intimately involved in development of Florida's first numeric nutrient standard: the Total Phosphorus criterion for the Everglades Protection Area. This agency invested 11 years and millions of dollars to ensure that the final criterion was scientifically defensible and protective of that unique ecosystem. During the last decade, the District also fully participated in the Florida Department of Environmental Protection's Technical Advisory Committee that led to the development of draft numeric nutrient criteria by the State in July 2009 and provided technical review for EPA's guidance documents on numeric nutrient criteria development, published in 2000-2001.

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This extensive experience has shaped the District's firm position that while numeric nutrient criteria are important for protecting Florida's water resources, successful numeric nutrient criteria must be developed through a science-based process. Further, any criteria must address Florida's remarkable ecological diversity in order to achieve appropriate and protective water quality standards.

With this in mind, the District offers the following technical comments along with ready access to the expertise of our scientists and staff plus several decades of South Florida water quality data. We believe that shared resources, sound science and reasonable timeframes can be used to formulate a Final Rule that is technically defensible and achieves our mutual goal of protecting and improving the water quality of Florida's rivers, lakes and streams.

Comments Overview

The District respectfully recommends reconstruction of the proposed rule to achieve a scientifically defensible Final Rule that provides the right level of protection for the diverse water bodies of Florida. The attached comments demonstrate that the current state of the science, particularly scientific data for canals, requires a realistic timeframe for development rather than the timelines currently proposed. Specifically for canals, the District requests that EPA defer numeric criteria for Florida's canal systems until such time that defensible criteria for downstream water bodies are established. Policy decisions must address classification of these heavily impacted, highly managed conveyance systems so that protection for their designated uses of flood control and water supply is achieved while also balancing potential impacts downstream.

After extensive review of EPA's proposed rule, the District submits these key comments:

- Lakes: The District is concerned with utilizing total nitrogen (TN) as a criterion for all Florida lakes and recommends more work be undertaken to understand the significant regional, biological and ecological differences throughout the State.
- Streams and Rivers: With no scientifically established relationship between nutrient levels and biological response, coupled with unreliable scientific results, utilization of the reference approach raises concerns.
    - Many other factors in the stream environment influence biological communities within the water body, and the District recommends a thorough investigation of these factors.
    - Should EPA adopt a reference approach, the District reiterates its support for the Florida Department of Environmental Protection's 90^{th} percentile reference-based approach and accompanying biological validation process. The State's technical methodologies were developed through 14 years of study and should prevail over any other reference approach.

- <u>South Florida Canals</u>: Scientific studies of canals and canal ecology are very limited. The attached Canal Science Inventory demonstrates that minimal research exists on these complex, managed systems, which are currently classified as Class III water bodies. Protection for a healthy population of fish and wildlife in a natural stream, also classified as Class III, is fundamentally different than for a flood control canal.
    - The District is concerned with how a "one-size-fits-all" approach would affect operation of the regional flood control system. Adoption of an appropriate methodology and consideration of all available science and research is necessary to set scientifically valid criteria and demonstrate the exact nature of the relationship between nutrients and biological conditions in the more than 2,600 miles of canals that comprise the system.
    - When canal criteria are appropriately developed, the District strongly recommends that sub-regionalization be considered, given the extensive variability in types of canals and their influencing factors, such as soils and groundwater.
- <u>Statistics</u>: Many statistical assumptions are not tested or shown in the proposed rule. The District respectfully asks that EPA provide data demonstrating how statistical assumptions were tested.

The District further recommends that EPA engage in a thorough and transparent peer review process, utilizing the expertise of the EPA's own Scientific Advisory Board, the National Academy of Sciences, National Research Council or other nationally recognized scientific panels to determine the validity of the technical and scientific underpinnings of the proposed criteria. Statewide numeric nutrient criteria that are not scientifically valid have the real potential to disrupt Everglades restoration progress, including the 50:50 cost-share relationship established in the Water Resources Development Act of 2000 with the U.S. Army Corps of Engineers for the implementation of the Comprehensive Everglades Restoration Plan. Additionally, basin management plans, now under way to improve Florida's water bodies, may be delayed, and South Florida's recent successes in wastewater reuse to protect freshwater resources may be unintentionally hindered if nutrient criteria are poorly matched to the water bodies they were designed to protect.

Finally, given the far-reaching implications of the proposed rule and in the interest of open government, the District respectfully requests that EPA resubmit any change to the final rule to the public for additional analysis and comment. The District's attached comments have analyzed EPA's currently proposed methodology, and any alternative chosen as the basis for a Final Rule would not necessarily be a "logical outgrowth" of the proposed rule.

The District continues to review the proposed rule and will expand on the attached comments with further written submissions. Thank you again for the opportunity to provide this feedback. If you have questions or concerns, please contact Kevin Carter at (561) 682-6949 or kcarter@sfwmd.gov.

Sincerely,

Carol Ann Wehle

Carol Ann Wehle
Executive Director
South Florida Water Management District

CAW/kc

Attachment

c: Kevin Carter, SFWMD

Comments of the South Florida Water Management District

(April 28, 2010)

concerning

Proposed 40 CFR Part 131 – Water Quality Standards for the State of Florida's Lakes and Flowing Waters

published in the
Federal Register, Volume 75, No. 16
Tuesday, January 26, 2010

Docket No. EPA-HQ-OW-2009-0596

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I. South Florida Water Management District Response to USEPA Proposed Numeric Nutrient Criteria: Lakes

A. Nutrient-Chlorophyll *a* Relationships Do Not Show Direct Cause and Effect

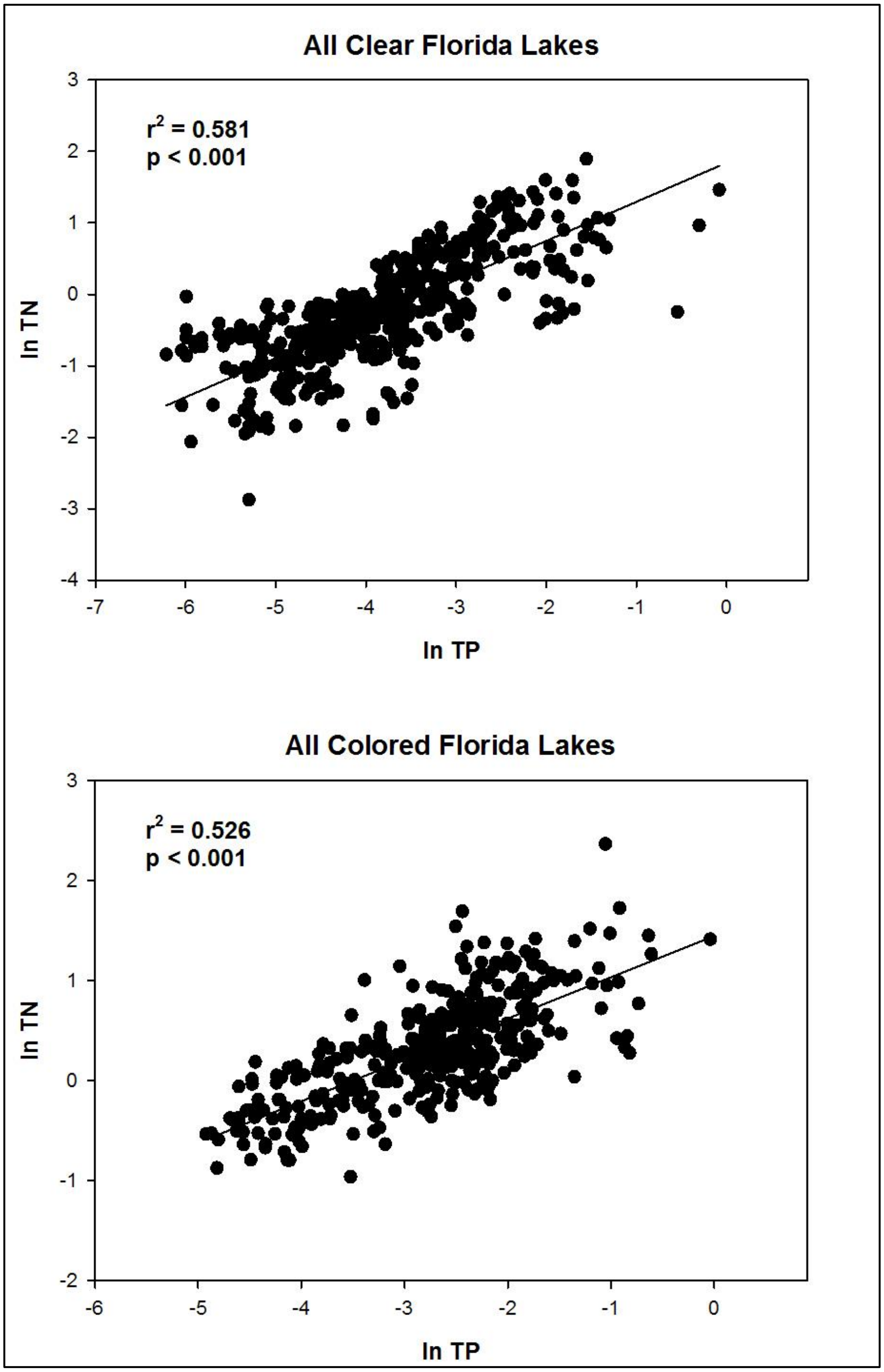
The assumptions underlying the use of regression relationships between individual nutrients and chlorophyll *a* to derive numeric criteria need to be clearly stated. The chlorophyll *a* -nutrient regressions do not reflect simple cause-effect relationships. In reality, the presumed stressor (nutrients) and response (chlorophyll *a*) values are intertwined such that lakes with high phytoplankton biomass will necessarily have high concentrations of both water-column total nitrogen (TN) and total phosphorus (TP) since these nutrients are a component of the algal biomass. Therefore, the mere presence of such relationships does not show that both TN and TP are responsible for increased chlorophyll *a* in lakes throughout the state. Concentrations of TN and TP are themselves correlated in Florida lakes (Figure 1), making it impossible to tease out cause-effect relationships between individual nutrients and chlorophyll *a* based on a simple regression analysis. Additional analyses should be performed to identify the limiting nutrient for reference lakes in different regions of the state and to focus regulatory efforts towards controlling inputs of that nutrient to impaired lakes in the same region. In summary, the proposal to target both TN and TP in all Florida lakes is not supported by the simple fact that these nutrients are associated with chlorophyll *a*.

B. **Limitations to the Use of Statewide Empirical Relationships for Establishing Nutrient Criteria Need to be More Fully Evaluated**

While simple empirical relationships are widely used as screening tools for examining effects of increased nutrients on lake productivity, their power to predict nutrient thresholds for individual lakes or sets of lakes is often quite low (Welch and Jacoby 2004). The United States Environmental Protection Agency (EPA) (2000) provided guidance to the States and Tribes for the development of numeric nutrient criteria for lakes. The limitation to the use of nutrient-chlorophyll *a* relationships for establishing these criteria is noted in this guidance document:

"In summary, although they have some utility, empirical models (and particularly those based on global data) do not usually have the required precision upon which high-cost decisions can be made. As such, empirical models should be relegated to broad screening applications and for identifying atypical lakes. However, they may have sufficient precision if developed and applied for regional populations of lakes and reservoirs."

Figure 1: Total Phosphorus (TP) – Total Nitrogen (TN) relationships for clear and colored lakes from same log (ln) transformed data set used by USEPA in criteria development.



Statewide nutrient-chlorophyll *a* relationships are being used to set numeric criterion for individual lakes across the state. Few analyses are presented to test the key assumption that these statewide relationships are equally applicable to lakes in different regions of the state. A set of graphs (figures 1-1, 1-2, 1-9, 1-10) is presented as evidence that lakes within 5 stream ecoregions (as opposed to the 47 distinct lake regions identified by Griffith et al. 1997) exhibit similar chlorophyll *a* responses to TP and TN. However, visual examination of the linear regression lines in these graphs suggests that lakes in some regions show very different responses, and no statistics are provided to show that regression lines for different regions are coincident or that regression lines for individual regions do not provide greater explanatory value than a single statewide regression relationship. Examples of regional differences based on visual examination of regression lines:

- For clear lakes, the TP value corresponding to a chlorophyll *a* concentration of 20 micrograms per liter (µg/L) ranges from approximately 40 µg/L (Bone Valley) to approximately 200 µg/L (North Central);
- For clear lakes, the TN value corresponding to a chlorophyll *a* concentration of 20 µg/L ranges from approximately 1 milligrams per liter (mg/L) (Bone Valley) to approximately 1.6 mg/L (North Central);
- For moderately colored lakes, the TP value corresponding to a chlorophyll *a* concentration of 20 µg/L ranges from approximately 65 µg/L (Peninsula) to approximately 330 µg/L (Panhandle);
- For moderately colored lakes, the TN value corresponding to a chlorophyll *a* concentration of 20 µg/L ranges from approximately 1 mg/L (Northeast) to approximately 1.6 mg/L (Peninsula);
- All (or nearly all) moderately colored lakes in the Bone Valley have chlorophyll *a* values >20 µg/L regardless of nutrient concentrations.

C. Log-Log Transformations need to be Augmented with Further Scientific Data

The reliance on log-log relationships based on large datasets for identifying nutrient concentrations that cause impairment masks considerable variation in the response of individual lakes and lake regions to nutrient enrichment (Lewis and Wurtsbaugh 2008). And, even after log transformation, the resulting relationships between nutrients and chlorophyll *a* for Florida lakes still include considerable unexplained variation and, in the case of moderately colored lakes, have poor predictive power (see Prairie 1996 for a discussion of the use and misuse of empirical relationships in the aquatic sciences). The USEPA approach apparently presumed that observed inter-lake variation in the empirical relationships is random error; however, it is not apparent that much effort was devoted to attempting to extract information from this variation in order to derive more robust and defensible relationships. USEPA should perform a more rigorous and thoughtful analysis of the data to identify the causes of observed variation rather than simply applying a transformation in order to force a linear regression through the data swarm.

D. The Classification Method for Colored Lakes is Overly Simplistic and Nutrient Criteria for Highly Colored Lakes is Indefensible

Classification of lakes into two color categories (<40 PCU vs. >40 PCU) facilitates analysis but ignores the reality that the effects of color on nutrient-chlorophyll *a* relationships represent a continuum. The more colored a lake's waters, the less closely its productivity (chlorophyll *a* concentration) is tied to ambient nutrient levels. The references used to support the two-tier classification used by USEPA are Shannon and Brezonik (1972) and Gerritsen et al. (2000). Neither of these investigations supports a "natural" separation of lakes into just two color categories.

Shannon and Brezonik (1972) relied on cluster analysis to separate 55 Florida lakes into categories based on measured water chemistry parameters. While they determined that color was an important factor distinguishing different lake types, they also concluded that lakes within their "colored" category were highly heterogeneous. In particular, they concluded that, with respect to nutrients and chlorophyll *a*, "a simple harmonious oligo- to eutrophic gradation may not occur in highly colored lakes." They go on to state that their colored lakes could be subdivided into "anywhere from two to six or more [trophic] groups, none of them satisfactorily interpretable."

Gerritsen et al. (2000) use ordination (principal components analysis) to separate 570 Florida lakes into categories based on 8 water chemistry variables. Again, these investigators identified color as an important lake classification factor. However, their results also show considerable variability within their colored lakes categories and do not support the proposition that these lakes can be considered as a single homogeneous group. The authors state that their results "confirm" the classification of Shannon and Brezonik, which, as already noted, was inconclusive with respect to colored lakes.

The USEPA analyses of colored lakes revealed these classification problems. It was concluded that nutrient-chlorophyll *a* relationships for this category were weak and lacked predictive power and that "color in excess of approximately 150 PCU depresses the nutrient response." On the basis of additional statistical analyses, it was possible to identify two subcategories for colored lakes: (a) moderately colored lakes (40-140 PCU) that could be used to derive improved (but still weak) nutrient-chlorophyll *a* relationships (fig 1-11); (b) a second subset of highly colored lakes (>140 PCU) where chlorophyll *a* concentrations could not be predicted from nutrient levels (fig 1-12). Clearly, other environmental factors strongly influence primary productivity in colored lakes and additional information is required before scientifically or statistically defensible nutrient criteria can be developed for highly colored lakes.

The USEPA established separate nutrient criteria for colored and highly colored lakes as follows: (a) determined that the empirical relationship between nutrients and chlorophyll *a* was poor when applied to all colored lakes (>40 PCU); (b) determined that an improved relationship could be obtained if analysis was limited to lakes with a color range of 40-140 PCU; (c) used this improved relationship to establish numeric nutrient criteria for this subset of colored lakes; (d) then applied these criteria to the highly colored (>140 PCU) lakes that had been removed from the analysis in order to generate the improved relationship. There is no scientific basis for extrapolating the results of the analysis on one subset of lakes to a second subset of lakes that had been intentionally removed from the analysis in order to generate a satisfactory statistical relationship.

There are scientific explanations for why chlorophyll *a* concentrations are poorly correlated with nutrient levels in highly colored lakes. For example, as discussed in USEPA's Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs (USEPA 2000):

"Highly colored lakes have been termed dystrophic because they often are observed to have low productivity in spite of moderate to high nutrient concentrations (Wetzel, 1975). Colored water not only reduces light penetration, but the dissolved organic matter also can chelate nutrients, making them unavailable for algal uptake. Therefore, water color is an important classification variable (or covariate; see below) for lake nutrient criteria."

In other words, the simple presence of high nutrients (particularly TN) in highly colored lakes is not a good indicator of either nutrient availability or impacts. It is unclear why established science was ignored and arbitrary criteria set for this lake type.

E. Minimally Impacted (Reference) Lakes May Be Classified As Impaired for Nitrogen

Lakes within the South Florida Water Management District (the District) fall into the colored and highly colored categories defined by FDEP and USEPA. Minimally impacted (i.e., reference) lakes within this region have not been routinely monitored for water quality. However, water quality in three of these lakes (Lakes Preston, Joel, and Myrtle) was surveyed by the District in February 2009 and the findings from this preliminary assessment were that these lakes:

- Are highly colored (>250 PCU);
- Have low TP concentrations (17-20 µg/L);
- Have high TN concentrations (1.94-2.31 mg/L);
- Appear to be strongly P limited (based on TN:TP ratios >100:1) and, therefore, unresponsive to N levels;
- Are highly unproductive (Chl*a* values in the 1-3 µg/L range).

These findings are consistent with the broader scientific literature on highly colored lakes (noted above) and with USEPA analyses showing that productivity (chlorophyll *a*) in highly colored lakes is poorly correlated with nutrient levels. Yet, these minimally impacted lakes have TN concentrations that approach or even exceed the upper allowable limit proposed by USEPA.

High background N levels in these lakes are likely a consequence of high inputs of dissolved organic nitrogen (DON) from the surrounding, largely undeveloped watershed. The south

Florida watershed contains large areas of wetland and riparian habitat, which has been found to be a significant natural source of DON to downstream waters in other watersheds (Daley and McDowell 2002, Pellerin et al. 2004). Much of this DON is refractory in nature and, therefore, not capable of promoting phytoplankton productivity in either the lake where it is measured or in downstream waters (streams, estuaries). Therefore, TN may not be a reliable predictor of either N availability or anthropogenic N enrichment in south Florida lakes.

F. How Are Lake Criteria Influenced by Downstream Criteria?

Most Florida lakes discharge into streams or man-made canals. In these situations, USEPA has not explained whether lake numeric nutrient criteria are to be determined based on the proposed lake criteria or on the criteria for the downstream waterbody. For example, within the District, all of the Lake Management Areas of the Kissimmee-Chain-of-Lakes discharge into canal segments, which are classified as streams in that region. The lakes are the sole or primary source of water for these canals. Does this mean that TN and TP concentrations in lake discharges cannot exceed stream nutrient criteria (annual geometric mean concentrations) of 0.107 mg/L for TP and 1.203 mg/L for TN? Given that background TN levels in at least some of these lakes may be above 1.2 mg/L (see comment E above), this could require treatment to remove naturally occurring N.

G. Period of Record Requirements Need to be Defined

Within the District boundaries (and probably elsewhere), some lakes have water quality (nutrient, chlorophyll *a*) data stretching as far back as the early 1980s. This period of record encompasses the period when secondary treatment infrastructure was installed in wastewater treatment plants to reduce nutrient discharges from these point sources. Several District lakes exhibited marked improvements in water quality during the 1980s and early 1990s following these treatment upgrades (James et al. in press). Poor water-quality conditions prior to the implementation of these effective nutrient reduction measures should therefore not be included in current determinations of nutrient impairment. USEPA should adjust its period of record requirements for determining compliance to account for past improvements in water quality.

H. Text Specific Comments

Comment #	Page	Comment
1	2	"Nutrient concentrations, chlorophyll concentration, specific conductance, and alkalinity were log-transformed (natural log) for statistical analyses." Please clarify that the transformations were for raw data. Why was natural log used? Were other transformations considered? How was it determined that transformations were needed?

Comment #	Page	Comment
2	2	"FDEP categorized lakes into clear and colored lakes on the basis of the geometric mean color for the period of record." This is not consistent with the footnote statement on Table 1-4 "Platinum Cobalt Units (PCU) assessed as true color free from turbidity. Long-term average color based on a rolling average of up to seven years using all available lake color data."
3	2	How were shifts between colored and clear classification of some lakes (including Lake Okeechobee) handled?
4	2	"Lakes showed similar chl. *a* responses regardless of location, with some differences in the range of nutrient concentrations (Figures 1-1 and 1-2)." Please show analysis of covariance to justify the statement. It appears that some of the lake sets have different slopes or are significantly separated to justify sub-setting based on location.
4	4	Salas and Martino (1991) do not discuss Trophic State Indices (TSIs). The citation is inappropriate here. The District suggests the following Kratzer & Brezonik (1981), Brezonik (1984), Dierberg *et al.* (1988).
5	5	Salas & Martino (1991) did not consider trophic state indices. They considered trophic states based on total phosphorus concentrations.
6	5	Havens (2000) did not suggest averaging the TSIs, rather he suggested looking at differences to define the general mechanism that is maintaining the TSI at the given level. A better citation for this procedure is Carlson & Havens (2005).
7	5	"Salas and Martino considered that same range of TSI values to be mesotrophic in warm-water lakes." Salas and Martino (1991) did not consider TSI values, but rather TP concentrations.
8	12	For designated uses, USEPA should consider Bachmann *et al.* (1996).
9	13	"The USEPA proposes the TAC suggested nutrient thresholds in clear, high-specific conductance lakes be based on preventing the annual average chl. *a* from exceeding 20 μg/L." Please clarify: Is this proposal for high (> 100 uS/cm) conductivity, or are you including these in high alkalinity lakes (> 50 mg $CaCO_3$/L or conductivity > 250 uS/cm). How are lakes with conductivity between 100 and 250 uS/cm and alkalinity < 50 mg $CaCO_3$/L considered?
10	14	There are also strong relationships among TP, TN, and color. Thus, light is limited because of higher color, TN and TP, making chlorophyll values lower.
11	14	"Regional differences among the moderately colored lakes (color between 40 and 140 PCU) were evaluated, but USEPA found that those colored lakes show similar chl. *a* responses regardless of location, although there were differences in the range of nutrient concentrations (Figures 1-9 and 1-10)." USEPA should demonstrate this statistically using analysis of covariance (it appears that the slopes and positions of the curve are quite different).

Comment #	Page	Comment
12	14	"Without a strong and robust nutrient-chl. *a* relationship in the highly colored (> 140 PCU) lakes, fully protective criteria for these systems can be developed on the basis of the response relationships from the moderately colored lakes (40–140 PCU), although the criteria will be somewhat overprotective, given that high color will reduce algal response and biomass." If TP and TN are not related to chlorophyll *a* in highly colored lakes, then using a surrogate to impose a standard is not logical because based on the chlorophyll *a* standard only five or six of these highly colored lake samples exceed the standard. Most meet the standard throughout the range of TN and TP values. Setting TN and TP values would misclassify most of these lakes as impaired when they are not.
13	14	Given this approach and using annual average chl. *a* values of 20 μg/L for colored lakes and higher-specific conductance clear lakes, and 6 μg/L for clear, low-specific conductance Florida lakes, respectively, criteria ranges associated with protection of designated uses can be defined on the basis of the 50% prediction intervals depicted in Figures 1-11 and 1-13." The axes should be reversed. Since you are trying to define TP and TN values based on chlorophyll *a* of 20, then the independent variable is chlorophyll *a* and TN and TP are the dependant variables
14	14	"Results indicate that a 5-year rolling average was generally sufficient to ensure minimization of the variance (for an example data set, see Figure 1-14). Yet a 7-year average is the basis to determine color in the rule.
15	17	"The 50% prediction interval is the range within which one-half of chl. *a* observations are expected to fall for a given nutrient concentration (TN or TP), centered on the mean expectation at the regression line. In other words, the lower and upper bounds approximate the 25th and 75th percentiles of expected chl. *a* response for the given TN or TP, as predicted by the regression equations (Figures 1-11, 1-13)." See comment 13 above.
16	19	"…the cool season (October to April) and the warm season (May to September)." For the southern part of the state these are considered dry (October to April) and wet (May to September) seasons.
17	19	TP, TN, chlorophyll, and specific conductance are all correlated with alkalinity in the described data set (Figure 1-16)." The data are compressed by the natural log. USEPA should provide figures showing results if the data are un-transformed.
18	19	"The acidic and alkaline lakes appeared to lie on the same regression relationship, although alkaline lakes had higher mean nutrient and chlorophyll concentrations." USEPA should use analysis of covariance to demonstrate this.
19	22	Table 1-1. Only the TP values are from Salas and Martino (1991)

I. An Alternative Approach for Establishing Lake Numeric Nutrient Criteria

The following alternative approach is provided by the District for developing Lakes Numeric Nutrient Criteria. The purpose of this alternative approach is to offer another tool for USEPA in the development of lake criteria. The previous concerns listed in Sections A through H still apply, especially in terms of nitrogen criteria. A major benefit of this approach is its independence of relying on any specific nutrient and chlorophyll *a* relationship (e.g., does not assume a linear response). It does not assume any statistical distribution, skewness or kurtosis for the parameters TN, TP, and chlorophyll *a* as presented in detail below.

Given that both total nitrogen and total phosphorus (TN and TP) are associated with each other, with chlorophyll *a*, as well as other water quality parameters (such as color, dissolved organic carbon, etc.) using regression techniques to define criteria of nutrients for Lakes is not ideal.

The method considers each individual point (chlorophyll *a*, TN, TP) in the data set and classifies them as either meeting the chlorophyll *a* criterion (chlorophyll *a* $\leq$ 20 µg/L) or not (chlorophyll *a* > 20 µg/l). This analysis is presented for TP and TN in clear and moderately colored lakes.

Frequency diagrams of nutrients (TP or TN) for each set can be compared, and nutrient criteria can be suggested as corresponding to the majority of non-impaired samples meeting the chlorophyll *a* criterion and a majority of the impaired samples having chlorophyll *a* above this threshold (see Attachment A). The procedure becomes more powerful, more precise, and more robust as more samples are added. Tradeoffs between categories of percent correctly identified, percent false positives (categorizing samples as impaired when they are not), and percent false negatives (categorizing samples as not impaired when they are) based on chlorophyll *a* criterion can be compared and optimal nutrient criteria values (or ranges) can be chosen.

The FDEP's data set of averaged annual lake observations is used to illustrate an alternative method for establishing TP and TN thresholds. Using some basic statistical concepts of error rate (i.e. type I or false positive, and type II or false negative), the available data can be used to set nutrient criteria. These criteria can be set by choosing nutrient values associated with the desired outcome of type I /type II errors being low. While the ideal values (e.g. 5% false positive, and 10% false negative) are not always attainable, reasonable accommodation may be attained through understanding of the information.

Annual averaged data for Florida lakes were obtained from: publicfiles.dep.state.fl.us - /DEAR/Weaver/Inland TSD Data/02) Lakes/All Lakes Ann Av N4.xls

From the 924 annual-lake averaged observations, data sets were created for moderately colored lakes (apparent color values between 40 and 140 PCU and predefined as "col", 308 observations) and clear lakes (apparent color values below or equal to 40 PCU and predefined as "clr", 509 observations).

The analysis was done separately for each nutrient (TP and TN) and for clear lakes and moderately colored lakes. Each lake type data set provided by USEPA contains chlorophyll *a*, TP and TN natural log transform values that were averaged for each lake-year. Prior to performing the current analysis, chlorophyll *a*, TP and TN data were back transformed.

Individual data records (containing chlorophyll *a*, TP and TN values) were classified as either meeting the chlorophyll *a* criterion (chlorophyll $a \leq 20$ µg/L) or not (chlorophyll $a > 20$ µg/l). Histograms of TP and TN from these data sets were produced for each lake type in Microsoft Excel. The cumulative percentage of all samples correctly identified at a given nutrient value as exceeding or meeting the criterion (20 µg/L) was plotted for all values of TN and TP. In addition the cumulative percentage of samples that exceeded the nutrient value but met the chlorophyll *a* criterion (false positive) was also plotted, as was the cumulative percentage of samples that did not exceed the nutrient value but did exceed the chlorophyll *a* criterion (false negative).

These plots can be evaluated to determine the nutrient value that:

- Correctly identifies a large percentage of samples that meet or exceed the chlorophyll *a* criteria;
- Maintains a low percent of false positives;
- Maintains a low percent of false negatives.

For colored lakes there were 178 observations that did not exceed the criteria and 131 that did (Figure 1). Nutrient values for the samples that did not exceed the chlorophyll *a* criterion ranged from 0.004 to 0.55 mg/l for TP (Figure 1A) and 0.22 to 2.6 mg/l for TN (Figure 2A). Conversely, nutrient values for samples that did exceed the chlorophyll *a* criterion ranged from 0.04 to 0.96 mg/l for TP and 1.14 to 10.6 mg/l for TN (Figures 1B, 2B). The maximum percent of lakes correctly identified as meeting or exceeding the chlorophyll *a* criterion were 0.059 mg/l (77%) of TP and 1.4 mg/l (82%) for TN (Figures 1C, 2C). No matter what nutrient criterion value is selected, there will also be some false positives and negatives. The curves (Figures 1C, 2C) can be used to identify the tradeoffs for each criteria value. For example at the TP value of 0.059 mg/l, 19% of the lakes exceed this value but meet the chlorophyll *a* criterion (i.e. a false positive). As a tradeoff, using higher values of TP for the nutrient criteria will result in fewer lakes correctly identified, but will also result in fewer false positives. Most statisticians use a false positive (Type I) error rate of 5% although 10% is sometimes used.

Three values from each lake type and nutrient (TP and TN) are presented that are closest to the type I error rate of 5%. (Table 1). Using a 5% type I error rate for colored lakes gives nutrient criteria of 0.136 mg/L for TP and 1.71 mg/l for TN, resulting in 67.7% and 80.5%, respectively, of the lakes being correctly identified as meeting or exceeding the chlorophyll *a* criterion. However this is offset with a 27.5% and 15.3% false negatives (or Type II error rate), respectively. In this case 27.5% and 15.3% of the samples are classified as meeting the given nutrient criteria but actually exceed the chlorophyll *a* criterion.

For alkaline lakes, there were 325 observations that did not exceed the chlorophyll *a* criterion and 185 that did (Figure 3). Nutrient values for samples that did not exceed the chlorophyll *a* criterion ranged from 0.002 to 0.25 mg/l for TP (Figure 3A) and 0.06 to 1.89 for TN (Figure 4A). Conversely, nutrient values that did exceed the chlorophyll *a* criterion ranged from 0.019 to 0.921 mg/l for TP (Figure 3B) and 0.89 to 6.6 mg/l for TN (Figure 4B). The maximum percent of samples correctly identified as meeting or exceeding the chlorophyll *a* criterion occurred at 0.026 mg/l for TP (85%) and 1.15 for TN (93%) (Figures 3C, 4C). Using these values to set nutrient criteria would result in type I errors of 12.9% and 2.7%, respectively. Using the values that are closest to the 5% error rate (0.050 mg/l and 1.14 mg/l for TP and TN, respectively) produce Type II error rates of 15.4% and 4.3%, respectively.

For comparison the baseline values for clear alkaline lakes proposed by USEPA (Table 2) would result in 12.9% and 5.6% false positives for TP and TN, respectively. The baseline values for colored lakes proposed by USEPA would result in approximately 18.9 and 16.3% false positives for TP and TN respectively.

Table 1: Potential criteria for TN and TP by lake type and the associated percentage of samples correctly identified (as meeting or exceeding the chlorophyll *a* criterion) as well as percentage of type I and type II errors.

Lake Type	Nutrient	Standard value	Number of False positive (type I error)	Number of False negative (type II error)	Number of correctly identified lakes	Percent false positive	Percent false negative	Percent correctly identified
Colored	TP	0.103	21	61	209	7.22%	20.96%	71.82%
		0.136	14	80	197	4.81%	27.49%	67.70%
		0.180	5	104	182	1.72%	35.74%	62.54%
	TN	1.396	30	30	248	9.74%	9.74%	80.52%
		1.711	13	47	248	4.22%	15.26%	80.52%
		2.097	2	67	239	0.65%	21.75%	77.60%
Clear Alkaline	TP	0.037	34	43	427	6.75%	8.53%	84.72%
		0.050	20	78	406	3.97%	15.48%	80.56%
		0.070	12	108	384	2.38%	21.43%	76.19%
	TN	0.892	39	10	459	7.68%	1.97%	90.35%
		1.147	14	22	472	2.76%	4.33%	92.91%
		1.474	5	61	442	0.98%	12.01%	87.01%

Table 2: USEPA Proposed Nutrient Criteria for colored and alkaline lakes (From 40 CFR Part 131 EPA-HQ-OW-2009-0596; Water Quality Standards for the State of Florida's Lakes and Flowing Waters, 2010)

Long Term Average Lake Color and Alkalinity	Chl*a* (µg/L)	Baseline Criteria		Modified Criteria (within these bounds)	
		TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)
Colored Lakes > 40 PCU	20	0.050	1.23	0.050-0.157	1.23-2.25
Clear Lakes, Alkaline ≤ 40 PCU and > 50 mg/L $CaCO_3$	20	0.030	1.00	0.030-0.087	1.00-1.81

Figure 2: Histogram and percent cumulative distribution of TP values in moderately colored lakes: (A) shows plot for samples with chlorophyll *a* ≤ 20 µg/l; (B) shows plot for samples with chlorophyll *a* > 20 µg/l; and (C) plot shows cumulative percent of samples that are correctly identified (as meeting or exceeding the chlorophyll *a* criterion) for a given TP concentration, cumulative percent of all samples incorrectly identified as exceeding the standard when they do not (false positive), and cumulative percent of samples incorrectly identified as meeting the standard at or below a given TP when they do not (false negative).

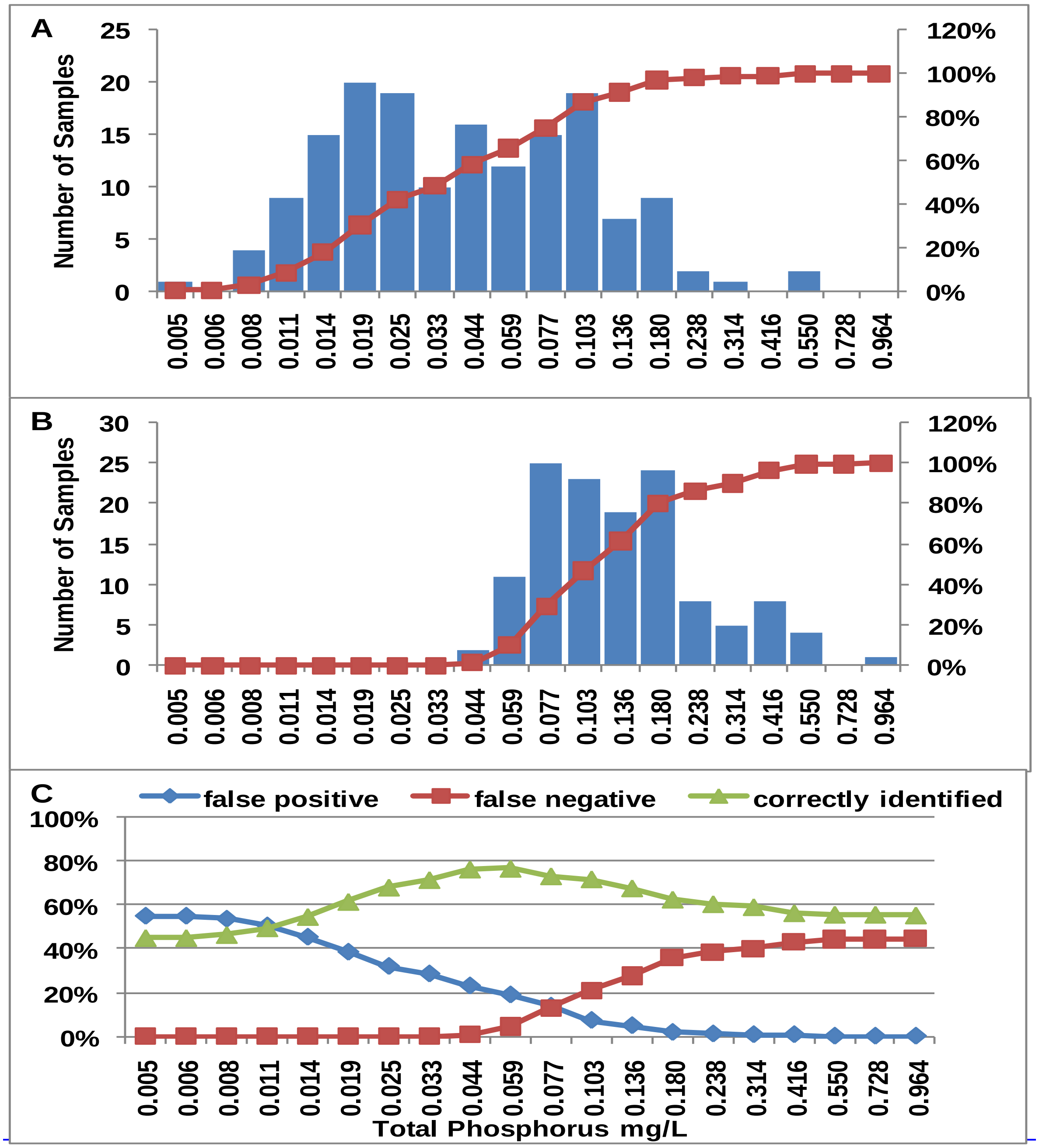


Figure 3: Histogram and percent cumulative distribution of TN values in moderately colored lakes: (A) shows plot for samples with chlorophyll *a* ≤ 20 µg/l; (B) shows plot for samples with chlorophyll *a* > 20 µg/l; and (C) plot shows cumulative percent of samples that are correctly identified (as meeting or exceeding the chlorophyll *a* criterion) for a given TN concentration, cumulative percent of all samples incorrectly identified as exceeding the standard when they do not (false positive), and cumulative percent of samples incorrectly identified as meeting the standard at or below a given TN when they do not (false negative).

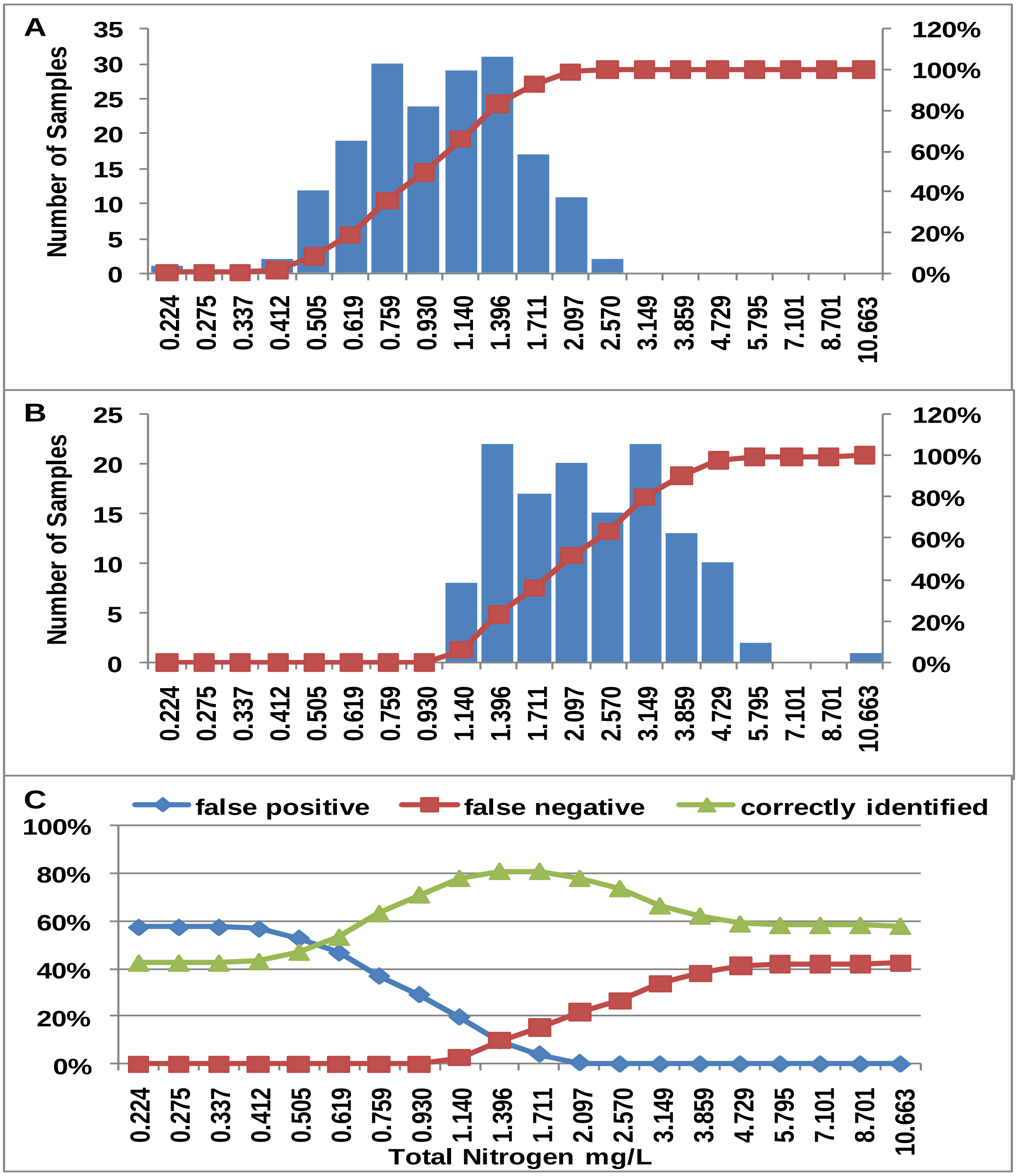


Figure 4: Histogram of TP in clear alkaline lakes and cumulative percent of lakes: A) with chlorophyll *a* < 20 µg/l; B) with chlorophyll *a* > 20 µg/l; C) Percent of lakes that are correctly identified as meeting or exceeding the chlorophyll *a* criterion at a given TP value, cumulative percent of all lakes incorrectly identified as exceeding the standard when they do not (false positive), and incorrectly identified as meeting the standard at or below a given TP when they do not (false negative).

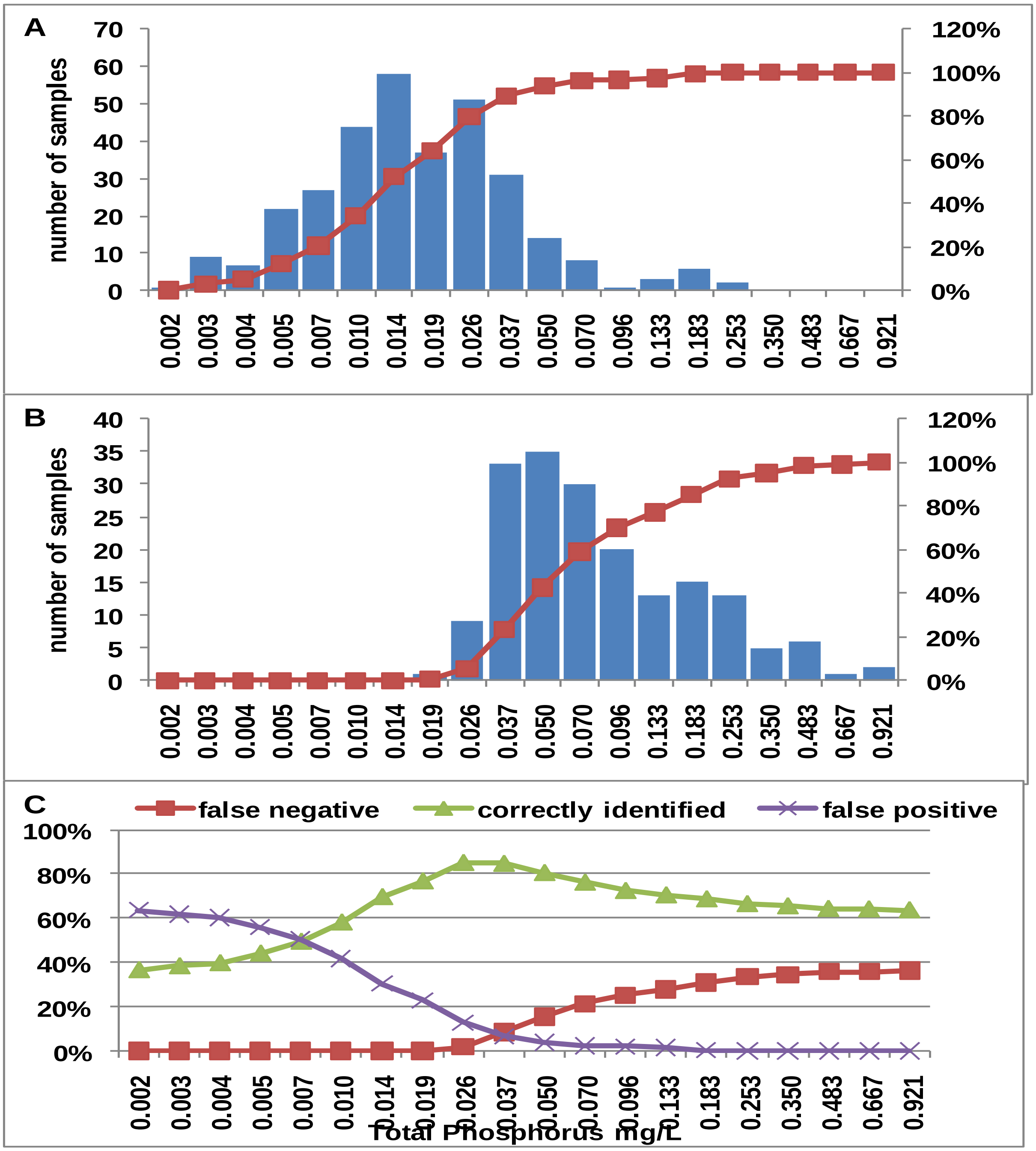
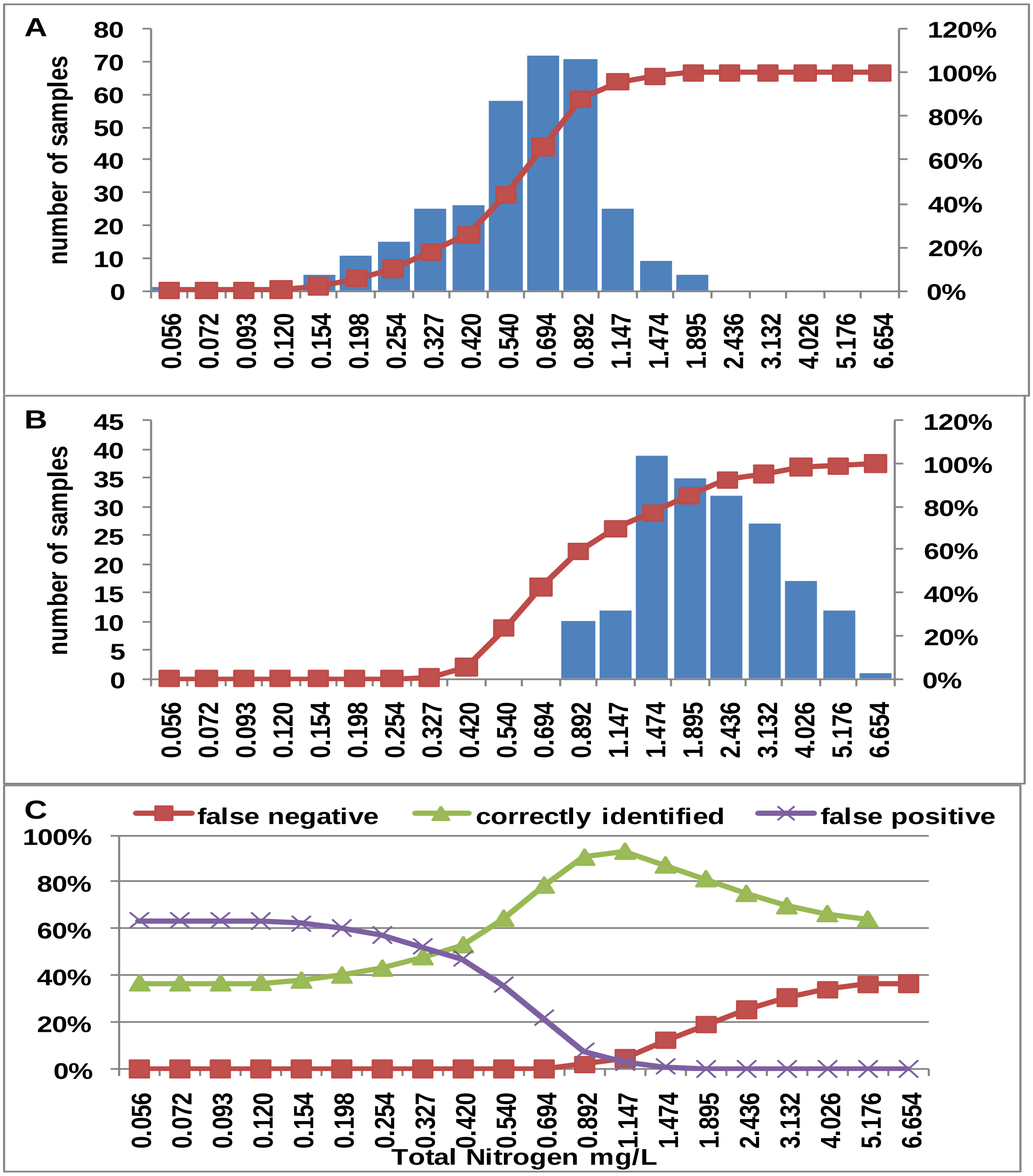


Figure 5: Histogram of TN in alkaline clear lakes and cumulative percent of lakes: A) with chlorophyll *a* < 20 µg/l; B) with chlorophyll *a* > 20 µg/l; C) Percent of lakes that are correctly identified as meeting or exceeding the chlorophyll *a* criteria at a given TN value, cumulative percent of all lakes incorrectly identified as exceeding the standard when they do not (false positive), and incorrectly identified as meeting the standard at or below a given TN when they do not (false negative).



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II. South Florida Water Management District Response to USEPA Proposed Numeric Nutrient Criteria: River and Streams

Numerous papers have been published on using landscape classification (e.g., ecoregions, bioregions) to define reference conditions for environmental management. A recent review of published papers over the last 25 years (Hawkins et al. 2010) made the following conclusions with regard to the use of reference sites to set numeric water quality criteria that are applicable to USEPA's proposed numeric criteria for nutrients.[1]

A. USEPA Has Not Adequately Assessed Several Critical Assumptions Necessary to Set Defensible Water Quality Criteria Using a Reference Approach

The proposed Nutrient Watershed Regions produced coarse estimates of reference conditions leading to numeric criteria that may not be ecological meaningful. The lack of predictive modeling that links nutrients to a biological response is a major shortcoming (see comment B below). USEPA has not provided evidence to demonstrate that it adequately assessed the natural variability in the data to minimize predictive bias. No analysis has been provided supporting the assertion that the reference data, and the 75th percentile, are an accurate statistic for defining the distribution and natural variability in the data at reference and other sites. The application of this statistic to all sites in the region cannot be assessed with any degree of confidence without this assessment of data variability. Variations in time and space at any particular site may be greater than the variation within the region. Hydrologic variability, day-to-day, season-to-season, and year-to-year, make the interpretations of criteria exceedances difficult to assess without a large number of measurements taken over a long period of time (see comment E below).

B. USEPA Has Failed to Demonstrate a Link Between Its Proposed Nutrient Criteria and a Biological Response

Dodds and Welch (2000) outlined the many difficulties in setting nutrient criteria in streams, including the multiple management reasons for setting the criteria, the uncertainties associated with biological responses, and the high variability associated with nutrient data collected in streams. Although this white paper is 10 years old, these conclusions are relevant to the criteria proposed by USEPA today.

It is necessary that the proposed thresholds (i.e., criteria) have a quantified link to a biological response. Without such a link, there is no basis that reducing nutrients will have a measureable effect on the biota, and could lead to costly and unnecessary controls. Existing water quality criteria (e.g., temperature, dissolved oxygen, pH, metals) use laboratory bioassays to link stressors to biology. Studies of natural systems use modeling to relate stressors to biology as has

[1] FDEPs comments can be found at: http://www.dep.state.fl.us/water/wqssp/nutrients/docs/federal/fdep_comments_streams_criteria.pdf . Cross-references to FDEP draft comments dated March 12, 2010, are provided where applicable.)

been done for nutrients and chlorophyll biomass in New Zealand rivers. (Snelder et al., 2004). Such evidence has not been provided for Florida streams. This conclusion was made by FDEP (see FDEP comments D, F, and J) and acknowledged by USEPA in the proposed rule.

The natural environment is an uncontrolled experiment with biological conditions affected regionally by geology, climate, and land use. FDEP should be commended for assessing many of these regional patterns by developing specific bioregions for the Stream Condition Index (SCI), Nutrient Watershed Regions (NWR), and the Landscape Development Intensity (LDI) index. However, these tools do not fully explain the high spatial and temporal variability of nutrients in Florida streams. Highly variable flow conditions in streams, compared to lakes, and seasonal changes in macrophyte and periphyton growth make correlations between nutrients and biology (e.g., SCI and component metrics) statistically weak. They may need to be assessed on a site-by-site basis rather than a broad regional basis (see FDEP comment E and Appendices A-C). Both USEPA and FDEP have recognized this limitation and have additionally identified the importance of shade in regulating stream primary production.

C. USEPA Should Document Why They Did Not Adopt the FDEP's Benchmark Approach

The District supports the comments provided by FDEP (see FDEP comment C1-C4) and sees no defensible reasons why USEPA did not adopt the FDEP benchmark approach. USEPA failed to provide the significant lines of evidence needed to support its approach. If the reference approach, with its inherent shortcomings, is the tool used to develop numeric nutrient criteria, it is appropriate to utilize the technical methodologies from the state agency that developed the tool for the state in question.

Furthermore, the state agency in this instance has invested significant time and resources in the development of their benchmark approach to ensure validity of its approach. Specifically, the FDEP has spent over a decade and over three million dollars refining their SCI based benchmark approach (FDEP Numeric Nutrient Criteria Development Plan, March 2009).[2] They also went to extra quality control measures in the selection of their benchmark sites, a process not followed by USEPA in its approach.

Where the data sets have been rigorously developed, the selection of the 90th percentile for the criterion development should be used in favor of the 75th percentile due to the documented rigor associated with FDEP's methodology. More importantly, FDEP has evidenced the importance of a biological validation as part of a rule developed with the reference approach. The District strongly supports the use of the biological confirmation as a mechanism to handle the uncertainty associated with criteria developed without known dose-response relationships.

[2] FDEP's NNC Development Plan is available at http://www.dep.state.fl.us/water/wqssp/nutrients/docs/fl-nutrient-plan-v030309.pdf.

D. The Precision Associated with the Percentiles Used to Define Nutrient Thresholds Have Not Been Adequately Assessed

The reference condition approach ignores the lack of evidence on nutrient stressors in streams, leading to the high potential for over-protection or possibly under-protection. There is no technical basis supporting the assertion that levels of nutrients at a few reference sites accurately define what is achievable at other sites to meet some prescribed level of biological condition or use. Selecting a threshold based on a probability value (e.g., 75th percentile) assumes that all the sites in the population of that region function similarly, and ignores the spatial and temporal (seasonal) variability inherent in the data. The precision of the proposed criteria is determined by an analysis of the variability in the data at both reference sites and sites where the proposed criteria will be applied to determine use attainment. Such analyses have not been completed.

The District substantially agrees with comments made by FDEP in its Streams Document (See FDEP comment D) and supports FDEP's 90th percentile approach with accompanying biological validation given the uncertainties inherent in a reference basal approach.

E. Analyses to Support Duration and Frequency Criteria are Incomplete

Water quality criteria include magnitude (concentration that exerts an adverse effect), duration (exposure period, or averaging period) and frequency (how long it takes the system to recover) criteria. Frequency criteria are generally less definitive than threshold and duration criteria because the magnitude and duration of an adverse event are measured directly by dose-response studies while the frequency requires judgment to determine how often an adverse event can be allowed to occur without causing unacceptable harm. The lack of dose-response information for Florida streams makes selection of both the magnitude and duration criteria subjective and arbitrary.

USEPA provided no analysis as part of its proposed rule that defines the proposed annual geometric mean as the averaging period that best defines ecological effects, and specifically requested comments on this component. It is not possible to assess this and any other alternative without a good understanding of the dose-response relationships. The lack of technical support for the duration criterion further illustrates the difficulties setting numeric criteria without an understanding of dose-response. Without this understanding, numeric criteria define only where there are values that exceed 75% of those measurements at reference sites.

The District substantially agrees with FDEP comments D2, G, and I and requests that USEPA provide support and analysis as to why the proposed F and D were chosen. Additionally, based on existing evidence, USEPA should undertake additional peer review and research to properly produce and confirm a defensible D and F.

F. The Different Criteria for Canals and Streams Produces Inconsistencies in Their Applications Throughout The District (Also See District Comments On Canals)

Fla. Admin. Code R. 62-302.400 articulates the designated uses for Florida's waters. Class III waters are designated for recreation and the propagation and maintenance of a healthy, well balanced population of fish and wildlife (i.e. "fishable and swimmable"). While both streams and canals are designated as Class III waters, as noted in the attached Canal Science Inventory, the physical and biological nature of canals is significantly different than that of a natural stream. In other words, what is protective of recreation and a healthy, well balanced population of fish and wildlife in a natural stream is entirely different than that in a canal. Both waterbodies can be classified as Class III waterbodies, but USEPA must still examine how the use specifically applies to the physical and biological attributes of a given waterbody instead of subjectively promulgating criteria that does not reflect the nature of the designated use on an eco-region basis. It is therefore arbitrary and capricious to treat canals outside of the South Florida Region as streams under the proposed rule since they are operated and managed the same as canals in the South Florida Region.

USEPA has provided no support for approaching canals north of the South Florida Region in this manner. Additionally, USEPA has not proposed any solutions regarding how to address systems that are heavily managed in certain sections but qualify as natural streams in others.

G. Promulgating Numeric Criteria for Streams in Advance of Setting Criteria for Downstream Waterbodies Such As Estuaries May Cause Confusion With the TMDL Process

Nutrients effects occur over long time frames and are most severe in downstream waterbodies (e.g., lakes and estuaries) that accumulate nutrients over time in sediments and in the water column. Establishing numeric criteria for streams in advance of estuaries may require revising the criteria for streams after the criteria for estuaries have been adopted. It seems most effective to adopt numeric criteria for downstream waterbodies first because (1) nutrient effects are cumulative over time, and (2) focuses management attention on the most severe nutrient problems in Florida, (3) the knowledge base for nutrient problems is the most well understood for downstream waterbodies (e.g., lakes and estuaries) compared to flowing water systems such as streams and canals.

In addition, criteria designed to protect downstream waters may cause confusion between water quality standards and the TMDL process. Water quality standards for a particular waterbody are designed to protect the designated uses of that waterbody. Setting criteria to protect downstream uses will likely be based on tools and modeling currently used to set TMDLs, and may blur the distinctions between these regulatory tools. This creates difficulties for both unimpaired and impaired streams (and canals). Unimpaired streams discharging to a heavily impaired lake or estuary could have higher criteria, and allow higher nutrient loadings, compared to streams discharging to higher quality downstream waterbody. Conversely, heavily impaired streams discharging to high quality lake or estuary could have lower criteria, and require lower nutrient loadings, compared to other streams discharging to a lower quality downstream waterbody.

There is substantial agreement between FDEP and the District (see FDEP comment E), and FDEP Appendices A-C provide a process for setting numeric criteria on a watershed basis.

H. Site Specific Alternative Criteria (SSAC) Were Designed to Address Unique or Unusual Situations, and Should Not Be Used to Overcome Weakly Supported Regional Criteria

EPA proposes the option of developing SSACs as a way to address the technical uncertainties of the proposed regional criteria are somewhat addressed by the. However, the implication of such an approach is difficult to assess without a detailed estimate of the number of SSACs that would likely be required. If the number is very large, which is likely given the lack of dose-response relationship and the proportion of reference sites that do not meet the criteria (see FDEP comment J, Tables 2 and 3), then it may be more efficient to adopt site-specific criteria from the start. For instance, the District supports the adoption of TMDLs previously set and approved by USEPA and FDEP as protective of a given water body as automatic SSACs requiring no further submissions under the rule. SSACs should not be used to support regional or statewide numbers without a detailed estimate of the expected numbers of SSACs.

SSACs are costly and time consuming, and can be contentious in the context of stringent criteria. They are intended to apply to unique and unusual cases, and should not be used to supplement weakly supported regional or statewide criteria.

I. Potential Additional Research Pathways

Additional research for streams (and canals) might include two basic types; (1) studies of natural systems and (2) controlled experimental designs that include bioassay and mesocosm studies. Empirical studies of natural systems include assessments of water quality and biological communities at reference sites compared to sites with similar physiographic characteristics and high nutrient concentrations.

Hydrology and water quality are more variable in streams than lakes and wetlands, making it more difficult to define relationships between nutrients and biology in the natural environment. Controlled testing will likely be required. Such studies would identify the “potential” for streams to exhibit nutrient related problems, and identify those factors (geology, habitat, land use) that define the degree of impact in specific streams or watersheds. The types of research conducted on phosphorus limitations for the Everglades over the last two decades can provide a template for such research in streams. It will be important to define the expectation for such research: it will take several years of targeted research of both types to establish numeric criteria for streams.

J. Literature Cited

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III. South Florida Water Management District Response to USEPA Proposed Numeric Nutrient Criteria: Canals

A. Sound Scientific and Regulatory Foundations Are Not Provided for Protective Numeric Nutrient Criteria (NNC) in South Florida Canals by USEPA

In the USEPA proposed rule, there is no quantified linkage between nutrients and impaired biology in south Florida canals, and no evidence is provided that canal ecosystems are even sensitive to total nitrogen (TN) or total phosphorus (TP). As a result of these scientific weaknesses, the District cannot support any conclusion that these nutrients will adversely affect the designated uses of canals in south Florida. The USEPA does not provide a valid regulatory connection between the NNC values and achievement of the designated use of the waterbody, the heart of the Clean Water Act. Without a proper foundation, it is entirely possible that the State of Florida could spend millions of dollars and many years of effort on nutrient controls that would have little or no measureable benefit to the designated uses of canals. Simply stated, USEPA can provide no evidence to demonstrate what recreation or a healthy population of fish and wildlife are for canals and thereby cannot develop criteria to support them, particularly given the uncertainties inherent in their highly managed states and design.

Similarly, no data are provided that link chlorophyll *a* (Chl*a*) concentrations to designated uses in south Florida canals, and even if USEPA could furnish some such evidence, they would need to separate Chl*a* generated from within the canal from that imported during periods of discharges from upstream systems, particularly lakes. Additionally, USEPA notes that TP and Chl*a* are correlated, but then fails to account for their mutual chemistry. Much of the TP measured in water samples with significant concentrations of algae is derived from the chlorophyll-containing algae, so naturally the two parameters will be correlated. However, due to the complexity of canal flow patterns, the regression of TP and Chl*a* is weak and cannot be used for any regulatory purposes unless it is corrected for this lack of independence, seasonal flow patterns and for the proportion imported into the canal.

B. The Volume of Scientific Studies (Especially in Ecology) Available for Canals is Much Lower Than Those Found for Other South Florida Ecosystems (e.g., the Everglades Marsh Systems)

Determining the appropriate protective numeric nutrient criteria is premature if it is not clear what comprises the ecological community which is being protected. The District's recent 'Canal Science Inventory' (see District Attachment 1) has clearly shown the lack of canal ecological studies as compared to other systems in Florida (e.g., the Everglades, see '2010 South Florida Environmental Report; see District Attachment 2). FDEP's own Technical Advisory Committee (TAC) consistently struggled with the lack of available information on the ecological components of canals and how nutrients may or may not have an impact. In fact many of the

TAC's conversations often would focus on what is the appropriate designated use of these conveyance systems and what a canal biological community should look like.

C. Imbalances in Flora and Fauna Cannot be Used as a Basis for Determining Impairment in Canals Maintained for Conveyance Purposes

In order to function as conveyance systems, canals must be maintained by removing or limiting vegetation, creating immediate imbalances in canal flora and potentially fauna. The congressional authority for the Central and Southern Florida Project, which upgraded and expanded South Florida canals, specifies their primary uses as flood control and water supply, including environmental supply for the Water Conservation Areas and other natural systems. The designated uses derived under the Clean Water Act for maintenance of healthy, well balanced flora and fauna were not considered in this legislated intent. To keep their conveyance capacity and protect public safely, canals and their banks must be maintained open and free of obstructive vegetation, natural habitat, through mechanical harvesting or the use of herbicides. The FDEP TAC has discussed the extreme challenge of determining biological 'normalcy' under such circumstances and therefore, has noted on several occasions that it is extremely problematic to determine a rational basis upon which to develop numeric nutrient criteria in these systems.

D. Establishing Numeric Nutrient Criteria for Canals Requires the Analysis of Different Parameters and Derivation Techniques Than Those Used for Streams, Springs or Lakes

USEPA recognizes that canals are modified systems that behave in unnatural patterns, sometimes acting like reservoirs, other times flowing more like streams, and other times flowing more like slow moving rivers. Simple compilations of data cannot describe such complexity. As a result of these complex interactions, canals cannot be subject to the same parameters and derivation approaches applied to streams or lakes. Consider:

- **Using annual geometric means is not representative for canals.**

Canals behave like streams when the water is flowing for flood control or water supply, and then behave like lakes/reservoirs when water is not flowing, sometimes for months at a time. A single annual geometric mean (for Chl*a*, TP and TN) used by USEPA to establish nutrient criteria may not be representative of the actual conditions for a conveyance waterbody in light of their rainfall driven and seasonal complexity. Analysis of a certain year and across years should be done separately for flowing and not flowing regimes. Flow weighted means rather than annual geometric mean Chl*a*/TN/TP concentrations might be more appropriate for analysis.

- **Averaging over an entire waterbody is not representative for the canals crossing multiple ecoregions or other landscape types.**

Some primary canals in South Florida can cut across different geologic or ecological regions. Applying an annual geometric mean over the entire waterbody (canal WBID) might mask regional differences and provides statistics reflecting none of the actual environments being considered. The District's statistical comment section (see Section IV) provides a quantitative example of this problem.

- **There is no means provided by USEPA to deal with any sporadic stratification in canals.**

There is little doubt that deeper primary canals have the potential to stratify thermally during periods with no flow. However, all samples are taken at 0.5 m near the surface. During stratification, surface values can be reduced temporarily and during subsequent mixing with flow, surface values will be elevated. This process could add greatly to data variance and could contribute to future exceedances in some canals whether the reference canals representative of stratification patterns of canals as a whole! USEPA does not indicate one way or the other.

E. Setting Regional Criteria Based on Statistical Analyses of Diverse Environments is Invalid

Nutrient levels are highly variable (site specific), and USEPA provides no basis for the establishment of reference sites upon which to examine designated uses and potential impairment. The reference condition approach used for canals and the regional/ecoregional scheme for streams also ignores the lack of evidence that nutrients are key stressors in canals or streams (see above), leading to the high potential for unnecessary protection with little or no net benefit to the environment. As stressed by USEPA reviewers, both their Scientific Advisory Board and reviewers of the proposed rule (Attachments 3 and 4), there must be more information on stressor-response and impairment before any criterion can be justified for canals. An alternative approach would establish numeric nutrient criteria on a more rational watershed basis using available site specific information, such as setting criteria for a downstream body and then determining the proper way to operate the system and build projects to achieve this objective (i.e., the TMDL process). USEPA must identify specific canals that are nutrient sensitive, identify those impaired and the associated water quality levels, and then put into place numeric nutrient criteria to protect uses of these systems. The 303d list used by USEPA does not do this, even partially. No evidence was provided supporting the unimpaired status of selected canals as a basis for finding a threshold concentration of TN, TP or Chl*a* applicable to all canals.

F. Using Water Quality Monitoring Sites Not Included in Florida's Clean Water Act Section 303(d) List ("303(d) List) as 'Reference Sites' is Highly Biased, Provides No Evidence Concerning Ecological Balance, and is an Inappropriate Interpretation of the Listing Process

The 303(d) list was developed to identify areas appearing not to meet water quality standards and therefore requiring prioritization for TMDL development. Using the list to select unimpaired canals is scientifically unsound and may be contrary to Section 403.067, Fla. Stat., which states that the 303(d) list is not to be used for any regulatory purpose, at least under Florida law.

Any canal reference site should reflect direct evidence of conditions fully meeting the designated use and should be selected based on known thresholds that define imbalances in flora and fauna (e.g., land use, riparian habitat, pollution sources, etc.) and encompass physiographic differences (e.g., ecoregions). As noted above (#2), USEPA would have to demonstrate for the south Florida water management system canals, how imbalance would be defined for devices maintained for water conveyance purposes.

Due to the fact that canals are conveyance devices and flow dynamics can vary greatly based on location, USEPA must also match any potential reference sites with representative flow regimes. It would not be defensible to use canals draining small undeveloped areas as reference sites for those draining large, developed areas. The selection process for reference sites should not be based upon the target parameters (TN & TP) to avoid obvious circularity and lack of independence.

By USEPA's logic, a site is a reference site for contaminant A because the levels of contaminant A are low without any consideration of biological functions. In addition, sites used must be independent of each other to avoid spurious correlation and unintended data bias (multiple sites in one canal are NOT independent). Bias is self-evident in the fact that the draft criteria for TP (42 ppb) and Chl*a* (4 ppb) in South Florida canals are substantially lower than those for natural streams (TP, 107 ppb) and lakes (Chl*a*, 20 ppb), respectively; an absurd result. There is no justification for this inconsistency and none is apparent from general principles of ecological science.

Additionally, USEPA supplied no justification for using the 75th percentile of the reference site data. If USEPA's selection process is sound, then the 90th or even 95th percentile could be used to provide a reasonable margin of safety. Using the 75th percentile, forces up to 25% of canals in the reference set to become impaired when split off at the 75th percentile and to require unnecessary regulation. In addition, the use of an alternative percentile analyses (e.g. 25th) using an "all canals" approach is not justified for developing criteria for canals. The problems with this methodology have been well documented by FDEP and its TAC.

G. Proper Justification Is Not Provided for Separate NNC for South Florida Canals, While Canals in More Northern locations Are Classified as 'Streams'

There is no technical basis for setting different NNC for canals in the Everglades Nutrient Watershed (South Florida canals) and canals in the Peninsula Nutrient Watershed that use the NNC for "streams" (i.e., canals in all nutrient watersheds should be classified as canals). In fact, USEPA excluded data from Peninsula canals in the development of the NNC for the nutrient watershed (Chapter 2: Methodology for Deriving USEPA's Proposed Criteria for Streams, page 2-34). This would appear to mean USEPA appreciates the many different characteristics that exist between canals and natural streams.

For example, there are 11 significant canals in the Lower Kissimmee and Lake Istokpoga watershed (e.g., C38, C40 and C41) and 4 major canals along the Upper East Coast (C44, C23, 24, &25). In fact, these canals in the Peninsula Bioregion are typical, large artificial conveyances. Some canals in the Lake Okeechobee watershed have segments that are somewhat natural and others that are fully engineered. Many canals in South Florida were built in part along gradients provided by natural steams and some drain into former streams. Under such conditions, how does USEPA propose differentiation between a canal and stream, and what guidance will be provided on deciding between which instream criterion applies along a single canal? What is a stream and what is a canal, and how do canals in the north differ from canals farther south? Some rationale should be provided by USEPA for deciding which designation applies within and between regions.

This disparity between streams and canals has significant impacts. Canals in the Peninsula Region have no Chl*a* criterion at all, according to USEPA, but they do have a TP NNC more than 2.5 times the 42 ppb requirement farther south. Based on land use, location and design, canals are clearly more prone to higher baseline nutrient levels, and if anything, their NNCs should be less stringent than those of more natural streams. Some canals north of the EAA and some canals south of the EAA discharge directly to tide. What justification does USEPA have for the large difference in the NNC north versus south, both discharging into nitrogen limited marine systems?

H. The Use of the Everglades Protection Area TP Rule Criterion of 10 ppb as an Instream Criterion is Unsound

The TP Rule for the Everglades Protection Area was developed after extensive research on biotic community responses to TP in P-limited marshes. The Rule was based on evidence from many different experimental and observational data sets, but did not include any use of or reliance upon a TP to Chl*a* relationship in marshes or in canals. In fact, the TP rule included no data whatsoever on canal nutrient effects. This fact and the nearly complete lack of ecological similarity between canals and marsh sloughs, precludes the use of a criterion developed for marshes as an instream NNC for South Florida Canals in the Everglades Protection Area without qualification.

If USEPA is going to justify the scientifically inappropriate application of the TP criterion to canals, then it must clearly specify that it is not an instream protection number, but is being asserted based upon downstream or in this case, lateral marsh interactions. Justification must be provided by USEPA for protecting some canals to 10 ppb, while neighboring canals on the other side of a levee are held to 42 ppb with Chl*a* at 4 ppb and those 20 miles north are at 107 ppb TP and no Chl*a*. This unjustified segmentation of criteria is not defensible.

I. USEPA Has No Documented Peer Review of the South Florida Canal Numeric Nutrient Criteria

In the District's review of the USEPA's rule and supporting documentation (on USEPA website: Docket Folder containing Supporting Technical Documents), we have not found any reference on scientific peer review of the South Florida Canal nutrient watershed criteria or methodology used to create those criteria. In addition, we have not observed scientific peer review for the alternatives reviewed by USEPA for the South Florida Canal nutrient watershed. The District requests any information that USEPA may have gathered as a scientific peer review for the South Florida Canal nutrient watershed. If no such peer review has been undertaken, the District strongly suggests such a review by USEPA's own SAB, the NAS, NRC, or other recognized body of experts.

IV. South Florida Water Management District Response to USEPA Proposed Numeric Nutrient Criteria: Comments on Statistical Methods and Assumptions

A. Statistical Flaws in the Derivation Process: Global Issues

Universally, USEPA has not documented that their data assumptions are validated or satisfied based on the distribution of the data. Use of transformations, parametric tests and other more complex statistical measures need direct evidence of meeting all assumptions. For example, USEPA never appears to test for the log-normality of the water quality data; this untested assumption is important in setting criteria.

The calculation of percentiles as presented by USEPA from means and standard deviations of log-transformed data distributions is unnecessary and potentially incorrect. If USEPA elects to use percentiles of the data approach to criteria setting, then they should derive percentiles from the available data directly, without log-transforming. Using data from different regions for TP, TN and Chl*a* can bias the results and render them inappropriate for application across the region, as proposed by USEPA. For example, canals may cross different landscape types, as noted above, and data being summarized for a single threshold number using an assumption of a single statistical distribution can be invalid because multiple distributions may be present in the underlying data.

For the linear regression analyses used by USEPA, the assumptions of log-normality and constant variance of residuals could lead to large discrepancies. Measurement error associated with using average values has not been unaccounted for. Beyond these global concerns, the following text focuses on specific statistical concerns within the lakes and South Florida canals section of the proposed rule.

B. Statistical Flaws in the Derivation Process: Lakes

The statistical results used to derive numeric nutrient criteria are only valid if various assumptions about the distribution of the data are met. The document provides no evidence that any of these assumptions were considered or tested. Consequently, the resulting prediction intervals (criteria) generated by USEPA may be inaccurate. The following statistical assumptions and considerations should be tested and/or considered.

(1) Distributional Assumptions

Log-normal distribution of data: USEPA assumes that all the water quality data used in their assessments are log-normally distributed. The document does not provide any evidence that this assumption is correct. In other words, there are no formalized tests (outside of an occasional plot) to support/validate this assumption. While normal probability and cumulative distribution plots are helpful in identifying severe skewness and kurtosis, more formal tests should be used to account for cases where the departure from normality is not obvious. This is especially true when setting strict compliance criteria.

(2) Linear Regression Assumptions

Log-normal distribution of residuals: USEPA used the (log transformed) chlorophyll *a* to nutrient relationship to set the nutrient criteria for lakes. These criteria are based on a statistical model (linear regression) between the two parameters. It does not appear that the normality of the residuals from this model was tested or discussed in the document. If the residuals statistically deviate from normality, then the prediction intervals are erroneous. However, the District did test the residuals of chlorophyll *a* vs TP for colored and clear lakes and found the residuals deviating from normality at the 0.05 level. Distribution assumptions should be tested using formalized tests rather than visual examinations (see Item 1).

(a) Constant variance of residuals (heteroskedasticity or homoskedasticity)

It appears the USEPA assumed (and did not test) that the residuals had constant variance. This assumption can be tested by doing a plot of residuals versus predicted values. High concentration of residuals above zero or below zero indicates the variance is not constant (systematic error exists). In addition, performing a plot(s) of the residuals versus the X value(s) can be done. A Fanning effect in the residuals indicates the variance is not constant. Formal tests such as White's and Breusch-Pagan's can also be performed.

A violation of constant variance assumption will cause the ordinary least squares (OLS) standard errors to be biased, so the usual confidence intervals and test statistics will be incorrect, and may lead to incorrect conclusions such as described below:

- If errors increase as X increases (fanning out as X increases) OLS underestimates true variance/standard errors and overestimates test statistics yielding p-values that are too small for tests of hypotheses and confidence/prediction intervals that are too narrow (Type I error inflation);

- If errors decrease as X increases (funneling inward as X increases) OLS underestimates true variance/standard errors and overestimates test statistics yielding p-values that are too small for tests of hypotheses and confidence/prediction intervals that are too narrow (Type I error inflation);

- If errors increases (up to a point) and then decreases as X increases (fanning out and then funneling inward as X increases) OLS overestimates true variance/standard errors and underestimates test statistics, yielding p-values that are too large for test of hypotheses and confidence/prediction intervals that are too wide (Type II error inflation).

(b) Measurement Error

A basic assumption of linear regression is that the data points are measured without error. The data points used in the regressions are annual means. Any mean has an error associated with it. How are these errors being accounted for in the determination of nutrient limits from the regression analyses? Based on the USEPA document, it is not apparent that this error was accounted for.

(c) Independence of Error Terms - successive residuals are not correlated

This assumption can be tested as follows by a plot of residual versus predicted value. Patterns in residuals such as successive positive residuals followed by successive negative residuals (positively correlated errors) or alternating positive and negative residuals (negatively correlated errors).

In addition, the Durbin-Watson test can be performed. Violation of the Independence assumption causes the ordinary least squares (OLS) standard errors to be biased, so the usual confidence intervals and test statistics are incorrect, and may lead to incorrect conclusions.

Positively correlated errors have the following effects on statistics. OLS underestimates standard errors and overestimates test statistics, yielding p-values that are too small for tests of hypotheses and confidence/prediction intervals that are too narrow (Type I error inflation). R^2 will be higher than it should be;

Negatively correlated errors has the following effects on statistics. OLS overestimates standard errors and underestimates test statistics, yielding p-values that are too large for tests of hypotheses and confidence/prediction intervals that are too wide (Type II error inflation). R^2 will be lower than it should be.

(d) Predictive Ability

The coefficient of determination (R^2) expresses the amount of variability in the Y-variable that is explained by the X-variable. It also determines how well the regression predicts the dependent value (Y-variable). Models with $R^2 \leq 0.65$ have low predictive power (Prairie 1996).

(3) Linear Regression Approach: Predictor/Predicted Values

Based on the regression plots as presented in the document, the nutrients (TP and TN) are the predictor variables (X-axis) and chlorophyll *a* is the predicted variable (Y-axis). USEPA establishes the chlorophyll *a* limit of 20 µg/L (based on a TSI=60) to set the nutrient criteria. Rather than regressing chlorophyll *a* as the predicted variable, USEPA should use it as the predictor because the interest is in establishing a nutrient limit for a given/required/fixed chlorophyll *a* concentration.

(4) Seasonal Differences: Comparison of Data

USEPA used a simple box plot of wet and dry season chlorophyll *a* data for clean and colored lakes (their Figure 1-3) to show that there is not a statistically significant difference between seasons. A notched box and whisker plot would have provided more information. However, a formal (two-sample) statistical test (e.g., t-test, Wilcoxon rank sum) should have been done and would provide more conclusive results.

(5) Handling varying method detection limits (MDLs) within the dataset

USEPA did not provide any information on how differing MDLs for a particular parameter (chlorophyll *a*, TN, TP) were handled. For instance, chlorophyll *a* MDL could range from 0.1 µg/L to 10 µg/L (based on STORET). It is not clear how USEPA applied these varying limits with regards to using significant figures for the overall data analyses. The spread in MDL values could be highly influential for lakes with low chlorophyll *a* criterion (e.g. clear acidic lakes have a proposed limit of 6 µg/L).

C. Statistical Flaws in the Derivation Process: Canals

As stated in Section III of this document the District does not believe the inference model used by USEPA is appropriate for setting numeric nutrient criteria for South Florida Canals. Beyond the global concern of the methodology not being appropriate, the following comments on focused solely on concerns we have the statistical methodologies of the Canal section.

(1) Distributional Assumptions:

(a) Log-normal distribution of data

USEPA assumes that all the water quality data used in their assessments are log-normally distributed. The document does not provide any evidence that this assumption is correct. In other words, there are no formalized tests (outside of an occasional plot) to support/validate this assumption. Normal probability and cumulative distribution plots are helpful in identifying severe skewness and kurtosis. However, more formal tests should be used to account for cases where the departure from normality is not obvious. This is especially true when setting strict compliance criteria.

(b) Annual geometric mean is not representative for canals

Canals behave as streams when the water is flowing (mostly during the wet season) and as lakes/reservoirs when water is not flowing (mostly during the dry season). Therefore the annual geometric mean (for Chl*a*, TP and TN) used by USEPA to establish nutrient criteria may not be representative of the actual conditions for the waterbody since canals may not behave as either category (stream or lake) on an equal basis. Analysis of a certain year and across years should be done separately for flowing and not flowing regimes in canals. Flow weighted means rather than annual geometric mean Chl*a*/TN/TP concentrations might be more appropriate for analysis.

(c) Averaging over an entire waterbody is not representative for the canals crossing multiple regions.

Some canals cross 2-3 landscape regions and annual geometric mean over entire waterbody (canal WBID) might mask natural differences between different ecoregions. The table and the graph below present the TN annual geometric mean for the waterbody "3245" for the interval 1996 through 2009. This canal crosses two ecoregions: HESEA and SEA. TN annual geometric mean averaged over the stations along for the entire waterbody is compared to TN annual geometric mean averaged over the stations placed in ecoregions HESEA and SEA separately. Note in the graph that each ecoregions appear to differ from the average over the entire canal. In addition when the annual geomeans for the entire canal and the ecoregions are compared, they were all found to be significantly different statistically.

(d) Improper use of a single distribution to determine a percentile

Using a single distribution (of Chl*a*, TN or TP respectively) to determine a percentile as the threshold for chlorophyll *a* and nutrients may be incorrect because different distributions may exist between different ecoregions. We used the canal data set provided by USEPA and arithmetic averages of the annual geometric means were calculated by ecoregion for Chl*a*, TN and TP. These averages are provided below and clearly show that differences exist between these means across ecoregions. The tables suggest that the data may not come from a single distribution and such differences need to be investigated. Also the disparity in the number of records and the period of records between the nutrient and Chl*a* datasets might produce a bias in the analysis.

Table 3: Arithmetic averages of the annual geometric means calculated by ecoregion.

Ecoregion	Period of Records	# data points	TN (mg/L)
HESEAA	1973 - 2009	399	2.80
HESEPA	1976 - 2009	771	1.81
SAS	1973 - 2009	490	1.08
SEA	1974 - 2009	1305	1.41

Ecoregion	Period of Records	# data points	TP (mg/L)
HESEAA	1973 - 2009	471	0.078
HESEPA	1976 - 2009	1023	0.027
SAS	1973 - 2009	582	0.048
SEA	1974 - 2009	1705	0.071

Ecoregion	Period of Records	# data points	CHLA (µg/L)
HESEAA	1994 - 2007	19	7.75
HESEPA	1994 - 2007	79	3.06
SAS	1996 - 2008	227	3.27
SEA	1996 - 2008	271	4.32

(2) Percentiles

(a) Percentile calculations

The use of percentiles generated from lognormal distributions to derive chlorophyll *a* and nutrient criteria is unsubstantiated because documentation has not been provided showing that the data follow a lognormal distribution (i.e., no formalized test to prove that log transformation normalized data). It would be more appropriate to simply calculate the percentiles from the available data, instead of generating them based on summary statistics (mean and standard deviation) of an assumed distribution of the data. In other words, use the available data and determine desired percentiles.

(b) Regional limits for chlorophyll *a* and nutrients

It appears that different regions were used to calculate the 75th percentiles for chlorophyll *a*, Total P and Total N. It is not clear from the document whether the preponderance of the data comes from one particular region or if the data are approximately evenly distributed across the regions. This could result in a region being under/over represented in the data. It appears from the map (Figure 4-3), that certain canals may be over represented (due to the close proximity of sampling sites along the same canal) while other canals are underrepresented.

(3) Setting Criteria

(a) Unimpaired canals

It is not clear why the 75th percentile is being used to set a nutrient criterion from unimpaired canal data. This means that 25% of the "clean" canals do not meet criteria. The nutrient criteria should be set to maximum nutrient level using "unimpaired" canal data sets.

(b) Chlorophyll *a* criterion

The Chl*a* data set contains approximately 5-fold fewer stations than the nutrient data sets. Based on the geometric mean and 75th percentile, it would be a safe assumption to say that some stations (~25%?) in the EVPA would not meet the criterion. The chlorophyll *a* criterion based on the 75th percentile is at (or within) the PQL range. The District's freshwater Chl*a* MDL is 1.0 µg/L. Collier County has an MDL level for Chl*a* at 3.0 µg/L.

It appears that the statistical analyses performed for chlorophyll *a* may be highly skewed by data with concentrations between the MDL and PQL. Is it the contention of USEPA that Chl*a* criterion should be set at practically the method detection limit? USEPA has categorized several District canals (e.g., C-44, C-43) as streams rather than canals. Both of these canals carry Lake Okeechobee water to tide. Since these canals have been classified as streams, there is no proposed Chl*a* criterion. What makes these canals different from other canals (such as C-51) that discharge to tide and not to the EVPA?

In canals, the relationship Chl*a* vs nutrients is hard to define and quantify. Chlorophyll *a* can be produced within the canal when discharges are less frequent and of smaller volume. During periods of flow, chlorophyll *a* will be transported from other regions and therefore no correlation with the nutrient concentrations would be expected, just as it was not found in streams. Based on the USEPA's analyses, they realized that the correlation between waterbody annual geometric mean chlorophyll *a* vs nutrients (TN/TP) was weak and was not used in the determination of nutrient criteria.

(4) Linear Regression Assumptions

The District has the same concerns with the USEPA's linear regression assumptions for South Florida Canals as stated in this section for Lakes.

V. South Florida Water Management District Response to USEPA Proposed Numeric Nutrient Criteria: Criteria Implementation Issues

A. Restoration Programs and Projects

The implementation of the numeric nutrient criteria from USEPA will have significant affects on current environmental restoration efforts being conducted by the South Florida Water Management District, including the Comprehensive Everglades Restoration Plan (CERP). CERP was approved by Congress as the framework for Everglades Restoration in the Water Resources Development Act of 2000 (WRDA-2000). CERP components include Stormwater Treatment Areas (STA's), surface water storage reservoirs, aquifer storage and recovery, seepage management, operational changes, and other components to be implemented over 35 years. To date, the state of Florida has invested over 1.8 billion dollars towards CERP.

The Florida Legislature in 2007 adopted the Northern Everglades and Estuaries Protection Act (NEEPA) to strengthen protection for the Northern Everglades. NEEPA recognizes Lake Okeechobee, Caloosahatchee and St. Lucie watersheds are critical water resources of the State and consolidates numerous restoration activities into a comprehensive approach.

All restoration projects, including CERP and Northern Everglades, are regulated under Chapter 373, Florida Statutes (F.S) to ensure protection of the State's water resources and specifically need to meet the State's water quality criteria. There are a variety of specific regulations for restoration projects with varying water quality requirements. For example for CERP projects, state water quality standards, including water quality criteria will be met. Under no circumstances shall the project component cause or contribute to violations of state water quality standards. However, for Lake Okeechobee restoration projects, discharges must be "of equal or better quality than inflows" and "not pose a serious danger to public health, safety, or welfare" for water quality parameters other than phosphorus. Fla. Stat. § 373.4595(7)(d).

Implementation of the nutrient criteria may have a significant impact on restoration projects in Florida, depending on how the criteria are applied. Strict application of the criteria could result in project redesigns, the need for additional land acquisition, project delays, increased costs, and ultimately could result in the inability to move forward with restoration projects. The criteria will also likely result in reduced flexibility of operations, and operational constraints that may reduce or negate the effectiveness of restoration projects.

For example, the initial WRDA of 1996 authorized the United States Army Corps of Engineers (Corps) to cost share with the state of Florida (50-50) on CERP water quality features the Secretary of Army deemed to be essential to Everglades Restoration. In addition, the April 1999 Feasibility Report ("the Yellow Book") determined 22 project components with water quality features to be essential to Everglades Restoration and recommended 50-50-costs share on these. However, the Corps has subsequently interpreted the "essential to Everglades Restoration" cost share requirement to apply only to those projects or components that provide WQ improvement beyond the State WQS that would need to be achieved prior to inflow to the project. For example, through the Lake Okeechobee Watershed Project process the Corps has indicated that they are unsure if there will be federal cost sharing water quality elements of this project as a result of the establishment of a TMDL for Lake Okeechobee, even though the TMDL is a restoration standard. For example, the Corps has indicated reluctance regarding possible federal cost sharing on water quality elements of the Lake Okeechobee Watershed Project as result of the establishment of a TMDL for Lake Okeechobee, even though the TMDL is a restoration standard.

The District is unsure how the Corps will work within the context of numeric nutrient criteria as we continue our discussions with them on this complex issue. However, the development of numeric nutrient criteria without sound science will lead to even more challenges for our Federal Partners in Everglades restoration The proposed rule will result in inherent conflicts between CERP's overall South Florida restoration goals (i.e., "getting the water right," Quality, Quantity, Timing and Distribution of water) and new federally imposed water quality standards that have poor scientific linkages to protecting the environment and no linkages to the region's current comprehensive restoration plan.

In order to avoid these affects on environmental restoration projects, USEPA needs to include restoration specific provisions within the new regulations, which recognize the unique nature of restoration projects. Typically, restoration projects are not a source of pollutants, rather they result in a net improvement to water quality and/or quantity. A restoration project should not be held responsible for fully resolving water quality problems caused by other point and non-point sources, therefore restoration specific provisions such as net improvement provisions, exemptions, variances and/or compliance schedules for large scale restoration projects and STA's should be included within the new regulations.

With regard to water quality restoration projects, most of the emphasis in Everglades Restoration has been on nutrient reduction. To date, the focus has primarily been on the use of natural treatment systems (e.g., Stormwater Treatment Areas) for phosphorus reduction. Significant data collection and management practices have been in place to ensure maximum performance for phosphorus removal. STA's have not been focused on or designed to reduce other nutrients that are included in the proposed nutrient criteria rule (e.g. nitrogen or chlorophyll *a*). It is not currently clear, the extent to which these natural treatment systems can be optimized to reduce nitrogen or chlorophyll *a* to levels consistent with the proposed criteria.

In addition, several restoration projects are planned and designed to address water quantity rather than quality (e.g., storage reservoirs, hydropattern restoration, Aquifer Storage and Recovery). If the proposed criteria are applied in a strict manner, a restoration project designed to improve water quantity issues could also be held responsible for resolving water quality issues and ensuring discharges could comply with proposed criteria. Currently as a part of the

Comprehensive Everglades Restoration Plan, the District and U.S. Army Corps of Engineers have NPDES permits for their ASR pilot projects that allow them to return water back to its regional source (e.g., canal). The proposed criteria have the potential to adversely impact those permits.

It has always been recognized that Everglades Restoration will take a comprehensive approach involving a large number of projects that work together to achieve restoration. Applying water quality criteria in a way that forces each project to fully achieve/address water quality issues will significantly impact the current approach to restoration. Therefore, consideration of alternatives specific for restoration projects is imperative in order for restoration to continue.

B. Effects on State of Florida's Current Total Maximum Daily Load Program

The District is concerned that the numeric nutrient criteria proposed by USEPA does not consider fully the current total maximum daily load program (TMDLs) and Basin Management Action Plan (BMAP) processes already in place. Through programs such as the Northern Everglades (see section IV.A.), the District has been participating and investing significant time and resources with both the TMDL and BMAP processes.

As noted by USEPA in its preamble of the numeric nutrient criteria rule, the state of Florida is a leader across the nation in terms of its (TMDLs). From the rule:

"Moreover, Florida is one of the few states that has in place a comprehensive framework of accountability that applies to both point and nonpoint sources and provides the enforceable authority to address nutrient reductions in impaired waters based upon the establishment of site specific total maximum daily loads (TMDLs)."

Through the Florida Watershed Restoration Act (Fla. Stat. § 403.067), the Florida Department of Environmental Protection has developed a prototype five-step program to manage the listing of impaired waters, the development and implementation of TMDLs across the state. These are the same TMDLs that have been approved by the USEPA. Yet, in the rule, USEPA states

"TMDL targets submitted to USEPA by the State for consideration as new or revised WQS could be reviewed under this SSAC process."

The District is uncertain how this affects current TMDLs. The District cannot support the requirement that TMDLs be resubmitted under the Site Specific Alternative Criteria process. This would slow down water quality restoration efforts across the state and run in conflict with USEPA's stated goal of speeding up the process with numeric nutrient criteria. For example, it would seem stakeholders in a BMAP planning process would be hesitant to start planning for load allocations if the TMDL has a significant chance of being delayed and/or changing.

In addition, the District has concerns with the Proposed Restoration Water Quality Standards (WQS) Provision and its comparability with the BMAP program. Initially some portions of the

Restoration WQS provision reads similar to BMAP language. In fact, USEPA acknowledges the Florida BMAP program covers many of the provisions in the Restoration WQS process. However, USEPA goes on to state:

"To the extent necessary, FDEP could potentially use aspects of the BMAP process and plans such as these to help form the basis for Restoration WQS."

The District is uncertain how this affects current BMAPs. Will current BMAPs for nutrients need to be resubmitted under the Restoration WQS process? If so, this would seem to slow down water quality restoration efforts significantly across the state and run in conflict with USEPA's stated goal of speeding up the process with numeric nutrient criteria. For example, it would seem stakeholders in a BMAP planning process would be hesitant to start planning and allocating funding for restoration projects if a BMAP has a significant chance of being delayed and/or changing.

If BMAP components would need to be integrated with the USEPA's Restoration WQS process then it would appear from the rule that Use Attainability Analyses would need to be retroactively performed for all current nutrient TMDLS and BMAP processes. The District requests USEPA to determine the number of UAAs developed nationwide over the last 5 years and the approximate length of time and resources it has taken to develop them. This information will assist us in understanding how the Restoration WQS process will be implemented.

Overall, the District supports the FDEP's approach for the TMDL and BMAP process as the proper alternatives. As stated in the draft numeric nutrient criteria (draft revisions Florida Administrative Code [F.A.C.] July 2009) presented at a public workshop (Marco Island Florida July 22, 2009) the FDEP would, in effect, take all current TMDLs as SSACs immediately within their rule without further administrative review. In addition, the District requests the USEPA to utilize the FDEP's current BMAP process over the Restoration WQS.

C. Effects on Water Supply Reuse Programs and Projects

Although the District does not directly operate or regulate water reuse, it has actively promoted, encouraged, and funded water reuse programs. The District is concerned that the proposed criteria may impact the ability of local wastewater utilities to provide reclaimed water – and it may have a ripple effect throughout the water management activities in the District. Reclaimed water has been a valuable resource in meeting existing water needs and is critical to meet future water needs. Currently, almost 240 million gallons per day of previously wasted water is being reused in the District.

In response to the state objectives in Sections 373.250 and 403.064, Florida Statutes, of "encouraging and promoting reuse," the State of Florida has developed a comprehensive reuse program. The Florida Department of Environmental Protection (FDEP) has created extensive rules dealing with water reuse which are contained in Chapter 62-610, F.A.C.

Water reuse involves taking domestic wastewater, giving it a high degree of treatment, and using the resulting high-quality reclaimed water for a new, beneficial purpose. Extensive treatment and disinfection ensure that public health and environmental quality are protected.

Florida Statutes state, "A water management district may require the use of reclaimed water in lieu of surface water or groundwater when the use of uncommitted reclaimed water is environmentally, economically, and technically feasible and of such quality and reliability as is necessary to the user." Fla. Stat. § 373.250. Additionally, "The South Florida Water Management District shall require the use of reclaimed water made available by the elimination of wastewater ocean outfall discharges … in lieu of surface water or groundwater when the use of uncommitted reclaimed water is environmentally, economically, and technically feasible and of such quality and reliability as is necessary to the user. This legislation directed that each domestic wastewater facility that discharges through an ocean outfall shall install a functioning reuse system no later than December 31, 2025." Fla. Stat. § 403.086.

The District is concerned that the proposed criteria will trigger violations related to water reuse, causing local wastewater utilities to abandon or reduce the practice – thus eliminating or reducing the reuse of a beneficial, fresh-water resource. As an example, consider a south Florida wastewater utility that has invested to upgrade its facilities so it can produce reclaimed water. As in many cases in south Florida, the utility delivers its reclaimed water to a storm-water pond at a local golf course. The golf course, in turn, uses the combination storm-water/reclaimed water pond for irrigation of the golf course and, in some cases, residences. The pond is connected for flood protection purposes to the regional drainage canal. As a result of the proposed criteria for canals, the utility might be in violation of its NPDES municipal separate storm sewer system (MS4) permit. If so, the utility either pays for costly upgrades to its treatment facility to meet the criteria, or it chooses to dispose of the reclaimed water in a deep injection well previously used as a backup.

Other main concerns with the numeric nutrient criteria on reuse programs include:

- Reclaimed water is a valuable, fresh-water resource (i.e., water management tool) for the District. As a water management agency, the use of reclaimed water is essential to reducing the dependence on limited fresh-water sources, such as groundwater and surface water. If water reuse declines as a result of the proposed criteria, stress on these limited resources would increase.
- Any reduction in existing or projected water reuse would result in unmet water needs, and increased additional investment in costly alternative water supplies would be required, if available.

- Effluent disposal, in lieu of reuse, would increase (e.g., deep-well injection)
- For those utilities that decide to continue a water reuse program, wastewater treatment costs will dramatically increase. Such cost increases, ultimately to be borne by the rate payer, may not be economically or politically feasible and reduce water reuse in the future.
- Those utilities that are required by State legislation to reuse a minimum 60% of their ocean discharge (Ocean Outfall Legislation, Chapter 2008-232) might be severely handicapped in their ability to meet those requirements.
- The proposed criteria could affect the availability and timing of water in environmentally-sensitive areas. The loss of reclaimed water might adversely affect water reservations that the District is developing to secure the long-term availability of water for thousands of fish and wildlife species throughout the region. The effect may come directly from disposal instead of reuse (e.g., deep-injection wells) or indirectly by increasing groundwater and surface water withdrawals to substitute for the loss of reclaimed water. Those additional groundwater and surface water allocations may be in direct competition with the environmental needs.
- The proposed criteria could limit or eliminate the use of Aquifer Storage and Recovery (ASR) technology as a component in the federally-partnered Comprehensive Everglades Restoration Plan (CERP). Currently, the District and U.S. Corps of Engineers have NPDES permits for their ASR pilot projects that allow them to return water back to its regional source (e.g., canal). The proposed criteria have the potential to adversely impact those permits and therefore ASR technology, which is a vital component to restoring America's Everglades.

D. District Regulatory Programs

The proposed NNC rule may require existing regulatory programs (Rules 40E-61 and 63, F.A.C. for the District) that currently focus on total phosphorus source control Best Management Practices (BMPs), the limiting nutrient for the waterbodies of concern, to be amended to include nitrogen source control BMPs. These programs have reduced phosphorus loads up to 50% compared to historic levels. Amending and implementing these rules to add BMPs for nitrogen will require additional resources from the District to conduct research, monitoring, rulemaking, implementation and compliance with no real ecological benefit since nitrogen is not the limiting nutrient.

The proposed NNC rule has the potential to erroneously increase the number of impaired waterbodies, thus, increasing the complexity of Environmental Resource Permit (ERP) applications and the resources necessary for the agencies implementing the program and the entities applying for the permits. The District issues an average 1,800 permits per year. The District and the other 4 water management districts, along with FDEP, issue these permits throughout the State.

The State ERP program, in existence since the mid 1980s, and a proposed comprehensive statewide revision to the water quality treatment aspects of the ERP program (focusing on nutrient reduction) are predicated on a rebuttable presumption that an applicant will not cause or contribute to violations of surface water standards if the applicant is in compliance with the design criteria within the rules. In addition, the ERP program provides state water quality certification. The proposed NNC rule could require a change in the water quality analysis methodology and compliance requirements to be similar to NPDES permits, which the state agencies do not have the authority to implement. This could result in the State no longer being able to issue water quality certification.

Currently, the State has a net improvement provision for retrofit or restoration projects submitted for ERP applications. The proposed NNC rule does not have these provisions, which could severely limit the number of retrofit or restoration projects being submitted. Without net improvement provisions local governments and other entities would not be able to get ERP permits for projects designed to improve waterbodies that are impaired.

E. Additional Peer Review and Comment

EPA's own Scientific Advisory Board ("SAB") found substantial shortcomings in the technical guidance documents published by EPA in order to assist states in developing their own numeric standards, yet EPA did not return to the SAB for a peer review of the scientific methodologies and approaches underlying the current proposed rule. In fact, no review of the methodology and approaches utilized to develop the canal criteria was ever undertaken or included in the proposed rule. The District strongly recommends that EPA delay promulgating criteria, particularly for streams and canals in the state, until such time as a more thorough peer review is undertaken by the SAB, National Academy of Sciences, or other nationally recognized scientific panel to determine the validity of the technical and scientific underpinnings of the proposed criteria.

Although EPA requested that stakeholders comment on the alternatives considered as part of the rulemaking process, it failed to include adequate methodological explanations or explanations of scientific assumptions underlying these alternatives, instead addressing the alternatives in "general terms." *See Amer. Med. Ass'n. v. U.S.,* 887 F.2d 760 (7^{th} Cir. 1989) (holding that notice was inadequate when an issue was only addressed in general terms in the initial proposal). The District was therefore unable to thoroughly address the validity of the science and methodologies supporting the considered alternatives. The District has also had no opportunity to address any alternatives proposed by other commenting stakeholders. The District respectfully requests that should the EPA change its approach and methodology to adopt a different rule than that proposed based on either those alternatives considered in the proposed rule or any alternative proposed by a commenting stakeholder, it republish the proposed rule to allow additional time for review and comment on the newly adopted alternatives. A substantially changed final rule based on alternatives utilizing different methodologies and scientific assumptions that currently lack an adequate explanation of scientific assumptions and methodologies would not qualify as a logical outgrowth of the rulemaking process and EPA should not promulgate a final rule based on these alternatives until a new round of comments was held so that stakeholders would be provided "their first occasion to offer new and different criticisms that the agency might find convincing," regarding the newly adopted alternatives. *See Assoc. of Battery Recyclers Inc. v. U.S. EPA*, 208 F.3d 1047 at 1059 (C.A.D.C. 2000).