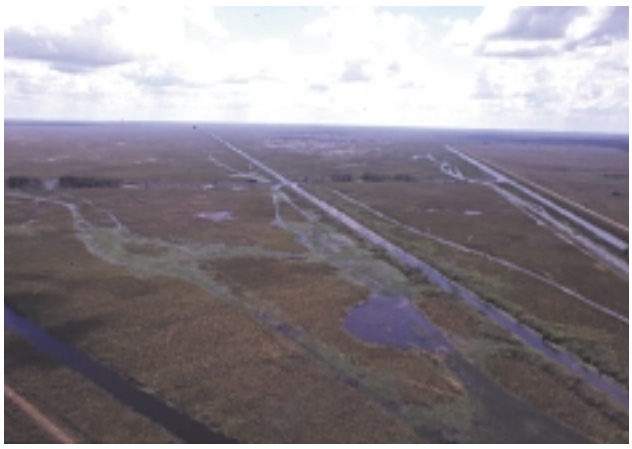
BROWARD COUNTY, FLORIDA HISTORICAL WATER QUALITY ATLAS: 1972-1997

Confluence Intracoastal Waterway and New River, Ft. Lauderdale, eastern Broward County.



Water Conservation Areas, western Broward County.

Port Everglades Inlet and Atlantic Ocean.

North New River Canal at Sewell Lock and Interstate 595, east-central Broward County.

BROWARD COUNTY
FLORIDA

DEPARTMENT OF PLANNING AND ENVIRONMENTAL PROTECTION

BROWARD COUNTY DEPARTMENT OF PLANNING AND ENVIRONMENTAL PROTECTION

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BROWARD COUNTY, FLORIDA HISTORICAL WATER QUALITY ATLAS: 1972-1997

FEBRUARY 28, 2001

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EXECUTIVE SUMMARY

The following report summarizes twenty-five years of water quality data from freshwater canals and estuarine waters of Broward County, Florida (USA). The types of analyses are described and results presented in terms of water quality over time, seasonally and in relation to compliance of Broward County's local water quality standards (Broward County 2000). Research questions and needs are discussed for each basin and summarized for the overall county. This document is divided into four sections with the first discussing the county's general characteristics and the second describing the methodologies used for the study. The third section focuses on the freshwater canal system, primarily operated by the South Florida Water Management District, and the fourth describes the estuarine waters of the county.

Located in Southeast Florida, Broward County was established in 1915 and contains thirty municipalities, as well as many unincorporated neighborhoods. Geographically, the populated region of Broward County is tucked between the Everglades to the west and the Atlantic Ocean to the east. Connecting these two large aquatic systems are more than 266 miles of natural and dredged canals that traverse the county's urban corridor (Broward County Planning Council 1989). Overall, the hydrology of Broward County is highly manipulated by a series of water control structures and levees that have altered the natural hydroperiods and flows of the South Florida watershed.

The primary drainage system is managed by the South Florida Water Management District (SFWMD) and consists of nine major canals and their corresponding drainage basins: Hillsboro Canal, C-14 (Cypress Creek) Canal, Pompano Canal, C-13 (Middle River) Canal, C-12 (Plantation) Canal, North New River Canal, C-11 (South New River) Canal, C-9 (Snake Creek) Canal, and the C-10 (also called Hollywood Canal, Cooper and Lane 1987). These nine major canals, along with secondary and tertiary canals, eventually drain to the estuarine areas (e.g., Intracoastal Waterway, ICW). The exception is the western segment of the C-11 Canal that is normally backpumped into the Water Conservation Areas (WCAs).

While a major function of the freshwater canal system has been and continues to be conveyance, the waterways are considered waters of the state of Florida also known as Class III waters (see Florida Administrative Code [FAC] 62-302, State of Florida 1998). In addition, all estuarine waters are Class III water bodies. The designated uses for Class III are "recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife" (FAC 62-302.400). Furthermore, Broward County has local water quality standards within Chapter 27 of the Broward County Municipal Code (Broward County 2000) which apply to both fresh and marine (i.e., estuarine) waters.

Since 1972, the Broward County Department of Planning and Environmental Protection (BCDPEP), then named the Broward County Pollution Control Board, has monitored the water quality of the primary water bodies (Figure 1). Initially the main objective of the network was to monitor the effluent of wastewater treatment plants (WWTPs) that was discharged into Broward's surface waters until

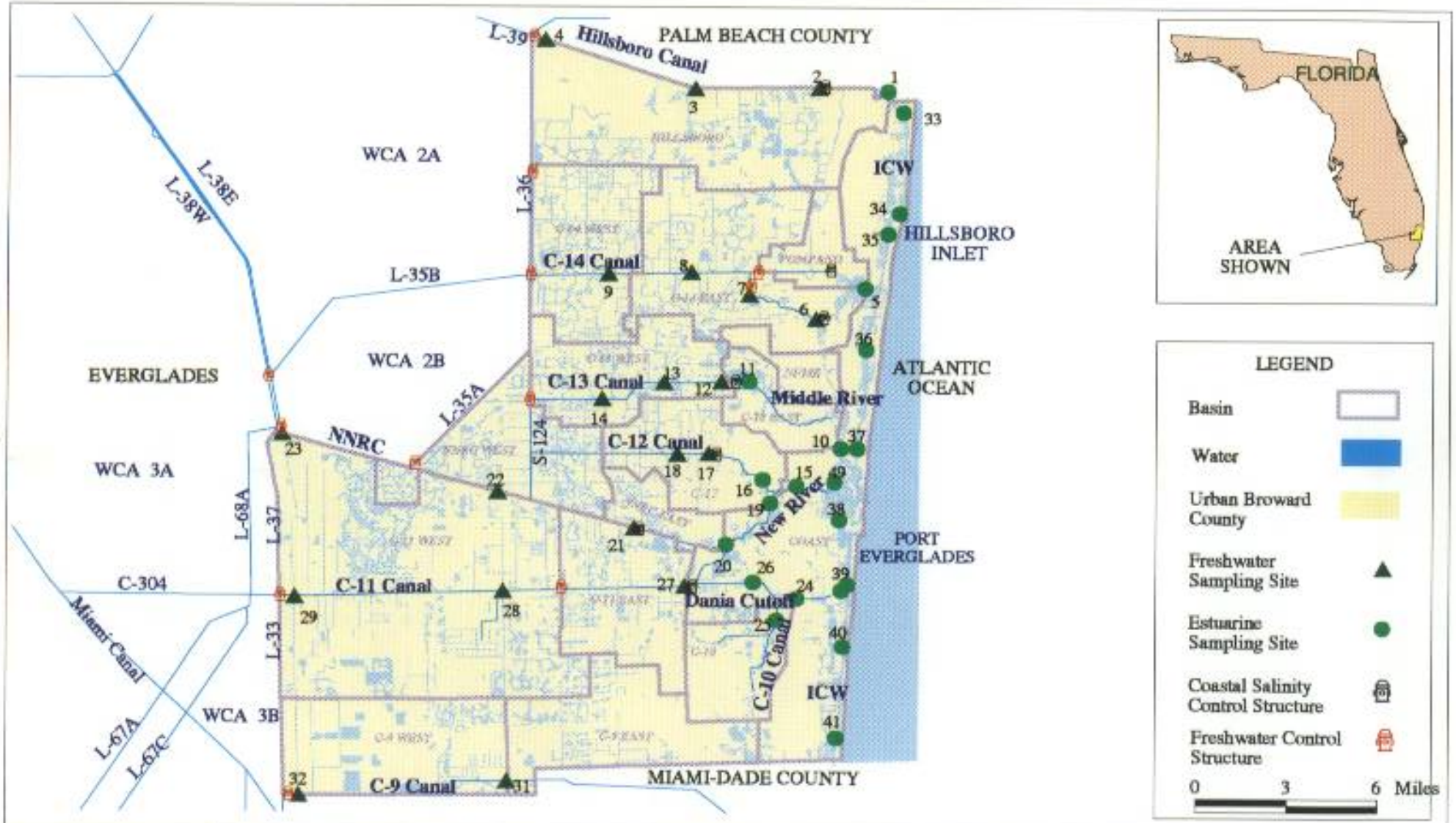


Figure 1. Urban Broward County Drainage Basins and Major Waterways. Estuarine and freshwater ambient water quality sampling sites are also shown. Coastal salinity structures, as well as water control structures (operated by South Florida Water Management District) on freshwater canals are also displayed.

1988. BCDPEP's main goal since 1988 has been to understand ambient water quality conditions throughout the urban portions of the county as part of the habitat realm of biological populations they may sustain. However, a comprehensive study of all ambient monitoring performed by the county has not been compiled. Thus, the current report aims to bridge the eras of data collection by BCDPEP in both the freshwater and estuarine regions. The main objectives of this study were to:

1. Determine (long-term and current) basin-specific water quality conditions by analyzing data from each sampling site;

2. Determine compliance patterns with Broward County Code, Chapter 27 water quality standards (Broward County 2000);

3. Determine similarities and differences existing within each basin or region; and

4. Formulate research questions, needs, and direction for better water quality management of Broward's surface waters.

At the core of this historical investigation is a three-part data analysis performed at each sampling site in a particular basin.

- An initial descriptive statistical analysis of all parameters and data collection years for each site;

- Graphical analyses of major parameters (dissolved oxygen, total phosphorus, total nitrogen, and fecal coliform) at each site; and

- Graphical and statistical analyses of major parameters (dissolved oxygen, total phosphorus, total nitrogen, and fecal coliform) collected during post wastewater treatment plant discharge years with a focus on seasonal concentrations.

For this report, the county's water quality monitoring network was divided into the freshwater canals and estuarine waters in order to investigate similar systems. The freshwater canals include the following eight major canals from north to south- Hillsboro, C-14, Pompano, C-13, C-12, North New River (NNRC), C-11, and C-9. A consistent long term data set does not exist for the Pompano Canal, thus, seven of the eight freshwater basins were addressed in this report (Section III).

The estuarine regions in Broward County include the eastern, tidal components of the Hillsboro, C-14, C-13, and North New River Canals. The Dania Cut-off Canal is the eastern tailwaters of the S-13 control structure whose headwaters are the freshwater C-11 Canal system. The C-10 Canal is directly connected to the Dania Cut-off Canal and no structure exists between the two water bodies. In addition, remnant tidal rivers such the New River and Middle River exist in the central part of the

county. The ICW is the main part of the estuary and has the only two connections to the Atlantic Ocean. For this report, the Broward estuary (primarily the Coastal Basin; Cooper and Lane 1987) has been divided into five main areas including the division of the ICW into three geographical basins-north (NICW), central (CICW), and south (SICW), as well as the New River and Dania Cut-off/C-10 Canals (Section IV). The ICW divisions were based on the proximity of the specific oceanic inlets and the western freshwater canals. Some hydrological overlaps likely exist between the basins but this classification at least provided geographical continuity between the estuarine sampling locations.

Sixteen parameters were in the analyses including: temperature, pH, specific conductance, salinity (estuarine sites only), dissolved oxygen (DO), biochemical oxygen demand, total organic carbon and turbidity. Nutrient analyses included total phosphorus (TP), total nitrogen (TN; total Kjeldahl nitrogen plus nitrite+nitrate-nitrogen), and ammonia-nitrogen. The three bacteriological parameters investigated were total and fecal coliform (FC), as well as fecal streptococcus. While sixteen parameters were studied, much of this document focuses on four major parameters DO, TP, TN, and FC because of their importance to ecological and/or human health. In addition, all four of these constituents have a local county standard (Broward County 2000). A county standard also exists for turbidity but an initial data review revealed the vast majority of ambient samples are at least half the ten nephelometric turbidity unit standard in both freshwater and estuarine environments. Thus, the following text will summarize the results of the study based on the four original objectives and primarily focus on the four major parameters.

1. Determine (long-term and current) basin specific water quality conditions by analyzing each sampling site.

A major finding from the historical water quality analysis was the prohibition of WWTP discharges into surface water bodies was a sound regulatory decision resulting in improved water quality at most of Broward's freshwater canal and estuarine sampling sites. Although some exceptions existed (e.g., Hillsboro Canal), nutrient (total phosphorus and total nitrogen) concentrations were typically the best indicator of water quality improvements after WWTPs ceased discharging in a specific waterway. The C-12 Basin, in particular, realized two orders of magnitude improvement in TP levels. Other basins such as the C-13 and C-14 also exhibited substantial improvements in TP concentrations. The estuarine areas also showed improvements, particularly in the New River and CICW where WWTPs were located. Thus, a sound conclusion can be made that the elimination of WWTP discharges into surface water bodies resulted in improvements of water quality in Broward County's freshwater canals and estuarine system.

The post-WWTP era (primarily 1989 to 1997) revealed some instream variability in many basins but specific patterns were observed for two parameters, DO and FC. Ambient DO levels were often depressed below 4.0 mg/l (single sample standard) throughout the western segments of the freshwater canals. This was particularly evident in the southwestern portion of the county (e.g., C-9 Canal). The low dissolved oxygen levels in the freshwater segments have been attributed to groundwater seepage

due to the relatively low elevation of the region (SFWMD 1976). The results from this study appear to confirm the close relationship between groundwater and surface water DO content. An interesting exception to the low DO values was observed in the western C-14 Canal. Potentially, the land elevation, land uses and/or water management practices in this area reduce the influence of groundwater leading to higher DO concentrations (typically above 5.0 mg/l) in the C-14 Canal than observed in the other freshwater canals.

Beyond the C-14 Canal, the highest DO levels were typically observed in the eastern segments of the other freshwater canals. In addition, most of the estuarine sites had DO levels greater than 4.0 mg/l. This suggests the influence of western seepage water decreases as the canal water moves east into the more urban areas and tidal waters provide more flow and exchange. Ambient DO levels did not appear to be depressed due to pollutant loadings at most sites. Potential exceptions exist in the Hillsboro Canal and the eastern C-11 Canal, as well as the North Fork of the New River in the estuarine section. Stormwater events likely lower DO levels countywide but on finer time scales than measured in this ambient study.

Ambient FC values were typically low (< 200 colonies/100 ml) throughout the freshwater canals and estuarine segments. Few areas had single sample FC measurements greater than 800 colonies/ 100 ml (single sample standard) with the main exception being the North Fork of the New River. As with DO, stormwater events have been demonstrated to increase FC content throughout all water bodies in the county. The low ambient levels described in this report, however, do suggest consistent inputs of FC are not prevalent in most areas of the county.

A challenge remains using FC as an indicator for contamination because of the test's inability to determine the origin (i.e., human or non-human) of the FC concentrations observed. Thus, the variability of FC levels associated with rain events coupled with the potential urban sources are two of the main reasons the Broward County branch of the Florida Department of Health does not recommend swimming in the county's inland water bodies with the exception of four permitted and monitored swimming lakes and the Atlantic Ocean.

Nutrient measurements were a large portion of the overall study and the results were often different for each specific basin. The following will mainly describe the nutrient concentrations observed at each canal.

A. Hillsboro Canal (freshwater)

Overall, the Hillsboro Canal exhibited poor water quality based primarily on nutrient content (high TN and high TP). The western segment of the canal had enhanced TN concentrations (Site 4 median = 2.18 mg/l, Figure 2) which decreased moving eastward along the canal. While, TN decreases downstream, TP levels increase to levels of concern (medians > 0.100 mg/l) in the central and eastern segments of the canal (Sites 2 and 3, see Figure 3). Thus, nutrient concentrations in the western area of the canal are more reflective of incoming water from WCA 1, while local land uses (golf courses,

Figure 2. Total Nitrogen Values at each Freshwater Water Quality Site from 1989-1997. Box plots describe data for each individual site from the Hillsboro (HILL), C-14, C-13, C-12, North New River (NNR), C-11, and C-9 Canal Basins. In addition, Site 11 is shown which exists downstream of the S-36, immediately east of the C-13 basin. Individual sites are also compared to the median, 25th, and 75th percentile values for all freshwater sites through the time period (n=1042).

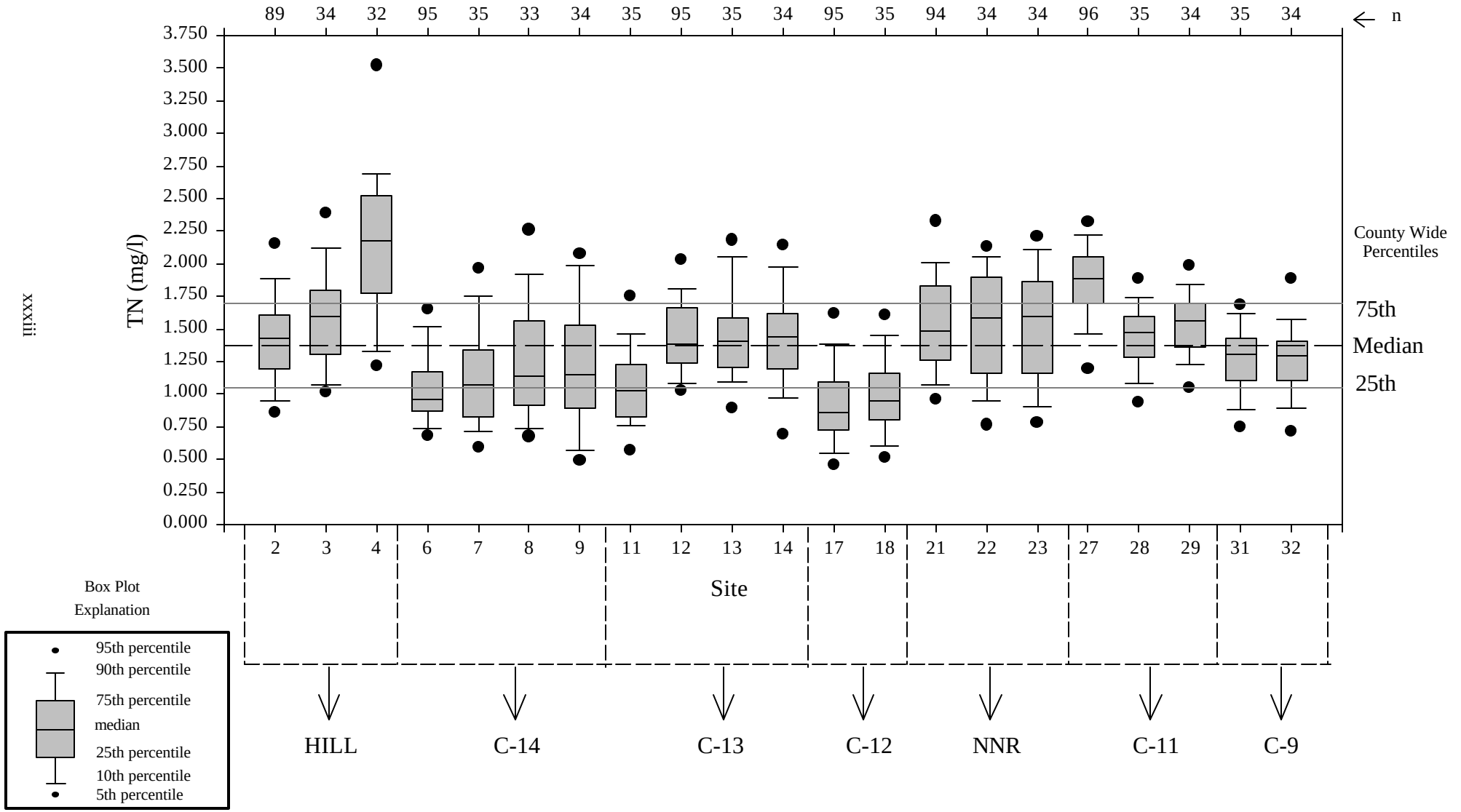
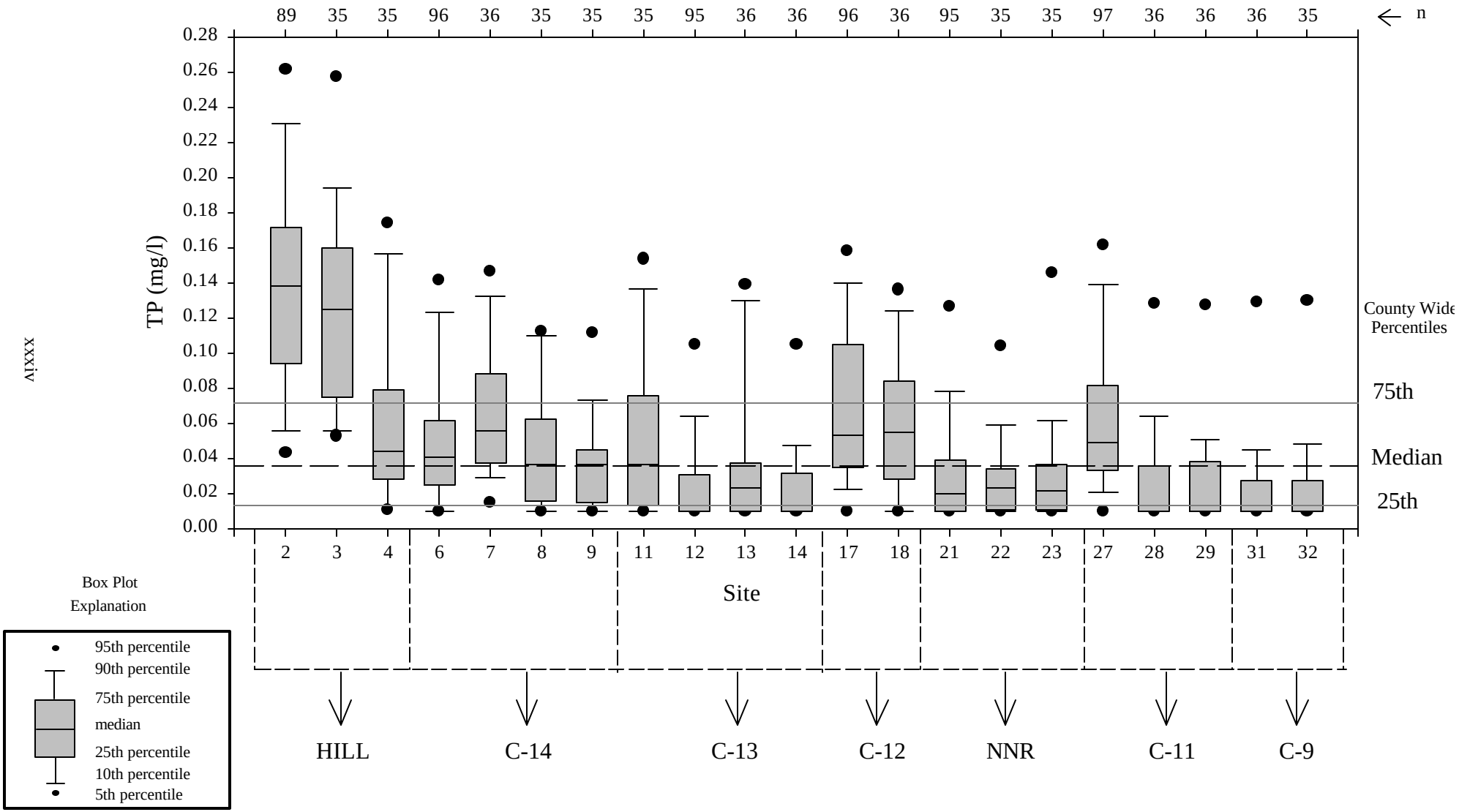


Figure 3. Total Phosphorus Values at each Freshwater Water Quality Site from 1989-1997. Box plots describe data for each individual site from the Hillsboro (HILL), C-14, C-13, C-12, North New River (NNR), C-11, and C-9 Canal Basins. In addition, Site 11 is shown which exists at downstream of the S-36, immediately east of the western C-13 basin. Individual sites are also compared to the median, 25th, and 75th percentile values for all freshwater sites through the time period (n=1065).



residential areas, agriculture, and areas served by septic tanks) and secondary canal inputs likely increase phosphorus loading to the east. The SFWMD is currently investigating water quality of the Hillsboro Basin (Palm Beach and Broward) on more intensive time and space scales (S. Kone, personal communication). The results from their study should assist in determining nutrient sources and developing management strategies to decrease loadings.

B. C-14 Canal (freshwater)

The C-14 Canal had good water quality based on low TN content (Figure 2) but only fair to poor based on moderate TP concentrations (Figure 3). As with the Hillsboro Canal, the western areas of the canal had the highest levels of TN while the eastern areas of the canal had the highest TP concentrations. However, C-14 nutrient concentrations (especially TN) were not at the levels seen in the Hillsboro Basin. Potential sources for TP in the eastern C-14 region include residential lawns and golf courses.

C. C-13 Canal (freshwater and estuarine)

In general, water quality ranges from fair to good within the C-13 Basin, particularly from 1993 to 1997. The freshwater portion of the canal was characterized with moderate TN values (Figure 2) and relatively low TP content (Figure 3). Nutrient concentrations in the freshwater segment were relatively similar throughout the C-13 Canal when compared to other basins (e.g., Hillsboro). Site 13 in the central region of the canal did have slightly higher TP concentrations than other areas of the canal but the differences were not statistically significant (see Figure 3). Site 11 (estuarine) exhibited higher TP values than the upstream Site 12, especially from 1993 to 1997. Conversely, Site 11 had lower TN values throughout the sampling period (post-WWTP) than the freshwater segments. The influence of eastern tidal water and/or the discharge pattern of the S-36 coastal salinity structure may be possible explanations for slightly different nutrient observations at Site 11.

D. C-12 Canal (freshwater)

The C-12 Canal has low TN content (Figure 2) but moderate TP concentrations (Figure 3). In some cases (approximately 25% of observations), TP levels were greatly enhanced (0.100 mg/l). Nutrient concentrations were very similar at both sampling sites (17 and 18) which is likely due to the relatively stagnant nature of the canal. The C-12 Canal is the only major freshwater body that is removed from western inputs (i.e., WCAs) of freshwater. In addition, its coastal structure (S-33) rarely discharges to the downstream North Fork of the New River (BCDPEP 1999). Thus, local groundwater seepage and stormwater runoff are the major inputs of freshwater to the water body contributing to the observed nutrient values.

E. NNRC (freshwater)

The North New River Canal was characterized by moderate to high (medians near 1.500 mg/l) TN concentrations (see Sites 21 thru 23, Figure 2) and low TP levels (Figure 3). Similar to the C-13

Canal, the years from 1993 to 1997 had the best water quality based on nutrient content. The three sampling sites generally reflected each other in nutrient content which suggests the influence of the upstream sources of water (i.e., WCA seepage water) exists throughout much of the canal.

F. C-11 Canal (freshwater)

The C-11 Canal nutrient characteristics are the most disparate for a freshwater canal due to the uniqueness of the current water management in the area. Unlike most other basins, a water control structure (S-13A) separates the western and eastern portions of the C-11 canal. Thus, the western C-11 Canal normally flows to the west because of a pump station (S-9) bordering the Everglades draws water in that direction. Conversely, the eastern C-11 Canal discharges eastward thru the S-13 coastal salinity structure to the estuarine Dania Cut-off Canal.

The western C-11 Canal (Site 28 and 29) typically had moderate ambient TN (Figure 2) concentrations and along with the C-9 Canal had the county's the lowest ambient median TP (0.013 mg/l; Figure 3) concentration. In addition, the years from 1993 thru 1997 exhibited the lowest TP values as observed in the C-13 and NNRC. Current studies by the SFWMD (Morban, unpublished) are finding nutrient concentrations elevated above ambient concentrations during storm events. The SFWMD's investigations will assist in managing flows from the C-11 westward to the WCAs, an important area of the Everglades ecosystem.

The eastern C-11 Canal (Site 27) exhibited some of the poorest water quality in the county with high TN content and moderate to high TP levels. Beyond water management practices, land use, septic tanks, and older public stormwater infrastructure may be responsible for the poor quality in the eastern C-11.

G. C-9 Canal (freshwater)

The C-9 canal had good water quality based on nutrient content. Moderate to low TN (Figure 2) values were observed and the lowest overall median TP values (0.013 mg/l) in the county were observed for this waterway (Figure 3). As with most of the other freshwater canals, the lowest TP values were observed from 1993 to 1997. The two sampling sites generally reflected each other with Site 32 exhibiting the direct influence of WCA seepage water and Site 31 displaying only a slight influence of the more urban land use portion of the canal.

H. NICW (estuarine)

The Northern Intracoastal Waterway (NICW) exhibited two distinct areas of nutrient concentrations. For TN, only the brackish reach of the Hillsboro Canal (Site 1) had moderate TN concentrations (Figure 4). Overall most of the NICW's TN concentrations were low (< 1.00 mg/l).

The northern part of the basin (Sites 1 and 33) had poor water quality, primarily due to TP concentrations (see Figure 5). The remaining areas (Sites 5, 33, and 35) were statistically lower than

Figure 4. Total Nitrogen Values at Each Estuarine Water Quality Site from 1989-1997. Box plots describe data from the Northern, Central, and Southern Intracoastal Waterway Basins (NICW, CICW, and SICW), as well as the New River and Dania Cut-off/C-10 Canal Basins. The number of samples (n) per site is shown on the upper x-axis. Individual sites are also compared to the median, 25th, and 75th percentile values for all Broward County sites through the time period (n=691).

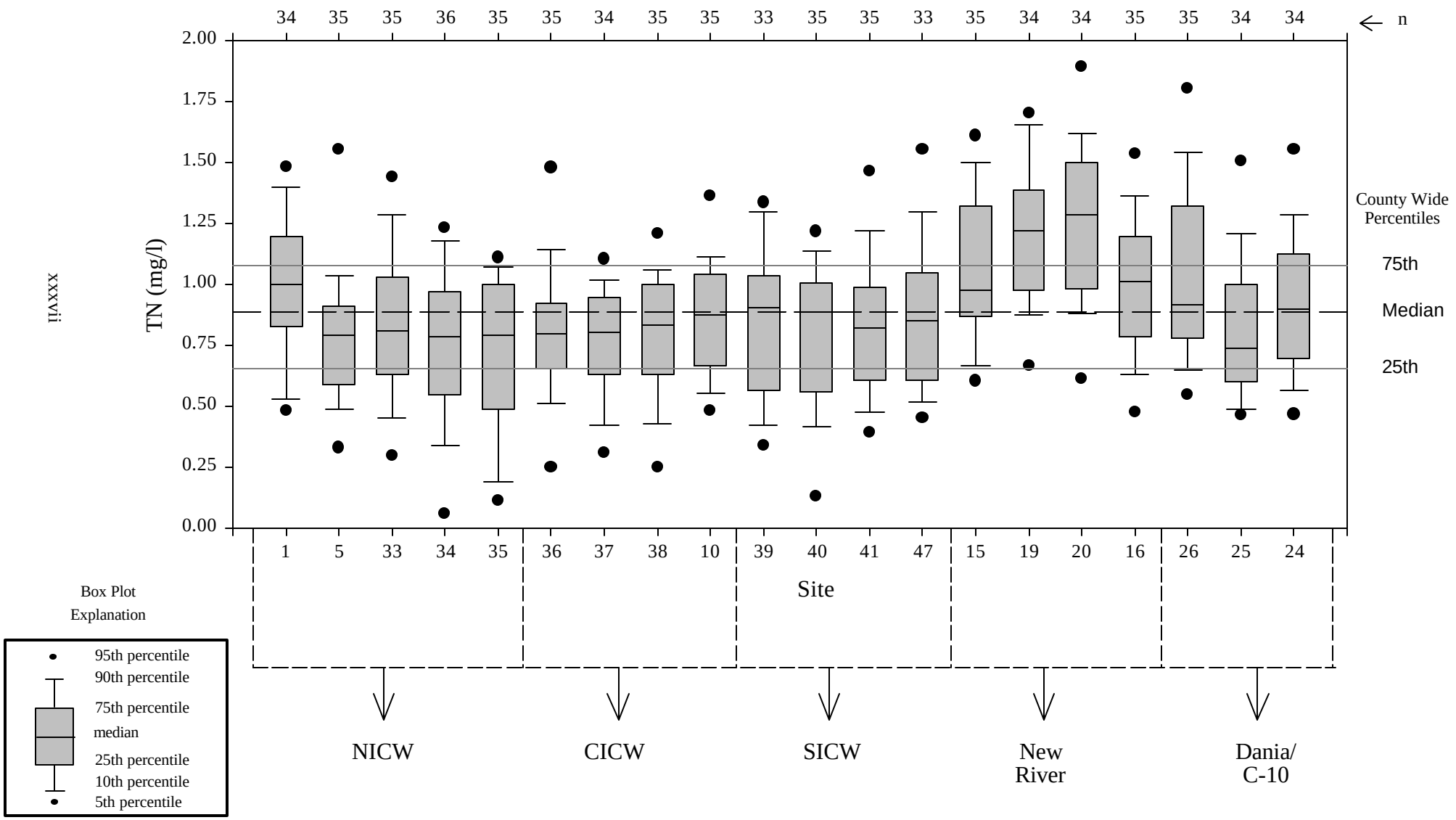
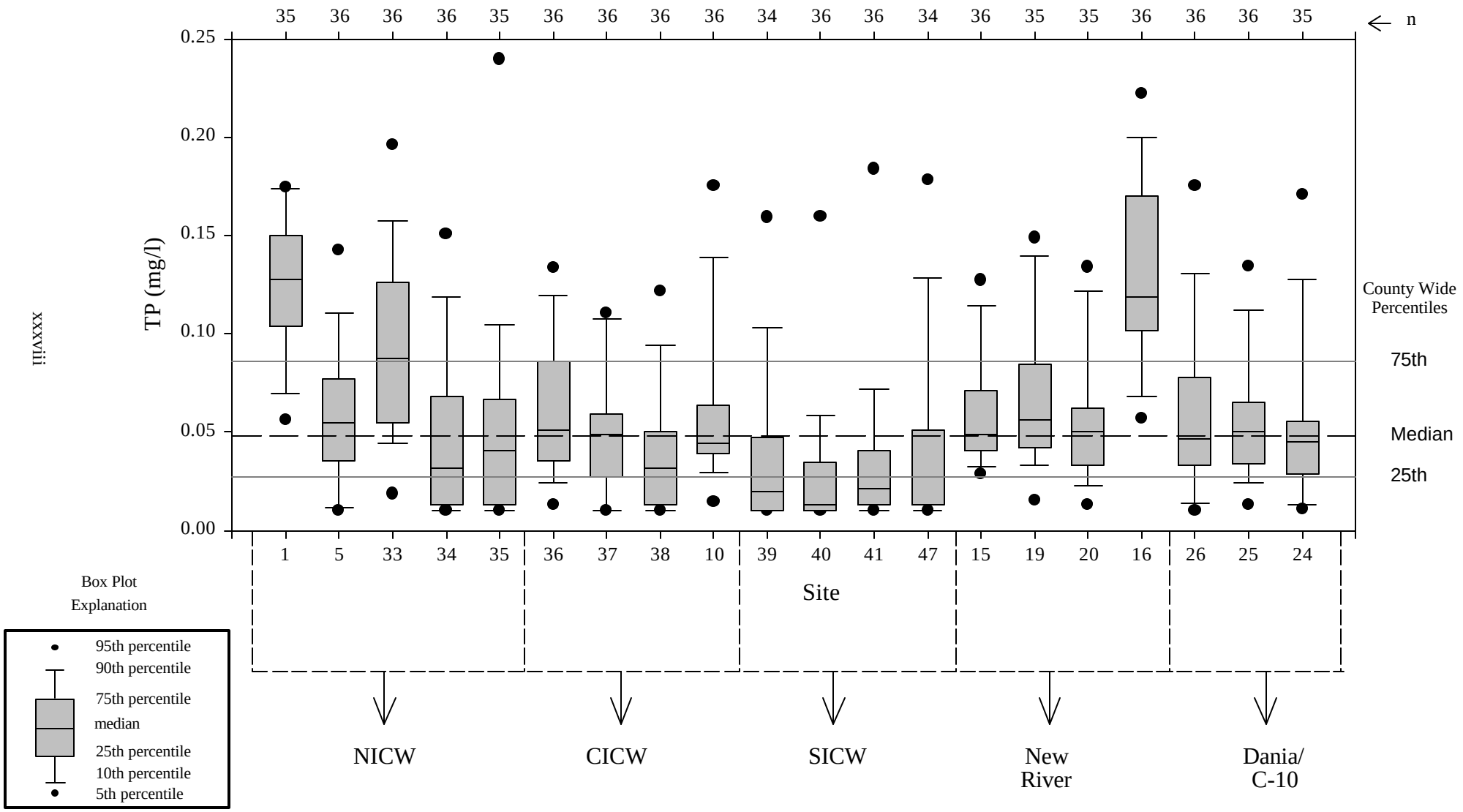


Figure 5. Total Phosphorus Values at Each Estuarine Water Quality Site from 1989-1997. Box plots describe data from the Northern, Central, and Southern Intracoastal Waterway Basins (NICW, CICW, and SICW), as well as the New River and Dania Cut-off Canal/C-10 Basins. The number of samples (n) per site is shown on the upper x-axis. Individual sites are also compared to the median, 25th, and 75th percentile values for all Broward County sites through the time period (n=711).



the northern areas and generally had low to moderate levels of TP. The influence of the freshwater Hillsboro Canal, which had the highest TP concentrations in the county (see Figure 3), undoubtedly influenced the NICW concentrations at Sites 1 and 33.

I. CICW (estuarine)

The CICW basin's ambient water quality, based on nutrient content, was relatively good. Only occasionally elevated TP concentrations (e.g., Site 36) were noted but the number of samples greater than the overall county 75th percentile value (0.086 mg/l) was low (Figure 5). Site 38, generally had the lowest TP of the basin, due in part to the close proximity to the Port Everglades Inlet. Basinwide, TN values were generally good being less than 1.00 mg/l (Figure 4). The TN values throughout the CICW were relatively similar with Site 10, at the mouth of the Middle River, having slightly higher, though not statistically significant, TN concentrations than the other areas (Sites 36 thru 38).

J. SICW (estuarine)

The SICW had the best water quality in the estuary due, in part, to its consistent salinity regime that suggests a strong and consistent input of coastal water. In addition, much of the basin is not directly influenced by pulsed discharges from the western freshwater canals. Large areas of natural pervious land use (e.g., mangrove forests) exist in the central and northern part of the SICW also contribute to the good water quality. Median TP concentrations in the SICW were the lowest observed in the estuary (Figure 5). Median TN values were consistent with much of the ICW sites throughout the county with values typically less than 1.000 mg/l (Figure 4).

K. New River (estuarine)

The western New River Basin showed relatively high TN content with median TN at sites 19 and 20 being statistically significantly different from thirteen of the twenty estuarine sampling sites (Figure 4). The relatively enhanced TN values in the New River are likely due to the discharges of the freshwater NNRC (see Figure 3). Still most of the TN observations were below the local county standard of 1.500 mg/l. Potentially this standard is too high as the Florida Department of Environmental Protection uses a TN content of 1.220 mg/l as a screening level to indicate possible poor water quality (Paulic et al. 1996). Only Site 19 and 20 (New River sites) had median TN values equal to or barely over 1.220 mg/l.

The North Fork of the New River sampling Site 16 had the highest TP levels in the estuary (Figure 5) and moderate TN content (Figure 4). The unusually high FC values coupled with the nutrient and DO concentrations make this area the poorest water quality in the county. Fortunately, remediation efforts (e.g., dredging) are underway by BCDPEP, SFWMD, and the City of Ft. Lauderdale to improve the water quality of the area (BCDPEP 1999).

The New River sampling site in downtown Ft. Lauderdale (Site 15) had relatively moderate TN and TP concentrations suggesting enhanced TP from the North Fork and enhanced TN from the South

Fork decreases moving downstream. However, only the Site 16 and 15 median TP content were statistically significantly different (Figure 5). The large fluctuations in salinity observed at Site 15 (0.3 to 30.2 ppt) suggest tidal stage is critical in determining whether the freshwater or coastal water inputs are affecting water quality in this stretch of the river.

L. Dania Cut-off/C-10 Canals (estuarine)

In general, moderate nutrient concentrations were observed in the Dania Cut-off/C-10 Canals (Figure 4 and 5). However a consistent pattern was not observed between sites. Some of the highest estuarine TN values were observed at the western end of the Dania Cut-off Canal (Site 26) while Site 25 (C-10 Canal) had one of the lowest median TN values (Figure 4). This difference is due, in part, to the periodic discharges from the eastern C-11 Canal that had high TN levels (see Figure 2). The C-10 Canal does not receive flows from a western freshwater canal. Site 25 had the highest median TP (Figure 5) but differences between all three sites were not significantly different for either nutrient.

2. Determine compliance patterns with the Broward County Code, Chapter 27 water quality standards (Broward County 2000).

A. Freshwater Canals

The percentage of samples within compliance of the Broward County Code, Chapter 27 water quality standards (Broward County 2000) was investigated for three different time periods and graphically shown with "stoplight" pie charts. Compliance levels after WWTPs ceased discharging visibly improved throughout most of the freshwater and estuarine sites. To better understand current ambient water quality, post-WWTP compliance levels were also investigated. Table 1 summarizes the percent compliance after WWTPs closed. The exact number of years may vary with basin because WWTPs closed over a sixteen year period that was completed by 1988.

The low percentage of DO compliance in the western areas of the freshwater canals (e.g., Site 29, C-11 Canal) was likely due to the influence of groundwater seepage as described earlier. The more eastern located sites were typically above 75.0 % compliance with the DO standard of 4.0 mg/l. Meanwhile, ambient FC values were normally at or above a 90.0% compliance rating based on the single sample standard of 800 colonies/100 ml. The lowest level of compliance was observed for TP concentrations with half the sampling sites being below the 50.0% level. The freshwater standard for TP is 0.020 mg/l. Overall TN compliance was higher than observed for TP with a county wide median of 75.0% compared to 48.8%, respectively.

B. Estuarine Waters

Generally, estuarine water quality standard compliance levels were better than those observed for freshwater canals. This is likely due to the influence of coastal Atlantic Ocean water that helps dilute the effect of land based pollutant loading. In addition, much of the estuarine water bodies are deeper and wider than the freshwater canals and this increases their assimilative capacity of nutrients. Thirteen of twenty estuarine sites had compliance levels equal to or higher than 90.0% for DO readings (Table 2). Almost half (8 sites) of the sites reached 100.0% compliance with the single sample FC standard

Table 1. Summary of Broward County Local Water Quality Standard Compliance at each Freshwater Canal Sampling Site After the Elimination of Wastewater Treatment Plant Discharges. The exact years and number of samples may vary between basins and are fully described in Section III. Seven canals are shown including Hillsboro (Hills), C-14, C-13, C-12, North New River (NNRC), C-11 and C-9 listed north to south. The four major parameters investigated were dissolved oxygen (DO), total phosphorus (TP), total nitrogen (TN), and fecal coliform (FC). Numbers represent the percentage of samples above 4.0 mg/l (single sample standard) for DO. For TP, percentages are the number of samples below the 0.020 mg/l TP standard except for Site 11 where the marine standard of 0.050 mg/l was used because it is officially an estuarine site although characterized by freshwater. The TN numbers represent the percentage of samples under 1.500 mg/l, while the FC values are the percent of samples under the 800 colonies/100 ml single sample standard.

		Percent Compliance			
Canal	Site	DO	TP	TN	FC
Hills	2	61.4	4.5	47.4	96.4
Hills	3	38.6	0.0	52.6	95.3
Hills	4	40.0	12.2	21.1	92.9
C-14	6	81.5	10.7	90.0	94.1
C-14	7	83.0	17.4	80.0	95.3
C-14	8	89.6	23.9	65.0	91.5
C-14	9	91.7	29.8	78.9	95.8
C-13	11	60.5	60.5	85.0	93.0
C-13	12	82.8	59.1	75.0	94.5
C-13	13	65.9	48.8	80.0	95.3
C-13	14	65.3	55.8	78.9	100.0
C-12	17	77.1	57.3	95.0	91.8
C-12	18	75.0	55.6	90.0	86.1
NNRC	21	77.9	51.0	68.4	96.1
NNRC	22	38.9	48.6	55.5	97.3
NNRC	23	52.8	47.2	63.2	100.0
C-11	27	60.8	9.3	15.0	91.8
C-11	28	44.4	55.5	65.0	94.4
C-11	29	25.0	60.0	68.4	100.0
C-9	31	13.9	66.7	85.0	97.2
C-9	32	2.8	71.4	89.5	100.0
	County wide Median	61.4	48.8	75.0	95.3

Table 2. Summary of Broward County Local Water Quality Standard Compliance at each Estuarine Sampling Site After the Elimination of Wastewater Treatment Plant Discharges. The exact years and number of samples may vary between basins and are described fully in Section IV. Five basins are shown including Northern Intracoastal Waterway (NICW), Central Intracoastal Waterway (CICW), Southern Intracoastal Waterway (SICW), New River (NEW), and Dania Cutoff/C-10 Canal (DAN). The four major parameters investigated were dissolved oxygen (DO), total phosphorus (TP), total nitrogen (TN), and fecal coliform (FC). Numbers represent the percentage of samples above 4.0 mg/l (single sample standard) for DO. For TP, values are the percentage of samples below the standard of 0.050 mg/l. The TN numbers represent the percentage of samples under 1.500 mg/l standard, while the FC values are the percent of samples under the 800 colonies/100 ml single sample standard.

		Percent Compliance			
Canal	Site	DO	TP	TN	FC
NICW	1	87.5	0.0	95.7	95.7
NICW	33	91.7	31.8	95.8	100.0
NICW	34	100.0	72.8	100.0	100.0
NICW	35	100.0	65.2	100.0	100.0
NICW	5	96.0	54.2	95.8	91.3
CICW	36	95.8	58.3	95.8	95.7
CICW	37	100.0	62.5	95.8	100.0
CICW	38	100.0	87.5	100.0	100.0
CICW	10	78.3	62.5	95.8	91.3
SICW	39	96.2	83.3	96.2	100.0
SICW	40	96.0	91.6	100.0	100.0
SICW	41	100.0	87.5	95.8	100.0
SICW	47	100.0	87.5	95.8	100.0
NEW	15	77.1	52.7	88.6	80.6
NEW	16	69.4	2.7	94.3	54.1
NEW	19	72.2	42.9	82.4	100.0
NEW	20	64.8	51.4	77.1	91.7
DAN	24	90.0	70.8	95.8	87.5
DAN	25	91.7	54.2	100.0	90.1
DAN	26	79.1	70.8	91.7	95.8
County wide Median		93.8	62.5	95.8	97.9

of 800 colonies/100 ml. A notable exception was the North Fork of the New River (Site 16) which only had 54.1% compliance. All estuarine sampling sites had over 75.0% compliance level for the TN standard (1.500 mg/l) and seventeen out of twenty were over 90.0%. As with the freshwater sites, TP observations had lower water quality standard compliance county wide (62.5%) than seen for TN (95.8%). However, only four of the twenty estuarine sites were below the 50.0% compliance levels for TP. The higher TP compliance ratings for the estuarine sites as compared to freshwater sites are likely influenced by the different standards for those two areas. The estuarine (i.e., marine) TP standard is 0.050 mg/l versus the freshwater TP standard which is 0.020 mg/l.

3. Determine similarities and differences existing within each basin or region

A. Freshwater Canals

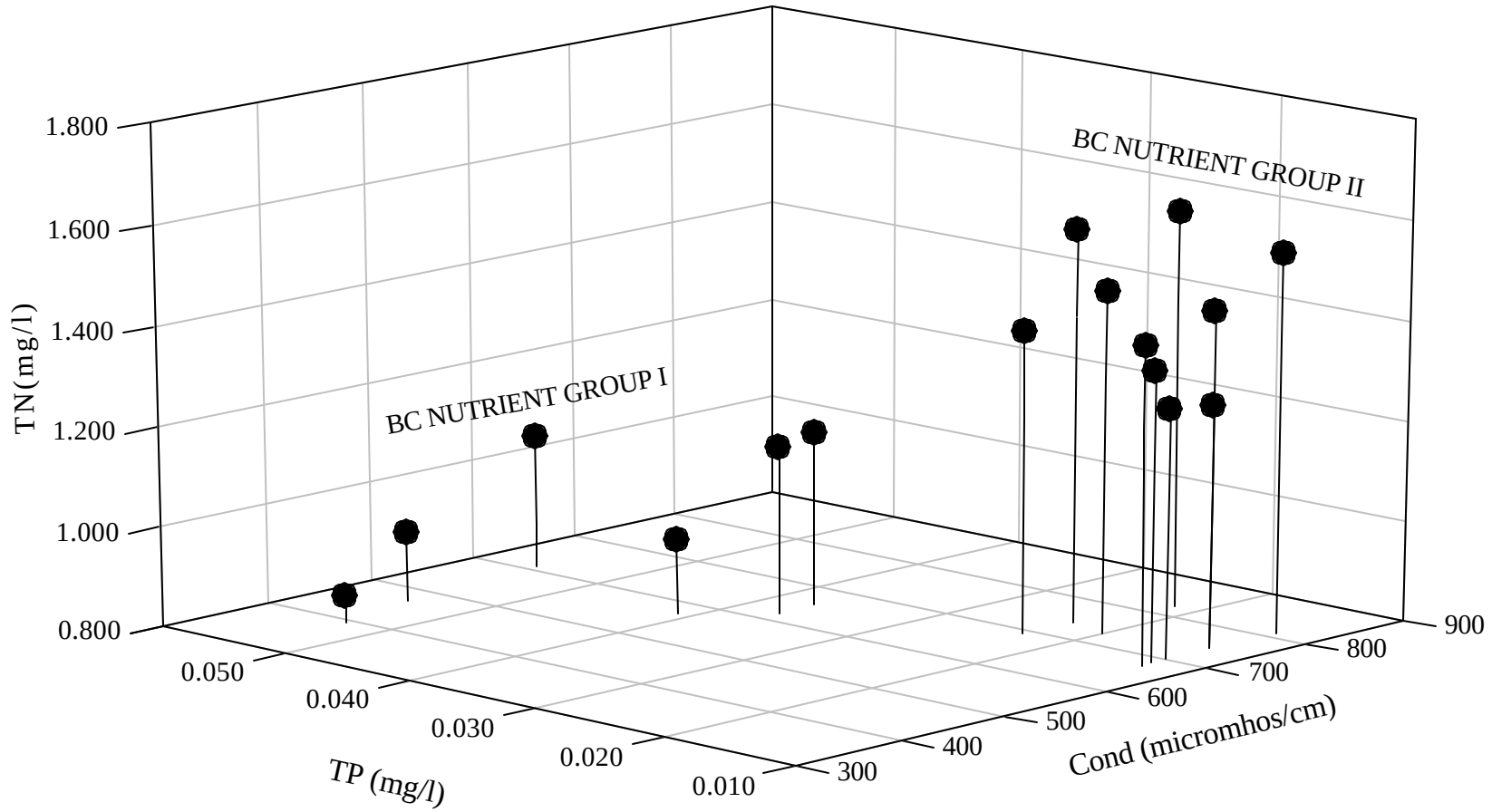
Figures 2 and 3 both show the Hillsboro Canal (Sites 2-4) and eastern C-11 Canal (Site 27) as the areas with largest differences in water quality compared to the overall county median. These two areas also had the largest number of statistical significant differences (see Section III.K.3) among the other locations. Furthermore, the Hillsboro Canal and eastern C-11 Canal displayed the lowest compliance levels with nutrient standards (see Table 1).

Beyond those two areas, a preliminary Broward County freshwater canal nutrient group designation was derived to begin a framework for understanding loading and assimilation dynamics. The groupings were based on the relative TP and TN concentrations at all sampling sites and the results were basin specific. The C-12 and C-14 Canals were placed in BC Nutrient Group I (Moderate TP:Low TN) while the C-13, NNRC, Western C-11, and the C-9 Canal fell into BC Nutrient Group II (Low TP:Moderate TN). BC Nutrient Group III consisted of water bodies with highly elevated TP and/or TN (i.e., Hillsboro Canal and the Eastern C-11).

The relatively moderate TN (BC Nutrient Group II) areas were clustered more tightly than the moderate TP sites (BC Nutrient Group I) and were characterized by specific conductance values primarily above 750 Fmhos/centimeter, although a few exceptions did exist (Figure 6). The moderate TP sites had specific conductance values which were below 700 Fmhos/centimeter. Though the differences in specific conductance are not large, the inclusion of nine years of sampling suggests some degree of distinctness in the water masses of the different canals. Furthermore, correlation analyses revealed a strong relationship between median nutrient values and specific conductance. Specifically, TN had a positive correlation ($r = 0.91$) while TP values were inversely correlated with median specific conductance values ($r = -0.82$). These correlations do not necessarily mean that specific conductance is the forcing agent of canal nutrient content. Instead, specific conductance may be seen as a tracer of water, particularly of WCA water, entering the western low-lying canals. The use of specific conductance as a tracer of water bodies in the South Florida watershed has been shown in a previous study of the WCAs (USGS 1987).

Throughout almost every freshwater basin, TP values were relatively enhanced during the period of 1990-1992 with some sites also displaying high values in 1989 while concentrations were lowest from 1993 thru 1997. In particular, the BC Nutrient group II (Low TP: Moderate TN) illustrated this general pattern based on a rolling quarterly average TP analysis. The period of 1988 to 1990 is

Figure 6. Median Total Phosphorus (TP) Versus Total Nitrogen (TN) Versus Specific Conductance (Cond) for BC Nutrient Groups I and II. Medians calculated from 1989-1997 observations.



typically recognized as a drought period in South Florida. The low rainfall and groundwater levels likely reduced overall canal flow and elevation, as well as WCA seepage into the western basins. A weekly rolling average of NNRC water elevations depicted a generalized pattern of low to high canal elevations from 1989 to 1997 with a distinct increase at the beginning of the 1992 wet season. Thus, low flow and elevations during the 1990-1992 period may, in part, explain the elevated TP levels because of the likely stagnation of the western canals. Stagnation would contribute to elevated nutrient levels in these areas because of concentration of nutrients, less input of low TP seepage water from the WCAs, and lack of flow in the waterways.

B. Estuarine Region

A major influence on water quality in an estuary is salinity. As would be expected median salinities were highest near the coastal inlets and lowest near the coastal salinity structures. However, a large salinity range was present at many sites. To further investigate salinity range, data from BCDPEP's sites were compared to five estuarine zones as defined by Bulger et al. (1990, cited in Chamberlain and Hayward 1996) based on a range of salinity values (Table 3). Most sites had minimum and/or maximum values characteristic of at least three estuarine zones. In fact, five sites had salinities within all five zones. This wide range of salinities is due, in part, to the artificially manipulated hydrology of the main western freshwater sources and likely impacts water quality, particularly in the upper to mid-estuarine regions.

Inland sites (upper to mid-estuary) such as the Hillsboro Canal, New River, and the Dania Cut-off Canal typically exhibited higher concentrations of nutrients than observed in the Intracoastal. The close proximity of the oceanic waters, most notably the Gulf Stream (Florida Current), would dictate a west to east decrease in nutrient concentrations. Furthermore, inland waters are surrounded by relatively higher land use drainage area to water body volume than the ICW. Thus, waters, such as the New River, typically have less assimilation capacity for nutrient loads than the wider and deeper ICW. Despite having relative high assimilation capacity, the ICW has the potential to transport nutrients offshore to a relatively oligotrophic coral reef ecosystem and coastal fisheries. Thus, a better understanding of the relationship between the Broward estuary and the coastal waters is needed.

4. Formulate research questions, needs, and direction for better water quality management of Broward's surface waters.

Basin specific questions were formulated based on the water quality analyses. In some cases, similar research questions or management needs were similar through many of the basins. Thus, several recommendations were made for both the freshwater and estuarine regions. A future management plan should consider incorporating the following recommendations based on feasibility and resources.

Table 3. Summary of the Salinity Regime within Broward County Estuarine Waters. Salinity values were collected from 1989 to 1997 for the inland sites and the ICW. Maxium and minimum values for each site were compared to Bulger *et al. 's** five estuarine zones. The number of Bulger *et al. 's* zones refers to the occurrence of maximum and minimum values for each site to the corresponding five (I-V) zone values. Median concentrations provide a reference for the maximum and minimum.

Site or Zone	Median Salinity (ppt)	Maximum Salinity (ppt)	Minimum Salinity (ppt)	# Bulger *et al. 's* Zones*
Bulger *et al. 's* Zone I*	N/A	4.0	Fresh	I
Bulger *et al. 's* Zone II*	N/A	15.0	2.0	II
Bulger *et al. 's* Zone III*	N/A	19.0	11.0	III
Bulger *et al. 's* Zone IV*	N/A	28.0	15.0	IV
Bulger *et al. 's* Zone V*	N/A	Marine	23.0	V
BCDPEP Site 1	7.4	22.8	0.25	I-IV
BCDPEP Site 5	16.9	29.8	0.25	I-V
BCDPEP Site 33	26.4	34.5	1.4	I-V
BCDPEP Site 34	32.1	36.2	9.0	II-V
BCDPEP Site 35	29.5	36.5	8.3	II-V
BCDPEP Site 36	24.3	31.9	3.9	II-V
BCDPEP Site 37	24.3	32.7	9.1	II-V
BCDPEP Site 38	29.9	34.8	3.9	II-V
BCDPEP Site 10	17.7	31.0	1.5	I-V
BCDPEP Site 39	32.5	36.2	19.1	IV-V
BCDPEP Site 47	31.5	35.2	6.8	II-V
BCDPEP Site 40	31.0	36.0	16.8	IV-V
BCDPEP Site 41	30.0	35.4	15.7	IV-V
BCDPEP Site 15	11.3	25.3	0.25	I-IV
BCDPEP Site 16	3.6	15.9	0.25	I-III
BCDPEP Site 19	3.9	19.2	0.25	I-III
BCDPEP Site 20	1.6	15.7	0.25	I-III
BCDPEP Site 24	19.8	33.9	0.5	I-V
BCDPEP Site 25	10.7	23.3	0.25	I-IV
BCDPEP Site 26	12.6	30.1	0.25	I-V
BCDPEP Site 11**	0.5	9.5	0.25	I-II

* Bulger *et al.* refers to Bulger, A.J, B.P. Hayden, M.G. McCormick-Ray, M. E. Monaco, and D.M. Nelson (1990) estuarine classification scheme as reported in Chamberlain and Hayward (1996, see their Table 4).

** Site 11 was primarily described in the Freshwater Chapter (see Section III).

A. Freshwater Canals

- Continue ambient water quality program to augment overall post-WWTP database for benchmarking performance measures and impacting regulatory processes.

- Since the canals act as conveyance systems, a coupling of water quality conditions with water management activities (e.g., flow rates) and meteorological conditions should be performed and compared to ambient water quality.

- Determine the influence of land use and public infrastructure (e.g., sewer systems) on water quality by coupling ambient water quality information with upcoming NPDES stormwater and land use analyses.

- Perform more in-stream water quality investigations during and immediately after storm events that would allow a more comprehensive understanding of these systems than currently exists.

- Expand database of other parameters of interest (e.g., potential toxics) in the urban canals, particularly after rain events.

- Continue ambient chlorophyll a monitoring but consider increasing sampling periodicity to understand if areas of high nutrients are causing ecological imbalances.

- Perform biological characterization (phytoplankton, zooplankton, fish, and macroinvertebrates) to understand what types of organisms are living in these Class III waters of the state and determine if ecological imbalances have been and/or are occurring because of water quality conditions.

B. Estuarine Waters

- Continue ambient water quality program to augment overall post-WWTP database for benchmarking performance measures and impacting regulatory processes.

- Determine flow characteristics of all major salinity structures along with rainfall over time and compare with water quality.

- Understand the fate and transport of nutrients in the estuary, including hydrological residence times and discharge characteristics to coastal systems.

- Inestigate flow information and residence times, the feasibility of salinity targets needs to be investigated similar to other Florida estuaries (e.g., Indian River Lagoon, http://www.evergladesplan.org/projects/irl_main.htm).

- Determine the sources and fate of total phosphorus in the Hillsboro Canal and NICW basin. Also, characterize orthophosphate concentrations in that basin first and then other areas of the county as well.

- Determine the importance of nitrogen species to water column biology throughout estuary, in particular chlorophyll a concentrations. Initially this effort should start with dissolved inorganic nitrogen dynamics in the C-11 eastern basin and Dania Cut-off Canal.

- Continue ambient chlorophyll a monitoring but consider increasing sampling periodicity to understand if areas of high nutrients are causing ecological imbalances.

- Perform biological characterization (phytoplankton, zooplankton, fish, and macroinvertebrates) to understand what types of organisms are living in the estuary and if ecological imbalances have been and/or are occurring.

- Continue protection of large natural areas and Outstanding Florida Waters (e.g., West Lake Park) which have large areas of pervious ground cover should be considered a high priority for future water quality management.

- Compile available information on water quality studies in the coastal waters to better understand the influence of estuarine water quality on those systems.

- Continue the development and use of better fecal contamination indicators to better understand potential human health concerns that the fecal coliform test does not allow.

- Continue the development of remote recorder deployments (See BCDPEP 1999) to better understand diel and seasonal patterns in parameters such as DO and salinity.

- Compile available data on groundwater and surface water interaction (e.g., seepage rates) to understand the extent of inflows and outflows. This may also include using the current soil characterization maps.

- Ascertain the chronic and acute effects of overall stormwater input, particularly in the New River basin and the Northern Intracoastal/ Hillsboro area.

- Determine extent of impact of petroleum by-products and heavy metals in stormwater in the different basins and their fate and transport characteristics.

Literature Cited

Broward County. 2000. Code of Broward County, Florida - Chapter 27: Pollution Control. Municipal Code Corporation, Tallahassee, Florida.

Broward County Department of Planning and Environmental Protection (BCDPEP). 1999. North Fork of the New River Restoration Projects: Final Report (submitted to the Florida Department of Environmental Protection) Ft. Lauderdale, FL.

Broward County Planning Council, Ft. Lauderdale, Florida - 1989. Broward County Land Use Plan.

Bulger, A.J., B.P. Hayden, M.G. McCormick-Ray, M.E. Monaco, and D.M. Nelson. 1993. A Proposed Estuarine Classification: Analysis of Species Salinity Ranges. ELMR Report, No. 5, Strategic Assessment Branch, NOS/NOAA. Rockville, Maryland, 28 p.

Chamberlain, R. and D. Hayward. 1996. Evaluation of Water Quality and Monitoring in the St. Lucie Estuary. Water Resources Bulletin. V. 32 (4): p. 681-696.

Cooper, R.M. and J. Lane. 1987. An Atlas of Eastern Broward County Surface Water Management Basins. South Florida Water Management District. Technical Memorandum, DRE 231. West Palm Beach, Florida 76 p.

Indian River Lagoon Restoration Feasibility Study. http://www.evergladesplan.org/projects/irl_main.htm.

Paulic, M,. Joe Hand, and L. Lord. 1996. 1996 Water-Quality Assessment For the State of Florida, Section 305 (B) Main Report. Florida Department of Environmental Protection, Tallahassee,Florida.317p.or http://199.73.196.31/water/division/monitoring/pdf/main305b.pdf.

South Florida Water Management District (SFWMD), W. Palm Beach, Florida - Resource Planning Department. 1976. Water Management Plan for the Western C-9 Basin. Technical Publication, August 1976.

State of Florida 1998. Florida Administrative Code 62-302. http://www.dep.state.fl.us/ogc/documents/rules/shared/62-302t.pdf.

United States Geological Survey. 1987. Analysis of Trends in Water-Quality Data for Water Conservation Area 3A, The Everglades, Florida Editors, H.G. Mattraw, D.J. Scheidt, and A.C. Federico. Tallahassee, Florida.

I. Introduction

Located in Southeast Florida (United States of America), Broward County was established in 1915 and currently contains thirty municipalities and more than thirty unincorporated neighborhoods. Geographically, the populated region of Broward County is tucked between the Everglades to the west and the Atlantic Ocean to the east (Figure I.1). Connecting these two large aquatic systems are over 266 miles of natural waterways and dredged canals that traverse the county's urban corridor (Broward County Planning Council 1989). Overall, the hydrology of Broward County is highly manipulated by a series of water control structures and levees that have altered the natural hydroperiods and flows of the South Florida watershed.

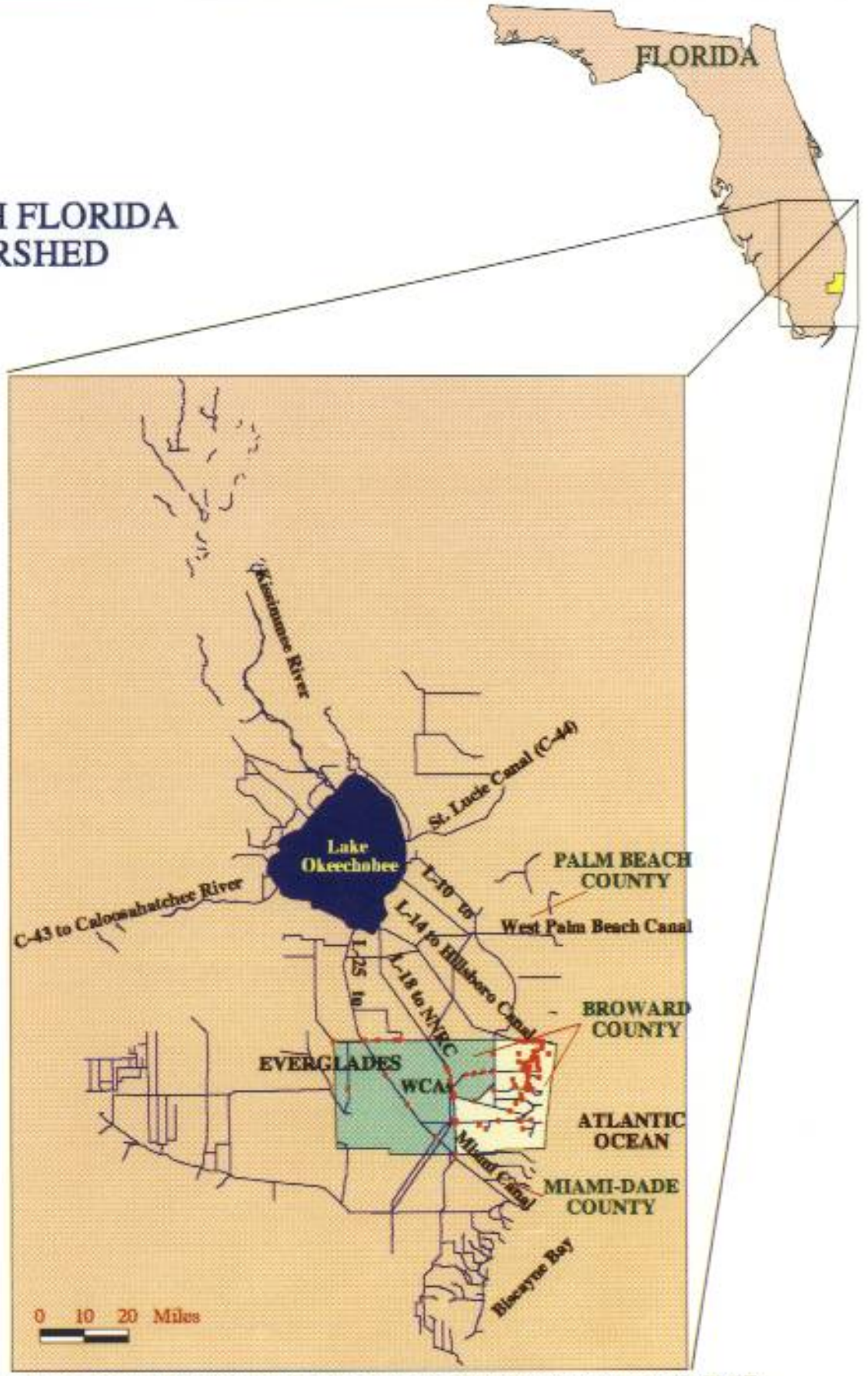
Since 1972, the Broward County Department of Planning and Environmental Protection (BCDPEP), then named the Broward County Pollution Control Board (BCPCB), has monitored the water quality of Broward County's waterways. The main objective was to monitor the impact of wastewater treatment plant (WWTP) effluent on surface waters. The regionalization of WWTPs ended the discharge of treated sewage to surface waters by 1988. Thus, BCDPEP's main surface water quality network goal since 1988 has been to understand ambient water quality conditions throughout the urban portions of the county as part of the habitat realm of biological populations they may sustain. In addition, the ability to predict potential 'downstream effects' on receiving water bodies (e.g., Everglades) by these urban stormwater conveyance systems may be more readily achieved.

Annual reports of Broward County water quality were published until 1989 by the agency then named Broward County Environmental Quality Control Board (see BCEQCB 1989). Basin specific studies have been performed in the nineties by the department which became an official Broward County Board of County Commissioners agency named originally the Office of Natural Resource Protection and then evolving to the Department of Natural Resource Protection (BCDNRP, see BCDNRP 1993, 1996). A broad, countywide, water quality technical investigation was done in the 1970's (Waller et al. 1975) but did not include most of the estuarine portions of the county. Thus, a compilation or atlas of all ambient monitoring performed by the county has not been done. The current report aims to bridge the eras of data collection from the BCPCB years to current BCDPEP monitoring in the freshwater and estuarine realm.

A. Objectives

This study provides a comprehensive update on Broward County's ambient water quality and depicts the historical characteristics. The results from this work will lead to a Broward County water quality management plan to coincide with regional planning (e.g., Comprehensive Everglades Restoration Plan) and permitting (e.g., United States Environmental Protection Agency's (USEPA) National Pollutant Discharge Elimination System, NPDES) efforts. The following are the four major objectives of the study:

THE SOUTH FLORIDA WATERSHED



This map is for informational purposes only. For further information, please contact BCDPDP Water Resources Division (954) 519-1270.

Figure I.1. Broward County in Relation to the South Florida Watershed. Names of major waterways are shown and are primarily operated by the South Florida Water Management District (SFWMD). The urban portion of Broward County is shown in the yellow. The green portion of Broward County depicts the areas covered by the Water Conservations Areas. Red dots represent the major SFWMD water control structures in Broward County.

1. Determine (long-term and current) basin specific water quality conditions by analyzing data from each sampling site.

2. Determine compliance patterns with Broward County Code, Chapter 27 water quality standards (Broward County 2000).

3. Determine similarities and differences existing within each basin or region; and

4. Formulate research questions, needs, and direction for better water quality management of Broward's surface waters.

B. Background Information

1. Watershed

Broward County is located in the South Florida watershed that is defined by the Southern Florida Flood Control Project, an engineered water management system of numerous canals, levees, and water control structures constructed fifty years ago (Figure I.1). Today this system is operated by the South Florida Water Management District (SFWMD). Within the urban areas, the waterways are primarily used for flood control, however, secondary uses include drainage of land for development, discharge of excess water to and from the Water Conservation Areas of the Everglades, prevention of saltwater intrusion, public water supply, and local wellfield recharge (Cooper and Lane 1987). Two ocean inlets connect the conveyance system to the tidal influence of the Atlantic Ocean. All major waterways shown in Figure I.2 are considered Class III waters of the state of Florida (Florida Administrative Code Section 62-302; State of Florida 1998) which are designated as recreational (i.e., fishable and swimmable) and regulated under those specific standards as well as Broward County's local water quality regulations and standards under the county's code (Chapter 27, Article V; Broward County 2000).

2. Climate

The climate of the lower east coast of Florida is characterized as semitropical marine (SFWMD 1991). The wet season runs from June through October and has average rainfalls of 35 inches. Average temperatures during the summer range from 80-85 ^{o}F. The dry season (November- May) experiences average rainfalls of 17.4 inches and average temperatures are in the mid-60s ^{o}F (McPherson and Halley 1997). Rainfall is the major source of aquifer recharge which is the foundation of the South Florida ecosystems. The Biscayne Aquifer, the sole source of Broward County's drinking water, is typically recharged by rainfall during the wet season and by the canal system during dry periods (Reynolds, Smith and Hills Inc., 1972).

3. Municipalities

Figure I.3 shows the thirty municipalities in Broward County in which an estimated 1,375,378 people live (Broward County Planning Council 1995). The Cities of Ft. Lauderdale (156,121 persons) and

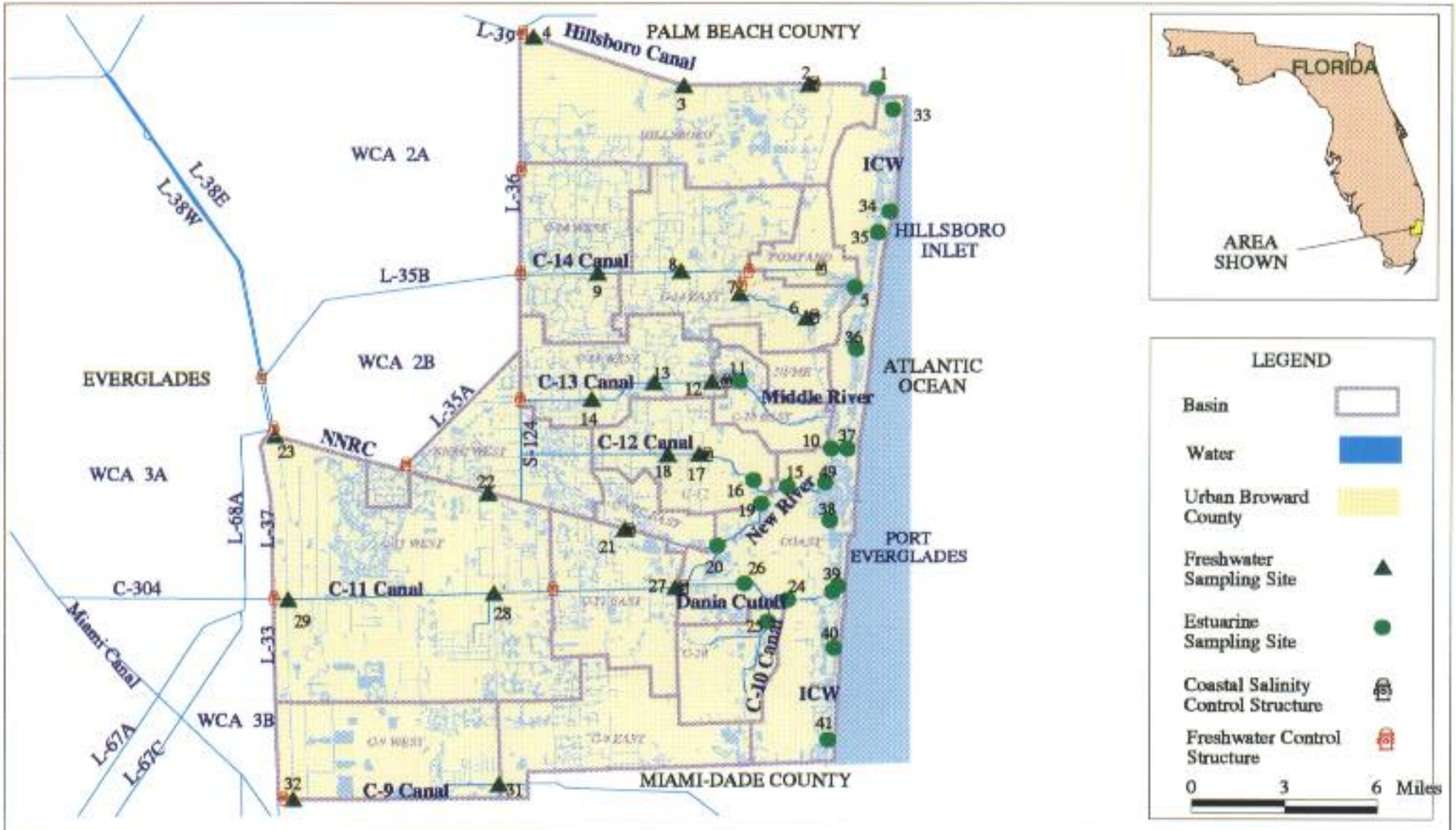


Figure 1.2. Urban Broward County Drainage Basins and Major Waterways. Estuarine and freshwater ambient water quality sampling sites are also shown. Coastal salinity structures, as well as water control structures (operated by South Florida Water Management District) on freshwater canals are also displayed.

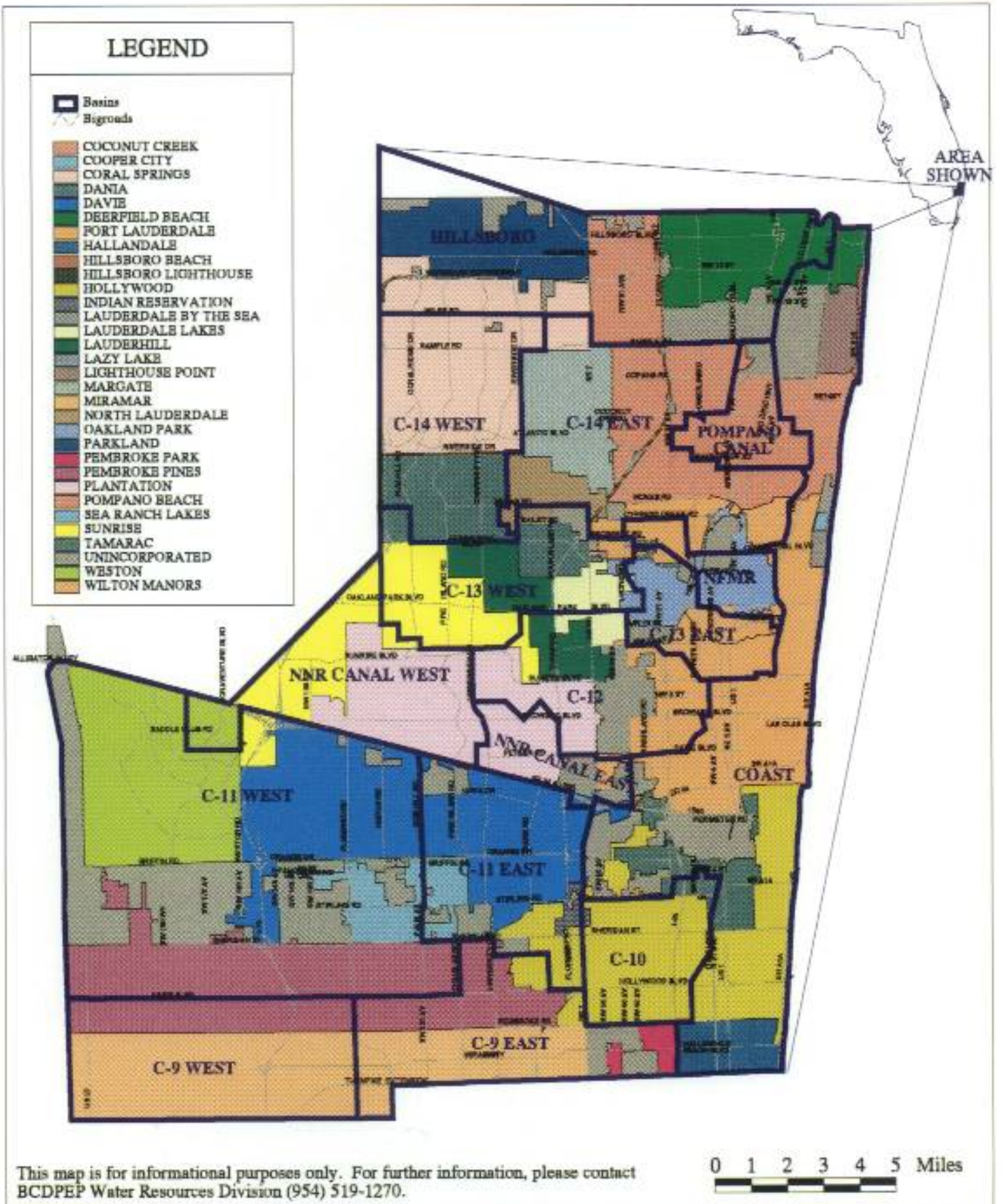


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Figure I.3. Location of Municipalities and Drainage Basins in Broward County. Names of individual cities, towns, and villages are shown in legend. Gray areas represent unincorporated areas of Broward County.

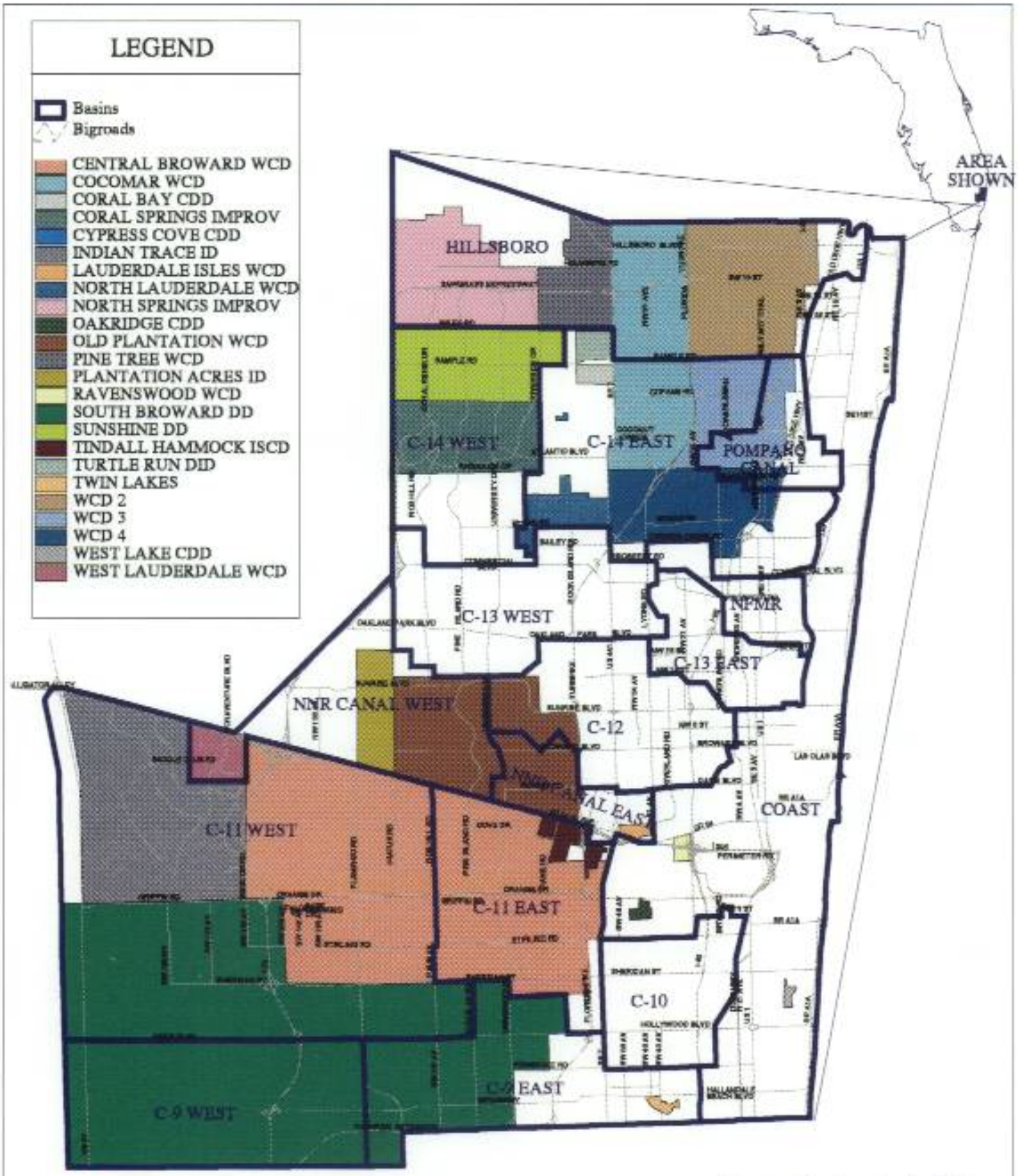
Hollywood (134,022 persons) have the two largest populations. Many of the cities border at least one major water body and may encompass more than one basin. Basin specific descriptions will be provided in Sections III and IV.

4. Drainage Districts

Twenty-four independent and dependent districts have jurisdiction over water related issues (Figure I.4) and several cities also manage surface waters within their boundaries http://www.co.broward.fl.us/oes/wmi00500.htm. The Broward County Office of Environmental Services maintains surface waters for the seven dependent drainage districts as well as Broward County's unincorporated neighborhoods that do not exist within an independent drainage districts. Surface water permitting is done by the independent drainage districts in their districts and by BCDPEP for all other areas of the county. In addition, the South Florida Water Management District (SFWMD) permits the larger developments throughout the county.

5. Other Characteristics

Many other characteristics may influence water quality in Broward County's waterways including soils (Figure I.5) and land use (Figure I.6). Basin specific information will be presented in sections III and IV for each of these. In addition, a 1993 septic tank coverage map is available online at (http://www.broward.org/moi00600.htm).



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BROWARD COUNTY

Figure I.4. Location of Drainage Districts and Drainage Basins in Broward County. Names of individual districts are shown on legend. Water Control Districts (WCD) 2, 3, and 4 are operated by Office of Environmental Services.

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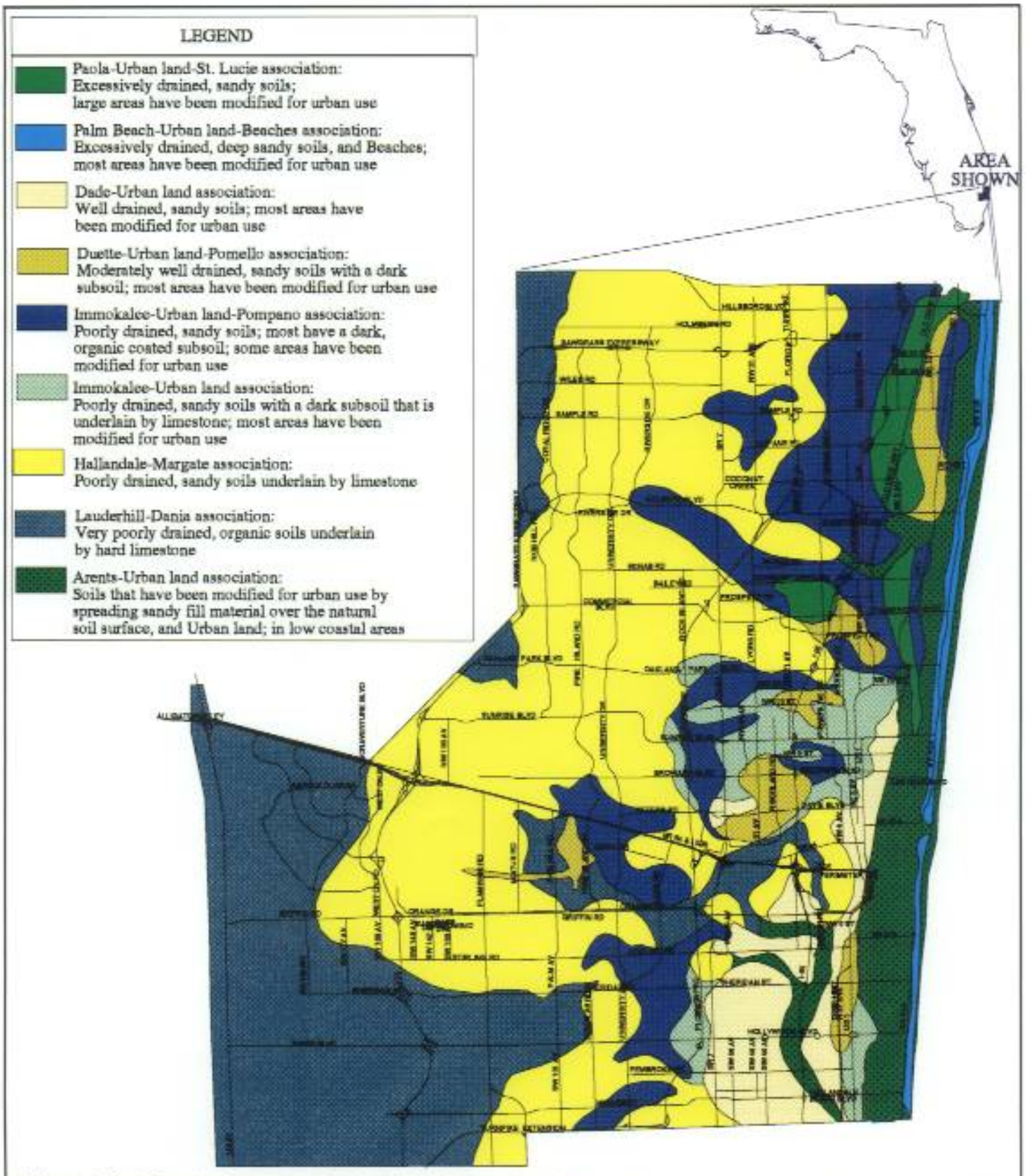

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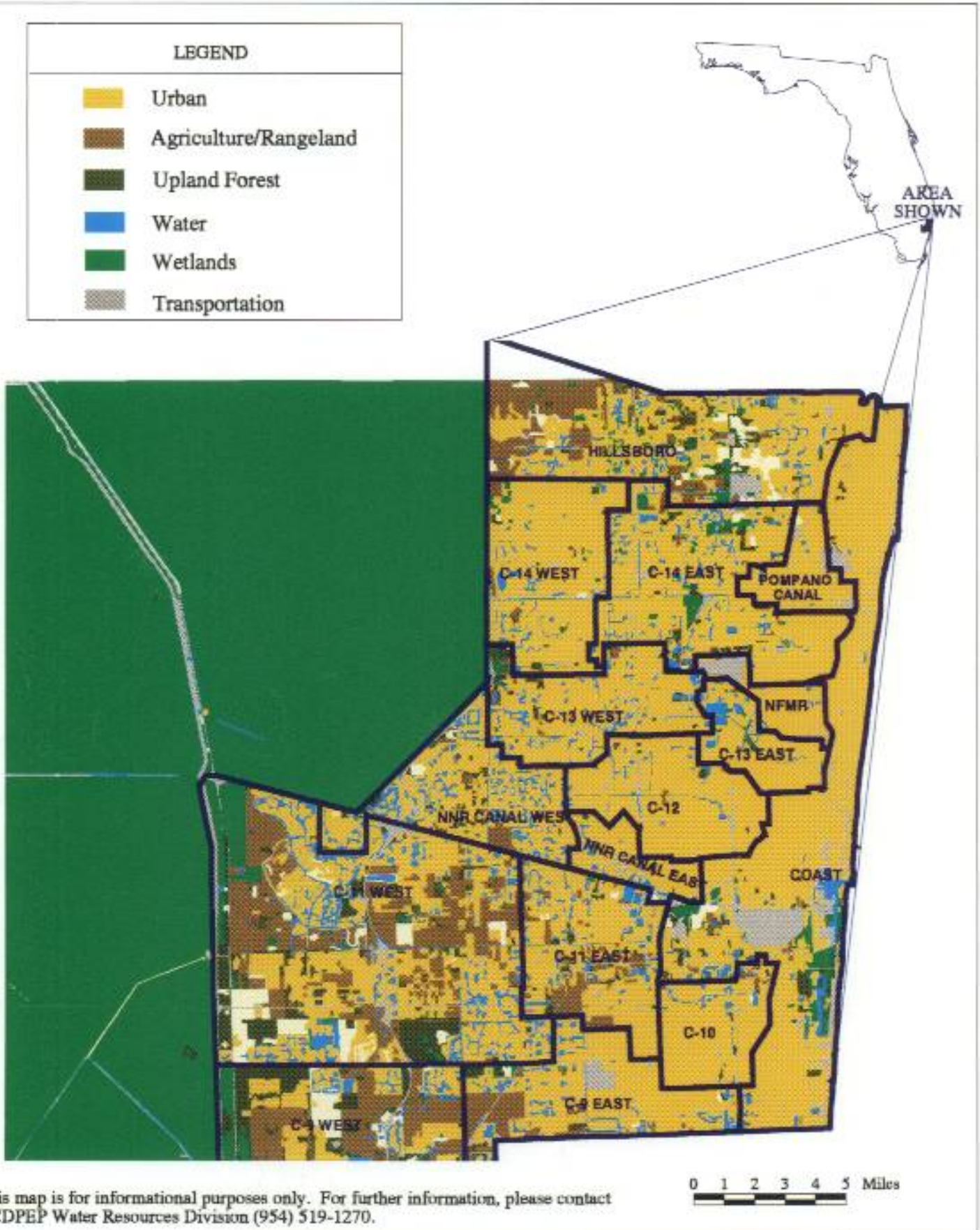
BROWARD COUNTY

Figure 1.5. Major Soil Types of Broward County, Florida.



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BROWARD COUNTY

Figure I.6. Location of Drainage Basins in Broward County with Corresponding 1995 Land Use.

C. Literature Cited

Broward County. 2000. Code of Broward County, Florida - Chapter 27; Pollution Control. Municipal Code Corporation, Tallahassee, FL.

Broward County Department of Natural Resource Protection (BCDNRP). 1993. New River Study: Final Report. Technical Report Series, TR 93-06. Ft. Lauderdale, FL.

Broward County Department of Natural Resource Protection (BCDNRP). 1996. Surface Water Quality of the C-9 (Snake Creek) Canal, Broward County, Florida. Technical Report Series, TR: 96-05. Ft. Lauderdale, FL.

Broward County Environmental Quality Control Board (BCEQCB). 1989. 1988-89 Annual Report. Ft. Lauderdale, FL.

Broward County Planning Council. 1989. Broward County Land Use Plan. Ft. Lauderdale, FL.

Broward County Planning Council - H.A. Sniezek, W.A. Ishmael, D.A. Holmes, E. Mumby, S.N. Buenaventura, J.F. Maggied, J. A. Wells-Jones, D.J. Waldron, E.J. Matej, R.G. Lorber, L.V. Henry, A. Loos, S.A. Wheeler. 1995. Broward County Land Use Plan Evaluation and Appraisal Report. Ft. Lauderdale, FL.

Cooper, R.M. and J. Lane. 1987. South Florida Water Management District (SFWMD) - Water Resources Division. An Atlas of Eastern Broward County Surface Water Management Basins. Technical Memorandum, DRE 231. West Palm Beach, FL.

http://www.co.broward.fl.us/oes/wmi00500.htm. Broward County Office of Environmental Services web page. September 2000.

http://www.broward.org/moi00600.htm. Broward County Department of Planning and Environmental Protection web page. September 2000.

McPherson, B.F. and R. Halley. 1997. The South Florida Environment: A Region Under Stress. United States Geological Survey Circular 1134. Tallahassee, FL.

Reynolds, Smith and Hills Architects-Engineers-Planners, Inc. 1972. Urban Design Study. Broward County Area Planning Board. Ft. Lauderdale, FL.

South Florida Water Management District (SFWMD). 1991. Broward County Water Supply Plan, Phase 1. West Palm Beach, FL.

State of Florida 1998. Florida Administrative Code 62-302. Tallahassee, FL. and/or http://www.dep.state.fl.us /ogc/documents/rules/shared/62-302t.pdf.

Waller, B.G., W.L. Miller, and T.R. Beaven. 1975. Water Quality Data for Canals in Eastern Broward County, Florida. 1969- 1974. United States Geological Survey. Tallahassee, FL.

II. Methodology

A. Field and Laboratory

The Broward County Department of Planning and Environmental Protection laboratory (Environmental Monitoring Division) is a Florida Department of Health certified laboratory (#E46053) and follows a comprehensive quality assurance plan (#870191G). The first certification procedure occurred in 1977 when the agency was known as the Broward Environmental Quality Control Board.

Sampling of freshwater canals and their estuarine portions (e.g., Hillsboro Canal at US 1) was primarily performed from bridge crossings across specific canals. Appendix I describes the geographical location of all sites. Surface grab samples were mainly collected via a Kemmerer bottle which was lowered to collect water from a canal. The Intracoastal Waterway and adjacent sites in the Middle River (Site 10 only) and Dania Cut-off Canal (Site 47 only) were sampled by small vessel and were grab sampled with individual bottles or whirlpacks. Samples for individual constituents were then placed into clean glass bottles or whirlpack depending on the parameter to be analyzed. Samples were normally placed on ice and brought back to the laboratory within four hours of collection. Table II.1 describes the methodologies used over time for each parameter. Appendix II describes what each parameter measures and its importance to water quality. All of the parameters were not sampled through the entire study. Thus, the overall sampling years for each parameter will be presented with each specific basin in Sections III and IV.

B. Database Formation

As much of the data was collected before personal computers (1970's to middle 1980's), data were transferred from original field note cards into a computer spreadsheet (Lotus IV® for Windows®). The data was checked via quality control measures periodically. A major factor that assisted the historic search of data was the continuity in the BCDPEP's laboratory (Environmental Monitoring Division) which has several employees with at least twenty years of service and at least three with over twenty-five years. Thus, some members have been with BCDPEP since the initial water quality sampling network was established in 1972.

Once within the database, the field note card data was added to the current BCDPEP database that has been and is currently submitted to the United States Environmental Protection Agency's STORET database. Both the data submitted to STORET and the data collected beforehand are available to anyone in the public per request. Ambient water quality maps depicting water quality indices are available on the Internet (http://205.166.161.20/dpep/ wqi/index.html).

Table II.1. Broward County's Laboratory Methodologies for Water Quality Parameters. Total nitrogen was calculated by adding nitrite+nitrate-nitrogen and total Kjeldahl nitrogen concentrations.

Parameter	Technique	Method	Ref.
Temperature	Thermometric, mercury/mechanical/thermister	EPA 170.1	EPA
Specific Conductance	Whetstone bridge or equivalent	EPA 120.1	EPA
pH	Electrometric, glass electrode	EPA 150.1	EPA
Salinity	Electrical conductivity	SM 209A	SM
Turbidity	Nephelometric	EPA 180.1	EPA
Dissolved Oxygen	Membrane electrode (1972-present) Winkler titration (1972-present)	EPA 360.1 EPA 360.2	EPA EPA
Biochemical Oxygen Demand	@ 20 ° C, 5-day (1972-1980) @ 20 ° C, 7-day (1981-present)	EPA 405.1 EPA 405.1	EPA EPA
Total Organic Carbon	Thermal oxidation, NDIR (1981-1994) Persulfate oxidation, NDIR (1994-present)	EPA 415.1 EPA 415.2	EPA EPA
Total Phosphorus	Acid, block digestion, automated, ascorbic acid	EPA 365.4	EPA
Nitrite+Nitrate-Nitrogen	Cadmium reduction, automated	EPA 353.2	EPA
Ammonia-Nitrogen	Specific ion electrode (1980) Automated phenate (1981-present)	EPA 350.2 EPA 350.1	EPA EPA
Total Kjeldahl Nitrogen	Acid, block digestion, automated phenate	EPA 351.2	EPA
Fecal Coliform	Membrane filter	SM 909C	EPA
Total Coliform	Membrane filter	SM 909A	EPA
Fecal Streptococcus	Membrane filter	SM 910B	EPA

EPA = Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, March 1983

SM = Standard Methods for the Examination of Water and Waste Water, 14th ed., APHA, Washington, D.C. 1975

C. Data Analysis

At the core of this historical investigation is a three-part data analysis performed at each sampling site in a particular basin.

- An initial descriptive statistical analysis of all parameters and data collection years for each site;
- Graphical analyses of major parameters (dissolved oxygen, total phosphorus, total nitrogen, and fecal coliform) at each site; and
- Graphical and statistical analyses of major parameters collected during post-wastewater treatment plant discharge years with a focus on seasonal concentrations.

The descriptive analysis provides a historic snapshot of the total sampling effort at each particular site. Graphical analysis was performed to investigate inter- and intra- annual variation. Furthermore, graphical analyses were performed to better understand the influence of wastewater treatment plant (WWTP) discharges to surface waters to both the observed concentrations and water quality standard compliance. Finally, an attempt to discern seasonal differences was performed graphically and statistically for the years 1989 through 1997. This also allowed for better interpretation of overall water quality post-WWTPs, as well as integrating known dry, wet, and average rainfall years similar to modeling efforts of the Water Preserve Areas (WPA) Feasibility Study (http://www.evergladesplan.org/projects/wpa_main.htm). The WPA study is looking at the possibility of storing water in the western portions of developed south Florida for better management of water supply to Everglades Restoration and public water supplies.

For data manipulation, concentrations below the method detection limit (MDL) were transformed to half of the MDL. Concentrations below the practical quantitation limit but above the MDL were retained at their observed values. Data manipulation was primarily performed with Lotus IV® for Windows and Corel® Quattro Pro. Graphical analysis was performed with Sigmaplot® and the statistical package used was SigmaStat® that are both Windows based software.

D. Literature Cited

http://205.166.161.20/dpep/wqi/index.html. Broward County Department of Planning and Environmental Protection web page. September 2000.

http://www.evergladesplan.org/projects/wpa_main.htm. Water Preserve Feasibility Study Analysis. September 2000.