APPENDICES

Appendix 1: Broward County Department of Planning and Environmental Protection (BCDPEP) Water Quality Monitoring Site Locations

BCDPEP SITE#	LATITUDE	LONGITUDE	DESCRIPTION
1	26 19 30.0N	080 05 27.6W	HILLSBORO CANAL; FEDERAL HIGHWAY (US 1)
2	26 19 40.8N	080 07 51.6W	HILLSBORO CANAL; WEST SIDE OF SALINITY CONTROL STRUCTURE
3	26 19 37.2N	080 12 10.8W	HILLSBORO CANAL; STATE RD. 7 (US 441)
4	26 21 10.8N	080 17 24.0W	HILLSBORO CANAL; BRIDGE TO SOUTHEAST GROWERS' ASSOCIATION
5	26 13 19.2N	080 06 14.4W	C-14(CYPRESS CREEK) CANAL; FEDERAL HIGHWAY (US 1)
6	26 12 21.6N	080 07 58.8W	C-14 (CYPRESS CREEK) CANAL; DIXIE HIGHWAY BRIDGE
7	26 13 08.4N	080 10 15.6W	C-14 (CYPRESS CREEK) CANAL; SOUTH PALMAIRE DRIVE
8	26 13 48.0N	080 12 18.0W	C-14 CANAL; STATE RD 7 (US 441)
9	26 13 48.0N	080 15 10.8W	C-14 CANAL; UNIVERSITY DRIVE
10	26 08 16.8N	080 07 04.8W	MIDDLE RIVER; EAST SUNRISE BLVD
11	26 10 22.8N	080 10 15.6W	MIDDLE RIVER; NORTHWEST 21ST AVE BRIDGE
12	26 10 22.8N	080 11 13.2W	C-13 CANAL; NORTHWEST 31ST AVE
13	26 10 22.8N	080 13 15.6W	C-13 CANAL; ROCK ISLAND RD
14	26 09 00.4N	080 15 25.2W	C-13 CANAL; UNIVERSITY DRIVE
15	26 07 04.8N	080 08 38.4W	NEW RIVER; ANDREWS AVE BRIDGE

BCDPEP SITE#	LATITUDE	LONGITUDE	DESCRIPTION
16	26 07 15.6N	080 09 46.8W	NORTH FORK NEW RIVER; BROWARD BLVD
17	26 08 06.0N	080 11 42.0W	C-12 (PLANTATION) CANAL; W EST SIDE OF SALINITY CONTROL STRUCTURE
18	26 08 06.0N	080 12 46.8W	C-12 (PLANTATION) CANAL; NORTHWEST 9TH DRIVE
19	26 06 32.4N	080 09 32.4W	SOUTH FORK NEW RIVER; RIVER REACH CONDO - SEAWALL
20	26 05 13.2N	080 11 02.4W	CONFLUENCE SOUTH FORK NEW RIVER/NORTH NEW RIVER CANAL; BRADFORD MARINA DOCK
21	26 05 49.2N	080 14 16.8W	NORTH NEW RIVER CANAL; WEST SIDE OF COASTAL SALINTIY CONTROL STRUCTURE ON THE NORTH SIDE, 1/4 MI WEST OF TURNPIKE
22	26 06 57.6N	080 19 01.2W	NORTH NEW RIVER CANAL; SW 125TH AVE BRIDGE (C15)
23	26 07 19.2N	080 20 34.8W	NORTH NEW RIVER CANAL; US 27
24	26 03 32.4N	080 08 38.4W	DANIA CUT-OFF CANAL; US 1 BRIDGE
25	26 02 52.8N	080 09 18.0W	C-10 (HOLLYWOOD) CANAL; STIRLING ROAD BRIDGE (E OF BRYAN BLVD)
26	26 04 04.8N	080 10 08.4W	DANIA CUT-OFF CANAL; RAVENSWOOD ROAD BRIDGE
27	26 03 57.6N	080 12 32.4W	C-11 (SOUTH NEW RIVER) CANAL; WEST SIDE OF COASTAL SALINTIY CONTROL STRUCTURE (S-13)
28	26 03 46.8N	080 18 50.4W	C-11 (SOUTH NEW RIVER) CANAL; FLAMINGO ROAD BRIDGE
29	26 03 39.6N	080 26 02.4W	C-11 (SOUTH NEW RIVER) CANAL; US 27 BRIDGE
31	25 57 50.4N	080 18 43.2W	C-9 (SNAKE CREEK) CANAL; FLAMINGO ROAD BRIDGE
32	25 57 25.2N	080 25 55.2W	C-9 (SNAKE CREEK) CANAL; US 27 BRIDGE

BCDPEP SITE#	**LATITUDE**	**LONGITUDE**	**DESCRIPTION**
33	26 18 50.4N	080 04 55.2W	INTRACOASTAL WATERWAY (ICW) HILLSBORO BLVD BRIDGE
34	26 15 39.6N	080 05 02.4W	ICW; HILLSBORO INLET; 100' NORTH OF MARKER 71; 50' WEST OF E BANK
35	26 15 00.0N	080 05 27.6W	ICW; 100' NORTH OF NE 14TH STREET BRIDGE; EAST FENDER; 100' WEST OF EAST BANK
36	26 11 20.4N	080 06 14.4W	ICW; 100' NORTH OF COMMERCIAL BLVD BRIDGE EAST FENDER; 100' WEST OF EAST BANK
37	26 08 16.8N	080 06 32.4W	ICW; 100' NORTH OF SUNRISE BLVD BRIDGE EAST FENDER; 100' WEST OF E BANK
38	26 06 00.0N	080 07 12.0W	ICW; 100' NORTH OF 17TH STREET CAUSEWAY BRIDGE E FENDER 100' WEST OF E BANK
39	26 03 57.6N	080 06 54.0W	ICW; 300' NORTH OF MARKER #35; 50' WEST OF EAST BANK
40	26 02 02.4N	080 07 04.8W	ICW; 100' NORTH OF SHERIDAN STREET BRIDGE E FENDER; 50' WEST OF E BANK; WEST LAKE PROJECT SITE #W-3.
41	25 59 09.6N	080 07 15.6W	ICW; 100' N OF HALLANDALE BEACH BLVD BRIDGE E FENDER; 50' WEST OF EAST BANK
47	26 03 46.8N	080 07 04.8W	DANIA CUT-OFF CANAL; 200' WEST OF CONFLUENCE WITH ICW

Appendix 2: Description of Water Quality Parameters Water Quality Parameters

A. Introduction

The freshwater canals and estuarine waters included in this report have been sampled for 16 water quality parameters. Individually or in combination, the parameters have been used to measure different characteristics or functions of these surface waters over 25 years (1972-1997). The parameters, analyses, and interpretation of the results, collectively represent the science that has been applied to each of the sampling sites in order to summarize water quality over time, seasonally, and compliance of Broward County's local water quality standards. Much of the document focuses on four major parameters - dissolved oxygen, total phosphorus, total nitrogen, fecal coliform - because of their importance to ecological and/or human health.

B. Bacteriological Parameters

Total coliform bacteria generally indicate the presence of soil associated bacteria and result from natural influences on a water body such as rainfall runoff and sediment resuspension. Total coliforms have been found in numerous studies to increase by a factor of 100 after heavy rainfall events. A majority of total coliform can survive and reproduce naturally in the environment, therefore, these bacteria often act as a broad measure of the bacterial communities entering a surface water system.

Fecal coliforms (FC) are a subset of the total coliform group and indicate the presence of fecal contamination from warm blooded animals, thereby making them a more useful health risk indicator. Fecal pollution comes from many sources including raw sewage, septic tank seepage, treated sewage from wastewater treatment plants, boats, animal waste, and stormwater runoff. However, there are a number of limitations in the use of coliform bacteria for water quality monitoring. One of the most limiting is their relatively short lifespan of approximately 48 hours in freshwater and even less in saltwater. This makes rapid discovery, proper sampling, and analysis for sewage contaminated sites essential if valid results are to be obtained. Additionally, the survivability of FC bacteria is very temperature sensitive. Survivability is reduced as water temperatures approach 30 degrees Celsius.

Fecal streptococci bacteria are not part of the coliform group. These organisms inhabit the intestinal tract of warm-blooded animals, therefore are another indicator of fecal pollution. However, these bacteria are generally found in greater densities in animals other than humans. There are no established water quality criteria for fecal streptococci bacterial counts but they can be used as an indicator of the source of the contamination (warm-blooded animals).

The United States Environmental Protection Agency (EPA) and Florida Department of

Environmental Protection (FDEP) have established standards and criteria for the presence of certain bacteria as indicators of sewage pollution, human health risks, and for the maintenance of water quality for fish and wildlife in Florida Class III waters. Broward County standards are similar to FDEP for bacteria: total coliform should not exceed 2,400 colonies/100mL and fecal coliform should not exceed 800 colonies/100 ml in any sample. Furthermore, total coliform should not exceed 1,000 colonies/100 ml and fecal coliform should not exceed 200 colonies/100 ml for the monthly average with ten samples.

C. Carbon, Nitrogen, and Phosphorus

Carbon, nitrogen, and phosphorus compounds are found naturally in the environment and are essential nutrients in the living cells of all organisms. Macronutrients also originate from a variety of point and nonpoint sources, of which urban and agricultural runoff and sewage effluent are particularly important. Nutrients are required for growth, maintenance, reproduction, and regeneration of all organisms but if the concentration is too high, some organisms may die or the water may become unsuitable for some uses.

Carbon compounds are usually present in concentrations to adequately support life whereas nitrogen and phosphorus compounds can be limiting for aquatic plant growth in aquatic systems. Increased nitrogen or phosphorus loading to these systems may cause excessive algal and macrophyte growth, and consequent environmental degradation.

Carbon is the molecular building block for all organic compounds and can occur in either organic or inorganic forms. Organic forms are contributed primarily by plants and animal cells and detrital matter. **Total Organic Carbon** (TOC) is the measure of all the organic carbon in the water sample. Inorganic carbon, primarily bicarbonate ions, is the dominant form of carbon and enters the water mainly by solution of calcite ($CaCO_3$) in the soil and rock.

Nitrogen occurs naturally in water in several forms, either as inorganic or organic compounds. In an ideal aquatic ecosystem, nitrogen compounds are in dynamic equilibrium and the form they are in depends on factors such as oxygen level, biochemical reactions, and assimilation by plants. Inorganic nitrogen is readily assimilated by plants and algae and is easily recycled in the aquatic environment. Ammonia is oxidized to nitrite and quickly to **nitrate** by bacteria, making nitrate and ammonia the most common inorganic species. The nitrogen that is assimilated and becomes part of an organism is called **organic nitrogen**. Organic nitrogen is derived from living and dead plants and animals and is usually in the form of amino acids and proteins. The concentration of the organic nitrogen and ammonia is referred to as the **Kjeldahl nitrogen** (TKN). The sum of the Kjeldahl and the nitrite and nitrate is the **total nitrogen** (TN) - the sum of both the organic and inorganic compounds. The Broward County standard for TN is 1.5 mg/l.

The wide range of sources for nitrogen includes wastewater, fertilizers, septic tanks, feed lots and agricultural runoff. Significant nonpoint sources include atmospheric inputs (rainfall), lawn fertilizers, and organic runoff from soil. Bluegreen algae and other bacteria can "fix" and store nitrogen and tend to dominate when nitrogen levels are low.

Phosphorus (P) also occurs naturally in many organic and inorganic forms. Organic P is usually derived from living plants or detrital matter and inorganic P is found in rocks and sediments. Inorganic forms may also be introduced to a water body by application of fertilizers. Orthophosphate is the inorganic dissolved form of P and is readily assimilated by plants. **Total phosphorus** (TP) is the sum of the organic and inorganic forms and is the best species to monitor as a water quality parameter. The Broward County standard for TP is 0.5 mg/l for marine water and 0.2 mg/l for freshwater.

Phosphorus is an essential nutrient for plant and algae growth and its concentration in the water is usually low due to its quick assimilation by plants. Increased P loading may result in increased productivity and in some instances, anthropogenic activities increase P loads to the point where growth of macrophytes and algae becomes excessive, especially in freshwater systems. This increased growth can be an aesthetic nuisance and render a body of water unfit for some uses.

Phosphorus levels can be more critical in lentic sytems (e.g., lakes) than in lotic systems (flowing water) primarily due to the retention time needed for P to be assimilated. Sediments serve as a P "sink" or places of storage, however, if disturbed (dredging) the P can be released back to the environment and increase primary productivity. The many sources of P in the environment include natural phosphorus (phosphate) deposits, sewage, stormwater runoff, runoff from agricultural lands, feedlots, domestic and wild waterfowl populations, and atmospheric input (rain).

D. Dissolved Oxygen

In aquatic systems oxygen is present as **dissolved oxygen** (DO) and must be maintained at an acceptable level to support fish and wildlife. DO is necessary for aerobic respiration and to allow certain chemical reactions to take place.

Water can hold only a limited supply of DO and it comes from two sources - diffusion from the atmosphere and as a by-product of photosynthesis. Several complex interactions occur between plants, aquatic animals, and microbial organisms to determine the amount of DO that is available. During the day, DO levels increase as photosynthesis takes places. At night, photosynthesis ceases and respiration continues, causing DO to decrease. The death and decomposition of algae blooms by oxygen-consuming bacteria have also been shown to deplete DO concentrations. Depending upon other related factors such as water temperature and weather conditions, depletion of DO adversely affects many animal populations and can cause fish kills. Purely chemical reduction (oxidation) also occurs, but the processes in aquatic habitats are primarily limited to the bacterial action in the sediments. Generally, the greater the area of the sediments in contact with the water, the more DO can be depleted, but this process is extremely variable. DO levels also fluctuate with water temperature as cold water holds more DO than warm water. The Broward County standard for dissolved oxygen is 4.0 mg/l for any single reading and 5.0 mg/l for a daily average.

E. Other Parameters

pH is a measure of the hydrogen ion activity, based on the negative base 10 logarithm of the hydrogen ion concentration. For our purposes in this document, pH is the indication of the acidity or alkalinity of the aquatic environment. pH levels in a water system can hinder the reproductive success of many aquatic organisms. Also, lower pH levels (acidity) can release toxic substances, such as metals, from the sediments back into the water column were they can be taken up by the organisms and produce harmful results. The Broward County standard for pH is not less than 6.5 nor more than 8.5 units.

When evaluating the effects of pH on an aquatic system for fish and wildlife populations it must be noted that a non-lethal pH range is not the same as the range for unimpaired fish and wildlife growth and reproduction. As pH values shift from the narrow optimum range (7-9) for fish and wildlife, a gradual deterioration of the ecosystem occurs until the point of acute toxicity is reached. The overall pH of the system depends on the basin's geology, hydrology, basic ion composition, and macrophyte communities. pH values can also be affected by photosynthesis. Increased photosynthetic activities can raise pH values and are usually higher in the late afternoon and in the summer months.

Specific conductance (conductivity) is a measure of the ability of water to conduct an electrical current and provide an estimate of the amount of dissolved ions. Specific conductance in distilled water is nearly zero. The greater the concentration of ions in the water, the greater its conductance. Thus, specific conductivity can be used as an index of water quality to estimate the amount of dissolved solids present (i.e., a measure of the impurities in the water). Conductance can also be used as an indirect measure of **salinity**. Ocean water (saltwater) has a conductance greater than 5000 µmhos. Conductance can vary depending on a number of factors such as geology of the basin, rainfall, stormwater runoff, groundwater intrusion, and ocean tidal effects.

Temperature is one of the most critical parameters for aquatic species and affects the long term ecological health of an aquatic ecosystem. Most aquatic organisms are poikilotherms (cold-blooded) and therefore their life functions are directly related to the water temperature. As the temperature increases so does the organism’s metabolism, and vice versa. Without appropriate temperature regulation within an organism’s natural temperature range, and reduced fluctuations within that range, few organisms could survive. Temperature can affect all aspects of life such as reproduction, migration, behavior, feeding, respiration, growth, sensitivity to disease, and spatial distribution of the organisms.

Temperature also affects the "self-purification" of an aquatic environment and therefore the aesthetic and sanitary conditions. Increased temperatures accelerate the biodegradation of organic material both in the water column and in the sediments. This in turn can decrease the dissolved oxygen that is needed for this activity. Also, the higher the temperature, the less dissolved oxygen the water column can hold. Consequently, as the demand for oxygen increases due to biological activity, a water body's ability to physically hold dissolved oxygen decreases. This phenomena can cause total oxygen depletion and result in anaerobic conditions.

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10. SUPPLEMENTARY NOTES

11. ABSTRACT

This report summarizes twenty-six years of water quality data (1972-1997) from over 266 miles of 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. Sixteen parameters were in the analyses including: temperature, pH, specific conductance, salinity, dissolved oxygen, biochemical oxygen demand, total organic carbon and turbidity. Nutrient analyses included total phosphorus, total nitrogen (total Kjeldahl nitrogen plus nitrite+nitrate-nitrogen), and ammonia-nitrogen. Three bacteriological parameters investigated were total and fecal coliform, as well as fecal streptococcus. 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. Research questions and needs are discussed for each basin and summarized for the overall county. A major overall finding was the negative influence of wastewater treatment plants (WWTPs) on the water quality at most freshwater canal and estuarine sampling sites. 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. In addition, freshwater canals are grouped into three areas based on nutrient concentrations observed after WWTPs halted discharges to surface waters. Distinct estuarine water quality patterns, especially in terms of salinity regime are also discussed.

12. KEY WORDS
Freshwater Canals
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Water Quality, Historical, Sub-tropical
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