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SUMMARY OF BACTERIOLOGICAL TESTING IN THE LAS OLAS ISLES AUGUST 1994 THROUGH AUGUST 1995

ENVIRONMENTAL MONITORING DIVISION
WATER RESOURCES DIVISION

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EXECUTIVE SUMMARY

In 1991, the Department of Natural Resource Protection revamped its surface water quality monitoring network and began studies of individual drainage basins with the goal of establishing a comprehensive picture of baseline water quality. Data from the first basin to be studied, the New River basin, showed that the Las Olas Isles area of Fort Lauderdale was adversely impacted by fecal bacteria. This impact was characterized by exceedances of the county's standard for total and fecal coliform bacteria. Three likely sources of the bacteria were identified: stormwater runoff, periodic failures of the sewage conveyance system and discharges of sanitary waste from inhabited, moored vessels (IMVs). An intensive study of water quality during the period July 1993 through August 1994 concluded that the probable source of the bacteria was the discharge of sanitary wastes from the IMVs. In 1993, the Fort Lauderdale City Commission passed an ordinance intended to mitigate the impact of IMVs. This ordinance required landowners who rent, lease or in any way permit IMVs, to provide for sanitary waste disposal. Infrastructure improvements have also been made to minimize impacts from the sanitary sewer system. However, water quality data collected over the past year indicate no improvement in water quality. In fact, water quality with respect to fecal coliform levels has deteriorated at 12 of the 13 stations monitored. Despite a reported 85-95% compliance by landowners with the provisions of the ordinance (personal communication, Keith Allen, Division Manager, Inspection Services, Fort Lauderdale Fire Rescue and Building Department, October 1995), the area has failed to achieve improvement in water quality. The effectiveness of the ordinance, which relies on voluntary compliance by the IMV occupants, has not been demonstrated. There continues to be a very strong positive relationship between high bacteria levels and the density of IMVs.

1. INTRODUCTION

1.1 BACKGROUND

This report summarizes water quality monitoring data collected in the Las Olas Isles area of Fort Lauderdale for the period of August 1994 through August 1995.

The monitoring of surface water quality in Broward County is conducted to evaluate long-term changes in water quality and to evaluate the effectiveness of regulations designed to protect the environment. The Broward County Department of Natural Resource Protection (DNRP) has conducted this monitoring since 1971. In 1991, a program of intensive testing of the county's surface water on a basin-by-basin approach revealed an area of the Las Olas Isles that appeared to be adversely impacted by fecal coliform bacteria. Fecal coliform levels more than 15 times the Broward County standard (800 colonies/100ml in any sample) were recorded. Total coliform values exceeded the Broward County standard (1,000 colonies/100ml) 80% of the time. These bacteria were suspected of originating from the very dense concentration of inhabited, moored vessels (IMVs) (DNRP, 1993). In 1993, the Fort Lauderdale City Commission passed an ordinance that was designed to mitigate this impact by requiring waterfront landowners who rent, lease or in any way permit IMVs to provide on-shore restrooms, holding tank pump-out facilities or a contract with a mobile pump-out service to empty holding tanks. However, the effectiveness of this ordinance is entirely dependent upon the cooperation of the occupants of the IMVs. In June 1993, in cooperation with the City of Fort Lauderdale, a network of water quality monitoring stations was established to (1) further refine knowledge of the sources of bacteria in the area and to (2) evaluate the effectiveness of the regulation. In October 1994, a report summarizing the findings for the period of July 1993 through August 1994 was published (DNRP, 1994). That report found a strong positive relationship between the density of IMVs and contamination of the water with fecal coliform bacteria. This report summarizes data collected during the period of August 1994 through August 1995, the second full year of monitoring.

1.2 DESCRIPTION OF THE STUDY AREA

Figure 1 highlights the study area with respect to east-central Broward County. Figure 2 illustrates the actual study area and identifies the sampling locations. Figure 3 is an aerial photograph of the area. In general, the Las Olas Isles study area is defined on the north by Rio Barcelona, on the west by Rio Navaro and Lake Stranahan, on the south by Las Olas Blvd., and the east by Rio Balboa. A portion of the area is zoned to permit IMVs. IMVs are particularly prevalent on the Isle of Venice and Hendricks Isle. A count of vessels moored in the area taken from aerial photographs (Dec. 1993) indicated nearly 600 vessels in the study area. More than half this number (340) vessels were moored on the Isle of Venice and Hendricks Isle alone. A subsequent count of vessels in the area from the waterways in September 1995, verified the aerial count and indicates that the count is uniform both seasonally and annually.

Figure 1: Map of East-Central Broward County

Figure 2: Diagram of Las Olas Isles Study Area (Approximate Scale; 1" equals 500')

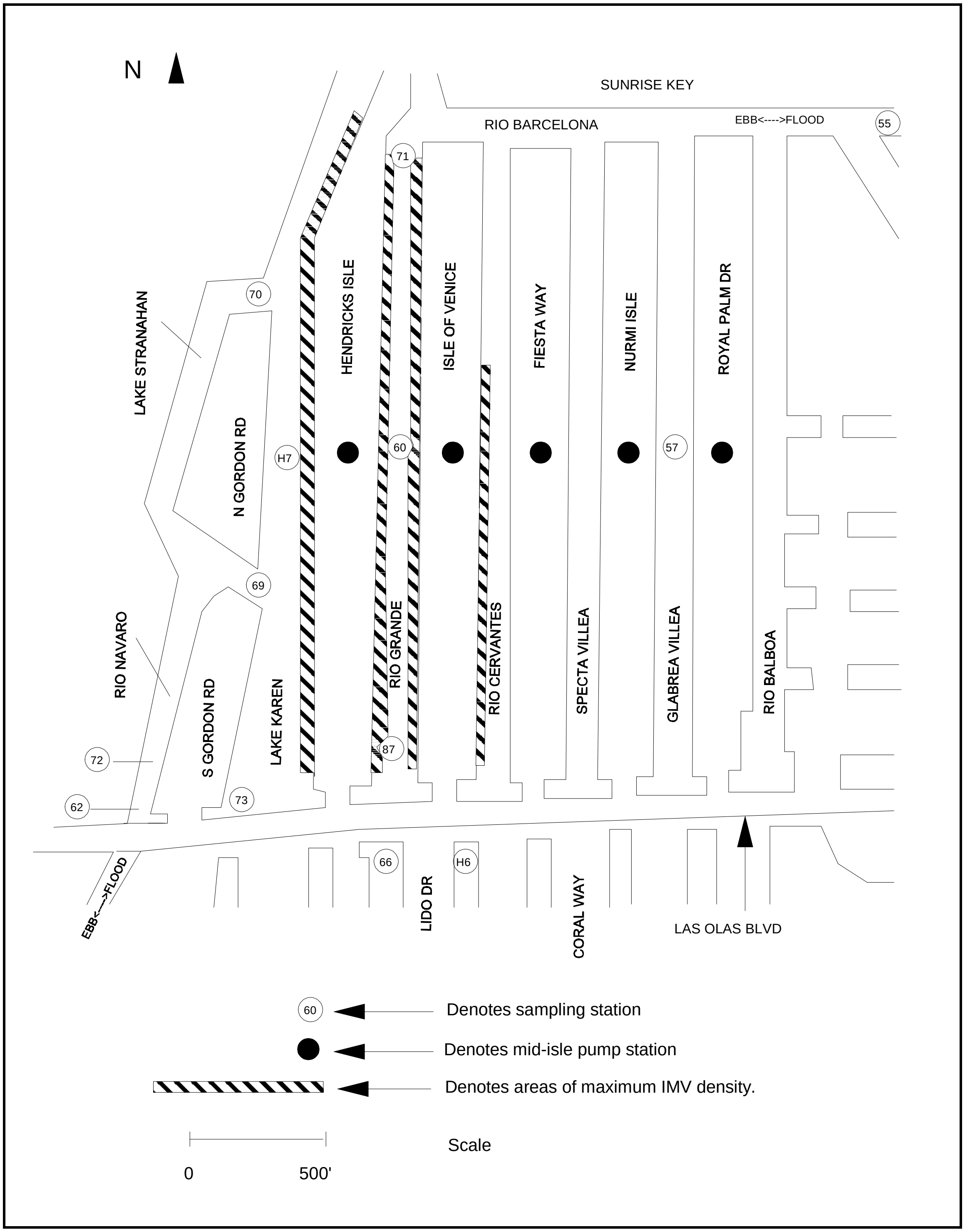


Figure 3: Aerial Photograph of Study Area, April 1993

2.0 METHODOLOGY

2.1 SAMPLING SITE SELECTION AND RATIONALE

In cooperation with the City of Fort Lauderdale Public Services Department, DNRP sampled a set of monitoring stations at least monthly (see Table 1). Station 55 monitors water quality entering the Isles from the east during the ebb (outgoing) tide and the outflow during the flood (incoming) tide. Water samples collected at station 62 represent water entering the area from the New River proper during the flood tide and the outflow during the ebb tide. Stations H7, 71, 60 and 87 monitor water quality where IMVs are most common while Station 57 serves as a nearby comparison site where IMVs are less prevalent. Data from stations 72 and 73 are used to evaluate the quality of water flowing out of Rio Navaro and Lake Karen respectively during an ebb tide. Stations 69 and 70 serve to monitor water from Rio Navaro and Lake Stranahan. Stations 66 and H6 test for leakage from the Las Olas force main. IMVs are not permitted in this area. Except for the bridge under Las Olas Blvd. at station 62, there is no direct connection between the waters on the north and south sides of Las Olas Blvd.

The rate of water flow past any particular station is variable and dependent upon tidal stage. A thorough analysis of flows through the canals in the area has not been done. However, visual assessments indicate minimal flows in the central canals with most water moving between the New River proper and the Middle River via Lake Karen.

Descriptions of sampling stations monitored during this period of the study appears in Table 1.

TABLE 1
SAMPLING LOCATIONS

DNRP SITE #	FORT LAUDERDALE SITE #	STATION DESCRIPTION	*VESSELS WITHIN 300 FT.
55	H1	INTERSECTION OF RIO BARCELONA & MIDDLE RIVER	3
57	H2	MID-POINT, GLABREA VILLEA	2
60	H3	MID-POINT, RIO GRANDE	53
62	H4	N SIDE OF LAS OLAS BRIDGE OVER RIO NAVARO	3
66	H5	N END OF CANAL W OF LIDO DR.	3
69	NO EQUIV.	CENTER OF N PASSAGE BETWEEN LAKE KAREN & RIO NAVARO	33
70	NO EQUIV.	CENTER OF N PASSAGE BETWEEN LAKE KAREN AND LAKE STRANAHAN	18
71	NO EQUIV.	N END OF RIO GRANDE AT RIO BARCELONA	31
72	NO EQUIV.	RIO NAVARO, 50 YD. N OF LAS OLAS BLVD.	3
73	NO EQUIV.	E SIDE OF S. GORDON RD. BRIDGE AT LAS OLAS BLVD.	2
87	NO EQUIV.	S END OF RIO GRANDE, 50 YD. N OF LAS OLAS BLVD.	36
NO EQUIV.	H6	N END OF CANAL E OF LIDO DR.	5
NO EQUIV.	H7	MID-POINT LAKE KAREN	35

* From aerial photography, December 1993

2.2 SAMPLING AND ANALYSIS PROTOCOLS

All samples were collected by hand at the water's surface from a small boat. A 250 milliliter (ml) sterile glass bottle was lowered into the water while the boat was held into the current. Sample collection was conducted mornings without regard to tidal phase. Immediately after collection, samples were cooled to 4 degrees Celsius in ice. The samples were taken to the laboratory and analyzed within six hours using EPA-approved membrane filter techniques.

2.3 BACTERIOLOGICAL PARAMETERS

While no bacteria test can absolutely identify the origin of sewage in water, there are tests that help in identifying the presence of fecal material. Four different bacteriological indicator groups have been monitored in the Las Olas Isles area.

The **total coliform** test is best suited to identify contamination of potable water supplies since bacteria measured by this test may result from many sources. Chapter 27 of the Broward County Code of Regulations (DNRP Pollution Control Code, 1994) specifies a maximum total coliform density of 1,000 colonies/100ml in marine and fresh waters.

Fecal coliform represent the fecal component of the coliform group and are differentiated by their ability to colonize in the appropriate medium at an elevated incubation temperature. The fecal coliform test (membrane filter technique) gives a 93% accuracy in differentiating between coliform found in the feces of warm-blooded animals and those from other environmental sources (Standard Methods, 1992, p. 9-60). The fecal coliform group is also a useful indicator of remoteness of a source of bacteria because the non-fecal members of the coliform group may be expected to survive longer than the fecal members in the unfavorable environment provided by the water (Standard Methods, 1992, p. 9-1). DNRP code specifies a maximum fecal coliform density of 200 colonies/100ml for a monthly average, 400 colonies/100ml for 10% of samples, and 800 colonies/100ml in any sample.

The **fecal streptococcus** group consists of several species of the genus Streptococcus, such as *S. faecalis, S. faecium, S. avium, S. bovis* and *S. gallinarum*. They all give a positive reaction with Lancefield's Group D antisera and have been isolated from the feces of warm-blooded animals. *S. faecalis* and *S. faecium* once were thought to be more human-specific than other Streptococcus species. Other species have been observed in human feces but less frequently (Watanabe et. al., 1981). Similarly, *S. bovis, S. equinus,* and *S. avium* are not exclusive to animals, although they usually occur at higher densities in animal feces (Thomas & Levin, 1978). Certain streptococcal species predominate in some animal species and not in others, but it is not possible to differentiate the source of fecal contamination based on speciation of fecal streptococcus (Standard Methods, 1992, p. 9-70). Neither the Florida Administrative Code nor the Broward County Code provide a standard for fecal streptococcus.

The **enterococcus** group is a subset of the fecal streptococcus that includes *S. faecalis, S. faecium, S. gallinarum* and *S. avium* and are differentiated from fecal streptococcus by their ability to grow under different incubation conditions. In marine waters, the EPA has established a water quality guideline of 35 colonies/100 ml based upon the association of gastroenteritis with poor water quality as indicated by the enterococcus test. The Florida Administrative Code and the Broward County Code of Ordinances do not provide a standard for enterococcus.

2.4 FILTERING THE DATA FOR STORMWATER AND SEWER FAILURE EFFECTS

There are three potential sources of the bacteria found in the Las Olas Isles area: stormwater runoff, emissions from the sanitary sewer system, and discharges from IMVs. In order to differentiate the effects of stormwater runoff and failures of the sanitary sewer system from the effects of IMVs, it is necessary to remove data collected on those sampling days that are suspected to be influenced by rain and sewer events. Stormwater runoff has the effect of dramatically, though temporarily, elevating surface water bacteria levels as fecal material from assorted wild and domestic animals is washed from the land surfaces to the storm sewer and ultimately to surface waters. Similarly, short-term failures of the sanitary sewer system (force main breaks, pump failures, man hole overflows, etc.) can result in bacteria concentration spikes.

Records of rainfall are maintained at the Fort Lauderdale Public Service Department's Dixie-Peele water plant at approximately 1500 S. State Road 7. Although this measuring station is somewhat distant (5 miles west) from the study area, rainfall events in excess of 0.5" at the measuring station would likely signal a concurrent rain event in the study area. The Fort Lauderdale Public Service Department also maintains extensive records of sewer failure and repair activities. Both of these sources were used to identify events that may have affected fecal coliform readings during any of the sampling events.

2.5 INFILTRATION/EXFILTRATION OF SANITARY SEWER SYSTEM

To evaluate the potential of chronic leakage from the sanitary sewer system into the surrounding ground and surface waters, a study of sewage conductivity was performed. Since the shallow groundwater in this area is essentially seawater, infiltration (and potentially exfiltration) would be indicated by an increase in conductivity as tides raised the groundwater level above the various sewer conveyances. Two sites were selected for this study: (1) the mid-isle pump on the Isle of Venice and (2) the mid-isle pump on Royal Palm Drive. The Isle of Venice was selected because of the high density of IMVs and the high bacteria levels that have been recorded there. Royal Palm Drive was the other site because IMVs are absent there and bacteria levels are low. Conductivity readings were taken approximately every 15 minutes according to EPA Method 120.1 (USEPA, 1983) using a Fisher Digital Conductivity meter with automatic temperature compensation. The monitoring period began before the predicted high tide and concluded after the subsequent low tide, a period of approximately 10 hours.

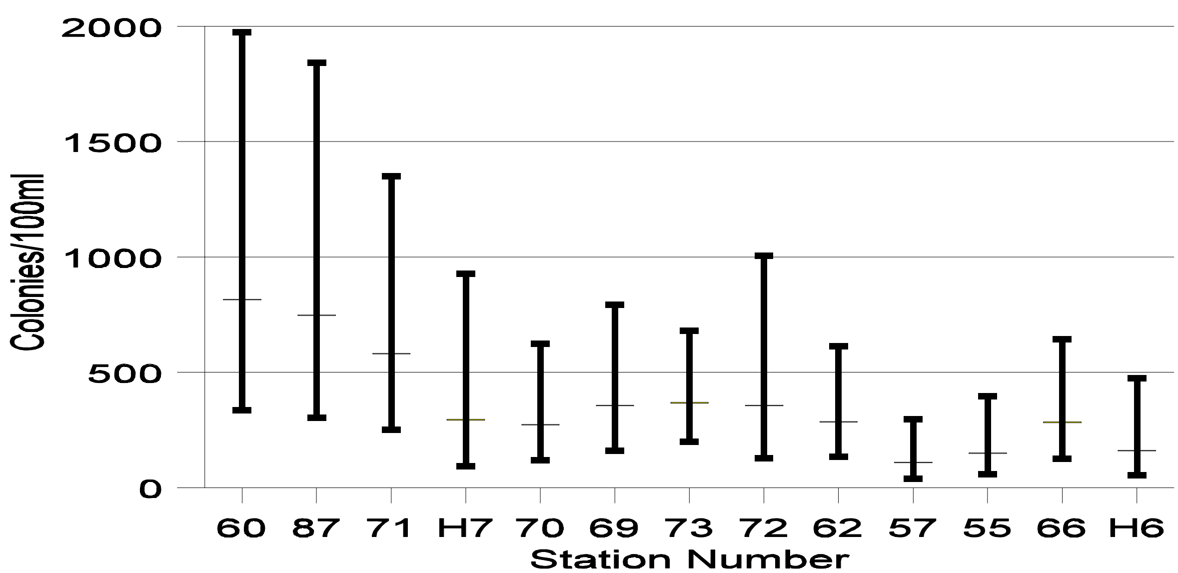
3.0 RESULTS

In most chemical analyses the distribution of analytical results follows the Gaussian curve, which has symmetrical distribution of values about the mean. Microbial distributions are not necessarily symmetrical. Bacterial counts often are characterized as having a skewed distribution because of many low values and a few high ones. These characteristics lead to an arithmetic mean that is considerably larger than the median. The frequency curve of this distribution has a long right tail and is said to display positive skewness. Application of the most rigorous statistical techniques requires the assumption of symmetrical distributions such as the normal (Gaussian) curve. Therefore it is usually necessary to convert skewed data so that a symmetrical distribution resembling the normal distribution results. An approximately normal distribution can be obtained from positively skewed data by converting numbers to their logarithms (Standard Methods, 1992). All mean and standard deviation calculations used in this report are based upon log-transformed data.

3.1 FECAL COLIFORM

Annual mean fecal coliform levels ranged from 110 colonies/100 ml to 816 colonies/100 ml. The highest annual mean value (Fig. 4) was recorded at station 60 at the center of the Rio Grande canal. Twenty-seven violations of the state and county standard fecal coliform standard (800 colonies/100ml) were recorded during this study on the Rio Grande canal, site of maximum IV density. The DNRP standard for fecal coliform is (a) not to exceed 200 colonies/100ml for a monthly average, (b) not to exceed 400 colonies/100ml for 10% of samples, or (c) not to exceed 800 colonies/100ml in any sample.

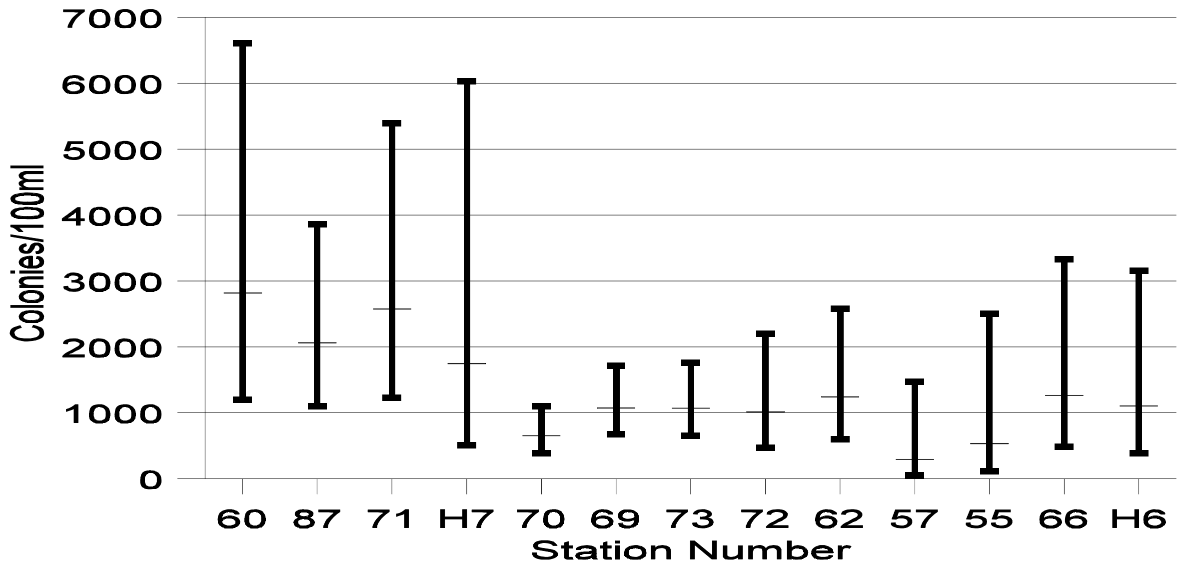
Figure 4: Fecal coliform levels (8/94-8/95) at individual stations in the Las Olas Isles. The vertical bar represents the annual mean (horizontal bar) +\- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



3.2 TOTAL COLIFORM

Annual mean total coliform levels ranged from 296 colonies/100 ml to 2,818 colonies/100 ml. The highest annual mean value (Fig. 5) was recorded at station 60 at the center of the Rio Grande canal. The Broward County standard for total coliform is 1,000 colonies/100 ml in any sample.

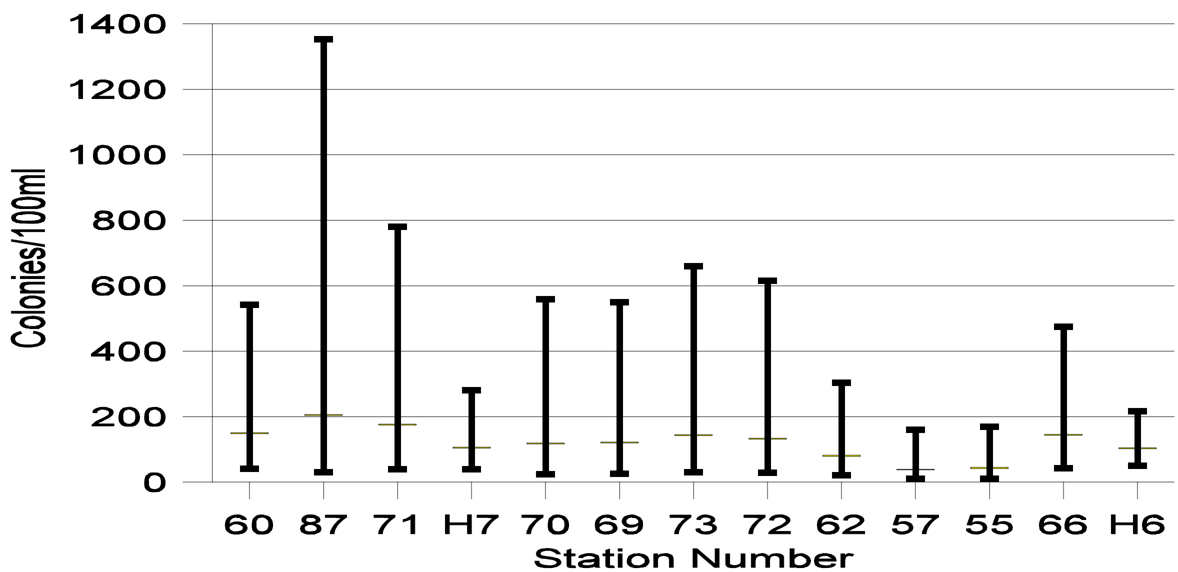
Figure 5: Total coliform levels (8/94-8/95) at individual stations in the Las Olas Isles. The vertical bar represents the annual mean (horizontal bar) +\- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



3.3 FECAL STREPTOCOCCUS

Annual mean fecal streptococcus levels ranged from 39 colonies/100 ml to 206 colonies/100 ml. The highest annual mean value (Fig. 6) was recorded at station 87 at the south end of the Rio Grande canal. Neither DNRP not the State provide a standard for fecal streptococcus.

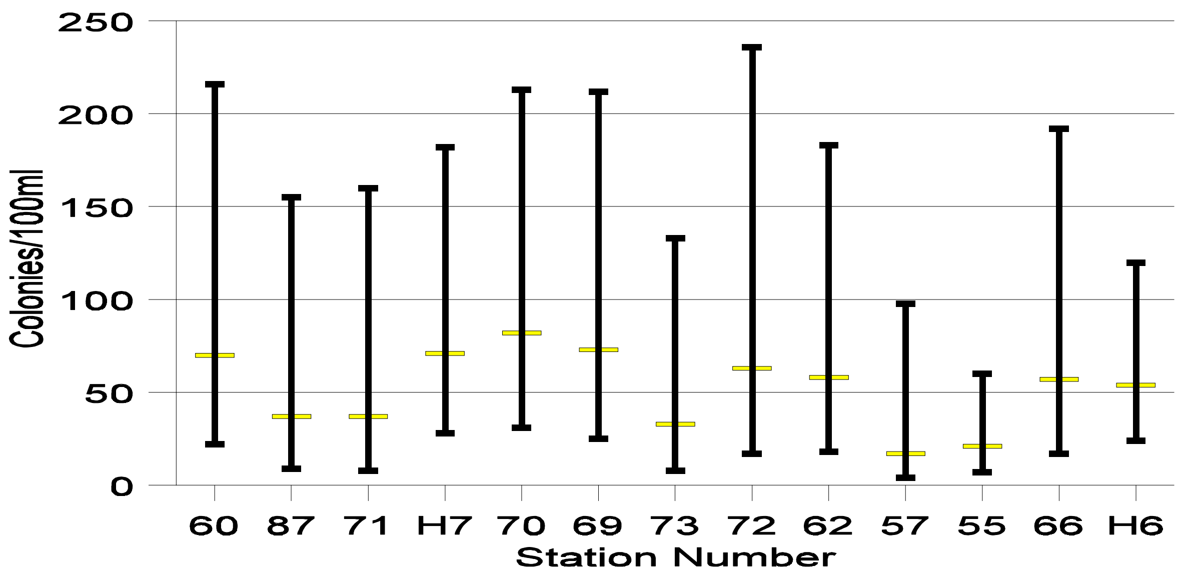
Figure 6: Fecal streptococcus levels (8/94-8/95) at individual stations in the Las Olas Isles. The vertical bar represents the annual mean (horizontal bar) +\- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



3.4 ENTEROCOCCUS

Annual mean enterococcus levels ranged from 17 colonies/100 ml to 82 colonies/100 ml. The highest annual mean value (Fig. 7) was recorded at station 70 at the intersection of Lake Stranahan and Lake Karen. Neither DNRP nor the State provide a standard for enterococcus. The USEPA has established a guideline of 35 colonies/100ml in marine bathing waters based upon the association of gastroenteritis with poor water quality as indicated by the enterococcus test.

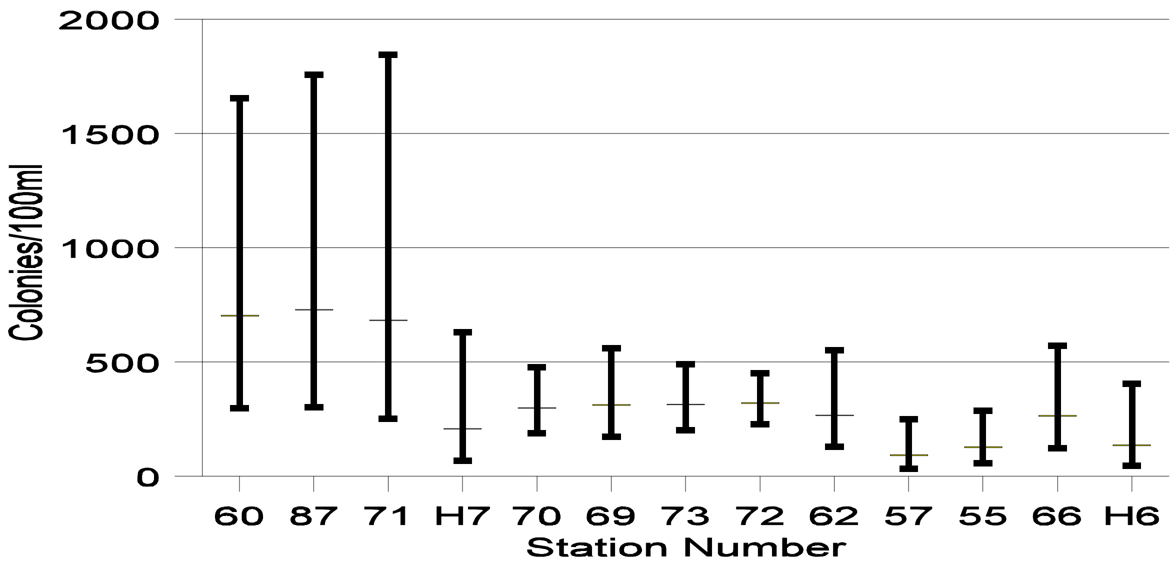
Figure 7: Enterococcus levels (8/94-8/95) at individual stations in the Las Olas Isles. The vertical bar represents the annual mean (horizontal bar) +/- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



3.5 FECAL COLIFORM, FILTERED FOR RAIN AND SEWER EVENTS

Figure 8 illustrates fecal coliform data that has been filtered to exclude rain or sewer events. The difference between the annual mean at station 60, the center of maximum IMV density (703 colonies/100ml), and the annual mean at station 57 the control station (92 colonies/100ml) was found to be statistically significant on a two-tailed Students' t-test (t=6.928, $p<0.05$) (Sage Publications, 1978).

Figure 8: Fecal coliform levels (8/94-8/95) at individual stations in the Las Olas Isles excluding data collected within 24 hr after rain or sewer problems. The vertical bar represents the annual mean (horizontal bar) +/- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



4.0 DISCUSSION

The positive relationship between high bacteria levels in the surface waters of the Las Olas Isles and IMV density that was observed during the period of July 1993 through August 1994 (DNRP, 1994) persists. Figures 4-6 illustrate the positive relationship between IMV density and the annual mean concentrations of fecal coliform, total coliform, and fecal streptococcus bacteria in the surface water.

The annual mean fecal coliform levels exceeded the Broward County standard for a monthly average (200 colonies/100 ml) at 10 of the 13 stations monitored. The annual mean total coliform levels exceeded the Broward County standard (1,000 colonies/100 ml) at 10 of the 13 stations.

The clearest relationship between IMV density and bacteria levels is exhibited by the fecal coliform group. Since the period of viability of fecal coliform in surface waters is the briefest of all the bacteria groups monitored (90% die-off in 2.2 hr) (Chamberlin & Mitchell, 1978), the source of the bacteria may be expected to be near where the highest fecal coliform levels are measured. Figure 7 does not show any clear relationship between IMV density and enterococcus concentration levels. This is likely due to the long period of viability of these bacteria in surface water (90% die-off in 2.4 days) (Hanes & Fragala, 1967). These bacteria may have traveled great distances due to tides before being measured at the sampling point.

4.1 USE OF FECAL COLIFORM TO DESCRIBE WATER QUALITY

Although four different bacteriological indicators were monitored during this project, to simplify presentation and interpretation of the data from this study, only fecal coliform results will be discussed further. The rationale for this approach is as follows:

- **Fecal coliform** are very sensitive to environmental conditions and do not survive for extended periods outside the gut. They are therefore good indicators of the proximity of a source of sewage. Median time for 90% die-off has been estimated at 2.2 hours (Chamberlin & Mitchell, 1978).
- **Total coliform** are not very useful for detecting fecal contamination since they can originate from sources other than the gut of warm-blooded animals.
- **Fecal streptococcus** generally persist longer in water than similarly exposed fecal coliform and are thus less useful indicators of source proximity than fecal coliform (Geldrich, 1976).
- **Enterococcus**, although showing good correlation with gastroenteritis in humans exposed to marine waters used for recreational purposes, are too long-lived to be useful for identifying nearby sources of sewage. The median time for 90% die-off has been estimated at 2.4 days (Hanes & Fragala, 1967). In addition, there are no accepted state or local water quality standards adopted for enterococcus.

4.2 SOURCE OF BACTERIA

There are three potential sources of the bacteria found in the Las Olas Isles area: stormwater runoff, emissions from the sanitary sewer system, and discharges from IMVs. Stormwater carries fecal matter from the land surface and causes short-term increases in bacteria populations. Such elevations are seen in all areas of the county shortly after significant rain events. Likewise, failures of the sanitary sewer system can cause acute, short-term elevations of bacteria populations until the failure is corrected. IMVs represent a potential chronic source of bacteria through the discharge of untreated or inadequately treated sanitary wastes.

Since the bacteria may come from multiple sources, identifying their origin can be difficult. However, using rainfall and sewer repair records, it is possible to “filter” the data that may have been influenced by these sources.

Using the convention established in last year’s report (DNRP, 1994), the data was filtered for any rain events or sewer problems. The convention is that data from any sampling events that occurred within 24 hours after a rainfall of greater than 0.5" or within 24 after a documented sewer malfunction, repair, or resident complaint would be filtered out. This process is designed to illustrate the effect of IMVs without the influence of these other bacterial impacts. Table 2 depicts the sampling days and whether or not a rain event or sewer problem was documented. The documentation of a sewer malfunction does not mean that a release of sewage to surface waters actually occurred.

TABLE 2: Sampling Events Versus Rainfall Events and Sewer Problems

SAMPLE DATE	RAIN W/I 24 HRS?	SEWER PROBLEM W/I 24 HRS?	SAMPLE DATE	RAIN W/I 24 HRS?	SEWER PROBLEM W/I 24 HRS?
08-23-94	NO	YES	02-07-95	NO	NO
09-07-94	NO	NO	02-14-95	NO	YES
09-20-94	NO	NO	02-21-95	NO	YES
09-26-94	YES	YES	03-07-95	NO	NO
10-04-94	NO	NO	03-21-95	NO	NO
10-18-94	NO	NO	03-28-95	NO	YES
10-25-94	NO	NO	04-04-95	NO	NO
11-08-94	NO	NO	04-11-95	NO	NO
11-21-94	NO	NO	05-09-95	NO	NO
11-29-94	NO	NO	05-16-95	NO	NO
12-06-94	YES	NO	06-07-95	YES	NO
12-13-94	NO	YES	06-13-95	YES	YES
12-20-94	NO	NO	07-05-95	NO	NO
01-10-95	NO	YES	07-11-95	NO	NO
01-17-95	NO	YES	08-09-95	NO	NO
01-24-95	NO	YES	08-15-95	NO	NO

As a result of rain or sewer problems, data from 12 of the 32 sampling dates may have been affected. Rain and sewer problems were coincident on two of the sampling days.

The presence of these other potential sources of bacteria in the area complicates the identification of the main source of elevated concentrations of fecal coliform bacteria in the Las Olas Isles. However, using rainfall and sewer repair records to identify and filter out those data that may have been affected, the relationship between IMV density and elevated fecal bacteria levels persists (see

Figure 8). The fact that water quality at station 57 meets county water quality standards while the water quality at station 60 doesn't further implicates discharges from IMVs. If other sources such as mammallian or avian inputs were at fault, such differences would not exist. The difference between these two stations is the high concentration of IMVs. The persistence of the relationship of high fecal coliform levels and high IMV density leads to the conclusion that the discharge of sanitary wastes from IMVs is the primary cause of fecal pollution in the area.

4.3 SEASONAL VARIABILITY

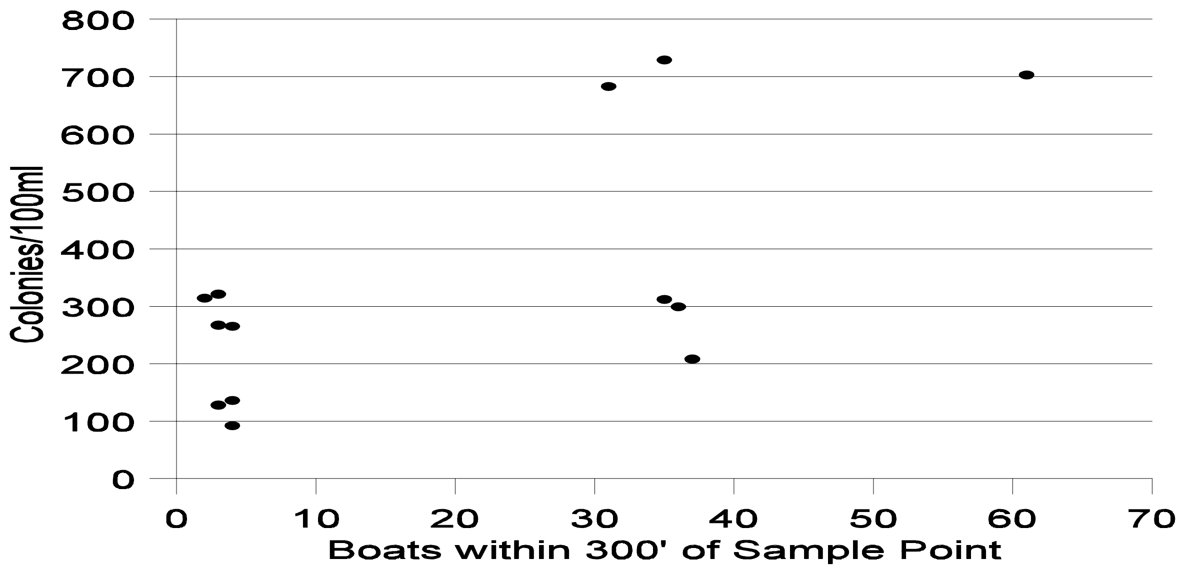
Although a count of vessels in the area from the waterways done in September 1995 agreed with counts from aerial photots taken in December 1993 (approximately 600), the changes in population with the seasons in south Florida make it appropriate to evaluate any relationship between the seasons and bacteria levels. If the south Florida tourist season, when occupancy rates may be expected to be highest, is defined as the six month period from November 1st through April 30, it appears that fecal coliform bacteria levels are similar to levels occurring in the tourist season at Station 60. Five of the ten highest readings (50%) occurred during this time interval. Fifty-six of the readings recorded during the tourist season were in violation of the DNRP fecal coliform standard of 800 colonies/100ml in any sample. Three of the 10 highest readings at Station 57 occurred during the tourist season. The general uniformity of the data over the year may result from more consistent occupancy rates in the area due to long-term lease agreements. There were no violations of the DNRP standard at Station 57 (excluding samples collected coincident with rain or sewer events) during the study period.

When comparing data from one season to the next it should be kept in mind that differences in water temperature, sunlight and rainfall patterns may also influence fecal coliform levels.

4.4 RELATIONSHIP BETWEEN IMV DENSITY AND FECAL COLIFORM LEVELS

If the source of bacteria in an area is the result of discharges from IMVs and there were no other mechanisms for the dispersion of the resulting fecal matter other than a current flow constant in both speed and direction, then there should be a direct relationship between the bacteria levels at the monitoring station and the number of boats moored nearby. In the case of this study, not only are current speeds and directions influenced by tidal phases, but the circuitous nature of the canal system in the Las Olas Isles precludes the expectation of any simple relationship. Indeed, Figure 9 shows only a weak positive relationship exists (Spearman's rank order correlation coefficient = 0.283; 95% confidence interval, -0.32 to +0.70)) (Sage Publications, 1978) between IMV density and fecal coliform levels. The figure also illustrates that the 7 stations in low IMV density areas (<10 boats within 300') had annual mean fecal coliform levels near 300 colonies/100ml or less, while 50% of stations in the higher density areas had annual mean fecal coliform levels near 700 colonies/100ml.

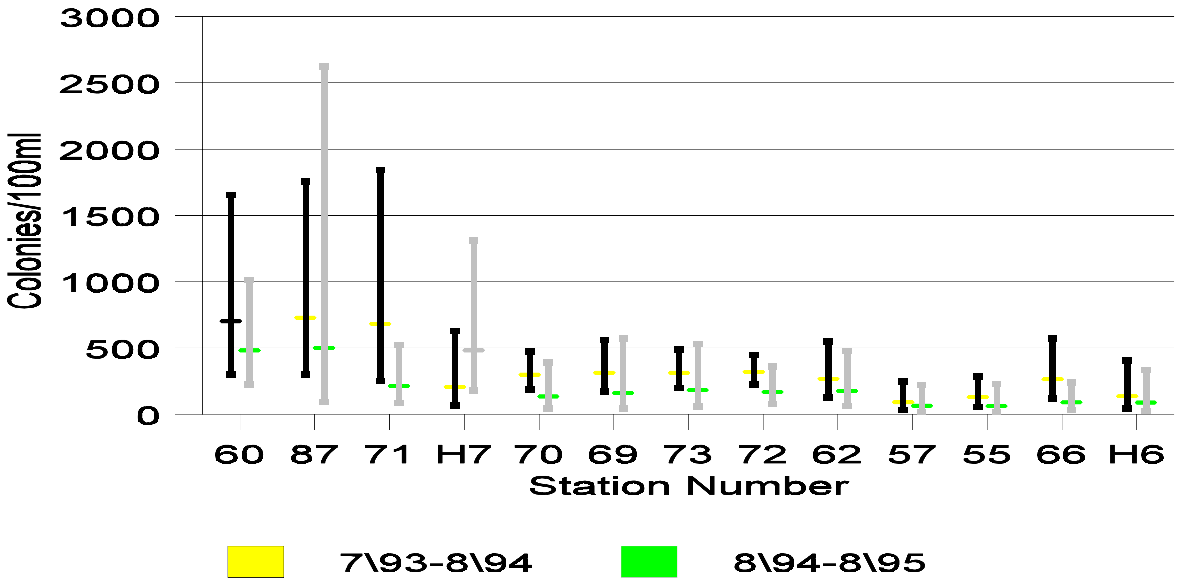
Figure 9: Scatter Plot of IMV Density Versus Fecal Coliform Levels



4.5 DETERIORATION OF WATER QUALITY

Figure 10 compares mean fecal coliform levels recorded over the course of the last 12 months to the data from the previous study period (DNRP, 1994). Both data sets were filtered for rain and sewer events. The figure illustrates that the relationship between IMV density and fecal coliform levels is essentially unchanged. In spite of the enactment of the city's new ordinance, water quality with respect to fecal coliform levels has deteriorated at 12 of the 13 stations monitored. This deterioration was determined to be statistically significant by the Mann-Whitney U-test (p=0.05) (Sage Publications, 1978) at stations H6, H7, 55, 57, 60, 62, and 66. There were insufficient data points to compute statistics at stations 69, 70, 71, 72, 73, and 87.

Figure 10: Fecal coliform levels at individual stations in the Las Olas Isles, 7/93-8/94 versus 8/94-8/95, excluding data collected during rain and sewer problems. The vertical bar represents the annual mean (horizontal bar) +/- one standard deviation at each station. Station numbers are sequenced along the x-axis with proximity to maximum IMV density decreasing from left to right.



4.6 BACTERIAL CONTAMINATION OF SURFACE WATER BY SEWER LEAKAGE

Sewage from buildings on the Las Olas Isles is conveyed to the regional waste water treatment plant at Port Everglades by a system of pipes and pumps. Pipes from individual residences and apartment buildings carry sewage by gravity to a pipe under the street on each isle. Sewage then flows to a pump located near the mid-point of each isle. This pump then transfers the sewage under pressure over the bridges to another gravity sewer under Las Olas Blvd.

The sanitary sewer system in the Las Olas Isles is quite old and deteriorated. In recognition of this situation, the City of Fort Lauderdale has invested significant resources to improve the condition of the various pipes and appurtenances of the system in order to minimize the release of sewage to surface waters and the resultant impact on fecal bacteria levels. In the past year such improvements included (personal communication, Rich Reily, Environmental Program Coordinator, Fort Lauderdale Public Service Department, October 1995):

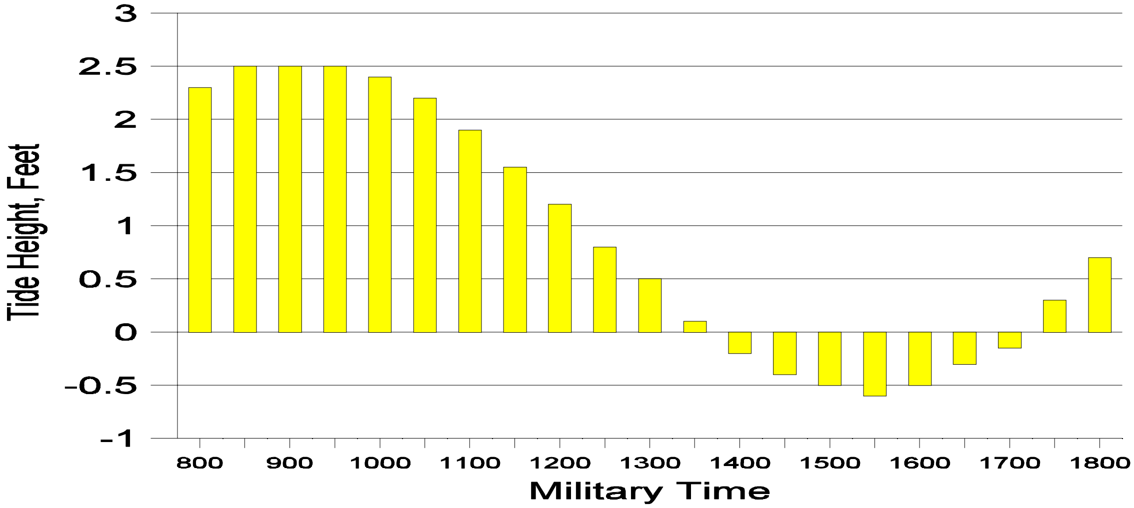
- Replacement of water mains, sewage force mains, storm drainage and sewage pump stations on Isle of Venice, Fiesta Way, Nurmi Dr., Coral Way, and Royal Plaza Dr (south of Las Olas Blvd.).
- Replacement of force main from pump station D-38 (west side of ICW) along E. Las Olas Blvd. to SE 25 Avenue.
- Replacement of force main E Las Olas Blvd. between SE 17th Way and SE 19th Ave.

Figure 11 (reproduced with permission, Fort Lauderdale Public Services Department) depicts the sewage force main replacement schedule for the Las Olas Isles.

Figure 11: Las Olas Isles Sewer Force Main Replacement Schedule

The integrity of the sewer system in the background area (Royal Palm Drive) and also where highest bacteria readings occur (Isle of Venice) was evaluated by measuring the conductivity of sewage at the pump stations. Since the shallow groundwater in this area is essentially seawater, infiltration (and potentially exfiltration) would be indicated by an increase in conductivity as tides raised the groundwater level above the various sewer pipes. Figure 11 depicts the predicted tide heights during the same time interval that the sewage conductivity readings were taken. Figures 12 and 13 depict the conductivity readings in the pumps on Royal Palm Drive and Isle of Venice respectively. The conductivity readings from the Royal Palm Drive pump indicate that infiltration occurs on this isle. However, there is no indication of infiltration at the pump on the Isle of Venice. Thus, although it appears the potential for sewage to impact surface water quality near Royal Palm Drive exists, no such impact is evident in the data. On the other hand, although bacteria levels are very high near the Isle of Venice, the sewage conductivity readings do not indicate that sewage is escaping the sanitary sewer system. The older pneumatic pot station on the Isle of Venice has been replaced by a more reliable electrically-operated pump while the pump on Royal Palm has yet to be upgraded. The improvement to the system on the Isle of Venice has apparently been effective in reducing infiltration to the sanitary sewer system as compared to Royal Palm Drive. Despite the older equipment in place on Royal Palm Drive, chronic problems with fecal coliform contamination has not been documented here. This observation further points to the high density of IMVs on Isle of Venice and Hendricks Isle as the source of the pollution.

Figure 12: Predicted Tide Heights, Bahia Mar Yacht Basin, March 2, 1995



5.0 CONCLUSIONS

Water quality monitoring in the Las Olas Isles continues to indicate an adverse impact from fecal bacteria. The positive relationship between the high bacteria levels and IMV density that was observed last year persists. In addition, overall water quality with respect to fecal bacteria levels has deteriorated. No improvement in water quality is evident in spite of improvements to the sanitary sewer system and the estimated 85-95% compliance with the City ordinance requiring landowners to provide for sewage disposal to their moored tenants. However, the ordinance makes no provision to require the cooperation of the IMV occupants. Twenty-seven violations of the state and county standard fecal coliform standard (800 colonies/100ml) were recorded during this study on the Rio Grande canal, site of maximum IMV density. A comparison between data collected at the heart of

Figure 13: Sewage Conductivity readings, Royal Palm Pump Station, March 2, 1995

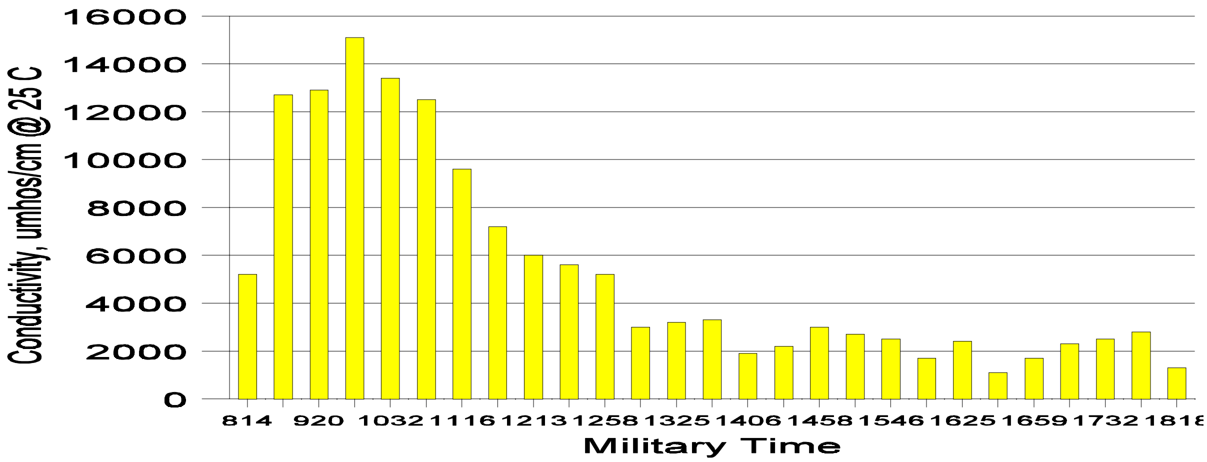
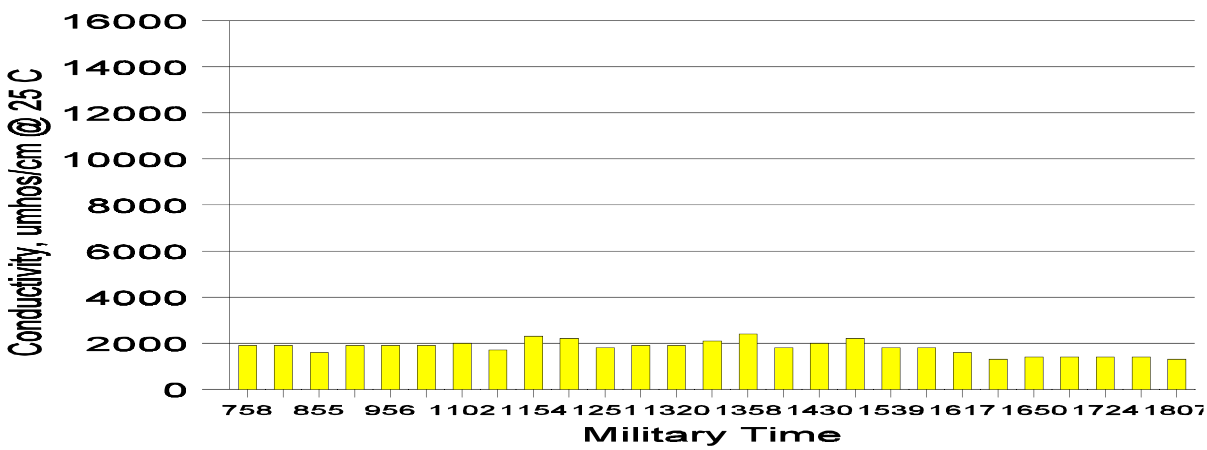


Figure 14: Sewage Conductivity Readings, Isle of Venice Pump Station, March 2, 1995



IMV density and a nearby background area where IMVs are absent indicates that annual mean fecal coliform bacteria levels were more than 7 times higher after controlling for other factors such as stormwater runoff and sanitary sewer failures. There was no apparent infiltration/exfiltration of the sanitary sewer system where bacteria levels were highest. The evidence strongly suggests that the persistent water quality problems in the area are a result of the continued discharge of sanitary wastes from the IMVs.