

**TMDL INVESTIGATION FOR BACTERIA IN CORPUS CHRISTI BAY BEACHES  
INTERIM MONITORING REPORT  
FISCAL YEAR 2011 (YEAR-ONE)**

Prepared for:

**Texas Commission on Environmental Quality  
Total Maximum Daily Load Program  
P.O. Box 13087  
Austin, Texas 78711-3087**

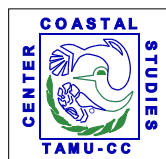


Performed as part of Contract No. 582-11-90501

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## **1.0 INTRODUCTION**

### **1.1 Background**

Disease causing microorganisms, or pathogens, can adversely affect human health in estuarine systems. Densities of these microorganisms when considered unsafe often result in adverse effects to human health. Microbial pathogens are transmitted to humans typically during recreational use involving primary contact with water (i.e., wading, swimming, fishing, etc.) (Heilman *et al.* 2000; USEPA 2002; Nicolau and Nunez 2004). While protecting public health is the primary concern, potential loss of recreational beach use from swimming advisories and beach closures, results in lost economic opportunities to coastal communities (TCEQ 2008).

Typically, high pathogen concentrations in the water column result from sources such as polluted stormwater runoff, wastewater overflows, boating wastes, and malfunctioning septic systems that carry microorganisms from fecal material into the environment. Besides humans, it may indicate contamination by fecal matter originating from other warm-blooded animals (i.e. domestic dogs, birds, etc.). While it is not possible to monitor all pathogens present in recreational waters, The Texas Commission on Environmental Quality (TCEQ) analyzes concentrations of three organisms to determine support of the Primary Contact Recreation (PCR) criteria: fecal coliform and *Escherichia coli* in freshwater, and *Enterococcus* in tidal water. TCEQ guidance stresses that full support of the PCR does not necessarily guarantee that freshwater or tidal waters are completely free of disease causing organisms. However, TCEQ addresses this type of water quality impairment through 303(d) listing and the TMDL process (TCEQ 2008).

In 2008, based on data collected under the Texas Beach Watch Program, EPA took action to list Corpus Christi Bay (Segment 2481) on the [303\(d\) List of Impaired Waters](#) for bacteria and subsequently listed the entire water body in Category 5a, meaning a TMDL will be scheduled. Upon request by TCEQ, EPA reconsidered listing the entire Corpus Christi Bay segment and changed the listing to include only the beaches at Cole Park and Ropes Park, and designated them into separate assessment units (Segment 2481CB\_03 and 2481CB\_04, respectively). In addition, the listing category changed to 5c, meaning additional bacteria data were needed before a TMDL is conducted. These actions have resulted in establishment and funding for the current project, “*TMDL Investigation for Bacteria in Corpus Christi Bay Beaches.*”

### **1.2 Water Quality Standards**

Goals to maintain surface water quality that supports public health, protects aquatic life, and are consistent with sustainable economic development are defined in the Texas Surface Water Quality Standards. These standards identify appropriate uses, including aquatic life, recreation, and public water supply (or drinking water) sources. Criteria for evaluating use support include dissolved oxygen, temperature, pH, dissolved minerals, toxic substances, and bacteria. Primarily, comparison of individual parameter values to either numerical criteria or screening levels determines the number of values exceeded. Based on number of exceedances, the assessment classifies a segment as either being in full support, partial support, or not supportive of the official designated use. Statewide water quality standards are revised on a triennial basis.

TCEQ analyzes concentrations of *E. coli* and fecal coliform in freshwater, and *Enterococcus* in marine or tidal water to determine PCR support. Presence of these naturally occurring organisms in high numbers within the water column indicates contamination by fecal matter originating from warm-blooded animals, including humans. [TCEQ 2010 Guidance for Assessing and Reporting Surface Water Quality in Texas](#) stresses that full PCR support does not necessarily guarantee that waters are completely free of disease causing organisms.

Depending on the analytical test performed, results are reported as colony forming units (CFU) or most probable number (MPN). The membrane filtration test (EPA Method 1600) counts actual colonies (CFU) of bacteria and the newer defined substrate tests such as Enterolert<sup>®</sup> is a statistical representation of the MPN of enterococci likely present in a sample. Both methods are used and considered interchangeable by regulatory agencies.

Support of the TCEQ PCR utilizes a 10-sample minimum per individual site taken over the assessment period (two to seven years). For routinely monitored bacteria data, the geometric mean for enterococci is 35 CFU or MPN/100 ml in tidal water. For individual samples in tidal water and recreational beaches, the old criterion of 89 CFU or MPN/100 ml has been revised to 104 CFU or MPN/100 ml, which is the same as the national EPA Beach Watch Program that monitors Texas beaches for enterococci concentrations to determine closures based on elevated bacterial concentrations.

The following information was obtained from the *Draft 2010 Guidance for Assessing and Reporting Surface Water Quality in Texas*. In 2010, the assessment method considered recreational beaches a sub-category of the recreation use. According to the [Beaches Environmental Assessment and Coastal Health \(BEACH\) Act of 2000](#), states are required to participate with EPA in monitoring coastal recreation waters adjacent to public bathing beaches for pathogens and pathogen indicators. The Act requires public notification when water quality standards are exceeded for bacteria.

Currently, the Texas General Land Office (GLO) administers the Texas Beach Watch Program (TBWP) and collects water samples from 163 stations along the Texas coast in Aransas, Brazoria, Cameron, Galveston, Jefferson, Kleberg, Matagorda, Nueces, and San Patricio Counties. Sample collection occurs weekly (one time at each station) during the peak beach season from May through September and bi-weekly from October through April with water samples collected 0.6 m (2 ft.) from the surface or at knee depth. The GLO maintains a website at [Texas Beach Watch](#) where maps and bacteria water quality information are available. Bacteria results are updated each time sample data are entered into the TBWP database. Local government entities typically post Beach Watch advisory signs at beach access points and issue advisories that warn the public not to swim in affected waters when bacterial levels are exceeded.

TBWP advisories are issued when the average of two samples exceed EPA's recommended single sample maximum density (SSMD) criteria of 104 CFU or MPN/100 ml. Once issued, that beach is subject to continued monitoring every 24 hours until bacteria levels fall to <104 CFU or MPN/100 ml. Advisories last for 24 hours, and are extended if bacteria levels continue to exceed SSMD recommended levels. All samples are collected under a QAPP

consistent with TCEQ bacteria collection and analysis protocols and analyzed for enterococci bacteria using EPA's Method 1600 or the IDEXX Enterolert® system.

TCEQ is provided with a compilation of all beach data collected by GLO under the TBWP. Based on total number of samples for each beach and the number of days each beach is under an advisory, TCEQ assesses each individual year within the multi-year assessment period of record. For all available data, the total number of advisory days are divided by the total number of samples collected. If there are numerous sites monitored at one beach area, only one advisory is counted per beach per day.

TCEQ includes TBWP information in the 303(d)/305(b) assessment process in order to protect human health by identifying beaches with persistent advisories. Assessment consists of identifying the percentage of days each beach has an advisory. The recreation use is not supported if the geometric mean of the samples collected over the assessment period exceeds the criterion (35 CFU or MPN/100 ml) or if the criteria for individual samples (104 CFU or MPN/100) ml are exceeded greater than 25% of the time.

Beach advisories <25% of the time—Fully Supporting

Beach advisories 20-25% of the time—Concern and Fully Supporting

Beach advisories < 20% of the time—Delisted and Fully Supporting

Beach advisories ≥ 25% of the time—Not Supporting

### **1.3 Project Objectives**

The Center for Coastal Studies (CCS) at Texas A&M University was contracted to provide support to TCEQ and future Total Maximum Daily Load (TMDL) development for *Enterococcus* bacteria concerns at beaches along Corpus Christi Bay (Segment 2481). Project goals require the collection of supplementary *Enterococcus* data in Corpus Christi Bay. Data collection specifically targets beaches at Cole Park (Segment 2481CB\_03), Ropes Park (Segment 2481CB\_04), Emerald Beach (Segment 2481CB\_07), McGee Beach (Segment 2481CB\_05), Poenisch Park (Segment 2481CB\_06), Corpus Christi Beach (Segment 2481CB\_02), and University Beach (Segment 2481CB\_08). Public and stakeholder meetings will be hosted as necessary to support the TCEQ TMDL Team.

To ensure that data generated for the purposes described herein are scientifically valid and legally defensible, this project is being conducted under a TCEQ approved Quality Assurance Project Plan (QAPP). This ensures that data submitted to the TCEQ Surface Water Quality Monitoring Information System database have been collected and analyzed in a way that guarantees its reliability.

## **2.0 STUDY AREA DESCRIPTION**

### **2.1 Corpus Christi**

According to data obtained from the City of Corpus Christi Department of Developmental Services, the total area within the city limits is 1060.6 km<sup>2</sup> (409.5 mi<sup>2</sup>). Land represents 409.7 km<sup>2</sup> (158.2 mi<sup>2</sup>) with water and right-of-way easements contributing 526.3 km<sup>2</sup> (230.2 mi<sup>2</sup>) and 54.6 km<sup>2</sup> (21.1 mi<sup>2</sup>), respectively.

The population was 305,215 at the [2010 census](#) making it the eighth-largest city in Texas. The population of the Corpus Christi Metropolitan Statistical Area, which consists of Nueces, Aransas, and San Patricio Counties, was 428,185. Corpus Christi is a popular tourist destination and the [Corpus Christi Convention and Visitors Bureau](#) actively promotes coastal living and area beaches as a premier attraction.

### **2.2 Climate**

Corpus Christi is located between a humid subtropical region to the northeast and a semiarid region to the west and southwest of the city. Summers are hot and humid, with June through August high temperatures exceeding 32.2 °C (90.0 °F) 83.0% of the time with an average morning humidity of 93.0% (National Climatic Data Center 2010). Moderate winters, where the average high in January is 18.3 °C (65.0 °F) and the low is 7.2 °C (45.0 °F), may occasionally produce a freeze following the passage of strong northerly high-pressure fronts (Jones 1975; Chabreck 1990). December through February low temperatures are below freezing only 11% of the time (National Climatic Data Center 2010).

Mean annual precipitation recorded at Corpus Christi International Airport is approximately 77.6 cm yr<sup>-1</sup> (30.6 in yr<sup>-1</sup>) (NOAA 2010). This is offset by evaporation rates ranging from 90 to 115 cm yr<sup>-1</sup> (35.4 to 45.3 in yr<sup>-1</sup>) but may reach as high as 150 cm yr<sup>-1</sup> (TWC 1991). Peak rainfall months are from May to September with the winter months being the driest season. Southeasterly prevailing winds serve as a primary source of atmospheric moisture. The hurricane season runs from June to November (peak months are August and September), with tropical storms and hurricanes occasionally yielding substantial amounts of rainfall during late summer and early fall (Armstrong 1987).

## 3.0 METHODS

### 3.1 Sampling Process Design and Frequency

The sample design for this study is based on program requirements of the Total Maximum Daily Load Program. These requirements involve collection of sufficient quantity and quality of data to characterize water quality under varied conditions, identify the presence or absence of impairments, and to support water quality modeling, load allocation development, and other TMDL information needs for *Enterococcus* concerns at several beaches along Corpus Christi Bay.

Due to the public health nature of this TMDL, sites were selected based on the presence of established beaches or public access points to the water with additional sites selected in the offshore waters of Corpus Christi Bay (Fig. 3.1) for comparison of enterococci concentrations between nearshore and offshore locations. As the beaches at Cole Park and Ropes Park are listed on the 303(d) List of Impaired Waters for bacteria these beaches were the primary focus for this intensive data collection effort. After discussions with the TMDL team, additional locations were added along the Corpus Christi Bay shoreline to obtain sufficient spatial comparison information of aquatic bacteria concentrations within this urban watershed.

The areas chosen along Corpus Christi Bay (Fig. 3.1) represent 10 urban beach/public access sampling locations (Figs. 3.2 through 3.11) that also coincide with existing stations sampled by the Texas Beach Watch Program. Due to the size of Cole Park, four locations were established for *Enterococcus* sampling. However, for advisory and assessment purposes Cole Park is treated as one single location regardless of the number of exceedances on a given day (i.e. if four samples exceed the 104 MPN/100 ml criteria that day only one advisory is issued for Cole Park). Four stations were established at each of the 10 sampling locations (three nearshore and one offshore) for a total of 30 nearshore sampling stations and 10 offshore sampling locations (Figs. 3.2 through 3.11). Samples collected at each nearshore location were collected along a transect line starting at the beach and continuing offshore. While the distance from the beach varied at each of the 30 nearshore stations, the total depth to the bottom at each point a sample was collected will be approximately at 0.6 m, 1.0 m, and 1.5 m, with the actual sample being collected at the standard 0.3 m depth in the water column. These samples are considered representative of ambient water quality conditions at the “knee,” “waist,” and “chest” high depths often encountered by the public in the water at these public access locations.

In order to document the fate and transport of *Enterococcus*, the fourth station was located along each transect line in the deeper waters (>3.0 m) of Corpus Christi Bay. Samples were collected from a boat at the appropriate depth from the surface (0.3 m). The intent of data collection at varying distances from the shoreline is to determine if bacteria concentrations are similar or if concentrations decrease as distance from shore increases.

To supplement the water quality sampling, sediment samples were collected at shoreline locations for analysis of bacteria in the swash zone, or zone of wave interaction. These data were collected for background and supporting information purposes to better understand the extent of bacterial concentrations that exist in the sediment layer at these urban beach/public access locations. Additional rainfall collection events occurred at the 30 nearshore locations

within 24 and 48 hours following a rainfall event to collect data on bacterial concentrations entering the bay from stormwater runoff.

This effort involved the collection of field and microbiological data as described in the QAPP and listed in Table 3.1. Sampling took place from 5/4/2011 through 8/27/2011 to correspond with the Texas Beach Watch “Beach Season” (5/1 through 9/30) when beach use by the public is high. Sampling occurred a minimum of two times per week at the 10 urban beach/public access sampling locations (30 total nearshore stations) with offshore (10 stations), rain event (30 nearshore stations), and sediment (10 beach locations) sampling occurring at a reduced frequency.

During the four-month period, the 30 nearshore stations were sampled 49 times (43 non-rainfall and six rainfall) and the 10 offshore stations were sampled three times. In addition, sediment sampling took place four times at the 10 beach locations. All data underwent quality assurance checks and complied with TCEQ Data Management protocol. Data will be available to the public and stored in the TCEQ SWQMIS database to be utilized for TMDL development.



Fig. 3.1. Aerial photo depicting Corpus Christi Bay Beaches TMDL sampling locations and three major drainage ditches at Louisiana Parkway, Brawner Parkway, and Carmel Parkway. Retrieved on 4/5/2011 from Google Earth.



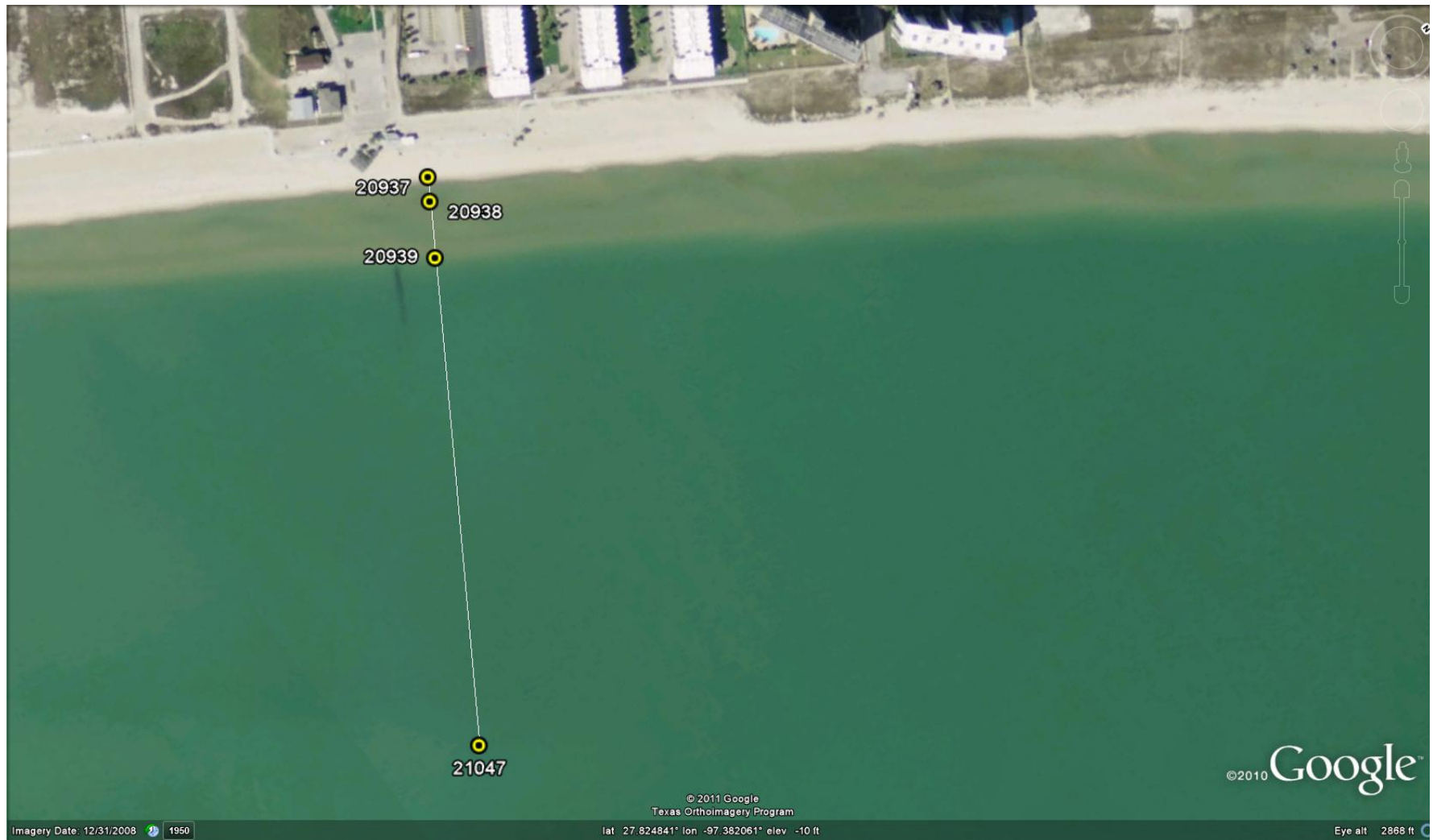


Fig. 3.2. Aerial photo depicting the four Corpus Christi Beach (North Beach) sampling locations. Retrieved on 4/5/2011 from Google Earth.

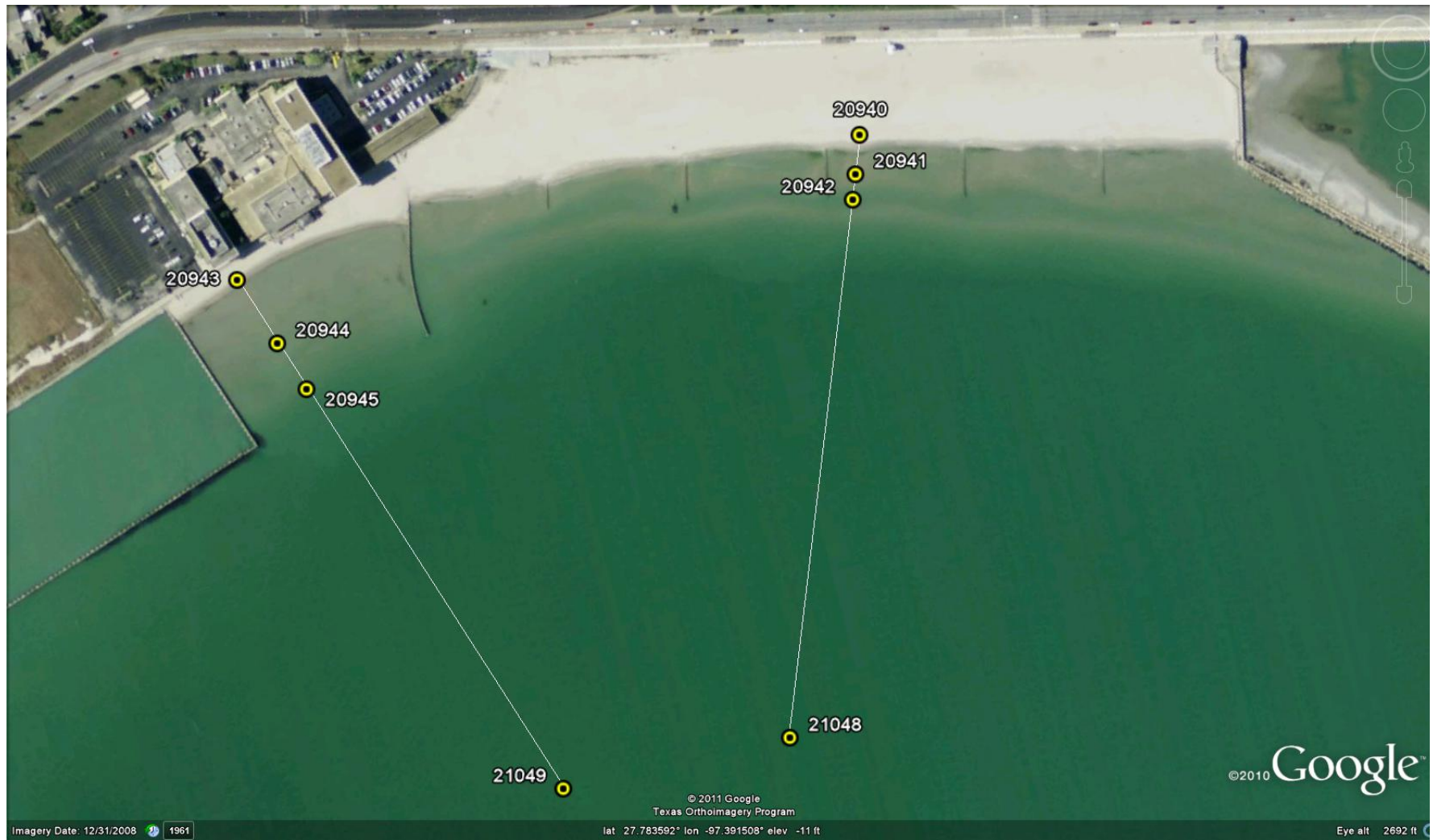


Fig. 3.3. Aerial photo depicting the four McGee Beach (20940, 20941, 20942, and 21048) and four Emerald Beach sampling locations. Retrieved on 4/5/2011 from Google Earth.



Fig. 3.4. Aerial photo depicting the four Cole Park sampling locations (16 stations). Retrieved on 4/5/2011 from Google Earth.

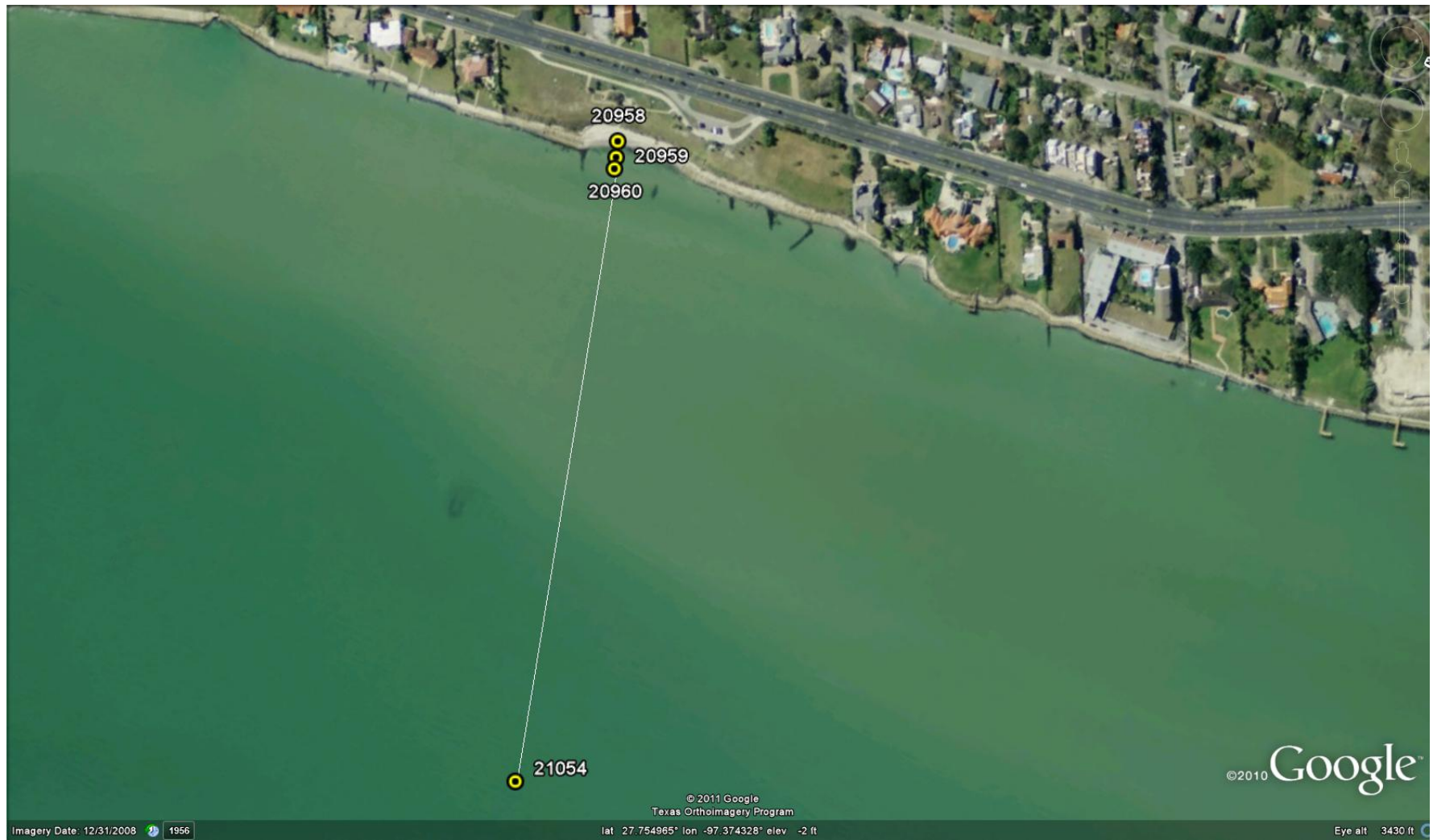


Fig. 3.5. Aerial photo depicting the four Ropes Park sampling locations. Retrieved on 4/5/2011 from Google Earth.

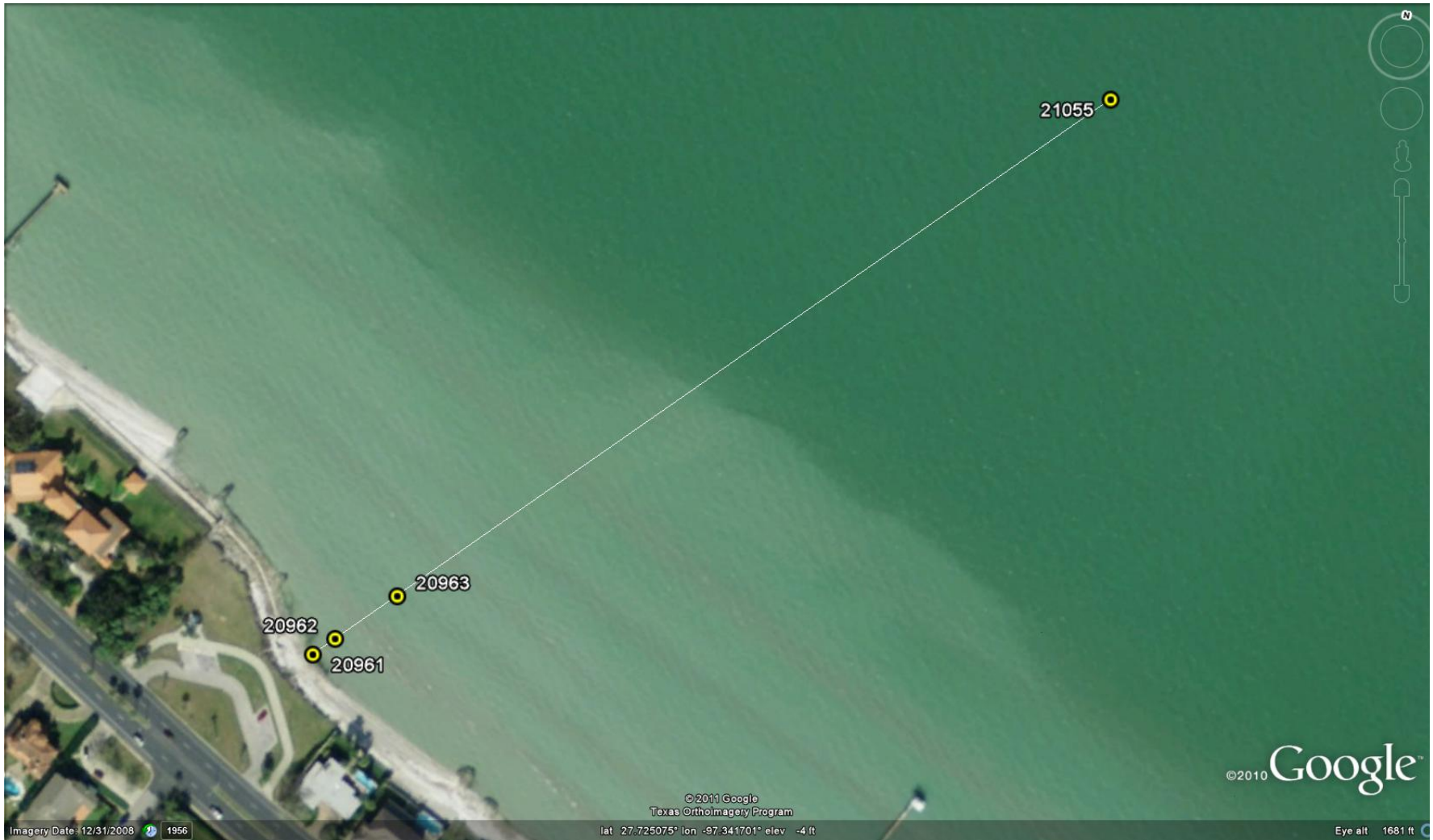


Fig. 3.6. Aerial photo depicting the four Poenisch Park sampling locations. Retrieved on 4/5/2011 from Google Earth.

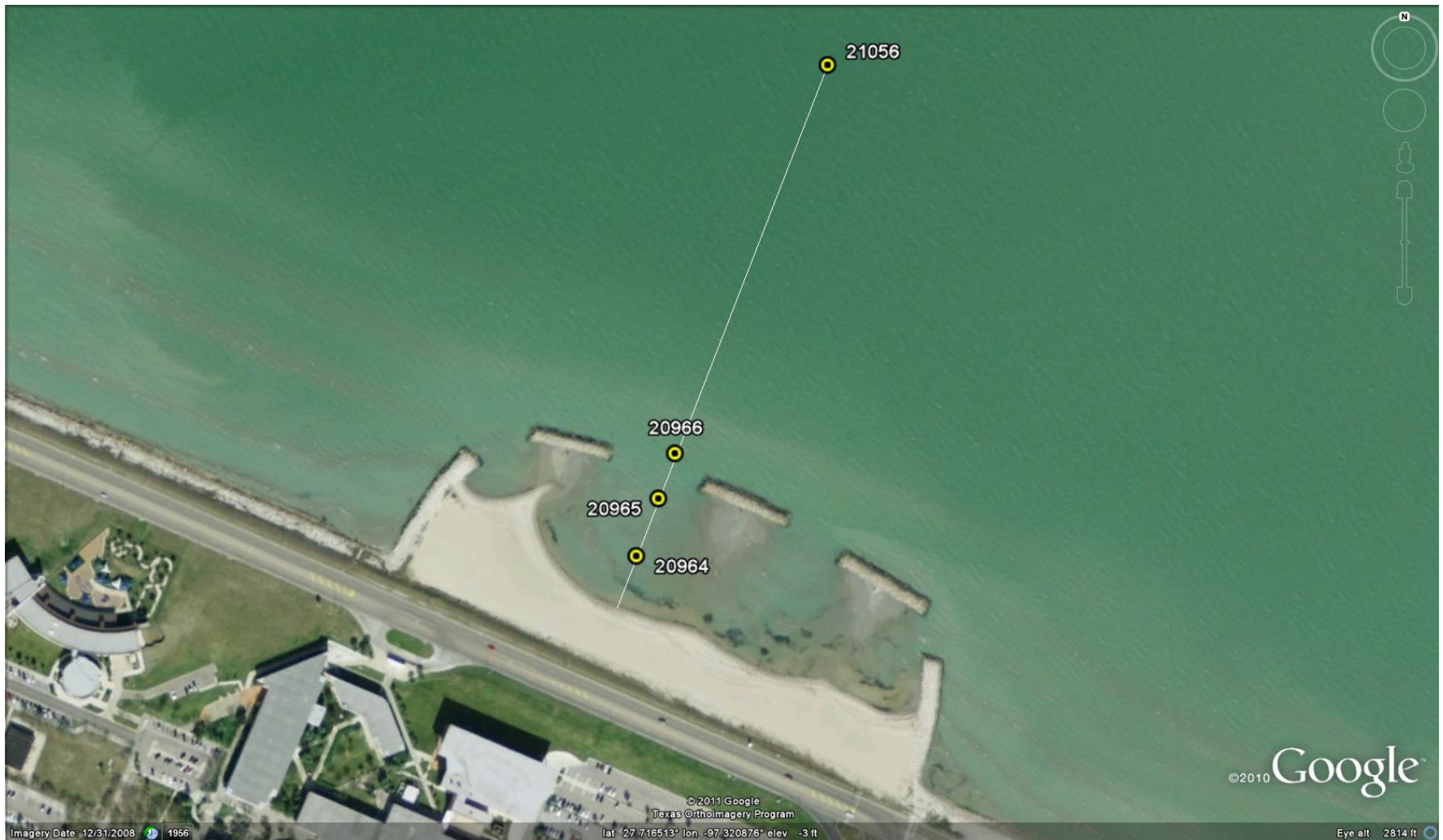


Fig. 3.7. Aerial photo depicting the four University Beach sampling locations. Retrieved on 4/5/2011 from Google Earth.

Table 3.1. Parameters analyzed for the Corpus Christi Bay Beaches TMDL project.

<b>Routine Field Parameters</b>	<b>Units</b>	<b>Parameter Codes*</b>
Depth of Bottom of Water Body at Site	Meters	82903
Depth of Measurement	Meters	13850
Sediment core sample, Upper Depth	Inches	81900
Temperature, Water (Grab)	°C	00010
Dissolved Oxygen (Grab)	mg/L	00300
Dissolved Oxygen (Grab)	% Saturation	00301
Salinity (Grab)	ppt (psu)	00480
Specific Conductance (Grab)	µS/cm	00094
PH (Grab)	s.u.	00400
Turbidity	NTU	82078
Days Since Last Significant Precipitation	Days	72053
<b>Routine Field Observations</b>		
Air Temperature	°C	00020
Present Weather	Visual Assessment	89966
Wind Intensity	MPH	89965
Wind Direction	Compass Direction	89010
Tide Stage	Meters	89972
Water Surface	Visual Assessment	89968
Current/Wind Direction	Onshore/Offshore	70224
Density of People in Park	Number	89960
Bather Density in Water	Number	89964
Bather Density on Shoreline	Number	89967
Boats (within 500 meters of sampling area)	Number	89970
Number Live Animals on Beach/Shore	Number	89897
Number Dead Animals on Beach/Shore	Number	89898
Area of Beach Clean	Percent	89886
Debris found on beach, aquatic vegetation	Percent	89887
Debris found on beach, aluminum/metal	Percent	89889
Debris found on beach, glass	Percent	89890
Debris found on beach, animal waste	Percent	89892
Debris found on beach, paper/cardboard	Percent	89893
Debris found on beach, plastic/Styrofoam	Percent	89894
Debris found on beach, medical waste	Percent	89895
Debris found on beach, wood	Percent	89896

Table 3.1. (continued).

<b>Microbiological</b>		
Enterococci, Enterolert, Water, IDEXX	MPN/100 ml	31701
Enterococci, Sediment, IDEXX Enterolert, WetWt	MPN/100 ml	31703
<b>Sediment Grain Size</b>		
Sediment Particle Size Class < 0.0039 Clay	% dry weight	82009
Sediment Particle Size Class 0.0039 –0.0625 Silt	% dry weight	82008
Sediment Particle Size Class, Sand 0.0625 – 2.00 mm	% dry weight	89991
Sediment Particle Size Class > 2.0 mm Gravel	% dry weight	80256
<b>Sediment Conventionals</b>		
Total Organic Carbon, NPOC (TOC)	mg/kg dry weight	81951
Solids in Sediment	% dry weight	81373

## 3.2 Sampling Methods

The CCS followed sampling procedures as documented in the TCEQ-approved QAPP for this project. A three-person field crew conducted water and sediment sampling on a weekly basis either from shore or by boat. At each sampling site, field crews collected a core set of water quality and field parameters following methods and protocols described in the TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue* (TCEQ RG-415), and the QAPP. Core water quality and field parameters included those specified in Table 3.1 with additional or modified procedures for field sampling clarified in detail below.

### 3.2.1. Field Parameter Measurements

The first activities conducted upon arriving onsite were routine field observations such as ambient weather, water conditions, and beach survey information (see Table 3.1 Routine Field Observations).

### 3.2.2. Hydrographic Profile

Water column profiles were conducted at each station to measure routine water quality parameters (see Table 3.1 Routine Field Parameters) using a YSI multiparameter water quality instrument with a cable connection to a hand held display. Hydrographic profiles were conducted according to the TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue* (December 2003) requirements for vertical depth profiles.

### 3.2.3. Microbiological Samples - Water

Before sample collection, sampling sites and date were written on the bottle label and on the field log sheet. In order to reduce possible contamination before collecting samples from a



station, all field personnel washed hands and arms with alcohol wipes or a disinfectant lotion to reduce exposure to potentially harmful bacteria or other microorganisms. After drying washed areas, all field personnel wore latex gloves while performing sample collection.

Personnel removed the protective seal from the sterile collection bottles just before obtaining each sample and protected them from contamination by not touching the inside of the bottle itself or the inside of the lid. While collecting the surface water sample, personnel avoided disturbing the bottom sediment at the sampling station and positioned the bottle upstream of any water current to avoid sample contamination. The bottle mouth was positioned into the current away from the hand of the personnel and pushed downward into the water to avoid introducing surface scum. Sampling depth was 0.3 m below the water surface at all locations.

Upon removing the bottle from the water, the sample was inspected for any debris, contaminants, or excessive sediment/sand. If the personnel felt the sample might have been contaminated, a new bottle was used to take a new sample. Upon taking a successful sample, the lid was tightly closed and the bottle labeled with the time the sample was collected. Samples were immediately placed on ice at  $< 6$  °C for transport to the laboratory. Care was taken to ensure sample bottles were not immersed in melt water during storage or transit to the laboratory. After collecting samples from a station, personnel washed hands and arms with alcohol wipes or a disinfectant lotion and dried affected areas to reduce exposure to potentially harmful bacteria or other microorganisms.

#### ***3.2.4. Microbiological Samples - Sediment***

Microbiological sediment samples followed all applicable procedures mentioned above for microbiological sampling in water regarding prevention of contamination and sample bottle labeling. As no established microbiological sediment sampling procedures exist, this sampling method deviates from established TCEQ protocols. Sampling occurred in the swash zone, or zone of wave action, depending on the water level at the beach during time of sampling. The surficial sediment layer (2 cm) was collected by pushing the sampling container in a direction parallel to the beach face until full. If water was collected along with the sediment sample, the water was poured off. All samples were placed on ice at  $< 6$  °C during transit to the laboratory and care was taken to ensure sample bottles were not totally immersed in melt water during transit or storage.

#### ***3.2.5. Total Organic Carbon, Sediment Grain Size, Percent Solids***

As a companion to sampling sediment for microbiological organisms, the standard TCEQ sediment conventionals were also collected for analysis. As it is impractical to use a sediment dredge sampler, collection methods did deviate from TCEQ protocols. As with microbiological sediment sampling procedures outlined above, the surficial sediment layer (2 cm) in the swash zone was collected by spatula or scoop and composited (minimum of 12 scoops) to provide adequate sediment for the analyses of total organic carbon (TOC), grain size, and percent solids. Approximately 114 g of sediment was placed into two clean, pre-labeled, wide-mouth glass jars and all samples were placed on ice at  $< 6$  °C during transit to the laboratory with care taken to ensure sample bottles were not totally immersed in melt water during transit or storage.

## **4.0 INTERIM DATA RESULTS**

This report represents data for the first year of this multi-year project. Until sufficient data is collected, data interpretation will be minimal and no conclusions will be drawn.

### **4.1 Field Data (Non-rainfall events)**

Descriptive statistics for Water Temperature (°C), Dissolved Oxygen (mg/L), Salinity (PSU), pH (s.u.), and Turbidity (NTU) for all 30 nearshore stations sampled May through August 2011 and the 10 offshore stations sampled in August 2011 are provided in Tables 4.1 through 4.5. As the 10 offshore stations were only sampled in August, the discussion will be primarily on the 30 nearshore stations sampled for the duration of the project.

During year-one, water temperature was consistent with water temperatures for the region based on the season sampling occurred. Water temperature ranged from 19.14 °C to 33.07 °C with both low and high recorded at Station 20964 at University Beach (Table 4.1). Water temperature increased from May 2011 through the summer months with mean temperatures relatively consistent for all stations sampled.

Dissolved oxygen (DO) ranged from 4.79 mg/L at Station 20964 at University Beach to 10.99 mg/L at Station 20958 at Ropes Park (Table 4.2). Mean DO was greatest at Station 20958 at Ropes Park and of the 1290 DO readings recorded at the 30 nearshore stations, only three fell below the 5.00 mg/L exceptional aquatic life criteria established for Corpus Christi Bay.

Salinity ranged from 21.91 PSU at Station 20952 at Cole Park (Louisiana) to 44.06 PSU at Station 20965 at University Beach (Table 4.3). Mean salinity of all stations combined was 37.49 PSU. Continued lack of significant rainfall intensified the existing drought throughout Texas. As a result, Corpus Christi Bay had a 10 PSU increase in salinity by August.

pH ranged from 7.53 at Station 20937 at Corpus Christi Beach-Surfside Park to 8.41 at Station 20958 at Ropes Park (Table 4.4). Mean pH of all stations combined was 8.18 over the course of the four-month sampling period.

Turbidity is a measurement of water clarity by measuring the amount of suspended particles resulting from such sources as natural sediment erosion (clay, silt, and sand particles), organic decay, plankton, and other microscopic organisms. Due to the consistent action of wind and waves on the shoreline where sampling occurred, turbidity fluctuations were the greatest of all parameters during the study. Turbidity ranged from 0.90 NTU at Station 20946 at Cole Park (North) to 1862.40 NTU at Station 20953 at Cole Park (Louisiana) (Table 4.5). Mean turbidity for all stations combined was 30.00 NTU over the course of the four-month sampling period. Lowest turbidity occurred during the summer months when wind speeds typically are lower compared to other times of the year.

Table 4.1. Water Temperature (°C) descriptive statistics for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n	Min	Max	Mean
20937	CC Beach Surfside Park	43	21.93	32.60	29.23
20938		43	21.98	32.33	29.51
20939		43	21.99	32.16	29.58
21047		3	30.26	31.03	30.72
20940	McGee Beach	43	22.09	32.84	29.76
20941		43	22.15	32.43	29.73
20942		43	22.39	31.85	29.71
21048		3	30.49	31.77	31.06
20943	Emerald Beach	43	22.20	32.23	29.87
20944		43	22.07	31.70	29.67
20945		43	22.30	31.68	29.64
21049		3	30.37	31.61	31.01
20946	Cole Park North	43	21.81	32.28	29.73
20947		43	21.66	32.06	29.68
20948		43	21.58	32.13	29.71
21050		3	30.49	31.34	30.94
20949	Cole Park Pier	43	21.74	31.94	29.44
20950		43	21.96	31.51	29.47
20951		43	22.17	31.57	29.46
21051		3	30.57	31.28	31.02
20952	Cole Park Louisiana	43	21.83	32.12	29.37
20953		43	21.87	32.05	29.34
20954		43	21.62	31.92	29.36
21052		3	30.58	31.28	31.02
20955	Cole Park Oleander Point	43	21.34	31.60	29.25
20956		43	21.46	31.56	29.18
20957		43	21.64	31.67	29.25
21053		3	30.61	31.14	30.94
20958	Ropes Park	43	21.18	31.96	29.57
20959		43	21.29	31.87	29.45
20960		43	21.42	31.60	29.36
21054		3	30.36	31.29	30.75
20961	Poensch Park	43	20.03	32.56	29.69
20962		43	20.05	32.17	29.47
20963		43	20.58	32.01	29.41
21055		3	30.34	30.90	30.68
20964	University Beach	43	19.14	33.07	28.79
20965		43	19.79	32.14	28.76
20966		43	19.92	31.57	28.88
21056		3	30.35	30.72	30.57

Table 4.2. Dissolved Oxygen (mg/L) descriptive statistics for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n	Min	Max	Mean
20937	Corpus Christi Beach Surfside Park	43	5.59	9.09	7.44
20938		43	5.59	9.58	7.31
20939		43	5.52	10.10	7.25
21047		3	7.19	7.62	7.41
20940	McGee Beach	43	5.32	8.63	7.31
20941		43	5.40	8.60	7.23
20942		43	5.16	8.71	7.15
21048		3	6.91	7.54	7.19
20943	Emerald Beach	43	5.62	9.03	7.17
20944		43	5.70	9.03	7.03
20945		43	5.81	9.04	6.89
21049		3	6.80	7.55	7.12
20946	Cole Park North	43	5.62	9.23	7.43
20947		43	6.21	8.78	7.32
20948		43	6.13	8.70	7.28
21050		3	6.91	7.39	7.16
20949	Cole Park Pier	43	5.25	8.44	6.80
20950		43	6.01	8.48	7.16
20951		43	5.85	8.33	7.06
21051		3	6.90	7.48	7.13
20952	Cole Park Louisiana	43	6.05	9.84	7.65
20953		43	5.89	9.59	7.32
20954		43	5.77	8.98	7.20
21052		3	6.87	7.22	7.00
20955	Cole Park Oleander Point	43	5.94	10.11	7.73
20956		43	5.81	9.38	7.25
20957		43	5.81	9.22	7.22
21053		3	6.84	7.23	6.98
20958	Ropes Park	43	5.64	10.99	8.39
20959		43	5.32	10.58	7.87
20960		43	5.15	9.30	7.21
21054		3	6.77	7.26	7.08
20961	Poensch Park	43	5.95	10.47	7.95
20962		43	5.62	9.68	7.47
20963		43	5.48	9.41	7.35
21055		3	6.76	7.14	6.90
20964	University Beach	43	4.79	9.19	6.80
20965		43	4.98	9.23	6.59
20966		43	5.12	8.60	6.57
21056		3	6.73	7.54	7.15

Table 4.3. Salinity (PSU) descriptive statistics for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n	Min	Max	Mean
20937	CC Beach Surfside Park	43	32.87	41.61	36.82
20938		43	29.89	41.63	36.71
20939		43	32.93	41.60	36.86
21047		3	39.70	40.49	40.11
20940	McGee Beach	43	33.58	41.32	37.22
20941		43	30.66	41.38	37.05
20942		43	33.61	41.41	37.20
21048		3	39.15	41.05	40.06
20943	Emerald Beach	43	32.48	41.32	37.17
20944		43	33.61	41.32	37.23
20945		43	33.60	41.32	37.22
21049		3	39.10	41.02	40.06
20946	Cole Park North	43	29.91	41.20	37.24
20947		43	33.72	41.26	37.34
20948		43	30.18	41.26	37.24
21050		3	39.21	40.95	40.08
20949	Cole Park Pier	43	26.23	41.17	36.86
20950		43	33.81	41.15	37.26
20951		43	33.82	41.19	37.27
21051		3	39.23	40.91	40.10
20952	Cole Park Louisiana	43	21.91	41.16	37.20
20953		43	33.78	41.22	37.52
20954		43	30.88	41.19	37.41
21052		3	39.40	40.90	40.17
20955	Cole Park Oleander Point	43	33.45	41.33	37.62
20956		43	33.79	41.35	37.60
20957		43	29.92	41.26	37.45
21053		3	39.39	40.86	40.15
20958	Ropes Park	43	33.65	41.61	37.59
20959		43	33.80	41.61	37.61
20960		43	33.86	41.58	37.59
21054		3	39.28	40.91	40.08
20961	Poensch Park	43	33.10	41.69	38.01
20962		43	33.47	41.72	38.02
20963		43	33.21	41.67	37.97
21055		3	39.49	41.08	40.31
20964	University Beach	43	31.30	44.05	38.95
20965		43	33.82	44.06	38.99
20966		43	29.06	43.02	38.59
21056		3	39.76	41.28	40.56

Table 4.4. pH (s.u.) descriptive statistics for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n	Min	Max	Mean
20937	CC Beach Surfside Park	43	7.53	8.25	8.03
20938		43	8.00	8.29	8.12
20939		43	8.04	8.30	8.15
21047		3	8.18	8.24	8.21
20940	McGee Beach	43	7.86	8.32	8.17
20941		43	8.11	8.33	8.20
20942		43	8.07	8.32	8.19
21048		3	8.23	8.25	8.24
20943	Emerald Beach	43	8.02	8.29	8.17
20944		43	8.02	8.29	8.18
20945		43	8.04	8.29	8.18
21049		3	8.21	8.24	8.23
20946	Cole Park North	43	8.10	8.34	8.19
20947		43	8.04	8.32	8.19
20948		43	8.10	8.32	8.20
21050		3	8.19	8.25	8.23
20949	Cole Park Pier	43	7.90	8.29	8.15
20950		43	8.07	8.31	8.18
20951		43	8.01	8.31	8.17
21051		3	8.23	8.25	8.24
20952	Cole Park Louisiana	43	7.83	8.31	8.18
20953		43	7.93	8.31	8.20
20954		43	7.98	8.34	8.21
21052		3	8.24	8.26	8.25
20955	Cole Park Oleander Point	43	7.86	8.35	8.18
20956		43	8.05	8.35	8.20
20957		43	8.02	8.35	8.20
21053		3	8.23	8.23	8.23
20958	Ropes Park	43	7.90	8.41	8.21
20959		43	8.00	8.35	8.21
20960		43	8.01	8.31	8.20
21054		3	8.21	8.23	8.22
20961	Poensch Park	43	7.93	8.38	8.21
20962		43	8.04	8.32	8.20
20963		43	8.09	8.33	8.21
21055		3	8.21	8.24	8.23
20964	University Beach	43	7.74	8.30	8.12
20965		43	7.99	8.32	8.19
20966		43	8.05	8.36	8.21
21056		3	8.21	8.25	8.24

Table 4.5. Turbidity (NTU) descriptive statistics for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n	Min	Max	Mean
20937	CC Beach Surfside Park	42	1.90	83.50	23.39
20938		42	1.70	70.20	20.45
20939		42	1.40	68.50	20.65
21047		3	3.10	10.30	5.93
20940	McGee Beach	42	3.00	52.70	17.03
20941		42	4.20	54.50	16.76
20942		42	4.00	55.90	16.55
21048		3	5.30	10.30	7.03
20943	Emerald Beach	42	1.30	108.60	21.57
20944		42	3.70	59.30	18.80
20945		42	3.00	58.40	16.90
21049		3	5.20	9.30	6.87
20946	Cole Park North	42	0.90	1132.20	58.47
20947		42	2.40	1138.80	47.04
20948		42	2.10	1132.10	45.68
21050		3	4.60	12.80	7.37
20949	Cole Park Pier	42	1.80	58.50	16.38
20950		42	3.00	62.60	15.61
20951		42	2.40	96.60	17.88
21051		3	4.50	8.20	6.10
20952	Cole Park Louisiana	42	2.20	1861.60	71.63
20953		42	3.70	1862.40	68.58
20954		42	3.70	1854.90	65.59
21052		3	4.70	9.20	7.10
20955	Cole Park Oleander Point	42	2.10	422.20	41.18
20956		42	3.00	361.90	31.62
20957		42	2.80	371.70	30.81
21053		3	5.00	7.30	6.20
20958	Ropes Park	42	2.00	89.40	21.10
20959		42	2.00	66.70	18.38
20960		42	3.50	59.90	19.23
21054		3	4.20	7.30	5.63
20961	Poensch Park	42	1.70	141.80	24.55
20962		42	2.50	61.60	22.58
20963		42	2.40	69.80	20.96
21055		3	4.20	8.30	5.93
20964	University Beach	42	3.60	117.80	35.87
20965		42	3.90	115.90	30.01
20966		42	3.50	128.80	24.65
21056		3	3.10	4.20	3.60

## 4.2 Precipitation

To determine precipitation for the study area, four locations were used to determine approximate amounts of rainfall preceding a rainfall sampling event. The four stations were: KTXINGLE6 located at the Air Liquide Plant in Ingleside, Texas, KTCORPU19 located at King Estates, KNGP located at Naval Air Station-Corpus Christi, and KCRP located at Corpus Christi International Airport (Fig. 4.1). Using Ropes Park as the approximate center point of the shoreline being sampled, these four locations were used since no rain gauge instrumentation exists in close proximity to the sampling stations. Table 4.6 gives station information and individual rainfall amounts recorded prior to, and during, rainfall event sampling.

The greatest amount of rainfall occurred during the first rainfall event in May 2011. Rainfall amounts declined in subsequent events as the drought progressed through the summer months (Table 4.6 and Fig. 4.2).



Fig. 4.1. Aerial photo depicting shoreline area being sampled (red) and location of gauged rainfall station (yellow) in relation to Ropes Park (white) used for obtaining precipitation data. Retrieved on 12/1/2011 from Google Earth.



Table 4.6. Station location information for gauged rainfall stations with individual station rainfall amounts (inches) and a mean of all stations combined for the three rainfall events. Note: PWS = Personal Weather Station and NWS = National Weather Service.

Station Call Sign	KTXINGLE6	KNGP	KTXCORPU19	KCRP	
Station Name	Air Liquide	NAS-CC	King Estates	CC Int. Airport	
Station Type	PWS	NWS	PWS	NWS	
Miles to Ropes Park	12 to NE	7 to ESE	7.5 to S	7.5 to W	
Date					Mean
5/12/2011	1.01	1.22	1.28	1.90	1.35
5/13/2011			0.01		<0.01
5/14/2011					
6/22/2011	0.38	0.21	0.81	0.37	0.44
6/23/2011		0.05	0.13	0.63	0.20
6/24/2011					
8/25/2011	0.77	0.05	0.25	0.28	0.34
8/26/2011	0.04				0.01
8/27/2011					

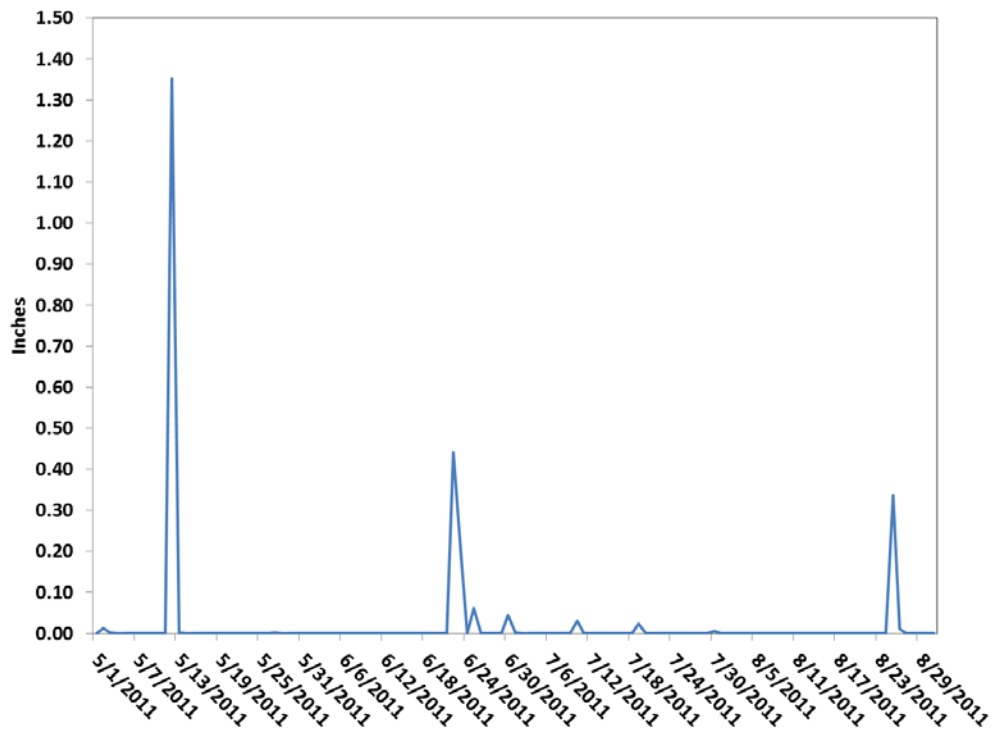


Fig. 4.2. Mean rainfall calculated from the four weather stations from 5/1/2011 through 8/31/2011.

### 4.3 Field Data (Rainfall events)

Data is provided in Tables 4.7 through 4.11 for Water Temperature (°C), Dissolved Oxygen (mg/L), Salinity (PSU), pH (s.u.), and Turbidity (NTU) for all 30 nearshore stations sampled during rainfall events (see Table 4.6 for rainfall amounts). Except for turbidity, where readings fluctuated the greatest, data collected for all other parameters was consistent with data obtained during non-rainfall events.

Table 4.7. Water Temperature (°C) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled during rainfall events.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	26.39	26.93	30.25	31.53	31.36	31.38
20938		26.13	26.75	29.80	31.26	31.25	31.58
20939		26.01	26.99	29.32	30.89	31.37	31.62
20940	McGee Beach	26.46	26.77	28.82	31.66	31.67	32.00
20941		26.17	26.71	28.73	30.38	31.34	31.92
20942		25.94	26.83	28.48	30.30	31.91	31.92
20943	Emerald Beach	26.33	26.70	28.59	30.10	31.32	31.75
20944		26.04	26.74	28.63	29.88	31.25	31.77
20945		26.10	26.67	28.69	29.86	31.26	31.63
20946	Cole Park North	26.24	26.97	28.17	30.23	31.59	31.80
20947		25.80	27.06	27.78	29.63	31.49	31.65
20948		25.84	27.09	28.17	30.02	31.42	31.68
20949	Cole Park Pier	25.63	26.37	28.04	29.68	30.79	31.22
20950		25.45	26.77	28.36	29.41	31.13	31.50
20951		25.44	26.77	28.50	29.62	31.21	31.42
20952	Cole Park Louisiana	25.73	26.13	27.90	29.82	30.48	31.76
20953		25.58	26.12	27.59	29.37	30.55	31.45
20954		25.32	26.24	28.21	29.28	30.81	31.44
20955	Cole Park Oleander Point	24.82	25.55	27.74	29.45	29.82	29.88
20956		24.71	25.75	27.76	29.18	29.97	30.28
20957		25.10	25.84	27.82	29.26	30.11	30.26
20958	Ropes Park	24.98	25.49	27.91	28.92	30.66	30.94
20959		24.98	25.57	27.91	28.81	30.59	30.93
20960		24.96	25.72	27.88	28.71	30.51	30.99
20961	Poenisch Park	24.51	24.17	27.26	29.03	30.12	30.57
20962		24.45	24.17	27.40	28.92	30.04	30.69
20963		24.27	24.16	27.42	28.98	30.19	30.77
20964	University Beach	24.18	23.70	26.95	28.73	29.60	29.49
20965		24.33	23.91	27.11	28.55	30.07	29.92
20966		24.61	24.34	27.51	28.69	30.41	30.44

Table 4.8. Dissolved Oxygen (mg/L) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled during rainfall events.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	6.96	8.05	8.57	7.84	7.60	7.78
20938		7.29	8.33	8.20	9.11	7.56	7.35
20939		6.76	8.53	8.05	9.99	7.30	7.09
20940	McGee Beach	7.11	7.51	8.70	9.11	6.47	7.71
20941		6.94	7.79	8.70	10.57	6.21	6.31
20942		6.31	8.14	8.43	10.61	6.53	5.96
20943	Emerald Beach	7.05	7.21	8.47	10.50	7.36	7.92
20944		6.78	7.02	8.39	10.30	6.91	6.91
20945		6.29	7.47	8.13	10.30	6.92	6.66
20946	Cole Park North	6.82	6.77	8.29	10.26	7.19	7.68
20947		6.52	6.46	7.65	9.44	6.66	7.46
20948		6.51	6.31	8.18	9.97	6.26	7.21
20949	Cole Park Pier	7.09	7.71	7.24	9.62	5.28	5.40
20950		6.64	7.78	8.09	9.11	6.91	6.90
20951		6.55	6.41	8.11	8.12	6.94	7.22
20952	Cole Park Louisiana	6.31	7.54	8.12	10.20	5.87	6.15
20953		6.25	7.39	7.44	9.27	5.70	6.60
20954		6.16	7.50	8.20	9.45	5.93	6.54
20955	Cole Park Oleander Point	6.60	7.43	7.69	10.31	6.09	6.27
20956		6.21	7.49	7.70	9.08	5.75	6.40
20957		6.09	7.43	7.81	9.00	5.98	6.38
20958	Ropes Park	6.14	7.67	7.52	8.26	5.81	7.29
20959		5.82	7.19	7.48	7.77	5.47	5.85
20960		5.73	6.99	7.32	7.84	4.96	5.70
20961	Poensch Park	7.02	7.32	7.33	8.80	7.02	6.82
20962		6.57	7.16	6.82	8.04	6.50	6.71
20963		6.38	7.12	7.40	8.18	6.36	6.78
20964	University Beach	7.32	7.51	7.10	7.38	6.37	5.47
20965		6.27	7.43	7.10	7.84	6.06	5.82
20966		5.92	6.56	6.59	7.54	6.23	5.74

Table 4.9. Salinity (PSU) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled during rainfall events.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	33.93	33.06	34.53	35.10	40.78	40.15
20938		34.11	29.33	34.56	34.98	40.71	40.26
20939		34.17	32.98	34.92	34.96	40.57	40.30
20940	McGee Beach	35.82	33.25	34.80	34.79	39.97	40.38
20941		35.22	30.43	34.76	34.77	40.04	40.47
20942		34.91	33.25	34.67	34.77	40.35	40.53
20943	Emerald Beach	35.63	33.26	34.86	34.79	39.94	40.25
20944		35.85	33.18	34.79	34.78	40.09	40.29
20945		35.83	33.18	34.73	34.78	40.09	40.31
20946	Cole Park North	35.44	26.23	34.68	34.47	39.62	40.49
20947		35.47	33.25	34.75	34.92	40.14	40.48
20948		35.62	32.98	35.02	34.93	40.11	40.50
20949	Cole Park Pier	35.55	33.22	34.82	34.95	39.27	40.42
20950		35.56	33.20	35.08	35.06	40.38	40.58
20951		35.46	33.31	35.04	35.07	40.43	40.60
20952	Cole Park Louisiana	35.78	33.59	34.94	33.68	38.33	40.52
20953		35.93	33.44	35.39	35.18	39.65	40.54
20954		35.92	33.31	35.26	35.21	40.16	40.54
20955	Cole Park Oleander Point	35.93	33.52	35.16	35.05	38.29	39.87
20956		35.87	33.64	35.42	35.28	38.77	40.16
20957		35.87	33.61	35.53	35.27	38.85	40.15
20958	Ropes Park	35.53	34.04	35.89	36.00	40.25	40.67
20959		35.55	34.06	35.89	35.97	40.28	40.71
20960		35.54	34.05	35.84	35.91	40.33	40.69
20961	Poensch Park	34.68	33.76	37.86	37.15	41.47	41.46
20962		34.80	33.81	37.82	37.10	41.49	41.45
20963		34.98	33.82	37.88	37.05	41.49	41.45
20964	University Beach	34.81	34.24	38.93	38.15	42.02	42.04
20965		34.89	27.57	39.03	38.25	41.87	42.01
20966		34.88	33.96	38.52	38.08	41.77	41.93

Table 4.10. pH (s.u.) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled during rainfall events.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	8.03	8.14	8.11	8.17	8.25	8.21
20938		8.03	8.14	8.08	8.24	8.25	8.20
20939		8.03	8.14	8.05	8.26	8.25	8.20
20940	McGee Beach	8.16	8.16	8.12	8.24	8.13	8.19
20941		8.13	8.16	8.13	8.26	8.17	8.15
20942		8.12	8.19	8.12	8.27	8.21	8.17
20943	Emerald Beach	8.13	8.14	8.11	8.26	8.18	8.15
20944		8.14	8.16	8.13	8.26	8.22	8.16
20945		8.14	8.17	8.12	8.26	8.23	8.18
20946	Cole Park North	8.12	8.17	8.10	8.27	8.19	8.20
20947		8.13	8.15	8.10	8.26	8.20	8.21
20948		8.15	8.16	8.14	8.27	8.20	8.21
20949	Cole Park Pier	8.16	8.17	8.08	8.23	8.14	8.12
20950		8.13	8.16	8.13	8.24	8.23	8.19
20951		8.14	8.16	8.14	8.25	8.25	8.20
20952	Cole Park Louisiana	8.10	8.11	8.05	8.20	8.17	8.14
20953		8.13	8.10	8.11	8.24	8.19	8.19
20954		8.14	8.11	8.16	8.25	8.21	8.18
20955	Cole Park Oleander Point	8.07	8.09	8.07	8.24	8.12	8.18
20956		8.10	8.13	8.14	8.25	8.17	8.18
20957		8.13	8.16	8.16	8.25	8.20	8.18
20958	Ropes Park	8.03	8.06	8.07	8.24	8.11	8.11
20959		8.04	8.07	8.10	8.24	8.12	8.14
20960		8.05	8.10	8.14	8.24	8.16	8.17
20961	Poensch Park	8.04	8.02	8.04	8.26	8.23	8.21
20962		8.05	8.04	8.15	8.27	8.25	8.23
20963		8.06	8.05	8.20	8.29	8.27	8.25
20964	University Beach	7.92	7.92	8.05	8.27	8.15	8.16
20965		7.97	8.02	8.14	8.24	8.25	8.23
20966		8.03	8.08	8.16	8.30	8.29	8.25

Table 4.11. Turbidity (NTU) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled during rainfall events.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	32.40	25.80	16.60	7.60	1.20	4.70
20938		27.70	25.10	17.60	11.30	2.90	6.60
20939		25.10	24.00	30.90	6.30	4.60	6.90
20940	McGee Beach	23.00	22.90	10.50	9.30	3.20	4.30
20941		22.70	28.10	9.50	7.20	4.30	7.70
20942		19.10	22.36	8.00	7.80	3.70	7.40
20943	Emerald Beach	35.80	83.90	13.30	6.20	10.20	11.70
20944		23.20	27.50	10.20	6.80	15.00	7.40
20945		22.30	25.30	10.70	5.50	4.20	5.80
20946	Cole Park North	29.80	39.80	86.90	12.30	16.30	5.50
20947		21.00	37.30	79.50	8.20	15.90	10.80
20948		18.90	38.40	45.30	6.80	7.80	9.10
20949	Cole Park Pier	18.00	25.30	20.00	3.60	8.50	5.70
20950		19.10	23.80	19.10	12.90	3.60	5.40
20951		19.40	20.60	18.90	4.50	3.50	4.00
20952	Cole Park Louisiana	37.20	44.10	188.00	13.60	17.80	10.60
20953		24.60	43.10	121.40	14.10	9.40	9.70
20954		28.70	43.10	188.90	12.70	10.80	9.00
20955	Cole Park Oleander Point	39.10	763.00	55.00	7.20	29.80	10.70
20956		30.40	774.80	31.50	7.10	12.80	12.50
20957		21.30	784.50	54.80	6.10	9.30	14.30
20958	Ropes Park	50.20	45.10	115.50	9.00	33.10	3.80
20959		28.70	43.10	135.30	5.60	29.70	5.10
20960		28.10	42.80	117.00	4.90	13.40	6.10
20961	Poensch Park	32.80	59.50	61.20	3.20	23.70	10.00
20962		28.90	95.00	69.10	5.10	14.30	7.60
20963		26.30	95.00	69.40	4.70	8.00	7.70
20964	University Beach	29.60	20.00	103.30	8.90	113.90	21.20
20965		26.20	99.70	117.60	10.60	14.40	49.60
20966		26.40	59.00	121.60	7.40	13.60	14.80

#### 4.4 *Enterococcus* concentrations in water (all events)

Data results from 147 bacteria samples (129 non-rainfall and 18 rainfall) collected from 5/4/2011 through 8/27/2011 were used to characterize these Corpus Christi Bay urban beach locations. Information presented in this section provides a summary of data collected to date, with the first station listed as closest to shore and subsequent station numbers progressing offshore as shown in Figs. 3.2 through 3.7. As the 10 offshore stations were only sampled in August, and all values were <10 MPN/100 ml, the discussion will focus on the 30 nearshore stations sampled for the duration of the project.

*Enterococcus* values ranged from <10 MPN/100 ml to >24,196 MPN/100 ml with the largest concentrations recorded after rainfall events at locations near storm water outfalls. Some of the highest *Enterococcus* values occurred in August 2011, which corresponded with the lowest rainfall recorded (Table 4.13). Concentrations recorded throughout the study typically declined the farther from shore the samples were taken (Tables 4.12 and 4.13). When analyzed on a month-by-month basis, data indicates that *Enterococcus* concentrations increase as you move closer to Cole and Ropes Parks. A strong correlation in May ( $r^2=0.78$ ) (Fig. 4.3) decreased during the summer months (Figs. 4.4 through 4.6) but the trend was still evident when all samples collected from 5/4/2011 through 8/27/2011 are evaluated (Fig. 4.7).

Out of 1470 *Enterococcus* samples collected (49 at each station or 147 per location), the single sample criteria of 104 MPN/100 ml was exceeded 87 times, or 5.9%. May was highest month with 36 exceedances followed by 27, zero, and 24 exceedances in June, July, and August, respectively with Cole Park (stations combined) and Ropes Park having the highest number of exceedances (Fig. 4.8). When viewed by individual location, Ropes Park had the highest percentage of exceedances followed by Cole Park Oleander Point and Cole Park Louisiana (Fig. 4.9). There were no exceedances at McGee Beach, which is the most utilized public beach in the downtown area.

Evaluating the data based on the rating scheme utilized by the Texas Beach Watch Program showed that 88.4% of the samples were <35 MPN/100 ml, 5.6% were >35 MPN/100 ml but <104 MPN/100 ml, and 5.9% were >104 MPN/100 ml. As previously stated, based on exceedances of the >104 MPN/100 ml criterion, the Texas Beach Watch Program will issue an advisory day for that location. If multiple samples are collected at a location such as at Cole Park, then only one advisory day is listed regardless of how many samples may have exceeded the criterion.

For assessment purposes, the TCEQ Surface Water Quality Monitoring Program in turn calculates the percentage of days that resulted in advisories by dividing the number of advisory days by the number of sampling days. An assessment in this manner shows that Cole Park, as expected, had the highest percentage of advisory days followed by Ropes Park and University Beach (Fig. 4.10). Based on proposed Recreational Beach Assessment methods the number of beach advisories for Cole Park is between 20% and 25% indicating “concern but fully supporting” the Recreational Beach. A time series of all nearshore samples collected for a location is shown in Figs. 4.11 through 4.20. There were some random spikes in elevated bacteria concentrations at some locations, especially when rainfall occurred.

Table 4.12. *Enterococcus* concentrations (MPN/100 ml) for all 30 nearshore (May – August 2011) and 10 offshore (August 2011) Corpus Christi Bay Beaches TMDL stations sampled during all events.

Station ID	Sampling Location	n	Min	Max	Geometric mean (all events)	Geometric mean (no rain events)
20937	CC Beach Surfside Park	49	10	230	12.2	12.5
20938		49	10	63	11.1	10.8
20939		49	10	52	10.3	10.4
21047		3	10	10	10.0	
20940	McGee Beach	49	10	41	11.0	10.8
20941		49	10	52	11.9	11.2
20942		49	10	75	11.8	11.5
21048		3	10	10	10.0	
20943	Emerald Beach	49	10	110	11.9	11.5
20944		49	10	110	11.3	10.7
20945		49	10	84	11.3	10.7
21049		3	10	10	10.0	
20946	Cole Park North	49	10	650	15.1	12.1
20947		49	10	390	13.4	11.0
20948		49	10	220	12.4	10.7
21050		3	10	10	10.0	
20949	Cole Park Pier	49	10	860	18.7	14.2
20950		49	10	1200	13.2	11.2
20951		49	10	120	12.4	10.8
21051		3	10	10	10.0	
20952	Cole Park Louisiana	49	10	10,000	20.9	12.8
20953		49	10	2900	15.8	11.6
20954		49	10	2700	14.6	10.6
21052		3	10	10	10.0	
20955	Cole Park Oleander Point	49	10	6900	22.4	14.4
20956		49	10	7700	17.3	11.9
20957		49	10	3900	14.3	10.3
21053		3	10	10	10.0	
20958	Ropes Park	49	10	>24,196	26.4	15.9
20959		49	10	5800	22.4	15.1
20960		49	10	4100	19.5	13.6
21054		3	10	10	10.0	
20961	Poensch Park	49	10	210	15.2	13.1
20962		49	10	520	13.6	11.0
20963		49	10	280	12.8	11.1
21055		3	10	10	10.0	
20964	University Beach	49	10	740	19.1	16.3
20965		49	10	400	16.1	14.1
20966		49	10	180	15.0	14.5
21056		3	10	10	10.0	



Table 4.13. *Enterococcus* concentrations (MPN/100 ml) for all 30 nearshore Corpus Christi Bay Beaches TMDL stations sampled after rainfall events. Mean rainfall (inches) for the day preceding the sampling event were May 1.35, June 0.44, and August 0.34.

Station ID	Sampling Location	5/13/11	5/14/11	6/23/11	6/24/11	8/26/11	8/27/11
20937	CC Beach Surfside Park	10	10	10	10	10	10
20938		10	10	63	10	10	10
20939		10	10	10	10	10	10
20940	McGee Beach	10	20	20	10	10	10
20941		31	10	41	10	30	10
20942		10	10	10	10	75	10
20943	Emerald Beach	10	10	10	10	110	10
20944		20	10	10	10	110	10
20945		20	10	10	10	84	10
20946	Cole Park North	250	10	490	20	650	10
20947		75	20	390	10	160	31
20948		30	10	220	20	170	10
20949	Cole Park Pier	140	84	860	30	570	30
20950		75	30	140	10	180	10
20951		110	10	92	10	120	10
20952	Cole Park Louisiana	670	1100	1300	120	10,000	98
20953		63	450	210	10	2900	63
20954		96	260	130	10	2700	100
20955	Cole Park Oleander Point	370	860	560	75	6900	230
20956		160	640	130	10	7700	240
20957		130	130	140	10	3900	98
20958	Ropes Park	1100	260	8200	400	>24,196	52
20959		330	160	5800	85	2700	41
20960		270	130	4100	10	910	260
20961	Poenisch Park	74	210	41	10	150	10
20962		41	300	75	10	520	10
20963		30	280	31	10	63	10
20964	University Beach	140	740	41	10	63	20
20965		20	400	84	10	63	10
20966		31	74	20	10	10	10

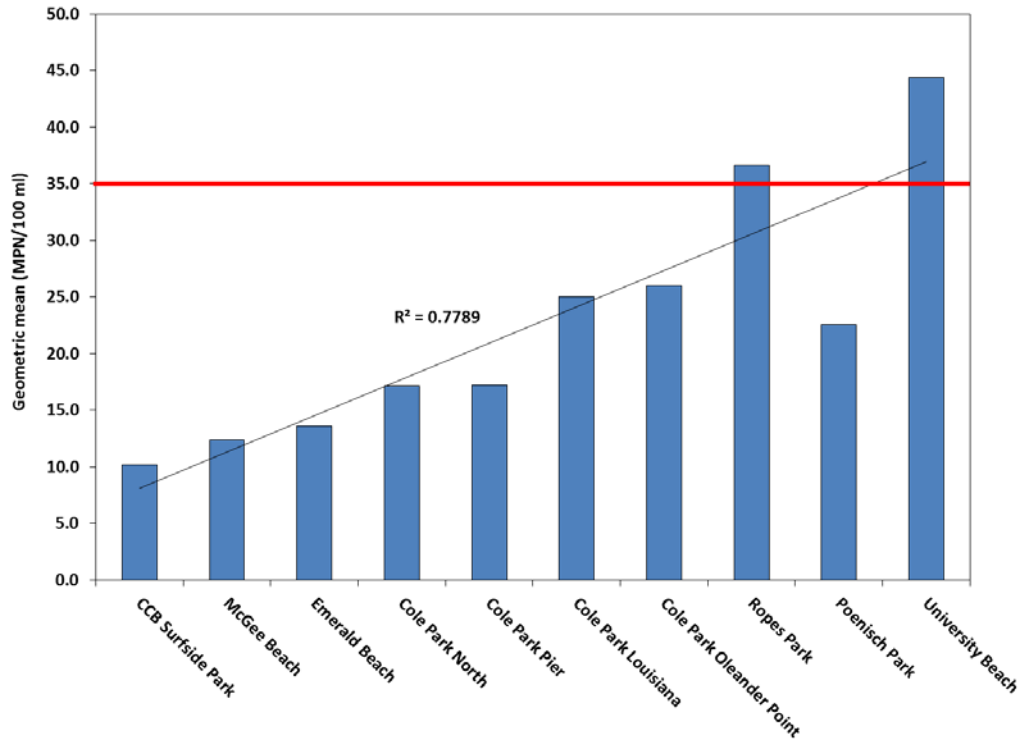


Fig. 4.3. The geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at each sampling location in May 2011.

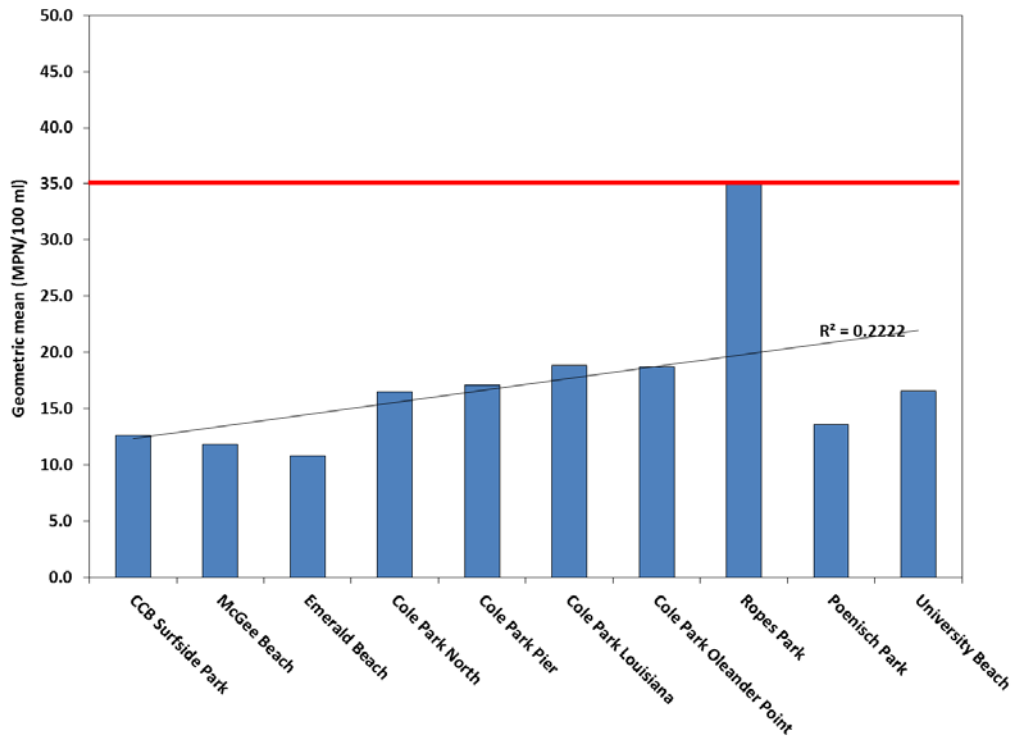


Fig. 4.4. The geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at each sampling location in June 2011.

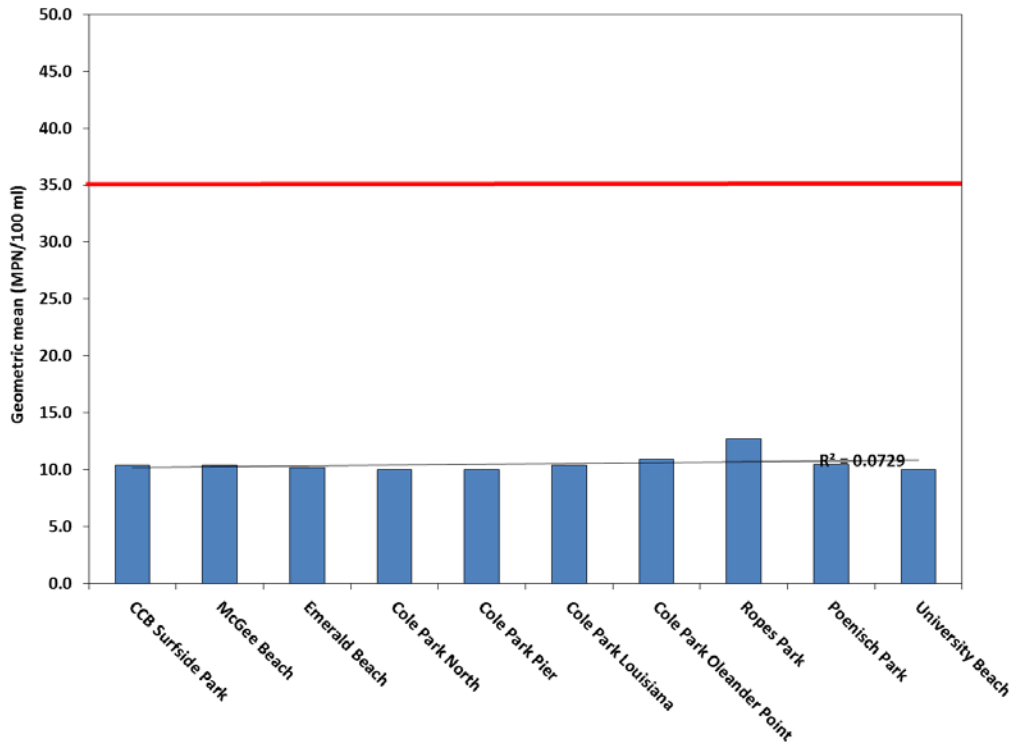


Fig. 4.5. The geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at each sampling location in July 2011.

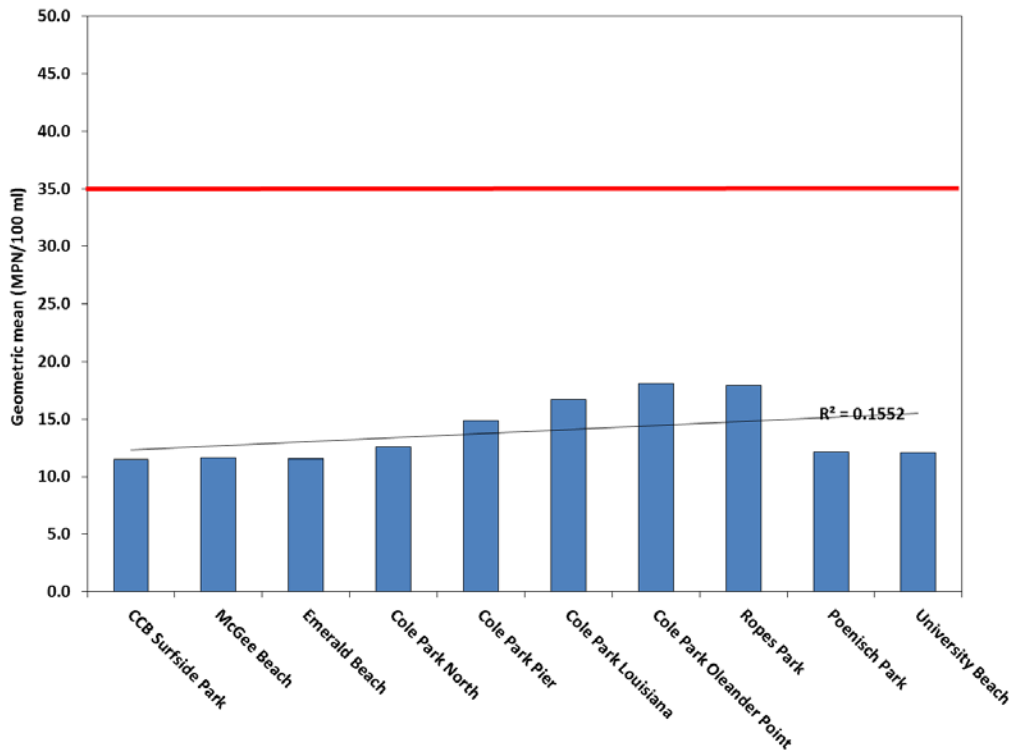


Fig. 4.6. The geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at each sampling location in August 2011.

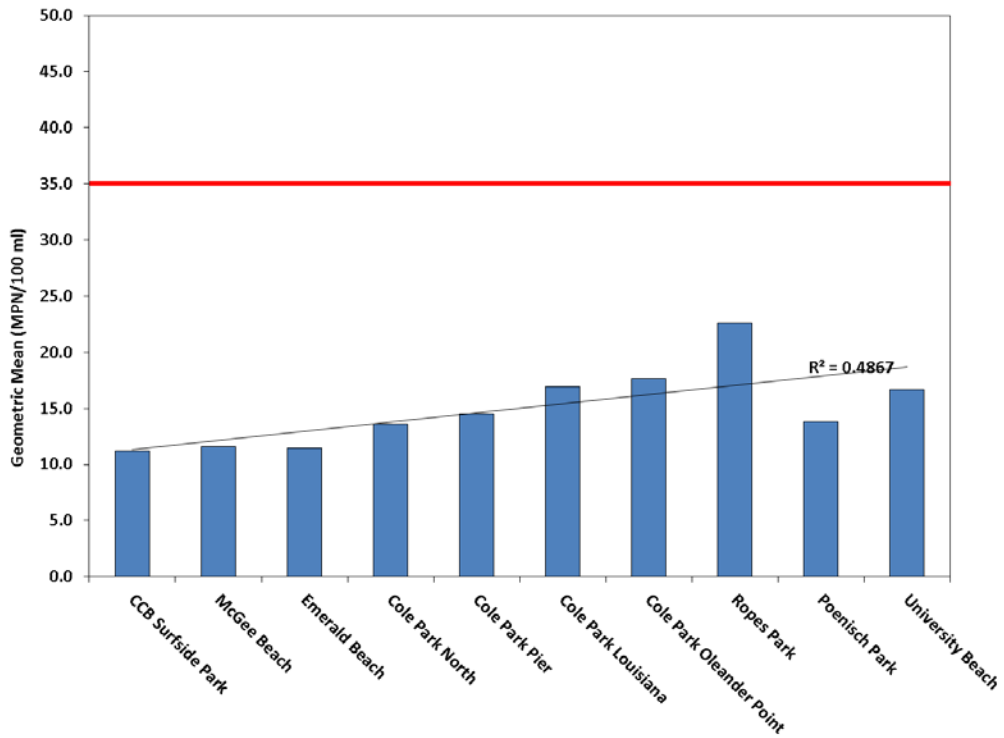


Fig. 4.7. The geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at each sampling location from 5/4/2011 through 8/27/2011.

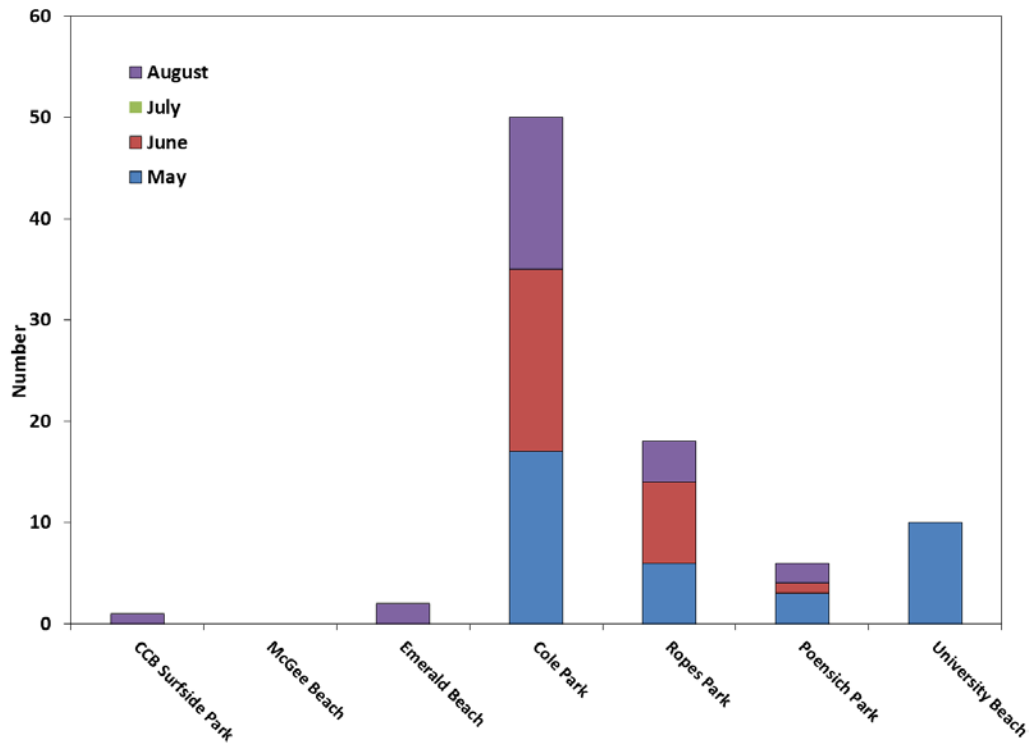


Fig. 4.8. Number of all exceedances (n=1470 or 147 per location) of the single sample criteria of 104 MPN/100 ml at each location (Cole Park locations combined).

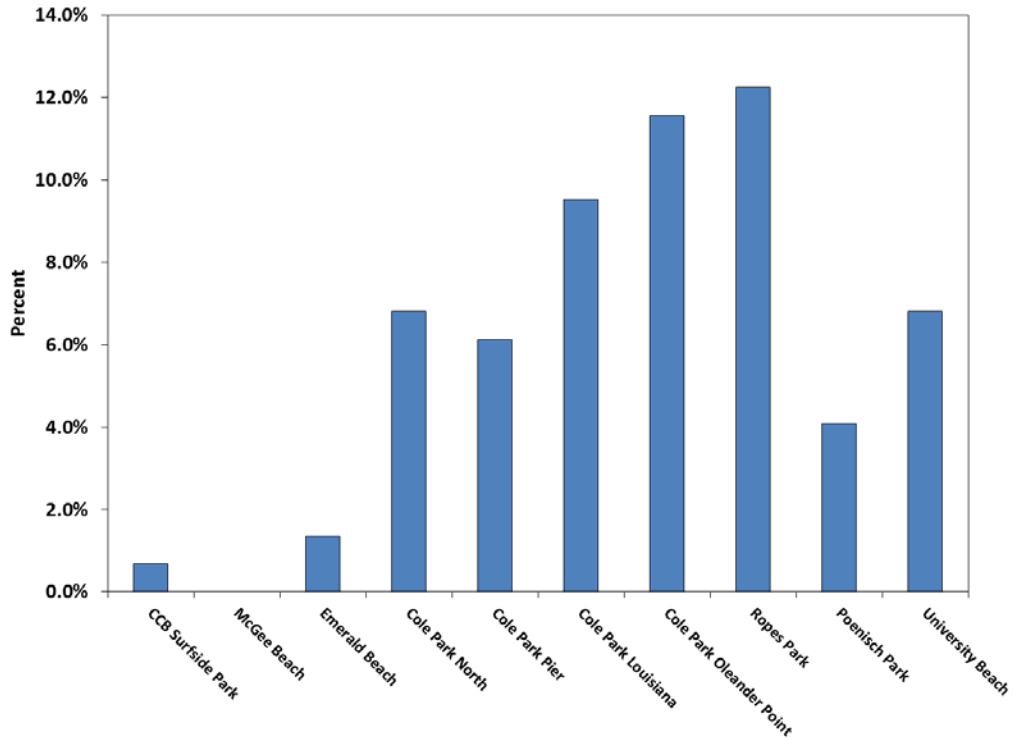


Fig. 4.9. Percentage of samples (n=1470 or 147 per location) exceeding the single sample *Enterococcus* criteria of 104 MPN/100 ml at each location from 5/4/2011 through 8/27/2011.

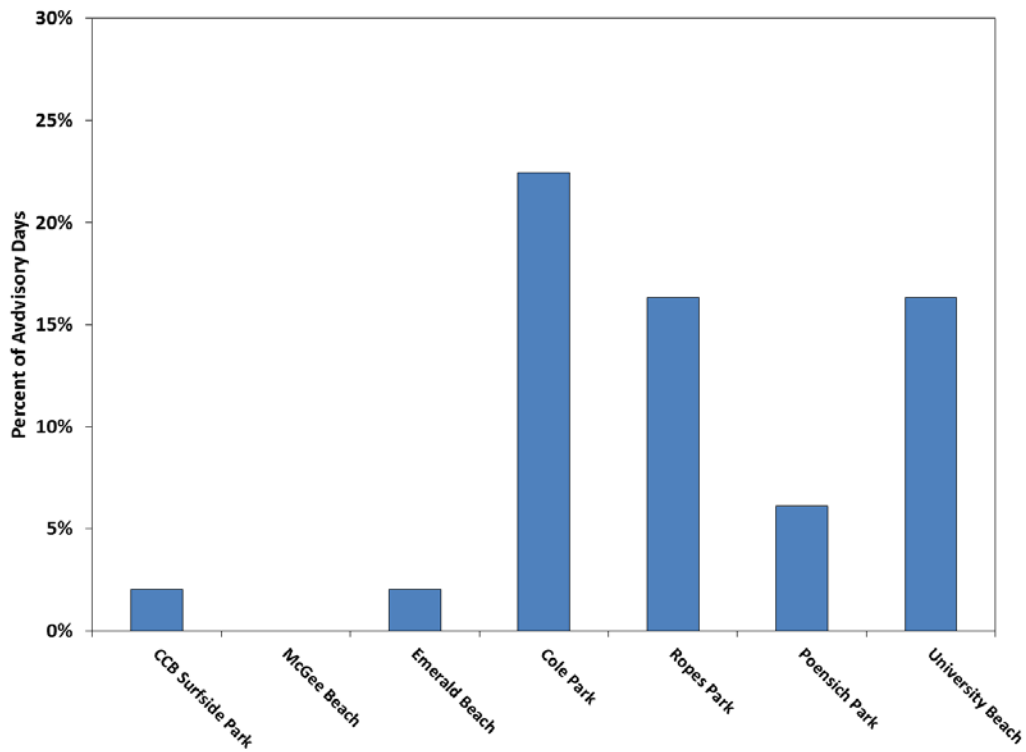


Fig. 4.10. Percentage of advisory days issued at each location (Cole Park combined) from 5/4/2011 through 8/27/2011.

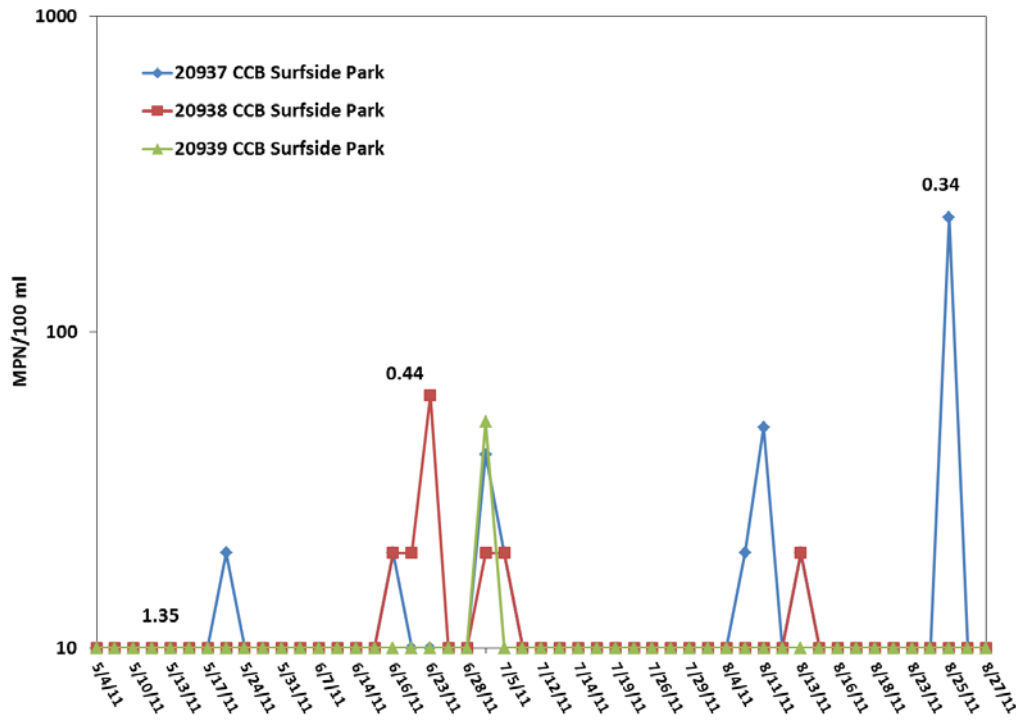


Fig. 4.11. *Enterococcus* concentrations (MPN/100 ml) at Corpus Christi Beach at Surfside Park nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

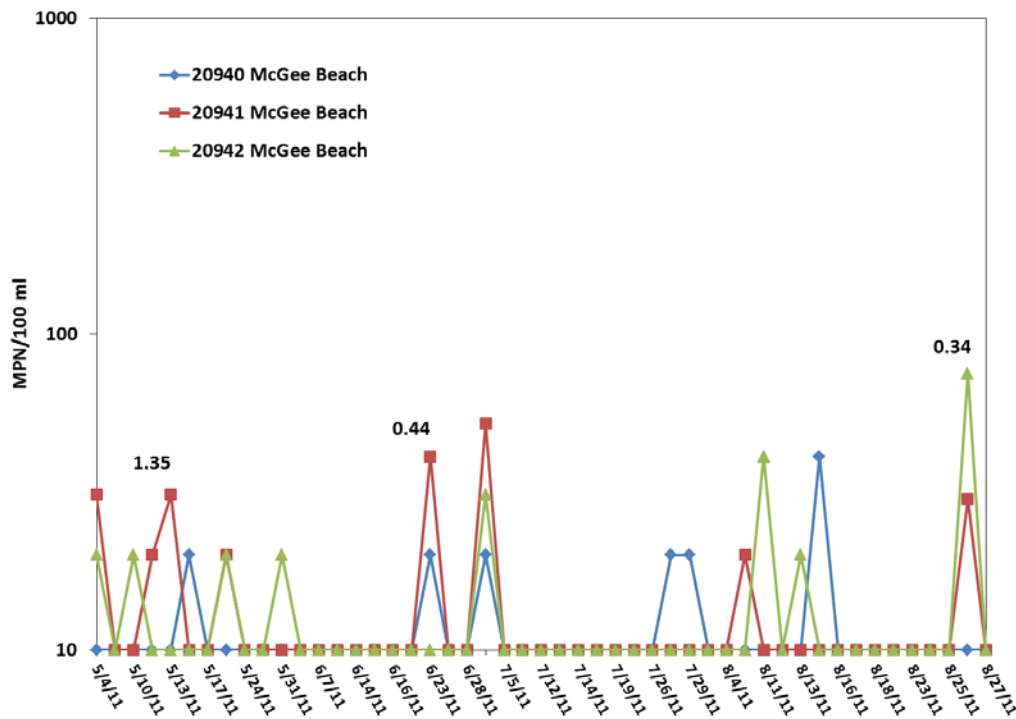


Fig. 4.12. *Enterococcus* concentrations (MPN/100 ml) at McGee Beach nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

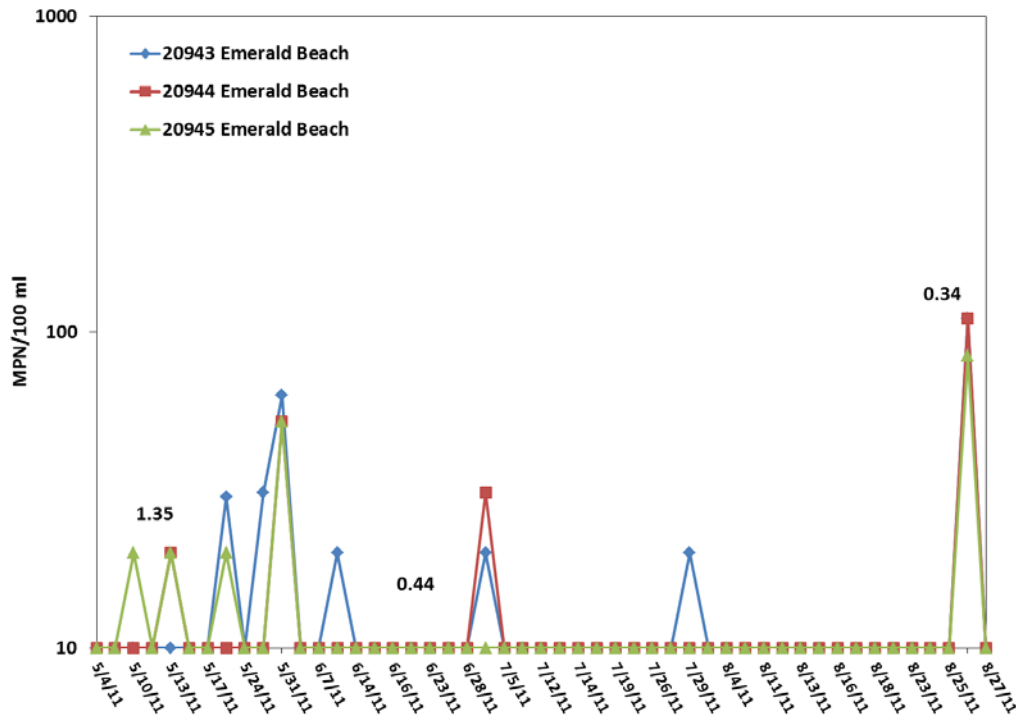


Fig. 4.13. *Enterococcus* concentrations (MPN/100 ml) at Emerald Beach nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

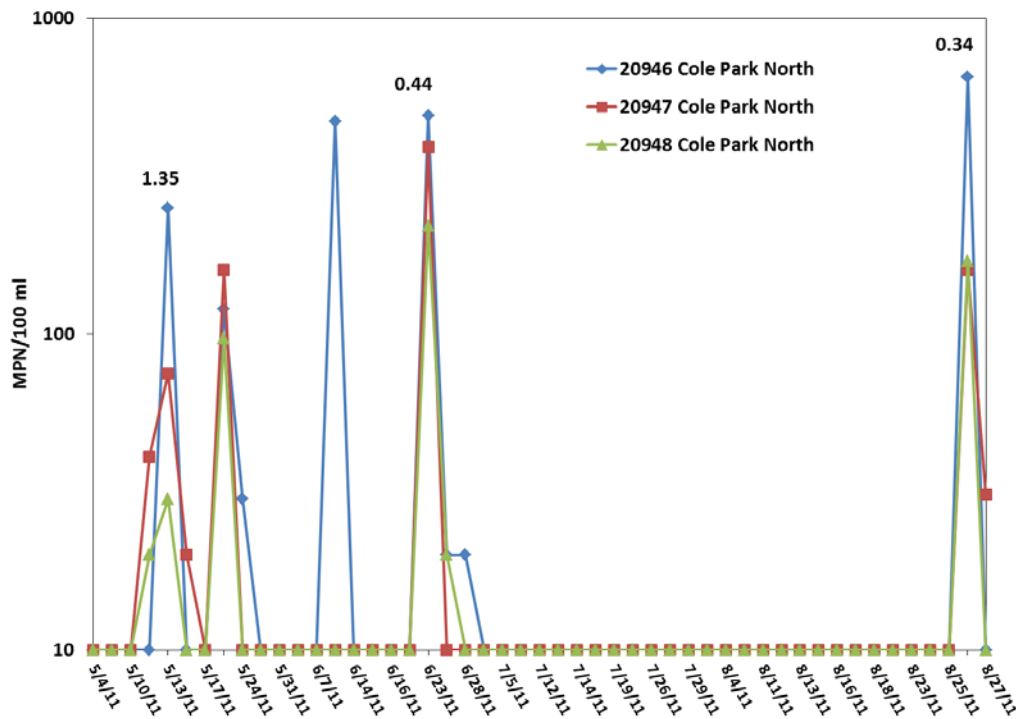


Fig. 4.14. *Enterococcus* concentrations at (MPN/100 ml) Cole Park North nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

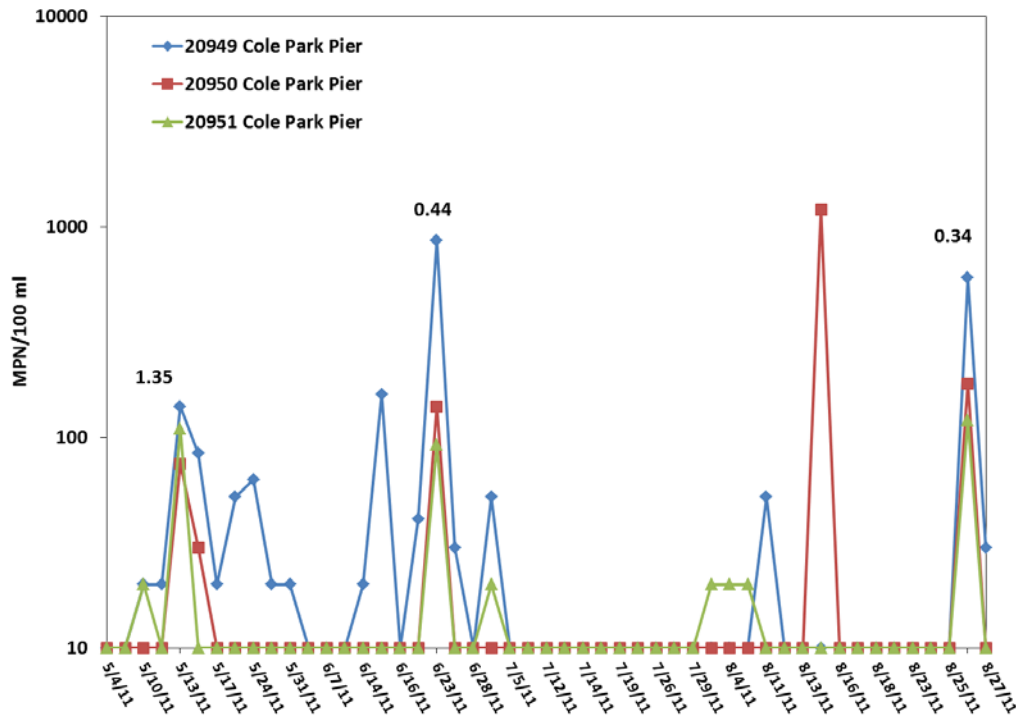


Fig. 4.15. *Enterococcus* concentrations (MPN/100 ml) Cole Park Pier nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

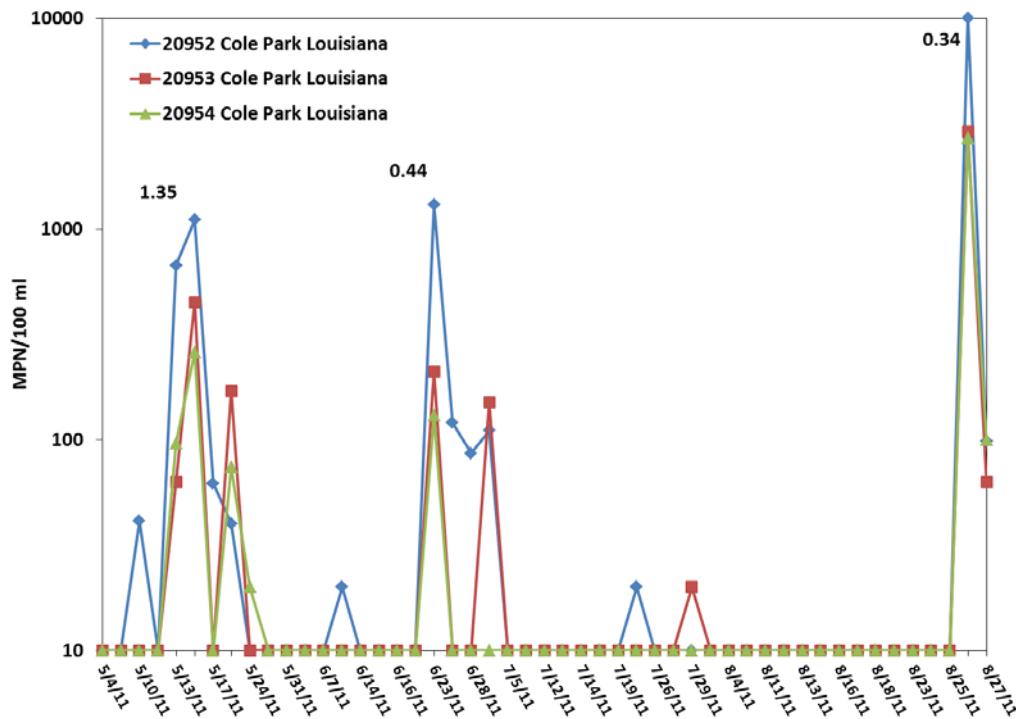


Fig. 4.16. *Enterococcus* concentrations (MPN/100 ml) at Cole Park Louisiana nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.



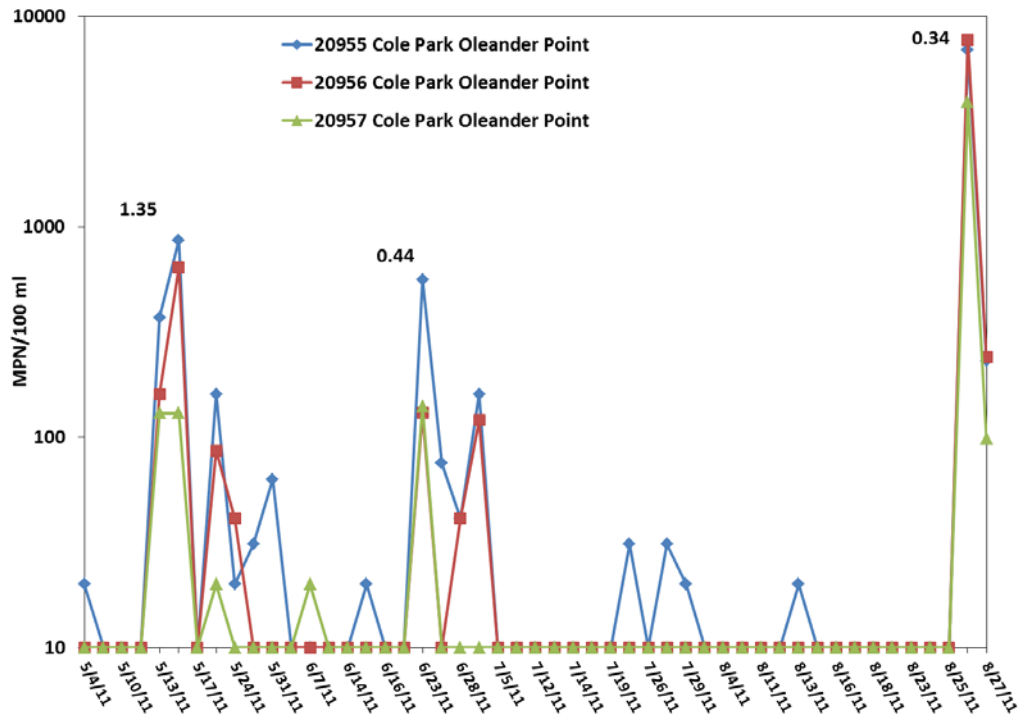


Fig. 4.17. *Enterococcus* concentrations (MPN/100 ml) at Cole Park Oleander Point nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

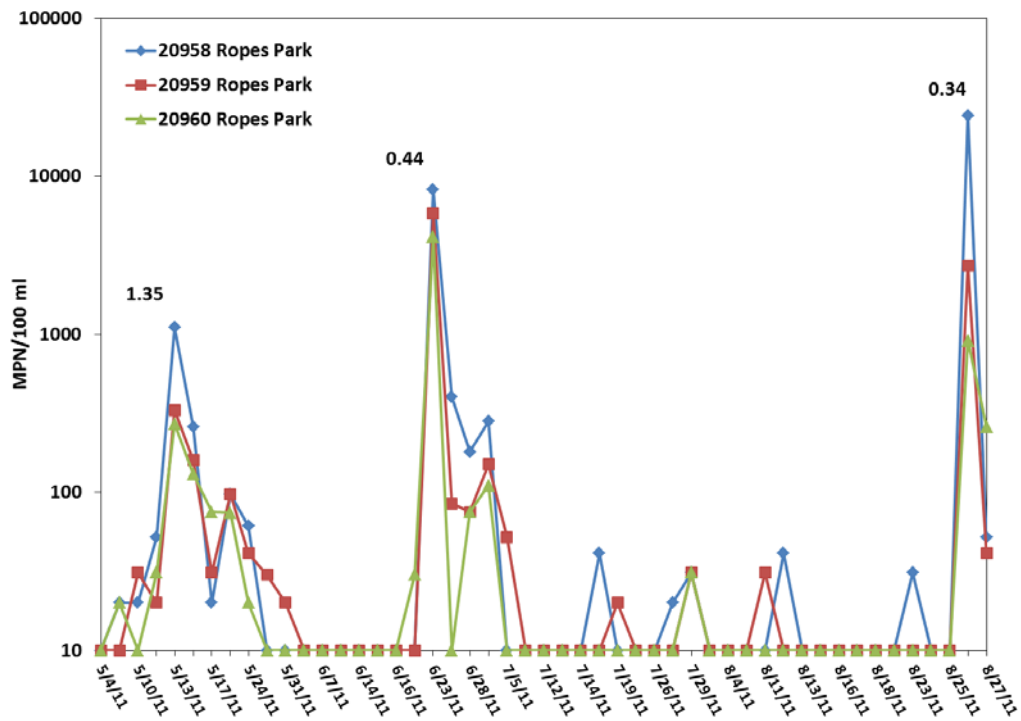


Fig. 4.18. *Enterococcus* concentrations (MPN/100 ml) at Ropes Park nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

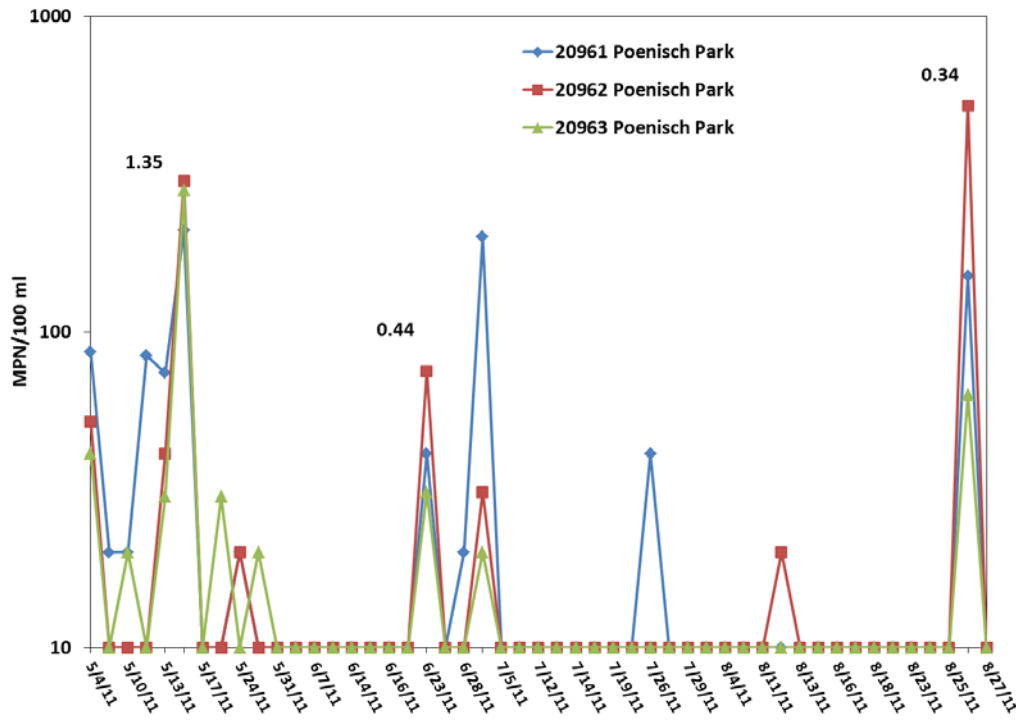


Fig. 4.19. *Enterococcus* concentrations (MPN/100 ml) at Poenisch Park nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

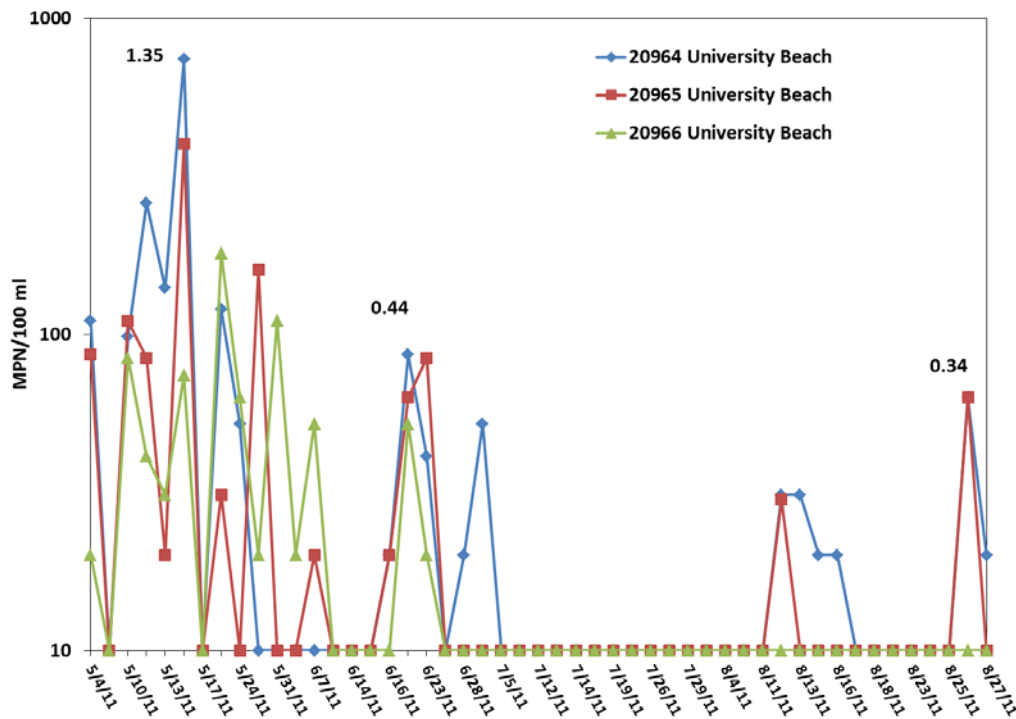


Fig. 4.20. *Enterococcus* concentrations (MPN/100 ml) at University Beach nearshore stations from 5/4/2011 through 8/27/2011. Numbers indicate rainfall (inches) the day preceding the rainfall sampling events of 5/13/2011, 6/23/2011, and 8/26/2011.

#### 4.5 *Enterococcus* concentrations in sediment

As previously stated, water quality sampling was supplemented by the collection of sediment samples at all shoreline locations for analysis of bacteria in the swash zone, or zone of wave interaction. These data were collected for background and supporting information purposes to better understand the extent of bacterial concentrations that exist in the sediment layer at these urban beach/public access locations. Thirty-seven sediment samples were collected from 5/4/2011 through 8/27/2011. In June 2011, collections ceased at the Cole Park Pier location, as no beach exists at the location and obtaining a valid sample was difficult in this area due to wave refraction along the seawall.

Sediment sampling showed very little *Enterococcus* bacteria in the sediments at these locations. Except for one sample collected at Emerald Beach and Cole Park at Oleander Point on 8/5/2011 all concentrations were <10 MPN/100 ml (Table 4.14). The higher concentration at Emerald Beach could not be correlated with any known event. Bacteria concentrations were not elevated in the water column on the day of sampling or during previous events that week. There is a high degree of variability seen in sediment bacteria concentrations, which are influenced by such sources as enteric shedding from adults and children on the beach or in the water, the deposition of dog feces along the shoreline or high avian activity. Further sampling may point directly to possible sources but at this point, no conclusion can be made. However, it does indicate that changes in sediment *Enterococcus* concentrations can occur rapidly and that sediment sampling of beaches may provide valuable information concerning *Enterococcus* concentrations found at recreational beaches.

Table 4.14. *Enterococcus* sediment bacteria concentrations (MPN/100 ml) at all sampling locations for the Corpus Christi Bay Beaches TMDL.

Station ID	Sampling Location	5/12/2011	6/15/2011	7/13/2011	8/5/2011
20937	CC Beach Surfside Park	<10	<10	<10	<10
20940	McGee Beach	<10	30	<10	<10
20943	Emerald Beach	<10	<10	<10	385
20946	Cole Park North	<10	<10	<10	<10
20949	Cole Park Pier	<10			
20952	Cole Park Louisiana	<10	<10	<10	<10
20955	Cole Park Oleander Point	<10	<10	<10	27
20958	Ropes Park	<10	<10	<10	<10
20961	Poenisch Park	<10	<10	<10	<10
20964	University Beach	<10	<10	<10	<10

## 4.6 Park Use by Location

In addition to bacteria sampling, beach survey information was collected to document the number of people who visited each location and categorized their activity in the park, beach, and water. Data indicated the three public beach areas (Corpus Christi Beach Surfside Park, McGee Beach, and Emerald Beach) had the highest number of people observed on the beach and in the water (Fig. 4.21). As these are the three areas where entering the water for swimming and other water activities are actively encouraged it is good to note that these three areas had the lowest number of exceedances of the single sample *Enterococcus* criteria of >104 MPN/100 ml during the sampling conducted for this project (see Fig. 4.8).

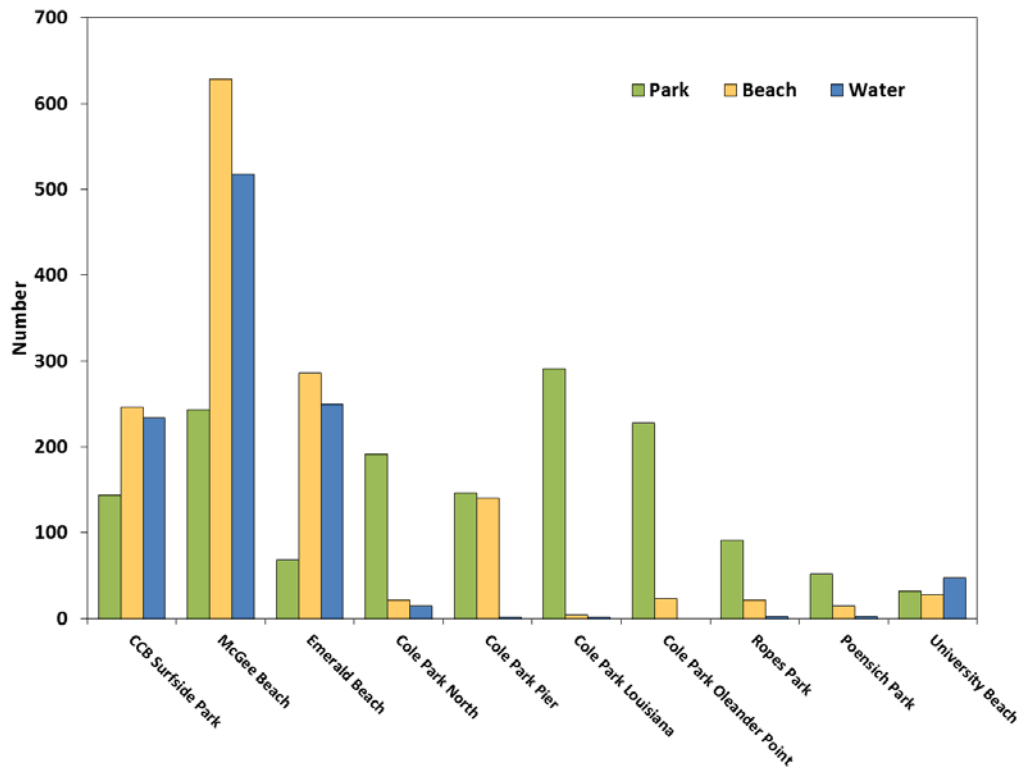


Fig. 4.21. Total number and location of people observed at each beach location from 5/4/2011 through 8/27/2011.

## 4.7 Avian Use by Location

As stated in the Historical Data Review for this project (Nicolau *et al.* 2011), the contribution of bacteria from wildlife in TMDL development for this project is important. Fecal matter deposited on the land may be carried into the municipal storm water drainage system, or directly into Corpus Christi Bay. Currently the lack of sufficient data to estimate avian populations and spatial distribution makes assessment difficult at these urban locations. To provide these data, avian surveys were conducted during each sampling event. Preliminary data analysis identified that birds preferred the University Beach location as the incidence of resting was highest at this location and was the only location where active nesting occurred by Least Terns (Fig. 4.22). However, high numbers of birds observed at University Beach did not correlate with increased concentrations of bacteria in the water.

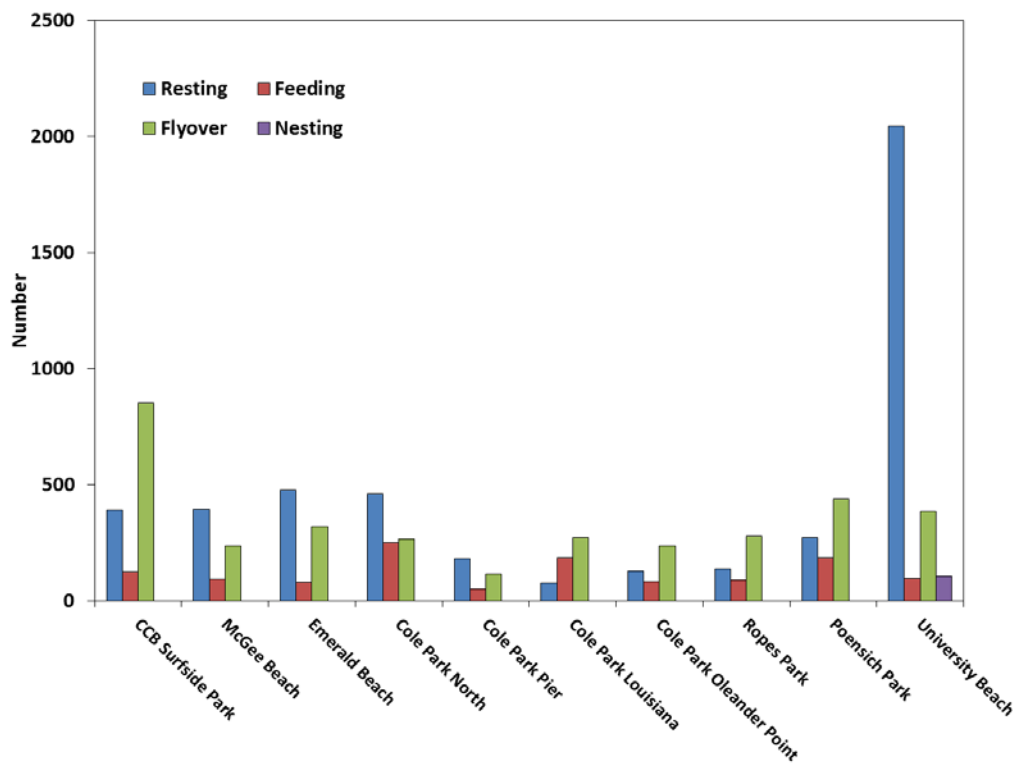


Fig. 4.22. Total number of birds and bird activity observed at each beach location from 5/4/2011 through 8/27/2011.

## 4.8 Beach Debris by Location

The final component of beach survey data collected for this project was on debris present along the shoreline at each location during each sampling event. Organic debris deposited on a beach either by direct stormwater drain discharge or by littering provides an area where bacteria can survive and reproduce. Field investigations in California showed the wrack line acted as a bacterial reservoir that can affect receiving water quality (Martin and Gruber 2005). Excluding Cole Park Louisiana, which has no actual beach, the least amount of debris on beaches were those routinely cleaned by City of Corpus Christi Park Department employees or hotel personnel in the case of Emerald Beach (Fig. 4.23). All locations had some debris from the nine categories listed. With the most common types of debris being algae/seaweed, wood, plastic/Styrofoam, and grass clippings. The high volume of debris deposited from stormwater drain discharge after rainfall events was most notable at Cole Park (Fig. 4.24).

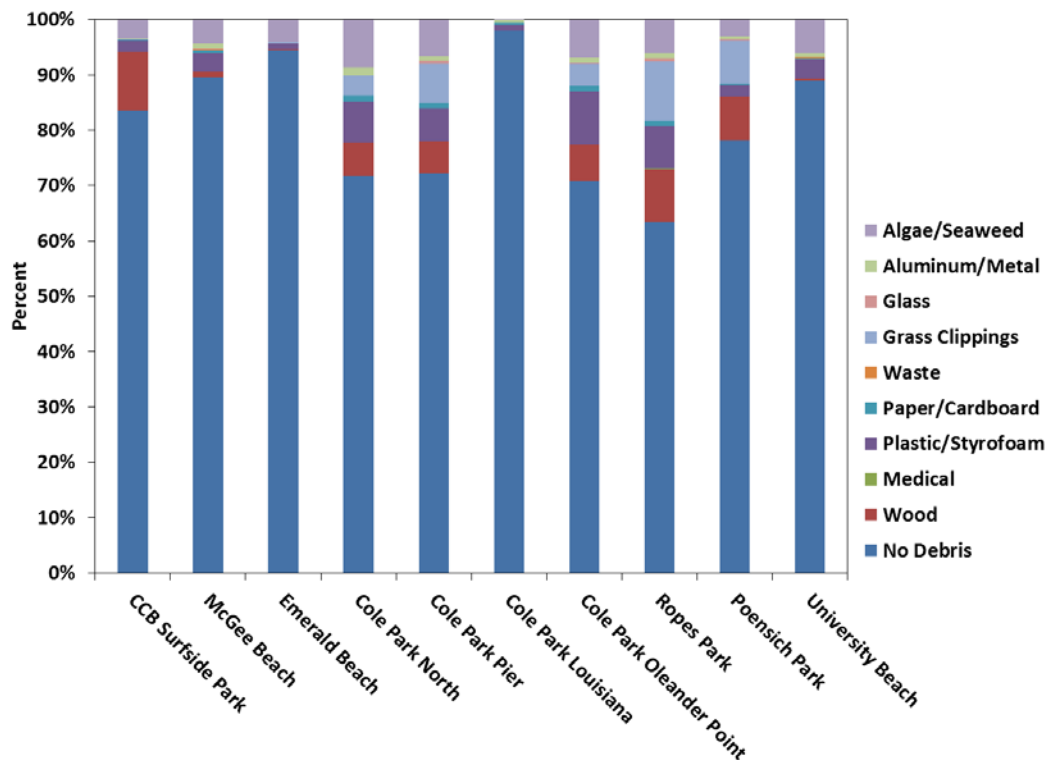


Fig. 4.23. Percent of debris observed at each location from 5/4/2011 through 8/27/2011.



Fig. 4.24. Wrack line debris observed at Cole Park following the rainfall event of 6/23/2011.

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