TMDL INVESTIGATION FOR BACTERIA IN CORPUS CHRISTI BAY BEACHES

INTERIM DATA MONITORING REPORT

FISCAL YEAR 2011 (YEAR-ONE) and FISCAL YEAR 2012 (YEAR-TWO)

Prepared for:

Texas Commission on Environmental Quality
Total Maximum Daily Load Program
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Funding for the second year of this project was through grants from the Texas Commission on Environmental Quality (Contract No. 582-11-90501) and the U.S. Environmental Protection Agency – FY 2009-2011 Clean Water Act Section 106 Categorical Grant, Federal Grant #98665305 and State USAS Grant #998810.

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1.0 INTRODUCTION

1.1 Background

In 2008, based on data collected under the Texas Beach Watch Program, EPA asked the State of Texas to list Corpus Christi Bay (Segment 2481) on the state's 303(d) List of Impaired Waters for bacteria and subsequently asked TCEQ to list the entire water body in Category 5a, meaning a TMDL would be scheduled. Upon request by TCEQ, EPA reconsidered its initial request for listing the entire Corpus Christi Bay segment and agreed to limit the listing to include only the beaches at Cole Park and Ropes Park. EPA also endorsed designation of the two beaches as separate assessment units to be determined by TCEQ at a later date (Segment 2481CB_03 and 2481CB_04, respectively) and endorsed a change in the listing category for these two segments from 5a to 5c; meaning additional bacteria data were needed before a TMDL is conducted.

In 2010, both Cole Park and Ropes Park were place on the Texas 303(d) List of Impaired Waters in Category 5a, and a TMDL was scheduled. These actions have resulted in establishment and funding for this project, *"TMDL Investigation for Bacteria in Corpus Christi Bay Beaches."* This report constitutes the second year effort of data collection with a review and comparison of the data collected in Year-one. For detailed results of Year-one sampling, please see Nicolau and Hill 2011.

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 Primary Contact Recreation (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® is a statistical representation of the MPN of enterococci likely present in a sample. Both methods are used and considered interchangeable by regulatory agencies.

To determine if a water body supports the TCEQ PCR standard, a 10-sample minimum per individual site must be taken over the assessment period (two to seven years). For bacteria data collected routinely, the geometric mean of enterococci values must not exceed 35 CFU or MPN/100 ml in tidal waters. For individual samples collected in tidal waters and recreational beaches, the single sample

criterion of 89 CFU or MPN/100 ml used in 2010 has been revised to 104 CFU or MPN/100 ml. The national EPA Beach Watch Program uses this same criterion for monitoring enterococci concentrations at Texas beaches to determine closures based on elevated bacterial concentrations.

The following information was obtained from the *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 TBWP 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 sample concentration exceeds 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 in successive days following the initial advisory. 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 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 is 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 impairments and concerns at beaches along Corpus Christi Bay (Segment 2481). Project goals require the collection of supplementary *Enterococcus* data in Corpus Christi Bay. Data collection in Year-one was from May 2011 through August 2011 and in Year-two from February 2012 through July 2012. 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, which was renamed North Beach (Segment 2481CB_02) in July 2012, 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 (SWQMIS) 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^2 (409.5 mi^2). Land represents 409.7 km^2 (158.2 mi^2) with water and right-of-way easements contributing 526.3 km^2 (230.2 mi^2) and 54.6 km^2 (21.1 mi^2), respectively. The population was 305,215 in 2010 as recorded by the 2010 US 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 the Corpus Christi International Airport is approximately 76.9 cm yr^{-1} (30.3 in yr^{-1}) (NOAA 2011). This is offset by evaporation rates ranging from 90 to 115 cm yr^{-1} (35.4 to 45.3 in yr^{-1}) but may reach as high as 150 cm yr^{-1} (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* impairments and 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 TCEQ'S 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 3.7) that also coincide with existing stations sampled by the TBWP. 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).

In Year-one, 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 3.7). 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 to be collected was approximately 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.

Sample collection involved the acquisition of field data, water and sediment microbiological data, and beach survey data as described in the QAPP and listed in Table 3.1. In Year-one, sampling took place from 5/4/2011 through 8/27/2011 to correspond with the TBWP "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 days) and the 10 offshore stations were sampled three times (3 non-rainfall). In addition, sediment sampling took place four times at the 10 beach locations.

In Year-two, several modifications occurred to the sampling program. In addition to the sampling stations described above, limited sample collection began in June 2012 at seven stormwater outfall locations along the bay front. Sampling only occurred on rain event days when flow was evident at the outfalls. Four stormwater outfalls are located at existing sampling points at Louisiana Avenue, Cole Park at Oleander Point, Ropes Park, and Poenisch Park and at three outfalls located in proximity to existing sampling locations at Brawner Parkway, Carmel Parkway, and South Shore Place. These stations are designated by green dots on Figs. 3.4 through 3.6 with more detailed provided in Figs. 3.8 through 3.15. In addition, starting with stormwater outfall sampling on 6/21/2012, rainfall event sampling occurred within 12 hours of rainfall and at the standard 24 and 48 hours following the rainfall event.

Year-two sampling took place from 2/16/2012 through 7/26/2012 at the 10 urban beach/public access sampling locations (30 total nearshore stations), with stormwater outfall (7 stations), offshore (10 stations), rain event (30 nearshore stations, 10 offshore, and 7 stormwater outfall stations), and sediment (10 beach locations) sampling occurring at the reduced frequency explained below.

Sampling occurred bi-weekly from 2/16/2012 through 4/30/2012 and occurred on the weeks that the Texas Beach Watch Program was not collecting their samples. From 5/1/2012 through 7/26/2012, sampling took place on a weekly basis. During the six-month period of February through July of 2012, 27 of the 30 nearshore stations were sampled 34 times (16 non-rainfall and 18 rainfall days).

Sampling was suspended at the three stations at the Cole Park Pier location due to a bulkhead stabilization and erosion control project that closed the area to access. Sampling at the Cole Park Pier location was reinstated 6/18/2012 through 7/26/2012 with 12 sampling events conducted (3 non-rainfall and 3 rainfall days) within that time interval.

The 10 offshore stations were sampled 5 times (2 non-rainfall and 3 rainfall days), and the stormwater outfall stations were sampled 6 times (6 rainfall days). In addition, sediment sampling took place 4 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 Avenue, Brawner Parkway, and Carmel Parkway. Retrieved 8/1/2012 from Google Earth.

Fig. 3.2. Aerial photo depicting the four North Beach, formally Corpus Christi Beach, transect sampling locations. Retrieved 8/1/2012 from Google Earth.

Fig. 3.3. Aerial photo depicting the four McGee Beach (20940, 20941, 20942, and 21048) and four Emerald Beach (20943, 20944, 20945, and 21049 transect sampling locations. Retrieved 8/1/2012 from Google Earth.

Fig. 3.4. Aerial photo depicting the four Cole Park transect sampling locations (16 stations) and the Louisiana Avenue (21143) and Cole Park-Oleander Point (21144) stormwater outfall sampling locations. Retrieved 8/1/2012 from Google Earth.

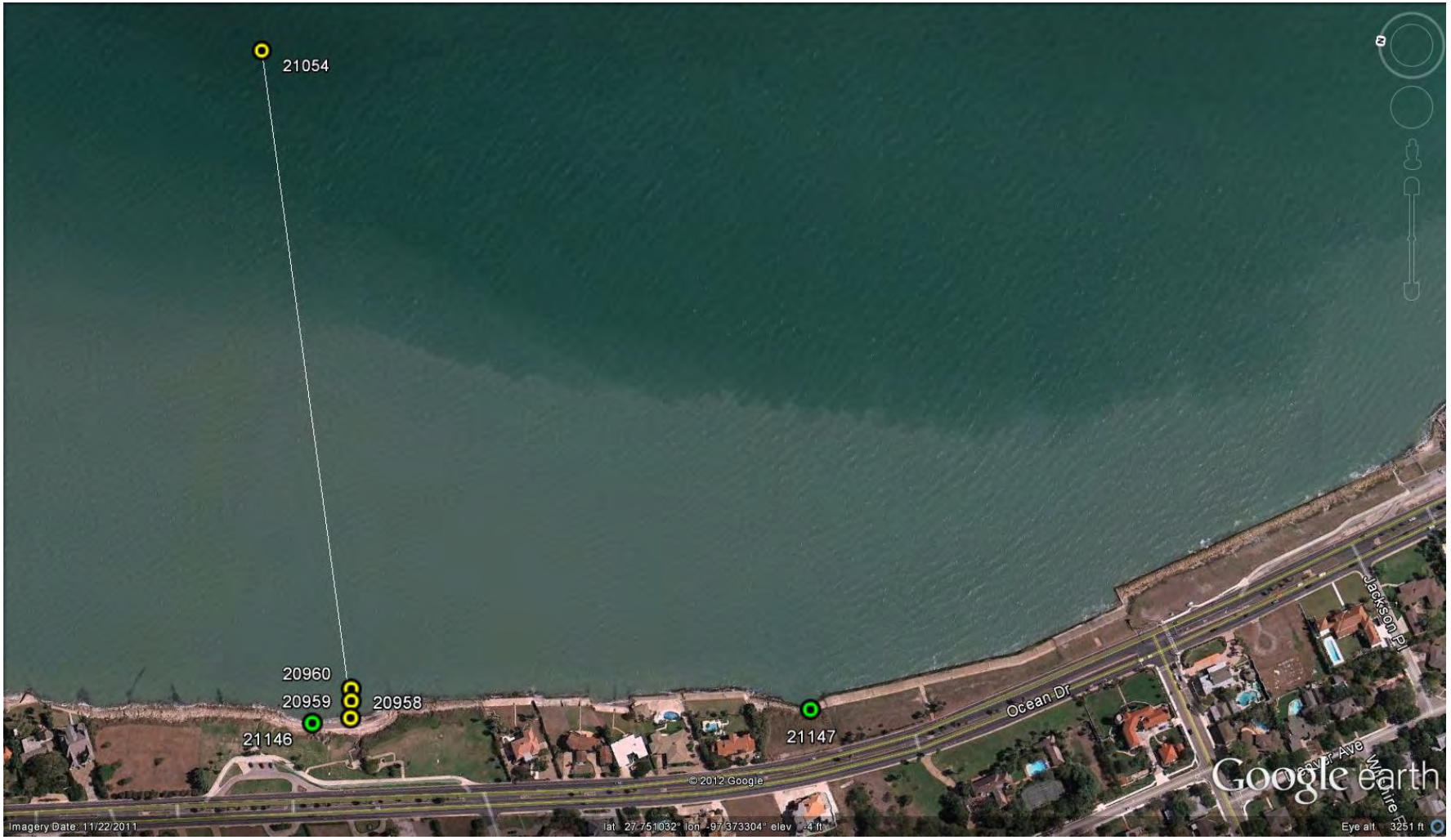

Fig. 3.5. Aerial photo depicting the four Ropes Park transect sampling locations and the Ropes Park (21146) and Brawner Parkway (21147) stormwater outfall sampling locations. Retrieved 8/1/2012 from Google Earth.

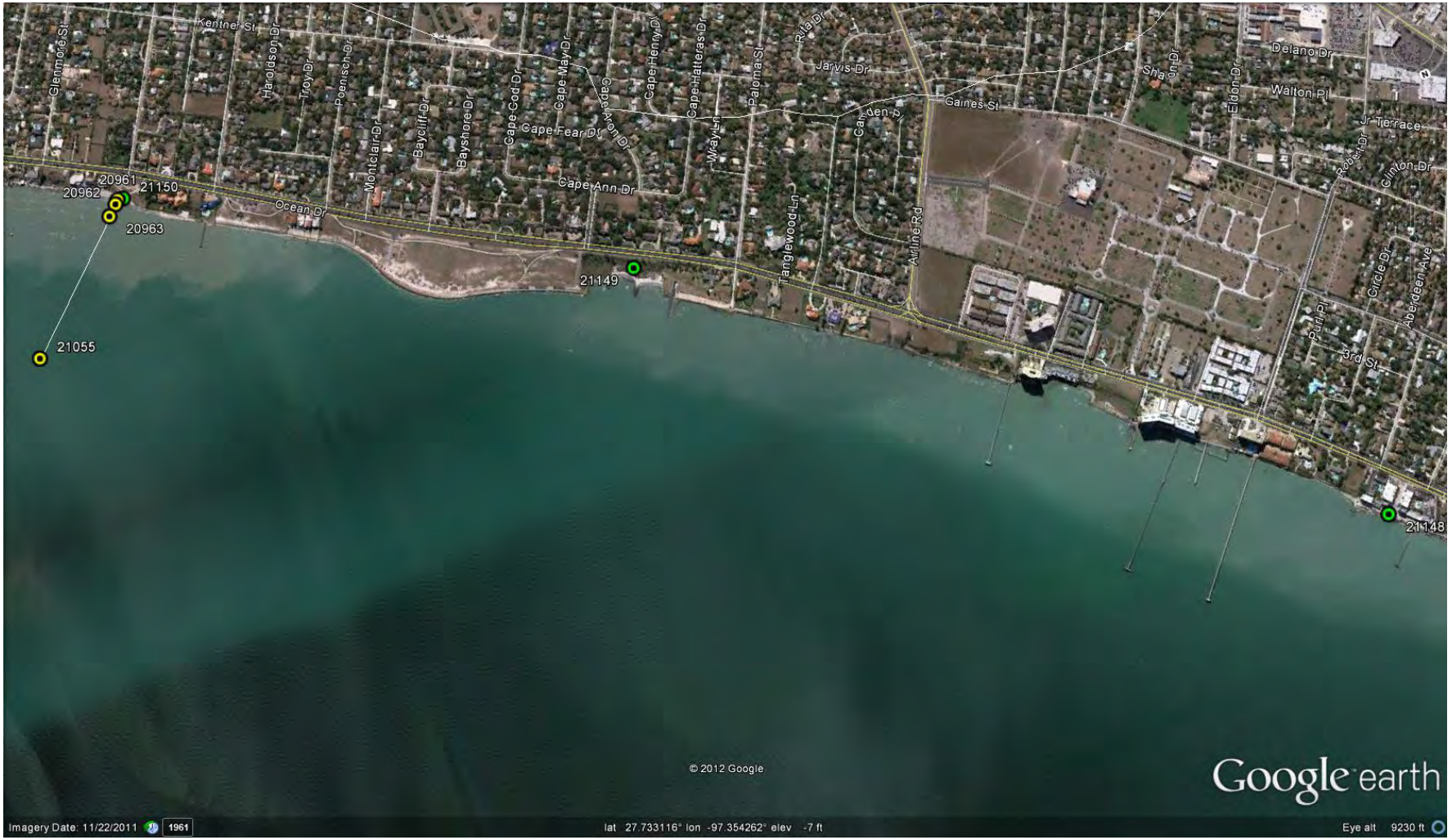

Fig. 3.6. Aerial photo depicting the four Poenisch Park transect sampling locations and the Poenisch Park (21150), South Shore Place (21149), and Carmel Parkway (21148) stormwater outfall sampling locations. Retrieved 8/1/2012 from Google Earth.

Fig. 3.7. Aerial photo depicting the four University Beach transect sampling locations. Retrieved 8/1/2012 from Google Earth.

Fig. 3.8. Cole Park Louisiana stormwater outfall (Station 21143).

Fig. 3.9. Cole Park Oleander Point stormwater outfall (Station 21144).

Fig. 3.10. Ropes Park stormwater outfall (Station 21146).

Fig. 3.11. Brawner Parkway stormwater outfall (Station 21147).

Fig. 3.12. Carmel Parkway stormwater outfall (Station 21148).

Fig. 3.13. South Shore Place stormwater outfall (Station 21149).

Fig. 3.14. South Shore Place stormwater outfall (Station 21149) showing large ponded area.

Fig. 3.15. Poenisch Park stormwater outfall (Station 21150).

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

Routine Field Parameters	Units	Parameter Codes*
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
Routine Field Observations		
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).

Microbiological		
Enterococci, Enterolert, Water, IDEXX	MPN/100 ml	31701
Enterococci, Sediment, IDEXX Enterolert, WetWt	MPN/100 ml	31703
Sediment Grain Size		
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
Sediment Conventionals		
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 (*TMDL Investigation for Bacteria in Corpus Christi Bay Beaches*; updated 2/14/2012 and amended on 6/18/2012). A three-person field crew conducted water and sediment sampling 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 site and date information was written on the sample 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 person sampling, and pushed downward into the water to avoid introducing surface scum. Sampling depth was 0.3 m below the water surface at all locations where such a depth was feasible.

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 is not an established TCEQ protocol. 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

The standard TCEQ sediment conventional parameters were also collected for analysis as a companion to sampling sediment for microbiological organisms. As it is impractical to use a sediment dredge sampler, collection methods deviated from established TCEQ sediment sampling protocols. As with the microbiological sediment sampling procedures outlined above, the surficial sediment layer (2 cm) in the swash zone was collected. However, the swash zone samples were collected using a spatula or scoop and were 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 collection efforts for the first two years of this multi-year project. Until all data is collected, data interpretation will be minimal and limited conclusions may be drawn. The discussion primarily focuses on the 30 nearshore stations sampled for the duration of the project with limited discussion and data presentation for stations and parameters sampled less frequently. All data are submitted to TCEQ and can be accessed through the TCEQ SWQMIS database.

4.1 Field Data (non-rainfall events)

Water Temperature (°C)

During both years, water temperature was typical for the region based on the season in which the sampling occurred. In Year-one, water temperature ranged from 19.14 to 33.07 with both the lowest and highest temperatures recorded at the University Beach location (Station 20964). Mean water temperature was highest at the Emerald Beach location (Station 20943) at 29.87.

In Year-two, water temperature ranged from 15.78 at Poenisch Park (Station 20963) to 32.48 at the McGee Beach location (Station 20940). Mean water temperature was highest at the Cole Park Pier location (Station 20951) at 30.25. Minimum water temperatures recorded in Year-two are lower due to sampling beginning in February as opposed to May in Year-one. Water temperature increased through the summer months with mean temperatures staying relatively consistent for all stations sampled.

Dissolved Oxygen (DO in mg/L)

In Year-one, DO ranged from 4.79 at University Beach (Station 20964) to 10.99 at Ropes Park (Station 20958). Mean DO of all stations sampled was greatest at Ropes Park at 8.39. Of 1290 total DO readings recorded at the 30 nearshore stations, only two fell below the 5.00 exceptional aquatic life criteria established in the Texas Surface Water Quality Standards for Corpus Christi Bay. Both of the DO readings below 5.00 occurred at the University Beach location.

In Year-two, both the lowest and highest DO concentrations occurred at the same locations as seen in Year-one (University Beach and Ropes park, respectively). Dissolved oxygen ranged from 4.73 at the University Beach location (Station 20966) to 10.04 at Ropes Park (Station 20960). Mean DO for all stations was greatest at North Beach (formerly known as Corpus Christi Beach) at Surfside Park (Station 20939) with a concentration of 8.07. As in Year-one, of 504 total DO readings recorded at the 30 nearshore stations in year two, the University Beach location had three readings that fell below the 5.00 exceptional aquatic life criteria.

Salinity (Practical Salinity Units or PSU)

In Year-one Salinity ranged from 21.91 at Cole Park Louisiana (Station 20952) to 44.06 at the University Beach location (Station 20965). Mean salinity for all stations sampled in Year-one was greatest at University Beach (Station 20965) with 38.99. Mean salinity of all stations combined was 37.49. Continued lack of significant rainfall intensified the existing drought throughout Texas. As a result, Corpus Christi Bay had a 10.00 increase in salinity by August 2011.

Salinity in Year-two ranged from 33.92 at Cole Park Louisiana (Station 20952) to 44.62 at the University Beach location (Station 20965). Again, University Beach location had the greatest mean salinity of all stations sampled at 38.62 (Station 20964). Mean salinity of all stations combined in Year-two was 37.09. While Year-two experienced more rainfall events than Year-one, the continuing

effects of the drought in the South Texas region is evident in the 12.01 increase (21.91 versus 33.92) seen in minimum values recorded at the Cole Park Louisiana location.

pH (Standard Units)

In Year-one pH ranged from 7.53 at the North Beach-Surfside Park location (Station 20937) to 8.41 at Ropes Park (Station 20958). Highest mean pH concentration of 8.21 occurred at multiple locations (Cole Park Louisiana, Ropes Park, Poenisch Park, and University Beach). Mean pH of all stations combined was 8.18 over the four-month sampling period.

In Year-two pH was slightly higher in the waters along the shore of Corpus Christi Bay with the lowest and highest pH concentrations occurring at the University Beach location (Station 20954) where pH ranged from 7.81 to 8.65. The highest mean pH of all stations sampled occurred at the Cole Park North location (Station 20946) at 8.21. Mean pH of all stations combined was 8.20 over the six-month sampling period.

Turbidity (Nephelometric Turbidity Units or NTU)

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 are the greatest of all parameters sampled during the study.

In Year-one, turbidity ranged from 0.90 at Cole Park North (Station 20946) to 1862.40 at Cole Park Louisiana (Station 20953). Mean turbidity was also highest at the Cole Park Louisiana location (Station 20952) at 71.63. Mean turbidity for all stations combined was 30.00 over the course of the four-month sampling period. Lowest turbidity occurred during the summer months when wind speeds typically decline compared to other times of the year.

In Year-two, turbidity ranged from <0.10 at multiple locations along the bay, to 404.60 at the Cole Park Louisiana location (Station 20953). Highest mean turbidity of all 30 nearshore stations sampled was 47.53 at the Cole Park Louisiana location (Station 20952). Mean turbidity for all stations combined was 15.09 over the course of the six-month sampling period.

Higher mean turbidity in Year-one was a result of more samples taken (1260 versus 504) and higher maximum concentrations, with three concentrations >1100 and three concentrations >1800. All other concentrations in Year-one were <423. This is in contrast to Year-two when two concentrations recorded were >400 and all others were <154.

4.2 Precipitation

To estimate precipitation for the study area, six locations have been used to determine approximate amounts of rainfall preceding rainfall sampling events. Using Ropes Park as the approximate center point of the shoreline sampled for this project, these locations were used since no rain gauge instrumentation existed in close proximity to the sampling stations. The four stations used in Year-one were KTXINGLE6 located to the northeast at the Air Liquide Plant in Ingleside, Texas, KTCORPU19 located at King Estates on the south side of Corpus Christi, KNGP located at Naval Air Station-Corpus Christi to the east of the sampling area, and KCRP located to the west at Corpus Christi International Airport (Fig. 4.1).

In Year-two, station KTXINGLE6 stopped producing reliable data and went offline in mid April 2012. A new station, KTXINGLE7, located approximately 2.5 miles to the southeast of this station was selected and beginning 4/1/2012 rainfall data has been obtained from this location. In addition to the substitution of a new location in Ingleside, a Personal Weather Station was installed on South Morningside Drive, which is located 0.75 miles from Ropes Park. Data from this station has been used in rainfall approximations since the station went online 5/1/2012. Table 4.1 gives station information and individual rainfall amounts recorded prior to, and during, rainfall event sampling in Year-one and Year-two.

Lack of significant precipitation in Year-one, coupled with sampling beginning in May, as opposed to February in Year-two, resulted in only three rainfall sampling events occurring during the four-month sampling period (Fig. 4.2). Increased frequency of precipitation in Year-two produced seven rainfall sampling events with at least one event in each month except February (Fig. 4.2). In both years of sampling (Year-one and Year-two), the greatest amount of rainfall occurring during a rainfall event was during the month of May. Rainfall amounts declined in subsequent events as the drought intensified through the summer months (Table 4.1 and Fig. 4.2).

Attention is drawn to the sampling event of 7/12/2012, as the data shows no appreciable rainfall occurring in the area (Table 4.1 and Fig. 4.2). On that day, a large thunder cell formed over Corpus Christi Bay and moved over the eastern half of the sampling area from just east of Ropes Park to the University. Slight amounts of precipitation were recorded to the northeast and east and no precipitation occurred at any of the other stations. However, significant rainfall (estimates are 1 inch) did occur over the eastern half of the sampling area so sampling began with the hope that the rain would spread to the west. The expectation of this movement was short lived as the storm event ceased before sampling crews reached the Ropes Park area. Precipitation recorded the next day to the south and west remained localized and had no effect on the drainage basin being sampled. This event did yield rainfall event data for the stations on the eastern half of the sampling area and demonstrated the effect that localized events can have on runoff and water quality.

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

Table 4.1. 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 in Year-one and the seven rainfall events in Year-two. Note: PWS = Personal Weather Station and NWS = National Weather Service.

Station Call Sign	**KTXINGLE6 - 7**	**KNGP**	**KTXCORPU19**	**KCRP**	**KTXCORPU35**	
Station Name	Air Liquide/Ingleside	NAS-CC	King Estates	CC Int. Airport	Morningside	
Station Type	PWS	NWS	PWS	NWS	PWS	
Miles to Ropes Park	12 to NE	7 to ESE	7.5 to S	7.5 to W	0.75 to ESE	
Date						**Mean**
Year-One						
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						
Year-Two						
3/11/2012	0.17	0.12	0.13	0.19		0.15
3/12/2012			0.01			<0.01
3/13/2012			0.01			<0.01
3/20/2012	0.94	0.78	0.18	0.54		0.61
3/21/2012	0.06	0.03				0.02
3/22/2012						
4/2/2012	0.53	0.39	0.19	0.41		0.38
4/3/2012						
4/4/2012						
4/16/2012	2.73	2.70	1.49	2.16		2.27
4/17/2012						
4/18/2012						
5/10/2012	0.33	3.74	8.52	2.61	1.83	3.41
5/11/2012	0.92	0.85	2.36	0.04	0.24	0.88
5/12/2012	0.92					0.18
6/21/2012	1.07	1.10	1.52	0.48	1.57	1.15
6/22/2012						
6/23/2012						
7/12/2012	0.02	0.06				0.02
7/13/2012			0.29	0.78		0.21
7/14/2012			0.02	0.06		0.02

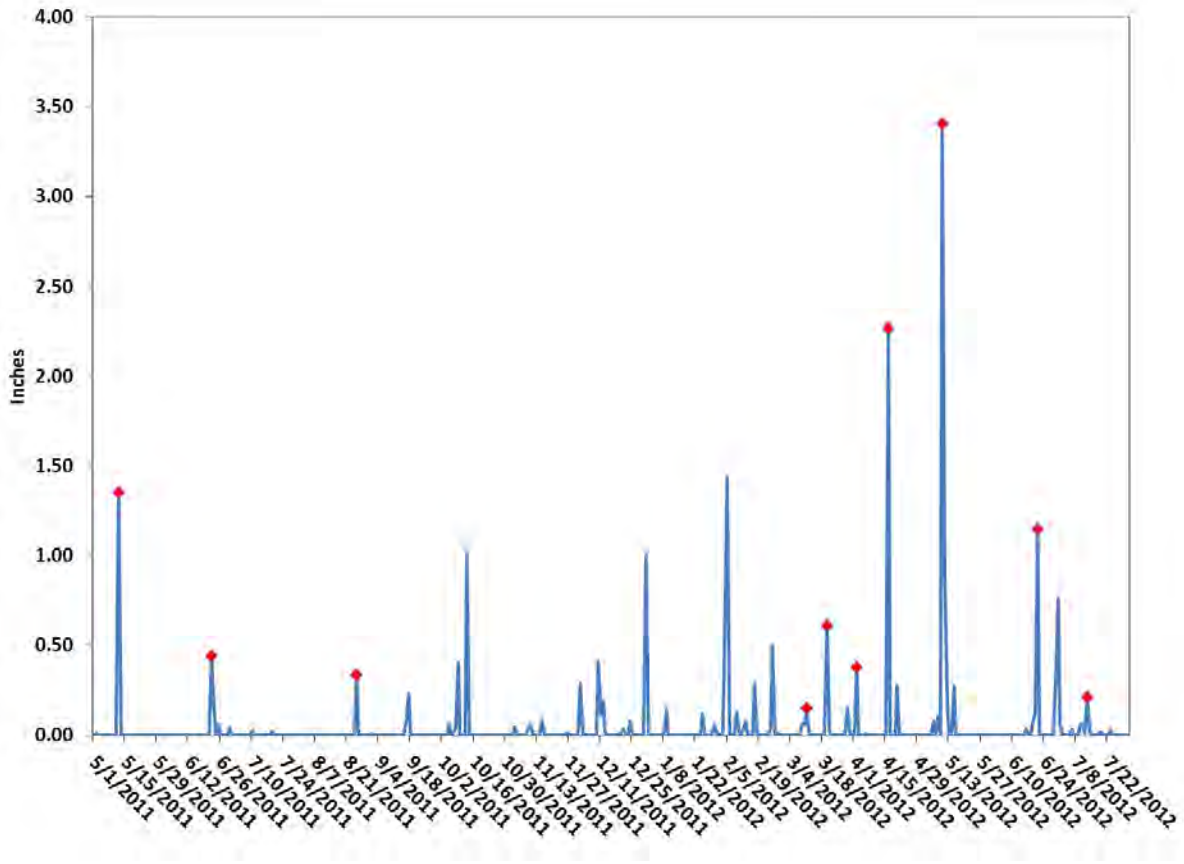

Fig. 4.2. Mean rainfall calculated from weather stations from 5/1/2011 through 7/26/2012. Red triangles denote rainfall sampling events.

4.3 Field Data (Rainfall events)

A brief summary of field data for both Year-one and Year-two is provided for the 30 nearshore, 7 stormwater outfall, and 10 offshore stations sampled during rainfall events (see Table 4.1 for rainfall amounts). Typically, most of the values for the parameters were similar to non-rainfall event sampling with the exception of salinity and DO fluctuations possibly resulting from stormwater inflows and mixing within the water column. Extremely low DO levels at the South Shore Place outfall (Station 21149) are probably due to the large ponded area that has formed directly in front of the semi-submerged twin outfalls (see Fig.3.13 and Fig. 3.14). Typically, this area sits undisturbed and forms a stagnant pool and water is circulated with Corpus Christi Bay waters only during storm or high tide events. The low DO observed during Year-two occurred when sample collection for a rainfall event took place as the first stormwater began flowing. For further details, all parameters are submitted to TCEQ and can be accessed through the TCEQ SWQMIS database.

Water Temperature (°C)

In Year-one, water temperature during rainfall events ranged from 23.70 at the University Beach location (Station 20964) to 32.00 at the McGee Beach location (Station 20940). Mean water temperature was highest at the North Beach Surfside Park location (Station 20937) at 29.64. In Year-two, water temperature ranged from 17.64 at University Beach (Station 20965) to 30.51 at the South Shore Place stormwater outfall location (Station 21149). Mean water temperature was also highest at this location (Station 21149) at 28.56.

Dissolved Oxygen (DO in mg/L)

In Year-one, DO ranged from 4.96 at Ropes Park (Station 20960) to 10.61 at McGee Beach (Station 20942). Mean DO of all stations sampled during rainfall events was greatest at Emerald Beach at 8.09. Of 180 total DO readings recorded, only the one reading at Ropes Park fell slightly below the 5.00 exceptional aquatic life criteria established for Corpus Christi Bay.

In Year-two DO ranged from 0.25 at the South Shore Place stormwater outfall location (Station 21149) to 10.03 at Cole Park North (Station 20946). Mean DO for all stations was greatest at the Ropes Park stormwater outfall (Station 21146) with a concentration of 8.63. However, this station was only sampled once due to no flow being present in other rainfall sampling events. For stations sampled multiple times, mean DO was greatest at McGee Beach (Station 20941) with 8.33.

Of 511 DO readings recorded during rainfall events, 11 fell below the 5.00 exceptional aquatic life criteria. All instances occurred at stormwater outfall locations. The DO concentrations falling below 5.00 ranged from 0.25 at South Shore Place (Station 21149) to 4.98 at the Cole Park Louisiana outfall (Station 21143).

Salinity (Practical Salinity Units or PSU)

During Year-one rainfall sampling events, salinity ranged from 26.23 at Cole Park North (Station 20946) to 42.04 at University Beach (Station 20964). Mean salinity for all stations sampled in Year-one was greatest at University Beach (Station 20964) with 38.37. Mean salinity of all stations combined was 36.72.

During Year-two rainfall sampling events, salinity ranged from 0.25 at Cole Park Louisiana (Station 20952) to 40.09 at University Beach (Station 20966). Mean salinity for all stations sampled in Year-

two was greatest at University Beach (Station 20964) with 36.94. Mean salinity of all stations combined in Year-two rainfall sampling was 35.13.

pH (Standard Units)

In Year-one pH ranged from 7.92 at University Beach (Station 20964) to 8.30 at University Beach (Station 20966). Highest mean pH concentration of 8.19 occurred at multiple locations (Cole Park North, Cole Park Pier, Poenisch Park, and University Beach).

During Year-two rainfall events pH ranged from 7.19 at the Cole Park Oleander Point outfall (Station 21144) to 8.93 at the Carmel Parkway outfall (Station 21148). The highest mean pH of all stations sampled during rainfall events occurred at the Cole Park Louisiana outfall location (Station 21143) at 8.25.

Turbidity (Nephelometric Turbidity Units or NTU)

In Year-one, turbidity during rainfall event sampling ranged from 1.20 at North Beach Surfside Park (Station 20937) to 784.50 at Cole Park Oleander Point (Station 20957). Mean turbidity was also highest at the Cole Park Oleander Point (Station 20955) at 150.80. Mean turbidity for all stations combined for the three rainfall sampling events was 40.20.

In Year-two, turbidity ranged from <0.10 at North Beach Surfside Park (Station 20939) to 261.90 at the Carmel Parkway outfall location (Station 21148) which also yielded the highest mean turbidity concentration of 49.60. For the seven rainfall sampling events in Year-two, the mean turbidity for all stations combined was 14.43.

4.4 *Enterococcus* concentrations in water (all events)

Summary data results for both years are presented for the 30 nearshore stations located at the ten urban beach/public access locations on Corpus Christi Bay. Due to the limited dataset for the 10 offshore stations and the 7 stormwater outfall stations only data for the June 2012 rainfall event is discussed in any detail. Concerning the non-rainfall sampling events at the 10 offshore locations, in 2011 and 2012 *Enterococcus* concentrations were all <10 MPN/100 ml.

Information presented in this section provides a summary of data collected to date, with number and type of sample (non-rainfall versus rainfall) collected detailed in Table 4.2. In subsequent tables and graphs where station numbers appear, the first station listed is always the closest to shore with subsequent station numbers progressing farther offshore as shown in Figs. 3.2 through 3.7.

In both years, *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 stormwater outfalls. Concentrations recorded throughout the study typically declined the farther from shore the samples were taken in Year-one (Table 4.3) and Year-two (Table 4.4).

Table 4.2. Number and type (non-rainfall versus rainfall) of bacteria samples collected for each of the 30 nearshore stations, 10 Offshore stations, and 7 stormwater outfall stations, with total number and type of sample for each year. Note: Due to the closure of Cole Park Pier, only 6 non-rainfall and 6 rainfall events occurred in 2012.

Type of sample	2011	2012
Thirty (30) Nearshore Stations		
Non-rainfall Sampling Events	43	18
Rainfall Sampling Events	6	16
Total Sampling Events	49	34
Total Non-rainfall samples collected	1290	504
Total Rainfall samples collected	180	450
Total samples collected	1470	954
Ten (10) Offshore Stations		
Non-rainfall Sampling Events	3	2
Rainfall Sampling Events		3
Total Sampling Events	3	5
Total Non-rainfall samples collected	30	18
Total Rainfall samples collected		30
Total samples collected	30	48
Seven (7) Stormwater Outfall Stations		
Non-rainfall Sampling Events		
Rainfall Sampling Events		6
Total Sampling Events		6
Total Non-rainfall samples collected		
Total Rainfall samples collected		31
Total samples collected		31

Table 4.3. *Enterococcus* concentrations (MPN/100 ml) for all 30 nearshore (May 2011 – August 2011) and 10 offshore Corpus Christi Bay Beaches TMDL stations sampled.

Station ID	Sampling Location	n (events)	Min	Max	Geometric mean (all events)	Geometric mean (no rain events)
20937	NB 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	Poenisch 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 4.4. *Enterococcus* concentrations (MPN/100 ml) for all 30 nearshore (February 2012 – July 2012) and 10 offshore Corpus Christi Bay Beaches TMDL stations sampled. For reference, the shaded yellow identifies concentrations that exceed the 35 MPN/100 ml geometric mean.

Station ID	Sampling Location	n (events)	Min	Max	Geometric mean (all events)	Geometric mean (no rain events)
20937	NB Beach Surfside Park	34	<10	327	18.8	18.5
20938		34	<10	122	14.1	14.6
20939		34	<10	280	12.0	10.4
21047		5	<10	<10	<10.0	<10.0
20940	McGee Beach	34	<10	780	21.5	16.0
20941		34	<10	860	21.5	16.2
20942		34	<10	983	20.7	14.9
21048		5	<10	422	21.1	10.0
20943	Emerald Beach	34	<10	1240	26.2	14.7
20944		34	<10	884	19.0	14.5
20945		34	<10	650	18.1	16.4
21049		5	<10	379	20.7	10.0
20946	Cole Park North	34	<10	7700	28.0	17.7
20947		34	<10	7700	24.7	13.5
20948		34	<10	8160	19.4	12.7
21050		5	<10	393	20.8	10.0
20949	Cole Park Pier	12	<10	1840	36.0	26.6
20950		12	<10	2310	18.3	11.2
20951		12	<10	1110	18.0	10.0
21051		3	<10	539	37.5	10.0
20952	Cole Park Louisiana	34	<10	>24196	101.6	35.4
20953		34	<10	>24196	46.2	13.2
20954		34	<10	>24196	35.0	16.3
21052		5	<10	3650	32.5	10.0
20955	Cole Park Oleander Point	34	<10	8160	73.5	23.0
20956		34	<10	14100	47.6	16.5
20957		34	<10	19900	31.0	11.9
21053		5	<10	3080	31.5	10.0
20958	Ropes Park	34	<10	>24196	81.9	28.2
20959		34	<10	13000	71.2	28.0
20960		34	<10	17300	57.1	17.5
21054		5	<10	>24196	73.1	10.0
20961	Poenisch Park	34	<10	>24196	51.8	19.6
20962		34	<10	12000	36.0	10.8
20963		34	<10	8200	28.6	13.7
21055		5	<10	41	17.5	10.0
20964	University Beach	34	<10	570	29.9	19.4
20965		34	<10	620	20.6	12.6
20966		34	<10	788	24.2	14.9
21056		5	<10	<10	<10.0	<10.0

While the geometric mean of 35 MPN/100 ml for routinely monitored bacteria data in tidal water is not applicable for recreational beaches it still is a useful gauge for evaluating the data. While the geometric mean of values recorded at sampling stations in 2011 did not exceed 35 MPN/100 ml (Table 4.3 and Fig. 4.3), increased rainfall event sampling in 2012 revealed multiple stations with geometric mean concentrations exceeding 35 MPN/100 ml, specifically at Cole Park, Ropes Park, and Poenisch Park (Table 4.4 and Fig. 4.3). When all station data at a location were grouped together, the data continues to indicate that *Enterococcus* concentrations increase as you move closer to Cole and Ropes Parks and clearly show the elevated values seen in 2012 (Fig. 4.3)

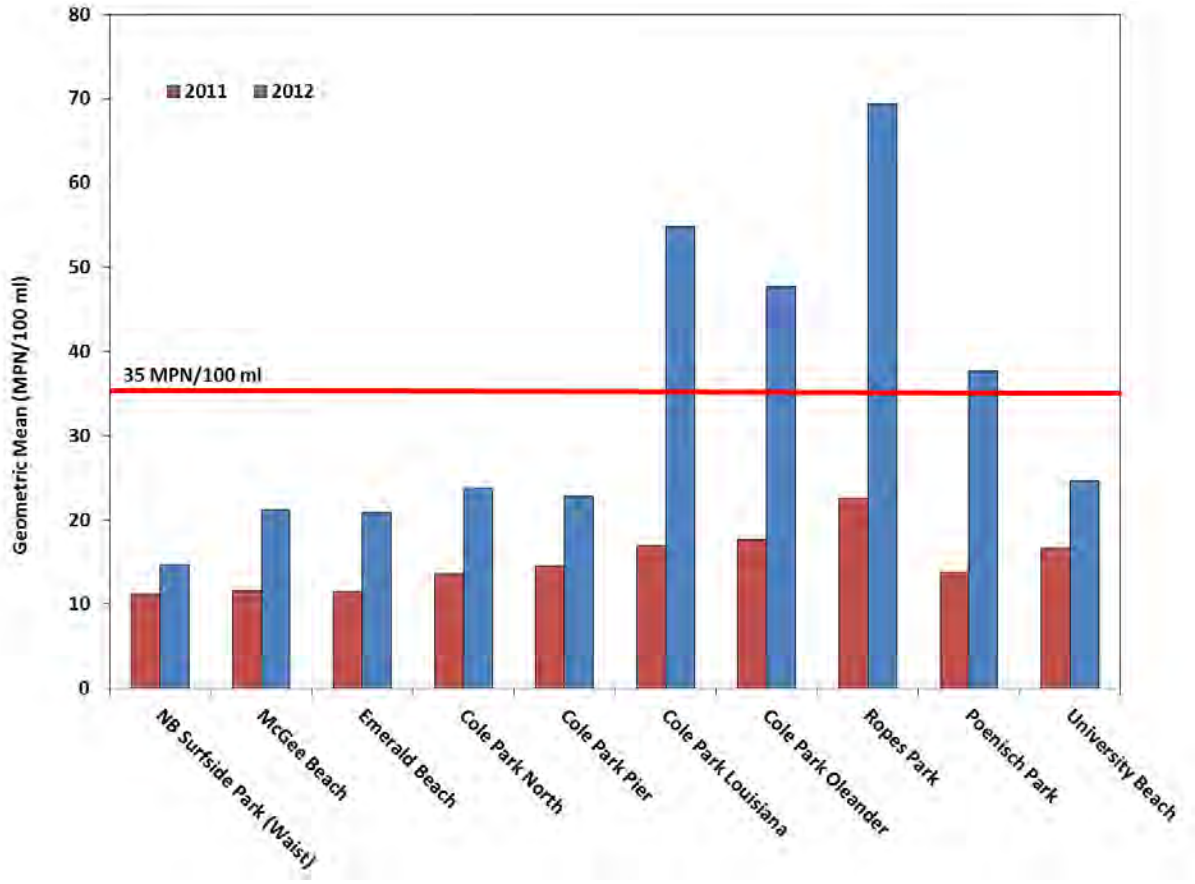

Fig. 4.3. Geometric mean of all *Enterococcus* concentrations (MPN/100 ml) at nearshore sampling locations for 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

Out of 1470 *Enterococcus* samples collected at the 30 nearshore locations in 2011, the single sample criteria of 104 MPN/100 ml was exceeded 87 times (5.9%). May 2011 was highest month with 36 (41.4%), followed by June with 27 (31.0%), and August with 24 (27.6%). No exceedances were recorded in July 2011. Cole Park (all stations combined) and Ropes Park had the highest number of exceedances in the 2011 or Year-one sampling period (Fig. 4.4).

In Year-two, 954 *Enterococcus* samples were collected for the 2012 sampling period and the single sample criteria was exceeded 180 times (18.9%). Higher numbers relate directly to increased numbers of rainfall event sampling in 2012. All six months had single sample criteria exceedances with February 2012 having 6 (3.3%), followed by March with 38 (21.1%), April with 46 (5.6%), May with 30 (16.7%), June with 56 (31.1%), and July with 4 (2.2%). As seen in 2011, Cole Park and Ropes Park had the highest number of single sample exceedances in 2012 followed by Poenisch Park and University Beach (Fig. 4.4).

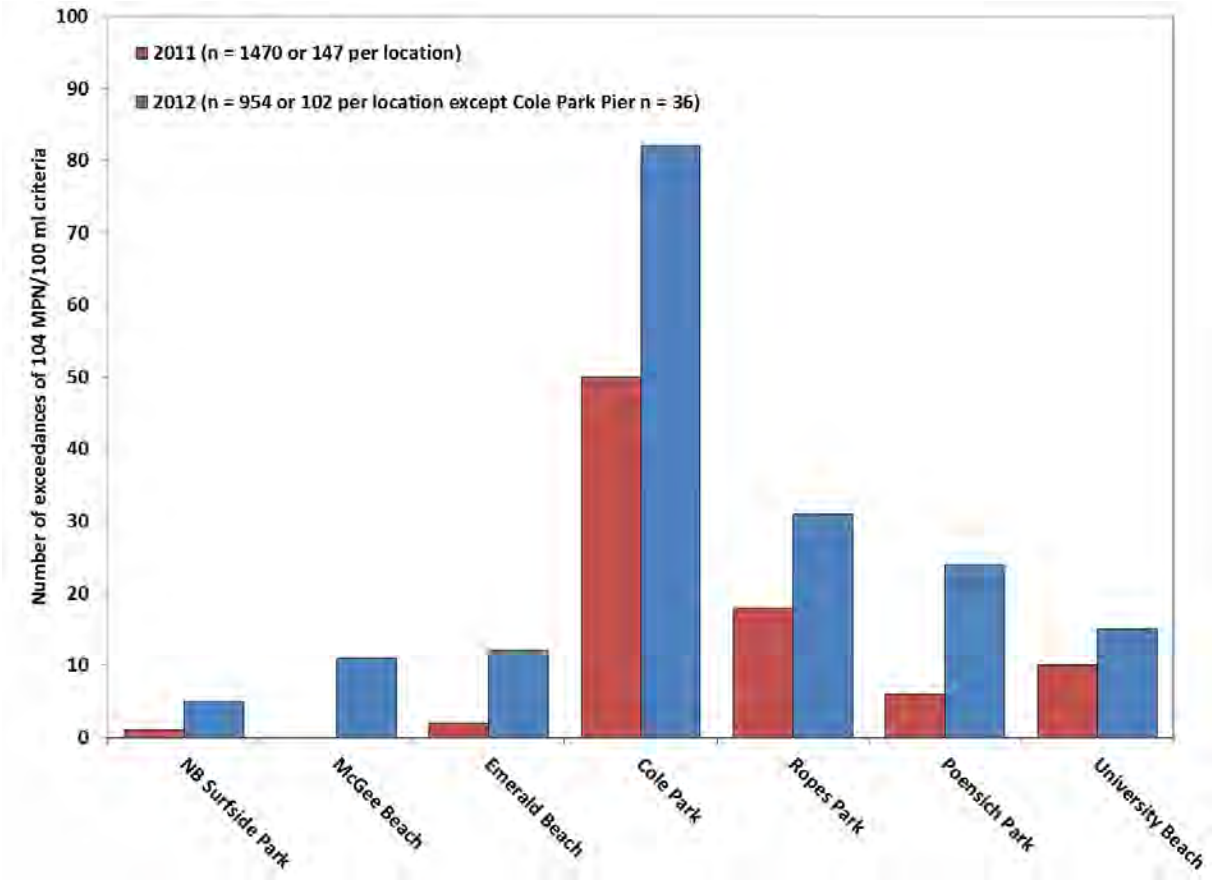

Fig. 4.4. Number of all exceedances of the single sample criteria of 104 MPN/100 ml at nearshore sampling locations (Cole Park locations combined) for 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

In 2011, Ropes Park had the highest percentage of single sample exceedances when viewed by individual location, followed by Cole Park Oleander Point and Cole Park Louisiana (Fig. 4.5). There were no single sample exceedances at McGee Beach, which is the most utilized public beach in the downtown area. In 2012, increased rainfall event sampling showed higher percentages of single sample exceedances at all locations, with Cole Park Oleander Point producing the highest percent of single sample criteria exceedances followed by an equal number of single sample exceedances at Cole Park Louisiana and Ropes Park (Fig. 4.5). In addition, Poenisch Park continues to produce a significant number of single sample criteria exceedances.

Evaluating the data for 2011 based on the assessment scheme utilized by the TBWP 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. In 2012, these percentages were 69.9%, 11.2%, and 18.9%, respectively.

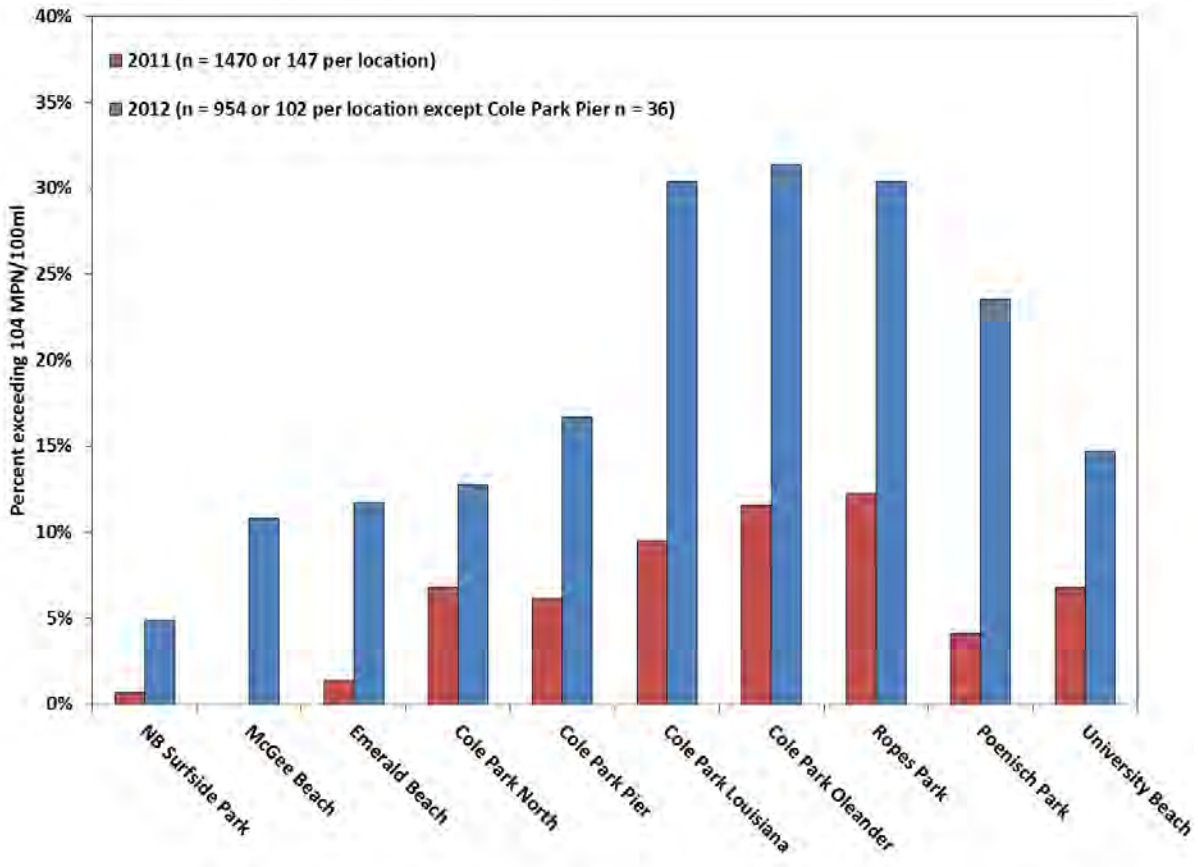

Fig. 4.5. Percentage of samples exceeding single sample *Enterococcus* criteria of 104 MPN/100 ml at nearshore sampling locations for 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

As stated before, the actual regulatory assessment is based on exceedances of the >104 MPN/100 ml criterion and number of advisory days issued by the Texas Beach Watch Program for a particular location. If multiple samples are collected at a location, such as at Cole Park, then only one advisory day is issued regardless of multiple samples exceeding the criterion. For Clean Water Act 303(d) assessment purposes, the TCEQ in turn calculates the percentage of days that resulted in advisories by dividing the number of advisory days by the number of sampling days.

Assessments are typically conducted for longer periods of record, but a limited assessment of the data collected for the current TMDL project shows that for the 2011 sampling period Cole Park, as expected, had the highest percentage of advisory days followed by Ropes Park, and University Beach (Fig. 4.6). Based on Recreational Beach Assessment methods contained in TCEQ *2010 Guidance for Assessing and Reporting Surface Water Quality in Texas*, the number of 2011 beach advisories for Cole Park was between 20% and 25% indicating a "concern but fully supporting" the Recreational Beach criteria. However, applying the assessment method to samples collected in 2012 produces beach advisories ≥ 25% of the time or "Not Supporting" the Recreational Beach criteria at not only Cole Park, but at Ropes Park, Poenisch Park, and Emerald Beach as well (Fig. 4.6). When combining all advisory days issued over the two sampling years only Cole Park and Ropes Park exceed the >25% criteria with advisory days occurring 37.3% and 25.3% of the time, respectively.

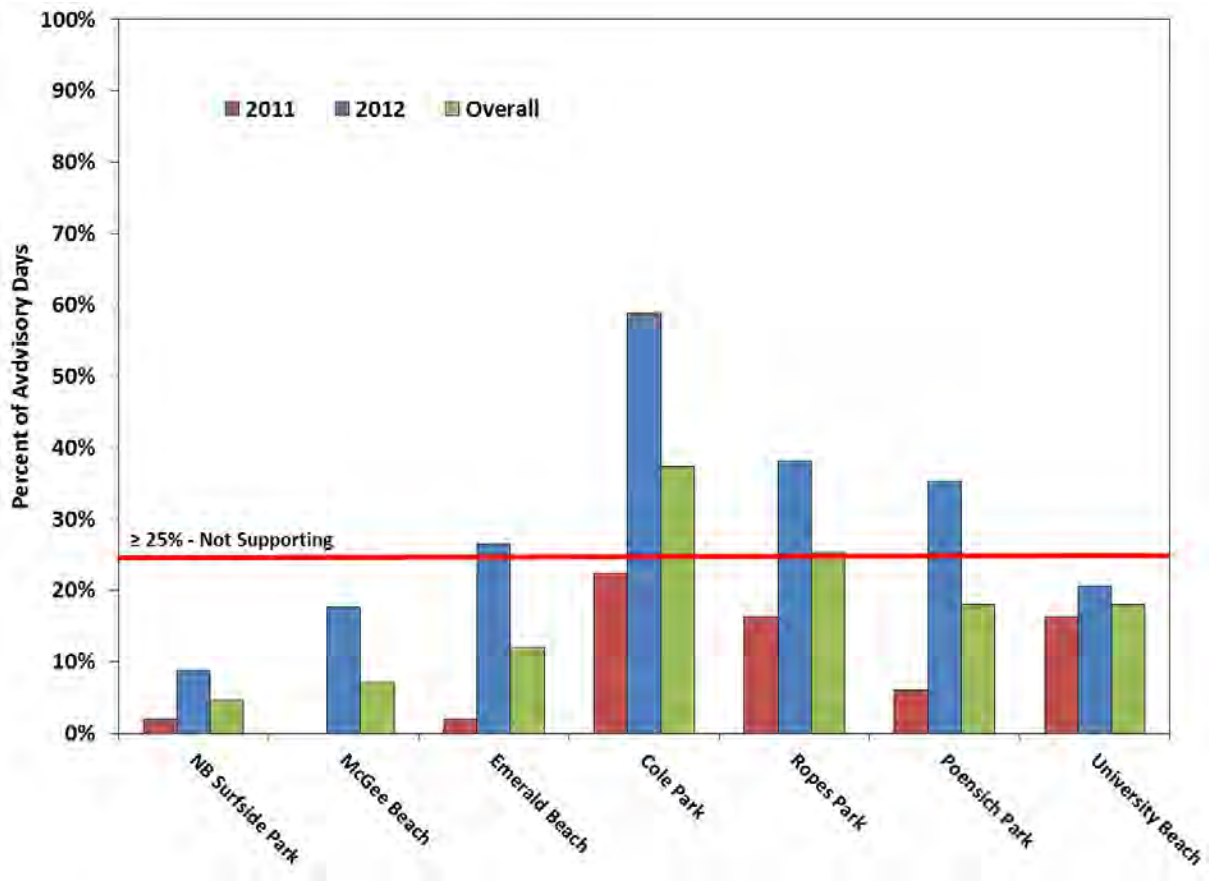

Fig. 4.6. Percentage of advisory days issued at nearshore sampling locations (Cole Park locations combined) for 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

As discussed, sources such as polluted stormwater runoff, wastewater overflows, boating wastes, and malfunctioning septic systems may carry microorganisms from fecal material into the environment and produce high pathogen concentrations in the water column. Besides humans, it may indicate contamination by fecal matter originating from other warm-blooded animals (i.e. domestic dogs, birds, etc.).

Analysis of data for the 6/21/2012 through 6/23/2012 rainfall sampling event showed the effect that stormwater runoff has on these urban beach/public access locations. Sampling took place directly at the outfall and along a nearby transect at <12 hours after rainfall began and then again at approximately 24 and 48 hours after the first samples were collected. Average rainfall for the five weather stations combined was 1.15 inches. However, the Morningside station, located 0.75 miles from Cole and Ropes Park, recorded 1.57 inches on that day so the average rainfall amount is probably a conservative estimate.

The first samples of stormwater collected during the 6/21-23/2012 rainfall event produced *Enterococcus* concentrations >24,196 MPN/100 ml at all stormwater outfalls and at points offshore along the sampling transect (Figs. 4.7 through 4.11). Most notable was the Ropes Park sampling location where elevated concentrations extended all the way to the offshore sampling point approximately 500 meters from the outfall (Fig. 3.5 and Fig. 4.9). This is most likely due to the contributions from the Brawner Parkway outfall located approximately 350 meters to the south of Ropes Park, which showed elevated concentrations. Typically, flow from this outfall would be pushed offshore in the general direction of all the Ropes Park stations (Fig. 3.5 and Fig. 4.10). As no sampling occurred at the Ropes Park outfall after the first day, due to no observable flow coming through the pipe, the Brawner Parkway outfall seems the likely source of continued elevated concentrations at Ropes Park.

Poenisch Park also produced three days of >24,196 MPN 100/ml concentrations at the stormwater outfall located in the park, but flow was minimal, as evident by the rapidly dropping concentration levels seen nearshore and offshore (Fig. 4.11). This location was the only site to have <104 MPN/100 ml concentrations by the third day. While the impact of the Carmel Parkway and South Shore Place stormwater outfalls on these sampling locations is yet to be determined, continued elevated *Enterococcus* concentrations for extended periods of time following a rainfall event are evident at these locations (Fig. 3.6 and 4.11).

A plot of the time series of all nearshore samples collected for each location for both years is shown in Figs. 4.12 through 4.21. While several random spikes in elevated bacteria concentrations occur at some locations during non-rainfall events, it is evident the impact that rainfall and subsequent runoff have in elevating *Enterococcus* concentrations in Corpus Christi Bay, especially at the locations where outfalls exist (Figs. 4.17 through 21).

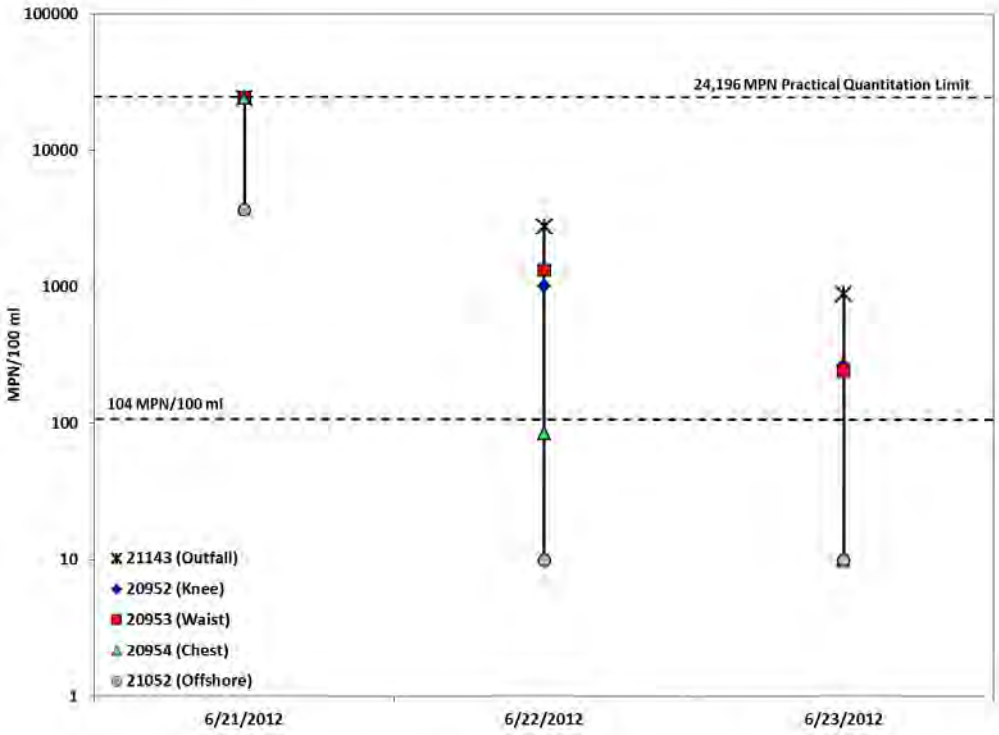

Fig. 4.7. *Enterococcus* concentrations (MPN/100 ml) starting at the Cole Park Louisiana outfall and proceeding offshore along the sampling transect located to the east of the outfall for the 6/21/2012 through 6/23/2012 rainfall sampling event.

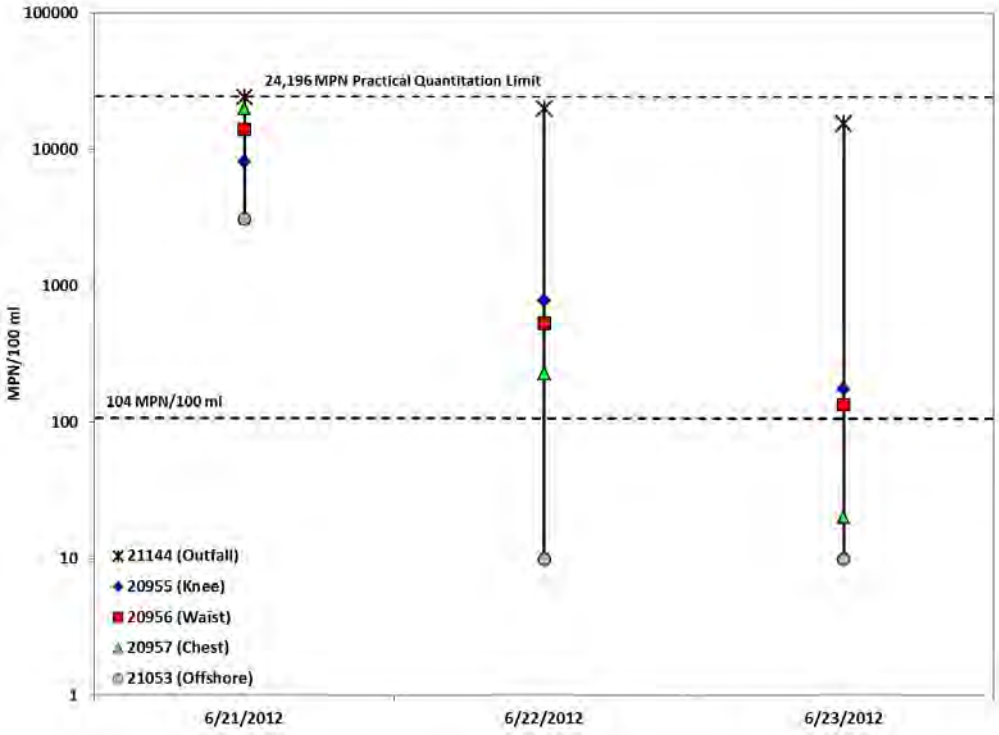

Fig. 4.8. *Enterococcus* concentrations (MPN/100 ml) starting at the Cole Park Oleander Point outfall and proceeding offshore along the sampling transect located adjacent to the outfall for the 6/21/2012 through 6/23/2012 rainfall sampling event.

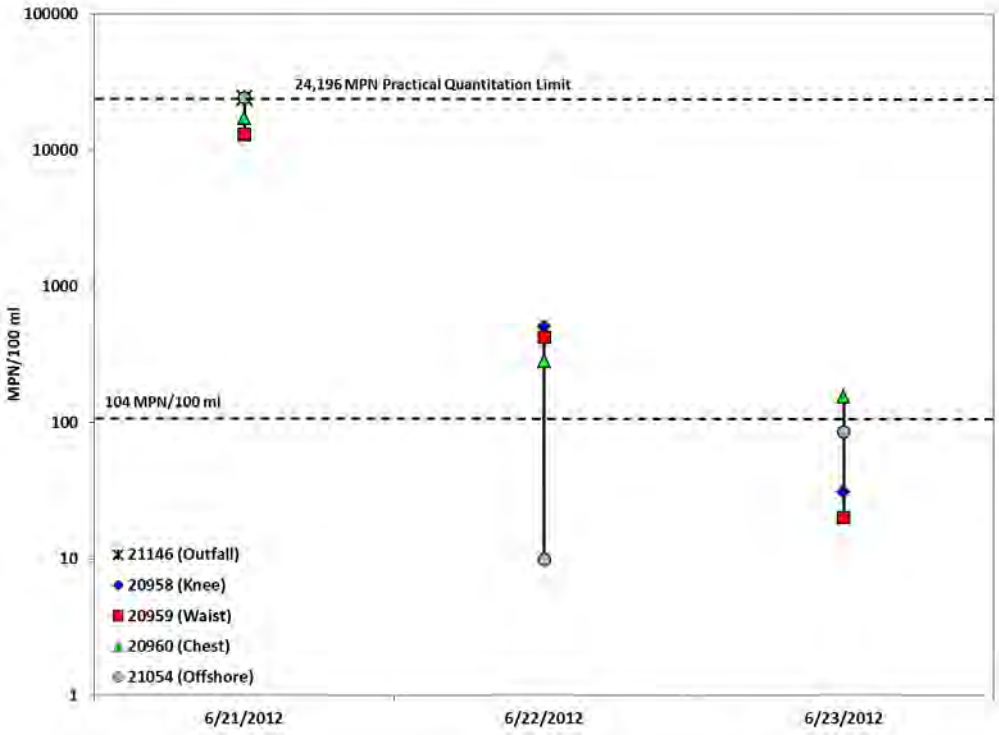

Fig. 4.9. *Enterococcus* concentrations (MPN/100 ml) starting at the Ropes Park outfall and proceeding offshore along the sampling transect located adjacent to outfall for the 6/21/2012 through 6/23/2012 rainfall sampling event.

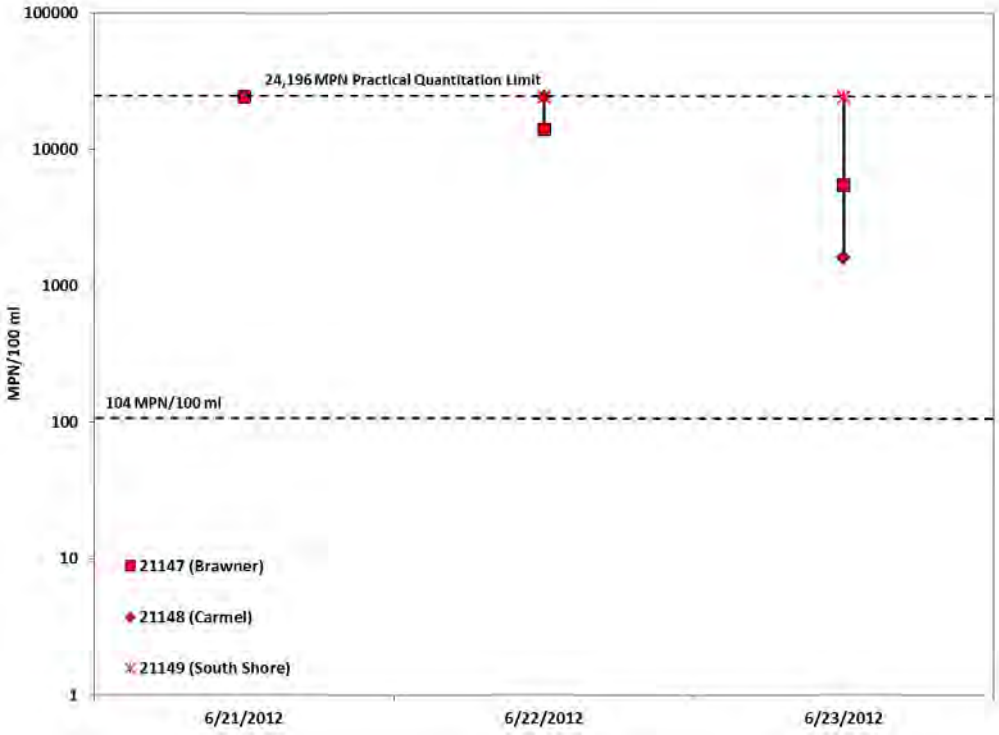

Fig. 4.10. *Enterococcus* concentrations (MPN/100 ml) at the Brawner Parkway, Carmel Parkway, and South Shore Place outfalls for the 6/21/2012 through 6/23/2012 rainfall sampling event.

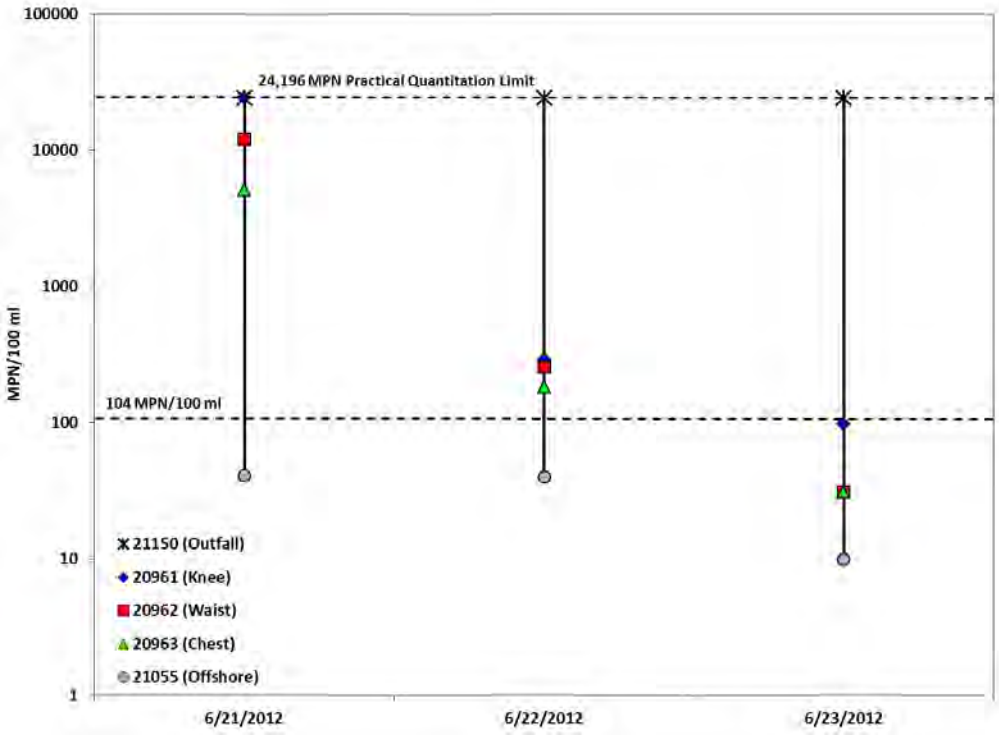

Fig. 4.11. *Enterococcus* concentrations (MPN/100 ml) starting at the Poenisch Park outfall and proceeding offshore along the sampling transect located on the beach adjacent to outfall for the 6/21/2012 through 6/23/2012 rainfall sampling event.

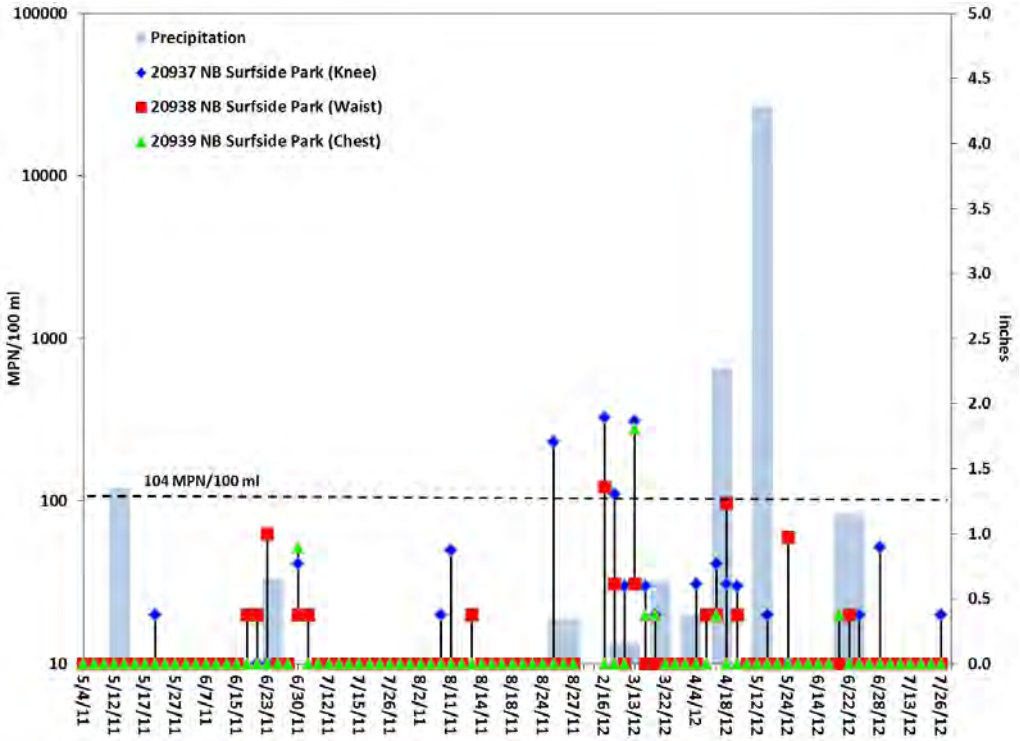

Fig. 4.12. *Enterococcus* concentrations (MPN/100 ml) at North Beach-Surfside Park nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

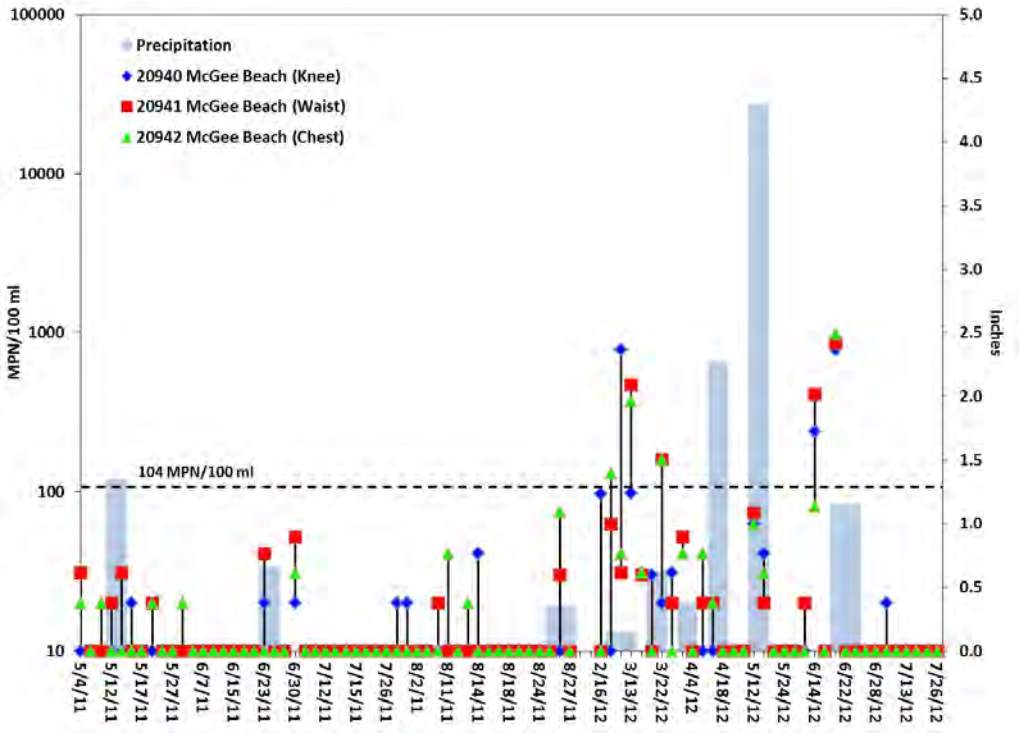

Fig. 4.13. *Enterococcus* concentrations (MPN/100 ml) at McGee Beach nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

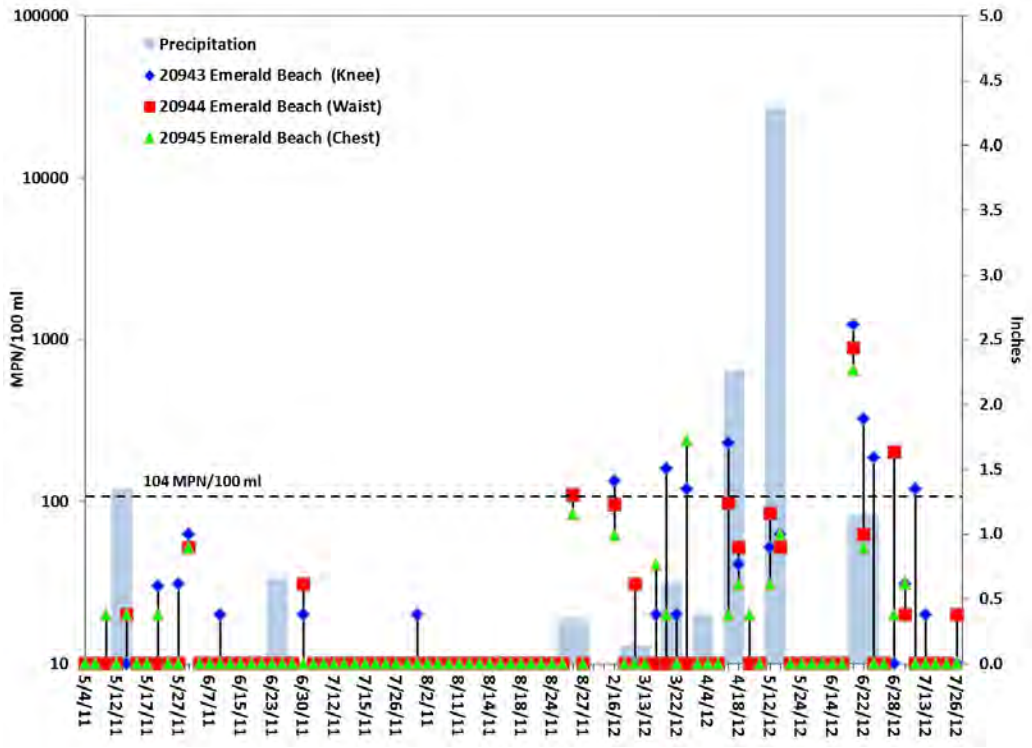

Fig. 4.14. *Enterococcus* concentrations (MPN/100 ml) at Emerald Beach nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

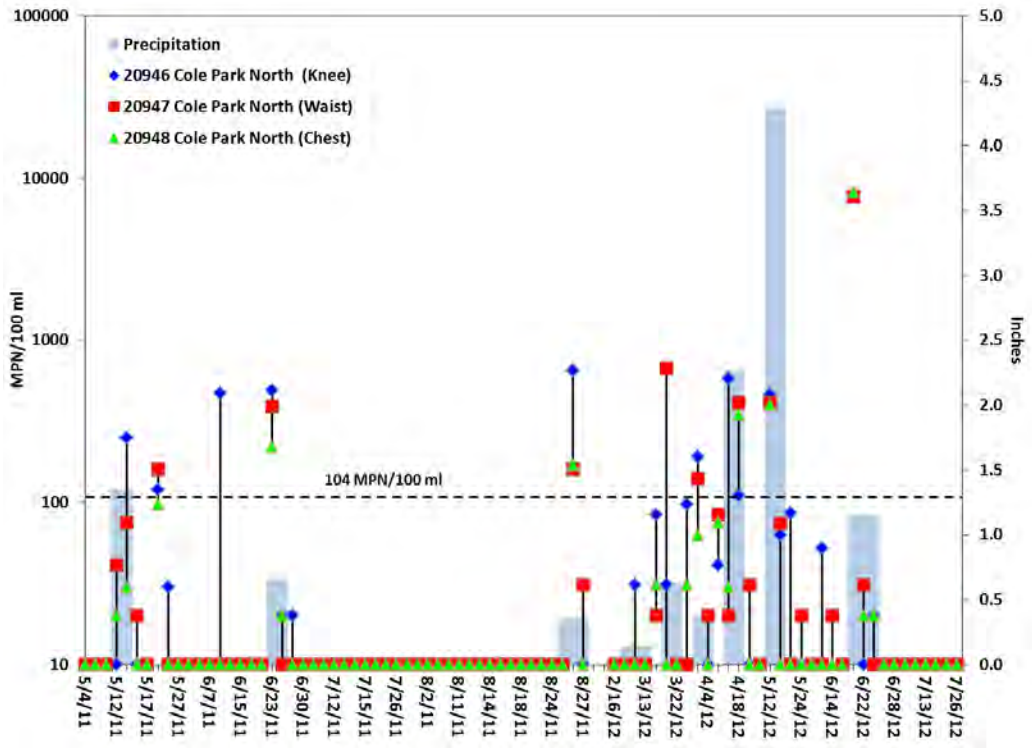

Fig. 4.15. *Enterococcus* concentrations at (MPN/100 ml) Cole Park North nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

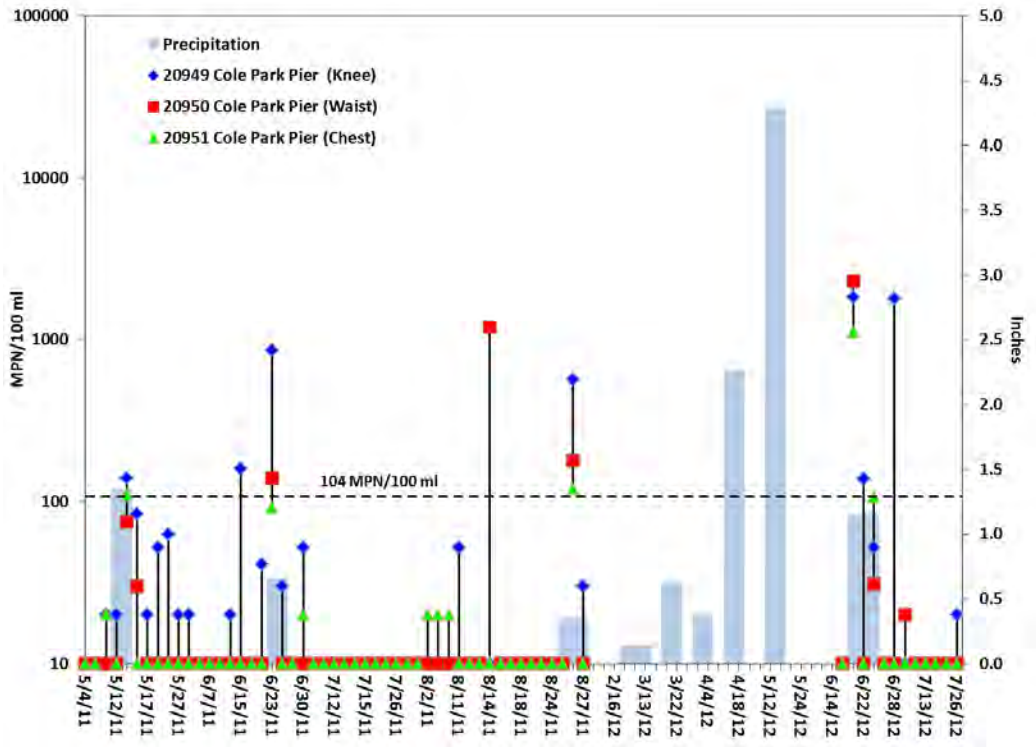

Fig. 4.16. *Enterococcus* concentrations (MPN/100 ml) Cole Park Pier nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 6/18/2012 through 7/26/2012 (Year 2).

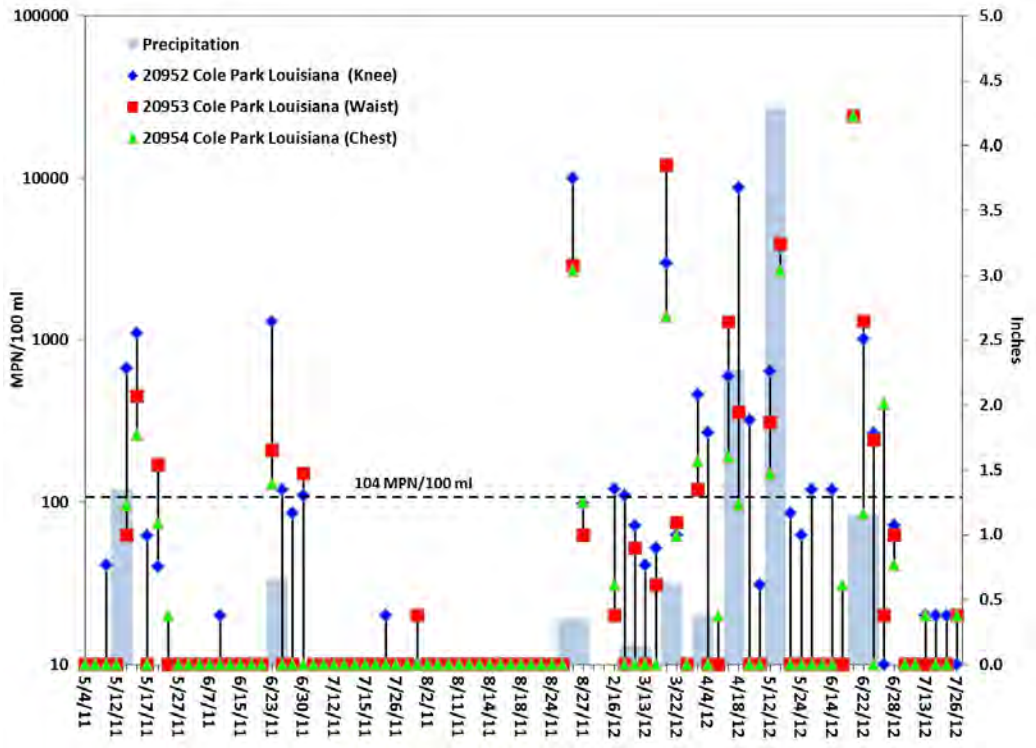

Fig. 4.17. *Enterococcus* concentrations (MPN/100 ml) at Cole Park Louisiana nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

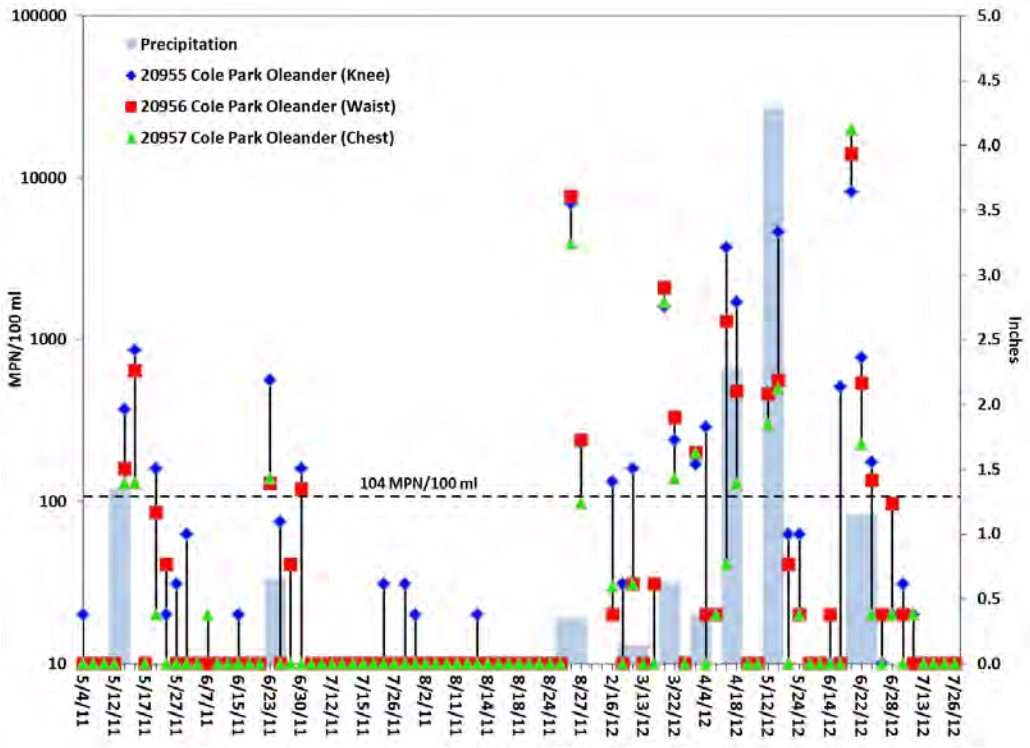

Fig. 4.18. *Enterococcus* concentrations (MPN/100 ml) at Cole Park Oleander Point nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

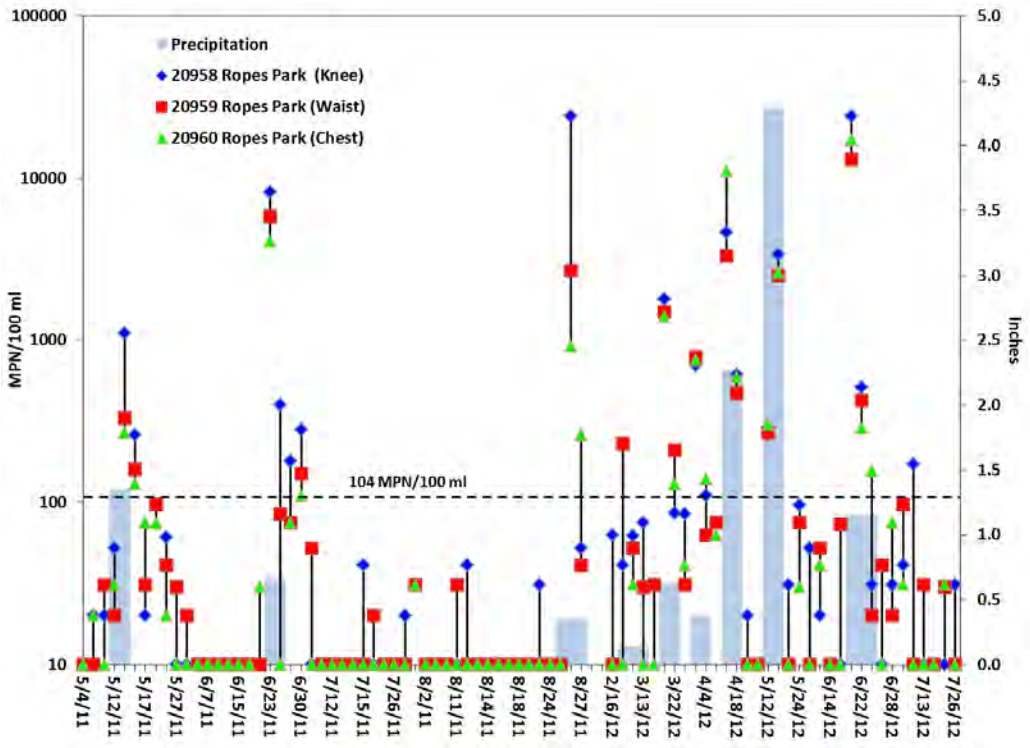

Fig. 4.19. *Enterococcus* concentrations (MPN/100 ml) at Ropes Park nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

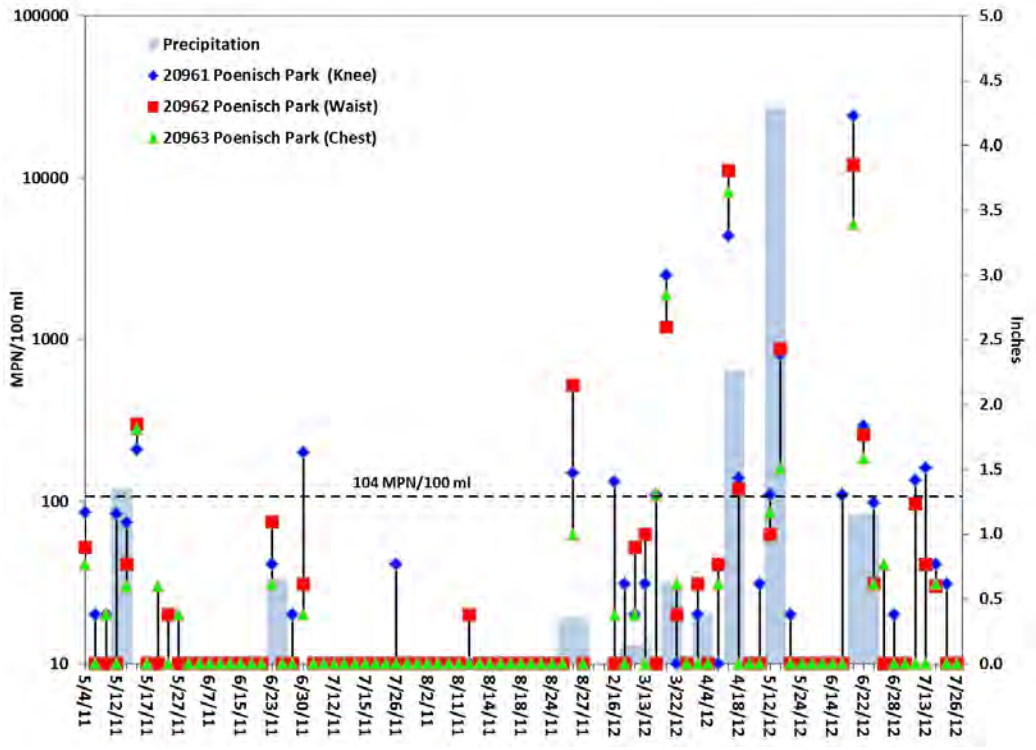

Fig. 4.20. *Enterococcus* concentrations (MPN/100 ml) at Poenisch Park nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

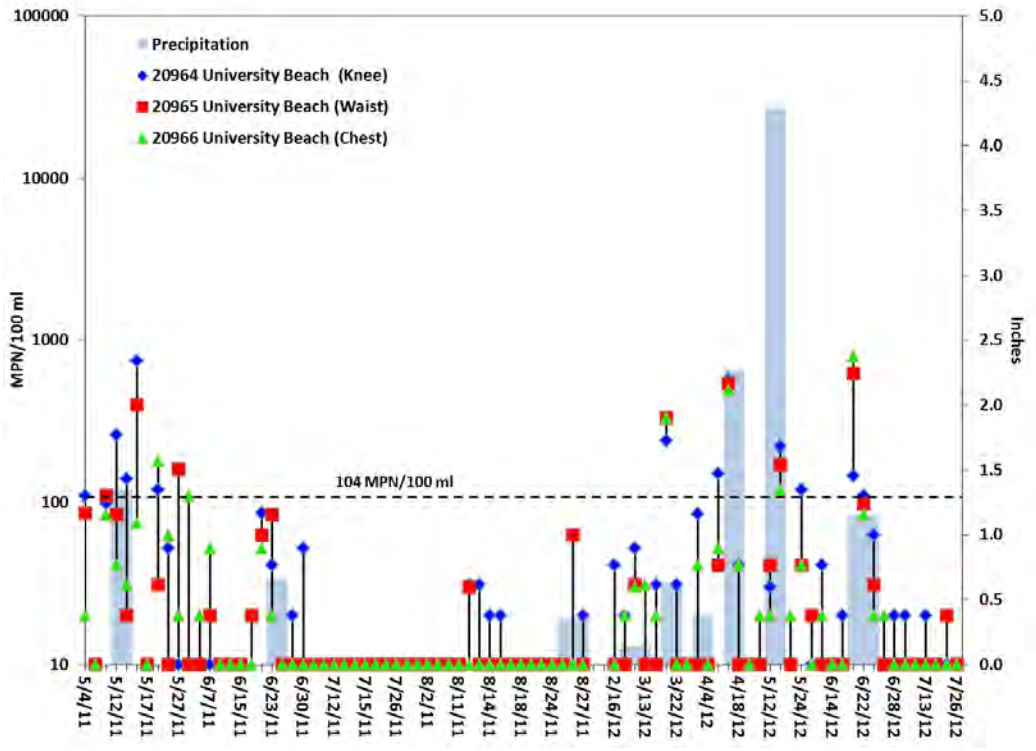

Fig. 4.21. *Enterococcus* concentrations (MPN/100 ml) at University Beach nearshore stations from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

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 in Year-one. 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. In Year-two there were 36 samples collected for the four sampling events.

Typically, sediment sampling showed very little *Enterococcus* bacteria in the sediments at most locations. Except for the four samples collected at Emerald Beach and one each at and McGee Beach, Cole Park North, and Cole Park at Oleander Point all concentrations were <13 MPN/100 ml (Table 4.14). Higher concentration at Emerald Beach, a beach utilized by guests of the adjacent hotel, on 6/27/2012 could not be correlated with any known event. For the three previous water sampling events, bacteria concentrations were not elevated in the water column on the day of sampling, and on 6/27/2012 *Enterococcus* concentrations were <10 MPN/100 ml at the sampling station closest to the beach. However, rain event sampling at the "knee", "waist", and "chest" water locations did occur the previous week on 6/21/2012 through 6/23/2012 in which *Enterococcus* concentrations were 1240, 323, and 187 MPN/100 ml for each day, respectively.

One aspect of Emerald Beach that is different from all other sampling locations, except University Beach, which does not attract as many people, is protection from excessive wave action afforded by a breakwater. This reduction in sediment perturbation may allow bacteria to colonize sediments rather than be re-suspended.

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 for the four events in Year-one and four events in Year-two.

Sampling Location	5/12/11	6/15/11	7/13/11	8/5/11	3/15/12	5/31/12	6/14/12	6/27/12
North Beach Surfside Park	<10	<10	<10	<10	<12	<11	<11	<12
McGee Beach	<10	30	<10	<10	<12	<12	<12	<13
Emerald Beach	<10	<10	<10	385	<13	53	52	801
Cole Park North	<10	<10	<10	<10	<13	39	<12	<13
Cole Park Pier	<10							
Cole Park Louisiana	<10	<10	<10	<10	<11	<13	<12	<12
Cole Park Oleander Point	<10	<10	<10	27	<11	<12	<12	<11
Ropes Park	<10	<10	<10	<10	<13	<12	<12	<12
Poenisch Park	<10	<10	<10	<10	<13	<13	<13	<12
University Beach	<10	<10	<10	<10	<12	<11	<11	<13

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 categorize their activity in the park, beach, and water. Data indicated the three public beach areas (North Beach-Surfside Park, McGee Beach, and Emerald Beach) had the highest number of people observed on the beach and in the water for both Year-one and Year-two (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).

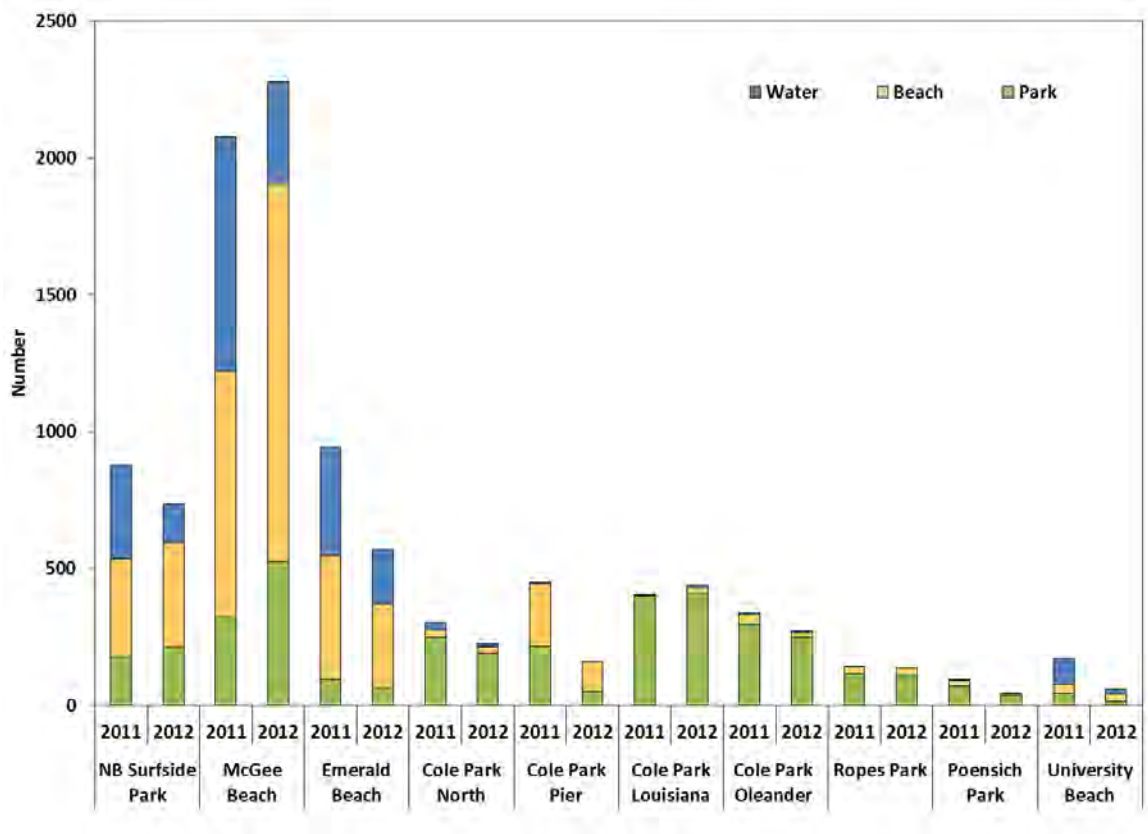

Fig. 4.21. Total number and location of people observed at each location from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

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 stormwater 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, nesting, and mating was highest at this location and is the only location where active nesting occurred (Fig. 4.22). However, high numbers of birds observed at University Beach did not correlate with increased concentrations of bacteria in the water.

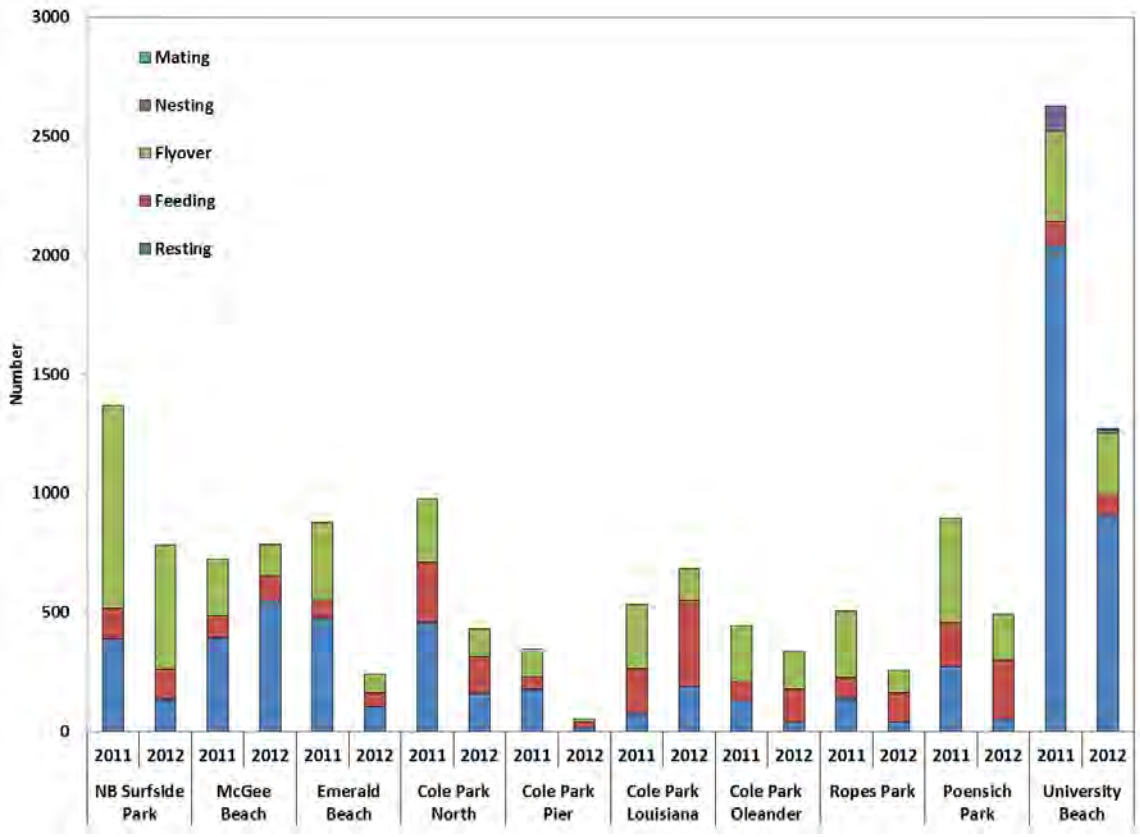

Fig. 4.22. Total number of birds and bird activity observed at each location from 5/4/2011 through 8/27/2011 (Year 1) and 2/16/2012 through 7/26/2012 (Year 2).

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 outfall discharge or by littering provides a medium where bacteria can survive and reproduce. Field investigations in California showed the wrack line in beaches in Southern California acted as a bacterial reservoir that can affect beach water quality (Martin and Gruber 2005).

The least amount of debris found on beaches was the locations routinely cleaned by City of Corpus Christi Park Department employees or personnel from nearby hotels. 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 (Fig. 4.23 and Fig. 4.24). Grass clippings from residential neighborhoods were most prevalent at the Ropes Park location in Year-one, representing 10.8% of the debris surveyed. In Year-two, grass clippings were highest at the Cole Park Louisiana location representing 38.8% and at Ropes Park representing 14.9% of the debris found (Fig. 4.24).

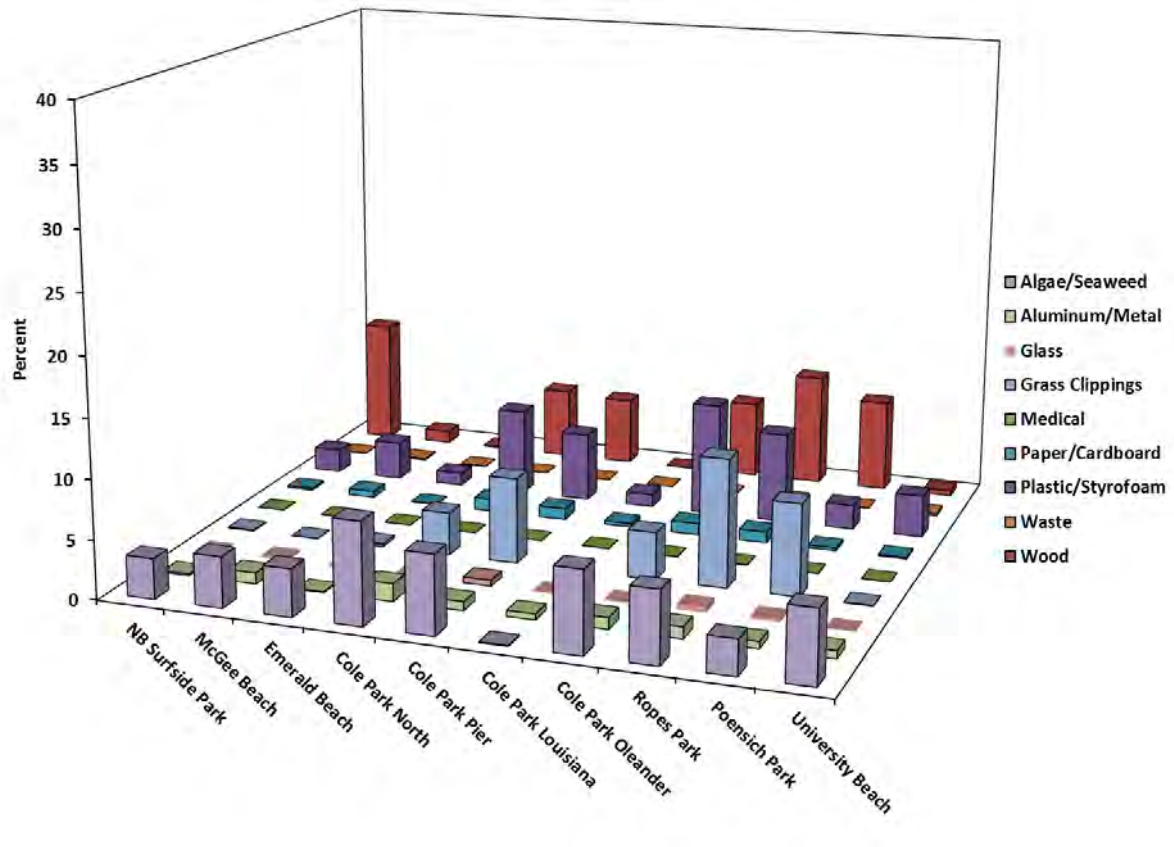

Fig. 4.23. Percent of debris observed at each location in Year-one (5/4/2011 through 8/27/2011).

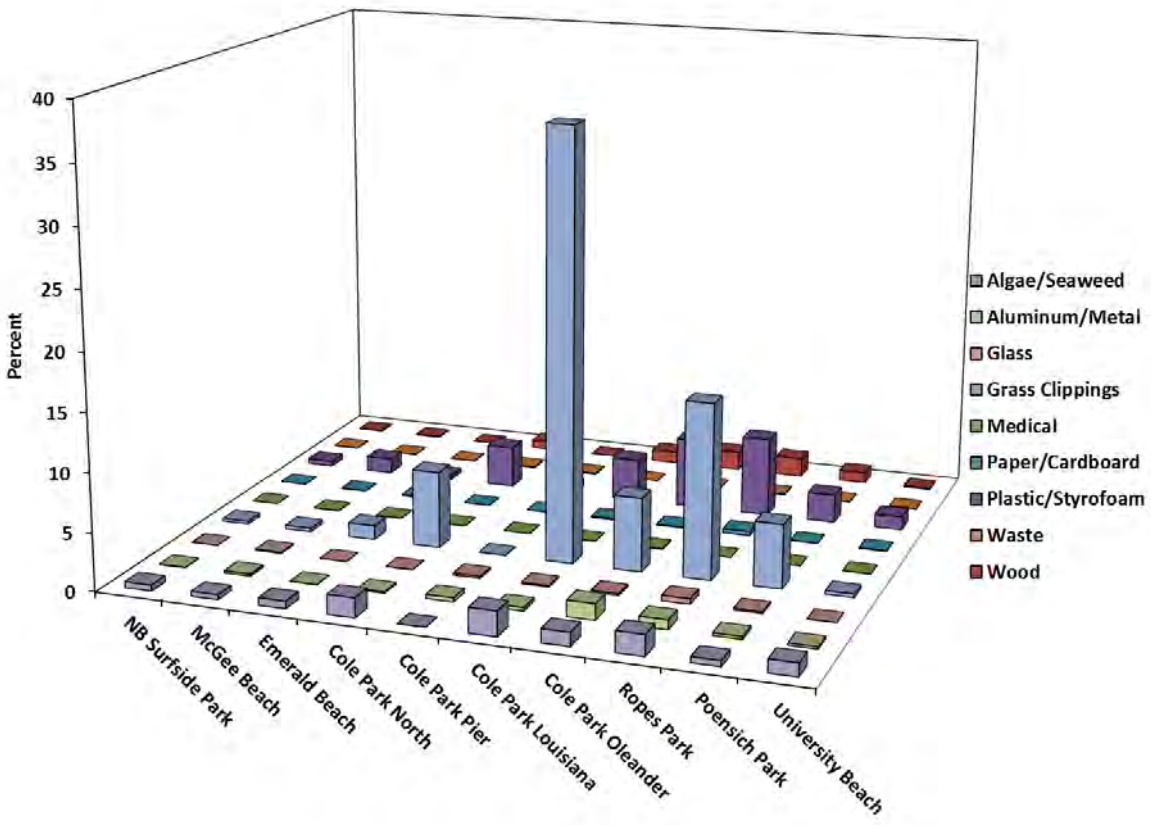

Fig. 4.24. Percent of debris observed at each location in Year-two (2/16/2012 through 7/26/2012).

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