Oso Creek and Oso Bay Bacteria
Total Maximum Daily Load Model
Final Report

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Executive Summary

The objective of this project was to calculate current loading, allowable load and load reductions of the fecal indicator bacteria *Enterococcus* in the Oso Creek/ Oso Bay hydrologic system using a calibrated numerical model. This project supports the first phase of a Total Maximum Daily Load program for Oso Creek and Oso Bay.

Water quality parameters were collected from May 19, 2005 through June 8, 2006 and the numerical model created in Work Order 1 was refined to better fit the observed data. Model revision included separate decay rates for freshwater and saltwater, the inclusion of dry day loading to represent an unknown flux that contributes to high bacteria concentrations unrelated to runoff or known point sources, and the use of event concentrations to represent bacteria concentrations in the runoff (first flush) rather than average decayed concentrations found in channel flow. These modifications improved the RMSE (a statistical measure of model accuracy) from 2.1 log(concentration) to 0.68 log(concentration), well within the environmental variability of the collected samples. This provided a tool that could be used to create an unbiased dataset of *Enterococcus* concentrations and loadings.

Current loading was determined in a model simulation of conditions over the watershed during the same period as the data collection period. Allowable loads were calculated using the numerical model in an iterative fashion beginning with the upper most station and moving progressively downstream until *Enterococcus* concentrations met water quality goals at each station. At each station, first the dry day loading was removed and then the contribution from runoff was reduced. Point sources were not substantial enough to effect overall loadings.

The required load reduction was calculated as the difference between the current loading and the allowable loading. With the exception of station 13441, there were no load reductions required in Oso Bay to meet water quality goals. Data for station 13441 indicate that it is not representative of Oso Bay, behaving more as a tributary to the bay. Removal of dry day loads from this subbasin reduced *Enterococcus* loading enough to meet water quality goals. Water quality objectives for Oso Creek may be met by removing dry day loadings for all creek subbasins, and then reducing the non-point source (runoff) loadings in 4 of the subbasins: 18499 by 93%; 18500 by 90%; 16712 by 90%; and 13027 by 50%.

Dry day loading is a small but critical element in the bacteria loading of Oso Creek, however its source is currently unknown. Identification of the source or sources of the dry day loading is crucial in developing and implementing a load reduction strategy for Oso Creek.

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1 Introduction

The Clean Water Act (CWA), which has developed over the past thirty years, outlined the need for water quality standards to ensure the health and safety of the public. To satisfy this need, the CWA requires states to establish and enforce these water quality standards. These water quality standards deal primarily with the quantity of anthropogenic pollutants that may be discharged into the nations water bodies. Under the CWA each state is required by law to periodically evaluate waters using designated uses, standards and screening procedures established and adopted by the states. Those bodies that do not support the designated uses are classified as impaired. A state responsible for an impaired water body is required by the CWA to initiate a Total Maximum Daily Load (TMDL) program. The purpose of a TMDL is to determine the maximum amount or load of a pollutant that a water body can receive daily and still support its beneficial uses. The end goal of the TMDL program is attainment of water quality standards by allocating the allowable load among all potential sources.

The Texas Commission for Environmental Quality (TCEQ), formerly the Texas Natural Resource Conservation Commission (TNRCC), is responsible for the identification and remediation of all surface waters in the state of Texas that do not meet the water quality standards. As part of this responsibility, the TCEQ is establishing TMDL programs for all impaired waters in the state of Texas. As the TMDL process proceeds, the TCEQ develops an implementation plan to address excess loading in the affected water bodies.

1.1 Objectives

Oso Creek and Oso Bay (segment 2485A and segment 2485 respectively, Figure 1) have been placed on the 2004 Texas Water Quality Inventory and the 303d list of impaired waters for not meeting contact recreation single sample criteria of no more than 25% of the measured values exceeding 104 cfu/100ml, or the geometric mean criteria of 35 cfu/100ml for the indicator bacteria *Enterococcus*. The Total Maximum Daily Loads (TMDL) process has been implemented to improve water quality in impaired waters so that they will meet their designated use criteria. This process consists of three parts: determination of current loadings, allowable loadings, and load reduction; stakeholder development of strategies to meet the required load reduction; and implementation of the load reduction strategies.

This work order (W.O. #2) authorized the continuation of field sampling for the measurement of bacteria concentrations (*Enterococcus*) in Oso Creek and Oso Bay through June 8, 2006 and the continued development of the numerical bacteria loading model to capture new insights into the source, transport and fate of bacteria in this hydrologic system. The overall objectives of the modeling effort are to calculate current loadings, allowable loads, and load reductions (where applicable) of *Enterococcus* bacteria in the Oso Creek/Oso Bay hydrologic system so that water quality goals for these segments will be met.

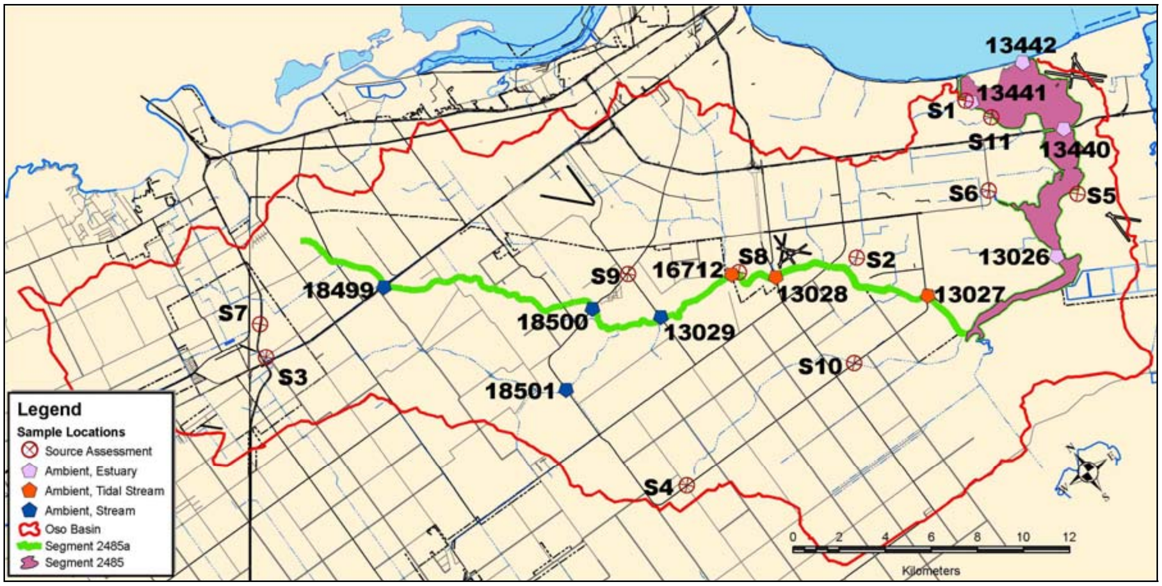

Figure 1. Oso Creek Watershed Segments 2485 and 2485a.

2 Review of collected data

Field data were collected in Oso Creek and Oso Bay for eleven ambient monitoring sites and eleven targeted sites from September 1, 2005 through June 8, 2006 under Work Order 2 (W.O. #2) and from May 19, 2005 through August 31, 2005 under Work Order 1 (W.O. #1), together providing water quality data on 24 parameters (Table 1) for 47 sampling events. Different collection intervals were used during this time span to facilitate the observation patterns that may have been of interest. Initially (under W.O. #1) weekly samples were collected. With the start of the W.O. #2 samples were collected on a monthly interval with the provision to monitor at increased frequency (daily) during three significant rain events. The influence of migratory birds and colder temperature are considered to have a significant effect on bacteria concentrations and so W.O. #2 provided for increased temporal sampling over part of these occurrences to gain more insight into the magnitude of these effects on bacteria loading and survival in the Oso Watershed.

The collected data thus presented information on various climatic environments. Four rain events were sampled (6/1/2005 through 6/4/2005, 10/12/2005 through 10/16/2005, 11/27/2005 through 12/1/2005, and 6/1/2006 through 6/8/2006) providing runoff data for 19 sampling events of both targeted and ambient stations. There were 23 dry period events sampling only ambient stations and two dry events that sampled both ambient and targeted stations. Increased (weekly) sampling frequency of ambient stations occurred during part of the migratory season (December 1, 2005 through December 22, 2005) and over cold weather (February 9, 2006 through March 2, 2006).

2.1 General water quality parameters

Water temperature (parameter code 00010) ranged from a low of 8.1°C during the winter months to a high of 33.1°C in the summer for all stations over the period of measurement with a mean value of 24.2°C. Water temperature in the Oso Creek segment (2485a) was slightly cooler, with a mean temperature of 23.3°C, compared to the Oso Bay segment

PARAMETER	UNITS	CODE
Temperature, Water	*degrees centigrade*	*00010*
Temperature, Air	*degrees centigrade*	*00020*
Flow Stream, Instantaneous	*cubic feet per sec*	*00061*
Transparency, Secchi Disc	*meters*	*00078*
Specific Conductance, Field	*uS/cm*	*00094*
Oxygen, Dissolved	*mg/l*	*00300*
PH	*Standard units*	*00400*
Salinity	*ppt*	*00480*
Flow Severity	*1=no flow, 2=low, 3=normal, 4=flood, 5=high, 6=doppler*	*01351*
Enterococci	*#/100ml*	*31649*
Days Since Precipitation Event	*days*	*72053*
Stream Flow Estimate	*cfs*	*74069*
Rainfall In 1 Day Inclusive Prior To Sample	*inches*	*82553*
Rainfall last 7 Days	*inches*	*82554*
Depth of water	*meters*	*82903*
Wind Direction	*1=N, 2=S, 3=E, 4=W, 5=NE, 6=SE, 7=NW, 8=SW*	*89010*
Flow Method	*1=gage 2=elec 3=mech 4=weir/flu 5=doppler*	*89835*
Maximum Pool Width	*meters*	*89864*
Wind Intensity	*1=calm, 2=slight, 3=mod., 4=strong*	*89965*
Present Weather	*1=clear, 2=ptcldy, 3=cldy, 4=rain*	*89966*
Water Odor	*1=sewage, 2=oil/ chemical, 3=rotten eggs, 4=musky, 5=fishy, 6=none, 7=other*	*89971*
Water Surface	*1=calm, 2=ripple, 3=wave, 4=whitecap*	*89968*
Water Color	*1=brwn 2=red 3=grn 4=blck 5=clr 6=other*	*89969*
Tide Stage	*1=low, 2=falling, 3=slack, 4=rising, 5=high*	*89972*

Table 1. Parameters measured.

(2485), which had a mean temperature of 25.5°C, reflecting the relatively stronger influence of cold weather on the narrow and shallow creek over the broader and deeper bay.

Stream flow was measured or estimated (parameter codes 00061 and 74069 respectively) at ambient non-tidal stations (13029, 18499, 18500, 18501) and at targeted stations. Flow rate for the non-tidal ambient stations ranged from zero cubic feet per second (cfs), which was recorded frequently during dry periods at stations 18499 and 18501, to 4250 cfs at station 13029 during a precipitation event (June 2, 2006). Targeted sites ranged from zero cfs at the end of wet weather event sampling to an estimated 100 cfs at station S6 (June 1, 2006).

Secchi disc transparency (parameter code 00078) varied over all stations from zero meters to a maximum of 1.4 meters, recorded at station 13026. Mean Secchi disc transparency in the bay segment (2485) at 0.231 meters was deeper than a mean of 0.163 meters for the creek segment (2485a) indicating generally less turbid waters in the bay. Overall mean Secchi disc transparence for this time period was 0.203 meters.

All values for dissolved oxygen (parameter code 00300) ranged from a minimum of 0.03 mg/l at targeted station S10 (October 16, 2005) to a maximum of 15.2 mg/l at targeted station S11 (December 1, 2005). Excluding the targeted stations, values for dissolved oxygen varied from a minimum of 1.4 mg/l at station 18501 (October 16, 2005) to a maximum of 13.3 mg/l at station 13440 (December 1, 2005). Overall mean dissolved oxygen for the period of measurement was 5.9 mg/l, however, mean dissolved oxygen in the bay (segment 2485) at 6.6 mg/l was significantly higher than dissolved oxygen in the creek (segment 2485a) at 5.9 mg/l.

Acidity of the water (parameter code 00400 – pH) ranged from 6.3 to 9.0 standard units (su) for all values over the period of measurement. Mean pH for all stations 7.8 su. The mean value of pH in the creek (segment 2485a) of 7.7 su was only slightly lower than the mean value of pH in the bay (segment 2485) of 8.0 over the period of measurement.

Specific conductance (parameter code 00094) is used as an indirect means of measuring salinity (parameter code 00480) and as such, salinity will be used to characterize both measurements. Salinity for all stations ranged from zero parts per thousand (ppt) to 54.9 ppt measured at station 13440 (August 18, 2005). Mean salinity for all stations over the measurement period was 7.8 ppt. Oso Bay (segment 2485) stations ranged in salinity from 0.5 ppt to 54.9 ppt with a mean salinity of 24.6 ppt. Low values occurred generally during runoff events and high values were measured during dry period events. Oso Creek (segment 2485a) salinities were much lower overall, ranging from zero to 5.3 ppt with a mean salinity of 1.6 ppt.

2.2 Bacteria concentrations.

Concentrations of the indicator bacteria *Enterococcus* (parameter code 31649) for all stations over the period of measurement ranged from 1 colony forming units (cfu)/100ml to 97,000 cfu/100 ml with a mean value of 3,752 cfu/100 ml and a geometric mean value of 483 cfu/100 ml. Many of the highest *Enterococcus* concentration measurements occurred during the wet weather sampling event of June 2006, including the highest concentration (97,000 cfu/100 ml) measured on June 2, 2006 at targeted station S6. Many of the targeted stations produced high bacteria concentrations during wet sampling, which yields a geometric mean concentration for all targeted stations of 1572 cfu/100 ml. *Enterococcus* concentrations in Oso Bay (segment 2485) ranged from 1 to 11650 cfu/100 ml with a geometric mean of 41 cfu/100 ml however, considering only dry weather sampling events the geometric mean concentration was only 17 cfu/100 ml. In Oso Creek (segment 2485a) overall *Enterococcus* concentrations were significantly higher, ranging from 9 to 76,500 cfu/100 ml with a mean concentration of 3,637 cfu/100 ml and a geometric mean concentration of 984 cfu/100 ml. Excluding wet weather events, *Enterococcus* concentrations in Oso Creek ranged from 9 cfu/100 ml to 16,500 cfu/100 ml and had a geometric mean concentration of 481 cfu/100 ml.

2.3 Trends and observations

General trends in data can be clearly seen in the surface plots of *Enterococcus*, salinity, dissolved oxygen, and water temperature (Figure 2, Figure 3, Figure 4, and Figure 5) where constituent concentrations (z-axis) are plotted against time (x-axis) and monitoring stations listed in sequence from upstream to downstream (y-axis). *Enterococcus* concentrations (Figure 2) are generally higher at stations upstream of station 13026 (Oso Creek – Segment 2485a) than those downstream of and including station 13026 (Oso Bay – Segment 2485). Additionally higher *Enterococcus* concentrations are observed during

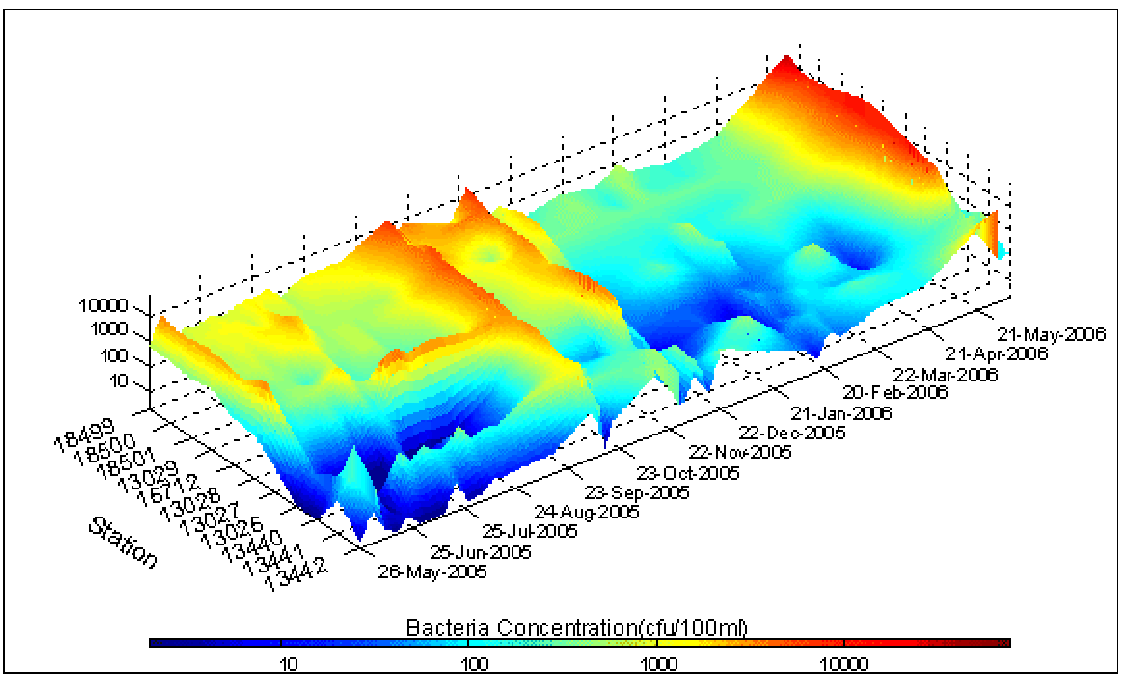

Figure 2. ***Enterococcus*** **concentrations measured at ambient monitoring stations from May 19, 2005 through June 8, 2006. Stations are listed from furthest upstream (back) to furthest downstream (front).**

warmer periods and lower concentrations during colder periods as reflected by water temperature measurements (Figure 4). The abrupt change in salinity between Oso Creek (Segment 2485a) and Oso Bay (Segment 2485) due to the influx of cooling water diverted from a hypersaline lagoon (Laguna Madre) at the Barney David Power Plant is clearly evident (Figure 3) and elevated values of dissolved oxygen (Figure 5) can be observed in response to colder water temperatures.

Linear features oriented along the y-axis (stations listed in sequence) are clearly evident in Figure 2 (*Enterococcus*),Figure 3 (salinity), Figure 4 (water temperature), and Figure 5 (dissolved oxygen). These features can be associated with runoff events that alter the water chemistry for a short period of time. These linear features indicate an increase in *Enterococcus* concentrations, a decrease in salinities in Oso Bay, some decrease in dissolved oxygen, and a contrast in water temperatures depending on the seasonal climate as a response to runoff and it's associated constituents entering the Oso hydrologic system.

Linear features oriented along the x-axis (time) are also evident, indicating anomalies or events specific to a particular station. X-axis linear features can be observed in Figure 2, where high *Enterococcus* concentrations are persistent at station 13027 when compared to upstream and downstream stations during July and August 2005, as well as for station 13441 where generally higher concentrations are found compared to other Oso Bay stations. Other x-axis oriented linear features are observed for station 13441 on plots of salinity (Figure 3) where fresher water at this station is persistent throughout the period of measurements, and water temperature (Figure 4) where warmer temperatures are persistent through out the colder months of December, January, and February.

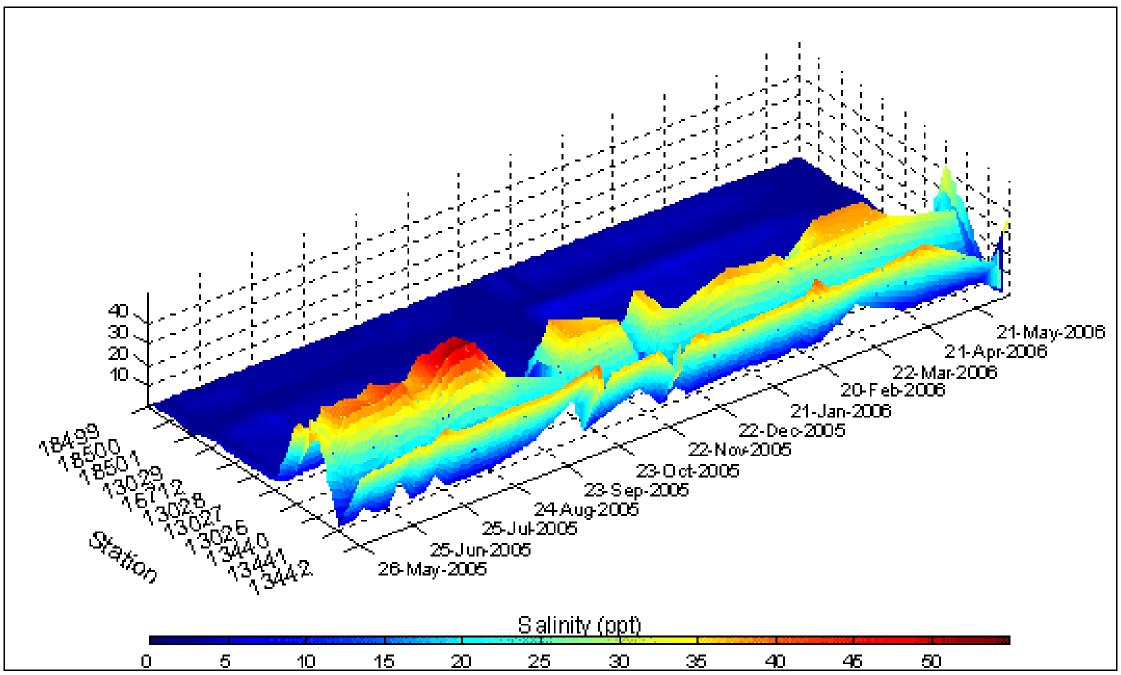

Figure 3. Salinity concentrations measured at ambient monitoring stations from May 19, 2005 through June 8, 2006. Stations are listed from furthest upstream (back) to furthest downstream (front).

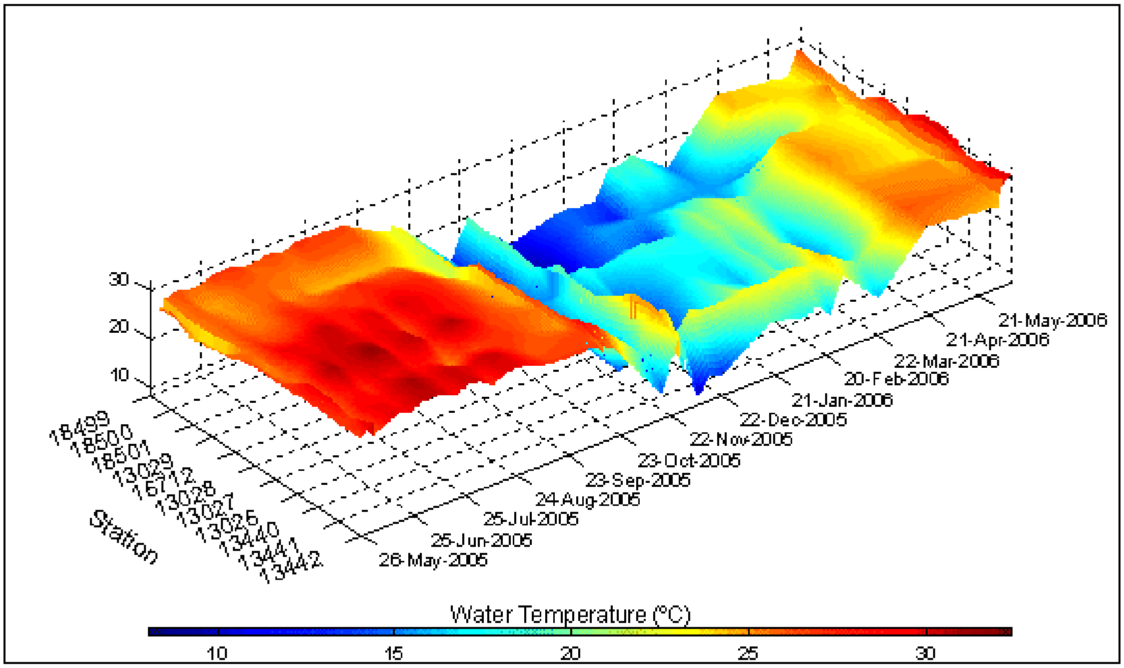

Figure 4. Water temperature measured at ambient monitoring stations from May 19, 2005 through June 8, 2006. Stations are listed from furthest upstream (back) to furthest downstream (front).

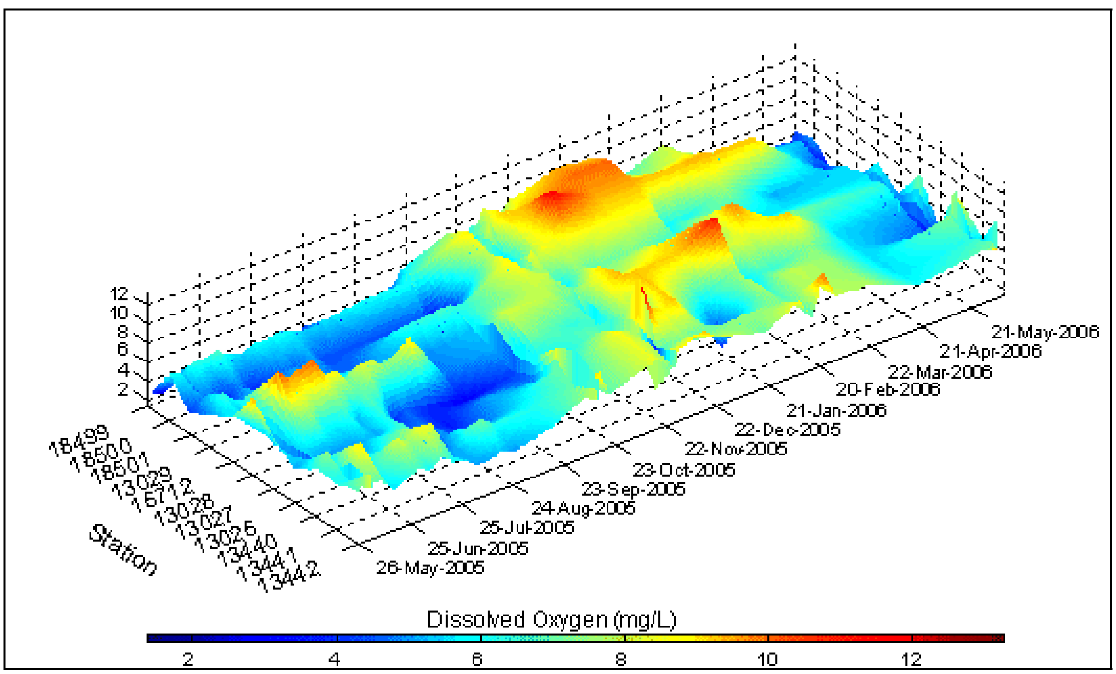

Figure 5. Dissolved oxygen measured at ambient monitoring stations from May 19, 2005 through June 8, 2006. Stations are listed from furthest upstream (back) to furthest downstream (front).

The occurrence of time oriented linear features at station 13441 like elevated temperature during cold periods, higher *Enterococcus* values, and persistently lower salinities indicate that this station is strongly influenced by the neighboring Oso WWTP and is best treated as a tributary feeding into the Oso hydrologic system rather than being representative of broader conditions in Oso Bay. The time oriented linear features at station 13027 indicate higher concentrations of *Enterococcus* bacteria during condition devoid of runoff. This strongly suggests that another source of *Enterococcus* is present between this station and the next station upstream (station 13028). Since stream flow during this period is very low, potential sources for this flux can include leaking or failed septic systems in a nearby subdivision, leaking municipal sewer lines near the creek, wildlife activity in and around the creek (nesting under bridges, feeding at waters edge), equestrian activities (exercising horses in the creek), and illegal discharge/disposal of sewage in the creek.

3 Post Audit of the August 2005 Model

A post audit of the model completed in August 2005 for W.O. #1 was performed after additional data had been collected under W.O. #2. The models that were developed during W.O. #1 were able to iterate on either a monthly time step or a bi-hourly time step. Figure 6 illustrates the modeling process used in both models. Although the monthly model displayed low root mean squared error (Figure 8), the bi-hourly model root mean squared error (RMSE) was much higher (Figure 7). The bi-hourly model with its high temporal resolution offered the most detailed analysis of the bacteria loading process and so development of this model continued through W.O. #2. The purpose of the post audit is to evaluate a calibrated and tested model on a newer set of data. In this case the data collected under W.O. #2 was used.

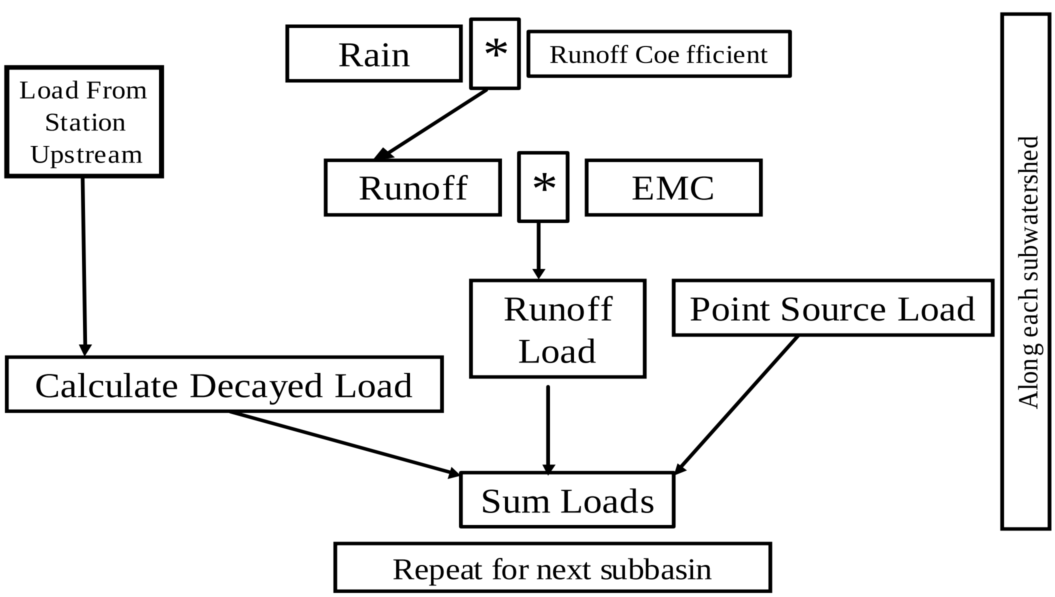

Figure 6. Model process flow chart.

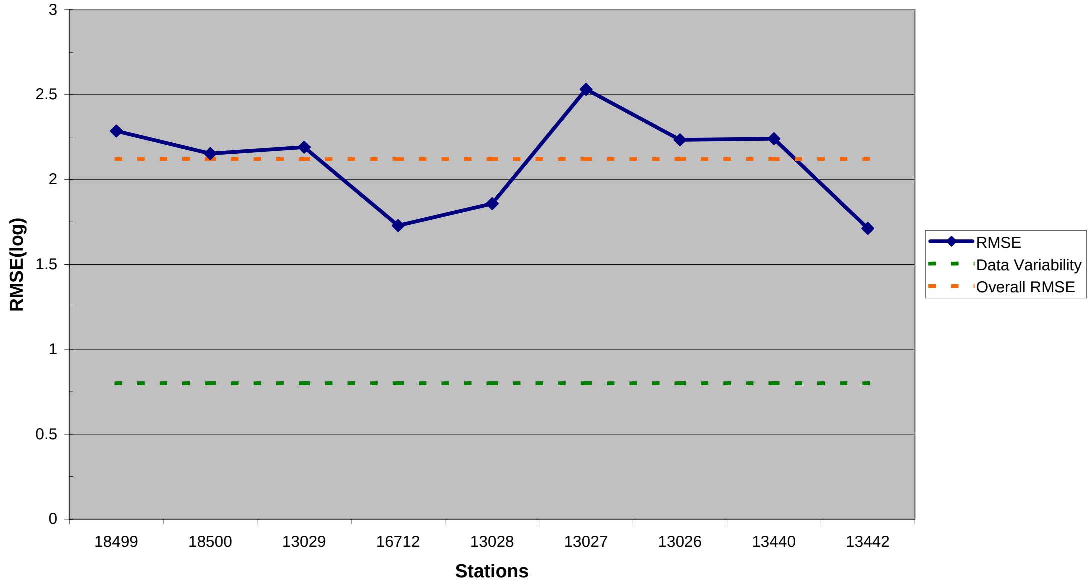

Figure 7. Overall RMSE(log) August 2005 bi-hourly model.

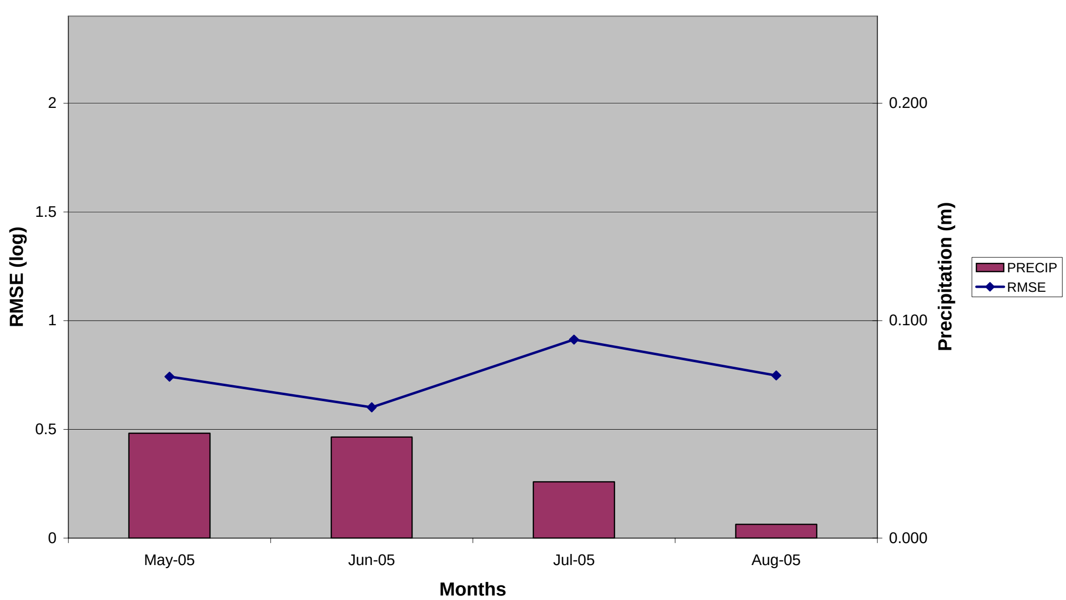

Figure 8. RMSE for Monthly Model during verification period May 2005 to August 2005.

3.1 Under Predicting

Under prediction of *Enterococcus* loads during runoff events was noted for the August 2005 bi-hourly model using data collected from May through August 2005 and continued to occur when tested using data collected from September 2005 through January 2006. It can be seen from Figure 6 that the EMC value sets an upper limit on the bacteria concentrations that can be calculated by the model. For the bi-hourly model to improve *Enterococcus* concentration predictions during the peak flow of runoff events and achieve a lower RMSE, the current EMC values must be reevaluated in light of the high temporal resolution of the model.

3.2 Unaccounted loading during dry periods

Under prediction also occurs during some dry periods when there is only point source loading to the creek. The conceptual model for this process assumes that *enterococcus* loading to the creek occurs either through known point sources or through non-point source loads due to runoff. At many of the stations in Oso Creek (segment 2485a) *Enterococcus* concentrations increase or remain at high levels without runoff and with no evident point source. Potential causes for this additional load could be ground water base flow carrying bacteria from leaky septic systems, or avian loading due to direct input of bacteria from birds wading in the creek or roosting under bridges or in wooded areas over the creek. Other elements could include livestock wading or exercising in the stream channel or wild animals seeking water or a cool refuge from the summer heat in the creek. The most illustrative example of this type of loading can be seen in Figure 2 where a time oriented linear feature of high *Enterococcus* concentrations is evident during a dry period (Figure 9) at station 13027 during part of July, all of August and part of September 2005.

4 Initial Investigations

Two smaller models were used to provide analyses of the data that would address the model's tendency to under predict the bacteria concentrations during the peak flow of rain events and occurrence of loading not due to runoff or point sources. The purpose of these analyses was to determine site-specific parameters that would improve model performance.

4.1 Runoff Concentrations

Event Mean Concentrations are useful for estimating runoff loads for rain events. They are determined by measuring the flow rate and the concentration at regular intervals during and after a rain event. The EMCs are then calculated by forming a weighted average of the concentrations using the flow rates for the weights. Loads for future rain events can then be estimated based upon the EMCs observed for past rain events. In order for the estimates made using EMCs to be accurate, the environment must not interact with the load so as to decrease the load observed. If the environment does

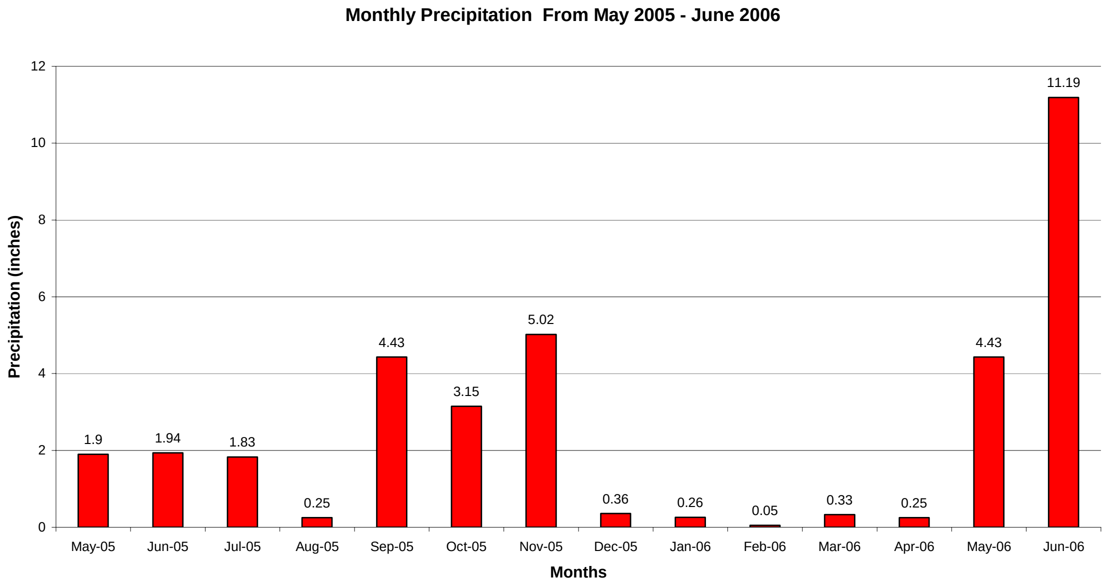

Figure 9. Monthly precipitation at Corpus Christi International Airport for the period of study.

interact in such a manner (decay and predation) then the resulting EMCs will tend to underestimate the loads.

Since fecal coliform has been the primary indicator bacteria until recently, there currently do not exist any event mean concentration values for *Enterococcus* in this area. For the development of the August 2005 model, we assumed that the relative loadings between the different land types would be the same as that observed for fecal coliform, for which EMCs had been determined. Equation 1 was used to calculate the total *Enterococcus* EMC value for station S6 watershed during the rain event occurring in June 2005. Since this sub basin has many different land uses, the ratio between fecal coliform EMC values and different land use area was used to determine specific contributing land use *Enterococcus* EMC values from the overall EMC for the sub basin.

Since EMCs represent a mean concentration over an entire runoff event they cannot be used to predict actual concentrations measured during a runoff event. This is why low

Equation 1. Calculation of Event Mean Concentration (Lee et al. 2002).

$$EMC_T = \frac{\Sigma[\mathrm{C}_t Q_t \Delta t]}{\Sigma[Q_t \Delta t]}$$

where

EMC_T = Total *enterococci* EMC of runoff

C_t = time variable concentration (cfu/100ml)

Q_t = time variable flow (m^3 / day)

Δt = discrete time interval

RMSE values were achieve for the August 2006 monthly model and not for the bi-weekly model. Also, fecal indicator bacteria are subject to predation and inactivation (die off) due to sunlight and sedimentation, which is not accounted for in the calculation of the original EMC values, thus EMC values for bacteria are inherently low. Thus EMCs are inappropriate for accurately estimating bacteria concentrations at time intervals less than that of an entire runoff event. In the case of the EMCs estimated from the first rain event, bacteria concentrations were only available for the days following the rain event and not the day of the rain event and so although the *Enterococcus* EMC values calculated for the August 2005 model were an improvement over the use of fecal coliform values, they continued to represent mean concentration over the entire runoff event and not a value that represents the concentration of the runoff entering channel flow.

To find a more appropriate value that represents the actual runoff concentration the following assumptions that are already incorporated into the model were used

1. The runoff as it is generated has an initial concentration that is dependent upon the land type from which it originated and

2. This concentration is constant from event to event and

3. The decay rate is constant.

Under the above assumptions the quantity that would be most useful for estimating loads from rain events would be the maximum runoff concentration. The assumption of a

Equation 2. Estimation of runoff concentration *Enterococcus* from measured values in channel.

$$C_n = \frac{C_i * Q_o * K_B + C_r * (Q_n - Q_o)}{Q_n}$$

where C_n = New concentration

C_i = Old concentration

C_r = Runoff concentration

Q_o = Original Flow

Q_n = New Flow

K_B = First order decay rate

constant decay rate allows for the possibility that the maximum runoff concentration could be calculated from an Event Mean Concentration, estimated from the days following a rain event, by the use of some factor, which would be dependent upon the decay rate.

To better understand the magnitude of such a factor and the maximum runoff concentrations required, simplified models were constructed for several of the subbasins over each of the rain events. These models used the average daily flow rates generated by the August 2005 model and the *Enterococcus* concentrations observed at each station over the rain event sampling period, usually 4-5 days. The concentration observed at a station was assumed to represent the average concentration of all waters upstream of the station. Rain events were assumed to occur uniformly upon all waters upstream of the station. Prior to the rain event the concentration was assumed to be zero. If the flow rate increased indicating a runoff event for a given time step, the concentration for that time step was calculated using Equation 2.

Assuming that the observed concentrations may have an error of plus or minus 0.25 $\log_{10}$, there are a limited number of runoff concentration and decay rate combinations that can fit the observations and meet error criteria. The variations in the allowable combinations across rain events and stations provided some additional insight into what changes must be incorporated to improve the bi-hourly model.

Although all stations exhibited a reduction in the calculated decay rates during the days following the rain event, the highest decay rates were generally observed at the stations in basin receiving the most rainfall and the first day of sampling after the rain event. The smaller the rain event, the sooner the decay rate would diminish to zero. Since the primary concern was to determine a decay rate associated with the bacteria due to runoff, the highest allowable decay rate would be most applicable. The analysis estimates that maximum runoff concentration is on average 4.3 (± 2.4) times larger than the event mean concentrations used in the August 2005 model.

4.2 Agricultural EMC values

Cropland makes up sixty two percent of all the land in the Oso Watershed. Over half of the subbasins delineated in the watershed are made up of greater than sixty percent cropland. Currently there exists little data on *Enterococcus* EMC values for cropland. The EMC values used for the August 2005 model were based on those reported by Baird et al (1996). For agricultural land types, the Baird et al (1996) report made use of EMC values for fecal coliform collected in the Seco Creek watershed, which consists primarily of rangeland. The Baird et al (1996) concluded that there were insufficient data to determine an EMC for cropland and so the EMC value used in the August 2005 model assumed zero contribution of *Enterococcus* from this land use type.

Elevated bacteria concentrations were observed in runoff from subbasins that are predominantly cropland in this study. Therefore, it is unlikely that a zero EMC value for cropland is valid even though agricultural practices in this area no longer include the application of manure fertilizers.

An EMC value for cropland was estimated by examining modeled runoff concentrations for each of the subbasins and comparing them with the observed concentrations. This analysis overlooked the possibility that the observed concentrations at a particular station are correlated not only with the runoff from its respective subbasin but also with the bacteria concentration of all upstream stations. Errors due to this assumption are offset by the large portion (> 80%) cropland found in all basins above station 16712. This error is not applicable to station 18501, which is on a tributary to Oso Creek that drains only one basin. Only three of the rain events had sufficient data to perform this analysis (10/12/2005 through 10/16/2005, 11/27/2005 through 12/1/2005, and 6/1/2006 through 6/8/2006).

The EMC value for crop/range land use was found to be on average 12,000 cfu per 100ml with a standard deviation of 6600 cfu per 100 ml using data from stations S7, 18499,18500,18501 and 13029. Since urban runoff could have significant contributions to *Enterococcus* concentrations at stations 18499 and S7 they were eliminated from the calculation. The remaining stations yielded an average EMC of 8900 cfu/100ml with a standard deviation of 3900 cfu/100mL. This value was close to that measured at station 18501, which receive virtually all runoff from cropland, and so EMC value 8500 cfu/100mL for cropland/rangeland was adopted.

5 Calibration

The key approach that has been utilized in the development of the TMDL model for Oso Creek has been simplicity. There is a great amount of uncertainty in decay rates, the significance of factors effecting decay rates, and the establishment of EMC's of fecal indicator bacteria as can be seen in the wide range or reported decay rates and analyses of contributing factors (Appendix I). This uncertainty coupled with lack of temporal density and natural variability seen in *Enterococcus* samples (Hay and Mott 2005) make it difficult to justify the creation of complex bacteria loading models. With this in mind we fitted the model to the data by focusing on three different parameters: decay rates, other loadings, and event concentrations.

5.1 Decay Rates

Decay rate is a first order parameter that determines die off, sequestration, uptake or predation of the bacteria and allows for the removal of bacteria from the model. Elevated bacteria levels observed at station 13027 during the summer and fall months led to very low bacteria values at station 13026, the next station downstream (Figure 2) suggesting a much higher decay rate may be applicable to the stations downstream of station 13027. Additionally, the Barney Davis power plant cooling water discharges saline water between these two stations causing an abrupt change in salinity and dilution of the bacteria concentrations, but this dilution is not enough to account for the abrupt change in decay rate.

5.1.1 Decay rates from literature review

The decay rates observed by Sinton et al (1994,1999) and Davies-Colley et al (1999) suggest that there is a relation between salinity, sunlight and decay rates. In sunlit seawater decay rates ranged from 6.57 day^{-1} to 40.61 day^{-1} whereas dark seawater decay rates ranged from 0.12 day^{-1} to 0.67 day $^{-1}$(Sinton et al 1994, Davies-Colley et al 1999).

In sunlit fresh water decay rates were in the range 3.8 day^{-1} to 18.4 day^{-1} whereas dark freshwater decay rates ranged from0.29 day^{-1} to 0.41 day^{-1}(Sinton et al 2002). The vast difference between the dark and sunlit decay rates for freshwater and seawater suggest that a more accurate modeling of the decay process would benefit from employing a dark decay rate and a sunlit decay rate. However the frequency of sampling for this project was no greater than once in a day making the use of night and day decay rates an unjustified addition to the model. Instead, the decay rates in the model represent an average daily decay rate assuming that equal time for day and night observations would have ranges equal to half of the sunlit ranges observed by Sinton et al (1994).

Medema et al (1997) performed a study on *enterococcus* to quantify the effect of temperature and predation on decay rates in river water with no sunlight. The decay rates (0.18 day^{-1} to 0.54 day^{-1}) were similar to those observed by Sinton et al (2002) for dark waters. This study also involved observing decay rates at two different temperatures, 5°C and 15° C. The decay at the lower temperature appeared to be constant requiring roughly sixty days to bring the bacteria concentration from 10^6cfu/100ml to 10 cfu/100ml. At the higher temperature the decay was biphasic exhibiting two different rates, an initial rapid die off from 10^6 cfu/100ml to 10^2 cfu/100ml for the first twenty days, at a rate three times that of the lower temperature, followed by a slow decay from 10^2 cfu/100ml down to 10cfu/100ml over the next twenty days. Since the study involved temperatures no greater than 15° C, the results are only applicable to the winter months for Oso Creek where observed temperatures ranged from 8.1° C to 20° C. There have been few studies (Bordalo et al 2002) observing dark decay rates at the temperatures found throughout the majority of the year in Oso Creek, 20° C to 30° C. The presence of biphasic behavior at these temperatures could offer in the absence of any other bacteria loadings, an explanation for elevated concentrations observed in Oso creek during the summer. Some studies suggest that given the right nutrient levels, *enterococcus* could potentially grow in fresh and sea waters in the absence of light (Lessard and Sieburth1983, Hartke et al 1998).

Alkan et al (1995) examined the role of light, turbidity, mixing, sewage content and temperature and depth upon *enterococcus* decay rates in seawater. His analysis showed that temperature was the least important factor. With the accepted importance of light in the process of bacteria die-off, light, turbidity and mixing correlated well with decay rate. The decay rates observed ranged from 2.45 day^{-1} to 115 day^{-1}. These results were generated entirely under laboratory conditions, the seawater used was filtered and sterilized and the bacteria used were laboratory cultured and so the results may not accurately represent bacteria response in the field. Also none of these experiments allowed for a diurnal variation in light intensity levels so the results again emphasize sunlight, when present, is the dominant contributor to bacteria die-off. Noble et al (2004) examined both saltwater and freshwater and found that while temperature had a significant affect upon decay rates, they did not vary significantly between freshwater and seawater. These experiments were conducted with unsterilized water and bacteria from wastewater and storm water.

Another study (Davies-Colley et al 1999) examined the variance in decay rates of fecal indicator bacteria in waste stabilization ponds. The parameters examined included dissolved oxygen, pH, ultraviolet light and dissolved solids. Bacteria die off in a miniature waste stabilization pond was observed over a period of 5-7 hours. The results showed that increased dissolved oxygen levels increased bacteria die off rates, presumably to be due to increased photooxidation occurring inside and outside of the bacteria. Also, *enterococcus* was unaffected by changes in pH.

In Oso Creek, dissolved oxygen levels exhibited a seasonal trend with the lowest levels being observed during the warmer months from May through the middle of October and coinciding with elevated *Enterococcus* concentrations. During the cooler months *Enterococcus* concentrations were low, while dissolved oxygen levels were high (Figure 2, Figure 5). Dissolved oxygen then, may be responsible for some seasonal variability in the die off rate, however due to the short nature of the experiments (Davies-Colley et al 1999), the daily and seasonal effects of dissolved oxygen are not entirely evident. The increased photooxidation brought about by elevated dissolved oxygen levels and sunlight may not result in a total destruction of the bacteria but rather an inactivation that could be remedied during the night potentially resulting in no net change of the average daily decay rate due to elevated dissolved oxygen levels.

Other models (Boehm et al 2005) have been used for indicator bacteria at beaches in southern California. These models used *Enterococcus* decay rates that incorporated transport, decay and predation. The decay rates came primarily from published data (Sinton et al 1994, 2004) based upon insolation and inactivation. The predation rate of 0.56 day^{-1} (Boehm et al 2005) was comparable to the other dark inactivation rates (Sinton et al 1994,2004) and the die off rates observed by Medema et al (1997).

5.1.2 Revision of model decay rates

Literature review of the decay rates offers sufficient justification for employing two different decay rates in the model, one for the creek (segment 2485a) which is freshwater and another for the bay (segment 2485) which is saltwater. The two decay rates were selected by performing a visual fit of the modeled values to the observed data using data from the first three rain events and some representative dry period days in which elevated bacteria levels were observed at station 13027 but not at 13026. The visual fit allowed no more than an order of magnitude error in the measured bacteria concentrations, a value similar to the environmental variability of the samples of 0.8 log (concentrations) by Hay and Mott (2005).

The decay rates that were chosen for the final model were 2 day^{-1} in Oso Creek (freshwater) and 4 day^{-1} in Oso Bay (saltwater). These decay rates correspond to a 90 percent die off times of 1.2 days for Oso Creek and 0.6 days for Oso Bay. The lesser decay rate was used for the segments associated with stations 18499, 18500, 18501, 13029, 16712, 13028, 13027 and 13441. The slower decay rate was used for Oso Bay station 13441 based on the field data indicating a freshwater environment similar to the stations in the creek segment.

5.2 Dry Day Loading

Adjusting only decay rates would have required the use of decay rates well outside published values to account for the elevated bacteria levels observed in the dry periods. With addition of a dry day loading parameter for each basin the decay rates could be restricted to those observed in the literature.

The August 2005 bi-hourly model was based on the assumption that the only sources of bacteria to the creek and bay were runoff and known point sources (i.e. WWTP) and that the *Enterococcus* bacteria die off when removed from their natural habitat (feces). However, persistent elevated bacteria concentrations in the fresh water portion of the system suggested that another flux of bacteria to the creek exists that is not related to runoff or known point sources. This flux, referred to in this report as dry day loading, has a profound influence on the geometric mean value of *Enterococcus* concentrations that determine whether a stream segment meets water quality objectives and could have a number of various sources.

Fecal *Enterococcus* are naturally found in the intestines of warm-blooded animals. Their entrance to extraintestinal environments is primarily via the feces of warm-blooded animal. There are numerous potential sources for the dry day loading including include leaking or failed septic systems in a nearby subdivision, leaking municipal sewer lines near the creek, wildlife activity in and around the creek (nesting under bridges, feeding at waters edge), equestrian activities (exercising horses in the creek), and illegal discharge/disposal of sewage in the creek.

In rural and suburban areas, septic systems provide a steady source of fecal bacteria to the ground. Ideally the chemical and bacterial processes in the septic tank and mechanical processes and bacteria in the soil will serve to eliminate the fecal bacteria. Poorly maintained or leaking septic systems can undermine these processes. Clay soils, dominant in the Oso Creek watershed, are poorly suited for septic systems. Low permeability in soils such as clay require additional planning because they must have significantly larger leaching fields to effectively treat the water without contaminating the groundwater. Many studies suggest that *Enterococcus* may be capable of surviving and growing within certain soil environments (Cools 2001). Groundwater, once contaminated, can be a steady long lasting flux of bacteria to surface waters.

5.2.1 Calculation of the Dry Day Loads

Based upon the results of the August 2005 bi-hourly model the residence times and decay rate for any one segment of the creek are insufficient to remove all the bacteria in that segment and so each stream (or bay) segment transfers some bacteria load to the segment immediately downstream. Therefore, calculation of dry day loads must begin at the uppermost stream segment in the hydrologic system. Since the temporal resolution of data collection was at intervals not less than daily, dry day loading was represented in the model as a constant loading (flux) applied to each bi-hourly time step. To determine the dry day load a model simulation was run to equilibrium (seven days) prior to the date of a sampling event. A binary search algorithm was used to determine, to the nearest hundredth of a $\log_{10}$, the bacteria load that would yield the observed concentration after the model reaches equilibrium. If the resulting load at a station was sufficient to generate the observed concentrations at the next station down stream, then the dry day loading determined for the down stream station was limited to a value two orders of magnitude less than the load receive from upstream. This was done to constrain the log values of concentrations to the measurement limits of the analytical technique. Once dry loads were determined for each dry day of each segment, the average dry day loading was calculated for each of the segments. The dry day loads for the revised bi-hourly model are listed in Table 2. A dry day load was not calculated for West Oso Creek, the tributary associated with station 18501, because this segment is an intermittent stream.

5.3 Event Concentrations

The preliminary analysis of the data had indicated that the bacteria concentrations of the runoff during a rain event average as much as 4.3 (±2.4) times the event mean concentration calculated from concentrations observed in the days following the rain event. The August 2005 bi-hourly model EMC values were based upon the concentrations measured at station S6. Station S6 was chosen because it monitored runoff from a subbasin that had all of the land types used in the model. Although the recalculated EMC values were higher than the values taken from literature (Baird et al 1996) and performed well in the August 2005 monthly model, the bi-hourly model consistently under predicted *Enterococcus* concentrations during peak flow events. Station 18501, also a tributary, was chosen to recalculate agricultural EMC values because the subbasin is primarily cropland.

Station	Bacteria Load (cfu)
18499	4.59E+09
18500	5.44E+09
13029	6.40E+08
16712	1.13E+10
13028	3.79E+10
13027	1.41E+11
13026	2.46E+10
13440	3.07E+10
13441	1.68E+09
13442	6.50E+10

Table 2. Dry Day Loadings in cfu/2hr time step.

The bi-hourly model iterates in time steps much shorter than a complete rain event, hence EMC values are no longer appropriate. Since the model is calculating concentrations that represent discrete intervals within the rain event, values representing the *Enterococcus* concentrations of the runoff before it enters channel flow and begins decaying (event concentrations) are required. Using the new decay rate of 2.0 day^{-1}for fresh water segments, event concentration (EC) values were back calculated (Table 3) from EMC

EC Value	Type	NLCD Equivalent
353829	Residential	21,22
305332	Commercial/Industrial/Transportation	23
62807	Cropland/Rangeland	51,71,81,82,85
0	Not Classified	11,31,32,471,42,43,91,92

Table 3. Event Concentration values for *Enterococcus* in runoff.

values assuming the EMC values represented about 1 day of decay. These values are comparable to the bacteria concentrations for fecal coliform observed by the City of Corpus Christi in its storm water, which had concentrations as high as 445000 cfu/100ml (City of Corpus Christi 2003).

Cropland was not well represented in the development of EMC values from the subbasin for station S6. However, station 18501 on West Oso Creek, a tributary of Oso Creek, was used earlier in model development to determine a cropland EMC value appropriate for this area. This value was then used to calculate the EC for cropland.

6 Audit of Revised Bi-hourly Model

Applying the concepts and results discussed in sections 5.1, 5.2, and 5.3 to the August 2005 bi-hourly model resulted in a slightly different conceptual model (Figure 10) and a better statistical fit of the modeled bacteria concentrations to the observed concentrations. Most significantly the revised model includes dry day load, which appears to be responsible for elevated *Enterococcus* concentrations during periods without loading from runoff. Statistically, the revised model displayed an overall RMSE of 0.68 log(concentration) (Figure 12), well within the environmental variability in the samples of 0.8 log (concentrations) (Hay and Mott 2005). The revised model was also tested using the historic data used to calibrate the August 2005 bi-hourly and monthly models, yielding an RMSE of 1.04 log(concentration)(Figure 11), much lower than the 2.1 log(concentration) of the August 2005 bi-hourly model (Figure 7). RMSE calculated for stations in Oso Bay using either the historic or new data display a significantly higher RMSE value than those calculated in Oso Creek. This occurs as a result of using log

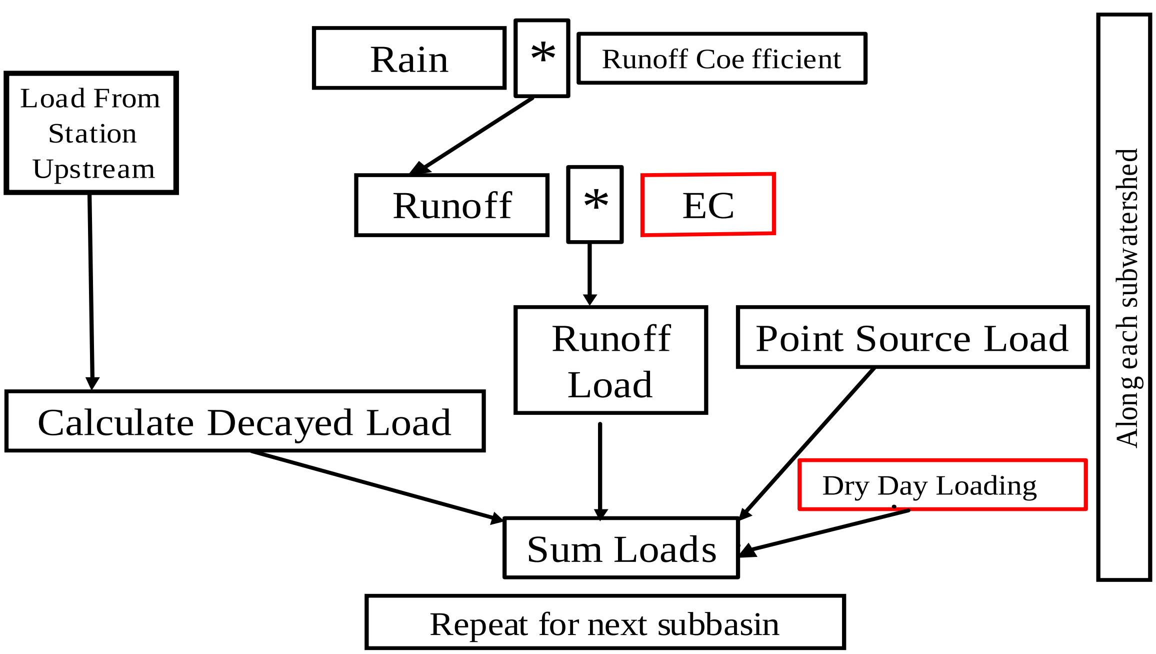

Figure 10. Revised bi-hourly model process flow chart with modifications highlighted in red.

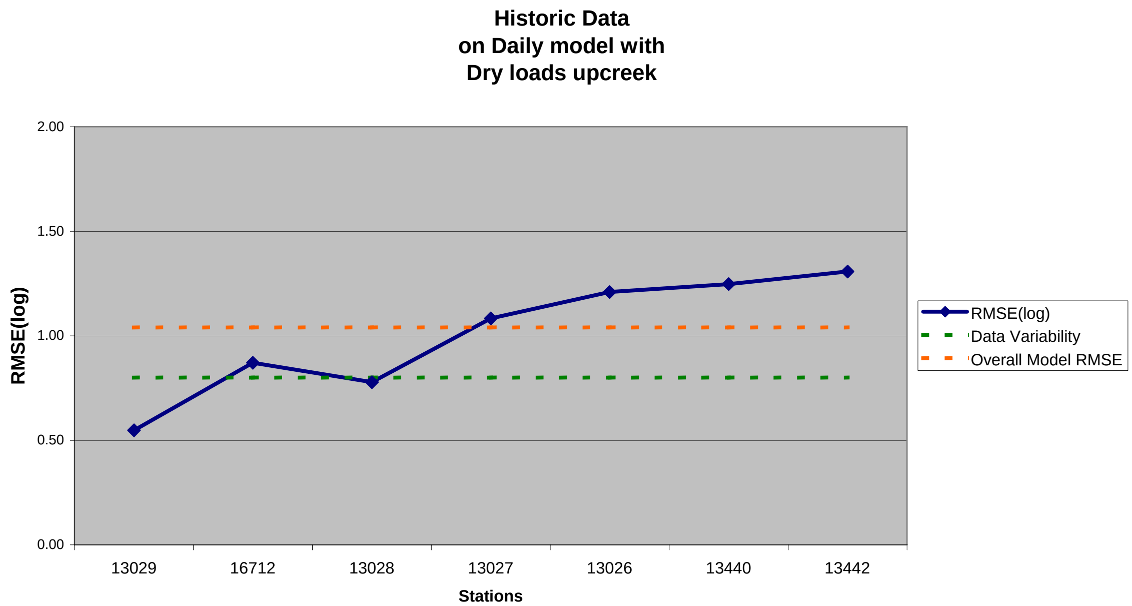

Figure 11. RMSE for revised bi-hourly model applied to historic data (October 1999 - September 2000) displaying an overall RMSE of 1.04 log(concentration).

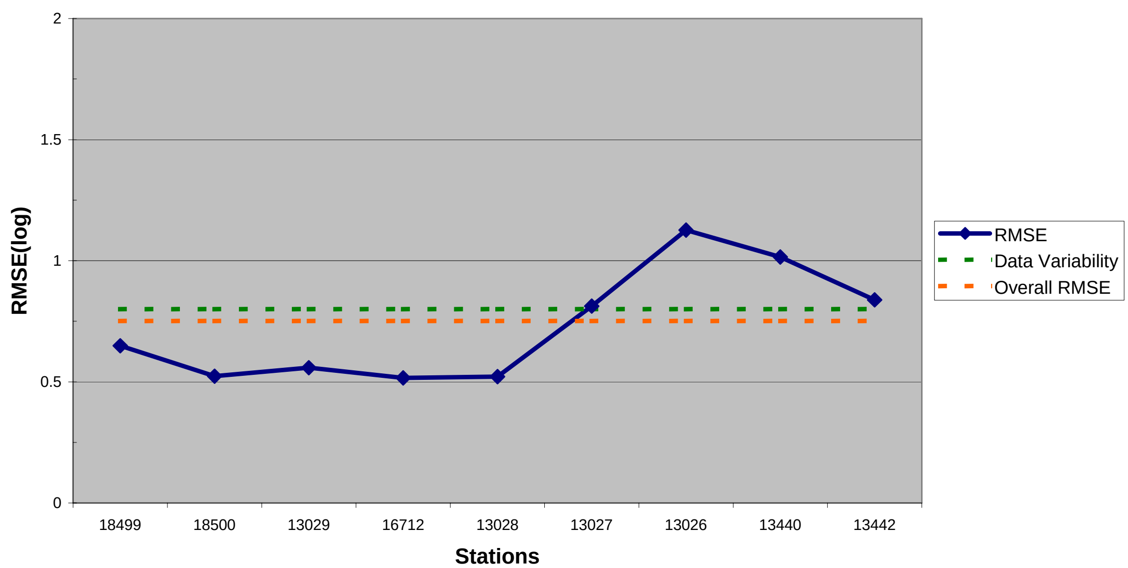

Figure 12. Overall RMSE by Station for the revised bi-hourly model.

(concentrations) instead of the actual concentration value, since *Enterococcus* concentrations in Oso Bay are generally low values (e.g. 0, 1, 10) and the difference between a model calculation of 0.1 cfu/100ml and a observed value of 10 cfu/100ml is a 2 log(concentration) difference.

7 Loadings

Two different approaches were considered for determining the allowable loads and load reductions for each of the segments in Oso Creek and Oso Bay. One approach considered the lognormal distribution of the *Enterococcus* concentration data collected over this project and the parameters variance and geometric mean. The second approach relied on running model simulations over the same period as the data collection in this project.

The lognormal distribution technique using collected data was helpful in determining which of the criteria, geometric mean or single sample, was critical in meeting the water quality objectives at each station (Figure 13). A graph of the data (Figure 13) indicates that the *Enterococcus* concentrations at station 13027 exceed both the geometric mean criteria (green lines) and the single sample criteria (red lines). However, the temporal distribution of the data is such that about one third of the measurements represent wet weather events, whereas the overall fraction of wet days for that period was only one fifth of the total days. This suggests that the collected data is biased towards wet weather, skewing the observed data toward higher *Enterococcus* loading and thus increasing the geometric mean value as well as the relative frequency of exceedance of the single

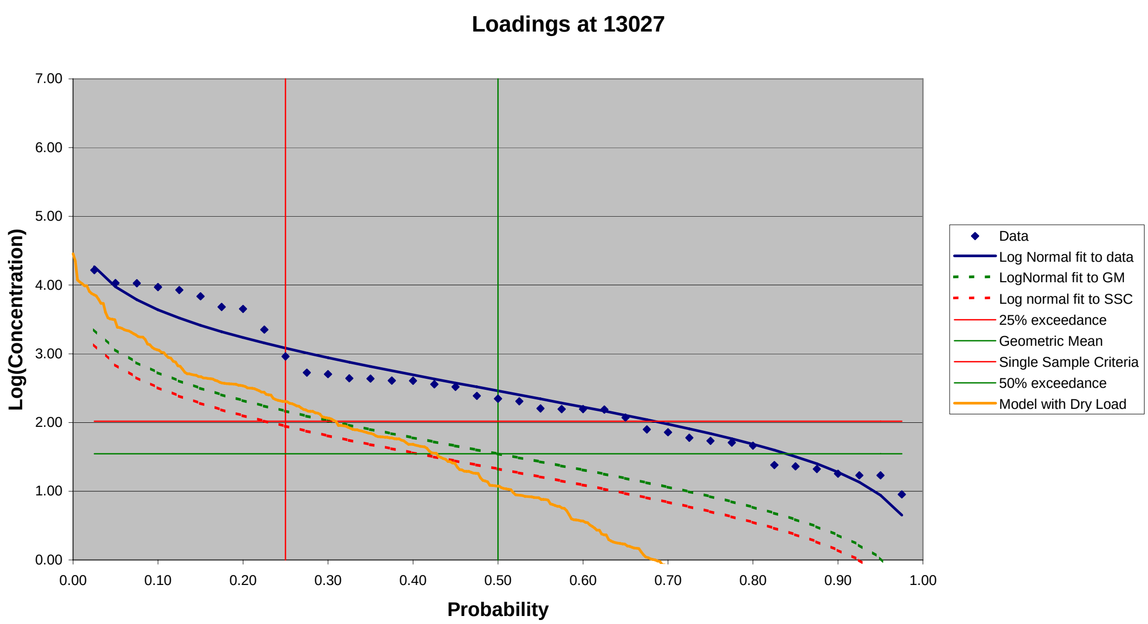

Figure 13. Lognormal distribution of observed *enterococci* concentrations, single sample and geometric mean criteria and modeled concentration values at station 13027. The green dashed line represents a lognormal distribution satisfying the geometric mean criteria, the red dashed line represents a lognormal distribution satisfying the single sample criteria, and the blue dots represent the observed concentrations.

	18499	18500	13029	16712	13028	13027	13026	13440	13441	13442
Annual Dry Day Load (Modeled)	20	24	3	50	166	616	108	134	7	285
Annual WWTP Load	0.07	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.79	0.00
Annual Runoff Load (Modeled)	1513	283	232	1743	523	2154	1428	1209	708	948
Total Annual Load	1533	307	235	1793	689	2770	1536	1343	716	1233
GM Concentration (Modeled)	**1366.3**	**1321.6**	**909.0**	**569.1**	**367.6**	**349.3**	*7.9*	*7.7*	**80.5**	*12.6*
25% Exceedence (Modeled)	**1199.9**	**1471.3**	**1108.7**	**797.5**	**434.5**	**380.0**	*5.8*	*5.7*	*50.1*	*9.3*

All loadings in 10^{12} colony forming units

Table 4. Modeled current annual load with resulting annual geometric mean concentrations and single sample criteria exceedances at each main channel sampling station. Bold font highlights values that do not meet water quality objectives and italic font highlight values that meet water quality objectives. Concentrations in cfu/100ml.

sample criteria. Use of this technique would result in an over estimate of current loadings and load reductions, so the technique was abandoned.

Model simulations, using the revised bi-hourly model to generate *Enterococcus* concentrations for every day of the year, provided a dataset that is not bias toward wet weather and more likely to represent actual *Enterococcus* concentrations throughout the year. With this in mind, model simulations were run to determine allowable loads at each monitoring station along Oso Creek and Oso Bay by systematically reducing input loads generated by runoff, as well as dry day loads. Since reductions in input loads from runoff and dry day loading will be reflected as reduced upstream load on the next station downstream, input load reduction began at the furthest upstream station (18499). Input loads were reduced in the 18499 subbasin until concentrations at that station met water quality goals. Once the water quality goals were met at station 18499, simulated bacteria concentrations at the next downstream station (18500) were evaluated to determine if water quality goals were being met at that site. If the goals were being met, no further reductions were applied to the subbasin. This procedure was iterated continuing downstream until input loadings were low enough for each station to meet water quality objectives.

7.1 Current loading

Current input loadings were established by model simulations using the revised bi-hourly model. This model was used to simulate *Enterococcus* concentrations over a one-year period (May 2005 though April 2006). Annual input loadings were determined by summing the daily loadings at each station. Input loads include point source loads (where present), runoff load, and dry day load, however the decayed upstream load, where present, is included in the determination of *Enterococcus* concentration at each station used to calculate the geometric mean concentration and the single sample 25% exceedance criteria (Table 4).

It can be seen in Table 4, that water quality goals are not met at stations 18499, 18500, 13029, 16712, 13028, and 13027, all located in Oso Creek. The 25% exceedance criteria are met at stations 13026, 13440, 13441, and 13442, all located in Oso Bay. Geometric mean criteria are met at station 13026, 13440, and 13442, but not met at station 13441.

	18499	18500	13029	16712	13028	13027	13026	13440	13441	13442
Annual Input Load without Dry Day Loading (Modeled)	1513	283	232	1743	523	2154	1428	1209	709	948
GM Concentration (Modeled)	**36.0**	**39.4**	**38.6**	**45.9**	*26.4*	*20.8*	*2.7*	*2.5*	*13.6*	*2.5*
25% Exceedence (Modeled)	**419.4**	**929.0**	**793.4**	**558.1**	**247.4**	**175.7**	*2.3*	*2.2*	*5.4*	*2.1*

All loadings in 10^{12} colony forming units

Table 5. Modeled annual input (in cfu x 10^{12}) by subbasin at individual stations in Oso Creek and Oso Bay with dry day loading removed. Geometric mean concentrations either meet or only slightly exceed water quality criteria at each station. Concentrations in cfu/100ml.

The subbasins generating the largest loads were also the subbasins with the largest areas of urban land use. High loading contributions from cropland are generally due to the large areal extent of this land use in some of the subbasins. Residential areas generated the highest loading in the subbasins for stations 13441, 13440, and 13442.

Equation 3. Annual Dry Day Load.

$$D_{Annual} = d(ts)days$$

$$\begin{aligned} \text{where } D_{Annual} &= \text{Annual Dry Day Load.} \\ d &= \text{Dry Day Load applied to each model timestep.} \\ ts &= \text{Number of time steps per day.} \\ days &= \text{Days in year.} \end{aligned}$$

Annual dry day loadings, calculated using Equation 3, were generally 1 to 2 orders of magnitude less than the total loading from each subbasin but they play a key role in meeting water quality goals due to their significance in calculating the geometric mean concentration (Table 6).

Station	Modeled as point source		Modeled as non-point source				Total Non-Point Source Load	Upstream Decayed Load
	Annual Dry Loading	WWTP Annual Loading	Residential	Urban	Crop	Range		
18499	20	0.07	341	219	886	67	1513	NA
18500	24	0.00	5	2	263	12	283	1206
13029	3	0.00	2	2	219	8	232	965
16712	50	0.40	299	575	753	117	1743	954
13028	166	0.00	14	23	453	33	523	2132
13027	616	0.00	1153	631	294	76	2154	1551
13026	108	0.00	144	125	737	422	1428	1470
13440	134	0.00	668	300	84	156	1209	596
13441	7	0.79	516	178	0	14	708	NA
13442	285	0.00	448	403	38	59	948	898

All loadings in 10^{12} colony forming units

Table 6. Modeled annual input distribution (in cfu x 10^{12}) by subbasin at individual stations in Oso Creek and Oso Bay.

7.2 Allowable loads

The allowable loads were determined in a similar manner to dry day loadings (Section 5.2), using an iterative process, beginning with the station furthest upstream. Since the dry day loadings are the most significant factor in meeting the geometric mean criteria, this input was removed from the model at all stations and a new simulation was run. The results of this simulation (Table 5) display lower geometric mean concentrations at all stations, with some values meeting or only slightly higher than the water quality objectives. Additionally the 25% single sample criteria are much closer to meeting the 104 cfu/100ml goal.

Runoff loadings were reduced uniformly in the subbasin furthest upstream and the model simulation rerun until the station met both water quality criteria. Then the same process was repeated on the next station down stream until all stations met water quality goals. In some cases (subbasins 13029 and 13026), where the subbasin received large loadings from the upstream subbasin, the process of reduction to meet water quality goals at the upstream station resulted in the downstream station also meeting water quality goals. No reductions in runoff loadings were made to subbasins that met water quality goals.

Allowable loads (Table 7) for three of the Oso Bay stations (13026, 13440, and 13442) are much higher than the current load, reflecting the ability of Oso Bay to assimilate the bacteria loading better than Oso Creek.

7.3 Load reductions

The required load reductions for each station is the difference between the current annual loading and the allowable annual load. Load reductions ranged from zero in some basins to 1,693x10^{12} cfu (Table 7). Removal of dry day loading and a reduction in loading from runoff was required for subbasins 18499, 18500, 16712, 13027. Removal of dry day loading alone was adequate for subbasins 13029, 13028, and 13441. Upstream load reductions were sufficient to allow station 13026 to meet water quality objectives without any load reductions. Oso Bay stations 13440 and 13442 required no load reductions.

	18499	18500	13029	16712	13028	13027	13026	13440	13441	13442
Total Input Load (Modeled)	1533	307	235	1793	689	2770	1536	1343	716	1233
Allowable load	106	28	232	175	523	1077	114340	36398	7080	28734
Dry Day Load Reduction	20	24	3	50	166	616	0	0	7	0
Runoff Load Reduction	1407	255	0	1568	0	1077	0	0	0	0
Total Load Reduction	1427	279	3	1618	166	1693	0	0	7	0
Percent Reduction	93.1%	90.8%	1.3%	90.3%	24.1%	61.1%	0.0%	0.0%	1.0%	0.0%
GM Concentration (Modeled)	*13.5*	*10.8*	*13.2*	*15.7*	*10.8*	*11.6*	*20.0*	*21.3*	*23.5*	*28.4*
25% Exceedence (Modeled)	*31.8*	*68.6*	*96.6*	*67.7*	*59.9*	*78.7*	*68.1*	*71.4*	*15.6*	*58.2*

All loadings in 10^{12} colony forming units

Table 7. Annual modeled total load, allowable load, and load reductions. Values for water quality goals at each station are calculated from the allowable load for each basin and include any loads transferred down from the upstream basin. Concentrations in cfu/100ml.

The most effective load reduction was the removal of dry day loading. Dry day loading accounted for less than 12% of the total annual load yet when removed from the system all stations either met the geometric mean criteria or were only slightly higher.

Reduction in runoff loading was required in only four of the 10 subbasins modeled. Annual loadings from point sources accounted for less than 0.01% of the total annual loadings and, although they remained in the model, they were not used as part of the load reduction strategy.

8 Conclusions

Revision of the August 2005 bi-hourly model provided a well calibrated numerical model capable of forecasting *Enterococcus* concentrations and loadings in the Oso watershed. The model is driven by inputs such as precipitation, non-point source loadings, point source loadings, and decay rates. Over the course of the investigation, a number of significant factors were uncovered that were key in computing actual loading, allowable load and load reduction.

Analysis of the data generated from the sampling portion of this project revealed bacteria concentrations had a lognormal distribution and that the geometric mean criteria was significant in attaining the water quality objective in this watershed. Also, the sampling schedule created a dataset that was somewhat biased toward wet weather conditions and, consequently skewed toward higher *Enterococcus* concentrations and higher bacteria loadings. This bias results in a geometric mean concentration that is higher than that of a data set representative of the ratio of wet days to dry days in this study area. So, direct use of the *Enterococcus* concentrations to determine current loadings was abandoned in favor of simulations using the revised and calibrated bi-hourly model.

Elevated concentrations of *Enterococcus* were observed over dry periods during this study. These high values could not be attributed to runoff or known point sources but were a significant contributor to high geometric mean values and there was little chance of meeting water quality objectives without addressing this issue. Although the source of the dry day loading could not be ascertained, the magnitude of the loading could be calculated and applied as a flux to the bi-hourly model. This revision allowed the bi-hourly model to provide better simulations of loadings to the creek and bay. Other revisions to the model included the calculation of event concentrations to represent bacteria concentrations in the runoff rather than in the channels, and separate bacteria decay rates for the creek and bay segments. Together these modifications improved the accuracy of the model from a RMSE of 2.1 log(concentration) to a RMSE of 0.68 log(concentration). The revised numerical model provides us with a tool that can produce a year of bacteria concentration measurements for each station that is statistically accurate with average errors less that the 0.8 log(concentration) due to environmental variability (Hay and Mott 2005), and not skewed towards wet weather conditions.

Initial model simulations for Oso Bay indicated that all stations except 13441 meet water quality goals and no load reductions were required. Analysis of data from station 13441 indicated that it responded in a manner similar to the creek stations, where dry day loading was an important factor in not meeting water quality goals. This station is not representative of ambient conditions in Oso Bay as indicated by bacteria concentrations, salinity, and water temperature, and should not be incorporated into an evaluation of the overall ambient conditions of the bay.

Dry day loading was modeled at all stations, and its removal was key to meeting water quality objectives at all stations except the bay stations 13026, 13440, and 13442. The other stations could attain water quality objectives by managing loading from runoff, in addition to the dry day load reduction, in 4 subbasins: 18499 with a 93% reduction; 18500 with a 90% reduction; 16712 with a 90% reduction; and 13027 with a 50% reduction.

Although Oso Bay (with the exclusion of station 13441) meets all water quality objectives related to *Enterococcus* concentrations, Oso Creek presents a challenge for the reduction and management of *Enterococcus* loading. Without the removal of dry day loading, water quality objectives in the creek cannot be met. Any strategies to reduce overall loading in Oso Creek must include identification of the sources of dry day loading. Further investigations are recommended, and should focus on ground water influx containing sewage from ineffective or failed septic systems, ground water inflow containing sewage from broken or leaking municipal sewage mains, wildlife populations around the creek that could provide direct fecal input to the creek, and domesticated animal activities (large and small) in and around the creek. Other investigations, such as the sequestration and reactivation (or resuspension) of *Enterococcus* in the streambed, or reactivation of chlorine treated *Enterococcus* in an effluent dominated stream, could provide some insight into the influence of *Enterococcus* survivability on dry day loadings.

9 References

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Appendix I. Literature Review of Die-off Rates

Medema et al(1997)

Temp (°C)	Time (days)	log_{10} Die off rate per day	95 % confidence Interval	log_e Die Off Rate ($days^{-1}$)	T90 (days)
5	42	0.077	.066-.090	0.18	12.99
15	0-14	0.233	.160-.306	0.54	4.29
	14-42	0.025	.0-.050	0.06	40

Noble et al(2003)

	Temp (°C)	kd per hour	se/n	Die-Off Rate($days^{-1}$)	T90 (days)
Seawater	20	0.02	.0014/12	0.48	4.79
Varied Nutrients Temperature, TSS,Bacteria concentration	14	0.013	.0017/12	0.31	7.38
Seawater	20	0.019	.0017/6	0.46	5.05
Varied Temperature,bacteria concentration and inoculant type,(influent,effleunt,runoff)	14	0.016	.0021/6	0.38	6.00
Seawater		0.2572	.0074/8	6.17	0.37
Varied solar irradiation, TSS, inoculant type(influent, effluent)		0.2434	.0221/8	5.84	0.39
Freshwater		0.2724	.0068/8	6.54	0.35
Varied solar irradiation, TSS, inoculant type(influent, effluent)		0.2434	.0133/8	5.84	0.39

Bordalo et al(2002)

		Average T90 survival rate(h)	Die-Off Rate ($days^{-1}$)	T90 (days)
Low Salinity	Light	40.9 ±0.4	1.35	1.70
	Dark	97.5 ±0.4	0.57	4.06
Progressive mixing	Light	33.7 ±2.1	1.64	1.40
	Dark	73 ±8.8	0.76	3.04
Fast Mixing	Light	20.6 ±1.2	2.68	0.86
	Dark	31.6 ±2.5	1.75	1.32

Sinton et al(2002)

	Die-Off Rate (h^{-1})	T90(h)		Die-Off Rate ($days^{-1}$)	T90 (days)
Dark inactivation rates WSP	0.0168	135		0.40	5.625
RS	0.012	192		0.29	8

	Solar Inactivation Rate (m^2MJ^{-1})	T90(h)	Insolation S90(MJm^{-2})	Equivalent Die-Off Rate ($days^{-1}$)	T90 (days)
Sunlight WSP Summer	0.276	3	8.4	18.55	0.77
RS Summer	0.137	6.4	16.8	8.63	0.36
Sunlight WSP Winter	0.11	14.5	21	3.82	0.16
RS Winter	0.138	12.6	16.7	4.39	0.18

Alkan et al(1995)

Experiment No.	Light (W/m^2)	Turb (abs)	Sewage (%, v/v)	Mixing (cm^2/s)	Temp (°C)	Botom Port	Surface Port	Bottom Port $\log_e$ Die Off Rate ($days^{-1}$)	Bottom Port T90 (days)	Surface Port $\log_e$ Die Off Rate ($days^{-1}$)	Surface Port T90 (days)
1	300	0.288	1.00	0.43	25	0.0156	0.0179	22.46	0.10	25.78	0.09
2	700	0.288	1.00	0.43	15	0.0203	0.0259	29.23	0.08	37.30	0.06
3	300	0.674	1.00	0.43	15	0.0088	0.0114	12.67	0.18	16.42	0.14
4	700	0.674	1.00	0.43	25	0.0113	0.014	16.27	0.14	20.16	0.11
5	300	0.0288	2.50	0.43	15	0.0079	0.0096	11.38	0.20	13.82	0.17
6	700	0.288	2.50	0.43	25	0.0094	0.0113	13.54	0.17	16.27	0.14
7	300	0.674	2.50	0.43	25	0.0063	0.0081	9.07	0.25	11.66	0.20
8	700	0.674	2.50	0.43	15	0.0099	0.0108	14.26	0.16	15.55	0.15
9	300	0.288	1.00	1.21	15	0.0164	0.0216	23.62	0.10	31.10	0.07
10	700	0.288	1.00	1.21	25	0.0184	0.0171	26.50	0.09	24.62	0.09
11	300	0.674	1.00	1.21	15	0.0142	0.0183	20.45	0.11	26.35	0.09
12	700	0.674	1.00	1.21	25	0.0152	0.0143	21.89	0.11	20.59	0.11
13	300	0.288	2.50	1.21	15	0.0147	0.0186	21.17	0.11	26.78	0.09
14	700	0.288	2.50	1.21	15	0.016	0.0175	23.04	0.10	25.20	0.09
15	300	0.674	2.50	1.21	25	0.0077	0.0087	11.09	0.21	12.53	0.18
16	700	0.483	2.50	1.21	20	0.0157	0.0106	22.61	0.10	15.26	0.15
17	500	0.483	1.75	0.82	20	0.0165	0.0185	23.76	0.10	26.64	0.09
18	500	0.483	1.75	0.82	20	0.0154	0.0193	22.18	0.10	27.79	0.08
19	500	0.483	1.75	0.82	20	0.0136	0.0137	19.58	0.12	19.73	0.12
20	500	0.483	1.75	0.82	20	0.0126	0.0184	18.14	0.13	26.50	0.09
21	500	0.483	1.75	0.82	20	0.0145	0.0175	20.88	0.11	25.20	0.09
22	100	0.483	1.75	0.82	20	0.0047	0.0065	6.77	0.34	9.36	0.25
23	900	0.483	1.75	0.82	20	0.0207	0.0264	29.81	0.08	38.02	0.06
24	500	0.044	1.75	0.82	20	0.0279	0.03	40.18	0.06	43.20	0.05
25	500	0.864	1.75	0.82	20	0.0093	0.0159	13.39	0.17	22.90	0.10
26	500	0.483	0.25	0.82	20	0.0208	0.0289	29.95	0.08	41.62	0.06
27	500	0.483	3.25	0.82	20	0.0144	0.0162	20.74	0.11	23.33	0.10
28	500	0.483	1.75	0.04	20	0.0017	0.0799	2.45	0.94	115.06	0.02
29	500	0.483	1.75	1.6	20	0.015	0.0164	21.60	0.11	23.62	0.10
30	500	0.483	1.75	0.82	10	0.0123	0.0156	17.71	0.13	22.46	0.10
31	500	0.483	1.75	0.82	30	0.0117	0.0146	16.85	0.14	21.02	0.11
32	500	0.483	1.75	0.82	20	0.0135	0.0159	19.44	0.12	22.90	0.10
33	300	0.288	1.00	0.82	25	0.0174	0.0188	25.06	0.09	27.07	0.09
34	700	0.288	1.00	0.43	15	0.0187	0.0281	26.93	0.09	40.46	0.06
35	300	0.674	1.00	0.43	15	0.0075	0.0087	10.80	0.21	12.53	0.18
36	700	0.674	1.00	0.43	25	0.0133	0.0141	19.15	0.12	20.30	0.11
37	300	0.288	2.50	0.43	15	0.0099	0.0103	14.26	0.16	14.83	0.16
38	700	0.288	2.50	0.43	25	0.0113	0.0134	16.27	0.14	19.30	0.12
39	300	0.674	2.50	0.43	25	0.0066	0.0102	9.50	0.24	14.69	0.16
40	700	0.674	2.50	0.43	15	0.01	0.01025	14.40	0.16	14.76	0.16
41	300	0.288	1.00	1.21	15	0.0129	0.0172	18.58	0.12	24.77	0.09
42	700	0.288	1.00	1.21	25	0.0212	0.0175	30.53	0.08	25.20	0.09
43	300	0.674	1.00	1.21	25	0.0157	0.0165	22.61	0.10	23.76	0.10
44	700	0.674	1.00	1.21	15	0.0141	0.0171	20.30	0.11	24.62	0.09
45	300	0.288	2.50	1.21	25	0.017	0.0177	24.48	0.09	25.49	0.09
46	700	0.288	2.50	1.21	15	0.0166	0.0144	23.90	0.10	20.74	0.11
47	300	0.674	2.50	1.21	15	0.0078	0.009	11.23	0.21	12.96	0.18
48	700	0.674	2.50	1.21	25	0.0142	0.0209	20.45	0.11	30.10	0.08
49	100	0.483	1.75	0.82	20	0.0053	0.0079	7.63	0.30	11.38	0.20
50	900	0.483	1.75	0.82	20	0.0192	0.0238	27.65	0.08	34.27	0.07
51	500	0.044	1.75	0.82	20	0.0247	0.00285	35.57	0.06	4.10	0.56
52	500	0.864	1.75	0.82	20	0.0085	0.0177	12.24	0.19	25.49	0.09
53	500	0.483	0.25	0.82	20	0.0192	0.0244	27.65	0.08	35.14	0.07
54	500	0.483	3.25	0.82	20	0.0139	0.0148	20.02	0.12	21.31	0.11
55	500	0.483	1.75	0.04	20	0.0029	0.083	4.18	0.55	119.52	0.02
56	500	0.483	1.75	1.6	20	0.0173	0.0176	24.91	0.09	25.34	0.09
57	500	0.483	1.75	0.82	10	0.0114	0.0134	16.42	0.14	19.30	0.12
58	500	0.483	1.75	0.82	30	0.0133	0.0149	19.15	0.12	21.46	0.11

Sinton et al(1994)

	Expt no.	Die-Off Rate (h^{-1})	T90 (h)	Die-Off Rate (days-1)	T90(days)
Sewage Cold	5,6	0.005	461	0.12	19.21
Sewage Warm	4,6	0.008	288	0.19	12.00
Meatworks Cold	5,6	0.008	288	0.19	12.00
Meatworks Warm	4,6	0.009	256	0.22	10.67

Sunlight inactivation Parameters	Expt no.	Solar Inactivation Rate (m^2MJ^{-1})	S90 (MJm^{-2})	T90 (h)	Die-Off Rate ($days^{-1}$)	T90(days)
Sewage	7	0.31	6.04	12.00	3.74	0.50
	1,2,3,8		11.82	6.40	13.74	0.27
	1,2,3,7,8		10.66	6.40	12.39	0.27
Meatworks	7		3.82	7.30	4.68	0.30
	1,2,3,8	0.37	10.12	5.20	17.42	0.22
	1,2,3,7,8		8.86	5.20	15.25	0.22

Where Cold is 8 to 10 degrees Celsius and Warm is 15 to 20 degrees Celsius
Experiment 7 was performed in winter whereas 1,2,3 and 8 were performed in Summer.

Sinton et al(1994)

	Die-Off Rate(h^{-1})	T90(h)	Die-Off Rate ($days^{-1}$)	T90 (days)
Dark Inactivation Rate in the summer	0.005	446	0.12	18.58

	Solar Inactivation Rate (m^2MJ^{-1})	T90(h)	S90 (MJ/m^2)	Die-Off Rate ($days^{-1}$)	T90 (days)
Summer mean sunlight inactivation parameter	0.27	6.9	15.8	14.84	0.29

Appendix II. Observed Usage

Station I.D.	Date	Time	Human Use	Comments
18499	05/19/05	805	none	algae, wood debirs, surface scum
18500	05/19/05	830	none	wood debris, trash in water, birds in area
18501	05/19/05	850	none	tire in water
13028	05/19/05	914	none	dead fish and trash on shore
16712	05/19/05	937	none	none
13029	05/19/05	1001	none	wood debris in water; extremely muddy
13027	05/19/05	1043	none	trash in water, 20 birds in area
13026	05/19/05	1102	1 fisherman	trash on shore and 1 dead fish
13440	05/19/05	1127	1 boater, 2 fishermen	trash on shore
13441	05/19/05	1200	none	10 birds at site
13442	05/19/05	1225	6 fishermen	4 cars on shore
18499	05/26/05	902	none	none
18501	05/26/05	929	none	wood debris and trash in water, site down from cow pasture
18500	05/26/05	944	none	none
13029	05/26/05	959	none	wood debris in water; dense vegetation on bank
13028	05/26/05	1016	none	trash in surrounding area
16712	05/26/05	1035	none	none
13026	05/26/05	1109	1 fisherman	trash along shore
13027	05/26/05	1136	none	dense vegetation on bank
13440	05/26/05	1200	2 fishermen	none
13441	05/26/05	1228	none	dead fish on shore, about 12 birds in area
13442	05/26/05	1240	2 fishermen	none
S1	06/01/05	1320	none	"chlorine like" smell
S3	06/01/05	1320	none	brush and trash in water
S2	06/01/05	1336	none	flow measurements being conducted at site
S7	06/01/05	1336	none	none
S9	06/01/05	1401	none	site near houses
S8	06/01/05	1422	none	grass and trash in water; runoff from landfill
S10	06/01/05	1502	none	vegetation in water
S4	06/01/05	1516	none	site near colonials
S6	06/01/05	1545	none	construction around area; trash on bank
S5	06/01/05	1557	none	fish and crabs in water; down from horse pasture
S11	06/01/05	1615	none	green coloration in water (maybe algae)
18499	06/02/05	753	none	stagnant water; wood debris in water
S3	06/02/05	815	none	trash floating in water; 2 birds in area
S7	06/02/05	828	none	birds in water
18501	06/02/05	855	none	none
18500	06/02/05	909	none	20 birds at site
S9	06/02/05	921	none	wood debris in ditch; next to houses
13029	06/02/05	937	none	flow measurements being conducted at site; water very turbid
13028	06/02/05	954	none	trash in surrounding area; dense vegetation around site
S8	06/02/05	1011	none	stagnant water, trasha and vegetation in water
16712	06/02/05	1023	none	softball and vegetation in water
S2	06/02/05	1047	none	1 bird in water, 1 keyboard in water
13027	06/02/05	1102	none	30 birds in area
S10	06/02/05	1138	none	oil slick on water surface
S4	06/02/05	1155	none	ditch next to colonials
S6	06/02/05	1224	none	wood debris and trash in water (styrofoam, plastic bottles)
13026	06/02/05	1239	boaters in area	trucks and trailers on shore
S5	06/02/05	1251	none	film on top of water
13440	06/02/05	1310	4 fishermen	none
S11	06/02/05	1326	none	site at Oso golf course
S1	06/02/05	1340	none	Oso WWTP
13441	06/02/05	1351	none	dead fish on shore, about 20 birds in area
13442	06/02/05	1410	none	trash on shore
18499	06/03/05	800	none	wood debris and plastic bottles in water

Station I.D.	Date	Time	Human Use	Comments
S3	06/03/05	825	none	trash debris in area
S7	06/03/05	844	none	green tint to water, trash and debris in area
18501	06/03/05	903	none	cow pasture nearby
18500	06/03/05	917	none	debris in water; flow measurement being conducted
S9	06/03/05	927	none	trash and what looks like raw sewage in water
13029	06/03/05	949	none	dense vegetation on bank; wood debris in water
13028	06/03/05	1009	none	trash in water
S8	06/03/05	1028	none	trash in water; film on water surface
16712	06/03/05	1039	none	dense vegetation on bank
S2	06/03/05	1102	none	dense vegetation along bank
13027	06/03/05	1144	none	dense vegetation along bank
S10	06/03/05	1151	none	wood debris and vegetation in water
S4	06/03/05	1209	none	cow pasture and colonials nearby
S6	06/03/05	1232	none	brown tint to water, trash and wood debris in water
13026	06/03/05	1248	none	none
S5	06/03/05	1301	none	near horse pasture
13440	06/03/05	1317	none	none
S11	06/03/05	1334	none	down from golf course
S1	06/03/05	1356	none	"chlorine like" smell
13441	06/03/05	1406	none	dead fish and trash on shore, 10 birds in area
13442	06/03/05	1428	none	5 birds in area, trash on shore
18499	06/04/05	808	none	wood debris and trash along bank
18501	06/04/05	827	none	down from cow pasture
18500	06/04/05	840	none	15 birds in water
13029	06/04/05	855	none	dense vegetation along bank
13028	06/04/05	912	none	wood debris and trash in water
16712	06/04/05	928	none	dense vegetation along bank
13027	06/04/05	952	none	about 20 birds in area, 1 person mowing grass near site
13026	06/04/05	1012	2 fishermen	2 cranes in water, 5 birds in area
13440	06/04/05	1027	2 boats, 3 fishermen	birds in area
13441	06/04/05	1049	none	2 dead fish in water and 4 along banks
13442	06/04/05	1106	1 kayak, 5 wading fishermen	3 vehicles
18499	06/09/05	918	none	trash in area
18501	06/09/05	940	none	trash in water
18500	06/09/05	953	none	brush in water
13029	06/09/05	1007	none	tire in creek
13028	06/09/05	1024	none	trash in water
16712	06/09/05	1044	none	down from landfill
13027	06/09/05	1117	none	none
13026	06/09/05	1133	4 fishermen	none
13440	06/09/05	1150	none	some trash in area
13441	06/09/05	1213	none	dead fish in water, 10 birds in area
13442	06/09/05	1233	3 fishermen	none
18499	06/16/05	827	none	dark green film on top of water
18501	06/16/05	846	none	down from cow pasture
18500	06/16/05	858	none	birds nesting above water
13029	06/16/05	916	none	trash in water
13028	06/16/05	932	none	trash in water and along shore
16712	06/16/05	949	none	none
13027	06/16/05	1016	none	none
13026	06/16/05	1030	1 fisherman	none
13440	06/16/05	1047	2 fishermen	none
13441	06/16/05	1106	none	about 30 birds in area
13442	06/16/05	1125	3 fishermen	none
18499	06/23/05	828	none	excess surface scum, wood debris in water, birds in area
18501	06/23/05	847	none	snake in water, tire in water
18500	06/23/05	900	none	none
13029	06/23/05	912	none	wood debris in water, dense vegetation along bank
13028	06/23/05	926	none	none

Station I.D.	Date	Time	Human Use	Comments
16712	06/23/05	944	none	large amount of insects on water
13027	06/23/05	1006	none	none
13026	06/23/05	1021	4 fishermen	1 vehicle, 2 pelicans
13440	06/23/05	1035	none	fish in water
13441	06/23/05	1053	none	1 birdwatcher
13442	06/23/05	1109	2 fishermen	2 vehicles
18499	06/30/05	812	none	leaf and wood debris in water
18501	06/30/05	828	none	cable and trash in water, down from cow pasture
18500	06/30/05	841	none	wood and leaves in water
13029	06/30/05	859	none	none
13028	06/30/05	917	none	trash in water and on bank
16712	06/30/05	934	none	trash along bank; dense vegetation
13027	06/30/05	954	none	houses along bank; dense vegetation along bank
13026	06/30/05	1016	2 fishermen	foam and grass in water
13440	06/30/05	1037	5 fishermen	trash on shore
13441	06/30/05	1058	none	one dead fish in water, trash on shore
13442	06/30/05	1134	none	trash on shore
18499	07/07/05	826	none	algae on surface of water and along bank
18501	07/07/05	850	none	no flow, very low water level; one large pool
18500	07/07/05	910	none	very low water level, trash on bank
13029	07/07/05	927	none	trash and wood debris in water
13028	07/07/05	948	none	downstream from dump, dense vegetation along bank
16712	07/07/05	1009	none	trash and brush on banks
13027	07/07/05	1045	none	birds nesting under bridge, about 300 swallows
13026	07/07/05	1058	2 fishermen	foam on top of water, some trash on banks
13440	07/07/05	1115	none	trash on banks
13441	07/07/05	1136	none	trash on shore, about 500 birds in area
13442	07/07/05	1154	12 fishermen, 1 kayak	trash on shore
18499	07/14/05	830	none	wood and leaf debris in water
18501	07/14/05	850	none	one large pool of water beneath bridge
18500	07/14/05	903	none	algae growing along bank, leaf debris in water
13029	07/14/05	916	none	algae growing along bank
13028	07/14/05	932	none	downstream from landfill
16712	07/14/05	945	none	algae along bank, dense vegetation along bank
13027	07/14/05	1008	none	houses along bank
13026	07/14/05	1030	3 fishermen	foam along banks and on top of water
13440	07/14/05	1048	3 fishermen	3 vehicles
13441	07/14/05	1112	none	"chlorine like" smell: 120 birds in surrounding water
13442	07/14/05	1129	4 fishermen	2 vehicles, foam along waters edge
18499	07/21/05	841	none	tire in water
18501	07/21/05	905	none	site is one large; tadpoles throughout; not much change from previous week
18500	07/21/05	915	none	bleach bottle near water
13029	07/21/05	940	none	dense vegetation along bank, trash on bank
13028	07/21/05	1000	none	trash near on bank, water very green
16712	07/21/05	1019	none	leaf debris in water
13027	07/21/05	1105	none	sparrows nesting under bridge
13026	07/21/05	1121	3 fishermen	seagulls in area; fish abundant in water
13440	07/21/05	1136	none	trash on shore
13441	07/21/05	1157	none	high water level, trash on shore
13442	07/21/05	1215	4 fishermen, 1 kayaker	about 25 birds in area
18499	07/28/05	833	none	leaf debris in water
18501	07/28/05	858	none	tadpoles in water; medium size pool of water
18500	07/28/05	910	none	trash on bank
13029	07/28/05	920	none	trash in water
13028	07/28/05	937	none	bulldozing on other side of creek
16712	07/28/05	953	none	none
13027	07/28/05	1014	none	none
13026	07/28/05	1030	3 fishermen	trash on shore

Station I.D.	Date	Time	Human Use	Comments
13440	07/28/05	1046	none	2 birds and trash on shore
13441	07/28/05	1106	none	birds in water, trash on shore
13442	07/28/05	1133	4 fishermen	birds in water, trash on shore
18499	08/04/05	636	none	tire in water
18501	08/04/05	733	none	one large pool of water beneath bridge
18500	08/04/05	740	none	bleach bottle near water, trash on bank
13029	08/04/05	751	none	brush debris in water
13028	08/04/05	810	none	trash on banks and in water
16712	08/04/05	819	none	dense vegetation along bank
13027	08/04/05	838	none	housing along creek
13026	08/04/05	848	2 fishermen	thick foam on shore
13440	08/04/05	904	1 fisherman	cameraman on shore, trash on shore
13441	08/04/05	933	none	trash on shore, about 300 birds
13442	08/04/05	951	2 fishermen	trash on shore, about 45 birds
18499	08/11/05	735	none	next to farmland
18501	08/11/05	752	none	very shallow, tadpoles in water, trash on shore
18500	08/11/05	807	none	birds nesting under bridge
13029	08/11/05	817	none	tire in water, trash in water; water very turbid
13028	08/11/05	836	none	trash on banks, old BBQ pit in water
16712	08/11/05	848	none	dense brush along banks
13027	08/11/05	912	none	housing along creek, storm drain down from site
13026	08/11/05	932	3 fishermen	dead fish on bridge, foam on water
13440	08/11/05	948	none	trash on shore
13441	08/11/05	1010	none	trash on shore, about 600 birds in area, water level low
13442	08/11/05	1025	5 fishermen, 1 kayaker	trash on shore
18499	08/18/05	723	none	water looks more turbid, leaf debris and brush in water
18500	08/18/05	751	none	cotton in water, bleach bottle on bank
13029	08/18/05	806	none	water looks more clear than usual
18501	08/18/05	818	none	no sample taken, pool of water <0.08m
16712	08/18/05	834	none	dense brush on bank
13028	08/18/05	851	none	dense brush on bank, trash on opposite bank
13027	08/18/05	911	none	very green water, dense vegetation on bank
13026	08/18/05	937	none	foam on shoreline
13440	08/18/05	954	none	trash on shore
13441	08/18/05	1013	none	about 300 birds in area
13442	08/18/05	1041	7 fishermen	trash on shore
18499	08/25/05	733	none	trash and leaf debris in water
18500	08/25/05	752	none	trash along bank
18501	08/25/05	756	none	site dried up, unable to take sample
13029	08/25/05	804	none	trash and leaf debris in water
13028	08/25/05	817	none	trash in water and in surrounding area
16712	08/25/05	833	none	some trash in area
13027	08/25/05	848	none	very green water, dense vegetation on bank
13026	08/25/05	902	none	foam on top of water, strong current
13440	08/25/05	918	none	trash on shore, 1 dead fish
13441	08/25/05	940	none	bird feathers in water, trash on shore
13442	08/25/05	955	4 fishermen	trash on shore, 10 birds in water
18499	09/15/05	708	none	wood debris in water; biofilm on water surface
18500	09/15/05	732	none	wood debris in water
18501	09/15/05	737	none	site dried out, unable to take sample
13029	09/15/05	746	none	wood debris in water
13028	09/15/05	805	none	trash in surrounding area
16712	09/15/05	820	none	dense vegetation along bank, wood debris in water
13027	09/15/05	842	none	houses along creek edge
13026	09/15/05	857	none	about 20 birds in area
13440	09/15/05	914	1 fisherman	one human performing yoga on water edge
13441	09/15/05	935	none	chemical smell, slight drizzle rain
13442	09/15/05	954	1 fisherman	slight drizzle rain
S3	10/12/05	859	none	trash debris in water

Station I.D.	Date	Time	Human Use	Comments
S7	10/12/05	912	none	brush removed, side of ditch replaced with asphalt
18499	10/12/05	935	none	no biofilm present as previously seen
18501	10/12/05	957	none	runoff from ditch, horse and cow pasture to right of station
18500	10/12/05	1017	none	none
S9	10/12/05	1028	none	some debris; 1 plastic coffee container, plastic sheet
13029	10/12/05	1036	none	none
13028	10/12/05	1051	none	samples taken closer to shore, water level very high
S8	10/12/05	1102	none	no sample taken at site water <0.10m
16712	10/12/05	1111	none	none
S2	10/12/05	1126	none	dense grass brush on side
S10	10/12/05	1142	none	none
S4	10/12/05	1155	none	reddish water color near road intersection
13027	10/12/05	1219	none	none
S6	10/12/05	1234	none	none
13026	10/12/05	1247	1 fisherman	birds along shore
S5	10/12/05	1257	none	site down from cow pasture
13440	10/12/05	1314	none	none
S11	10/12/05	1331	none	green water on edges along bank
S1	10/12/05	1342	none	dense brush debris on shore
13441	10/12/05	1351	none	trash on shore, about 100 birds in area
13442	10/12/05	1411	none	trash on shoreline
S3	10/13/05	748	none	trash in water
S7	10/13/05	953	none	none
18499	10/13/05	1010	none	green scum on surface of water (biofilm)
18501	10/13/05	1026	none	brush debris in water
18500	10/13/05	1038	none	none
S9	10/13/05	1044	none	no sample taken at site water <0.10m
13029	10/13/05	1053	none	brush and trash in water (plastic bottles)
13028	10/13/05	1108	none	trash on banks and in water
S8	10/13/05	1118	none	no sample taken at site, water <0.02m
16712	10/13/05	1124	none	dense brush on bank
S2	10/13/05	1148	none	dense brush on waters edge
13027	10/13/05	1211	none	dense grass and brush on bank
S10	10/13/05	1216	none	dense grass and brush on bank and in water
S4	10/13/05	1231	none	none
S6	10/13/05	1253	none	none
13026	10/13/05	1305	4 fishermen	none
S5	10/13/05	1314	none	brush in water, horse pasture upstream, 3 horses
13440	10/13/05	1331	none	none
S11	10/13/05	1418	none	raining at time of sample, dark green water color
S1	10/13/05	1429	none	none
13441	10/13/05	1440	none	ducks in area (about 10)
13442	10/13/05	1455	none	none
S3	10/14/05	925	none	trash debris in water (plastic bottles and aluminum cans); algal growth alone bank
S7	10/14/05	939	none	wood debris on water surface
18499	10/14/05	956	none	oily film on water surface
18501	10/14/05	1016	none	floating manure in water, submerged vegetation
18500	10/14/05	1027	none	dense vegetation along bank
S9	10/14/05	1030	none	no sample taken, <0.08m of water
13029	10/14/05	1046	none	leaf debris and trash in water
13028	10/14/05	1234	none	leaf debris and trash in water
S8	10/14/05	1241	none	no sample taken, no water
16712	10/14/05	1246	none	dense vegetation along bank
S2	10/14/05	1302	none	vegetation along bank
13027	10/14/05	1315	none	none
S10	10/14/05	1333	none	decaying vegetation in water
S4	10/14/05	1345	none	leaf and wood debris floating in water
S6	10/14/05	1408	none	vegetation along water banks

Station I.D.	Date	Time	Human Use	Comments
13026	10/14/05	1420	none	foam on water surface
S5	10/14/05	1432	none	horses directly up from site
13440	10/14/05	1443	none	none
S11	10/14/05	1458	none	oily film on water surface
S1	10/14/05	1510	none	water from Oso WWTP
13441	10/14/05	1519	none	20 ducks and 3 pelicans at site
13442	10/14/05	1535	1 fisherman	trash along shoreling
S3	10/15/05	732	none	none
S7	10/15/05	741	none	none
18499	10/15/05	758	none	biofilm on water surface
18500	10/15/05	817	none	none
18501	10/15/05	830	none	brush debris in water
S9	10/15/05	835	none	no sample taken; no water
13029	10/15/05	843	none	leaf debris and trash in water
13028	10/15/05	1128	none	trash on bank and in water
S8	10/15/05	1143	none	no sample taken; no water
16712	10/15/05	1149	none	dense brush on bank
S2	10/15/05	1213	none	trash on bank
S4	10/15/05	1229	none	no sample taken; very little water <0.08m
S10	10/15/05	1240	none	submerged vegetation
13027	10/15/05	1249	none	dense brush and grass along bank
S6	10/15/05	1304	none	trash in water, submerged brush
13026	10/15/05	1314	none	none
S5	10/15/05	1325	none	brush in water, downstream from pasture
13440	10/15/05	1339	10 fishermen	trash debris on shore
S11	10/15/05	1347	none	trash on shore
S1	10/15/05	1356	none	dense brush on shore, 8 dead fish
13441	10/15/05	1403	none	about 50 birds in area (pelicans and ducks)
13442	10/15/05	1418	6 fishermen	trash on shore
18499	10/16/05	837	none	biofilm on water surface
S3	10/16/05	848	none	vegetation on water surface
S7	10/16/05	859	none	down from Robstown WWTP
18501	10/16/05	921	none	dead and decaying vegetation in water
18500	10/16/05	931	none	vegetation along bank, wood debris in water
S9	10/16/05	936	none	no sample taken, no water
13029	10/16/05	942	none	vegetation along bank, flow measurements being taken
13028	10/16/05	957	none	none
16712	10/16/05	1000	none	landfill closed, no access to sites
S8	10/16/05	1000	none	landfill closed, no access to sites
S2	10/16/05	1017	none	none
S10	10/16/05	1033	none	decaying vegetaton in water
S4	10/16/05	1040	none	no sample taken, very little water <0.05m
13027	10/16/05	1050	none	none
S6	10/16/05	1101	none	trash in water
13026	10/16/05	1116	3 fishermen, 5 kayakers	none
S5	10/16/05	1124	none	none
13440	10/16/05	1138	none	1 human sunbathing/napping on rocks
S11	10/16/05	1151	none	none
S1	10/16/05	1200	none	none
13441	10/16/05	1207	3 fishermen, 1 boat	none
13442	10/16/05	1224	4 fishermen	none
18499	10/20/05	846	none	biofilm on water surface; looks like some gas production as well (bubbles)
18501	10/20/05	908	none	one large pool of water, no flow
18500	10/20/05	923	none	none
13029	10/20/05	938	none	tire and trash in water
16712	10/20/05	1012	none	none
13027	10/20/05	1031	none	none
13026	10/20/05	1051	2 fishermen	trash on shore

Station I.D.	Date	Time	Human Use	Comments
13440	10/20/05	1114	2 fishermen, 1 lady living under bridge	trash on shore and strong sewage smell on shore
13441	10/20/05	1140	none	about 200 birds in area
13442	10/20/05	1200	3 fishermen	none
13028	10/20/05	1955	none	trash in water and in surrounding area
18499	11/17/05	839	none	none
18501	11/17/05	858	none	trash and tire in water
18500	11/17/05	915	none	none
13029	11/17/05	928	none	none
13028	11/17/05	942	none	trash in area
16712	11/17/05	957	none	none
13027	11/17/05	1017	none	none
13026	11/17/05	1034	4 fishermen	none
13440	11/17/05	1052	1 boat, 1 fisherman, 1 transient	none
13441	11/17/05	1101	none	200 birds present
13442	11/17/05	1134	2 fishermen	20 birds at station
16712	11/27/05	NA	NA	landfill closed, no access to sites
S8	11/27/05	NA	NA	landfill closed, no access to sites
S3	11/27/05	941	none	trash and brush debris in water
S7	11/27/05	952	none	trash on shore
18499	11/27/05	1009	none	leaf debris and trash in water
18501	11/27/05	1028	none	none
18500	11/27/05	1044	none	very high water level, dense brush on bank
S9	11/27/05	1057	none	none
13029	11/27/05	1115	none	dense brush debris
13028	11/27/05	1140	none	none
S2	11/27/05	1155	none	dense brush on shore
13027	11/27/05	1248	none	dense brush on bank
S10	11/27/05	1259	none	none
S4	11/27/05	1311	none	none
S6	11/27/05	1335	none	trash in water
13026	11/27/05	1351	2 fishermen	none
S5	11/27/05	1402	none	none
13440	11/27/05	1416	none	trash on shore
S11	11/27/05	1431	none	very green water
S1	11/27/05	1446	none	none
13441	11/27/05	1456	none	about 100 birds at station
13442	11/27/05	1513	5 fishermen	none
S3	11/28/05	1043	none	none
S7	11/28/05	1056	none	none
18499	11/28/05	1115	none	none
18501	11/28/05	1131	none	none
18500	11/28/05	1150	none	brush in water
S9	11/28/05	1202	none	tire in ditch
13029	11/28/05	1217	none	dense brush on bank
13028	11/28/05	1230	none	trash on bank
S8	11/28/05	1245	none	brush in water
16712	11/28/05	1255	none	none
S2	11/28/05	1318	none	trash at station
13027	11/28/05	1407	none	none
S10	11/28/05	1419	none	birds in trees above/near creek
S4	11/28/05	1431	none	none
S6	11/28/05	1502	none	none
13026	11/28/05	1513	4 fishermen	very turbid water
S5	11/28/05	1527	none	dense brush debris on bank
13440	11/28/05	1542	none	trash on shoreline
13441	11/28/05	1542	none	about 200 birds in area
S11	11/28/05	1554	none	water very green
S1	11/28/05	1609	none	none

Station I.D.	Date	Time	Human Use	Comments
13442	11/28/05	1633	4 fishermen	trash on shore
S3	11/29/05	656	none	trash in water
S7	11/29/05	707	none	trash in water
18499	11/29/05	722	none	none
18501	11/29/05	737	none	brush in water
18500	11/29/05	757	none	birds nesting under bridge
S9	11/29/05	805	none	none
13029	11/29/05	817	none	dense brush in water
13028	11/29/05	833	none	none
S8	11/29/05	847	none	scum layer on water surface
16712	11/29/05	857	none	dense brush in water
S2	11/29/05	916	none	none
13027	11/29/05	949	none	none
S10	11/29/05	1004	none	none
S4	11/29/05	1017	none	2 dogs in area
S6	11/29/05	1044	none	one truck at station
13026	11/29/05	1057	1 fisherman	none
S5	11/29/05	1110	none	dense brush on shore
13440	11/29/05	1124	none	trash on shore
S11	11/29/05	1139	none	none
S1	11/29/05	1154	none	none
13441	11/29/05	1205	none	about 200 birds ducks, dead fish and crab in water
13442	11/29/05	1223	2 fishermen	trash on shore
S8	11/30/05	NA	none	no sample taken <10cm of water
S3	11/30/05	1047	none	1 bird (crane) in water
S7	11/30/05	1100	none	none
18499	11/30/05	1133	none	none
18501	11/30/05	1151	none	none
18500	11/30/05	1206	none	none
S9	11/30/05	1218	none	none
13029	11/30/05	1229	none	none
13028	11/30/05	1247	none	none
16712	11/30/05	1304	none	trash in water
S2	11/30/05	1320	none	trash around station
13027	11/30/05	1354	none	trash in water
S10	11/30/05	1409	none	none
S4	11/30/05	1432	none	trash in area
S6	11/30/05	1456	none	trash in area
13026	11/30/05	1510	3 fishermen	none
S5	11/30/05	1523	none	trash in water
13440	11/30/05	1549	1 boat	4 birds at station
S11	11/30/05	1607	none	trash in water, green/blue tint
S1	11/30/05	1622	none	ducks in area
13441	11/30/05	1632	none	500 birds
13442	11/30/05	1654	1 kayaker, 1fisherman, 2 people on shore	none
S8	12/01/05	NA	none	no sample taken <10cm of water
S3	12/01/05	846	none	trash in water
S7	12/01/05	858	none	trash in water and in surrounding area
18499	12/01/05	916	none	trash in and around water
18501	12/01/05	934	none	trash in area
18500	12/01/05	952	none	trash in water, a few birds nesting under bridge
S9	12/01/05	1001	none	trash in ditch
13029	12/01/05	1013	none	none
13028	12/01/05	1030	none	trash in water
16712	12/01/05	1046	none	1 bird nest in water
S2	12/01/05	1103	none	trash in area, 1 snowy egret, 3 grebes in water
13027	12/01/05	1144	none	1 great egret present
S10	12/01/05	1155	none	trash in area

Station I.D.	Date	Time	Human Use	Comments
S4	12/01/05	1207	none	trash in area
S6	12/01/05	1232	none	trash and wood debris in water
13026	12/01/05	1244	1 fisherman	trash and tire in water, 3 birds in water
S5	12/01/05	1300	none	trash in water
13440	12/01/05	1316	1 fisherman	snowy egret feeding in water
S11	12/01/05	1331	none	trash on shoreline
S1	12/01/05	1345	none	15 ducks at station
13441	12/01/05	1357	none	about 800 birds present
13442	12/01/05	1416	2 kayakers, 3 fishermen	trash on shore
18499	12/08/05	943	none	none
18501	12/08/05	1003	none	trash and tire in water
18500	12/08/05	1024	none	none
13029	12/08/05	1038	none	no trash!
13028	12/08/05	1053	none	none
16712	12/08/05	1106	none	trash in water
13027	12/08/05	1135	none	none
13026	12/08/05	1153	3 fishermen	trash on shoreline
13440	12/08/05	1212	none	none
13441	12/08/05	1228	none	50 birds at station
13442	12/08/05	1250	5 fishermen	none
18499	12/15/05	923	none	oily film on water surface
18501	12/15/05	942	none	one large pool of water
18500	12/15/05	956	none	brush in water
13029	12/15/05	1010	none	water very clear
13028	12/15/05	1026	none	dense brush on shore, trash on shore
16712	12/15/05	1042	none	none
13026	12/15/05	1132	none	none
13027	12/15/05	1147	none	30 birds on shore
13440	12/15/05	1204	none	trash on shore
13441	12/15/05	1226	none	est. 1000 birds in area, trash on shore
13442	12/15/05	1247	3 fishermen	trash on shore
18499	12/22/05	739	none	none
18501	12/22/05	814	none	no flow, large pool of water approx. 50 ft long
18500	12/22/05	830	none	none
13029	12/22/05	850	none	none
13028	12/22/05	909	none	none
16712	12/22/05	929	none	none
13027	12/22/05	956	none	none
13026	12/22/05	1013	1 fisherman	trash along shoreline
13440	12/22/05	1030	none	none
13441	12/22/05	1052	none	approx. 200 birds (shorebirds, gulls, ducks)
13442	12/22/05	1112	3 fishermen	cabagehead jellies littered along shoreline, trash on shore
S3	01/19/06	855	none	trash in water
S7	01/19/06	915	none	2 ducks in water
18499	01/19/06	938	none	trash in water
18501	01/19/06	1000	none	2 horses nearby, medium sized pool of water
18500	01/19/06	1013	none	brown algae along water edge, trash in water
S9	01/19/06	1030	NA	DRY
13029	01/19/06	1036	none	tire and trash in water
13028	01/19/06	1055	none	trash in water
S8	01/19/06	1108	NA	DRY
16712	01/19/06	1112	none	trash in water, 8 vultures at site
S2	01/19/06	1130	none	3 ducks, trash in area
13027	01/19/06	1210	none	1 bird, christmas tree in middle of water, trash in water
S10	01/19/06	1224	none	one large pool of water, swallows nesting under bridge, trash in water
S4	01/19/06	1236	NA	DRY
S6	01/19/06	1325	none	trash, lots of green algae
13026	01/19/06	1348	none	8 pelicans, tires and trash in water

Station I.D.	Date	Time	Human Use	Comments
S5	01/19/06	1404	none	20 cows up from site
13440	01/19/06	1444	none	very low tide, water very turbid
S11	01/19/06	1512	none	trash in water, water very green
S1	01/19/06	1524	none	25 ducks at station
13441	01/19/06	1538	none	300 birds at station
13442	01/19/06	1552	1 fisherman	none
18499	02/09/06	842	none	birds in area
18501	02/09/06	916	NA	DRY
18500	02/09/06	924	none	birds nesting above water, nesting under bridge
13029	02/09/06	950	none	none
13028	02/09/06	1007	none	trash debris in water, about 50 birds at station
16712	02/09/06	1024	none	trash and turtles in water
13027	02/09/06	1044	none	birds present
13026	02/09/06	1059	1 fisherman	tires and trash in water, birds present
13440	02/09/06	1118	none	trash in water, birds present
13441	02/09/06	1139	none	lots of bird feces on shore
13442	02/09/06	1158	1 kayaker, 4 fishermen	trash on shore
18499	02/16/06	853	none	trash in water, turtle in water
18501	02/16/06	910	NA	NA
18500	02/16/06	918	none	trash in area
13029	02/16/06	944	none	trash in water
13028	02/16/06	1002	none	numerous gulls flying overhead to landfill
16712	02/16/06	1019	none	3 birds in water, trash in water
13027	02/16/06	1041	none	3 birds in water
13026	02/16/06	1054	1 fisherman	tires in water, trash on banks
13440	02/16/06	1110	none	200 ducks in water
13441	02/16/06	1140	none	1000 birds in water, lots of bird feces on bank
13442	02/16/06	1204	5 fishermen	10 birds at station
18499	02/23/06	852	none	trash in water, birds nesting under bridge and near station
18501	02/23/06	917	NA	DRY
18500	02/23/06	921	none	trash and algae in water
13029	02/23/06	938	none	trash in water
13028	02/23/06	956	none	trash in water, est. 1000-2000 seagulls flying toward landfill
16712	02/23/06	1015	none	trash in water
13027	02/23/06	1039	none	3 pelicans and 12 ducks in water, trash in water
13026	02/23/06	1056	none	trash in area
13440	02/23/06	1114	none	trash in area
13441	02/23/06	1147	none	est. 200-400 seagulls in water, pelicans, and ducks
13442	02/23/06	1208	1fisherman in water, 1 fisherman on shore	trash in area
18499	03/02/06	855	none	birds in trees surrounding station
18501	03/02/06	914	NA	DRY
18500	03/02/06	924	none	leaf debris in water
13029	03/02/06	946	none	trash in water
13028	03/02/06	1010	none	trash in area
16712	03/02/06	1029	none	turtles in water at station
13027	03/02/06	1055	none	3 birds at station
13026	03/02/06	1119	none	6 birds at station
13440	03/02/06	1140	none	none
13441	03/02/06	1206	none	50 pelicans, 100 ducks, 50 gulls
13442	03/02/06	1227	1 fisherman	none
18499	03/23/06	857	none	trash in water
18501	03/23/06	916	none	DRY
18500	03/23/06	923	none	trash in water, swallows nesting under bridge
13029	03/23/06	936	none	algal mats on water surface 20 yards upstream
13028	03/23/06	952	none	seagulls flying overhead to landfill
16712	03/23/06	1009	none	trash in area
13027	03/23/06	1030	none	trash in area

Station I.D.	Date	Time	Human Use	Comments
13026	03/23/06	1042	none	none
13440	03/23/06	1058	none	10 birds in water
13441	03/23/06	1120	none	100 birds at station
13442	03/23/06	1140	2 fishermen	35 birds
S3	04/20/06	823	none	trash in area
S7	04/20/06	837	none	trash in area
18499	04/20/06	901	none	swallows nesting under bridge down from station
18501	04/20/06	919	NA	DRY
18500	04/20/06	927	none	swallows nesting under bridge
S9	04/20/06	937	NA	DRY
13029	04/20/06	942	none	none
13028	04/20/06	958	none	seagulls flying overhead toward/from landfill
S8	04/20/06	1009	NA	DRY
16712	04/20/06	1014	none	trash in area
S2	04/20/06	1033	none	2 ducks in water
13027	04/20/06	1049	none	5 birds, trash in area
S10	04/20/06	1113	NA	DRY
S4	04/20/06	1120	NA	DRY
S6	04/20/06	1138	NA	none
13026	04/20/06	1147	none	trash in area
S5	04/20/06	1158	none	cow feces floating in water, biofilm present, city of robstown truck drawing water from drainage ditch
13440	04/20/06	1216	none	trash in area
S11	04/20/06	1227	none	trash in area
S1	04/20/06	1240	none	10 ducks at station
13441	04/20/06	1254	none	about 40 birds at station
13442	04/20/06	1315	1 fisherman	trash in area
13442	06/01/06	1207	none	2 diapers on shore
S1	06/01/06	1228	none	5 birds at station
13441	06/01/06	1237	none	5 ducks at station
S11	06/01/06	1302	none	trash on banks, steady flow coming from golf course
13440	06/01/06	1314	none	1 heron in water
S5	06/01/06	1327	none	6 cows at station
13026	06/01/06	1340	3 fishermen	large plumes in water
S6	06/01/06	1352	none	4 birds in water, trash onshore, 1 goat in area
S4	06/01/06	1416	none	about 50 birds in area
S10	06/01/06	1427	none	trash in water
13027	06/01/06	1442	none	none
S2	06/01/06	1513	none	trash in water
16712	06/01/06	1528	none	very high water level
S8	06/01/06	1541	none	trash in water
13028	06/01/06	1553	none	none
13029	06/01/06	1618	none	none
S9	06/01/06	1628	none	none
18500	06/01/06	1638	none	trash debris built up on side of bridge
18501	06/01/06	1647	none	none
18499	06/01/06	1704	none	trash and leaf debris in water
S3	06/01/06	1710	none	trash on banks, street sign in water, 20 birds near site
S7	06/01/06	1723	none	1 turtle in water, trash on banks
18499	06/02/06	733	none	none
S3	06/02/06	744	none	trash in water
S7	06/02/06	756	none	trash on banks
18501	06/02/06	819	none	50 birds at station
18500	06/02/06	827	none	none
S9	06/02/06	834	none	trash debris in water
13029	06/02/06	843	none	none
13028	06/02/06	855	none	none
S8	06/02/06	907	none	trash in water
16712	06/02/06	914	none	sample taken on edge of creek, extreme flooding

Station I.D.	Date	Time	Human Use	Comments
S2	06/02/06	929	none	trash debris in water
13027	06/02/06	958	none	none
S10	06/02/06	1011	none	trash and leaf debris in water
S4	06/02/06	1023	none	none
S6	06/02/06	1045	none	trash in water
13026	06/02/06	1054	none	6 birds at station
S5	06/02/06	1104	none	cow excrement surrounding station
13440	06/02/06	1118	none	6 dead fish on shore
S11	06/02/06	1130	none	swallows nesting in trees above/around station
S1	06/02/06	1140	none	3 ducks and 5 seagulls at station
13441	06/02/06	1148	none	10 birds at station (ducks and seagulls)
13442	06/02/06	1206	3 fishermen	trash on shore (diapers)
18499	06/03/06	701	none	none
S3	06/03/06	711	none	trash in water
S7	06/03/06	721	none	none
18501	06/03/06	742	none	some trash in water
18500	06/03/06	753	none	swallows nesting under bridge (about 30)
S9	06/03/06	800	none	6 chickens in yard next to station
13029	06/03/06	810	none	none
13028	06/03/06	821	none	trash debris in water, swallows nesting under bridge
S8	06/03/06	831	none	none
16712	06/03/06	838	none	none
S2	06/03/06	855	none	15 swallows in area
13027	06/03/06	927	none	swallows nesting under bridge
S10	06/03/06	944	none	swallows nesting around station
S4	06/03/06	1001	none	no flow one large pool
S6	06/03/06	1024	none	goat herd next to station (northeast)
13026	06/03/06	1035	none	none
S5	06/03/06	1045	none	1 blue crab at station
13440	06/03/06	1059	none	deadfish on shore
S11	06/03/06	1110	none	none
S1	06/03/06	1120	none	3 ducks at station
13441	06/03/06	1128	none	18 birds in area around station
13442	06/03/06	1145	6 fishermen	1 herring at station
18499	06/04/06	715	none	brush debris in water
S3	06/04/06	727	none	trash in water
S7	06/04/06	736	none	none
18501	06/04/06	758	none	swallows nesting around area and under bridge
18500	06/04/06	808	none	2 ducks at station
S9	06/04/06	817	none	none
13029	06/04/06	824	none	none
13028	06/04/06	837	none	swallows nesting under bridge
16712	06/04/06	845	NA	landfill closed, unable to access station
S8	06/04/06	845	NA	landfill closed, unable to access station
S2	06/04/06	926	none	swallows nesting in area
13027	06/04/06	939	none	swallows nesting under bridge
S10	06/04/06	1004	none	none
S4	06/04/06	1015	none	one large pool of water
S6	06/04/06	1036	none	none
13026	06/04/06	1049	none	birds in area around station
S5	06/04/06	1100	none	cows around in area at station
13440	06/04/06	1113	1 fisherman	none
S11	06/04/06	1126	none	none
S1	06/04/06	1137	none	none
13441	06/04/06	1145	none	50 birds in area around station
13442	06/04/06	1202	10 fishermen, 1 kayaker, 1 boat	dead fish on shore, trash on shore
18499	06/05/06	722	none	most of water surface covered with brush debris
S3	06/05/06	731	none	trash in water
S7	06/05/06	743	none	none

Station I.D.	Date	Time	Human Use	Comments
18501	06/05/06	803	none	cows upstream from station
18500	06/05/06	812	none	swallows nesting under bridge
S9	06/05/06	820	none	tadpoles in water
13029	06/05/06	828	none	none
13028	06/05/06	841	none	swallows nesting in area
S8	06/05/06	854	NA	no sample taken <0.10m of water
16712	06/05/06	902	none	none
S2	06/05/06	922	none	trash in water, swallows nesting in area around station
13027	06/05/06	951	none	swallows nesting under bridge
S10	06/05/06	959	none	none
S4	06/05/06	1011	none	one large pool of water
S6	06/05/06	1032	none	large amounts of algae growing in water at station
13026	06/05/06	1042	1 fisherman	2 birds along shore
S5	06/05/06	1054	none	trash in water
13440	06/05/06	1106	none	6 birds in area around station
S11	06/05/06	1121	none	swallows nesting in area around station
S1	06/05/06	1131	none	1 duck
13442	06/05/06	1141	none	about 60 birds at station
13441	06/05/06	1158	2 fishermen	8 seagulls at station
13028	06/08/06	1015	none	none
18499	06/08/06	1053	none	entire water surface covered with leaf and grass debris, strong smell of sewage
18501	06/08/06	1110	none	swallows nesting under bridge, large pool of water
18500	06/08/06	1121	none	swallows nesting under bridge
13029	06/08/06	1130	none	none
16712	06/08/06	1150	none	none
13027	06/08/06	1210	none	swallows nesting under bridge
13026	06/08/06	1227	none	trash on shore
13440	06/08/06	1241	none	dead fish on shore
13441	06/08/06	1258	none	20 pelicans, 7 ducks, 3 spoonbills and 30 seagulls
13442	06/08/06	1314	4 fishermen, 1 kayaker	dead fish on shore (from fishermen)