Oso Watershed Characterization – Groundwater Monitoring

Final Report

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Table of Contents

List of Tables

List of Figures

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Executive Summary

Groundwater was monitored for nutrients, indicator bacteria Enterococcus, temperature, specific conductance, salinity and depth to water to characterize the water table aquifer in the Oso Creek watershed and determine if groundwater could be a significant pathway of contamination to the creek. Hydraulic properties of the aquifer were determined.

A slug test was performed on many of the wells to provide a value of hydraulic conductivity for modeling groundwater movement. The results of these tests showed that hydraulic conductivities were very low and characteristic of the clay-dominated subsurface in the Beaumont Formation around Oso Creek and Oso Bay.

Groundwater in the Oso Watershed was found to be slightly saline to super-saline, with higher specific conductance values than surface water at most of the 18 sites with the exception of the three sites along the east side of Oso Bay. The residual dissolved solids retained in the subsurface from the time of deposition and the low depth to water (relatively close proximity to the surface at low elevations) may account for most of this salinity. Less saline groundwater is evident in areas of higher elevation furthest from tidal influence.

Nutrients were comparable to surface water in some cases, however several sites raise concern for high concentrations of nitrogen (3.16 mg/l in GW05B) and nine groundwater monitoring locations had total phosphorous values in the high range (> 1 mg/l) for groundwater. Modeling groundwater movement to the creek and bay provided flux values for the transport of nutrients to surface waters. The modeling indicated that only a very small flux (5.38 $x10^{-6}$ mg/l N and < 5.51 $x10^{-6}$ mg/l P) of nutrients to the surface water is possible due to the low hydraulic conductivity of the formations and the low hydraulic head to provide a gradient for advection.

Bacteria (Enterococcus) concentrations in groundwater were found to be low (< 10 cfu/100 ml excluding outliers) compared to historic values of bacteria (average 3,845 cfu/100 ml) in the adjacent surface water. However there were three sites of concern. Site 14 at Oso Creek and FM 665 had elevated levels at both wet weather (average 152 cfu/100 ml) and dry weather sampling events (average 23 cfu/100 ml), Site 11 at Oso Creek and FM 43 measured very high during the wet weather event (average 1503 cfu/100 ml), possibly due to runoff contamination in GW06A, and Site 18 in Flour Bluff measured a very high value during a dry weather event (1,450cfu/100ml) in GW12A. Bacteria fluxes were modeled using the aquifer properties determined by aquifer testing and were found to be very low due to the poor hydraulic conductivity ($12x10^{-6}$cm/day) and low hydraulic gradient. The highest flux of bacteria calculated was 4,800,000 cfu/day or the amount that would increase the concentration of Enterococcus in that segment of the creek about 3 cfu/m^3.

Although there were individual measurements of nutrients and bacteria that were high, modeled fluxes indicate that the potential of groundwater to be a significant pathway for either of these constituents to surface water is very low.

Section A. Introduction

A1. Problem Definition/Background

Oso Bay (TCEQ segment 2485), a small (≈ 7.2 square miles) and shallow (<1 meter) secondary bay off Corpus Christi Bay receives freshwater from Oso Creek (TCEQ Segment 2485a). The Oso Watershed drains an area of approximately 255 square miles. The Texas Commission on Environmental Quality (TCEQ) lists 19 permitted industrial wastewater discharges into Oso Bay. Corpus Christi is experiencing major growth into the Oso Watershed, resulting in significant runoff from subdivisions within and adjacent to the watershed. The upper portion of the watershed is dominated by farming activities, resulting in significant agricultural runoff into Oso Creek.

Because of the watershed's small size, the large number of permitted industrial discharge, and the large volume of both municipal and agricultural runoff (especially following heavy rains); Oso Creek and Oso Bay are consistently on the TCEQ's 303(d) list of impaired water bodies. Recently both Oso Creek and Oso Bay have been selected for implementation of a Total Maximum Daily Load plan due to high concentrations of bacteria (Enterococcus). The Center for Water Supply Studies (CWSS) at Texas A&M University-Corpus Christi and the Texas A&M University-Corpus Christi Environmental Microbiology Laboratory (TAMUCCEML) completed an investigation (Hay and Mott, 2006) funded by the Texas Commission on Environmental Quality (TCEQ) to: acquire additional water quality measurements; develop a numerical model of bacteria loading in Oso Bay and Oso Creek; and determine the total allowable daily load, the actual daily load, and the required load reduction to meet the water quality objectives of these segments. The final report of this investigation concluded that:

1. Oso Bay meets current water quality objective with the exception of TCEQ monitoring station 13441, which was found to be unrepresentative of ambient conditions in Oso Bay;
2. Oso Creek bacteria loading consisted of two processes, dry weather loading and runoff loading;
3. Dry weather loading in Oso Creek (although small in magnitude) must be eliminated to meet water quality objectives (geometric mean standard) for the segment;
4. Sources of dry weather loading of bacteria may include groundwater contributions to the creek.

As a result of this report and the data gathered during the investigation, the water quality criteria for TCEQ monitoring site 13441 was modified from contact recreation to non-contact recreation. This has placed Oso Bay into compliance with water quality requirement set by the TCEQ and completed part of the TMDL implementation. The remaining part of the TMDL implementation concerns Oso Creek. Because of the broad reaching implications for a number of entities (agriculture, municipalities, private residences, etc.) in managing this issue several interconnected projects have been funded by the Coastal Bend Bays and Estuary Program (CBBEP) and the Texas State Soil and Water Conservation Board to determine the source of the bacteria (human,

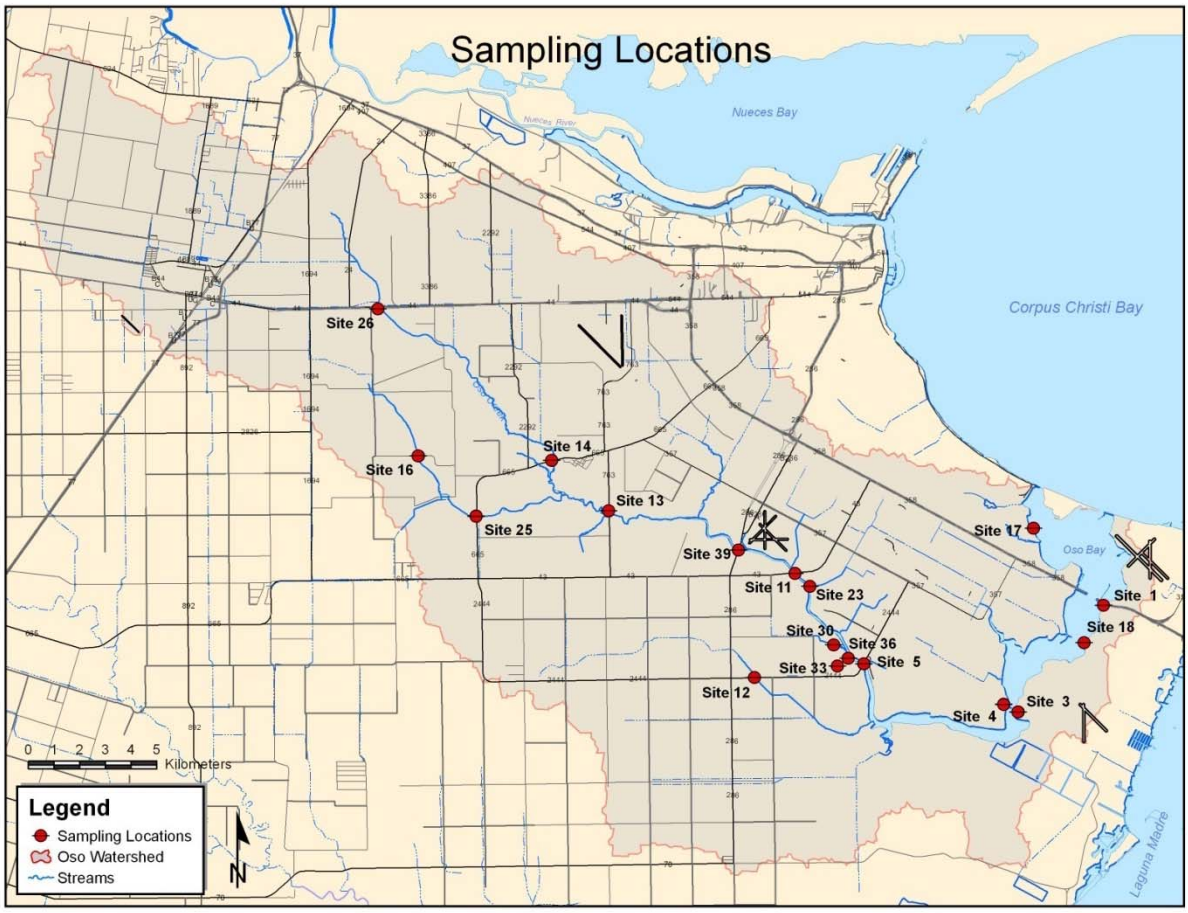

Figure A.1. Oso Watershed Study area.

wildlife, domesticated animals, OSS, WWTP, agricultural practices). These projects include soil sampling, sediment sampling, and groundwater sampling as well as continued monitoring for 3-4 years.

The primary objective of this project was to collect data to characterize the interaction between surface water in Oso Creek /Oso Bay and the adjacent groundwater system using heat flow as a proxy for groundwater flow. There was one secondary objective: collect groundwater samples to identify the presence of nutrients in support of an ongoing NPS surface water investigation, and collect groundwater samples to identify the presence of bacteria (Enterococcus) in support of an ongoing bacteria TMDL for Oso Creek.

Section B. Methods

Specific environmental data was to be collected to evaluate the relative interaction between surface-water and groundwater in Oso Creek and Oso Bay and the presence of bacteria or nutrients in the groundwater of the Oso Watershed. This project was composed of several distinct tasks.

Task 1. Site selection.

Before data collection could begin, site selection and installation of groundwater monitoring wells was completed. Each sampling location consists of two groundwater monitoring wells screened at different depth intervals, an existing (TCEQ) surface water monitoring location (where possible), and a streambed "thermal profiler" designed with multiple (4) zones of interchange to allow temperature measurements through the streambed. The number of sampling locations (18) was constrained by well installation costs, but did fall between the anticipated 15 and 20 locations.

Task 2. Well installation, testing, and instrumentation.

Two wells were scheduled to be installed by a licensed water well driller at each location. One well was to be installed in the first penetrated fully saturated sand or to a depth of 20 feet, whichever is shallower, and completed with five feet of 2 inch 0.01 inch slot well screen and two inch casing to the surface. The second well was to be completed in the next fully saturated sand that is at least ten feet deeper or to a depth of 30 feet, whichever is shallower, and completed with five feet of 2 inch 0.01 inch slot well screen and two inch casing to the surface. A single well slug test was performed on a representative well in each segment to determine the hydraulic conductivity of the sands penetrated. All deep wells were instrumented with a temperature data logger, two wells were instrumented with water level recording devices, and one well was instrumented with a combination water level and specific conductivity recording device. A small (0.75 inch x 39 inch) thermal profiler was installed through the streambed at each sampling location and instrumented with small temperature loggers to record the temperature profile through the streambed.

Task 3. Field data collection.

Primarily, data collection focused on temperature measurements in groundwater monitoring wells, surface-water (Creek and Bay), and the streambed using automatic data loggers. Other monitored parameters include specific conductivity, salinity, groundwater level, and ambient atmospheric conditions like air temperature, wind speed, wind direction, and recent precipitation depth (Table B1.1). Each location was to be sampled at least monthly for these parameters. Parameters collected by automatic instrumentation were to be collected at hourly intervals and downloaded monthly.

Task 4. Groundwater quality data collection (nutrients and bacteria)

Since previous studies have shown high concentrations (~16,500 cfu/100ml) of the indicator bacteria *Enterococcus* in surface water during dry weather flows, each well was to be tested for

the bacteria *Enterococcus* to test the hypothesis of groundwater being a source of bacteria loading to the creek (Table B1.2). Groundwater samples were to be collected from each of the monitoring wells and tested for the indicator bacteria *Enterococcus* twice during the course of this project, once during wet weather and once during dry weather to help determine if groundwater in this watershed is a significant source of bacteria. Groundwater samples were to be collected once from each of the deep wells and analyzed for nutrients to help understand if groundwater could be a source for nutrient loading (Table B1.3). Two well bores were to be cored during well installation; soil samples from the cores were to be collected and tested for the indicator bacteria Enterococcus (Table B1.2).

Task 5. Data analysis.

Temperature profiles and groundwater level fluctuations were to be examined and compared at each sampling location and graphed. Nutrient data were to be compared to results from adjacent stations sampled under the concurrent Agricultural NPS study conducted by TAES and the USGS. Bacteria results were to be compared to bacteria results from adjacent stations and the contributing watershed monitored under the Oso Watershed TMDL program, and those samples collected as part of the concurrent Agricultural NPS study. Statistical analysis was to be performed where appropriate. For example, if there is sufficient data, a statistical analysis using one-way analysis of variance (ANOVA) was to be done to determine if there are statistically significant differences in counts among monitoring wells in the study depending on whether the conditions are dry or wet.

Task 6. Water budget.

To better understand the groundwater component of the freshwater budget with respect to the bay, the movement of water between the surface-water regime and the groundwater regimes was to be quantified. This would be accomplished by incorporating aquifer property information and heat measurements into a variably saturated porous media groundwater flow and heat transport model (VS2DH) for calculating the flux of water moving between the surface-water and groundwater flow regimes.

B1. Sampling Process Design

B.1.1 Site Selection Criteria

The data collection effort involved measuring surface-water and groundwater quality parameters for the purpose of evaluating the interaction of groundwater and surface water in terms of heat flux, which can then be modeled to develop fluid flux. There are three components to this data collection: groundwater conditions; streambed (hyporheic) conditions; and surface-water conditions. Some of the data collection must support a concurrent bacteria TMDL implementation and an agricultural NPS (nutrients) study.

B.1.2 Monitoring Sites

There were 20 tentative site locations (Table B1.5, Table B1.6, Table B1.7) that could potentially meet all site selection criteria. Each comprised of four monitoring stations:

1. One surface water station;
2. One streambed station;
3. One deep well station; and
4. One shallow well station.

Six tentative sites were selected (1, 2, 3, 4, 17, and 18) along Oso Bay, four tentative sites were selected (5, 11, 23, and 39) along the tidal section of Oso Creek, two tentative sites were selected (12 and 16) near USGS NPS monitoring stations, four tentative sites were selected (13, 14, 25, and 26) along the non-tidal Oso Creek, and four tentative sites were selected (30, 33, 35,and 36) near a subdivision using OSSFs.

B.1.3 Data collection

This project was designed to collect high temporal and spatial resolution data at low cost that can be used to characterize surface-water/groundwater interaction in the Oso Watershed. The project uses heat flow between the surface-water regime and the groundwater regime to assess interaction and quantify the flux (heat and water) both temporally and spatially. The measurement of temperature in the surface-water, the groundwater, and the intermediate hyporheic zone are the most crucial data and were sampled at frequent intervals using temperature data loggers (Table B1.4, Table B1.7). Less frequent (monthly) measurements of groundwater hydraulic head, relative stream stage, conductivity, and salinity were made to help constrain the flux calculations made using the heat flow data (Table B1.4, Table B1.6). Three wells were instrumented to collect continuous groundwater level data (Table B1.4, Table B1.6). Surface water data was collected concurrently with the monthly groundwater sampling at an adjacent location (Table B1.4, Table B1.5)

Limited ancillary sampling to support a concurrent agricultural non-point source study and a bacteria TMDL implementation occurred to address the potential of groundwater as a source of nutrients (Table B1.3), or bacteria (Table B1.2) to Oso Creek. The objective was to collect a set of groundwater samples characteristic of dry weather and another characteristic of wet weather conditions for bacteria and a set of deep groundwater samples for nutrients (Table B1.6). Wet weather events and dry weather events were coordinated with the TAMUCC-EML to coincide with similar sampling events occurring in an ongoing NPS project. Additionally, soil samples were collected at two-foot intervals using a split spoon sampler on two deep wells located near the agricultural runoff stations and tested for Enterococcus.

Table B1.1. Measurement performance specifications for field parameters

PARAMETER	UNITS	METHOD	PARAMETER CODE	AWRL	Lab Reporting Limits	Recovery at Reporting Limits	PRECISION (RPD of LCS/LCSD)	BIAS (% Rec. LCS/LCSD mean)	Completeness (%)
***Field Parameters (Accessory)* – Laboratory Performing Analysis: Field**									
Conductivity	µS/cm	EPA 120.1 and TCEQ SOP	00094	NA	NA	NA	NA	NA	90
Salinity	Ppt	SM 2520 and TCEQ SOP	00480	NA	NA	NA	NA	NA	90
Water Temperature	°C	EPA 170.1 and TCEQ SOP	00010	NA	NA	NA	NA	NA	90
Days since last significant rainfall	Days	TCEQ SOP	72053	NA	NA	NA	NA	NA	90
Flow Severity	1 – no flow, 2 – low, 3 – normal, 4 – flood, 5 – high, 6 – dry	TCEQ SOP	01351	NA	NA	NA	NA	NA	90
Total water depth	Meters	TCEQ SOP	82903	NA	NA	NA	NA	NA	90
Flow estimate	cfs	TCEQ SOP	74069	NA	NA	NA	NA	NA	90
Maximum pool width	meters	TCEQ SOP	89864	NA	NA	NA	NA	NA	90
Tidal stage	1 – low, 2 – falling, 3 – slack, 4 – rising, 5 – high	TCEQ SOP	89972	NA	NA	NA	NA	NA	90
Rainfall (inches in past 1 day)	Inches	TCEQ SOP	82553	NA	NA	NA	NA	NA	90
Rainfall (inches in past 7 days)	Inches	TCEQ SOP	82554	NA	NA	NA	NA	NA	90
Water color	1 – brown, 2 – red, 3 – green, 4 – black, 5 – clear, 6 – other	TCEQ SOP	89969	NA	NA	NA	NA	NA	90

PARAMETER	UNITS	METHOD	PARAMETER CODE	AWRL	Lab Reporting Limits	Recovery at Reporting Limits	PRECISION (RPD of LCS/LCSD)	BIAS (% Rec. LCS/LCSD mean)	Completeness (%)
Water odor	1 – sewage, 2 – oily/chemical, 3 – rotten eggs, 4 – musky, 5 – fishy, 6 – none, 7 – other	TCEQ SOP	89971	NA	NA	NA	NA	NA	90
Water surface	1 – calm, 2 – ripple, 3 – wave, 4 – whitecap	TCEQ SOP	89968	NA	NA	NA	NA	NA	90
Air Temperature	°C	TCEQ SOP	00020	NA	NA	NA	NA	NA	90
Wind intensity	1 – calm, 2 – slight, 3 – moderate, 4 – strong	TCEQ SOP	89965	NA	NA	NA	NA	NA	90
Wind direction	1 – north, 2 – south, 3 – east, 4 – west, 5 – northeast, 6 – southeast, 7 – northwest, 8 – southwest	TCEQ SOP	89010	NA	NA	NA	NA	NA	90
Present weather	1 – clear, 2 – partly cloudy, 3 – cloudy. 4 – rain	TCEQ SOP	89966	NA	NA	NA	NA	NA	90
***Field Parameters (Groundwater)* – Laboratory Performing Analysis: Field**									
Depth, Water Level from meas. pt.	meters	TWDB UM-52	004195	NA	NA	NA	NA	NA	90
Depth, Total of well from meas. pt.	meters	TWDB UM-52	004194	NA	NA	NA	NA	NA	90

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), "Standard Methods for the Examination of Water and Wastewater," 21st Edition, 2005

TCEQ SOP - *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue* (December 2003) or subsequent editions.

American Society for Testing and Materials (ASTM) Annual Book of Standards, Vol. 11.02

Table B1.2. Measurement performance specification for bacteria.

PARAMETER	UNITS	METHOD	PARAMETER CODES	AWRL	Lab Reporting Limits	Recovery at Reporting Limits	PRECISION (RPD of LCS/LCSD)	BIAS (% Rec. LCS/LCSD mean)	Completeness (%)
Conventional Parameters - Laboratory Performing Analysis: TAMUCC-EML									
Enterococcus	CFU/100 mL	EPA Method 1600	31649	1.0	1.0	NA	NA	NA	90
Enterococcus (soil)**	CFU/g	EPA Method 1600	NA	NA	1.0	NA	NA	NA	90

United States Environmental Protection Agency (USEPA), "Methods for Chemical Analysis of Water and Wastes," Manual #EPA-600-4-79-020

Weaver, R.W., S. Angle, and P. Bottomley, 1994. Methods of Soil Analysis. Part 2. Microbiological and Biochemical Properties 1994 1121 pages

** Enterococcus in soils will be performed once on cores from 2 well borings only.

Table B1.3. Measurement performance specifications for nutrients.

PARAMETER	UNITS	METHOD	PARAMETER CODES	AWRL	Lab Reporting Limits	Recovery at Reporting Limits	PRECISION (RPD of LCS/LCSD)	BIAS (% Rec. LCS/LCSD mean)	Completeness (%)
Nutrients - Laboratory Performing Analysis: Xenco Laboratories									
Nitrogen, ammonia	mg/L	SM4500NH3	00610	N/A	1.0	80-120	20	80-120	90
Nitrogen, Kjeldahl, total	mg/L	EPA 351.2	00625	N/A	0.3	80-120	20	80-120	90
Nitrogen, nitrite, dissolved	mg/L	EPA 300.0	00615	N/A	0.1	80-120	20	80-120	90
Nitrogen, nitrate, dissolved	mg/L	EPA 300.0	00620	N/A	0.1	80-120	20	80-120	90

PARAMETER	UNITS	METHOD	PARAMETER CODES	AWRL	Lab Reporting Limits	Recovery at Reporting Limits	PRECISION (RPD of LCS/LCSD)	BIAS (% Rec. LCS/LCSD mean)	Completeness (%)
Phosphorus, dissolved	mg/L	EPA 365.1/200.8	00666	N/A	0.02	80-120	20	80-120	90
Phosphorus, total	mg/L	EPA 365.1/200.8	00665	N/A	0.02	80-120	20	80-120	90
Phosphorus, phosphate, ortho	mg/L	EPA 300.0	00671	N/A	0.2	80-120	20	80-120	90

References:

United States Environmental Protection Agency (USEPA), "Methods for Chemical Analysis of Water and Wastes," Manual #EPA-600-4-79-020

American Public Health Association (APHA), "Standard Methods for the Examination of Water and Wastewater", 21st Edition

Table B1.4. Field Sampling Schedules, Parameters, and Frequency.

Parameter (Storet code)	Groundwater Field Sampling Schedule 1	Groundwater Field Sampling Schedule 2	Groundwater Field Sampling Schedule 3	Surface-water Field Sampling Schedule 1	Streambed Sampling Schedule 1
Conductivity (00094)	Once/month for 12 months	Once/month for 12 months	Hourly by datalogger/downloaded monthly	Once/month for 12 months	NA
Salinity (00480)	Once/month for 12 months	Once/month for 12 months	Hourly by datalogger/downloaded monthly	Once/month for 12 months	NA
Water Temperature (00010)	Hourly by datalogger/downloaded monthly	Hourly by datalogger/downloaded monthly	Hourly by datalogger/downloaded monthly	Hourly by datalogger/downloaded monthly	Hourly by datalogger/downloaded monthly
Days since last significant rainfall (72053)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Flow Severity (01351)	NA	NA	NA	Once/month for 12 months	NA
Total water depth (82903)	NA	NA	NA	Once/month for 12 months	NA
Flow estimate (74069)	NA	NA	NA	Once/month for 12 months	NA
Maximum pool width (89864)	NA	NA	NA	Once/month for 12 months	NA
Tide stage (89972)	NA	NA	NA	Once/month for 12 months	NA
Rainfall (inches past 1 day) (82553)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Rainfall (inches past 7 days) (82554)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Water color (89969)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Water odor (89971)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Water surface (89968)	NA	NA	NA	Once/month for 12 months	NA
Air temperature (00020)	Once/month for	Once/month for	Once/month for	Once/month for	NA

Parameter (Storet code)	Groundwater Field Sampling Schedule 1	Groundwater Field Sampling Schedule 2	Groundwater Field Sampling Schedule 3	Surface-water Field Sampling Schedule 1	Streambed Sampling Schedule 1
	12 months	12 months	12 months	12 months	
Wind intensity (89965)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Wind direction (89010)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Present weather (89966)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA
Depth, Water Level From Meas.Pt. (04195)	Once/month for 12 months	Hourly by datalogger/downloaded monthly	Hourly by datalogger/downloaded monthly	NA	NA
Depth, Total Of Well, From Below Meas.Pt. (04194)	Once/month for 12 months	Once/month for 12 months	Once/month for 12 months	NA	NA

Table B1.5. Surface water sampling locations and schedule. *See Table B1.4 for parameters and frequency of measurements. † Not official TCEQ monitoring sites, absolute coordinates depend on meeting selection criteria.

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	Nutrients	Bacteria
13440	Oso Bay at Padre Island Drive west	Site 1	-97.309944	27.678612	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 01	Oso Bay at Turtle Cove Park (Oriole and Lovebird)	Site 2			AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 02	Oso Bay at Yorktown east bank nr 13026	Site 3	-97.343454	27.640404	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
13026	Oso Bay at Yorktown west bank	Site 4	-97.345	27.6399	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
13027	Oso Creek at Staples	Site 5	-97.4011	27.65694	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 03	Oso Creek at Weber N. Bank dn strm	Site 11	-97.4285	27.68871	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 04	Unnamed trib to Oso Creek at FM 2444 - USGS Site 2	Site 12	-97.4449	27.65211	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
13029	Oso Creek at FM 763	Site 13	-97.501663	27.71111	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
18500	Oso Creek and FM 665	Site 14	-97.52357	27.72947	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 05	West Oso Creek at Merritt Rd - USGS Site 1	Site 16	-97.577083	27.731267	AM/AM	NA	Surface-water Field Schedule 3*	NA	NA
SW 06	Oso Bay at Suter Park on Ennis Joslin nr 13441	Site 17	-97.334241	27.704209	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 07	Oso Bay at Holly Rd east bank (FB water	Site 18	-97.317453	27.664500	AM/AM	NA	Surface-water Field	NA	NA

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	Nutrients	Bacteria
	tower)						Schedule 1*		
SW 08	Oso Creek at unnamed trib S of Weber Rd. NE Bank	Site 23	-97.422687	27.6841563	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
18501	West Oso Creek at FM 665	Site 25	-97.55422	27.70936	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
18499	Oso Creek at SH 44	Site 26	-97.59243	27.78325	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 09	Unnamed trib to Oso Creek at N end of S. Oso Pkwy	Site 30	-97.413510	27.663745	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 10	N. side of drainage ditch and S. Oso Pkwy dn strm .25mi N FM 2444	Site 33	-97.411997	27.655862	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 11	Staples side of Gator Lake at Bot. Gardens	Site 35			AM/AM	NA	Surface-water Field Schedule 1*	NA	NA
SW 12	Botanical Gardens on flats between bluff and creek	Site 36	-97.406725	27.659096	AM/AM	NA	Surface-water Field Schedule 2*	NA	NA
13028	Oso Creek and SH286.	Site 39	-97.4505	27.6975	AM/AM	NA	Surface-water Field Schedule 1*	NA	NA

Table B1.6. Groundwater Monitoring Wells and Sampling. * See Table B1.4 for parameters and frequency of measurement. ** See Table B1.2 **for bacteria parameters. †See Table B1.3 for Nutrient parameters. † Not official TCEQ monitoring sites, absolute coordinates depend on locations meeting all selection criteria.**

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	Nutrients†	Bacteria**
GW 01A	Oso Bay at Padre Island Drive west bank nr 13440 -Shallow	Site 1	-97.306694	27.676781	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 01B	Oso Bay at Padre Island Drive west bank nr 13440 -Deep	Site 1	-97.306694	27.676781	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 02A	Oso Bay at Turtle Cove Park (Oriole and Lovebird) -Shallow	Site 2	-97.297318	27.683905	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 02B	Oso Bay at Turtle Cove Park (Oriole and Lovebird) -Deep	Site 2	-97.297318	27.683905	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 03A	Oso Bay at Yorktown east bank nr 13026 - Shallow	Site 3	-97.341354	27.639582	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 03B	Oso Bay at Yorktown east bank nr 13026 - Deep	Site 3	-97.341354	27.639582	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 04A	Oso Bay at Yorktown west bank nr 13026 - Shallow	Site 4	-97.346634	27.641947	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 04B	Oso Bay at Yorktown west bank nr 13026 - Deep	Site 4	-97.346634	27.641947	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 05A	Oso Creek at Staples nr 13027 -Shallow	Site 5	-97.401749	27.656637	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 05B	Oso Creek at Staples nr 13027 -Deep	Site 5	-97.401749	27.656637	AM/AM	NA	Groundwater Field Schedule 3*	One event	One wet event/One dry event
GW 06A	Oso Creek at Weber N. Bank dn strm -Shallow	Site 11	-97.428467	27.688776	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 06B	Oso Creek at Weber N. Bank dn strm -Deep	Site 11	-97.428467	27.688776	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	**Nutrients†**	**Bacteria****
GW 07A	Unnamed trib to Oso Creek at FM 2444 - USGS Site 2 -Shallow	Site 12	-97.444946	27.652046	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 07B	Unnamed trib to Oso Creek at FM 2444 - USGS Site 2 -Deep	Site 12	-97.444946	27.652046	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 08A	Oso Creek at FM 763 nr 13029 (dn strm N bank) -Shallow	Site 13	-97.501900	27.711351	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 08B	Oso Creek at FM 763 nr 13029 (dn strm N bank) -Deep	Site 13	-97.501900	27.711351	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 09A	Oso Creek and FM 665 nr 18500 (Upstream West Bank) -Shallow	Site 14	-97.524254	27.729265	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 09B	Oso Creek and FM 665 nr 18500 (Upstream West Bank) -Deep	Site 14	-97.524254	27.729265	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 10A	West Oso Creek at Merritt Rd - USGS Site 1 -Shallow	Site 16	-97.576775	27.731150	AM/AM	NA	Groundwater Field Schedule 2*	NA	One wet event/One dry event
GW 10B	West Oso Creek at Merritt Rd - USGS Site 1 -Deep	Site 16	-97.576775	27.731150	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 11A	Oso Bay at Suter Park on Ennis Joslin nr 13441 -Shallow	Site 17	-97.334282	27.703966	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 11B	Oso Bay at Suter Park on Ennis Joslin nr 13441 -Deep	Site 17	-97.334282	27.703966	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 12A	Oso Bay at Holly Rd east bank (FB water tower) -Shallow	Site 18	-97.314796	27.663424	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 12B	Oso Bay at Holly Rd east bank (FB water tower) -Deep	Site 18	-97.314796	27.663424	AM/AM	NA	Groundwater Field Schedule 2*	One event	One wet event/One dry event
GW 13A	Oso Creek at unnamed trib S of Weber Rd. NE Bank -Shallow	Site 23	-97.422630	27.684216	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	**Nutrients†**	**Bacteria****
GW 13B	Oso Creek at unnamed trib S of Weber Rd. NE Bank -Deep	Site 23	-97.422630	27.684216	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 14A	West Oso Creek at FM 665 S. bank d. strm nr 18501 -Shallow	Site 25	-97.553978	27.709423	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 14B	West Oso Creek at FM 665 S. bank d. strm nr 18501 -Deep	Site 25	-97.553978	27.709423	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 15A	Oso Creek at SH 44 nr 18499 (Upstream West Bank) -Shallow	Site 26	-97.593315	27.783936	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 15B	Oso Creek at SH 44 nr 18499 (Upstream West Bank) -Deep	Site 26	-97.593315	27.783936	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 16A	Unnamed trib to Oso Creek at N end of S. Oso Pkwy -Shallow	Site 30	-97.413551	27.663687	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 16B	Unnamed trib to Oso Creek at N end of S. Oso Pkwy -Deep	Site 30	-97.413551	27.663687	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 17A	N. side of drainage ditch and S. Oso Pkwy dn strm .25mi N FM 2444 -Shallow	Site 33	-97.412224	27.655954	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 17B	N. side of drainage ditch and S. Oso Pkwy dn strm .25mi N FM 2444 -Deep	Site 33	-97.412224	27.655954	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 18A	Staples side of Gator Lake at Bot. Gardens -Shallow	Site 35	-97.403465	27.654419	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 18B	Staples side of Gator Lake at Bot. Gardens -Deep	Site 35	-97.403465	27.654419	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event
GW 19A	Botanical Gardens on flats between bluff and creek -Shallow	Site 36	-97.409103	27.659132	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 19B	Botanical Gardens on	Site 36	-97.409103	27.659132	AM/AM	NA	Groundwate	One event	One wet

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	Nutrients†	Bacteria**
	flats between bluff and creek -Deep						r Field Schedule 1*		event/One dry event
GW 20A	Oso Creek and SH286. E.side of bridge. N bank nr 13028 -Shallow	Site 39	-97.450439	27.697535	AM/AM	NA	Groundwater Field Schedule 1*	NA	One wet event/One dry event
GW 20B	Oso Creek and SH286. E.side of bridge. N bank nr 13028 -Deep	Site 39	-97.450439	27.697535	AM/AM	NA	Groundwater Field Schedule 1*	One event	One wet event/One dry event

Table B1.7. Streambed Thermal Profiler Sampling Schedule. See Table B1.4 for parameters and frequency of measurements. ** See Table B1.2 for bacteria parameters. †See for Nutrient parameters. ‡ Not official TCEQ monitoring sites, absolute coordinates depend on locations meeting all selection criteria.

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	Nutrients†	Bacteria**
SB 01	Oso Bay at Padre Island Drive west bank nr 13440	Site 1	-97.309944	27.678612	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 02	Oso Bay at Turtle Cove Park (Oriole and Lovebird)	Site 2	-97.297318	27.683905	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 03	Oso Bay at Yorktown east bank nr 13026	Site 3	-97.341354	27.639582	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 04	Oso Bay at Yorktown west bank nr 13026	Site 4	-97.345	27.6399	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 05	Oso Creek at Staples nr 13027	Site 5	-97.4011	27.65694	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 06	Oso Creek at Weber N.	Site 11	-97.428467	27.688776	AM/AM	NA	Streambed	NA	NA

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	**Nutrients†**	**Bacteria****
	Bank dn strm						Field Schedule 1*		
SB 07	Unnamed trib to Oso Creek at FM 2444 - USGS Site 2	Site 12	-97.314796	27.663424	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 08	Oso Creek at FM 763 nr 13029 (dn strm N bank)	Site 13	-97.501663	27.71111	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 09	Oso Creek and FM 665 nr 18500 (Upstream West Bank)	Site 14	-97.52357	27.72947	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 10	West Oso Creek at Merritt Rd - USGS Site 1	Site 16	-97.576775	27.731150	AM/AM	NA	Streambed Field Schedule 3*	NA	NA
SB 11	Oso Bay at Suter Park on Ennis Joslin nr 13441	Site 17	-97.334282	27.703966	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 12	Oso Bay at Holly Rd east bank (FB water tower)	Site 18	-97.314796	27.663424	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 13	Oso Creek at unnamed trib S of Weber Rd. NE Bank	Site 23	-97.42324	27.68403	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 14	West Oso Creek at FM 665 S. bank d. strm	Site 25	-97.55422	27.70936	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 15	Oso Creek at SH 44 nr 18499 (Upstream West Bank)	Site 26	-97.59243	27.78325	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 16	Unnamed trib to Oso Creek at N end of S.	Site 30	-97.41339	27.66375	AM/AM	NA	Streambed Field	NA	NA

Station_id	Description	site_id	Lon	Lat	SC1/SC2	Program Code	Sampling Schedules		
							Field Sampling	**Nutrients†**	**Bacteria****
	Oso Pkwy						Schedule 1*		
SB 17	N. side of drainage ditch and S. Oso Pkwy dn strm .25mi N FM 2444	Site 33	-97.41329	27.65578	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 18	Staples side of Gator Lake at Bot. Gardens	Site 35	-97.40402	27.6587	AM/AM	NA	Streambed Field Schedule 1*	NA	NA
SB 19	Botanical Gardens on flats between bluff and creek	Site 36	-97.40854	27.65899	AM/AM	NA	Streambed Field Schedule 2*	NA	NA
SB 20	Oso Creek and SH286. E.side of bridge. N bank nr 13028	Site 39	-97.4505	27.6975	AM/AM	NA	Streambed Field Schedule 1*	NA	NA

Section C. Results

C1. Groundwater monitoring

Groundwater monitoring took place in three phases: monitoring well installation and development, water quality monitoring, and aquifer testing.

C.1.1 Well Installation

Well installation took place between April 15, 2009 and May 19, 2009 and was performed by a licensed water well driller. Wells were installed on all proposed sites except for Site 2, Site 35, and Site 1. Site 2, located at Turtle Cove Park, was drilled to 45 feet (13.7 meters) without encountering a water bearing zone and subsequently abandoned. Site 35 was not drilled due to drilling rig logistics. One well was drilled at Site 1, however a second boring could not be advanced after repeated attempts due to various obstructions (rubble) buried at the site. A total of 35 monitoring wells were installed at 18 sites (0). Well development took place once wells were installed. This process consists of surging and bailing each well until sands and clays left in the well by

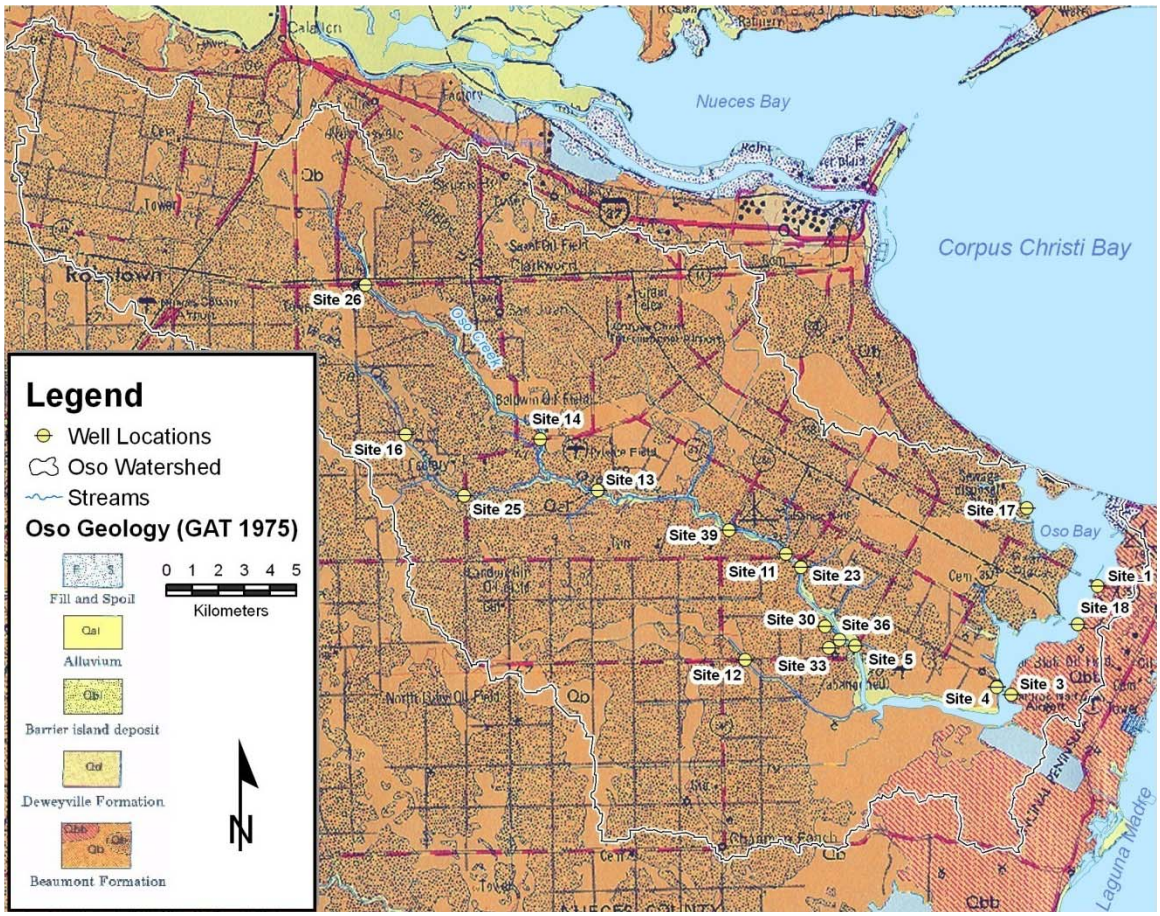

Figure C.1. Geology of Oso Watershed (University of Texas at Austin. Bureau of Economic Geology., 1975).

Table C1.1 Typical Hydraulic Conductivity (cm/s) for Geologic Media (Fetter, 1988).

Material	Hydraulic Conductivity	
	from	to
Clay	10^{-9}	10^{-6}
Silt, sandy silt, clayey sand	10^{-6}	10^{-4}
Silty sand, fine sand	10^{-5}	10^{-3}
Well sorted sand	10^{-3}	10^{-1}
Well sorted gravel	10^{-2}	1

the drilling process are removed and the well can flow freely with clear water. This process was severely impeded by the low sand content in the formation (low hydraulic conductivity), which delayed the recharge of many of the wells by hours or days. Slug tests were performed on 24 of the wells. Reduced data was processed using the Hvorslev Method (Fetter, 1988). Average hydraulic conductivity for the wells was $21.1x10^{-09}$ cm/sec, which is characteristic of clay materials (Table C1.1).

C.1.2 Geologic setting

The Oso Creek/Oso Bay watershed reposes on the outcrop of the Pleistocene Beaumont Formation (Figure C.1). This formation was formed under several depositional environments such as fluvial (meandering shallow gradient coastal streams), deltaic (coastal marsh, mud flats, lagoons), and barrier island systems (Bureau of Economic Geology, 1975). Depositional environments in the Oso watershed fall into three general categories, with the majority of the basin being fluvial, localized areas (possibly) of deltaic (lagoon or coastal marsh) origin, and the area east of Oso Bay being primarily barrier island deposits over deltaic sediments. Most of the watershed is composed of interdistributary mud, abandoned channel fill mud, and fluvial overbank mud that are seen in the well borings as various types of clay. Small areas of the basin are composed of meander belt, levee, crevasse splay and distributary sands, which are seen in the well borings as silty clay, silt, silty sand, and sand.

Borings at many of the locations along Oso Creek and Oso Bay penetrated clay, silty clay, and silt (Site 4, Site 5, Site 11, Site 13, Site 14, Site 17, Site 18, Site 23, Site 25, Site 26, Site 30, Site 33, Site 36, and Site 39), which are noted as very low hydraulic conductivity materials (Table C1.1) and so these wells have very low recovery rates. Only three locations (Site 3, Site 12, and Site 16) penetrated significant sand or silty sand strata having higher hydraulic conductivity (Table C1.1) and allowing the wells to recover faster during sampling. The boring at Site 1 penetrated fill material to a depth of

12 feet (~3.7 meters) and then gray clay to 19 feet (~5.8 meters) where the well was completed.

C.1.3 Groundwater sampling

Groundwater sampling began in July 2009, or as wells became developed enough to produce water and continued through May 2010. Sampling was conducted on 35 monitoring wells. At times, several of the shallow wells were dry or the borehole did not have sufficient water to test in-situ.

C2. Surface Water Monitoring

Surface water monitoring was conducted on a monthly schedule (Table B1.4) at each site to provide contemporaneous surface water quality measurements adjacent to the monitoring wells. Five of the sites use historic TCEQ monitoring stations (13026-Site 4, 13027-Site 5, 13028-Site 39, 13029-Site 13, and 13440-Site 1). Three of the sites (18499-Site 26, 18500-Site 14, and 18501-Site 25) were new TCEQ stations added for a bacteria TMDL project (Hay and Mott, 2005). Ten sites were added for this project (SW02-Site 3, SW03-Site 11, SW04-Site 12, SW05-Site 16, SW06-Site 17, SW07-Site 18, SW08-Site 23, SW09-Site 30, SW10-Site 33, and SW12-Site 36) to provide surface water quality measurements adjacent to the monitoring wells that are not adjacent to official TCEQ monitoring sites.

C3. Groundwater and Surface Water Quality

For the purposes of comparing groundwater and surface water quality using specific conductance in this report a consistent set of terminology must be used. Water having a specific conductance less than or equal to 1,493 uS/cm will be regarded as fresh and has the potential to be used as a drinking water supply. Water having a specific conductance between 1,493 uS/cm and 4,478 uS/cm will be referred to as slightly saline water and is suitable for livestock and some irrigation. Water having a specific conductance between 4,478 uS/cm and 14,925 uS/cm is regarded as moderately saline and generally unsuitable for irrigation or livestock. The inland reaches of estuaries typically have water in this range of specific conductance. Water having a specific conductance greater than 14,925 uS/cm but less than 52,239 uS/cm is referred to as very saline. Some aquifers yield water in varying amounts in this class. Coastal waters generally fall within this range and typical seawater is at the upper end of this range. Water having a specific conductance greater than 52,239uS/cm but less than 104,478 uS/cm is referred to as hyper-saline. Hyper-saline water is typical of closed lakes, outflow-restricted basins, or extensive shallow marine environments where outflow is primarily through evaporation or

	Total Dissolved Solids (ppm)		Specific Conductance (uS/cm)	
Salinity	Minimum	Maximum	Minimum	Maximum
Fresh	1	1,000	1	1,493
Slightly Saline	1,000	3,000	1,493	4,478
Moderately Saline	3,000	10,000	4,478	14,925
Very Saline	10,000	35,000	14,925	52,239
Hyper-saline	35,000	70,000	52,269	104,478
Super-saline	70,000	>	104,478	>

Table C2.1. Water quality definition reference (Modified from Winslow and Kister, 1956).

evapotranspiration. Water having specific conductance greater than 104,478 uS/cm is regarded as super-saline. Super-saline water found in enclosed basins like the Dead Sea, Lake Assal or Don Juan Pond.

Site 1 observes water quality and levels on the east side of Oso Bay and is composed of one monitoring well, GW01A, one surface water site, 13440, and one thermal profiler, SB01. Monitoring well GW01A was instrumented with a sonde/logger collecting temperature and pressure (hydraulic head) measurements at 15 minute intervals.

Specific Conductance, a measure of dissolved solids in water averaged 50,039 uS/cm in surface water and 58,134 uS/cm in groundwater at this location. Little variation in specific conductance (σ = 3,011 uS/cm) was observed over the study period in groundwater however larger variations were observed in surface water over the same period (σ = 21,292 uS/cm) especially as rainfall frequency increased and the surface water regime changed from the influx of runoff (Figure C.2).

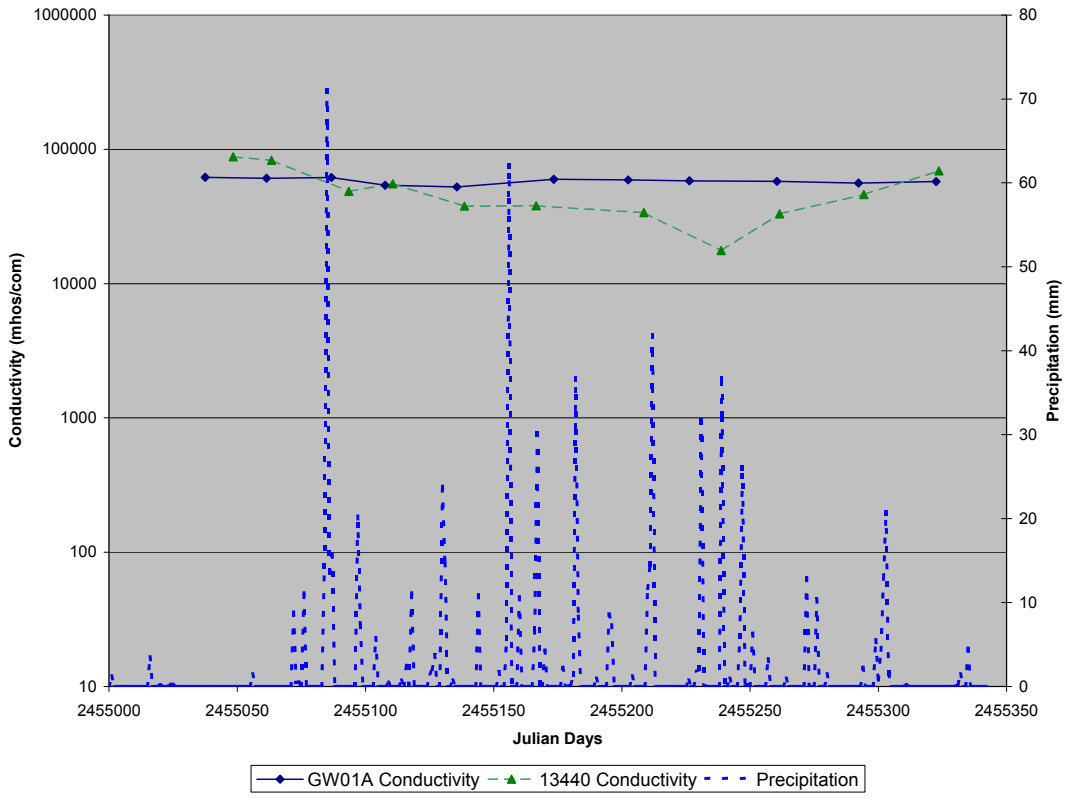

Figure C.2. Specific Conductance and Precipitation at Site 1.

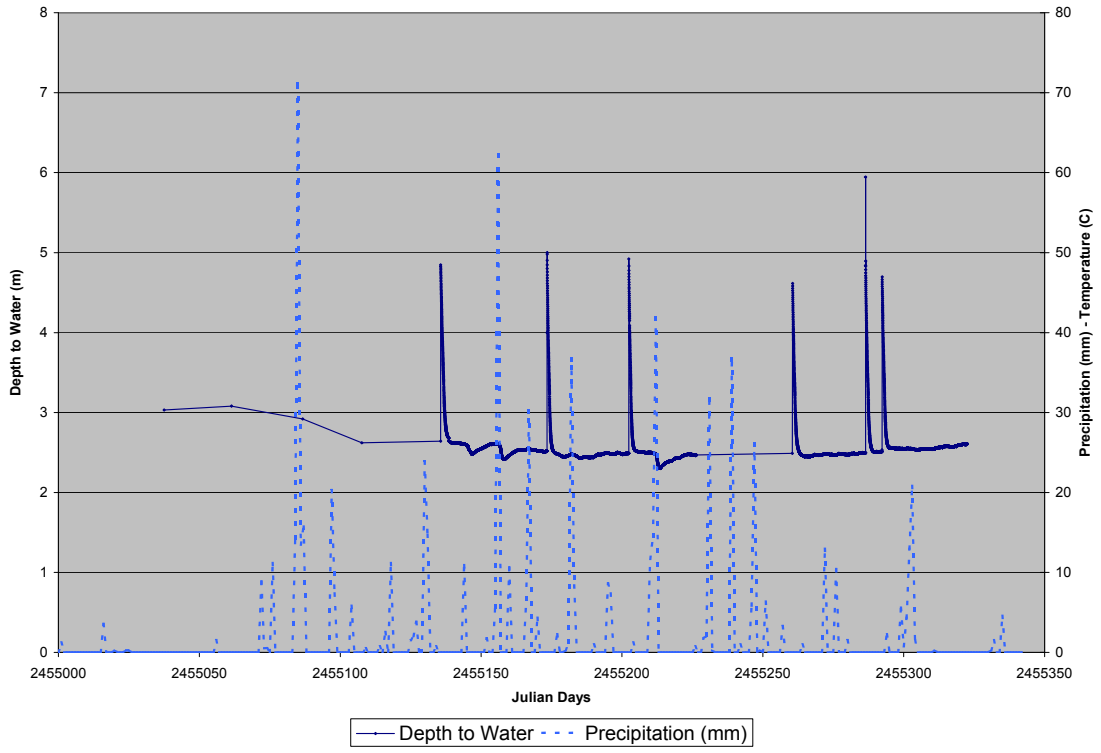

Figure C.3. Depth to Water and Precipitation at Site 1.

Groundwater level can be seen to change over time as rainfall frequency increases after a prolonged drought. As recharge occurred, the depth to water decreased in the well (Figure C.3). Depth to water measurements averaged 2.57 m with only a small variation ($\sigma = 0.288$ m). However, several dramatic changes are evident in Figure C.3 and represent two separate phenomena. Six spikes indicating a sharp increase in depth to water (a drop in the water table) show the effects of bailing water from the well prior to sampling and a slow recovery to initial (steady-state) conditions. The slow recovery indicates the low hydraulic conductivity of the aquifer. Two instances are evident where a decrease in depth to water (a rise in the water table) coincides with a precipitation event. This suggests a short recharge period due to the rainfall and then an immediate discharge to equilibrium.

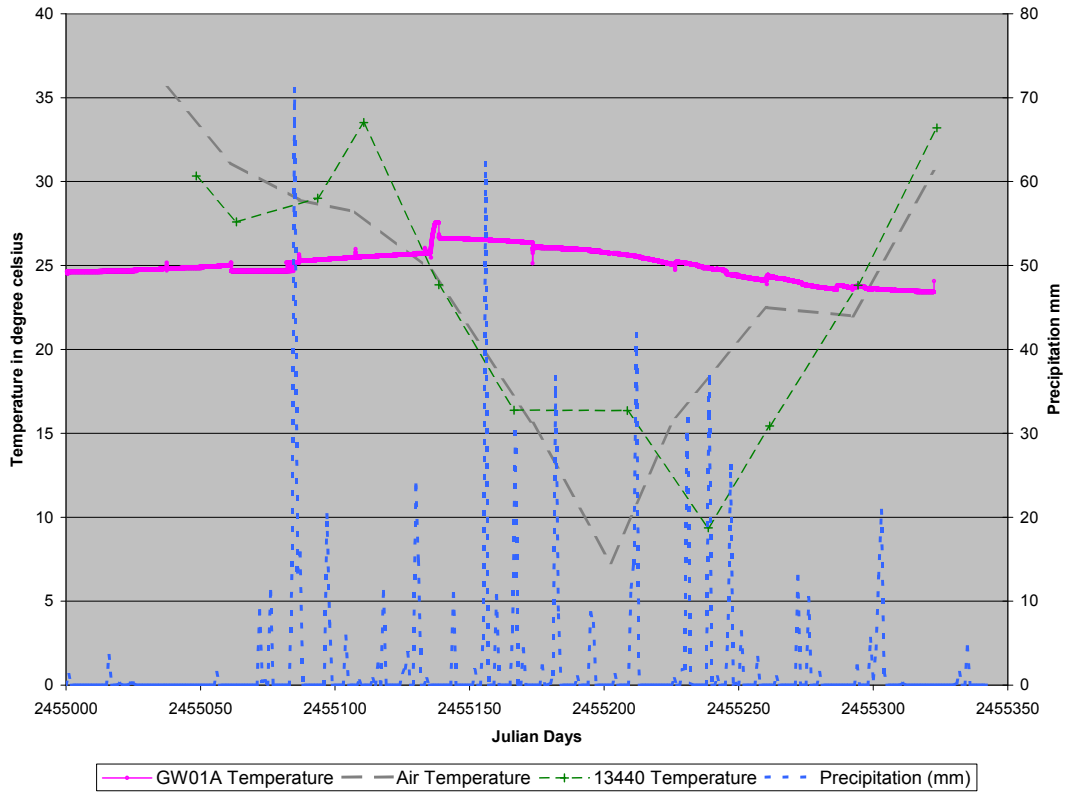

Figure C.4. Temperature and Precipitation at Site 1.

Temperature (Figure C.4) in the surface water varies widely as the seasons change with air temperature taken at sampling events having a $\sigma = 7.45$ °C and surface water temperature having a $\sigma = 8.09$ °C. Groundwater temperature fluctuated slightly around an average of 25.01 °C ($\sigma = 0.897$ °C). Groundwater lags surface water and air temperature by about 115 days.

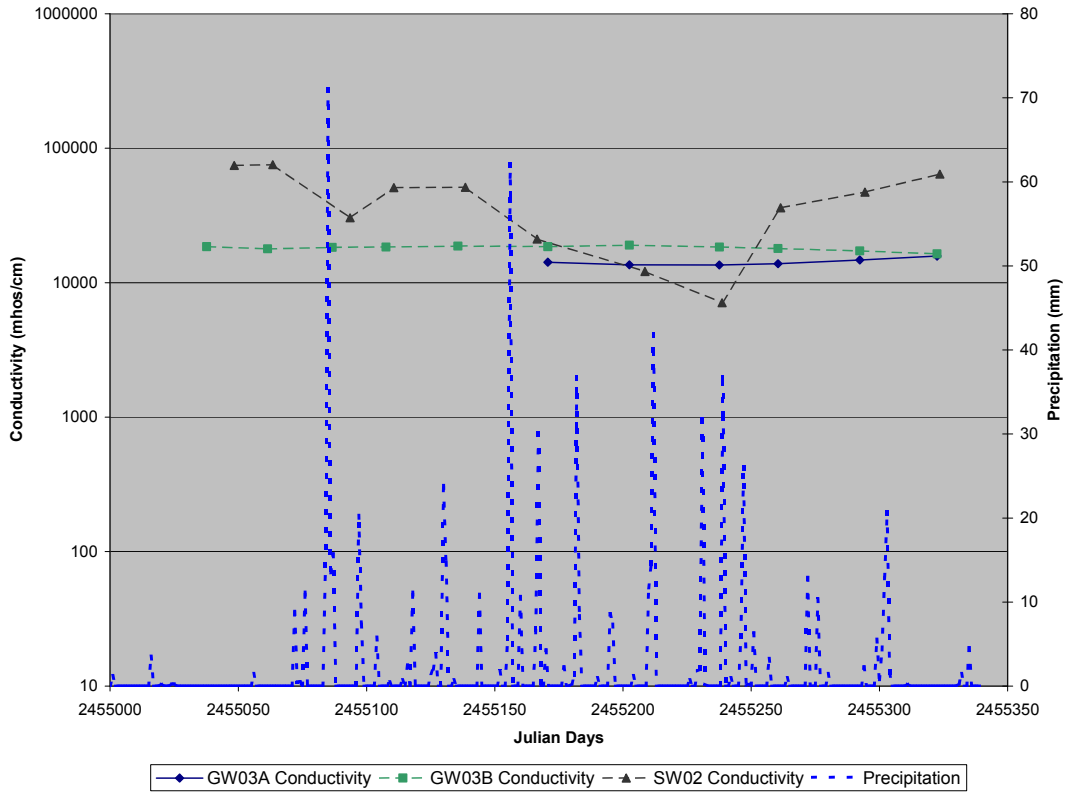

Figure C.5. Specific Conductance and Precipitation at Site 3.

Site 3 observes water quality and levels on the east side of Oso Bay and is composed of two monitoring wells, GW03A and GW03B, one surface water site, SW02, and shares a thermal profiler (SB04) with Site 4. The first five sampling events at this location found the shallow monitoring well (GW03A) with too little water to sample although sometimes enough to measure the depth to water.

Specific conductance of the surface water at this site varied more than an order of magnitude from moderately saline to hyper-saline over the period of investigation (σ = 23,590uS/cm). Some inverse correlation can be seen between specific conductance and the frequency and magnitude of precipitation in Figure C.5. This inverse correlation between rainfall and specific conductance in Oso Creek has been shown in prior studies (Hay and Mott, 2005). Average specific conductance of the groundwater was similar in each well, with GW03A averaging 14,279 uS/cm and GW03B averaging 18,100 uS/cm over the course of the investigation.

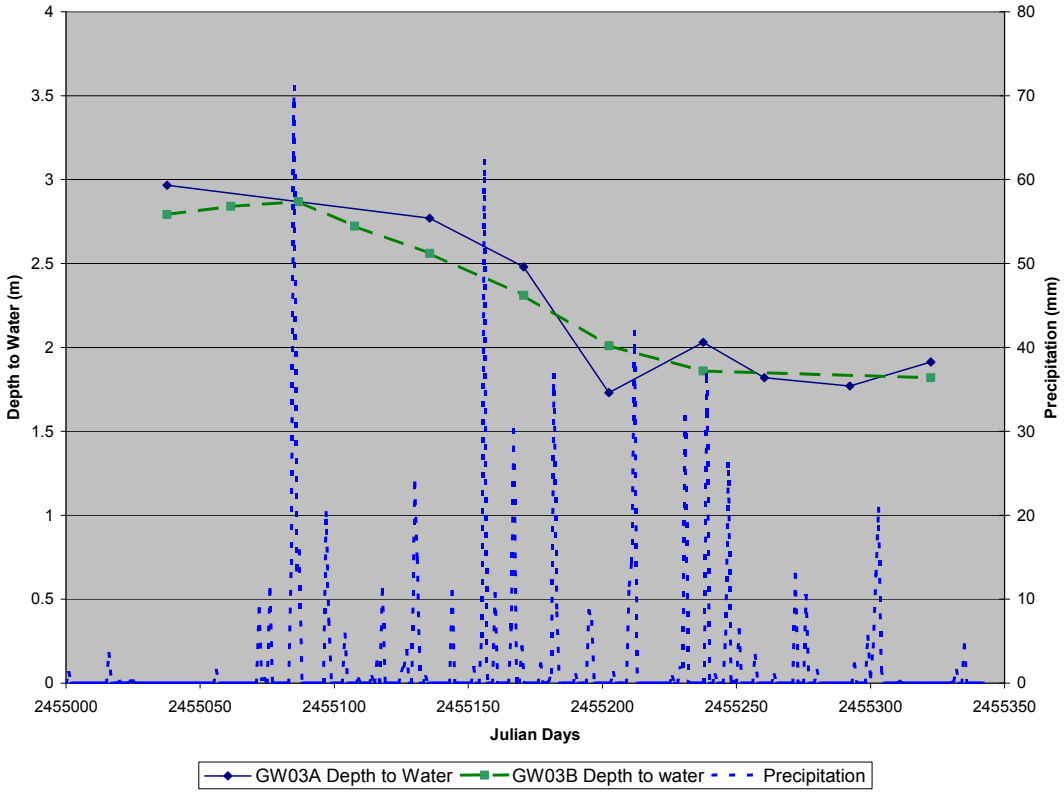

Figure C.6. Depth to Water and Precipitation at Site 3.

Depth to water in both wells can be seen to decrease over the period of data collection in response to precipitation events recharging the aquifer (Figure C.6). Depth to water values level out as the frequency and magnitude of precipitation decreases. This location is one of three where a sandy aquifer was penetrated. The similar values for specific conductance and the close tracking of water levels between the wells at this site suggest that they are both monitoring the same water table aquifer. Depth to water averaged 2.19 m in GW03A and 2.25 in GW03B.

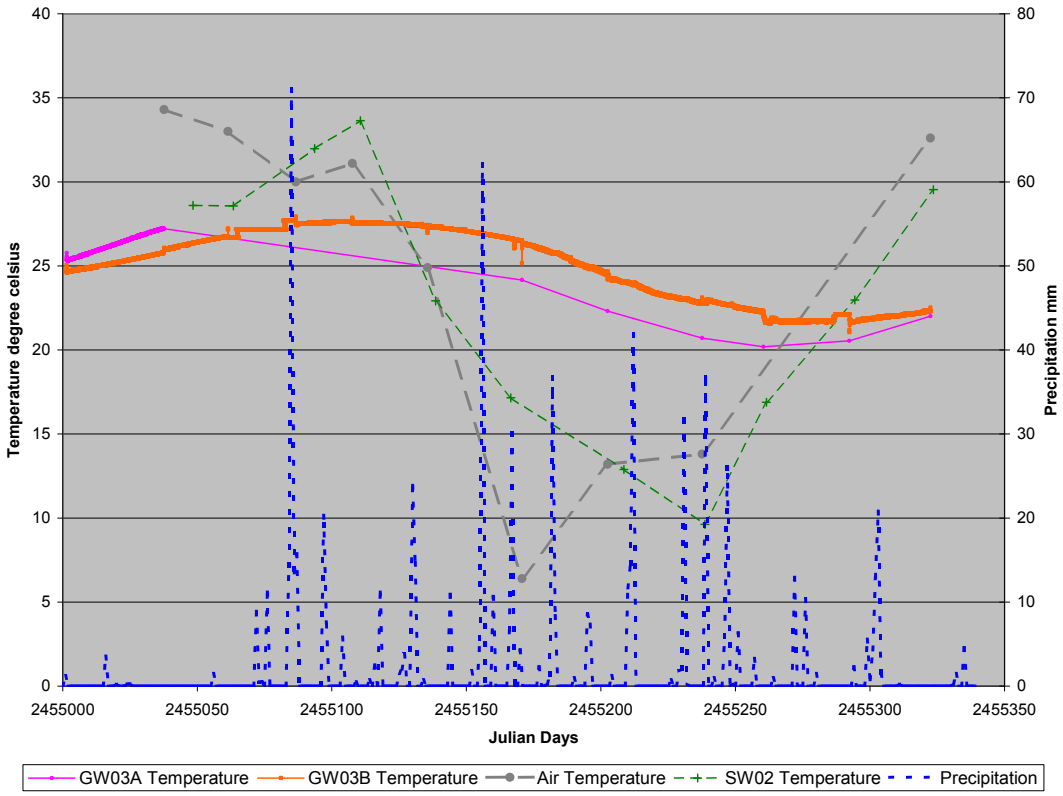

Figure C.7. Temperature and Precipitation at Site 3.

Temperature (Figure C.7) in the surface water varies widely and tracks the seasonal change of air temperature. Air temperature at the time of sampling had a $\sigma = 9.46$ °C and surface water temperature at this location had a $\sigma = 8.07$ °C. Groundwater temperature fluctuated around an average of 25.00 °C ($\sigma = 2.14$ °C) in GW03B, but slightly higher average water temperature (26.28 °C) was collected from the shallower GW03A. This well pair demonstrates that the positioning of the wells in the aquifer can reveal a vertical thermal gradient. In this case, low levels of water in GW03A indicate that it is positioned at the top of the water table aquifer in the capillary fringe, while GW03B penetrates much deeper into the water table. When the water table is low during dry periods the screened interval of GW03A is located in the capillary fringe where the ground is only partially saturated with water. This allows temperature to fluctuate a little more. Groundwater lags surface water and air temperature by more than 100 days.

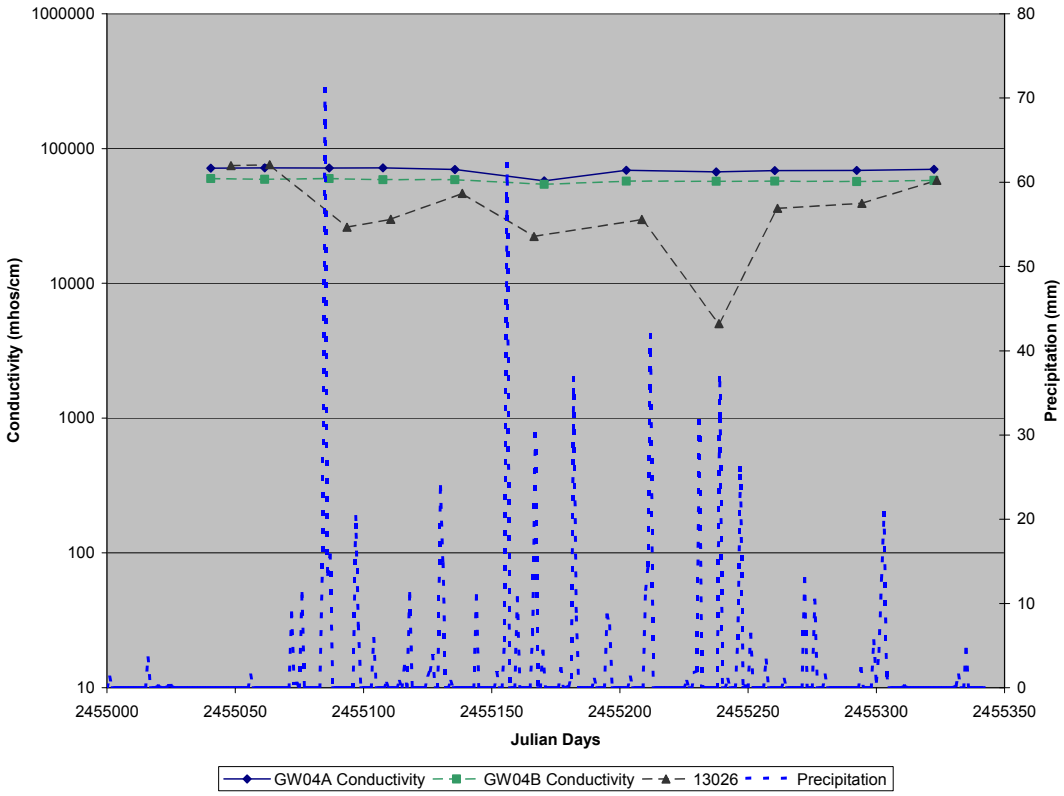

Figure C.8. Specific Conductance and Precipitation at Site 4.

Site 4 observes water quality and levels on the west side of Oso Bay and is composed of two monitoring wells (GW04A and GW04B), one surface water site (13026), and shares a thermal profiler (SB04) with Site 3.

Specific conductance (Figure C.8) of surface water at 13026 averaged 40,286 uS/cm and was generally lower than the adjacent groundwater where GW04A averaged 68,894 uS/cm and GW04B averaged 57,491 uS/cm. The water at all of these stations can be considered hyper-saline. Variations in surface water specific conductance correspond, to some extent, with the magnitude and frequency of precipitation events.

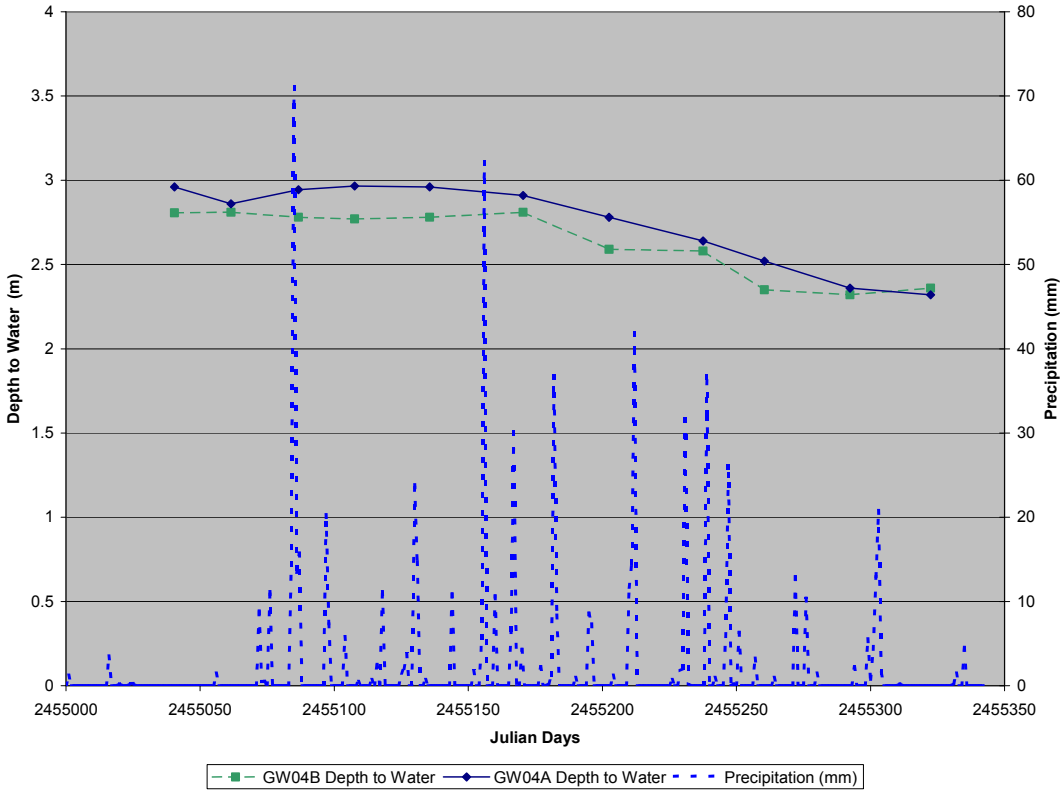

Figure C.9. Depth to Water, Precipitation at Site 4.

Groundwater levels in both well GW04A and GW04B (Figure C.9) demonstrate slow and gradual recharge to the aquifer over the period of measurement. The last three sampling events occurred during a period of subdued precipitation. The water levels become constant at this point indicating that recharge and discharge from the aquifer are approaching equilibrium.

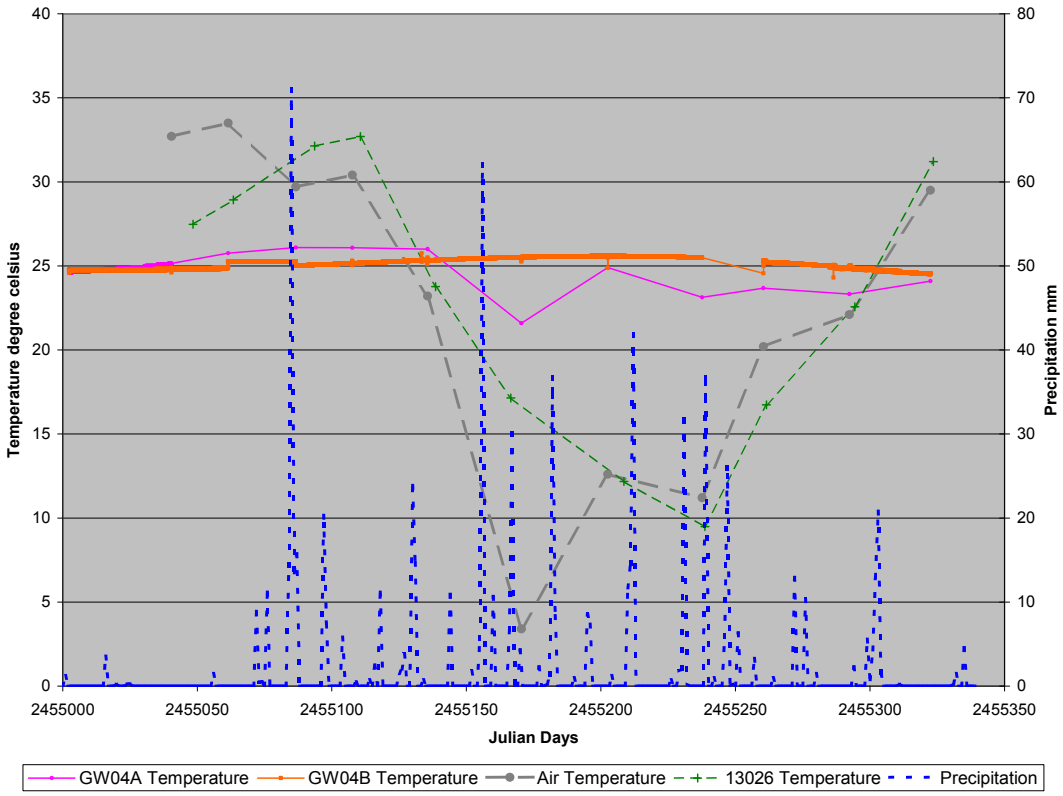

Figure C.10. Temperature and Precipitation at Site 4.

Air temperatures (Figure C.10) measured at this location reflect seasonal temperatures with surface water temperature lagging by more than 50 days. Water temperature in the deeper well, GW04B averaged 25.15 °C and varied slightly, ranging from a low of 24.3°C to a high of 25.7°C. GW04A ranged from 21.6°C to 26.1°C, perhaps responding to significant recharge events on Julian Day 2455156 and Julian Day 2455212, although the deeper well did not respond to any individual precipitation events.

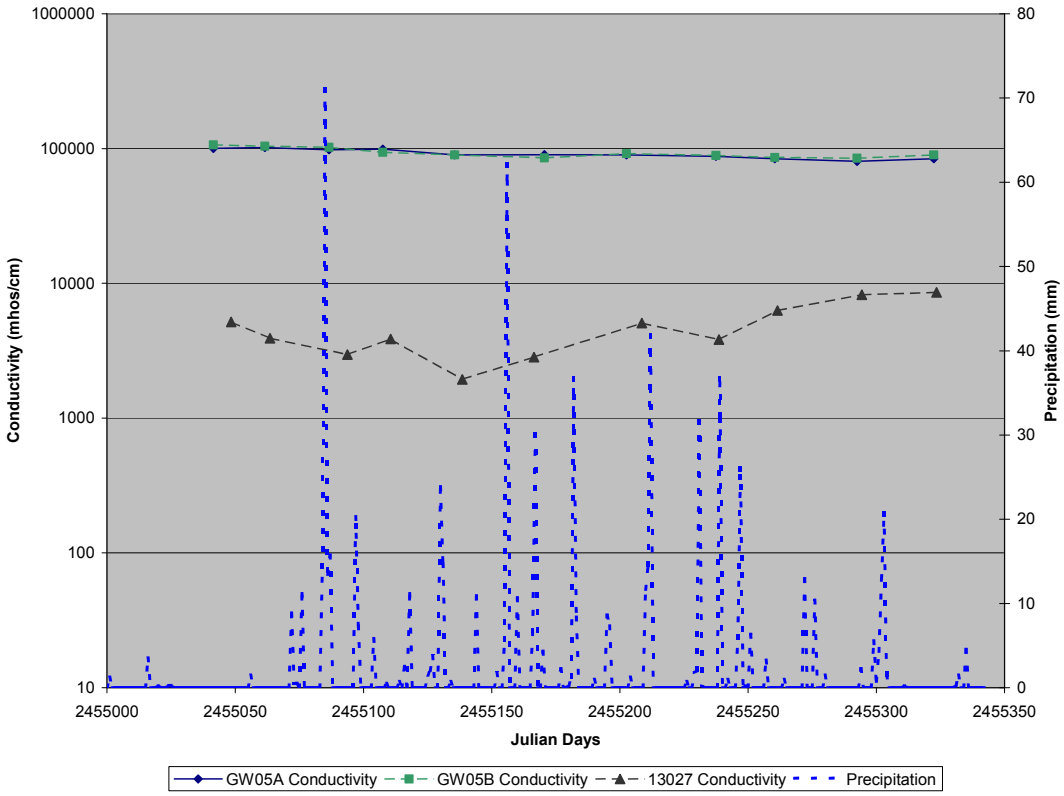

Figure C.11. Specific Conductance and Precipitation at Site 5.

Site 5 observes water quality and levels on the south side of the tidal section of Oso Creek near FM 2444, and is composed of two monitoring wells, GW05A and GW05B, one surface water site, 13027, and thermal profiler SB05.

Specific conductance (Figure C.11) of the surface water at this site averaged 4,788 uS/cm over the period of investigation characterizing water quality in this section of the creek as fresh to moderately saline. Specific conductance of the groundwater at this site is high in both GW05A and GW05B averaging 91,245 uS/cm in GW05A and 92,960 uS/cm in GW05B with maximum values exceeding 101,000 uS/cm or approximately double that of seawater. Both wells track together in specific conductance suggesting they are both completed in the same zone. A small downward trend in the groundwater specific conductance over the investigation may indicate a freshening of the aquifer, however this may be only a seasonal occurrence.

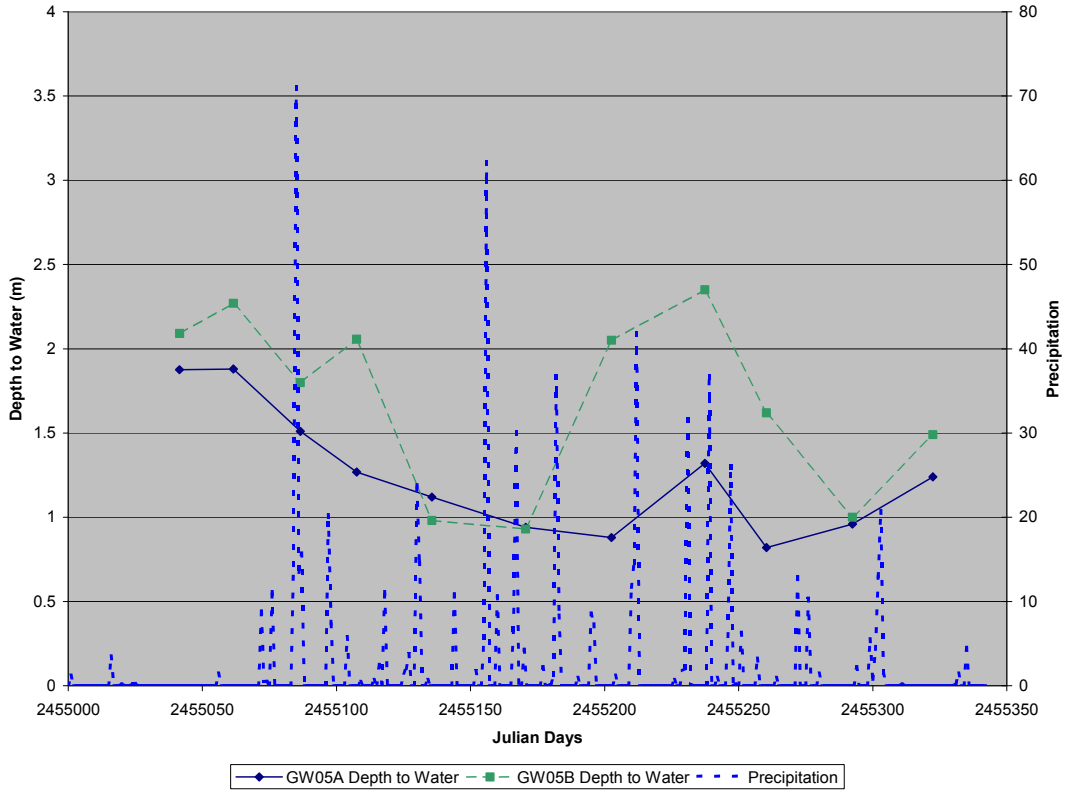

Figure C.12. Depth to Water and Precipitation at Site 5.

Groundwater levels (Figure C.12) in the two wells do not track well together suggesting that these wells are measuring hydraulic potential in two different zones. However, both of these wells are completed in clayey strata of low hydraulic conductivity making recovery to hydraulic equilibrium a slow process. The divergence in measured water levels between the two wells is probably due to replacing the well cap very tightly after the well was bailed for sampling and before the water levels could recover to hydrostatic equilibrium. When the wells were sampled at the next event the water levels were depressed because the air trapped in the well prevented the water level from reaching equilibrium. The shallower well (GW05A) was able to recover to hydrostatic equilibrium faster because its higher position in the aquifer required a much smaller volume of water to flow into the well to reach the static water level.

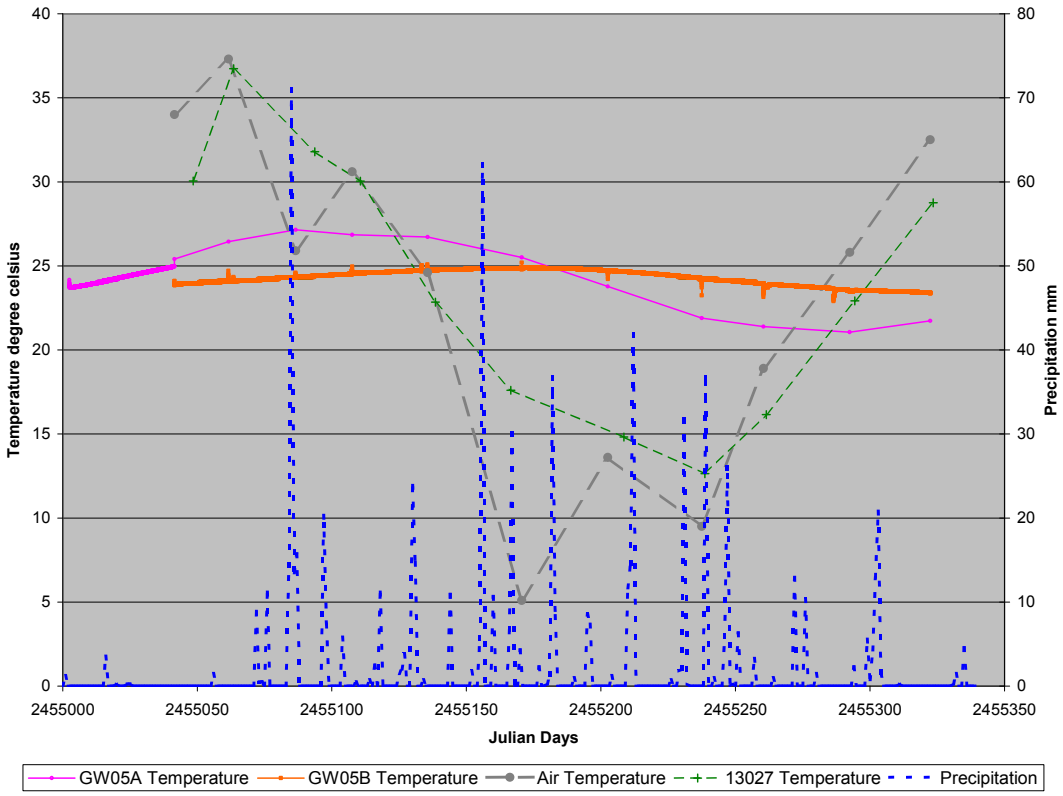

Figure C.13. Temperature and Precipitation at Site 5.

Surface water and air temperatures (Figure C.13) track well at this location with a lag of about 90 days. Surface water temperature averages 24.03°C (σ = 7.98°C) and air temperature averaged 23.44 °C (σ = 10.48 °C). Groundwater temperature in GW05A averaged 24.31 °C (σ = 0.394 °C) and 24.29 °C (σ = 0.453 °C) in the deeper well (GW05B). A seasonal temperature signal is evident (Figure C.13) in both the shallow and the deep well with the deep well lagging the shallow well by about 100 days.

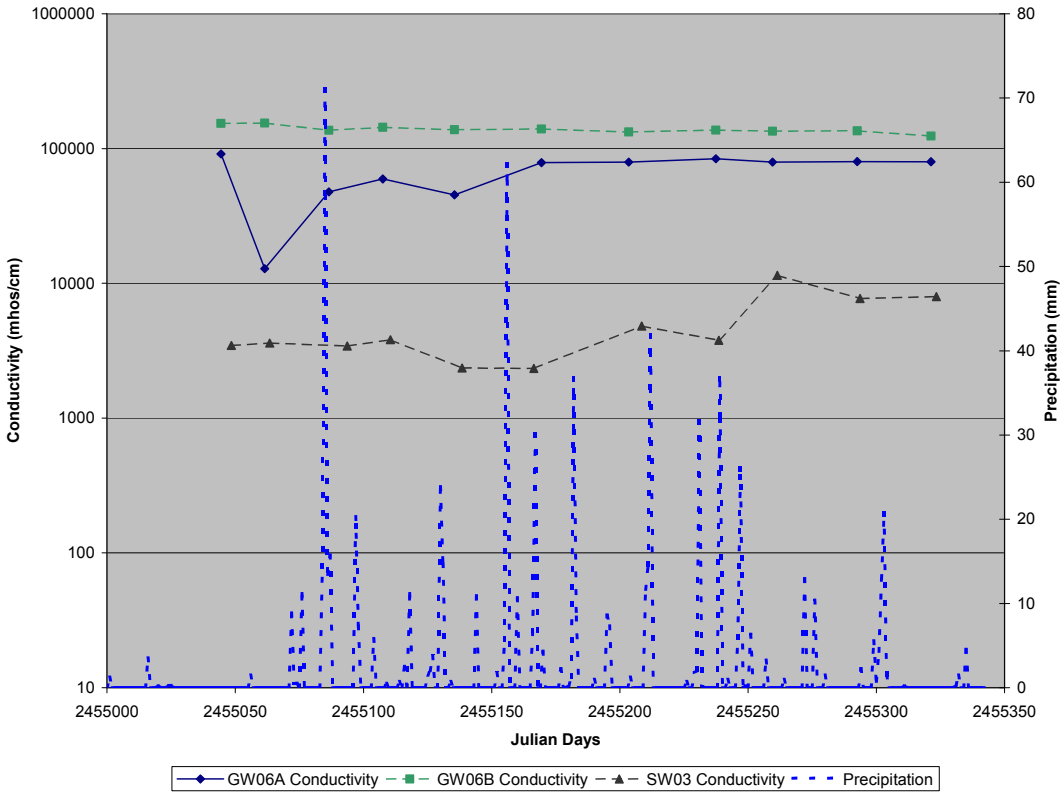

Figure C.14. Specific Conductance and Precipitation at Site 11.

Site 11 observes water quality and levels on the north side of the tidal section of Oso Creek, near FM 43 and is composed of two monitoring wells, GW06A and GW06B, one surface water site, SW03, and a thermal profiler SB06.

Specific conductance (Figure C.14) in the surface water (SW03) ranged from a minimum of 2,338 uS/cm to a maximum of 11,450 uS/cm indicating that water in this section of the creek is slightly saline to moderately saline. By contrast, specific conductance of the adjacent groundwater ranged from 12,852 uS/cm to 91,162 uS/cm in GW06A and from 123,666 uS/cm to 154,681 uS/cm in GW06B. GW06A had one excursion of specific conductance, which measured 12,852 uS/cm and occurred following some small, initial precipitation after well installation that may have allowed surface water (overland flow from precipitation) to bypass a not fully effective bentonite seal in the well (ineffective due to drought conditions and little soil moisture). Once the bentonite absorbed the moisture from the precipitation it attained its effectiveness at preventing water migration along the outside of the casing. Subsequent precipitation events did not make entry to the borehole and the measured specific conductance gradually returned to its initial hyper-saline conditions near 90,000 uS/cm. The deeper well GW06B maintained super-saline conditions throughout the period of investigation averaging 139,036 uS/cm or about 3.5 times that of seawater.

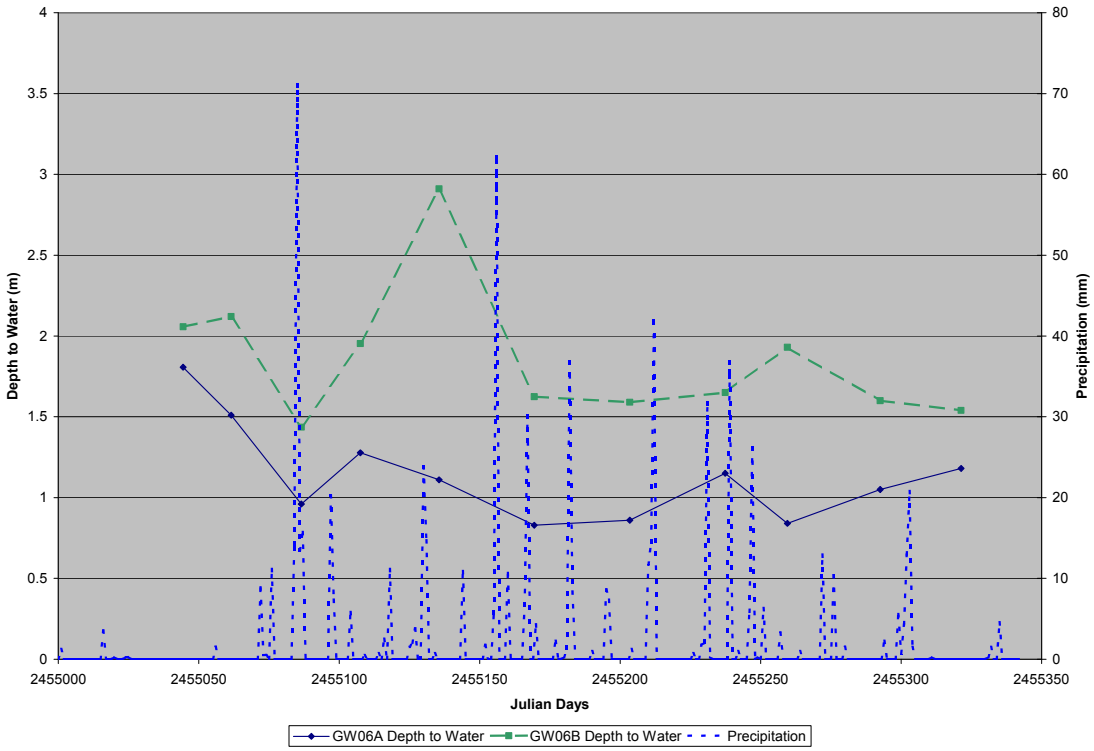

Figure C.15. Depth to Water and Precipitation at Site 11.

Depth to water (Figure C.15) averaged 1.14 m in GW06A and 1.86 m in GW06B. Neither well shows a marked decrease in water level as the frequency and magnitude of precipitation increases, however an excursion can be seen in GW04B that is probably a result of inadequate time to recharge between bailing the well from the previous sampling event and tightly capping the well.

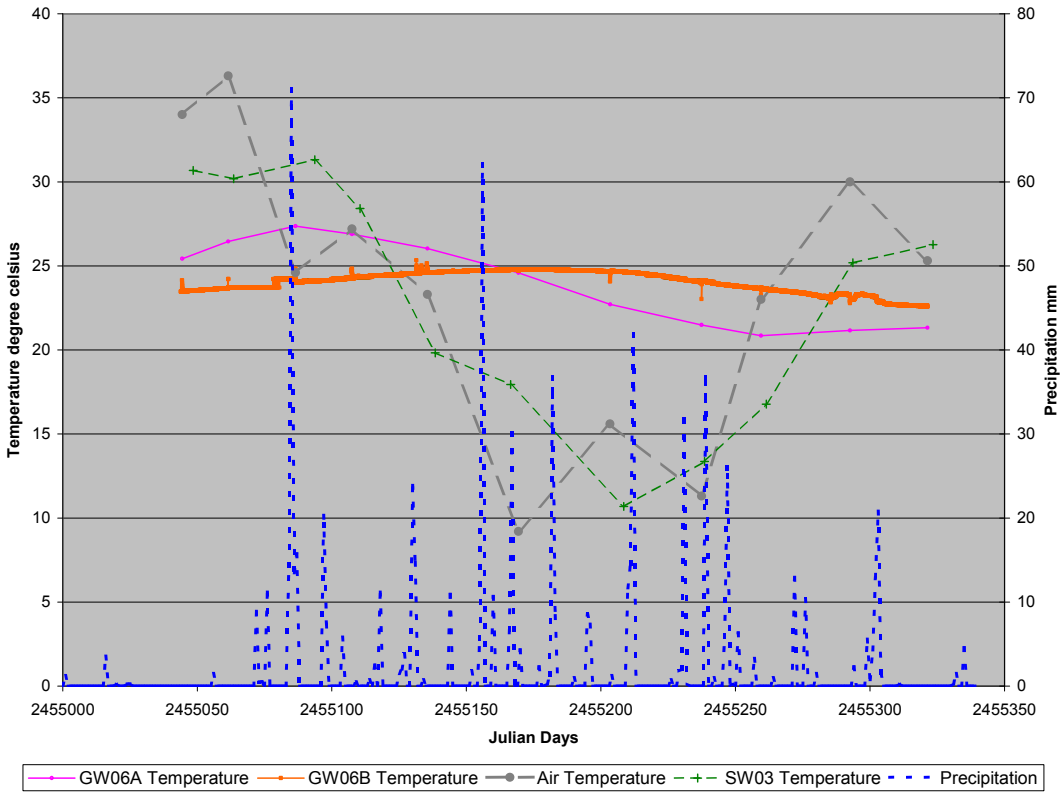

Figure C.16. Temperature and Precipitation at Site 11.

Surface water and air temperature track each other well at this site. Surface water temperature lags air temperature by about 30 days. Surface water temperature averaged 22.78 °C (σ = 7.368°C) and air temperature at the time of sampling averaged 23.62 °C (σ = 8.622°C). Groundwater temperature in GW06A and GW06B display a seasonal signal with the deeper well lagging the shallower well by about120 days. Temperature averaged 24.04°C (σ = 0.62°C) in GW06B and 24.03°C (σ = 2.555°C) in GW06A.

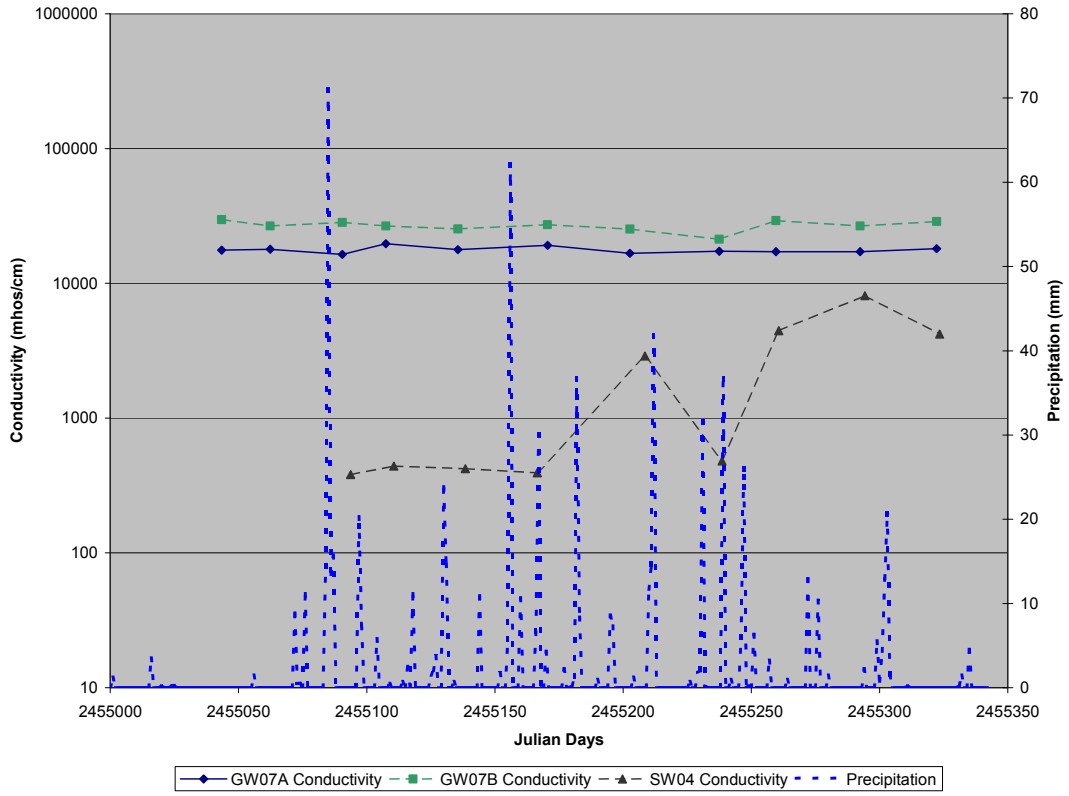

Figure C.17. Specific Conductance and Precipitation at Site 12.

Site 12 observes water quality and levels on the west side of an unnamed tributary to Oso Creek crossing FM 2444, and is composed of two monitoring wells, GW07A and GW07B, one surface water site, SW04, and a thermal profiler SB07. This site was selected to compliment an agricultural non-point source runoff project that was conducted by the USGS and the Texas A&M University Agricultural Experiment Station (Ockerman, 2008).

Specific conductance (Figure C.17) of surface water at this site averaged 2,421 uS/cm over the period of this study characterizing water quality at this site as fresh to moderately saline. This site had no surface water at the time of the first two sampling events. The stream channel filled with water after significant precipitation began on Julian Day 2455085. As precipitation became less frequent and of lower magnitude specific conductance rose. Specific conductance in GW07A averaged 17,720 uS/cm (very saline) over the period of investigation. The deeper GW07B can be characterizes as very saline, averaging 26,811 uS/cm. Specific conductance of groundwater at this site varied only slightly.

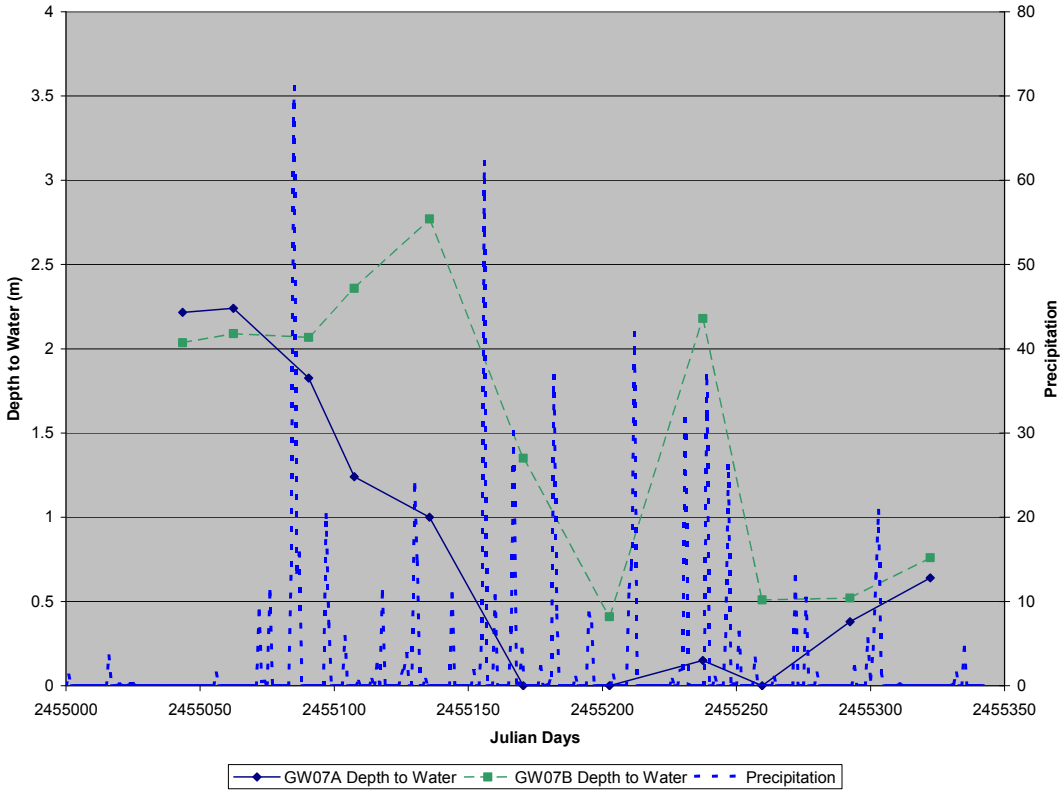

Figure C.18. Depth to Water and Precipitation at Site 12. Note: occasional artesian flow in GW07A.

Depth to water (Figure C.18) in the shallow well, GW07A, can be seen to respond with recharge (decreased depth to water) with frequency and magnitude of precipitation, however the deeper well GW07B has several measurement that seem anomalous and are probably due to a very slow recovery rate after sampling and a very tight fitting well cap trapping air in the casing. This pair of wells were installed in a topographic low and several measurements were made in GW07A where the well, after removal of the well cap, displayed a decreased in depth to water until the water reached the top of the casing and overflowed (flowing artesian well). GW07B, when left uncovered did not reach the point of overflowing the casing.

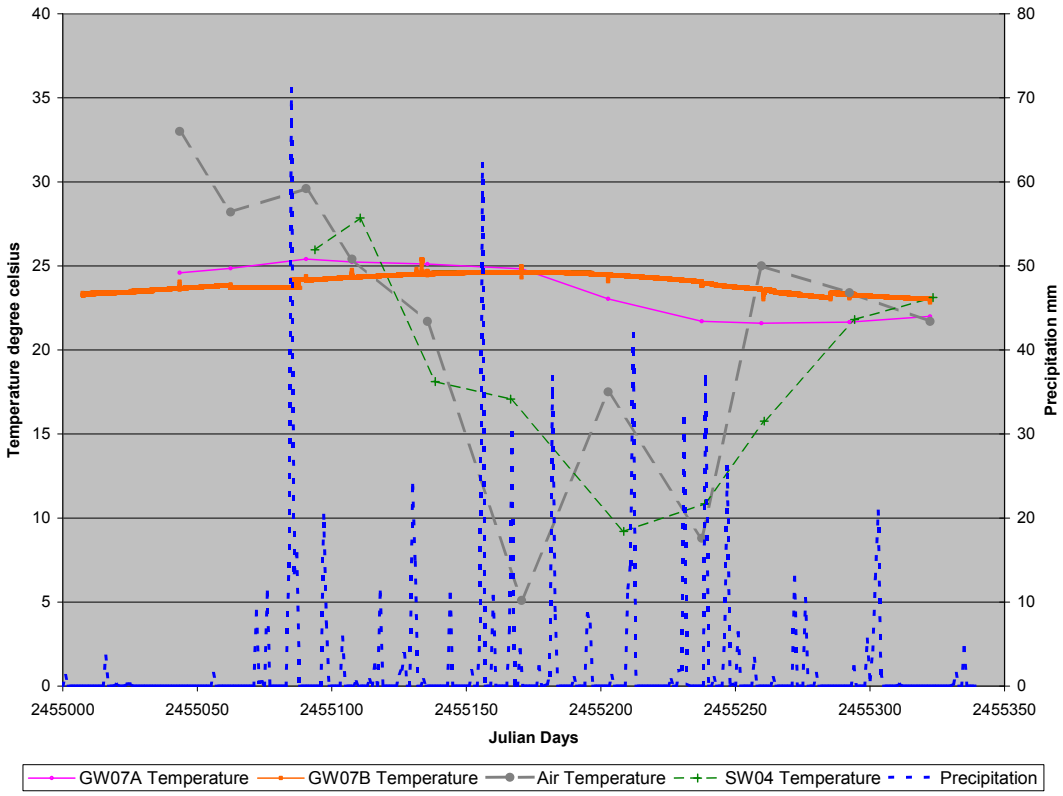

Figure C.19. Temperature and Precipitation at Site 12.

Surface water and air temperature (Figure C.19) track together at this site with surface water lagging by about 40 days. Surface water temperature averaged 18.86°C (σ = 6.412°C) and air temperature averaged 21.76°C (σ = 8.482°C). Groundwater temperature in GW07A averaged 23.63°C (σ = 1.628°C) and 23.94°C (σ = 0.524°C) in the deeper well, GW07B. A seasonal temperature signal is evident (Figure C.19) in both the shallow and deep well, with the deep well lagging by about 80 days.

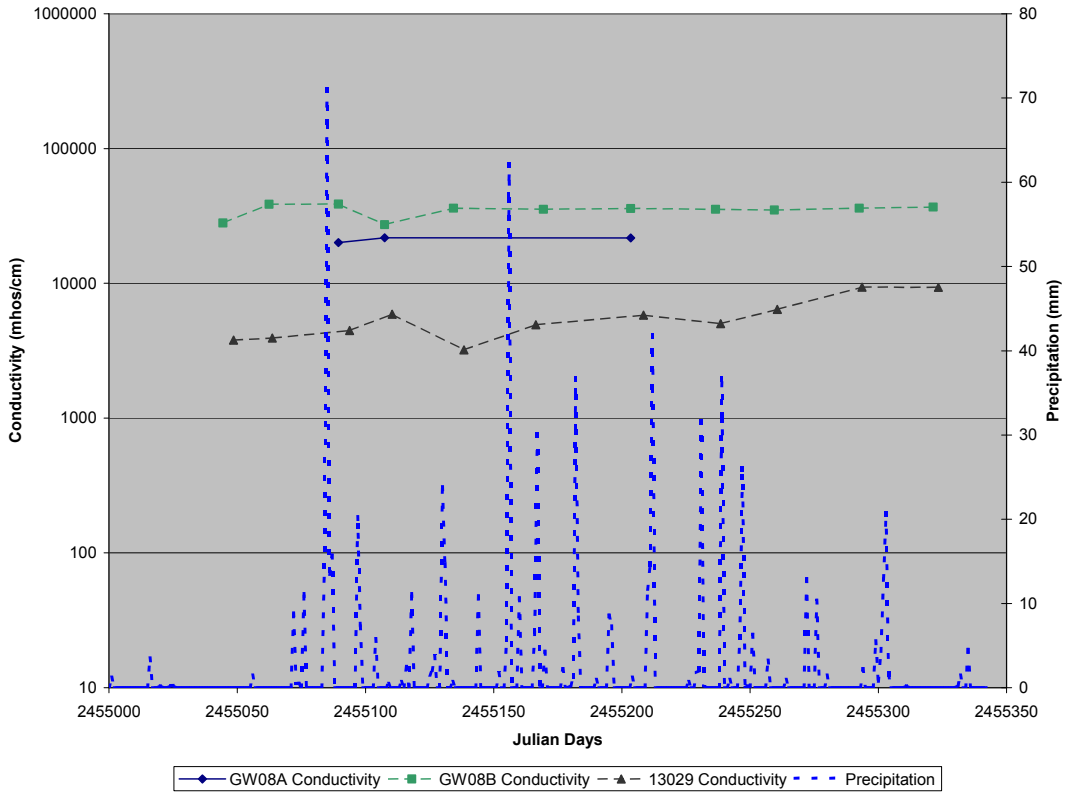

Figure C.20. Specific Conductance and Precipitation at Site 13. Low water levels in GW08A limited testing of some constituents.

Site 13 observes water quality and levels on the north side of the non-tidal section of Oso Creek and is composed of two monitoring wells, GW08A and GW08B, one surface water site, 13029, and a thermal profiler SB08. Groundwater levels in GW08A were sufficiently high enough to test water quality three times during this study, although depth to water was measurable at all sampling events except the first.

Specific conductance (Figure C.20) of surface water at this site averaged 5,654 uS/cm over the period of investigation, characterizing water quality in this section of the creek as moderately saline. A slightly increasing trend in specific conductance can be seen in surface water over the course of the investigation. Specific conductance in GW08A (three measurements) averaged 21,178 uS/cm and averaged 34,829uS/cm in GW08B, both characterized as very saline. Specific conductance remained steady in the groundwater over the period of measurement.

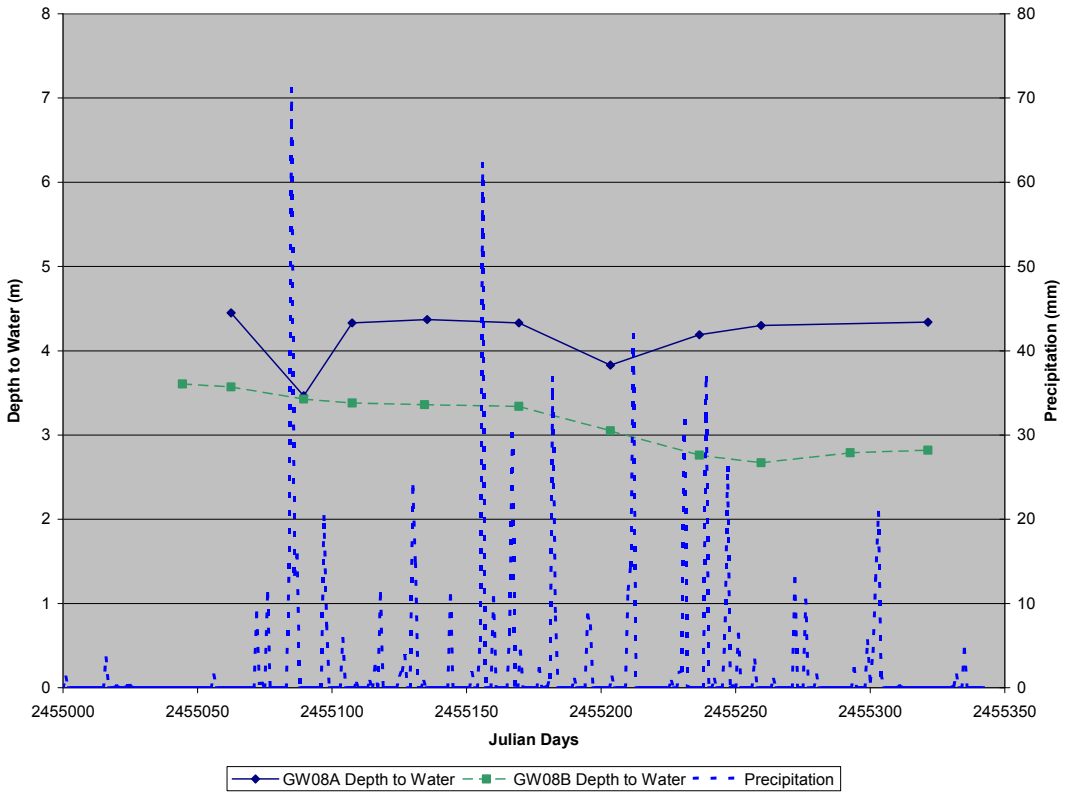

Figure C.21. Depth to Water and Precipitation at Site 13. Low water levels in GW08A limited testing of some constituents.

Depth to water (Figure C.21) in GW08A was always near total depth of the well (4.62 m), averaging 4.18 m. Groundwater levels did not track together, but the deeper well, GW08B, averaging 3.16 m depth to groundwater decreased gradually over the sampling period indicating recharge to the aquifer.

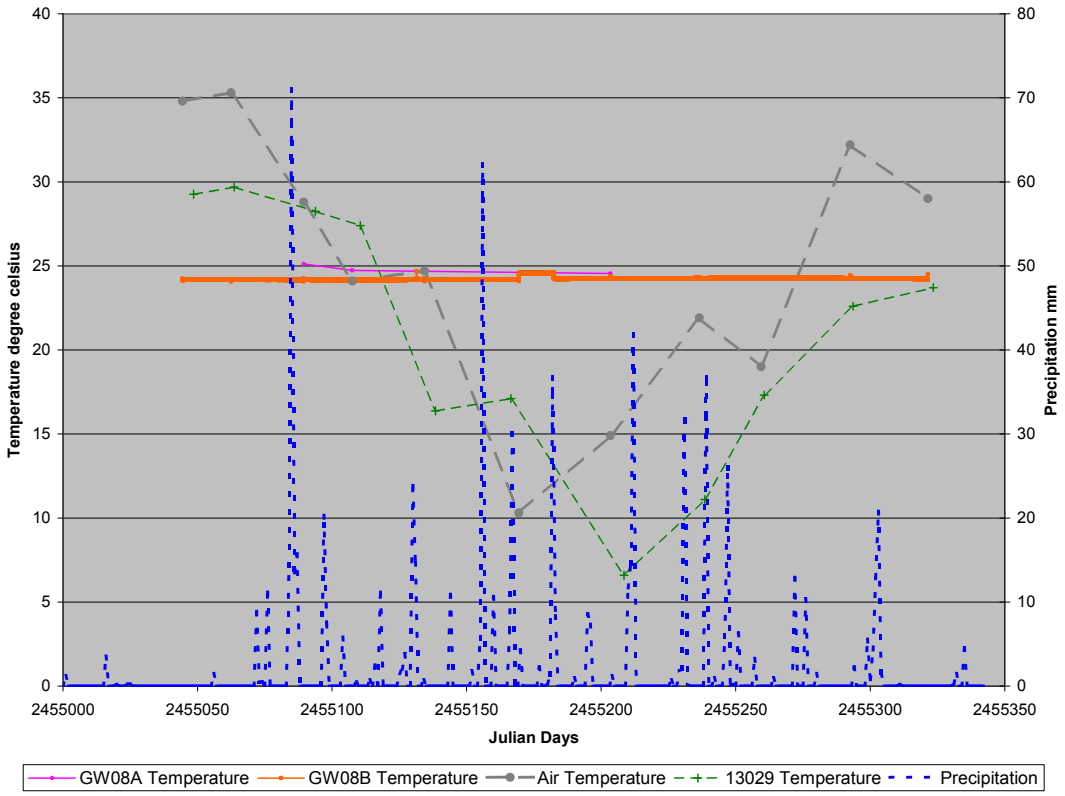

Figure C.22. Temperature and Precipitation at Site 13. Low water levels in GW08A limited testing of some constituents.

Surface water and air temperatures (Figure C.22) track well at this location with a lag of about 40 days. Surface water temperatures averaged 20.85°C (σ = 7.763°C) and air temperature averaged 25.80°C (σ = 8.641°C). There were only three measurement of groundwater temperature in GW08A, averaging 24.80°C (σ = 0.291°C). Groundwater temperature of GW08B averaged 24.24°C (σ = 0.083°C) as values remained flat over the length of the investigation. No seasonal signal in temperature is evident in the groundwater at this site.

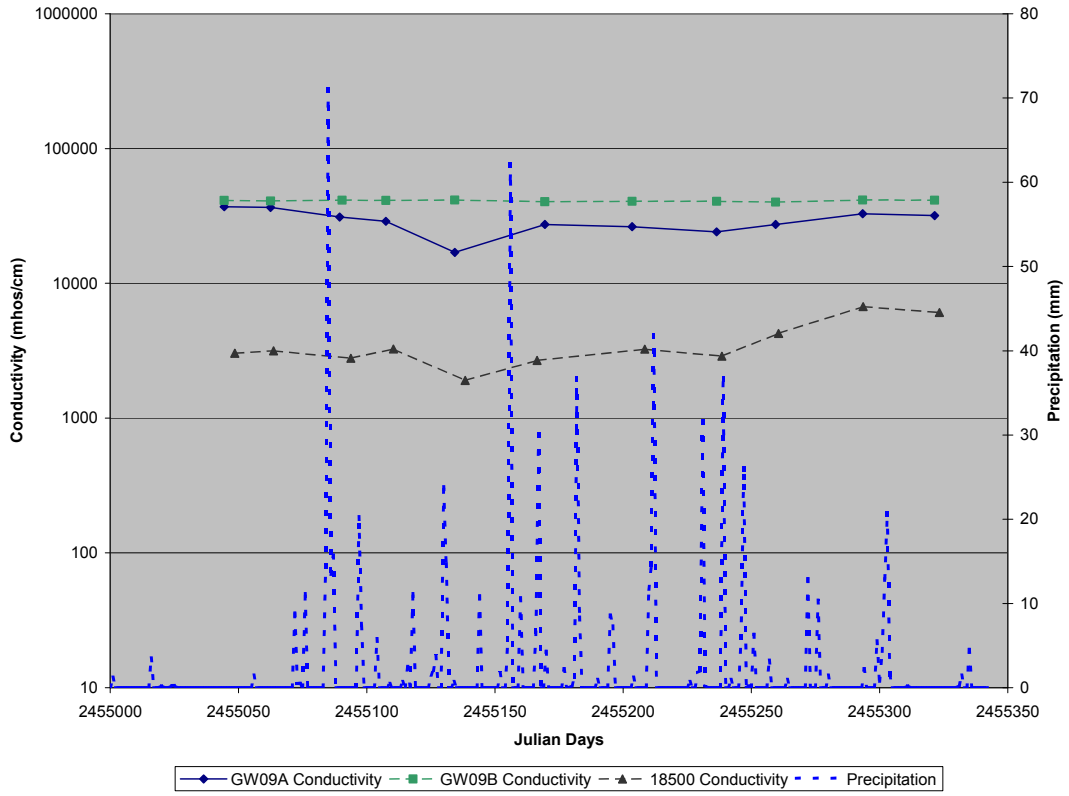

Figure C.23. Specific Conductance and Precipitation at Site 14.

Site 14 observes water quality and levels on the west side of the non-tidal section of Oso Creek and is composed of two monitoring wells, GW09A and GW09B, one surface water site, 18500, and a thermal profiler SB09.

Specific conductance (Figure C.23) in the surface water (18500) ranged from a minimum of 1,903 uS/cm to a maximum of 6,719 uS/cm, indicating that this section of the Oso Creek is slightly saline to moderately saline. Specific conductance in groundwater at this site can be characterized as very saline with GW09A averaging 29,091 uS/cm and GW09B averaging 40,967 uS/cm. Specific conductance in surface water shows a slightly increasing trend over the course of the study where as groundwater measurements remain relatively stable.

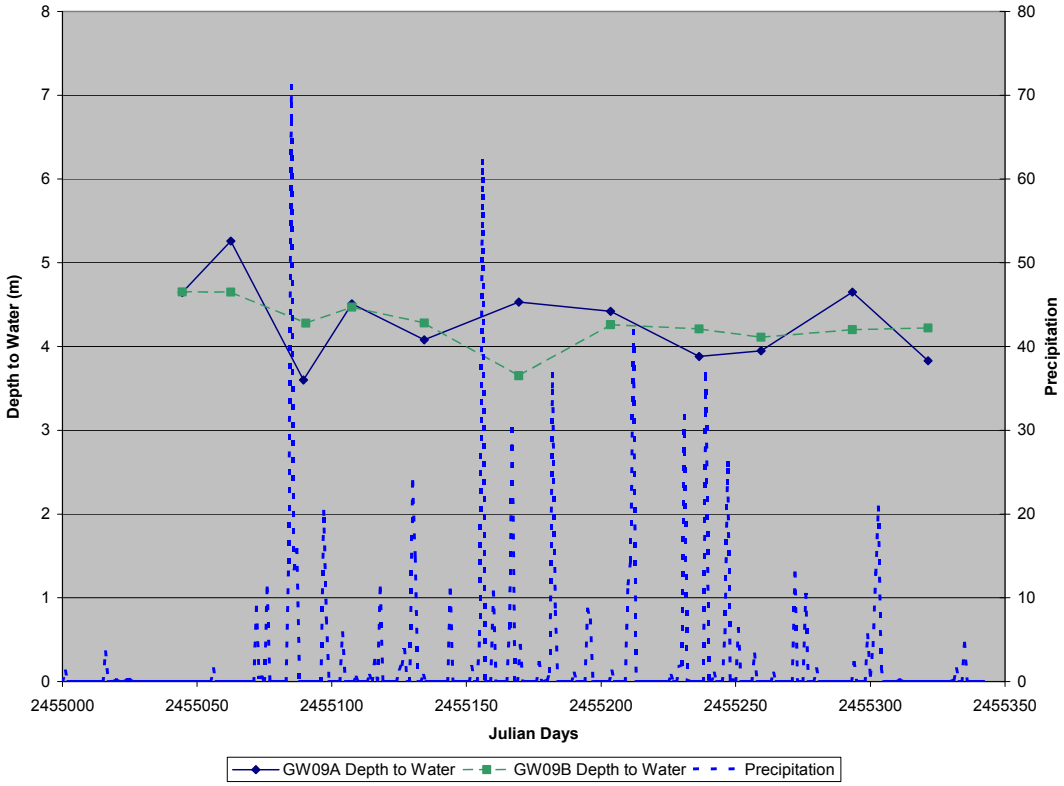

Figure C.24. Depth to Water and Precipitation at Site 14

Depth to water (Figure C.24) averaged 4.31 m in GW09A and 4.27 m in GW09B. Some fluctuations are seen in the depth to water measurements over the study period, but a slightly decreasing trend is evident, indicating a gradual recharge to the aquifer over this time period.

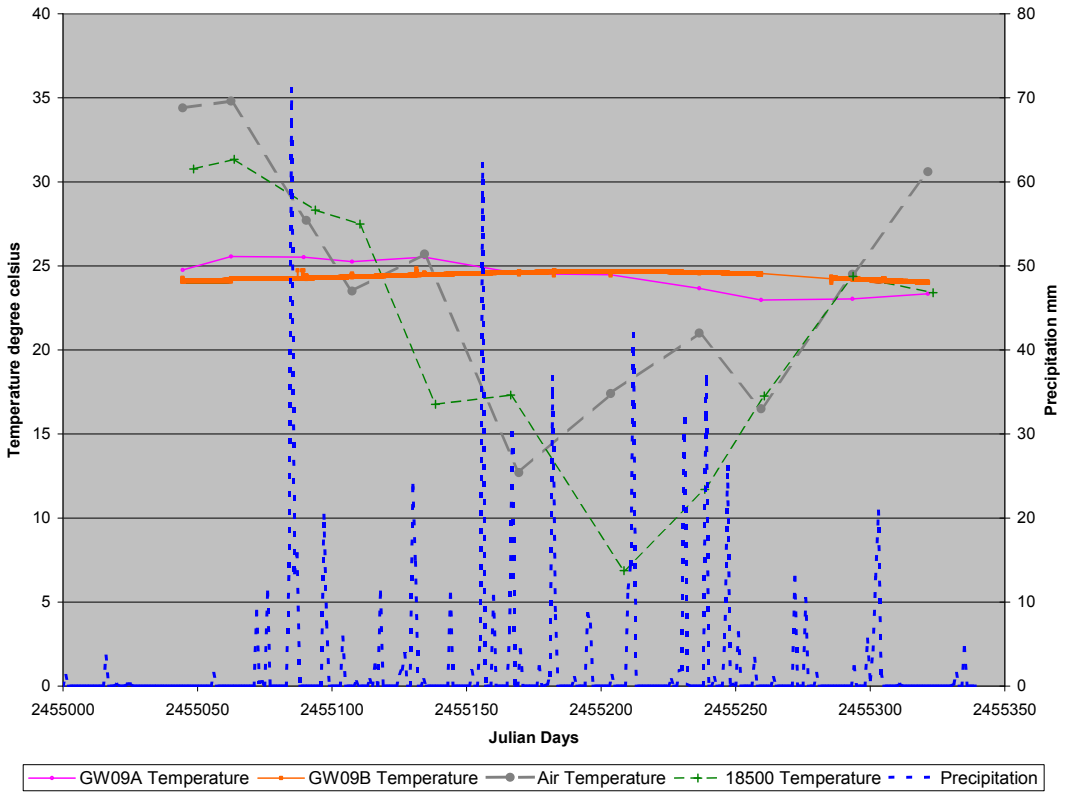

Figure C.25. Temperature and Precipitation at Site 14.

Surface water temperature (Figure C.25) and air temperature track each other at this location with surface water lagging air temperature by about 40 days. Surface water temperature averages 21.42°C (σ = 8.080°C) and air temperature averaged 24.44°C (σ = 7.210°C). Groundwater temperature in GW09A averaged 24.42°C (σ =1.013°C) and 24.42°C (σ = 0.210°C) in the deeper well GW09B. A seasonal temperature signal is visible (Figure C.25) in both GW09A and GW09B with the deeper well lagging the shallower well by about 116 days.

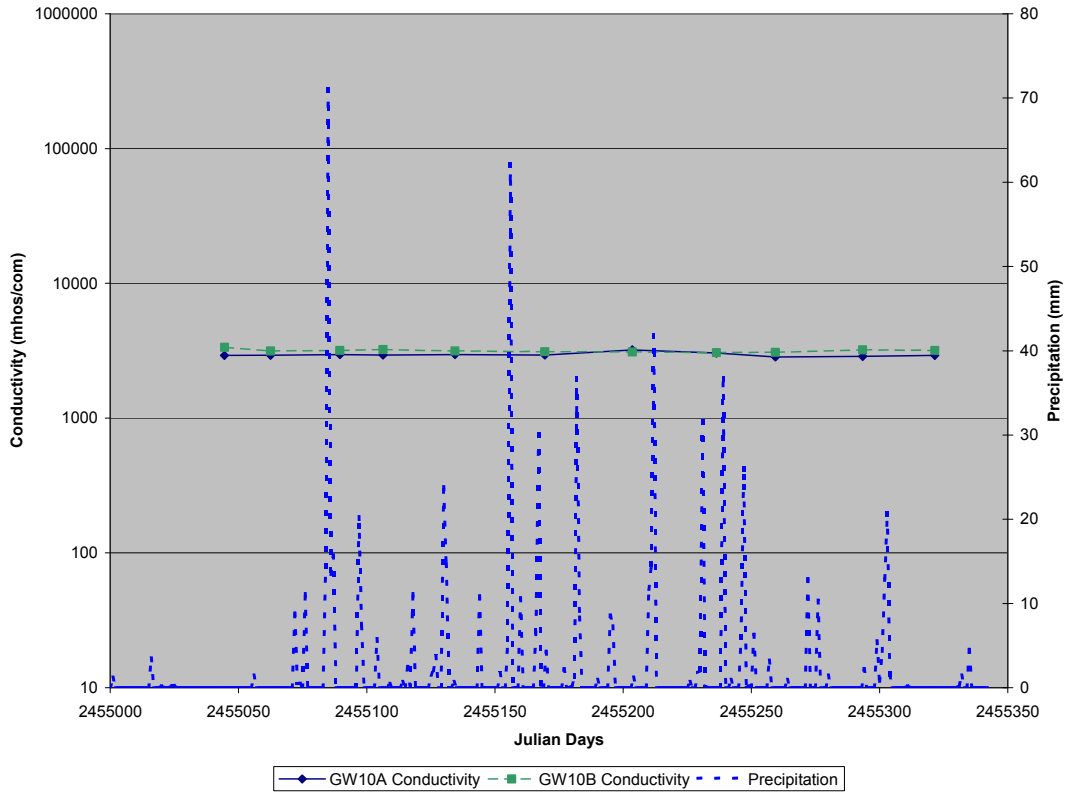

Figure C.26. Specific Conductance and Precipitation at Site 16.

Site 16 observes water quality and levels on the east side of West Oso Creek and is composed of two monitoring wells, GW10A and GW10B, one surface water site, SW05, and a thermal profiler SB10. This location was selected to coincide with monitoring on another project (Ockerman, 2008). This location is in the upper reach of West Oso Creek and has only a trace of a channel due to agricultural endeavors both up gradient and down gradient of this site, and so there was no surface water present at this site during any of the sampling events over the course of this study.

Specific conductance (Figure C.26) of surface water at Site 16 was not measured. Specific conductance of the groundwater at this location was low. GW10A averaged 2,955 uS/cm (σ=98.06) and GW10B averaged 3,162 uS/cm (σ=84.66), which characterizes both wells as being slightly saline water. Specific conductance values were similar between wells at all sampling events and there was no apparent response to precipitation events during this sampling period.

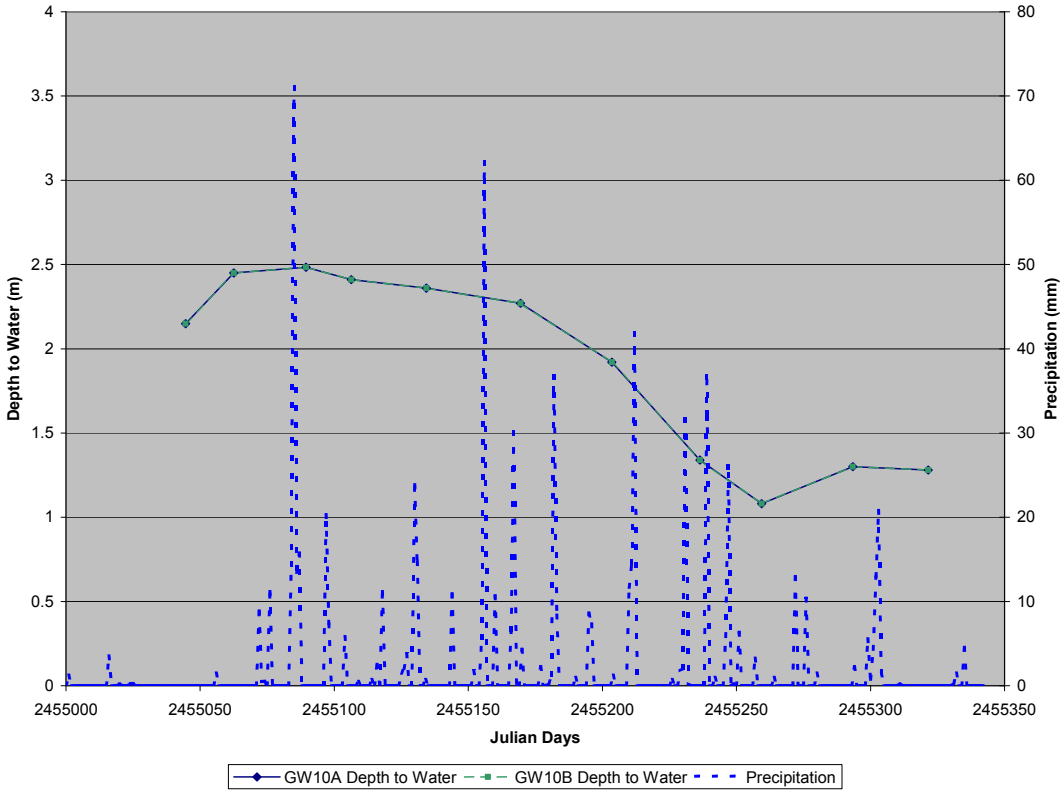

Figure C.27. Depth to Water and Precipitation at Site 16.

Depth to water measurements (Figure C.27) track well together as both wells seem to respond to the frequency and magnitude of precipitation events. Depth to water in GW10A averaged 1.90 m (σ=0.551) and 1.91 m (σ=0.552) in GW10B. The wells at this location are one pair of three that intersected a significant sand with some thickness. The similarity in water quality (specific conductance) and water level response suggest that these wells are monitoring the same zone. Both wells at this site show decreasing depth to water (increasing water table elevation) over much of the study indicating that recharge is occurring here in response to precipitation.

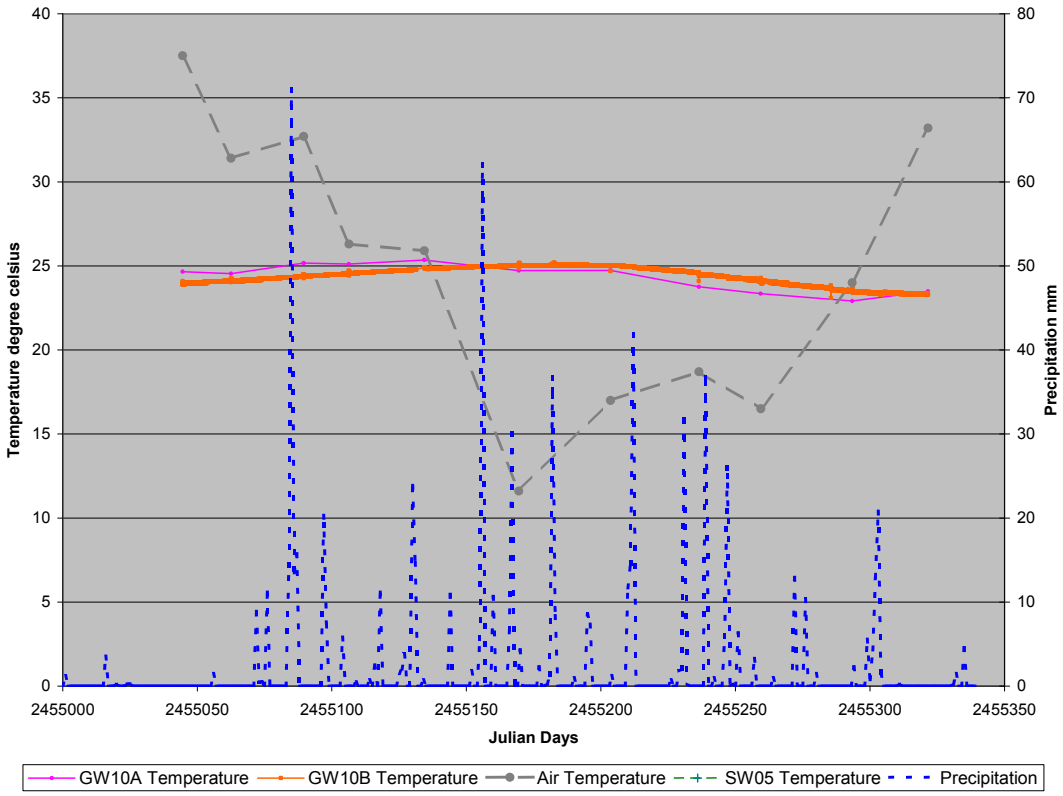

Figure C.28. Temperature and Precipitation at Site 16.

Temperature was not measured in surface water at this location. Air temperature (Figure C.28) at Site 16 averaged 24.98°C (σ = 8.262°C) at sampling events. Groundwater temperatures averaged 24.34°C (σ = 0.826°C) in GW10A and 24.39°C (σ = 0.541°C) in the deeper well, GW10B. Temperature in both wells shows a seasonal signal with the deeper well lagging by about 40 days.

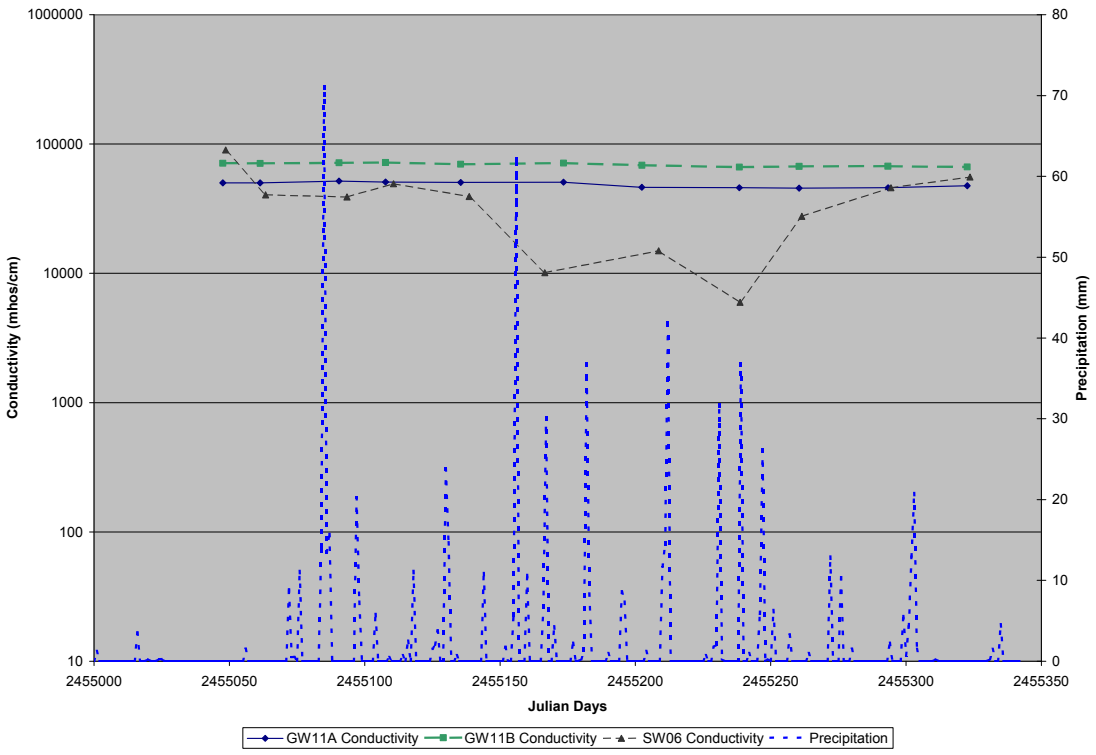

Figure C.29. Specific Conductance and Precipitation at Site 17.

Site 17 observes water quality and levels on the east side of Oso Bay (Suter Park) and is composed of two monitoring wells, GW11A and GW11B, one surface water site, SW06, and a thermal profiler SB11.

Specific conductance (Figure C.29) in the surface water (SW06) has a wide range of values, from a minimum of 5,965 uS/cm to 90,044 uS/cm, indicating a water quality regime that oscillates from moderately saline to hyper-saline where mderately saline intervals are a response to influx from rainfall and runoff (Hay and Mott, 2005). Specific conductance in groundwater averaged 48,655 uS/cm (σ=2,386) in the shallow well and 69,336 uS/cm (σ=2,168) in the deeper well (GW11B). Groundwater in both of these wells can be characterized as very saline to hyper-saline. Specific conductance of the groundwater does not appear to respond to precipitation or recharge at this location.

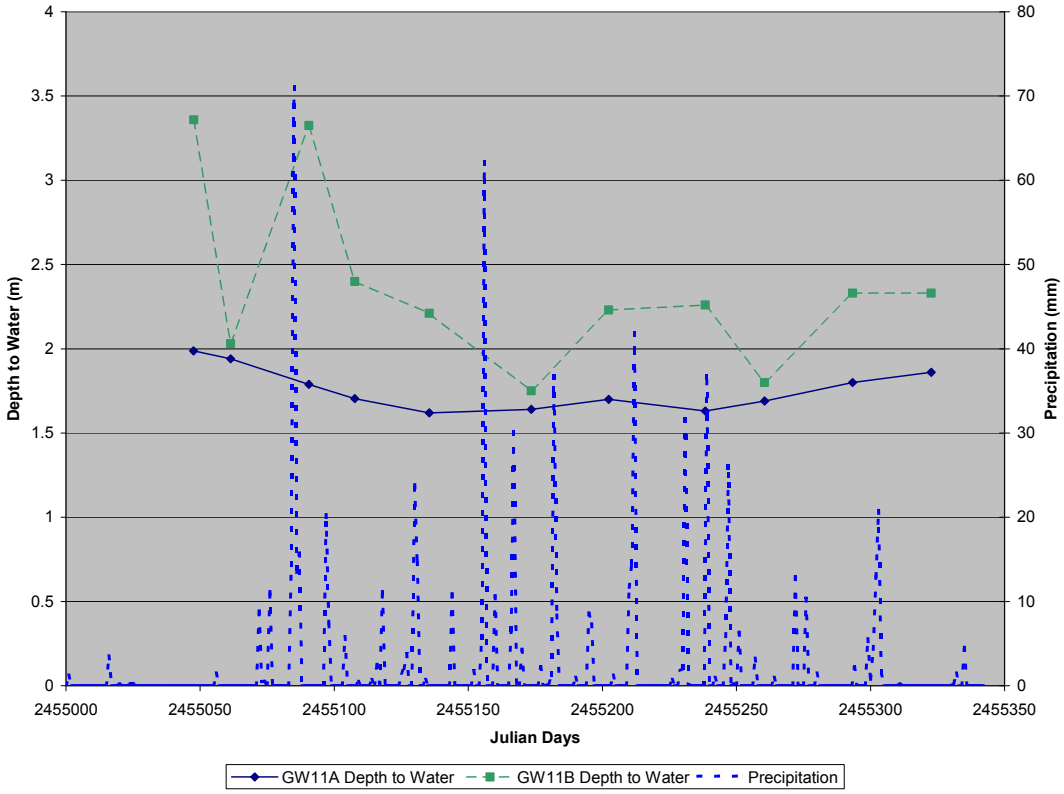

Figure C.30. Depth to Water and Precipitation at Site 17.

Depth to water measurements (Figure C.30) in GW11B averaged 2.37 m and ranged from 1.75 m to 3.36 m. Depth to water measurements in GW11A averaged 1.76 m and had a narrower range than GW11B from 1.62 m to 1.99 m. Water level measurement in GW11B appear to occasionally suffer from slow recovery after sampling and trapped air in the casing that prevents the water level in the well from reflecting true groundwater levels. Water levels in GW11A however, reflect an increase in water levels (decrease in depth to water) during "wet" conditions and an increase near the end of the sampling period as precipitation becomes less frequent and less intense.

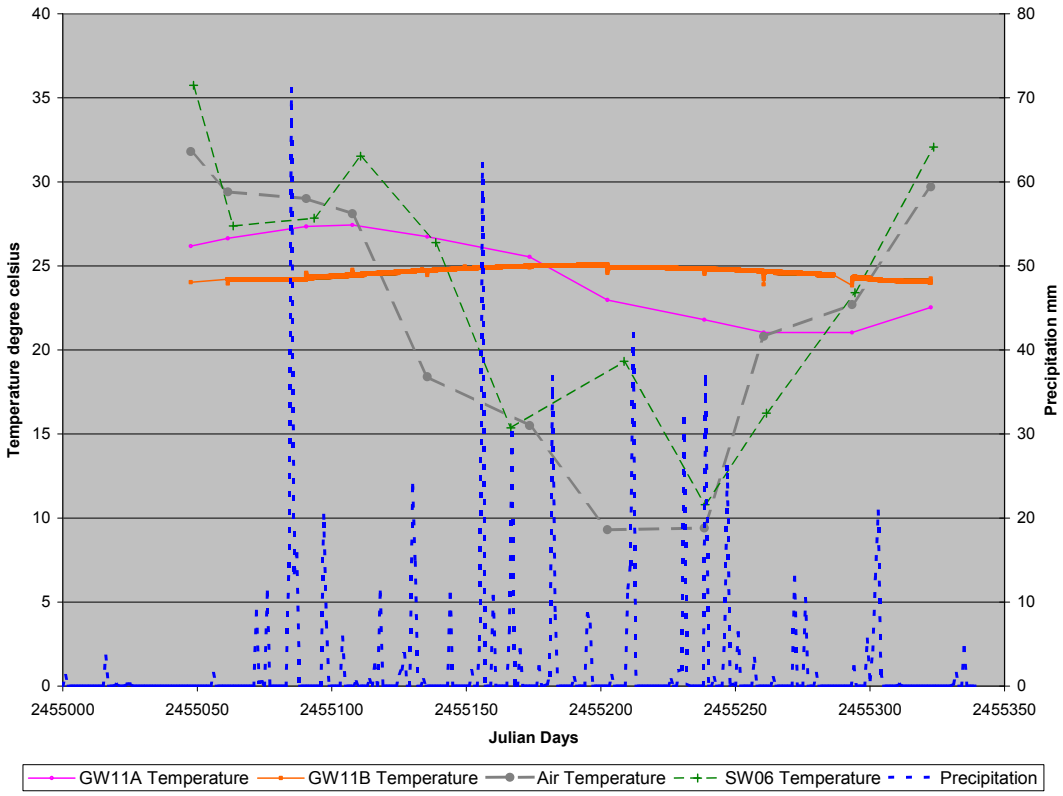

Figure C.31. Temperature and Precipitation at Site 17.

Surface water temperature (Figure C.31) and air temperature track each other at this location with surface water temperature lagging by about 36 days. Surface water temperature averaged 24.17°C (σ = 7.887°C) and air temperature at the time of groundwater sampling averaged 22.19°C (σ = 8.204°C). Groundwater temperature in GW11A averaged 24.48°C (σ = 2.601°C) and in the deeper well (GW11B) groundwater temperature averaged 24.62°C (σ = 0.301°C). A seasonal temperature signal can be seen in both wells (with greater amplitude in GW11A). Groundwater temperature in the deep well (GW11B) lagged the shallow well by about 88 days. Water temperature in the wells did not seem to fluctuate with the frequency or magnitude of precipitation.

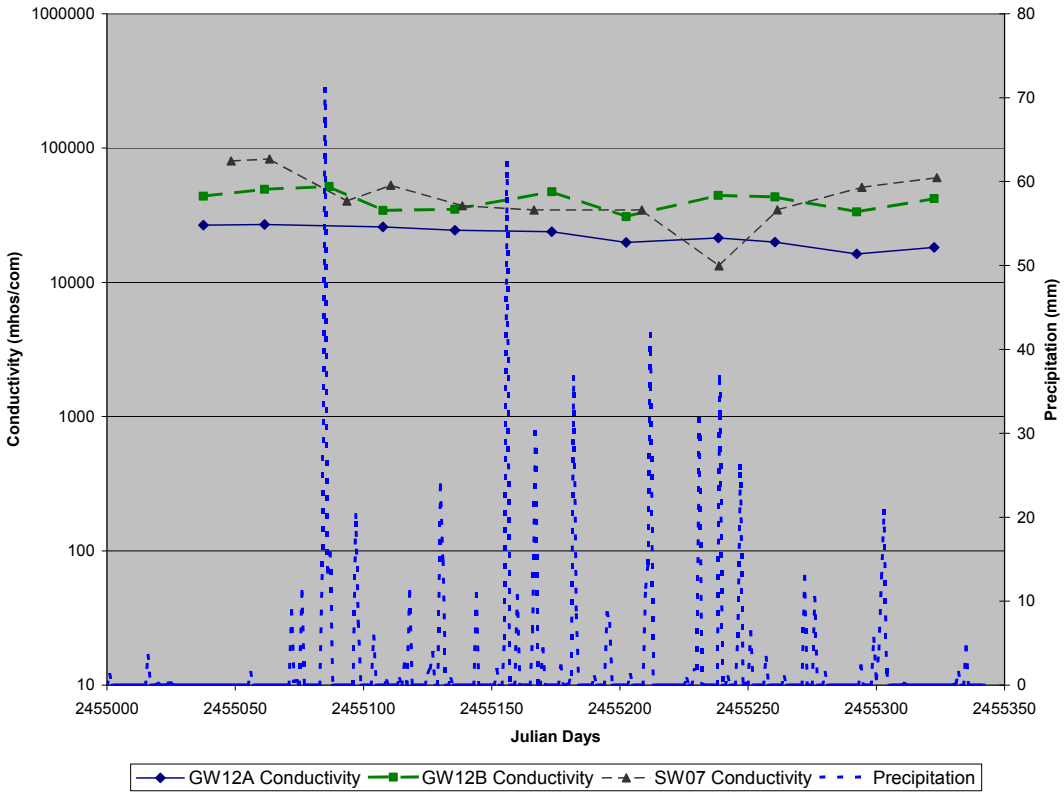

Figure C.32. Specific Conductance and Precipitation at Site 18.

Site 18 observes water quality and levels on the west side of Oso Creek Bay and is composed of two monitoring wells, GW12A and GW12B, one surface water site, SW07, and a thermal profiler SB12.

Specific conductance (Figure C.32) of surface water (SW07) at Site 17 ranged from 13,234 uS/cm to 82,796 uS/cm over the sampling period and averaged 47,371 uS/cm, characterizing the section of Oso Bay as moderately saline to hyper-saline. Specific conductance of surface water showed a subdued response to precipitation at this site. Specific conductance of groundwater averaged 22,333 uS/cm in GW12A and almost twice that (41,374 uS/cm) in the deeper GW12B indicating a "fresher" body of groundwater overlies the more saline water in the deeper well. Specific conductance of groundwater in the deeper well shows little response to precipitation at this site, however slight trend toward lower specific conductance values can be seen in the shallow well over the period of this investigation.

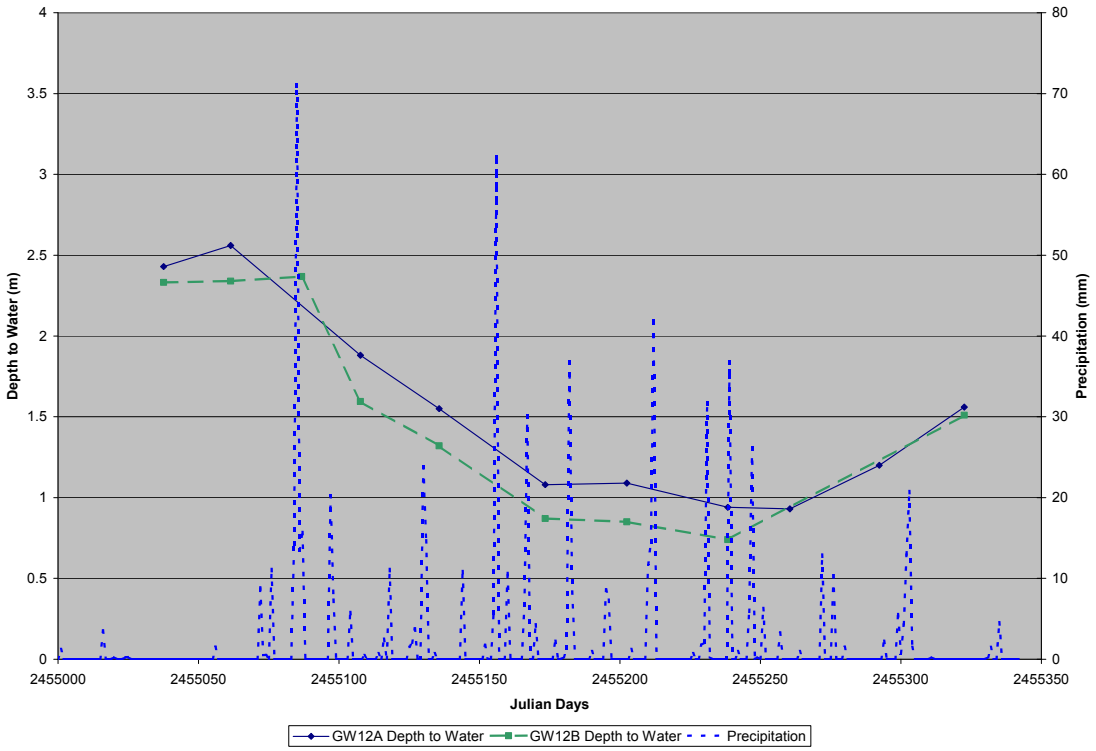

Figure C.33. Depth to Water and Precipitation at Site 18.

Depth to water (Figure C.33) tracks well between GW12A and GW12B (except for one excursion at the third sampling event) and displays a distinct downward trend (increasing water level) as precipitation increased in frequency and magnitude and later, an upward trend as precipitation decreased in frequency and magnitude. Depth to water averaged 1.52 m (σ = 0.597 m) in GW12A and 1.43 m (σ = 0.656 m) in GW12B.

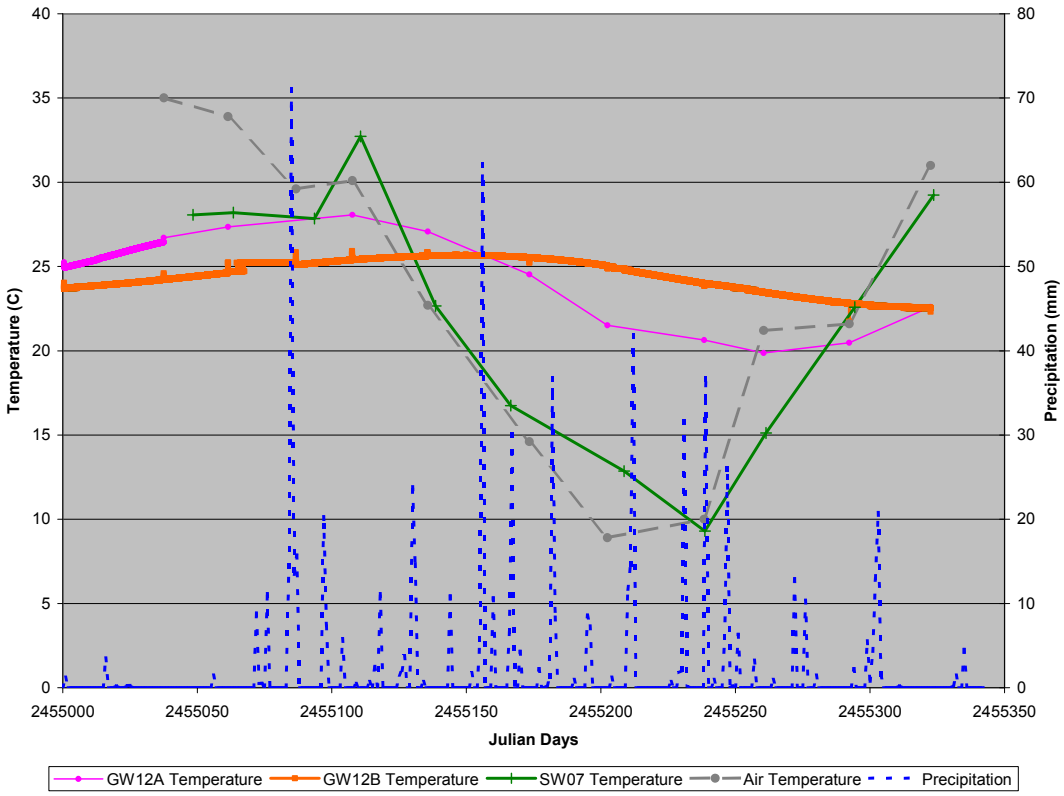

Figure C.34. Temperature and Precipitation at Site 18.

Surface water temperature (Figure C.33) and air temperature tracked well together following a seasonal pattern with surface water temperature lagging air temperature by about 36 days. Surface water averaged 22.30°C (σ = 7.722°C) and air temperature at the time of groundwater sampling averaged 23.51°C (σ = 9.282°C).

Groundwater temperature (Figure C.34) averaged 25.69°C (σ = 0.488°C) in GW12A and 24.46°C (σ = 0.993°C) in the deeper GW12B. Both wells demonstrate a seasonal temperature signal with the shallower well (GW12A) displaying greater amplitude. GW12B lags the temperature in GW12A by about 84 days.

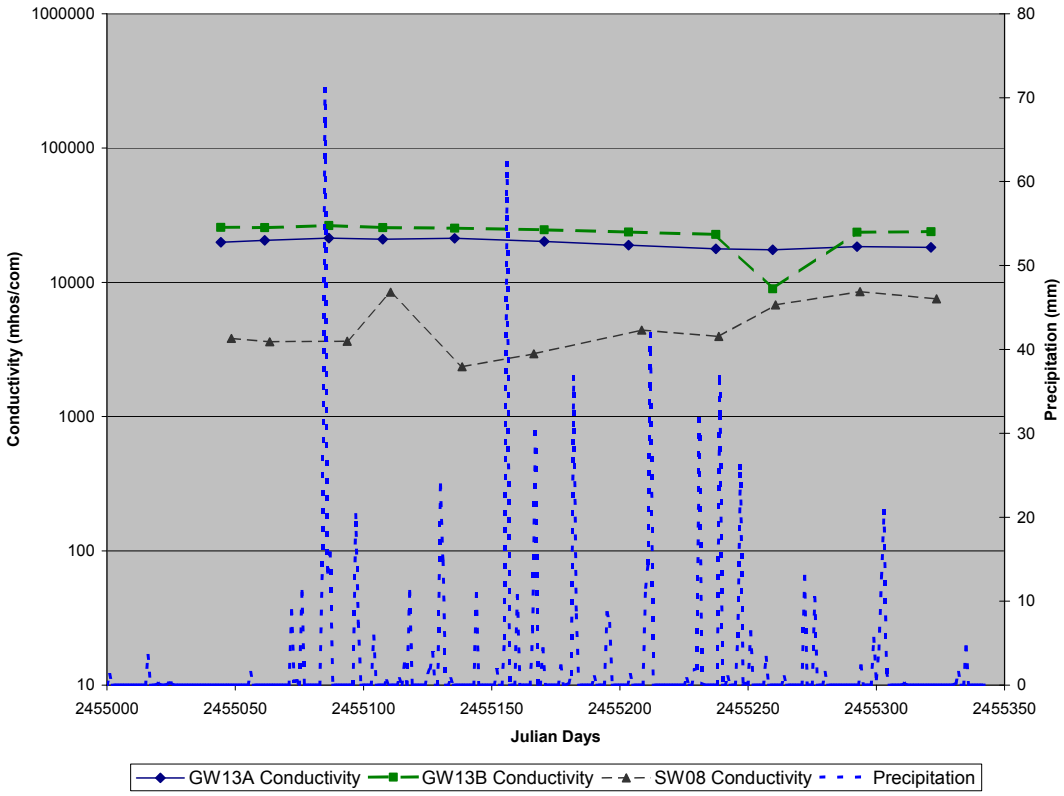

Figure C.35. Specific Conductance and Precipitation at Site 23.

Site 23 observes water quality and levels on the north side of the tidal section of Oso Creek near its confluence with an unnamed tributary and is composed of two monitoring wells, GW13A and GW13B, one surface water site, SW08, and a thermal profiler SB13.

Specific conductance (Figure C.35) of the surface water at this site ranged from 2,349 uS/cm to 8,827 uS/cm, averaging 5,091 uS/cm. Surface water in this section of Oso Creek can be characterized as slightly saline to moderately saline. A slightly increasing trend in specific conductance can be observed in the last several sampling events reflecting a decrease in the frequency and intensity of precipitation. Groundwater at this location can be characterized as slightly very saline with GW13A averaging 19,527 uS/cm and GW13B averaging 23,256 uS/cm over the period of investigation. Specific conductance of groundwater at this location remained relatively stable.

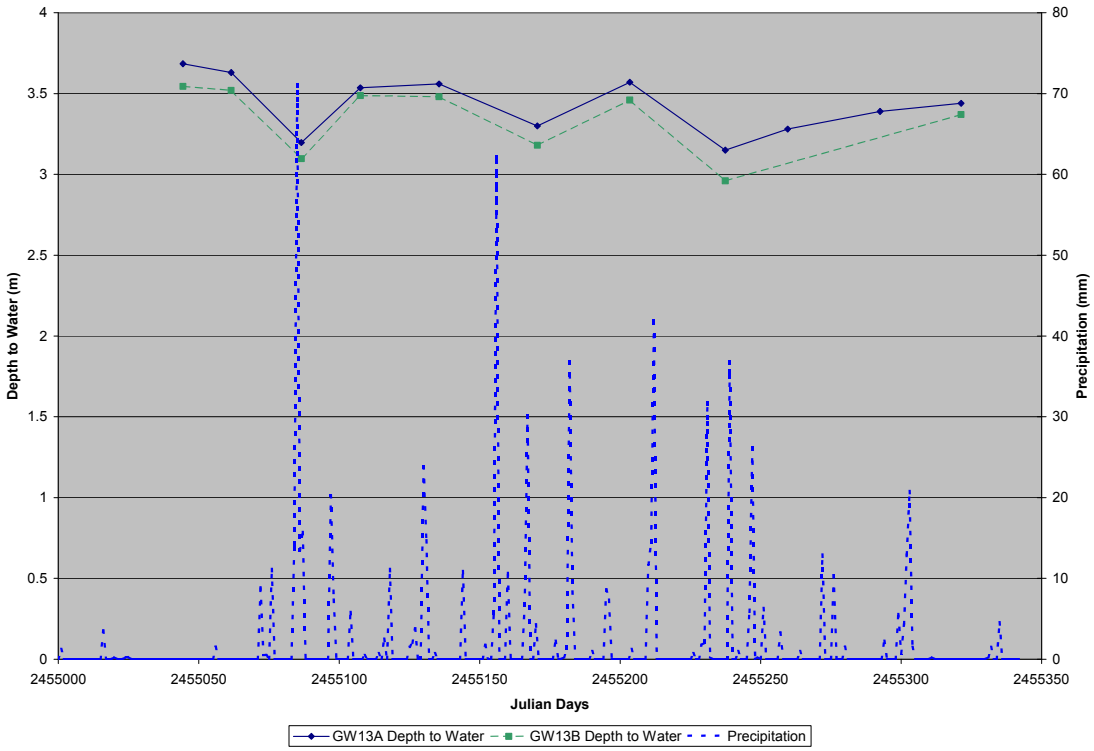

Figure C.36. Depth to Water and Precipitation at Site 23.

Depth to water (Figure C.36) averaged 3.43 m (σ=0.181 m) in GW13A and 3.35 m (σ=0.208 m) in the deeper well, GW13B. Groundwater levels tracked well between the shallow and deep well. No strong trends of increasing or decreasing groundwater levels were evident.

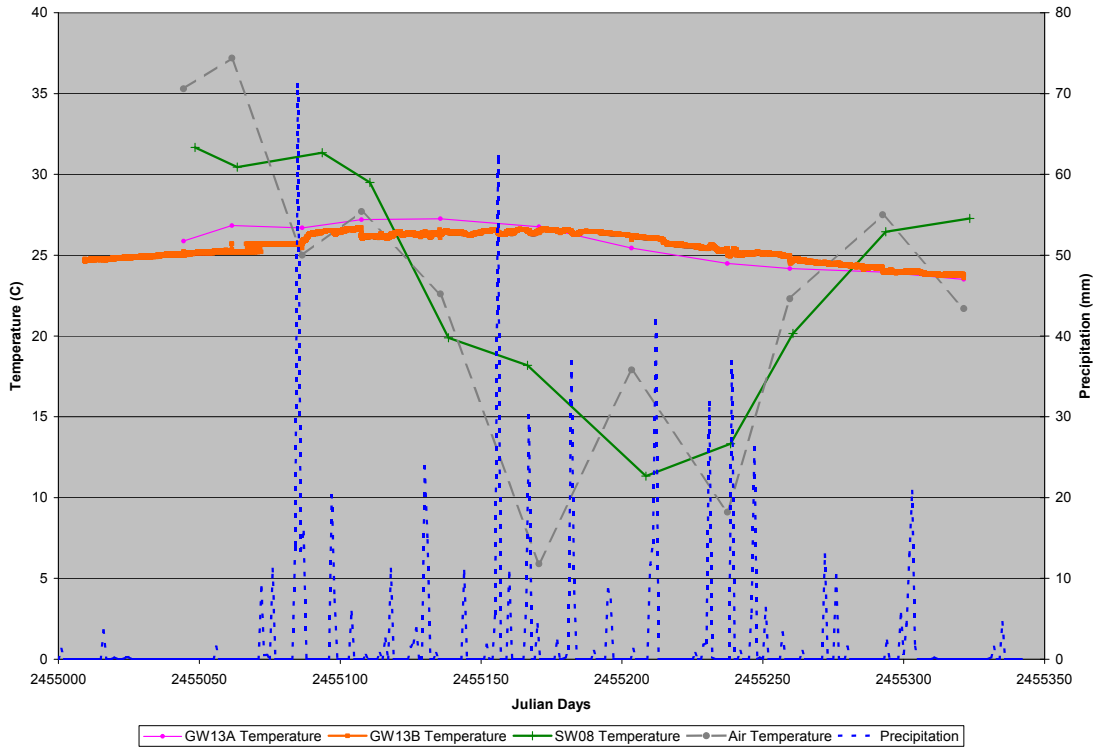

Figure C.37. Temperature and Precipitation at Site 23.

Surface water temperature (Figure C.37) and air temperature at the time of groundwater sampling track each other well with surface water lagging air temperature by 40 days. Surface water temperature (SW08) averaged 23.60°C (σ = 7.345°C) and air temperature averaged 22.93°C (σ = 9.556°C).

Groundwater temperature in GW13A averaged 25.65°C (σ = 1.406°C) and 25.49°C (σ = 0.860°C) in the deeper well, GW13B. A seasonal temperature signal is apparent in both wells of about the same amplitude. The temperature in the deeper well lags the shallow well by about 32 days.

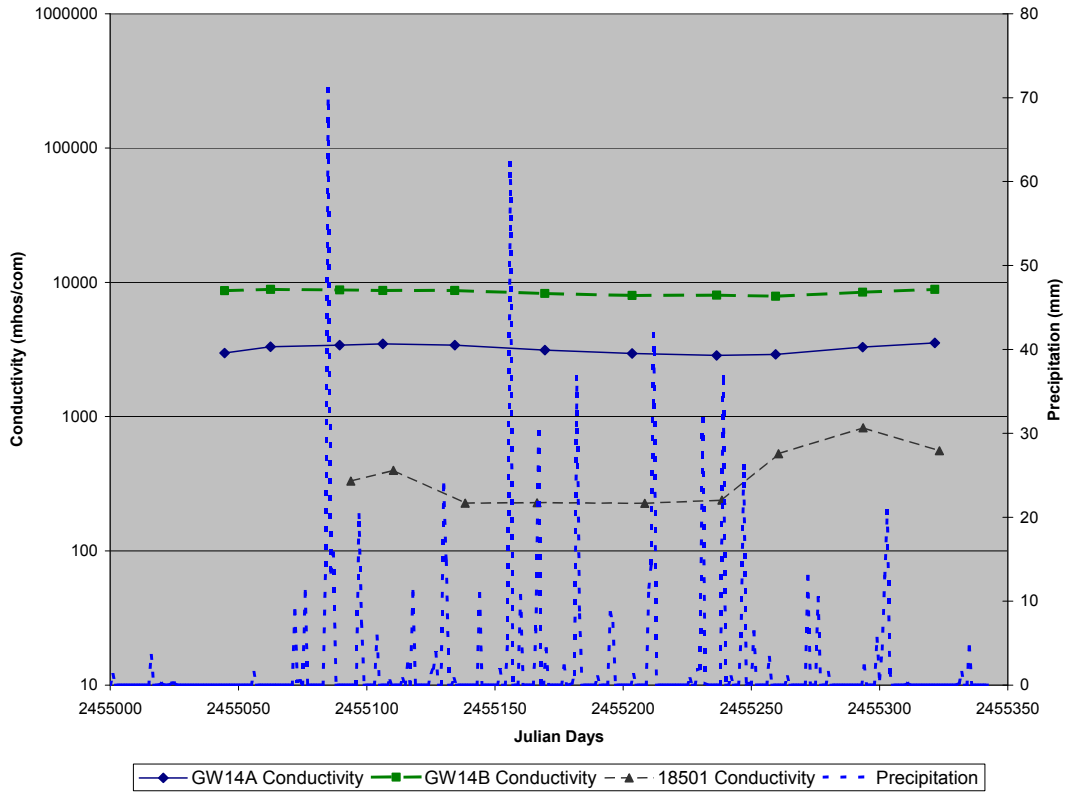

Figure C.38. Specific Conductance and Precipitation at Site 25.

Site 25 observes water quality and levels on the north side of West Oso Creek and is composed of two monitoring wells, GW14A and GW14B, one surface water site, 18501, and a thermal profiler SB14. Several surface water sampling events found this site to be dry.

Specific conductance (Figure C.38) of surface water (18501) ranged from a minimum of 226 uS/cm to a maximum of 826 uS/cm and averaged 395 uS/cm, characterizing this site as a fresh water section of West Oso Creek.

Specific conductance (Figure C.38) of groundwater averaged 3,203 uS/cm in GW14A and ranged from 2,849 uS/cm to 3,544 uS/cm. GW14B averaged 8,461 uS/cm and ranged from 7,884 uS/cm to 8,855 uS/cm. Groundwater at this site can be characterized as slightly saline to moderately saline. The specific conductance of groundwater remained relatively constant at this location, however the specific conductance of surface water increases slightly as the frequency of precipitation decreases near the end of the sampling period.

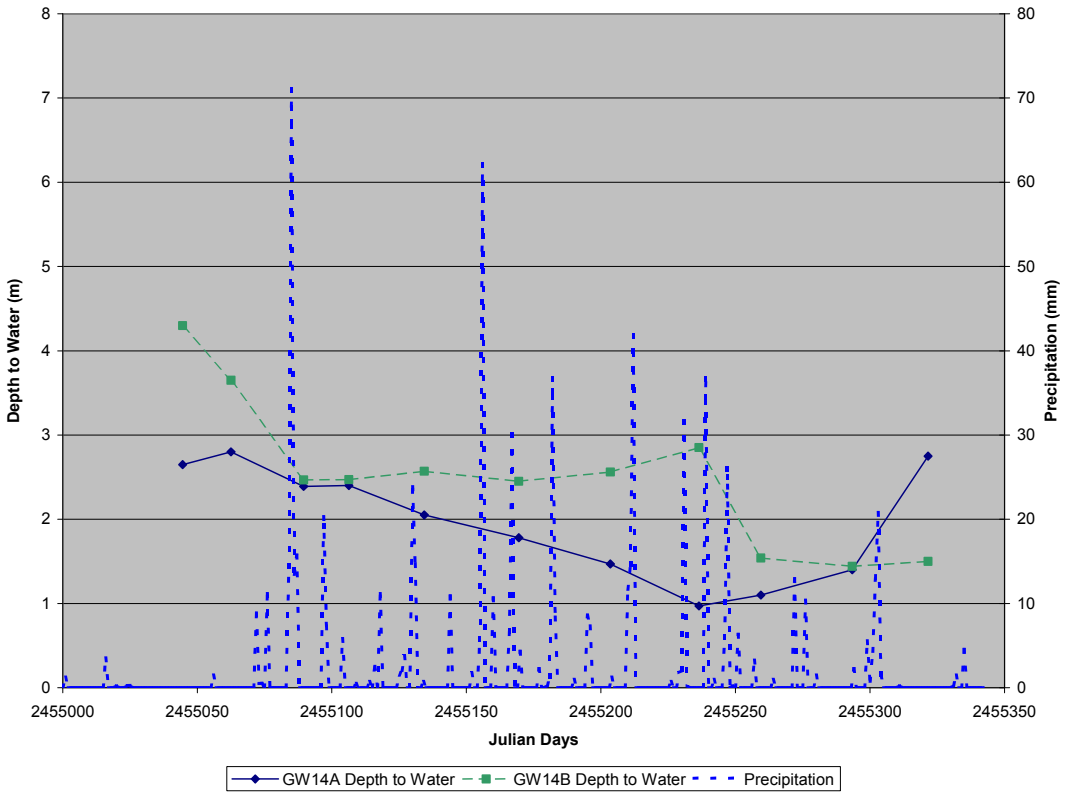

Figure C.39. Depth to Water and Precipitation at Site 25.

Depth to water (Figure C.39) averaged 1.98 m (σ = 0.670 m) in GW14A and 2.53 m (σ = 0.879 m) in the deeper GW14B. Both wells reveal a decreasing trend in depth to water (rising water table) as frequency and magnitude of precipitation increases. GW14A also shows a clear increase in depth to water (falling or discharging water table) when the frequency of precipitation decreases near the end of the sampling period.

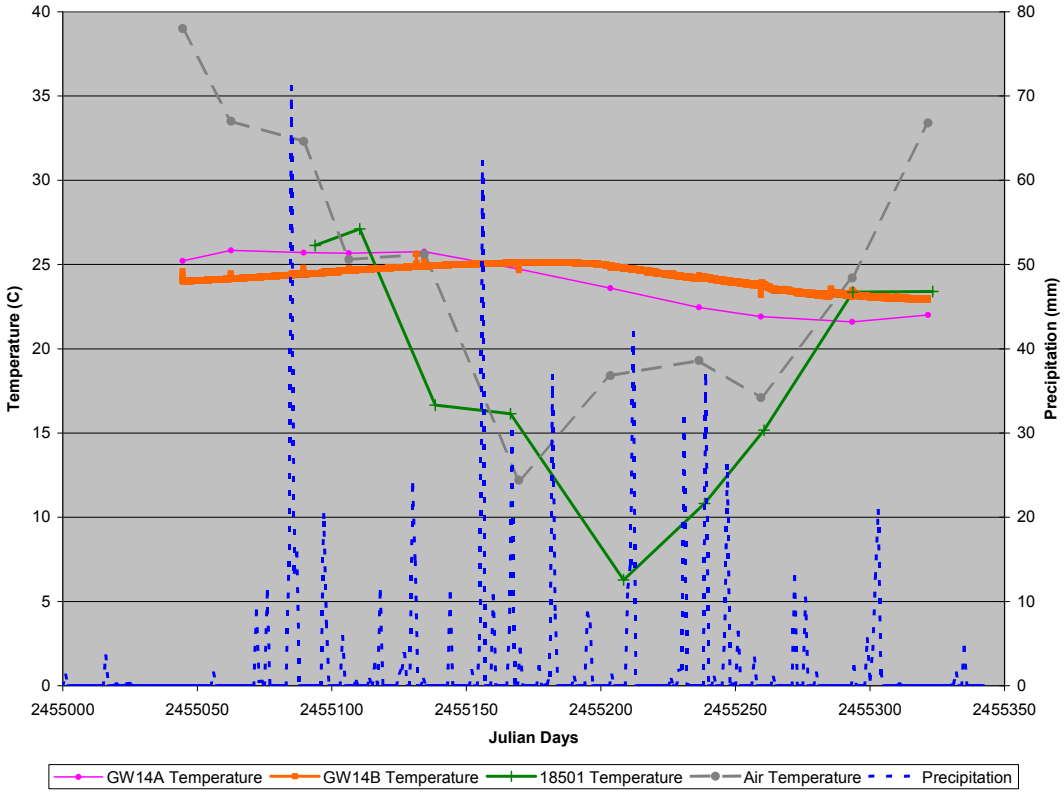

Figure C.40. Temperature and Precipitation at Site 25.

Surface water temperature (Figure C.40) and air temperature track together with surface water lagging air temperature by 40 days. Surface water (18501) averaged 18.34°C (σ = 7.144°C) over the sampling period. Air temperature at the time of groundwater sampling averaged 25.48°C (σ = 8.324°C).

Groundwater temperature in GW14A averaged 24.04°C (σ = 1.757°C) and 24.29°C (σ = 0.678°C) in GW14B. Both wells display a seasonal temperature signal of about the same amplitude. Temperatures in the deeper well lag the GW14A by about 94 days.

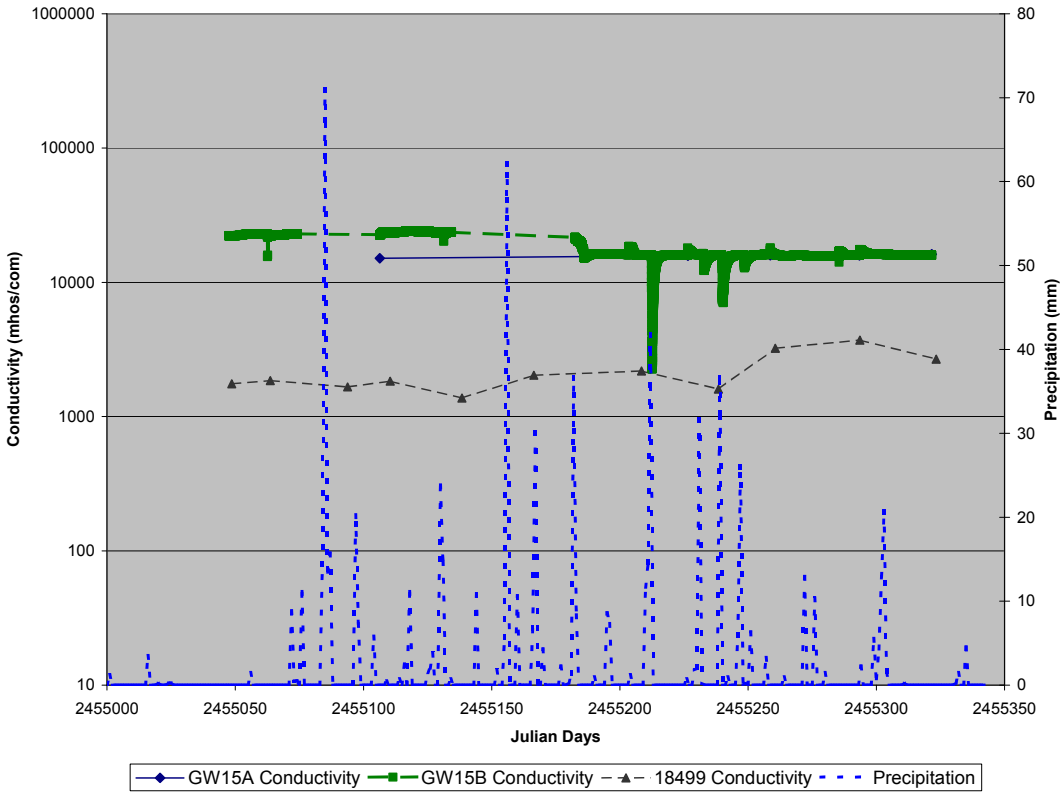

Figure C.41. Specific Conductance and Precipitation at Site 26.

Site 26 observes water quality and levels on the west side of the non-tidal section of Oso Creek and is composed of two monitoring wells, GW15A and GW15B, one surface water site, 18499, and a thermal profiler SB15. GW15A, the shallow well at this location, rarely contained sufficient water to measure water quality although there was always enough to measure levels. Monitoring well GW15B was instrumented with a data sonde/logger measuring and recording temperature, pressure (hydraulic head), specific conductance, pH and oxidation/reduction potential measurements at 15 minute intervals.

Specific conductance (Figure C.41) of surface water at this location (18499) ranged from 1,373 uS/cm to 3,713 uS/cm and averaged 2,174 uS/cm, characterizing this section of Oso Creek as having fresh to slightly saline water.

Specific conductance of groundwater in the shallow well GW15A averaged 15,762 uS/cm ($n=5, \sigma=404$) and is similar to the deeper well (GW15B) averaging 17,683 ($\sigma=3,414$). Groundwater at this site can be characterized as very saline.

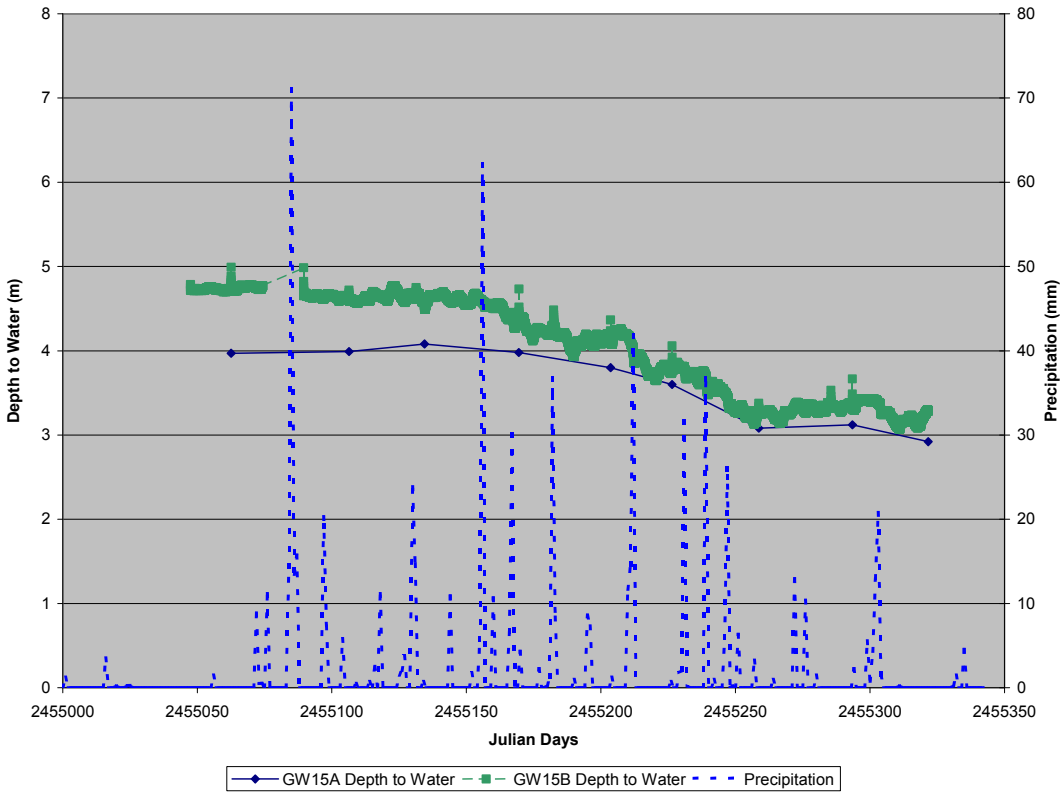

Figure C.42. Depth to Water and Precipitation at Site 26.

Depth to water (Figure C.42) measurements in both wells display a decreasing (increasing water table level) trend as the frequency and magnitude of precipitation increases. When the frequency of precipitation decreases the trend becomes neutral. Depth to water averaged 3.62 m (σ=0.456 m) in GW15A and 4.02 m (σ=0.577 m) in GW15B.

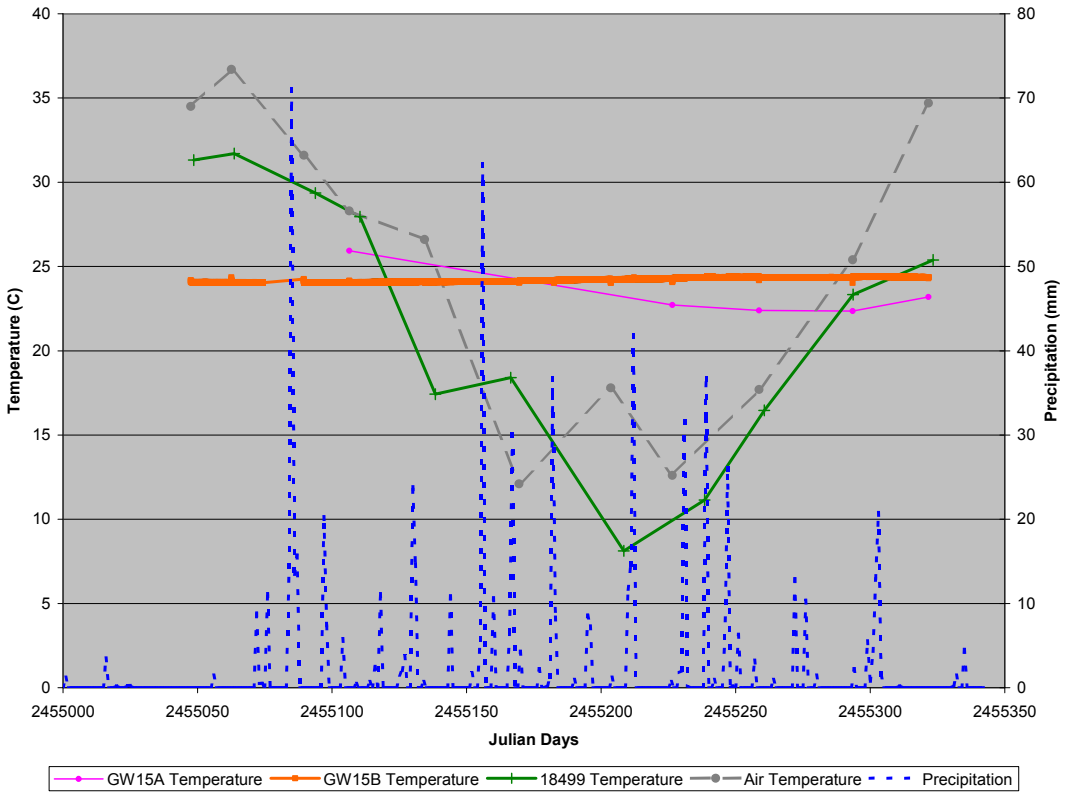

Figure C.43. Temperature and Precipitation at Site 26.

Surface water temperature (Figure C.43) and air temperature track well together, following a seasonal pattern. Surface water temperature lags air temperature by about 40 days. Surface water temperature averaged 21.87°C (σ = 8.115°C) and air temperature measured at the time of groundwater sampling averaged 25.27°C (σ = 8.960°C).

Groundwater temperature averaged 23.32°C (n=5, σ = 1.500°C) in GW15A and averaged 24.21°C (σ = 0.127°C) in the deeper GW15B. A seasonal signal in groundwater temperature is evident in both wells, however the shallow well (GW15A) has more pronounced amplitude than the subdued response from GW15B. Temperature in the deeper well lags the shallower well by about 180 days at this location.

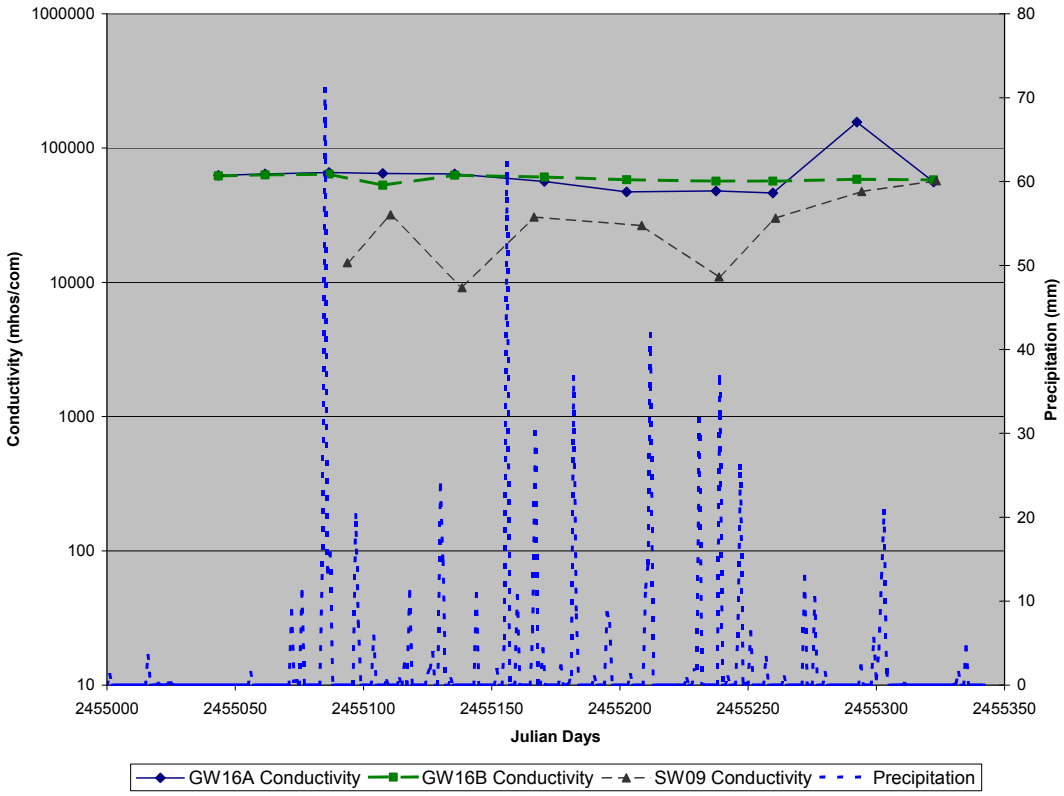

Figure C.44. Specific Conductance and Precipitation at Site 30.

Site 30 observes water quality and levels on the east side of an unnamed tributary in the tidal section of Oso Creek and is composed of two monitoring wells, GW16A and GW16B, one surface water site, SW09, and a thermal profiler SB16.

Specific conductance (Figure C.44) of the surface water (SW09) at this site ranged widely from 9,114 uS/cm to 56,957 uS/cm and averaged 28,590 uS/cm (σ=16,136 uS/cm). Water quality in this tributary can be characterized as moderately saline to hyper-saline. Specific conductance appears to respond (inversely) to some precipitation events.

Groundwater at this site can be characterized as hyper-saline with GW16A averaging 66,389uS/cm (σ=30,558 uS/cm) and averaging 59,363 uS/cm (σ=3,408 uS/cm) in the deeper well, GW16B.

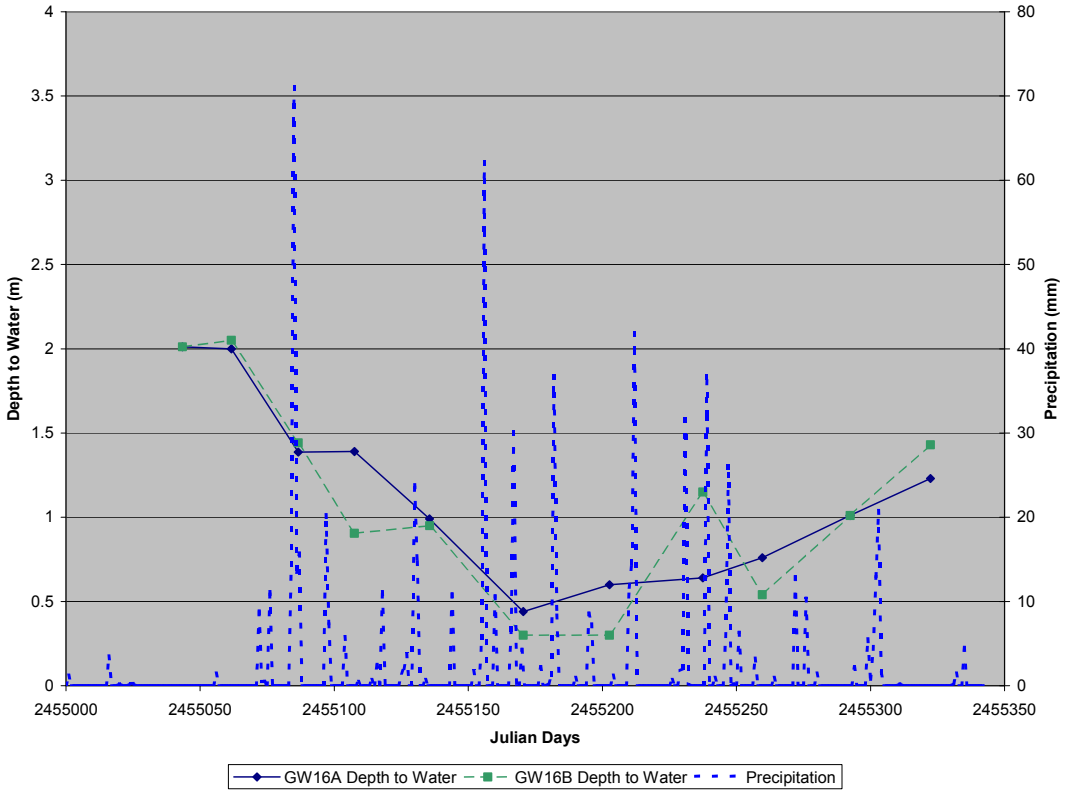

Figure C.45. Depth to Water and Precipitation at Site 30.

Depth to water (Figure C.45) tracks well between the shallow and deep well. A decreasing depth to water (increasing water table level) trend is evident as the frequency of precipitation increases, with a reversal of this trend as the frequency of precipitation decreases. Depth to water averaged 1.13 m (σ=0.534 m) in GW16A and averaged 1.10 m (σ=0.602 m) in GW16B.

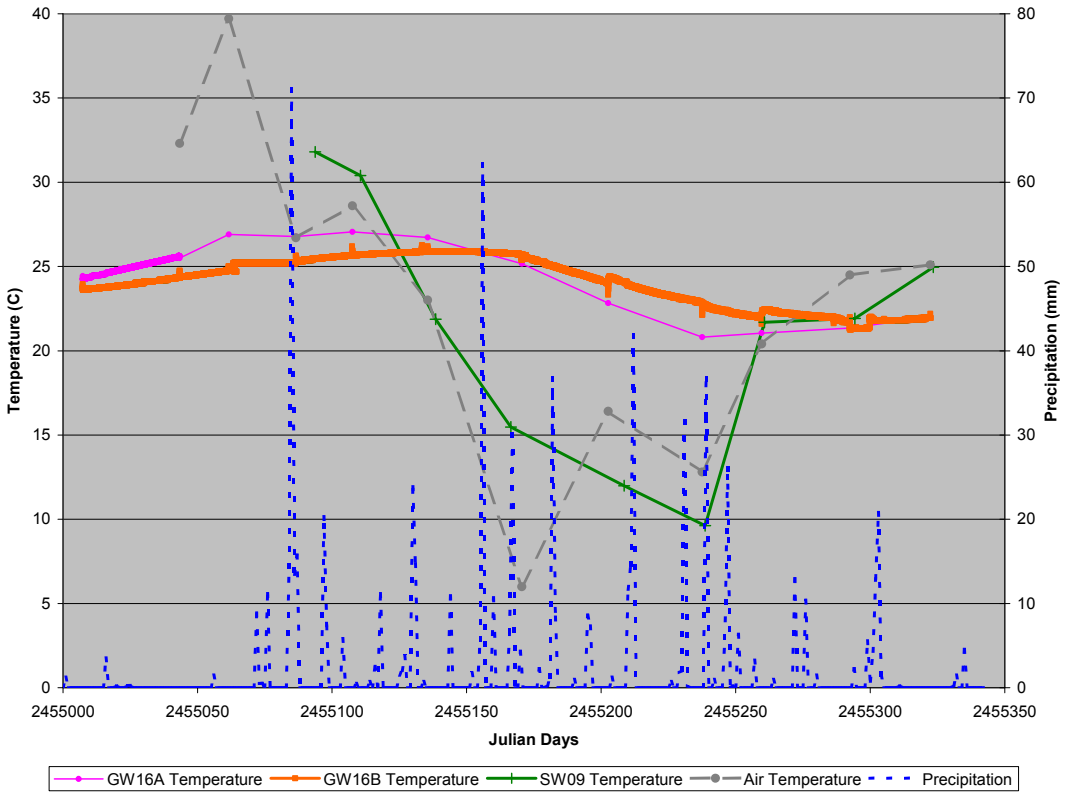

Figure C.46 Temperature and Precipitation at Site 30.

Surface water temperature (Figure C.46) and air temperature track well together, following a seasonal pattern. Surface water lags air temperature by about 60 days. Surface water temperature averaged 21.08°C (σ = 7.614°C) and air temperature at the time of groundwater sampling averaged 23.23°C (σ = 7.614°C).

Groundwater temperature in GW16A averaged 24.93°C (σ = 0.414°C) over the period of investigation. Water temperature in GW16B averaged 24.08°C (σ = 1.471°C). A seasonal temperature signal is evident in measurement from both wells of similar magnitude. Temperatures in the deeper well lag the shallower well by about 72 days in this well pair.

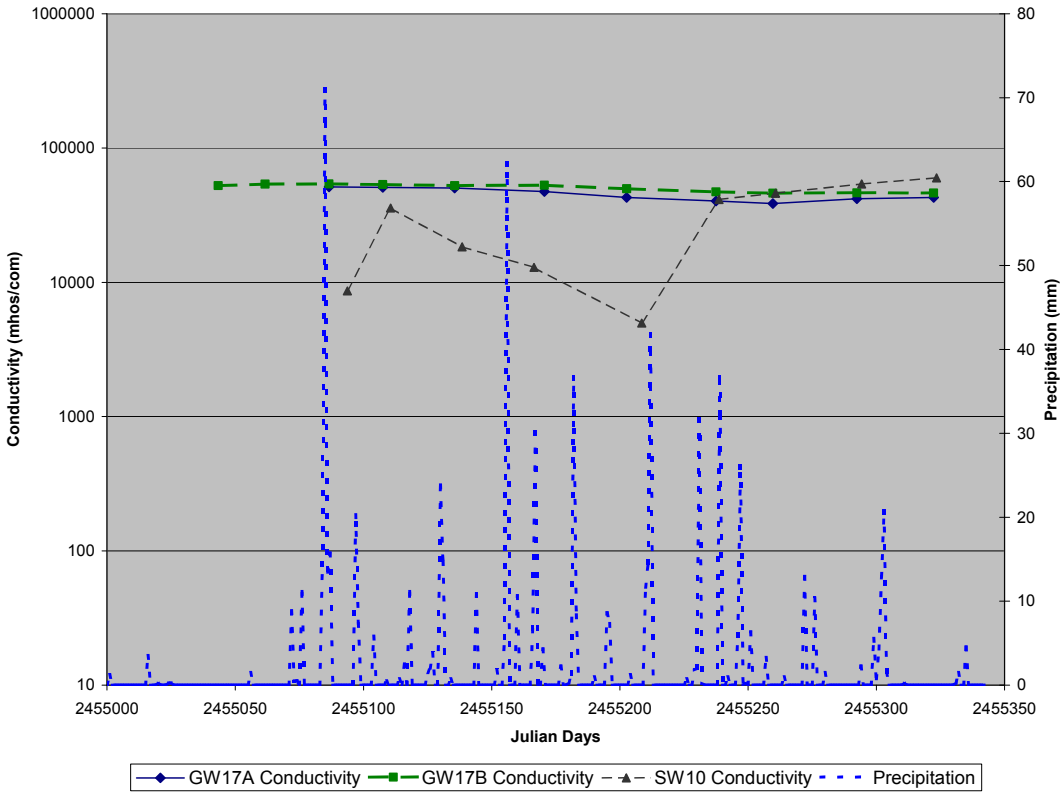

Figure C.47. Specific Conductance and Precipitation at Site 33.

Site 33 observes water quality and levels on the north bank of a drainage ditch leaving the Country Creek Subdivision area and is adjacent to the South Texas Botanical Gardens. This site is composed of two monitoring wells, GW17A and GW17B, one surface water site, SW10, and a thermal profiler SB17. SW10 was occasionally dry or stagnant at this location.

Specific conductance (Figure C.47) of surface water at this site ranged from 4,997 uS/cm to 60,046 uS/cm and averaged 31,348 uS/cm. Surface water at this location can be characterized as moderately saline to hyper-saline and strongly influenced by runoff.

Specific conductance measurements in groundwater at this location ranged from 38,589 uS/cm to 51,410 uS/cm and averaged 45,155 uS/cm (σ=4,907 uS/cm) in GW17A. In GW17B, specific conductance measurements ranged from 46,015 uS/cm to 53,936 uS/cm and averaged 50,421 uS/cm (σ=3,349 uS/cm). Groundwater can be characterized as very saline to hyper-saline.

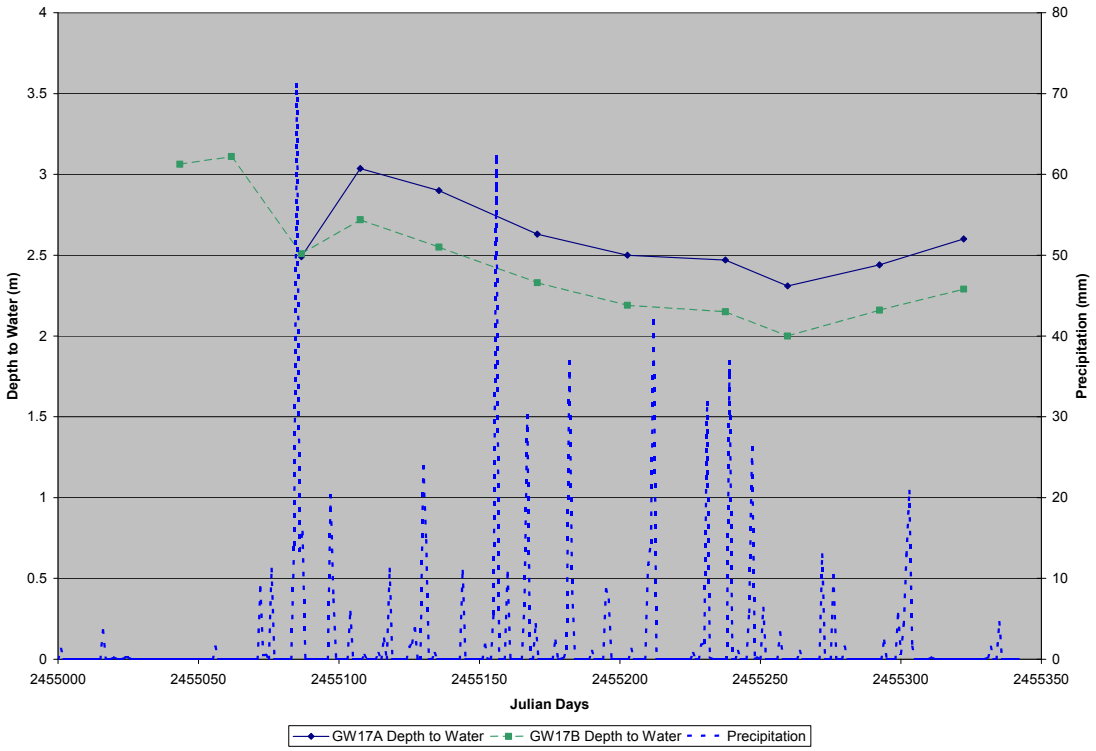

Figure C.48. Depth to Water and Precipitation at Site 33.

Depth to water (Figure C.48) in both wells (GW17A and GW17B) responded to the increasing frequency and magnitude of precipitation with a decreasing trend. Depth to water increased as precipitation frequency decreased and groundwater was discharged. Water level in these wells track each other with an offset that reflects the difference between measurement point elevations.

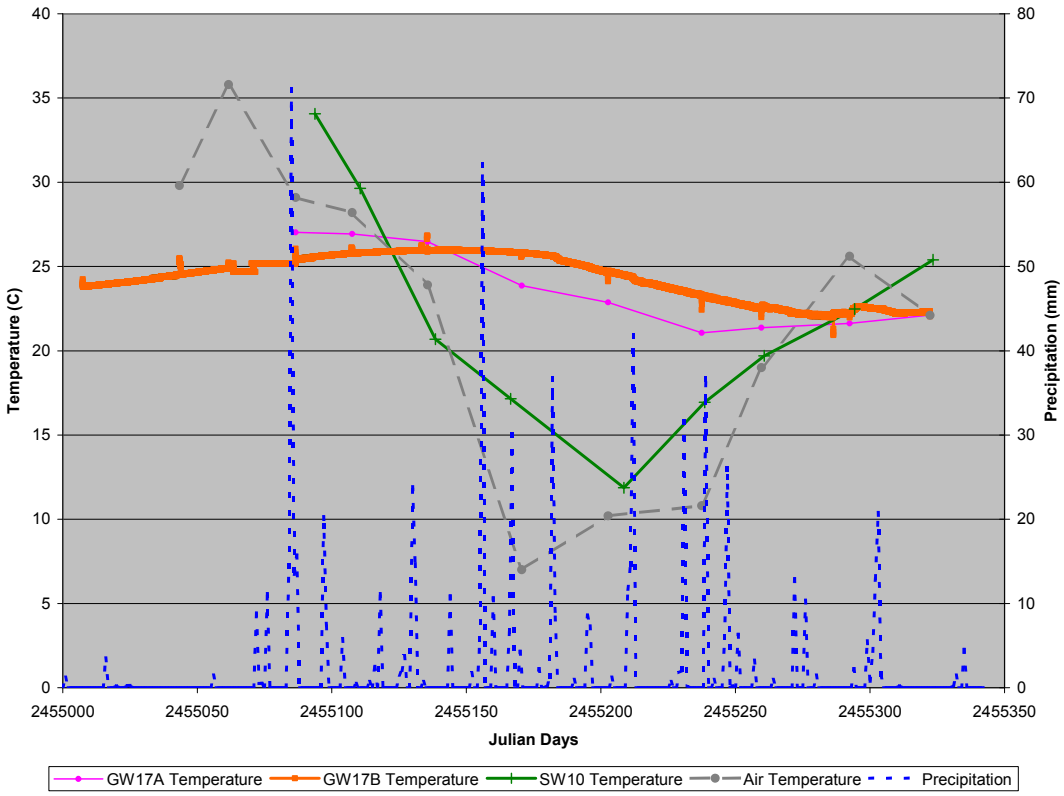

Figure C.49. Temperature and Precipitation at Site 33.

Surface water temperature (Figure C.49) and air temperature tracked well together, following a seasonal pattern. Surface water temperature lagged air temperature measured at groundwater sampling events by about 40 days. Surface water temperature averaged 21.99°C (σ = 6.839°C) and air temperature averaged 21.95°C (σ = 9.249°C) during the course of this study.

Groundwater temperatures averaged 23.70°C (σ = 2.477°C) in monitoring well GW17A and 24.34°C (σ = 1.332°C) in the deeper monitoring well GW17B. A seasonal temperature signal is evident in both monitoring wells of approximately equal amplitude. Groundwater temperature in the deeper well lags the shallow well by about 72 days.

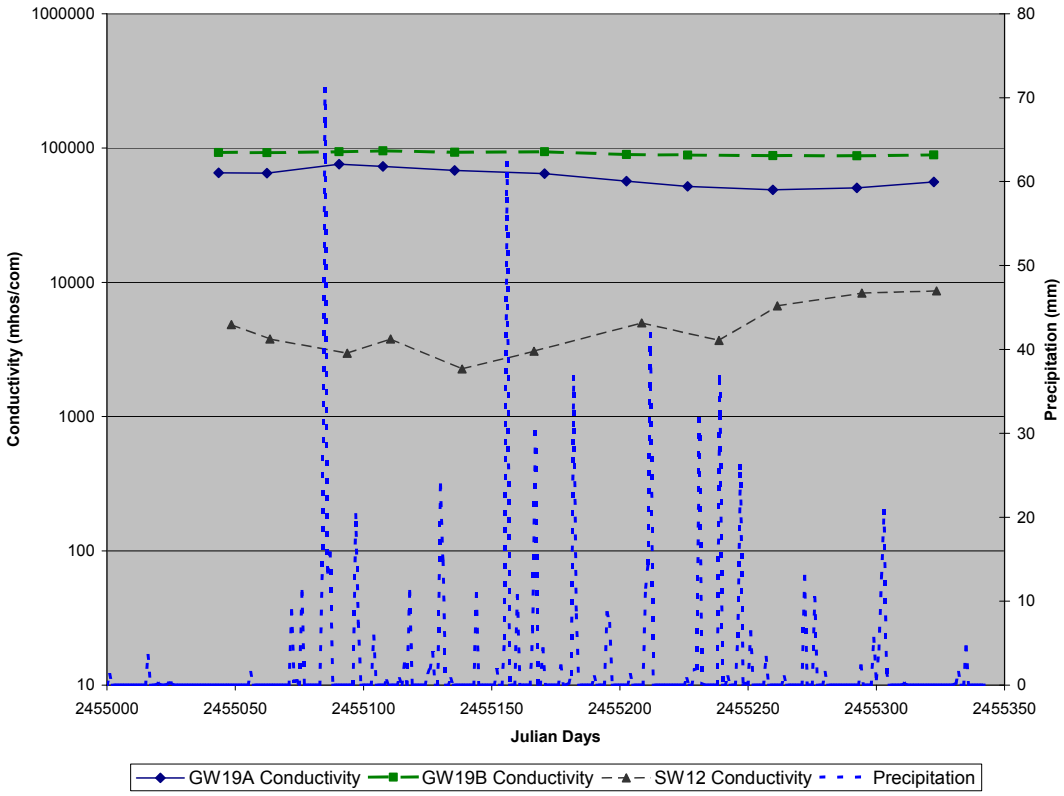

Figure C.50. Specific Conductance and Precipitation at Site 36.

Site 36 observes water quality and levels on the south side of the tidal section of Oso Creek and adjacent to a retention pond at the South Texas Botanical Gardens. This site is composed of two monitoring wells, GW19A and GW19B, one surface water site on Oso Creek, SW12, and a thermal profiler SB19. Monitoring well GW19B was instrumented with a sonde/logger and measured temperature and pressure (depth to water level) at 15 minute intervals.

Specific conductance (Figure C.50) of surface water at Site 36 ranged from 2,265 uS/cm to 8,638 uS/cm and averaged 4,817 uS/cm. Surface water quality at this site can be characterized as slightly saline to moderately saline.

Specific conductance of groundwater averaged 61,396 uS/cm in GW19A and averaged 91,186 uS/cm in GW19B. Groundwater quality in the shallower monitoring well GW19A and the deeper well GW19B can be characterized as hyper-saline.

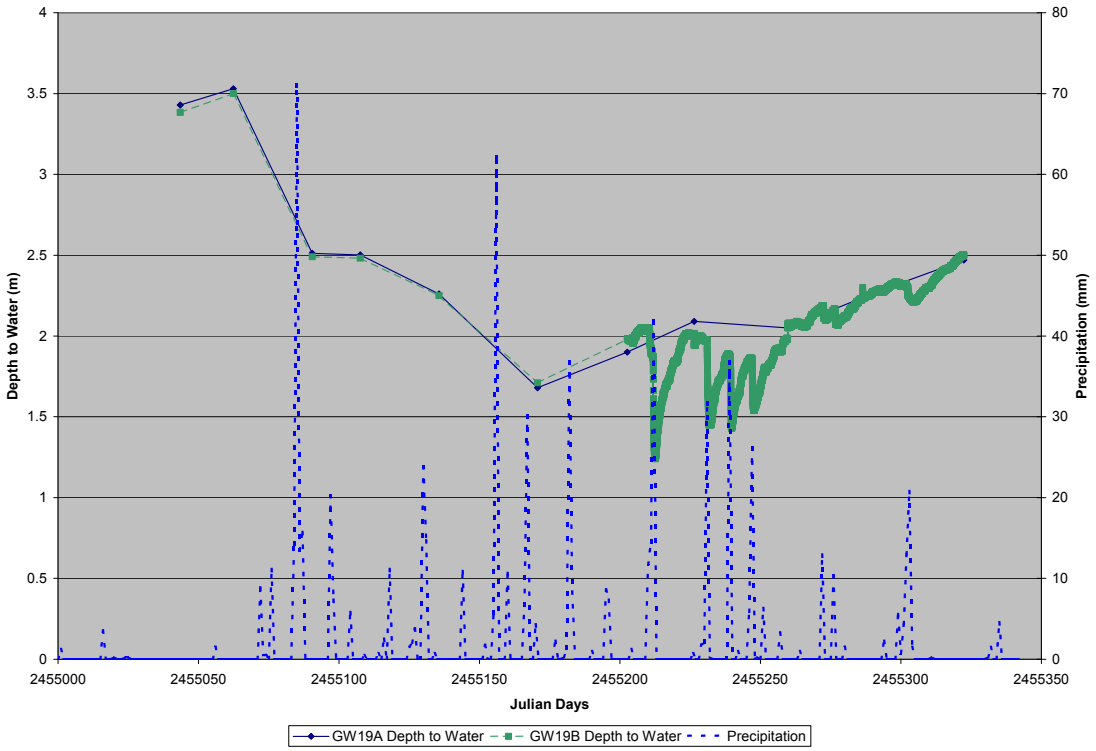

Figure C.51. Depth to Water and Precipitation at at Site 36.

Depth to water (Figure C.51) tracks well between GW19A and GW19B. Deployment of a data sonde reveals an interesting aquifer response to precipitation events on Julian Days 2455212, 2455231, 2455239, and 2455247. Depth to water averaged 2.43 m (σ=0.581 m) in GW19A and averaged 2.04 m (σ=0.262) in GW19B. Depth to groundwater can be seen to decline in response to precipitation events and increase as the frequency and magnitude of precipitation decreases.

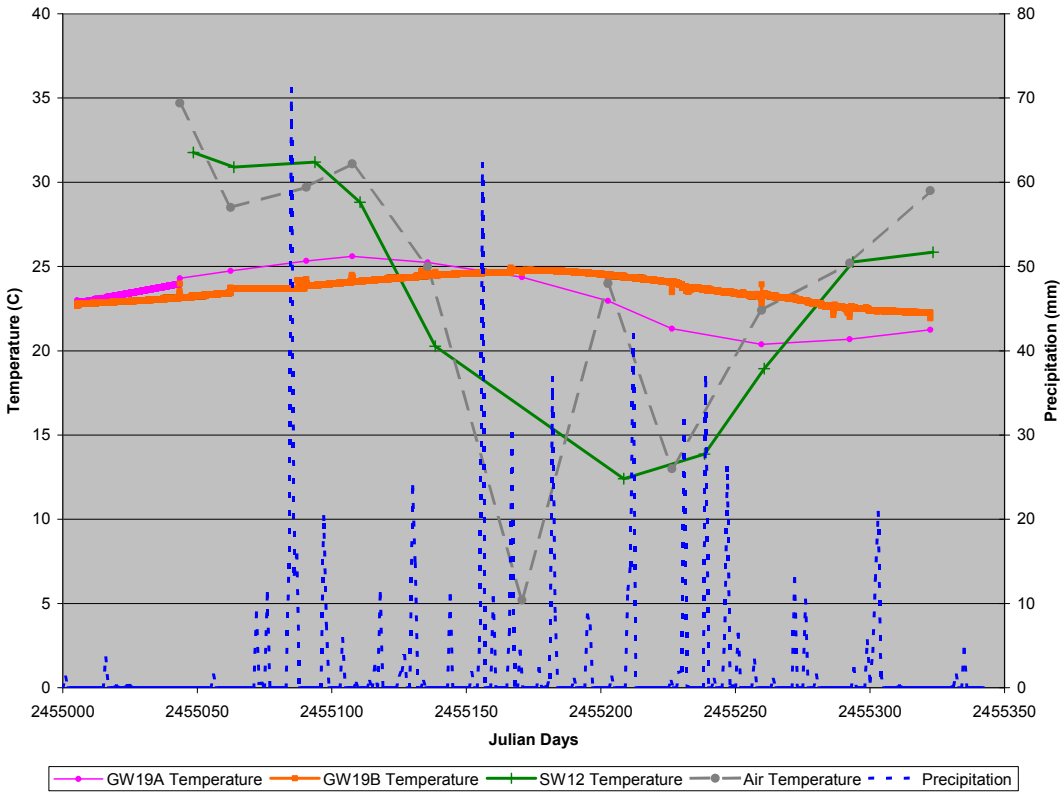

Figure C.52. Temperature and Precipitation Site 36.

Surface water temperature (Figure C.52) and air temperature at the time of groundwater sampling track together. Surface water lags air temperature by 44 days. Surface water temperature averaged 23.14°C (σ = 7.572°C) and air temperature averaged 24.39°C (σ = 8.519°C).

Groundwater temperature averaged 23.40°C (σ = 0.340°C) in GW19A and 23.27°C (σ = 1.119°C) in the deeper GW19B. A seasonal signal is apparent in the temperature measurements of both wells. Temperature in GW19B lagged temperature in GW19A by about 76 days.

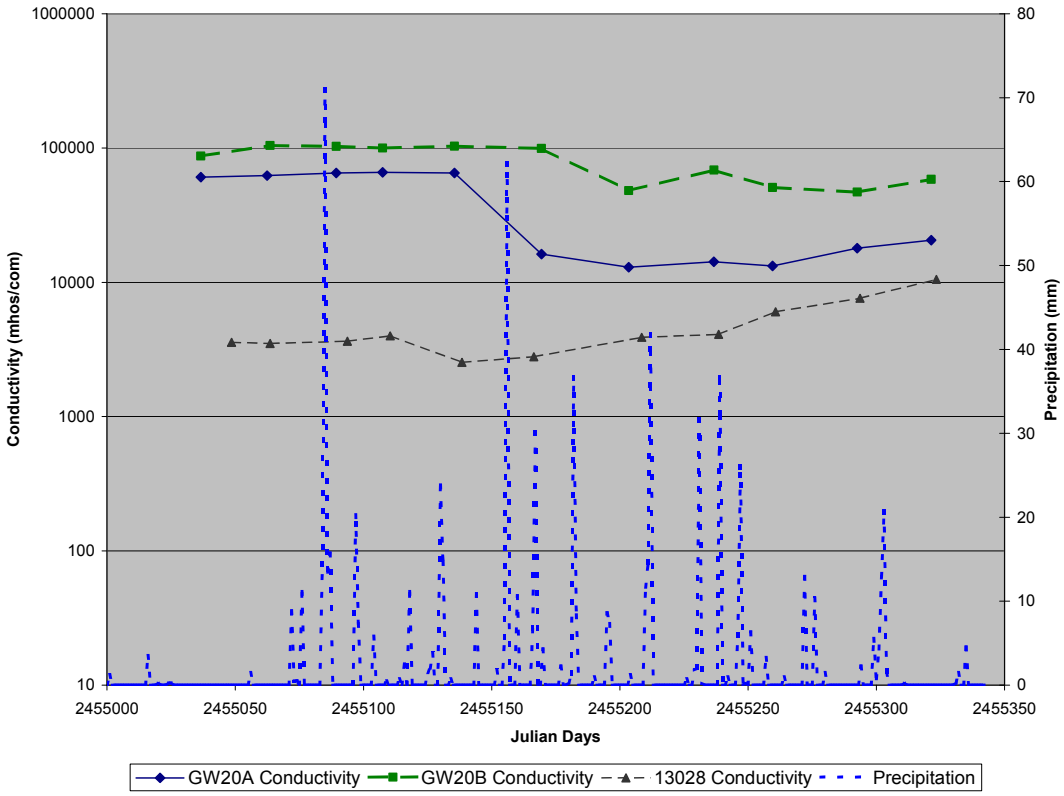

Figure C.53. Specific Conductance and Precipitation at Site 39.

Site 39 observes water quality and levels on the north and south sides of the tidal section of Oso Creek. This site is composed of two monitoring wells, GW20A and GW20B on the south side of the creek, one surface water monitoring site, 13028 on the north side of the creek, and a thermal profiler SB20 located on the south side of the creek.

Specific conductance (Figure C.53) of surface water at 13028 ranged from 2,535 uS/cm to 10,505 uS/cm over the period of investigation averaging 4,741 uS/cm. Water quality in this section of the creek can be characterized as slightly saline to moderately saline. Specific conductance in groundwater ranged from 12,968 uS/cm to 65,895 uS/cm in GW20A and from 47,038 uS/cm to 104,334 uS/cm in GW20B. Specific conductance measurements shifted after a precipitation event on Julian Day 2455156 (November 20, 2009), which caused overbank flooding at this location. The shift is most dramatic in the shallow well GW20A where specific conductance measurements shifted almost an order of magnitude. An upward trend is evident at each monitoring station as precipitation becomes less frequent and of lower magnitude.

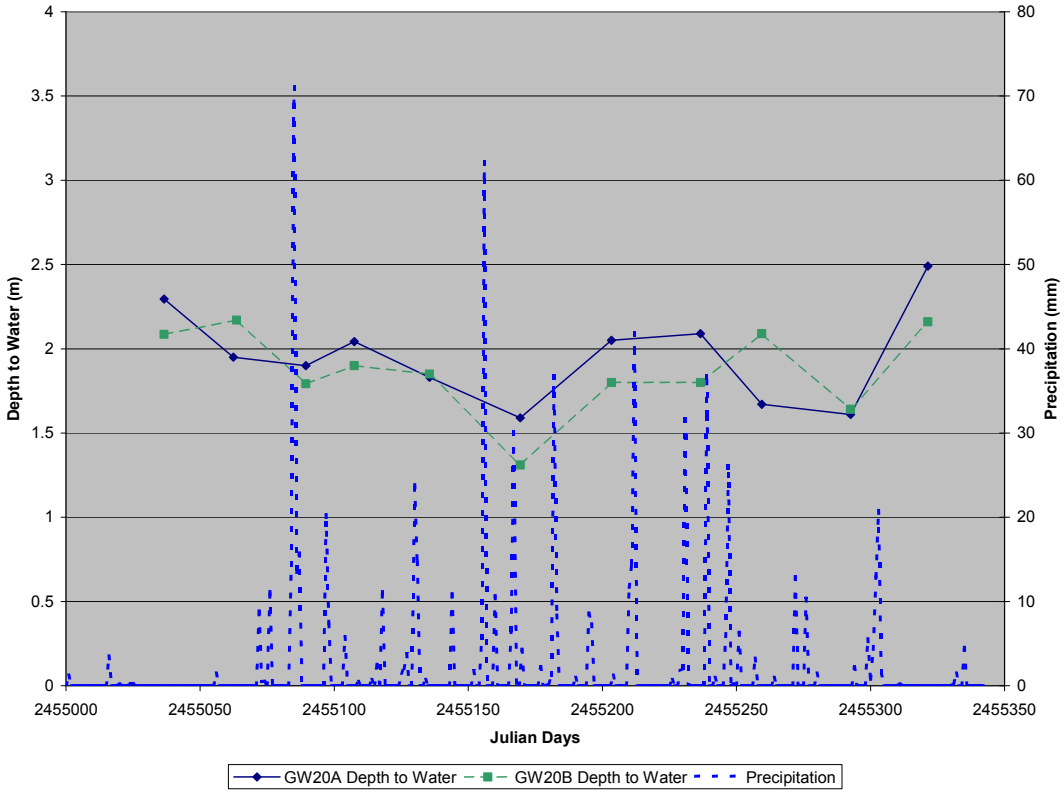

Figure C.54. Depth to Water and Precipitation at Site 39.

Depth to water (Figure C.54) tracks well between GW20A and GW20B. Average depth to water was 1.96 m (σ=0.281 m) in GW20A and 1.87 m (σ=0.255 m) GW20B.

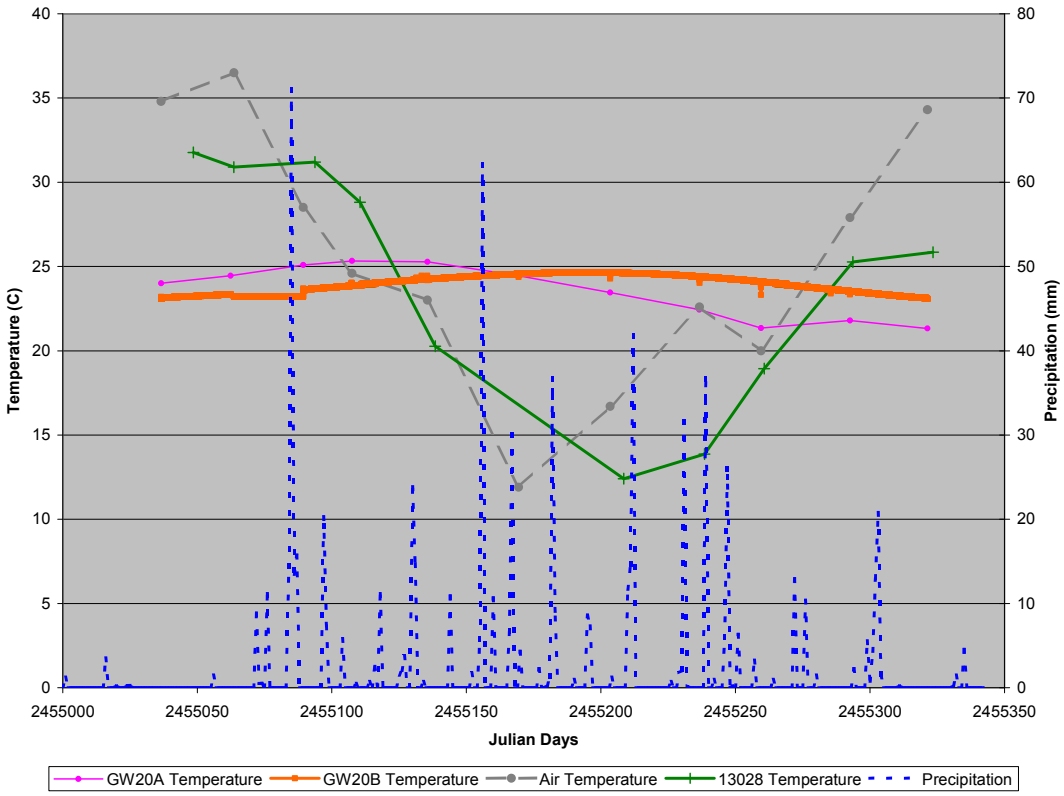

Figure C.55. Temperature and Precipitation at Site 39.

Surface water temperature (Figure C.55) and air temperature tracked well together following a seasonal pattern with surface water lagging air temperature by about 40 days. Air temperature at the time of groundwater sampling averaged 25.53°C (σ = 7.796°C) and surface water temperature averaged 23.93°C (σ = 7.181°C). Groundwater temperature averaged 23.54°C (σ = 1.565°C) in GW20A and 23.96°C (σ = 0.526°C). A seasonal temperature signal is apparent in both monitoring wells with the deeper well lagging by 88 days.

C4. Special Sampling (Nutrients and Bacteria)

Sampling for bacteria (Enterococcus – Parameter Code 31649) was conducted twice on each monitoring well with sufficient water over the course of this project to characterize groundwater potential as a source of bacteria to Oso Creek and Oso Bay. Soil cores advanced during the drilling of monitoring wells were collected at Site 16 and Site 13 and analyzed for bacteria (Enterococcus) in the 0-2 foot interval, the 2-4 foot interval and the 4-6 foot interval in support of an ongoing bacteria source tracking project. Sampling for nutrients (Table B1.3) was conducted on all deep wells to characterize groundwater as a potential source of nutrients to Oso Creek and Oso Bay.

Bacteria (Enterococcus) in groundwater.

Monitoring wells were sampled on October 28 and 29, 2009 after 24 mm of rain fell on October 25 and 15 mm of rain fell on October 26 for a total of 39 mm. This event was considered a wet sampling event. Thirty-two monitoring wells contained a sufficient

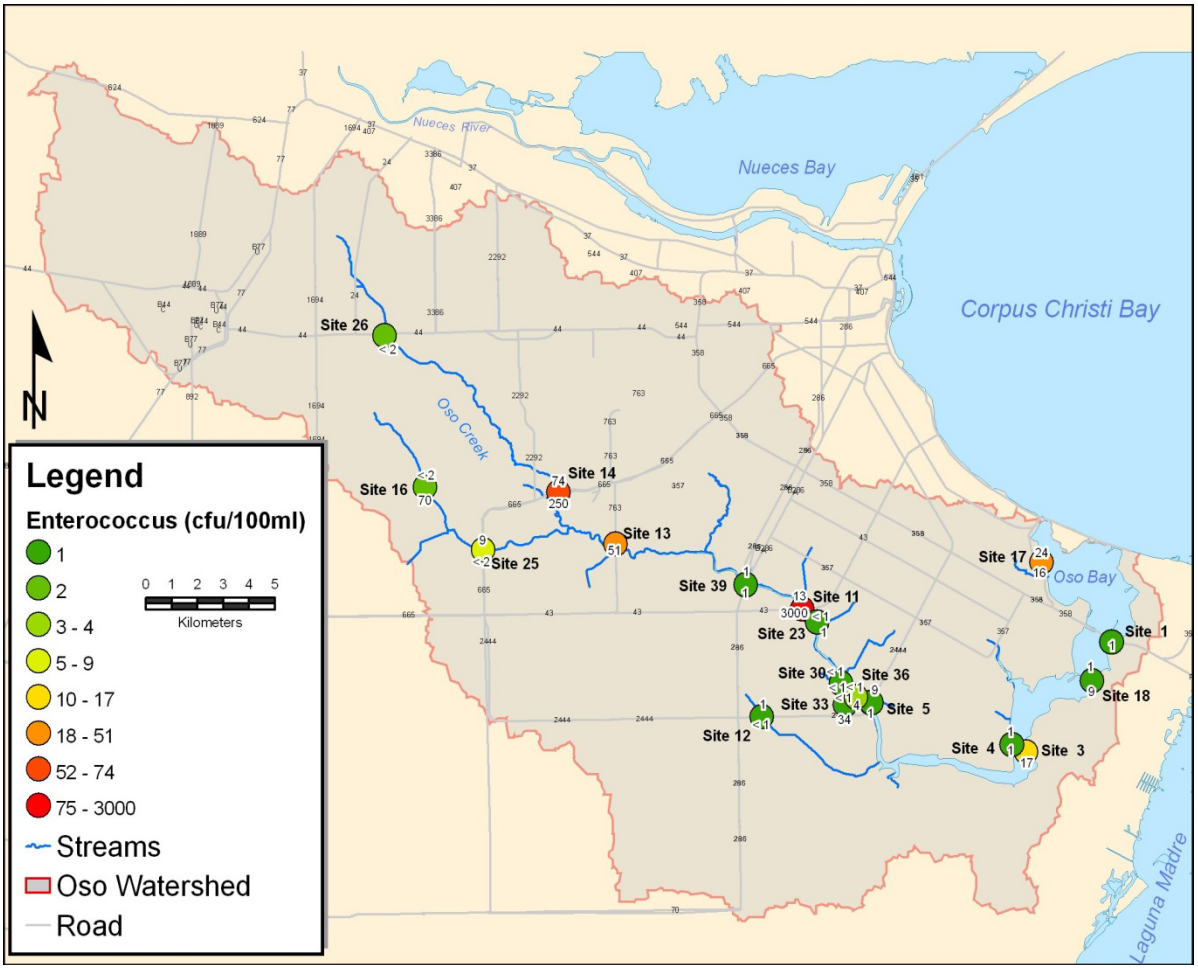

Figure C.56. Enterococcus Concentrations 10/30/2009 - Wet Conditions. Top value references shallow well and the bottom value references deeper well. One value where only one well had sufficient water to sample.

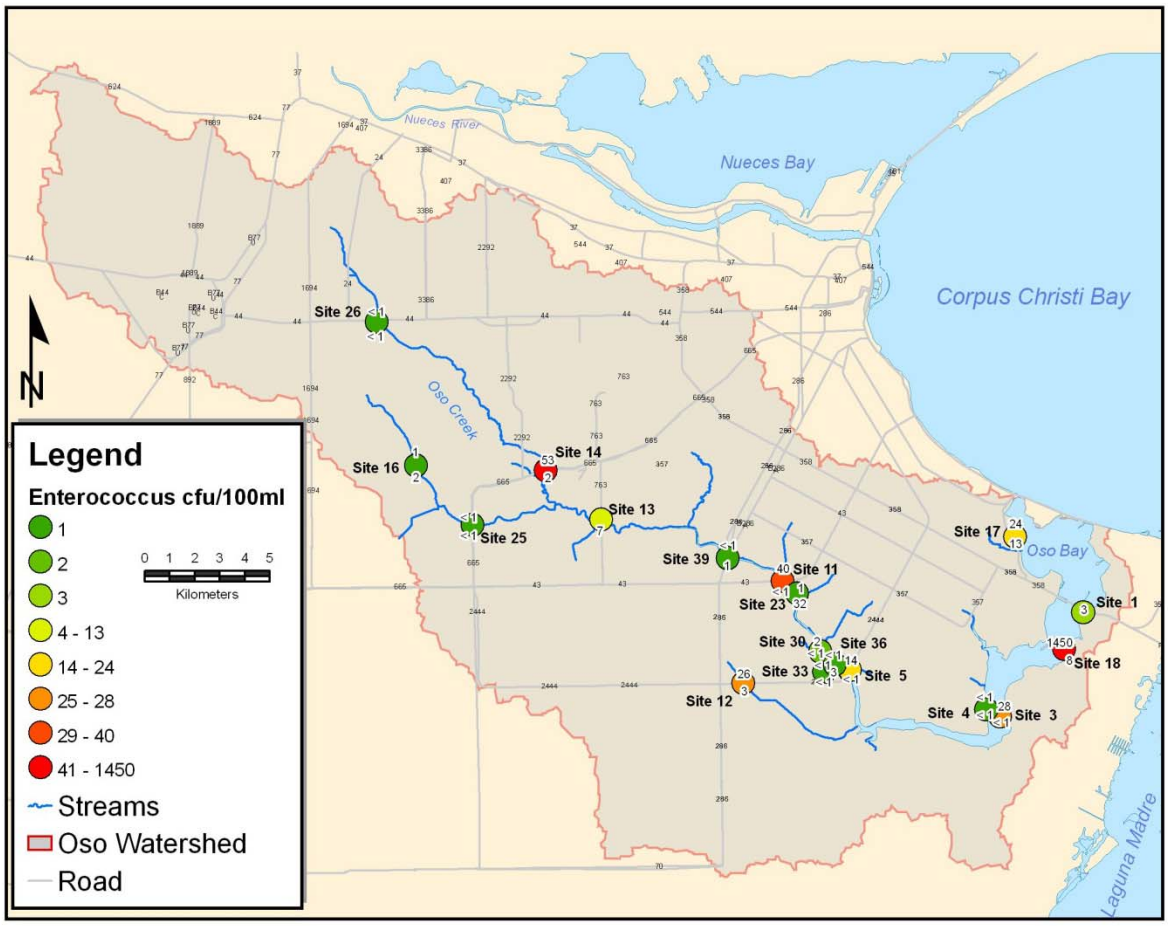

Figure C.57. Enterococcus concentrations 03/30/2010 - Dry Conditions. Top value references shallow well and the bottom value references deeper well. One value where only one well had sufficient water to sample.

amount of water for sampling (Figure C.56). Concentrations of Enterococcus for this event ranged from less than one cfu/100 ml occurring at nine wells to a maximum of 3,000 cfu/100 ml measured at Site 11 (GW06A). Average concentration for this event was 112 cfu/100 ml with a geometric mean of 4.9 cfu/100 ml.

Monitoring wells were again sampled on March 29 and 30, 2010 after 37 days without significant rainfall. Thirty-four monitoring wells had a sufficient amount of water for sampling (Figure C.57). Concentrations of Enterococcus for this dry event ranged from less than one cfu/100 ml occurring at 14 locations to 1,450 cfu/100 ml measured at Site 18 (GW12A). Average concentrations of enterococcus for this event was 50 cfu/100 ml with a geometric mean of 3.5 cfu/100 ml.

Bacteria (Enterococcus) in soil.

Soil cores were recovered from Site 13 and Site 16 using a split spoon sampler on May 18 and 19, 2009 during well installation. Three cores were taken at each site, from zero to two feet, two feet to four feet and four feet to six feet. Enterococcus concentrations in soil at Site 13 in the first interval from 0 to 2 feet was less than 92 cfu/100 gdw, from 2 to 4 feet was less than 91 cfu/100 gdw and from 4 to 6 feet was less than 95 cfu/100 gdw. Enterococcus concentrations in the soil at Site 16 in the first interval from 0 to 2 feet was 6,868 cfu/100 gdw, from 2 to 4 feet was 9,402 cfu/100 gdw, and from 4 to 6 feet was less than 88 cfu/100 gdw.

Nutrients in groundwater

Groundwater was sampled and tested for nutrients in 18 monitoring wells over the period from May 11th to 15th, 2010. Each sample was tested for ammonia (00610), nitrite (00615), nitrate (00620), total nitrogen (00625), total phosphorous (00665), dissolved phosphorous (00666), and orthophosphate (00671).

Ammonia as Nitrogen (Figure C.58) averaged 0.784 mg/l having a maximum value of 7.72 mg/l at Site 5 (GW05B). Other relatively high values were measured at Site 36 with 1.23 mg/l (GW19B) and Site 11 with 1.39 mg/l (GW06B).

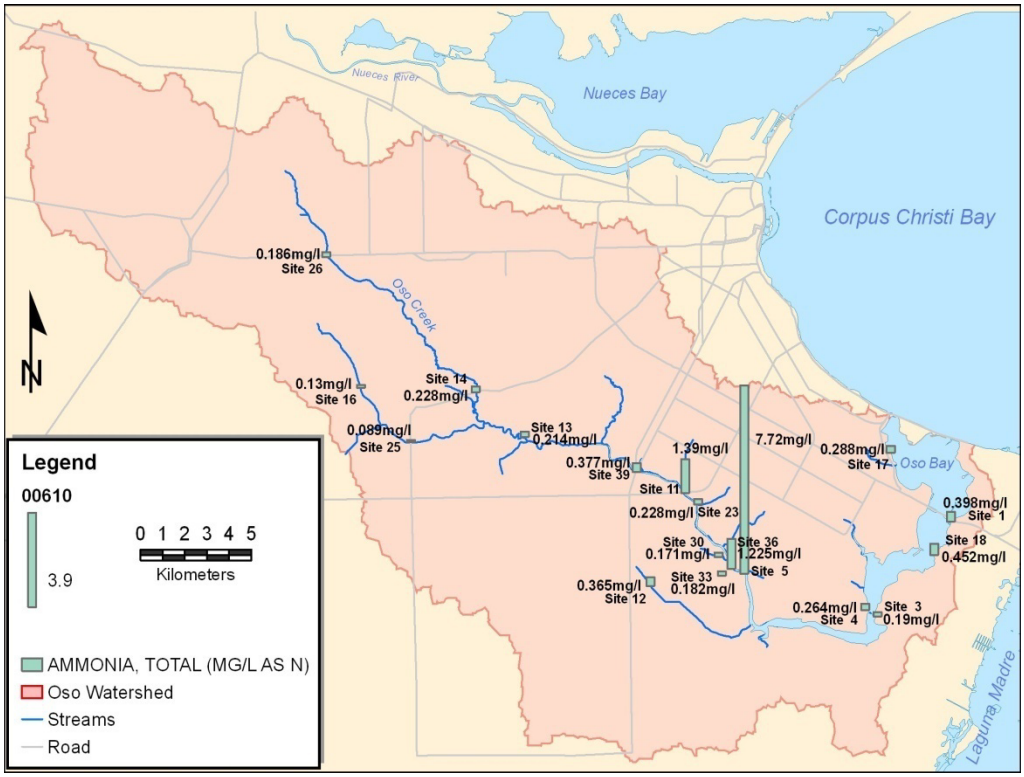

Figure C.58. Parameter Code 00610, Ammonia as Nitrogen.

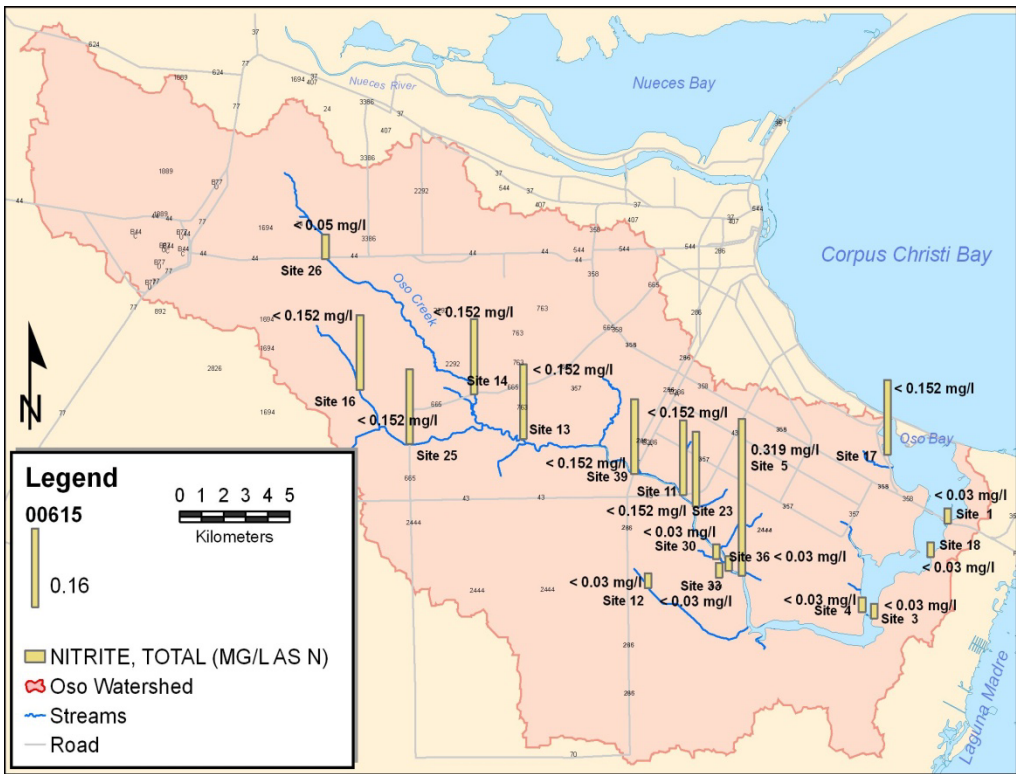

Figure C.59. Parameter Code 00615, Total Nitrite as Nitrogen.

Measurements of nitrite as nitrogen (00615, Figure C.59) were all less than method detection limits except for Site 5 (GW05B), which measured 0.319 mg/l.

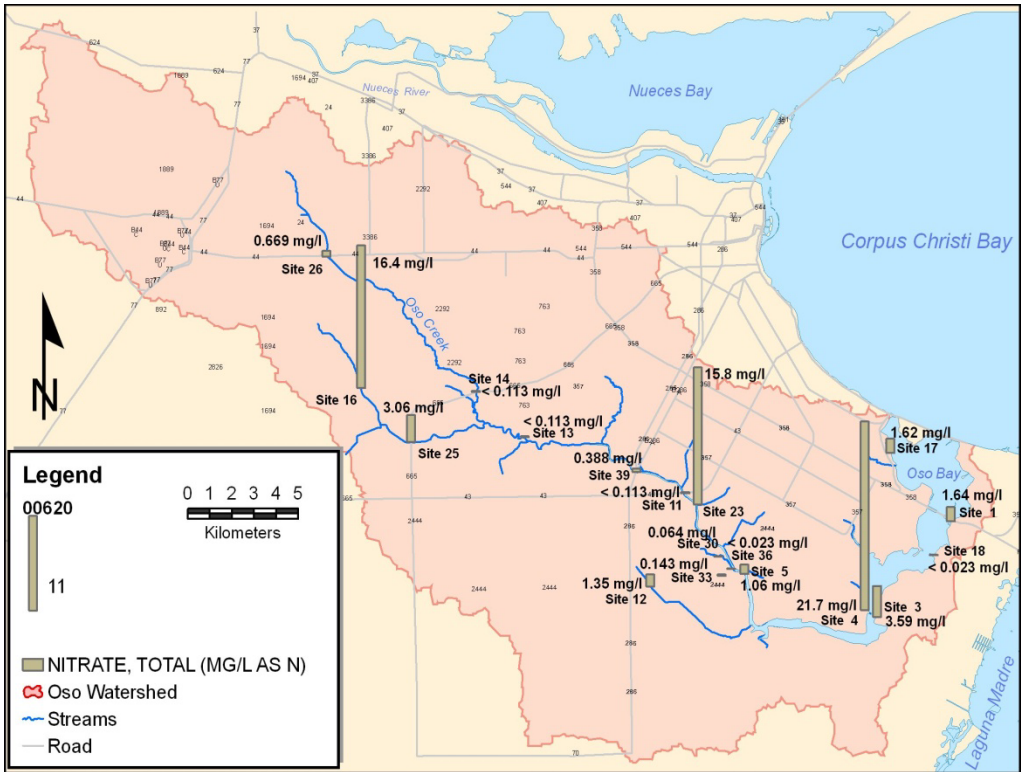

Figure C.60. Parameter Code 00620, Nitrate as Nitrogen

Measurements of nitrate as nitrogen (00620, Figure C.60) averaged 3.41 mg/l and ranged from 0.23 (detection limits) to 21.7 mg/l. Elevated values were detected at 3 locations: Site 4 (GW04B) measuring 21.7 mg/l; Site 23 (GW13B) measuring 15.8 mg/l; and at Site 16 (GW10B) measuring 16.4 mg/l.

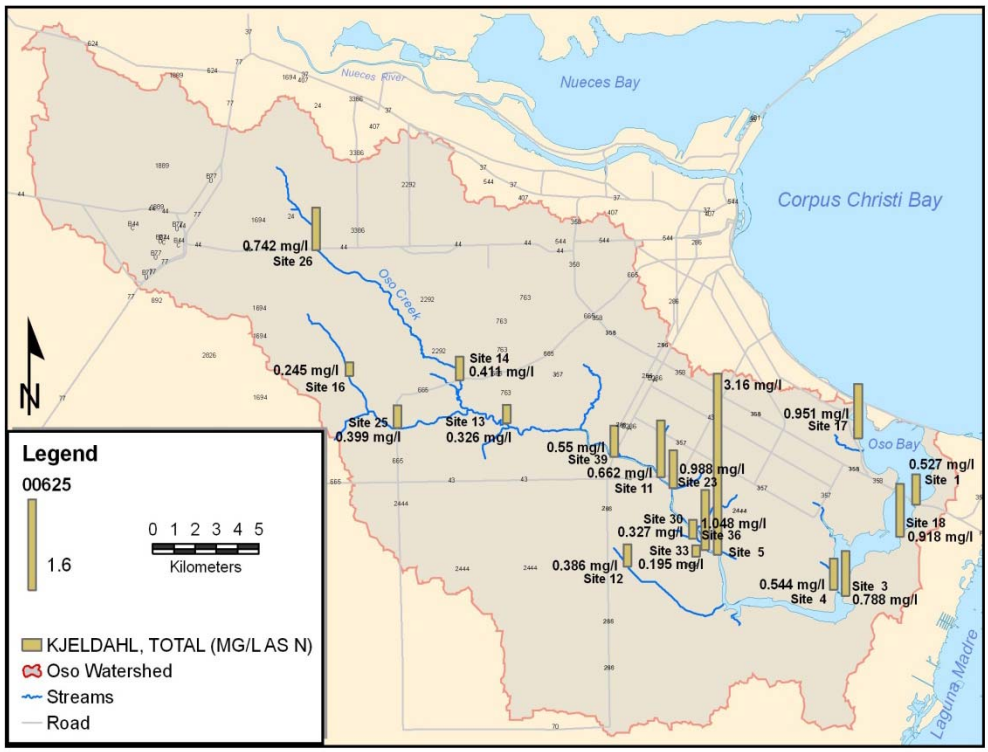

Figure C.61. Parameter Code 00625 Total Kjeldahl Nitrogen.

Measurements of total nitrogen (00625, Figure C.61) averaged 0.738 mg/l and ranged from 0.195 mg/l to 3.16 mg/l. Elevated levels of total nitrogen were detected at Site 5 (GW05B).

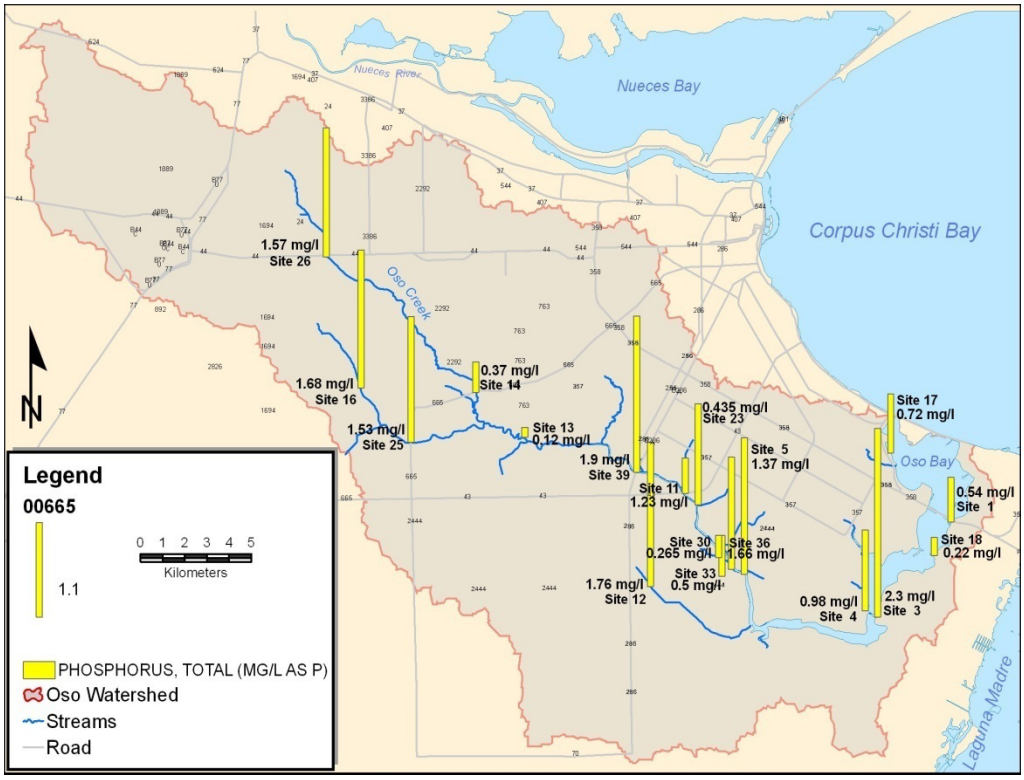

Figure C.62. Parameter Code 00665, Total Phosphorous as P.

Total phosphorous (00665, Figure C.62) averaged 1.121 mg/l and ranged from 0.12 mg/l to 2.3 mg/l. Elevated values were seen at Site 3 (GW03B), Site 5 (GW05B), Site 12 (GW07B), Site 16 (GW10B), Site 23 (GW13B), Site 25 (GW14B), Site 26 (GW15B), Site 36 (GW19B) and Site 39 (GW20B).

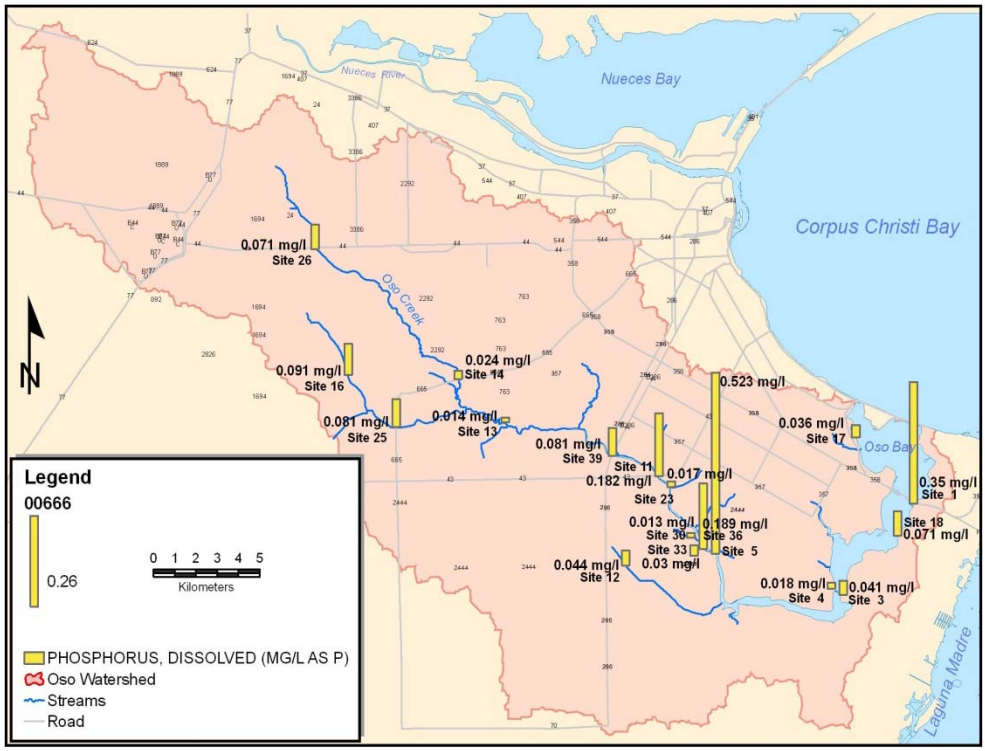

Figure C.63. Parameter Code 00666, Dissolved Phosphorous as P.

Dissolved phosphorous (00666, Figure C.63) averaged 0.107 mg/l and ranged from 0.013 to 0.523 mg/l measured at Site 5 (GW05B). Dissolved phosphorous was also elevated at Site 1 (GW01A).

Dissolved Orthophosphate (00671, Figure C.64) averaged 2.67 mg/l and ranged from 0.02 (detection limits) to 8.54 mg/l. Elevated levels were measured at Site 5 (GW05B), Site 11 (GW06B), Site 13 (GW08B), Site 14 (GW09B), Site 16 (GW10B), Site 17 (GW11B), Site 23 (GW13B), Site 25 (GW14B), and Site 39 (GW20B).

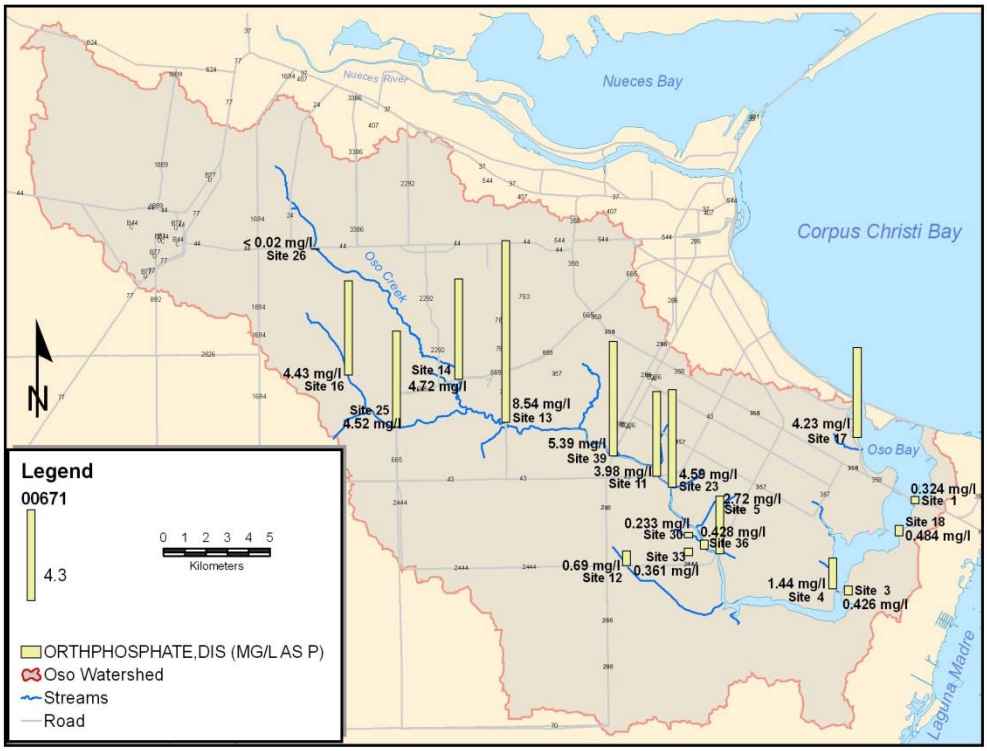

Figure C.64. Parameter Code 00671, Dissolved Orthophosphate.

C5. Hyporheic Zone

C.5.1 Stream bed thermal profilers

Stream bed thermal profilers were deployed at each site and collected temperature data at four depths at intervals of 15 minutes. The upper-most measurement was made in the

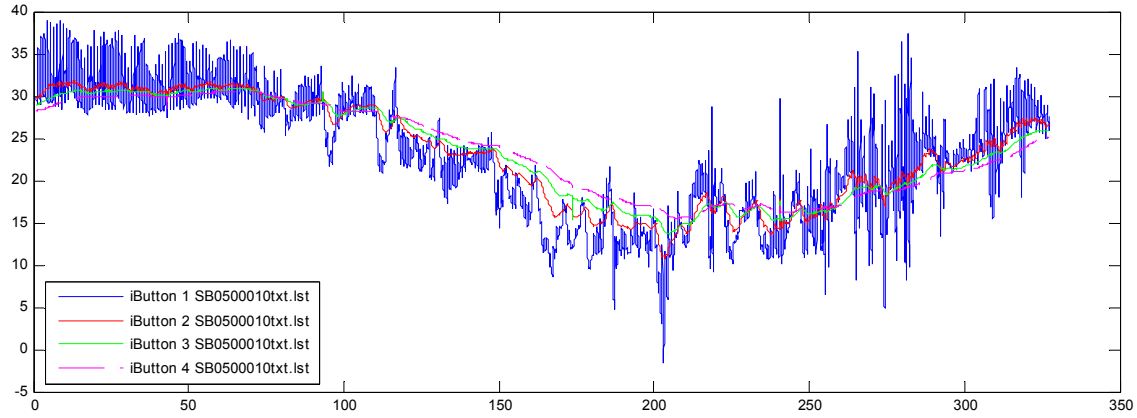

Figure C.65. SB05 Temperatures (Site 05 – FM2444 at Oso Creek)

water column just above the stream bed, and then at 33 cm intervals through the stream bed. This data revealed daily, weekly monthly and seasonal cycles in water temperatures.

Examples of this data can be seen in Figure C.65, Figure C.66, Figure C.67.

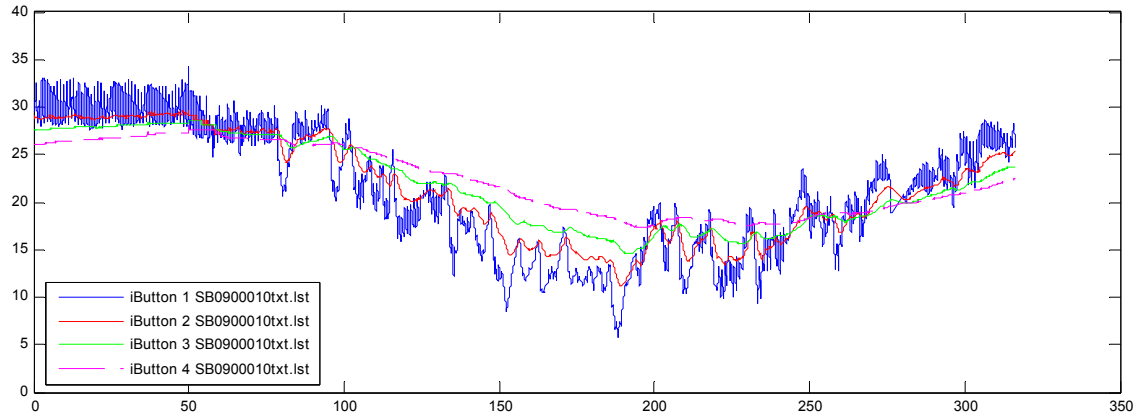

Figure C.66. SB09 Temperatures (Site 14 – Oso Creek at FM665)

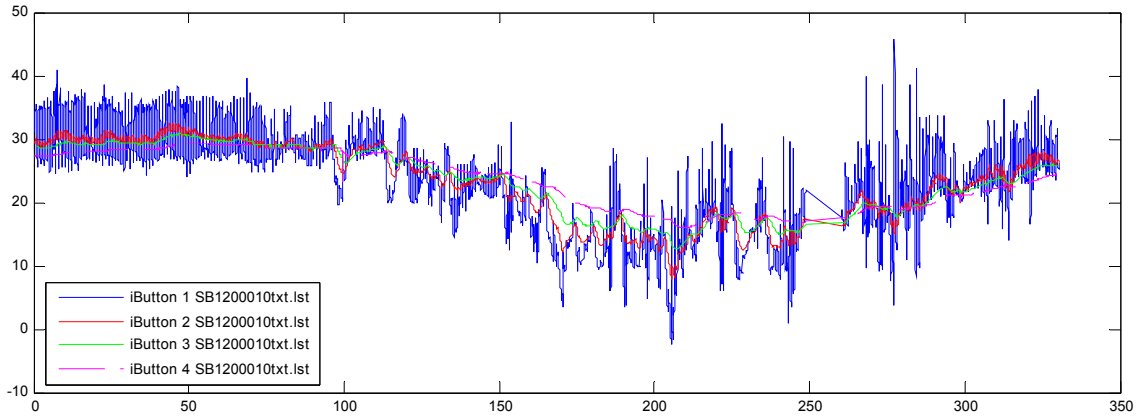

Figure C.67. SB12 Temperatures (Site 18 Oso Bay at Holly – east side)

Section D. Discussion

D1. General water quality parameters.

Specific conductance and temperature can be used to clearly compare water quality regimes. Specific conductance is the primary measurement for other parameters such as total dissolved solid and salinity and temperature can be used to characterize water by source.

Figure D.1 compares average specific conductance values measured at surface water and groundwater sites. The average specific conductance of surface water exceeds groundwater only on the east side of Oso Bay. This condition may be due to the influx of high salinity cooling water from a nearby power generation facility along the east bank of Oso Bay upstream from Site 3 and tidal exchange with Corpus Christi Bay. Generally, specific conductance in surface water and groundwater is higher in the bay and tidal creek sections than the non-tidal creek and tributaries further inland. This reflects the increasing elevation inland and the longer period of time that the formation has had to flush the saline connate (depositional) water from the sediments ((Shafer, 1968)).

Shallow groundwater (light blue bars) is generally of lower specific conductance than the deeper groundwater. This suggests that infiltration from precipitation over the basin has some influence on the water quality in the water table aquifer and dissolved solids from

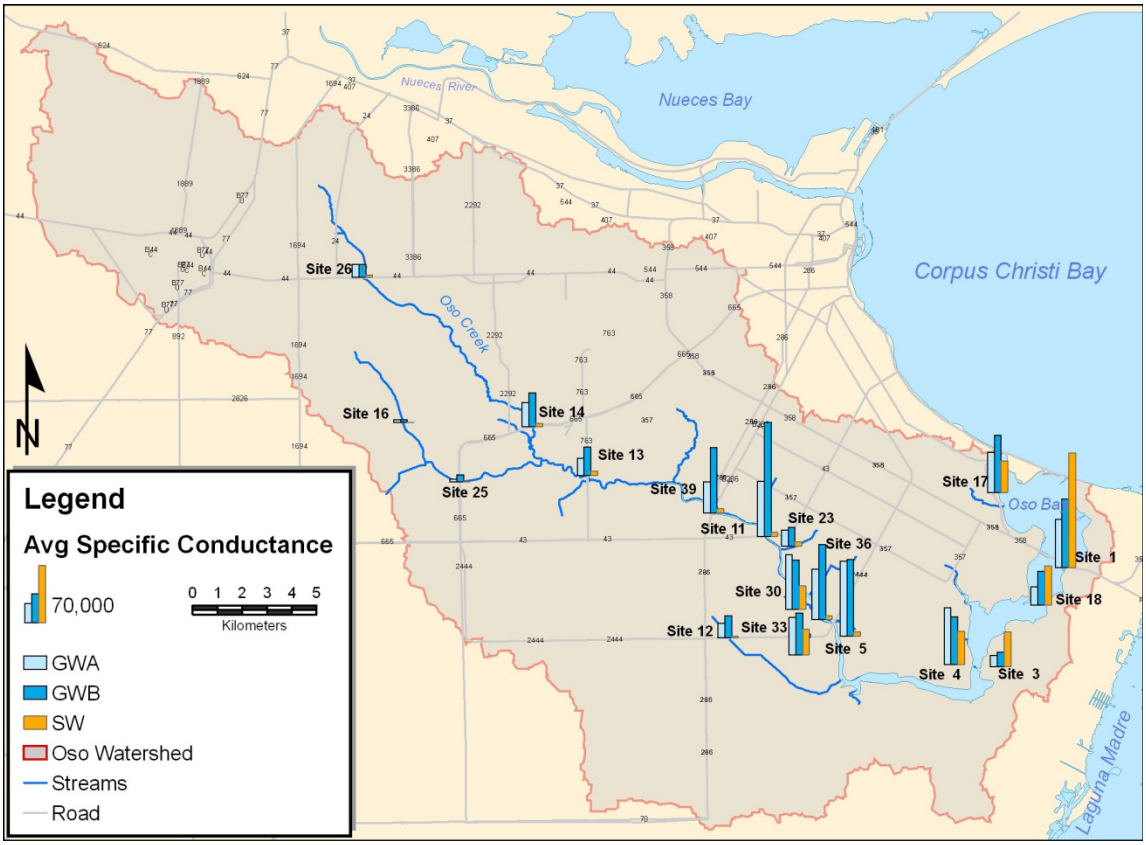

Figure D.1. Specific conductance of groundwater.

deposition in estuarine conditions and retained in the clays has more influence over the deeper groundwater (Shafer, 1968).

Temperature variation of groundwater in the study area is shown in Figure D.2 as degrees (Celsius) deviation from mean. Warmer groundwater temperatures are found along Oso Bay and cooler temperatures are found in the upper creek and tributaries, which correlates well (inversely) with depth to water.

D2. Nutrients in groundwater

Groundwater samples were collected from all deep monitoring wells, submitted to Xenco Laboratory, and analyzed for the presence of nitrogen and phosphorous.

Nitrogen occurs in an oxidized state such as nitrate (NO_3^-) and nitrite (NO_2^-) or a reduced state like ammonium (NH_4^+) and cyanide (CN^-). Nitrogen can also be bound to organic matter as amino acids. Microbes generally facilitate oxidation and reduction of nitrogen in groundwater and soil. Ammonia for example can be oxidized to a highly reactive nitrite, which is in turn oxidized rapidly to nitrate. Nitrites in groundwater are usually found in low concentrations because of this reactivity (Fetter, 1999). Nitrate concentrations in shallow unconsolidated sand beneath forest or permanent pasture were

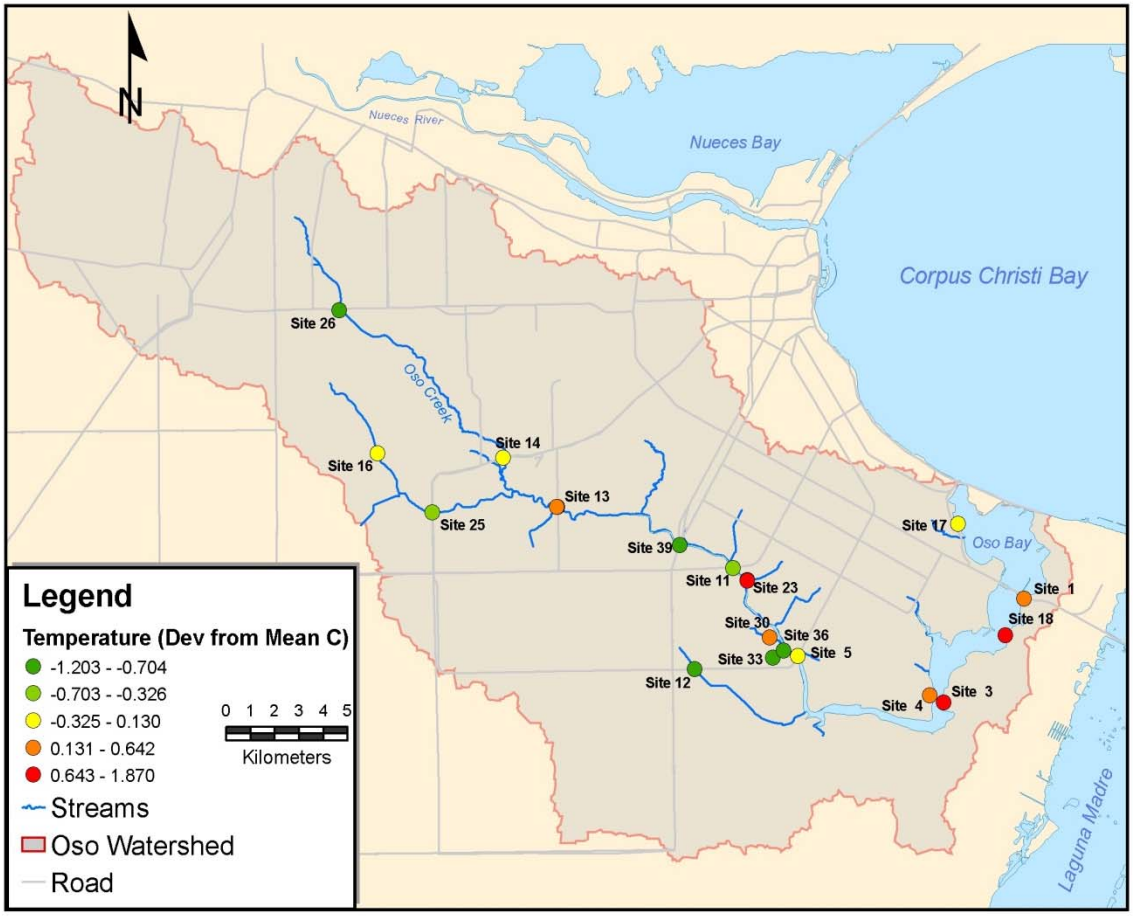

Figure D.2. Average groundwater temperatures as deviation from the mean.

found to be less than 1 mg/l, however beneath heavily fertilized potato fields, concentrations were found in excess of 10 mg/l (Hill, 1982). In Nueces County, average concentrations of nitrate, nitrite and ammonia (expressed as nitrogen) are 0.914 mg/l, 0.056 mg/l and 0.082 mg/l respectively (Shafer, 1968; TWDB, 2005)

Groundwater flux with its associated constituents (i.e. nutrients and bacteria) was calculated for each stream segment using Darcy's Law (Equation 1) to estimate advective transport. It was assumed that no adsorption, decay, diffusion or dispersion of the dissolved or suspended constituents of interest occurred. This method requires values for hydraulic conductivity (K), cross-sectional area (A), and the hydraulic gradient (dh/dl). Hydraulic conductivity values for each segment were determined by performing slug tests on wells representative of each stream segment. Values of area were estimated using average stream width and segment length along the stream course. The hydraulic gradient was determined using the distance between the creek and the well as length (dl) and an estimate of dh. The change in water elevation (dh) was estimated based on the following assumption:

> *The initial water level measurements in the wells were made at the end of a period of little or no rainfall that had persisted for more than 10 months so the water table aquifer of this small basin was close to being fully discharged (dh/dl was very small).*
>
> *During the investigation, the drought broke and the water table was seen to increase in many of the wells, indicating groundwater recharge. This increase in water level occurred until the precipitation events became less intense and less frequent near the end of the investigation. At the maximum head value recorded in each well, dh/dl would have been at its greatest value.*
>
> *So, for the calculations of flux in terms of advective flow from the water table aquifer to the creek, the difference between the maximum and minimum water level measurement in each well (that is representative of a particular segment) was chosen as dh in the hydraulic gradient calculation (dh/dl).*

This reasoning yields an upper limit of groundwater flux to the creek that could be expected if the measurements of hydraulic conductivity, cross-sectional area, and hydraulic gradient are representative of the stream segment. The estimates of groundwater flux and the transported constituents could be underestimated if localized, preferential flow paths exist in the subsurface along a segment. The estimates of transported constituent concentrations could be over-estimated if adsorption, decay or diffusion occurs.

Nitrate, nitrite, and ammonia (as nitrogen) measured in this study averaged 3.414 mg/l, <0.100 mg/l, 0.784 mg/l, respectively. Nitrate concentrations were high at three locations (Site 4, Site 23, and Site 16) with values greater than 15 mg/l (Figure C.60). Excluding these values nitrate (as nitrogen) averaged 0.846 mg/l. Site 16 is located adjacent to active agriculture and Site 23 is located in an area recently converted from agriculture to residential. Site 4 is located along Oso Bay in an agricultural area, but high nitrogen in the groundwater at this location could be related the presence of an active clay dune field receiving high organic content from the adjacent mud flats through aeolian processes. Nitrite concentrations were at or below the detection limits in all wells tested except for Site 5. Ammonia levels were low in most wells except for Site 5 (Figure C.58).

Groundwater at Site 5 frequently smelled of "rotten eggs" (indicative of a reducing environment) so it is not unexpected to find nitrogen in a reduced state here. This also explains the high nitrite concentrations at this site. This well is not located near agricultural interests but is located in an area that is somewhat marshy (Figure C.59).

Phosphorous in natural waters occurs primarily in the +5 valance state. Dissolved phosphorous occurs primarily as orthophosphate ions and is readily sorbed to soil, making it's mobility limited in the subsurface (Fetter, 1999). Average concentrations of dissolved phosphorous and total phosphorous in Nueces County are 0.01mg/l and 0.053 mg/l respectively (Shafer, 1968; TWDB, 2005). Phosphorous values measured in this study averaged 1.121 mg/l (total phosphorous) and were generally high throughout the basin (Figure C.62). Dissolved phosphorous values averaged 0.107 mg/l but are notably higher in the vicinity of Oso Bay and the lower tidal section of Oso Creek. Dissolved Orthophosphate averaged 2.67 mg/l and was notably higher in the non-tidal and fresher sections of the watershed.

Nutrients were measured in surface water at Site 16 and at Site 12 in an agricultural runoff study of Oso Creek Watershed (Ockerman, 2008). At Site 16, on West Oso Creek, nitrate, nitrite, and ammonia (as nitrogen) measured in groundwater was 16.4 mg/l, <0.152 mg/l, 0.13 mg/l, and respectively. Total nitrogen and ammonia (as nitrogen) measured in surface water was much lower than groundwater at this site. Surface water was collected during runoff events, where total nitrogen and ammonia (as nitrogen) averaged 3.15 mg/l and 0.087 mg/l respectively. Total phosphorous in surface water averaged 0.31 mg/l (Ockerman, 2008) and 1.68 mg/l in groundwater. Nitrate, nitrite, and

Segment Identified by Site ID	Total Nitrogen Flux (mg/day)	Increased Total Nitrogen Concentration In Segment (mg/l)
Site 26	6.55E+0	992.91E-9
Site 14	2.58E+0	254.33E-9
Site 13	193.71E-3	45.79E-9
Site 39 (above tidal)	1.58E+0	448.29E-9
Site 39 (tidal)	12.15E+0	448.29E-9
Site 11	9.36E+0	451.37E-9
Site 23	6.01E+0	624.80E-9
Site 36	4.04E+0	98.95E-9
Site 5	5.00E+0	594.44E-9
Site 4	203.35E+0	154.58E-9
Site 18	1.20E+3	730.66E-9
Site 1	5.39E+3	5.38E-6
Site 17	959.58E+0	480.22E-9

Table D2.1. Estimated Total Nitrogen Flux from Groundwater.

ammonia (as nitrogen) in groundwater at Site 12 on an unnamed tributary of Oso Creek was measured as 1.35 mg/l, <0.03 mg/l, 0.365 mg/l respectively. Total nitrogen in surface water was similar to groundwater at this site and averaged 1.63 mg/l. Ammonia as nitrogen concentration was less in surface water at 0.037 mg/l.

A flux of total nitrogen from the groundwater to the creek can be modeled based on measured values of hydraulic conductivity, average concentrations of total nitrogen in groundwater, average creek width, average creek depth, segment of interest length, and the maximum measured water table elevation range in each segment. The creek and bay were divided up into segments defined by the location of each monitoring site along the main reach of Oso Creek and Oso Bay and a flux for each nutrient parameter was calculated based on the measured values in this study and Darcy's Law (Equation 1). Flux values (Table D2.1) ranged from 193.71 $x10^{-3}$ mg/day added to the segment above Site 13 to 5.39 $x10^{3}$ mg/day added to the segment above Site 1. None of these daily fluxes calculated where great enough to increase the surface water concentrations by more than 5.38 $x10^{-6}$ mg/l.

Segment Identified by Site ID	Total Phosphorous Flux (mg/day)	Increased Total Phosphorous Concentration In Segment (mg/l)
Site 26	13.87E+0	2.10E-6
Site 14	2.32E+0	228.96E-9
Site 13	71.30E-3	16.86E-9
Site 39 (above tidal)	3.59E+0	1.02E-6
Site 39 (tidal)	27.61E+0	1.02E-6
Site 11	4.12E+0	198.73E-9
Site 23	11.17E+0	1.16E-6
Site 36	7.46E+0	182.69E-9
Site 5	2.63E+0	312.27E-9
Site 4	366.32E+0	278.47E-9
Site 18	287.57E+0	175.10E-9
Site 1	5.52E+3	5.51E-6
Site 17	726.50E+0	363.58E-9

Table D2.2. Estimated Total Phosphorous Flux from Groundwater.

A flux of total phosphorous from the groundwater to the creek can be modeled based on measured values of hydraulic conductivity, average concentrations of total nitrogen in groundwater, average creek width, average creek depth, segment of interest length, and the maximum measured water table elevation range in each segment. The creek and bay were divided up into segments defined by the location of each monitoring site located along the main reach of Oso Creek and Oso Bay and a flux was calculated base on the above-mentioned parameters and Darcy's Law (Equation 1). Flux values (Table **D2**.**2**) ranged from 71.3 $x10^{-3}$ mg/day added to the segment above Site 13 in Oso Creek to $5.52x10^{3}$ mg/day added to the segment above Site 1 in Oso Bay. None of the calculated daily fluxes were great enough to increase the surface water concentrations by more than $5.51x10^{-6}$ mg/l.

Equation 1, Darcy's Law

$$Q = -KA\left(\frac{dh}{dl}\right)$$

Where:

Q = discharge

K = hydraulic conductivity

A = Area

dh/dl = hydraulic gradient

D3. Bacteria concentrations/flux

Bacteria concentrations were measured during wet and dry conditions over the course of this project (Figure C.56 and Figure C.57) to evaluate groundwater as a potential source of fecal bacteria to the Oso Creek/Oso Bay hydrologic system. Fecal organisms such as Enterococcus are commonly used by regulatory agencies to monitor recreational waters as an indicator of the presence or absence of pathogens. Previous studies (Hay and Mott, 2005, 2006), suggest that groundwater influx could be a source of bacteria to Oso Creek and Oso Bay, particularly during dry weather conditions.

Average concentrations of Enterococcus in the groundwater of Oso watershed measured 80 cfu/100ml. Wet event concentrations averaged 112 cfu/100ml and dry event concentrations averaged 50 cfu/100 ml. Only two wells exceeded the Texas State Water Quality Standard single sample criteria for Enterococcus of 104 cfu/100ml, GW06A (Site 11) at 3,000 cfu/100ml and GW09B (Site 14) at 250 cfu/100 ml during the wet weather, and only one well, GW12A (Site 18) exceeded the standards during dry weather sampling. The single sample criteria was exceeded in 4.6% of the samples and the geometric mean criteria of 35 cfu/100 ml was exceeded by 12.1% of the samples.

Approximately 58% of the groundwater samples had Enterococcus concentrations of less the 2 cfu/100 ml. By contrast, historic Enterococcus concentrations in the surface waters of Oso Creek and Oso Bay averaged 2,918 cfu/100 ml over all events and stations (Hay and Mott, 2006).

Two historic water quality stations on Oso Bay have measurements of Enterococcus concentrations from prior studies and routine monitoring, and are located adjacent to three groundwater monitoring locations. TCEQ Station 13440 (Figure D.3) is located near GW01A at Site 1. This station had average Enterococcus concentrations of 183 cfu/100 ml in previous studies (Hay and Mott, 2006). Groundwater concentrations of Enterococcus in the adjacent groundwater in this study averaged 2 cfu/100 ml. TCEQ station 13026 is located in Oso Bay adjacent to Site 3 and Site 4. Enterococcus concentrations at this site averaged 908 cfu/100 ml in previous studies (Hay and Mott, 2006) however groundwater concentrations at Site 3 (GW03A and GW03B) averaged 12 cfu/100 ml and at Site 4 (GW04A and GW04B) averaged 1 cfu/100 ml. The shallow well (GW03A) at Site 3 accounted for the majority of the Enterococcus detected at this site with a value of 28 cfu/100 ml.

Historic concentrations of Enterococcus in the Oso Creek tidal section were collected at two stations 13027 and 13028 (Hay and Mott, 2006). Four monitoring wells were colocated with these historic sites. Monitoring wells GW05A and GW05B at Site 5 are adjacent to historic sampling site 13027 and GW20A and GW20B at Site 39 are adjacent to (across the creek) 13028. Historic Enterococcus concentrations averaged 2,708 cfu/100 ml at 13027 where groundwater concentrations of Enterococcus in this study averaged 6 cfu/100 ml at Site 5 (GW05A and GW05B). Historic Enterococcus concentrations averaged 2,391 cfu/100 ml at station 13028 where groundwater concentrations of Enterococcus in this study averaged 1 cfu/100 ml at Site 39 (GW20A and GW20B).

The non-tidal Oso Creek has three monitoring sites, 13029, 18500, and 18499 that are colocated with groundwater monitoring wells and have historic Enterococcus measurements (Hay and Mott, 2006). Average Enterococcus concentration in surface water at station 13029 measured in a previous study was 3,709 cfu/100 ml. Groundwater adjacent to this location (Site 13) in this study averaged 29 cfu/100 ml of Enterococcus. Average Enterococcus concentration in surface water at station 18500 measured in a previous study was 2,939 cfu/100 ml. Groundwater concentrations of Enterococcus adjacent to this location (Site 14) in this study averaged 95 cfu/100 ml. Average Enterococcus concentration in surface water at station 18499 measured in a previous study 6,183 cfu/100 ml. Groundwater adjacent to this location (Site 26) in this study averaged 1.5 cfu/100 ml of Enterococcus.

Additionally three tributaries have water quality stations from two previous studies (Hay and Mott, 2006; Ockerman, 2008) with data that includes Enterococcus measurements, 18501 (West Oso Creek at FM665), 08211517 (West Oso Creek at Merritt Road), and 08211525 (Unnamed tributary and FM 2444). Site 08211525 (Ockerman, 2008) is colocated with groundwater monitoring wells at Site 12 (GW07A and GW07B). Historic Enterococcus concentrations in surface water at this site averaged 32,560 cfu/100 ml while groundwater data from this study averaged 8 cfu/100 ml. Site 08211525 (Ockerman, 2008) is colocated with Site 16 (GW10A and GW10B). Historic Enterococcus concentrations in surface water at this site averaged 75,340 cfu/100 ml while groundwater data from this study averaged 19 cfu/100 ml. Surface water data collection at these two sites was focused on high flow events, which typically contain

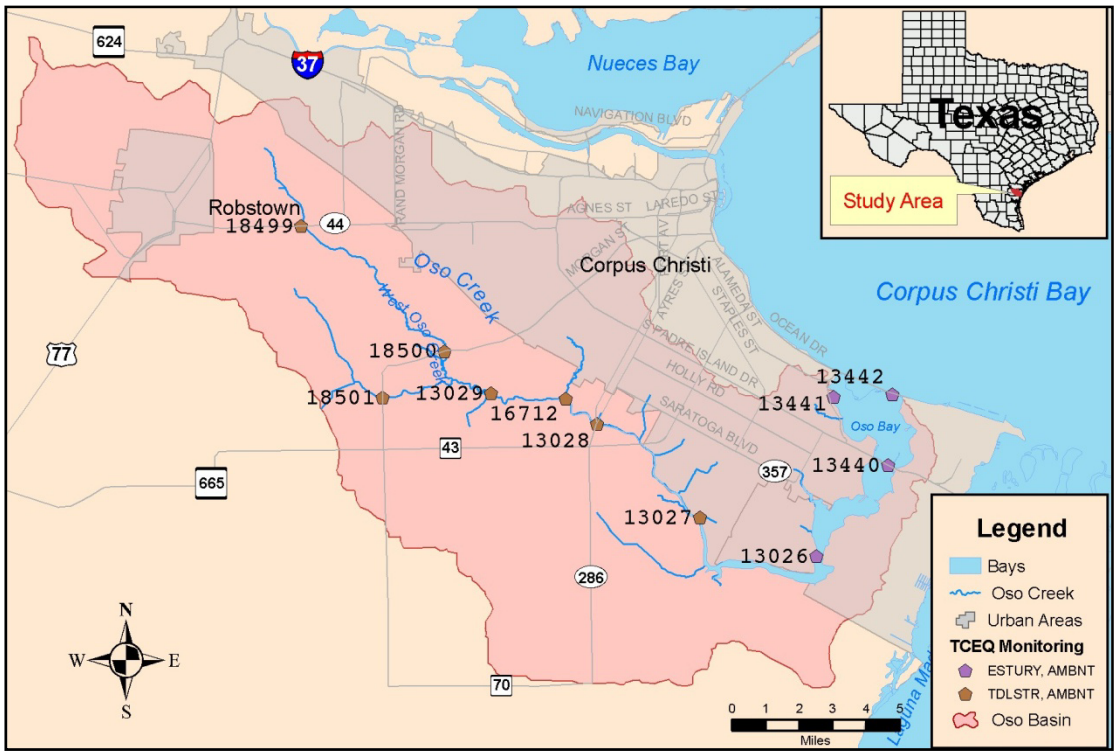

Figure D.3. Historic TCEQ monitoring stations.

high concentrations of bacteria and nutrients. Surface water data collected at site 18501 (Hay and Mott, 2006) measured average Enterococcus concentrations of 4,323 cfu/100 ml and is colocated with Site 25 (GW14A and GW14B) where groundwater concentrations of Enterococcus averaged 3 cfu/100 ml.

Overall, groundwater concentrations of Enterococcus were several orders of magnitude less than surface water. Groundwater concentrations of Enterococcus in contaminated fractured limestone aquifers have been reported at concentrations generally below 10 cfu/100 ml, but as high as about 115 cfu/100 ml with about 58% of the samples having greater that 1 cfu/100 ml (Celico et al., 2004) suggesting that even in contaminated aquifers groundwater concentrations of Enterococcus are very low compared to the adjacent surface water measurement.

Although groundwater during dry weather (03/29 and 03/30/2010) averaged 50 cfu/100 ml and 112 cfu/100 ml during wet weather (10/26 and 10/28/2009), three sites stand out (Site 18, Site 14 and Site 11) with exceptionally high Enterococcus concentrations. Site 11 during the first sampling event (wet weather) had Enterococcus concentrations of 3,000 cfu/100 ml in the deep well but only 13 cfu/100 ml in the shallow well. Subsequent sampling during dry weather presented a value of < 1 cfu/100 ml in the deep well and 40 cfu/100 ml in the shallow well suggesting that the previously measured concentration of Enterococcus may be an outlier that is unrepresentative of Enterococcus in groundwater. The occurrence of this outlier may be explained by a failure in the bentonite grout seal in the annulus of the well between the casing and the soil. This seal relies on moisture to swell the low permeability bentonite clay so that surface water flowing overland around the well head can not migrate into the well through this annulus. This well was installed during a severe drought with very little soil moisture and a low water table, which may have left this seal incompetent until sufficient water from a rain event had wetted the bentonite and the seal made effective. So the first precipitation event may have introduced surface water (overland flow), temporarily contaminating the well. With this value discounted, the average Enterococcus concentration for groundwater during wet weather decreases to 20 cfu/100 ml. Site 18 during the dry weather sampling had Enterococcus concentrations of 1,450 cfu/100 ml in the shallow well and 8 cfu/100 ml in the deeper well. However, during previous (wet weather) sampling Enterococcus concentration in the shallow well measured 1 cfu/100 ml and the deeper well measured 9 cfu/100 ml suggesting that the higher shallow well measurement is spurious. Since this well had been installed ten months prior to obtaining this sample, the water table was close to the surface, and there had been several prior precipitation events, there is no reason to believe that the annular bentonite seal was incompetent in this well. However field personnel observed this area was habitually used for illegal dumping of domestic waste, construction debris, plumbing fixtures, yard waste, and automobile parts. It is possible that the shallow well could have been impacted by some of this waste combined with a precipitation event that flushed the contamination down through the loose soil at the surface. Although this may not represent ambient conditions, groundwater contamination can fluctuate significantly at the field scale with irregular precipitation events (Celico et al., 2004). With this value discounted, the average Enterococcus concentration for groundwater during dry weather decreases to 8 cfu/100 ml. Site 14 had elevated concentrations of Enterococcus during wet and dry weather events. The shallow well measured 74 cfu/100 ml for the wet weather and 53 cfu/100 ml

Segment Identified by Site ID	Enterococcus Flux (cfu/day)	Increased Enterococcus Concentration In Segment (cfu/m^3)
Site 26	132.48E+0	20.07E-3
Site 14	5.97E+3	587.86E-3
Site 13	172.32E+0	40.74E-3
Site 39 (above tidal)	18.88E+0	5.36E-3
Site 39 (tidal)	145.32E+0	5.36E-3
Site 11	72.30E+3	3.49E+0
Site 23	90.84E+0	9.44E-3
Site 36	122.45E+0	3.00E-3
Site 5	98.97E+0	11.76E-3
Site 4	22.43E+3	17.05E-3
Site 18	4.80E+6	2.92E+0
Site 1	204.62E+3	204.12E-3
Site 17	194.24E+3	97.21E-3

Table D3.1. Estimated flux of Enterococcus from groundwater to surface water in Oso Creek and Oso Bay.

during dry weather which suggests that there is some bacteria source near this location, although, the only activity observed adjacent to this well is agricultural activity (row crops) within about 25 meters and a residence within about 200 meters. The deeper well measured 250 cfu/100 ml during wet weather and 2 cfu/100 ml during dry weather. The higher value may indicate some contamination from overland flow during the first precipitation events after well installation.

Although the first sampling event was after wet weather and higher concentrations are expected due to the mobilization of fecal matter on the surface, initial Enterococcus concentrations may owe part of their elevated values to some cross contamination from shallower soils during well installation. This occurs as the auger advances and drags some material from shallower soils, which are more likely to contain some fecal contamination, to deeper strata that are less likely to be contaminated. This type of contamination is normally addressed during well development, however low hydraulic conductivity in the aquifers impeded well development with slow well recharge time.

A flux of Enterococcus bacteria from the groundwater to the creek can be modeled based on measured values of hydraulic conductivity, average concentrations of Enterococcus in groundwater, average creek width, average creek depth, segment of interest length, and the maximum measured water table elevation range in each segment. The creek and bay were divided up into segments defined by the location of each monitoring site located along the main reach of Oso Creek and Oso Bay and a flux was calculated base on the previously mentioned parameters and Darcy's Law (Equation 1). Flux values (Table D3.1) ranged from 18.9 cfu/day added to the non-tidal portion of the segment above Site 39 to 4,800,000 cfu/day added to the segment above Site 18. None of these daily fluxes calculated were great enough to increase the surface water concentrations by more than 3.59 cfu/m^3.

Section E. Conclusions

Groundwater was monitored for nutrients, bacteria, temperature, specific conductance, salinity and depth to water to characterize the water table aquifer in the Oso Watershed and determine if groundwater could be a significant pathway of contamination to the creek. Hydraulic properties of the aquifer were determined.

A slug test was performed on many of the wells to provide a value of hydraulic conductivity for modeling groundwater movement. The results of these tests showed that hydraulic conductivities were very low and characteristic of the clay dominated subsurface in the Beaumont Formation.

Groundwater in the Oso Watershed was found to be slightly saline to super-saline, with higher specific conductance values than surface water at all sites except along the east side of Oso Bay. The residual dissolved solids retained in the subsurface from the time of deposition and the low depth to water (relatively close proximity to the surface at low elevations) may account for most of this salinity. Fresher groundwater is evident in areas of higher elevation furthest from the tidal regime.

Nutrients were comparable to surface water in some cases, however several sites raise concern for high concentrations of nitrogen and many monitoring wells had total phosphorous values in the high range for groundwater. Modeling groundwater movement to the creek and bay provided some flux values for the transport of nutrient to surface waters. The modeling efforts indicated that only a very small flux of nutrients to the surface water is possible due to the low hydraulic conductivity of the formations and the low hydraulic head to provide a gradient for advection.

Bacteria concentrations (Enterococcus) in groundwater were found to be low compared to historic values of bacteria in surface water. However there were three sites of concern, Site 14 at Oso Creek and FM 665 had elevated levels at both wet weather and dry weather sampling events, Site 11 at Oso Creek and FM 43 measured very high during the wet weather event, possibly due to runoff contamination, and Site 18 in Flour measured a very high value during a dry weather event. Bacteria fluxes were modeled using the aquifer properties determine by aquifer testing and were found to be very low due to the poor hydraulic conductivity and low hydraulic gradient. The highest flux of bacteria calculated was 4,800,000 cfu/day, an equivalent to increasing the Enterococcus concentration in the creek by 3 cfu/m^3.

Although there were individual measurements of nutrients and bacteria that were high, modeled fluxes indicate that the potential of groundwater to be a significant pathway for either of these constituents to surface water is very low.

Two areas presented interesting data that warrant further investigation. Water level measurements made around the retention pond at the South Texas Botanical Gardens responded quickly to precipitation events with what appears to be a quick infiltration of surface water to the water table aquifer and then a gradual drop in the water table over the next few days to the initial water levels prior to the event. This small system with a single channel inflow would make an excellent system to evaluate the effectiveness of a retention pond at moderating flooding, cycling nutrients, and reducing bacteria

concentration by detention and filtration through the aquifer. The second area located at Oso Creek and Weber Road contained super-saline water with specific conductance values as high as 155,705 uS/cm. This area may have been part of a salt pond, which built-up high salinities through small (1 m) sea level changes that allowed sea water to enter and then evaporate, leaving high salt content in the subsurface as a remnant of the paleoecology at this site.

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Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 9203 SPID , Corpus Christi, TX

Date Drilling: started: 4/15/2009 completed: 4/15/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	19

Depth (ft.)	Lithology	Description
0 to12	fill material	gray
12 to 19	clay gray	

Drilling Method: Hollow Stem Auger; Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	14	40
2	NEW	PVC Screen	14	19	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 10	to 0	1
Bentinite	from 12	to 10	1
Sand	from 19	to 12	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 1. Well ID GW01A.Tracking number 181366

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.1: Well Report GW01A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 3232 Yorktown, Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	10

Depth (ft.)	Lithology	Description
0 to 7	clay	gray
7 to 8	clay sand	lt brown
8 to 10	clay sand	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	5	40
2	NEW	PVC Screen	5	10	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 2	to 0	1
Bentinite	from 4	to 2	1
Sand	from 10	to 4	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 3. Well ID GW03A.Tracking number 181369

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.2: Well Report GW03A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 3232 Yorktown, Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	14

Depth (ft.)	Lithology	Description
0 to 5	loam	gray
6 to 7	silty	lt brown
8 to 14	clay sand	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	9	40
2	NEW	PVC Screen	9	14	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 5	to 0	1
Bentinite	from 7	to 5	1
Sand	from 14	to 7	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 3. Well ID GW03B.Tracking number 181368

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.3: Well Report GW03B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 8460 Yorktown , Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	15

Depth (ft.)	Lithology	Description
0 to 4	slightly sandy clay	gray
4 to 6	clay	gray clay
6 to 8	clay	brownish clay
8 to 14	clay	brownish clay
14 to 15	clay	gray clay

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	17	40
2	NEW	PVC Scree	17	22	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 13	to 0	1
Bentinite	from 15	to 13	1
Sand	from 22	to 15	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 4. Well ID GW04A.Tracking number 181371

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.4: Wells Report GW04A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 8460 Yorktown , Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	22

Depth (ft.)	Lithology	Description
0 to 4	slightly sandy clay	gray
4 to 7	slightly sandy clay	
7 to 8	clay	gray tain yellow clay
10 to 15	clay	it gray clay
15 to 20	slightly silty	it gray slighty silty
20 to 22	clayey silt	brown clay slightly silty

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	17	40
2	NEW	PVC Screen	17	22	0.01

Surface Completion: Surface slab installed

Water Level: static level (ft.) no data below land surface; Date; Artesian flow no data gpm; Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 13	to 0	1
Bentinite	from 15	to 13	1
Sand	from 22	to 15	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test: Type test: no data; Yield: (gpm) with ft.; drawdown hrs.

Comments: Site 4. Well ID GW04B.Tracking number 181370

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.5: Wells Report GW04B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well FM 2444, Corpus Christi, TX

Date Drilling: started: 5/14/2009 completed: 5/14/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	12

Depth (ft.)	Lithology	Description
0 to 2	loam	grayish brown
2 to 10	clay	grayish brown
10 to 12	clay	lt brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	7	40
2	NEW	PVC Screen	7	12	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 3	to 0	1
Bentinite	from 5	to 3	1
Sand	from 12	to 5	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 5. Well ID GW05A.Tracking number 181373

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.6: Wells Report GW05A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well FM 2444, Corpus Christi, TX

Date Drilling: started: 5/14/2009 completed: 5/14/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	23

Depth (ft.)	Lithology	Description
0 to 3	clay loam	gray
3 to 10	clay	gray
10 to 18	tain clay	brown
18 to 23	clay sand	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	18	40
2	NEW	PVC Screen	18	23	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 14	to 0	1
Bentinite	from 16	to 14	1
Sand	from 23	to 16	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 5. Well ID GW05B.Tracking number 181372

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.7: Wells Report GW05B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: 7522 Weber , Corpus Christi, TX

Date Drilling: started: 4/22/2009; completed: 4/22/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	10

Depth (ft.)	Lithology	Description
0 to 6	clay	gray
6 to 10	silty clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	5	40
2	NEW	PVC Screen	5	10	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 2	to 0	1
Bentinite	from 4	to 2	1
Sand	from 10	to 4	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 11. Well ID GW06A.Tracking number 181374

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.8: Wells Report GW06A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 7522 Weber , Corpus Christi, TX

Date Drilling: started: 4/22/2009 completed: 4/22/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	19

Depth (ft.)	Lithology	Description
0 to 3	clay loam	lt gray
3 to11	clay loam	soft sticky dark gray
12 to 16	sandy clay	lt gray
16 to 19	clay	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	14	40
2	NEW	PVC Screen	14	19	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 10	to 0	1
Bentinite	from 12	to 10	1
Sand	from 19	to 12	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 11. Well ID GW06B.Tracking number 181375

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.9: Wells Report GW06B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 2444, Corpus Christi, TX

Date Drilling: started: 5/14/2009; completed: 5/14/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	14

Depth (ft.)	Lithology	Description
0 to 2	loam	dark gray
2 to 10	clay	lt gray
10 to 14	sand	lt gray to brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	9	40
2	NEW	PVC Screen	9	14	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 6	to 0	1
Bentinite	from 8	to 6	1
Sand	from 14	to 8	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 12. Well ID GW07A.Tracking number 181377

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.10: Wells Report GW07A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well FM 2444, Corpus Christi, TX

Date Drilling: started: 5/14/2009 completed: 5/14/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	23

Depth (ft.)	Lithology	Description
0-13	clay	gray
13-22	sand	
22-23	clay	

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	15	40
2	NEW	PVC Screen	15	20	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 11	to 0	1
Bentinite	from 13	to 11	1
Sand	from 20	to 13	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 12. Well ID GW07B.Tracking number 181378

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.11: Wells Report GW07B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 663, Corpus Christi, TX

Date Drilling: started: 5/19/2009; completed: 5/19/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	15

Depth (ft.)	Lithology	Description
0 to 4	clay loam	dark gray
4 to 5	clay	dark gray to bluish
5 to 10	clay	bluish to gray
10 to 14	clay	bluish to brown
14 to 15	clay	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	29	40
2	NEW	PVC Screen	29	34	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 6	to 0	1
Bentinite	from 8	to 6	1
Sand	from 15	to 8	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 13. Well ID GW08A.Tracking number 181379

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.12: Wells Report GW08A

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 663, Corpus Christi, TX

Date Drilling: started: 5/19/2009; completed: 5/19/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	34

Depth (ft.)	Lithology	Description
0 to 4	loam clay	dark gray
4 to 6	clay	dark gray
6 to 12	clay	grayish black
12 to 14	clay	brownish
14 to 28	clay	reddish brown
28 to 34	clay	dark reddish brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	29	40
2	NEW	PVC Screen	29	34	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 25	to 0	1
Bentinite	from 27	to 25	1
Sand	from 34	to 27	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 13. Well ID GW08B.Tracking number 181380

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.13: Wells Report GW08B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 665 and Oso Creek, Corpus Christi, TX

Date Drilling: started: 5/15/2009; completed: 5/15/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	18

Depth (ft.)	Lithology	Description
0 to 4	clay loam	lt gray
4 to 8	clay	dark gray
8 to 15	clay	lt gray
15 to 18	sandy clay	slightly brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	13	40
2	NEW	PVC Screen	13	18	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 9	to 0	1
Bentinite	from 11	to 9	1
Sand	from 18	to 11	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 14. Well ID GW09A.Tracking number 181381

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.15: Wells Report GW09A

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 665 and Oso Creek, Corpus Christi, TX

Date Drilling: started: 5/15/2009; completed: 5/15/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	28

Depth (ft.)	Lithology	Description
0 to 5	clay loam	gray to dark gray
5 to 7	clay	dark gray
7 to 16	clay	lt gray
16 to 20	clay	reddish brown
20 to 23	sandy clay	
23 to 28	silty clay with sand	

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	23	40
2	NEW	PVC Screen	23	28	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 19	to 0	1
Bentinite	from 21	to 19	1
Sand	from 28	to 21	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 14. Well ID GW09B.Tracking number 181382

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) _____ (Licensed well driller) (Signed) _____ (Registered Driller Trainee)

Figure E.16: Wells Report GW09B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: Merritt Rd (CR 30), Corpus Christi, TX

Date Drilling: started: 5/18/2009; completed: 5/18/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	17

Depth (ft.)	Lithology	Description
0 to15	clay	dark gray
15 to 17	sand	

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	12	40
2	NEW	PVC Screen	12	17	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 8	to 0	1
Bentinite	from 10	to 8	1
Sand	from 17	to 10	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 16. Well ID GW10A.Tracking number 181914

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.17: Wells Report GW10A

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: Merritt Rd (CR 30), Corpus Christi, TX

Date Drilling: started: 5/18/2009; completed: 5/18/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	25

Depth (ft.)	Lithology	Description
0 to 4	clay loam	dark gray
4 to 8	tain clay	lt gray
8 to 13	tain clay	
13 to 25	tain sand	

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	20	40
2	NEW	PVC Screen	20	25	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 16	to 0	1
Bentinite	from 18	to 16	1
Sand	from 25	to 18	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 16. Well ID GW10B.Tracking number 181915

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.18: Wells Report GW10B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Sutter Park Ennis Joslen Rd , Corpus Christi, TX

Date Drilling:		Type of Work:	Proposed Use:	Monitor
started:	4/15/2009	New Well	Diameter of Hole:	
completed:	4/15/2009	If Public Supply Well, were plans submitted to the TNRCC? --	Dia (in.)	From (ft.) / To (ft.)
			6.5	0 / 12

Depth (ft.)	Lithology	Description
0-12	clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) / to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	7	40
2	NEW	PVC Screen	7	12	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 3	to 0	1
Bentinite	from 5	to 3	1
Sand	from 12	to 5	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 17. Well ID GW11A.Tracking number 181916

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.19: Wells Report GW11A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Sutter Park Ennis Joslen Rd , Corpus Christi, TX

Date Drilling:		Type of Work:	Proposed Use:	Monitor
started:	4/15/2009	New Well	Diameter of Hole:	
completed:	4/15/2009	If Public Supply Well, were plans submitted to the TNRCC? --	Dia (in.)	From (ft.) / To (ft.)
			6.5	0 / 21

Depth (ft.)	Lithology	Description
0-21	sandy clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) / to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	16	40
2	NEW	PVC Screen	16	21	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 12	to 0	1
Bentinite	from 14	to 12	1
Sand	from 21	to 14	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 17. Well ID GW11B.Tracking number 181917

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.20: Wells Report GW11B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: Holly Rd. Oso Bay Flour Bluff side, Flour Bluff

Date Drilling: started: 4/17/2009; completed: 4/17/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	10

Depth (ft.)	Lithology	Description
0 to 7	sandy loam	gray
7 to 8	clay loam	gray
8 to 10	clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ; to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	5	40
2	NEW	PVC Screen	5	10	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 2	to 0	1
Bentinite	from 4	to 2	1
Sand	from 10	to 4	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 18. Well ID GW12A.Tracking number 181918

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.21: Wells Report GW12A

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: Holly Rd. Oso Bay Flour Bluff side, Flour Bluff

Date Drilling: started: 4/17/2009; completed: 4/17/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	15

Depth (ft.)	Lithology	Description
0 to 6	sandy loam	gray
6 to 7	clay	gray
7 to 9	clay	lt gray
9 to 15	clay slightly silty	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	10	40
2	NEW	PVC Scree	10	15	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 6	to 0	1
Bentinite	from 8	to 6	1
Sand	from 15	to 8	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 18. Well ID GW12B.Tracking number 181919

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) _____ (Licensed well driller)

(Signed) _____ (Registered Driller Trainee)

Figure E.22: Wells Report GW12B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Yorktown Blvd and Sun Valley Dr , Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	15

Depth (ft.)	Lithology	Description
0 to 8	clay loam	dark
8 to 10	clay	dark gray
10 to 13	clay	dark dns
13 to 15	sandy clay	gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	10	40
2	NEW	PVC Screen	10	15	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 6	to 0	1
Bentinite	from 8	to 6	1
Sand	from 15	to 8	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 23. Well ID GW13A.Tracking number 181920

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.23: Wells Report GW13A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Yorktown Blvd and Sun Valley Dr , Corpus Christi, TX

Date Drilling: started: 4/21/2009 completed: 4/21/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	20

Depth (ft.)	Lithology	Description
0 to 12	clay loam	gray
12 to 14	clay	lt gray
14 to 20	sandy clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	14	40
2	NEW	PVC Screen	14	19	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 10	to 0	1
Bentinite	from 12	to 10	1
Sand	from 20	to 12	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 23. Well ID GW13B.Tracking number 181921

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.24: Wells Report GW13B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: FM 665 and West Oso Creek , Corpus Christi, TX

Date Drilling: started: 5/19/2009; completed: 5/19/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	12

Depth (ft.)	Lithology	Description
0 to 4	clayey loam	dark gray
4 to 7	clay	dark gray
7 to 12	clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc.	Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casing Screen
2	NEW	PVC	Riser	0	7	40
2	NEW	PVC	Scree	7	12	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 3	to 0	1
Bentinite	from 5	to 3	1
Sand	from 12	to 5	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) ____ with ____ ft.

drawdown ____ hrs.

Comments: Site 25. Well ID GW14A.Tracking number 181922

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.25: Wells Report GW14A

Figure E.26: Wells Report GW14B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well SH 44 and Oso Creek , Corpus Christi, TX

Date Drilling: started: 5/18/2009 completed: 5/18/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	14

Depth (ft.)	Lithology	Description
0 to 4	clay loam	gray
4 to 8	clay	dark gray
11 to 14	sandy clay	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	9	40
2	NEW	PVC Scree	9	14	0.01

Surface Completion: Surface slab installed

Water Level: static level (ft.) no data below land surface; Date; Artesian flow no data gpm; Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 5	to 0	1
Bentinite	from 7	to 5	1
Sand	from 14	to 7	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test: Type test: no data; Yield: (gpm) with ft.; drawdown hrs.

Comments: Site 26. Well ID GW15A.Tracking number 181924

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well FM 665 and West Oso Creek , Corpus Christi, TX

Date Drilling: started: 5/19/2009 completed: 5/19/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	20

Depth (ft.)	Lithology	Description
0 to 5	loam	dark gray
6 to 20	clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion:

Figure E.27: Wells Report GW15A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well SH 44 and Oso Creek , Corpus Christi, TX

Date Drilling: started: 5/18/2009 completed: 5/18/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	25

Depth (ft.)	Lithology	Description
0 to 4	clay loam	gray
4 to 5	clay	dark gray
6 to 10	clay	very dark gray
10 to 18	sandy clay	lt gray
18 to 25	sandy clay	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc.	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	20	40
2	NEW	PVC Scree	20	25	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 16	to 0	1
Bentinite	from 18	to 16	1
Sand	from 25	to 18	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above di no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 26. Well ID GW15B.Tracking number 181925

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.28: Wells Report GW15B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 4824 S. Oso Pkwy, Corpus Christi, TX

Date Drilling: started: 4/20/2009 completed: 4/20/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	10

Depth (ft.)	Lithology	Description
0 to 10	sandy clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	5	40
2	NEW	PVC Screen	5	10	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 2	to 0	1
Bentinite	from 4	to 2	1
Sand	from 10	to 4	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 30. Well ID GW16A.Tracking number 181927

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.29: Wells Report GW16A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 4824 S. Oso Pkwy, Corpus Christi, TX

Date Drilling: started: 4/20/2009 completed: 4/20/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	14

Depth (ft.)	Lithology	Description
0 to 14	sandy clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	9	40
2	NEW	PVC Screen	9	14	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 5	to 0	1
Bentinite	from 7	to 5	1
Sand	from 14	to 7	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 30. Well ID GW16B.Tracking number 181929

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.30:: Wells Report GW16B

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: 4876 S. Oso Pkwy, Corpus Christi, TX

Date Drilling: started: 4/20/2009; completed: 4/20/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	11

Depth (ft.)	Lithology	Description
0 to 11	sandy clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ____ to (ft.) ____

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	6	40
2	NEW	PVC Screen	6	11	0.01

Surface Completion: Surface slab installed

Water Level: static level (ft.) no data below land surface; Date; Artesian flow no data gpm; Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 2	to 0	1
Bentinite	from 4	to 2	1
Sand	from 11	to 4	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test: Type test: no data; Yield: (gpm) ____ with ____ ft. drawdown ____ hrs.

Comments: Site 33. Well ID GW17A. Tracking number 181930

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) ____ (Licensed well driller) (Signed) ____ (Registered Driller Trainee)

Figure E.31:: Wells Report GW17A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 4876 S. Oso Pkwy, Corpus Christi, TX

Date Drilling: started: 4/20/2009 completed: 4/20/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	15

Depth (ft.)	Lithology	Description
0 to 15	sandy clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	10	40
2	NEW	PVC Screen	10	15	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 6	to 0	1
Bentinite	from 8	to 6	1
Sand	from 15	to 8	3

Method used Hand mixed

Cemented by ECI

Distance to septic system field lines or other contamination no data

Method of verification of above distance no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments Site 33. Well ID GW17B. Tracking number 181931

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.32: Wells Report GW17B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well 8020 South Staples, Corpus Christi, TX

Date Drilling: started: 4/22/2009 completed: 4/22/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	12

Depth (ft.)	Lithology	Description
0 to 4	sandy clay	gray
6 to 9	clay	gray
10 to 12	sandy clay	lt gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	7	40
2	NEW	PVC Screen	7	12	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 3	to 0	1
Bentinite	from 5	to 3	1
Sand	from 12	to 5	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 36. Well ID GW19A. Tracking number 181933

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.33: Wells Report GW19A

Center for Water Supply Studies Well Report Form

Owner: CWSS Address: 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well: 8020 South Staples, Corpus Christi, TX

Date Drilling: started: 4/22/2009; completed: 4/22/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	19

Depth (ft.)	Lithology	Description
0 to 4	loamy silt	it gray
5 to 14	sandy clay	it gray
15 to 19	clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) ; to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	14	40
2	NEW	PVC Screen	14	19	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.): no data below land surface

Date:

Artesian flow: no data gpm

Date:

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 10	to 0	1
Bentinite	from 12	to 10	1
Sand	from 19	to 12	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 36. Well ID GW19B. Tracking number 181934

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name: EnviroCore Inc Well Driller's License No.: 4694

Address: 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.34:: Wells Report GW19B

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Ayers St. and Oso Creek Corpus Christi, TX

Date Drilling: started: 5/15/2009 completed: 5/15/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	12

Depth (ft.)	Lithology	Description
0-12	sandy clay	it gray

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval: from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, Etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	7	40
2	NEW	PVC Screen	7	12	0.01

Surface Completion: Surface slab installed

Water Level: static level (ft.) no data below land surface; Date; Artesian flow no data gpm; Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 3	to 0	1
Bentonite	from 5	to 3	1
Sand	from 12	to 5	3

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test: Type test: no data; Yield: (gpm) with ft.; drawdown hrs.

Comments: Site 39. Well ID GW20A. Tracking number 181935

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.35:: Wells Report GW20A

Center for Water Supply Studies Well Report Form

Owner CWSS Address 6300 Ocean Drive, Corpus Christi, TX 78412

Address of Well Ayers St. and Oso Creek Corpus Christi, TX

Date Drilling: started: 5/15/2009 completed: 5/15/2009

Type of Work: New Well

If Public Supply Well, were plans submitted to the TNRCC? --

Proposed Use: Monitor

Diameter of Hole:

Dia (in.)	From (ft.)	To (ft.)
6.5	0	20

Depth (ft.)	Lithology	Description
0 to 5	clay	tain gray
5 to 13	clay	gray
13 to 16	clay	lt gray
16 to 20	silty clay	brown

Drilling Method: Hollow Stem Auger

Other:

Borehole Completion: no data

If Gravel Packed give interval from (ft.) to (ft.)

Casing, Blank Pipe, and Well Screen Data:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen mfg., if comm	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
2	NEW	PVC Riser	0	15	40
2	NEW	PVC Screen	15	20	0.01

Surface Completion: Surface slab installed

Water Level:

static level (ft.) no data below land surface

Date

Artesian flow no data gpm

Date

Cementing Data: [Rule 338.44(1)]

			No. of sacks used
Cemented (ft.)	from 11	to 0	1
Bentinite	from 13	to 11	
Sand	from 13	to 20	

Method used: Hand mixed

Cemented by: ECI

Distance to septic system field lines or other contamination: no data

Method of verification of above distance: no data

Well Test:

Type test: no data

Yield: (gpm) with ft.

drawdown hrs.

Comments: Site 39. Well ID GW20B.Tracking number 181937

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items will result in the log(s) being returned for completion and resubmittal.

Company Name EnviroCore Inc Well Driller's License No. 4694

Address 6913 Meadowbreeze Pkwy, Corpus Christi, TX 78414

(Signed) (Licensed well driller) (Signed) (Registered Driller Trainee)

Figure E.36:: Wells Report GW20B