Surface Water Quality Monitoring and Additional Data Collection Activities to Support the Implementation of the Plum Creek Watershed Protection Plan

FINAL REPORT
TSSWCB PROJECT #10-07

Guadalupe-Blanco River Authority

FUNDING PROVIDED THROUGH A CLEAN WATER ACT §319(h) NONPOINT SOURCE GRANT FROM THE TEXAS STATE SOIL AND WATER CONSERVATION BOARD AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY

Introduction

Plum Creek rises in Hays County north of Kyle and runs south through Caldwell County, passing Lockhart and Luling, and eventually joins the San Marcos River at their confluence, north of Gonzales County. Plum Creek is 52 miles in length and has a drainage area of 389 mi^2. Plum Creek has been listed as impaired on the Texas 303(d) List since 2004 due to bacterial contamination. Again, in the *2008 Texas Water Quality Inventory and 303(d) List*, Plum Creek (Segment 1810) was listed as impaired because of elevated bacteria concentrations. The *Inventory* also noted that Plum Creek exhibited nutrient enrichment concerns for ammonia, nitrate+nitrite nitrogen and total phosphorus. In April of 2006, TSSWCB and Texas A&M AgriLife Extension established the Plum Creek Watershed Partnership (PCWP). The PCWP Steering Committee completed the "Plum Creek Watershed Protection Plan" in February 2008, and the plan was subsequently accepted by EPA in July 2009. Because of this, in the 2012 Integrated Report, Plum Creek was moved from *Category 5c*, to *Category 4b*. Category 4b describes those stream segments where other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future, i.e. implementation of best management practices described in the watershed protection plan.

Information about the PCWP and the Watershed Protection Plan is available at http://plumcreek.tamu.edu/. Sources of pollutants identified in the Plum Creek WPP include urban storm water runoff, pet waste, failing or inadequate on-site sewage facilities (septic systems), wastewater treatment facilities, livestock, wildlife, invasive species (feral hogs), and oil and gas production.

Originally, the Plum Creek WPP was to be developed using only existing water quality data. However, discussions with stakeholders identified data gaps which would make source identification and establishment of water quality goals difficult. Accurate source identification is key to prioritizing implementation projects for funding. Through Texas State Soil and Water Conservation Board (TSSWCB) project 03-19, *Surface Water Quality Monitoring to Support Plum Creek Watershed Protection Plan Development*, the Guadalupe-Blanco River Authority (GBRA) collected water quality data to fill the identified data gaps. During the project, sampling of water quality data was severely hampered by a prolonged drought that covered the watershed, causing the tributaries to run dry and the springs to slow to almost negligible flow. To avoid a suspension of data collection the TSSWCB funded a stop gap monitoring project, 10-54, *Surface Water Quality Monitoring to Support the Implementation of the Plum Creek WPP*, until this project (10-07) could begin.

Implementation of the Plum Creek WPP is currently underway. To demonstrate improvements in water quality, the Plum Creek WPP describes a water quality monitoring program designed to evaluate the effectiveness of Best Management Practices (BMPs) implemented across the watershed and their impacts on instream water quality. Water quality data will be used in the adaptive management of the WPP in order to evaluate progress in implementing the Plum Creek WPP and achieving water quality restoration.

Project Overview

Through this project, GBRA continued to collect surface water quality monitoring (SWQM) data to characterize the Plum Creek watershed, including the contributing wastewater effluents. Monitoring data is used to assess and evaluate the effectiveness of the BMPs that have been or will be implemented in the watershed as a result of the Plum Creek WPP. The sampling regime included diurnal, spring flow, storm event and targeted monitoring under more typical base flow conditions from March 2011 through August 2014. The project has been extended in order to continue stream monitoring until the new SWQM project has an approved Quality Assurance Project Plan (QAPP).

The monitoring regime attempted to provide a more complete and representative data set to characterize the Plum Creek watershed and document water quality improvements.

GBRA performed the majority of the work under this project including technical and financial supervision, preparation of status reports, coordination with local stakeholders, surface water quality monitoring sample collection and analysis, and data management. GBRA participated in the PCWP, Steering Committee, and Technical Advisory Group (TAG) in order to communicate project goals, activities and accomplishments to affected parties. Through funding from an associated project (TSSWCB Project No. 11-07, *Coordinating Implementation of the Plum Creek Watershed Protection Plan*), Texas A&M University maintained the project's webpage http://www.gbra.org/plumcreek/ for the dissemination of information.

GBRA collected data under an approved QAPP to ensure data of known and acceptable quality was generated in this project. The QAPP was consistent with *EPA Requirements for Quality Assurance Project Plans (QA/R-5)*, the *TSSWCB Environmental Data Quality Management Plan*, and various Texas Commission on Environmental Quality (TCEQ) guidelines for monitoring procedures and methods. Figure 1 is a map of the routine monitoring locations, identified by task. The list of sites and associated tasks can be found in Appendix A.

Routine ambient water quality data was collected monthly at 3 main stem stations by GBRA (17406, 12640 and 12647) through the Clean Rivers Program (CRP). Through this project, GBRA conducted routine ambient monitoring at an additional 5 sites monthly, collecting field, conventional, flow and bacteria parameter groups.

GBRA attempted to collect targeted watershed monitoring at 35 sites twice per season, once under dry weather conditions and once under wet weather conditions, collecting field, conventional, flow and bacteria parameter groups. Spatial, seasonal and meteorological variation was captured in these snapshots of watershed water quality but was severely hampered by the prolonged drought.

Beginning in the third quarter of FY2013, GBRA installed refrigerated automated samplers in order to conduct storm event monitoring at 3 urban/residential sites, collecting field, conventional, flow and bacteria parameter groups.

GBRA conducted 24-hour Dissolved Oxygen (DO) monitoring at 8 sites monthly during the index period collecting field and flow parameter groups. These sites were the same as the sites for routine ambient monitoring. GBRA currently maintains a continuous water quality monitoring module that collects the flow and field parameters every fifteen minutes. Sampling period extends over 8 months during the index period of each year of the project.

GBRA conducted effluent monitoring at seven wastewater treatment facilities (WWTFs) once per month collecting field, conventional, flow, bacteria and effluent parameter groups. Monitoring of the wastewater effluent was used to characterize the WWTF contributions to flow regime and pollutant loadings. To supplement the data collected at the WWTFs, GBRA compiled all the weekly permit effluent monitoring data submitted by permitees that included BOD/CBOD, total suspended solids, volatile suspended solids (if available), *E. coli*, ammonia nitrogen and total phosphorus from seven WWTFs.

GBRA conducted spring flow monitoring at 3 springs once per season collecting field, conventional, flow and bacteria parameter groups. Spatial and seasonal variation in spring flow was captured. This monitoring component was used to characterize spring contributions to flow regime and pollutant loadings.

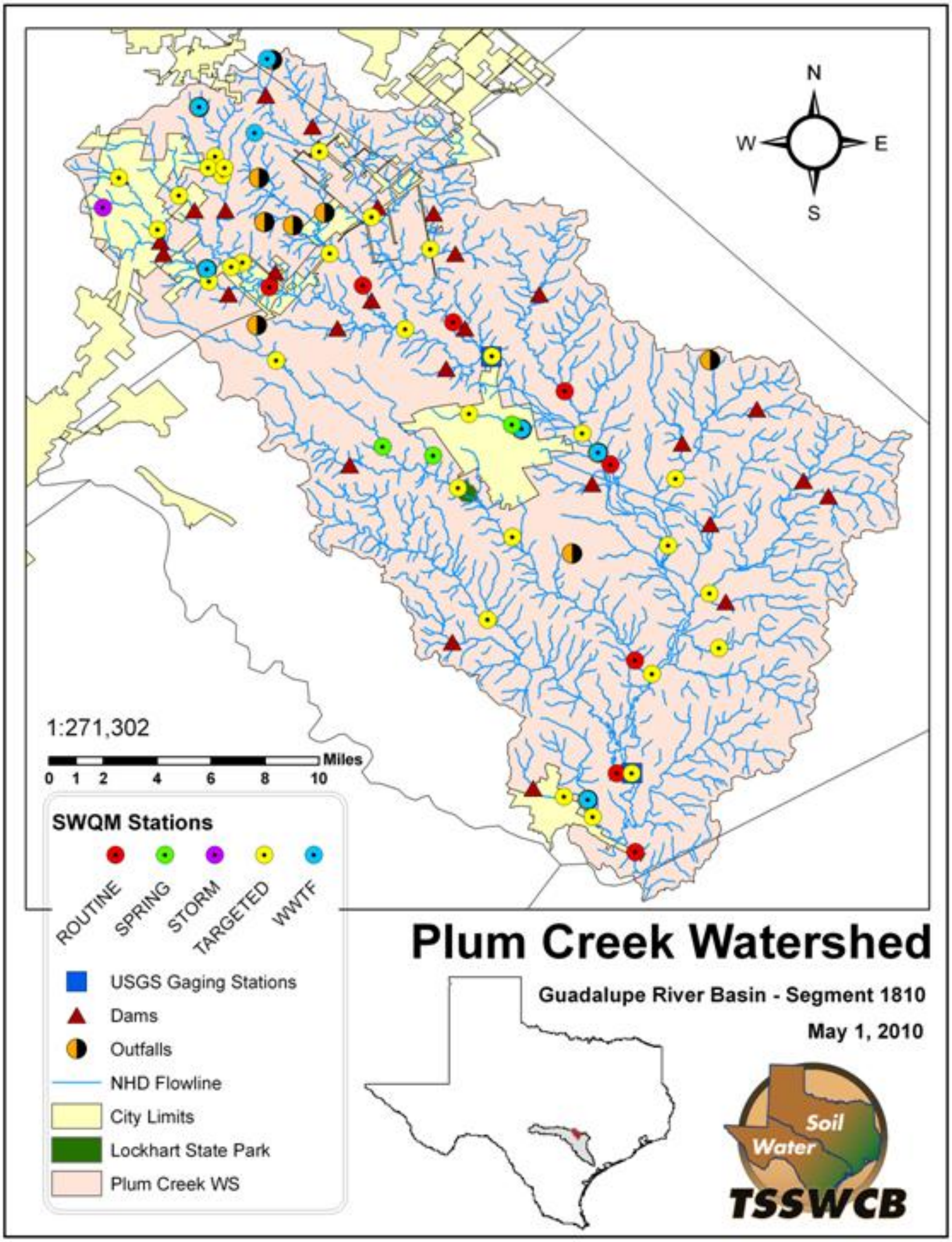

Figure 1. Map of sampling locations

In 2014 12 wells were inventoried in order to provide water quality and meta data (water depth, installation method, date of installation, cased, sealed or open, use of water, land use in immediate area and proximity to Plum Creek or tributary) from shallow wells that are in the Leona Geologic formation within the Plum Creek watershed, to determine if there is recharge of the Leona by the effluent-dominated Plum Creek or impacts of septic tanks to the shallow groundwater.

When the load duration curves for the WPP were being developed there was an observed loss of flow between mid- and lower index sites. As a result of this observation, the need for a gain/loss study was identified to better define the relationship between surface flows and groundwater recharge in the Plum Creek watershed. The United States Geological Survey (USGS) conducted a gain/loss study on the Plum Creek watershed, based on five locations within the watershed. The study included two synoptic (manually-collected) surveys. USGS provided a tabulation of the data collected. In general, in the Lockhart section of Plum Creek, there are some gains from the Lockhart springs. Also, the wastewater discharge are a primary influence on the base flow in the upper reaches of Plum Creek and the City of Luling No. 2 wastewater treatment plant discharge likely contributed to base flows in the lower reaches of Plum Creek.

Project Highlights

Interlocal Agreement for Funding of Local Watershed Coordinator

Since 2008 Texas A&M AgriLife Extension served as the watershed coordinator through the development and implementation of the WPP. Extension secured funding for implementation measures through grants, tracked the progress of implementation, and evaluated and reported water quality trends resulting in the implementation of management measures. As funding for facilitation by Extension was drawing to an end, GBRA, along with AgriLife and TSSWCB Staff, initiated discussions within the PCWP, looking for a means to sustain the progress on implementing the Plum Creek WPP. Twelve funding partners stepped up to participate in an interlocal agreement, drafted by GBRA legal counsel, which provides matching funds to establish a local watershed coordinator. The WPP states, “In addition to technical and financial assistance required for implementation of management measures and outreach programs, it is recommended that a full-time [Watershed] Coordinator be employed to facilitate continued progress [throughout the 10-year implementation schedule].” The local watershed coordinator oversees project activities, seeks additional funding, organizes and coordinates regular updates for the Plum Creek Watershed Partnership, maintains the website, and coordinates outreach and education efforts in the watershed.

GBRA made presentations to the funding partners’ boards and councils to explain the interlocal agreement and explain the distribution of funding allotments. In July 2011 the three-year interlocal agreement was signed and the work to find a local coordinator began. In March 2012 a local coordinator was hired. GBRA now serves as the managing partner for the TSSWCB Project 11-07, *Coordinating Implementation of the Plum Creek Watershed Protection Plan,* which funds the local coordinator.

Work on related grants

GBRA staff assisted cities in the watershed to write, obtain, and administer implementation grants. The cities of Kyle and Lockhart obtained Clean Water Act Section 319(h) grants through TCEQ. GBRA provided assistance in the managing of the grants. Primarily, GBRA provided assistance in writing the quality assurance project plans required for monitoring and mapping that were a part of each city’s grant and training if water quality samples were to be collected.

Other opportunities to assist entities in the watershed included assistance with the City of Lockhart's Keep Texas Beautiful Beautification grant, application for a grant to establish a riparian network in the watershed, application for a grant to work with the USGS on an isotope study that looked at sources of nitrates by looking at the isotopic signatures of nitrogen and oxygen.

Outreach and education

GBRA Education Department conducted outreach and education activities, including dissemination of information about the Plum Creek, the Partnership and related projects. Each school year, a Watershed Model, highlighting the Plum Creek watershed, is taken to classrooms located in the watershed. Over 4000 4th and 5th graders and over 80 teachers from the Hays Consolidated, Lockhart and Luling Independent School Districts learn about Plum Creek, its tributaries, and nonpoint source pollution. The classroom presentation was expanded to include a semester long water quality monitoring project. Students from selected classrooms had the opportunity to perform water quality analyses several times in the semester on water samples collected from the Plum Creek watershed or one of its tributaries. Some of the field parameters included dissolved oxygen, pH, and nitrate nitrogen.

GBRA also provided brochures titled "Don't be Clueless about Water Quality" to real estate offices for new homeowners in the Plum Creek watershed.

Stream Clean Ups

GBRA participated in the annual stream clean-ups held in Lockhart each fall, serving as facilitator until the local watershed coordinator was hired in 2012. GBRA scheduled planning meetings, set agendas, compiled and stored supplies, mailed letters to businesses for support, printed fliers, prepared news releases and maintained the accounting of local sponsorships. GBRA served as a site leader and provided a booth in the environmental fair that was held in conjunction with the annual clean-up. The GBRA booth at the environmental fair demonstrated the watershed model that includes a to-scale model of the Plum Creek watershed. After the event, GBRA staff prepared agendas for each post-event follow-up meeting and prepared certificates of appreciation for the sponsors and team leaders. Additionally, GBRA assisted with the City of Kyle's stream clean-up held each spring in conjunction with Earth Day, including planning, sponsorship and participation in their environmental fair.

Data transmittal and information transfer

The data collected in this project is uploaded to the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). A completed Data Summary was submitted with each data submittal. Corrective Action Reports were submitted by the GBRA field staff or the laboratory if there was a problem or deficiency encountered. Only three data sets were incomplete through August 2014 due to GBRA error, requiring a Corrective Action Report. If a problem occurred during a sampling event, every attempt was made to recollect the sample if the flow conditions remained the same so there was no loss in data. A secondary lab was included in the QAPP in order to perform analyses when there was an instrument failure in the GBRA laboratory. The deficiencies are listed in Table 1.

Table 1. Deficiencies resulting in a loss of data.

Date	Tag No.	Site Name	Deficiency	Explanation
February 2013	TX02968	Elm Creek	No TSS; No TKN or NH3 reported	TSS – analysis not performed within holding time; TKN/NH3-left off of chain of custody so no analyses performed
January 2014	TX03459; 03458; and 03469	Unnamed Trib; Plum Creek downstreamof NRCS #1; Plum Creek at Lehman Road	No TKN reported	Instrument failure
March 2014		All Routine Samples	No chlorophyll a reported	Analyst error

A critical part of the project has been to disseminate information on Plum Creek and the project to stakeholders and other interested parties throughout the state. GBRA summarized the results and activities of this project through inclusion in GBRA's Clean Rivers Program *Basin Highlights Report* and *Basin Summary Report*. Additionally, the results and activities of this project were summarized in quarterly reports to the stakeholders of the PCWP Steering Committee and in updates to the Plum Creek WPP.

Other meetings that GBRA attended in order to represent the project and/or the efforts of the Plum Creek Watershed Partnership included the Texas Water Utilities Association Operator District meeting, meetings on the Kyle Wastewater Reuse Feasibility Study, meetings with the staff of the Barton Edwards Groundwater District to discuss the reuse of Buda Wastewater effluent on rock and gravel operations over the transition zone of the aquifer. GBRA attended the Riparian Summit and local training events, the TCEQ's Environmental Summit held each year in the region and the quarterly TSSWCB Watershed Coordination Steering Committee meetings. GBRA attended these events in order to share information on the monitoring project and the status of implementation on Plum Creek. As other watersheds in the Guadalupe River Basin and across the state begin the process of addressing impaired waterbodies or look to protect threatened watersheds, GBRA staff has been called upon to share the Plum Creek watershed protection planning process as well as the Partnership's plans for sustainability.

In order to continue to raise awareness of water quality and stewardship in the Plum Creek watershed and make water quality data available to the public, GBRA installed three kiosks in public locations in Kyle, Lockhart and Luling. These kiosks linked the public to the real-time monitoring site, the project web site, and other pertinent water quality information, such as the GBRA River of Life and on-line training modules including the module on septic system operations (developed through TCEQ CWA Section 106 funds). The kiosks were available at three public libraries in the cities in the watershed. News releases were issued as each kiosk was made available at a site. As the project progressed, the kiosks were maintained and updated. Several times during the project the kiosks were down due to relocation, power or wi-fi issues or access issues. On a quarterly basis, the kiosks were visited remotely to assess the number of visits. The kiosks located in Kyle and Lockhart continue to be well-used. The kiosk installed in the Luling Library was under-utilized due to power and wi-fi issues or the poor location within the library. GBRA has found a new location in Luling. The City of Luling has agreed to relocate the kiosk in a new visitor center that is planned in the coming years.

The project's water quality monitoring schedule was included annually on the coordinated monitoring schedule maintained by TCEQ. As soon as data was reviewed and submitted to TCEQ, GBRA posted monitoring data to the GBRA website for access by the public.

Highlights and Evaluation of Water Quality Monitoring Data

Quality Assurance Project Plan

Water quality data was collected under an approved QAPP. The objective of the quality assurance task was to develop and implement data quality objectives (DQOs) and quality assurance/control (QA/QC) activities in order to ensure data of known and acceptable quality are generated through this project. The QAPP was amended as needed and was renewed annually.

As part of the QA task, GBRA Regional Laboratory staff worked on the standard operating procedure (SOP) for EPA method 1603, for the enumeration of *E. coli*, with the goal to become accredited for the method. Accreditation for EPA Method 1603 was granted in the second quarter of FY2013.

On September 29, 2014 GBRA participated in an audit of the monitoring program by the TSSWCB. The audit included the quality system of the laboratory and the field monitoring protocols. At the exit interview, no major findings were noted.

Routine Monitoring

GBRA conducted routine ambient monitoring at 5 sites monthly, collecting field, conventional, flow and bacteria parameter groups. Routine ambient monitoring is conducted monthly at 3 stations by GBRA (17406, 12640 and 12647) through the CRP. The objective of the routine monitoring was to provide water quality data to assess the effectiveness of implementing the Plum Creek WPP by enhancing current routine ambient monitoring regimes. The scheduling of routine water quality sampling was designed to complement existing routine ambient monitoring regimes such that routine water quality monitoring was conducted monthly at 8 sites in the Plum Creek watershed. GBRA's Regional Laboratory conducted the sample analysis. Field parameters were pH, temperature, conductivity, and dissolved oxygen. Conventional parameters were total suspended solids, turbidity, sulfate, chloride, nitrate nitrogen, ammonia nitrogen, total kjeldahl nitrogen, chlorophyll a, pheophytin, total hardness, and total phosphorus. Flow parameters were collected by gage, electric, mechanical or Doppler, including severity. Bacteria parameters are *E. coli*.

Beginning in April 2011 through September 2014, 42 routine sampling events were conducted. All the main stem sites sampled under the CRP program were flowing and were sampled. Of the routine sites monitored under this project (non-main stem), all at some time or another were dry. Dry Creek at FM 672 (Site no. 20491), had water flowing or had pools to sample only 17% of the time (7 out of 42 events); West Fork Plum Creek at Biggs Road (CR 131) (Site no. 20500) was only flowing or had water in pools 40% of the time (17 out of 42 events); Elm Creek at CR 233 (Site no. 12558) had water to sample only 50% of the time (21 out of 42 events); Brushy Creek at Rocky Road (Site no. 20488) had water to sample only 69% of the time (29 out of 42 events); and, Clear Fork Plum Creek at Salt Flat Road (Site no. 12556) was sampled 81% of the time (34 out of 42 events). The data presented in Table 2 compiles the data collected from 2008 through 2014. Concentrations of *E. coli* at two of the three main stem sites remain above the stream standard of 126 cfu/100 mL.

Table 2. Concentrations of *E. coli* under dry and wet conditions at the routine monitoring sites. Measurements calculated in cfu/100ml.

Site	No. of Samples	Median Flow-Dry (cfs)	E. coli Geomean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow-Wet (cfs)	E. coli Geomean - Wet	Range-Wet	% Change btwn Dry and Wet *	E. coli Geomean 2008-2014**
Plum Creek at Plum Creek Road	55	1.9	400	36-4840	30	8.6	664	64-24000	66.00	476
Plum Creek at CR 202	52	4.2	190	16-1200	33	14.6	440	36->24200	131.58	263
Plum Creek at CR 135	55	5	113	9-1200	31	34	444	26-13000	292.92	180
Clear Fork Plum Creek at Salt Flat Road	43	0.8	84	3-3150	28	4.6	609	41-12030	625.00	175
West Fork Plum Creek at Biggs Road	29	0	41	1-240	23	0.01	247	10-2500	502.44	91
Elm Creek at CR 233	21	0	49	4-690	21	0.01	323	5-17330	559.18	125
Dry Creek at CR 672	6	0.1	160	48-610	12	0.35	870	140-4400	443.75	480
Brushy Creek at Rocky Road	30	<0.01	71	5-1900	19	1.7	455	19-5480	540.85	162

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow geometric mean greater than the water quality standard of 126 organisms/100 mL under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 3 is a compilation of the Total Phosphorus data collected at the routine sites through August 2014. After adding the 2014 data to the data analyzed for the 2014 annual update there was a very slight drop (0.01 mg/L) in the mean concentrations during both dry and wet conditions. This drop was so slight that it is most likely explained by the increase in available sampling events over the extended dry period rather than an improvement in stream conditions. TCEQ uses a screening value of 0.69 mg/L to assess a concern for Total Phosphorus.

Table 3. Concentrations of total phosphorus under dry and wet conditions at the routine monitoring sites. Phosphorus concentration in mg/L.

Site	No. of Samples	Median Flow - Dry	Total P Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow	Total P Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	Tot P Mean 2008-2014**
Plum Creek at Plum Creek Road	56	1.5	3.1	0.04-5.26	29	4.4	1.26	0.27-4.56	-59.35	2.45
Plum Creek at CR 202	52	3.2	1.42	0.5-2.69	33	14.69	0.96	0.19-2.26	-32.39	1.24
Plum Creek at CR 135	56	5	0.97	0.22-2.69	31	28	0.78	0.20-2.12	-19.59	0.92
Clear Fork Plum Creek at Salt Flat Road	42	0.13	0.07	<0.05-0.31	29	5	0.17	<0.05-0.9	142.86	0.11
West Fork Plum Creek at Biggs Road	29	0	0.53	0.06-2.14	23	0.01	0.35	0.07-0.85	-33.96	0.44
Elm Creek at CR 233	21	0	0.13	0.06-0.27	23	0.6	0.16	0.06-0.45	23.08	0.15
Dry Creek at CR 672	6	0.1	0.35	0.23-0.47	12	0.35	0.37	0.17-0.69	5.71	0.35
Brushy Creek at Rocky Road	30	<0.01	0.11	<0.05-0.3	24	3.6	0.13	<0.05-0.37	18.18	0.12

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 0.69 mg/L Total Phosphorus, under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 4 is a compilation of the nitrate-nitrogen data collected from 2008 through August 2014. After adding the 2014 data to the data analyzed for the 2014 annual update there was slight rise in nitrate concentrations at two of the main stem sites (Plum Creek at Plum Creek Road and Plum Creek at CR 135). This slight rise was most likely due to the increase in the percentage of pollutant load of wastewater in the stream in those 8 months with lower base flows due to continued dry period.

Table 4. Concentrations of nitrate-nitrogen under dry and wet conditions at the routine monitoring sites. Nitrate concentrations in mg/L.

Site	No. of Samples	Median Flow - Dry	NO3-N Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow	NO3-N Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	NO3-N Mean 2008-2014**
Plum Creek at Plum Creek Road	56	1.5	16.07	2.68-34.8	29	4.4	7.4	0.37-29.3	-53.95	13.12
Plum Creek at CR 202	52	3.2	6.76	2.53-16.3	53	13	4.16	0.51-11.6	-38.46	5.75
Plum Creek at CR 135	56	5	1.75	<0.05-6.24	31	28	2.38	0.07-7.96	36.00	1.97
Clear Fork Plum Creek at Salt Flat Road	44	0.13	0.61	<0.05-3.02	29	5	0.71	<0.05-2.08	16.39	0.61
West Fork Plum Creek at Biggs Road	27	0	0.32	<0.05-1.06	24	0.01	0.33	<0.05-1.36	3.13	0.32
Elm Creek at CR 233	21	0	0.1	<0.05-0.35	23	0.6	0.27	<0.05-1.39	170.00	0.18
Dry Creek at CR 672	6	0.1	0.22	<0.05-0.8	12	0.35	0.63	<0.05-3.78	186.36	0.49
Brushy Creek at Rocky Road	30	<0.01	0.15	<0.05-0.69	25	3.6	0.25	<0.05-1.44	66.67	0.2

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 1.95 mg/L Nitrate Nitrogen, under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 5 is a compilation of the ammonia-nitrogen data collected from 2008 to August 2014. After adding the 2014 data to the data analyzed for the 2014 annual update there were slight changes, in both directions, most likely explained by the larger data set. Only one site, Plum Creek at Plum Creek Road remains above the TCEQ screening concentration of 0.33 mg/L. This site is the most impacted by the contributions of wastewater.

Table 5. Concentrations of ammonia-nitrogen under dry and wet conditions at the routine monitoring sites. Ammonia concentration in mg/L.

Site	No. of Samples	Median Flow - Dry	NH3-N Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow	NH3-N Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	NH3-N Mean 2008-2014**
Plum Creek at Plum Creek Road	54	1.5	0.43	<0.1-5.62	30	4.4	0.35	<0.1-3.16	-18.60	0.4
Plum Creek at CR 202	51	3.2	0.17	<0.1-0.9	33	13	0.17	<0.1-0.71	0.00	0.17
Plum Creek at CR 135	55	5	0.17	<0.1-0.38	31	27.5	0.21	<0.1-0.66	23.53	0.19
Clear Fork Plum Creek at Salt Flat Road	44	0.13	0.19	<0.1-1.2	30	5	0.18	<0.1-0.36	-5.26	0.19
West Fork Plum Creek at Biggs Road	28	0	0.21	<0.1-0.98	24	0.01	0.23	<0.1-1.91	9.52	0.22
Elm Creek at CR 233	21	0	0.31	<0.1-1.24	22	0.6	0.25	<0.1-1.04	-19.35	0.27
Dry Creek at CR 672	6	0.1	0.23	<0.10-0.46	12	0.35	0.31	<0.1-0.0.76	34.78	0.28
Brushy Creek at Rocky Road	30	<0.01	0.22	<0.1-1.08	24	3.6	0.17	<0.1-0.35	-22.73	0.22

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 0.33 mg/L Ammonia-Nitrogen, under dry conditions.

** Entire data set under all flow conditions through August 2014.

Statistical Analysis for Trends at Routine Sites

Multiple t-tests were conducted to determine the statistical significance of the correlations between concentrations for ammonia nitrogen, nitrate nitrogen, total phosphorus and *E. coli* versus time and stream flow at all eight Plum Creek routine monitoring stations. If the absolute value of the t-statistic was greater than 2 and the p value was less than or equal to a 0.05 significance level, then the correlation between each of the dependent variables and either time or stream flow was considered to be significant.

At station 12640 (Plum Creek at County Road 135) a statistically significant correlation was found between time and several water quality parameters. Ammonia Nitrogen; $t(86)=-3.80$, $p=0.00$, is increasing with time (Figure 2) and Nitrate Nitrogen; $t(86)=-3.68$, $p=0.00$, is also increasing with time (Figure 3). *E. coli*; $t(86)=-2.50$, $p=0.00$, is decreasing with time (Figure 4).

The ammonia nitrogen; $t(86)=3.76$, $p=0.00$, and *E. coli*; $t(86)=2.47$, $p=0.02$, also showed a statistically significant correlation with stream flow. The relationship between stream flow and ammonia nitrogen may explain why the ammonia nitrogen levels are increasing over time. Plum Creek is heavily wastewater dominant and any reduction in stream flows from ambient sources amplifies the effects of ammonia from point source discharges.

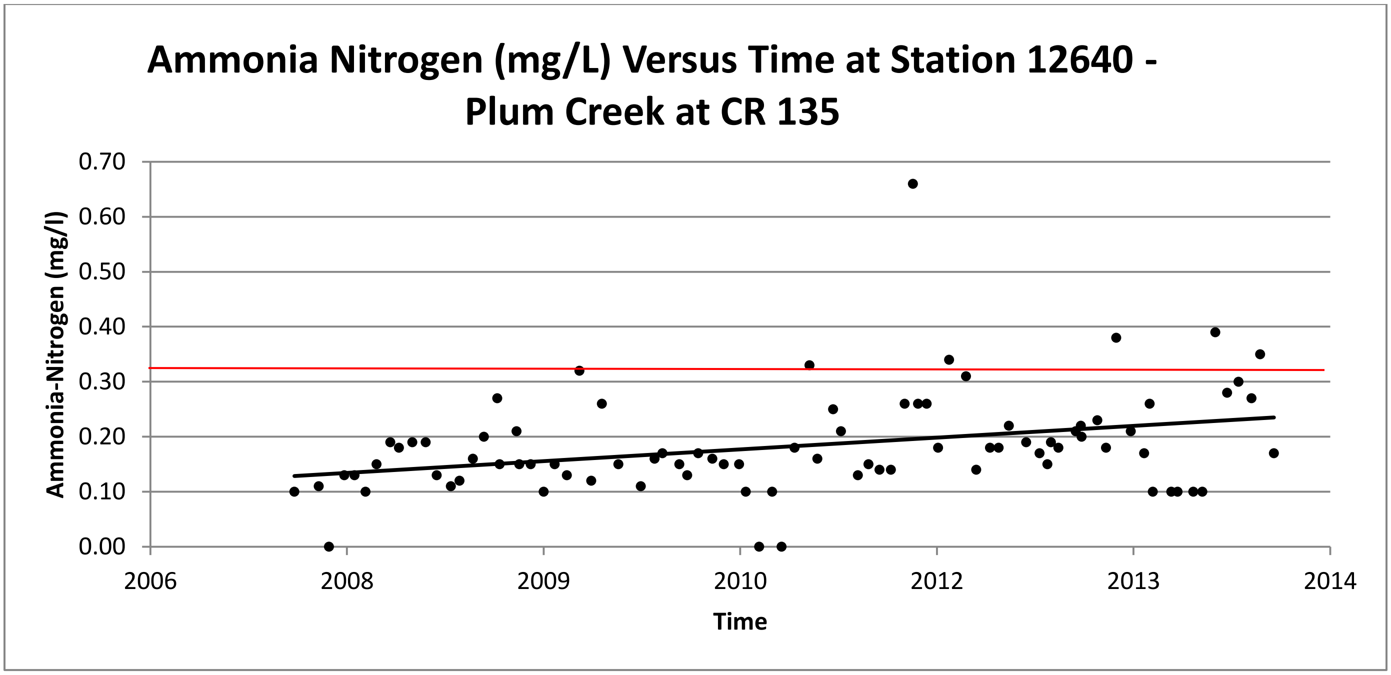

Figure 2. Ammonia Nitrogen versus Time at Station 12640 – Plum Creek at CR 135. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

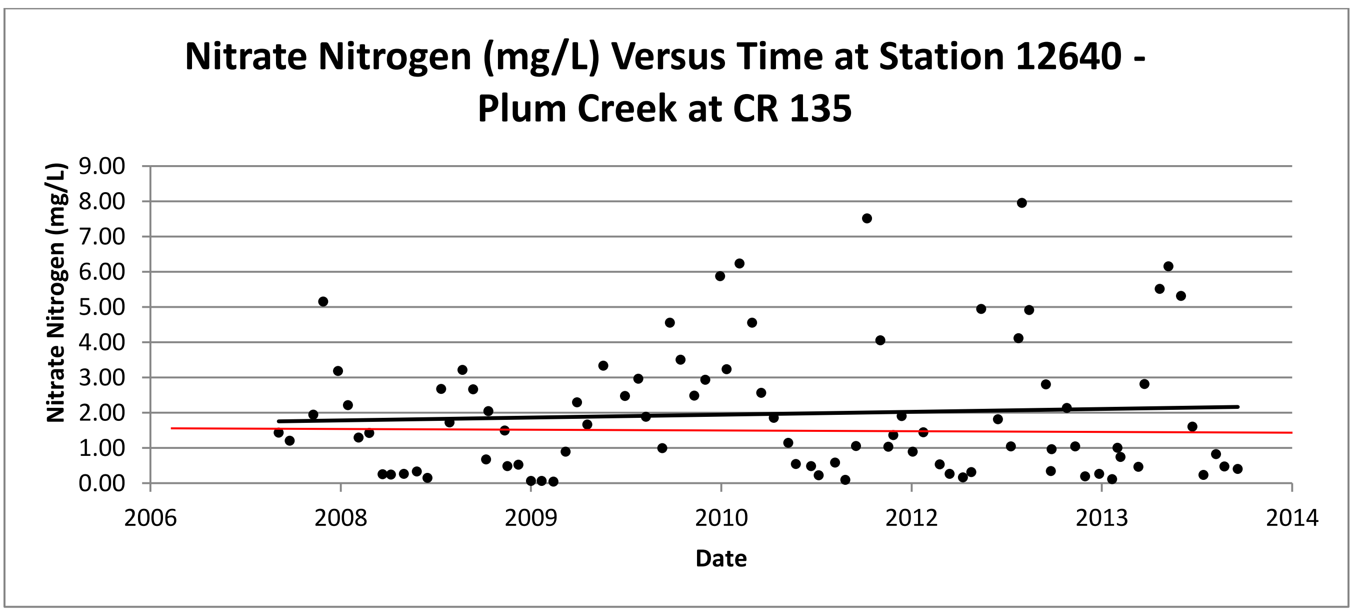

Figure 3. Nitrate Nitrogen versus Time at Station 12640 – Plum Creek at CR 135. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

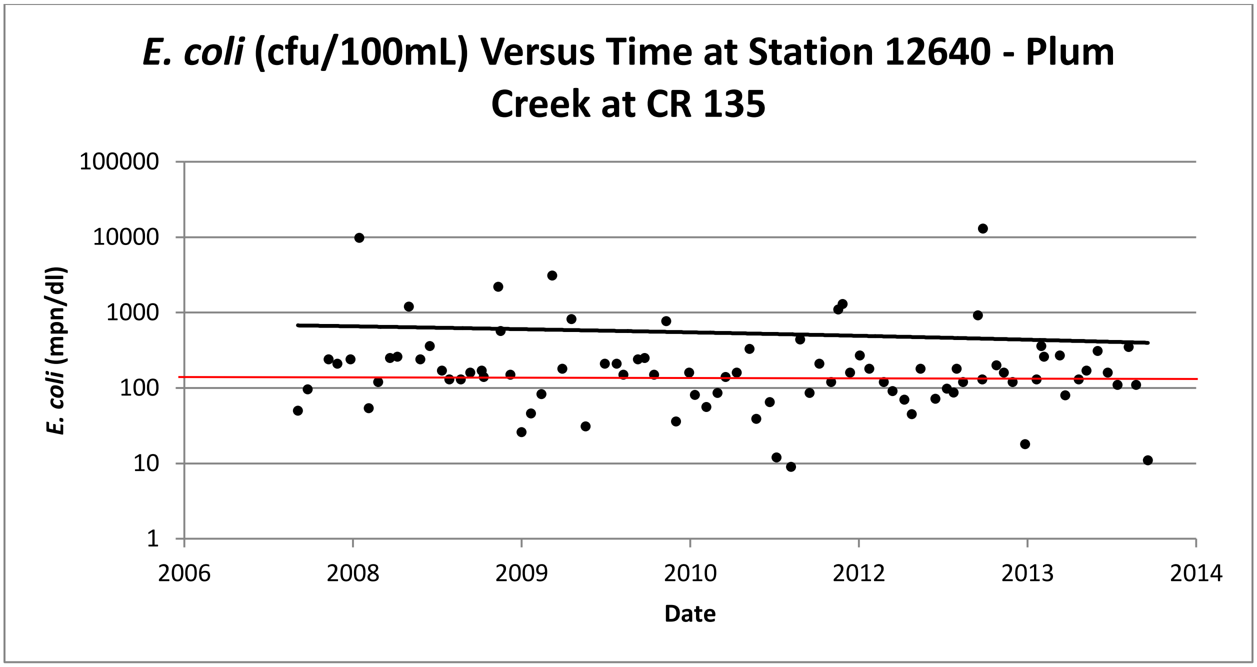

Figure 4. *E. coli* versus Time at Station 12640 – Plum Creek at CR 135. The red line is the recreational stream standard (126 cfu/100 mL). The black line is the trend line.

At station 12647 (Plum Creek at County Road 202) a statistically significant correlation was found between time and several water quality parameters. Ammonia Nitrogen; t(91)=-4.05,p=0.00, is increasing with time (Figure 5) and Nitrate Nitrogen; t(91)=-4.61, p=0.00,is also increasing with time (Figure 6).

The nitrate nitrogen; t(91)=-2.24, p=0.03, and Total Phosphorus; t(91)=-3.35 p=0.00, also showed a statistically significant correlation with stream flow. The relationship between stream flow and nitrate nitrogen may explain why the nitrate nitrogen levels are increasing over time. Much like ammonia nitrogen, nitrate nitrogen is a common wastewater byproduct from point source discharges that may increase in stream concentrations as stream flows from ambient sources disappear.

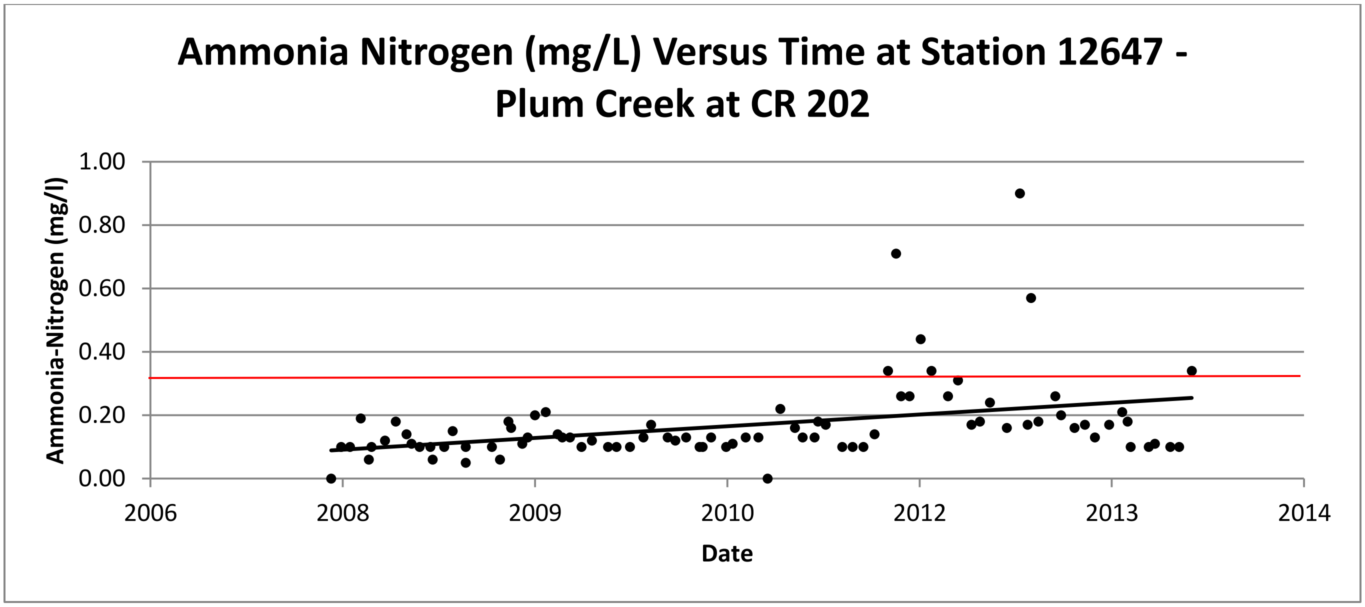

Figure 5. Ammonia-Nitrogen versus Time at Station 12647 - Plum Creek at CR 202. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

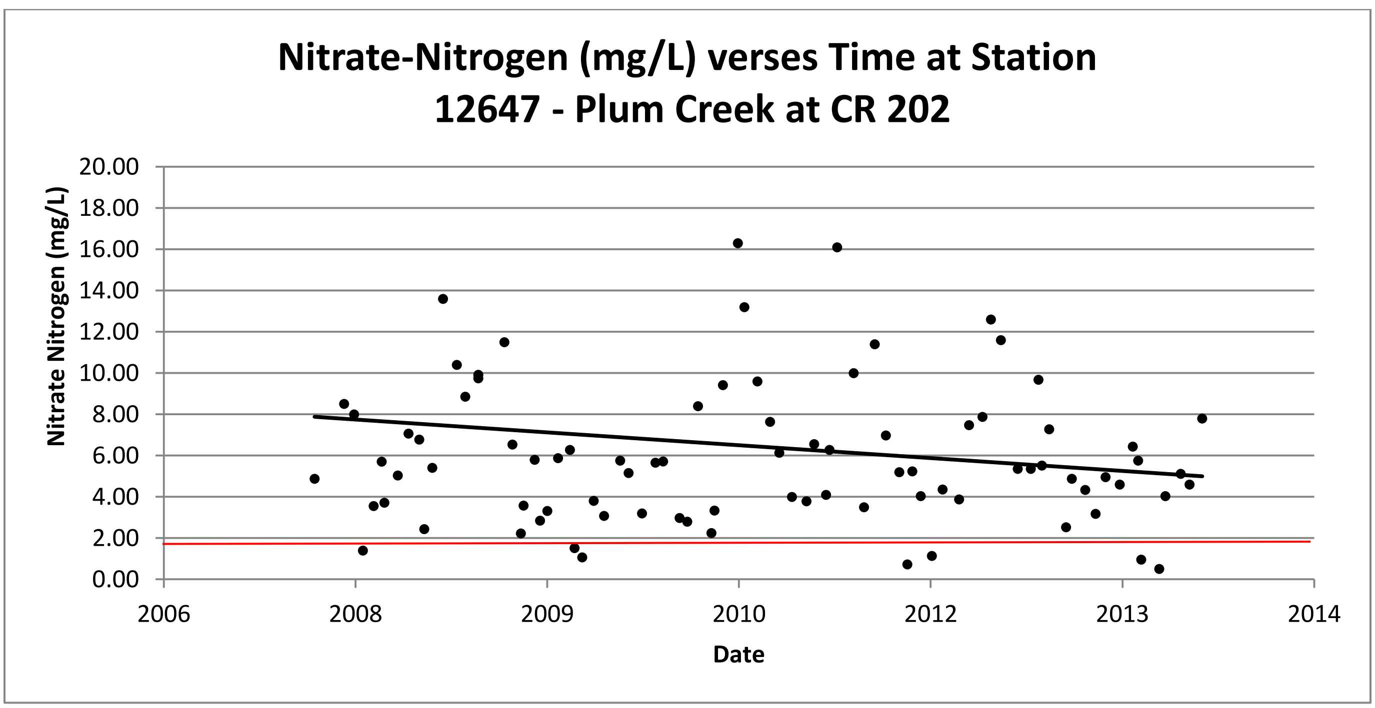

Figure 6. Nitrate-Nitrogen versus Time at Station 12647 - Plum Creek at CR 202. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

At station 17406 (Plum Creek at Plum Creek Road) a statistically significant correlation was found between time and several water quality parameters. Ammonia Nitrogen; $t(86)=-3.82, p=0.00$, is decreasing with time (Figure 7) and Nitrate Nitrogen; t(86)=-4.58, p=0.00, is increasing with time (Figure 8). This station is located downstream of the point source discharges from the City of Buda and the City of Kyle. Ammonia nitrogen is collected by a wastewater treatment plant and converted to nitrate nitrogen through nitrification. The decrease in ammonia nitrogen and increase in nitrate nitrogen in this stream segment may be a sign that these dischargers are becoming more efficient at the treatment process over time.

The Nitrate Nitrogen; t(86)=-2.62, p=0.01, p=0.03, and Total Phosphorus; t(86)=-2.81 p=0.01, and *E. coli*; t(86)=23.34 p=0.00 also showed a statistically significant correlation with stream flow. The monitoring station on this segment is particularly influenced by rainfall runoff events because there is very little natural spring flow upstream of this area.

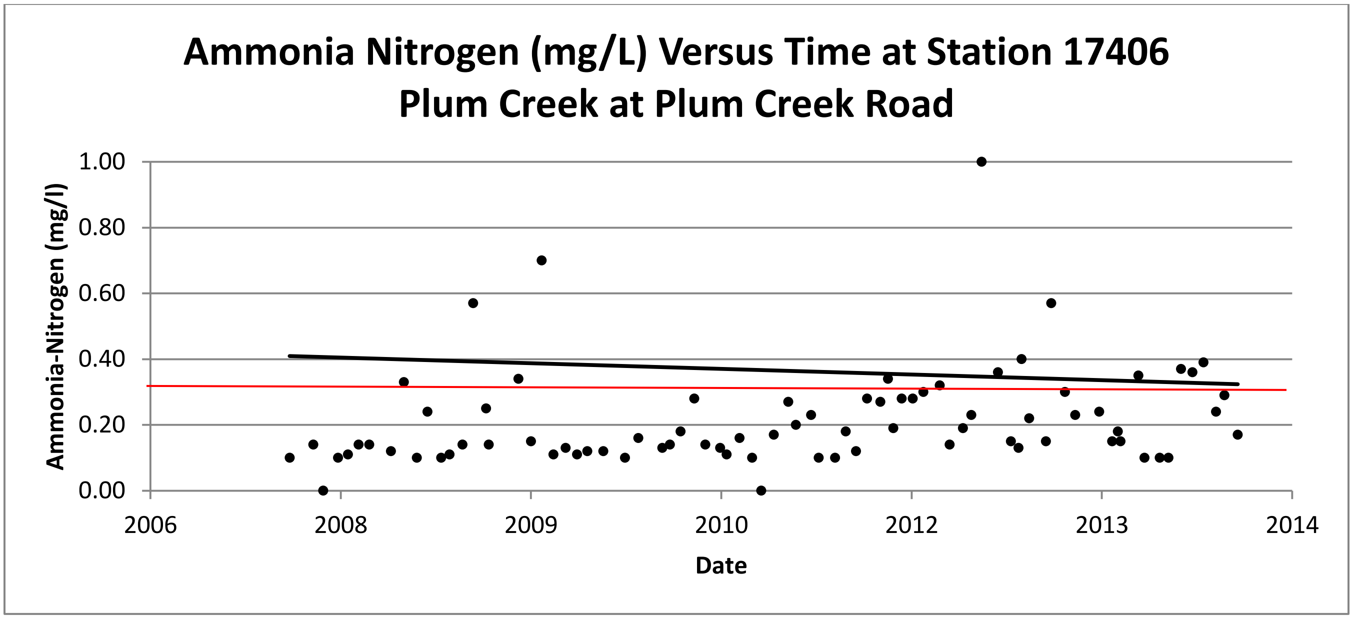

Figure 7. Ammonia-Nitrogen versus Time at Station 17406 - Plum Creek at Plum Creek Road. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

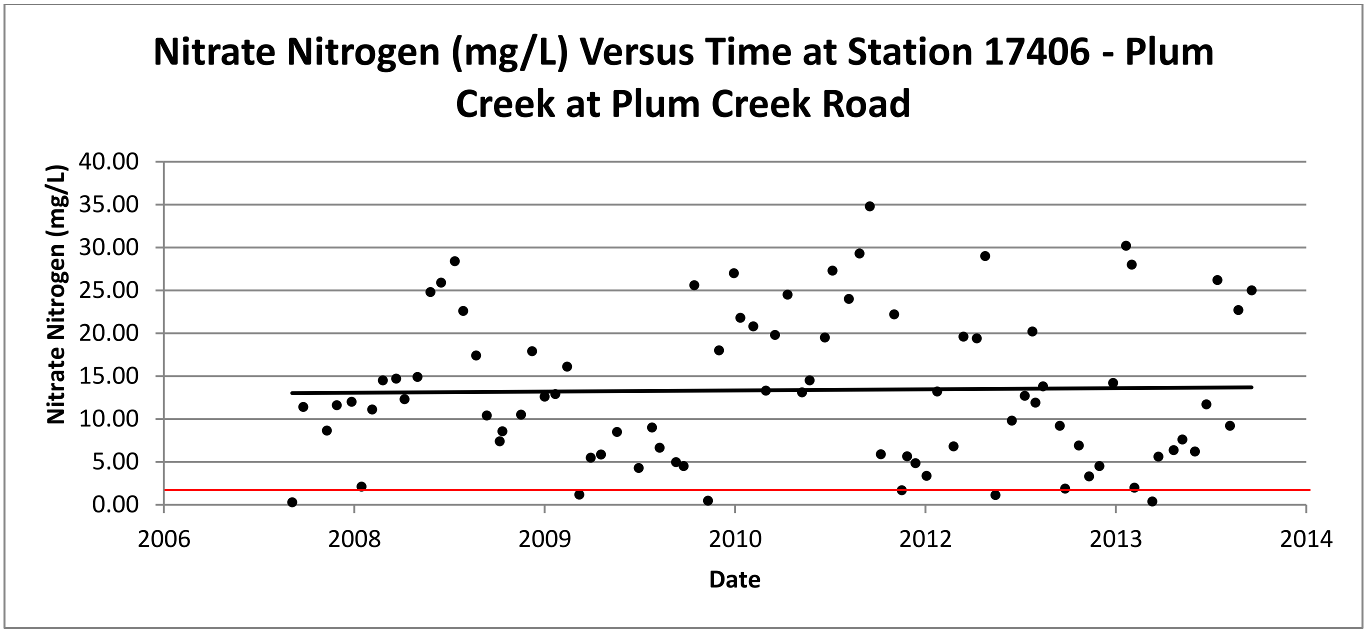

Figure 8. Nitrate-Nitrogen versus Time at Station 17406-Plum Creek at Plum Creek Road. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

At station 20500 (West Fork of Plum Creek at County Road 131) a statistically significant correlation was found between time and several water quality parameters. Total Phosphorus; t(43)=-3.85,p=0.00, is decreasing with time (Figure 9) and *E. coli*; t(43)=-2.46, p=0.02,is increasing with time (Figure 10). This station is located on a large tributary of Plum Creek that is highly influenced by non-point source runoff. This station is also located downstream of heavy agricultural land use and the increasing *E. coli* may be the result of increased use of the creek by farm animals and wildlife during times of drought.

The Nitrate Nitrogen; t(43)=2.53, p=0.02, and *E. coli*; t(43)=7.57 p=0.00 also showed a statistically significant correlation with stream flow. This stream frequently goes dry, and the majority of the samples have been collected during times of little or no stream flow. The correlation between flow and *E. coli* is consistent with a stream that is heavily influenced by nonpoint source.

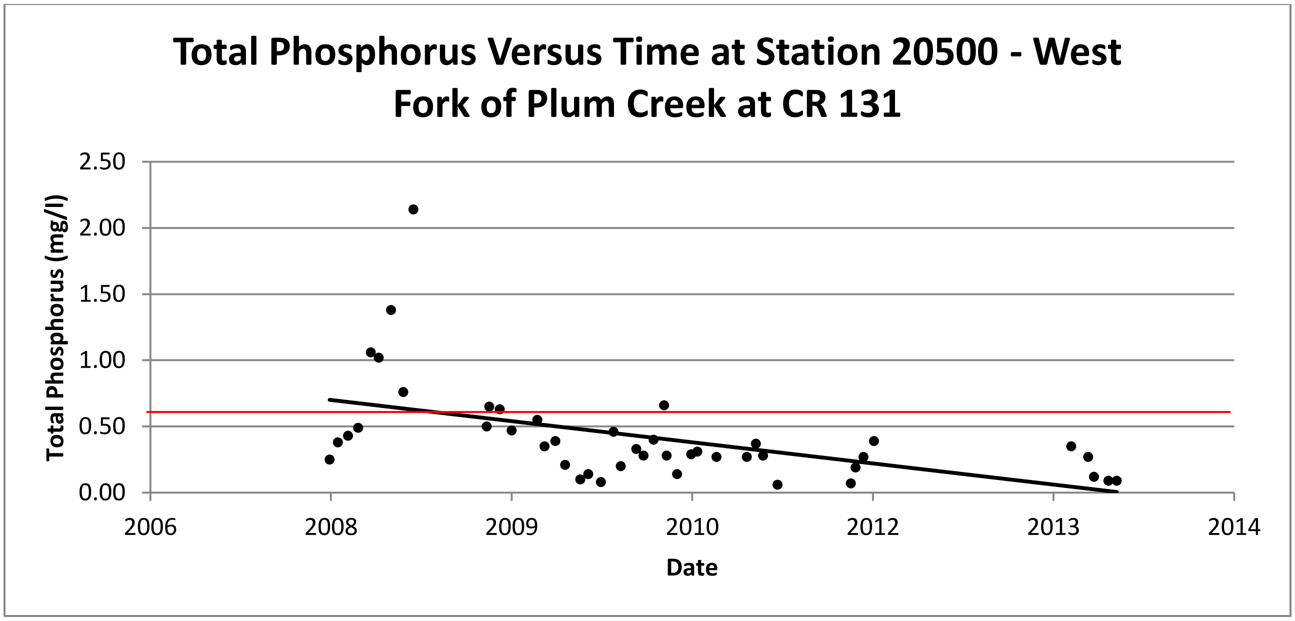

Figure 9. Total Phosphorus versus Time at Station 20500 - West Fork of Plum Creek at CR 131. The red line is the screening concentration (0.69 mg/L) for concerns set by TCEQ. The black line is the trend line.

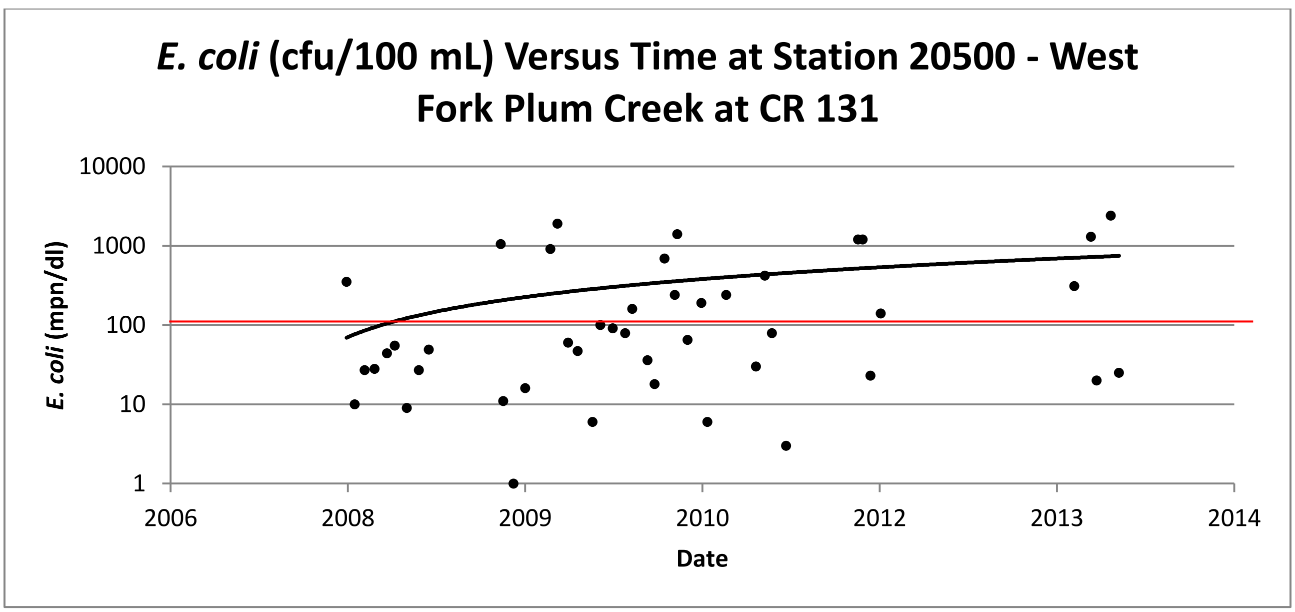

Figure 10. *E. coli* versus Time at Station 12640 – West Fork Plum Creek at CR 131. The red line is the recreational stream standard (126 cfu/100 mL). The black line is the trend line.

At station 12556 (Clear Fork at County Road 128), a statistically significant correlation was found between time and several water quality parameters. Ammonia nitrogen; $t(69)=-2.60, p=0.01$, is increasing with time (Figure 11) and Nitrate nitrogen; $t(69)=-3.02$, $p=0.00$, is decreasing with time (Figure 12). This station is located on a large tributary of Plum Creek that is driven by natural spring flow, but is also heavily influenced by nonpoint source runoff. The changes in nitrogen dynamics at this station may be the result of increased water usage by wildlife and livestock as a result of drought conditions. Additionally, Total Phosphorus; t(69)=4.79, p=0.00, showed a statistically significant correlation with stream flow, which did not significantly impact concentrations over time.

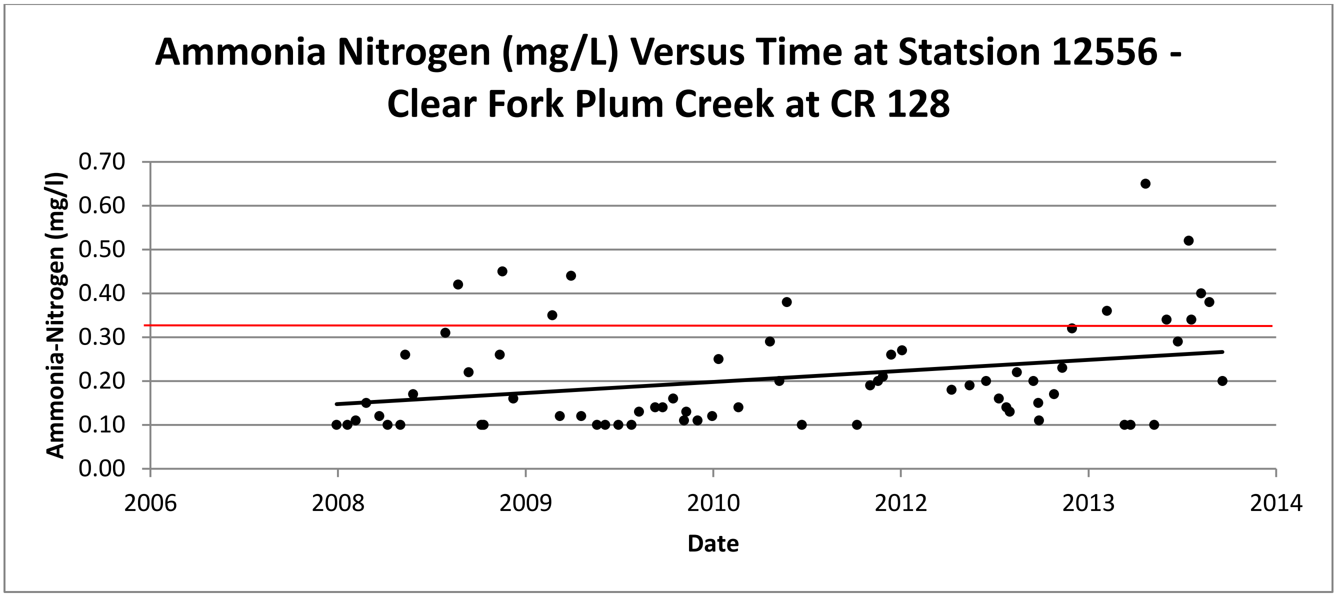

Figure 11. Ammonia-Nitrogen versus Time at Station 12556 – Clear Fork Plum Creek at CR 128. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

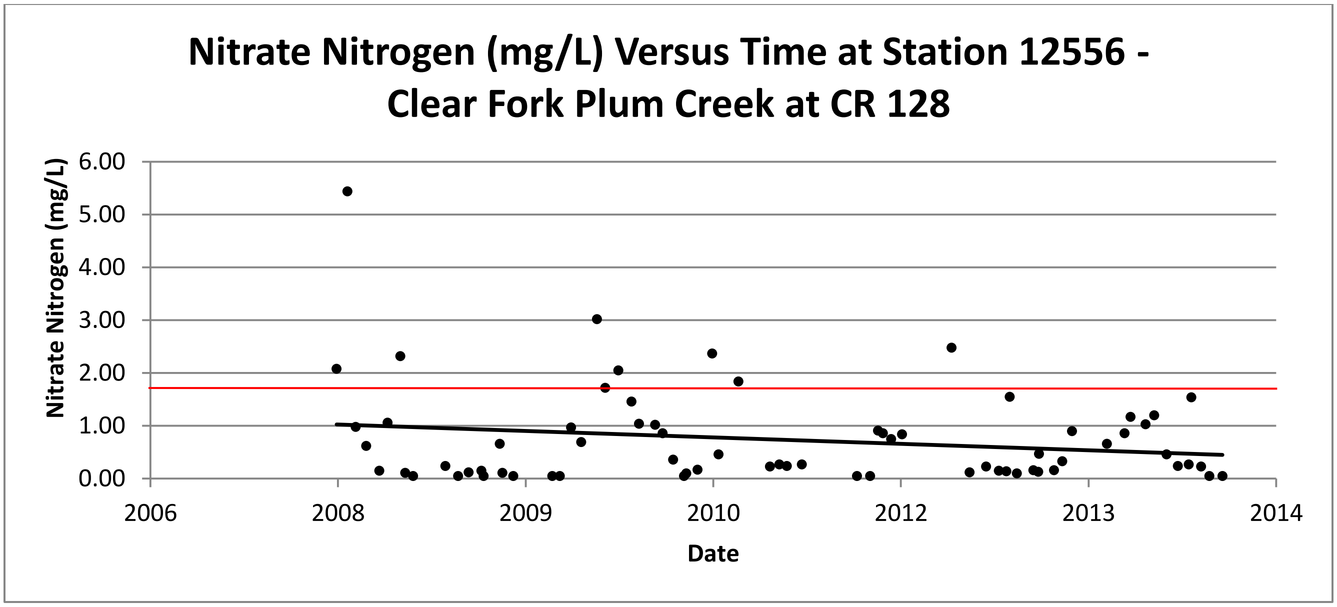

Figure 12. Nitrate-Nitrogen versus Time at Station 12556 – Clear Fork Plum Creek at CR 128. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

At station 12558 (Elm Creek at County Road 233) no statistically significant correlations were found between time and any of the water quality parameters analyzed. This station is located on a large tributary of Plum Creek that is primarily used for agricultural production and is heavily influenced by nonpoint source runoff. The lack of overall samples collected and variability of the stream flows during collection events due to drought conditions may have contributed to the lack of statistically significant correlations at this station. Ammonia Nitrogen; t(40)=2.66, p=0.01, did show a statistically significant correlation with stream flow, but this did not appear to have a significant effect on the concentration of ammonia over time.

At station 20488 (Brushy Creek at Rocky Road) a statistically significant correlation was found between time and increasing Ammonia Nitrogen; t(51)=2.20,p=0.03 (Figure 13). This station is located on a large tributary of Plum Creek that is primarily used for agricultural production and is heavily influenced by nonpoint source runoff. This station is located near several major impoundments, which frequently cause the waters of the creek to overflow into surrounding fields during flood conditions and go dry during drought conditions. The increase in ammonia nitrogen over time is most likely due to increased water use by livestock and wildlife during drought conditions. No parameter showed a statistically significant correlation with stream flow.

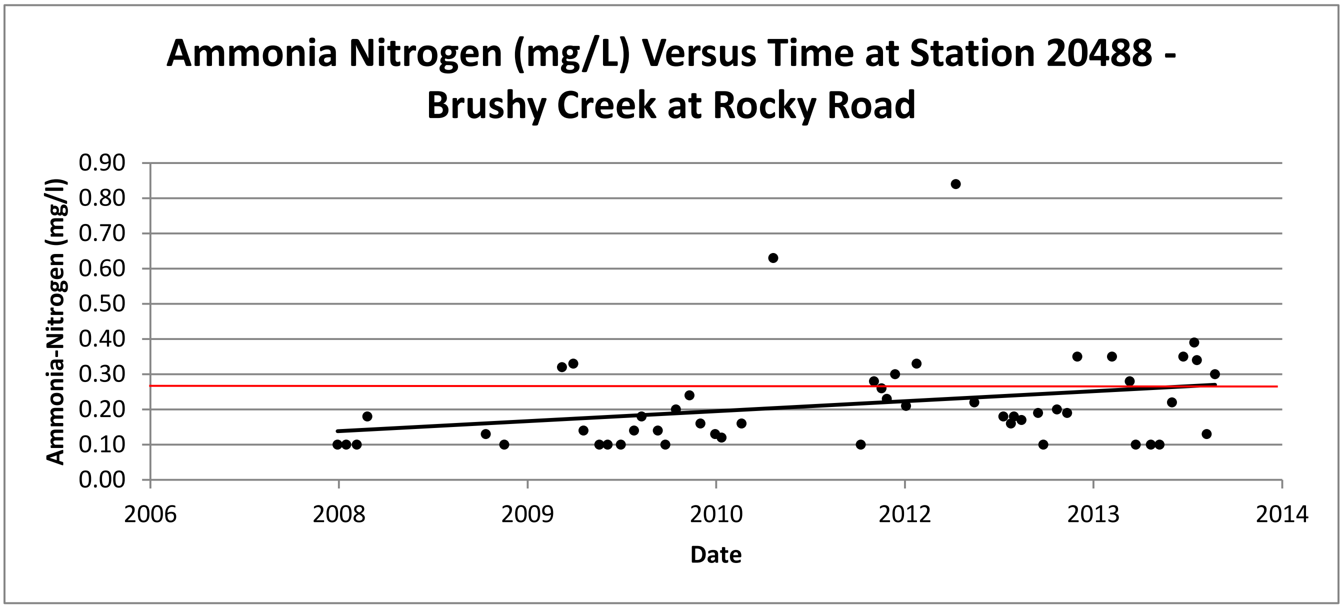

Figure 13. Ammonia-Nitrogen versus Time at Station 20488 – Brushy Creek at Rocky Road. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

At station 20491 (Dry Creek at FM 672) no statistically significant correlations were found between time or flow for any of the parameters analyzed. The Dry Creek covers a fairly large watershed, but does not hold water for any length of time. Only twenty samples have been collected at this site since 2008, and almost all of them have been collected under wet weather conditions. The limited sample size and small flow variability during collection events probably contributed to the lack of statistically significant correlations at this station.

Targeted Monitoring

The objective of the targeted watershed surface water quality monitoring task was to provide water quality data to assess the effectiveness of implementing the Plum Creek WPP during targeted flow conditions. GBRA attempted to conduct targeted watershed monitoring at 35 sites twice per season, once under dry weather conditions and once under wet weather conditions, collecting field, conventional, flow and bacteria parameter groups. Of these 35 sites, 8 sites were the same as the sites for routine ambient monitoring and 3 sites were the same as the sites for storm event monitoring, allowing for 24 sites for targeted watershed monitoring only. Spatial, seasonal and meteorological variations were captured in these snapshots of watershed water quality. USGS gaging stations were referenced to determine if a rain event had brought flows up enough from previous base flows to create wet weather targeted conditions.

Throughout the project period, targeted monitoring proved to be a challenge. A significant drought occurred during the project period, broken by a few severe flood events. The small rain events that did occur were not watershed-wide, so that many sites remained dry during a wet weather targeted sampling event. Twenty eight Soil Conservation Service dams are located in the Plum Creek Watershed. These structures were built in the 1960-70s (Plum Creek Conservation District). The structures retain flood waters and slowly release the captured water in a controlled manner. Because of this slow release after a rain event, the flows into the stream maintain elevated wet weather flows over an extended time. No dry weather targeted sampling was conducted in the fall of 2013 because fall rains in September and late October 2013 kept the streams under wet conditions, with high flows throughout November and December.

A compilation of the data collected at the targeted sites can be found in Table 6.

Table 6. Compilation of data collected at targeted sampling sites. Ecoli calculated in cfu/100ml. Total Phosphorus, (Tot. P) Nitrates (NO3-N), Ammonia (NH3-N) all are concentrations in mg/L.

Site	No. of Samples-Dry	Median Flow-Dry	E. coli Geomean-Dry	E. coli Range-Dry	No. of Samples-Wet	Median Flow-Wet	E. coli Geomean-Wet	E. coli Range-Wet	Tot P Mean-Dry	Tot P Range-Dry	Tot P Mean-Wet	Tot P Range-Wet	NO3-N Mean-Dry	NO3-N Range-Dry	NO3-N Mean-Wet	NO3-N Range-Wet	NH3-N Mean-Dry	NH3-N Range-Dry	NH3-N Mean-Wet	NH3-N Range-Wet
Andrews Branch at CR 131	18	0.9	203	36-1400	14	1.8	664	41-10460	0.31	0.18-0.55	0.21	0.13-0.44	15.17	2.49-24.6	7.74	0.67-20.6	0.35	0.1-1.82	0.23	0.05-0.44
Brushy Creek at FM2001	3	0.0	8	2-4	10	0.0	190	<1-6800	0.05	0.03-0.1	0.16	0.05-0.46	<0.05	<0.05-0.1	0.77	<0.05-5.7	0.17	0.05-0.42	0.26	0.05-0.47
Brushy Creek at SH21	12	0.0	31	1-160	13	1.8	740	72-7270	0.07	0.05-0.16	0.16	0.06-0.33	0.14	<0.05-0.65	0.61	<0.05-2.83	0.32	0.05-1.0	0.20	0.05-0.45
Bunton Branch at Dacy Lane (CR205)	14	0.0	52	15-400	11	0.6	602	50-3550	0.06	<0.05-0.25	0.07	0.02-0.22	0.11	<0.05-0.23	0.58	<0.05-1.63	0.21	0.1-0.57	0.21	0.05-0.42
Bunton Branch at Heidenreich Lane (CR152)	6	dry	89	12-210	11	1.1	634	190-2360	0.05	0.02-0.08	0.10	<0.05-0.22	0.42	0.09-0.86	0.65	0.14-1.82	0.27	<0.1-0.65	0.22	<0.1-0.51
Clear Fork Plum Creek at Old Luling Road (CR213)	19	0.7	55	10-270	16	1.0	258	20-2000	0.05	<0.05-0.16	0.15	<0.05-0.39	1.37	<0.05-7.12	1.35	0.06-5.4	0.22	<0.1-0.65	0.21	0.1-0.59
Clear Fork Plum Creek at CR 228	3	0.0	59	10-750	3	0.0	210	10-3080	0.14	0.13-0.15	0.14	0.06-0.24	0.03	<0.05	0.48	0.15-1.04	0.17	<0.1-0.29	0.14	<0.1-0.35
Clear Fork Plum Creek at PR 10	19	0.7	52	19-140	16	1.2	285	31-3870	0.03	<0.05-0.07	0.12	<0.05-0.39	2.47	0.12-5.3	2.55	0.12-5.44	0.29	<0.1-1.03	0.17	<0.1-0.33
Copperas Creek at Tenney Creek Rd (CR141)	2	0.0	342	180-650	5	0.0	747	10-17000	0.10	0.08-0.12	0.46	0.14-0.93	0.12	<0.05-0.22	0.40	<0.05-1.2	0.39	0.31-0.46	0.24	0.02-0.37
Cowpen Creek at Schuelke Rd (CR222)	0	dry	dry	NA	6	0.6	1572	160-46100	dry	NA	0.21	0.06-0.39	dry	NA	0.79	<0.05-2.32	dry	NA	0.36	<0.1-0.59
Dry Creek at FM713	3	0.0	228	10-2700	5	0.1	1328	420-16000	0.19	0.13-0.27	0.22	0.15-0.88	0.99	<0.05-2.79	0.47	0.1-1.24	0.36	0.14-0.78	0.25	<0.1-0.34
Elm Creek at SH 21	0	0.0	dry	NA	0	2.2	346	160-630	dry	NA	0.10	0.04-0.19	dry	NA	0.43	<0.05-1.4	dry	NA	0.25	<0.1-0.42
Hines Branch at Tenney Creek Rd (CR141)	2	0.0	121	70-210	7	0.0	640	30-24200	0.18	NA	0.24	0.06-0.44	0.03	<0.05	0.73	<0.05-1.55	0.22	<0.1-0.35	0.26	0.13-0.49
Plum Creek at Biggs Rd (CR131)	19	5.9	199	79-650	16	34.0	1145	170-15000	0.90	0.38-1.64	0.98	0.27-1.76	1.82	0.09-4.26	2.27	0.22-7.5	0.22	<0.1-0.57	0.25	0.12-0.77
Plum Creek at CR 186	19	3.2	222	70-610	16	10.6	687	150-24200	1.22	0.67-2.19	0.99	0.3-2.04	7.58	1.08-13	3.35	0.74-10.2	0.15	<0.1-0.27	0.20	<0.1-0.46
Plum Creek at CR 233	19	1.5	114	45-450	15	6.6	665	120-10460	2.37	0.68-4.27	1.36	0.22-3.96	10.02	2.0-21.3	5.12	0.38-22.8	0.19	<0.1-0.35	0.23	<0.1-0.4
Plum Creek at FM 1322	19	4.8	166	53-650	16	27.0	1095	73-16000	1.04	0.46-1.64	0.96	0.29-2.14	3.33	0.07-8.74	2.34	0.85-7.08	0.19	<0.1-0.34	0.19	<0.1-0.45

Stations highlighted have a base flow geometric mean concentration greater than the water quality standard of 126 organisms/100 mL under dry conditions.

Stations highlighted have a base flow mean concentration greater than the screening level of 0.69 mg/L under dry conditions.

Stations highlighted have a base flow mean concentration greater than the screening level of 1.95 mg/L under dry conditions.

Stations highlighted have a base flow mean concentration greater than the screening level of 0.33 mg/L under dry conditions.

Table 6 cont'd. Compilation of data collected at targeted sampling sites. (cont.) Ecoli calculated in cfu/100ml. Total Phosphorus, (Tot. P) Nitrates (NO3-N), Ammonia (NH3-N) all are concentrations in mg/L.

Site	No. of Samples - Dry	Median Flow - Dry	E. coli Geomean - Dry	E. coli Range- Dry	No. of Samples - Wet	Median Flow - Wet	E. coli Geomean - Wet	E. coli Range- Wet	Tot P Mean - Dry	Tot P Range- Dry	Tot P Mean - Wet	Tot P Range- Wet	NO3-N Mean - Dry	NO3-N Range- Dry	NO3-N Mean - Wet	NO3-N Range- Wet	NH3-N Mean - Dry	NH3-N Range- Dry	NH3-N Mean - Wet	NH3-N Range- Wet
Plum Creek at Heidenreich Lane (CR152)	23	2	1326	460-4840	14	3	2328	280->24200	3.84	2.71-5.02	1.76	0.33-4.36	15.99	6.07-26.5	10.17	0.65-28.7	1.21	<0.10-10.4	0.46	<0.1-1.96
Plum Creek at Lehman Rd	15	0	82	5-1300	16	1	740	85-19860	0.03	<0.02-0.08	0.08	<0.05-0.17	0.46	<0.05-3.28	0.85	<0.05-4.38	0.15	<0.1-0.34	0.18	<0.1-0.75
Plum Creek at Youngs Lane (CR197)	18	4	166	76-490	14	14	1320	520-17330	1.31	0.47-2.14	1.02	0.28-2.8	4.35	0.17-10.7	3.61	0.73-10.7	0.26	<0.1-1.26	0.17	<0.1-0.36
Plum Creek downstrm of NRCS 1	14	0	19	1-1120	16	0	96	10-4800	0.33	0.04-0.98	0.30	0.04-0.87	1.05	<0.05-7.84	0.66	<0.05-6.52	0.58	<0.1-2.81	0.18	<0.1-0.46
Plum Creek upstrm of Hwy 183	19	1	66	12-220	14	19	746	50->24200	1.87	0.64-3.42	1.19	0.23-3.18	4.86	0.13-10.3	2.97	0.63-9.67	0.18	<0.1-0.3	0.22	<0.1-0.65
Porter Creek at Dairy Rd (CR151)	13	0	195	8-580	13	2	744	120-24200	0.07	<0.05-0.16	0.10	<0.05-0.22	0.20	<0.05-1.22	0.58	<0.05-2.78	0.33	<0.1-0.9	0.23	<0.1-0.52
Porter Creek Trib at Quail Cove Rd	0	dry	dry	NA	8	0	806	40-4800	dry	NA	0.19	0.07-0.38	dry	NA	0.79	<0.05-3.14	dry	dry-0.26	0.21	<0.10-0.51
Richmond Branch at Dacy Lane (CR205)	14	0	199	44-2420	13	0	740	120-18600	0.11	<0.05-0.82	0.11	0.03-0.43	0.19	<0.05-0.72	1.01	0.06-3.89	0.58	<0.1-6.36	0.21	<0.1-0.76
Salt Branch at Salt Flat Road	15	0	570	40-4840	16	0	1681	170->24200	0.56	0.03-4.13	0.28	<0.02-0.7	0.39	<0.05-1.94	0.27	<0.05-1.33	0.48	<0.1-1.76	0.28	0.11-0.71
Salt Branch at FM 1322	18	0	193	17-2150	16	0	600	10-13000	3.31	1.93-4.22	1.55	0.24-3.69	10.03	0.08-29.5	3.02	0.23-11.6	0.44	0.17-2.59	0.39	0.15-0.82
Tenney Creek at Tenney Creek Rd (CR141)	0	dry w pools	dry	NA	5	1	511	5-10000	dry	NA	0.41	0.32-0.65	dry	NA	0.29	0.16-0.47	0.00	NA	0.19	<0.1-0.30
Town Creek at E. Market St	19	1	254	57-730	16	1	596	70-16000	0.05	<0.05-0.07	0.10	0.04-0.23	10.07	0.69-12.4	8.28	3.9-11.4	0.23	<0.1-0.86	0.15	<0.1-0.43
Town Creek W of Lockhart (Stueve Lane)	0	0	dry	NA	6	0	270	5->24200	dry	NA	0.72	0.15-1.71	dry	NA	0.81	<0.05-3.14	dry	NA	0.44	<0.1-1.54
West Fork Plum Creek at FM671	1	dry	37	NA	7	0	493	10-8160	0.12	NA	0.15	<0.05-0.29	0.03	NA	0.29	<0.05-0.75	0.84	NA	0.19	<0.1-0.41
			Stations highlighted have a base flow geometric mean concentration greater than the water quality standard of 126 organisms/100 mL under dry conditions.						Stations highlighted have a base flow mean concentration greater than the screening level of 0.69 mg/L under dry conditions.				Stations highlighted have a base flow mean concentration greater than the screening level of 1.95 mg/L under dry conditions.				Stations highlighted have a base flow mean concentration greater than the screening level of 0.33 mg/L under dry conditions.			

Storm Monitoring

GBRA attempted to conduct automated storm event monitoring at 3 urban/residential sites collecting field, conventional, flow and bacteria parameter groups. The deployment sites were located so that there was no duplication of monitoring with efforts funded through other projects or entities. The objective of this task was to provide water quality data to assess the effectiveness of implementing the Plum Creek WPP through storm event monitoring. GBRA's Regional Laboratory conducted sample analysis. Conventional parameters were nitrate-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen and total phosphorus. Bacteria parameters were E. coli. The storm water stations were not located at gaged, calibrated sites so flows were recorded by the automated samplers up to a point when overbanking occurred. It was recognized that an estimate of volume was rough at best after overbanking occurs.


Stormwater sampler


Stormwater sampling tube in the creek

The sampling period began in the third quarter of FY2013, after Revision 3 of the QAPP was approved. Up to 24 discreet samples were to be collected for bacteriological analyses, and the remaining volume was to be composited in order to produce event mean concentrations for other parameters. A storm event was defined as a one inch rise in the stream channel, measured by a bubble gauge on the autosampler. The autosampler was calibrated to reflect ambient flow conditions at the monitoring location and was equipped with a rain gauge. Holding times for conventional parameters began at the time that the last sample for the composite was collected. Bacteriological analyses were conducted on the proportional samples collected every hour by the automated sampler. Wireless communication links were established from each unit to GBRA.

An estimate of volume was done based on the measurement of the pressure gauge on the ISCO at the time of each hourly sample and used to calculate the flow-weighted composite and the estimated pollutant load. Samplers were triggered when water level had a greater than 1 inch rise over ambient flow, measured by a bubble gauge. The estimation of bacteriological load was calculated based on the volume of water that has passed between each sample and the concentration of *E. coli* measured at the previous hourly sample. The estimate of the total bacterial load will be the sum of each hourly load over the storm hydrograph. Only the samples collected when flow is over the trigger level will be used in the load calculation and nutrient composite sample.

During a storm event, the safety of the sampling crew was not compromised in case of lightning or flooding. In the instance that the storm flow sampler was inaccessible due to weather conditions or flooding, the sampler was retrieved when conditions allowed and the event was documented. Samples from these severe weather events were not analyzed if inaccessibility prevented compliance with holding times. EPA required samples be refrigerated during automated, hourly sample collection.

Capturing a storm event has been the most difficult task of this project. Meeting holding times, refrigeration of the automated sampler, communications from the sampling units were anticipated hurdles but did not prove to be the most challenging. Aspects of storm water monitoring that made the storm water monitoring difficult included 1) anticipation of a storm event with enough time to travel to the site to enable the automated samplers and establish the ambient base flow water level; 2) having batteries in place that have enough charge to operate a refrigerated sampler over 24 hours; and 3) rain events that met the definition of a storm event but were better classified as flood events, and either inundated the units or washed them downstream. An example of a storm event that was attempted but not sampled occurred on 09/20/2013. The batteries failed shortly after the event triggered the samplers. To operate the refrigerated sampler, it required quite a large amount of battery power. We also learned that the batteries life is shortened considerably due to the heat and long term storage of the batteries. Additionally, recharging the batteries takes several days. To overcome this hurdle, two batteries were installed in parallel at each monitoring station in order to prolong the battery life.

On October 31, 2013 a record-setting flood occurred that inundated all three storm water stations, and at two sites, washed the units downstream. After the flows receded enough to safely enter the area, the units were recovered and repaired. As soon as flows returned to base flow conditions the stations were put back in service and prepared for sampling the next qualifying storm event.

A qualifying storm event occurred on May 13, 2014, but only one sampling site was triggered – Plum Creek at Heidenreich (20484). Fourteen samples were collected for bacteriological analyses and one composite sample was prepared and analyzed for total suspended solids, chloride, sulfate, total phosphorus, nitrate nitrogen, ammonia nitrogen and Total Kjeldahl Nitrogen. The bacteriological concentrations ranged from 1000 to 120,000 MPN. Unfortunately, when the data collected for flow was being downloaded the computer froze and required a hard reboot to restart which erased all the data. Since there is no flow we could not calculate an event mean concentration or compile a hydrograph.

Diurnal Monitoring

Diurnal monitoring was conducted during the months of March through October of each year. Many times during the project period diurnal sites were dry. The three main stem sites maintained flow throughout the project. In March of 2012 diurnal monitoring was suspended at four sites due to high flows after a rainfall event. In March – May 2013, diurnal monitoring was not conducted due to a scheduling error. Diurnal monitoring resumed in June of that year. In order to get the required number of sampling events in under this task diurnal sampling was conducted in November and December of that year.

After reviewing the data, the following observations have been made:

Clear Fork Plum Creek at Salt Flat Road – During the months of June and July each year the site experiences spikes in dissolved solids, with the 24-hour average conductivities ranging from 2660 – 9020 micromhos per centimeter (umhos/cm). The average 24-hour average conductivity is 2300 umhos/cm, ranging over the entire monitoring period from a low of 399 umhos/cm to a high of 9020 umhos/cm. The daily fluctuation in conductivity averaged 120 umhos/cm. These spikes of elevated dissolved solids correspond to periods of low to no flow and could be attributed to the impact of salt water intrusion from oil field activity. The diurnal fluctuation in dissolved oxygen was the widest during the summer months, dropping below 1.0 milligram per liter to a high of greater than 10 milligrams per liter. This wide daily fluctuation is to be expected because of photosynthetic activity during the long summer days.

Dry Creek at FM 672 – Dry Creek is true to its name and was dry the majority of the project. Only three diurnal events were captured. Diurnal water quality conditions were typical of seasonal and low flow conditions.

Brushy Creek at Rocky Road – The stream showed typical seasonal diurnal fluctuations on all water quality parameters. The majority of the sampling events had a diurnal average dissolved oxygen concentration that was below 4.0 mg/L. Of the 14 diurnal events captured at Brushy Creek, 8 events had a maximum dissolved oxygen concentration below 4.5 mg/L. The lack of flow was the main contributor to these conditions. Evidence of the impact of low to no flow conditions can been seen when the opposite conditions occur. During the one event that was collected during high flow conditions (17 cubic feet per second (cfs)), the dissolved oxygen concentration ranged from 10.3 to 11.5 mg/L, averaging 10.8 mg/L.

Elm Creek at CR 233 – Elm Creek is another small tributary of Plum Creek that is impacted by the lack of water in the stream. The diurnal events were limited to sampling in no flow or dry with pools conditions. Only one event had a flow of greater than 1.0 cfs. Of the 14 events that had water in the stream, 8 events had a maximum dissolved oxygen concentration that never exceeded 4.0 mg/L. The event that was collected with a flow of 7.2 cfs, had very good water quality conditions.

West Fork Plum Creek at Biggs Road – West Fork Plum Creek is located in the lower reaches of the watershed where the majority of oil field activities have occurred. This area of the watershed is impacted by groundwater seeps that create base flows with high dissolved solids. The 24-hour average conductivity ranged from a low of 273 umhos/cm during a high flow event (relative to the normal base flows) to a high of 7460 umhos/cm, with an average of approximately 3000 umhos/cm. The pH values were slightly higher at this site in comparison to the routine sites in the upper part of the watershed. Under base flow conditions, the pH was in the range of 8 – 9 pH standard units. Runoff tended to lower the pH to a range of 7.2 to 8.0. Diurnal fluctuations in pH are most likely a result of photosynthetic activity. The West Fork site was regularly sampled from pools and had some of the highest chlorophyll concentrations measured in the watershed. During a diurnal cycle, algae take up carbon dioxide dissolved in water in the form of carbonic acid in the photosynthetic process to create sugars and release oxygen. This process creates higher pH in the afternoon when photosynthesis is at its peak and lower pH in the early morning hours when the plants are releasing carbon dioxide as part of their respiration.

Wastewater Effluent Monitoring

The objective of the task that covered effluent monitoring was to provide water quality data to access the effectiveness of implementing the Plum Creek WPP through effluent monitoring. GBRA conducted effluent monitoring at 7 WWTFs once per month, collecting field, conventional, flow, bacteria and effluent parameter groups. Sampling period extended through 51 months. GBRA’s Regional Laboratory conducted sample analysis.

Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are total suspended solids, sulfate, chloride, nitrate nitrogen, ammonia nitrogen, Total Kjeldahl Nitrogen and total phosphorus. Flow parameters are flow collected by gauge, electric, mechanical or Doppler, including severity. Bacteria parameters are *E. coli*. Effluent parameters are BOD, CBOD and COD.

Monitoring of the seven effluents began in April 2011. If there were problems noted at the time of sampling or if the quality of the effluent was not typical of clean, well- treated wastewater that was meeting the permit requirements, or if elevated *E. coli* counts were found in the wastewater effluent of any of the seven facilities monitored by the project, GBRA staff contacted the operators immediately. In the case of the effluent monitoring in July 2011 that found elevated counts coming from the Shadow Creek WWTP, plant operators were notified and the chlorine was found to be low. Adjustments were made at the plant, and the facility resampled the next day to confirm that the *E. coli* counts were down. Early on problems were noted (i.e. elevated concentrations of *E. coli*) at the facility that serves the City of Kyle and operated by Aqua TX. The City of Kyle was contacted after each exceedence. GBRA participated in several meetings with the city, Aqua TX and TCEQ to discuss possible sources of the elevated counts. GBRA confirmed the location that the project samples were being collected and took side by side samples. Additionally, Texas Stream Team contacted GBRA and Texas A&M AgriLife Extension to inform them that volunteer monitors that had collected monthly samples on Plum Creek, downstream of the City of Kyle's discharge found elevated concentrations of *E. coli* (above the contact recreation grab standard) since February 2011.

Spring Flow Monitoring

The objective of the spring flow monitoring task was to provide water quality data to access the effectiveness of implementing the Plum Creek WPP through spring flow monitoring. GBRA conducted spring flow monitoring at 3 springs once per season collecting field, conventional, flow and bacteria parameter groups. All sampling events were conducted.

GBRA's Regional Laboratory conducted sample analysis. Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are total suspended solids, sulfate, chloride, nitrate nitrogen, ammonia nitrogen, Total Kjeldahl Nitrogen and total phosphorus. Flow is collected by mechanical or Doppler, including severity. Bacteria parameters were *E. coli*.

Sampling of spring flow was done as close to the headwaters of each spring as possible. All three springs had elevated nitrate-nitrogen concentrations which is to be expected coming from the Leona Aquifer (mean concentrations: Boggy Creek Springs – 6.0 mg/L; Clear Fork Springs – 5.6 mg/L; and Lockhart Springs – 10.0 mg/L). One water quality condition that was somewhat unexpected was the elevated *E. coli* bacteria concentrations. All three sites had a geometric mean for *E. coli* that exceeded the contact recreation stream standard (Boggy Creek Springs – 165 cfu per 100 milliliter; Clear Fork Springs – 228 cfu per 100 milliliters; and Lockhart Springs – 288 cfu per 100 milliliters).

Leona Aquifer Groundwater Water Quality Monitoring

The objective of the Leona Aquifer monitoring was to provide water quality and metadata from shallow wells that are in the Leona formation within the Plum Creek watershed to determine if there is recharge of the Leona by the effluent-dominated Plum Creek. GBRA inventoried 12 wells, collecting metadata, including, if possible, water depth, installation method (hand-dug or mechanical), date of installation, cased, sealed or open, use of water, land use in immediate area of well, and proximity to Plum Creek or tributary. GBRA collected water samples from the 12 wells inventoried. GBRA's Regional Laboratory conducted sample analysis including *E. coli*, nitrate nitrogen, ammonia nitrogen and total phosphorus. Results will be shared with the participating landowners. In summary, there appears to be some recharge of the Leona Aquifer by Plum Creek based on conductivity data and ammonia. However, further investigation is needed to confirm findings.

Gain/Loss Study

The objective of the gain/loss study was to better define the relationship between surface flows and groundwater recharge in the Plum Creek watershed. USGS conducted a gain/loss study on the Plum Creek watershed, based on five locations within the watershed. Stations included in the study were Plum Creek at Plum Creek Road (17406), Plum Creek at CR 202 (12647), Plum Creek at CR 135 (12640), Clear Fork at Salt Flat Road (12556) and West Fork Plum Creek at Biggs Road (CR 131) (20500). The study included two synoptic condition surveys.

In general, in the Lockhart section of Plum Creek, there are some gains from the Lockhart springs. Also, the wastewater discharges are a primary influence on the base flow in the upper reaches of Plum Creek and the City of Luling No.2 wastewater treatment plant discharge likely contributes to base flows in the lower reaches of Plum Creek.

Appendix A List of Monitoring Sites

TCEQ Station ID	Site Description	Workplan Task	Monitor Type	DO 24hr	Bacteria	Conventional	Flow	Field	Comments
12556	Clear Fork Plum Creek at Salt Flat Road	3	RT		34	34	34	34	1
12556	Clear Fork Plum Creek at Salt Flat Road	6	BS	22			22	22	
12556	Clear Fork Plum Creek at Salt Flat Road	4	BF		11	11	11	11	
12556	Clear Fork Plum Creek at Salt Flat Road	10	BF				2		
12558	Elm Creek at CR 233	3	RT		34	34	34	34	1
12558	Elm Creek at CR 233	6	BS	22			22	22	
12558	Elm Creek at CR 233	4	BF		11	11	11	11	
12640	Plum Creek at CR 135	3	RT		34	34	34	34	1, 3
12640	Plum Creek at CR 135	6	BS	22			22	22	
12640	Plum Creek at CR 135	4	BF		11	11	11	11	
12640	Plum Creek at CR 135	10	BF				2		
12647	Plum Creek at Old McMahan Road (CR 202)	3	RT		34	34	34	34	1, 3
12647	Plum Creek at Old McMahan Road (CR 202)	5	BF		4	4	4	4	5
12647	Plum Creek at Old McMahan Road (CR 202)	6	BS	22			22	22	
12647	Plum Creek at Old McMahan Road (CR 202)	4	BF		11	11	11	11	
12647	Plum Creek at Old McMahan Road (CR 202)	10	BF				2		
17406	Plum Creek at Plum Creek Road	3	RT		34	34	34	34	1, 3
17406	Plum Creek at Plum Creek Road	6	BS	22			22	22	
17406	Plum Creek at Plum Creek Road	4	BF		11	11	11	11	
17406	Plum Creek at Plum Creek Road	10	BF				2		
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	3	RT		34	34	34	34	1
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	6	BS	22			22	22	
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	4	BF		11	11	11	11	
20491	Dry Creek at FM 672	3	RT		34	34	34	34	1
20491	Dry Creek at FM 672	6	BS	22			22	22	
20491	Dry Creek at FM 672	4	BF		11	11	11	11	
20500	West Fork Plum Creek at Biggs Road (CR 131)	3	RT		34	34	34	34	1
20500	West Fork Plum Creek at Biggs Road (CR 131)	6	BS	22			22	22	
20500	West Fork Plum Creek at Biggs Road (CR 131)	4	BF		11	11	11	11	
20500	West Fork Plum Creek at Biggs Road (CR 131)	10	BF				2		
12555	Salt Branch at FM 1322	4	BF		22	22	22	22	
12555	Salt Branch at FM 1322	5	BF		4	4	4	4	5
12557	Town Creek at E. Market St. (Upstream of Lockhart #l WWTP)	4	BF		22	22	22	22	
12559	Porter Creek at Dairy Road	4	BF		22	22	22	22	
12642	Plum Creek at Biggs Road (CR 131)	4	BF		22	22	22	22	
12643	Plum Creek at FM 1322	4	BF		22	22	22	22	
12645	Plum Creek at Young Lane (CR 197)	4	BF		22	22	22	22	
12648	Plum Creek at CR 186	4	BF		22	22	22	22	
12649	Plum Creek at CR 233	4	BF		22	22	22	22	
14945	Clear Fork Plum Creek at Old Luling Road (CR 213)	4	BF		22	22	22	22	
16709	Town Creek West of Lockhart	4	BF		22	22	22	22	
18343	Plum Creek Upstream of US 183	4	BF		22	22	22	22	
20480	Plum Creek Downstream of NRCS 1 Spillway	4	BF		22	22	22	22	
20481	Bunton Branch at Heidenreich Lane	4	BF		22	22	22	22	
20482	Brushy Creek at FM 2001 (Downstream of NRCS 12)	4	BF		22	22	22	22	
20487	Brushy Creek at SH 21	4	BF		22	22	22	22	
20483	Elm Creek at SH 21 (Downstream of NRCS 16)	4	BF		22	22	22	22	
20489	Cowpen Creek at Schuelke Road	4	BF		22	22	22	22	
20496	Tenney Creek at Tenney Creek Road	4	BF		22	22	22	22	
20490	Clear Fork Plum Creek at Farmers Road	4	BF		22	22	22	22	

TCEQ Station ID	Site Description	Workplan Task	Monitor Type	DO 24hr	Bacteria	Conventional	Flow	Field	Comments
20493	Clear Fork Plum Creek at PR 10 (State Park)	4	BF		22	22	22	22	
20497	West Fork Plum Creek at FM 671	4	BF		22	22	22	22	
12538	Andrews Branch at CR 131	4	BF		22	22	22	22	
20495	Dry Creek at FM 713	4	BF		22	22	22	22	
20484	Plum Creek at Heidenreich Lane (Downstream of Kyle WWTP)	4	BF		22	22	22	22	
20484	Plum Creek at Heidenreich Lane (Downstream of Kyle WWTP)	5	BF		4	4	4	4	5
20501	Salt Branch at Salt Flat Road (Upstream of Luling WWTP)	4	BF		22	22	22	22	
20498	Copperas Creek at Tenney Creek Road/Bronco Lane (CR 141, Downstream of Cal-Maine)	4	BF		22	22	22	22	
20505	Richmond Branch at Dacy Lane	4	BF		22	22	22	22	
20504	Porter Creek Tributary at Quail Cove Road	4	BF		22	22	22	22	
20510	Hines Branch at Tenney Creek Road (CR 141, Downstream of Cal-Maine)	4	BF		22	22	22	22	
20503	Plum Creek at Lehman Road	4	BF		22	22	22	22	
20502	Bunton Branch at Dacy Lane (upstream of NRCS 5)	4	BF		22	22	22	22	
20479	Unnamed Tributary at FM 150 near Hawthorn Dr.	4	BF		22	22	22	22	
20492	10210-001 City of Lockhart and GBRA #1(Larremore plant)	7	-		11	11	11	11	2
20494	10210-002 City of Lockhart and GBRA #2 (FM 20 plant)	7	-		11	11	11	11	2
20499	10582-001 City of Luling	7	-		11	11	11	11	2
20486	11041-002 City of Kyle and Aquasource Inc.	7	-		11	11	11	11	2
99923	11060-001 City of Buda and GBRA	7	-		11	11	11	11	2
99936	14431-001 GBRA Shadow Creek	7	-		11	11	11	11	2
99937	14377-001 GBRA Sunfield	7	-		11	11	11	11	2
20509	Lockhart Springs	8	BS		11	11	11	11	
20507	Clear Fork Springs at Borchert Loop (CR 108)	8	BS		11	11	11	11	
20508	Boggy Creek Springs at Boggy Creek Road (CR 218)	8	BS		11	11	11	11	

The eight "routine" sites double as "targeted" sites. "Targeted" sampling will collect biased flow (BF) samples twice per quarter – once under wet weather conditions and once under dry weather conditions. Whether these samples will satisfy the wet (biased high flow) or dry (biased low flow) weather conditions depends on the flow condition when samples are collected during the "routine' sampling that quarter.

2. The data collected from WWTF sampling will not be used for enforcement or compliance monitoring by TCEQ. As such, results will not be reported to TCEQ for inclusion in any data tracking system. Monitor type code is not applicable.
3. These samples are collected/analyzed by GBRA utilizing Texas CRP funding and serve as a portion of the non-federal match for this project.
4. Sites were adjusted to accommodate access.
5. These site doubles as the "stormflow" monitoring site and one of the "targeted" sampling sites.

List of Acronym's

BF………………. Biased Flow
BMP……………..Best Management Practices
BOD…………….. Biochemical Oxygen Demand
CBOD…………...Carbonaceous Biochemical Oxygen Demand
CFS……………… Cubic Feet per Second
CFU……………. Colony-Forming Unit
CRP……………… Clean Rivers Program
CWA…………… Clean Water Act
DO………………. Dissolved Oxygen
DQOs………….. Data Quality Objectives
EPA……………… Environmental Protection Agency
FY………………… Fiscal Year
GBRA…………… Guadalupe-Blanco River Authority
MG/L………….. Milligrams/Liter
ML………………. Milliliter
MPN……………. Most Probable Number
NO3-N………… Nitrate as Nitrogen
NH3-N…………. Ammonia Nitrogen
PCWP……………Plum Creek Watershed Partnership
QAPP…………... Quality Assurance Protection Plan
QA/QC………. Quality Assurance/Quality Control
UMHOS/CM… Measurement equal to 1 Seimens
SWQM…………Surface Water Quality Monitoring
TAG………………Technical Advisory Group
TCEQ…………… Texas Commission on Environmental Quality
TKN…………….. Total Kjeldahl Nitrogen
Total P…………. Total Phosphorus
TSS……………… Total Suspended Solids
TSSWCB………. Texas State Soil and Water Conservation Board
USGS…………….United States Geological Survey (agency)
WPP……………..Watershed Protection Plan
WWTF…………. Waste Water Treatment Facility