Surface Water Quality Monitoring to Support the Implementation of the Plum Creek Watershed Protection Plan

FINAL REPORT
TSSWCB PROJECT #14-11

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. In the *2008 Texas Water Quality Inventory and 303(d) List*, Plum Creek (Segment 1810) was again 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. Due to this change, the 2012 Texas Integrated Report of Surface Water Quality moved Plum Creek from assessment *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. No changes were made to the assessment status of the Creek in the 2014 Texas Integrated Report.

Information about the PCWP and the Watershed Protection Plan (WPP) 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 was identified as an important 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* 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 a full implementation monitoring project (10-07) could begin. The 10-07 monitoring project provided additional monitoring to demonstrate the water quality effects of implementing the WPP.

Implementation of the Plum Creek WPP is currently underway and the current 14-11 monitoring project was approved by the TSSWCB in order to further monitor the progress of implementing the WPP. In order 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, the 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 October of 2014 through December 2016. The project was extended in order to continue stream monitoring until a new SWQM project had 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.

The GBRA performed the majority of the work under this project including technical and financial supervision, preparation of status reports, surface water quality monitoring sample collection and analysis, and data management. The GBRA participated in the PCWP, Steering Committee, and Technical Advisory Group (TAG) in order to communicate project goals, activities and accomplishments to affected parties. The GBRA also worked with the Plum Creek Watershed Coordinator to assist local stakeholders with water quality concerns in the Plum Creek watershed. Through funding from an associated project (TSSWCB Project No. 14-10, *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.

The 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 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 the GBRA (stations #17406, 12640 and 12647) through the Clean Rivers Program (CRP). Through this project, the GBRA conducted routine ambient monitoring at an additional 5 sites monthly, collecting field, conventional, flow and bacteria parameter groups.

The 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 variations were captured in these snapshots of watershed water quality. Many of the tributary stations only held water during extreme runoff conditions, which often prevented their capture during dry weather.

The GBRA continued to maintain the refrigerated automated samplers that were installed during the previous 10-07 monitoring project in order to conduct storm event monitoring at 3 urban/residential sites, collecting field, conventional, flow and bacteria parameter groups.

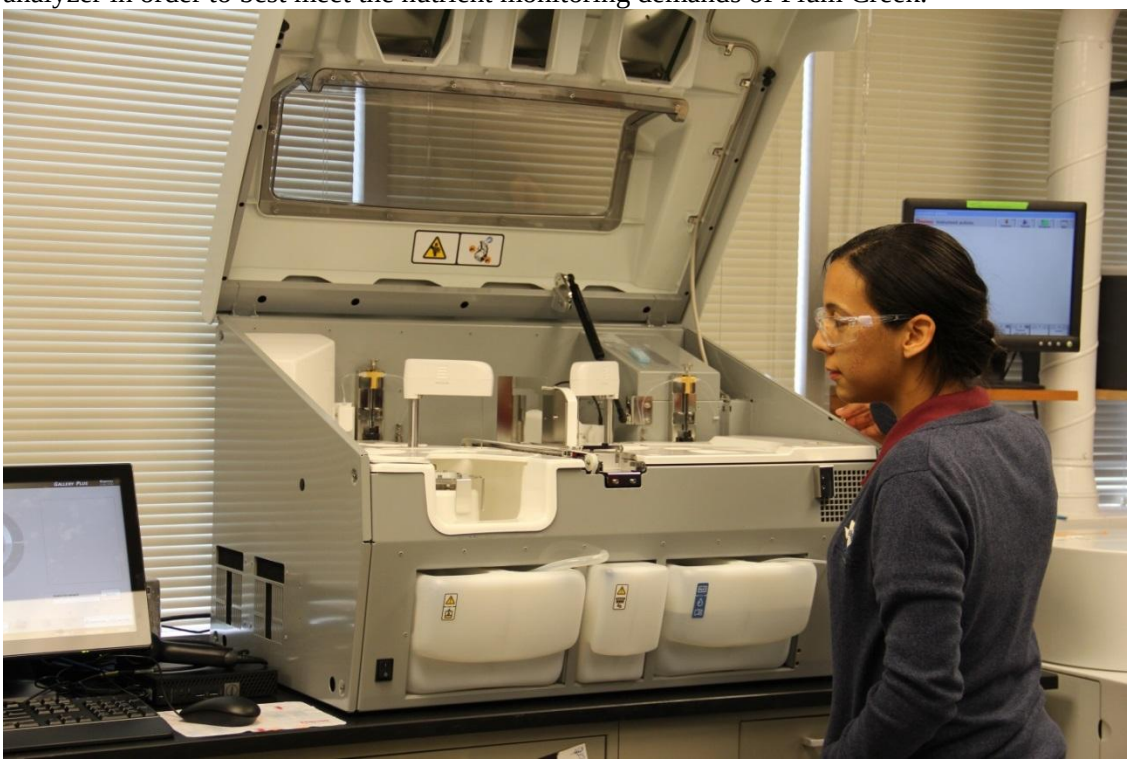
The GBRA conducted 24-hour Dissolved Oxygen (DO) monitoring at 8 sites monthly during the index period collecting field and flow parameter groups. These sites were the same as the sites for routine ambient monitoring. The GBRA maintains a continuous water quality monitoring probe station that collects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

The 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, the GBRA compiled 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.

The 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.

This project also partially funded the purchase of an automatic photometric analyzer in order to expedite and ensure redundancy for the analysis of nutrient monitoring parameters such as Total Phosphorus, Total Kjeldahl Nitrogen, & Ammonia Nitrogen. An intensive research and bidding process was undertaken by the GBRA laboratory, which resulted in the selection of the Thermo Fisher Scientific ™ Gallery ™ discrete analyzer in order to best meet the nutrient monitoring demands of Plum Creek.



GBRA laboratory analyst Miliana Hernandez is performing method development on the Thermo Scientific Photometric Analyzer.

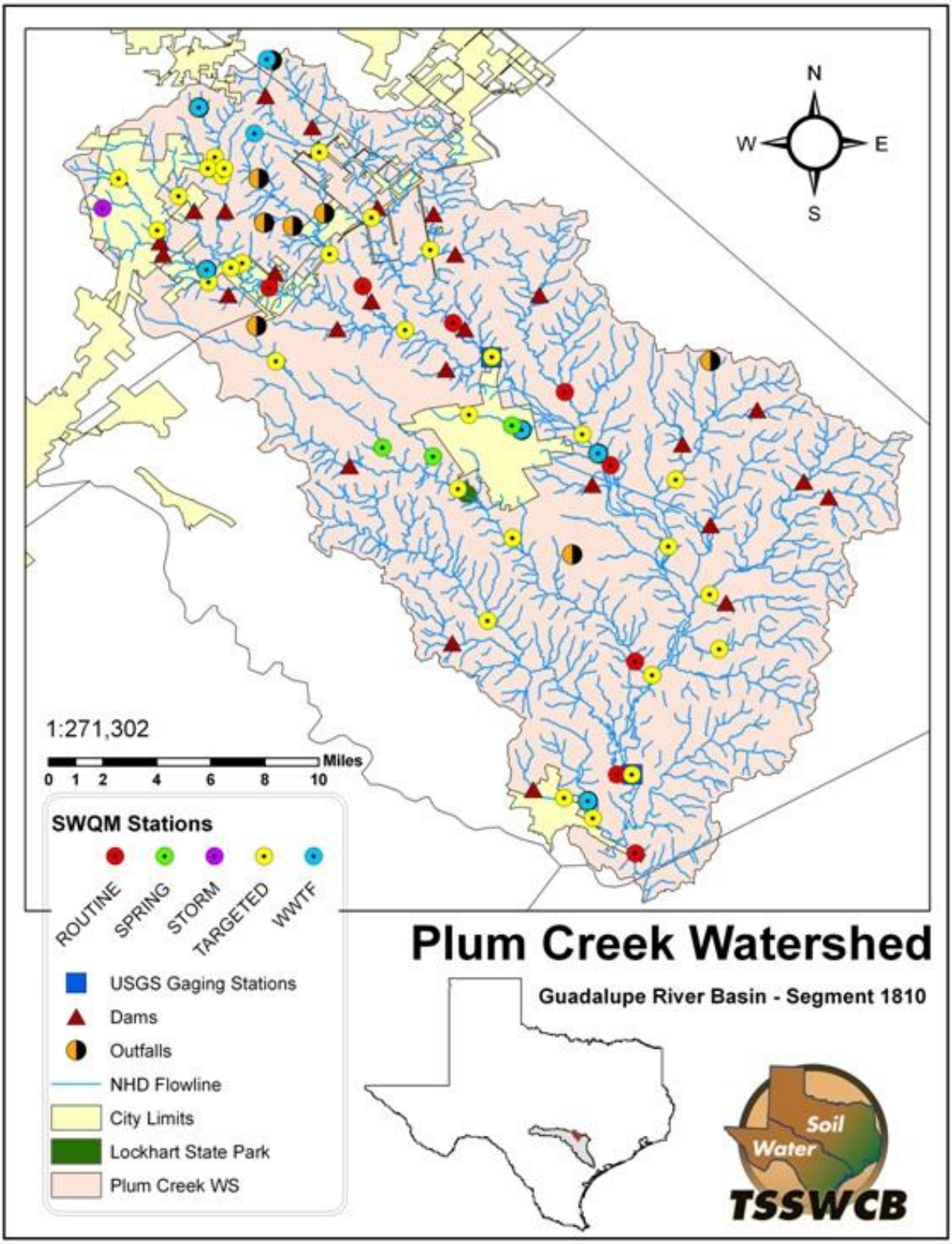


Figure 1. Map of sampling locations

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. 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, the 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, 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 PCWP, maintains the website, and coordinates outreach and education efforts in the watershed.

The 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 under TSSWCB project 11-07. The GBRA serves as the managing partner for the current TSSWCB Project 14-10, *Coordinating Implementation of the Plum Creek Watershed Protection Plan,* which funds the local coordinator.

Work on related grants

The GBRA staff assisted cities in the watershed to write, obtain, and administer implementation grants. The GBRA obtained additional Clean Water Act Section 319(h) grants through the TCEQ and the TSSWCB. The GBRA wrote the quality assurance project plan and conducted monitoring and mapping of the City of Lockhart's storm water conveyance system to identify illicit discharges into Plum Creek under TCEQ contract #582-14-43865, which was completed in August of 2016. The GBRA collected nitrogen and oxygen isotope data to determine sources of nitrate nitrogen in Plum and Geronimo Creeks through isotopic signatures with the United States Geological Survey (USGS) under TSSWCB Project 13-07, *Investigation into Contributions of Nitrate-Nitrogen to Plum Creek, Geronimo Creek and the Underlying Leona Aquifer*. The final reporting process for this grant project is currently underway and is scheduled to be completed before the end of the Q4 in FY 17. The GBRA also received a state funded grant Nonpoint Source grant 16-61 from the TSSWCB in FY 16 to collect bacterial source tracking data in the Plum Creek watershed at four main stem stations and 1 major tributary for a 1 year period ending in August of 2017.

Outreach and education

The 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 the 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.

The GBRA provided "Don't be Clueless" brochures, which address residential water quality awareness, to local real estate offices. These brochures are subsequently distributed to new homeowners in the Plum Creek watershed.

Stream Clean Ups

The GBRA participated in the annual stream clean-ups held in Lockhart each fall, assisting the Plum Creek watershed coordinator with facilitation of the event. The GBRA and the Plum Creek watershed coordinator 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, the GBRA staff and the Plum Creek watershed coordinator prepared agendas for each post-event follow-up meeting, prepared thank you gifts for the sponsors and prepared certificates of appreciation for the sponsors and team leaders. Additionally, the 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 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 four data sets were incomplete through December of 2016 due to the GBRA errors, requiring Corrective Action Report. If a problem occurred during a sampling event, every attempt was made to recollect the sample if the flow conditions remained, in order to prevent a 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
November 2014	TX05015	Clear Fork at CR 128 – Station 12556	Total Hardness was not reported	Total Hardness analysis not performed within holding time; The sample required dilution upon initial analysis and the diluted sample was not analyzed within holding time
December 2014	N/A – WWTF data not uploaded to SWQMIS as per QAPP	Kyle WWTF, Lockhart #1 WWTF, Lockhart #2 WWTF, Luling North WWTF, Shadow Creek WWTF, Sunfield WWTF	No Nitrates Reported	Nitrates were not analyzed within holding time due to analyst error.
July 2016	TX07409	Plum Creek at FM 1322 – Station 12643	No *E. coli* Reported	A required laboratory duplicate was not analyzed for the *E. coli* QC batch

A critical part of the project has been to disseminate information about Plum Creek and the project to stakeholders and other interested parties throughout the state. The GBRA summarized the results and activities of this project through inclusion in the GBRA's Clean Rivers Program *Basin Highlights Reports*. 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 the GBRA attended in order to represent the project and/or the efforts of the Plum Creek Watershed Partnership included meetings with the TCEQ to discuss permit renewals for the City of Kyle & City of Buda WWTFs. The GBRA attended the Riparian Summit and local training events, the TCEQ's Environmental Summit held each year in the region, quarterly TSSWCB Coordination Council meetings, and the annual TSSWCB conference in Waco, TX. The 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, the GBRA staff has been called upon to share the Plum Creek watershed protection planning process as well as the Partnership's plans for sustainability.

The GBRA continued to maintain the three kiosks that were installed in public locations in the cities of Kyle, Lockhart and Luling, in order to raise awareness of water quality and stewardship in the Plum Creek watershed and disseminate data to the public. 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 were well-used throughout the project, but the Kyle kiosk has since been removed for redeployment at a new location. The kiosk installed in the Luling Library was under-utilized due to power and wi-fi issues or the poor location within the library. The GBRA has found a new location in Luling. The City of Luling has agreed to relocate the kiosk to the new Zedler Mill Community Park.

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, the 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.

On September 29, 2014 the 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

The 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 the 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. The 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*.

For the period of October 2014 through December 2016, 27 routine sampling events were conducted. All the main stem monitoring stations sampled under the CRP program were flowing and sampling was successfully conducted every month. Of the 5 remaining routine stations monitored under this project (non-main stem), only the Clear Fork at CR 128 (12556) monitoring station did not go dry. Dry Creek at FM 672 (Site no. 20491), had water flowing or had pools to sample 48.1% of the time (13 out of 27 events); West Fork Plum Creek at Biggs Road (CR 131) (Site no. 20500) was flowing or had water in pools 77.8% of the time (21 out of 27 events); Elm Creek at CR 233 (Site no. 12558) had water to sample 85.2% of the time (23 out of 27 events); Brushy Creek at Rocky Road (Site no. 20488) had water to sample only 85.2% of the time (23 out of 27 events); and, Clear Fork Plum Creek at Salt Flat Road (Site

no. 12556) was sampled 100% of the time (27 out of 27 events). The data presented in Table 2 compiles the *E. coli* data collected from the beginning of watershed protection plan monitoring in 2008 through end of the 14-11 project in December of 2016. Concentrations of *E. coli* at all three main stem stations remains elevated above the stream standard of 126 cfu/100 mL. All of the tributary stations except for the West Fork at Biggs Road (20500) also have bacteria concentrations greater than the stream standard during all flow conditions. If the data set is reduced to only include the samples collected under dry weather conditions (not influenced by runoff), then the tributary stations at Elm Creek at CR 233 (12558) and Clear Fork at CR 128 (12556) also fall below the stream standard.

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

Monitoring Station	*E. coli* Geomean 2008 - 2016*	Median Flow (cfs) 2008 - 2016	*E. coli* Geomean - Wet	No. of Samples (Wet)	Range - Wet	Median Flow (cfs) Wet	*E. coli* Geomean - Dry	No. of Samples (Dry)	Range - Dry	Median Flow (cfs) - Dry	% Change Between Dry and Wet**
Plum Creek at Plum Creek Road	474	2.8	658	44	64 - >24,000	17.5	397	81	36 - >4,840	2.1	66%
Plum Creek at CR 202	287	7.7	496	47	36 - >24,000	43.5	204	76	16 - 1,400	5.4	143%
Plum Creek at CR 135	220	13	551	45	26 - 13,000	61	131	80	9 - 1,200	8.1	321%
Brushy Creek at Rocky Road	208	0.01	728	37	19 - >24,000	0.01	220	49	3 - 1,900	0	231%
Elm Creek at CR 233	154	0	475	36	5 - >24,000	0.4	56	41	<1 - >2,400	0	748%
Dry Creek at FM 672	513	0.3	1090	23	140 - 6,900	1.1	149	14	17 - 1,400	0	632%
Clear Fork at CR 128	225	2.1	601	41	41 - 12,030	5	122	68	3 - 3,150	1.1	393%
West Fork at Biggs Road	122	0.01	362	35	<10 - >11,000	0.02	53	45	<1 - 2,500	0.01	583%

*Entire data set under all flow conditions through December of 2016.

**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.

Table 3 is a compilation of the Total Phosphorus data collected at the routine sites from 2008 through December of 2016. TCEQ uses a screening value of 0.69 mg/L to assess a concern for Total Phosphorus. All three of the Plum Creek main stem stations had a mean Total Phosphorus concentration greater than the screening criteria during dry conditions that were not influenced by rainfall runoff. The mean concentration was also higher than the screening criteria when all weather conditions were included at the upstream stations of Plum Creek at Plum Creek Road (17406) and Plum Creek at CR 202 (12647). The most downstream station Plum Creek at CR 135(12640) fell slightly below the screening criteria when all weather events were included. The Plum Creek at Plum Creek Road main stem station experienced the greatest change in concentrations between dry and wet conditions, as rainfall runoff diluted total phosphorus levels by more than 90% during high flows. All 5 routine tributary stations fell below the nutrient screening criteria during all subsets of weather conditions.

Table 3. Concentrations of total phosphorus under dry and wet conditions at the routine monitoring sites. Total phosphorus concentrations are reported in mg/L.

Monitoring Station	Total P Mean 2008 - 2016*	Median Flow (cfs) 2008 - 2016	Total P Mean - Wet	No. of Samples (Wet)	Range - Wet	Median Flow (cfs) - Wet	Total P Mean - Dry	No. of Samples (Dry)	Range - Dry	Median Flow (cfs) - Dry	% Change Between Dry and Wet**
Plum Creek at Plum Creek Road	2.1	2.8	1.02	43	0.14 - 4.56	17.5	10.79	80	0.04 - 5.26	2.1	-90.55%
Plum Creek at CR 202	1.06	7.7	0.8	47	0.14 - 2.26	43.5	1.22	76	0.21 - 2.69	5.4	-34.43%
Plum Creek at CR 135	0.75	13	0.68	45	0.19 - 2.12	61	0.79	80	0.22 - 2.69	8.1	-13.92%
Brushy Creek at Rocky Road	0.12	0.01	0.14	37	0.03 - 0.37	0.01	0.1	49	0.03 - 0.3	0	40.00%
Elm Creek at CR 233	0.15	0	0.19	36	0.06 - 0.8	0.4	0.12	41	0.05 - 0.27	0	58.33%
Dry Creek at FM 672	0.3	0.3	0.31	23	0.11 - 0.69	1.1	0.27	14	0.08 - 0.47	0	14.81%
Clear Fork at CR 128	0.11	2.1	0.16	41	<0.02 - 0.9	5	0.08	68	<0.02 - 0.5	1.1	100.00%
West Fork at Biggs Road	0.4	0.01	0.35	35	0.07 - 0.85	0.02	0.44	45	0.06 - 2.14	0.01	-20.45%

*Entire data set under all flow conditions through December of 2016.

**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 Total P mean greater than the water quality screening criteria of 0.69 mg/L under dry conditions.

Table 4 is a compilation of the nitrate-nitrogen data collected from 2008 through December of 2016. TCEQ uses a screening value of 1.95 mg/L to assess a concern for Nitrate Nitrogen. The two upstream stations of Plum Creek at Plum Creek Road (17406) and Plum Creek at CR 202 (12647) had average concentrations of Nitrate Nitrogen greater than the screening criteria during dry conditions that were not influenced by rainfall runoff. The mean concentration at these stations was also higher than the screening criteria when all weather conditions were included. The most downstream station Plum Creek at CR 135(12640) was slightly above the screening criteria when all weather events were included. All 5 routine tributary stations fell below the nutrient screening criteria during all subsets of weather conditions.

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

Monitoring Station	NO3-N Mean 2008 - 2016*	Median Flow (cfs) 2008 - 2016	NO3-N Mean - Wet	No. of Samples (Wet)	Range - Wet	Median Flow (cfs) - Wet	NO3-N Mean - Dry	No. of Samples (Dry)	Range - Dry	Median Flow (cfs) - Dry	% Change Between Dry and Wet**
Plum Creek at Plum Creek Road	10.79	2.8	5.66	43	0.37 - 29.3	17.5	13.55	80	0.6 - 34.8	2.1	-58.23%
Plum Creek at CR 202	5.27	7.7	3.55	47	0.32 - 11.6	43.5	6.34	76	0.58 - 16.3	5.4	-44.01%
Plum Creek at CR 135	2	13	2.1	45	0.07 - 9.48	61	1.93	80	<0.05 - 6.24	8.1	8.81%
Brushy Creek at Rocky Road	0.19	0.01	0.3	37	<0.05 - 1.44	0.01	0.12	49	<0.05 - 0.69	0	150.00%
Elm Creek at CR 233	0.25	0	0.41	36	<0.05 - 4.02	0.4	0.11	41	<0.05 - 0.35	0	272.73%
Dry Creek at FM 672	0.46	0.3	0.56	30	<0.05 - 3.78	1.1	0.2	22	<0.05 - 0.80	0	180.00%
Clear Fork at CR 128	0.94	2.1	1.14	41	<0.05 - 5.69	5	0.82	68	<0.05 - 4.46	1.1	39.02%
West Fork at Biggs Road	0.29	0.01	0.29	35	<0.05 - 1.36	0.02	0.28	44	<0.05 - 1.06	0.01	3.57%

*Entire data set under all flow conditions through December of 2016.

**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 Nitrate concentration greater than the water quality screening criteria of 1.95 mg/L under dry conditions.

Table 5 is a compilation of the ammonia-nitrogen data collected from 2008 to December of 2016. The TCEQ uses a nutrient screening criteria of 0.33 mg/L The only station that has an average Ammonia Nitrogen concentration above the screening criteria is Plum Creek at Plum Creek Road (17406) The average ammonia concentrations at this station are above the screening criteria during all subsets of weather conditions and this station is most impacted by wastewater influences. All 7 other routine monitoring stations have average concentrations below the screening criteria during all weather conditions.

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

Monitoring Station	NH3-N Mean 2008 - 2016*	Median Flow (cfs) 2008 - 2016	NH3-N Mean - Wet	No. of Samples (Wet)	Range - Wet	Median Flow (cfs) - Wet	NH3-N Mean - Dry	No. of Samples (Dry)	Range - Dry	Median Flow (cfs) - Dry	% Change Between Dry and Wet**
Plum Creek at Plum Creek Road	0.59	2.8	0.34	44	<0.1 - 3.16	17.5	0.73	79	<0.1 - 9.68	2.1	-53.42%
Plum Creek at CR 202	0.19	7.7	0.16	47	<0.1 - 0.71	43.5	0.21	74	<0.1 - 1.43	5.4	-23.81%
Plum Creek at CR 135	0.18	13	0.19	45	<0.1 - 0.66	61	0.18	78	<0.1 - 0.74	8.1	5.56%
Brushy Creek at Rocky Road	0.2	0.01	0.16	37	<0.1 - 0.35	0.01	0.22	49	<0.1 - 1.08	0	-27.27%
Elm Creek at CR 233	0.22	0	0.21	35	<0.1 - 1.04	0.4	0.24	41	<0.1 - 1.24	0	-12.50%
Dry Creek at FM 672	0.25	0.3	0.23	22	<0.1 - 0.76	1.1	0.28	13	<0.1 - 0.71	0	-17.86%
Clear Fork at CR 128	0.18	2.1	0.17	41	<0.1 - 0.36	5	0.19	68	<0.1 - 0.65	1.1	-10.53%
West Fork at Biggs Road	0.2	0.01	0.19	35	<0.1 - 1.91	0.02	0.21	45	<0.1 - 0.98	0.01	-9.52%

*Entire data set under all flow conditions through December of 2016.

**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 ammonia-nitrogen mean of greater than the water quality screening criteria of 0.33 mg/L under dry conditions.

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. No significant trends in the concentrations of E. *coli* were identified at any of the routine monitoring stations, but significant changes in nutrient concentrations were observed at multiple 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. The p value is the statistical probability that a result will equal or exceed the actual observed value if there is no relation between the groups of variables being tested by the hypothesis.

At the Plum Creek at County Road 135 station (12640), a statistically significant correlation was found between time and several water quality parameters. Nitrate Nitrogen; t(124)=2.81, p=0.01, is increasing with time (Figure 2) and Total Phosphorus; t(124)=-4.27, p=0.00, is decreasing with time (Figure 3). Total phosphorus also shows correlation with stream flow at this station t(126)=-2.78, p=0.01. The decreasing phosphorus numbers are most likely a result of dilution of effluent water from spring flow and rainfall, as the watershed recovers from previous drought conditions.

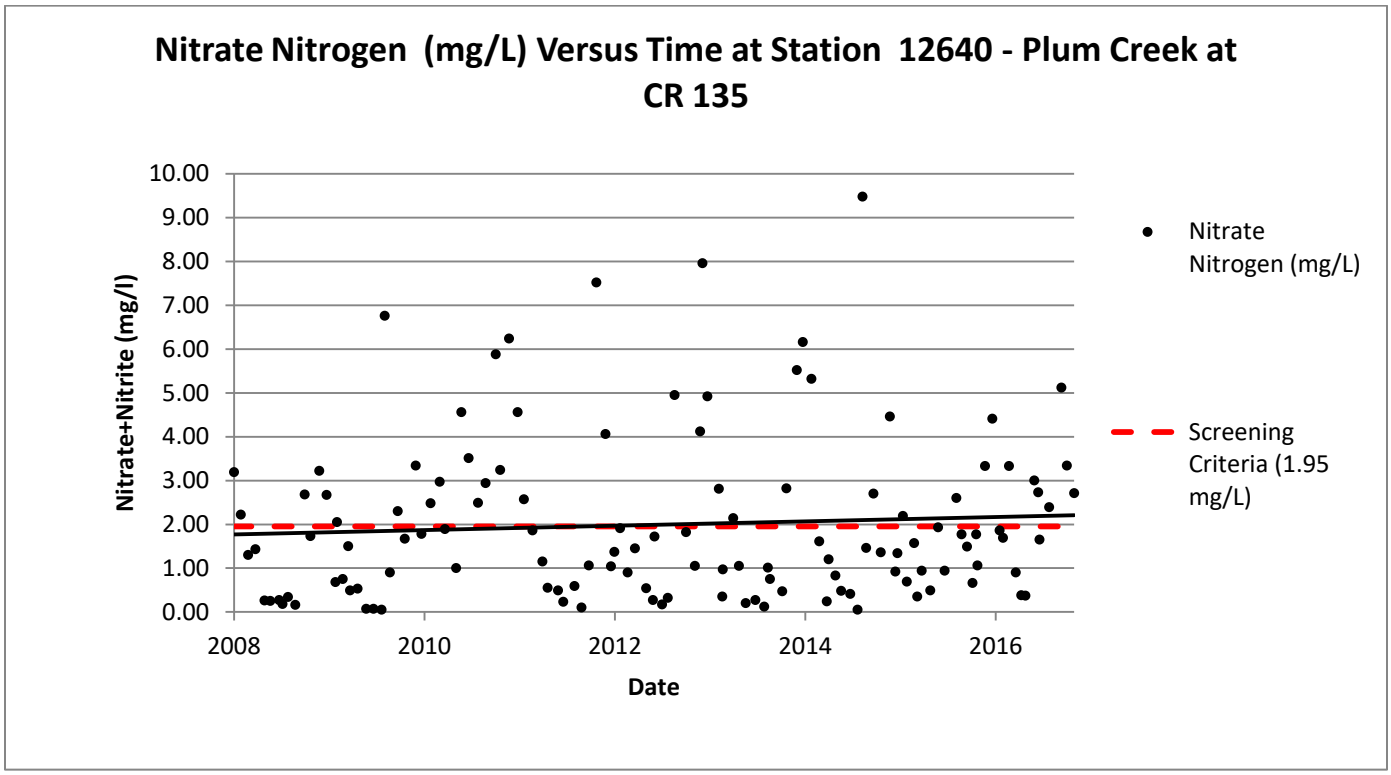


Figure 2. Nitrate-Nitrogen versus Time at Station 12640 – Plum Creek at CR 135. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

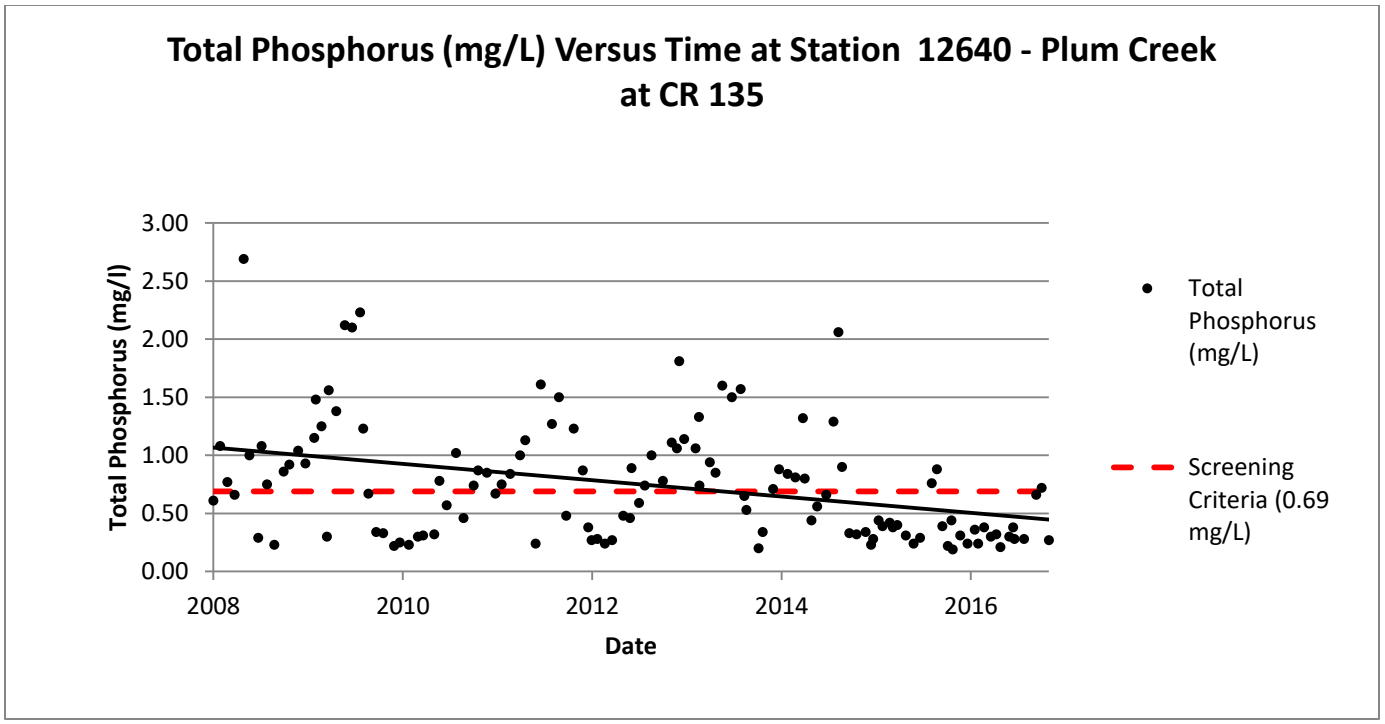


Figure 3. Total Phosphorus versus Time at Station 12640 – Plum Creek at CR 135. The red line is the screening concentration (0.69 mg/L) for concerns set by TCEQ. The black line is the trend line.

At the Plum Creek at County Road 202 station (12647), a statistically significant correlation was found between time and several water quality parameters. Nitrate-Nitrogen; $t(123)=3.65, p=0.00$, is decreasing with time (Figure 4) and Total Phosphorus; $t(123)=-4.61$, $p=0.00$,is also decreasing with time (Figure 5).

The Total Phosphorus; $t(122)=2.52$ $p=0.01$, also showed a statistically significant correlation with stream flow. The relationship between stream flow and total phosphorus may explain why the total phosphorus levels are decreasing over time. Much like ammonia nitrogen, total phosphorus is a common wastewater byproduct from point source discharges that may increase in stream concentrations as stream flows from ambient sources disappear.

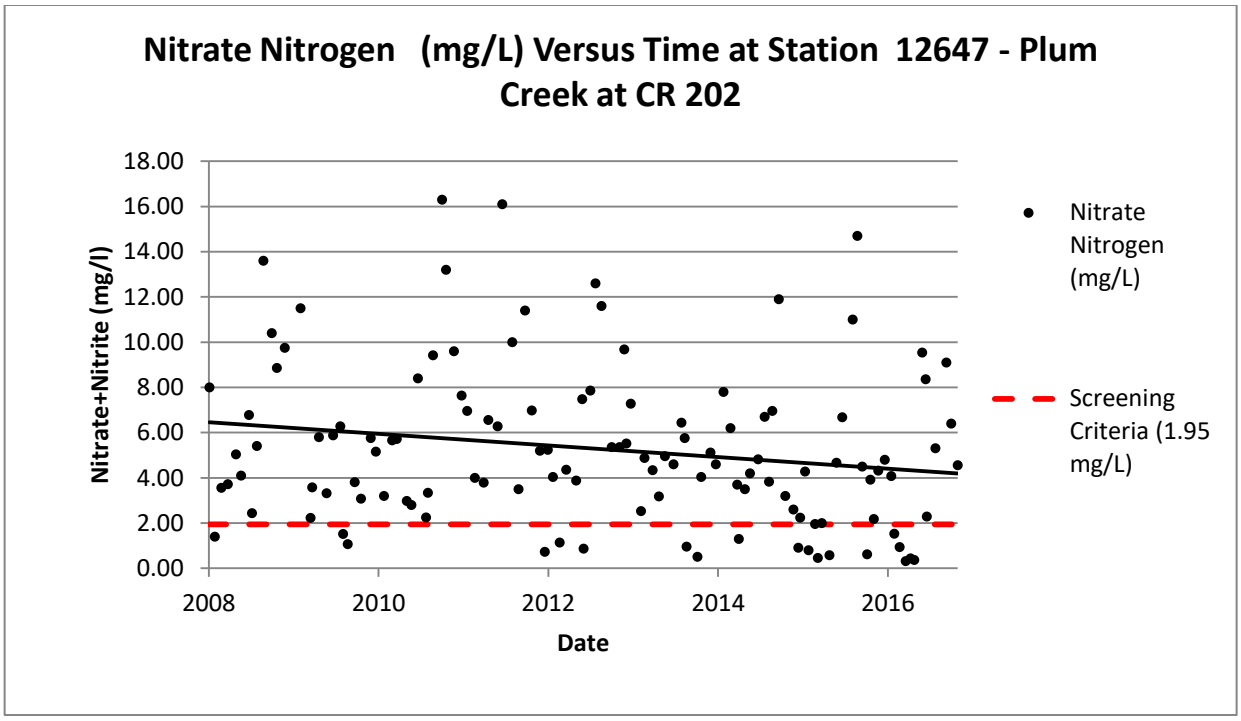


Figure 4. Nitrate-Nitrogen versus Time at Station 12647 - Plum Creek at CR 202. The red line is the screening concentration (1.95 mg/L) for concerns set by TCEQ. The black line is the trend line.

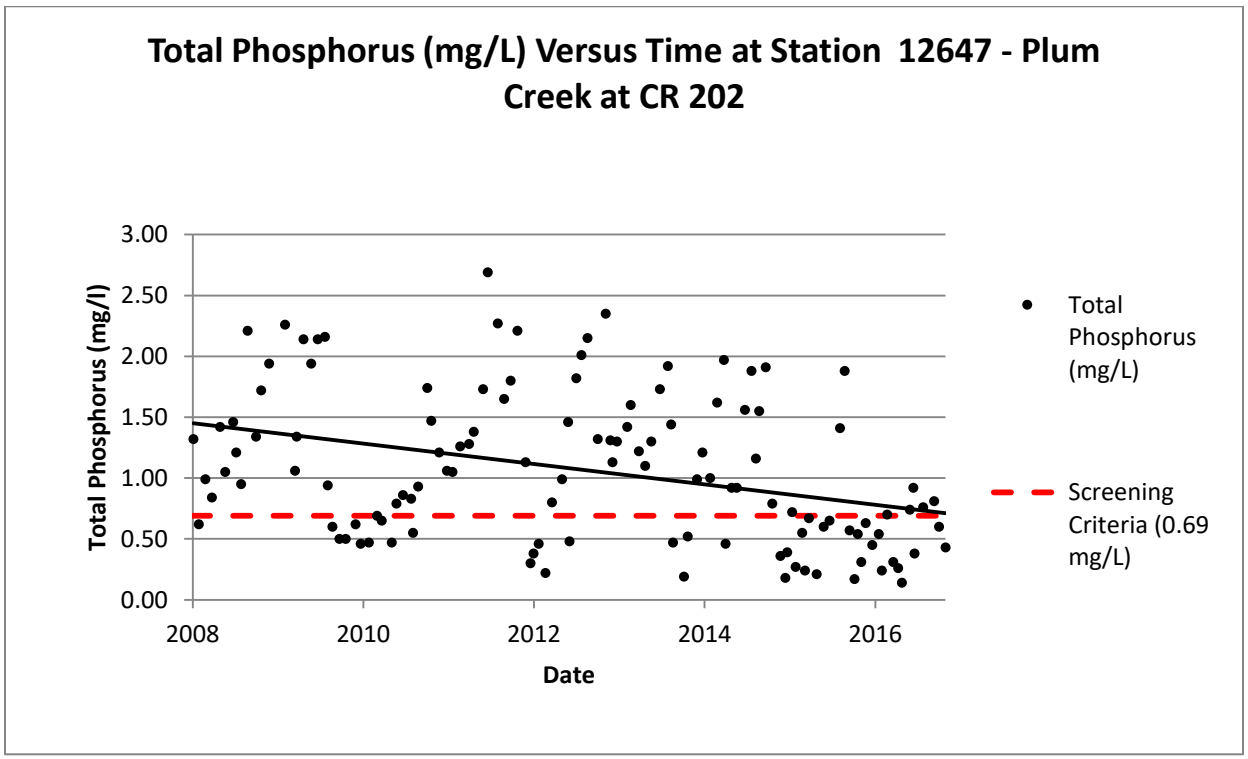


Figure 5. Total Phosphorus versus Time at Station 12647 - Plum Creek at CR 202. The red line is the screening concentration (0.69 mg/L) for concerns set by TCEQ. The black line is the trend line.

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(122)=2.17,p=0.03, is increasing with time (Figure 6) and Total Phosphorus; t(122)=-4.01, p=0.00, is decreasing with time (Figure 7). 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 from the incoming raw wastewater and converted to nitrate nitrogen through nitrification. The increase in ammonia nitrogen in this stream segment may be associated with the efficiency of this conversion process in wastewater dischargers. The increase in ammonia-nitrogen over time may be an indication of less efficiency in this WWTF nitrification process.

The Total Phosphorus; t(123)=-3.56 p=0.00 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, but it does receive the effluent from several major WWTF outfalls.

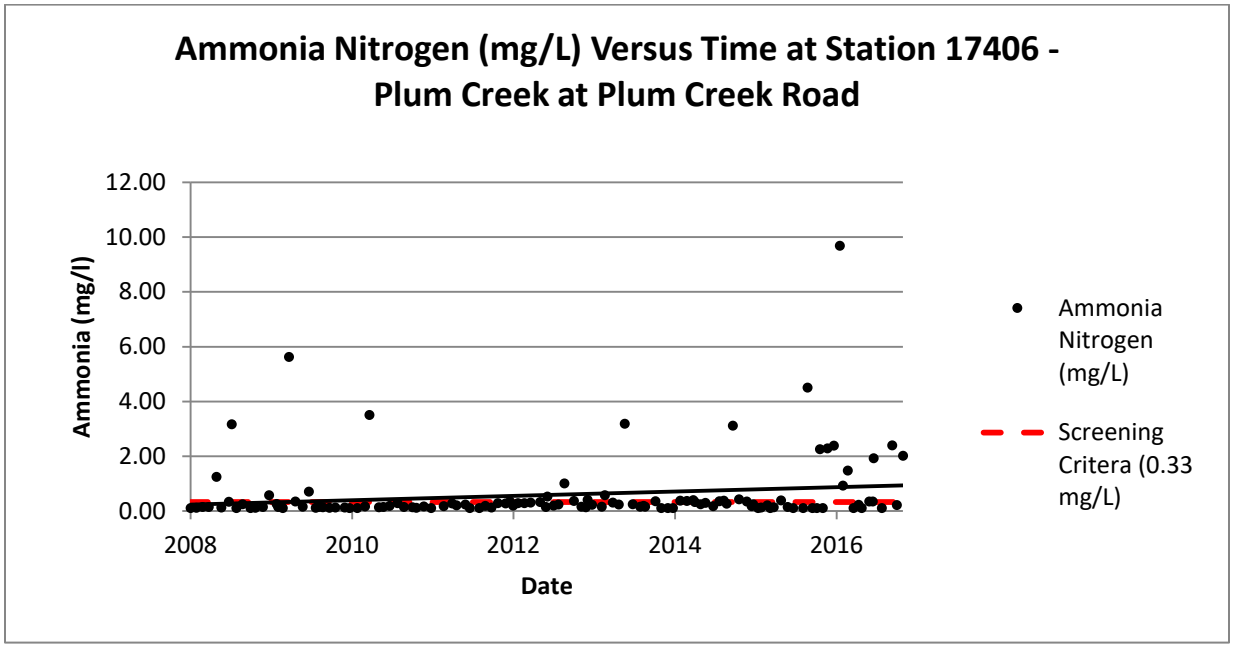


Figure 6. Ammonia-Nitrogen versus Time at Station 17406 - Plum Creek at Plum Creek Road. The red line is the screening concentration (0.33 mg/L) for concerns set by TCEQ. The black line is the trend line.

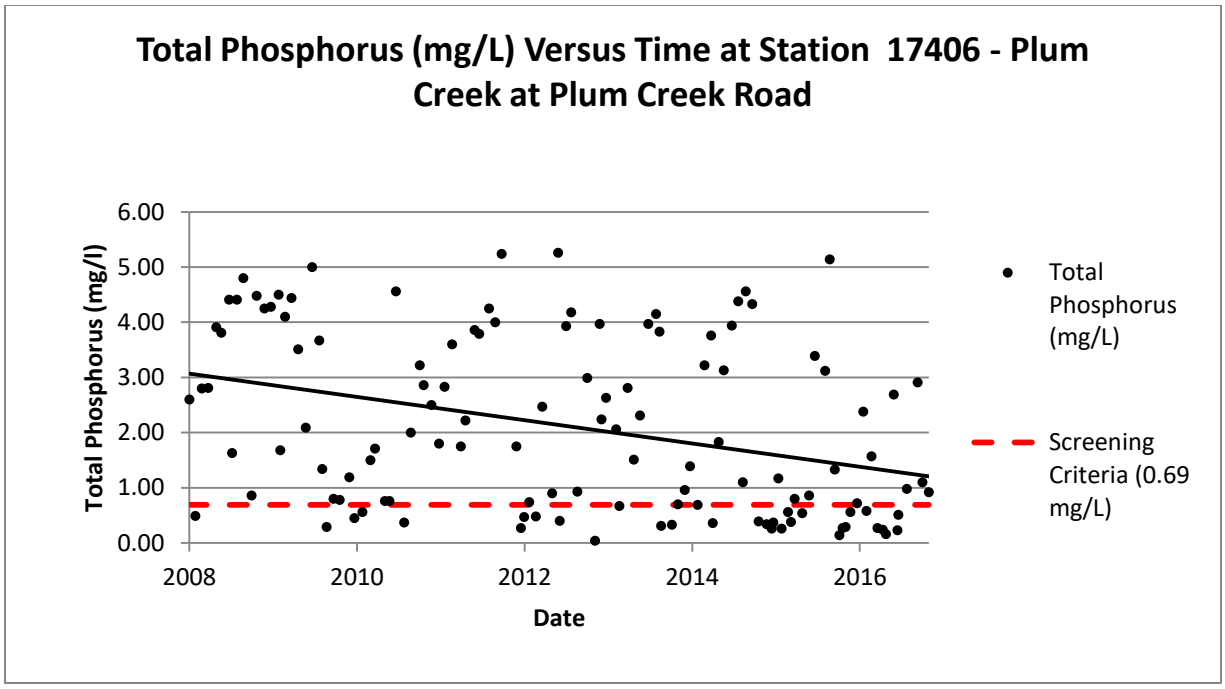


Figure 7. Total Phosphorus versus Time at Station 17406-Plum Creek at Plum Creek Road. The red line is the screening concentration (0.69 mg/L) for concerns set by TCEQ. The black line is the trend line.

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. The 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 increased flows enough from previous base flows to create wet weather targeted conditions.

Throughout the project period, targeted monitoring proved to be a challenge. Drought conditions caused many of the tributary stations to go dry for extended periods of time and these droughts were often broken by a few severe flood events. When small rain events did occur, they were often not watershed-wide, leaving many sites 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.

A compilation of the data collected at the targeted sites can be found in Tables 6, 7, 8 and 9. Tables 6 and 7 list the average *E. coli* and nutrient concentrations during wet and dry weather conditions at all of the Plum Creek main stem monitoring locations. Tables 8 and 9 list the same average monitoring parameter concentrations in tables 6 and 7 in all of the Plum Creek targeted tributary monitoring stations.

Table 6. Compilation of Stream Flow, *E. coli* and Total Phosphorus data collected at Plum Creek main stem routine and targeted sampling stations. *E. coli* calculated in MPN/100ml. Total Phosphorus,(Tot. P) concentrations are in mg/L. Stations are listed in order from upstream to downstream.

Monitoring Station	Median Flow (cfs) 2008 – 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	*E. coli* Geomean 2008 - 2016	*E. coli* Geomean - Wet	*E. coli* Geomean - Dry	Total P Mean 2008 - 2016	Total P Mean Wet	Total P Mean Dry
Plum Creek at NRCS #1	0.0	1.0	0.0	41	74	16	0.24	0.21	0.28
Plum Creek at Lehman	0.5	4.9	0.0	230	571	71	0.05	0.07	0.03
Plum Creek at Heidenreich	3.0	8.2	2.2	1237	1479	1055	2.57	1.76	3.45
Plum Creek at PC Rd	2.8	17.5	2.1	474	658	397	2.10	1.02	2.69
Plum Creek at CR 233	5.3	29.0	1.9	289	674	115	1.61	1.08	2.19
Plum Creek at HWY 183	5.1	31.0	1.8	221	641	70	1.28	0.90	1.70
Plum Creek at CR 186	6.3	20.0	3.2	392	670	209	0.93	0.77	1.12
Plum Creek at CR 202	7.7	43.5	5.4	287	496	204	1.06	0.80	1.23
Plum Creek at CR 197	8.2	31.0	4.9	400	739	188	0.96	0.81	1.14
Plum Creek at FM 1322	9.1	47.0	5.2	428	1013	162	0.87	0.79	0.97
Plum Creek at CR 131	13.0	74.0	6.4	471	1049	190	0.82	0.83	0.81
Plum Creek at CR 135	13.0	61.0	8.1	220	552	131	0.75	0.68	0.79

*Entire data set under all flow conditions through December of 2016.

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

Table 7. Compilation of Stream Flow, Nitrate Nitrogen and Ammonia Nitrogen data collected at Plum Creek main stem routine and targeted sampling stations. Nitrate Nitrogen (NO3-N) and Ammonia Nitrogen (NH3-N) concentrations are in mg/L. Stations are listed in order from upstream to downstream.

Monitoring Station	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	NO3-N Mean 2008 – 2016*	NO3-N Mean Wet	NO3-N Mean Dry	NH3-N Mean 2008 – 2016*	NH3-N Mean Wet	NH3-N Mean Dry
Plum Creek at NRCS #1	0.0	1.0	0.0	0.64	0.47	0.91	0.29	0.17	0.49
Plum Creek at Lehman	0.5	4.9	0.0	0.74	0.87	0.58	0.17	0.17	0.16
Plum Creek at Heidenreich	3.0	8.2	2.2	12.56	10.92	14.35	1.23	0.68	1.81
Plum Creek at PC Rd	2.8	17.5	2.1	10.79	5.66	13.55	0.59	0.35	0.73
Plum Creek at CR 233	5.3	29.0	1.9	6.59	4.16	9.22	0.19	0.20	0.18
Plum Creek at HWY 183	5.1	31.0	1.8	3.54	2.42	4.75	0.18	0.20	0.17
Plum Creek at CR 186	6.3	20.0	3.2	5.04	2.98	7.45	0.16	0.17	0.16
Plum Creek at CR 202	7.7	43.5	5.4	5.27	3.55	6.34	0.19	0.16	0.21
Plum Creek at CR 197	8.2	31.0	4.9	3.76	3.06	4.60	0.18	0.16	0.22
Plum Creek at FM 1322	9.1	47.0	5.2	2.71	2.01	3.53	0.18	0.18	0.17

Table 7 Continued.

Monitoring Station	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	NO3-N Mean 2008 – 2016*	NO3-N Mean Wet	NO3-N Mean Dry	NH3-N Mean 2008 – 2016*	NH3-N Mean Wet	NH3-N Mean Dry
Plum Creek at CR 131	13.0	74.0	6.4	2.20	2.30	2.08	0.21	0.22	0.20
Plum Creek at CR 135	13.0	61.0	8.1	2.00	2.10	1.93	0.18	0.19	0.18

*Entire data set under all flow conditions through December of 2016.
Stations highlighted have a base flow Nitrate concentration greater than the water quality screening criteria of 1.95 mg/L under dry conditions.

Table 8. Compilation of Stream Flow, E. coli and Total Phosphorus data collected at Plum Creek tributary routine and targeted sampling stations. Ecoli calculated in MPN/100ml. Total Phosphorus, (Tot. P) concentrations are in mg/L. Tributary stations are listed in order from upstream to downstream in the watershed.

Monitoring Stations	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	*E. coli* Geomean 2008 – 2016*	*E. coli* Geomean - Wet	*E. coli* Geomean - Dry	Total P Mean 2008 – 2016*	Total P Mean Wet	Total P Mean Dry
Unnamed at FM 150	0.30	0.60	0.08	224	298	89	0.03	0.02	0.03
Andrew's at CR 131	1.30	1.95	0.90	369	658	186	0.25	0.19	0.33
Richmond at Dacy	0.10	0.40	0.01	393	760	190	0.09	0.08	0.11
Unnamed at Quail Cove	0.03	0.06	0.01	552	858	39	0.12	0.13	0.03
Porter at Dairy Lane	1.30	4.80	0.60	481	894	168	0.09	0.11	0.07
Cowpen at Schuelke	2.40	2.60	0.00	1075	1643	45	0.21	0.22	0.17
Bunton at Dacy	0.40	2.60	0.02	181	529	52	0.06	0.06	0.06
Bunton at Heidenreich	0.80	7.10	0.40	343	587	124	0.07	0.09	0.05
Brushy at FM 2001	0.01	0.03	0.00	122	313	3	0.09	0.11	0.04
Brushy at SH21	0.20	5.50	0.01	232	899	31	0.11	0.13	0.07
Brushy Creek at Rocky Rd	0.01	0.01	0.00	208	728	220	0.12	0.14	0.10
Elm Creek at SH 21	0.80	2.05	0.00	296	436	63	0.09	0.11	0.03
Elm Creek at CR 233	0.00	0.45	0.00	154	475	56	0.15	0.19	0.12
Clear Fork at Farmers Rd	0.01	0.01	0.00	70	106	24	0.13	0.15	0.09
Clear Fork at PR10	1.20	2.10	0.90	156	344	62	0.08	0.12	0.04
Clear Fork at Old Luling Rd	1.00	2.90	0.80	143	288	63	0.11	0.15	0.05
Clear Fork at Salt Flat Rd	2.10	5.00	1.10	225	601	122	0.11	0.16	0.08
Town Branch at Stueve Ln	0.00	0.00	0.00	498	445	2400**	0.67	0.70	0.30
Town Branch at E. Market St	1.10	1.40	0.80	492	800	278	0.09	0.12	0.05
Dry Creek at FM 672	0.30	1.10	0.00	513	1090	149	0.30	0.31	0.27

Table 8 Continued.

Monitoring Stations	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	*E. coli* Geomean 2008 – 2016*	*E. coli* Geomean - Wet	*E. coli* Geomean - Dry	Total P Mean 2008 – 2016*	Total P Mean Wet	Total P Mean Dry
Dry Creek at FM 713	0.40	0.90	0.00	905	1319	340	0.23	0.26	0.18
Tenney Creek at Tenney Crk	4.00	4.00	0.00	1039	1039	N/A	0.36	0.36	N/A
Hines Branch at Tenney Crk Rd	0.00	0.00	0.00	350	487	68	0.27	0.29	0.18
Copperas at Tenney Crk Rd	0.10	0.20	0.01	1183	1413	616	0.83	1.03	0.09
West Fork at FM 671	0.03	0.06	0.00	541	628	37	0.18	0.17	0.12
West Fork at Biggs Rd	0.01	0.02	0.01	122	362	53	0.40	0.35	0.44
Salt Branch at Salt Flat Rd	0.01	0.06	0.00	904	1098	693	0.36	0.26	0.49
Salt Branch at FM 1322	0.30	0.70	0.20	318	479	196	2.46	1.59	3.48

*Entire data set under all flow conditions through December of 2016.

**The Town Branch at Stueve Lane did not receive regular flow during rain events due to a diversion of the water upstream. When water was available for collection it was usually limited to direct rainfall runoff from the nearby roadway, which may have caused elevated *E. coli* values. Stations highlighted have a base flow geometric mean greater than the water quality standard of 126 organisms/100 mL under dry conditions.

Table 9. Compilation of Stream Flow, Nitrate Nitrogen and Ammonia Nitrogen data collected at Plum Creek tributary routine and targeted sampling stations. Nitrate Nitrogen (NO3-N) and Ammonia Nitrogen (NH3-N) concentrations are in mg/L. Tributary stations are listed in order from upstream to downstream in the watershed.

Monitoring Stations	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	NO3-N Mean 2008 – 2016*	NO3-N Mean Wet	NO3-N Mean Dry	NH3-N Mean 2008 – 2016*	NH3-N Mean Wet	NH3-N Mean Dry
Unnamed at FM 150	0.30	0.60	0.08	1.72	1.99	0.85	0.18	0.19	0.14
Andrew's at CR 131	1.30	1.95	0.90	11.53	7.78	16.00	0.22	0.21	0.24
Richmond at Dacy	0.10	0.40	0.01	0.64	0.98	0.25	0.32	0.18	0.49
Unnamed at Quail Cove	0.03	0.06	0.01	0.35	0.40	0.06	0.16	0.17	0.10
Porter at Dairy Lane	1.30	4.80	0.60	0.73	0.71	0.81	0.24	0.20	0.30
Cowpen at Schuelke	2.40	2.60	0.00	0.53	0.59	0.05	0.21	0.23	0.10
Bunton at Dacy	0.40	2.60	0.02	0.44	0.59	0.26	0.18	0.17	0.19
Bunton at Heidenreich	0.80	7.10	0.40	0.72	0.56	1.04	0.19	0.18	0.22
Brushy at FM 2001	0.01	0.03	0.00	0.40	0.47	0.06	0.18	0.18	0.16
Brushy at SH21	0.20	5.50	0.01	0.33	0.42	0.13	0.21	0.15	0.28
Brushy Creek at Rocky Rd	0.01	0.01	0.00	0.19	0.30	0.12	0.20	0.16	0.22
Elm Creek at SH 21	0.80	2.05	0.00	0.33	0.40	0.08	0.17	0.19	0.10
Elm Creek at CR 233	0.00	0.45	0.00	0.25	0.41	0.11	0.22	0.21	0.23
Clear Fork at Farmers Rd	0.01	0.01	0.00	2.34	2.03	3.16	0.13	0.13	0.14

Table 9 Continued.

Monitoring Stations	Median Flow (cfs) 2008 - 2016	Median Flow (cfs) - Wet	Median Flow (cfs) - Dry	NO3-N Mean 2008 – 2016*	NO3-N Mean Wet	NO3-N Mean Dry	NH3-N Mean 2008 – 2016*	NH3-N Mean Wet	NH3-N Mean Dry
Clear Fork at PR10	1.20	2.10	0.90	2.69	2.50	2.91	0.21	0.17	0.26
Clear Fork at Old Luling Rd	1.00	2.90	0.80	1.69	1.67	1.72	0.20	0.19	0.20
Clear Fork at Salt Flat Rd	2.10	5.00	1.10	0.94	1.14	0.82	0.18	0.17	0.19
Town Branch at Stueve Ln	0.00	0.00	0.00	1.67	1.22	8.03	0.29	0.29	0.26
Town Branch at E. Market St	1.10	1.40	0.80	9.89	9.33	10.55	0.20	0.18	0.21
Dry Creek at FM 672	0.30	1.10	0.00	0.46	0.56	0.20	0.25	0.23	0.28
Dry Creek at FM 713	0.40	0.90	0.00	0.42	0.35	0.62	0.24	0.23	0.26
Tenney Creek at Tenney Crk Rd	4.00	4.00	0.00	0.36	0.36	N/A	0.15	0.15	N/A
Hines Branch at Tenney Crk Rd	0.00	0.00	0.00	0.51	0.60	0.05	0.23	0.23	0.24
Copperas at Tenney Crk Rd	0.10	0.20	0.01	0.29	0.34	0.11	1.37	1.66	0.29
West Fork at FM 671	0.03	0.06	0.00	0.34	0.36	0.05	0.20	0.16	0.84
West Fork at Biggs Rd	0.01	0.02	0.01	0.29	0.29	0.28	0.20	0.19	0.21
Salt Branch at Salt Flat Rd	0.01	0.06	0.00	0.28	0.22	0.36	0.88	0.23	1.77
Salt Branch at FM 1322	0.30	0.70	0.20	9.11	5.33	13.54	0.34	0.32	0.37

*Entire data set under all flow conditions through December of 2016.

Stations highlighted have a base flow Nitrate concentration greater than the water quality screening criteria of 1.95 mg/L under dry conditions.

Wastewater Effluent Monitoring

The GBRA conducted grab sampling at 7 wastewater treatment facilities that discharge into Plum Creek and its tributaries in order to monitor effects on the parameters of interest. These WWTF stations were monitored monthly for the same field, flow, bacteria, and conventional parameter groups that are analyzed at the routine monitoring stations, but are additionally monitored for wastewater specific parameters. The Plum Creek watershed protection plan made recommendations for commonly permitted discharge concentration limits of biochemical oxygen demand (BOD), total suspended solids (TSS), ammonia-nitrogen (NH3-N) and total phosphorus (Total P) in order to meet pollutant loading goals identified by the stakeholders. Table 10 identifies the common wastewater parameters that were analyzed and compares them to the Plum Creek WPP permit recommendations. Table 11 compares the results from the wastewater monitoring to the TCEQ stream standards and screening criteria. The 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.

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. The Buda WWTF

discharges into the Andrew's Branch of Porter Creek, which merges with Plum Creek just upstream of the Plum Creek at Plum Creek Road (17406) CRP monitoring station. The Kyle WWTF discharges into Plum Creek just upstream of the Plum Creek at Heidenreich Lane (20484) targeted monitoring station. The Sunfield and Shadow Creek facilities discharge into the Brushy Creek Tributary of Plum Creek, which merges with Plum Creek just upstream of the Plum Creek at CR 233 targeted monitoring station (12649). The Lockhart #1 facility discharges into the Town Branch tributary of Plum Creek, which merges with Plum Creek upstream of the Plum Creek at CR 186 (12648) targeted monitoring station. The Lockhart #2 facility discharges into Plum Creek upstream of the Plum Creek at CR 202 (12647) CRP monitoring station. The Luling North WWTF discharges into the Salt Branch Tributary of Plum Creek before it merges with Plum Creek upstream of the Plum Creek at CR 135 (12640) CRP monitoring station.

Table 10. Compilation of wastewater water quality sampling parameters compared to PC WPP recommended permit limits.

Monitoring Station	Median Flow (CFS)	Geomean *E. coli* (MPN/100 mL)	Mean pH (S.U.)	Mean D. O. (mg/L)	Mean TSS (mg/L)	Mean Total P (mg/L)	Mean BOD (mg/L)	Mean CBOD (mg/L)	Mean COD (mg/L)	Mean NH3-N (mg/L)
PC WPP Recommended Permit Limits	7Q2 = 2.3	126	6.5 to 9	5	5	1	5	5	N/A	2
Buda WWTF	1.4	2.3	7.5	8.3	1	0.41	1.7	1.2	16.1	0.41
Kyle WWTF	2.65	72.1	7.4	8.0	10	3.77	3.8	3.3	32.5	1.28
Sunfield WWTF	0.1	1.2	7.6	8.7	1	0.50	1.5	1.5	15.5	0.21
Shadow Creek WWTF	0.2	3.9	7.6	7.6	1	0.54	1.7	1.6	18.3	1.09
Lockhart #2 WWTF	1.4	11.7	7.6	8.5	5	2.55	1.5	1.5	21.4	0.48
Lockhart #1 WWTF	0.7	2.4	7.1	8.3	3	3.03	2.0	2.3	21.3	0.74
Luling North WWTF	0.31	2.0	7.0	8.2	10	4.10	2.1	2.6	28.1	0.52

Stations highlighted have concentration greater than the Plum Creek WPP recommended permit limits.

Table 11. Compilation of wastewater water quality sampling parameters compared to stream screening criteria.

Monitoring Station	Median Flow (CFS)	Geomean *E. coli* (MPN/100 mL)	Mean Temperature (°C)	Mean Conductivity (*uS*/cm)	Mean Total P (mg/L)	Mean NO3-N (mg/L)	Mean NH3-N (mg/L)	Mean Chloride (mg/L)	Mean Sulfate (mg/L)	Mean TKN (mg/L)
Stream Screening Criteria	7Q2 = 2.3	126	32.2	1723	0.69	1.95	0.33	350	150	N/A
Buda WWTF	1.4	2.3	25.1	1460	0.41	17.94	0.41	237	118	0.71
Kyle WWTF	2.65	72.1	26.0	1196	3.77	19.40	1.28	151	99	2.15
Sunfield WWTF	0.1	1.2	22.7	1567	0.50	42.68	0.21	237	153	0.37
Shadow Creek WWTF	0.2	3.9	25.2	1164	0.54	8.97	1.09	167	101	1.54
Lockhart #2 WWTF	1.4	11.7	23.3	976	2.55	7.38	0.48	127	61	1.13
Lockhart #1 WWTF	0.7	2.4	25.1	917	3.03	17.51	0.74	107	65	1.13
Luling North WWTF	0.31	2.0	22.6	959	4.10	28.67	0.52	122	54	0.91

Stations highlighted have concentration greater than the TCEQ water quality screening criteria.

Storm Monitoring

The 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 to prevent duplication of monitoring 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. The 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

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 hourly samples collected by the automated sampler. The holding time for the *E. coli* samples collected by the autosampler during a storm event was extended for up to 24 hours. This holding time was applied when transport conditions necessitated delays of longer than 8 hours from sample collection to analysis. Wireless communication links were established from each unit to notify the GBRA of triggering events.

An estimate of volume was done based on the measurement of the pressure gauge on the ISCO brand automated sampler 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 was over the trigger level were 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 was 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; 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; and 4) estimating the amount of dilution necessary to precisely analyze the *E. coli* samples collected. The batteries frequently failed shortly after the event triggered the samplers because they lost charge due to changes in ambient temperatures and long term deployment power draws. The refrigerated sampler also required a large amount of battery power, which quickly depleted the charge of older batteries. 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.

A total of five qualifying events were collected at the Plum Creek at Heidenreich (20484) and Plum Creek CR 202 (12647) stations located on the main stem of Plum Creek downstream of the Kyle WWTF and Lockhart #2 WWTFs, respectively. A total of four events were collected at the Salt Branch at FM 1322 (12555) storm monitoring location located downstream of the City of Luling WWTF. The results of the storm water monitoring revealed that all stations exceeded the stream standard for *E. coli* during rainfall runoff events for at least 24 hours following the initial 1" rise in stream level. The flow weighted composites from each sampling event revealed that Ammonia and TKN concentrations were always below the stream screening criteria, with the exception of the Ammonia concentrations at station 20484 on 11/05/2014. Total Phosphorus and Nitrate Nitrogen were generally quite high during storm events and did not appear to be diluted by rainfall to the degree that was expected. These concentrations may have increased during storm events due to influxes of fertilizer from nearby fields washed into the creek by rainwater.

Table 12. Compilation of Storm Monitoring water quality sampling parameters during triggered storm events.

Stormwater Station	Date	GeoMean E. coli (MPN/100 mL)	Max E. coli (MPN/100 mL)	Min E. coli (MPN/100 mL)	Composite NH3-N (mg/L)	Composite TKN (mg/L)	Composite Total P (mg/L)	Composite NO3-N (mg/L)
Plum Creek at Heidenreich Lane	5/3/2014	9240	120000	1000	0.61	1.71	2.27	13.5
Plum Creek at Heidenreich Lane	11/5/2014	4155	7700	2000	2.28	1.54	1.92	10.5
Plum Creek at Heidenreich Lane	1/22/2015	4983	13000	1300	0.3	1.33	0.31	0.86
Plum Creek at Heidenreich Lane	3/22/2015	3561	9800	790	0.7	4.1	0.2	1.84
Plum Creek at Heidenreich Lane	10/24/2015	37924	48000	14000	0.1	0.76	0.96	2.23
Plum Creek at Heidenreich Lane	3/9/2016	8298	31000	650	0.1	1.88	0.72	1.93

Table12 Continued.

Stormwater Station	Date	GeoMean E. coli (MPN/100 mL)	Max E. coli (MPN/100 mL)	Min E. coli (MPN/100 mL)	Composite NH3-N (mg/L)	Composite TKN (mg/L)	Composite Total P (mg/L)	Composite NO3-N (mg/L)
Plum Creek at CR 202	11/5/2014	2831	17000	130	0.3	1.01	1.2	2.76
Plum Creek at CR 202	1/22/2015	909	17000	80	0.22	1.84	0.69	1.37
Plum Creek at CR 202	3/21/2015	4726	24000	800	0.1	1.26	0.3	1.67
Stormwater Station	Date	GeoMean E. coli (MPN/100 mL)	Max E. coli (MPN/100 mL)	Min E. coli (MPN/100 mL)	Composite NH3-N (mg/L)	Composite TKN (mg/L)	Composite Total P (mg/L)	Composite NO3-N (mg/L)
Plum Creek at CR 202	10/24/2015	19670	48000	1200	0.26	1.37	0.95	4.2
Plum Creek at CR 202	3/9/2016	25528	48000	1900	0.8	1.56	0.49	2.95
Salt Branch at FM 1322	1/22/2015	15496	40000	480	0.17	1.48	0.77	1.93
Salt Branch at FM 1322	3/18/2015	3268	13000	1200	0.42	0.62	0.14	11.2
Salt Branch at FM 1322	10/24/2015	13527	48000	100	0.15	1.76	1.58	8.36
Salt Branch at FM 1322	3/9/2016	11033	35000	3600	0.12	1.19	2.12	13.6

Highlighted values exceed the TCEQ stream standard or screening criteria for Plum Creek.

Diurnal Monitoring

Diurnal monitoring was conducted during the TCEQ index period 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. The Dry Creek at FM 672 only had enough water to deploy a probe three times throughout the monitoring project in June, August and September of 2016. In March and April of 2016 no probes were deployed at the five tributary stations due to heavy flooding. In May of 2016 no probes were deployed at any stations due to heavy flooding and the possible loss of instrumentation. Diurnal monitoring resumed in June of 2016.

The deployed probes in the three Plum Creek monitoring stations (12640, 12647, & 17406) and the Clear fork tributary (12556) consistently reported dissolved oxygen values that met the TCEQ stream standard for high aquatic life use. The average dissolved oxygen concentrations at these four stations were above the 24 hour screening criteria of 5 mg/L and 24 hour minimum concentrations of 4 mg/L. The probes deployed at the Brushy Creek (20488), Elm Creek (12558), West Fork (20500) and Dry Creek (20491) tributaries generally reported values consistent with the presumed Limited aquatic life use for an unclassified intermittent stream with perennial pools. The limited aquatic life use criteria presumes an average dissolved oxygen level of 3 mg/L and a minimum dissolved oxygen level of 2 mg/L. All four tributaries fell below the minimum dissolved oxygen criteria on separate occasions.

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. The GBRA conducted spring flow monitoring at 3 springs once per season collecting field, conventional, flow and bacteria parameter groups. All sampling events were conducted.

The 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 consistent with previous analyses performed on the Leona Aquifer (mean concentrations: Boggy Creek Springs – 6.0 mg/L; Clear Fork Springs – 6.1 mg/L; and Lockhart Springs – 10.1 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 MPN per 100 milliliter; Clear Fork Springs – 261 MPN per 100 milliliters; and Lockhart Springs – 273 MPN per 100 milliliters). Table 12 summarizes the results of the water quality monitoring collected during this monitoring task.

Table 13. Compilation of water quality monitoring parameters collected in springs of the Leona Aquifer.

Monitoring Station	Median Flow CFS	Geomean E. coli MPN/100 mL	Mean TSS mg/L	Mean D. O. mg/L	Mean SC *uS*/cm	Mean Total P mg/L	Mean NO3-N mg/L	Mean Chloride mg/L	Mean Sulfate mg/L	Mean NH3-N mg/L	Mean TKN mg/L
Stream Screening Criteria		126		5	1723	0.69	1.95	350	150	0.33	
Boggy Creek Springs at Boggy Creek Road	0.2	165	8.1	7.5	729	0.05	6.04	14	50	0.27	0.35
Clear Fork Springs at Borchert Loop	0.9	261	8.9	8.8	774	0.04	6.10	25	86	0.15	0.36
Lockhart Springs	0.8	273	2.5	9.2	783	0.05	10.03	30	64	0.17	0.26

Highlighted values exceed the TCEQ stream standard or screening criteria for Plum Creek.

Appendix A List of Monitoring Sites

TCEQ Station ID	Site Description	Workplan Task	Monitor Type	DO 24hr	Bacteria	Conventional	Flow	Field
12556	Clear Fork Plum Creek at Salt Flat Road	3	RT		21	21	21	21
12556	Clear Fork Plum Creek at Salt Flat Road	6	BS	14			14	14
12556	Clear Fork Plum Creek at Salt Flat Road	4	BF		7	7	7	7
12558	Elm Creek at CR 233	3	RT		21	21	21	21
12558	Elm Creek at CR 233	6	BS	14			14	14
12558	Elm Creek at CR 233	4	BF		7	7	7	7
12640	Plum Creek at CR 135	3	RT		21	21	21	21
12640	Plum Creek at CR 135	6	BS	14			14	14
12640	Plum Creek at CR 135	4	BF		7	7	7	7
12647	Plum Creek at Old McMahan Road (CR 202)	3	RT		21	21	21	21
12647	Plum Creek at Old McMahan Road (CR 202)	6	BS	14			14	14
12647	Plum Creek at Old McMahan Road (CR 202)	4	BF		7	7	7	7
12647	Plum Creek at Old McMahan Road (CR 202)	5	BF		7	7	7	7
17406	Plum Creek at Plum Creek Road	3	RT		21	21	21	21
17406	Plum Creek at Plum Creek Road	6	BS	14			14	14
17406	Plum Creek at Plum Creek Road	4	BF		7	7	7	7
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	3	RT		21	21	21	21
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	6	BS	14			14	14
20488	Brushy Creek at Rocky Road (Upstream of NRCS 14)	4	BF		7	7	7	7
20491	Dry Creek at FM 672	3	RT		21	21	21	21
20491	Dry Creek at FM 672	6	BS	14			14	14
20491	Dry Creek at FM 672	4	BF		7	7	7	7
20500	West Fork Plum Creek at Biggs Road (CR 131)	3	RT		21	21	21	21
20500	West Fork Plum Creek at Biggs Road (CR 131)	6	BS	14			14	14
20500	West Fork Plum Creek at Biggs Road (CR 131)	4	BF		7	7	7	7
12555	Salt Branch at FM 1322	4	BF		14	14	14	14
12555	Salt Branch at FM 1322	5	BF		7	7	7	7

TCEQ Station ID	Site Description	Workplan Task	Monitor Type	DO 24hr	Bacteria	Conventional	Flow	Field
12557	Town Creek at E. Market St. (Upstream of Lockhart #l WWTP)	4	BF		14	14	14	14
12559	Porter Creek at Dairy Road	4	BF		14	14	14	14
12642	Plum Creek at Biggs Road (CR 131)	4	BF		14	14	14	14
12643	Plum Creek at FM 1322	4	BF		14	14	14	14
12645	Plum Creek at Young Lane (CR 197)	4	BF		14	14	14	14
20505	Richmond Branch at Dacy Lane	4	BF		14	14	14	14
20504	Porter Creek Tributary at Quail Cove Road	4	BF		14	14	14	14
20510	Hines Branch at Tenney Creek Road (CR 141, Downstream of Cal-Maine)	4	BF		14	14	14	14
20503	Plum Creek at Lehman Road	4	BF		14	14	14	14
20502	Bunton Branch at Dacy Lane (upstream of NRCS 5)	4	BF		14	14	14	14
20479	Unnamed Tributary at FM 150 near Hawthorn Dr.	4	BF		14	14	14	14
20492	10210-001 City of Lockhart and GBRA #1(Larremore plant)	7	-		21	21	21	21
20494	10210-002 City of Lockhart and GBRA #2 (FM 20 plant)	7	-		21	21	21	21
20499	10582-001 City of Luling	7	-		21	21	21	21
20486	11041-002 City of Kyle and Aquasource Inc.	7	-		21	21	21	21
99923	11060-001 City of Buda and GBRA	7	-		21	21	21	21
99936	14431-001 GBRA Shadow Creek	7	-		21	21	21	21
99937	14377-001 GBRA Sunfield	7	-		21	21	21	21
20509	Lockhart Springs	8	BS		7	7	7	7
20507	Clear Fork Springs at Borchert Loop (CR 108)	8	BS		7	7	7	7
20508	Boggy Creek Springs at Boggy Creek Road (CR 218)	8	BS		7	7	7	7

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