Surface Water Quality Monitoring to Support the Implementation of the Geronimo and Alligator Creeks Watershed Protection Plan

FINAL REPORT
TSSWCB PROJECT #17-08

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

In 2007, the TSSWCB Regional Watershed Coordination Steering Committee, using established criteria, ranked Geronimo Creek in the top 3 watersheds for selection of WPP development. The TSSWCB project 08-06 entitled, Development of a Watershed Protection Plan for Geronimo Creek, was begun in June 2008. The project included water quality monitoring, water quality modeling and WPP development. The development of the WPP for Geronimo and Alligator Creeks has been a stakeholder driven process lead by Extension with support from the GBRA. The Geronimo and Alligator Creeks Watershed Partnership (the Partnership) Steering Committee includes local officials, land and business owners and citizens and is supported by state and federal agency partners. With technical assistance from project staff, the Steering Committee has identified issues that are of particular importance to the surrounding communities, and has contributed information on land uses and activities that has been helpful in identifying the sources of nutrient and bacterial impairments, and in guiding the development of the WPP.

Historical data identified the impairment for bacteria and a concern for nutrients. The water quality monitoring program attempted to fill gaps in the historical data but was severely hampered by the drought of 2008-09. Data collection in the project further verified that periodic elevations of E. coli levels continue to exist. Routine ambient water quality data is collected at one site (12576) by GBRA through the Clean Rivers Program (CRP). Through projects 08-06, 11-06 and now 14-09, GBRA conducted water quality monitoring that included additional routine ambient and targeted stream sites on Geronimo and Alligator Creeks and three tributaries, and quarterly monitoring of springs, and wells.

The Geronimo Creek WPP has been completed and accepted by EPA. This monitoring project is warranted to provide critical water quality data that will be used to judge the effectiveness of WPP implementation efforts and serve as a tool to quantitatively measure water quality restoration. This effort will continue stakeholder engagement by maintaining the project website, participating in the watershed partnership meetings to provide technical assistance and to share water quality data, and to provide outreach and education to stakeholders including local schools, municipal officials, and the newly forming Guadalupe County Master Naturalists.

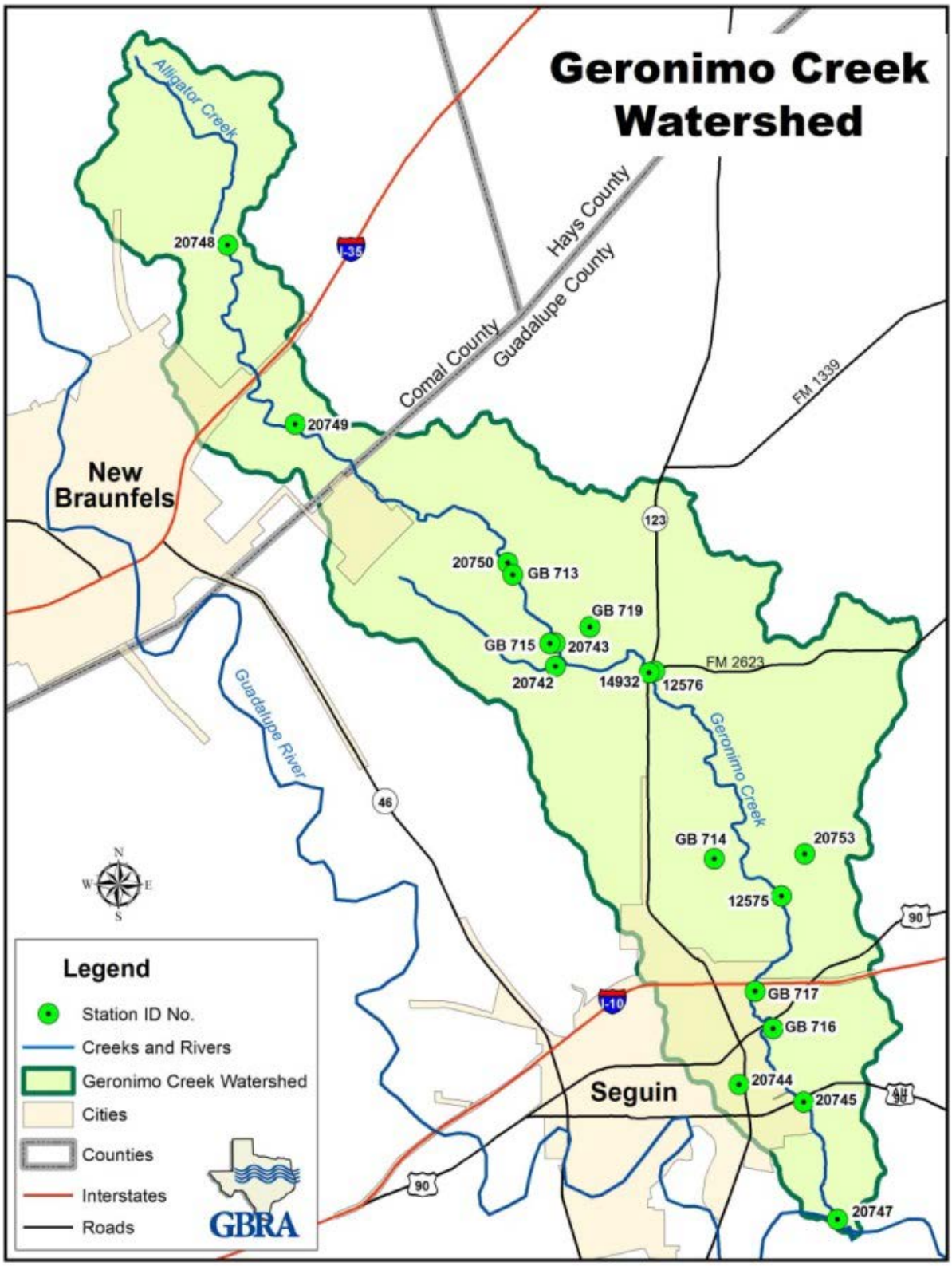

Figure 1. Map of watershed with sampling locations.

Project Highlights

Project Webpage

GBRA and Extension maintained the project webpage. Updates to the webpage over the project period include a photo gallery, monthly newsletters, meeting announcements and copies of meeting presentations. The quality assurance project plan (QAPP) for the current 17-09 monitoring project, along with the current water quality monitoring data tables have been posted on the Water Quality page of the GBRA website and are available for review by the public.

Public Communication and Outreach

A critical part of the project has been to disseminate information on Geronimo and Alligator Creeks and this project to stakeholders and other interested parties throughout the state. GBRA summarized the results and activities of this project in GBRA's CRP Basin Highlights Report and Basin Summary Report. Additionally, summaries of the results and activities of this project were distributed to the stakeholders and the Steering Committee.

Over the course of the project GBRA staff made presentations to classrooms in the Seguin ISD and Navarro ISD schools located in the watershed. Their presentations covered the water quality of Geronimo Creek, and included a water quality monitoring project using water collected from Geronimo Creek. GBRA Public Communication and Education staff prepared NPS activity kits for use with elementary classroom activities in the Geronimo and Alligator Creeks watersheds.

Data Collection and Transmittal

Data collected through the monitoring tasks of the project was collected under the approved QAPP that was updated annually. The objective of the quality assurance task was to develop and implement data quality objectives and quality assurance/control activities in order to ensure data of known and acceptable quality are generated through this project.

GBRA updates the TCEQ's Coordinated Monitoring Schedule each year to include the sites that were sampled under this project.

GBRA uploaded data collected in this project to the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). GBRA submitted a completed Data Summary with each data submittal. If applicable, corrective action reports were submitted by the GBRA field staff or the laboratory if there was a problem or deficiency encountered. If a problem occurred during a sampling event, GBRA field staff made every attempt to recollect the sample under similar environmental conditions, 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. GBRA collected and analyzed all data described in the associated work plan during the course of this monitoring project.

Highlights and Evaluation of Water Quality Monitoring Data

<u>Routine Monitoring</u>

GBRA conducted routine ambient monitoring at 7 sites monthly, collecting field, conventional, flow and bacteria parameter groups. Routine ambient monitoring was conducted monthly at 1 station by GBRA (Site no. 14932, Geronimo Creek at Haberle Road) through the TCEQ CRP. The

objective of the routine monitoring was to provide water quality data to assess the effectiveness of implementing the Geronimo and Alligator Creeks 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 watersheds. 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 electric, mechanical or Doppler, including severity. Bacteria parameter is *E. coli*.

GBRA conducted 23 routine sampling events from February 2018 through December 2019. All routine monitoring sites were flowing and sampled during all weather conditions, with one exception. The Geronimo Creek at Huber Road routine monitoring station is located upstream of the springs that feed the Geronimo Creek. This station routinely went dry and sampling was often limited to isolated pools of water, a significant rainfall influenced the event.

The following data tables compile the routine monitoring data collected from May of 2009 to December of 2019. The collection period for the Geronimo Creek at IH 10 and Geronimo Creek at HWY 90A monitoring stations begins in October of 2012 because monitoring of these stations began with the TSSWCB 11-06 implementation monitoring project in that year. Table 1 compares the geometric mean of the *E. coli* data collected at each routine site to the geometric mean of the data collected under wet weather conditions. The data shows that storm water carries a significant load of bacteria into the stream. Under dry conditions the geometric mean for six of the eight routine sites exceeded the stream standard for contact recreation (126 organisms per 100 milliliters).

Table 1. Concentrations of *E. coli* under dry and wet conditions at the routine & targeted monitoring sites.

Monitoring Station	E. coli Geomean 2008 - 2019**	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**
Alligator Creek at FM 1102	76	0	262	13	14 - 6,100	0.01	27	15	<1 - 2500	0	89.84%
Alligator Creek at FM 1101	184	0	480	14	10 - >48,000	<0.01	71	14	4 - 1,700	0	85.31%
Alligator Creek at Barbarossa Road	391	0	519	8	30 - 17,000	0	126	2	20 - 790	0	71.16%
Alligator Creek at Huber Road	66	<0.01	96	45	2 - >24,000	0.02	52	66	<1 - >2,400	<0.01	45.85%
Geronimo Creek at Huber Road	98	0	170	32	3 - 8,700	0	49	43	<1 - >24,000	0	51.27%
Geronimo Creek at SH 123	398	3.8	460	45	72 - 11,600	3.8	361	66	110 - 7,700	3.6	21.51%
Geronimo Creek at Haberle Road	216	5.8	361	69	51 - 16,000	7.9	202	78	54 - 3,080	5.4	43.95%
Unnamed Tributary at Laubach Road	265	0	534	9	4 - 14,0000	0	149	11	2 - 5,500	0	72.06%
Geronimo Creek at FM 20	231	11	310	25	35 - 13,000	10	179	29	60 - 4,350	12	42.24%
Geronimo Creek at IH 10	253	12	355	30	71 - 8,600	12	212	58	55 - 4,800	11	40.19%
Geronimo Creek at HWY 90A	185	9.7	211	45	20 - 8,700	9.7	170	64	21 - 2,400	9.7	19.49%
Bear Creek at Walnut Street	200	<0.01	223	23	4 - 12,000	<0.01	99	31	4 - 2,400	<0.01	55.49%
Geronimo Creek at HWY 90	210	11	290	32	60 - 8,200	14	174	55	38 - 2,400	11	39.92%
Geronimo Creek at Hollub Road	185	9.0	241	42	41 - 11,000	9.3	153	60	24 - 2,720	8.8	36.52%

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

Highlighted values indicate an** *E. coli* geometric mean greater than the water quality standard of 126 MPN/100 mL.

Table 2 is the mean of the concentrations of total phosphorus at the routine sites. Although at no time, or under any flow conditions, did the mean exceed the screening concentration of 0.69 milligrams per liter there was an increase in total phosphorus during wet weather conditions.

Table 2. Concentrations of total phosphorus under dry and wet conditions at the routine and targeted monitoring sites. At no time, or under any flow conditions, did the mean exceed the screening concentration of 0.69 milligrams per liter.

Monitoring Station	Total P Mean 2008 - 2019**	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**
Alligator Creek at FM 1102	0.32	0	0.43	14	0.14 - 1.05	0.01	0.21	15	0.11 - 0.56	0	51.05%
Alligator Creek at FM 1101	0.14	0	0.19	14	0.09 - 0.32	<0.01	0.10	14	0.03 - 0.28	0	48.14%
Alligator Creek at Barbarossa Road	0.31	0	0.3	8	0.17 - 0.63	0	0.36	2	0.09 - 0.64	0	-22.18%
Alligator Creek at Huber Road	0.07	<0.01	0.09	45	<0.02 - 0.28	0.02	0.05	64	<0.02 - 0.27	<0.01	42.04%
Geronimo Creek at Huber Road	0.24	0	0.28	32	0.03 - 0.62	0	0.21	40	<0.02 - 0.78	0	23.58%
Geronimo Creek at SH 123	0.04	3.8	0.06	45	<0.02 - 0.34	3.8	0.03	66	<0.02 - 0.11	3.6	47.55%
Geronimo Creek at Haberle Road	0.05	5.8	0.07	49	<0.02 - 0.51	7.9	0.03	88	<0.02 - 0.22	5.4	50.28%
Unnamed Tributary at Laubach Road	0.3	0	0.32	9	0.16 - 053	0	0.29	11	<0.02 - 0.79	0	11.13%
Geronimo Creek at FM 20	0.05	11	0.07	25	<0.02 - 0.47	10	0.03	29	<0.02 - 0.17	12	60.76%
Geronimo Creek at IH 10	0.04	12	0.07	30	<0.02 - 0.31	12	0.02	58	<0.02 - 0.06	11	66.83%
Geronimo Creek at HWY 90A	0.05	9.7	0.07	45	<0.02 - 0.32	9.7	0.04	64	<0.02 - 0.21	9.7	50.86%
Bear Creek at Walnut Street	0.12	<0.01	0.14	28	0.03 - 0.55	<0.01	0.10	25	<0.02 - 0.34	<0.01	37.12%
Geronimo Creek at HWY 90	0.04	11	0.07	32	<0.02 - 0.31	14	0.03	55	<0.02 - 0.07	11	60.63%
Geronimo Creek at Hollub Road	0.08	9.0	0.07	42	<0.02 - 0.35	9.3	0.08	60	<0.02 - 2.87	8.8	-12.50%

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

** All values were lower than the Total Phosphorus water quality screening criteria of 0.69 mg/L.

Table 3 is a compilation of the nitrate-nitrogen data collected from 2008 through December 2019. The Leona Aquifer is the source of the springs contributing to the base flow of the Geronimo Creek. Historically, the concentration of the nitrate-nitrogen found in the Leona is very high, exceeding the drinking water standard of 10.0 milligrams per liter. The impact of the Leona on the base flow can be seen in the mean concentrations of nitrate-nitrogen at all six Geronimo Creek sites. All six sites exceed the TCEQ screening concentration of 1.95 milligrams per liter. Under wet weather conditions, storm water dilutes the base flow and lowers the mean concentrations at all sites.

Table 3. Concentrations of nitrate-nitrogen under dry and wet conditions at the routine and targeted monitoring sites.

Monitoring Station	NO3-N Mean 2008 - 2019**	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**
Alligator Creek at FM 1102	0.41	0	0.60	14	<0.05 - 2.77	0.01	0.26	15	<0.05 - 1.92	0	56.83%
Alligator Creek at FM 1101	0.48	0	0.31	14	<0.05 - 0.97	<0.01	0.65	15	<0.05 - 2.09	0	-106.53%
Alligator Creek at Barbarossa Road	0.66	0	0.77	8	<0.05 - 2.74	0	0.21	2	<0.05 - 0.36	0	73.38%
Alligator Creek at Huber Road	6.70	<0.01	5.35	45	<0.05 - 19.8	0.02	7.62	65	<0.05 - 21.0	<0.01	-42.20%
Geronimo Creek at Huber Road	1.29	0	1.67	32	<0.05 - 16.8	0	0.99	40	<0.05 - 14.0	0	40.91%
Geronimo Creek at SH 123	8.44	3.8	7.94	45	0.09 - 11.3	3.8	8.78	66	1.27 - 12.0	3.6	-10.63%
Geronimo Creek at Haberle Road	9.82	5.8	8.78	49	<0.05 - 14.2	7.9	10.42	86	0.10 - 14.0	5.4	-18.65%
Unnamed Tributary at Laubach Road	0.73	0	1.46	9	<0.05 - 5.8	0	0.13	11	<0.05 - 0.69	0	91.30%
Geronimo Creek at FM 20	11.31	11	10.38	25	0.9 - 14.4	10	12.12	29	5.56 - 17.3	12	-16.84%
Geronimo Creek at IH 10	10.76	12	8.98	30	1.0 - 13.6	12	11.69	58	6.6 - 16.5	11	-30.22%
Geronimo Creek at HWY 90A	9.43	9.7	8.06	45	<0.05 - 13.6	9.7	10.40	64	3.2 - 16.0	9.7	-28.91%
Bear Creek at Walnut Street	0.60	<0.01	0.59	28	<0.05 - 8.36	<0.01	0.62	25	<0.05 - 1.76	<0.01	-5.52%
Geronimo Creek at HWY 90	10.25	11	8.97	32	1.47 - 13.8	14	10.99	55	5.6 - 13.6	11	-22.52%
Geronimo Creek at Hollub Road	8.13	9.0	6.82	42	<0.05 - 13.2	9.3	9.04	60	2.6 - 13.7	8.8	-32.68%

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

**Highlighted values indicate an NO3-N mean greater than the water quality screening criteria of 1.95 mg/L.

Table 4 is a compilation of the data collected for ammonia nitrogen from 2008 through December of 2019. At no time or under any flow conditions did the mean of any of the routine stations exceed the screening concentration of 0.33 milligrams per liter. Two targeted stations showed exceedances under specific weather conditions, but the data at these stations was extremely limited due to drought conditions.

Table 4. Concentrations of ammonia-nitrogen under dry and wet conditions at the routine and targeted monitoring sites.

Monitoring Station	NH3-N Mean 2008 - 2019**	Median Flow (cfs) 2008 - 2019	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**
Alligator Creek at FM 1102	0.16	0	0.20	14	<0.1 - 0.97	0.01	0.13	15	<0.1 - 0.4	0	34.93%
Alligator Creek at FM 1101	0.19	0	0.25	14	<0.1 - 1.00	<0.01	0.12	14	<0.1 - 0.26	0	53.65%
Alligator Creek at Barbarossa Road	0.15	0	0.16	8	<0.1 - 0.30	0	0.12	2	<0.1 - 0.13	0	28.68%
Alligator Creek at Huber Road	0.23	<0.01	0.35	45	<0.1 - 8.12	0.02	0.15	66	<0.1 - 0.7	<0.01	57.82%
Geronimo Creek at Huber Road	0.15	0	0.18	31	<0.1 - 2.0	0	0.13	40	<0.1 - 0.39	0	27.99%
Geronimo Creek at SH 123	0.14	3.8	0.14	45	<0.1 - 0.45	3.8	0.14	66	<0.1 - 0.94	3.6	-1.79%
Geronimo Creek at Haberle Road	0.19	5.8	0.14	44	<0.1 - 1.13	7.9	0.21	77	<0.1 - 6.06	5.4	-44.12%
Unnamed Tributary at Laubach Road	0.58	0	0.16	9	<0.1 - 0.26	0	0.93	11	<0.1 - 4.5	0	-474.98%
Geronimo Creek at FM 20	0.14	11	0.14	25	<0.1 - 0.39	10	0.13	29	<0.1 - 0.39	12	6.37%
Geronimo Creek at IH 10	0.13	12	0.14	45	<0.1 - 0.38	12	0.13	64	<0.1 - 0.37	11	4.35%
Geronimo Creek at HWY 90A	0.13	9.7	0.13	35	<0.1 - 0.45	9.7	0.13	43	<0.1 - 0.37	9.7	-1.82%
Bear Creek at Walnut Street	0.17	<0.01	0.18	28	<0.1 - 0.78	<0.01	0.15	25	<0.1 - 0.41	<0.01	17.24%
Geronimo Creek at HWY 90	0.14	11	0.15	22	<0.1 - 0.50	14	0.14	33	<0.1 - 0.57	11	5.62%
Geronimo Creek at Hollub Road	0.15	9.0	0.13	42	<0.1 - 0.45	9.3	0.16	60	<0.1 - 0.77	8.8	-23.60%

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

**Highlighted values indicate an Ammonia-Nitrogen mean greater than the water quality screening criteria of 0.33 mg/L.

Analysis of Routine Data for Trends

The Geronimo and Alligator Creeks monitoring stations were analyzed for statistically significant correlations between concentrations for ammonia-nitrogen, nitrate-nitrogen, total phosphorus and *E. coli* versus time and stream flow. Relationships were also explored for background water quality parameters such as total suspended solids (TSS), chlorides, sulfates, chlorophyll A, total kjeldahl nitrogen (TKN), temperature, dissolved oxygen, specific conductance and pH. GBRA conducted multiple t-tests to determine significance. 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 tested by the hypothesis. The dotted red lines on the accompanying charts represent nutrient screening values for concentration levels for concerns and solid red lines represent contact recreation limits for *E. coli*, if applicable.

The Geronimo Creek at Hollub Road monitoring station (20747) is located approximately 0.5 kilometers (km) upstream of the confluence with the Guadalupe River. During heavy flooding, the Guadalupe River backs up and influences the water quality of this portion of the Geronimo Creek. Only two statistically significant correlations with time at this location. The chloride anion, which forms table salt along with sodium was found to be decreasing with time $t(102)=-2.61$, $p=0.01$, (Figure 2). The sulfate salt anion was also found to be decreasing with time; $t(98)=-4.52$, $p=0.00$ (Figure 3). The total dissolved solids (TDS), includes both of these anions. The TDS concentration is also decreasing with time; $t(102)=-4.49$, $p=0.00$ (Figure 4). The nitrate nitrogen concentration is was also found to be increasing at this station; $t(102)=3.56$, $p=0.00$ (Figure 5). These correlations occurred partially due to changes in flow. A statistically significant correlation was found between chlorides and stream flow $t(89)=-3.76$, $p=0.00$ and sulfates with stream flow $t(89)=-3.73$, $p=0.00$. The water at this location appears to be becoming less saline as a result of increased flows. Observed increases in stream flow also significantly increased *E. coli* concentrations $t(89)=14.14$, $p=0.00$, but *E. coli* levels were not found to be significantly changing over time.

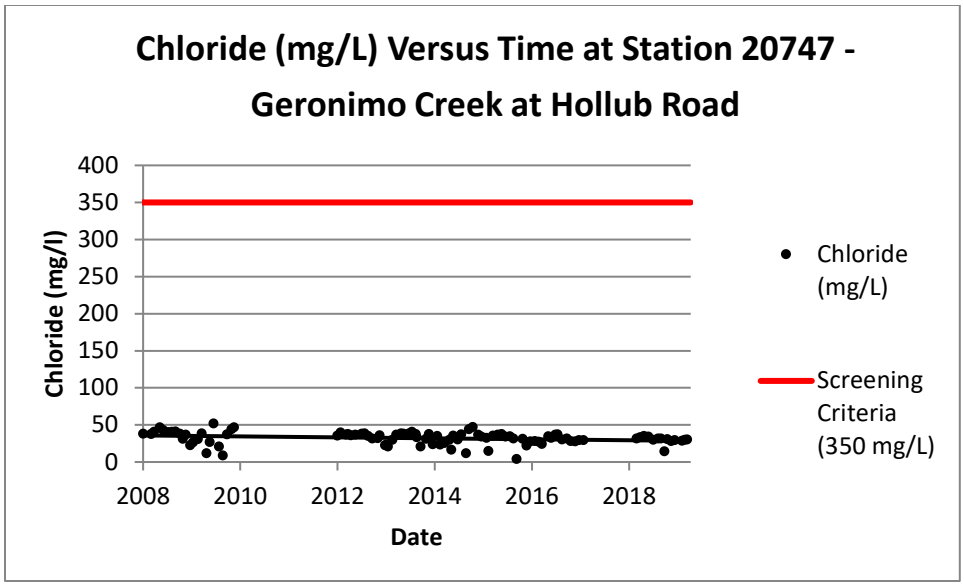

Figure 2. Chlorides (mg/L) versus Time at Station 20747 - Geronimo Creek at Hollub Road.

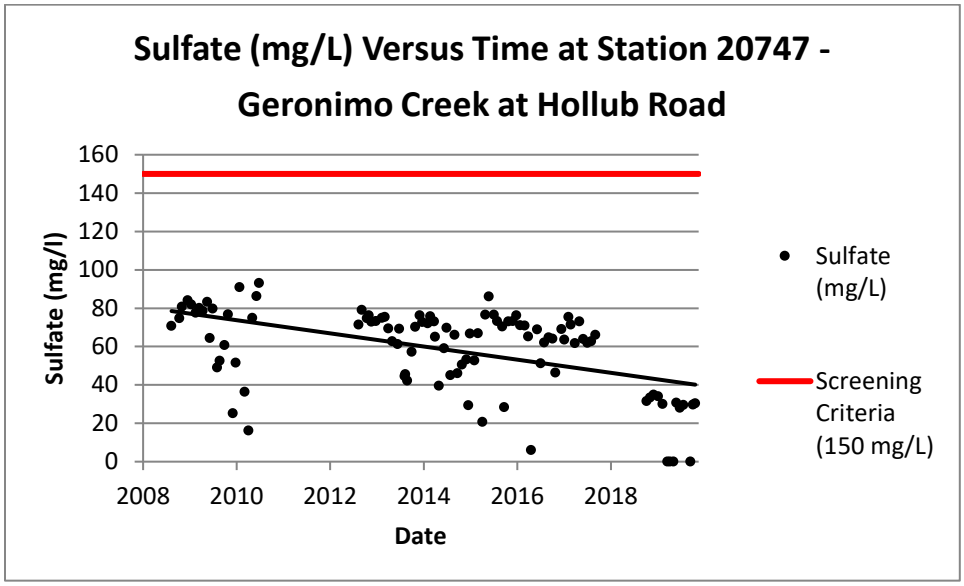

Figure 3. Sulfates (mg/L) versus Time at Station 20747 – Geronimo Creek at Hollub Road.

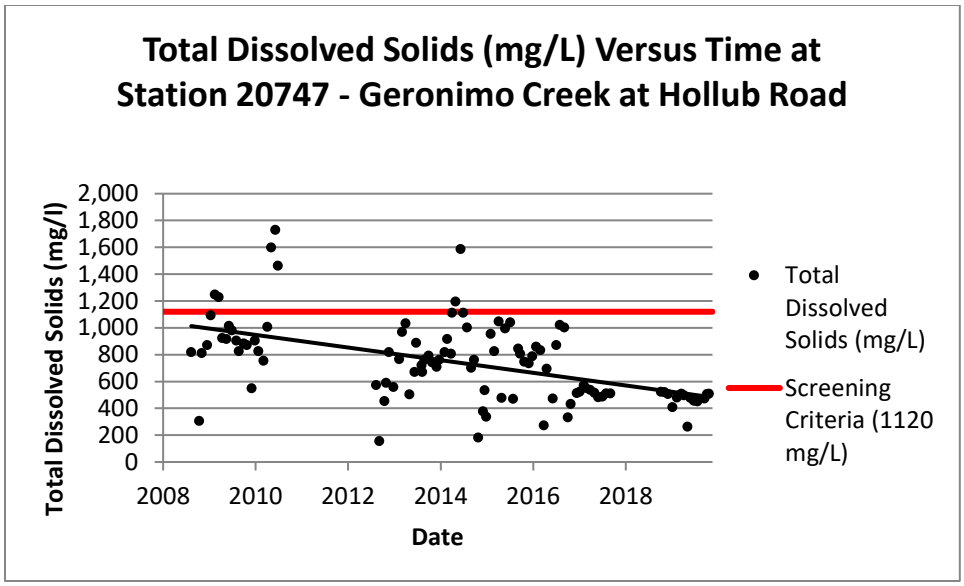

Figure 4. TDS (mg/L) versus Time at Station 20747 – Geronimo Creek at Hollub Road.

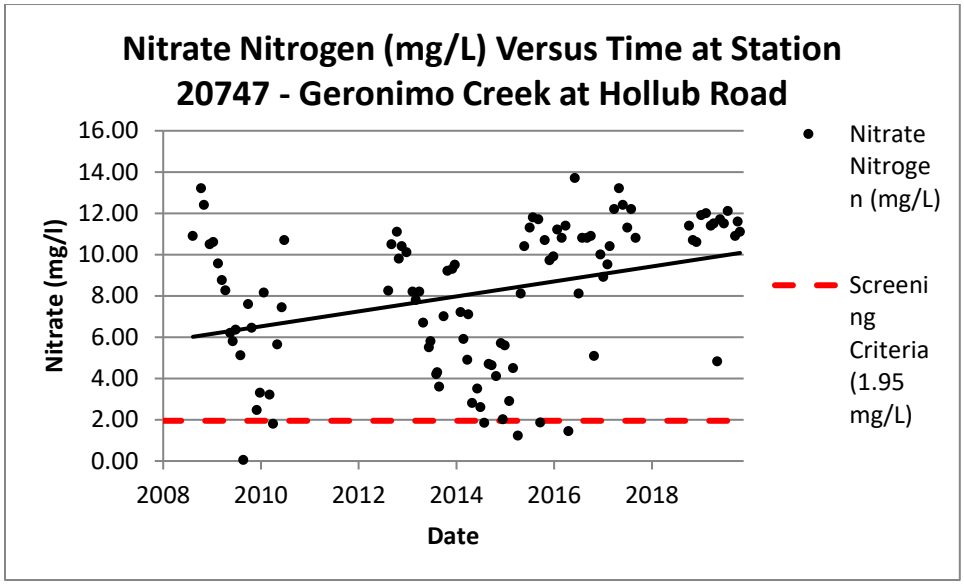

Figure 5. Nitrate (mg/L) versus Time at Station 20747 – Geronimo Creek at Hollub Road.

At the Geronimo Creek at Highway 90A station (20745) statistically significant correlations were found between several water quality parameters and time. Chlorides were decreasing with time; t(109)=-3.52, p=0.00 (Figure 6). Sulfates were also decreasing with time; t(109)=-3.29, p=0.00 (Figure 7). Nitrate nitrogen was increasing over time; t(109)=3.65, p=0.00 (Figure 8). Several parameters also showed significant correlations with stream flow. Both chloride t(89)=-3.25, p=0.00 and sulfate t(89)=-3.71, p=0.00 show an inverse relationship with streamflow. Total phosphorus is increasing with stream flow t(89)=6.55, p=0.00 and *E. coli* is also increasing with stream flow t(89)=10.01, p=0.00. This station is located only about 4 kilometers upstream of the

Geronimo Creek at Hollub Road station (20747) and 0.4 km upstream of the confluence of the Baer Creek tributary, but seems to be experiencing similar trending to the previous station downstream station.

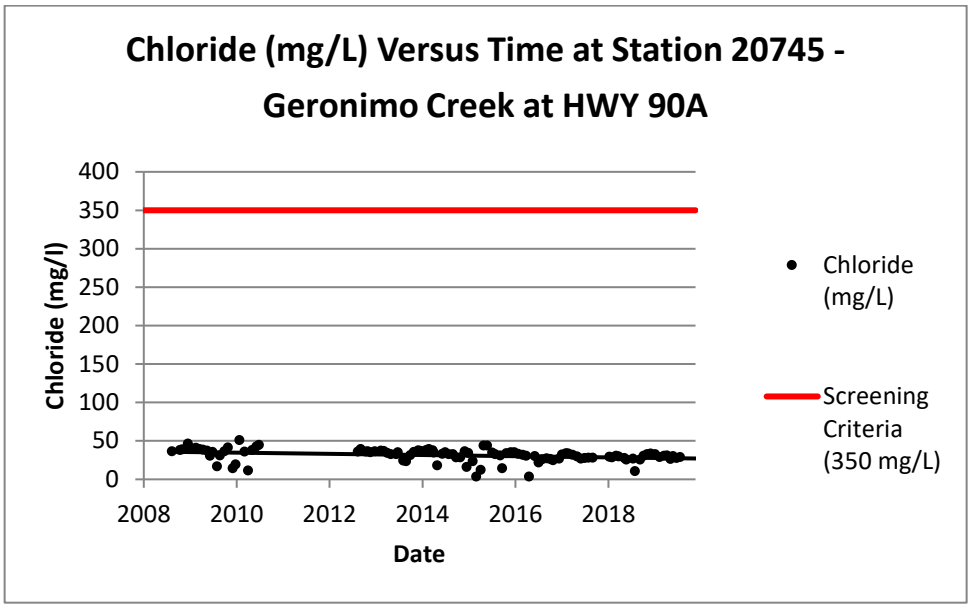

Figure 6. Chlorides (mg/L) versus Time at Station 20745 Geronimo Creek at Highway 90A.

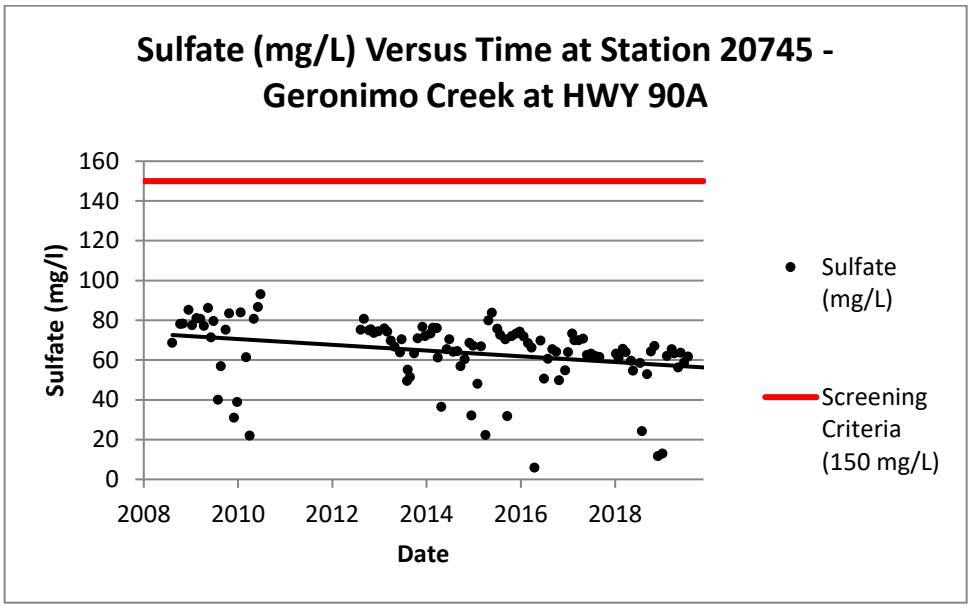

Figure 7. Sulfates (mg/L) versus Time at Station 20745 - Geronimo Creek at Highway 90A.

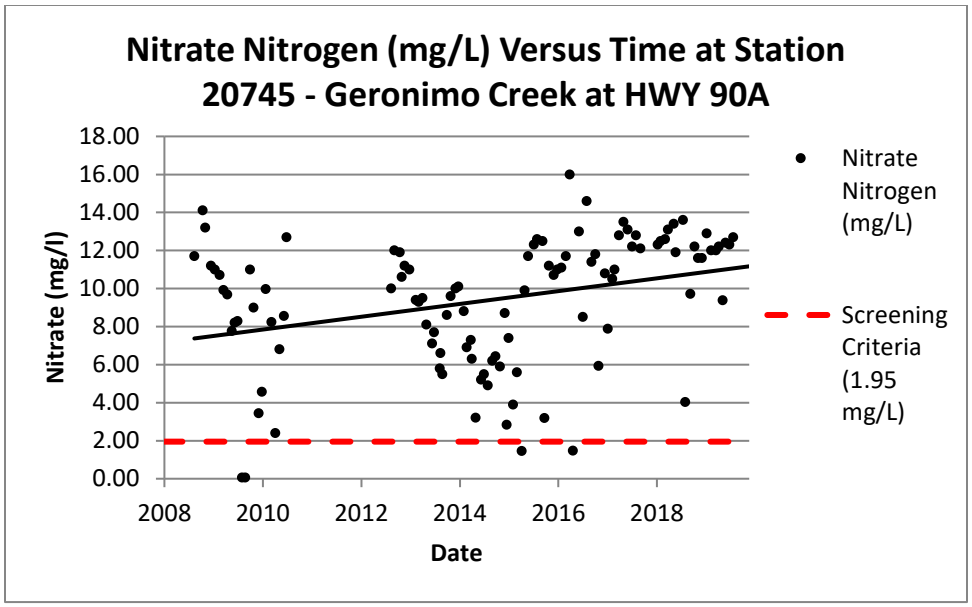

Figure 8. Nitrates (mg/L) versus Time at Station 20745 - Geronimo Creek at Highway 90A.

The Geronimo Creek at Highway 90 near the ILSOLC (21261) had four statistically significant correlations of water quality parameters with time. Ammonia-Nitrogen (mg/L); t(87)=-2.92 p=0.00, at this station is decreasing with time (Figure 9). Chlorides are decreasing over time; t(87)=-4.05, p=0.00 (Figure 10). Sulfates are also decreasing over time; t(87)=-3.11, p=0.01 (Figure 11). Nitrate nitrogen is increasing with time; t(87)=4.31, p=0.00 (Figure 12). The common log of *E. coli* is also increasing over time at this station; t(87)=4.31, p=0.00 (Figure 13). This station is only located about 2.1 kilometers upstream of the Geronimo Creek at Highway 90A station (20745), but water quality trends at this station are quite different. Station 21261 was added to the Geronimo Creek monitoring project in September of 2012 and has much less data available than many of the other monitoring stations on Geronimo Creek. The trends at this station may differ from other portions of the Geronimo Creek for this reason. The decrease in ammonia-nitrogen and salt anions concentrations at this location are generally indicators of better water quality conditions and are most likely due to a statistically significant increase in ambient stream flows at this station over the study period; t(87)=4.86, p=0.00. Four of the five parameters that were significantly changing over time, also showed statistically significant correlations with stream flow. Nitrate nitrogen was the only one of the identified parameters that did not have a significant correlation with stream flow.

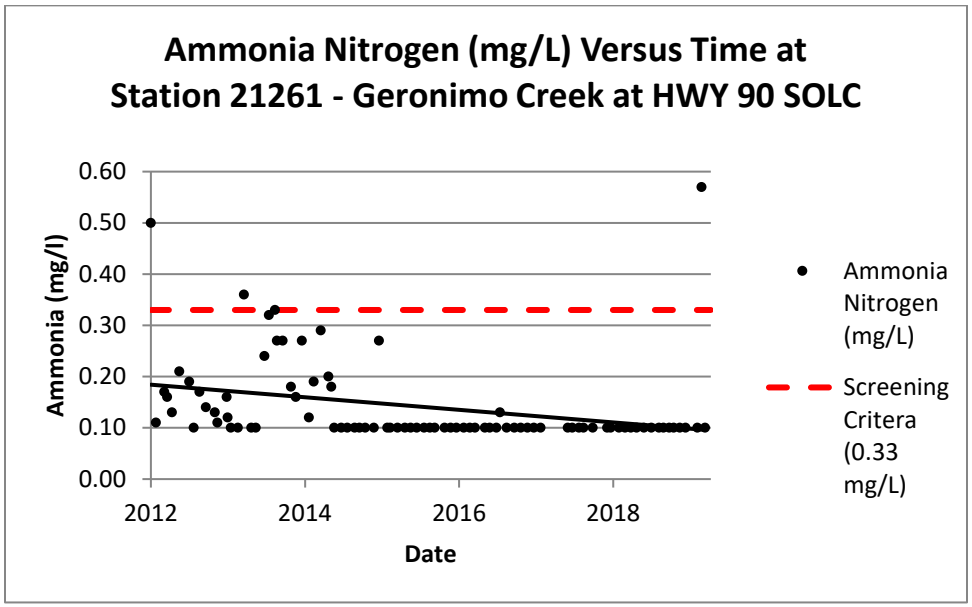

Figure 9. Ammonia-Nitrogen (mg/L) versus Time at Station 21261 - Geronimo Creek at Highway 90 near the Seguin Outdoor Learning Center.

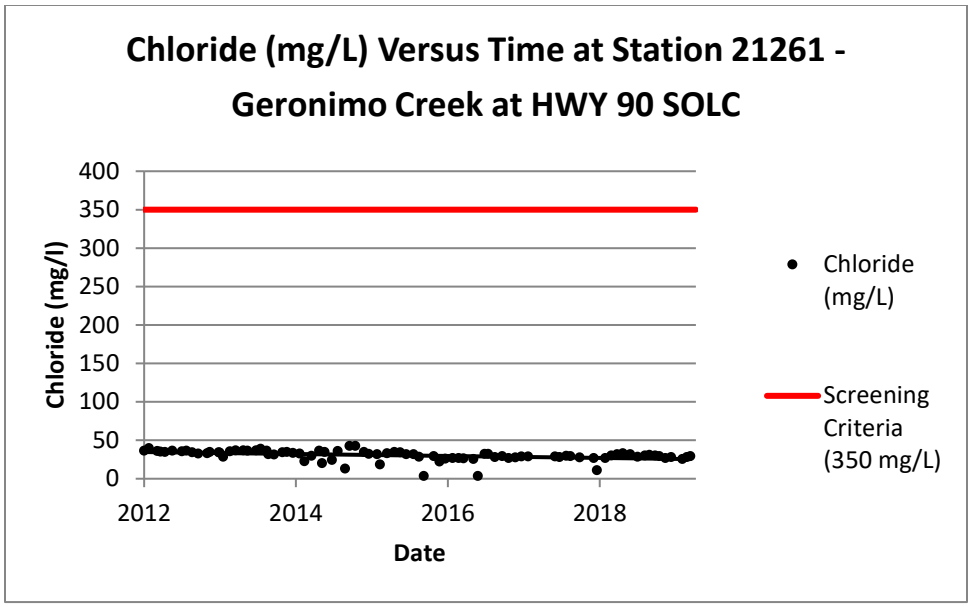

Figure 10. Chlorides (mg/L) versus Time at Station 21261 - Geronimo Creek at Highway 90 Near the ILSOLC.

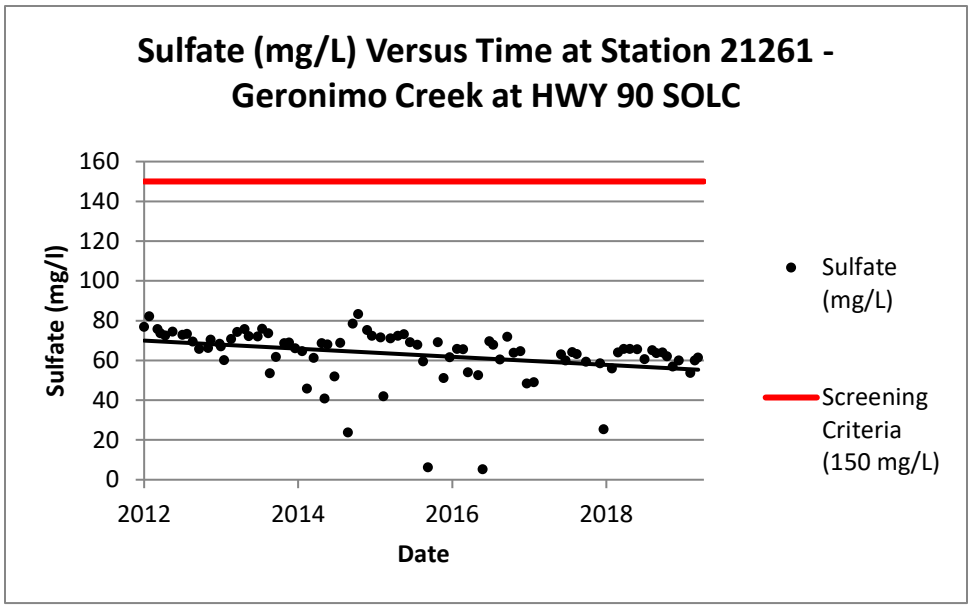

Figure 11. Sulfates (mg/L) versus Time at Station 21261 - Geronimo Creek at Highway 90 Near the ILSOLC.

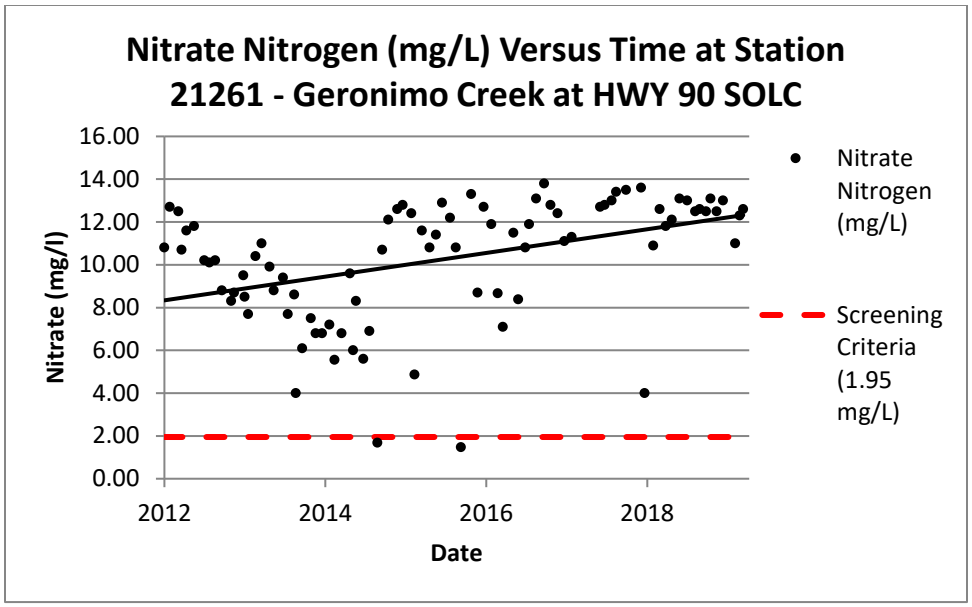

Figure 12. Nitrates (mg/L) versus Time at Station 21261 - Geronimo Creek at Highway 90 Near the ILSOLC.

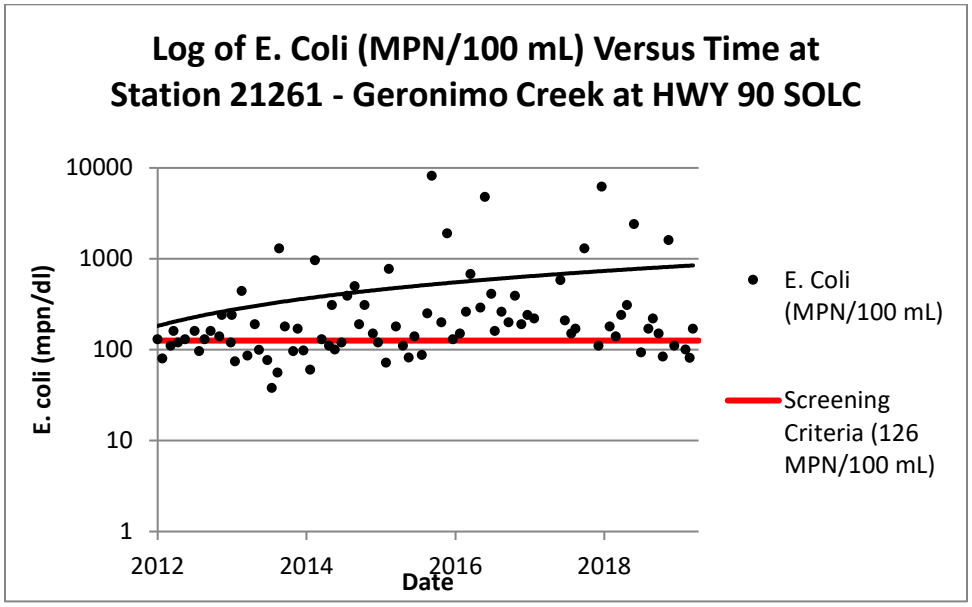

Figure 13. *E. coli* (mg/L) versus Time at Station 21261 - Geronimo Creek at Highway 90 Near the ILSOLC.

GBRA added the Geronimo Creek at IH 10 monitoring station (21260) to the Geronimo Creek and Alligator Creek Monitoring Project in September of 2012 along with the station at the ILSOLC. With the exception of *E. coli*, the water quality trends at this station share many similarities to the Geronimo Creek at Highway 90 near the ILSOLC (21261). Ammonia-nitrogen; t(100)=-5.34,p=0.00 (Figure 14), chlorides t(100)=-4.52, p=0.00 (Figure 15) and sulfates t(100)=-3.01, p=0.03 (Figure 16) are all decreasing with time and nitrate nitrogen is increasing with time; t(100)=4.38, p=0.00 (Figure 17) similar to the ILSODLC. All four of these water quality parameters significantly decreased as stream flows increased. Stream flow at this station is significantly increasing with time t(98)=5.49, p=0.00. The *E. coli* at this station is not significantly changing, despite positive correlation with increasing stream flows t(77)=4.67, p=0.00. The *E. coli* concentration stability at this station may be due to the efforts of localized BMP implementations, such as the condemnation of failing septic tanks at the Oak Village North subdivision immediately upstream. Station 21260 is located 1.25 km upstream of station 21261 and the close proximity of this station with station 21261 during the same truncated temporal monitoring interval may be the reason that these two stations showed such similar patterns.

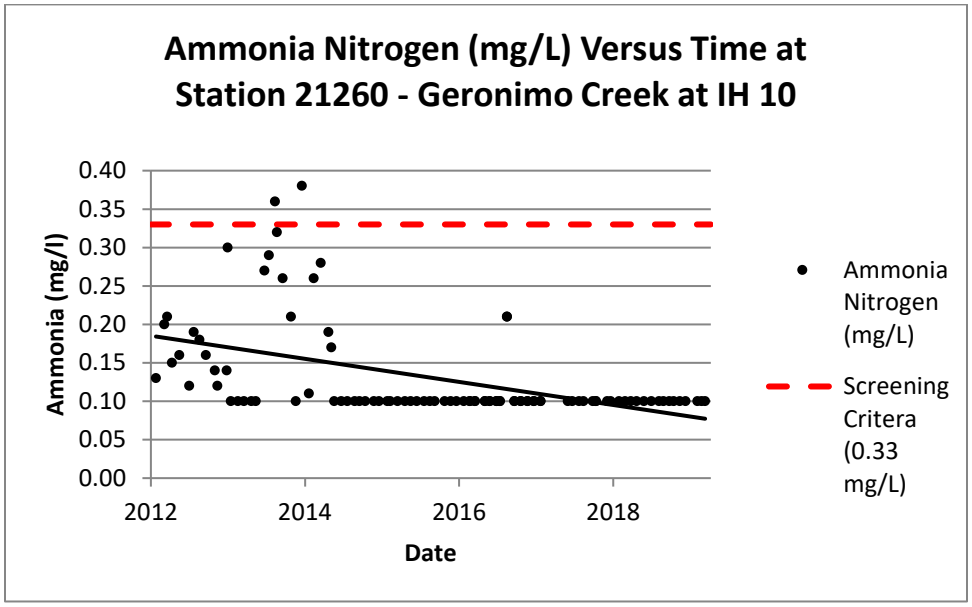

Figure 14. Ammonia-Nitrogen (mg/L) versus Time at Station 21260 - Geronimo Creek at IH-10.

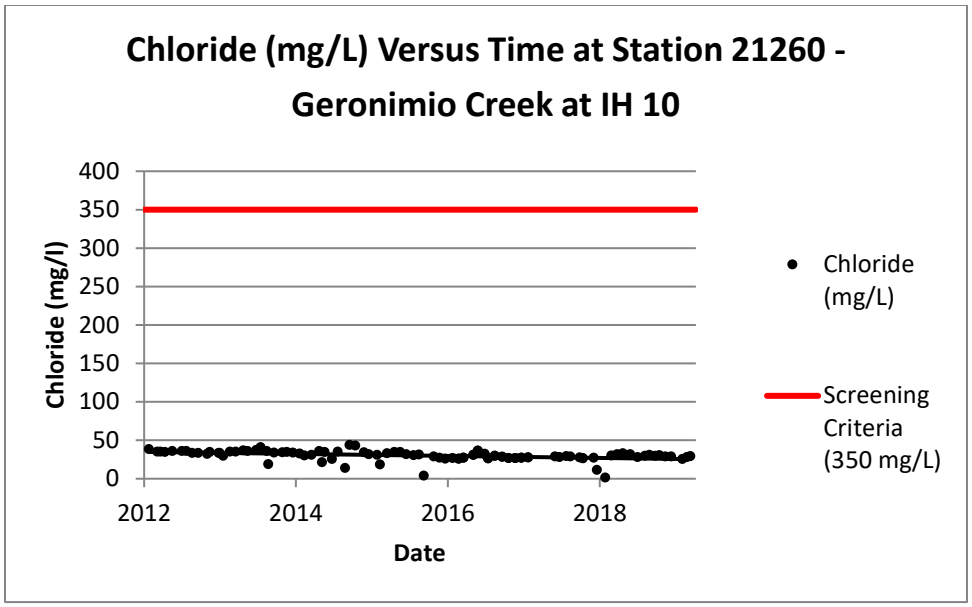

Figure 15. Chlorides (mg/L) versus Time at Station 21260 – Geronimo Creek at IH-10.

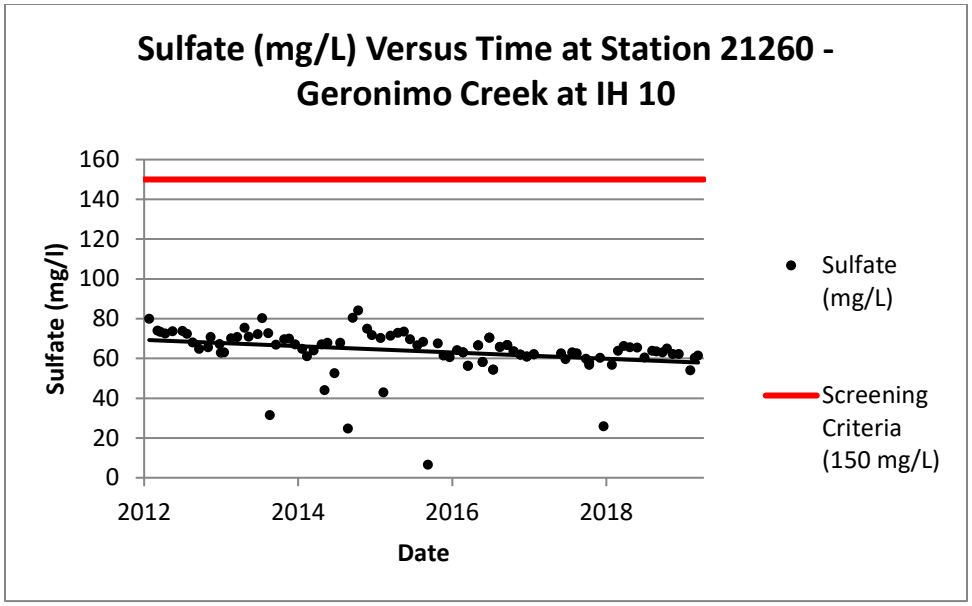

Figure 16. Sulfates (mg/L) versus Time at Station 21260 – Geronimo Creek at IH-10.

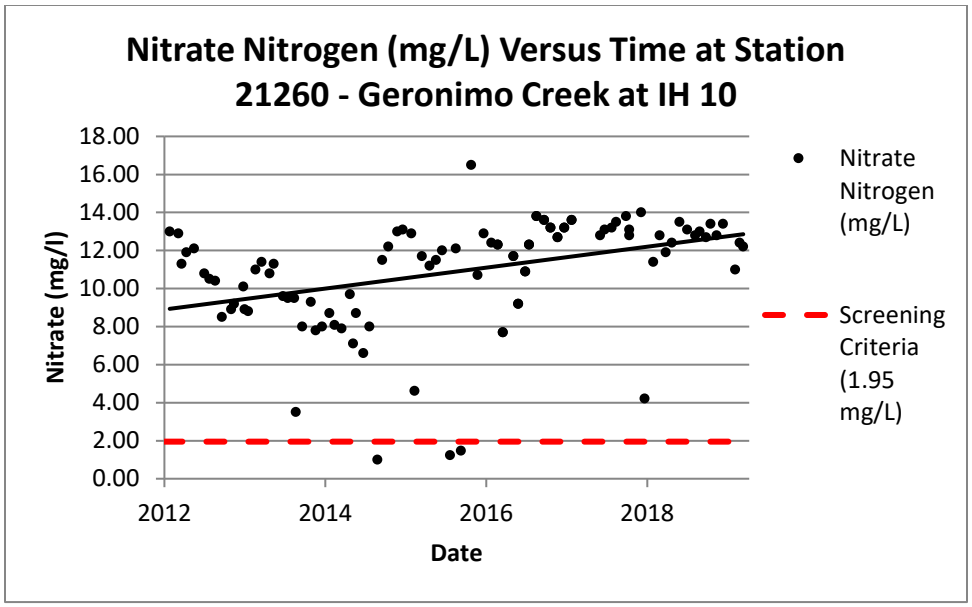

Figure 17. Nitrates (mg/L) versus Time at Station 21260 – Geronimo Creek at IH-10.

The Geronimo Creek at Haberle Road station (12576) is the current TCEQ CRP monitoring station on the Geronimo Creek and is the station with the greatest amount of data available during the span of the monitoring project. This station is located 4.3 km upstream of the Geronimo Creek at IH 10 station (21260) and contributed much of the data to the original noncompliance listing for this stream. Station 12576 showed three significant correlations with time. Ammonia-nitrogen; t(139)=-6.47,p=0.00 is decreasing over time (Figure 18) and sulfate is decreasing over time; t(139)=-5.10, p=0.00 (Figure 19). The common log of *E. coli* is significantly increasing over time; t(139)=2.14, p=0.03 (Figure 20). This trend is consistent with the data from the Geronimo Creek at Highway 90A station (20745), which spanned the same temporal monitoring interval and showed similar correlations between ammonia-nitrogen and time. The streamflow at station 12576 is increasing over time; t(139)=2.07, p=0.04. Chlorides and sulfates significantly decrease with stream flow, while *E. coli* significantly increases with higher flows; t(125)=5.27,p=0.00.

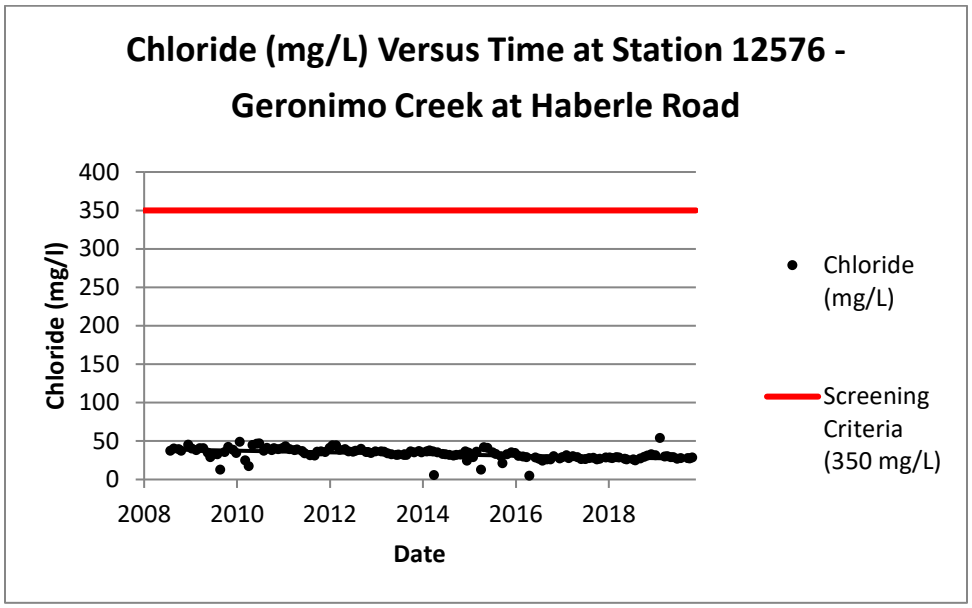

Figure 18. Chloride (mg/L) versus Time at Station 12576 - Geronimo Creek at Haberle Road.

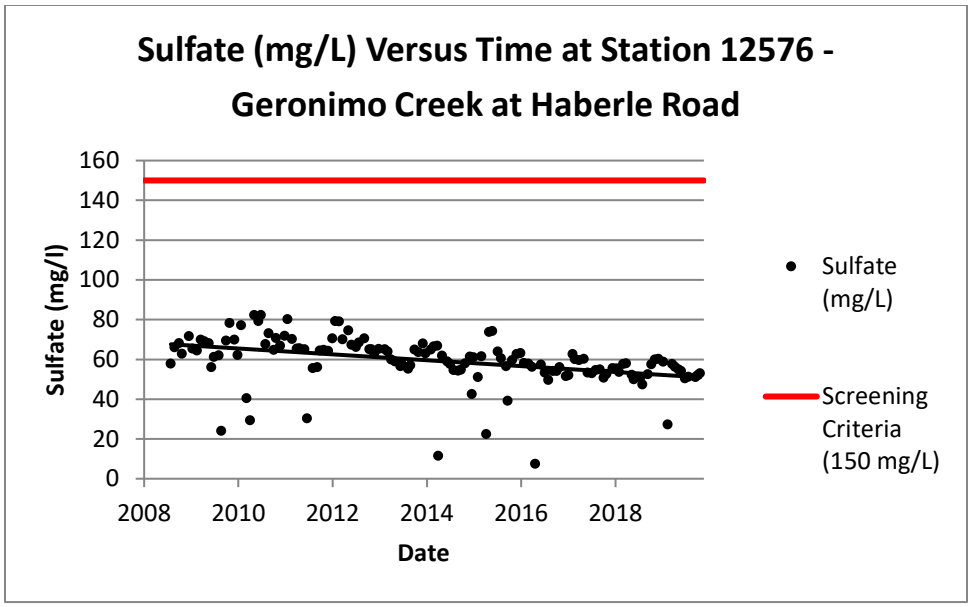

Figure 19. Sulfate (mg/L) versus Time at Station 12576 - Geronimo Creek at Haberle Road.

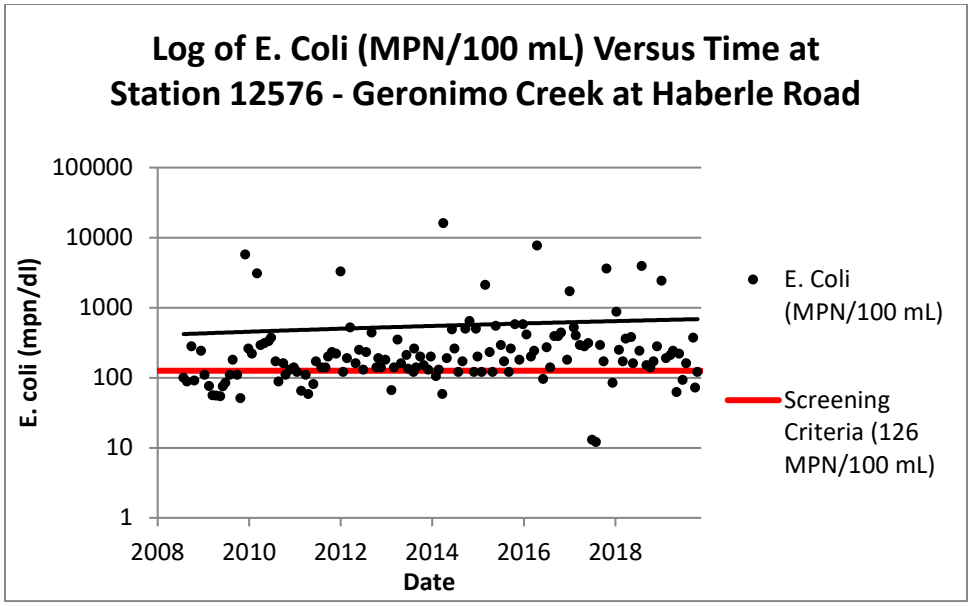

Figure 20. *E. coli* (MPN/100 mL) versus Time at Station 12576 - Geronimo Creek at Haberle Road.

At the Geronimo Creek at SH 123 station (14932) a statistically significant correlation was found between decreasing TSS; t(110)=-3.75,p=0.00 and time (Figure 21). This station also showed a significant correlation between decreasing chlorides; t(111)=-7.14, p=0.00 (Figure 22), and sulfates with time t(111)=-4.94, p=0.00 (Figure 23). In contrast to other parameters, nitrate nitrogen is increasing with time; t(111)=3.04, p=0.00 (Figure 24). This station is located

immediately downstream of the headwater springs of the Geronimo Creek and approximately 4 km upstream of station 12576 (Geronimo Creek at Haberle Road). The trends at this station are generally similar to the trends at the other Geronimo Creek main stem stations such as 20747 (Geronimo Creek at Hollub Road) and 20745 (Geronimo Creek at Highway 90A), that were collected during the same temporal monitoring period. During base flow conditions, this portion of the stream is influenced by underground spring discharges more than any other Geronimo Creek main stem station, due to its close proximity to the headwater springs of the creek. Much like the rest of the watershed, this station is experiencing a significant increase in stream flow over time; $t(110)=2.80$, $p=0.01$. The lack of significant correlations with any of the nutrient or bacteria parameters of interest at this station may be due to the consistent discharges from the Geronimo springs.

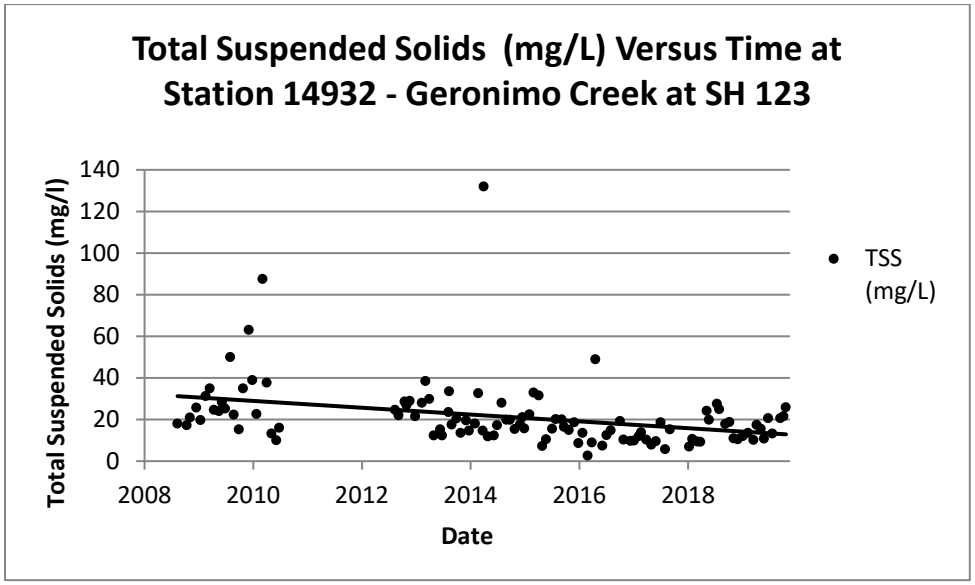

Figure 21. Total Suspended Solids (mg/L) versus Time at Station 14932 - Geronimo Creek at SH 123.

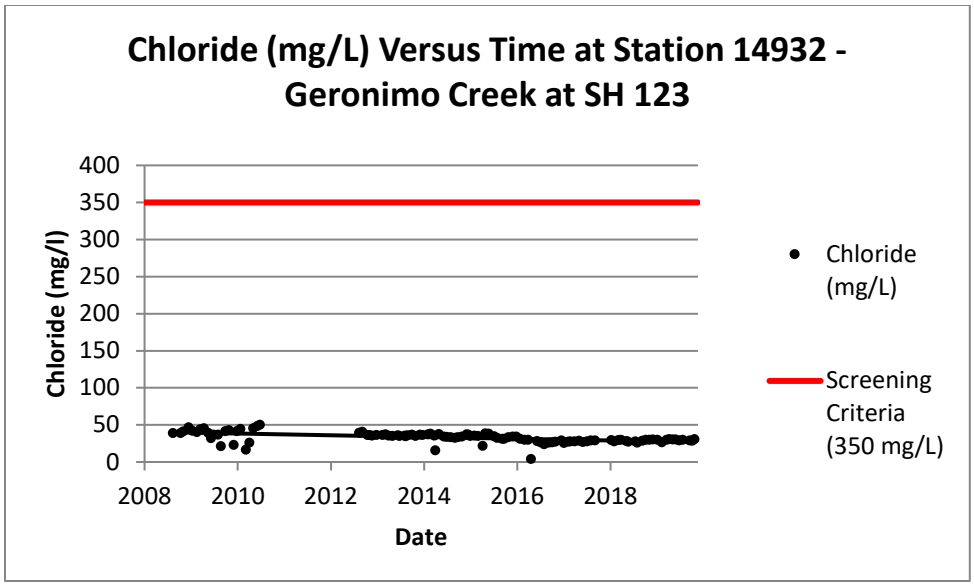

Figure 22. Chlorides (mg/L) versus Time at Station 14932 - Geronimo Creek at SH 123.

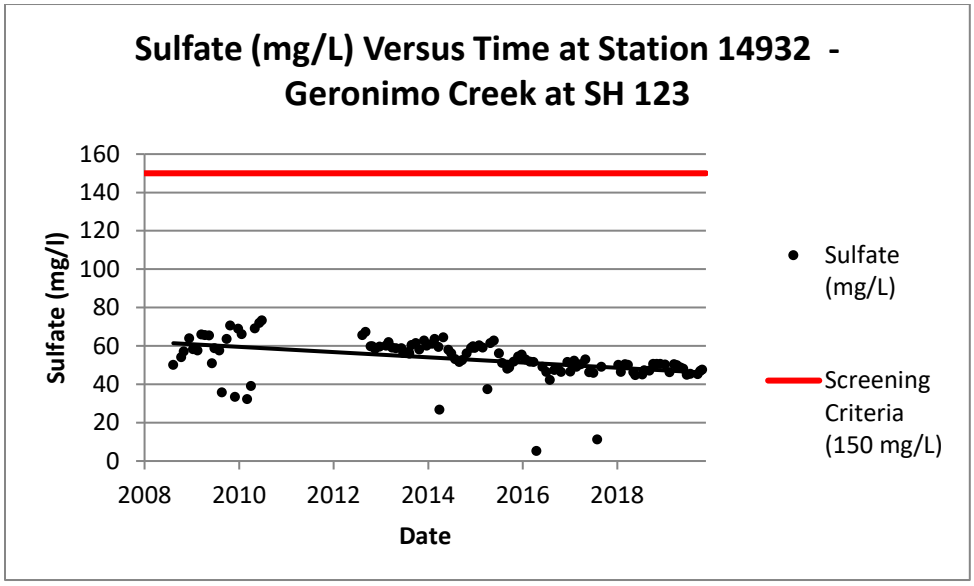

Figure 23. Sulfates (mg/L) versus Time at Station 14932 - Geronimo Creek at SH 123.

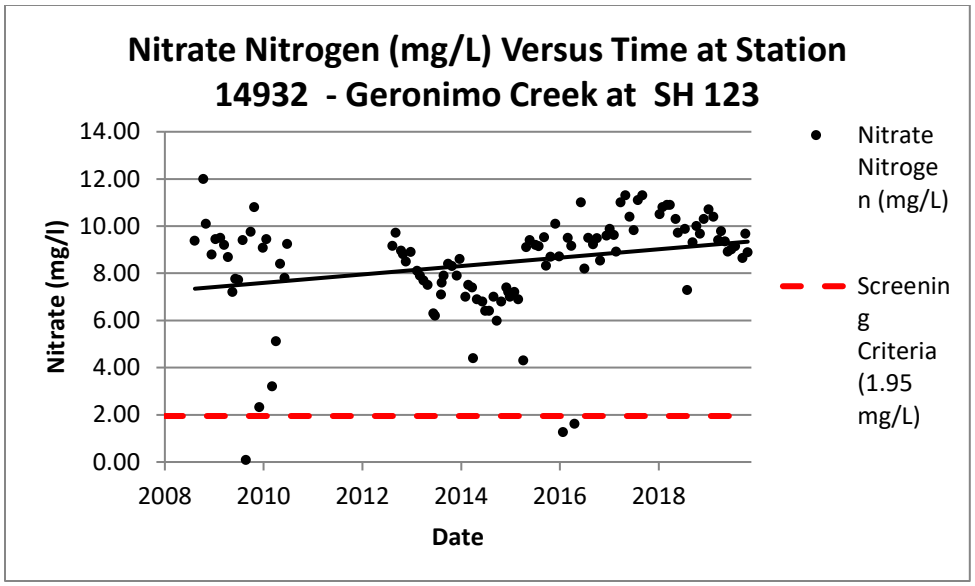

Figure 24. Nitrates (mg/L) versus Time at Station 14932 - Geronimo Creek at SH 123.

The Geronimo Creek at Huber Road monitoring station (20742), showed a statistically significant correlation between chlorophyll *a* and time t(72)=2.61, p=0.01 (Figure 25). Chlorophyll *a* is a pigment found in plants. GBRA measures this parameter to assess the effects of nutrient availability on plant and algae growth in a stream. Both total suspended solids (TSS); t(109)=3.65, p=0.00 (Figure 26), and total dissolved solids (TDS); t(111)=4.78, p=0.00 (Figure 27) are significantly increasing over time at this station. Total Kjeldahl nitrogen (TKN) is also increasing over time t(108)=6.57, p=0.00 (Figure 28). The Geronimo Creek at Huber Road is located 3.3 km upstream of the SH 123 station and approximately 0.3 km upstream of the confluence with Alligator Creek. Station 20742 is the only routine monitoring station in the watershed that do not receive spring discharges. The Geronimo Creek at this location is dry during much of the year and almost all of the data points have been collected under wet weather conditions or from a small pond situated in the middle of the creek that retains water long periods after a rainfall runoff event. Stream flow at this station is not significantly changing over time. The water in this portion of the creek may have had a long enough retention time to build up significant algae growth between rainfall runoff events, which flush the algae growth downstream.

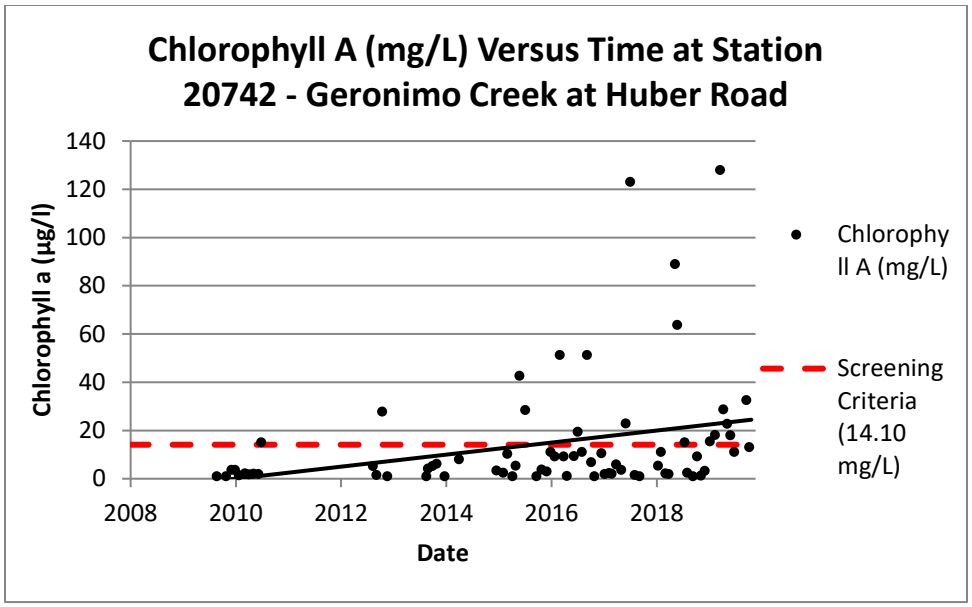

Figure 25. Chlorophyll *a* (ug/L) versus Time at Station 20742 - Geronimo Creek at Huber Road

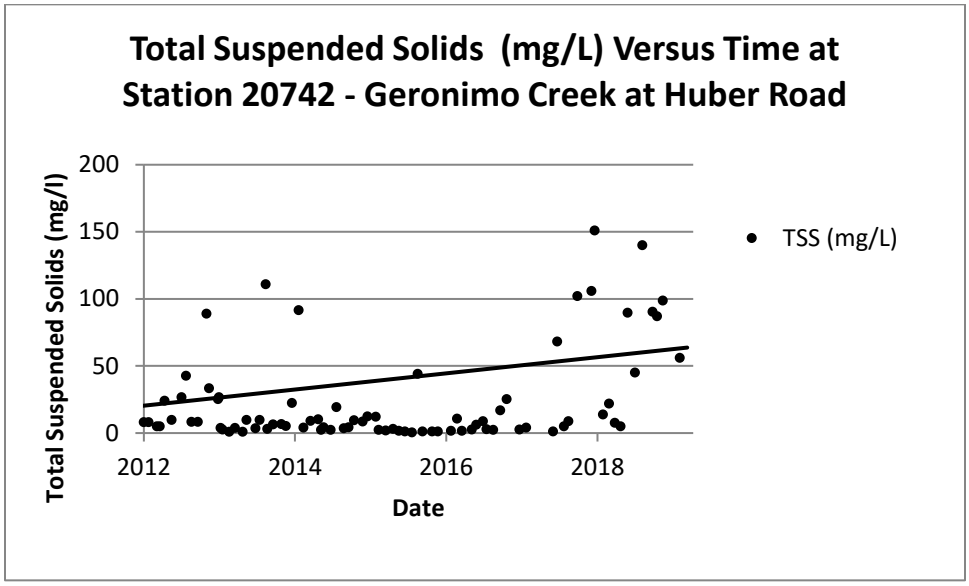

Figure 26. TSS (ug/L) versus Time at Station 20742 - Geronimo Creek at Huber Road

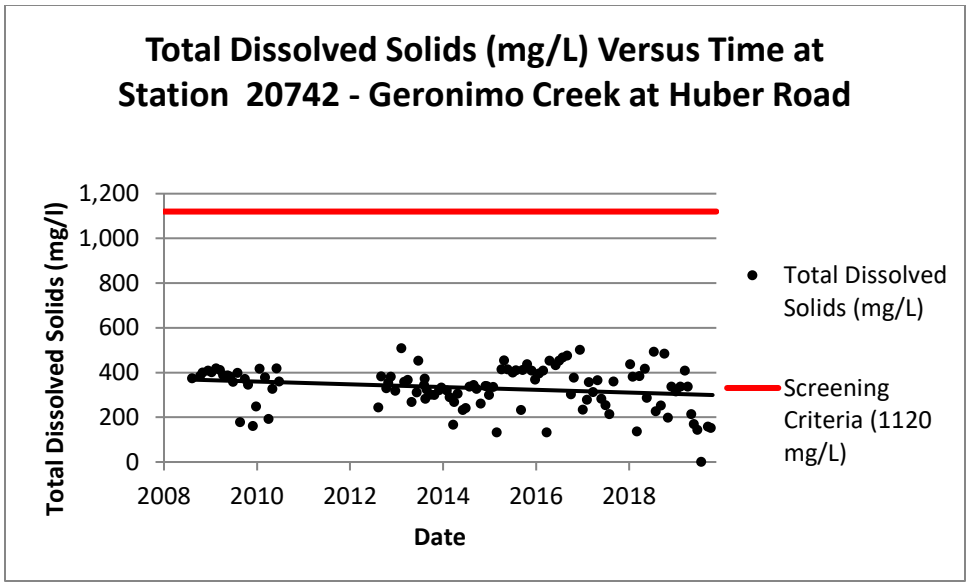

Figure 27. TDS (ug/L) versus Time at Station 20742 - Geronimo Creek at Huber Road

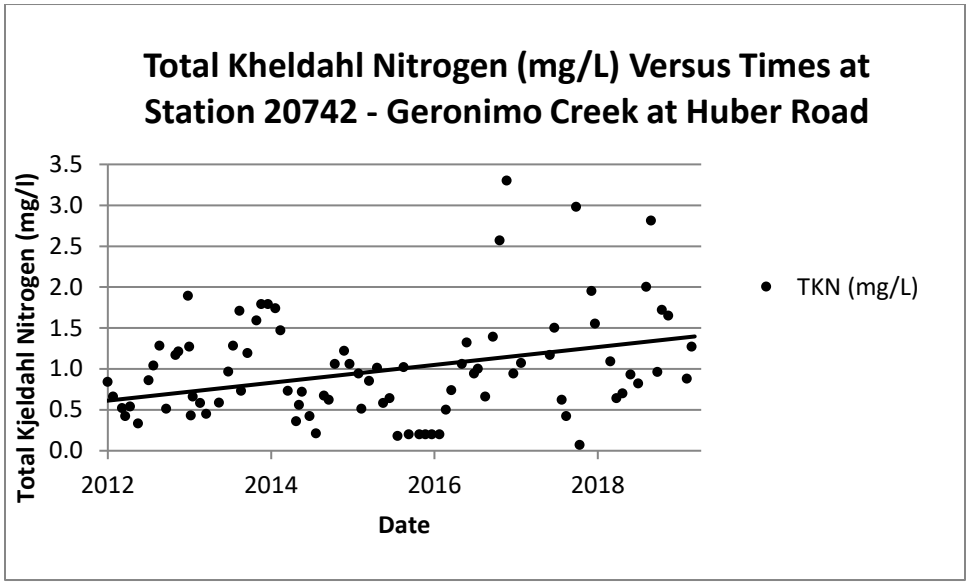

Figure 28. TKN (ug/L) versus Time at Station 20742 - Geronimo Creek at Huber Road

The Alligator Creek at Huber Road (20743) is the only routine monitoring station in the watershed located on the Alligator Creek tributary of Geronimo Creek. Station 20743 is located further upstream in the watershed than any other routine monitoring station and is 0.6 km upstream of the confluence with Geronimo Creek. A groundwater seep influences this station and it has never been dry during any sample collection events. The water at station 20743 disconnects from downstream monitoring stations and does not flow during times of extreme drought. Station 20743 showed a statistically significant increase in total suspended solids concentrations (TSS); $t(110)=-2.17$, $p=0.03$ (Figure 29). In contrast, total dissolved solids (TDS);

t(111)=3.99, p=0.00 (Figure 30) are significantly decreasing over time at this station. The TDS constituent nutrients of chloride and sulfate are trending in opposite directions, as chlorides decrease; t(111)=-2.66, p=0.00 (Figure 31) and sulfates increase; t(111)=3.28, p=0.00 (Figure 32). The increasing trend of TDS and generally low concentrations of chloride indicate that sulfate contributions from underground springs near this location are likely driving up TDS values. Nitrate nitrogen is also significantly increasing over time t(110)=9.48, p=0.00 (Figure 33). GBRA did not observe any other significant relationships between the bacteria or nutrient parameters of concern and stream flow at this station. The ambient stream flows at this station were also not significantly changing over time.

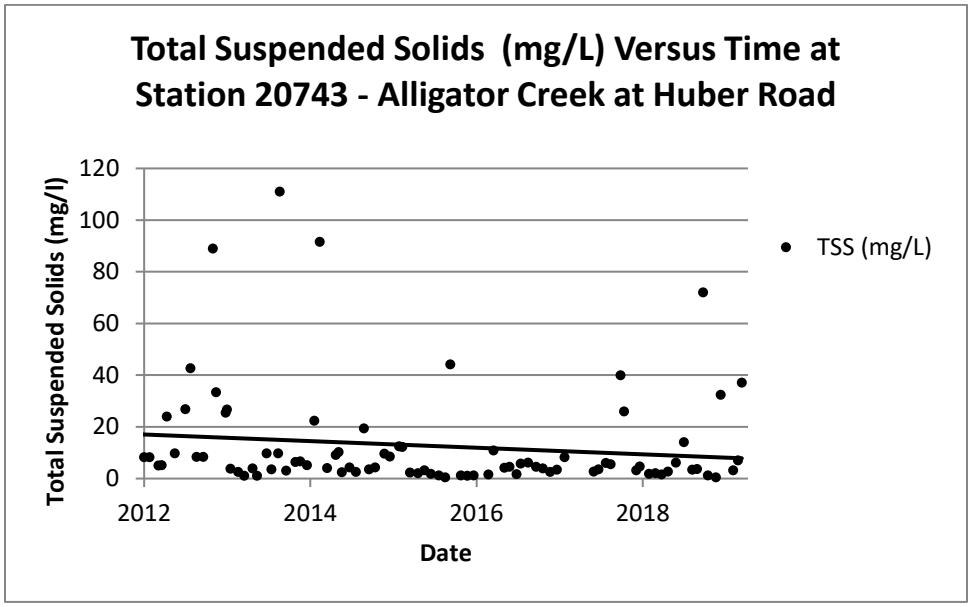

Figure 29. TSS (mg/L) versus Time at Station 20743 - Alligator Creek at Huber Road

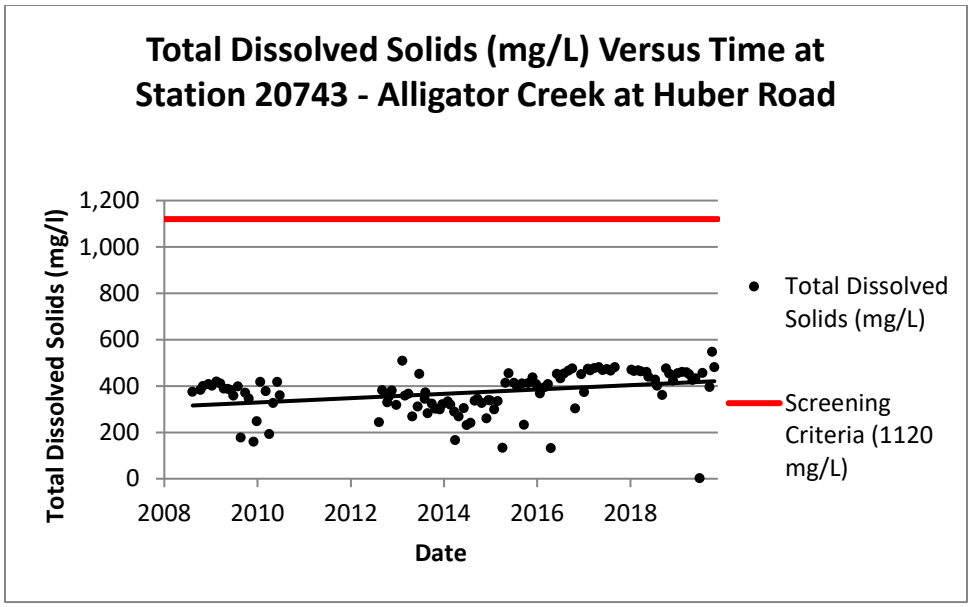

Figure 30. TDS (mg/L) versus Time at Station 20743 - Alligator Creek at Huber Road

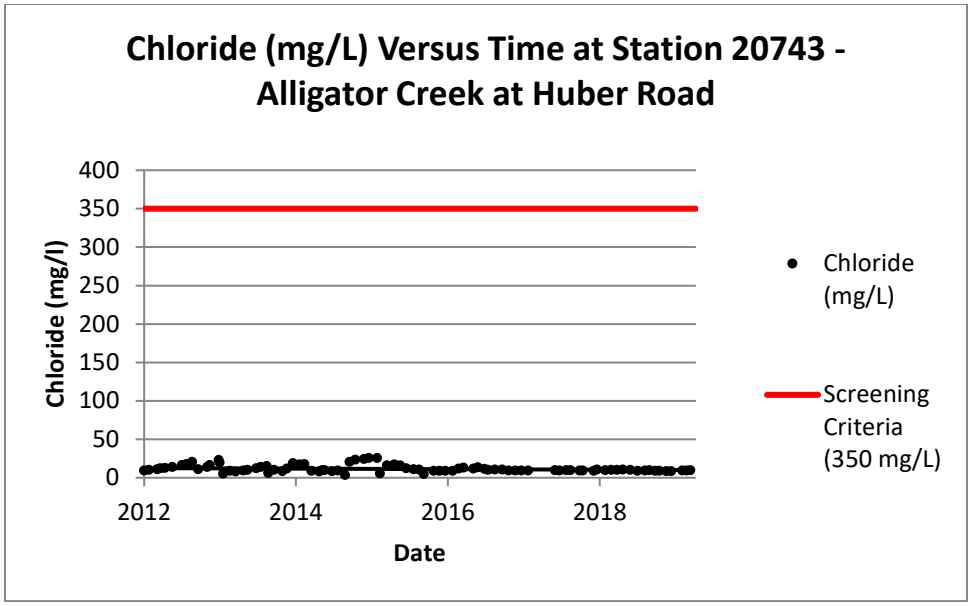

Figure 31. Chlorides (mg/L) versus Time at Station 20743 - Alligator Creek at Huber Road

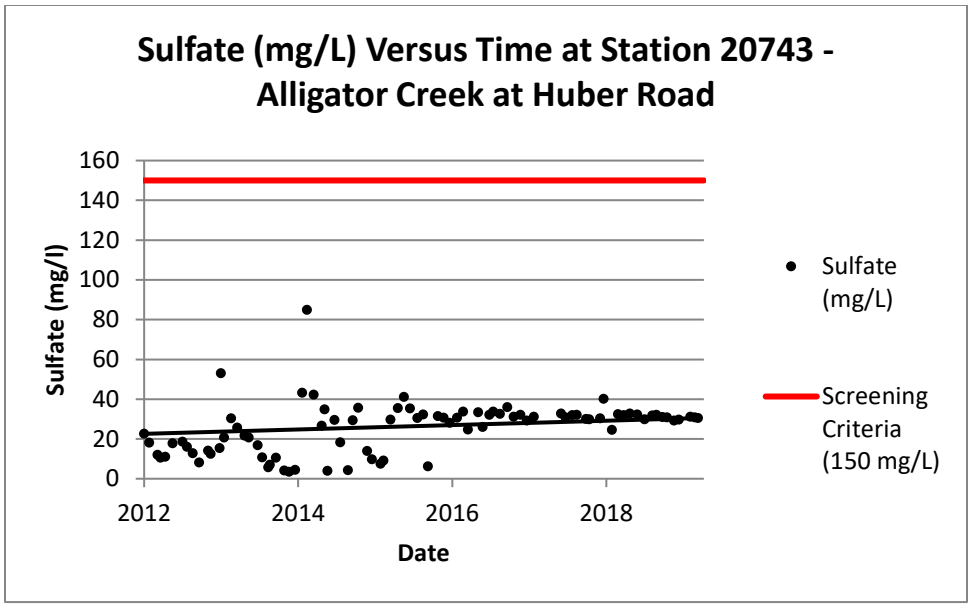

Figure 32. Sulfates (mg/L) versus Time at Station 20743 - Alligator Creek at Huber Road

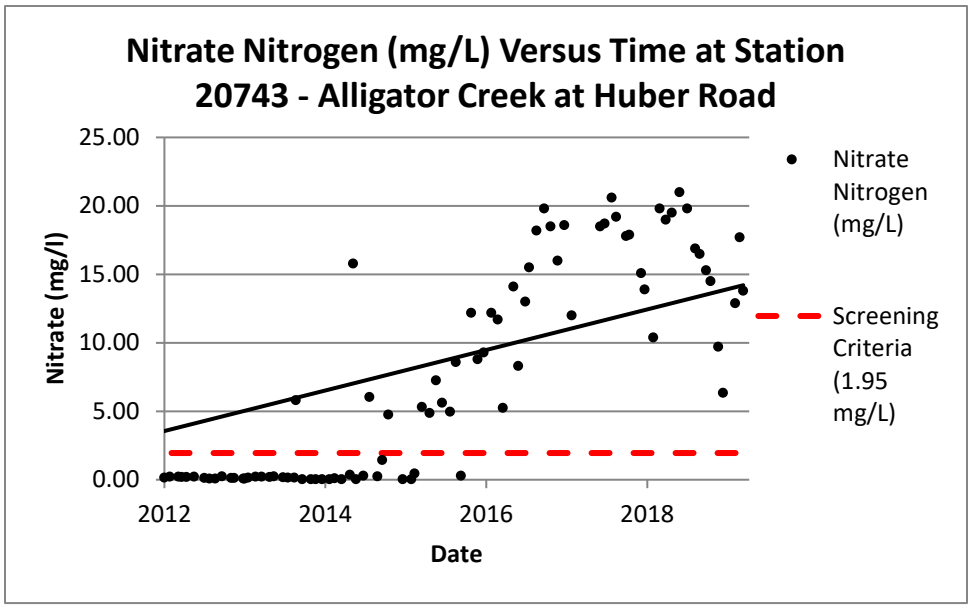

Figure 33. Nitrates (mg/L) versus Time at Station 20743 - Alligator Creek at Huber Road

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 Geronimo and Alligator Creeks WPP during targeted flow conditions. GBRA attempted to conduct targeted watershed monitoring at 14 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 14 sites, 8 sites were the same as the sites for routine ambient monitoring. Monitoring captured spatial, seasonal and meteorological variations in these snapshots of watershed water quality. GBRA's Regional Laboratory conducted the sample analysis. Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are TSS, sulfate, chloride, nitrate-nitrogen, ammonia-nitrogen, TKN and total phosphorus. GBRA collects flow by mechanical or acoustic Doppler flow measuring devices, and includes an evaluation of the flow severity. Bacteria parameters were *E. coli*.

GBRA collected data from six targeted monitoring stations throughout the Geronimo and Alligator Creek watersheds twice per quarter between February of 2018 and December of 2019. With the exception of a station on the Geronimo Creek main stem at FM 20 (12575), these monitoring stations were either completely dry or held isolated perennial pools for large portions of the monitoring project. The consequent data analysis at these stations did not result in enough available data to perform trending evaluations. The only quarterly monitoring station with perennial flow was located on the Geronimo Creek at FM 20 (12575). This station was located just downstream of the TCEQ CRP monitoring station and upstream of Geronimo Creek at IH 10 (21260) monitoring station. This station had 53 data points available for trend analysis and had significantly decreasing trends for ammonia nitrogen; $t(54)=-2.42$, $p=0.02$ (Figure 34) and increasing trends for nitrate nitrogen; $t(54)=3.62$, $p=0.00$ (Figure 35). The Bear Creek tributary of the Geronimo Creek was listed as a concern for bacteria with an assessed mean of 251.20 MPN/100 mL over 13 data points assessed in the 2014 TCEQ Texas Integrated Report. The 2018 integrated report increased the assessed mean to 310 MPN/100 mL. Using the most recent data collected at the Bear Creek at Walnut Street (20744) monitoring station GBRA calculated that the geometric mean had declined to 200 MPN/100 mL since the publication of this assessment. A review of the data showed that past exceedances of the state recreational stream standard often occurred after heavy rainfall events.

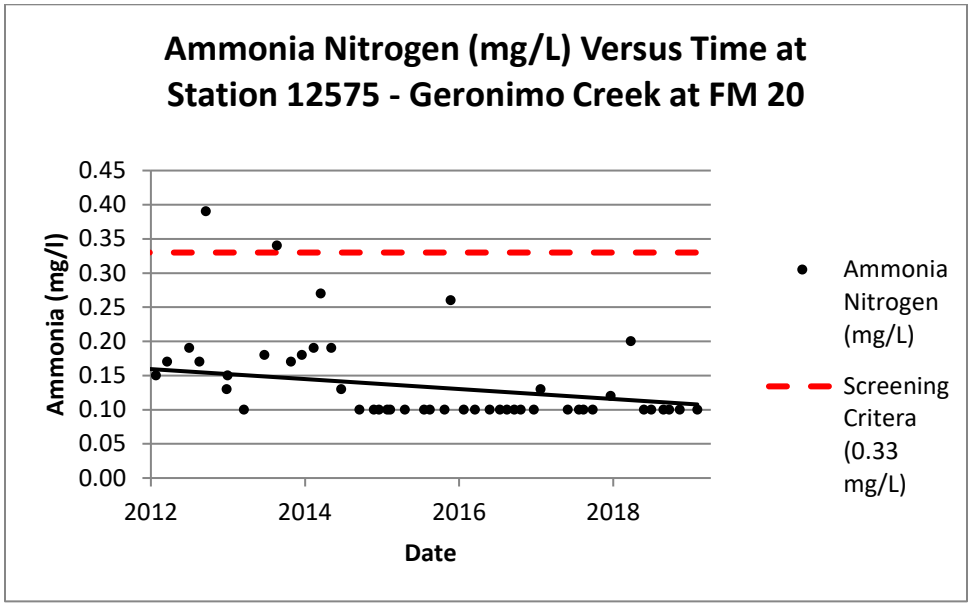

Figure 34. Ammonia (mg/L) versus Time at Station 12575 – Geronimo Creek at FM 20

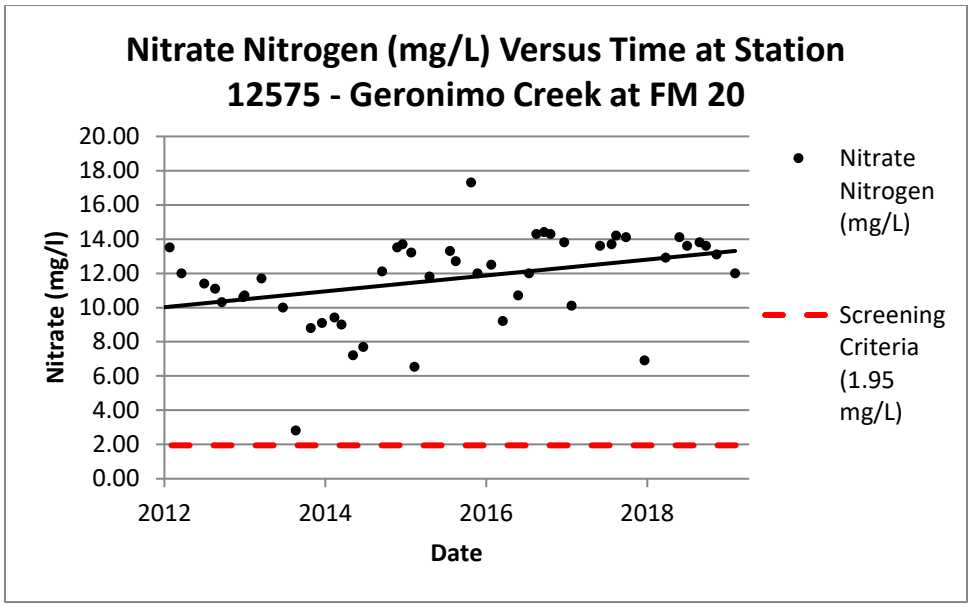

Figure 35. Nitrates (mg/L) versus Time at Station 12575 – Geronimo Creek at FM 20

Groundwater Monitoring

The objective of the groundwater monitoring task was to provide water quality data to access the effectiveness of implementing the Geronimo and Alligator Creeks WPP through spring flow and groundwater monitoring. GBRA conducted groundwater monitoring at 2 wells and one spring once per season collecting field, conventional, flow and bacteria parameter groups. All sampling events were conducted.

GBRA's Regional Laboratory conducted the sample analysis. Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are TSS, sulfate, chloride, nitrate-nitrogen, ammonia-nitrogen, TKN and total phosphorus. GBRA collects flow by mechanical or Doppler methodology, including flow severity. Bacteria parameters were *E. coli*. Data supports the source of the elevated nitrate-nitrogen concentrations from groundwater. Table 5 summarizes the results of this monitoring.

Table 5. Groundwater monitoring stations. GBRA began monitoring the two water wells in May of 2009 and Timmerman Springs was added to the monitoring schedule in November 2012. Data at these stations has continued through December of 2019.

Station	Median Flow (CFS)	Geometric Mean E. coli (MPN/100 mL)	Mean TSS (mg/L)	Mean pH (S.U.)	Mean Temperature (°C)	Mean Dissolved Oxygen (mg/L)	Mean Specific Conductance (uS/cm)	Mean Total Phosphorus (mg/L)	Mean Nitrate Nitrogen (*mg*/L)
Stream Screening Criteria	7Q2 = 0.1	126		6.5 to 9	32.2	5	1723	0.69	1.95
Huber Water Well	N/A	1	1.5	7.1	22.4	6.7	741	0.03	18.24
Timmerman Spring	0.3	3	22.7	7.1	22.1	7.2	770	0.03	18.31
Laubach Water Well	N/A	4	4.6	7.2	22.9	7.1	775	0.02	16.94

Conclusion

In summary, TSSWCB Project 17-08 titled *Surface Water Quality Monitoring in the Geronimo and Alligator Creeks Watershed to Support the Implementation of the Geronimo and Alligator Creeks Watershed Protection Plan* is complete and was essential to the continued water quality monitoring for the Geronimo and Alligator Creeks WPP. GBRA monitored water quality and presented updates to stakeholders. The Geronimo and Alligator Creek watershed coordinator used data from this monitoring project to inform and engage stakeholders through publications and educational training events. GBRA posted quality assured monitoring data on the project webpage and submitted data to the TCEQ surface water quality monitoring regulatory database for future assessments.

Implementation of the Geronimo and Alligator Creeks WPP is continuing through TSSWCB Project 19-07 titled *Surface Water Quality Monitoring to Support the Implementation of the Geronimo and Alligator Creeks Watershed Protection Plan.* This work plan continues the collection and dissemination of information of surface water quality on the Geronimo and Alligator Creeks and their tributaries. This work is essential to continue support of water resource adaptive management and expand public knowledge of the watershed through coordinated outreach and education efforts.

The GBRA monitoring in the Alligator and Geronimo Creek watersheds has shown that several significant trends in water quality are occurring in these watersheds. GBRA observed a significant increase in stream flow in all of the perennial flowing monitoring stations. This trend seems to be associated with an increase in precipitation and potential nonpoint source runoff throughout the course of the current monitoring project. Stream flow appears to be the driving force behind the majority of trends in the watershed. Nitrate nitrogen is increasing throughout the watershed, which increases with stream flow and is likely the result of additional nonpoint source contributions. Total dissolved solids concentrations and the chloride and sulfate anions that influence them are significantly generally decreasing throughout the watershed. These parameters decrease with stream flow and dilution of stream concentrations is likely occurring due to additional rainwater inputs. *E. coli* concentrations are generally stable throughout the watershed, but significant increases in concentrations occurred in the middle portion of the watershed, near the CRP station 12576 on Haberle Road. *E. coli* strongly correlates with stream flow and observed increases may be due to the isolated rural location of this station and its proximity to available wildlife and

agricultural bacterial runoff. The reductions associated with introduced best management practices are likely occurring along with increased nonpoint source pollution from population growth, impermeable cover and increased stream flows in the watershed. A USGS nitrate isotope study recently conducted by the USGS determined that nitrates in the watershed were not due to natural sources. Ammonia nitrogen has measurably declined at many of the monitoring stations in the watershed. The decline in ammonia-nitrogen may be a result of implementation efforts to reduce fertilizer runoff. The reduction in parameters such as ammonia nitrogen and TDS indicate that implemented best management practices are beginning to have an effect on the water quality of the Geronimo and Alligator Creeks. The nitrate nitrogen and *E. coli* water quality parameters targeted by the WPP are both increasing throughout the watershed. These trends are likely to continue so long as stream flows continue to increase. Best management practices targeted towards the reduction of these pollutants will need to overcome additional nonpoint source runoff associated with impermeable cover and urban growth before concentrations can stabilize and ultimately decline.

List of Acronym's

BF……. Biased for Flow
BMP……. Best Management Practices
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
ILSOLC…… Irma Lewis Seguin Outdoor Learning Center
ISD…… Independent School District
MG/L…….. Milligrams/Liter
ML……. Milliliter
MPN……. Most Probable Number
NPS…… Non Point Source
NO3-N…… Nitrate as Nitrogen
NH3-N…….. Ammonia Nitrogen
QAPP…….. Quality Assurance Protection Plan
QA/QC……. Quality Assurance/Quality Control
UMHOS/CM… Micromhos per Centimeter (Measurement unit for Specific Conductance)
UG/L……. Micrograms per Liter
RT…… Routine
SWCD…….. Soil and Water Conservation District
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