Lavaca - Navidad River Authority Basin Summary Report

Texas Clean Rivers Program

2012

Prepared by Water Monitoring Solutions, Inc. for the Lavaca – Navidad River Authority in cooperation with the Texas Commission on Environmental Quality under the authorization of the Clean Rivers Act

Water Monitoring Solutions

Texas Commission on Environmental Quality

Foreword

The Clean Rivers Program (CRP) is a water quality monitoring, assessment, and public outreach program administered by the Texas Commission on Environmental Quality (TCEQ) and funded by state collected fees. The Lavaca – Navidad River Authority (LNRA) coordinates the CRP for the Lavaca River Basin.

Under the CRP, biologists and field staff collect water quality and biological samples, field parameters and measure flow at sites throughout the basin. These data are used to assess a water body and determine if it meets the appropriate standards for its designated use. Monitoring and assessment often provide information about land use and possible sources of pollution. Also, collecting and storing these data allow for the development of trends over time.

The LNRA actively administers the CRP, which enables the LNRA to:

- Pay personnel to administer and complete CRP tasks in the Lavaca River basin
- Purchase equipment such as data sondes, boats, and monitoring supplies
- Accomplish additional water quality analyses
- Support volunteer organizations in the basin such as Texas Stream Team with the purchase of monitoring equipment and supplies
- Support Major Rivers, an educational program for fourth grade students in the schools located within the Lavaca River basin
- Encourage public participation through CRP meetings bringing together stakeholders, local municipalities, industries, and state agencies
- Quickly respond to potential environmental emergences such as spills, and to contact the appropriate enforcement and response agencies
- Perform continuous monitoring, monthly monitoring, quarterly monitoring, and special studies in the basin

Under the authorization of the Clean Rivers Act (1991), the LNRA completes reports detailing highlights in the basin, special studies, updates to on-going projects, and assessments of trends. These reports are used to inform the communities we serve about water quality and resource management. Opportunities for public participation are encouraged and information on how to get involved is included in this Basin Summary Report.

The LNRA contracted with Water Monitoring Solutions, Inc. (WMS) to complete this Basin Summary Report.

Cover photo courtesy of Patricia Kontak

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LIST OF ACRONYMS

303 (d) List	List of impaired water bodies – refers to section 303 (d) of the Federal Clean Water Act
ALU	Aquatic Life Use
AU	Assessment Unit
BBASC	Basin and Bay Area Stakeholder Committee
BBEST	Basin and Bay Expert Science Team
BSR	Basin Summary Report
cfs	Cubic feet per second (unit used to measure stream flows)
CR	County Road
CRP	Clean Rivers Program
DO	Dissolved oxygen (in water)
EPA	Environmental Protection Agency
FM	Farm-to-Market Road
FY	Fiscal Year
GPA	Grade Point Average
HWY	Highway
IR	Integrated Report
Km	Kilometer
LCRA	Lower Colorado River Authority
LNRA	Lavaca-Navidad River Authority
m	Meter
MGD	Million Gallons per Day
mg/L	Milligram per liter
mi	Miles
MPN/100 ml	Most Probable Number per 100 milliliters
PCR	Primary Contact Recreation
ppt	Parts per thousand
PS	Public Water Supply
s.u.	Standard Unit
SH	State Highway
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWQI	Texas Water Quality Inventory
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
UAA	Use Attainability Analysis
US	United States
USGS	United States Geological Survey
WMS	Water Monitoring Solutions, Inc.

Executive Summary

Each Clean Rivers partner is required to complete a basin summary report every five years as a comprehensive review of water quality conditions, significant trends, and impairments affecting water quality throughout the basin. This report, and others submitted throughout the State are used to develop and prioritize programs that will:

- protect the quality of healthy water bodies, and
- improve the quality of impaired water bodies.

The Lavaca River Basin is a coastal basin, located between the Colorado River watershed to the east and the Guadalupe drainage to the west. Roughly equal portions of the basin are drained by the Lavaca and Navidad Rivers, which together encompass 188 stream miles and a drainage area of 2,309 square miles. The Basin contains portions of Colorado, DeWitt, Fayette, Jackson, Lavaca and Wharton Counties. The Lavaca-Navidad watershed drains into upper Lavaca Bay, a secondary embayment in the Matagorda Bay system. Major population centers located within the Basin include Edna, Ganado, Hallettsville, Moulton, Shiner, Schulenburg, and Yoakum.

Water Quality Issues

Water quality data collected according to TCEQ-approved procedures are reported to the TCEQ and included in the Surface Water Quality Monitoring Information System (SWQMIS). Every 2 years the TCEQ assesses the available surface water quality data and produces the results in an Integrated Report. Any waters found not to be meeting the designated Water Quality Standard are placed on the List of Impaired Waters, known as the 303(d) List. Three main water quality issues were documented in the *2010 TCEQ Integrated Report*.

1. Depressed dissolved oxygen levels in the Lavaca River above Tidal (1602) reach
2. Bacteria levels above criteria in the Lavaca River above Tidal (1602) reach
3. Concern for nutrient levels in Lake Texana (1604)

Depressed Dissolved Oxygen in the Lavaca River above Tidal
Dissolved oxygen monitoring in this reach of the Lavaca River first began by the Texas Parks and Wildlife Department (TPWD) in response to a fish kill reported to the agency. A series of 24 hour dissolved oxygen measurements were collected and these data were included in the TCEQ database. These data were used for assessment purposes and resulted in the listing of Segment 1602 as impaired for depressed dissolved oxygen in 2004. The upper reaches of the Lavaca River were considered under studied, so the LNRA applied for assistance in funding a special study to gather additional 24-hour dissolved oxygen, flow, and field parameters. The goal of this special study was to collect data to determine the actual flow status of the reach so that the appropriate water quality standards could be established. The data generated were assessed by the TCEQ and resulted in the upper reach (AU 1602_01) of the Lavaca River being listed for depressed dissolved oxygen levels in the *2004 303(d) List*.

A Use Attainability Analysis (UAA) is an analysis that determines what the applicable water quality standard should be based on the attainable conditions for that water body. A UAA was conducted in the upper reaches of Segment 1602 from 2005 to 2006 by the TCEQ Water Quality Standards Team, the TPWD, and the LNRA. The 24-hour dissolved oxygen monitoring conducted in the study supported re-evaluation of the upper segment as an intermittent stream with perennial pools. The study concluded that conditions causing the stream to go intermittent in the upper reach were caused by naturally occurring seasonal low flow conditions. The TCEQ redefined the segment boundaries to appropriately characterize the stream. This change resulted in the proposal to adjust the water quality standards for the associated criteria.

The UAA completed review in TCEQ and was submitted to the EPA for review and approval. As of the completion of this report, approval is still pending.

Bacteria levels in the middle and lower AU's in the Lavaca River above Tidal

Segment 1602 runs from a point 8.6 km (5.3 miles) downstream of US 59 in Jackson County to a point 5.5 km (3.4 miles) upstream of SH 95 in Lavaca County. Wastewater plants in this segment include Hallettsville, Shiner, Yoakum, and Moulton. AU 1602_02 is the middle reach from Hallettsville downstream to the confluence with Beard Branch. The lower AU, 1602_03 begins at the confluence with Beard Branch and flows downstream to the confluence with NHD RC 12100101002463 south of Edna in Jackson County.

This segment was first assessed for bacteria in 2008. Prior to that, an insufficient amount of data existed for assessment. Bacteria levels from the upstream station in Hallettsville (12527) are generally lower and help keep the geomean lower. The land use in the upper northwestern area of the watershed is largely dominated by agricultural activities (> 70% from irrigated row crops to grazing land).

The City of Moulton is authorized to discharge treated domestic wastewater at a daily average less than or equal to 242,000 gallons per day. The City of Hallettsville also potentially impacts water quality with its authorized discharge of 800,000 gallons per day under TPDES Permit WQ0010013001 at its wastewater treatment plant. Additionally, Rocky Creek, (sub-segment 1602B) an unclassified water body, joins the Lavaca River below Hallettsville. One sampling station contains bacteria data on Rocky Creek west of US Highway 77 (18190). The geomean before it joins the Lavaca River is 267 MPN/100 ml.

Neither AU shows a statistically significant relationship for bacteria levels over time. When considering agricultural influence, forested lands, and permitted dischargers from wastewater treatment plants, higher bacteria levels are achieved through a combination of point, and non-point sources, such as rainfall runoffs. Rural streams in most basins experience higher bacterial counts after heavy rains due to the organics picked up from pastureland and wildlife during overland flow, but these numbers recede after a short time. It only takes a couple of precipitation spikes to exceed the geomean criteria.

Concern for nutrient levels in Lake Texana

Nutrient enrichment is a listed "concern" in Lake Texana due to the levels of phosphorus and nitrate nitrogen exceeding TCEQ screening levels. The *2010 Integrated Report* included nutrient screening analysis for nitrate, total phosphorus, ortho-phosphorus, ammonia, and chlorophyll-*a*. All constituents were present at all sample sites during the period of analysis; however, average levels for ammonia and chlorophyll-*a* were below screening levels and there was no concern for those parameters.

Nutrient concentrations continue to be above screening levels in the Lake Texana watershed during the current assessment period, particularly in the Mustang Creek Arm. Nitrogen levels were present in the Navidad Arm (1604_01), but average levels were below screening level and there is no concern for that parameter. Nitrogen concentrations exceed the screening levels throughout the remainder of Lake Texana. Total phosphorus and orthophosphorus concentrations often exceeded screening levels, resulting in additional concerns throughout the lake for nutrient enrichment. Nitrogen and phosphorus levels in the tributaries, the Navidad River, Sandy, West Mustang and East Mustang Creeks, were comparable to those in Lake Texana, but did not result in concerns because streams and reservoirs have different screening levels with more stringent screening levels for reservoirs.

Nutrient enrichment appears to be decreasing as do occasional elevated levels of total organic carbon and chlorophyll *a*. Both grab and diel dissolved oxygen monitoring results indicate that Lake Texana is continuing to assimilate its nutrient loading without major adverse consequence to water quality and aquatic life uses.

Trend Analysis

Trend analyses were conducted in assessment units throughout the Basin that have at least ten years of data, regular sampling and had a minimum of twenty to thirty data points. Trend analysis was performed using a linear regression with a ninety percent confidence interval. A trend was identified as statistically significant when meeting two criteria: the T-stat value was greater than the absolute value of two, and the p-value was less than 0.1. In addition to performing trend analysis, the mean, median and standard deviation were calculated for parameters with significant trends. In order to more simply demonstrate the variability of the historical sample results, the standard deviation was divided by the mean and expressed as a percentage.

An overall Increase in pH levels and decreasing specific conductance in most AU's were common trends found throughout the Basin. Although the pH trends met the criteria to be considered statistically significant, the standard deviation was typically around 0.3 standard units. For all assessment units with a significant pH trend, the variability (standard deviation divided by the mean) was within five percent meaning that the sample results had little variability and few outliers. These data show that although a significant trend for pH existed, the change in water quality and its effects on the biota were likely negligible.

Data results and trends for all parameters indicate decreasing tendencies in the lower parts of the Basin. The only consistent exception is dissolved oxygen which is increasing throughout Lake Texana and the Navidad River below the lake. Specific conductance, nutrients, chloride, sulfates and total dissolved solids are decreasing in Lake Texana and the Navidad River above the lake. Reduced freshwater inflows into Lake Texana caused by drought conditions are having the effect of reducing nutrient loads and it appears water quality is improving. However, extremely low rainfall levels in four of the past five years appear to be impacting trends and results.

Conclusions and Recommendations

The overall data review for the Lavaca–Navidad Basin addressed two objectives: (1) parameters listed as impaired or concerns in the *2010 TCEQ Integrated Report* were reviewed under similar criteria as assessed by the TCEQ, and (2) trends were identified for all data that met criteria discussed earlier in this report. The data assessed in this report document the state of the basin to 2012. This will be a useful tool to reference in the future of water quality. Human activity, wildlife, and land use are reflected in field and laboratory results of water quality analysis. The history of water quality in the Basin is well documented and updates to the LNRA's current open projects are available in the various reports generated through the CRP.

The Use Attainability Analysis study that took place from 2005 to 2006 adequately provided the required data to support reclassification of Segment 1602 to more accurately reflect the stream conditions present in the upper reaches of the Lavaca River above Hallettsville. The final UAA report remained under review at TCEQ until it was submitted to the US EPA Region 6 in late 2009. If the revised water quality standards are approved, these data will be reevaluated with the revised water quality standards. Analysis of these data indicate that when the 2010 Water Quality Standards are approved, this reach will most likely be removed from the 303(d) List of Impaired Waters for depressed dissolved oxygen

A more detailed monitoring approach would be required to positively identify the source for elevated bacteria entering the listed water body, but apparent evidence indicates livestock, feral hogs, and wildlife to be the major contributors.

Introduction

The TCEQ administers the Clean Rivers Program (CRP) and ensures its managing objectives are met throughout the state. TCEQ partners with river authorities, municipal water districts, councils of government, and other regional entities to pursue a coordinated approach to water quality issues and resource management to address monitoring needs in the watershed. A component of the CRP is interaction and input from stakeholders, local residents, or active members in the community affected by water quality issues.

The LNRA serves as the coordinator for managing and monitoring water quality in the Lavaca Basin. Accomplishing the tasks set forth in the CRP is a cooperative effort with other entities. In the past five years, the LNRA would like to thank the TCEQ, United States Geological Survey (USGS), TSSWCB, and TPWD.

Watershed Characterization

The Lavaca River Basin is a coastal basin, located between the Colorado River watershed to the east and the Guadalupe drainage to the west. Roughly equal portions of the basin are drained by the Lavaca and Navidad Rivers, which together encompass 188 stream miles and a drainage area of 2,309 square miles. The basin contains portions of Colorado, DeWitt, Fayette, Jackson, Lavaca and Wharton Counties. The Lavaca-Navidad watershed drains into upper Lavaca Bay, a secondary embayment in the Matagorda Bay system. Major population centers located within the Basin include Edna, Ganado, Hallettsville, Moulton, Shiner, Schulenburg, and Yoakum.

The waters of the Navidad River, Sandy Creek, and East and West Mustang Creeks are impounded in the Lake Texana reservoir in Jackson County. The Lavaca River is one of the last unrestricted (i.e. undammed) waterways in the State of Texas, and subsequently is considered to be a State treasure as a reference stream along with its associated bottomland hardwood habitats.

As a result of the characteristically flat coastal plain topography and the low permeability of its soils, flooding may occur within the Basin as a result of heavy precipitation. The Lavaca and Navidad Rivers are typical of Texas rivers in general in that their annual hydrographs can be characterized by extended low flow periods punctuated by high flow flooding events.

Headwaters of the Navidad River rise in the East and West forks in southern Fayette County at an elevation of 440 feet. These forks join near Oakland at an elevation of 201 feet and flow southward to Lake Texana. Constructed by the U.S. Bureau of Reclamation for municipal, industrial, fish and wildlife, and recreational benefits, Lake Texana has a firm yield of 79,000 acre feet per year.

The Lavaca River originates above Moulton in Lavaca County at an elevation of 470 feet and flows southeast into Lavaca Bay. The confluence of the Lavaca and Navidad Rivers is about two miles east of Vanderbilt in Jackson County. The Lavaca Basin is part of the West Gulf Coast Section of the Coastal Plain Physiographic Province and includes the Blackland Prairie, Claypan, and Coastal Prairie land resource areas.

In the upper part of the Basin, the Blackland Prairie is a level to rolling, well dissected grassland with rapid drainage. The Claypan area is a gently rolling moderately-dissected post oak savanna with moderate surface drainage. In the lower basin, the Coastal Prairie is a nearly level, practically undissected plain with slow surface drainage. The upper Lavaca Basin is underlain by gray clay of the

Fleming Formation of Tertiary age which dips gently toward the Gulf of Mexico. Overlying the Fleming Formation are gravel, sand, silt, and clay of the Willis, Lissie, and Beaumont Formations each of which are Pleistocene age formations. Recent alluvium occurs along streams of the Basin.

The Lavaca Basin lies within the warm temperate zone and is classified as humid and subtropical with hot summers. Due to the proximity of the Basin to the Gulf of Mexico and its prevailing southeasterly wind, a marine climate exists throughout spring, summer, fall, and much of the winter season. Summers are hot and humid with little variation in day-to-day weather conditions, except for occasional thunderstorms or tropical storms and/or hurricanes. Winters are short and mild, moderated by polar air masses which frequently push southward and bring weather to the Basin that alternates from cool, overcast, and drizzly to mild, sunny, and dry conditions. The mean annual precipitation in the Basin varies from 34 inches along the western boundary to approximately 41 inches along the eastern boundary. However in recent years drought has plagued the Lavaca Basin as well as most of the State of Texas.

Average annual net surface water evaporation rates range from about 20 inches along the eastern river basin boundary to about 28 inches along the western border. Relative humidity is often higher during winter and spring than in summer and fall since hot air has a greater capacity for holding moisture. Mean monthly relative humidity has been measured at noon as 63 percent in January and April and 54 percent in July and October.

Drought Conditions and Rainfall in the Basin

Water quality data in recent years was noticeably impacted by drought conditions. A relatively large number of CRP sampling sites were dry during sampling, and those streams that are not dry have little or no flow. Since the last Basin Summary Report in 2007, most of the state has been gripped by drought conditions. The overall lack of rainfall has resulted in the loss of stream flow and lowered reservoir storage levels throughout the Basin. In 2008, Rocky Creek, an unclassified sub-segment of the Lavaca River above Tidal (1602), was completely dry when LNRA staff arrived for quarterly sampling. This was a first since monitoring began at this site in 2004, but has been a repeated condition since. The following year, 2009, Lake Texana exceeded its historic low of 38 feet above mean sea level. That year and much of the time since, LNRA was unable to sample sites in the upper reaches of the lake in the Navidad Arm and in Sandy Creek (a sub-segment and tributary to Lake Texana) due to drought conditions. Lake Texana reached a new record low level of less than 31 feet by January 2012. All boat ramps to Lake Texana have been closed since mid-2011.

Figure I.1: *South Moulton low flow conditions*

Significant rainfall fell in the basin in late 2009 and January 2010 enabling the water in Lake Texana to only temporarily rise to near normal levels. Table I.1 shows the average monthly rainfall from January 2008 to December 2011. The average annual rainfall for the region is 41.10 inches (from monthly rainfall data collected since 1973). Rainfall totals for 2008 and 2009 were well below average by a significant amount. Despite a better than average year in 2010, 2011 was an exceptionally dry year measuring just under fourteen inches of rainfall. To access the monthly and annual rainfall totals, please visit http://www.lnra.org/monpre.asp.

Table I.1: *Average monthly rainfall recorded at LNRA weather station in Edna*

Average Monthly Rainfall at LNRA Weather Station (inches)													
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
2008	3.96	1.02	2.23	1.8	0.62	0.72	3.52	4.27	1.93	1.2	2.41	0.74	**24.42**
2009	0.15	0.17	2.01	2.07	2.12	0.07	0.68	2.33	4.85	6.27	3.58	4.5	**28.80**
2010	3.45	3.01	2.08	0.46	5.50	2.63	15.04	1.36	12.5	0.01	2.18	2.41	**50.63**
2011	3.32	0.57	0.73	0.01	1.11	2.09	0.51	0.37	1.12	1.90	0.63	1.59	**13.95**

Special Studies

Lavaca-Navidad River Authority contracts with the USGS to monitor Lake Texana and its tributaries (including Mustang and Sandy Creeks and the Navidad River) for pesticides, herbicides and metals.

The USGS monitors water quality in FY 2012 at nine sample sites concentrated in and near Lake Texana. Field parameters are collected at all nine sites, flow is measured at the five stream sites, and conventional laboratory analysis is run at one site. Samples are collected for metals at one site in Lake Texana near the spillway and at five other locations. Samples are collected for organic pollutants at eight sites in the basin. For locations of USGS sampling, please visit:
http://cms.lcra.org/schedule.aspx?qryDesc=&qrySite=&FY=2012&basin=16&qrySC1=GS.

For details of parameters for heavy metals and organic pollutants in water, please visit:
http://www.tceq.texas.gov/assets/public/compliance/monops/crp/guidance/2012/Task3.pdf.

Community Involvement

A component of the CRP is to facilitate opportunities for community involvement by using meetings, education, and programs in the basin it serves. The point of doing this allows the appropriate agency to address water quality issues from a coordinated perspective and establish communication between the community and LNRA, among others. This coordinated monitoring approach is guided by a steering committee that functions to participate in the watershed planning process. This helps to ensure resources are maximized and the most strategic plan possible can be used to address local concerns and impacts on water quality.

The Major Rivers Program

The Major Rivers Program was designed by the Lower Colorado River Authority (LCRA) and Texas Water Development Board (TWDB). The program is purchased by LNRA to educate fourth grade students in the Basin about how water is provided, used and treated. Bringing education and community together encourages participants to be better stewards of the watershed. The program personalizes student's education with their own environment, while using science, math, language arts, and social studies to meet mandated standards from the Texas Education Agency.

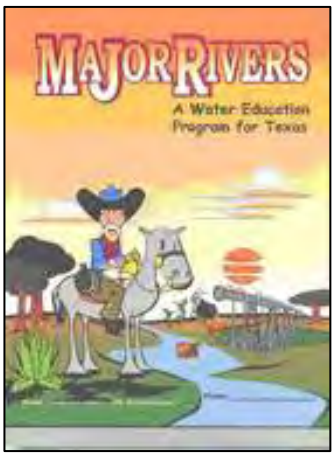


Figure I.2: *Major Rivers Program Cover*

Teacher's materials include: a variety of activities/lesson ideas in the core subjects, a full classroom set of instructional materials including student workbooks, pre and post-test sheets, home information leaflets, color overhead transparencies, and an introductory video. The LNRA provides learning materials to both public and parochial Lavaca Basin schools interested in teaching this program.

Please contact Sylvia Balentine at (361) 782-5229 or via e-mail sbalentine@LNRA.org for further information or to receive educational materials from LNRA.

The Lavaca Basin Steering Committee

The main opportunity for public involvement in the Basin is generated through the efforts of the Lavaca Basin Steering Committee. The Committee distributes information on water quality throughout the basin, sets priorities for monitoring, and provides guidance on resource management. Project planning and priorities are addressed with insight and knowledge from local members of the community combined with the experience of other professionals like TPWD, TCEQ, USGS, Natural Resources Conservation Service (NRCS), TSSWCB, and the County Agricultural Extension Service.

The LNRA mails out meeting notices to participants with documented contact information. Notices are required to be sent at least thirty days prior to the meeting date. Meeting announcements are also posted on the LNRA website and in all Basin newspapers (Edna, Hallettsville, Moulton, Schulenburg, Shiner, and Yoakum) for other interested parties. Participation improves with attendees signing in and providing contact information. News, announcements, and other information can then be shared with you through direct contact.

Topics addressed at the 2011 annual meeting included an overview of the CRP, a presentation updating the activities of the Colorado and Lavaca Basin and Bay Area Stakeholder Committee (BBASC), and a report on Senate Bill #3 – Environmental Flows Recommendations was presented by the Colorado and Lavaca Basin and Bay Expert Science Team (BBEST) Chairman, David Buzan.

Membership in the Committee is open to staff from state and local governments, private landowners, representatives of industry and agriculture, and all interested individuals. Anyone interested in participating as a member of the Steering Committee may contact the offices of LNRA and speak to General Manager, Patrick Brzozowski or Water Quality personnel, Sylvia Balentine or Chad Kinsfather or one may just attend the annual meetings which are open to the public. Local attendance and participation are encouraged.

The Lavaca-Navidad River Authority Scholarship Program

The LNRA has provided scholarships for area students to further their education. These scholarships are awarded to graduating high school seniors planning to enroll in an undergraduate program at a college, university, or technical school and/or students who are currently enrolled at one of these institutions. The application process includes an essay on a topic provided and completion of an application form that can be obtained on the LNRA website.

Figure I.3: *River otter below Lake Texana spillway*

Funding is awarded on a reimbursement basis and is dependent on semester grades. Students must maintain a minimum 12-hour course load and a 2.5 GPA to be eligible for payment. LNRA appreciates the opportunity to support the youth of Jackson County and hopes this financial assistance may enable our youth to fulfill their goals in life.

News and Information

LNRA Water Quality Database

Extensive water quality information for the Lavaca Basin is available via the LNRA web site. The “LNRA Water Quality Database” link connects to a dedicated server storing all state approved water quality data for the Lavaca Basin, both historical and recent. The data may be accessed by county, by segment, or by a Texas Surface Water Quality Monitoring (SWQM) site number. These site numbers are available by looking first under “County” or “Segment” where the sites are described and SWQM numbers are given. Current site numbers are also available from the LNRA water quality monitoring schedule or site map posted on the “Water Quality Program” web page.

Water quality data can be displayed as an HTML page, as an ASCII delimited text file that can be imported into a spreadsheet or database, or in graph format. Once a sampling site (also called “station”) is chosen, data can be retrieved either by sampling date or by parameter—both of which are displayed in pull down menus. Water quality parameters, e.g. dissolved oxygen, pH, salinity, etc. are listed on the

pull down menu to the right of the page. Recently added to this drop-down list are the metal and organic parameters (analyses contracted to USGS). Once a parameter is chosen, a date range should be entered, as instructed. If no date range is entered, all available data will be given. This is an excellent tool for students or anyone needing to access historical or current water quality information for the Lavaca Basin.

As a service to residents in the watershed, the LNRA maintains an Early Warning System on the LNRA website. Continuous monitoring stations around the basin are maintained for the following purposes:

Stream Level Alarms

Maximum stream levels are monitored at thirteen stations throughout the basin. Water levels for bank full (immediately before flood level), zero flow, alarm, warning, major flood, road closures, and record highs can be located on the LNRA website.

Current Weather Conditions

The LNRA posts hourly data for precipitation, wind speed and direction, humidity, temperature, barometric pressure, and lake elevation recorded at the meteorological station at the LNRA headquarters.

Rain and Stream Levels

Water level sensors are continuously monitored at several stations. Multiple sensors are included on the Lavaca River, Navidad River, Sandy Creek, East Mustang Creek, West Mustang Creek, Tres Palacios Bay, Carancahua Bay and Lavaca Bay.

24-Hour Precipitation Map

A map of the Lavaca – Navidad River basin contains the locations of 27 rainfall gauges throughout the Basin. Daily rainfall is measured and displayed to the one – hundredth of an inch at each location.

The above information can be found on the Early Warning System web page at http://www.lnra.org/ews.asp. Anyone wishing to be notified of certain conditions such as lake elevations, water releases, stream levels, alarm levels, or current temperatures can submit a request form also located at the address above.

Figure I.4: *Bald eagle and nest*

Segment Descriptions

Segment 1601 - The Lavaca River is divided into two segments. The lower portion is tidal and extends from the confluence with Lavaca Bay in Calhoun/Jackson County to a point 8.6 kilometers (5.3 miles) downstream of US 59 in Jackson County. The Menefee Lakes, Redfish Lake, Swan Lake, Catfish Bayou (1601A), Redfish Bayou (1601B), and Dry Creek (1601C) are tributaries included in this segment. The segment type is designated as a tidal stream.

Segment 1602 – The upper segment of the Lavaca River is the reach above the tidal influence from a point 8.6 kilometers (5.3 miles) downstream of US 59 in Jackson County to a point 5.5 kilometers (3.4 miles) upstream of State Highway 95 in Lavaca County. (This includes the proposed segment description still under review by EPA.) Unclassified tributaries include Big Brushy Creek (1602A) near Yoakum and Rocky Creek (1602B) south of Hallettsville. Wastewater effluents from the cities of Yoakum, Shiner, Moulton and Hallettsville enter either directly into the Lavaca River or into its tributaries.

Segment 1603 – This segment extends from the confluence with the Lavaca River in Jackson County upstream to the Palmetto Bend Dam, also in Jackson County and immediately below Lake Texana. Like Segment 1601, this portion of the Navidad River is classified as a tidal segment influenced by conditions present in Lavaca Bay. The dam serves as a saltwater barrier preventing saline waters from entering the lake. The flow from Lake Texana, and groundwater sources, introduces freshwater into this segment.

Segment 1604 – Lake Texana makes up this segment and the lake is fed by drainage areas from the Navidad River, East Mustang Creek (1604A), West Mustang Creek (1604B), Sandy Creek (1604C), and other small drains. Irrigation canals drain rice fields in the Sandy Creek watershed and the branches of Mustang Creek drain the portion of the Basin from the Garwood Irrigation Service Area to Lake Texana. Wastewater effluents from the treatment plants in Ganado and the lakeside parks discharge into Lake Texana. The WWTP of Louise discharges to the East Mustang Creek, and the wastewater effluent from the Sheridan community drains into Sandy Creek.

Figure I.5: *Lake Texana aerial view*

Segment 1605 – The Navidad River above Lake Texana from its confluence to its origin near Schulenburg is the last segment in the Basin. Many tributaries drain into this segment, including one in the northern portion of the Basin which channels wastewater effluent from Schulenburg. The majority of land use within this segment includes farming and ranching.

Factors with the potential to influence water quality in the Lavaca Basin include oil and gas exploration, concentrated animal feeding operations (CAFO's), agricultural activities, wildlife (including feral hogs), and municipal wastewater treatment facilities. Based on the analysis of water quality (and considering

factors like drought in the region) it appears water quality is improving with the upgrades to industrial pre-treatment and wastewater treatment plants.

Water Quality Parameters

LNRA collects and analyzes water quality samples in the Lavaca River Basin and submits the resulting data three times annually to TCEQ for inclusion in the state water quality database. After acceptance and approval by TCEQ, the data is made available via the LNRA website for public access.

Water quality monitoring includes collection of field parameters at 22 sites:

Table I.2: *Field parameters*

Field Parameters	
Temperature	Flow (at stream stations)
Dissolved Oxygen	Transparency
Specific Conductance	Salinity (at tidal stations)
pH	Flow Severity
Flow Method	

Temperature – Water temperature affects the oxygen content of the water, with warmer water unable to hold as much oxygen. When water temperature is too cold, cold-blooded organisms may either die or become weaker and more susceptible to other stresses, such as disease or parasites. Colder water can be caused by reservoir releases. Warmer water can be caused by removing trees from the riparian zone, soil erosion, or use of water to cool manufacturing equipment.

Dissolved Oxygen (DO) – Organisms that live in the water need oxygen. In stream segments where DO is low, organisms may not have sufficient oxygen to survive. Modifications to the riparian zone, human activity that causes water temperatures to increase, increases in organic matter, bacteria and over abundant algae may cause DO levels to decrease.

Specific Conductance – Conductivity is a measure of the water body's ability to conduct electricity and indicates the approximate levels of dissolved salts, such as chloride, sulfate and sodium in the stream. Elevated concentrations of dissolved salts can impact the water as a drinking water source and as suitable aquatic habitat.

pH – Most aquatic life is adapted to live within a narrow pH range. Different organisms can live at and adjust to differing pH ranges, but all fish die if pH is below four (the acidity of orange juice) or above 12 (the pH of ammonia). Industrial and wastewater discharge, runoff from quarry operations and accidental spills are examples of factors that can change the pH composition of a water body.

Flow – Flow is an important parameter affecting water quality. Low flow conditions common in the warm summer months create critical conditions for aquatic organisms. At low flows, the stream has a lower assimilative capacity for waste inputs from point and nonpoint sources.

Transparency – Transparency is a measure of the depth to which light is transmitted through the water column and thus the depth at which aquatic plants can grow. A low Secchi disk depth is an estimate of turbidity.

Salinity – Salinity is computed from specific conductance and temperature. It is recorded at tidally influenced stations only. Salinity plays a role in determining estuarine sites and the composition of saline water diluted by river water. Salinity has risen dramatically with the current drought because of a combination of evaporation (leaving behind salts) and lack of freshwater inflow.

Flow Severity – Flow severity is a parameter recorded at freshwater (non-tidally influenced) sites. It is an observational measurement that depends on the sampler's knowledge of the water body. This parameter is often used when assessing a water body and as supporting detail of conditions present during sampling. The reporting of flow severity consists of one of the following: 1=no flow, 2=low, 3=normal, 4=flood, 5=high, 6=dry.

Flow Method – The method used to measure flow is also recorded to provide information as to how the flow was determined. The following numbers are used to report flow method: 1 – flow gauge station; 2 – electric flow meter; 3 – mechanical flow meter; 4- weir or flume; and 5 – Doppler meter.

Water quality monitoring also includes laboratory analyses at 17 sites. Laboratory parameters include:

Table I.3: *Conventional parameters*

Laboratory Analysis	
Total Suspended Solids	Chloride
Ammonia	Sulfate
Nitrate-Nitrogen	*E. coli* bacteria
Total Kjeldahl Nitrate	Total Alkalinity
Total Phosphorus	Total Organic Carbon
Total Hardness	Chlorophyll-a
Turbidity	

** - E. coli bacteria are collected at eight sites*
*** - Chlorophyll-a is collected at six sites*

Total Dissolved Solids (TDS) – High total dissolved solids may affect the aesthetic quality of the water, interfere with washing clothes and corrode plumbing fixtures. High total dissolved solids in the environment can also affect the permeability of ions in aquatic organisms. Mineral springs, carbonate deposits, salt deposits and sea water intrusion are sources for natural occurring high concentration TDS levels. Other sources can be attributed to oil exploration, drinking water treatment chemicals, storm water and agricultural runoff and point/non-point wastewater discharges.

Total Suspended Solids (TSS) – All particles suspended in water which will not pass through a filter – commonly results from erosion of soils, run-off, and sediment.

Ammonia – Elevated levels of ammonia in the environment can adversely affect fish and invertebrate reproductive capacity and reduce the growth of young. Ammonia is excreted by animals and is produced during the decomposition of plants and animals. Ammonia is an ingredient in many fertilizers and is also present in sewage, storm water run-off, certain industrial wastewaters and runoff from animal feedlots.

Total Hardness – Hardness is a composite measure of certain ions in the water, primarily calcium and magnesium. The hardness of the water is critical due to its effect on the toxicity of certain metals. Higher hardness concentrations in the receiving stream can result in reduced toxicity of heavy metals.

Chloride – Chloride is an essential element for maintaining normal physiological functions in all organisms. Elevated chloride concentrations can disrupt osmotic pressure, water balance and acid/base balances in aquatic organisms which can adversely affect survival, growth and/or reproduction. Natural weathering and leaching of sedimentary rocks, soils and salt deposits can release chloride into the environment. Other sources can be attributed to oil exploration and storage, sewage and industrial discharges, run off from dumps and landfills and saltwater intrusion.

Sulfate – Effects of high sulfate levels in the environment have not been fully documented. However, sulfate contamination may contribute to the decline of native plants by altering chemical conditions in the sediment. Due to abundance of elemental and organic sulfur and sulfide mineral, soluble sulfate occurs in almost all natural water. Other sources are the burning of sulfur containing fossil fuels, steel mills and fertilizers.

***E. coli* (Bacteria) –** Although fecal coliform bacteria may not themselves be harmful to human beings, their presence is an indicator of recent fecal matter contamination and that other pathogens dangerous to human beings may be present. Present naturally in the digestive system of all warm blooded animals, these bacteria are in all surface waters. Poorly maintained or ineffective septic systems, overflow of domestic sewage or non-point sources and runoff from animal feedlots can elevate bacteria levels.

Figure I.6 *– Two alligators in Lake Texana*

Chlorophyll – *a* – High levels of chlorophyll can indicate algae blooms, decrease water clarity and cause swings in dissolved oxygen level due to photosynthesis. An increase in nutrients can increase growth and reproduction in algal species.

Turbidity – Turbidity is a measure of the water clarity or light transmitting properties. Increases in turbidity are caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms.

Nutrients (Nitrate, Phosphorus, Carbon) – Nutrients increase plant and algae growth. When plants and algae die, the bacteria that decompose them use oxygen. This reduces the dissolved oxygen in the water. High levels of nitrates and nitrites can produce nitrite toxicity, or "brown blood disease", in fish. This disease reduces the ability of blood to transport oxygen throughout the body. Nutrients are found in effluent released from wastewater treatment plants, fertilizers and agricultural runoff carrying animal waste from farms and ranches. Soil erosion and runoff from farms, lawns and gardens can add nutrients to the water.

With only three assessment units on the *2010 Texas Integrated Report – Texas 303(d) List* the Lavaca River Basin maintains some of the highest water quality throughout the state. The CRP allows the LNRA to coordinate efforts, facilitate public involvement, and strategically monitor the watershed. Protecting the Basin's water resources and biological communities while still serving municipal, industrial, agricultural, and recreational purposes is a high priority.

Water Quality Standards and Screening Levels

Water quality standards are the basis for assessing the status of Texas surface waters and for regulatory and non-regulatory control of pollutants when the levels of treatment used by permitted dischargers are inadequate to maintain water quality. According to TCEQ, standards are the foundation for managing surface water quality. A water quality standard is the combination of:

- A designated use, and
- The criteria necessary to attain and maintain that use.

TCEQ has been in the process of developing nutrient "standards" for several years. Once developed, the proposed standards will then need to pass an EPA approval process. The current screening levels (Table I.4) are used as a screening device to determine where there might be potential water quality problems as a result of elevated levels of phosphorus, nitrogen, ammonia or algal growth indicated by high chlorophyll-*a*.

Table I.4: *Texas Nutrient Screening Levels applied in the Lavaca River Basin in 2010*

Water Body Type	Parameter	2010 Screening Levels
Tidal Streams	Ammonia	0.46 mg/L
	Nitrate	1.10 mg/L
	Total Phosphorus	0.66 mg/L
	Orthophosphorus	0.46 mg/L
Reservoir	Ammonia	0.11 mg/L
	Chlorophyll-*a*	26.7 mg/L
	Nitrate	0.37 mg/L
	Total Phosphorus	0.20 mg/L
	Orthophosphorus	0.05 mg/L
Freshwater Streams	Ammonia	0.33 mg/L
	Chlorophyll-*a*	14.1 mg/L
	Nitrate	1.95 mg/L
	Total Phosphorus	0.69 mg/L
	Orthophosphorus	0.37 mg/L

Table I.5: *Texas Surface Water Quality Standards for the Lavaca River Basin*

LAVACA RIVER BASIN		USES			CRITERIA						
Segment No.	SEGMENT NAME	Rec	Aquatic Life	Domestic Water Supply	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)	Dissolved Oxygen (mg/L)	pH Range (SU)	Indicator Bacteria[1] #/100ml	Temp (°F)
1601	Lavaca River Tidal	PCR	H					4.0	6.5-9.0	35	95
1602	Lavaca River Above Tidal	PCR	H	PS	200	100	700	5.0	6.5-9.0	126	91
1602A[2]	Big Brushy Creek		H					5.0			
1602B[2]	Rocky Creek		H					5.0			
1603	Navidad River Tidal	PCR	H					4.0	6.5-9.0	35	91
1604	Lake Texana	PCR	H	PS	100	50	500	5.0	6.5-9.0	126	93
1604A[2]	East Mustang Creek		I					4.0			
1605	Navidad River Above Lake Texana	PCR	H	PS	100	50	550	5.0	6.5-9.0	126	91
1605[2]	West Navidad River		H					5.0			

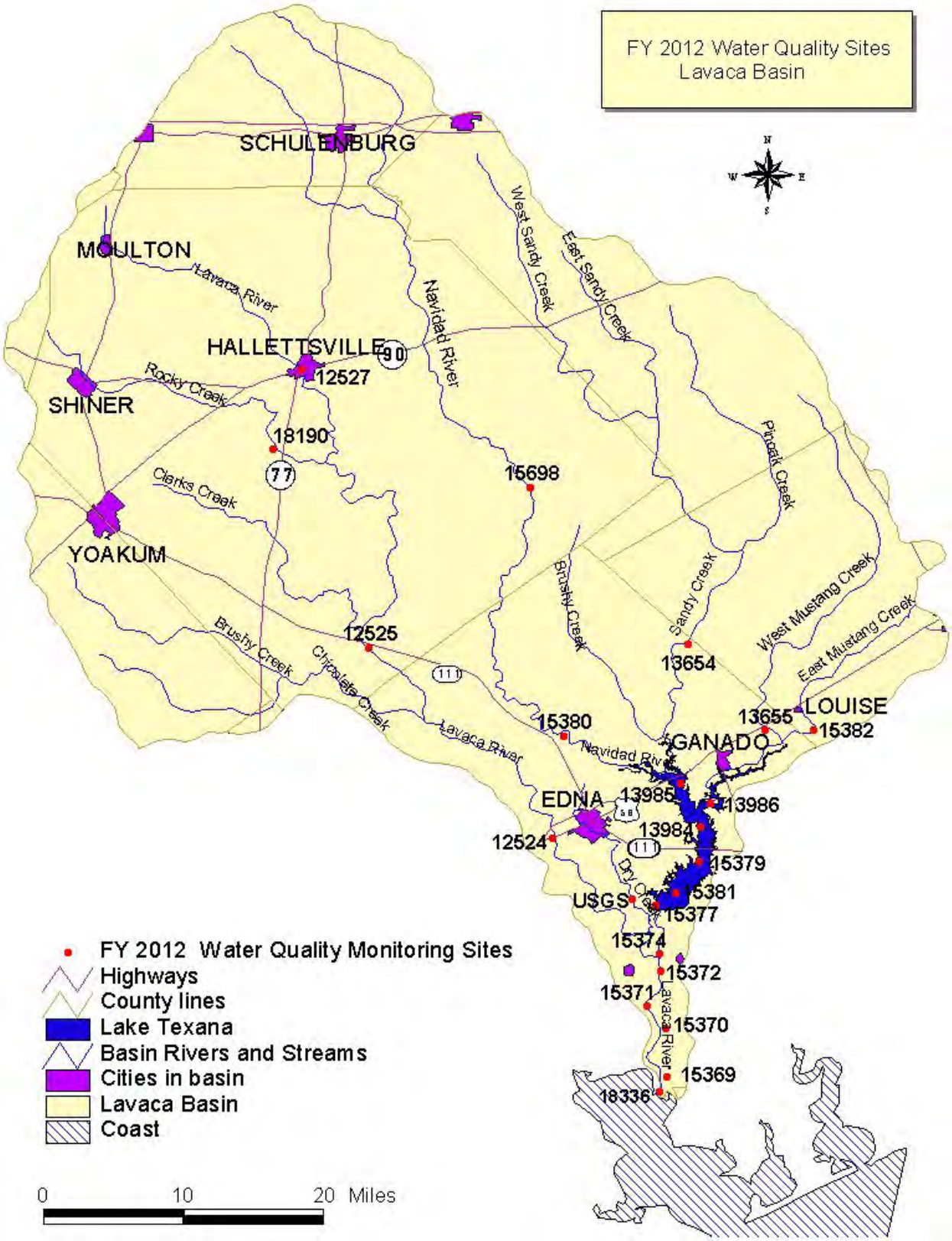
PCR – Primary Contact Recreation; H- High; I - Intermittent PS – Public Water Supply;
1. The indicator bacteria for freshwater is *E.coli* and Enterococci for saltwater
2. Unclassified Water Body

Some water quality standards are applied generally to multiple water bodies, and some are segment-specific. Also, the standards define an anti-degradation policy of the Clean Water Act to protect existing uses and water quality of less impacted water bodies. The surface water quality standards for Lavaca Basin, by River Segment, are listed in Table I.5.

The criteria for chloride, sulfate, and TDS (total dissolved solids) are listed in Table I.5 as maximum annual averages for the segment. Dissolved oxygen criteria are listed as minimum 24-hour averages at any site within the segment. The pH criteria are listed as minimum and maximum values expressed in standard units at any site within the segment. The criteria for temperature are listed as maximum values at any site within the segment. Streams have critical low flows calculated by TCEQ. When stream flows drop below these (known as 7Q2) calculations, some water quality standards do not apply.

Figure I.7 *– White ibises*

Figure I.8: *Fiscal Year 2012 LNRA Monitoring Stations*



Segment Assessment

The Segment Assessment chapter of this report details water quality impairments and concerns as shown in the *2010 Integrated Report*. Available historical data results are compared by parameter to the concerns and impairments listed in the 2010 TCEQ assessments. Comments and recommendations are included for each parameter.

Discussion for the Segment Review begins by covering each segment in numerical order. Our approach to the segments shown in the *2010 Texas §303(d) List* is to examine each segment by individual station in order to gain an understanding of the water quality within its Assessment Unit (AU). Each segment is discussed by its sub-segment(s) and Assessment Unit(s) in alphabetical and numerical order. Finally, available data for each station within an AU are addressed. Assessment Units are discussed in numerical order, and in the case of streams, the lowest numbered AU includes the most upstream reach while the highest numbered AU includes the lowermost portion. In reservoir segments, the highest numbered AU includes the area near the dam while the lowest numbered AU includes the headwaters of the lake or reservoir.

Data are reported as non-detectable when a sample result is below the detection limit of the laboratory instrumentation or method used in the analysis of the parameter. For the purposes of trend analyses, all non-detectable values were reduced to lowest detected value. This approach to non-detectable results assumes that the actual value lies somewhere between zero and the method detection limit. In all cases where the results were reported at or above the detection limit, the values were left unchanged.

It should also be noted that when comparing laboratory results with varying detection limits, the reliability of the data can be impacted, especially in situations where the method detection limit is at or near the screening level for the parameter of concern. Subtle variations in laboratory methodologies are another possible source of error. Unless the datum was remarked or guidance was provided by TCEQ, all data used for trend analyses were assumed to be valid and accurate.

Segment 1601 Lavaca River Tidal

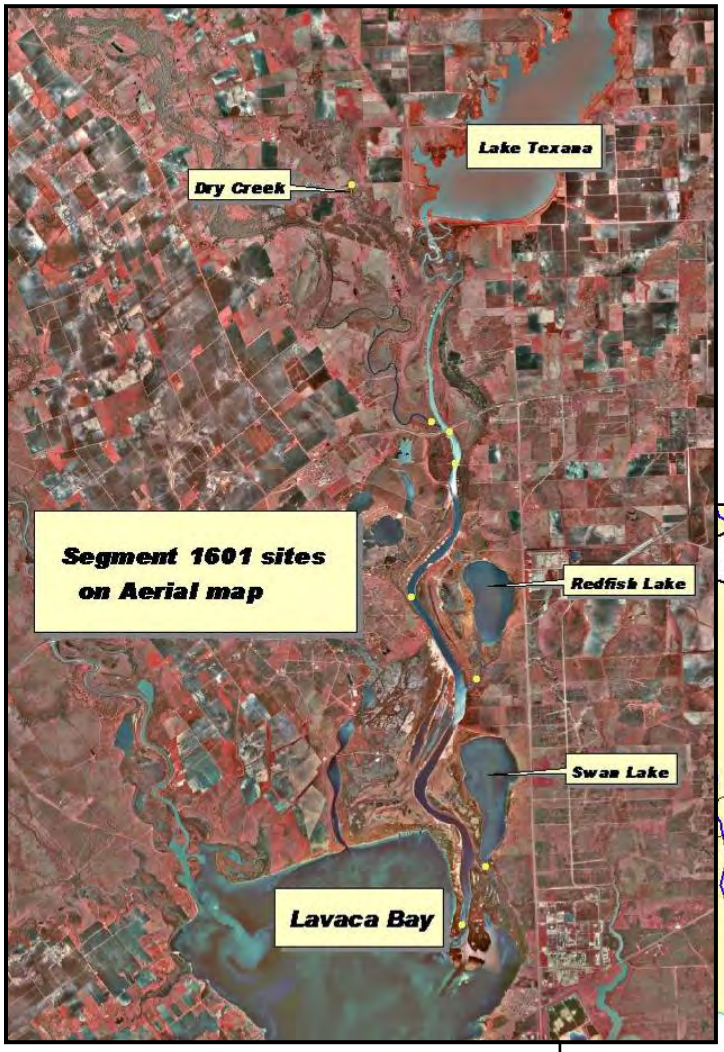


Figure 1601.1: *Aerial view of Segment 1601*

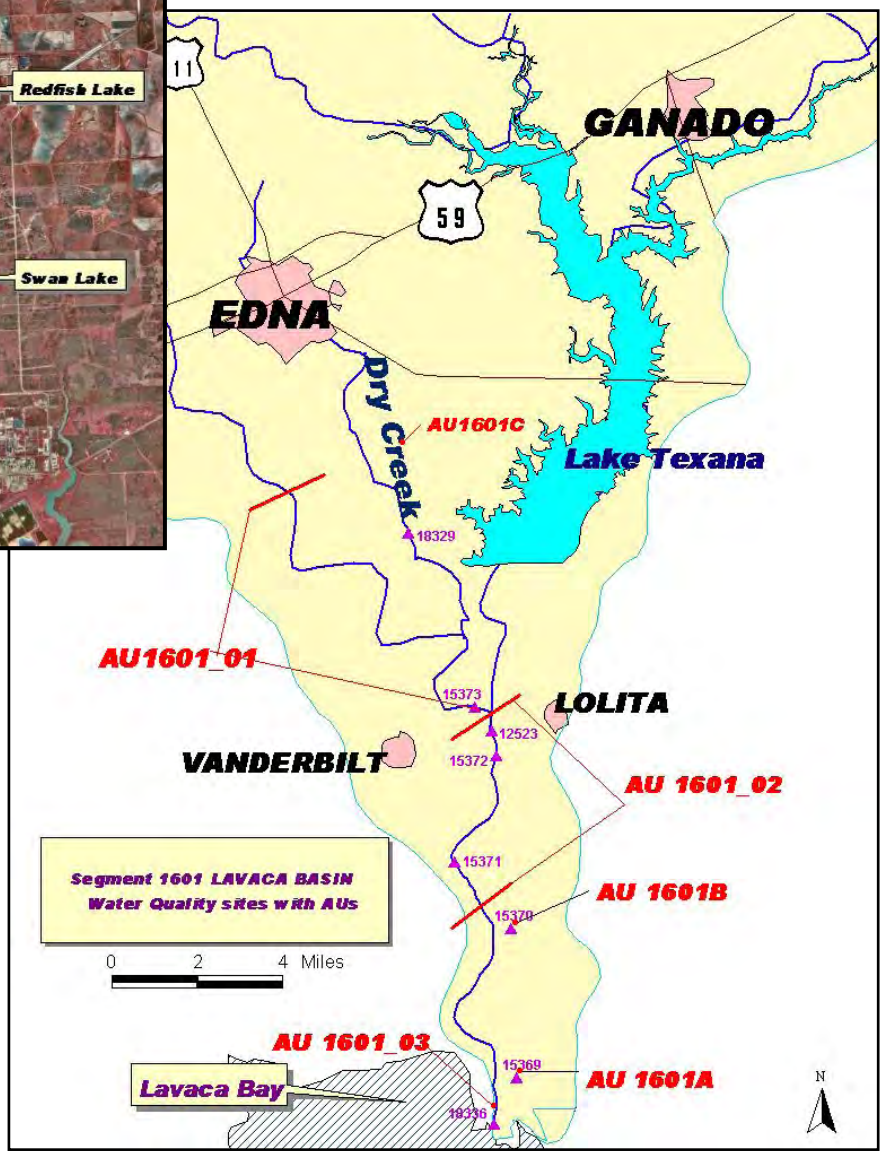


Figure 1601.2: *Segment 1601 sample sites*

AU 1601_01

This reach was not assessed in the 2010 TWQI. This portion of the Lavaca River extends from the confluence with the Navidad River upstream to a point 5.3 miles downstream of US 59 in Jackson County. Sampling at TCEQ station on Lavaca River thirty meters upstream of the Navidad River confluence (15373) ceased in January 2001.

AU 1601_02

AU 1601_02 extends from the confluence of unnamed tributary NHD RC 12100101002580 upstream to confluence with Navidad River. Data assessed for this AU includes results from three TCEQ sampling stations located downstream of FM 616 (12523), 3.5 miles downstream of SH 616 (15371), and at Frels Boat Ramp upstream of Frels Rd (15372). All parameters assessed in the 2010 TWQI were classified as no concern, or fully supporting of its designated use.

Trend analysis of 447 samples for temperature, 377 samples for specific conductance, 446 samples for dissolved oxygen, and 411 for pH revealed significant increase in all parameters.

Figure 1601.3 illustrates the cycling in specific conductance results characteristic of this reach since 1972. Sampling frequency decreased from 1992 to 1998, but increased significantly enough from 2000 to present to show a definite cyclical pattern over time.

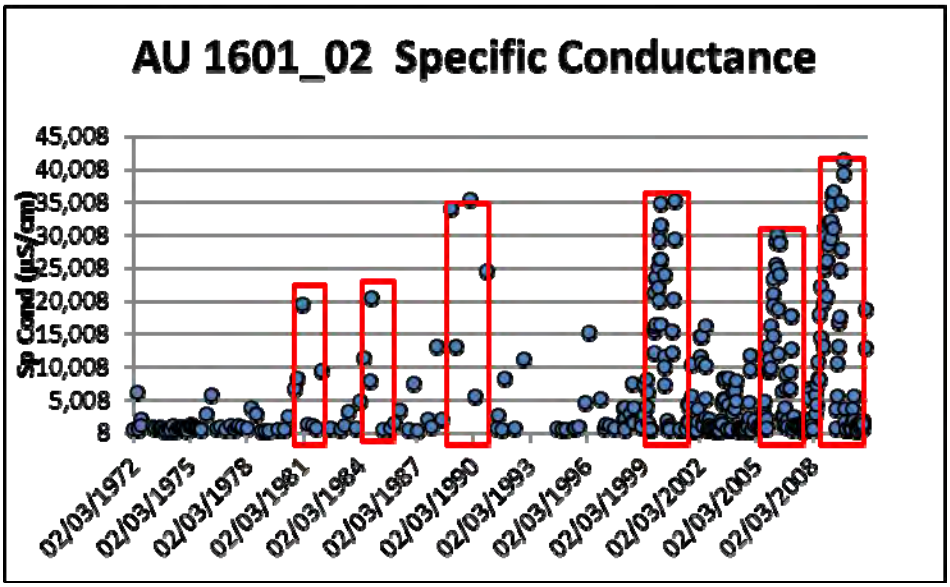


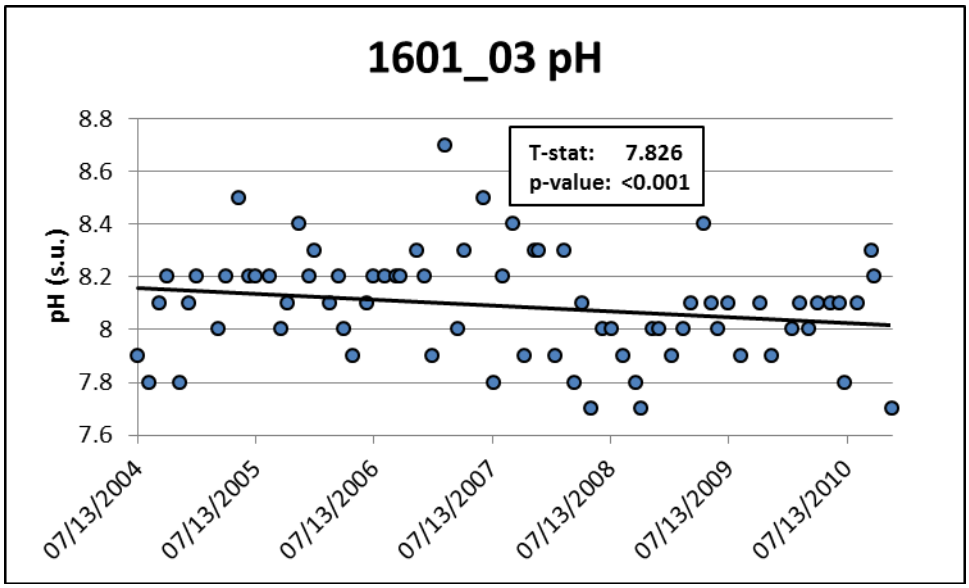
Figure 1601.3: *AU 1601_02 specific conductance results*

AU 1601_03

All data for this AU were collected from TCEQ Station # 18336, located near the mouth of Lavaca Bay, effectively the farthest downstream station in the entire watershed. The site was established (entered into SWQMIS) on June 14, 2004. LNRA previously collected data at nearby site #14720, but TCEQ considered that site to be in Bay & Estuary Segment 2453. That is why in 2004 LNRA moved the site slightly upstream in order for TCEQ to recognize the site as existing in Segment 1601. All parameters assessed in the *2010 TWQI* were classified as no concern, or fully supporting of its designated use.

A statistically significant decreasing trend was identified for pH indicating waters at this site are becoming slightly more acidic over time.

Figure 1601.4: *AU 1601_03 pH results*



Sub-Segment 1601A Catfish Bayou

Catfish Bayou receives waters from Swan Lake located west of FM 1593 east of the Lavaca River in southern Jackson County. The TCEQ sampling station 15370 is located just 30 meters downstream of the confluence of Swan Lake and Catfish Bayou. Bi-monthly sampling began at this station in 1996 and continued until 1998. Monthly sampling began in 1999 and continues to the present day.

Data sufficient for trend analysis shows statistically significant trends for transparency and ph. Results for transparency show the clarity of the bayou is increasing. This is indicative of lower flow conditions overall allowing suspended solids to settle. The increasing pH trend is consistent with increasing pH trends in the upper reaches of AU 1601_02 on the Lavaca River near its confluence with the Navidad River.

Sub-Segment 1601B Redfish Bayou

One TCEQ sampling site exists on record in Redfish Bayou. Sampling is conducted 30 meters above the confluence with the Lavaca River. Monitoring just before the bayou mixes with the Lavaca River allows the data to incorporate the entire drainage area of Redfish Lake and Redfish Bayou. Field parameters have been continuously recorded since 1996 for this sub-segment; however, the sub-segment was not included in the 2010 TWQI and Integrated Report.

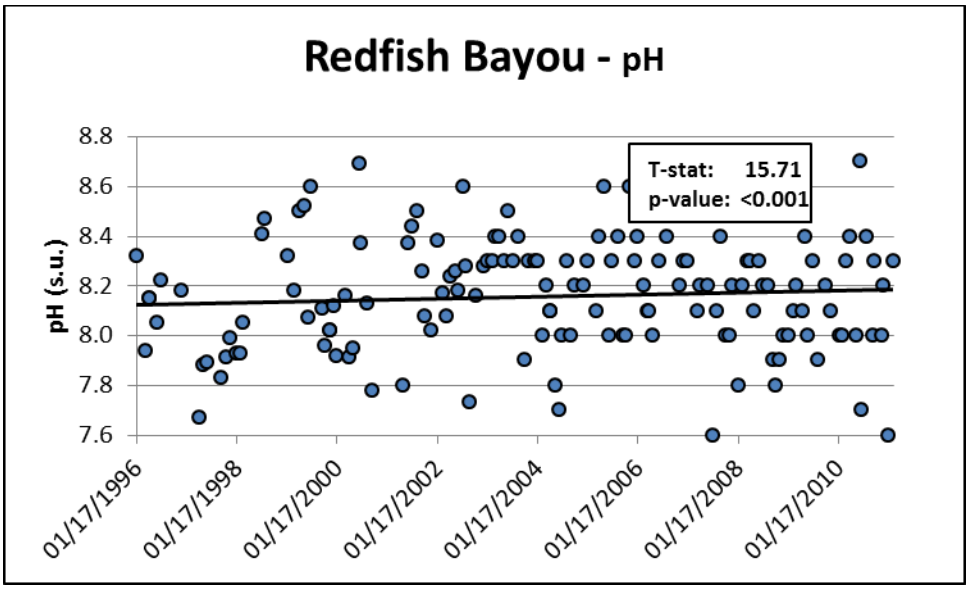


Figure 1601.5: *AU 1601B pH results v. Time*

Only one statistically significant trend was observed in Redfish Bayou. pH values appear to be increasing over time. Although a change has been identified and determined to be significant, you can see in Figure 1601.5 the magnitude of this change is less than 0.1 standard unit of measure for pH.

Sub-Segment 1601C Dry Creek

Dry Creek is located in Jackson County and flows southeast of Edna downstream between the Lavaca River Tidal (1601) and the Navidad River (1603). The creek is a receiving stream for the effluent outfall of the City of Edna WWTP. One sampling station exists on this tributary located immediately downstream of the FM 1822. Although the creek flows into the tidal portion of the Lavaca River; the reach itself is a non-tidal sub-segment. LNRA contracts with the USGS for twice per year monitoring at this station in response to possible dumping of herbicides. USGS samples for metals and organics (pesticides and herbicides) as well as field data. Results from the USGS sampling can be found on the LNRA website at: http://www.nueces-ra.org/CP/LNRA/SWQM/detail.php?stn=18329.

Not enough data exists for trend analysis of this sub-segment and the reach was not assessed in the *DRAFT 2010 TWQI.*

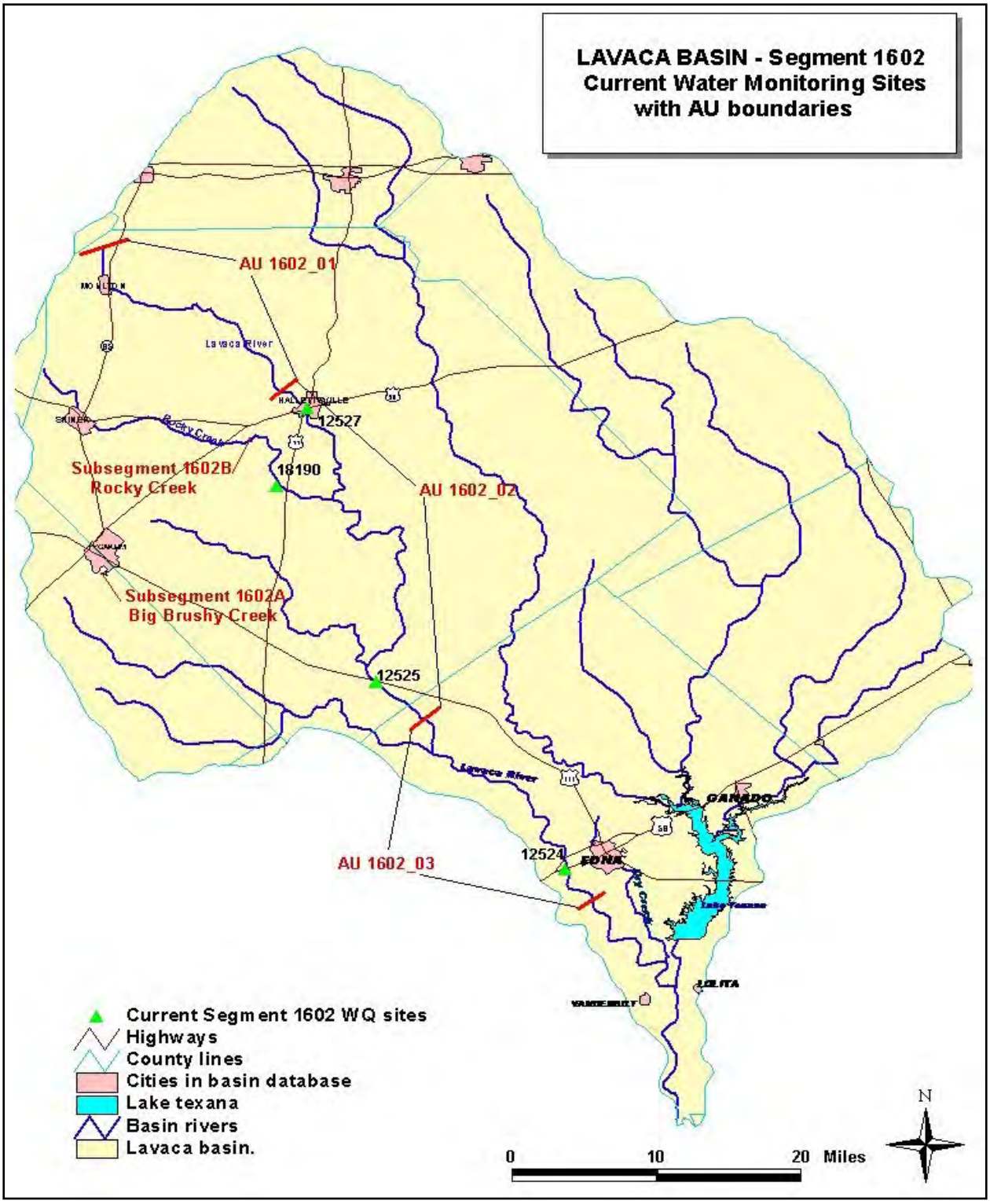
Figure 1601.6: *Segment 1601 - Lavaca River Tidal*

Table 1601.1: *FY 2012 coordinated monitoring for Segment 1601*

Sampling Location	Station ID	Lab Analyses	Metals in Water	Organic Water	Flow	Field
Lavaca River Tidal, 3.5 mi downstream of SH 616 and 740 m upstream of Menefee Bayou at Mobile Dock	15371					12
Lavaca River Tidal at Frels boat ramp mid-channel 50 m upstream of Frels Rd. approx. 1.1 km downstream of FM 616 between Vanderbilt and Lolita	15372					12
Lavaca River mid-channel 2.05 km south of confluence with Catfish Bayou near mouth of Lavaca Bay in south Jackson Co.	18336	4				12
Catfish Bayou east bank 30 m from confluence of Swan Lake approx. 2.5 mi north of Point Comfort	15369					12
Redfish Bayou mid-channel 30 m upstream of Lavaca River approx. 6 mi north of Point Comfort	15370					12
Dry Creek in Jackson Co immediately downstream of FM 1822 bridge. This is a non-tidal sub-segment of segment 1603	18329		1	2	2	

Segment 1602 Lavaca River above Tidal

Figure 1602.1: *Segment 1602 - Lavaca River above Tidal*



1602_01

The upper reach of this segment is the Lavaca River from the confluence with Campbell branch above Hallettsville upstream to just above Moulton. This reach was first listed in the *2004 Texas §303(d) List* as impaired for low dissolved oxygen levels. This listing was the result of 24-hour dissolved oxygen special studies funded by the CRP in an effort to reassess the classification of the Lavaca River in this region.

As discussed in other sections of this report, a Use Attainability Analysis (UAA) was completed for the upper portions of the Lavaca River during 2005 and 2006. The results of the UAA included the recommendation that this upper AU 1602_01 be reclassified as intermittent with perennial pools due to natural causes, and for the dissolved oxygen criteria to be modified during the time period of March 15th through October 15th when a site specific DO criteria of 2.0 mg/L as a 24-hours average and 1.0 mg/L as a minimum would apply. For the rest of the year, the AU maintains a high aquatic life use of 5.0 mg/L for 24 hour means and a 3.0 mg/L minimum. Since 2006 we have been awaiting approval by the EPA. More information on this can be found in the Discussion section.

Figure 1602.2: *LNRA staff measuring flow on Big Brushy Creek*

AU 1602_02

Data were available from three sampling stations in this middle portion of the segment. These sites are located on the Lavaca River at State Highway 111 southeast of Yoakum (12525), at US Highway 77 in Hallettsville (12527), and 150 meters upstream of Lavaca County Road 1S northwest of Ezzell (18700). The data from 18700 were collected in April and July from 2005-2006 for a Use Attainability Analysis (UAA) and did not include bacteria results. These data were consistent with results from the other two sites, so they were included.

This reach was first listed in the *2008 Texas §303(d) List* as impaired for bacteria levels due to a geomean value that exceeded the state standard. Forty-two samples were assessed in the *DRAFT 2010 TWQI* and 46 were assessed in this report. The water body is currently classified as 5c, as was the downstream AU. The geomean in next assessment is estimated to be 149.1 MPN/100mL; still above criteria, but with bacteria levels decreasing overall. Continued monitoring at these stations indicates a good probability that the segment will be delisted in future assessments if conditions remain the same, or are improved.

Although the period of record for samples at these locations extends back to February 1972, data were not consistently collected until 2001. In the ten years of data, decreasing trends were identified for specific conductance, pH, alkalinity, and hardness.

AU 1602_03

The most downstream AU in the segment extends from the confluence with an unnamed tributary NHD RC 12100101002463 south of Edna in Jackson County upstream to the confluence with Beard Branch. This AU is listed in the *DRAFT 2010 Integrated Report* as impaired for bacteria levels due to a geomean value above the state standard. This reach was first listed on the *2008 Texas §303(d) List*.

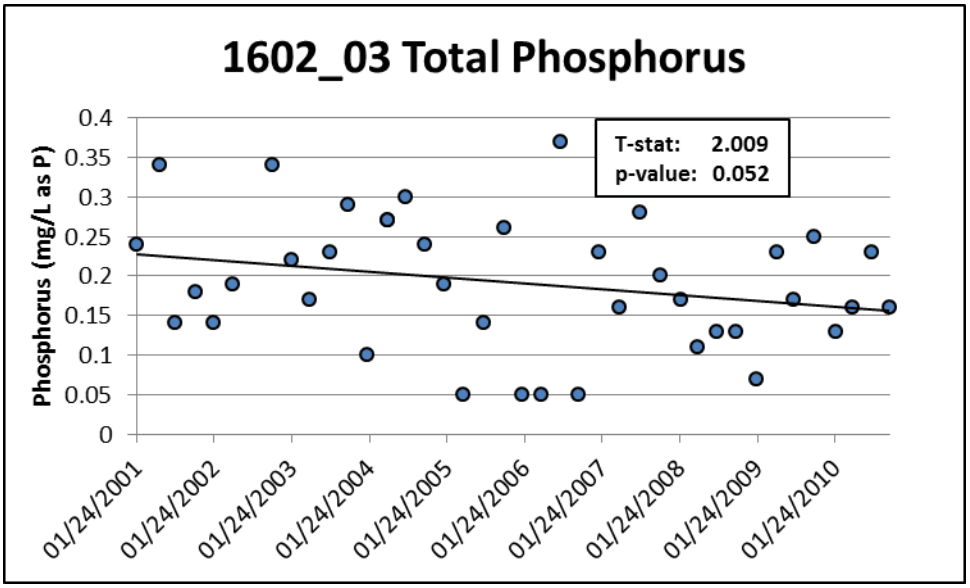


Figure 1602.3: *AU 1602_03 total phosphorus*

All samples assessed were at one monitoring station on the Lavaca River at US 59 (12524), southwest of Edna. Data for the period of record that will be assessed in the 2012 Integrated Report indicate that the geomean in next assessment is estimated to be 218.9 MPN/100mL; still above criteria, but with overall bacteria levels decreasing. Continued monitoring under the same conditions at these stations indicates a good probability that the segment will be delisted in future assessments. The water body is currently classified as 5c indicating additional data and information is to be collected prior to a TMDL.

Trend analysis revealed an overall increase in temperature, and overall decreasing values over time for specific conductance, pH, total phosphorus, and chloride.

Sub-Segment 1602A Big Brushy Creek

Big Brushy Creek originates in west Lavaca County 8.8 kilometers (5.5 miles) northwest of Yoakum. The stream flows southeast, briefly through DeWitt County, then south and west of Yoakum before its confluence with Clark's Creek near the intersection of US Highway 77 and SH 111. The drainage area of Big Brushy Creek consists of rolling terrain, rangeland for cattle, and fairly dense vegetation with scrub oak and mesquite providing exceptional habitat for wildlife.

One sampling station is located on Big Brushy Creek 20 meters downstream of Loop 51/US Business 77Q/County Highway 214 (17535). Data on record for this site spans from 2002 to 2003. This sampling

was conducted in support of the City of Yoakum's waste water treatment plant permit renewal. No additional data exists in SWQMIS and Big Brushy Creek was not assessed in the *DRAFT 2010 TWQI*.

Sub-Segment 1602B Rocky Creek

Rocky Creek begins west of State Highway 95 near Shiner in northwest Lavaca County. The stream measures 37.8 kilometers (23.5 miles) and ends at the confluence with the Lavaca River. Surrounding land use includes hay farming, corn production, and pasture for cattle and horses. Five sampling sites have been on Rocky Creek at:

- Ben J. Matula ranch 2.04 kilometers downstream of Boggy Creek confluence and approximately 2 miles downstream of the City of Shiner (12518);
- Ludmilla Street/Lavaca County Road 300 in the City of Shiner (12519);
- Upstream of Shiner Wastewater Treatment Plant directly south of the intersection of Bozska and Mulberry/Avenue 1 in the City of Shiner(12520);
- 10 meters downstream of FM 966 near the City of Shiner (12521);
- Immediately upstream of Lavaca County Road 387 approximately 5.3 miles south of Hallettsville on US Highway 77 and 0.92 miles west of County Road 387 (18190).

The only active site on Rocky Creek is site 18190 south of Hallettsville, and LNRA has sampled quarterly at this site since 2004. Trend analysis revealed a statistically significant increasing pH trend in the seven years of data available; however, the overall values for pH are increasing at a rate of less than 0.1 standard unit.

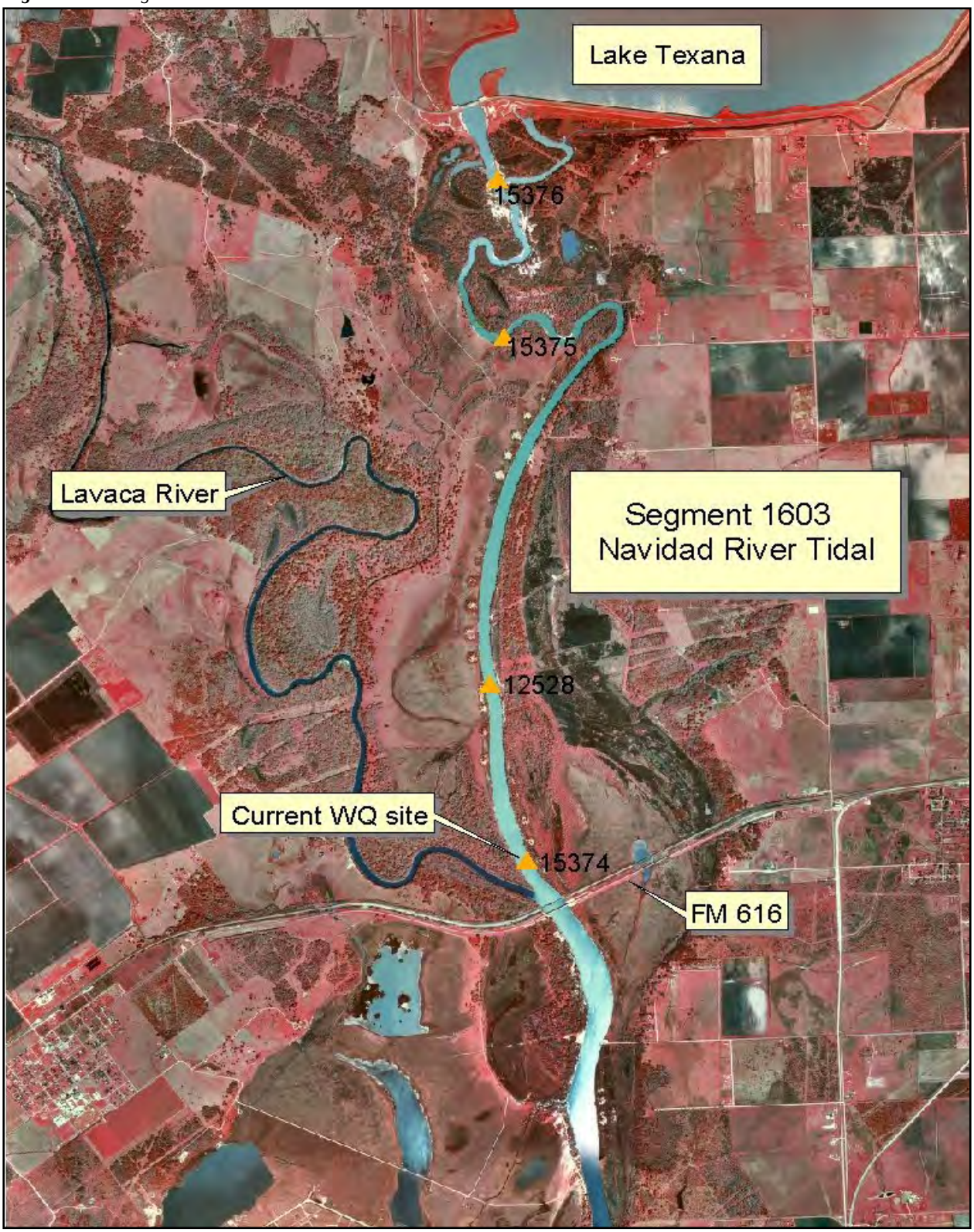
This reach was not assessed in the *DRAFT 2010 TWQI* and no concerns were listed for screening levels or near non-attainment.

Table 1602.1: *FY 2012 coordinated monitoring for Segment 1602*

Sampling Location	Station ID	Lab Analyses	Bacteria	Flow	Field
Lavaca River at upstream bridge on US 59 southwest of Edna	12524	4	4	12	12
Lavaca River at SH 111 60 m downstream of SH 111 southeast of Yoakum	12525	4	4	12	12
Lavaca River at US Alternate 90/US Highway 77 in Hallettsville	12527	4	4	4	4
Rocky Creek immediately upstream of Lavaca CR 387 approx. 5.3 mi south of Hallettsville on US 77 and 0.92 mi west on CR 387	18190	4	4	4	4

Segment 1603 Navidad River Tidal

Figure 1603.1: *Segment 1603 –Navidad River Tidal*



1603_01

The Navidad River Tidal segment extends from the confluence with the Lavaca River upstream to Palmetto Bend Dam which impounds Lake Texana in Jackson County. The river is classified as a tidal stream. Historically there have been four sampling stations in this segment on the Navidad River:

- Downstream of Lake Texana at power line crossing 1 mile upstream of the confluence with the Lavaca River (12528);
- Mid-channel 30 meters upstream of the Lavaca River confluence approximately 170 meters upstream of FM 616 between Vanderbilt and Lolita (15374);
- Mid-channel approximately 1.65 miles south of Palmetto Dam (15375); and
- Mid-channel at the buoy line 170 yards downstream of Palmetto Dam (15376).

Data for the *DRAFT 2010 Integrated Report* included results from station 15374. This segment was assessed for dissolved oxygen, water temperature, pH, and nutrient screening levels (ammonia, nitrate, ortho-phosphorus, and total phosphorus). Results for all parameters produced no concern and fully supported the segment's designated use.

The period of record for trend analysis extended back to September 1985, but consistent sample collection did not occur until 1996. Increasing trends were identified for transparency, dissolved oxygen, and salinity. Decreasing trends were identified for pH, total organic carbon (TOC), and phosphorus.

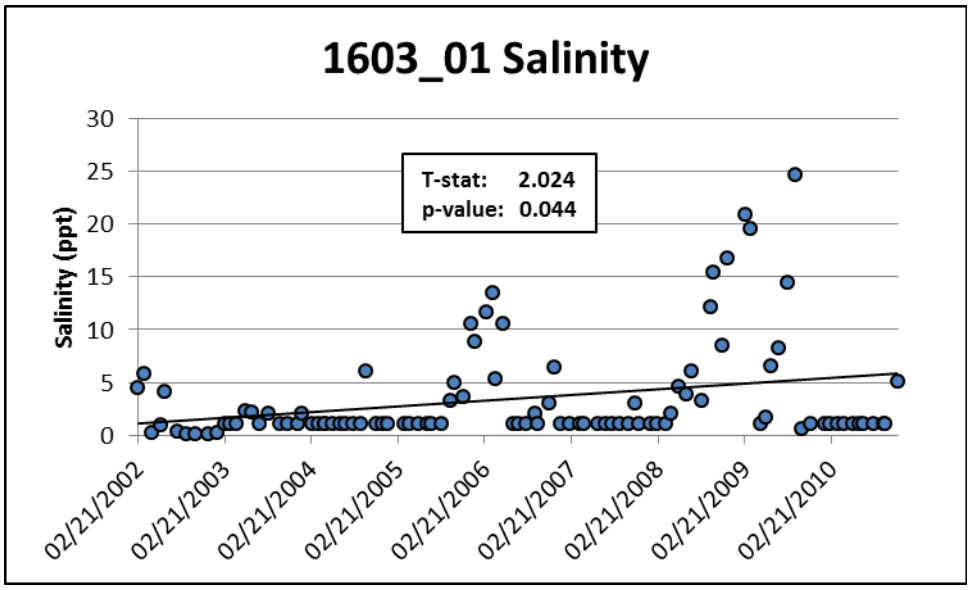


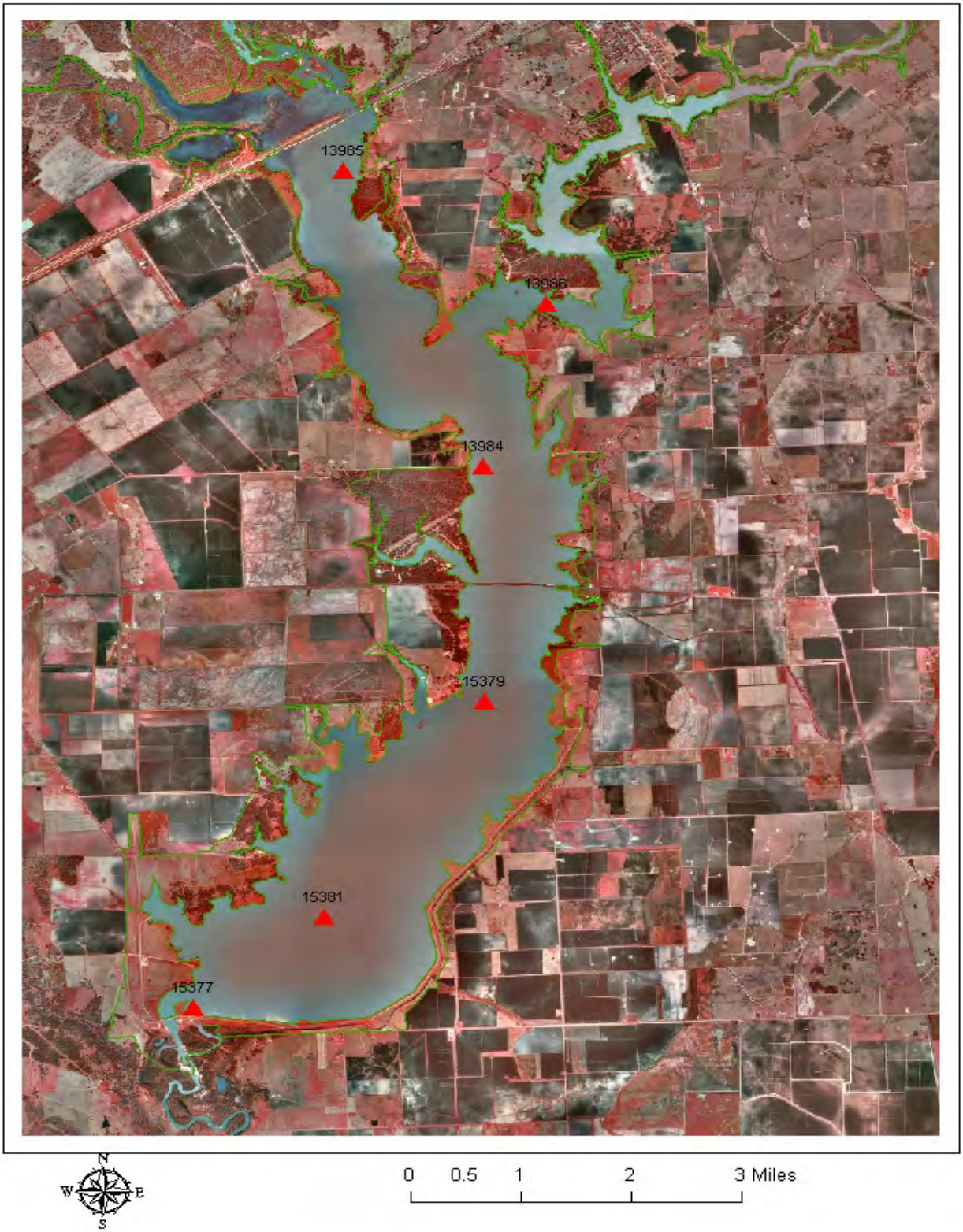
Figure 1603.1: *Segment 1603 salinity results*

Table 1603.1: *FY 2012 coordinated monitoring for Segment 1603*

Sampling Location	Station ID	Lab Analyses	Field
Navidad River Tidal mid-channel 30 m upstream of Lavaca River confluence approx. 170 m upstream of FM 616 between Vanderbilt and Lolita	15374	4	12

Segment 1604 Lake Texana

Figure 1604.1: *Segment 1604 – Aerial view of Lake Texana*



Lake Texana is the only reservoir in the Lavaca-Navidad River basin. It extends from Palmetto Dam in Jackson County to a point 100 meters downstream of FM 530 (also in Jackson County), up to a normal pool elevation of 44 feet. It impounds the Navidad River, Sandy Creek, and East and West Mustang Creeks. In the case of Lake Texana, all profile data collected at greater than 0.5 meter were excluded in this analysis.

1604_01

This most upstream AU in Lake Texana is the Navidad River Arm. It begins with the confluence of Navidad River and the lake on the northwest side of Lake Texana. There is one current site

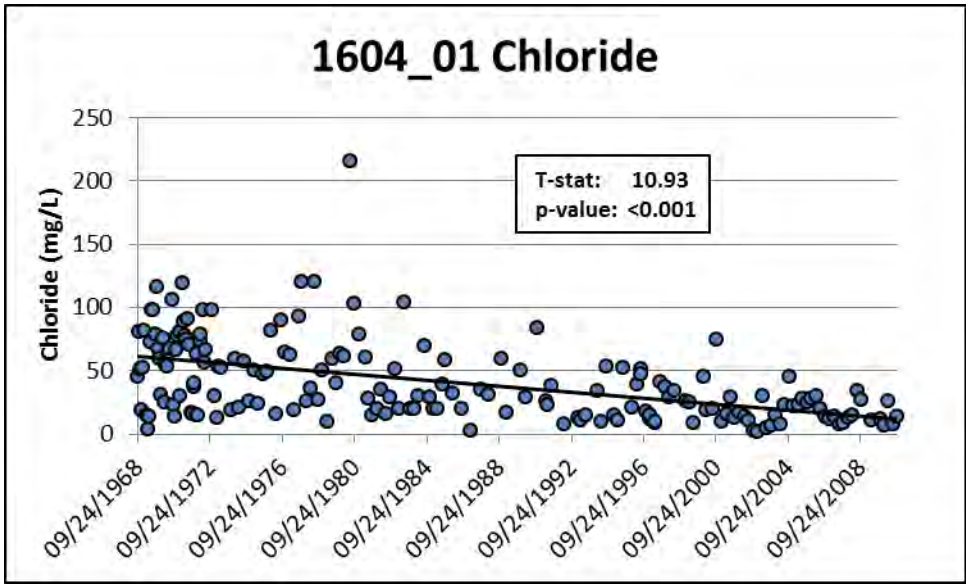


Figure 1604.2: *AU 1604_01 chloride results*

scheduled to be sampled in this AU by both LNRA (13985) and USGS (site DC). It was located near east bank 1.8 kilometers south and 100 meters east of the Sandy Creek confluence south of US 59 between Edna and Ganado. However, this site does not exist for the time being due to the severe drought of 2011. From 1968 through April 1992 there was also a historic site (12530) sampled by TCEQ located south of US 59, 235 meters south and 200 meters east of the Sandy Creek confluence southwest of Ganado.

The *2010 Draft TWQI* lists concern for screening levels for ortho-phosphorus and total phosphorus. Average values for these parameters were 0.1 mg/L and 0.3 mg/L, respectively. The listing for ortho-phosphorus contains a dataset qualifier that the assessment is based on "limited data" with only eight samples on record. Nitrate is listed as no concern for the level of support; however, 24 percent (7 of 29) of the

Figure 1604.3: *Alligator in Lake Texana*

samples on record exceeded screening levels and the average of those exceedances is 0.81 mg/L.

Data for this AU is among the oldest on record in the basin dating back to September 1968. Greater than 300 field parameter data points were analyzed for trends. Decreasing trends were observed for specific conductance, dissolved oxygen, pH, alkalinity, hardness, total organic carbon, phosphorus, chloride, and sulfate. Only one increasing trend was identified for temperature in this reach.

1604_02

The Mustang Creek Arm of Lake Texana is located south of Ganado. It merges with West Mustang Creek (sub-segment 1604B) to the east of Ganado. One station (13986) is located in this AU at 1.5 kilometers upstream of the confluence with the main lake at Mustang Creek Recreational Area south of Ganado. This site is also known as USGS Site EC.

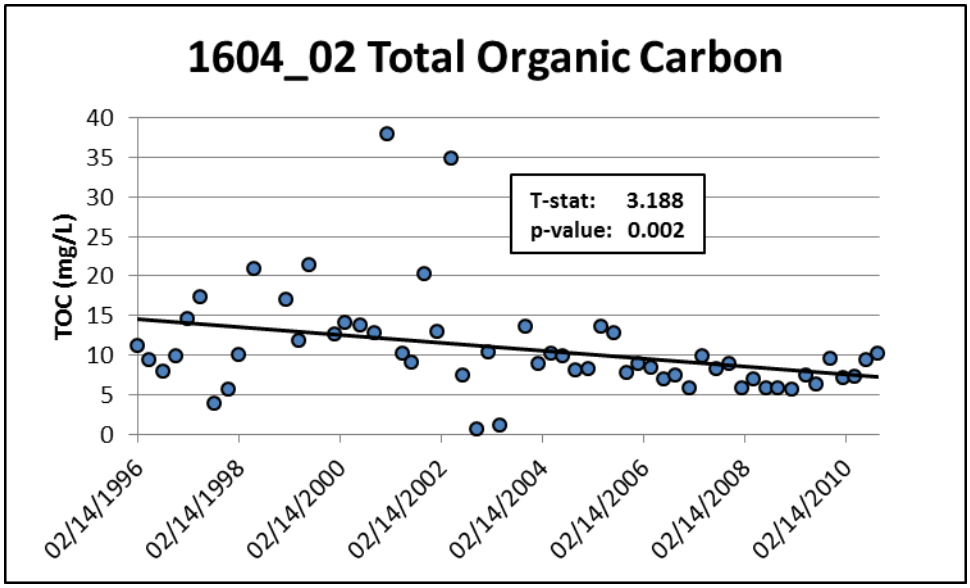


Figure 1604.4: *AU 1604_02 TOC results*

No concerns were identified for the field parameters assessed, and the reach appears to be fully supporting of its designated use. Data for the nutrient parameters nitrate, ortho-phosphorus, and total phosphorus revealed a concern for screening levels with the average values of 0.92 mg/L, 0.19 mg/L, and 0.20 mg/L, respectively. Nitrate and ortho-phosphorus loads appear to be increased in this AU, while total phosphorus levels are slightly lower than the main body of the lake.

Trend analysis was performed on these data and decreasing trends were identified for specific conductance and total organic carbon. An increase in overall values was observed for pH. See the Discussion section for more details.

1604_03

The upper middle portion of Lake Texana contains one sampling station 13984 located two km upstream of State Highway 111 east of Edna. This is also USGS Site CC. This station is scheduled for sampling on the Coordinated Monitoring Schedule for the fiscal year 2012 by both LNRA and USGS.

Data for field parameters were assessed and either no concern was identified, or the data were found to be fully supporting the AU's designated use. Data for the nutrient parameters nitrate, ortho-phosphorus, and total phosphorus were a concern for screening levels. Average values for these parameters were 0.64 mg/L, 0.14 mg/L, and 0.33 mg/L, respectively.

Trend analysis showed decreasing trends for specific conductance, alkalinity, hardness, and phosphorus. As with the downstream portions of the lake and Mustang Creek Arm, an increasing trend was observed for pH in this AU.

1604_04

The middle section of Lake Texana is divided into two assessment units. AU 1604_04 is the downstream middle portion. The current LNRA sampling station 15379 in this AU is located 1.9 kilometers (km) south of State Highway 111 near Brackenridge Plantation Recreation Area, east of Edna. There was a USGS site BC (13983—discontinued after 2007) in the river channel 3.7 km downstream of State Highway 111.

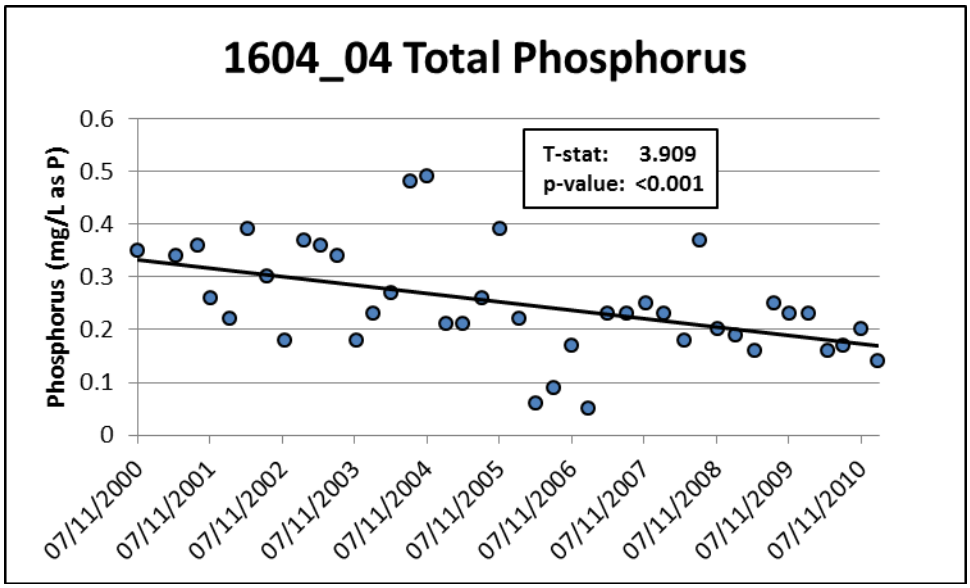


Figure 1604.5: *AU 1604_04 phosphorus results*

Data for field parameters were assessed and either no concern was identified, or the data were found to be fully supporting the AU's designated use. A concern for screening levels was identified in the data for nitrate, ortho-phosphorus, and total phosphorus. Averages for these parameters were 0.6 mg/L, 0.14 mg/L, and 0.31 mg/L, respectively. These values are consistent with those from the most downstream portion of the lake.

Decreasing trends for specific conductance, total organic carbon, phosphorus, and chloride were observed. Increasing trends for dissolved oxygen and pH were also identified during trend analysis. Figure 1604.5 above illustrates results for total phosphorus and shows the overall decreasing in this portion of the lake indicating water quality is improving in these areas.

1604_05

The downstream AU in Lake Texana contains four sampling stations at:

- 300 meters north and 685 meters east of the dam spillway centerpoint -- USGS Site AC (13981) test site for metals in Lake Texana;
- 200 meters north of the dam and 1.1 kilometers east of the spillway -- USGS Site AL (13982)—discontinued site after 2007;
- Near the spillway inlet 400 meters north and 435 meters east of Palmetto Dam centerpoint (15377)—current LNRA sampling site closest to spillway; and
- In Old Navidad River Channel approximately 1.75 kilometers north of the dam 2.56 kilometers east of the LNRA boat dock in the southwest arm (15381)—current LNRA sampling site.

There were inadequate data for assessment of 24-hour dissolved oxygen levels, but data for other field parameters were either no concern or fully supporting the AU's designated use. Data for the nutrient parameters nitrate, ortho-phosphorus, and total phosphorus revealed a concern for screening levels with average values of 0.69 mg/L, 0.16 mg/L, and 0.31 mg/L, respectively.

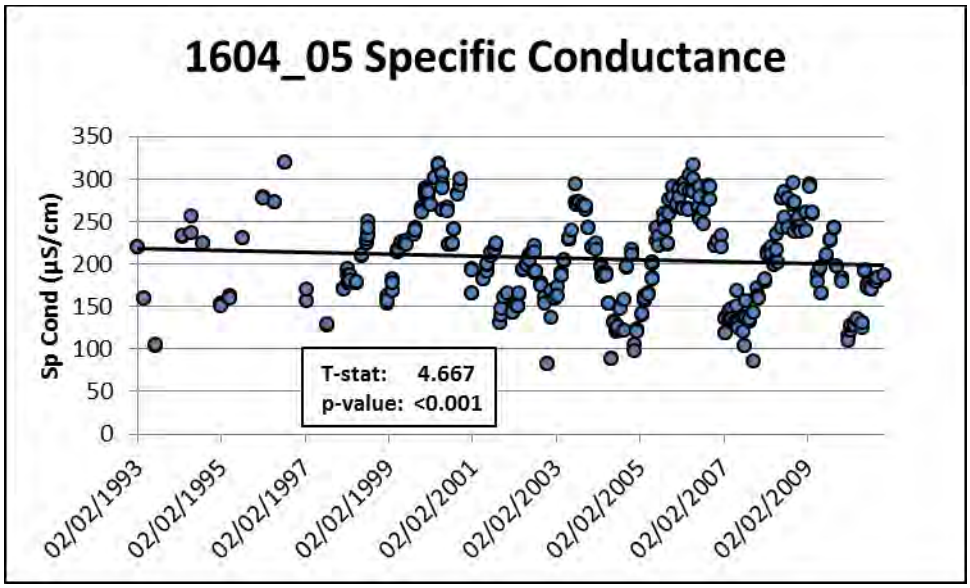


Figure 1604.6: *AU 1604_05 specific conductance fluctuation*

Historical data for this AU extended back to February 1993. Decreasing trends were observed for specific conductance, hardness, total dissolved solids, total organic carbon, phosphorus, and chloride. Increasing trends were identified for transparency, dissolved oxygen and pH. The density of sample points in Figure 1604.6 shows a more concentrated effort and regular sampling in this AU since 1998.

Sub-Segment 1604A East Mustang Creek

East Mustang Creek rises on the southeast border of the watershed in west central Wharton County one mile south of Jones Creek and north of FM 2546. The creek flows through Louise before its confluence with West Mustang Creek southeast of State Highway 59. One sampling station (15382) has existed at FM 647, three miles south of Louise, since 1996. USGS also samples at this same site, and there is a USGS gage station there.

Figure 1604.7: *East Mustang Creek (15382)*

This sub-segment was not assessed in the *DRAFT 2010 TWQI* and has no impaired parameters in the *DRAFT 2010 Texas §303(d) List*. It was last assessed in 2006 and no impairments or concerns were found at that time.

The data on record met criteria for trend analysis and decreasing trends were observed for temperature, total organic carbon, and sulfate. One increasing trend was identified for pH.

Sub-Segment 1604B West Mustang Creek

West Mustang Creek begins in south central Colorado County two miles west of Garwood and flows through northwestern Wharton County until its confluence with the east branch. The terrain is generally flat to slightly rolling with clay and sandy loam. Two stations exist on record at:

- Immediately downstream of Wharton County Road 328 approximately 11.3 kilometers/7 miles northwest of Louise (12522—this is a TCEQ site with little monitoring) and
- US 59, 30 meters downstream of northbound US 59, 3.6 miles east of Ganado 2.1 miles upstream from Middle Mustang Creek (13655—this is the current LNRA and USGS monitoring site)

Station 13655 is on the Coordinated Monitoring Schedule for the fiscal year 2012 **(see Table 1604.1)**. This sub-segment was not assessed in the *DRAFT 2010 TWQI* and it is not listed on the *DRAFT 2010 Texas §303(d) List*. It was last assessed in 2006, and no impairments or concerns were found at that time.

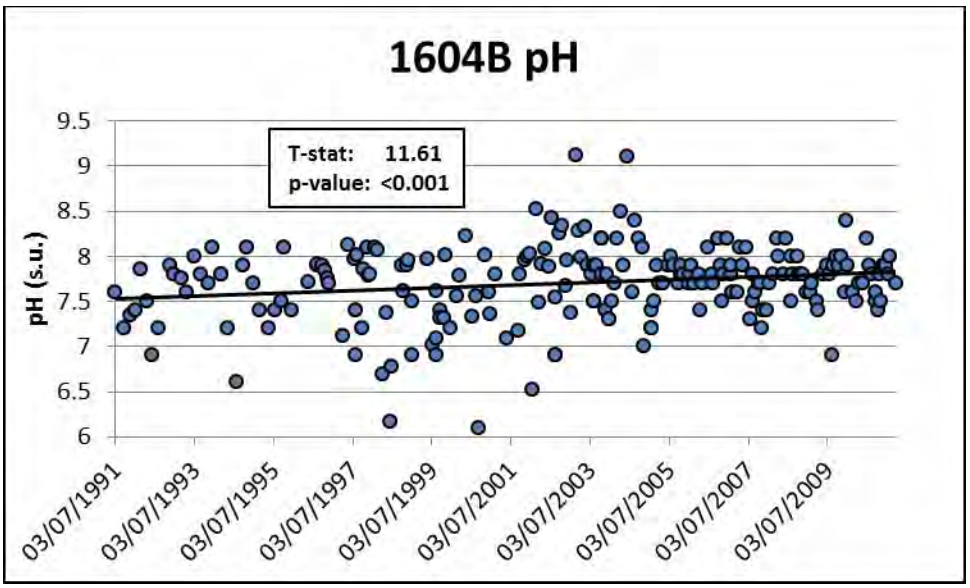


Figure 1604.8: *AU 1604B pH results*

The data on record met criteria for trend analysis and decreasing trends were observed for temperature, specific conductance, hardness, total organic carbon, phosphorus, chloride and sulfate. Two increasing trends were identified for dissolved oxygen and pH.

Sub-Segment 1604C Sandy Creek

Sandy Creek is an intermittent creek that drains a large portion of the east-northeast side of the basin in Jackson, Wharton, Lavaca, and Colorado Counties. Flow is mostly return irrigation from rice fields. One sampling station is located on Sandy Creek at FM 710, 20 meters upstream of FM 710, 9.1 miles northwest of Louise, 0.9 miles upstream from Goldenrod Creek (13654—current LNRA and USGS monitoring site).

Station 13654 is on the Coordinated Monitoring Schedule for the fiscal year 2012 (see Table 1604.1). This sub-segment was not assessed in the *DRAFT 2010 TWQI* and it is not listed on the *DRAFT 2010 Texas §303(d) List*. It was last assessed in 2006 and no impairments or concerns were found at that time.

The data on record met criteria for trend analysis and decreasing trends were observed for specific conductance, total organic carbon, chloride and sulfate. Three increasing trends were identified for temperature, dissolved oxygen, pH.

Table 1604.1: *FY 2012 coordinated monitoring for Segment 1604*

Sampling Location	Station ID	Lab Analyses	Metal Water	Organic Water	Bacteria	Flow	Field
Lake Texana 2 km upstream of SH 111 east of Edna USGS site CC	13984			2			2
Lake Texana 2 km upstream of SH 111 east of Edna USGS site CC	13984	4			4		12
Lake Texana near east bank 1.81 km south and 100 m east of Sandy Creek confluence of US 59 between Edna and Ganado/USGS Site DC	13985			2			2
Lake Texana near east bank 1.81 km south and 100 m east of Sandy Creek confluence of US 59 between Edna and Ganado/USGS Site DC	13985	4			4		12
Lake Texana Mustang Creek Arm 1.5 km upstream of confluence with Main Lake at Mustang Creek Recreation Area south of Ganado USGS Site EC	13986			2			2
Lake Texana Mustang Creek Arm 1.5 km upstream of confluence with Main Lake at Mustang Creek Recreation Area south of Ganado USGS Site EC	13986	4		4			12
Lake Texana near spillway inlet 400 m north and 435 m east of Palmetto Dam Centerpoint USGS site AC	15377	4	4				2
Lake Texana near spillway inlet 400 m north and 435 m east of Palmetto Dam Centerpoint	15377	4					12
Lake Texana River channel 3.693 km downstream of SH 111 near Brackenridge Plantation Recreation Area	15379	4		4			12

Table 1604.1, continued: *FY 2012 coordinated monitoring for Segment 1604*

Sampling Location	Station ID	Lab Analyses	Metal Water	Organic Water	Bacteria	Flow	Field
Lake Texana mid-lake in Old Navidad river channel approx. 1.75 km north of dam 2.56 km east of LNRA boat dock in southwest arm	15381	4					12
East Mustang Creek at FM 647, 3 mi south of Louise	15382		1	2		2	2
East Mustang Creek at FM 647, 3 mi south of Louise	15382	4				12	12
West Mustang Creek at US 59, 30 m downstream of northbound US 59, 3.6 mi east of Ganado, 2.1 mi upstream from Middle Mustang Creek	13655		1	2		2	2
West Mustang Creek at US 59, 30 m downstream of northbound US 59, 3.6 mi east of Ganado, 2.1 mi upstream from Middle Mustang Creek	13655	4				12	12
Sandy Creek at FM 710, 20 m upstream of FM 710, 9.1 mi northwest of Louise, 0.9 mi upstream from Goldenrod Creek	13654		1	2		2	2
Sandy Creek at FM 710, 20 m upstream of FM 710, 9.1 mi northwest of Louise, 0.9 mi upstream from Goldenrod Creek	13654	4				12	12

Figure 1604.9: *Sandy Creek dry (13654)*

Segment 1605 Navidad River above Lake Texana

Figure 1605.1: *Segment 1605 sampling sites for FY 2012*

1605_01

The upstream AU includes the upper 14.5 miles from the confluence with Sandy Branch to the confluence of East and West Navidad Rivers in Colorado/Lavaca County. One sampling station was previously sampled from 1967 to 2001 by USGS in this AU at US 90 Alternate, 1.2 miles west of Sublime (12532).

Chloride, sulfate, and total dissolved solids were assessed in the *DRAFT 2010 TWQI* and all results were identified to be fully supporting the AU's designated use. Data were unable to be extracted from SWQMIS to confirm these results, and no data met criteria for trend analysis.

1605_02

The middle reach of the Navidad River is 16.5 miles from the confluence with Sandies Creek upstream to the confluence of Sandy Branch. One LNRA current sampling station is located on this AU at FM 530, seventeen miles southeast of Hallettsville (15698). Previously there was a site at this same location (12531) that was sporadically sampled by what is now TCEQ from 1972 to 1997.

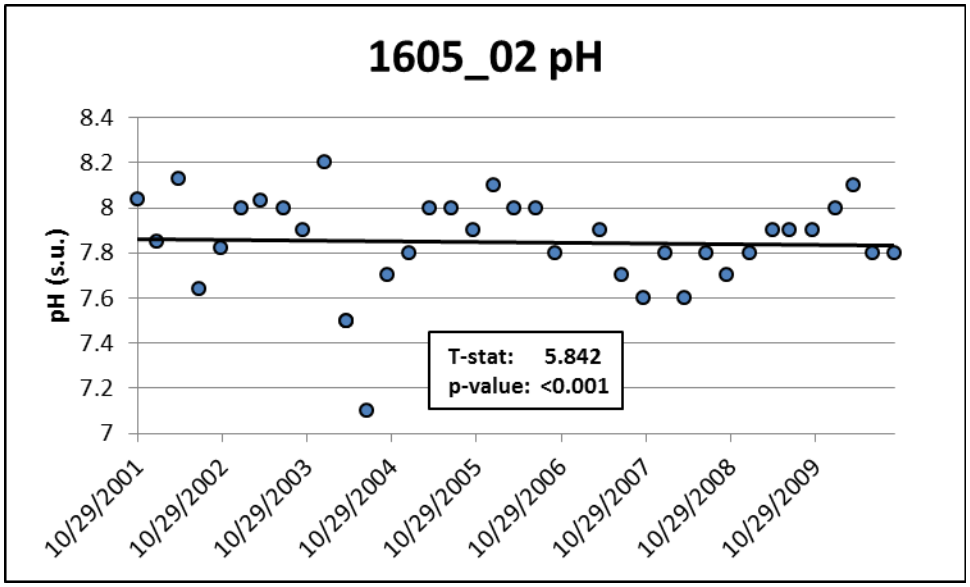


Figure 1605.2: *AU 1605_02 pH results*

Data for all parameters either showed no concern, or the data were found to be fully supporting the AU's designated use.

Sufficient data were available for trend analysis and only one trend was identified. Overall values were decreasing for pH.

1605_03

The boundaries for these lower 31 miles of the Navidad River begin from the confluence with Lake Texana and extend upstream to the confluence of Sandies Creek. One sampling station exists in SWQMIS on the Navidad River at Jackson County Road 401, five miles north of Edna (15380).

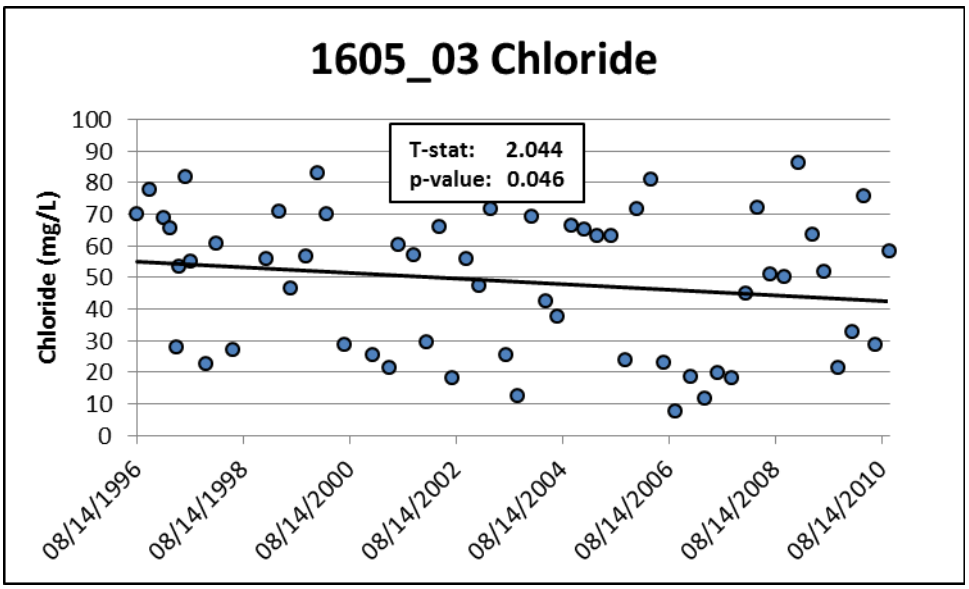


Figure 1605.3: *AU 1605_03 chloride results*

Data for dissolved oxygen, pH, and temperature were assessed and either no concern was identified, or the data were found to be fully supporting the AU's designated use. Data for the nutrient parameters nitrate, ortho-phosphorus, ammonia, and total phosphorus revealed no concern for screening levels; however, it was noted the assessment for ortho-phosphorus was based on limited data (seven samples). Dissolved solids were assessed through the parameters total dissolved solids, chloride, and sulfate and like the other parameters were either no concern, or fully supporting.

Trend analysis identified an overall decrease in levels for specific conductance, alkalinity, total dissolved solids, total organic carbon, phosphorus, and chloride. An increasing trend was observed for pH.

Table 1605.1: *FY 2012 coordinated monitoring for Segment 1605*

Sampling Location	Station ID	Lab Analyses	Metals in Water	Organic Water	Flow	Field
Navidad River at Jackson CR 401, 5 mi north of Edna	15380		1	2	2	2
Navidad River at Jackson CR 401, 5 mi north of Edna	15380	4			12	12
Navidad River at FM 530, 17 mi southeast of Hallettsville	15698	4			4	4

Trend Analysis

The Clean Rivers Program guidance document states that trend analyses should be conducted in assessment units that have at least ten years of data, regular sampling and had a minimum of twenty to thirty data points. Trend analysis was performed using a linear regression with a ninety percent confidence interval. A trend was identified as statistically significant when meeting two criteria: the T-stat value was greater than the absolute value of two, and the p-value was less than 0.1. In addition to performing trend analysis, the mean, median and standard deviation were calculated for parameters with significant trends. In order to more simply demonstrate the variability of the historical sample results, the standard deviation was divided by the mean and expressed as a percentage.

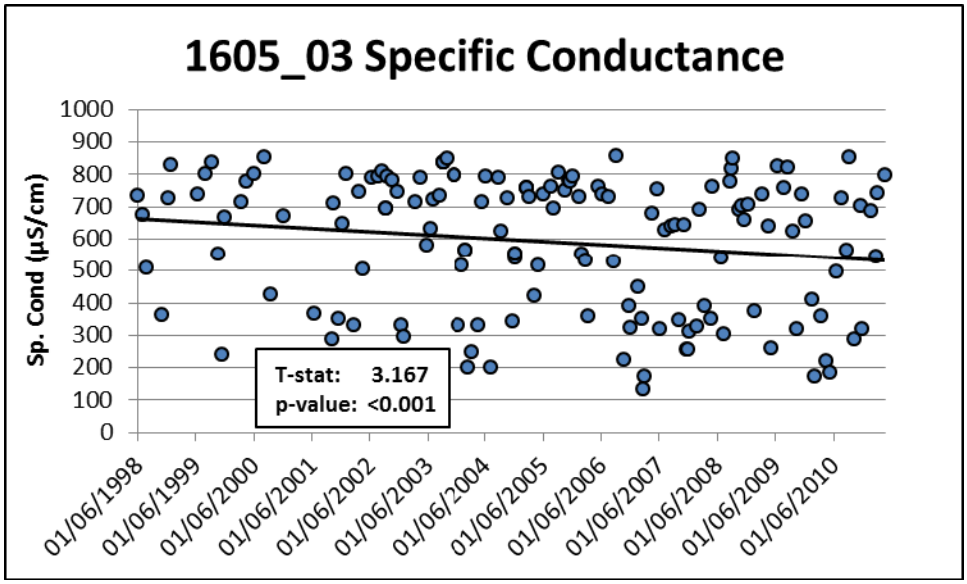


Figure T.1: *AU 1604_03 pH results*

Changes in pH and specific conductance were the most common trends found throughout the Basin. Although the pH trends met the criteria to be considered statistically significant, the standard deviation was typically around 0.3 standard units. For all assessment units with a significant pH trend, the variability (standard deviation divided by the mean) was within five percent meaning that the sample results had little variability and few outliers. These data show that although a significant trend for pH existed, the change in water quality and its effects on the biota were likely negligible.

Table T.1: *Trend analysis for Segment 1601*

Segment 1601: Lavaca River Tidal									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
From confluence of unnamed tributary upstream to confluence with Navidad River									
1601_02	Specific Conductance	377	-3.416	<0.001	↑	6600	1600	9455	143.3%
	pH	411	55.474	<0.001	↑	8.15	8.2	0.33	4.0%
From the confluence of Lavaca Bay upstream to the unnamed tributary NHD RC 12100101002580									
1601_03	pH	73	7.826	<0.001	↓	8.08	8.1	0.2	2.5%
Catfish Bayou									
1601A	Transparency	141	-3.579	<0.001	↑	0.5	0.45	0.28	56.0%
	pH	152	17.11	<0.001	↑	8.07	8.1	0.21	2.6%
Redfish Bayou									
1601B	pH	150	15.71	<0.001	↑	8.16	8.18	0.24	2.9%

Segment 1601:

There were significant trends for specific conductance, pH and transparency. Assessment Unit 1601_02 was the only portion of the watershed where there was a significant trend for specific conductance. The increasing trend may have been caused by the extended drought due to reduced freshwater inflow. The drought may also be responsible for the increased transparency in Segment 1601A (Catfish Bayou). The pH showed increasing trends in 1601_02, 1601A, and 1601B (Redfish Bayou), but had a decreasing trend in 1601_03. The median pH for these portions of Segment 1601 was 8.2, 8.1, 8.2, and 8.1 s.u., respectively. The highest standard deviation for all units was 0.33 s.u. in 1601_02, which was within 4% of the mean. Sub-segment 1601C, Dry Creek, did not have enough data to perform trend analysis.

Table T.2: *Trend analysis for Segment 1602*

Segment 1602: Lavaca River Above Tidal									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
The confluence of Campbell Branch in Hallettsville									
02	Specific Conductance	204	10.42	<0.001	↓	672	727	172.36	25.6%
	pH	144	12.16	<0.001	↓	7.98	8	0.24	3.0%
	Alkalinity	74	2.803	0.006	↓	241	254	60.07	24.9%
	Total Hardness	66	2.763	0.007	↓	260	270	60.55	23.3%
Lower portion of the segment from the confluence with NHD RC 12100101002463 south of Edna in Jackson County upstream to the confluence with Beard Branch									
03	Specific Conductance	134	2.578	0.011	↓	597	656	179.61	30.1%
	pH	121	10.54	<0.001	↓	7.95	8.00	0.27	3.4%
	Chloride	54	5.842	<0.001	↓	45.27	45.25	17.61	38.9%

Segment 1602:

Assessment Unit 02 of Segment 1602 had significant decreasing trends for Specific Conductance, pH, Alkalinity, and Total Hardness while 1602_03 showed an increasing trend for pH. The variability of the historical data for specific conductance, alkalinity and total hardness in 1602_02 was approximately 25%. The pH in 1602_02 had a

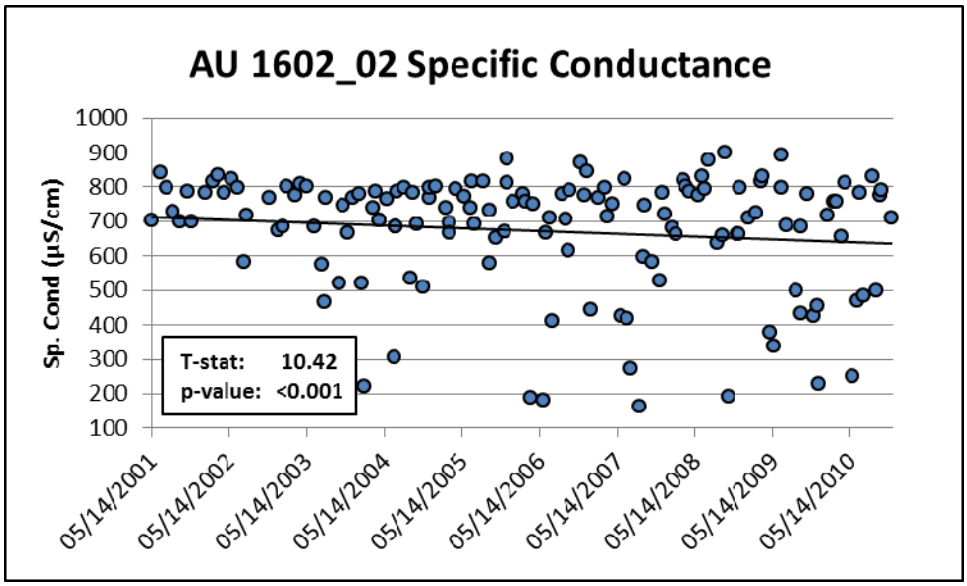


Figure T.2: *AU 1602_02 specific conductance results*

corresponding decreasing trend (as expected due to decreasing alkalinity); however, the pH variability was only three percent and standard deviation was 0.24 standard units. Similar results were found for pH upstream in 1602_03. Sub-segment 1602A, Big Brushy Creek, did not have enough data to perform trend analysis.

Table T.3: *Trend analysis for Segment 1603*

Segment 1603: Navidad River Tidal									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
From the confluence with the Lavaca River in Jackson County to Palmetto Bend Dam in Jackson County									
01	Transparency	227	-6.609	<0.001	↑	0.42	0.36	0.26	63%
	pH	264	22.58	<0.001	↓	8.17	8.2	0.32	3.9%
	Total Phosphorus	41	3.468	0.001	↓	0.20	0.19	0.10	49%
	Total Organic Carbon	79	3.008	0.004	↓	8.98	7.65	5.40	60%

Segment 1603:

In the tidal portion of the Lavaca River, Segment 1603, there were decreasing trends for pH, total phosphorus and total organic carbon, and this segment had an increasing trend for transparency. With the exception of pH, the ongoing drought is possibly responsible for these trends. Lower phosphorus and total organic carbon results along with increased transparency are likely due to reduced surface water runoff. Although pH had a significant decreasing trend, the variability of the pH values was less than four percent and had a median of 8.2 s.u.

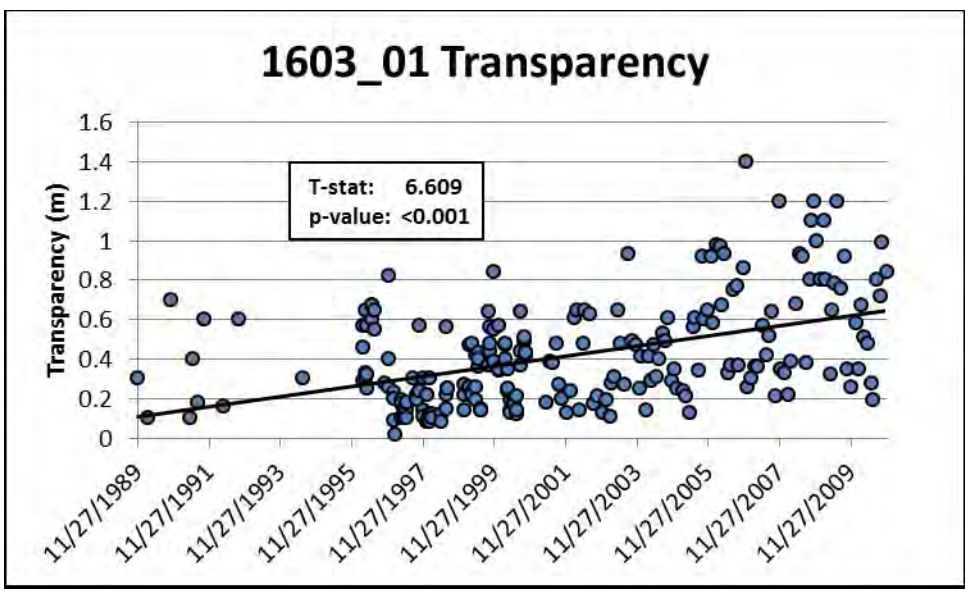


Figure T.3: *AU 1603_01 transparency results*

Table T.4: *Trend analysis for Segment 1604*

Segment 1604: Lake Texana									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
Navidad River Arm of Lake Texana									
01	Specific Conductance	289	14.72	<0.001	↓	256	236	103.94	40.6%
	pH	301	48.99	<0.001	↓	7.75	7.80	0.39	5.0%
	Alkalinity	54	2.069	0.044	↓	76.84	72.10	33.66	43.8%
	Total Phosphorus	40	2.799	0.008	↓	0.24	0.24	0.11	45.9
	Total Organic Carbon	107	4.006	<0.001	↓	12.15	10.9	5.58	45.9%
	Total Hardness	51	2.704	0.009	↓	87.35	79	33.75	38.6%
	Chloride	183	10.93	<0.001	↓	40.66	29.60	31.50	77.5%
	Sulfate	160	13.74	<0.001	↓	12.45	11.00	7.05	56.6%
Mustang Creek Arm of Lake Texana									
02	Specific Conductance	197	4.069	<0.001	↓	207	195	85.1	41.0%
	pH	215	11.04	<0.001	↑	7.67	7.7	0.36	4.7%
Upstream middle portion of Lake Texana									
03	Specific Conductance	194	4.147	<0.001	↓	200	203	56.11	28.1%
	pH	211	12.23	<0.001	↑	7.75	7.8	0.31	4.0%
	Total Hardness	52	2.893	0.006	↓	77.55	78	24.5	31.6%
Downstream middle portion of Lake Texana									
04	Specific Conductance	198	3.613	<0.001	↓	200	203	56.11	28.1%
	Dissolved Oxygen	213	2.065	0.04	↑	8.04	7.8	1.52	18.9%
	pH	212	13.69	<0.001	↑	7.82	7.84	0.3	3.8%
	Total Phosphorus	41	3.909	<0.001	↓	0.25	0.23	0.10	40.0%
	Total Organic Carbon	56	4.152	<0.001	↓	8.79	7.98	3.52	40.0%
Downstream portion of Lake Texana									
05	Specific Conductance	404	4.667	<0.001	↓	206	202	54.47	26.4%
	Transparency	353	2.465	0.014	↑	1.96	0.23	10.74	548.9%
	Dissolved Oxygen	437	2.964	0.003	↑	8.19	8	1.49	18.2%
	pH	435	17.62	<0.001	↑	7.9	7.9	0.32	4.1%
	Total Dissolved Solids	115	2.735	0.007	↓	11.90	9.30	8.74	73.4%
	Total Phosphorus	85	4.035	<0.001	↓	0.22	0.20	0.09	41.2%
	Total Organic Carbon	113	5.277	<0.001	↓	8.71	7.40	4.11	47.2%
	Total Hardness	143	3.286	0.001	↓	74.48	74.00	19.06	25.6%
	Chloride	173	2.938	0.004	↓	15.37	13.97	6.96	45.3%

Table T.4, continued: *Trend analysis for Segment 1604*

Segment 1604 (continued)									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
East Mustang Creek									
1604A	pH	168	8.08	<0.001	↑	7.79	7.8	0.42	5.4%
	Sulfate	56	2.425	0.019	↓	14.00	9.60	12.54	89.6%
West Mustang Creek									
1604B	Specific Conductance	286	8.195	<0.001	↓	551	534	292.05	53.0%
	pH	298	25.01	<0.001	↑	7.7	7.8	0.41	5.3%
	Total Phosphorus	42	2.007	0.052	↓	0.35	0.31	0.28	80.0%
	Total Hardness	59	2.908	0.005	↓	153	144	73.23	48.0%
	Chloride	147	5.212	<0.001	↓	73.88	67	45.44	61.5%
Sandy Creek									
1604C	Specific Conductance	232	5.375	<0.001	↓	324	294	205.28	63.3%
	pH	244	19.05	<0.001	↑	7.7	7.8	0.41	5.3%

Segment 1604:

Statistically significant trends were found for specific conductance and pH in all five assessment units of Segment 1604. Specific conductance was decreasing in all assessment units, and pH was increasing across Lake Texana except in 1604_01: Navidad Arm where it was decreasing along with Alkalinity.

Additionally, there were decreasing trends for total phosphorus, total organic carbon, total hardness, chloride and sulfate in this assessment unit. All of the aforementioned trends are likely related to the reduced surface water inflows due to the ongoing drought.

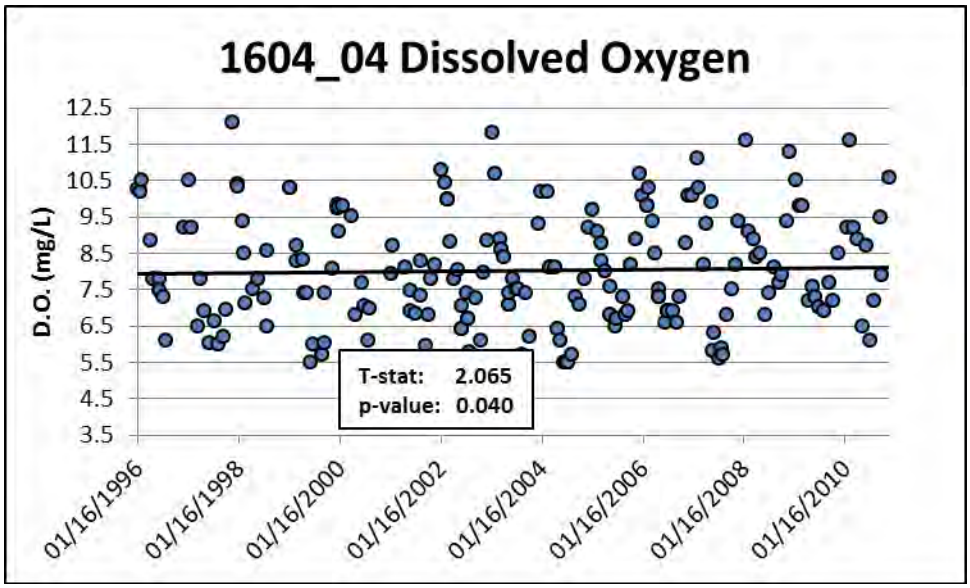


Figure T.4: *AU 1604_04 dissolved oxygen results*

Despite the drought and reduced freshwater inflows, increasing trends for dissolved oxygen were discovered in both the lower mid-lake and dam areas of Lake Texana. Both assessment units had decreasing trends for total phosphorus and total organic

carbon. In addition, 1604_05 showed decreasing trends for total hardness, chloride and total dissolved solids along with an increasing trend for transparency. Decreasing solids, total organic carbon and phosphorus along with an increasing transparency trend are likely due to the drought conditions.

Although 1604_01 had a decreasing trend for pH while the remainder of Lake Texana showed an increasing trend, the median pH of all of the assessment units ranged from 7.7 to 7.9 s.u., and all of the assessment units had a variability of less than five percent.

Similar to Segment 1604, increasing pH trends were found in Sub-segments 1604A, 1604B, and 1604C while decreasing specific conductance trends occurred in Sub-segments 1604B and 1604C. Sub-segment 1604B, West Mustang Creek, exhibited decreasing trends for total phosphorus, total hardness and chloride. These decreasing trends are possibly due to the ongoing drought and reduced surface runoff. The median pH in all sub-segments was 7.8 s.u. and had a variability of around five percent.

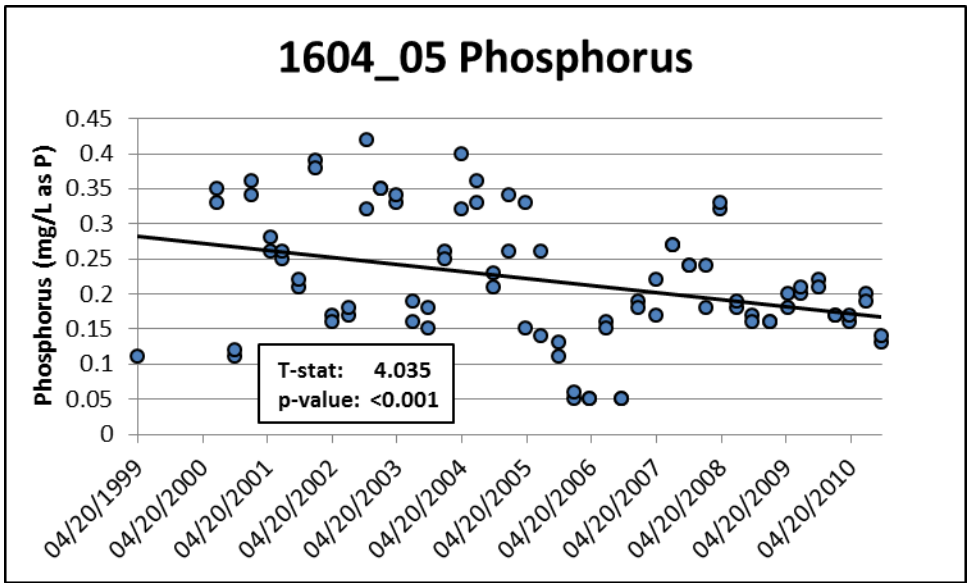


Figure T.5: *AU 1604_05 phosphorus results*

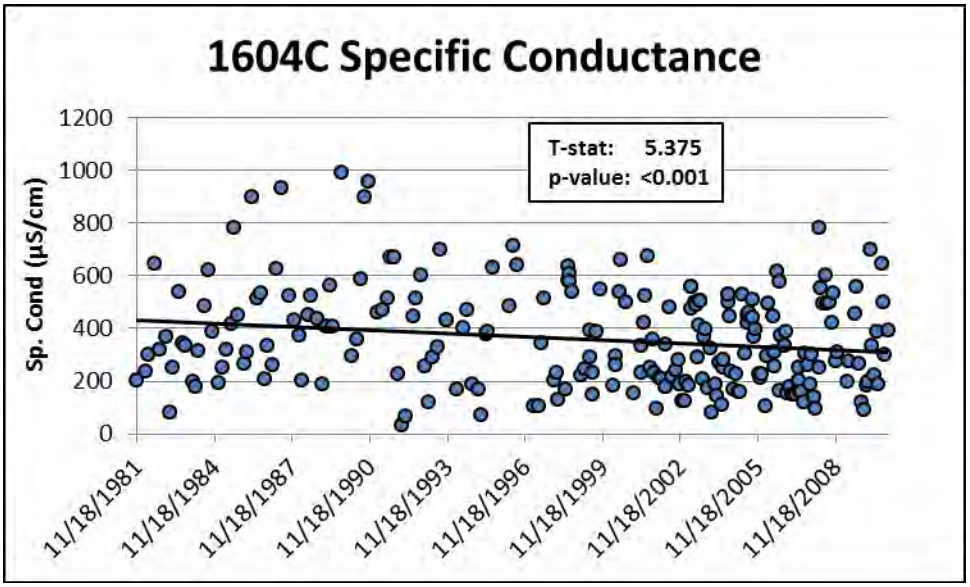


Figure T.6: *Sandy Creek (1604C) specific conductance results*

Table T.5: *Trend analysis for Segment 1605*

Segment 1605: Navidad River above Lake Texana									
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Trend**	**Mean**	**Median**	**Standard Deviation**	**Variability**
Lower 31 miles of segment from the confluence with Lake Texana upstream to the confluence of Sandies Creek									
1605_03	Specific Conductance	149	3.167	0.002	↓	591	672	206.24	34.9%
	pH	166	10.96	<0.001	↑	7.98	8	0.31	3.9%

Segment 1605:

There were not enough data to perform trend analysis in Assessment Unit 1605_01, and no significant trends were found in 1605_02. In 1605_03, a decreasing trend for specific conductance and an increasing trend for pH were calculated. The variability of pH was less than four percent and had a standard deviation of 0.3 s.u. The decreasing trend for specific conductance was similar to the trends found elsewhere in the basin.

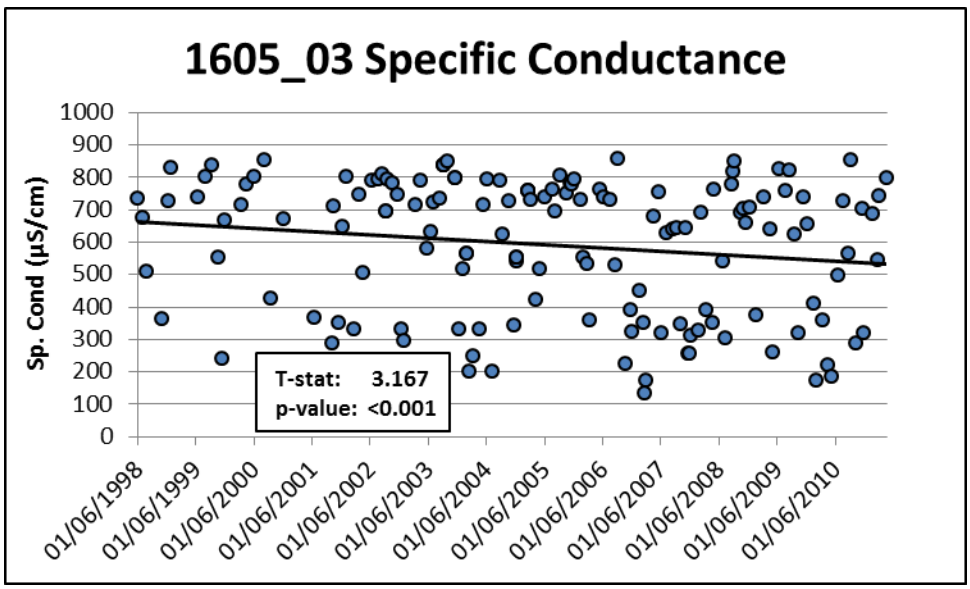


Figure T.7: *AU 1605_03 specific conductance results*

Discussion

The overall data review for the Lavaca–Navidad Basin addressed two objectives: (1) parameters listed as impaired or concerns in the *2010 TCEQ Integrated Report* were reviewed under similar criteria as assessed by the TCEQ, and (2) trends were identified for all data that met criteria discussed earlier in this report. The data assessed in this report document the state of the basin to 2012. This will be a useful tool to reference in the future of water quality. Human activity, wildlife, and land use are reflected in field and laboratory results of water quality analysis. The history of water quality in the Basin is well documented and updates to the LNRA's current open projects are available in the various reports generated through the CRP.

Issues noted in the *2010 Integrated Report* in the Lavaca Basin include: (1) upper reaches of the Lavaca River above tidal influence for depressed dissolved oxygen (addressed with a UAA to re-assess standards – awaiting final approval), (2) bacteria levels exceeding criteria in the middle and lower Lavaca River, and (3) concerns for nutrients exceeding screening levels in Lake Texana.

Depressed Dissolved Oxygen in the Lavaca River above Tidal (Segment 1602)

Dissolved oxygen monitoring in this reach of the Lavaca River first began in 1999 in response to a fish kill belatedly reported to the TPWD. The TPWD responded with random 24-hour dissolved oxygen monitoring. After two years of collection, the agency contacted the LNRA. The TPWD coordinated with LNRA to collect 24-hour dissolved oxygen samples. Stream flows were often low and some samples were collected under conditions below 7Q2 (seven-day, two-year low flow) for Segment 1602 which at that time was 0.7 cfs (based on historical flow at a USGS flow gage in Hallettsville maintained from 1939 to 1993). The segment was first listed as impaired in 2004 for depressed dissolved oxygen levels.

These events led to the re-evaluation of standards for the segment. LNRA reported to TCEQ that Segment 1602 lacked consistency in characteristics to define it as a single segment. The Lavaca River drainage is a very long reach (94 miles) that extends over 1,004 square miles and accounts for 43.3 percent of the entire watershed. Covering three unique ecoregions (Blackland Prairies, South Central Plains, and Western Gulf Coastal Plain), land and stream characteristics vary widely. Both streambed size and flow differ greatly over this long segment, and upper portions of the Lavaca have little in common with the lower portions of the river. Despite these facts, the entire segment is classified by TCEQ as High Aquatic Life Use (ALU) with associated water quality criteria. It is extremely doubtful that the intermittent flows of the upper portion of the Lavaca River can sustain the dissolved oxygen criteria of >5mg/L associated with "High" ALU.

The upper reaches of the Lavaca River were considered understudied, so the LNRA applied for assistance in funding a special study to gather additional 24-hour dissolved oxygen, flow, and field parameters. The goal of this special study was to provide data to support reclassification of the segment as intermittent with either an "Intermediate" or "Limited" ALU with associated criteria. The LNRA submitted the results of the special study to the TCEQ who proceeded forward with a Use Attainability Analysis (UAA). The data generated in the special study were assessed by the TCEQ and resulted in the upper reach (AU 1602_01) of the Lavaca River being listed for depressed dissolved oxygen levels in the *2004 303(d) List*.

LNRA responded immediately by adding monitoring at a new station and including additional parameters at an existing station in Segment 1602 to intensify sampling. Data collected reveal that dissolved oxygen levels were consistently high in the Lavaca River, except in the most upper reach where the stream flow becomes intermittent above Hallettsville.

A Use Attainability Analysis was conducted from 2005 to 2006 by the TCEQ Water Quality Standards Team with cooperation from TPWD and LNRA. The 24-hour dissolved oxygen monitoring conducted in the study supported reclassification of the segment to intermittent with perennial pools from Campbell's Creek above Hallettsville up to the West Prong of the Lavaca downstream of Moulton. Above the West Prong the stream is intermittent. Flow remained low, but consistent only in the lower reaches of the study area near and below Hallettsville. The middle reach had no flow intermittently, and the farthest two upstream stations had no flow consistently after the first monitoring event.

The study concluded that conditions causing the stream to go intermittent in the upper reaches were caused by naturally occurring seasonal low flow conditions, and the TCEQ supported and recommended reclassification of the segment to re-define the application of standards based on existing conditions. The final UAA report remained under review at TCEQ until it was submitted to the US EPA Region 6 in late 2009. At the time of this report, no comments have been received and approval has not yet been granted to promulgate the proposed reclassification.

Bacteria Levels in Middle and Lower AU's of the Lavaca River above Tidal

This segment was first assessed for bacteria in 2008. Prior to that, an insufficient amount of data existed for assessment. The middle and lower AU's were first listed as impaired for bacteria levels in 2008 and remain on the *2010 Integrated Report.*

Bacteria data in 1602_02 include results from two sampling stations, 12525 (downstream at State Highway 111) and 12527 (upstream at US Highway 90A in Hallettsville. Samples were collected only from the downstream site from 2001 to spring 2004 (nine samples), but quarterly sampling at both stations began in 2004. Bacteria levels from the upstream station in Hallettsville (12527) are generally lower and help keep the geomean lower. The land use in the upper northwestern area of the watershed is largely dominated by agricultural activities (> 70% from irrigated row crops to grazing land). The City of Moulton is authorized to discharge treated domestic wastewater at a daily average less than or equal to 242,000 gallons per day. The City of Hallettsville also potentially impacts water quality with its authorized discharge of 800,000 gallons per day under TPDES Permit WQ0010013001 at its wastewater treatment plant.

The geomean at the upstream station is 105 MPN/100mL, while the geomean at the station downstream exceeds criteria at 201 MPN/100 ml. This would indicate bacteria loading are occurring in the lower or middle reaches of the AU. Rocky Creek, (sub-segment 1602B) an unclassified water body, joins the Lavaca River below Hallettsville. One sampling station contains bacteria data on Rocky Creek west of US Highway 77 (18190). The geomean before it joins the Lavaca River is 267 MPN/100 ml. The City of Shiner's TPDES Permit WQ0010280001 is authorized to discharge treated domestic wastewater at a daily average less than or equal to 8.5 million gallons per day into Rocky Creek.

Understanding that bacteria loads are already entering the lower reaches of the segment, one can expect impairment would occur downstream as well. AU 1602_03 (the lower portion of Segment 1602 from south of Edna up to downstream of where the Lavaca River crosses State Highway 111) was assessed with data from a station at State Highway 59 (12524). If no additional bacteria are entering the stream, bacteria samples at the downstream end of the AU should not increase. Table D.1 shows that bacteria levels are increasing, so it's logical to infer additional bacteria loading is occurring in the drainage area for station 12524. The geomean of station 12524 was 215 MPN/100ml.

Big Brushy Creek flows into Clarks Creek which enters the Lavaca River just above site #12525 at SH 111. Its waters are influenced by the City of Yoakum and its TPDES Permit authorizing the discharge of treated domestic wastewater at a daily average less than or equal to 9.9 million gallons per day into Big Brushy Creek (1602A). One sampling station exists in 1602A twenty meters downstream of Loop 51/US Business 77A (17535). This station was established to support the wastewater treatment plant permit renewal, but sampling on record extends only from 2002 to 2003. No bacterial samples were collected.

Unclassified water bodies were not assessed in the *2010 Integrated Report*. Big Brushy Creek and Rocky Creek are unclassified water bodies, so concerns for supporting of its designated use cannot be identified. However, concern is warranted when data indicates bacteria levels that exceed criteria entering a classified segment that is assessed.

Table D.1: *Bacteria data for the middle and lower reaches of Segment 1602*

Bacteria Results	AU 1602_02	AU 1602_03
Number of Samples to be Removed from the 2012 Assessment	8	8
Geomean of Samples to be Removed (MPN/100 ml)	190	232
Number of Samples to be Included in the 2012 Assessment	16	8
Geomean of Samples to be Added (MPN/100 ml)	108	228
Current Geomean (MPN/100 ml)	171	215
Estimated Geomean in 2012 Assessment(MPN/100 ml)	149	219

Neither AU shows a statistically significant relationship for bacteria levels over time. When considering agricultural influence, forested lands, and permitted dischargers from wastewater treatment plants in the upper reaches of the watershed, higher bacteria levels are achieved through a combination of point, and non-point sources such as rainfall runoffs. It is possible that more intensive sampling on Rocky Creek and Big Brushy Creek would enable assessors to narrow the area where loading occurs in 1602. A more intensive sampling approach is recommended to identify sources.

In 2005 an informal bacterial study was conducted by LNRA in Rocky Creek. Samples were taken at eight sites from the headwaters of Rocky Creek (above the wastewater outfall in Shiner) downstream to the Rocky Creek sampling site above its confluence with the Lavaca River. The bacterial numbers were very low in the headwaters and below the wastewater outfall. Feral hogs and cattle are often seen in the water at the Rocky Creek sampling site, and it appears the bacterial numbers at this site might be attributed to their presence.

Rural streams in most basins experience higher bacterial counts after heavy rains due to the organics picked up from pastureland and wildlife during overland flow, but these numbers recede after a short time. It only takes a couple of precipitation spikes to exceed the geomean criteria.

In December 2011 TCEQ published the Watershed Action Plan. AU 1602_02 and 1602_03 are both listed as Category 5c (for bacteria) which means that additional data and information will be collected before a TMDL is scheduled. 1602_01 remains a category 5b (meaning a review of water quality standards for this water body will be conducted before a TMDL is scheduled) until the UAA recommending a change in dissolved oxygen criteria for this intermittent reach with perennial pools receives final approval by the EPA.

Nutrient Levels and Loading in Lake Texana (1604)

Nutrient enrichment is a listed "concern" in Lake Texana due to the levels of phosphorus and nitrate nitrogen exceeding TCEQ screening levels (Table D.2). LNRA began testing for chlorophyll-*a* in 2004, and thus far levels do not appear to indicate problems. Because of upstream land use, the inflows into Lake Texana carry nutrients lost from fields during run-off. However, nutrient levels in Lake Texana appear to be decreasing in recent years.

Table D.2: *Segment 1604 AUs with Concerns for Use Attainment in the 2010 TCEQ Integrated Report*

AU 1604	Description	Nitrogen	Total Phosphorus	Ortho-Phosphorus	Chlorophyll -*a*	Ammonia
01	Navidad Arm	NC	CS	CS	NC	NC
02	Mustang Creek Arm	CS	CS	CS	NC	NC
03	Upstream middle	CS	CS	CS	NC	NC
04	Downstream middle	CS	CS	CS	NC	NC
05	Downstream near dam	CS	CS	CS	NC	NC

The *2010 Integrated Report* included nutrient screening analysis for nitrate, total phosphorus, ortho-phosphorus, ammonia, and chlorophyll-*a*. All constituents were present at all sample sites during the period of analysis; however, averaged levels for ammonia and chlorophyll-*a*, were below screening levels. Therefore Lake Texana exhibits no concern for those two parameters. Since December 2001, only four of 159 chlorophyll-*a* samples and only four of 213 ammonia samples have exceeded the screening levels for their respective parameters.

Other nutrient concentrations continue to be above screening levels throughout much of Lake Texana during the current assessment period, particularly in Mustang Creek Arm (Table D.3). Nitrogen levels were present in the Navidad Arm (1604_01), but average levels were below screening levels and posed no concern for that parameter. Nitrogen concentrations exceed the screening levels throughout the remainder of Lake Texana. Total phosphorus concentrations often exceeded screening levels, resulting in additional concerns throughout the lake for nutrient enrichment. Nitrogen and phosphorus levels in the tributaries, the Navidad River, Sandy Creek, West Mustang Creek and East Mustang Creeks, were comparable to those in Lake Texana, but did not result in concerns because streams do not have to meet the same low screening levels as reservoirs. The tributary stations are not required to meet the more stringent nitrogen and phosphorus screening levels that apply to Lake Texana because streams tend to exhibit fewer adverse consequences (e.g., algal blooms, dissolved oxygen depletion) from nutrient enrichment than do lentic (lake or reservoir) environments where conditions are usually more conducive to the growth and accumulation of aquatic vegetation. The data set does not indicate any concerns with respect to ammonia nitrogen levels anywhere in the watershed. Over half (54 percent) of the ammonia results were less than the limit of quantitation (LOQ), or below the lowest detectable level capability at the analyzing laboratory.

Chlorophyll-*a* levels were detectable in most samples (87 percent), but below screening levels and results were decreasing in all assessment units throughout the Lake including the Navidad Arm and the Mustang Creek Arm. Total Organic Carbon (TOC) concentration results in the Lake Texana watershed are analyzed for the assessment period. In 2007, TOC results were highest in the Mustang Creek Arm followed by the Navidad River Arm. Currently the highest TOC levels are now in the Navidad Arm followed by the Mustang Creek Arm. Nutrient enrichment appears to be decreasing, as do occasional elevated levels of TOC and chlorophyll *a*. Both grab and diel dissolved oxygen monitoring results indicate

that Lake Texana is continuing to assimilate its nutrient loading without major adverse consequence to water quality and aquatic life uses.

***Table D.3**: Nutrient data for Lake Texana (Segment 1604)*

Nutrient Levels in Segment 1604: Lake Texana							
AU 1604	**Parameter**	**# of Data Points**	**Screening Level (mg/L)**	**Number Exceeding**	**% Exceeding**	**Average (mg/L)**	**Concern**
Navidad River Arm of Lake Texana							
01	Total Nitrogen	35	0.37	7	20	0.28	No
	Total Phosphorus	34	0.20	23	68	0.24	Yes
	Ortho-Phosphorus	7	0.05	7	100	0.11	Yes
Mustang Creek Arm of Lake Texana							
02	Total Nitrogen	35	0.37	19	54	0.53	Yes
	Total Phosphorus	36	0.20	33	92	0.36	Yes
	Ortho-Phosphorus	7	0.05	7	100	0.18	Yes
Upstream middle portion of Lake Texana							
03	Total Nitrogen	36	0.37	16	44	0.38	Yes
	Total Phosphorus	36	0.20	26	72	0.27	Yes
	Ortho-Phosphorus	7	0.05	7	100	0.14	Yes
Downstream middle portion of Lake Texana							
04	Total Nitrogen	36	0.37	14	39	0.34	Yes
	Total Phosphorus	36	0.20	22	61	0.24	Yes
	Ortho-Phosphorus	7	0.05	6	86	0.13	Yes
Downstream portion of Lake Texana							
05	Total Nitrogen	72	0.37	33	46	0.39	Yes
	Total Phosphorus	74	0.20	31	43	0.21	Yes
	Ortho-Phosphorus	14	0.05	12	86	0.14	Yes

Total Nitrogen = Nitrate-Nitrogen + Nitrite-Nitrogen

Ortho-phosphorus samples were last collected in fiscal year 2004. The *2012 Integrated Report* will not include any of these data to assess this parameter. Seven samples remain for each station resulting in limited data as well. TCEQ development of nutrient criteria does not include ortho-phosphorus, but instead total phosphorus will be used as its results include ortho-phosphorus levels.

Algal blooms do not appear to be a problem in Lake Texana, but invasive aquatic vegetation (e.g. water hyacinth and *Salvinia molesta*) is an ongoing problem in the Lake. LNRA operates an aquatic vegetation control program and cooperates with TPWD and the United States Department of Agriculture (USDA) on an integrated biological control program. TCEQ is currently working to develop nutrient standards for the state of Texas in cooperation with the EPA.

Recommendations

Routine monitoring sites and reservoir stations where significant trends were identified should be continued in order to determine if these trends endure over the coming years. These trends can also be used to determine if signs of drought are changing or reversing water quality conditions across the Basin.

Elevated bacterial levels and nutrient enrichment appear to be potential threats to the water quality in the Lavaca River and Lake Texana, respectively. *E. coli* values in Rocky Creek are a concern since they could indicate improperly treated effluent and non-point sources such as malfunctioning septic systems and agricultural run-off. However, a cursory bacterial study done several years ago across the reach of Rocky Creek indicated that bacterial levels there are likely due to livestock being allowed into the creek, feral hogs and other wildlife. The bacterial levels below the wastewater treatment plant in Shiner (whose effluent empties into Rocky Creek) were low.

Drought conditions have impacted the region reducing freshwater inflows in 2008 to 2009 and again in 2011. LNRA does monitor even its inland sites for salinity levels, but TCEQ does not want salinity reported to the State database except for tidally influenced sites. During times of drought, the lower Basin sites (which are tidally influenced) have high salinity values due to lack of freshwater inflow. The site in the Navidad below the spillway has run as high as 33.8 parts per thousand (ppt), and the salinity at the site in the Lavaca River closest to the mouth of Lavaca Bay ranged between 38.0 and 28.8 ppt during the months of September 2011 through February 2012 when the area finally began to receive some much needed rainfall. Ocean levels of salinity normally run ~35 ppt.

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USEPA. 2000. Level III Ecoregions of the Continental United States. US Environmental Protection Agency. Revision of Omernik, 1987.

Appendix A:

Statistical Review

Table A.1: *Summary of statistical analysis for Segment 1601*

Segment 1601: Lavaca River Tidal						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
From the confluence of unnamed tributary NHD RC 12100101002580 upstream to the confluence with the Navidad River						
1601_02	Temperature	447	8.530	<0.001	Yes	↑
	Transparency	300	-1.644	0.101	No	
	Specific Conductance	377	-3.416	<0.001	Yes	↑
	Dissolved Oxygen	313	1.142	0.254	No	
	pH	312	21.21	<0.001	Yes	↑
	Alkalinity	311	-0.997	0.319	No	
From the confluence of Lavaca Bay upstream to the unnamed tributary NHD RC 12100101002580						
1601_03	Temperature	74	1.178	0.243	No	
	Transparency	74	0.321	0.749	No	
	Specific Conductance	74	-1.107	0.272	No	
	Dissolved Oxygen	74	1.697	0.094	No	
	pH	73	7.826	<0.001	Yes	↓
	Alkalinity	26	0.699	0.492	No	
	Salinity	74	-1.212	0.230	No	
	Total Dissolved Solids	26	-1.235	0.229	No	
	Total Phosphorus	26	0.618	0.542	No	
	Total Organic Carbon	26	1.732	0.096	No	
	Total Hardness	25	-1.133	0.269	No	
	Chloride	25	-1.343	0.192	No	
	Sulfate	26	0.337	0.739	No	
	Turbidity	25	-1.030	0.314	No	
Catfish Bayou						
1601A	Temperature	149	1.637	0.104	No	
	Transparency	141	-3.579	<0.001	Yes	↑
	Specific Conductance	136	0.028	0.978	No	
	Dissolved Oxygen	150	-0.920	0.359	No	
	pH	152	17.11	<0.001	Yes	↑
	Salinity	148	0.354	0.724	No	
Redfish Bayou						
1601B	Temperature	148	1.146	0.254	No	
	Transparency	145	1.994	0.048	No	
	Specific Conductance	134	-1.204	0.231	No	
	Dissolved Oxygen	148	0.168	0.867	No	
	pH	150	15.71	<0.001	Yes	↑
	Salinity	147	-0.926	0.356	No	

Sub-segment 1601C – Dry Creek did not have enough data for trend analysis

Table A.2: *Summary of statistical analysis for Segment 1602*

Segment 1602: Lavaca River Above Tidal From the confluence of Campbell Branch in Hallettsville upstream to the end of the segment						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
1602_01	24-hr Dissolved Oxygen Average	23	-3.075	0.006	Yes	↑
From the confluence of Beard Branch upstream to the confluence of Campbell Branch in Hallettsville						
1602_02	Temperature	144	0.539	0.591	No	
	Discharge	80	-1.399	0.166	No	
	Specific Conductance	204	10.42	<0.001	Yes	↓
	Dissolved Oxygen	145	0.347	0.729	No	
	pH	144	12.16	<0.001	Yes	↓
	Alkalinity	74	2.803	0.006	Yes	↓
	Total Dissolved Solids	74	-0.776	0.440	No	
	Nitrate	45	-1.731	0.091	No	
	Total Phosphorus	74	0.342	0.733	No	
	Total Organic Carbon	73	1.349	0.182	No	
	Total Hardness	66	2.763	0.007	Yes	↓
	Chloride	74	-0.492	0.625	No	
	Sulfate	71	1.025	0.309	No	
	E. coli	63	-0.890	0.377	No	
	Turbidity	65	-0.858	0.394	No	
Lower portion of the segment from the confluence with NHD RC 12100101002463 south of Edna in Jackson County upstream to the confluence with Beard Branch						
1602_03	Temperature	303	9.500	<0.001	Yes	↑
	Discharge	126	-0.365	0.716	No	
	Specific Conductance	134	2.578	0.011	Yes	↓
	Dissolved Oxygen	121	0.875	0.38	No	
	pH	121	10.54	<0.001	Yes	↓
	Alkalinity	46	1.006	0.320	No	
	Total Dissolved Solids	46	0.101	0.920	No	
	Nitrate	23	-0.505	0.619	No	
	Total Phosphorus	40	2.009	0.052	Yes	↓
	Total Organic Carbon	54	1.747	0.087	No	
	Total Hardness	53	0.272	0.786	No	
	Chloride	54	1.940	0.058	No	
	E. coli	37	-0.710	0.483	No	
	Turbidity	48	-0.376	0.709	No	

Table A.2, continued: *Summary of statistical analysis for Segment 1602*

Segment 1602: Lavaca River Above Tidal						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
Rocky Creek						
1602B	Temperature	24	1.046	0.307	No	
	Discharge	24	1.763	0.092	No	
	Specific Conductance	24	1.443	0.163	No	
	Dissolved Oxygen	24	-0.747	0.463	No	
	pH	24	3.196	0.004	Yes	↑
	Alkalinity	23	1.333	0.197	No	
	Total Dissolved Solids	23	0.192	0.850	No	
	Total Phosphorus	23	-0.320	0.752	No	
	Total Organic Carbon	23	0.721	0.479	No	
	Total Hardness	23	0.686	0.500	No	
	Chloride	23	-0.216	0.831	No	
	Sulfate	23	-0.706	0.488	No	
	E. coli	22	0.505	0.619	No	
	Turbidity	22	0.251	0.805	No	

Sub-segment 1602A – Big Brushy Creek did not have enough data for trend analysis

Table A.3: *Summary of statistical analysis for Segment 1603*

Segment 1603: Navidad River Tidal						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
From the confluence with the Lavaca River in Jackson County to Palmetto Bend Dam in Jackson County						
1603_01	Temperature	265	1.949	0.052	No	
	Transparency	227	-6.609	<0.001	Yes	↑
	Specific Conductance	221	-0.214	0.830	No	
	Dissolved Oxygen	243	0.538	0.591	No	
	pH	264	22.58	<0.001	Yes	↓
	Alkalinity	83	1.946	0.055	No	
	Salinity	229	-2.024	0.044	Yes	↑
	Total Dissolved Solids	77	1.856	0.067	No	
	Total Phosphorus	41	3.468	0.001	Yes	↓
	Total Organic Carbon	79	3.008	0.004	Yes	↓
	Total Hardness	55	-0.868	0.390	No	
	Chloride	82	1.202	0.233	No	
	Sulfate	68	1.137	0.260	No	
	Turbidity	49	0.955	0.345	No	

Table A.4: *Summary of statistical analysis for Segment 1604*

Segment 1604: Lake Texana						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
Navidad River Arm of Lake Texana						
1604_01	Temperature	348	7.283	<0.001	Yes	↑
	Transparency	193	1.260	0.209	No	
	Specific Conductance	174	5.020	<0.001	Yes	↓
	Dissolved Oxygen	198	1.980	0.049	No	
	pH	199	10.95	<0.001	Yes	↑
	Alkalinity	54	2.069	0.044	Yes	↓
	Total Phosphorus	40	2.799	0.008	Yes	↓
	Total Organic Carbon	107	4.006	<0.001	Yes	↓
	Total Hardness	51	2704	0.009	Yes	↓
	Chloride	183	10.93	<0.001	Yes	↓
	Sulfate	160	13.74	<0.001	Yes	↓
	E. coli	29	-1.109	0.277	No	
	Chlorophyll *a*	25	1.140	0.266	No	
	Turbidity	48	-0.463	0.646	No	
Mustang Creek Arm of Lake Texana						
1604_02	Temperature	216	0.818	0.414	No	
	Transparency	187	1.880	0.062	No	
	Specific Conductance	197	4.069	<0.001	Yes	↓
	Dissolved Oxygen	216	1.936	0.054	No	
	pH	215	11.04	<0.001	Yes	↑
	Alkalinity	56	0.845	0.402	No	
	Total Dissolved Solids	50	0.944	0.350	No	
	Total Phosphorus	52	1.912	0.0062	No	
	Total Organic Carbon	56	3.188	0.002	Yes	↓
	Total Hardness	55	0.626	0.534	No	
	Chloride	55	1.772	0.082	No	
	Sulfate	56	0.7532	0.455	No	
	E. coli	29	0.088	0.931	No	
	Chlorophyll *a*	26	1.429	0.166	No	
	Turbidity	50	0.280	0.781	No	
Upstream middle portion of Lake Texana						
1604_03	Temperature	212	0.799	0.426	No	
	Transparency	199	1.860	0.064	No	
	Specific Conductance	194	4.147	<0.001	Yes	↓
	Dissolved Oxygen	212	1.334	0.184	No	
	pH	211	12.23	<0.001	Yes	↑
	Alkalinity	55	2.348	0.023	Yes	↓
	Total Dissolved Solids	49	0.960	0.342	No	
	Total Phosphorus	42	2.642	0.012	Yes	↓
	Total Organic Carbon	55	1.999	0.501	No	
	Total Hardness	52	2.893	0.006	Yes	↓

Table A.4, continued: *Summary of statistical analysis for Segment 1604*

Segment 1604: Lake Texana, con't						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
Upstream middle portion of Lake Texana						
1604_03	Chloride	68	0.393	0.695	No	
	Sulfate	55	1.267	0.211	No	
	Chlorophyll *a*	27	1.776	0.088	No	
	Turbidity	49	-0.725	0.472	No	
Downstream middle portion of Lake Texana						
1604_04	Temperature	213	0.618	0.537	No	
	Transparency	141	-1.818	0.071	No	
	Specific Conductance	198	3.613	<0.001	Yes	↓
	Dissolved Oxygen	213	2.065	0.040	Yes	↑
	pH	212	13.69	<0.001	Yes	↑
	Alkalinity	57	0.783	0.437	No	
	Total Dissolved Solids	50	1.180	0.286	No	
	Total Phosphorus	41	3.909	<0.001	Yes	↓
	Total Organic Carbon	56	4.152	<0.001	Yes	↓
	Total Hardness	53	1.637	0.108	No	
	Chloride	55	2.089	0.042	Yes	↓
	Sulfate	41	-0.008	0.994	No	
	Chlorophyll *a*	27	0.932	0.360	No	
	Turbidity	50	-0.140	0.890	No	
Downstream portion of Lake Texana						
1604_05	Temperature	437	0.677	0.499	No	
	Transparency	343	-2.465	0.014	Yes	↑
	Specific Conductance	380	4.146	<0.001	Yes	↓
	Dissolved Oxygen	402	1.975	0.049	No	
	pH	435	17.62	<0.001	Yes	↑
	Alkalinity	113	1.817	0.072	No	
	Total Dissolved Solids	115	2.735	0.007	Yes	↓
	Total Phosphorus	85	4.035	<0.001	Yes	↓
	Total Organic Carbon	113	5.278	<0.001	Yes	↓
	Total Hardness	143	3.286	0.001	Yes	↓
	Chloride	173	2.938	0.004	Yes	↓
	Sulfate	144	1.829	0.070	No	
	Chlorophyll *a*	54	0.831	0.410	No	
	Turbidity	101	-0.253	0.801	No	
East Mustang Creek						
1604A	Temperature	168	2.146	0.033	Yes	↓
	Discharge	147	0.498	0.619	No	
	Specific Conductance	150	0.445	0.657	No	
	Dissolved Oxygen	167	1.451	0.149	No	
	pH	168	8.080	<0.001	Yes	↑

Table A.4, continued: *Summary of statistical analysis for Segment 1604*

Segment 1604: Lake Texana, con't						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
East Mustang Creek						
1604A	Alkalinity	59	0.955	0.344	No	
	Total Dissolved Solids	49	1.468	0.149	No	
	Total Ammonia	49	0.957	0.343	No	
	Total Phosphorus	51	0.460	0.647	No	
	Total Organic Carbon	59	2.702	0.009	Yes	↓
	Total Hardness	56	1.478	0.145	No	
	Chloride	56	1.849	0.070	No	
	Sulfate	56	2.425	0.019	Yes	↓
	Turbidity	49	-0.257	0.798	No	
West Mustang Creek						
1604B	Temperature	300	5.768	<0.001	Yes	↓
	Discharge	257	1.701	0.090	No	
	Specific Conductance	206	2.995	0.003	Yes	↓
	Dissolved Oxygen	294	4.261	<0.001	Yes	↑
	pH	298	25.01	<0.001	Yes	↑
	Alkalinity	114	4.704	<0.001	Yes	↓
	Total Dissolved Solids	54	1.897	0.063	No	
	Total Ammonia	43	1.369	0.178	No	
	Total Nitrate	23	0.403	0.691	No	
	Total Phosphorus	42	2.007	0.052	Yes	↓
	Total Organic Carbon	60	3.044	0.004	Yes	↓
	Total Hardness	59	2.908	0.005	Yes	↓
	Chloride	147	5.212	<0.001	Yes	↓
	Sulfate	129	6.895	<0.001	Yes	↓
	Turbidity	51	1.012	0.316	No	
Sandy Creek						
1604C	Temperature	246	4.119	<0.001	Yes	↑
	Discharge	232	1.213	0.226	No	
	Specific Conductance	232	5.375	<0.001	Yes	↓
	Dissolved Oxygen	241	5.737	<0.001	Yes	↑
	pH	244	19.05	<0.001	Yes	↑
	Alkalinity	57	0.954	0.344	No	
	Total Dissolved Solids	49	1.662	0.103	No	
	Total Ammonia	38	-0.498	0.622	No	
	Total Nitrate	21	0.619	0.544	No	
	Total Phosphorus	40	1.039	0.306	No	
	Total Organic Carbon	56	2.781	0.007	Yes	↓
	Total Hardness	53	1.052	0.298	No	
	Chloride	132	4.154	<0.001	Yes	↓
	Sulfate	116	3.595	<0.001	Yes	↓
	Turbidity	48	1.685	0.099	No	

Table A.5: *Summary of statistical analysis for Segment 1605*

Segment 1605: Navidad River above Lake Texana						
AU	**Parameter**	**# of Data Points**	**T-stat**	**p-value**	**Significant Trend**	**Trend Direction**
Middle 16.5 miles of the segment from the confluence with Sandies Creek upstream to the confluence of Sandy Branch						
1605_02	Temperature	37	1.213	0.233	No	
	Specific Conductance	37	0.293	0.771	No	
	Dissolved Oxygen	37	0.949	0.349	No	
	pH	37	5.842	<0.001	Yes	↓
	Alkalinity	37	0.521	0.605	No	
	Total Dissolved Solids	37	-0.023	0.981	No	
	Total Phosphorus	37	-0.270	0.789	No	
	Total Organic Carbon	36	0.143	0.887	No	
	Total Hardness	36	0.933	0.358	No	
	Chloride	36	-1.120	0.271	No	
	Sulfate	37	0.503	0.618	No	
	Turbidity	37	-0.457	0.650	No	
Lower 31 miles of segment from the confluence with Lake Texana upstream to the confluence of Sandies Creek						
1605_03	Temperature	164	1.548	0.124	No	
	Discharge	144	0.654	0.514	No	
	Specific Conductance	149	3.167	0.002	Yes	↓
	Dissolved Oxygen	165	1.285	0.201	No	
	pH	166	10.96	<0.001	Yes	↑
	Alkalinity	60	2.158	0.351	Yes	↓
	Total Dissolved Solids	50	2.571	0.013	Yes	↓
	Total Phosphorus	41	2.514	0.016	Yes	↓
	Total Organic Carbon	58	2.460	0.017	Yes	↓
	Total Hardness	57	1.447	0.154	No	
	Chloride	58	2.044	0.046	Yes	↓
	Sulfate	41	-0.693	0.492	No	
	Turbidity	50	1.110	0.272	No	

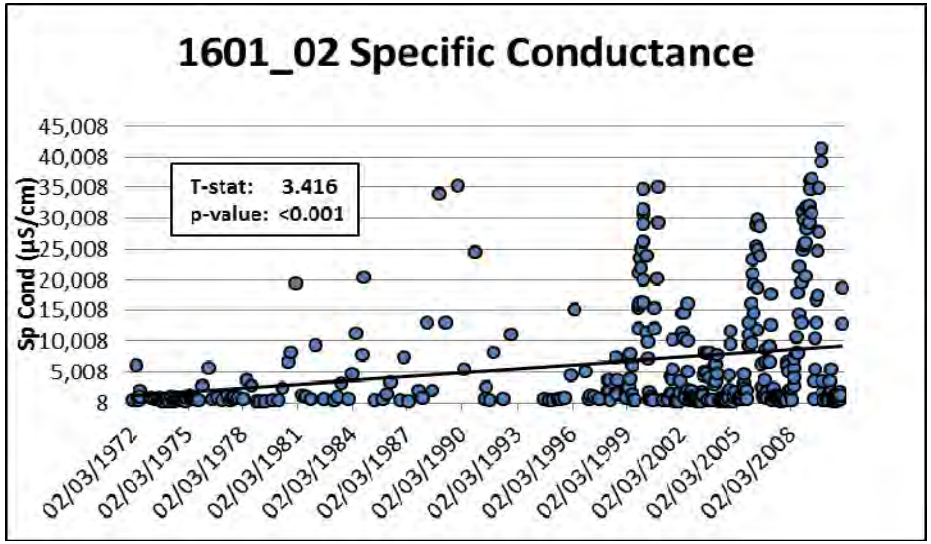
AU 1605_01 – The upper 14.5 miles of the segment from the confluence of Sandy Branch to the confluence of East and West Navidad Rivers did not have enough data for trend analysis

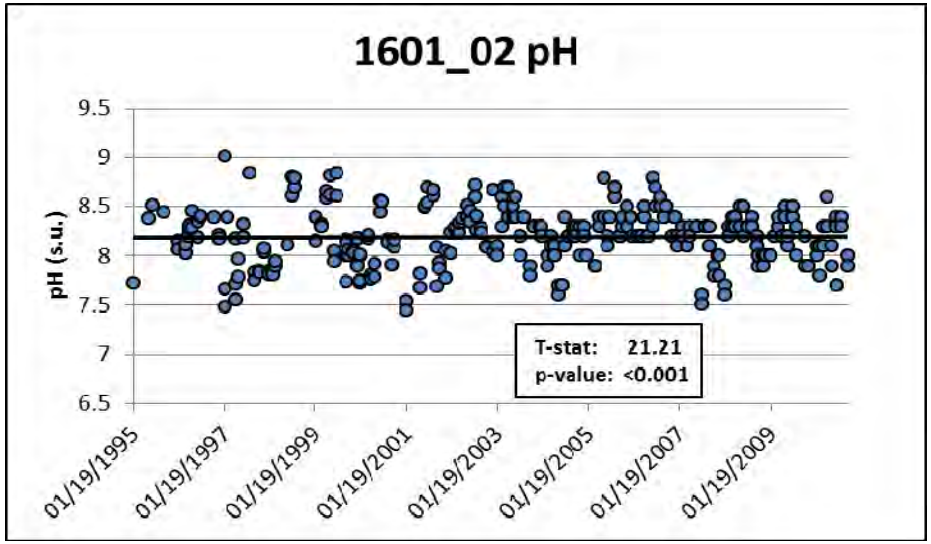
Appendix B:

Statistically Significant Trends

Segment 1601: Lavaca River Tidal

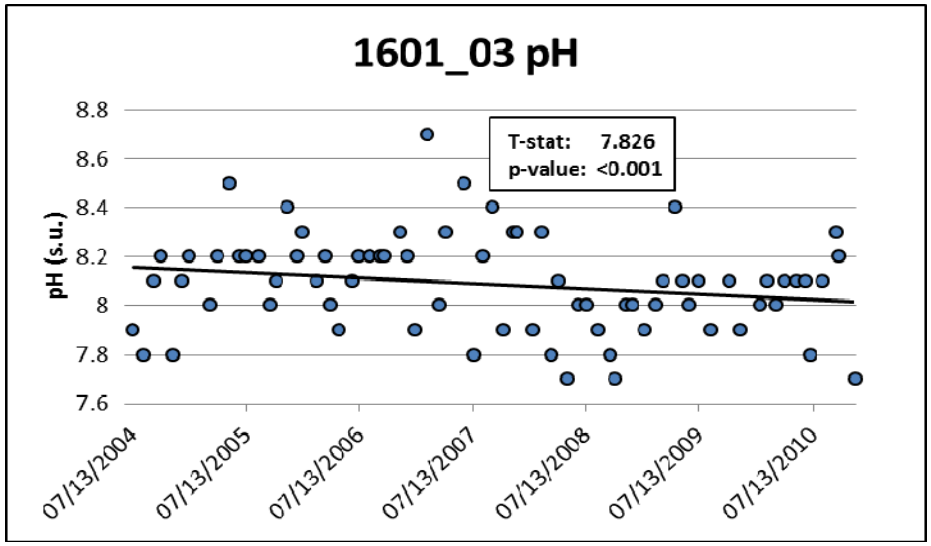
Upstream segment to confluence with the Navidad River

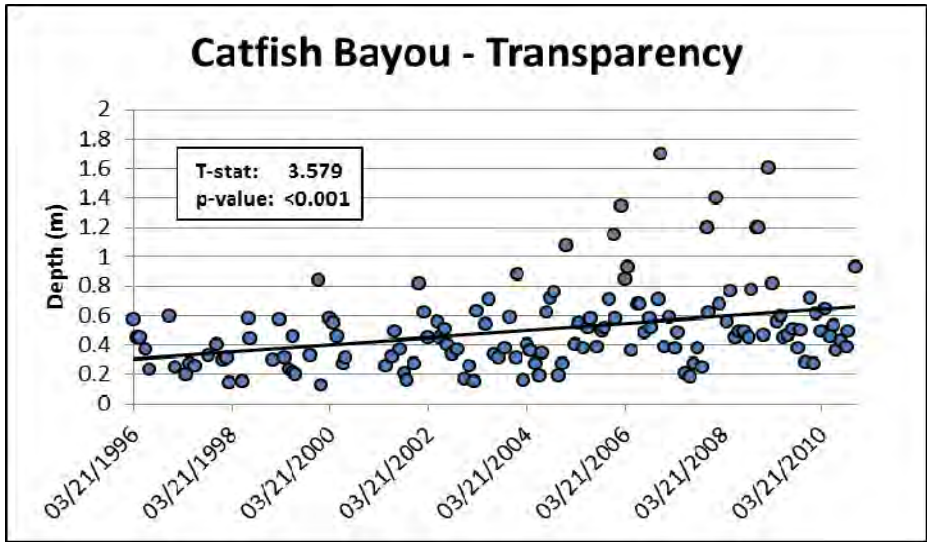




Segment 1601A: Catfish Bayou

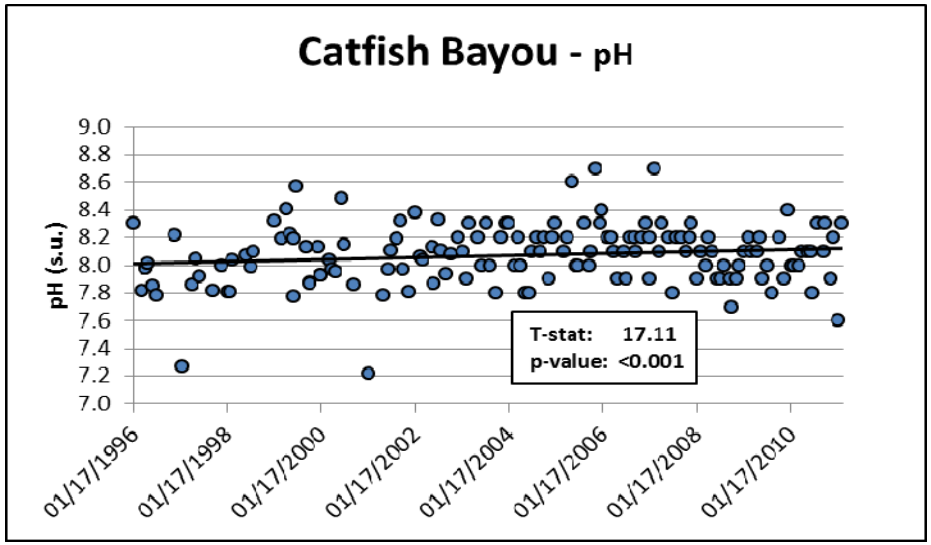
Entire Segment





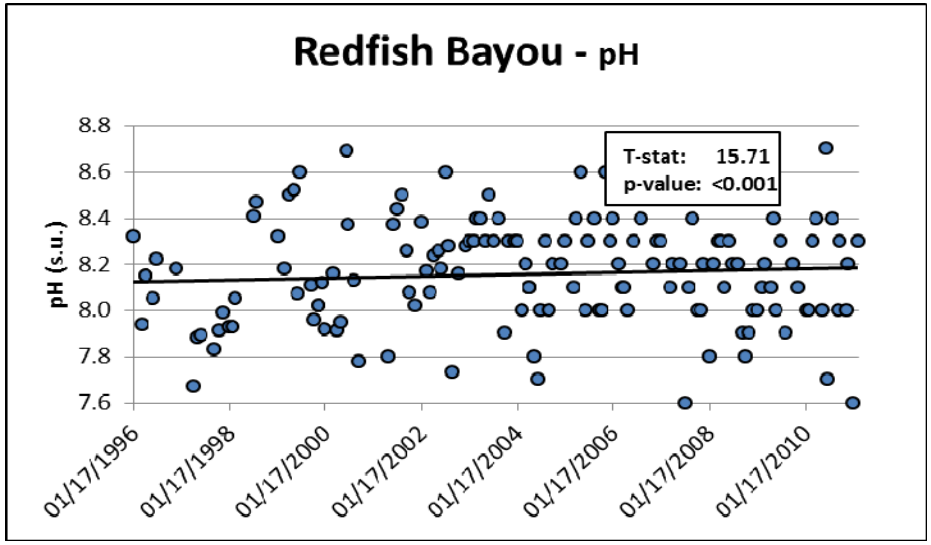
Segment 1601A: Catfish Bayou

Entire Segment



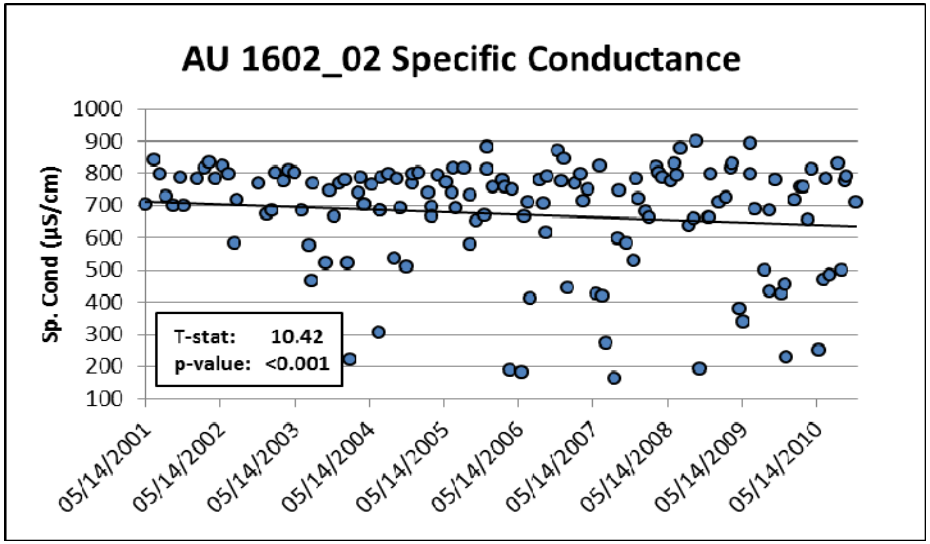
Segment 1601B: Redfish Bayou

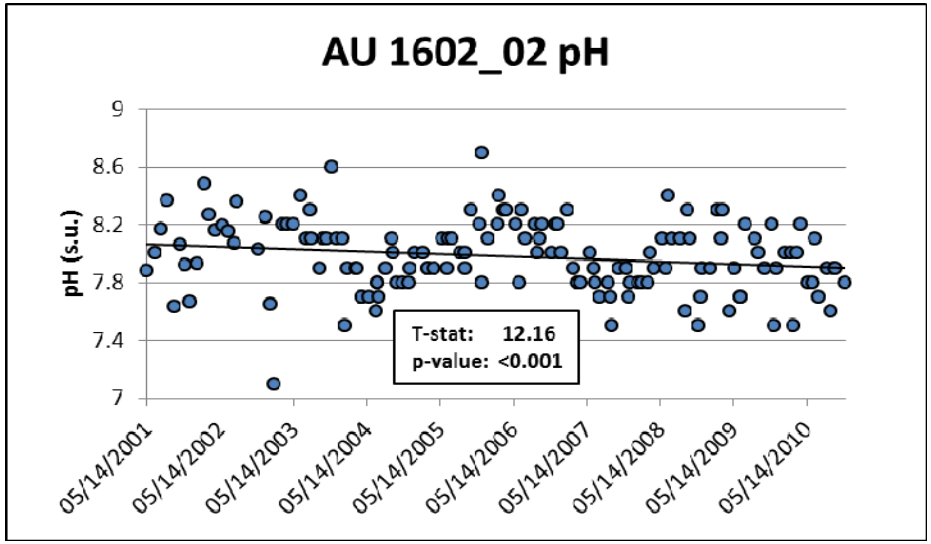
Entire Segment



Segment 1602: Lavaca River Above Tidal

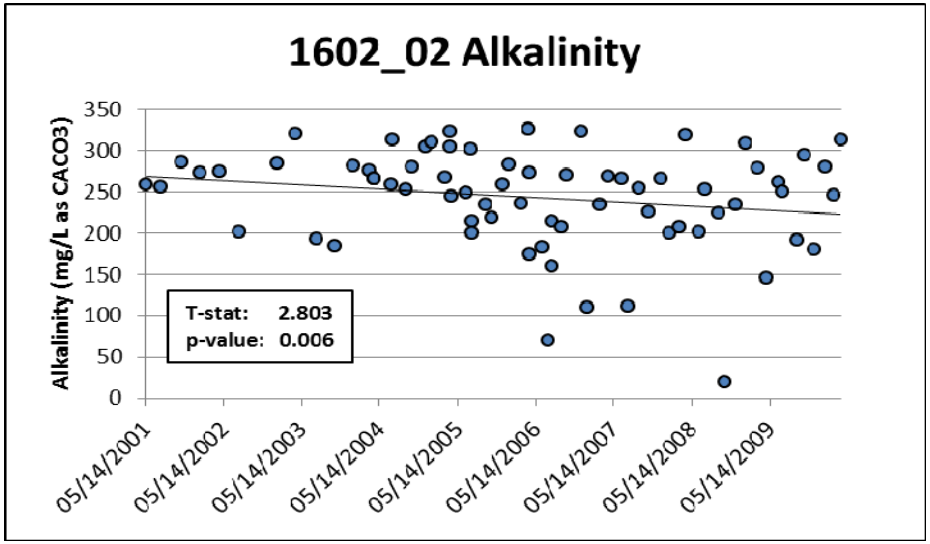
From 5.3 miles downstream of US 59 to 3.4 miles upstream of SH 94 in Lavaca County

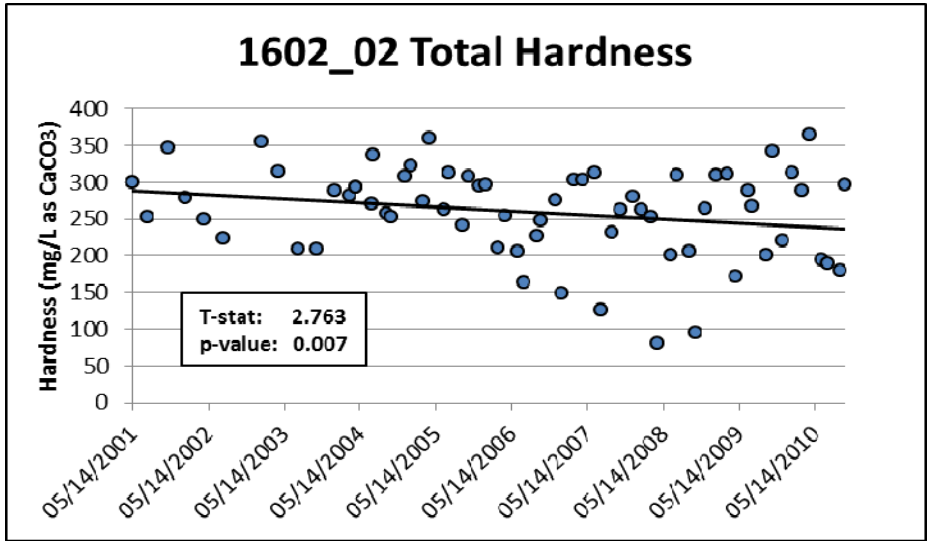


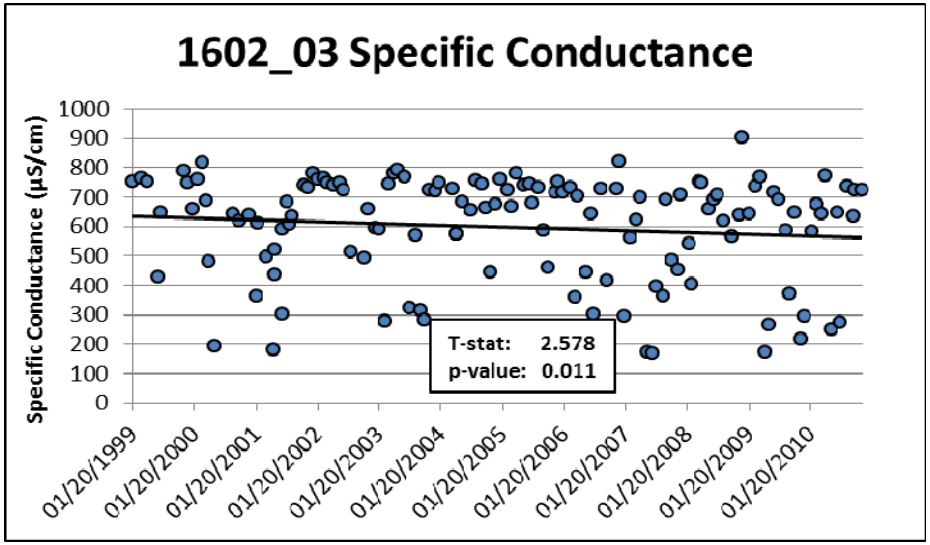


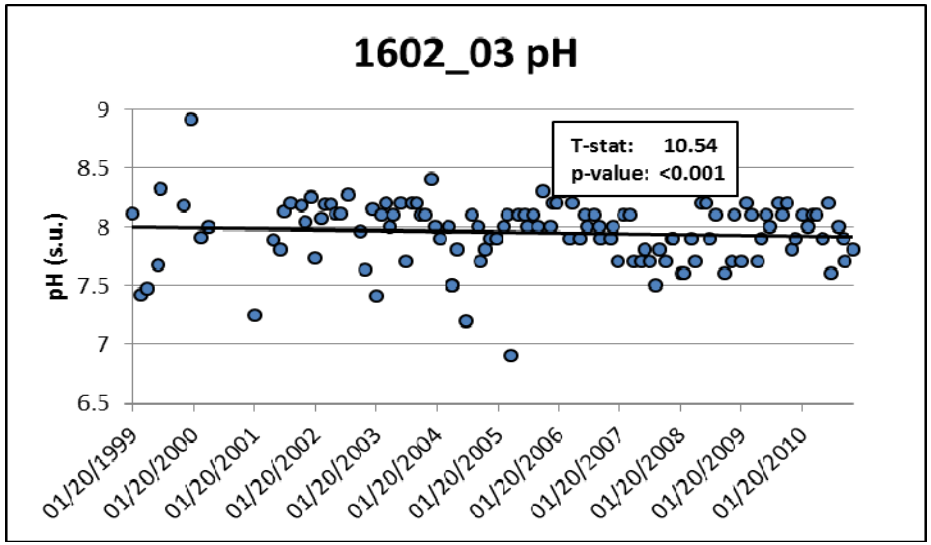
Segment 1602: Lavaca River Above Tidal

From 5.3 miles downstream of US 59 to 3.4 miles upstream of SH 94 in Lavaca County



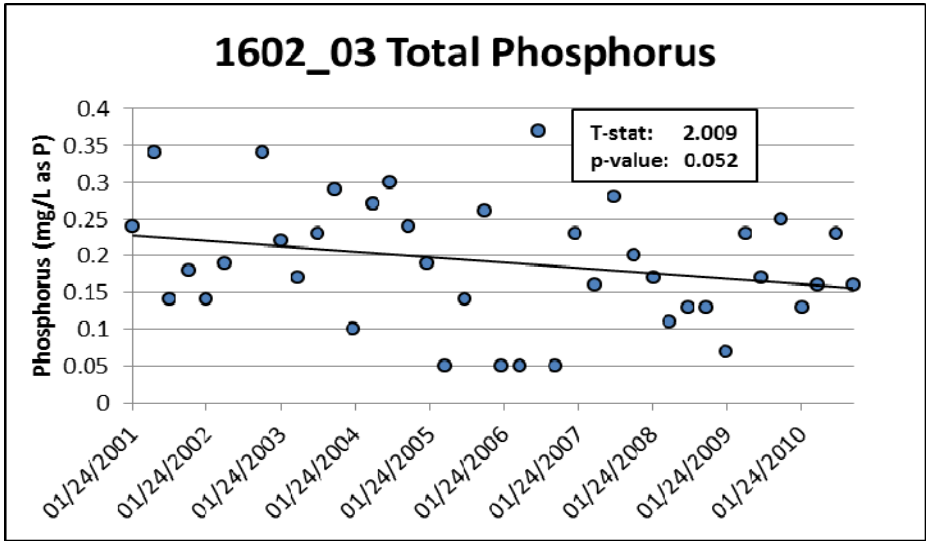


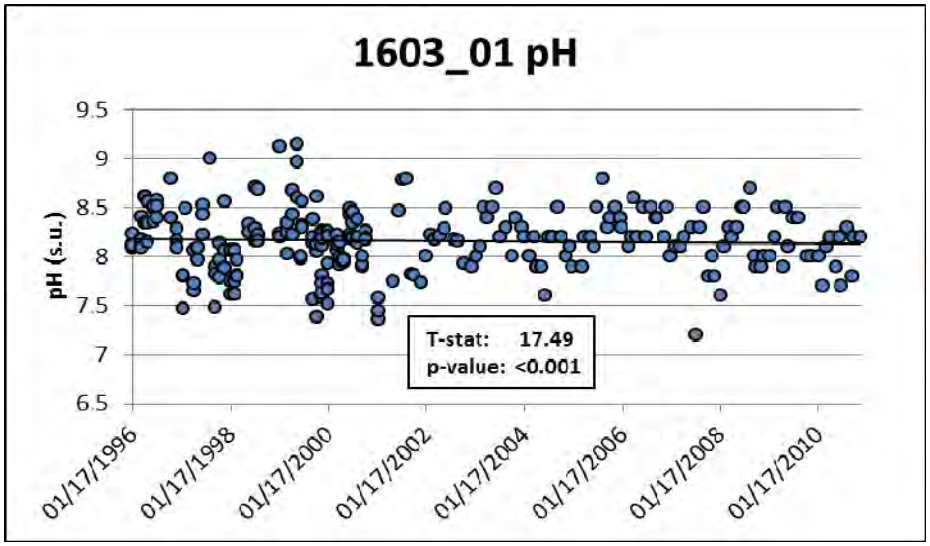




Segment 1602: Lavaca River Above Tidal

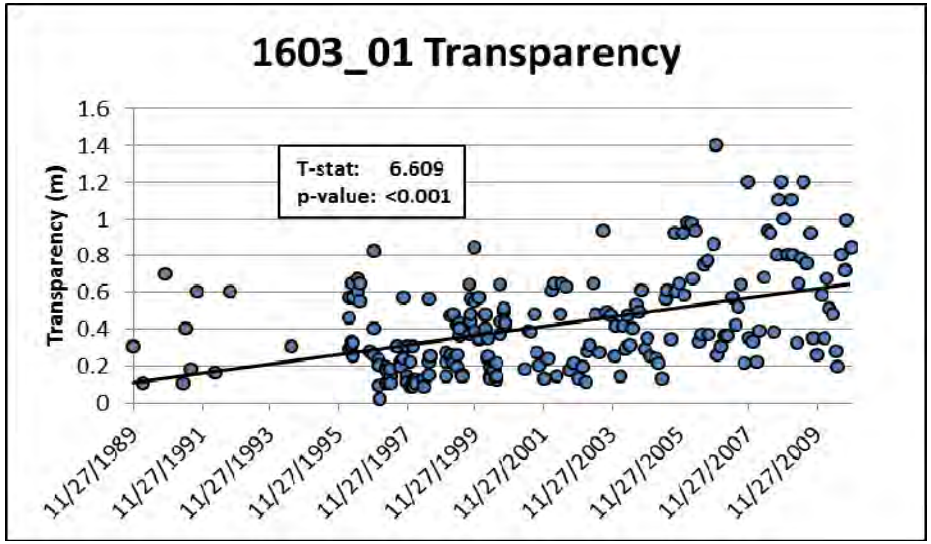
Continued

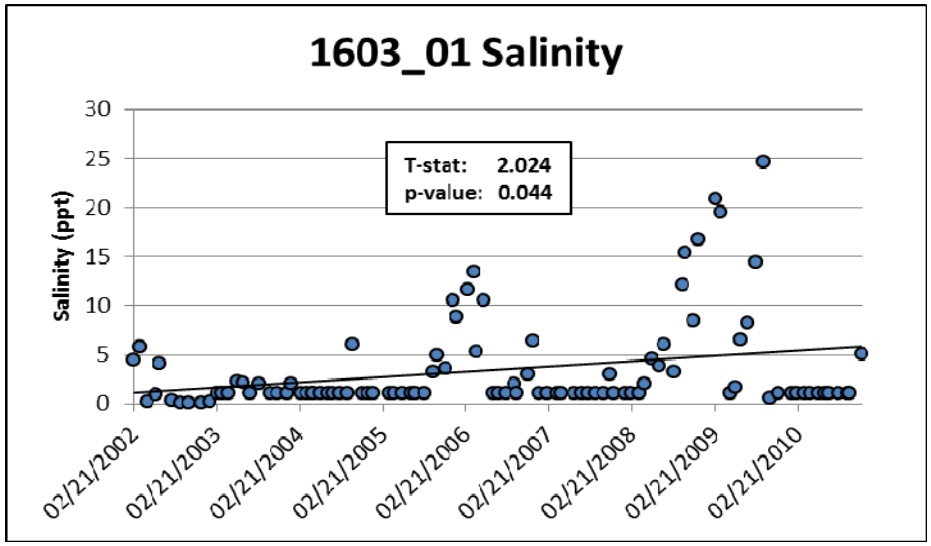




Segment 1603: Navidad River Tidal

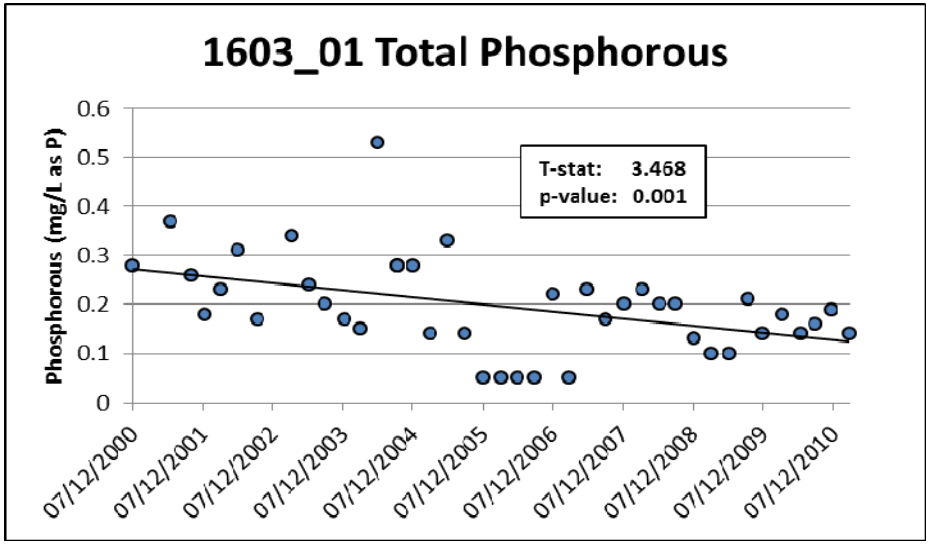
Entire Segment

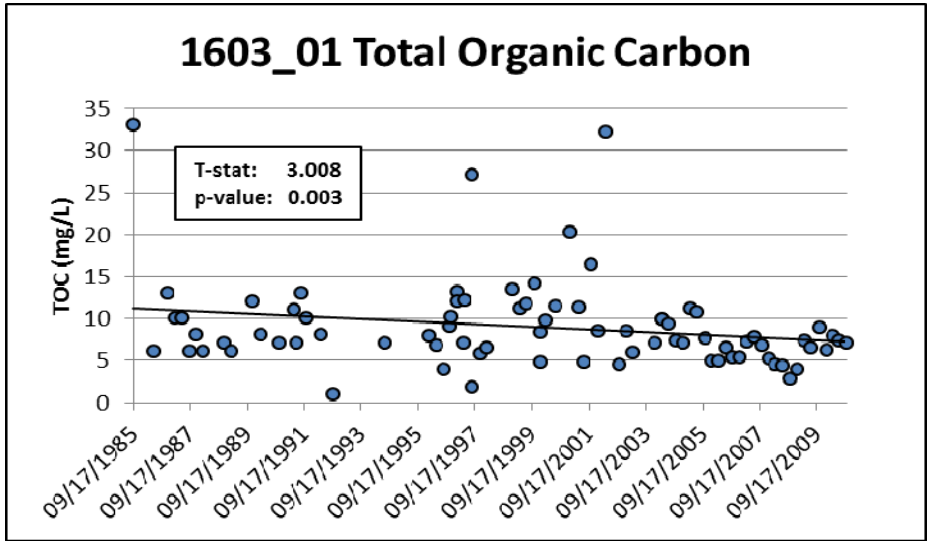




Segment 1603: Navidad River Tidal

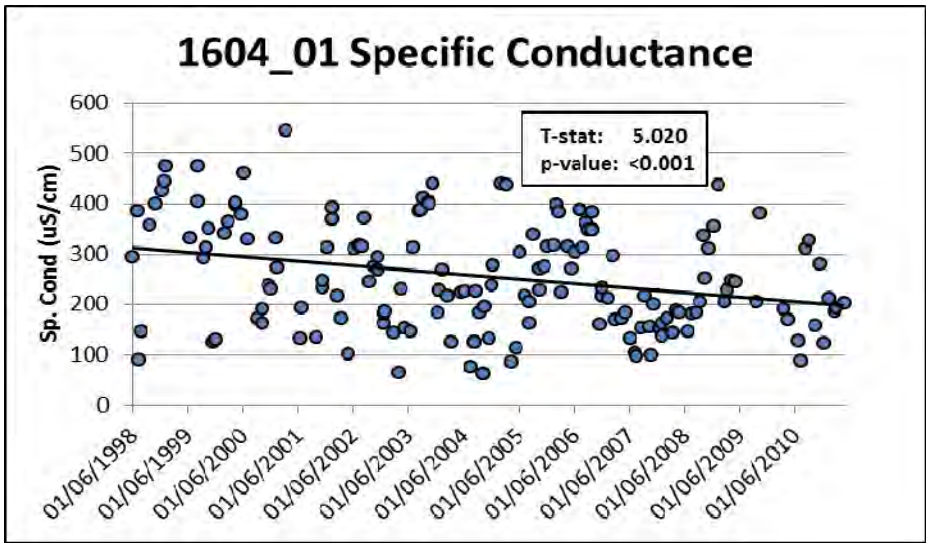
Entire Segment

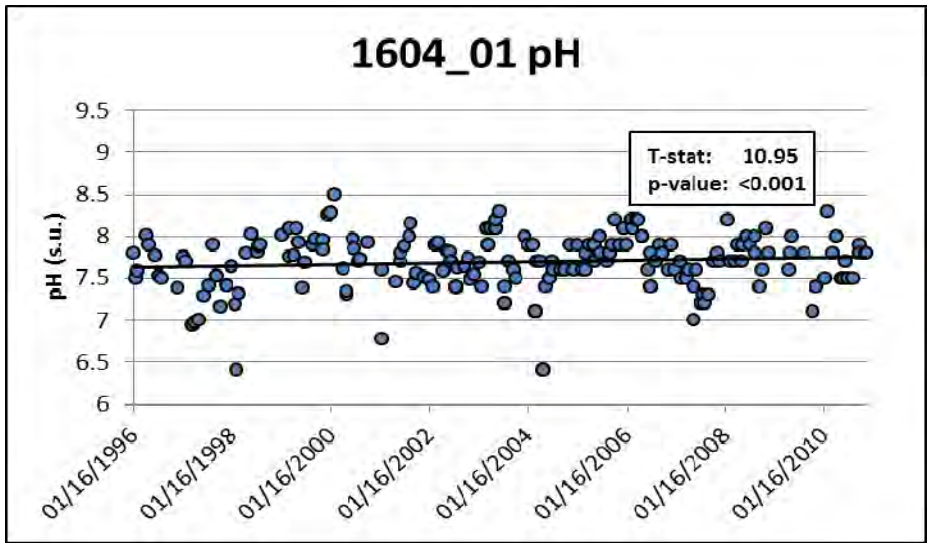




Segment 1604: Lake Texana

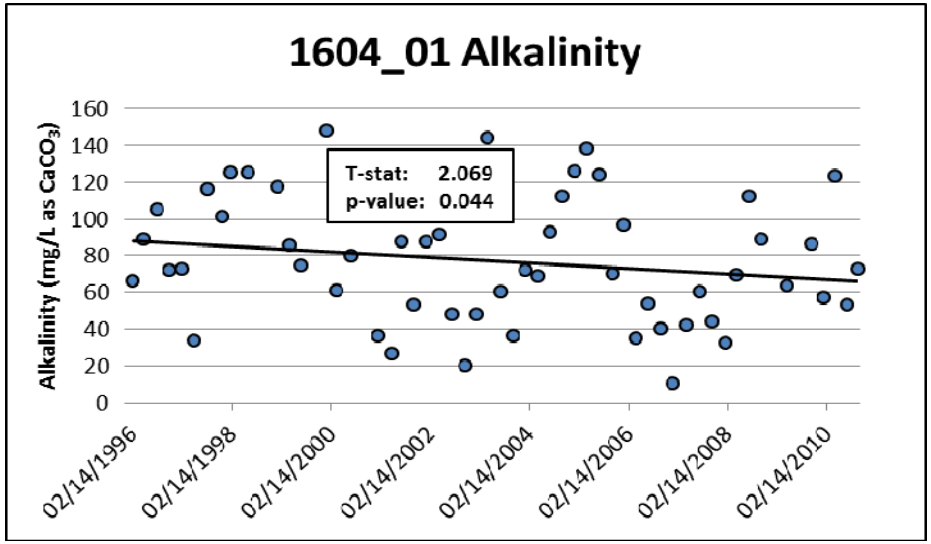
From Palmetto Bend Dam to a point 100 meters downstream of FM 530, up to 44 ft. elevation

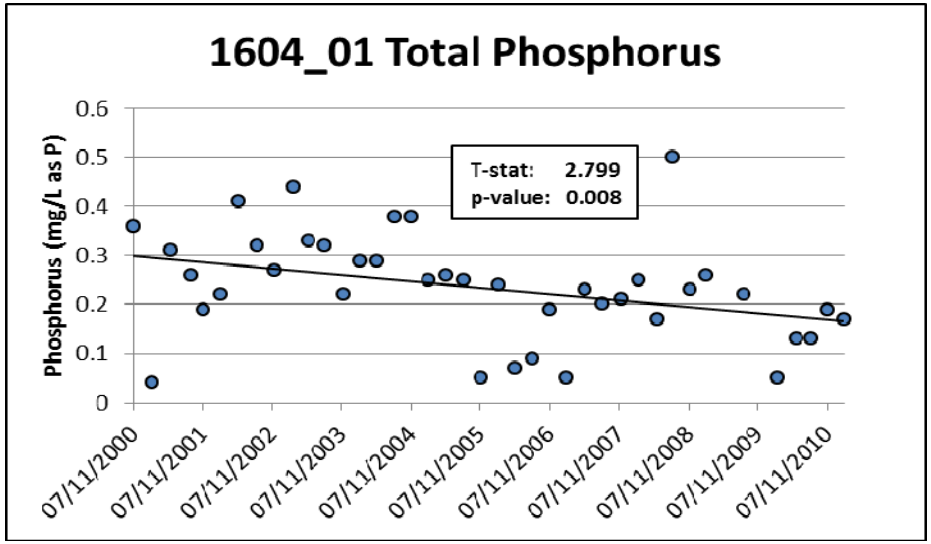


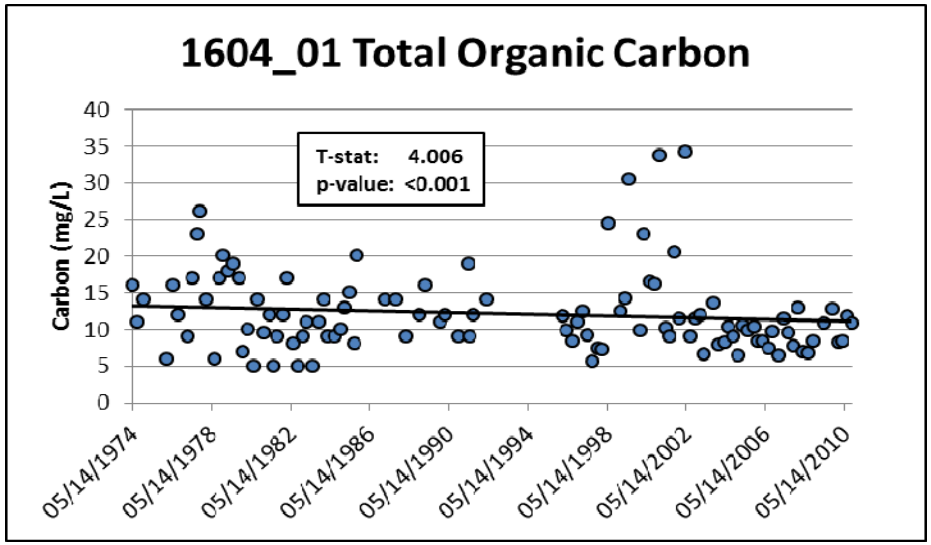


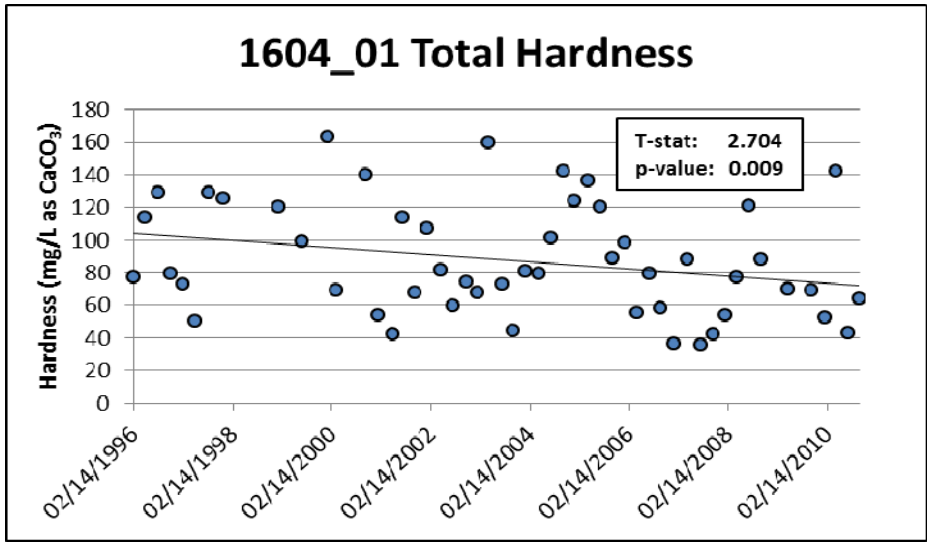
Segment 1604: Lake Texana

From Palmetto Bend Dam to a point 100 meters downstream of FM 530, up to 44 ft. elevation









Segment 1604: Lake Texana

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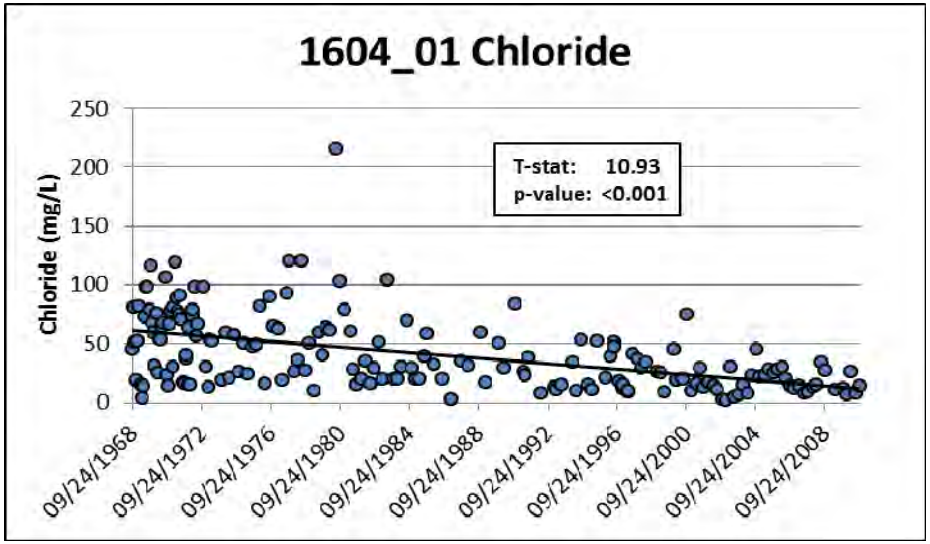

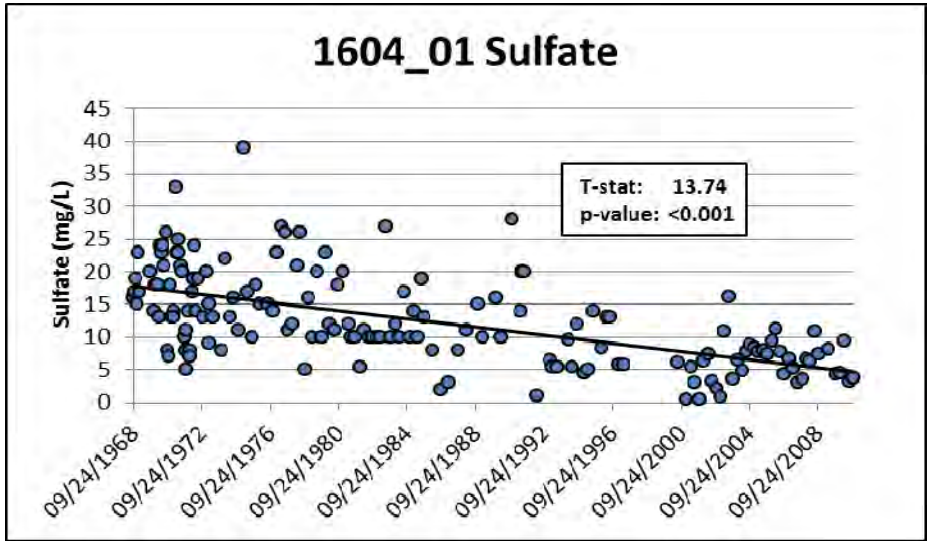

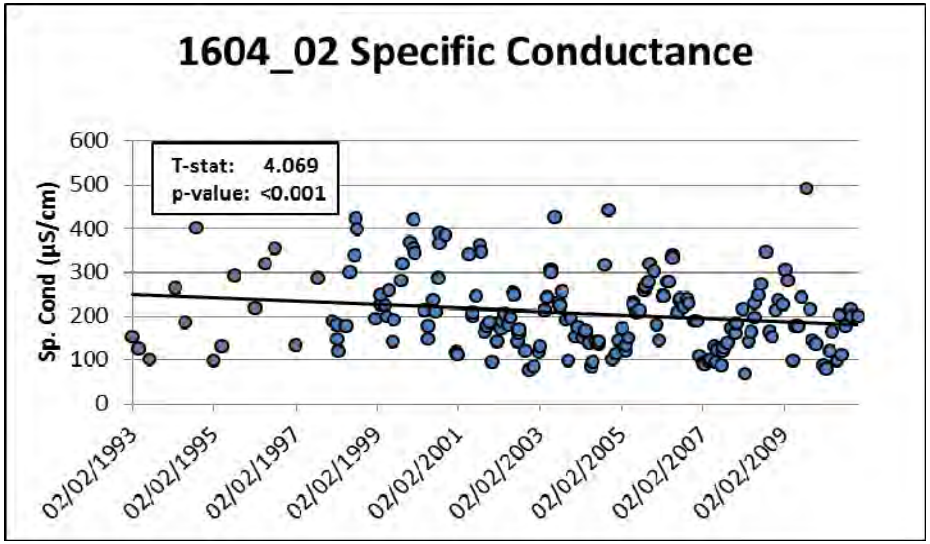

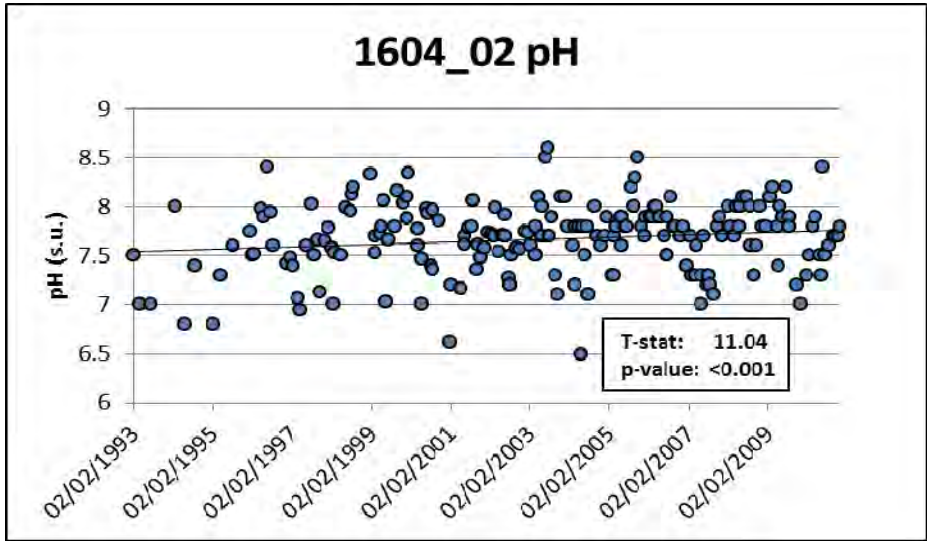

Segment 1604: Lake Texana

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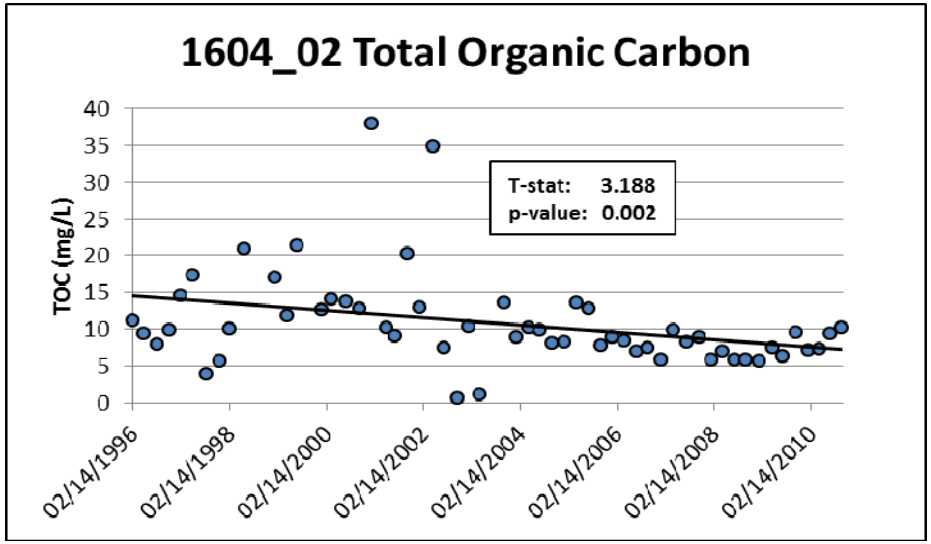

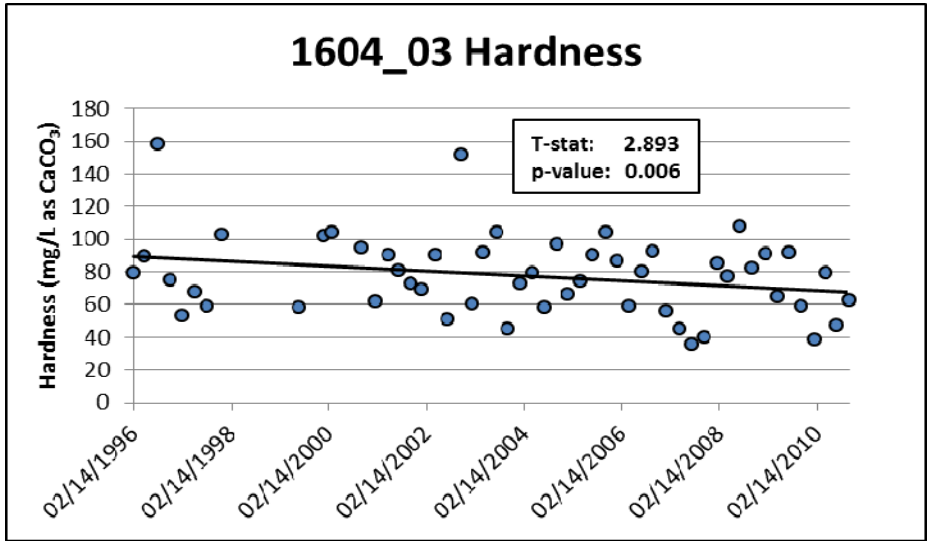

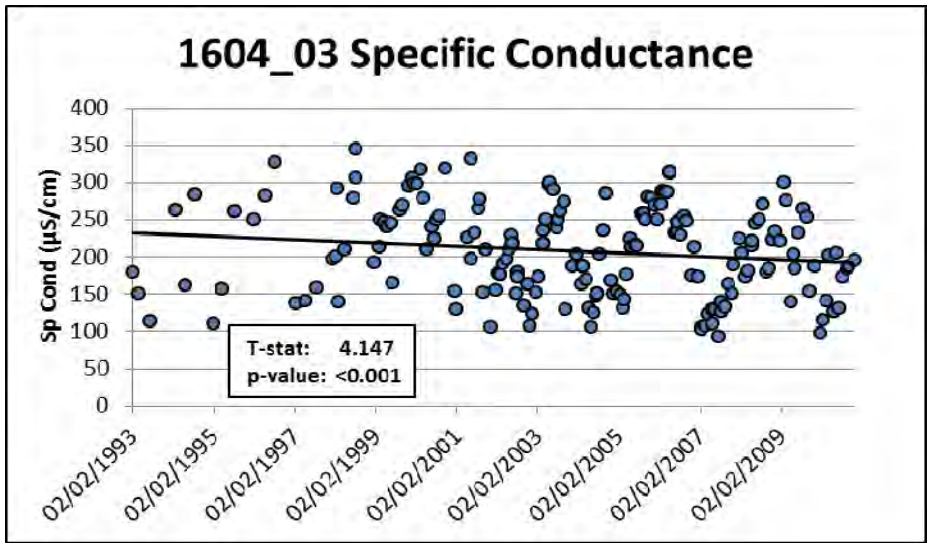

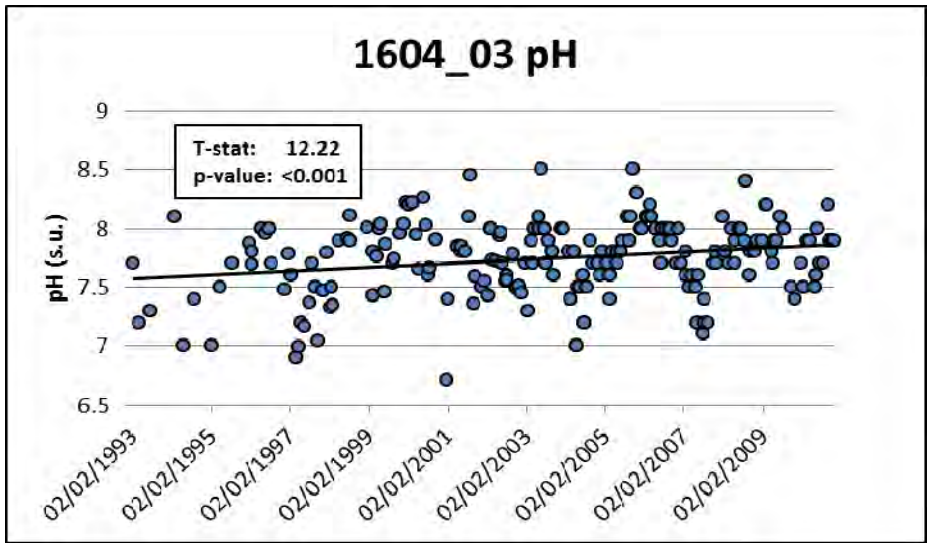

Segment 1604: Lake Texana

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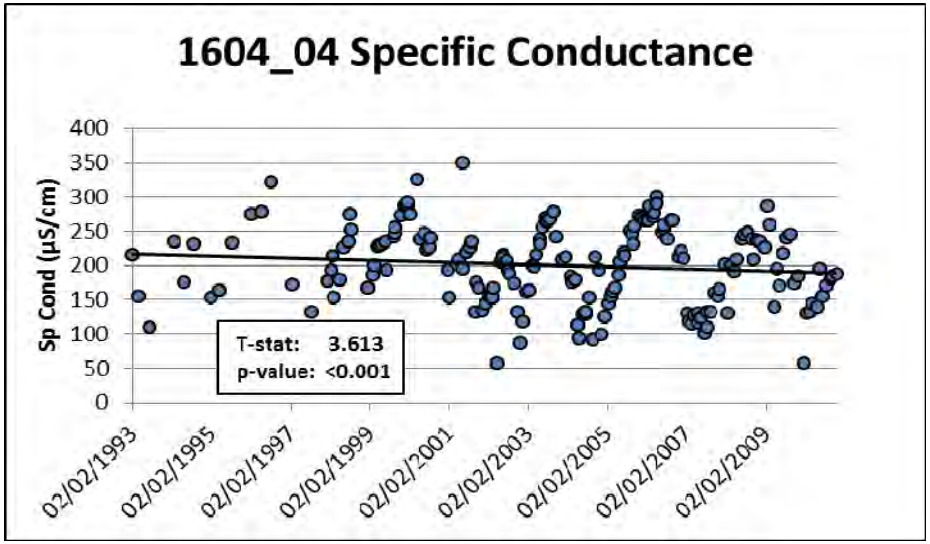

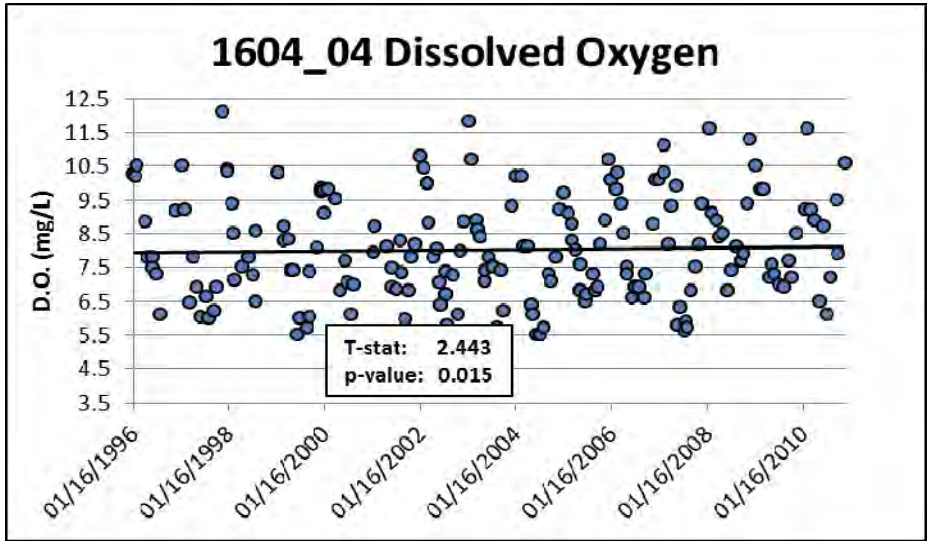

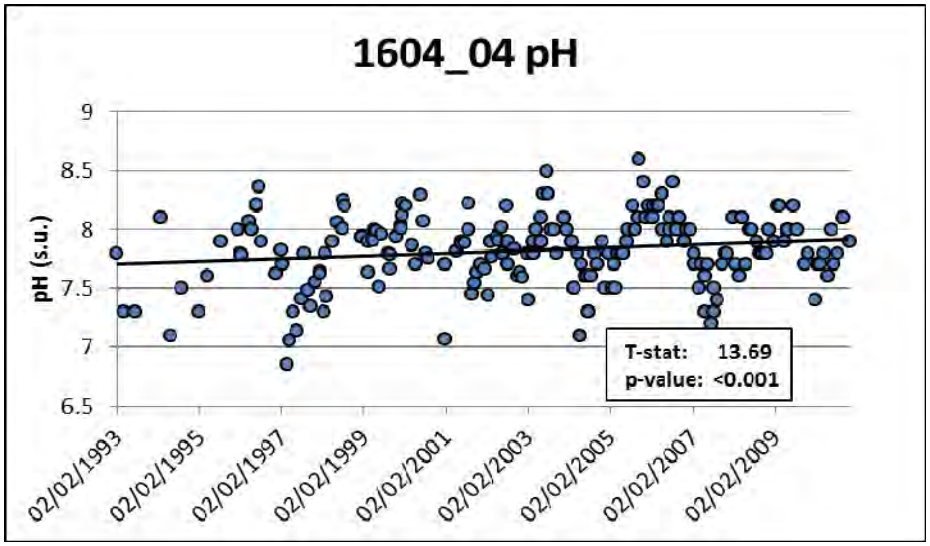

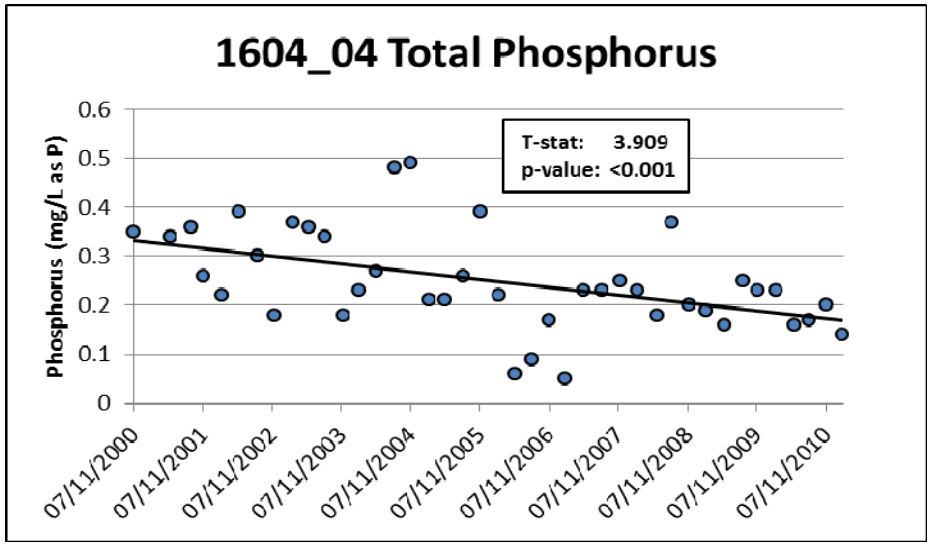

Segment 1604: Lake Texana

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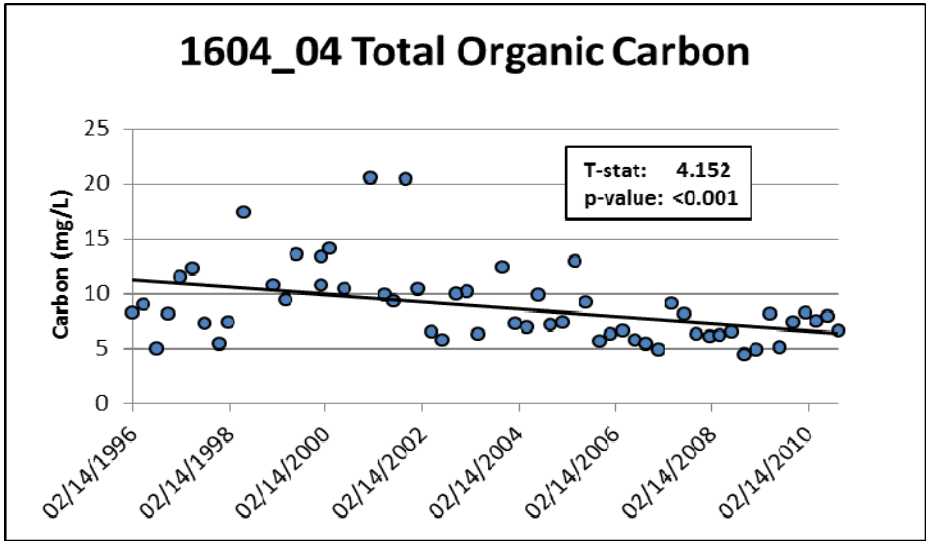

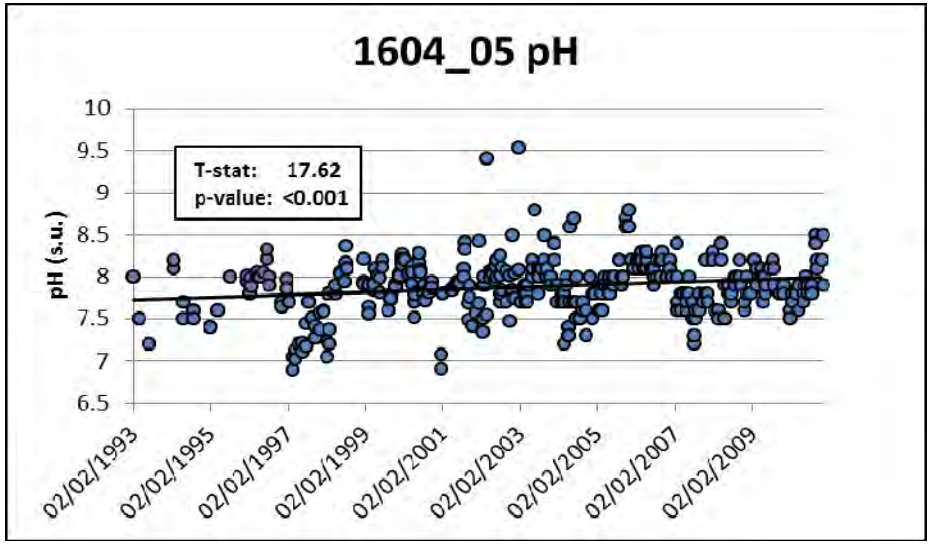

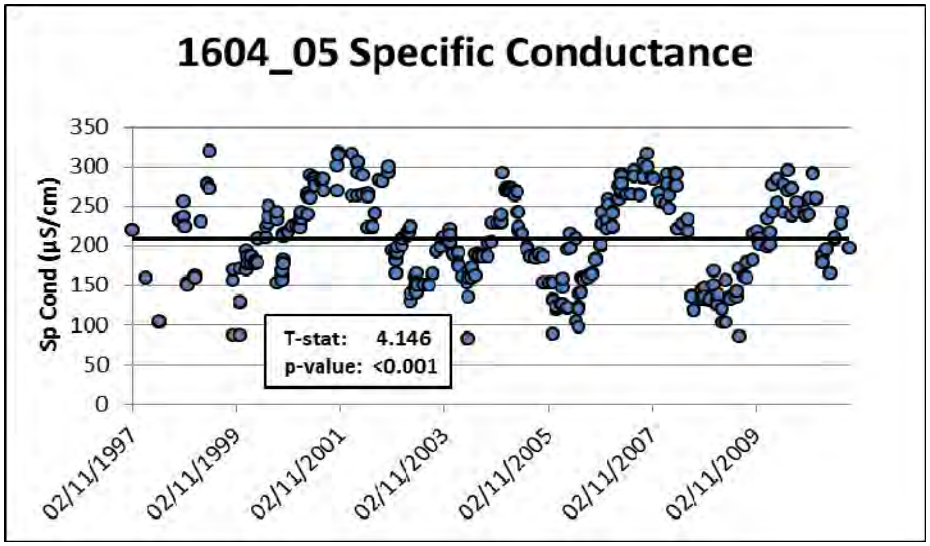

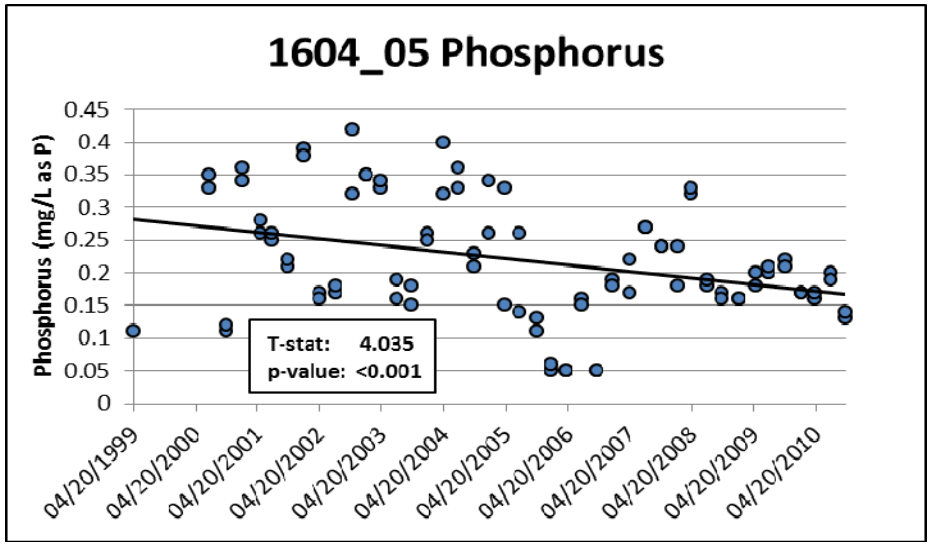

Segment 1604: Lake Texana

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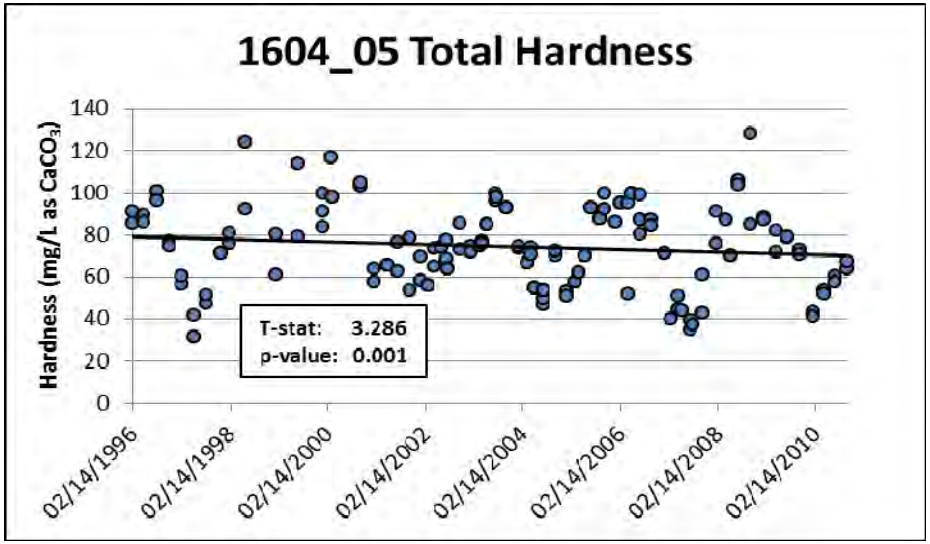
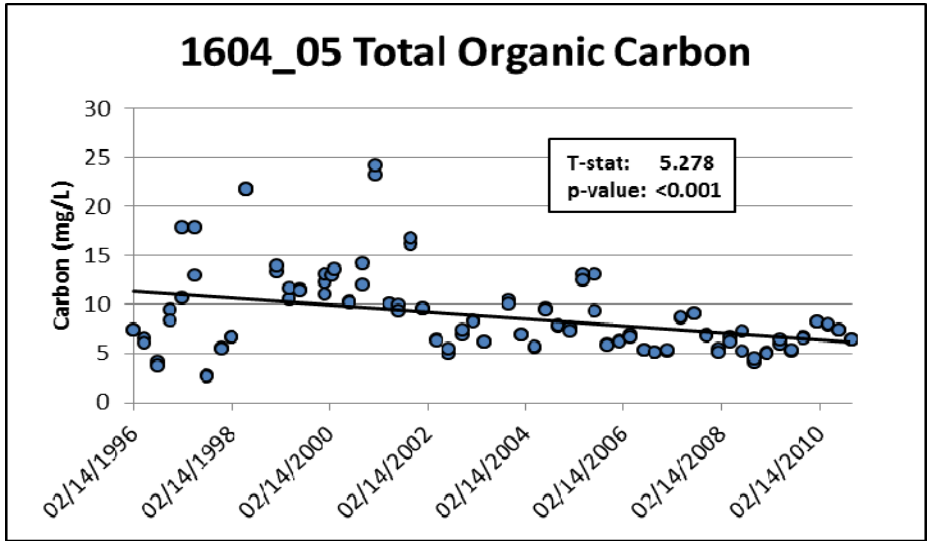
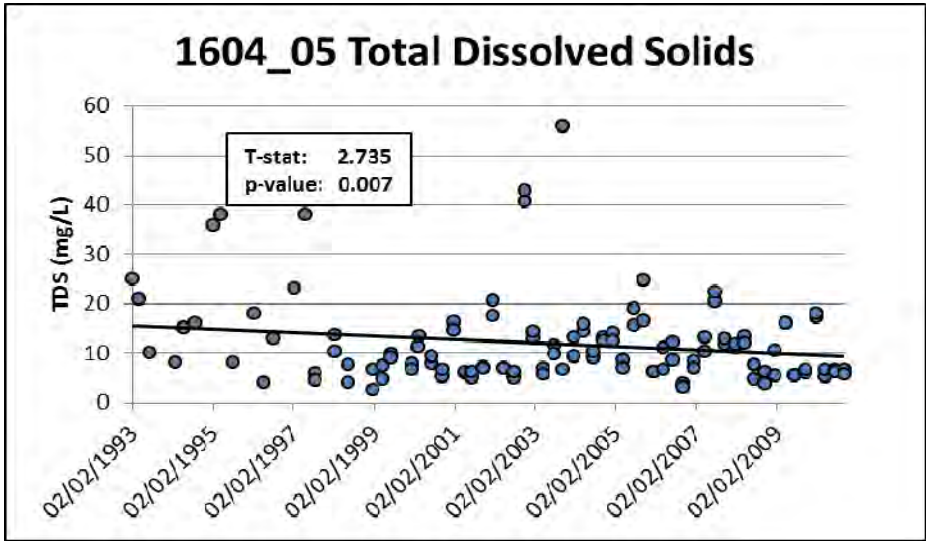
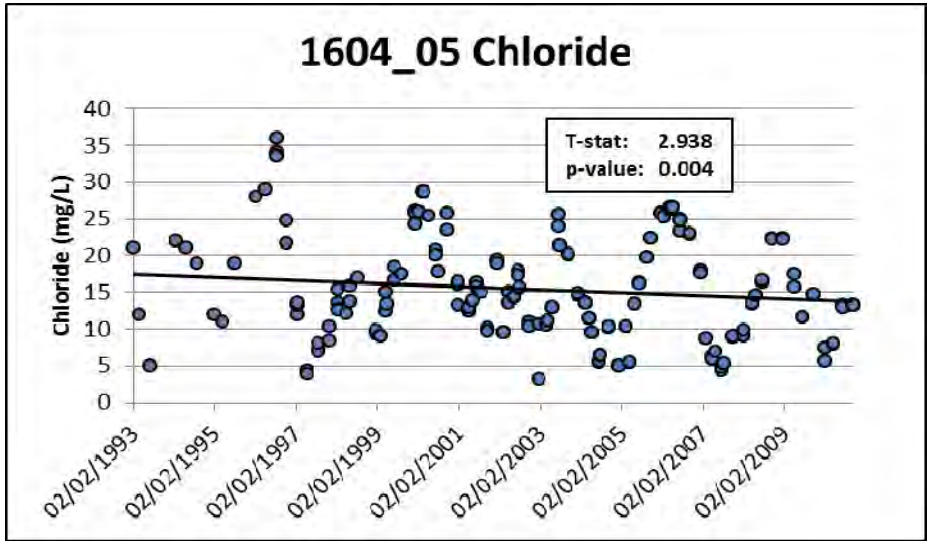


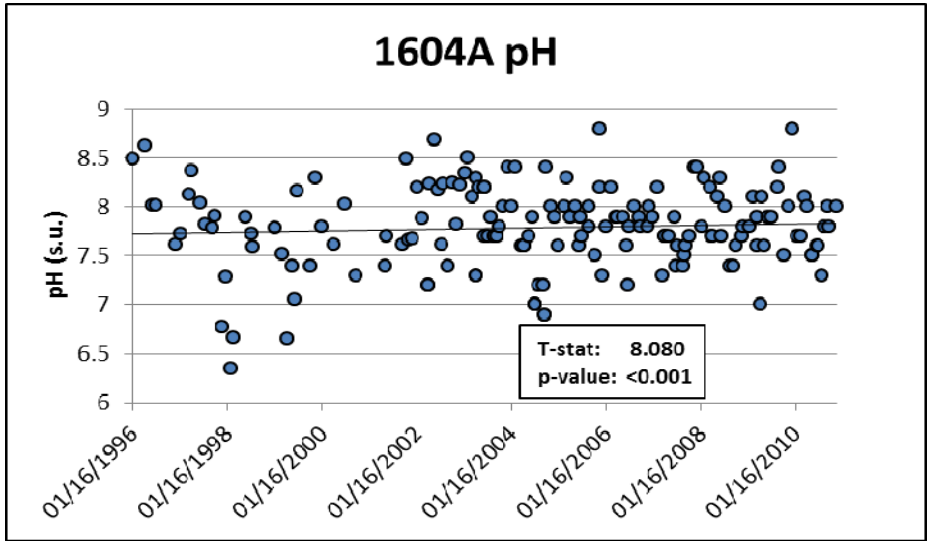


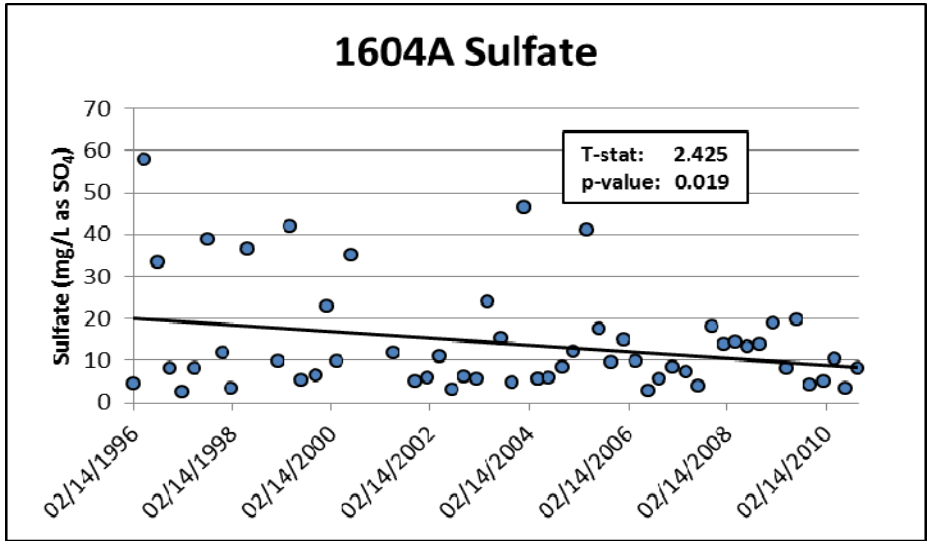




Segment 1604A: East Mustang Creek

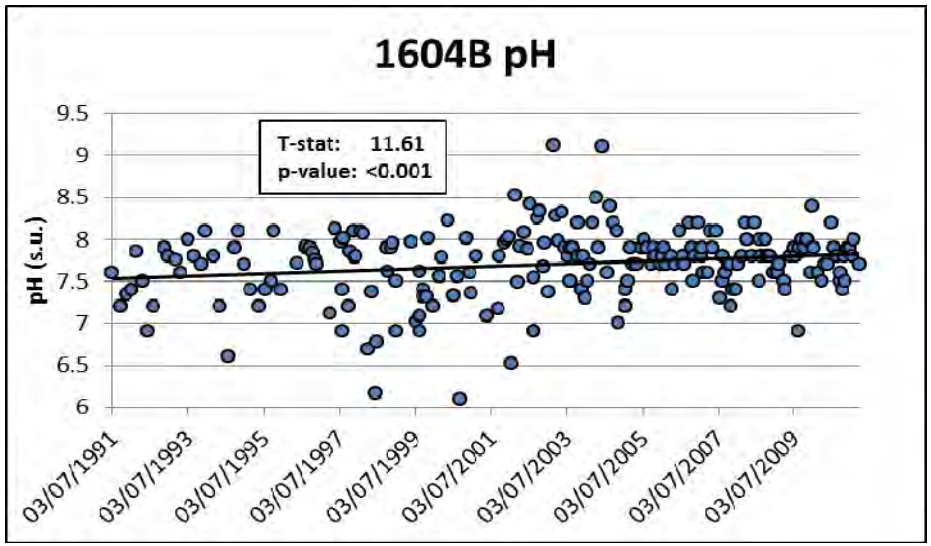
Middle Mustang Creek upstream 4.2 kilometers upstream of US 59

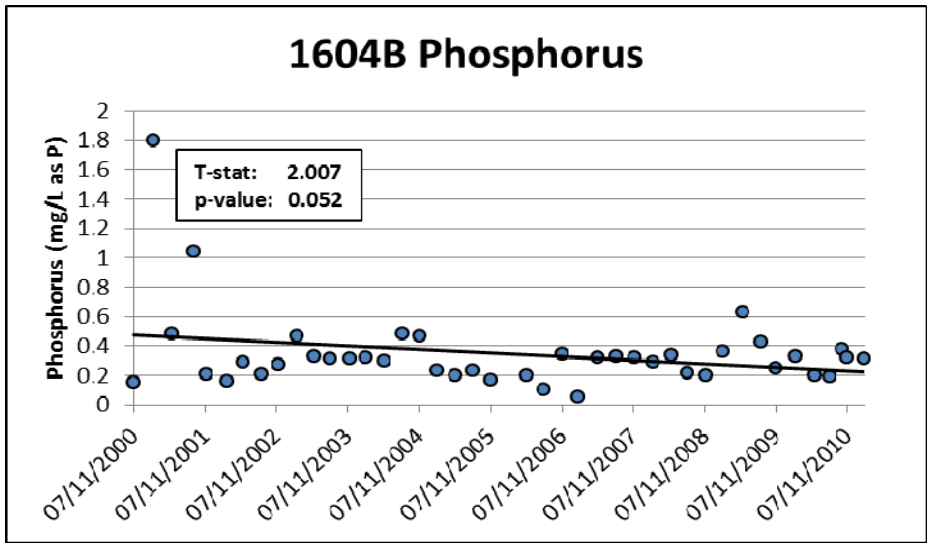




Segment 1604B: West Mustang Creek

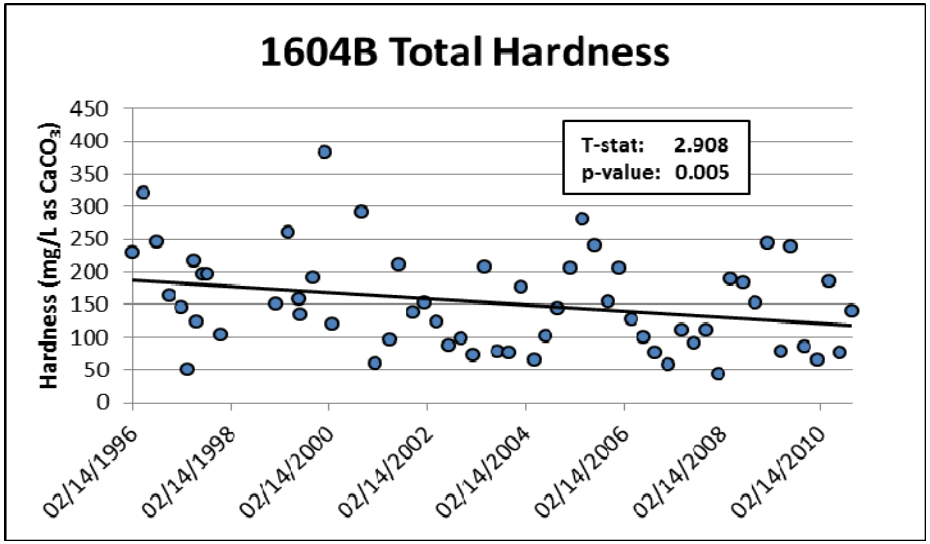
South-central Colorado County to its confluence with the East Branch

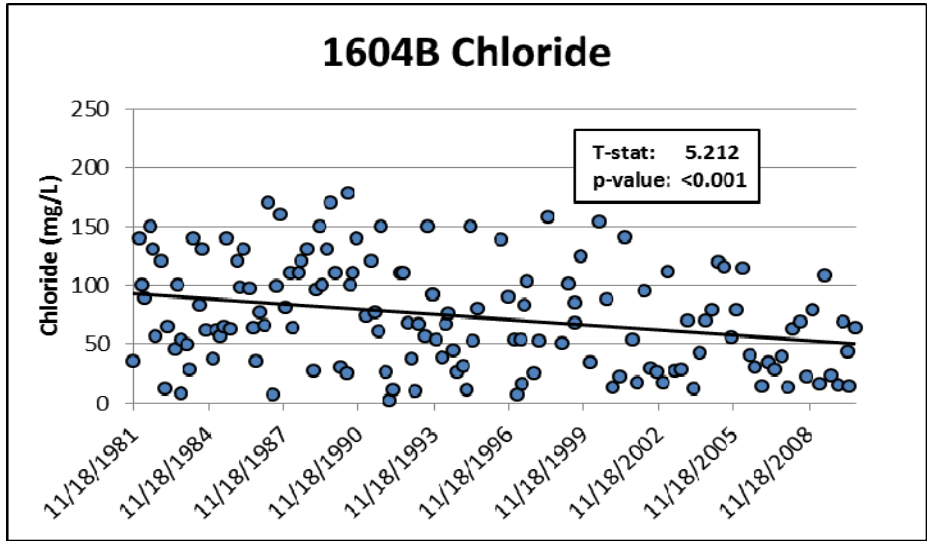


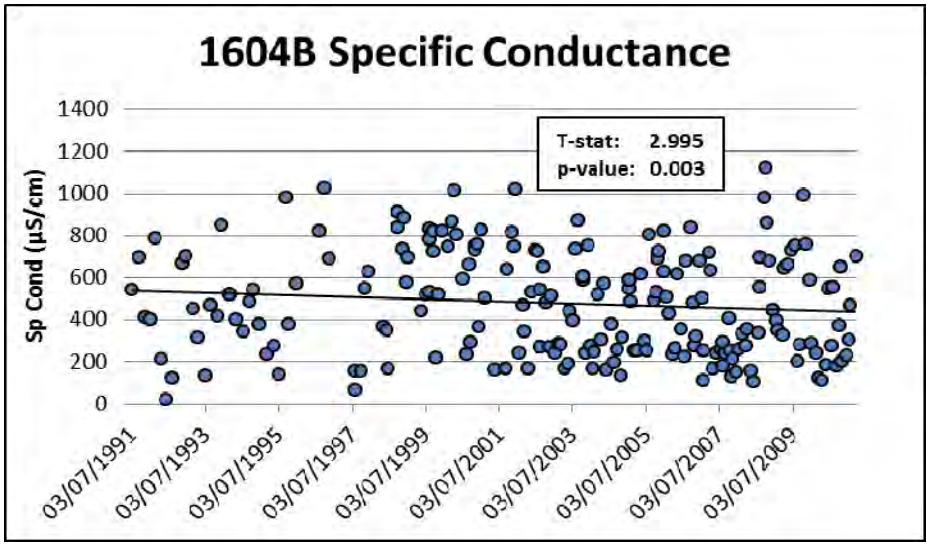


Segment 1604B: West Mustang Creek

(Continued)

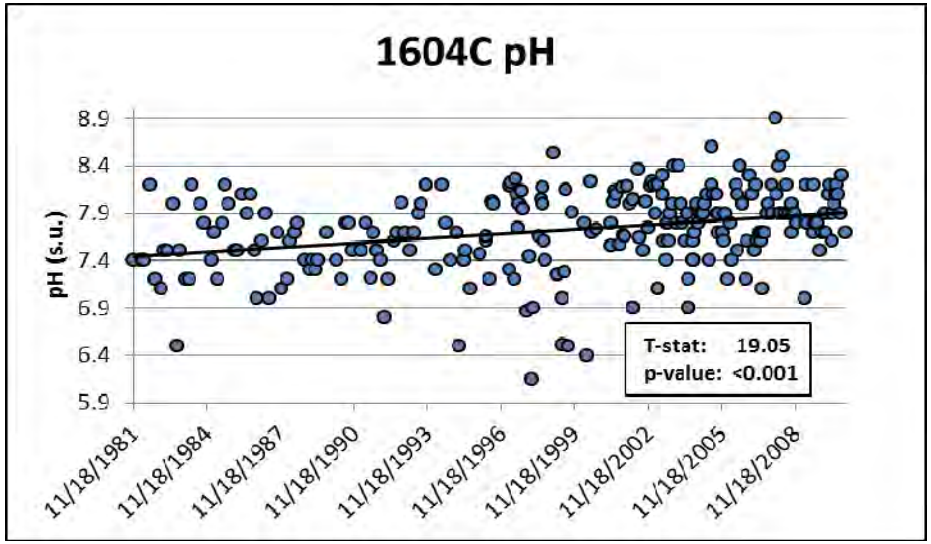


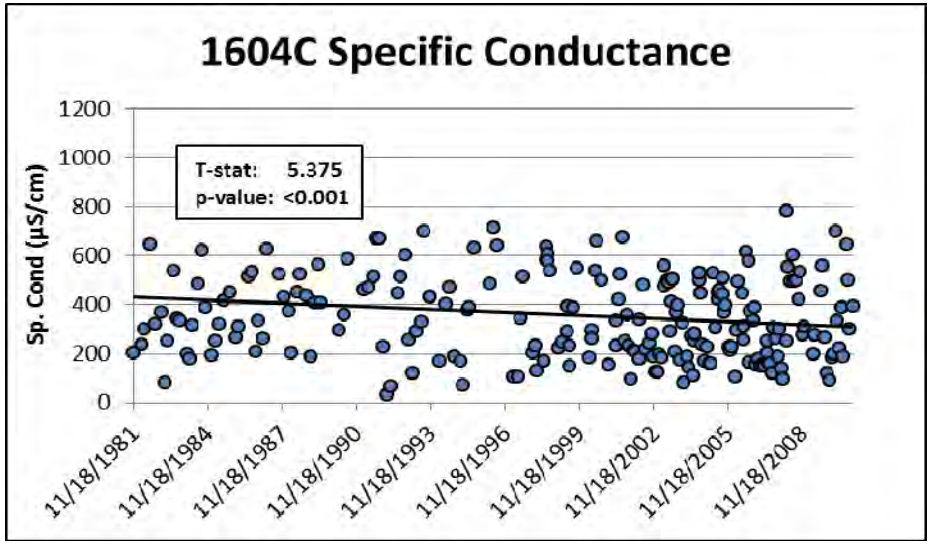




Segment 1604C: Sandy Creek

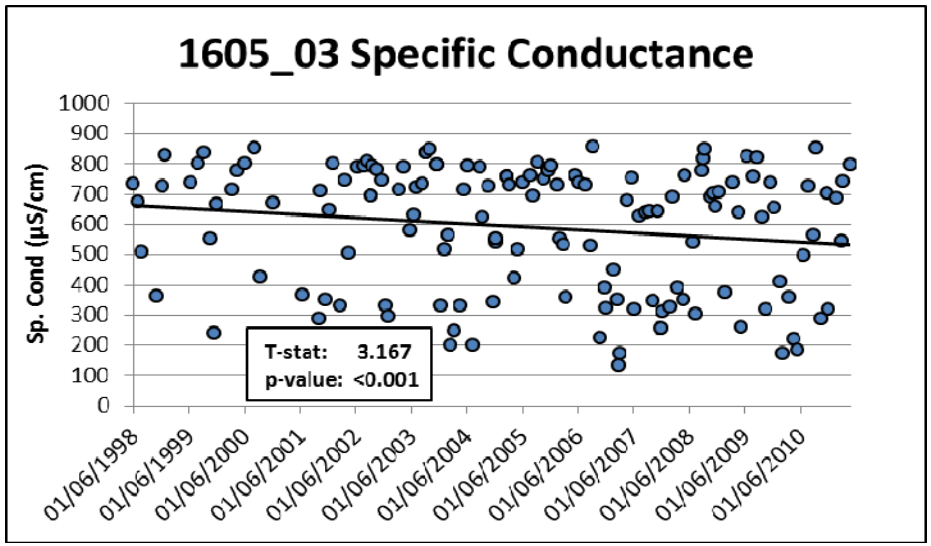
Entire Segment

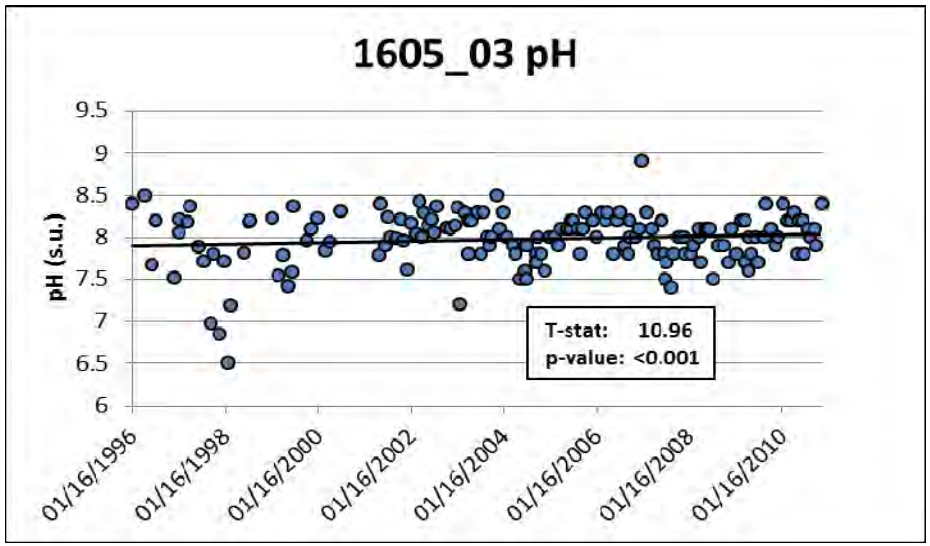




Segment 1605: Navidad River above Lake Texana

From 100 meters downstream of FM 530 to the confluence of the East Navidad River and West Navidad River





Appendix C:
Fish Species List

Table C.1: *Fish species identified in the Lavaca – Navidad River Basin and habitat where collected*

Common Name	Scientific Name	Habitat
Black Bullhead catfish	*Ameiurus melas*	slackwater/backwater/pools
Yellow Bullhead catfish	*Ameiurus natalis*	slackwater/backwater/pools
American eel	*Anguilla rostrata*	deep runs
Pirate perch	*Aphredoderus sayanus*	slackwater/backwater/pools
Freshwater Drum	*Aplodinotus grunniens*	deep runs
Alligator gar	*Atractosteus spatula*	slackwater/backwater/pools
River carpsucker	*Carpiodes carpio*	slackwater/backwater/pools
Red Shiner	*Cyprinella lutrensis*	shallow runs
Blacktail Shiner	*Cyprinella venusta*	shallow runs
Gizzard Shad	*Dorosoma cepedianum*	slackwater/backwater/pools
Threadfin Shad	*Dorosoma petenense*	slackwater/backwater/pools
Slough darter	*Etheostoma gracile*	slackwater/backwater/pools
Mosquito fish	*Gambusia affinis*	slackwater/backwater/pools
Blue catfish	*Ictalurus furcatus*	deep runs
Channel catfish	*Ictalurus punctatus*	deep runs
Smallmouth Buffalo	*Ictiobus bubalus*	slackwater/backwater/pools
Spotted Gar	*Lepisosteus oculatus*	slackwater/backwater/pools
Longnose Gar	*Lepisosteus osseus*	slackwater/backwater/pools
Redbreast Sunfish	*Lepomis auritus*	N/A
Green Sunfish	*Lepomis cyanellus*	slackwater/backwater/pools
Warmouth	*Lepomis gulosus*	slackwater/backwater/pools
Orangespotted Sunfish	*Lepomis humilis*	slackwater/backwater/pools
Bluegill	*Lepomis macrochirus*	slackwater/backwater/pools
Longear Sunfish	*Lepomis megalotis*	slackwater/backwater/pools
Ribbon Shiner	*Lythrurus fumeus*	slackwater/backwater/pools
Shoal Chub	*Macrhybopsis hyostoma*	deep runs
Largemouth Bass	*Micropterus salmoides*	slackwater/backwater/pools
Golden Shiner	*Notemigonus crysoleucas*	slackwater/backwater/pools
Silverband Shiner	*Notropis shumardi*	N/A
Weed Shiner	*Notropis texanus*	shallow runs
Mimic Shiner	*Notropis volucellus*	slackwater/backwater/pools
Tadpole Madtom	*Noturus gyrinus*	slackwater/backwater/pools
Pugnose Minnow	*Opsopoeodus emiliae*	slackwater/backwater/pools
Fathead Minnow	*Pimephales promelas*	slackwater/backwater/pools
Bullhead Minnow	*Pimephales vigilax*	shallow runs
Sailfin Molly	*Poecilia latipinna*	slackwater/backwater/pools
White crappie	*Pomoxis annularis*	shallow runs
Black crappie	*Pomoxis nigromaculatus*	N/A
Flathead catfish	*Pylodictis olivaris*	slackwater/backwater/pools

Table C.2: *Fish species identified in Lake Texana*

Common Name	Scientific Name
Gizzard Shad	*Dorosoma cepedianum*
Threadfin Shad	*Dorosoma petenense*
Red Shiner	*Cyprinella lutrensis*
Spottail Shiner	*Cyprinella venusta*
Golden Shiner	*Notemigonus crysoleucas*
Silverband Shiner	*Notropis shumardi*
Pugnose Minnow	*Opsopoeodus emiliae*
Bullhead Minnow	*Pimephales vigilax*
Yellow Bullhead	*Ameiurus natalis*
Channel Catfish	*Ictalurus punctatus*
Inland Silverside	*Menidia beryllina*
Sheepshead Minnow	*Cyprinodon variegatus*
Western Mosquitofish	*Gambusia affinis*
Sailfin Molly	*Poecilia latipinna*
Golden Topminnow	*Fundulus chrysotus*
Gulf Pipefish	*Syngnathus scovelli*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Longear Sunfish	*Lepomis megalotis*
Redear Sunfish	*Lepomis microlophus*
Largemouth Bass	*Micropterus salmoides*
White Crappie	*Pomoxis annularis*
Black Crappie	*Pomoxis nigromaculatus*

For more information, please contact:

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