Brazos River Below Possum Kingdom Lake Data Report

November 2010

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TCEQ

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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Introduction

Water Body Location: The Brazos River Below Possum Kingdom Lake is a segment of the Brazos River located near Mineral Wells, in North Texas. This segment (1206) spans from a point 100 meters upstream of FM 2580 in Parker County to Marris Sheppard Dam in Palo Pinto County (see map on pg. 6).

Texas Stream Team: Texas Stream Team is a volunteer based water quality monitoring program. In alignment with Texas Stream Team's core mission, monitors collect surface water quality data that may be used in decision-making processes to promote and protect a healthy and safe environment for people and aquatic inhabitants. Citizen monitoring occurs at set monitoring sites roughly the same time of day once a month. Citizen monitoring data provides a valuable resource of information supplementing professional data collection efforts where resources are limited. The data may be used by professionals to identify water quality trends, target additional data collection, identify pollution events, identify sources and causes of pollution, and show effectiveness of management measures towards improving water quality.

Texas Stream Tea data, however, is not used by the state to assess whether water bodies are meeting the designated surface water quality standards. The primary reason for this is that Texas Stream Team volunteers use different methods than the professional water quality monitoring community. Different methods are utilized by Texas Stream Team due to higher equipment costs, training requirements, and stringent laboratory procedures that are required of the professional community. The Texas Stream Team methods have been chosen because of relative ease of performing the methods in the field, while providing reliable results at low costs. As a result, Texas Stream Team data does not have the same accuracy or precision as professional data and is therefore not directly comparable. However, Texas Stream Team data are valuable records often collected in portions of water body that professionals are not able to monitor or monitor as frequently. This long-term data set is available to and may be considered by the surface water quality professional community to facilitate management and protection of Texas' water resources. For additional information about water quality monitoring methods and procedures, see:

- Texas Stream Volunteer Water Quality Monitoring Manual
- Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures for professional monitors

Information collected by Texas Stream Team volunteers is covered under a TCEQ approved quality assurance project plan (QAPP) to ensure a standard set of methods of known quality are used. All data used in data reports are screened by the Texas Stream Team for completeness, precision and accuracy where applicable, and scrutinized with data quality objective and data validation techniques.

The purpose of this report is to provide analysis of data collected by Texas Stream Team volunteers. The data presented in this report should be considered in conjunction with other relevant water quality reports prepared by the following programs in order to provide a holistic view of water quality in this water body:

- Texas Surface Water Quality Standards;
- Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) (or Texas Integrated Report; formerly the Texas Water Quality Inventory and 303(d) List);
- Texas Clean Rivers Program partners' reports such as Basin Summary Reports and Highlight Reports;
- TCEQ surface water quality special studies;
- TCEQ Total Maximum Daily Load reports;
- TCEQ and Texas State Soil and Water Conservation Board Nonpoint Source Program funded reports, including Watershed Protection Plans.

Questions about this report should be directed to the Texas Stream Team at (512) 245-1346.

Water Quality Terminology

The following paragraphs under this section provide general information about types of data collected by Texas Stream Team volunteers, along with the importance of these parameters for aquatic and human health.

Water Temperature

Water temperature, one of the simplest water quality measurements, is one of the most important to the health of an aquatic ecosystem (*A Guide to Freshwater Ecology*, TCEQ GI-034, August 2005). Water temperature influences physiological processes of aquatic organisms, and each species has optimum temperatures for survival. High water temperatures increase oxygen-demand for aquatic communities and can become stressful for fish and aquatic insects. Water temperature variations are most detrimental when they occur rapidly, leaving the aquatic community no time to adjust. Additionally, the ability of water to hold oxygen in solution (solubility) decreases as temperature increases.

Natural sources of warm water are seasonal as water temperatures tend to increase during summer and decrease in winter. Daily (diurnal) water temperature changes occur during normal heating and cooling patterns. Man-made sources of warm water include power plant effluent after it has been used for cooling or hydroelectric plants which release warmer water. Citizen monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases. While citizen data does not show diurnal temperature fluctuations, it may demonstrate the fluctuations over seasons and years.

Dissolved Oxygen

Oxygen is necessary for the survival of organisms like fish and aquatic insects. The amount of oxygen needed for survival and reproduction of aquatic communities varies according to species composition and adaptations to watershed characteristics like stream gradient, habitat, and available stream flow. The TCEQ Water Quality Standards list daily minimum dissolved oxygen criteria for specific water bodies, and presume criteria according to flow status (perennial, intermittent with perennial pools, and intermittent), aquatic life attributes, and habitat. These criteria are protective of aquatic life and can be used for general comparison purposes.

Dissolved oxygen concentrations can be influenced by other water quality parameters such as nutrients and temperature. High concentrations of nutrients can lead to excessive surface vegetation growth, which may starve subsurface vegetation of sunlight and limit the amount of dissolved oxygen in water produced as a product of photosynthesis. This process, known as eutrophication, is enhanced when the subsurface vegetation dies and is decomposed by oxygen-consuming bacteria.

Low dissolved oxygen levels may also result from high groundwater inflows as groundwater is typically low in dissolved oxygen, high temperatures which reduce oxygen solubility, or water releases from deeper portions of dams where conditions are anoxic.

Conductivity

Conductivity is measured to determine the amount of dissolved solids in the water. Conductivity is a measure of the ability of water to conduct electricity. The more dissolved solids a body of water has, such as inorganic salts (Ex. magnesium, calcium, chloride, and sulfate), the more electricity it conducts, or the more conductive it is. Conductivity is measured in microSiemens per centimeter (µS/cm). To determine total dissolved solids (TDS) in water, the Texas Surface Water Quality Monitoring Procedures call for a conversion of specific conductance by 65%.Sources of TDS can include agricultural runoff, domestic runoff, discharges from wastewater treatment plants, groundwater inflows, or naturally saline conditions resulting from the local geology and arid climate.

High concentrations of salt can inhibit water absorption and limit root growth for vegetation, lead to an abundance of more drought tolerant plants, and cause dehydration of fish and amphibians.

pH

pH is a measure of acidity or alkalinity. The scale measures the concentration of hydrogen ions on a range of 0 to 14 and is reported in standard units (su). The range is logarithmic; every 1 unit change means the acidity increased or decreased 10-fold. A pH of 7.0 is considered neutral. Values less than 7.0 are considered acidic; those greater than 7.0 are alkaline (basic).

The local geology in a watershed determines the general pH of water bodies. Underlying rock such as limestone dissolves and weathers easily, releasing minerals that buffer the water and cause a slight increase in pH (*A Guide to Freshwater Ecology*, TCEQ GI-034, August 2005). Harder, igneous bedrock tend to have less mineral content and lower pH. A typical pH range for buffered water bodies is 6.5 and 9. Regions of East Texas, with naturally acidic waters, have typical pH ranges from 5.5 to 9. Acidic contributions, indicated by a low pH level, can include runoff from acid-laden soils and acid rain. Sources that emit nitrogen oxide and sulphur dioxide into the atmosphere, such as car exhaust and coal power plants, contribute to acid rain.

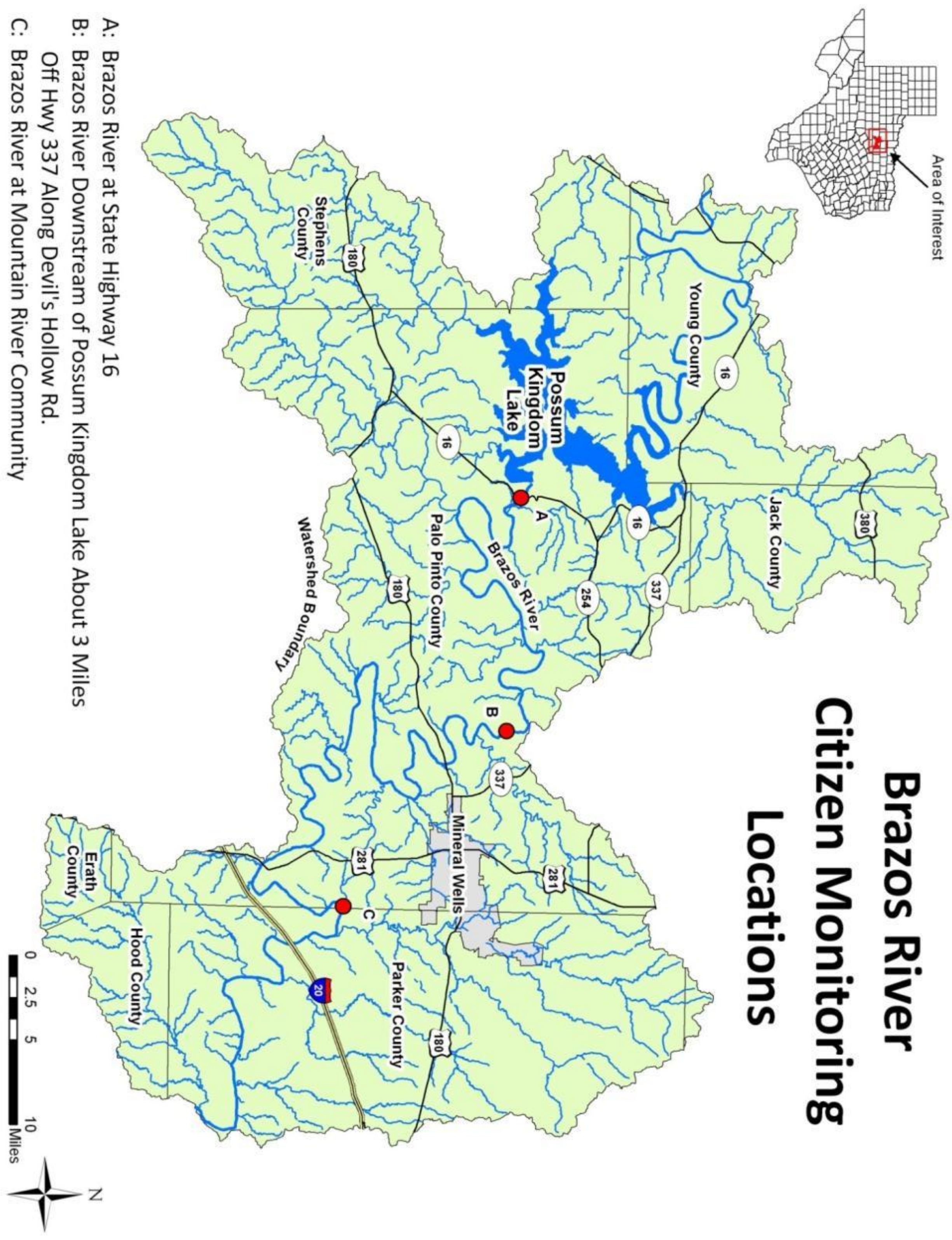
Water Clarity

Water clarity is the ability of sunlight to penetrate the water column, and is measured by a Secchi disk. The ability of light to reach submerged plants is impeded by reduced clarity, and can effect populations of beneficial phytoplankton, algae, and aquatic plants. This reduces the dissolved oxygen in the water due to reduced photosynthesis. Reduced visibility can also harm predatory fish or birds that depend on good visibility to find their prey.

Water clarity can be affected by natural as well as human activities. Watershed characteristics such as the potential for flooding, and loose soils contribute to reductions in water clarity through increasing sedimentation. Sedimentation can result from sediment washing away from construction sites, erosion of farms, mining operations, and waterway (riparian) disturbance. Reduced water clarity can also occur during algae blooms, which can be episodic or part of a longer term aging process, particularly in reservoirs.

E. *coli* Bacteria

Pathogens are microorganisms, such as bacteria, viruses, and protozoans, that can cause illness in humans. Pathogens can be transmitted by drinking or swimming in water containing fecal waste of warm-blooded animals, primarily through ingestion. The EPA has determined E. *coli* bacteria to be the best indicator of the degree of pathogens in a water body. Water bodies naturally contain E. *coli*. E. *coli* levels are therefore monitored to determine if there is a significant risk to human health in relation to contact recreation. Sources of E. *coli* may include livestock, pets, failing septic systems and wastewater treatment plants, or wildlife around the water body.



Note: This map shows 5 USGS 10-digit HUCs which encompass all three sites and Possum Kingdom Lake. This scale was more appropriate than an 8 digit HUC watershed.

Data Analysis

Texas Stream Team Citizen Water Quality Monitors, Michael and Constance Bales, have been collecting data on three sites along the Brazos River consistently since 2005. They began monitoring at these sites because residents of the Mountain River Community, a small rural neighborhood of roughly 200 people, were concerned about what they saw as declining conditions in water quality and stream environment in their community. The residents noted a silting of the bend, declining fish populations, and blackened mud layers which were absent prior to the landscape rock mining roughly 30 miles upstream of the site. Data were collected at Highway 16 to provide water quality data before the mining.

The previous report covering data from 2005-2006 showed values suitable for aquatic life as well, aside from one low dissolved oxygen measurement (1.5 mg/L) at the site at Highway 16. This report can be found at http://txstreamteam.rivers.txstate.edu/Data/Data-Reports/contentParagraph/0111/document/2006+BRAZOS+Possum+Kingdom+Lake+Report.pdf. The low dissolved oxygen value followed a discharge from the lower portion of the lake which is normally low in dissolved oxygen due to limited sunlight penetration and aeration. He noted a smell of rotten eggs approximately a half of a kilometer around the site. This is to expected following such a release as decomposing organic matter produces that smell. The data from the previous report show all observed water temperature values except for one were below the standard for maximum temperature of 32^{o}C. This value of 33.5^{o}C was observed at the Mountain River Community Park.

Citizen water quality monitoring data covered in this report span from 2006-2009. Data covered in this report show this segment to be suitable for aquatic life. All dissolved oxygen values stayed above the standard for this segment (3 mg/L). Dissolved oxygen values exhibit the natural cycle of increasing in the winter and decreasing in the summer due to an inverse relationship with water temperature (see water temperature section above). This indicates there are no unnatural causes of fluctuations of dissolved oxygen or water temperature.

Conductivity values are compared to the standard for total dissolved solids after it has been converted from mg/L to µS/cm. The resulting value for this segment is 3,577µS/cm. All annual averages of conductivity were below the TDS standard, and all pH values stayed within the standard range of 6.5-9.

Secchi disk transparency readings were consistently greater than total depth, indicating very clear water (The averages are different because there are more total depth measurements than Secchi disk measurements). However, monitors noted that the water was cloudy or turbid for 19% of the field observations. It is likely the water body is not deep enough to provide an accurate Secchi disk measurement. Texas Stream Team will soon be incorporating a “Transparency Tube” to alleviate this situation.

In the 2006 Texas Water Quality Inventory, this entire segment was listed as impaired by the TCEQ due to high levels of chloride. However, the 2010 Draft Texas Integrated Report no longer lists this portion as impaired. Two of the citizen water quality monitoring sites show a sharp drop in conductivity (which includes chlorides) in 2009 but only for one monitoring event. It will be interesting to see what data follow.

The portion stretching from the confluence with Elm Creek in Palo Pinto County to the portion 100 meters (110 yards) upstream of FM 2580 in Parker County was listed for an impaired macrobenthic community (living on or near the riverbed) in 2008, but this impairment was reduced to a concern in the 2010 list. This means the observed community meets the designated standards, but is approaching non-support. A concern has been listed for the same portion due to impaired habitat since 2008 as well.

The TCEQ has identified nonpoint source pollution from natural sources to be the cause of the high levels of chloride and impaired habitat, but the cause of the impaired macrobenthic community is still unknown. According to the 2007 Brazos River Basin Summary Report produced by the Brazos River Authority under the TCEQ's Clean Rivers Program, the elevated chloride concentrations observed in this segment are mostly the result of natural-salt bearing formations in the Salt and Double Mountain Forks of the Brazos River coupled with chronic drought conditions.[i] These meet the Brazos River roughly 200 river miles upstream of Possum Kingdom Lake. The 2007 Brazos River Basin Summary Report also pointed out an increasing trend in chloride levels throughout Possum Kingdom Lake.[ii] However, the lake has never been listed as impaired.

Chloride is carried to a water body when either soils or rock with chloride-containing minerals are deteriorated by storm-water runoff or by groundwater containing such minerals emerging from a spring. High levels of chloride can also be introduced when mining operations expose parent material, much of which is ground up as a result of the operations or when the soil of agricultural lands has been recently tilled. Drought conditions may intensify the effect as well when soils crack and expose more parent material, which may be washed into local waterbodies when it does rain.

Input into the segment covered under this report would come from Possum Kingdom Lake if the Salt and Double Mountain Forks of the Brazos River are the source of high levels of chloride. The site located just below the dam has an average conductivity level of 2,519 µS/cm. The averages at the two sites downstream show a decreasing trend from 2,191 to 2,051 µS/cm. The annual averages show the highest value at the site just below the dam as well, but they do not show the same gradual downward trend.

It appears the flood in June 2007 washed away many of the dissolved solids. During that flood, the floodgates were opened, releasing water from the lake. The conductivity graph on pg. 10 shows a sharp decrease in dissolved solids following a break in the data in June of 2007, which was caused by the flood making the site inaccessible. Notice the big change in conductivity following this flood. The observed value in April '07 is 3,800 µS/cm, and the observed value in July '07 is 2,200 µS/cm. The following value was even lower and has since gradually increased. Although the data for sites B and C show peaks and troughs, values gradually increase as well. Stormwater runoff should cause peaks and troughs according to rainfall events. The fluctuations observed here do not correlate with wet and dry periods, so we cannot deduce storm-water runoff to be the cause. It is possible the release of water with low levels of TDS caused the reduction in conductivity measurements.

There may be a source of dissolved solids in the area causing this gradual increase and extreme fluctuations in conductivity. Observed conductivity values normally range over a scale of hundreds, but sites B and C range over a scale of thousands, and although the higher end of this scale does not show levels exceeding the standard, it does show levels which would make the water difficult to use for drinking, irrigation, or livestock.[iii] The 2007 Brazos River Basin Summary Report includes a reference to a study conducted to determine the influence of mining activity in the area on the high chloride levels.[iv] However, the results were inconclusive.

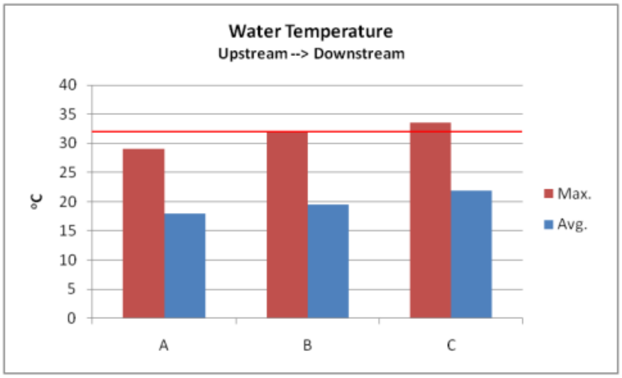
The 2000 Texas Water Quality Standards for Brazos River Below Possum Kingdom Lake are shown in red on the graphs below. Although new standards were written in 2010, they were not in effect at the time this report was written. The water temperature standard is a maximum level. The conductivity standard is a maximum annual average. A line is shown on some graphs only as a reference point, not as the particular standard when only particular amounts are displayed. The dissolved oxygen standard is a minimum amount, and the pH standards are a range.

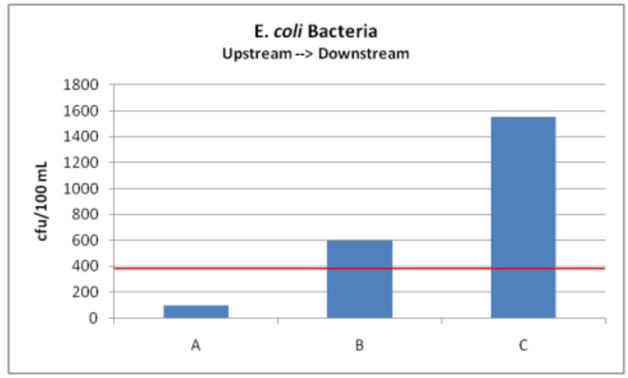
It is important to note that these standards are shown only for reference. Regulatory action by the TCEQ is based on professional water quality monitoring data. For the Integrated Report, the TCEQ determines a water body to be impaired for core parameters if approximately 10% of at least ten samples taken over the last seven years exceed the standard for each parameter. If there are at least five samples in the seven year period, then it is acceptable to go back for more samples up to ten years. For contact recreation, a water body is determined to be impaired when 25% of at least ten samples taken over the last seven years exceed the standard for *E.coli* bacteria. When the observed value is over the standard, it is referred to as an exceedance. At least ten samples from the last seven years must be collected over at least two years with the same reasonable amount of time between samples for a data set to be considered acceptable for use in assessments. Similar rules exist for other standards to ensure that assessments are made using enough data to account for normal seasonal changes as well as variations in rainfall and other conditions from year to year.

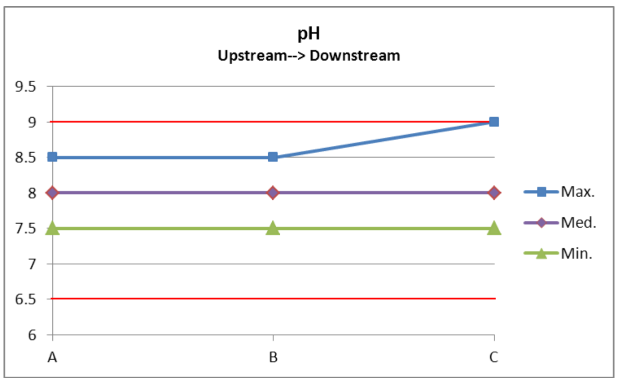
Upstream to Downstream Trends

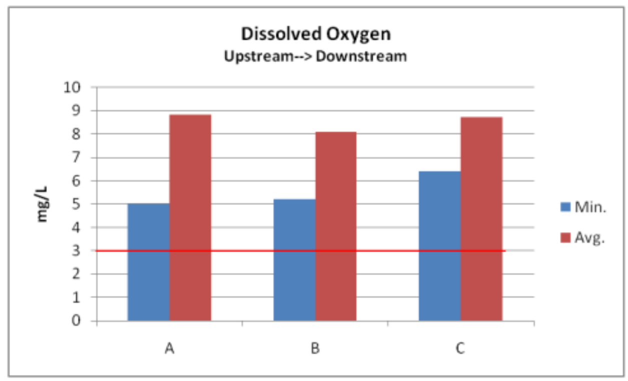
Upstream to downstream trends are shown on the graphs below. The letters on the x-axis reference the map above. It can be seen that water temperature increases from upstream to downstream. Site A is near the Morris Sheppard Dam, which may be releasing colder water from the bottom of the lake. Dissolved oxygen and pH stay mostly steady, except pH spiked slightly at site C. Conductivity is highest at site A, but there is no significant difference observed between sites B and C.

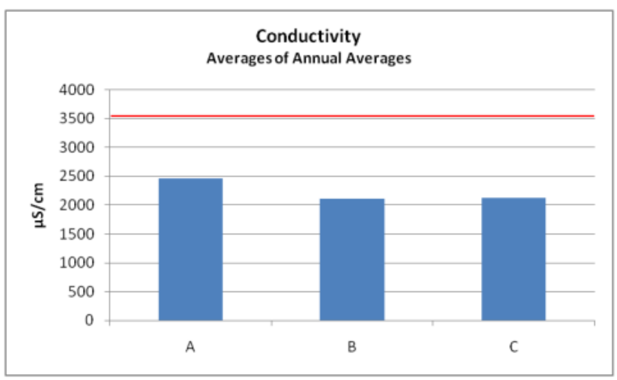
E. *coli* monitoring events were conducted on October 11th, 2009 at all three sites. The results are shown on the graph below. There was a significant rise in E. *coli* bacteria as the river moves downstream. The values observed at two sites were well above the single grab standard of 394 cfu/100 mL. However, this data is provided as a snapshot in time. As explained in the previous section, much more data is needed to adequately assess whether this segment of the river is generally meeting recreational use standards. Subsequent monitoring (outside of the data period for this report) has shown that the observed values dropped steadily until continual values of zero were observed soon after the high results were communicated to the Mountain River Community Home Owners Association by the monitors.











Site by Site Analyses

The site specific statistics and graphs shown below are presented in an upstream to downstream manner.

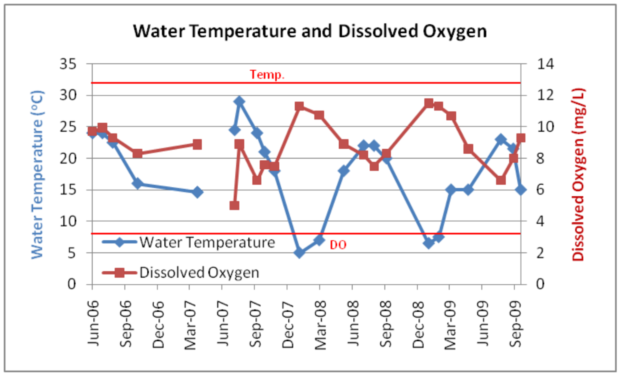
Site A: Brazos River at State Highway 16

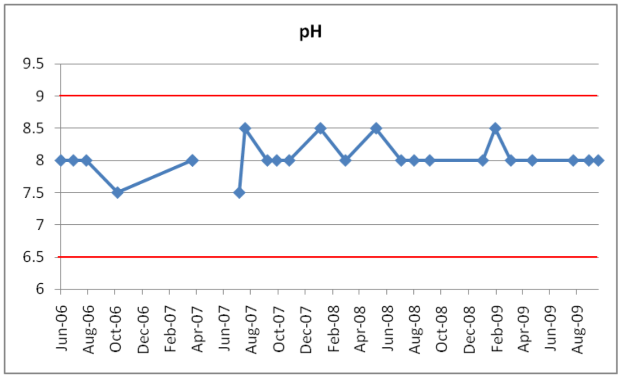
Parameter	% Complete	#	Min.	Mean	Max.	Std. Dev.
Dissolved Oxygen	96	24	5	8.81	11.5	1.62
Water Temperature	96	24	5	17.9	29	6.46
Conductivity	96	24	1160	2519.17	3800	654.97
pH	96	24	7.5	8.04	8.5	0.25
E. coli Bacteria	4	1	100	100	100	N/A
Secchi Depth	64	16	0.2	1.17	3	0.68
Total Depth	92	23	0.2	1.2	3	0.60
Sample Time	96	24	11:43	13:57	16:14	0.06

All data at this site were collected by Michael Bales. Michael has observed this area being used extensively both by humans and wildlife. It is a popular spot for fishing and swimming, and many birds, fish, and insects have been observed. Michael has noticed recreation increasing in this area since 2005.

He also noted a fishy odor at this site a few times. This site is just downstream from the Possum Kingdom Fish Hatchery. Releases from the hatchery would most likely be the cause of this. The surrounding land seems to be mostly forest except for the fish hatchery just upstream from this site.

Effluent from fish hatcheries can cause significant increases in temperature, pH, suspended solids, ammonia, nitrogen, and phosphorus. Dissolved oxygen can be decreased due to extensive respiration occurring in the hatchery.[v] It is possible the observed gradual upward trend in conductivity has been caused by releases from the hatchery. However, the other parameters have shown relatively stable conditions within the standards set for this area.


Water Temperature and Dissolved Oxygen
Temp.
DO
Water Temperature
Dissolved Oxygen
Water Temperature (°C)
Dissolved Oxygen (mg/L)
35
30
25
20
15
10
5
0
14
12
10
8
6
4
2
0
Jun-06
Sep-06
Dec-06
Mar-07
Jun-07
Sep-07
Dec-07
Mar-08
Jun-08
Sep-08
Dec-08
Mar-09
Jun-09
Sep-09


pH
9.5
9
8.5
8
7.5
7
6.5
6
Jun-06
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
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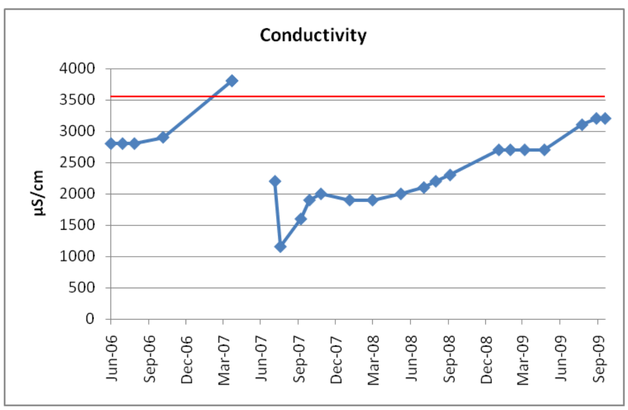
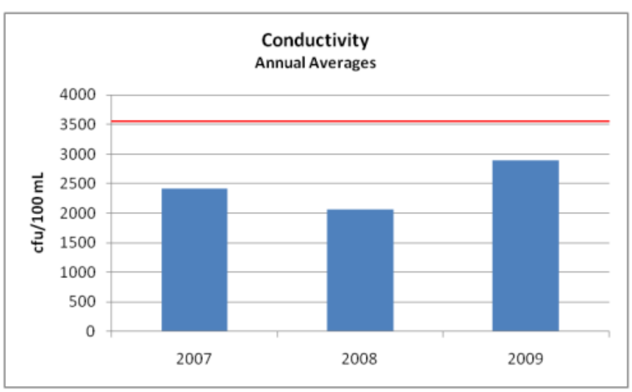
Apr-09
Jun-09
Aug-09

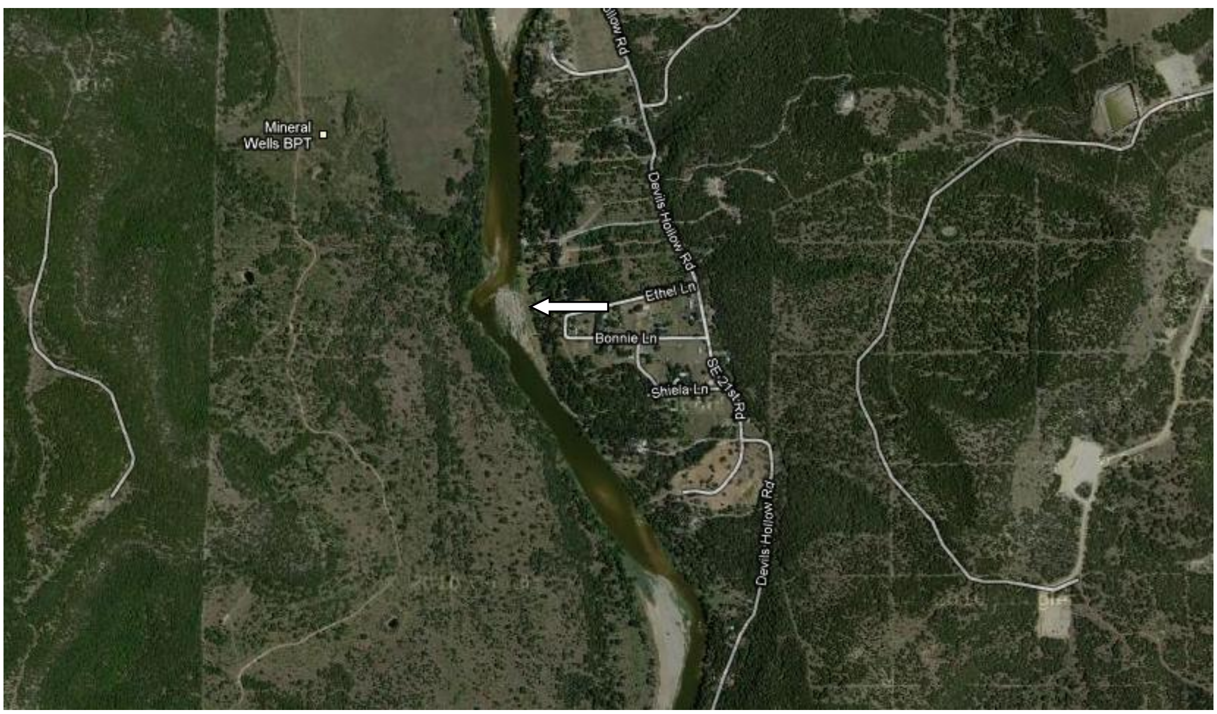

Conductivity
µS/cm
4000
3500
3000
2500
2000
1500
1000
500
0
Jun-06
Sep-06
Dec-06
Mar-07
Jun-07
Sep-07
Dec-07
Mar-08
Jun-08
Sep-08
Dec-08
Mar-09
Jun-09
Sep-09

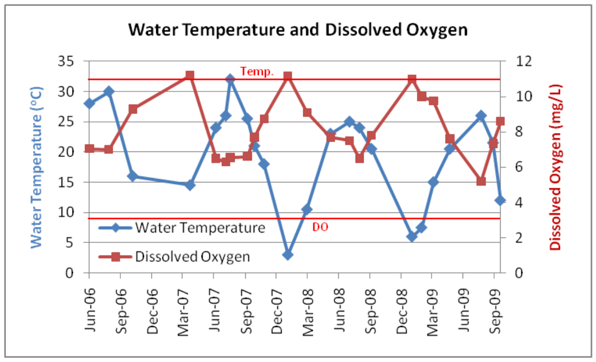

Conductivity
Annual Averages
cfu/100 mL
4000
3500
3000
2500
2000
1500
1000
500
0
2007
2008
2009

Site B: Brazos River - Downstream Of Possum Kingdom Lake, About 3 Miles Off Hwy 337 Along Devil's Hollow Rd

Parameter	% Complete	#	Min.	Mean	Max.	Std. Dev.
Dissolved Oxygen	100	23	5.2	8.1	11.2	1.68
Water Temperature	100	23	3	19.54	32	7.82
Conductivity	100	23	700	2191.3	3500	687.49
pH	100	23	7.5	8	8.5	0.21
E. coli Bacteria	4	1	600	600	600	N/A
Secchi Depth	30	7	0.1	0.31	0.8	0.26
Total Depth	83	19	0.1	0.33	0.8	0.18
Sample Time	100	23	10:15	13:28	16:55	0.09

All data for this site were collected by Constance Bales. Constance observed a variety of wildlife at this site such as birds, deer, raccoons, turtles, and fish. Given the extensive nature of her comments, it would be fair to assume she would have noted the presence of people if they were using this area, and she did not. Constance actually monitored this site during the flood in 2007 which caused the break in the data at the site at Highway 16. Bravo.




Water Temperature and Dissolved Oxygen
Water Temperature (°C)
Dissolved Oxygen (mg/L)
Temp.
DO
Water Temperature
Dissolved Oxygen
35
30
25
20
15
10
5
0
12
10
8
6
4
2
0
Jun-06
Sep-06
Dec-06
Mar-07
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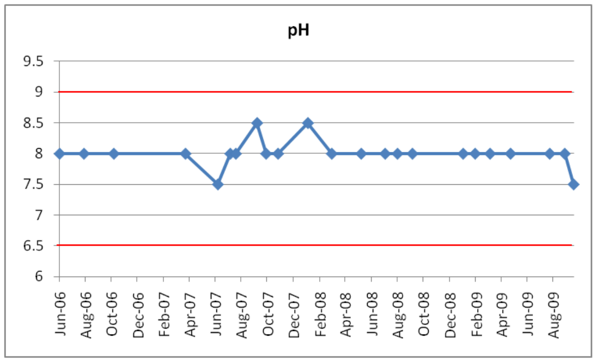
Mar-09
Jun-09
Sep-09


pH
9.5
9
8.5
8
7.5
7
6.5
6
Jun-06
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
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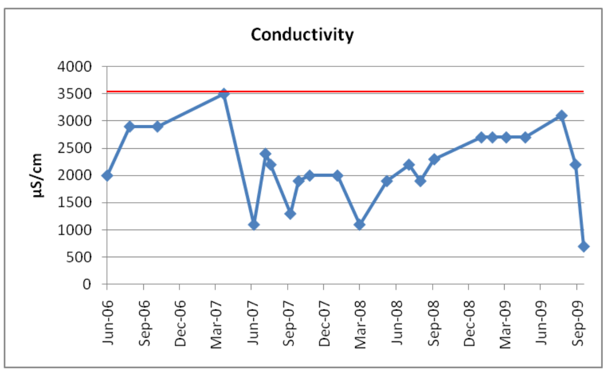
Apr-09
Jun-09
Aug-09


Conductivity
µS/cm
4000
3500
3000
2500
2000
1500
1000
500
0
Jun-06
Sep-06
Dec-06
Mar-07
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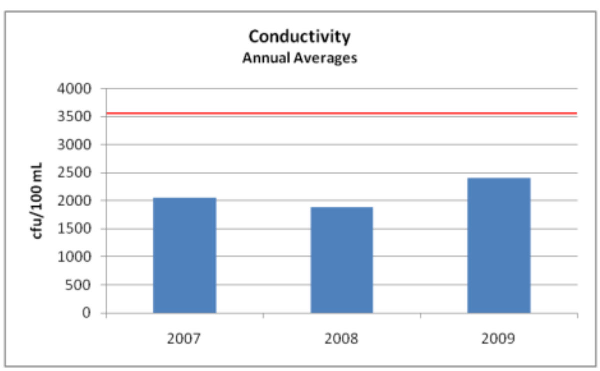
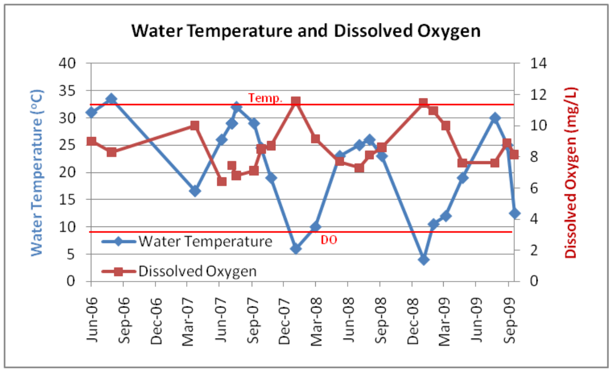
Mar-09
Jun-09
Sep-09

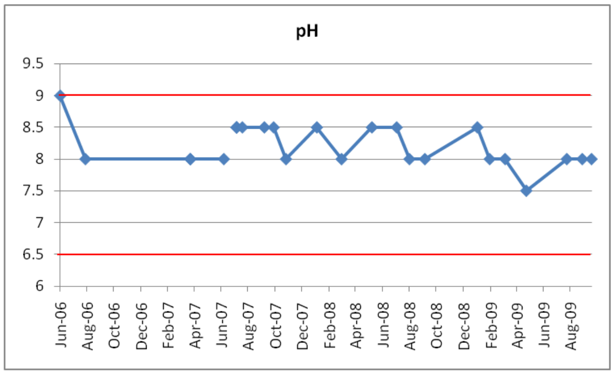

Conductivity
Annual Averages
cfu/100 mL
4000
3500
3000
2500
2000
1500
1000
500
0
2007
2008
2009

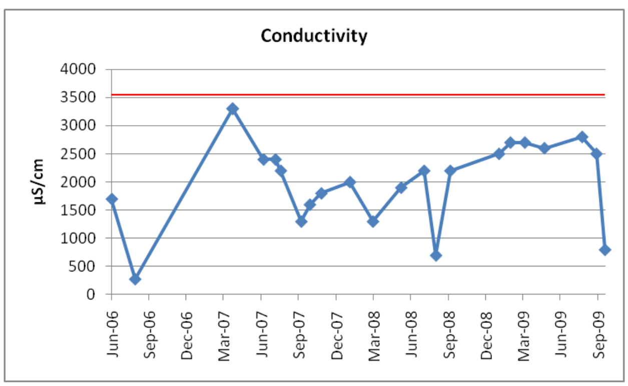
Site C: Brazos River at Mountain River Community Park

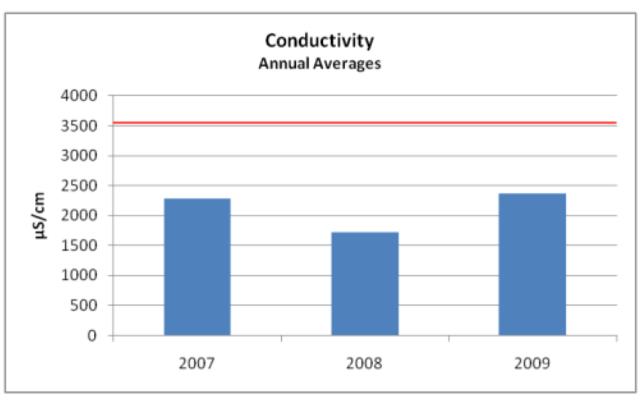
Parameter	% Complete	#	Min.	Mean	Max.	Std. Dev.
Dissolved Oxygen	96	22	6.4	8.72	11.55	1.45
Water Temperature	100	23	4	21.01	33.5	8.62
Conductivity	100	23	280	2051.3	3300	786.47
pH	96	22	7.5	8.18	9	0.33
E. coli Bacteria	4	1	1550	1550	1550	N/A
Secchi Depth	52	12	0.1	0.71	1.5	0.39
Total Depth	96	22	0.1	0.82	1.5	0.40
Sample Time	100	23	10:35	13:54	16:42	0.06

All data at this site were collected by Michael Bales. This site is located downstream of the community, so any impacts caused by the community are covered. Michael has observed this area being used both by humans and wildlife. Only Mountain River Community residents are allowed to recreate here, so human use is more limited than at Site A. Many birds, fish, and insects have been observed. Michael actually monitored this site during the flood in 2007 which caused the break in the data at the site at Highway 16. He noted a fishy odor at this site a few times. This may have been caused by releases from the fish hatchery near site A. Over the last five years, the main channel has widened and shorelines have eroded as a result of a flooding.


Water Temperature and Dissolved Oxygen
Water Temperature (°C)
Dissolved Oxygen (mg/L)
Temp.
DO
Water Temperature
Dissolved Oxygen
40
35
30
25
20
15
10
5
0
14
12
10
8
6
4
2
0
Jun-06
Sep-06
Dec-06
Mar-07
Jun-07
Sep-07
Dec-07
Mar-08
Jun-08
Sep-08
Dec-08
Mar-09
Jun-09
Sep-09


pH
9.5
9
8.5
8
7.5
7
6.5
6
Jun-06
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
Apr-08
Jun-08
Aug-08
Oct-08
Dec-08
Feb-09
Apr-09
Jun-09
Aug-09


Conductivity
µS/cm
4000
3500
3000
2500
2000
1500
1000
500
0
Jun-06
Sep-06
Dec-06
Mar-07
Jun-07
Sep-07
Dec-07
Mar-08
Jun-08
Sep-08
Dec-08
Mar-09
Jun-09
Sep-09


Conductivity
Annual Averages
µS/cm
4000
3500
3000
2500
2000
1500
1000
500
0
2007
2008
2009

[i] Brazos River Authority, *Basin Summary Report 2007,* available from http://www.brazos.org/crpPDF/UpperBrazos_2007.pdf; accessed 21 October 2010.
[ii] Ibid.
[iii] Mark McFarland, Robert Lemon and Charles Stichler, *Irrigation Water Quality*, available from http://www.extension.org/mediawiki/files/7/71/Irrigationwaterquality.pdf; accessed 12 April 2012.
[iv] Brazos River Authority, *Basin Summary Report 2007,* available from http://www.brazos.org/crpPDF/UpperBrazos_2007.pdf; accessed 21 October 2010
[v] Kendra,W. *Quality and Fate of Fish Hatchery Effluents During Summer Low Flow Season*, January 1989, available from http://www.ecy.wa.gov/biblio/8917.html; accessed 27 October 2010.