

Water & Environmental Reports of Investigation

An Examination of the Atchafalaya Basin's Water Quality During and After Flood of 2011

Douglas A. Carlson and Marty Horn

INTRODUCTION

The Atchafalaya Basin located in south-central Louisiana (Figure 1) was flooded when up to 17 gates of the Morganza spillway were opened in an effort to reduce downstream flooding in Baton Rouge and New Orleans area. The first gates were opened on May 14th, 2011. By May 18th a maximum number of 17 gates were opened. The closure of gates was slower and was not completed till July 7th, 2011 (Figure 2). During the flood event up to 190,000 cfs (5,380 cubic meters per second) flowed through the Morganza spillway (Figure 2). The basin is approximately 20km wide and 80 km long and trends in a direction of 145°.



Figure 1. Location of Atchafalaya Basin



METHODS

Field Methods

Surface water quality sampling was performed at approximately 300 sample sites within the basin by six agencies: Audubon Society, Louisiana Department of Environmental Quality (LDEQ), Louisiana Department of Wildlife and Fisheries (LDWF), Louisiana State University (LSU), US Geological Survey (USGS), and US Fish and Wildlife Service (USFWS). However, only three (Louisiana Department of Wildlife and Fisheries, US Geological Survey, and US Fish and Wildlife Service) directly collected samples for later laboratory analysis by Louisiana Geological Survey (LGS) staff. These three agencies also sent to the LGS staff their results for field measurements.

The LDWF collected field parameter results at 22 sites; at these sites usually measurements were made for turbidity, temperature, salinity, electrical conductance (EC) and dissolved oxygen (DO). These measurements were usually made with a YSI 650 Multiparameter Display System w/6600 V2 Multiparameter water quality sonde. The USFWS collected field parameter results at 11 sites; at these sites usually measurements were made for turbidity, temperature, EC and DO. The USGS collected field parameter results at over 100 sites, but usually approximately 25 sites were sampled during each of the nine sampling events. At these sites samples were taken at 10 cm below the surface and near the bottom or greatest depth possible for field meter's cable. At these sites EC, temperature, turbidity, pH, DO, and chlorophyll A concentration were measured. These measurements were usually made with a InSitu Troll 9500.

Laboratory Methods

The water samples collected earlier by the Louisiana Department of Wildlife and Fisheries, US Geological Survey, and US Fish and Wildlife Service (eleven sets of approximately 45) were analyzed in the Louisiana Geological Survey's lab, using LGS's Dionex ICS-1000 Ion Chromatography System. In addition colometer analysis was completed for phosphate (orthophosphate) by LGS staff.

The samples were also passed through a 10 micron filter to collect suspended particles. The mass of suspended particles and total suspended solids (TSS) was determined by gravimetric analysis. In general samples that were passed through 10 micron filter were between 200 ml and 500 ml.

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LGS Mission Statement

The goals of the Geological Survey are to perform geological investigations that benefit the state of Louisiana by:

- (1) encouraging the economic development of the natural resources of the state (energy, mineral, water, and environmental);
- (2) providing unbiased geologic information on natural and environmental hazards; and
- (3) ensuring the effective transfer of geological information.

The Louisiana Geological Survey was created by Act 131 of the Louisiana Legislature in 1934 to investigate the geology and resources of the State. LGS is presently a research unit affiliated with the Louisiana State University and reports through the Executive Director of the Center for Energy Studies to the Vice Chancellor for Research and Graduate Studies.

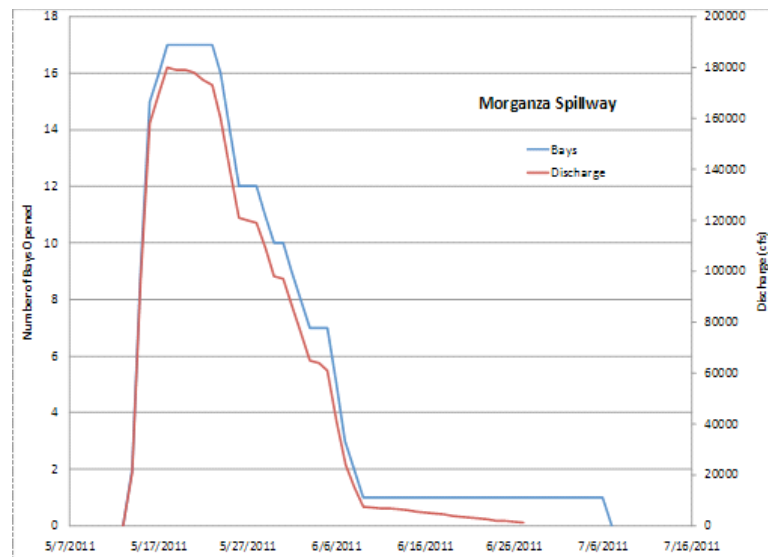


Figure 2. Opening sequence of the Morganza Spillway by the United States Army Corps of Engineers (Figure 2 of Carlson et al., 2011).

Statistical Method

For this study t-tests involving one test of data compared to no change (zero), or between two data sets collected at different times were completed. The first set involved comparison of changes of parameter values as function of depth. The second involved comparison of two data sets collected at different times. These comparison were completed using a computer program developed by Boersma (2011).

RESULTS

The LGS was contracted by LDNR to analyze the water samples for nitrate, nitrite, phosphorus and total suspended solids. In addition, LGS reported information for fluoride, chloride, sulfate, total phosphate and orthophosphate. Several ions appear to have consistent changes through time after the start of the Atchafalaya Basin flood as a result of opening gates of the Morganza spillway from May 26th to July 21st. The first seven set of samples May 19 to July 7 were collected when gates were open on the Morganza spillway. The last four sets of samples July 21 to October 12 were collected after the closing of all Morganza spillway gates.

Chloride increased slowly during the flooding event. The average chloride concentration is 9.88 ± 0.55 mg/L on May 26th and increase to 13.59 ± 1.08 mg/L on July 21st. T-test use determined this change to be significant with a confidence of this difference over 99.95% (Figure 3). Then chloride concentrations decrease to slightly lower values for August 4 of 9.40 ± 1.54 mg/L then a slightly higher value for September 9 of 12.93 ± 5.80 mg/L and for October 12 12.39 ± 2.51 mg/L (Figure 3). In general, chloride concentration for the Atchafalaya Basin flood is lower than typical results for the Mississippi River at Vicksburg, Mississippi (Figures 3 and 4). At the start of the flood chloride concentrations are not even half of the values typical in Vicksburg. However, from June 9 and later chloride concentrations is typically approximately 12 mg/L compared to typical median values for Mississippi River water at Vicksburg of approximately 15 to 20 mg/L.

The concentrations of chloride during 2011 were generally lower than those recorded in April of 1974 and far lower than values in August of 1974 (Wells and Demas, 1977). The concentration of chloride during the 2011 flood is also typically 10 mg/L lower than measured between 1944 and 1995 at eleven points along the Atchafalaya River (Garrison, 2001).

Fluoride concentration decreased between May 26th and June 16th and then increased between June 16th and July 21st (Figure 5). The average fluoride concentration is 0.237 ± 0.030 mg/L on May 26th and decreases to 0.196 ± 0.043 mg/L on July 21st. T-test use determined this change to be significant with a confidence of this difference over 99.95%. It appears that the concentration of fluoride is fairly constant between July 7 and October 12 (Figure 5). The fluoride concentration results during the flood are generally lower than results for the Mississippi River (Figure 6). In particular, fluoride concentration are relatively lower during the flood between approximately 25 and 50 days after the opening the Morganza spillway gates.

Average nitrate has been variable between a low on June 9th of 2.59 mg/L to a high of 4.07 mg/L on July 7th (Figure 7). The average nitrate concentration is 2.85 ± 1.35 mg/L on May 29 and increases to 3.96 ± 2.36 mg/L on July 21st. T-test use determined this change to be significant with a confidence of this difference over 98.5%. The variability of nitrate concentrations is nearly twice as large for July 21st as June 16th, as indicated by standard deviations that are on average 0.94 mg/L prior to June 16 and 2.44 mg/L June 16th and after (Figure 7). Lastly, the concentration of nitrate decreased to lower values on August 4 2.61 ± 1.96 mg/L, September 9, 1.52 ± 0.81 mg/L and October 12, 1.10 ± 0.66 mg/L. These values are lower than values prior to these dates (Figure 7). This pattern of low nitrate concentration in August-October appears to be consistent with past results of nitrate concentrations in the Mississippi River (Antweiler et al., 1996). The values of nitrate also appear to be consistent with those measured between 1944 and 1995 at seven points along the Atchafalaya River (Garrison, 2001).

Sulfate increased between May 19 and July 21 (Figure 8). The average sulfate concentration is 27.98 ± 0.67 mg/L on May 19th and increased to 44.89 ± 12.40 mg/L on July 21st. This change is determined with use of a t-test to be significant with a confidence of this difference over 99.95%. The variability of sulfate increased greatly as indicated by the standard deviation increase by a factor of 20 between May 19th and July 21st (Figure 8). After July 21 the average sulfate concentration remained fairly constant 42.53 ± 21.91 mg/L on August 4 and 43.74 ± 13.14 mg/L September 9 (Figure 8). Lastly there was a major increase in average sulfate concentration to 76.77 ± 9.67 mg/L. The results are similar to those in 1974. In April of 1974 sulfate concentrations were typically 33 mg/L. By August 1974 concentrations were often in the 50 mg/L with an average of 36.7 mg/L (Wells and Demas, 1977), which is close to the median recorded on August 5, 2011 of 40 mg/L (Figure 8). The pattern of increasing sulfate concentration appears to be similar to the increasing share of discharge in the Mississippi River that is from the Missouri River (Figure 9). On May 14 the Missouri River's contribution to Mississippi River flux at Vicksburg, Mississippi is approximately 8% to approximately 40% to 50% by August through October. There is usually a slight increase in sulfate concentration (Figure 10), but it far less than the change that occurred in the Atchafalaya Basin during and after the flood of 2011 (Figures 8 and 10). This could be a result of the difference of Missouri River share which maybe is usually fairly constant between May and December than during the year of 2011 where peak of flooding within the Mississippi River basin varied significantly by basin considered. Peak of Ohio River discharge at Metropolis, Illinois occurred on May 5 and 6. Peak

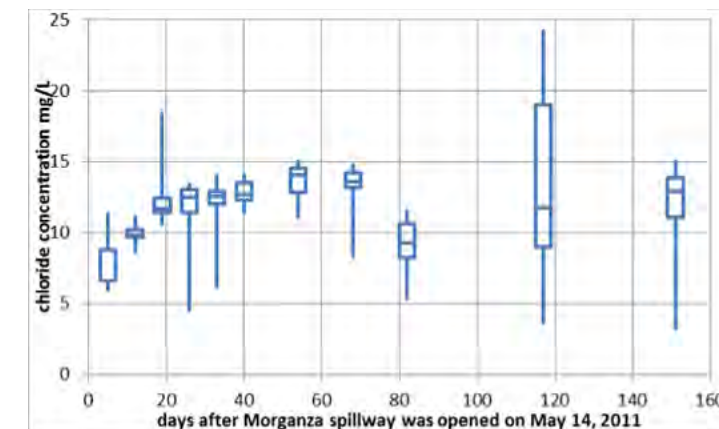


Figure 3. Change of chloride concentration throughout study area between May 19 and October 12. From left to right boxes represent samples collected on May 19, 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12. For this and all box and whiskers plots that follow the top tip whisker is at 95% rank, top of box is at 75%.

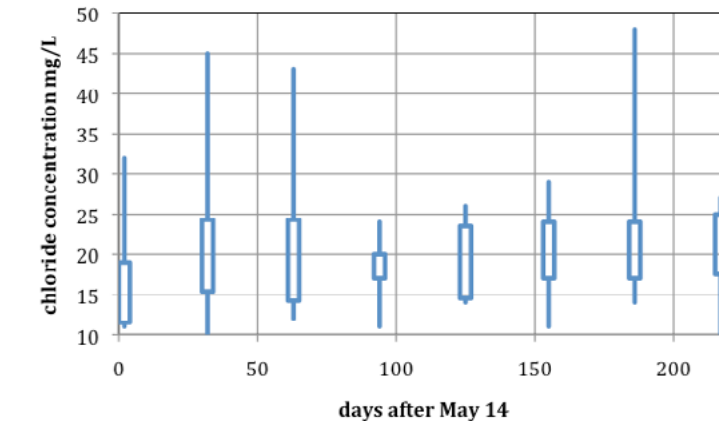


Figure 4. Monthly chloride concentrations measured for the Mississippi River at Vicksburg, Mississippi. Each month's data is displayed at a month center relative to May 14. These values were measured between 1961 and 1999. Source of data is U.S. Geological Survey (2011a).

of Upper Mississippi River discharge at Thebes, Illinois occurred on May 2. By contrast the peak of Missouri River discharge at St. Charles occurred almost three weeks later on May 28 (U.S. Geological Survey, 2011b). In addition, the rate of recession from the peak discharge was far slower for Missouri River than either Ohio River or Upper Mississippi River (U.S. Geological Survey, 2011b). In addition the share of Mississippi River water that is from the Missouri River increasing between May and October the sulfate concentration of Missouri River water is increasing relative to sulfate concentration in the Ohio River and Upper Mississippi River (Figure 11). The average concentration difference between Missouri River and the other two sources increased from 40.69 mg/L and 53.20 mg/L for Ohio River and Upper Mississippi River May samples to 104.27 mg/L to 117.56 mg/L for Ohio River and Upper Mississippi River October samples. The increase in this difference occurred mainly between June and August (Figure 11). The typical increase in value appears to occur approximately 30 days later at Vicksburg, Mississippi where sulfate reach a generally higher level between September and December (last four boxes). This increase appears to be further delayed for Atchafalaya Basin where the major increase starts between early September and early October (Figure 9). A minor peak of sulfate concentration observed July 21 in the Atchafalaya Basin appears to occur 42 days after expected peak as predicted by sulfate concentrations at the Missouri-Mississippi confluence (Figure 12). The major increase up to sulfate concentrations of approximately 80 mg/L is observed by October 12. By contrast expected arrival of this concentration is August 4, 69 days earlier (Figure 12). These differences are a result of the time it takes water to travel from confluence of Missouri River and Mississippi River down to Atchafalaya Basin, which is approximately 836 miles to the south (U.S. Army Corps of Engineers, 1998). This speed of approximately 20 miles/day is similar to speed of moving water through the Atchafalaya River in August of 1975 for a dye test which was approximately 34 miles/day (Wells and Demas, 1977). Difference of time is probably a result of slower moving water in August where discharge is approximately 60% lower than in early July (US Geological 2011b). The difference between observed and expected values in the early part of the study period is probably a result of Missouri Rivers sulfate concentration of 65 mg/L in May, 2011 versus the typical May values used for the generating red star values that appear in Figure 12. This difference between average and 2011 concentrations of sulfate largely disappear by June which explains why both observed and expected values of sulfate concentration appear to reach a maximum of approximately 80 mg/L (Figure 12).

Total suspended solids (TSS) decreased between May 19 and June 23 and an increase between June 23 and July 7 (Figure 13). The average fluoride concentration is 88.0 + 107.1 mg/L on May 19 and decreases to 43.8 + 33.5 mg/L on July 7. This change is determined with use of a t-test to be significant with a confidence of this difference over 97.5%. TSS continued to decrease to 38.3 + 30.9 mg/L on July 21st. This change between May 19 and July 7 is determined with use of a t-test to be significant with a confidence of this difference is 98.9%. There are a small number of sites with TSS concentrations less than 1 mg/L, but this is an increasing number of sites (Figure 12). After July 21 the concentration of TSS decreased to a fairly constant concentration of 26.03 ± 20.34 mg/L on August 4, 23.17 ± 9.72 mg/L on September (Figure 26), and 25.10 ± 12.12 mg/L on October 12 (Figure 13)

Phosphate appears to experience an early decrease between May 26th and June 2nd-June 9th, and then a slow increase to July 7th (Figure 14). The average phosphate concentration is 1.091 ± 0.044 mg/L on May 26th and decreases to 0.961 ± 0.105 mg/L on July

21st. This change is determined with use of a t-test to be significant with a confidence of this difference over 99.95%. The variability of phosphate concentrations as expressed by standard deviations appears to increase during the flood event increasing from 0.044 mg/L on May 26th to 0.388 mg/L July 7th and then decreasing to 0.105 mg/L on July 21st (Figure 14). After July 21 the concentration of phosphate decreased greatly for August 4 and September 9 (Figure 15). The overall phosphate concentrations between May 19 and October 12 appear to be similar to typical results measured between 1944 and 1995 (Garrison, 2001).

It appears that nutrients (nitrate and phosphate) concentrations are for the overall area fairly steady, but the variation across the basin increases during the flooding event as evidenced by increasing standard deviations indicative of concentration sites with low concentration increase slowly through time and high concentration areas increase more quickly through time (Figure 16). The decline of orthophosphate is also very different depending on area where area with higher concentrations decline faster than low concentration areas after July 21. This change of nutrients is not uniform across the basin. For example, the increase in orthophosphate varies across the basin (Figure 17). Increases tend to be highest in the northern portion of the basin and decrease southward. In addition, the increase of orthophosphate decreases from east to west across the basin (Figure 17). Change in sulfate tends to decrease towards the center of the basin and from north to south (Figure 18).

ACKNOWLEDGEMENTS

Thanks for staff of six agencies: Audubon Society, Louisiana Department of Environmental Quality (LDEQ), Louisiana Department of Wildlife and Fisheries (LDWF), Louisiana State University (LSU), US Geological Survey (USGS), and US Fish and Wildlife Service (USFWS) for collection of field measurements and collection of samples for later laboratory analysis.

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Thanks to Robert Paulsell for creating five of the basin maps.

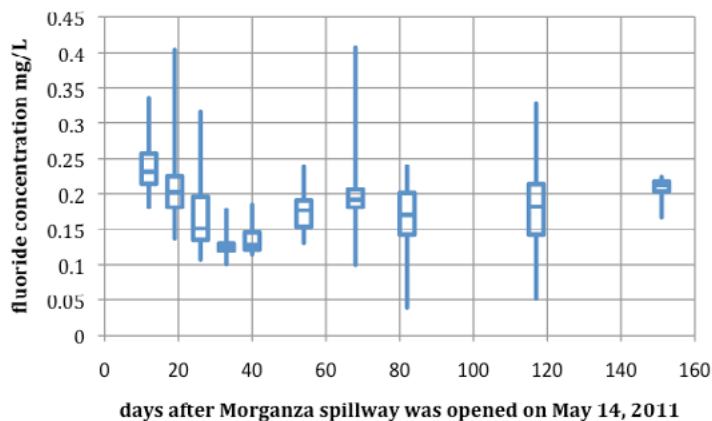


Figure 5. Change of fluoride concentration throughout study area between May 19 and September 9. From left to right boxes represent samples collected on May 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9, and October 12.

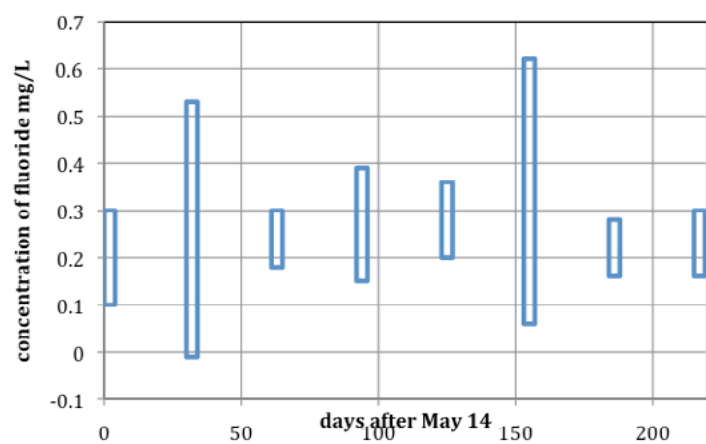


Figure 6. Monthly fluoride concentrations measured for the Mississippi River at Vicksburg, Mississippi. Each month's data is displayed at a month center relative to May 14. These values were measured between 1961 and 1999. Source of data is U.S. Geological Survey (2011a). This figure has a box that displays range of a standard deviation about a mean value of fluoride for each month.

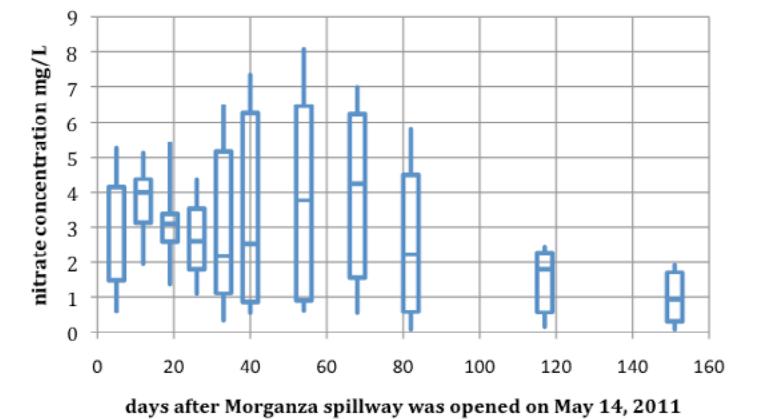


Figure 7. Change of nitrate concentration throughout study area between May 19 and September 9, 2011. From left to right boxes represent samples collected on May 19, 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12.

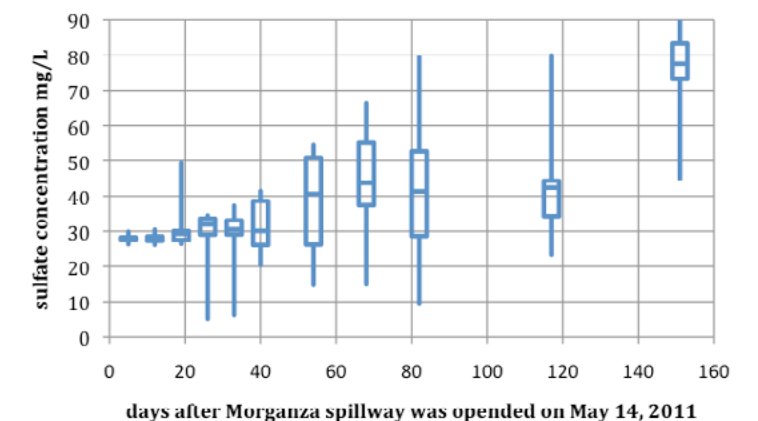


Figure 8. Change of sulfate concentration throughout study area between May 19 and September 9, 2011. From left to right boxes represent samples collected on May 19, 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12.

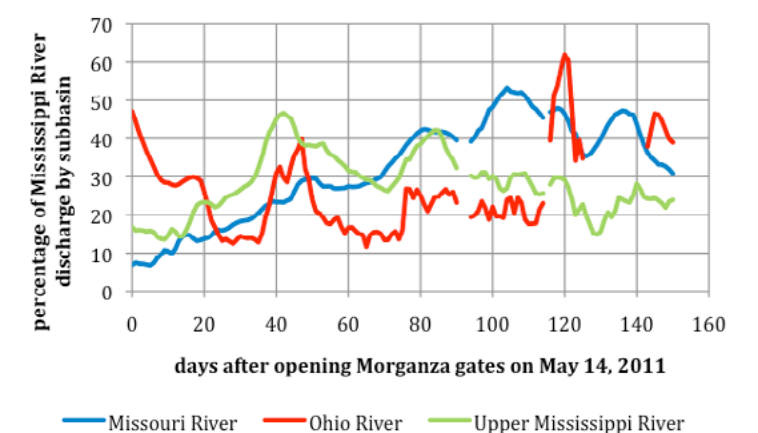


Figure 9. Share of Mississippi River discharge at Vicksburg, Mississippi that are from ub-basins north of Memphis Tennessee. Sum of percentage may exceed 100% due to use of provisional data and passage of water/flood crests that take time to travel downstream from St. Charles, Missouri for the Missouri River, Thebes, Illinois for upper Mississippi River minus Missouri River and Metropolis, Illinois for the Ohio River to lower Mississippi River at Vicksburg, Mississippi River, Data source is US Geological Survey, (2011b),

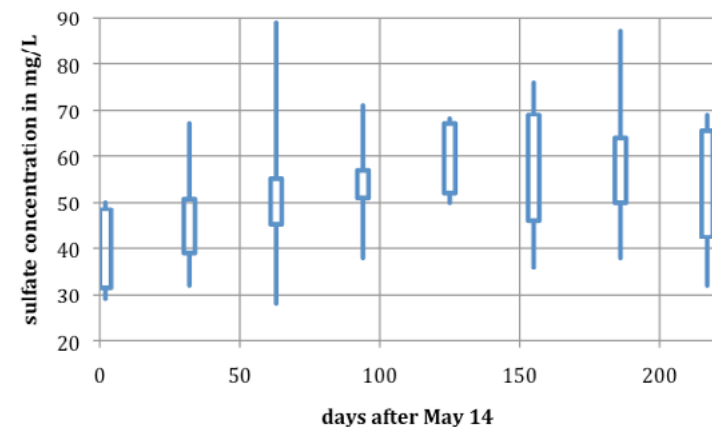


Figure 10. Monthly sulfate concentrations measured for the Mississippi River at Vicksburg, Mississippi. Each month's data is displayed at a month center relative to May 14. These values were measured between 1961 and 1999. Source of data is U.S. Geological Survey (2011a).

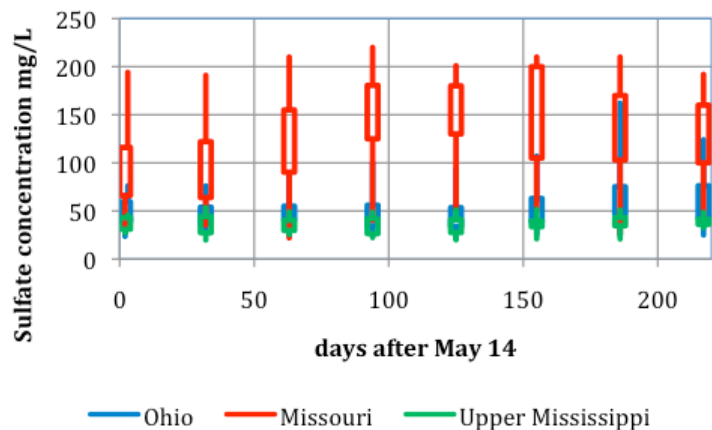


Figure 11. Monthly sulfate concentrations measured for major source rivers Ohio River at Gain Chain, Illinois, Missouri River at Hermann, Missouri and Upper Mississippi River at Grafton, Illinois. Source of data is U.S. Geological Survey (2011a). These values were measured between 1989 and 2011 for Upper Mississippi River, 1967 and 2011 for Missouri River and 1954 and 2011 for Ohio River.

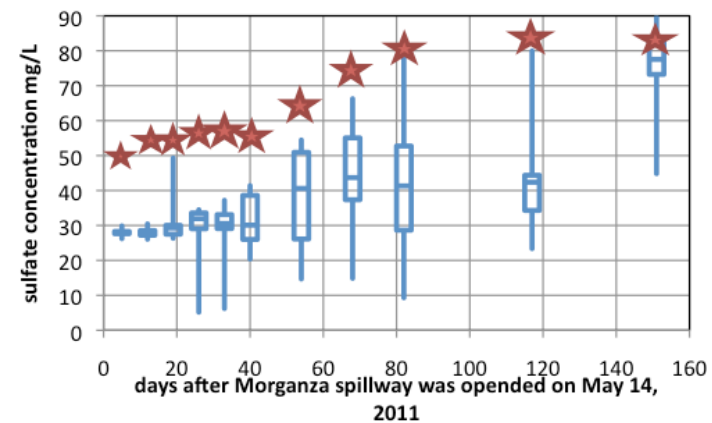


Figure 12. Expected sulfate concentrations and observed sulfate concentration throughout study area between May 19 and September 9, 2011. From left to right boxes represent samples collected on May 19, 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12. The red stars are expected concentrations given upper three basin concentration and discharge information from figures 9 and 11.

REFERENCES

Antweiler, Ronald C., Donald A. Goolsby, and Howard E. Taylor, 1996, Contaminants in the Mississippi River: U.S. Geological Survey Circular 1133, <http://pubs.usgs.gov/circ/circ1133/nutrients.html>, accessed October 28, 2011.

Boersma, Paul, 2011, Statistical tests: <http://www.fon.hum.uva.nl/Service/Statistics.html> accessed September 13, 2011

Carlson, Douglas A., Marty Horn, Thomas P. Van Biersel, and David Fruge, 2011, 2011 Atchafalaya Basin Inundation Data Collection and Damage Assessment Project, Mid-August Interim Report: Louisiana Department of Natural Resources, Baton Rouge, Louisiana, 84p.

Garrison, Charles R., 2001, Statistical Summary of Surface-Water Quality in Louisiana-Atchafalaya-Teche-Vermilion Basin, 1944-95: Louisiana Department of Transportation and Development, Water Resources Technical Report, no. 55F, 141p.

U.S. Army Corps of Engineers, 1998, 1998 Mississippi River Navigation Charts, Upper Mississippi River Mile 300 to Gulf of Mexico: <http://www.mvd.usace.army.mil/gis/navbook/main.html>.

U.S. Geological Survey, 2011a, National water quality data: <http://nwis.waterdata.usgs.gov/nwis/qwdata> accessed on November 5, 2011.

U.S. Geological Survey, 2011b, National surface water data: <http://nwis.waterdata.usgs.gov/> accessed on October, 28, 2011.

Wells, Frank C., and Charles R. Demas, 1977, Hydrology and Water Quality of the Atchafalaya River Basin: Louisiana Department of Transportation and Development, Water Resources Technical Report, no. 14, 53p.

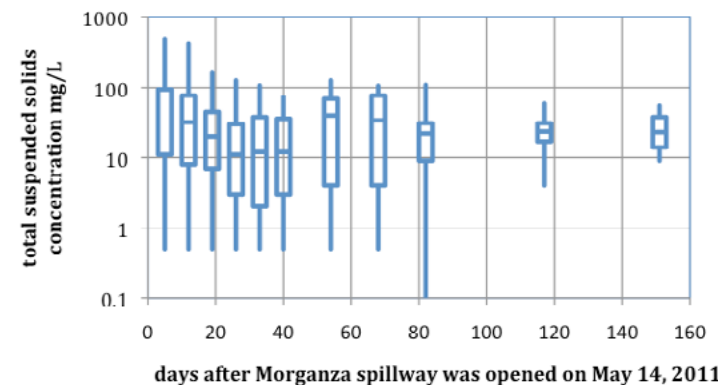


Figure 13. Change of total suspended solids concentrations throughout study area between May 19 and September 9, 2011. From left to right boxes represent samples collected on May 19, 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12.

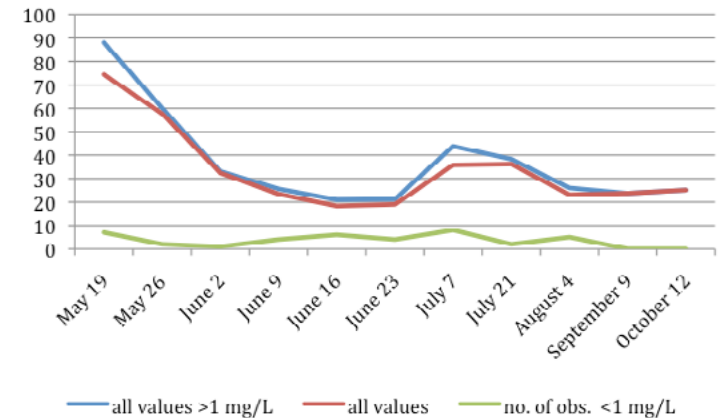


Figure 14. Change of average of TSS concentration throughout study area

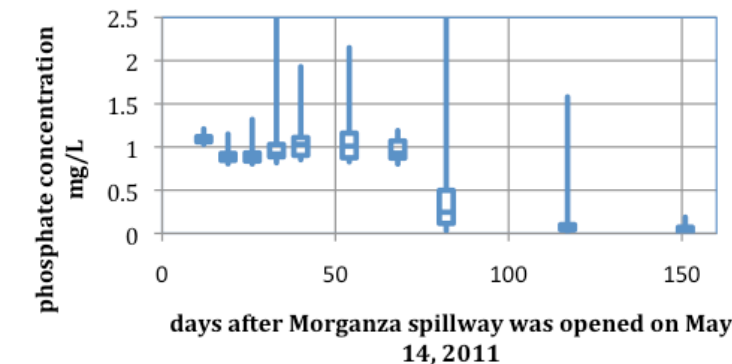


Figure 15. Change of phosphate concentration throughout study area between May 19 and September 9, 2011. From left to right boxes represent samples collected on May 26; June 2, 9, 16, 23; July 7, 21, August 4, September 9 and October 12.

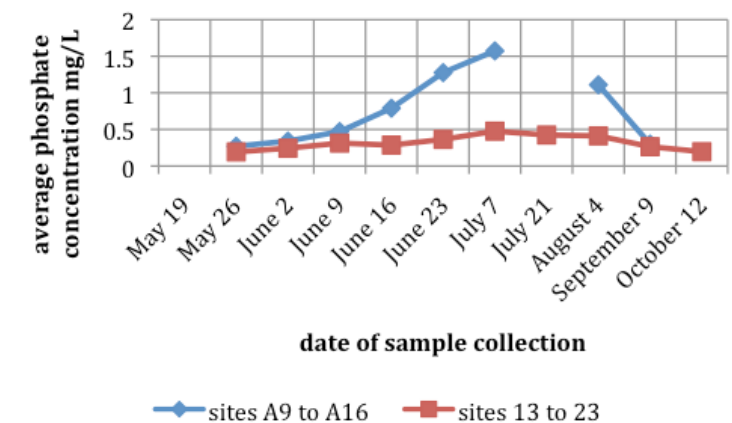


Figure 16. Change of orthophosphate concentrations for sites near I10 and near Wax Lake. The sites near I10 include A9 to A16. The sites near Wax Lake include 13 to 23.

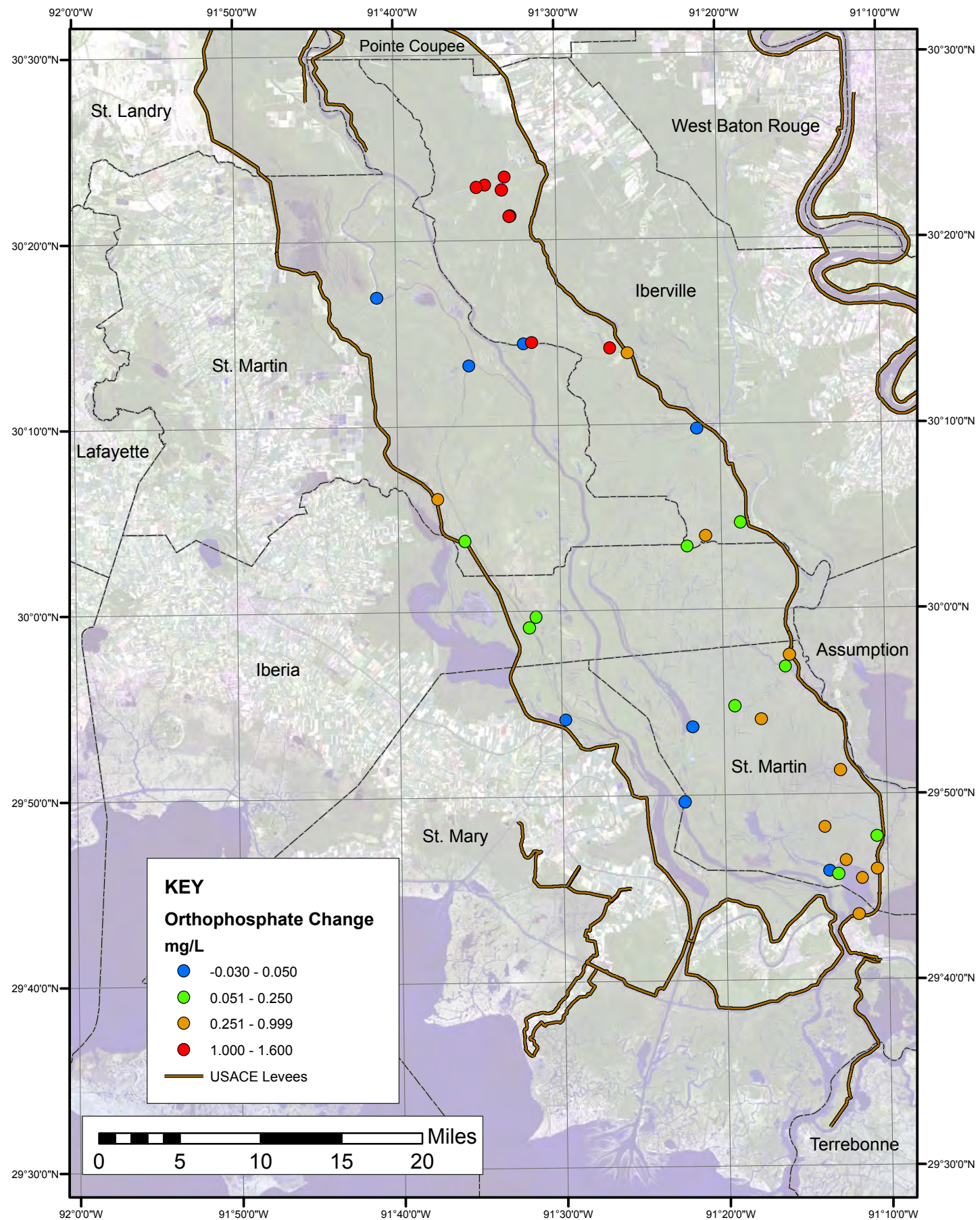


Figure 17. Change of orthophosphate concentration between May 26th and July 7th.

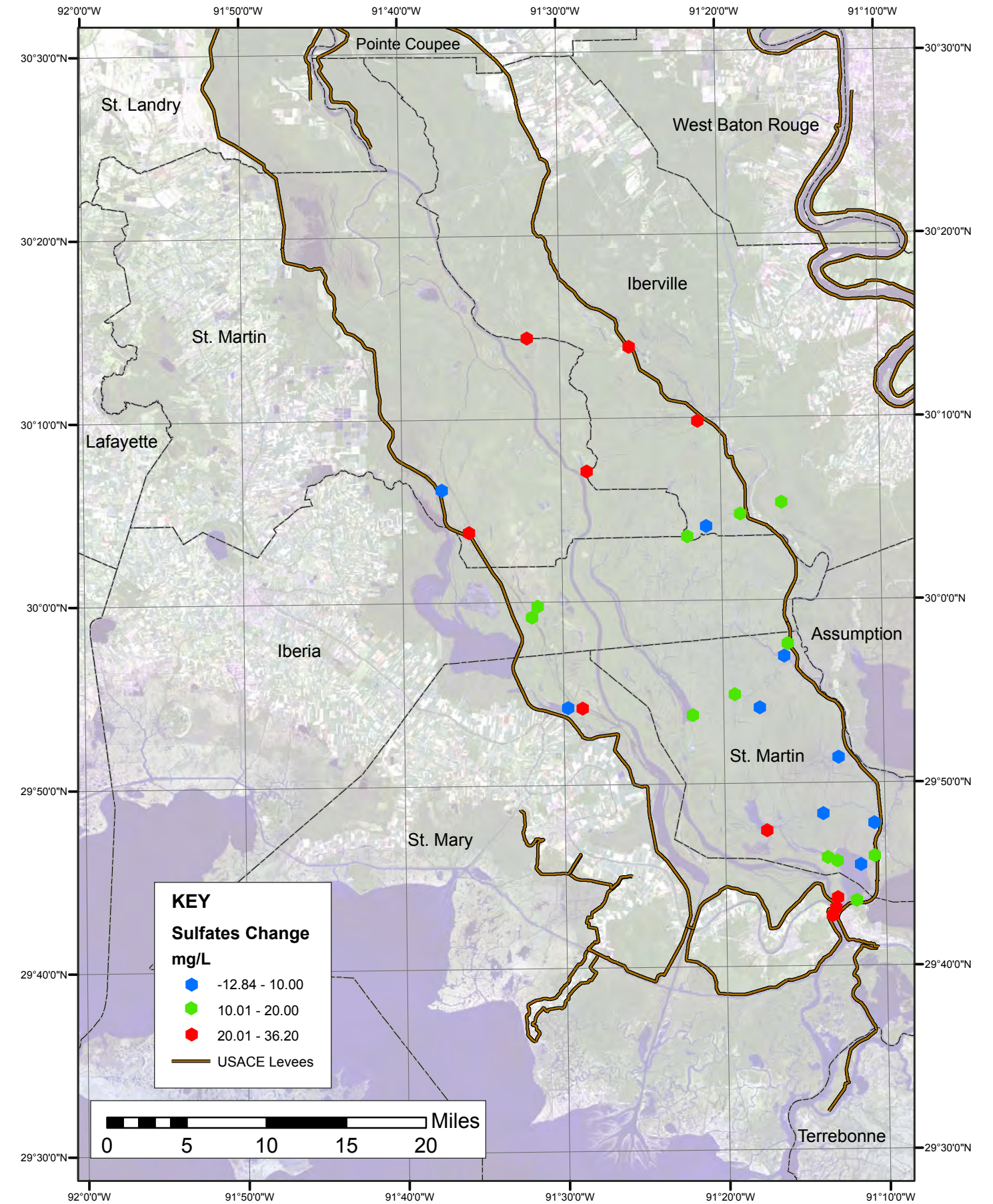


Figure 18 Change of sulfate concentration between May 19th and July 21st.

Progress Report on Baseline Water Quality Study of the Carrizo-Wilcox Aquifer in Northwest Louisiana

Douglas Carlson and Marty Horn

INTRODUCTION

Recently many baseline studies have been completed for a variety of reasons: general groundwater management (Arizona Department of Environmental Quality, 1998; Ground Water Monitoring and Assessment Program, 1998a and b, 1999a,b,c and d); nutrient concentrations in drinking water (Dakota County Environmental, 2003); land use impacts (Ground Water Monitoring and Assessment Program, 2001); nuclear waste storage (La Camera et al., 2005); impacts of artificial recharge (Ziegler et al., 1999); impacts of mine development (Smith et al., 2002; Kimball et al., 2006; and Clayton, 2011); impacts of oil and or gas field development (S.S. Papadopoulos & Associates Inc., 2007; and URS Corporation, 2007); impact of gas field development (Oram, 2010a and 2010b; Baker et al., 2011; BJAAM Environmental Inc., 2011; Kyshakevych, 2011; and Royster, 2011). Although there are 19 shale gas plays throughout the United States the Marcellus shale of Maryland, New York, Ohio, Pennsylvania, and West Virginia (Wikipedia, 2011) is the dominate shale in terms of technically recoverable gas (410.34 trillion cubic feet) out of 750.38 trillion cubic feet of technically recoverable gas in the United States and has the largest area at 94,893 square miles (US. Energy Information Administration, 2011). This probably accounts for the current interest in baseline studies of water quality of aquifers above the Marcellus gas play development (Oram, 2010a and 2010b; Baker et al., 2011; BJAAM Environmental Inc., 2011; Kyshakevych, 2011; and Royster, 2011). However, the Haynesville Shale gas play is the second largest of these shale gas plays in terms of technically recoverable resources (U.S. Energy Information Administration, 2011), but has received no interest until this study for a baseline of water quality prior to a large share of drilling and development that will be associated with the development of the Haynesville Shale gas play.

The Haynesville Formation shale has been recently estimated to contain up to 200 trillion cubic feet of natural gas. To develop this vast reserve of natural gas, it will be necessary to drill thousands of wells over a eight parish area (Bienville, Bossier, Caddo, De Soto, Natchitoches, Red River, Sabine and Webster Parishes). This drilling activity and associated hydraulic fracturing will involve use of vast volumes of groundwater, which will impact locally and regionally water levels. This activity could also impact the groundwater quality by possibly reversing flow of water from current conditions. For example, groundwater which flows towards the Red River, a river that has high chloride and total dissolved solids (TDS) concentrations generally over acceptable levels for drinking water, may flow in the opposite direction, affecting the local aquifer. Possible changes in pressure gradient in either horizontal or vertical direction could cause the movements of dissolved ions, methane, or other volatile organic compounds (VOCs) into groundwater wells. So, prior to a major portion of this activity, it would be advantageous to determine the pre-existing water quality throughout the study area before any impacts occur due to major development the Haynesville Formation.

There are thousands of households in southern Caddo, southern Bossier, and northern De Soto Parishes that are dependent on groundwater for their domestic supply of water. Many of these wells were completed since the mid1980s and have well completion reports within the Louisiana Department of Transportation and Development records. Furthermore, there are probably many additional older wells that supply water for households throughout the study area.

This source of potable water could be adversely impacted by drilling and hydraulic fracturing activity associated with the development of the Haynesville Formation shale natural gas field. It is estimated that approximately 3 to 4 million gallons of water will be used for each well during the initial development (Roberts, 2008; Gary Hanson personal communication, 2008). These estimates appear to be slightly lower, but similar to average hydraulic fracturing uses reported for ground water, 3.1 million gallons, of water and for surface water, 5.1 million gallons of water (Louisiana Department of Natural Resources, 2011), however, hydraulic fracturing uses per well are up to approximately 11 million gallons (Figure 1).

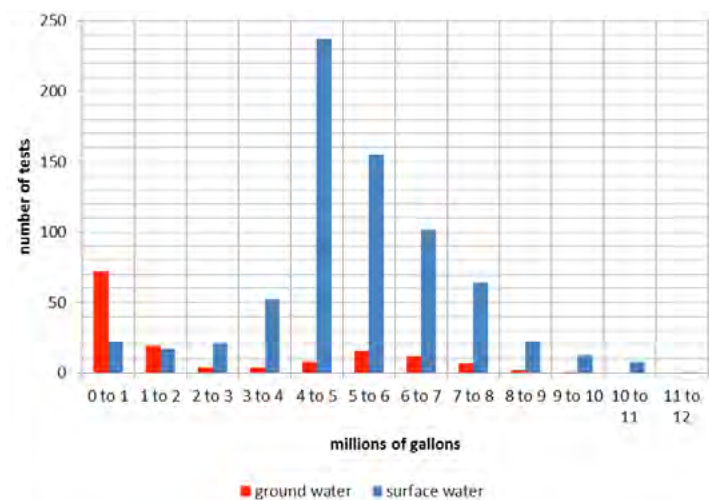


Figure 1. Volumes of water used for hydraulic fracturing of the Haynesville Shale. Results include 145 ground water tests and 714 surface water tests (Louisiana Department of Natural Resource, 2011a)

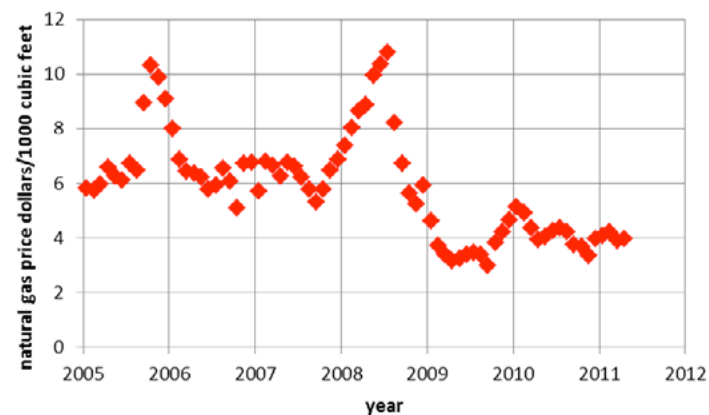


Figure 2. Price of natural gas at the wellhead January 2005 to April 2011 (Energy Information Administration, 2011).

The Haynesville Formation shale is considered a profitable play to drill when gas prices are above \$7/1000 cubic feet (Kurt Ley, personal communication, 2008). The price of gas over the past three years has been generally over \$4/1000 cubic feet (ft³) (Figure 2), however there is ongoing regional drilling (Figure 3). It is ideal for the baseline study is completed prior major development of the Haynesville Formation shale. This could occur anytime when gas prices are significantly over \$7/1000 ft³ for any extended period of

time. Recently the price has been significantly below \$7/1000 ft³. However, even with low prices for natural gas since this October 2008 (average \$4.09/1000 ft³) and only an average of (\$3.91/1000 ft³) and since March 2009 (Energy Information Administration, 2011) the drilling activity for the Haynesville play has been generally decreasing (Figure 4 and 5), but still drilling activity is over 20 new wells drilled each month (Figure 5).

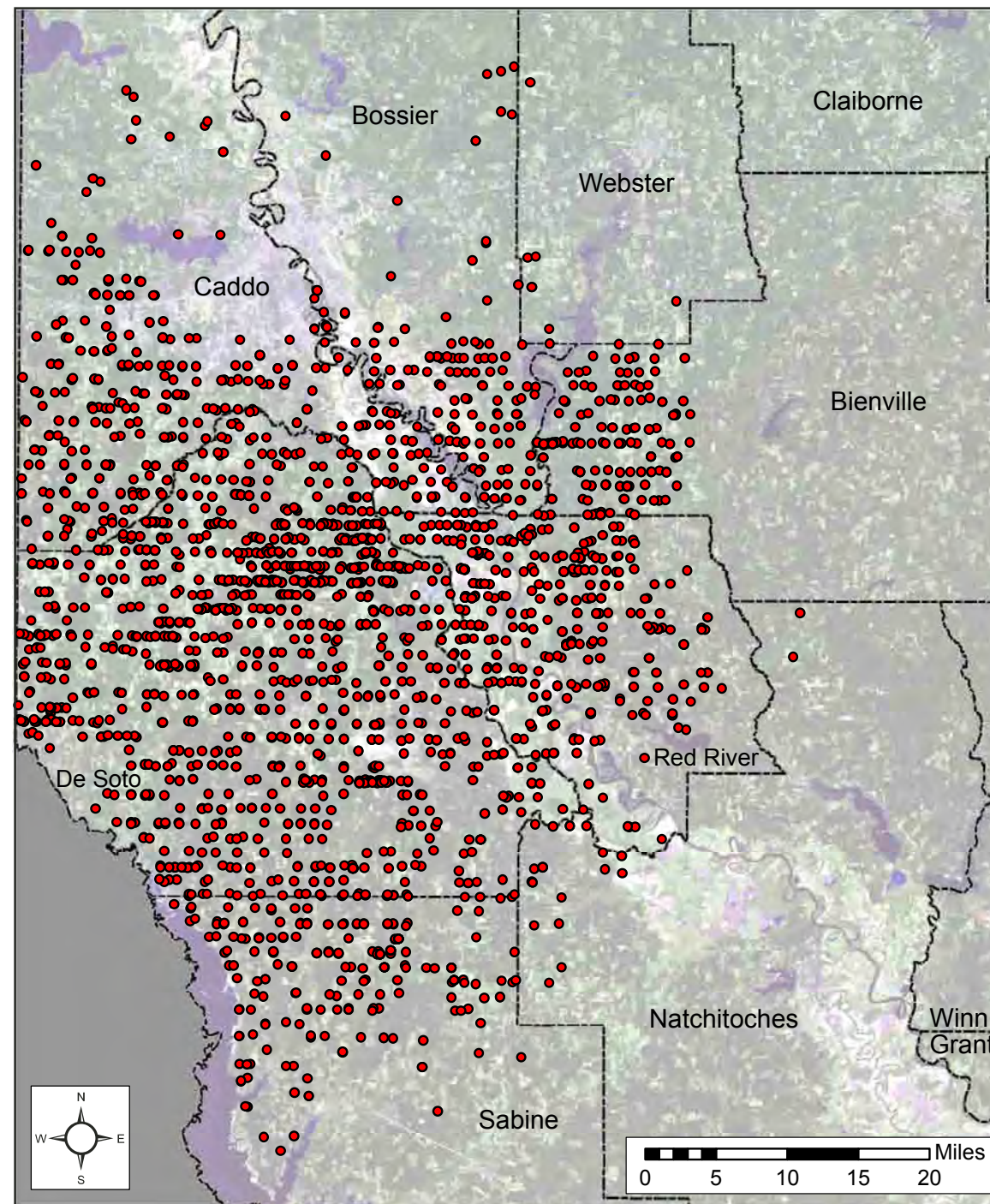


Figure 3. Location of current drilling associated with development of the Haynesville Formation. Purple dots are well sites (source of data is the Louisiana Department of Natural Resources, 2011b).

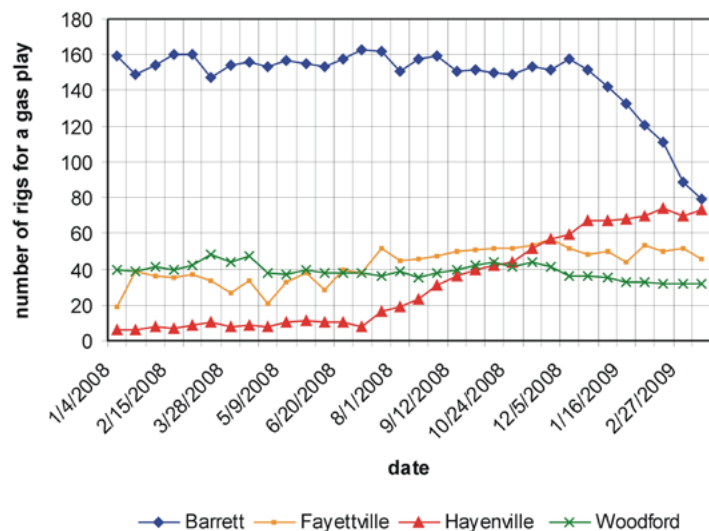


Figure 4. Drilling activity with Haynesville Formation compared to other major gas plays (Durham, 2009).

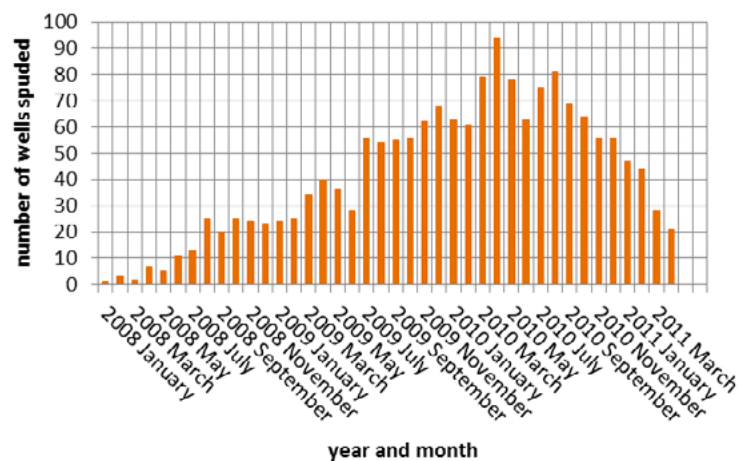


Figure 5. Drilling activity that is within the Haynesville Play as indicated by report scout information to Louisiana Department of Natural Resources (source of information: Louisiana Department of Natural Resources, 2011b).

METHODS

The study has included collection of samples from approximately 1,100 wells within the three parish study. This study has involved sampling more wells than are in either the United States Geological Survey (USGS) groundwater set, which was collected over a seventy year interval (USGS, 2011) or the Louisiana Department of Health and Hospitals (LA DHH) (Louisiana Department of Health and Hospitals, 2009) for all of Caddo, Bossier and De Soto Parishes, (Table 1). Many baseline studies of groundwater quality are far smaller; typically approximately 50 to 200 piezometers and/or wells are sampled for groundwater quality (Ground Water Monitoring and Assessment Program, 2001; Kimball, 2006; S.S. Papadopoulos & Associates Inc., 2007; and URS Corp., 2007). Even large regional baseline studies of Minnesota’s Principal Aquifers that cover 2,813 to 21,853 square miles included only 132 to 238 wells tested for a variety of parameters and ions (Ground Water Monitoring and Assessment Program, 1998a and b, 1999a,b,c and d). Whereas many other baseline studies include dozens of observations per county (parish) this study includes dozens of observations by community (Table 2).

These samples were collected from wells completed in mainly the Carrizo-Wilcox and a few samples from and Upland Terrace and Red River Alluvial aquifers. Samples were generally analyzed for Aluminum, Arsenic, Boron, Bromide, Cadmium, Calcium, Chloride, Chromium, Copper, Fluoride, Iron, Lead, Magnesium, Manganese, Nickel, Nitrate, Nitrite, Potassium, Phosphates, Phosphorus, Rubidium, Sulfate, Silicon, Sodium, Strontium, and Zinc, as well as pH and specific conductance in the field. All wells were field tested and laboratory tested for methane, within head space. Approximately 1 out of 10 wells had samples collected for full VOCs analysis and dissolved methane analysis in the laboratory.

Prior to sampling well owners were asked permission to access their property to collect a water sample. After the permission was granted, Louisiana Geological Survey (LGS) staff scheduled and collected the sample. The water wells were purged for approximately 20 minutes prior (approximately one casing and plumbing volume) prior to the collection of samples for field testing and later laboratory testing. Samples collected for laboratory testing were stored and cooled to 4 °C in the field, and transferred to a refrigerator in the lab. The unpreserved bottle was analyzed in the lab using LGS’s Dionex ICS-1000 Ion Chromatography System for chloride, bromide, nitrate, nitrite, phosphate, and sulfate and by gravimetric determination for TDS. The nitric acid preserved bottle was analyzed by either staff of LSU’s Department of Wetland Biochemistry using their Varian (ICP-OES model MPX) Inductively Coupled Plasma-Optical Emission Spectrometer or by staff of LSU’s School of Plant, Environment and Soil Sciences using their SPECTRO CIROSCCD Inductively Coupled Plasma-Optical Emission Spectrometer. In addition, while at the well site field measurements of specific conductance using LGS’s Hanna Instruments HI9033 multi-range conductivity meter and pH will be used using LGS’s EcoSense pH100 meter were conducted.

Table 1.

A comparison of wells sampled in three major data sets

| Parish | This study | USGS | LA DHH |
|---------|------------|------|--------|
| Bossier | 360 | 262 | 65 |
| Caddo | 477 | 358 | 72 |
| De Soto | 237 | 198 | 37 |
| total | 1074 | 858 | 174 |

Table 2.

Wells sampled by community as defined by zip code areas, top 10 zip code areas

| Parish | Zip code | community | Number of wells |
|---------|----------|--------------|-----------------|
| Caddo | 71106 | Shreveport | 148 |
| Bossier | 71112 | Bossier City | 133 |
| Bossier | 71037 | Haughton | 116 |
| Caddo | 71047 | Keithville | 108 |
| Bossier | 71051 | Elm Grove | 104 |
| De Soto | 71078 | Stonewall | 73 |
| De Soto | 71032 | Grand Cane | 73 |
| Caddo | 71119 | Shreveport | 67 |
| De Soto | 71046 | Keatchie | 50 |
| Caddo | 71129 | Shreveport | 42 |

All the water was screened for methane using an indirect methane emission method. A 750-ml sample will be collected from the water well sampling port (e.g. closest faucet to the well without treatment or aeration). The samples were collected at low-flow and poured into a modified 1-L bottle. The sample will be shaken for 30 seconds and set aside to stabilize for 10 minutes. After stabilization, the headspace above the sample will be tested for methane concentration (in ppm) using a Thermo Electron Corp. Innova LS. In addition to field check, a laboratory head space test for dissolved gas content was conducted on samples from most of the wells as measured by gas chromatography.

A randomly selected set of approximately 100 wells were sampled for volatile organic compounds (VOCs) and methane concentration directly dissolved in water. The samples will be collected and delivered to Ana-Lab Corp (a lab certified by the LA Dept. of Health and Hospital and LA Dept. of Environmental Quality) in Shreveport, Louisiana.

RESULTS

Currently 1,074 wells have been sampled from within the study area (Figure 6). Many sample locations are so close to each other that on a map of this scale a dot may include multiple homes where water samples were collected.

All of these samples have been field tested and laboratory tested for anions and total dissolved solids, see Table 2, 3 and 4. In general, average concentrations are less than standard deviation of concentrations indicating that median is lower than average. Differences in the number of observations are largely a function of the rate of completing analytical analysis, where typically anion analysis is completed first and metal analysis is completed last. For heavy metals such as lead, arsenic, chromium and cadmium that are relatively rare and often yield non-detection values causes the number of measured observations that yield numeric values to be smaller than number of observations listed for the more common metals such as iron and manganese. Note a numbers of observations in Tables 2, 3 and 4 can be larger than number of wells listed in Table 1 because 32 wells were checked for seasonal variation of ion concentrations and a few others were repeated throughout the study to consider possible impacts of the drought of 2009-2011.

In general, concentrations of ions are highest in Bossier Parish and lowest in De Soto Parish. Bossier Parish has the highest average concentration for: specific conductance, aluminum, arsenic, barium, boron, bromide, cadmium, calcium, chloride, chromium, fluoride, iron, magnesium, manganese, nitrate, nitrite, silicon, sodium, strontium and total dissolved solids (TDS) (Table 5). De Soto Parish has the lowest average concentration for: specific conductance, arsenic, barium, bromide, cadmium, calcium, chloride, chromium, fluoride, iron, magnesium, manganese, nitrate, potassium, strontium and zinc (Table 5). Caddo Parish appears to have average values of concentrations that tend to be intermediate between the extremes of Bossier and De Soto Parish (Table 5). Many of these differences (13 of 30) among the averages are small but for some ions the difference is over 50% of the lowest average parish concentrations (Table 6).

Only a very small share of measured values exceeded EPA primary drinking water standards (Table 7). For two elements (chromium and fluoride) not a single sample yielded a value of concentration above the EPA primary drinking water standard among the 1,799 values analyzed. For three other ions (arsenic, cadmium, and copper, lead) a total of 5 values were above the EPA primary drinking water standard out of 2,135 values analyzed, approximately 0.25%. The largest number of values over EPA primary drinking water standard for lead is 18 out of 691 samples analyzed. In each case the results were less than three times the EPA standard (Table 7).

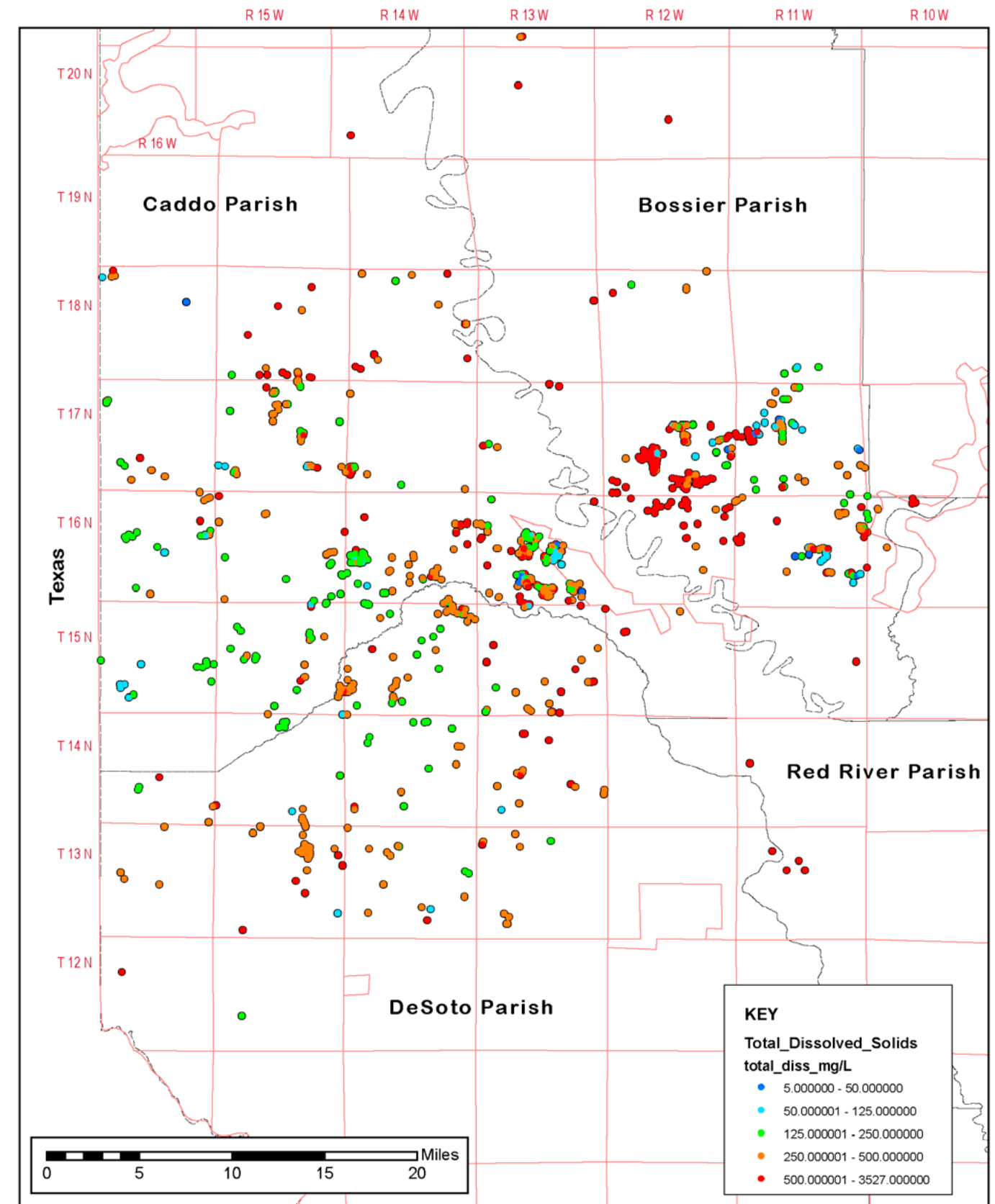


Figure 6. Location of samples analyzed to total dissolved solids through fifteen sample collection trips and approximately 1,000 wells sampled.

Table 2.
Concentrations of various ions analyzed for each of the samples collected in Bossier Parish.

| Parameter measured | Unit of measure | Number of observations | Average value | Standard deviation |
|------------------------------|-----------------|------------------------|---------------|--------------------|
| Field parameters (corrected) | | | | |
| pH | | 158 | 7.43 | 0.82 |
| Specific conductance | uS/cm | 177 | 1277 | 1138 |
| Temperature | centigrade | 155 | 20.8 | 2.35 |
| Nitrate | mg/L | 2 | 3.52 | 4.36 |
| Phosphate | mg/L | 2 | 0.66 | 0.38 |
| Sulfate | mg/L | 1 | 5.0 | |
| Laboratory parameters | | | | |
| Aluminum | ug/liter | 268 | 131 | 564 |
| Arsenic | ug/liter | 196 | 2.72 | 2.12 |
| Barium | mg/liter | 277 | 0.176 | 0.328 |
| Boron | mg/liter | 267 | 0.739 | 0.609 |
| Bromide | mg/liter | 267 | 0.781 | 0.691 |
| Cadmium | ug/liter | 73 | 0.481 | 0.277 |
| Calcium | mg/liter | 277 | 26.4 | 45.4 |
| Chloride | mg/liter | 356 | 125 | 178 |
| Chromium | ug/liter | 73 | 1.61 | 6.59 |
| Copper | ug/liter | 209 | 40.2 | 125 |
| Fluoride | mg/liter | 354 | 0.350 | 0.301 |
| Iron | mg/liter | 228 | 0.516 | 1.17 |
| Lead | ug/liter | 122 | 5.14 | 12.6 |
| Magnesium | mg/liter | 228 | 8.93 | 12.4 |
| Manganese | ug/liter | 214 | 81.0 | 411 |
| Nickel | ug/liter | 115 | 2.06 | 4.20 |
| Nitrate | mg/liter | 354 | 1.47 | 2.28 |
| Nitrite | mg/liter | 121 | 0.186 | 0.419 |
| Phosphate | mg/liter | 313 | 0.701 | 0.529 |
| Phosphorus | mg/liter | 226 | 0.188 | 0.187 |
| Potassium | mg/liter | 215 | 2.73 | 1.45 |
| Rubidium | ug/liter | 111 | 13.4 | 13.8 |
| Silicon | mg/liter | 215 | 10.0 | 6.23 |
| Sodium | mg/liter | 228 | 135 | 86.4 |
| Strontium | mg/liter | 227 | 0.575 | 0.527 |
| Sulfate | mg/liter | 294 | 8.64 | 26.4 |
| Total Dissolved Solids | mg/liter | 353 | 536 | 359 |
| Zinc | ug/liter | 228 | 73.0 | 264 |

Note: 1 mg/liter is approximately 1 ppm (1 part per million) and 1 ug/liter is approximately 1 ppb (1 part per billion).

Table 3.
Concentrations of various ions analyzed for each of the samples collected in Caddo Parish.

| Parameter measured | Unit of measure | Number of observations | Average value | Standard deviation |
|------------------------------|-----------------|------------------------|---------------|--------------------|
| Field parameters (corrected) | | | | |
| pH | | 391 | 7.85 | 0.78 |
| Specific conductance | uS/cm | 391 | 1004 | 1105 |
| Temperature | centigrade | 390 | 21.0 | 2.6 |
| Nitrate | mg/liter | 25 | 2.24 | 1.41 |
| Phosphate | mg/liter | 29 | 0.26 | 0.10 |
| Sulfate | mg/liter | 5 | 6.40 | 2.88 |
| Laboratory parameters | | | | |
| Aluminum | ug/liter | 255 | 94 | 461 |
| Arsenic | ug/liter | 163 | 1.94 | 1.17 |
| Barium | mg/liter | 255 | 0.108 | 0.115 |
| Boron | mg/liter | 250 | 0.445 | 0.404 |
| Bromide | mg/liter | 351 | 0.577 | 0.701 |
| Cadmium | ug/liter | 132 | 0.445 | 0.342 |
| Calcium | mg/liter | 254 | 15.9 | 26.2 |
| Chloride | mg/liter | 513 | 76.3 | 146 |
| Chromium | ug/liter | 115 | 0.897 | 1.57 |
| Copper | ug/liter | 245 | 51.1 | 174 |
| Fluoride | mg/liter | 513 | 0.279 | 0.288 |
| Iron | mg/liter | 254 | 0.498 | 1.93 |
| Lead | ug/liter | 132 | 5.78 | 6.62 |
| Magnesium | mg/liter | 275 | 6.04 | 11.2 |
| Manganese | ug/liter | 252 | 53.1 | 137 |
| Nickel | ug/liter | 176 | 2.87 | 7.43 |
| Nitrate | mg/liter | 482 | 0.909 | 1.23 |
| Nitrite | mg/liter | 223 | 0.0610 | 0.209 |
| Phosphate | mg/liter | 467 | 0.749 | 0.595 |
| Phosphorus | mg/liter | 224 | 0.287 | 0.257 |
| Potassium | mg/liter | 254 | 5.97 | 7.86 |
| Rubidium | ug/liter | 189 | 13.5 | 14.6 |
| Silicon | mg/liter | 254 | 8.18 | 8.69 |
| Sodium | mg/liter | 276 | 108 | 63.1 |
| Strontium | mg/liter | 224 | 0.562 | 0.818 |
| Sulfate | mg/liter | 501 | 10.1 | 34.5 |
| Total Dissolved Solids | mg/liter | 504 | 380 | 308 |
| Zinc | ug/liter | 276 | 79.4 | 405 |

Note: 1 mg/liter is approximately 1 ppm (1 part per million) and 1 ug/liter is approximately 1 ppb (1 part per billion).

Table 4.
Concentrations of various ions analyzed for each of the samples collected in De Soto Parish.

| Parameter measured | Unit of measure | Number of observations | Average value | Standard deviation |
|-------------------------------------|-----------------|------------------------|---------------|--------------------|
| Field parameters (corrected) | | | | |
| pH | | 178 | 8.13 | 0.61 |
| Specific conductance | uS/cm | 176 | 953 | 578 |
| Temperature | centigrade | 136 | 21.4 | 2.19 |
| Laboratory parameters | | | | |
| Aluminum | ug/liter | 159 | 103 | 324 |
| Arsenic | ug/liter | 95 | 1.61 | 1.60 |
| Barium | mg/liter | 159 | 0.0754 | 0.0866 |
| Boron | mg/liter | 159 | 0.449 | 0.403 |
| Bromide | mg/liter | 151 | 0.283 | 0.438 |
| Cadmium | ug/liter | 86 | 0.306 | 0.277 |
| Calcium | mg/liter | 159 | 11.4 | 19.9 |
| Chloride | mg/liter | 220 | 44.5 | 73.4 |
| Chromium | ug/liter | 70 | 0.578 | 1.20 |
| Copper | ug/liter | 146 | 24.4 | 52.2 |
| Fluoride | mg/liter | 220 | 0.271 | 0.336 |
| Iron | mg/liter | 159 | 0.362 | 1.04 |
| Lead | ug/liter | 72 | 6.59 | 5.68 |
| Magnesium | mg/liter | 138 | 3.45 | 9.49 |
| Manganese | ug/liter | 117 | 34.8 | 48.3 |
| Nickel | ug/liter | 73 | 2.60 | 2.61 |
| Nitrite | mg/liter | 67 | 0.133 | 0.440 |
| Nitrate | mg/liter | 211 | 0.714 | 0.734 |
| Phosphate | mg/liter | 201 | 0.772 | 0.606 |
| Phosphorus | mg/liter | 138 | 0.331 | 0.178 |
| Potassium | mg/liter | 117 | 2.05 | 0.909 |
| Rubidium | ug/liter | 121 | 13.9 | 17.0 |
| Silicon | mg/liter | 117 | 8.51 | 4.90 |
| Sodium | mg/liter | 138 | 122 | 54.6 |
| Strontium | mg/liter | 138 | 0.375 | 0.497 |
| Sulfate | mg/liter | 216 | 19.8 | 69.2 |
| Total Dissolved Solids | mg/liter | 208 | 389 | 224 |
| Zinc | ug/liter | 138 | 59.0 | 138 |

Note: 1 mg/liter is approximately 1 ppm (1 part per million) and 1 ug/liter is approximately 1 ppb (1 part per billion).

Table 5.
Comparison of ranks among the average ion measured concentrations by parish.

| Parish | first | second | third |
|---------|-------|--------|-------|
| Bossier | 20 | 3 | 7 |
| Caddo | 4 | 20 | 6 |
| De Soto | 6 | 7 | 17 |

Table 6.
Differences among average measured concentrations.

| Ion | Parish with lowest average | Parish with highest average | Difference of high relative to low (%) |
|-------------|----------------------------|-----------------------------|--|
| Nitrite | Bossier | Caddo | 205 |
| Potassium | Caddo | De Soto | 191 |
| Chloride | Bossier | De Soto | 181 |
| Chromium | Bossier | De Soto | 178 |
| Bromide | Bossier | De Soto | 176 |
| Magnesium | Bossier | De Soto | 159 |
| Manganese | Bossier | De Soto | 133 |
| Calcium | Bossier | De Soto | 131 |
| Barium | Bossier | De Soto | 133 |
| Sulfate | De Soto | Bossier | 129 |
| Copper | Caddo | De Soto | 109 |
| Nitrate | Bossier | De Soto | 106 |
| Phosphorous | De Soto | Bossier | 76 |
| Arsenic | Bossier | De Soto | 70 |
| Boron | Bossier | Caddo | 66 |
| Cadmium | Bossier | De Soto | 56 |
| Strontium | Bossier | De Soto | 53 |

Table 7.
Number of values measured that exceed primary EPA drinking water standards by ion, primary standards are focused on ions that can impact health.

| ion | Standard limit (mg/L) | Total number of samples | Number of samples exceeding standard value | Share of observations that exceed standard |
|----------|-----------------------|-------------------------|--|--|
| Arsenic | 0.01 | 712 | 1 | 0.1% |
| Cadmium | 0.005 | 712 | 1 | 0.1% |
| Chromium | 0.1 | 712 | 0 | 0% |
| Copper | 1.3 | 711 | 3 | 0.4% |
| Fluoride | 4.0 | 1,087 | 0 | 0% |
| Lead | 0.015 | 698 | 18 | 2.6% |
| Nitrate | 10 | 1,047 | 6 | 0.6% |
| Nitrite | 1.0 | 699 | 11 | 1.6% |

By contrast to primary EPA drinking water standards secondary EPA drinking water standards were exceeded frequently (Table 8). The samples exceeding secondary standards are not a health concern, but indicate water that may smell, taste, and appear less than ideal. For this study eight ions and two general parameters which are analyzed are among the EPA's list of secondary drinking water standards. For three ions (aluminum, iron, manganese) two general parameters (pH and total dissolved solids (TDS)) approximately a fifth of samples exceed EPA secondary drinking water standard (Table 8). Two of these iron and pH exceed EPA secondary drinking water standard for almost a quarter of samples tested (Table 8).

Field measurement of head space methane concentration (head space is air above sample of water in a sealed flask) was less than 1% (10,000 ppm) for 1,048 of 1,073 (97.5% of all samples) samples tested. In general, methane head space values are highest for Bossier Parish and lowest for De Soto Parish (Figures 7 and 8 and Table 9). For Bossier Parish laboratory results of head space methane concentration yielded an average of 0.42%, with a standard deviation of results of 0.64%, for the 265 samples analyzed. For Caddo Parish

laboratory results of head space methane concentration yielded an average of 0.074%, with a standard deviation of results of 0.22%, for the 280 samples analyzed (Table 9). For De Soto Parish laboratory results of head space methane concentration yielded an average of 0.031%, with a standard deviation of results of 0.11%, for the 140 samples analyzed.

Approximately 10% of all wells, 100, were sampled for dissolved volatile organic compounds and dissolved methane. For VOC's tested approximately 50 compounds were included in the analysis of each of the 100 samples. All of the values were less than detection value except one sample with a detection of only Acetone at a concentration of 5.35 ug/L/(5.35 ppb) just over detection limit of 5 ppb for Acetone. Most of the compounds were measured with low detection values often less than 1 part per billion (ppb). In general, the concentration of head space methane concentrations significantly lower than in Bossier Parish and higher than in De Soto Parish (Figures 8). The confidence of differences are noted between each of the box and whiskers plots and both cases they were well over 95%, which is usually considered the confidence necessary to be considered significant.

Table 8.

Number of values measure that exceed secondary EPA drinking water standards by ion or general water parameter. Secondary EPA standards are focused on aesthetic effects such as taste, smell, or odor.

| ion | Standard limit (mg/L) | Total number of samples | Number of samples exceeding standard value | Percentage of observations that exceed standard |
|-----------|-----------------------|-------------------------|--|---|
| Aluminum | 0.05 to 0.2 | 791 | 222 to 63 | 28.1% to 8.0% |
| Chloride | 250 | 1,089 | 91 | 8.4% |
| Copper | 1.0 | 711 | 4 | 0.6% |
| Fluoride | 2.0 | 1,087 | 5 | 0.5% |
| Iron | 0.3 | 643 | 164 | 25.5% |
| Manganese | 0.05 | 584 | 124 | 21.2% |
| pH | <6.5 & >8.5 | 727 | 182* | 25.0% |
| Sulfate | 250 | 1,016 | 6 | 0.6% |
| TDS | 500 | 1,067 | 310 | 29.0% |
| Zinc | 5.0 | 642 | 1 | 0.2% |

57 are less than 6.5 and 125 are over 8.5

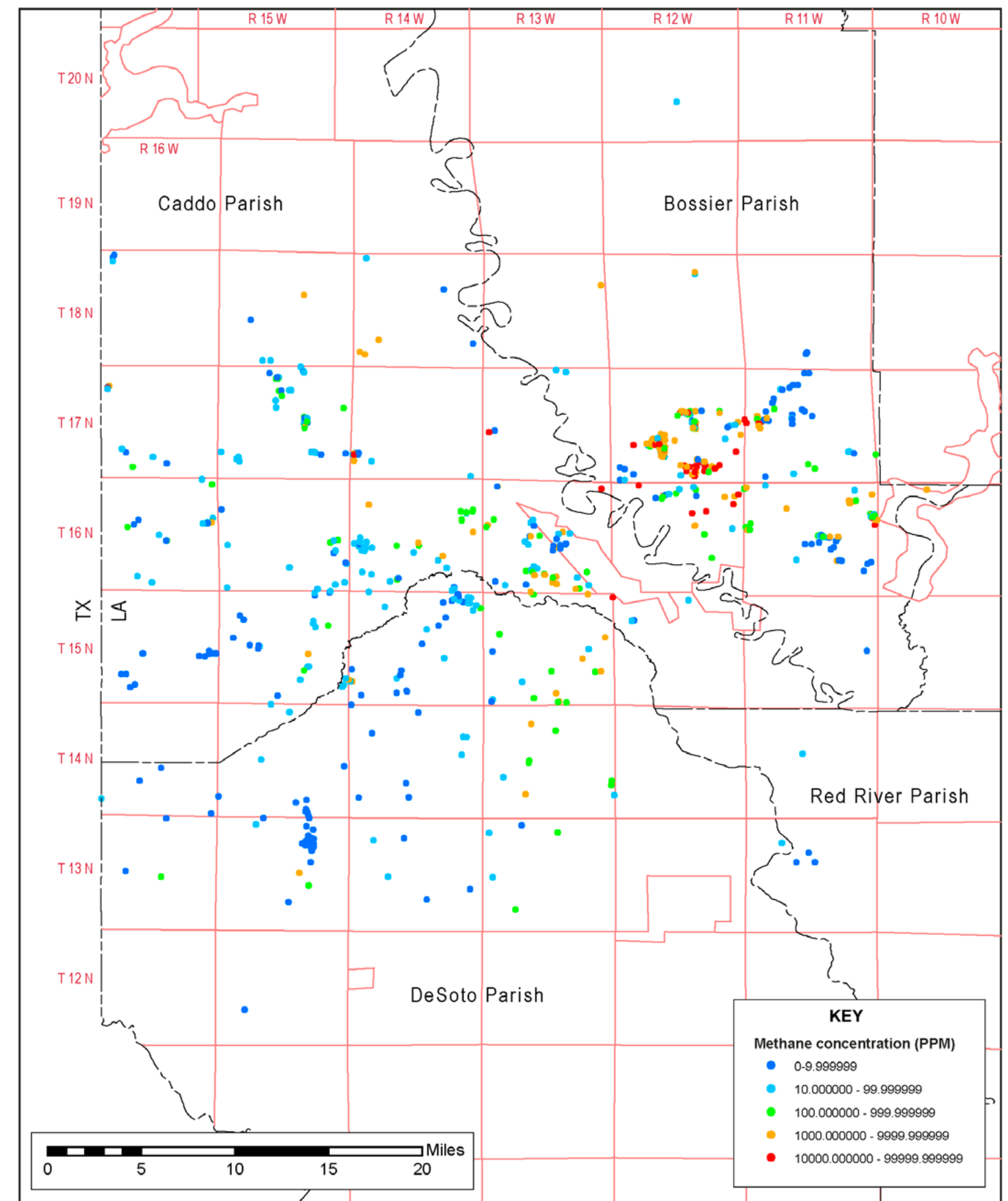


Figure 7. Location of samples analyzed for methane in head space through fifteen sample collection trips and approximately 700 wells sampled.

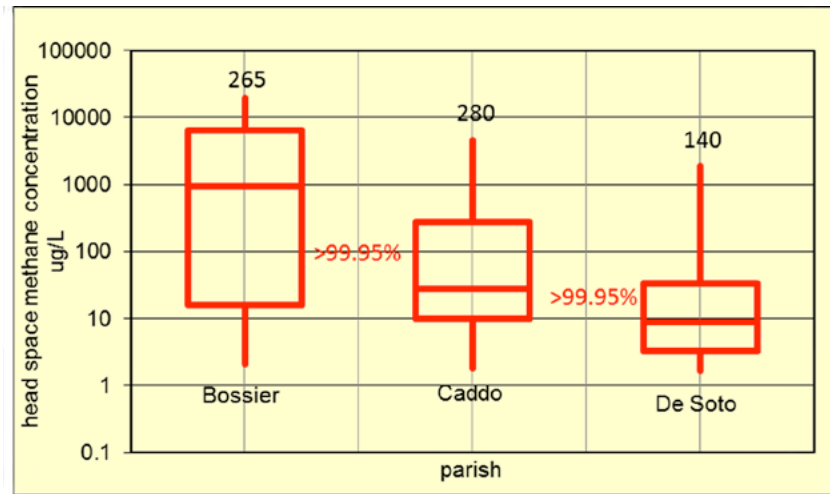


Figure 8. Distribution of methane head space concentrations measured for each parish. Note for the box and whiskers plot that top whisker is 95% rank, top of box 75% rank, median is line that bisects that box, bottom of box is 25% rank and bottom whisker is 5% rank.

Table 9.

Concentrations of methane analyzed for each of the samples collected in Bossier, Caddo, and De Soto Parishes, all concentrations are in ug/liter.

| Parish | Median value | Number of observations | Average value | Standard deviation |
|---------|--------------|------------------------|---------------|--------------------|
| Bossier | 951 | 265 | 4192 | 6394 |
| Caddo | 28.6 | 280 | 740 | 2241 |
| De Soto | 8.87 | 140 | 314 | 1059 |

Note: 1 ug/liter is approximately 1 ppb (1 part per billion).

REFERENCES

Arizona Department of Environmental Quality, 1998, Ambient Groundwater Quality of the Yuma Basin: A 1995 Baseline Study: Arizona Department of Environmental Quality, Open-File Report 98-7, 7p.

Baker, Leandra, Fiona Lowry, Molly E. Reed, Leslie Hasbargen, and Devin Castendyk, 2011, Pre-Gas Development, Baseline Water Quality Monitoring in the Susquehanna River Headwaters, Otsego County, New York: Part 1 Groundwater: Geological Society of America Abstracts with Programs, v. 43., no. 1., 98p.[abstract]

BJAAM Environmental Inc., 2011, Gas Drilling in the News: http://www.bjaam.com/water_testing.html accessed November 9, 2011.

Clayton, Reg, 2011, Water quality study provides baseline data to monitor impact of future Lower Black Sturgeon developments: Miner & News, <http://www.kenoradailyminerandnews.com/ArticleDisplay.aspx?e=2926367>, accessed November 11, 2011.

Dakota County Environmental Management, 2003, Hastings Area Nitrate Study, Final Report: Dakota County Environmental Management, Apple Valley, Minnesota, 90p.

Durham, L.S., 2009, No Recession for the Haynesville: American Association of Petroleum Geologists Explorer, v. 30, no. 7, p10 and 12.

Energy Information Administration, 2011, Monthly U.S. Natural Gas Wellhead Price: <http://tonto.eia.doe.gov/dnav/ng/hist/n9190us.3m.htm>. (accessed August 24, 2011).

Ground Water Monitoring and Assessment Program, 1999a, Baseline Water Quality of Minnesota's Principal Aquifers-Region 5, Southeast Minnesota: Minnesota Pollution Control Agency, St. Paul, 91p.

Ground Water Monitoring and Assessment Program, 1999b, Baseline Water Quality of Minnesota's Principal Aquifers-Region 3, Northwest Minnesota: Minnesota Pollution Control Agency, St. Paul, 66p.

Ground Water Monitoring and Assessment Program, 1999c, Baseline Water Quality of Minnesota's Principal Aquifers-Region 1, Northeast Minnesota: Minnesota Pollution Control Agency, St. Paul, 81p.

Ground Water Monitoring and Assessment Program, 1999d, Baseline Water Quality of Minnesota's Principal Aquifers-Region 6 Twin Cities Metropolitan Area: Minnesota Pollution Control Agency, St. Paul, 76p.

Ground Water Monitoring and Assessment Program, 1998a, Baseline Water Quality of Minnesota's Principal Aquifers-Region 2, North Central Minnesota: Minnesota Pollution Control Agency, St. Paul, 96p.

Ground Water Monitoring and Assessment Program, 1998b, Baseline Water Quality of Minnesota's Principal Aquifers-Region 4, Southwest Minnesota: Minnesota Pollution Control Agency, St. Paul, 90p.

Ground Water Monitoring and Assessment Program, 2001, Effects of Land Use on Ground Water Quality, St. Cloud Area, Minnesota-short report: Minnesota Pollution Control Agency, St. Paul, Minnesota, 28p.

Kimball, Briant, D. Kirk Nordstrom, Robert L. Runkel, Kirk R. Vincent, and Phillip L Verplanck, 2006, Questa baseline and pre-mining ground-water quality investigation., 23. Quantification of mass loading from mined and unmined area along the Red River, New Mexico: U.S. Geological Survey Scientific Investigations Report 2006-5004, 44p.

Kyshakevych, Roman, 2011, Baseline Water Quality Studies: A Method to Measure Potential Changes in Environmental Water Quality Due to Marcellus Drilling Activities: Geological Society of America Abstracts with Programs, v. 43, no. 1, 78p. [abstract]

LaCamera, Richard J., Glenn L Locke, and Aron M Habte, 2005, Selected Ground-Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, January-December 2003: U.S. Geological Survey, Open-File Report 2005-1286, 76p.

Louisiana Department of Health and Hospitals, 2009, Consumer Confidence Reports: <http://www.dhh.louisiana.gov/OPH/ENG/2009/> accessed November 13, 2011.

Louisiana Department of Natural Resources, 2011A, unpublished data of hydraulic fracturing pumpage values for Haynesville play: Louisiana Department of Natural Resources, unnumbered pages.

Louisiana Department of Natural Resources, 2011b, Haynesville Shale wells spreadsheet: <http://dnr.louisiana.gov/haynesvilleshale/> accessed August 28, 2011.

Oram, Brian, 2010a, Baseline Water Quality Testing Marcellus Shale Development What Parameters Should be Tested?: Go Marcellus Shale.com; <http://gomarcellusshale.com/profiles/blogs/baseline-water-quality-testing> accessed November 9, 2011.

Oram, Brian, 2010b, Citizen Water Quality Database for Northeastern Pennsylvania: Go Marcellus Shale.com; <http://gomarcellusshale.com/profiles/blogs/baseline-water-quality-testing> accessed November 9, 2011.

Roberts, J., 2008, Water a concern as more wells are drilled in the Haynesville Shale: <http://www.ktbs.com/news/water-a-concern-as-more-wells-are-drilled-in-Haynesville-Shale-15751/> accessed on November 25, 2008.

Royster, Whitney, 2011, DEQ calls for baseline data in Wyoming Range drilling proposal: Star-Tribune correspondent trib.com posted Sunday March 20, 2011: http://trib.com/news/state-and-regional/article_615ed330-c99e-56f4-b459-b9cc08521fda.html accessed November 9, 2011.

Smith, M.W., K.B.C. Brady, and J.W. Hawkins, 2002, Effectiveness of Pennsylvania's remaining program in abating abandoned mine drainage: water quality impacts: Society of Mining, Metallurgy and Exploration Inc., Transactions, v. 312, p 166-170.

S.S. Papadopoulos & Associates, Inc., 2007, Piceance Basin Phase IV Baseline Water Quality Study-Garfield County, Colorado, S.S. Papadopoulos & Associates Inc., Boulder, Colorado, 22p.

URS Corp., 2007, Ogallala Aquifer Baseline Study Report: URS Corporation, Denver, Colorado, Project 22239415, 12p.

USGS, 2011, USGS National Water Information System: Web Interface: http://nwis.waterdata.usgs.gov/al/nwis/qwdata?search_criteria-county_cd&submitted_form=introduction accessed November 8, 2011.

U.S. Energy Information Administration, 2011, Review of Energy Resources: US Shale Gas and Shale Oil Plays: U.S. Department of Energy, Washington, D.C., 105p.

Wikipedia, 2011, Shale gas in the United States: http://en.wikipedia.org/wiki/Shale_gas_in_the_United_States, accessed November 11, 2011.

Ziegler, Andrew C., Victoria G. Christiansen, and Heather C. Ross, 1999, Baseline Water Quality and Preliminary Effects of Artificial Recharge on Ground Water, South-Central Kansas, 1995-98: U.S. Geological Survey wrir 99-4250, <http://ks.water.usgs.gov/pubs/Reports/wrir.99-4250.html>, accessed November 9, 2011

EARTH SCIENCE WEEK

Earth Science Week 2011 was celebrated from October 9-15, 2011. This year the week focused on promoting scientific understanding of a current timely and vital topic – “Our Ever-Changing Earth”. At the request of the Louisiana Geological Survey, Governor of Louisiana Bobby Jindal issued a proclamation declaring October 9-15, 2011 as Earth Science week in the State of Louisiana. Earth Science week is sponsored annually by the American Geosciences Institute (AGI) and all its member societies on behalf of the geoscience community. More information about AGI and Earth Science week can be found on their websites (www.agiweb.org and www.earthscienceweek.org).

The Louisiana Geological Survey received 50 teaching kits containing teaching materials related to the focus area and these were distributed to Earth Science Teachers through the Program Coordinator (Jean M. Brett) of the East Baton Rouge Parish Schools Division of Standards Assessment and Accountability. LGS sent copies of the Earth Science Week Proclamation to all the geological societies in Louisiana.

LGS ADVISORY BOARD MEETING 2011

The annual LGS Advisory Board meeting was held on Thursday, September 22, 2011 in Room 3087 of the Energy, Coast, & Environment Building (LGS Conference Room). LGS Director and State Geologist Chacko John presented a summary review of the year’s activities including the LGS budget situation. LGS faculty and staff then made presentations of all current ongoing research projects. A list of the current research projects and their respective funding amounts were provided to the Advisory Board members. In his remarks after the presentations, Frank Harrison, Chair of the Advisory Board mentioned the serious concern the Board members had about the earlier LSU administration decision regarding cutting the LGS budget by a third each year for the next three years and said he had met with the LSU Chancellor to express the Board’s concern on the issue. LGS would like to thank the Advisory Board members and all those who wrote letters to the LSU administration supporting LGS during the budget crisis.

Staff Recognition

An LGS Service Award Certificate was presented to Research Associate & GIS Coordinator Hampton Peele at the staff meeting on September 1, 2011 in recognition of 20 years of dedicated service to the Louisiana Geological Survey/LSU.

DISTINGUISHED SERVICE AWARD FOR THE ADVANCEMENT OF SPATIAL ANALYSIS IN LOUISIANA PRESENTED BY THE EXECUTIVE BOARD OF THE LOUISIANA REMOTE SENSING AND GIS WORKSHOP

The *Distinguished Service Award for the Advancement of Spatial Analysis in Louisiana* is presented annually at the Louisiana Remote Sensing and GIS Workshop to a colleague who has made extraordinary contributions to the application of mapping sciences specifically in Louisiana. Mapping sciences includes environmental remote sensing, Geographic Information Systems (GIS), cartography, spatial analysis, surveying, and geospatial sciences. The recipient has won the esteem of colleagues by exhibiting exceptional dedication to service while recording noteworthy achievements of statewide impact and importance. These individuals have demonstrated professional expertise, leadership, management, and enterprise related to significant RS-GIS projects or programs in Louisiana. They have also shown an inclination for cooperation, outreach, assistance, and training of others; sharing of knowledge and data; and volunteering services

in the geospatial community. The award is conferred by a committee of peers in the GIS, remote sensing, and mapping professions in Louisiana representing federal, state, and local governments, academic institutions, industry, and professional societies.

At LGS, Peele has designed and developed more than 100 GIS products, contributed to more than 30 published maps. He is a member of the group that developed the Louisiana GIS CD and the Louisiana Digital Map DVD set. He served as a team leader for emergency GIS mapping support in the state Emergency Response Center during Hurricanes Katrina, Rita, Gustav and Ike and is a member of the LSU Hurricane Surge Modeling team.

Peele received a B.A. in Anthropology and a B.S. in Geography, and a master’s degree in mapping science from LSU.



Jerry Daigle, USDA, retired and service award recipient, R. Hampton Peele.

Conferences

GCAGS CONVENTION

ABSTRACTS SUBMITTED FOR THE 2012 GCAGS CONVENTION

The following research abstracts have been submitted for consideration for presentation at the 62nd Annual Convention of the Gulf Coast Association of Geological Societies (GCAGS) to be held in Austin, TX, from October 12-23, 2012:

Impact of Seasons, Nutrient Pulse and Mississippi River Flood of the Spring-Summer of 2011 on Water Quality in Atchafalaya Basin, Louisiana - Douglas Carlson and Marty Horn

Evidence that Old Oil and Gas Fields Influence Chemistry of Overlying Wilcox Aquifer, - Douglas Carlson and Marty Horn

Examination of Old Oil and Gas Field Properties that may Influence Methane Concentration in Overlying Wilcox Aquifer in Northwest Louisiana - Douglas Carlson, Marty Horn, Gary Hansen

Evidence that Old Oil and Gas Fields are the Main Source of Wilcox Aquifer Methane in Northwest Louisiana - Douglas Carlson, Marty Horn, Gary Hansen

Impact of 2010-2011 Drought of Wilcox Aquifer on Water Supply and Water Quality - Douglas Carlson, Marty Horn, Gary Hansen, Amanda Lewis, Dillon Soderstrom

Drought of 2010-2011 Causes Water Supply Crisis Throughout Northeast Texas and Northwestern Louisiana - Gary Hansen, Douglas Carlson, Amanda Lewis.

A Potential Geopressured-Geothermal Prospective Area in Southwest Louisiana - Warren Schulingkamp, Chacko John, Brian Harder, Reed Bourgeois

The Geologic Review Procedure: A Regulatory Intersection of Energy, Economics and the Environment - John Johnston

Potential for Carbon Dioxide in Five fields Along the Mississippi River Industrial Corridor in Louisiana - Chacko John, Brian Harder, Bobby Jones, Reed Bourgeois, Warren Schulingkamp

Contracts/Grants

Desoto Parish- Water Quality of Carrizo-Wilcox, Red River Alluvial and other Aquifers in Bossier, Caddo and Desoto Parishes (\$65,000)

Caddo Parish – Water Quality of Carrizo-Wilcox, Red River Alluvial and other Aquifers in Bossier, Caddo and Desoto Parishes (\$80,000)

Bossier Parish - Water Quality of Carrizo-Wilcox, Red River Alluvial and other Aquifers in Bossier, Caddo and Desoto Parishes (\$71,596)

DNR – Environmental Review of Act 955 Running Surface Water Use Applications (\$19,999)

USGS – LGS Statemap 2010-2011 Geologic Mapping and Compilation of Atchafalaya Bay, Monroe North, Morgan City, and Natchitoches 30 x 60 Minute Quadrangles, LA (\$153,785)

ULL – NCRDS N LA Coad Bed Methane Exploration/Development Data Compilation Assessment Program (\$4,000)

DNR – Atchafalaya Basin Water Quality & Mapping (\$79,997)

DNR – Geologic Review (\$105,000)

USGS – Coal Bed Atlas of LA (NCRDS) (\$15,000)

USGS – Inventory & Digital Infrastructure of Historic LA Geological Map Data (\$27,775)

EXCO Resources – Extension of Water Quality Study of Carrizo-Wilcox Red River Alluvial and other Aquifers in Bossier, Caddo and DeSoto Parishes for Methane and Volatile Organic Compounds (\$149,623)

DOE/Arizona Geological Survey – State Contributions to the National Geothermal Data System Project (\$299,952)

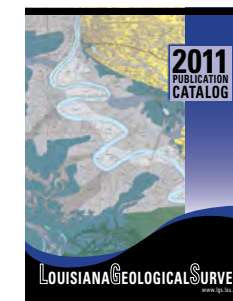
Michael Baker – Geoarchaeology and Natural Setting of the New Orleans Gateway Project Area (\$4,574)Statewide

LGS PUBLICATIONS

STATE PARKS AND LANDS SERIES

Thomas P. Van Biersel, 2011, Port Hudson State Historic Site and National Historic Landmark, and Surrounding Areas, Summarizes the geology, mineral resources, natural regions, and history of Port Hudson State Historic Site and National Historic Landmark and its environs. Includes information sources and a historic map, custom soil resource report, comprehensive gallery of photographs, related Web links, and self-guided driving trip.

McCulloh, R. P., 2011, Fontainebleau State Park, Summarizes the geology, mineral resources, natural regions, and archaeological sites of Fontainebleau State Park and its environs. Includes information sources and a glossary.



LA. GEOLOGICAL SURVEY’S 2011 PUBLICATION CATALOG ONLINE

Louisiana Geological Survey has published its 2011 Publication Catalog. Most maps, atlases, and geological reports are available for order.

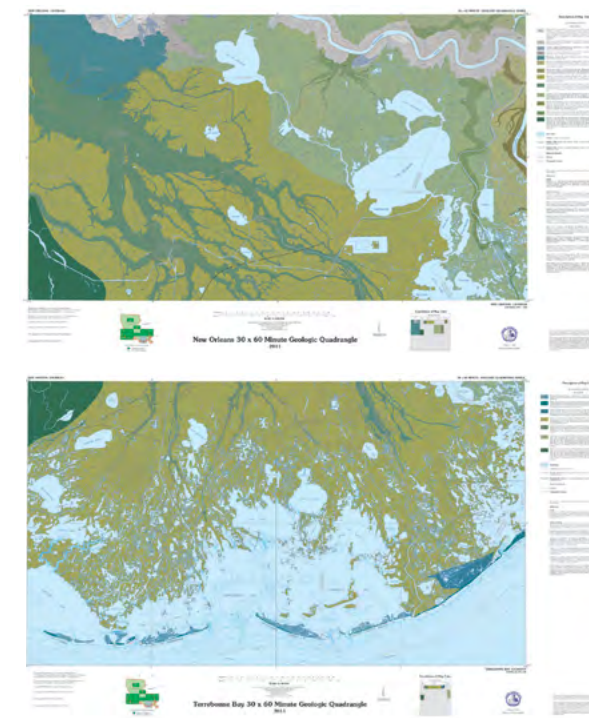
The collection features some of the Survey’s earliest geological reports, including an overview of mineral resources and topography dating back to 1869, available for viewing only at the LSU Hill Memorial Library. Copies of “newer” reports, such as 1931’s “Geology of Iberia Parish”, are available for order. An index provides a list of geological, mineral, and water reports and pamphlets available for Louisiana parishes.

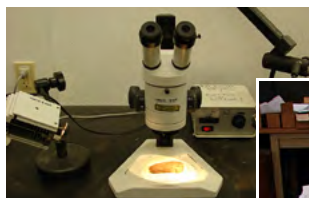
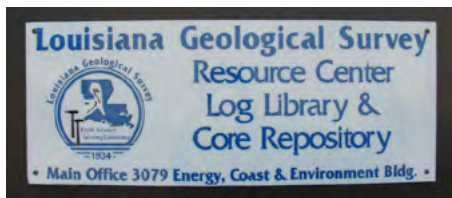
GEOLOGIC QUADRANGLE MAPS (1:100,000)

The LGS geologic quadrangle maps describe and illustrate the surface geology of the New Orleans and Terrebonne Bay quadrangles in the south Louisiana delta plain. The colorful 28”x 46” maps, identify the various surface geologic formations and their composition, and the locations of fault lines and waterways. In addition to rendering the geologic framework of the surface of these areas, the maps can serve as a potential guide to derivative engineering properties of surface materials, such as in connection with the design and construction of flood-protection structures. The 30 x 60 minute geologic quadrangle maps are at 1:100,000 scale.

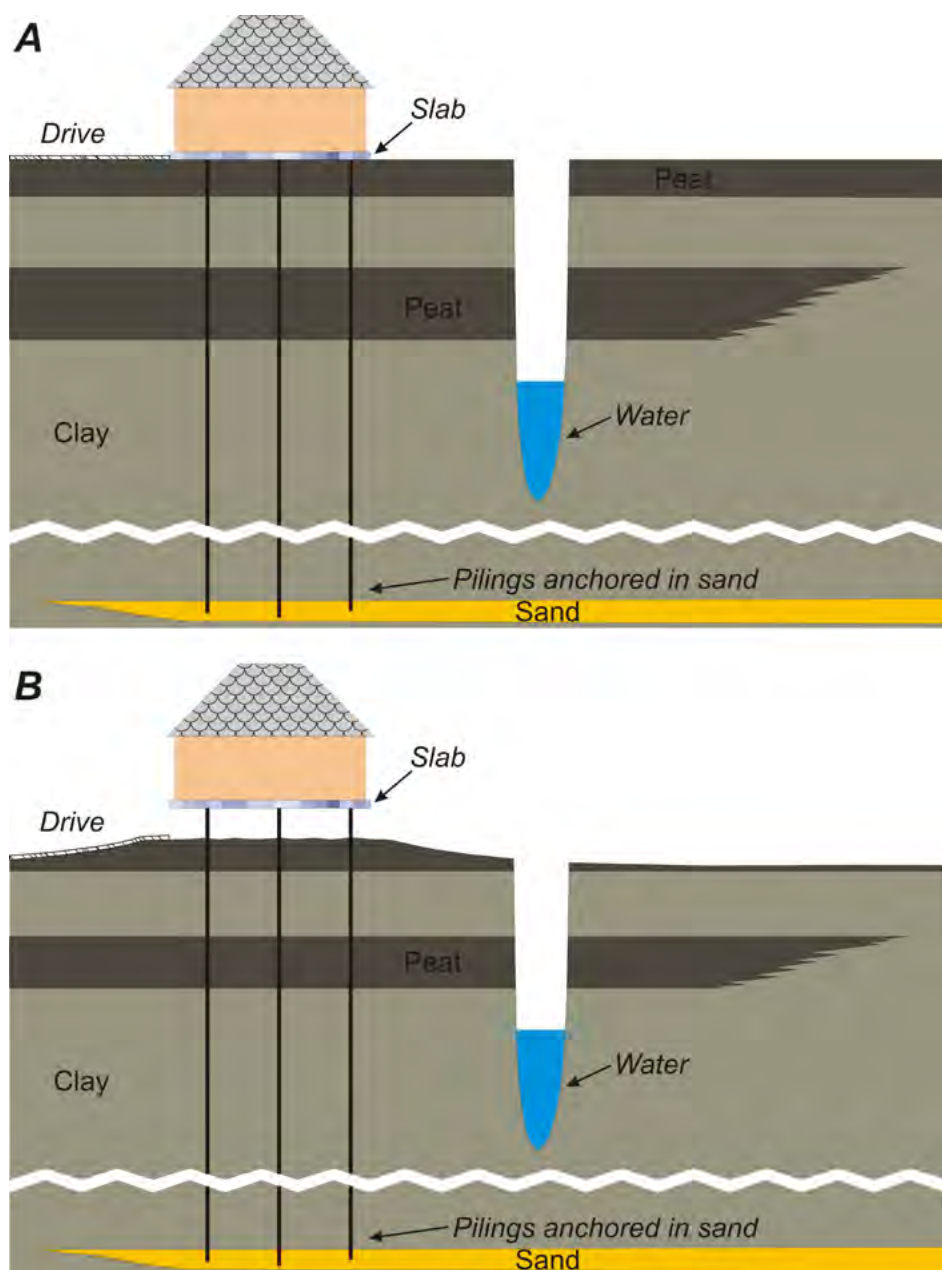
The New Orleans Geologic Quadrangle, by McCulloh, R. P and P. V. Heinrich, 2010, 28 X 48 in. Scale = 1:100,000. Multicolored. Describes and illustrates the surficial geology of the Monroe South quadrangle.

The Terrebonne Bay Geologic Quadrangle, by McCulloh, R. P and P. V. Heinrich, 2010, 28 X 48 in. Scale = 1:100,000. Multicolored. Describes and illustrates the surficial geology of the Monroe South quadrangle.





The LGS Resource Center is located just off the LSU campus and houses over 300 well cores from Louisiana, Mississippi, Texas, Arkansas, Alabama and Florida. Most of our cores are from the Smackover and Wilcox Formations. The Core Lab is equipped with climate controlled layout area, microscopes, and a small trim saw. Viewing and sampling of cores can be arranged by calling Patrick O'Neill at 225-578-8590. Please arrange visits two weeks in advance. Daily usage fee is \$300, Visa and MasterCard accepted. A list of available cores can be found at the LGS web site (www.lgs.lsu.edu).



Schematic diagram showing subsidence effects on a home built using the slab-on-pilings technique at a site underlain by wetland soils in the New Orleans area, based largely on the accounts given by Snowden and others (1980) and Saucier and Snowden (1995): A, shortly after construction; and B, some decades later. The structure is supported on pilings that ideally would be driven into a sand bed at depth, but otherwise could be driven into thick clay until meeting with refusal. (Not shown is a comparatively thin layer of fill material with which the homesite would be covered before the pouring of the slab.) With time the ground surface subsides relative to the house slab, taking the adjacent driveway with it. (The material directly underlying the home adheres to the pilings enough to decrease the apparent amount of subsidence immediately beneath it.) This “surficial” subsidence is a direct response to dewatering and compaction of clay and especially of peat in connection with activities accompanying development, primarily the establishment of artificial drainage networks.

REFERENCES

Saucier, R. T., and J. O. Snowden, 1995, Engineering geology of the New Orleans area, in C. J. John and W. J. Autin, eds., Guidebook of geological excursions: Geological Society of America annual meeting, New Orleans, Louisiana, November 6–9, 1995, p. 131–154.

Snowden, J. O., W. C. Ward, and J. R. J. Studlick, 1980, Geology of Greater New Orleans: its relationship to land subsidence and flooding: New Orleans Geological Society, New Orleans, Louisiana, 32 p.

www.lgs.lsu.edu