Louisiana Geological Survey

NewsInsightsonline

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The Louisiana Geological Survey (LGS) was first organized in 1869 and was permanently established by legislation in 1934 by Act 131 of the Louisiana State Legislature and has, since inception, been located on the campus of Louisiana State University (LSU) and was a unit of the Louisiana Department of Natural Resources (LDNR). It was legislatively transferred from DNR to Louisiana State University in 1997 and currently reports to the LSU Vice Chancellor of Research and Economic Development through the Executive Director of the Center for Energy Studies (CES) at LSU, though it functions independently of CES.

The LGS performs geological investigations designed to accomplish its primary mission to promote environmentally sound economic development of the natural resources of the state (energy, mineral, water and environmental). Information is transferred to all stakeholders through publications, conferences, and presentations at professional conferences and other venues as and when needed.

Personnel & Budget

LGS currently has a total number of full time staff of 14 and 2 part time staff including all categories of personnel. The LGS budget continues to decrease every year in the last five years due to budget cuts by LSU and has gone down by approximately 58% with the latest being a 41% cut for fiscal year 2012-2013 and 2013-2014. LGS has been successful in obtaining research grants to offset these budget cuts until now but the continuing economic downturn resulting in fewer opportunities and greater competition for research grants does not bode well for the future. LGS now has a critical number of personnel and cannot afford to lose any more personnel by layoff or staff leaving for better opportunities as has happened due to the critical budget situation if it is to successfully continue its mission and purpose for which it was legislatively established.

Ongoing and completed research projects are summarized in this online newsletter.

Contracts/Grants

LGS Contribution to the National Geothermal Data System

The focus of this three year US Department of Energy funded project with participation from all the 50 state surveys in the country represented by the Association of American State Geologists (AASG) and managed by the Arizona State Geological Survey is to identify, catalog, and create geothermal databases and maps for inclusion in the National Geothermal Data System (NGDS). LGS completed all its deliverables for this project in June 2013 which included well temperature data from over 91,000 wells and 8 relevant georeferenced geothermal related geologic maps. Final completion of this project by all state surveys will result in the creation of a very large database designed to facilitate the potential development of geothermal and geopressured-geothermal resources in the United States by helping to mitigate much of the upfront risks associated with this resource development.

Geologic Review

This is a continuing program which began in 1982 to provide regulatory technical assistance to the Coastal Management Division of the Louisiana Department of Natural Resources (LDNR) and to three districts of the US Army Corps of Engineers (USACE) and is renewed every year. Funding for this was provided by USACE (75%) and LDNR (25%). Unfortunately, due to cutbacks to the USACE, they eliminated their share of the funding which has resulted in not doing any geologic reviews for USACE. The purpose of this program is to review drilling permit applications in Louisiana's coastal zone to avoid and/or minimize environmental damage by proposing alternative concepts like reducing the size of ring levees and slips, reducing lengths of board roads and canals, directional drilling, and use of alternative access routes. This has been a very successful program which has resulted in significant reduction (approx. 75%) in average length of canals and board roads built in the Louisiana coastal zone. It is also, as far as we know, the only program of its kind in the country.

Louisiana Geological Survey
Earth Science Serving Louisiana
1934

The Louisiana Geological Survey

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The LGS NewsInsights is published annually and made available to professionals, state agencies, federal agencies, companies, and other organizations associated with geological research and applications.
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In this issue

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.

The Louisiana Geological Survey is housed on the second and third floors of the Energy, Coast & Environement Building.

Surface Water Gauging Network Improvements

LGS received a three year contract (2012-2015) from the Louisiana Department of Natural Resources (LDNR) titled "Surface Water Gauging Network Improvements". The main objective of this project is to provide additional assistance and data to supplement efforts to monitor and manage groundwater and surface water resources being conducted by the US Geological Survey for LDNR. Work involved the selection of approximately 50 gauging stations in collaboration with LDNR for seasonal discharge measurements. This data, combined with data available from other monitoring agencies, is being used to develop/revise existing rating curves and profiles for the sites. Four new surface gauging sites are being established with approval from LDNR at sites where there are no gauging stations. In addition, LGS will catalog and compile hydrologic and geologic data for publicly owned reservoirs and lakes gathered from existing records and site visits as needed. Project results will be published in annual reports to be provided to LDNR.

Marty Horn, assistant professor-research at the Louisiana Geological Survey, performs stream-measurement field work at Beaver Bayou.

National Coal Resources Data Systems (NCRDS)

The NCRDS project is a co-operative program between USGS and LGS and is currently funded for a five year period starting July 1, 2010. For the first year of this project, strike-oriented (east-west) cross sections through north Louisiana were prepared to illustrate stratigraphy and the lateral changes and occurrence of Wilcox coal beds in the area. Dip-orientated cross sections in the same area were prepared in the second year of the project. During the third year of the project, structural trend maps of the top of the Wilcox formation and the top of the Midway formation (= base of the Wilcox) were completed along with a data base of two commercial coal bed methane (CBM) sources in Louisiana. This list is comprised of wells drilled for CBM into these seams, subsea tops, and seam thickness in each well. The fourth year project work consists of preparation of the text chapters for the "Coal Bed Atlas of Louisiana" including a description of the geology of north Louisiana and its coal bearing strata.

LSU Petroleum Engineering Geothermal Project

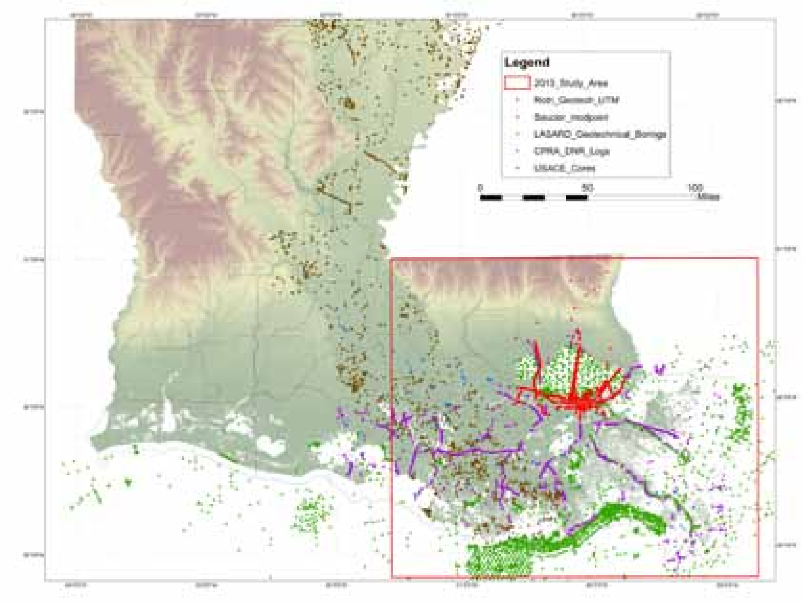
LGS researchers are continuing to work with faculty from the LSU Petroleum Engineering and other departments on this three year Department of Energy funded project titled "Zero Mass Withdrawal, Engineered Convection and Well Bore Energy Conversion" which is now in its second year. The project focuses on modeling potential underground technologies and equipment for energy extraction from hot geopressured geothermal brines which are a huge potential energy resource especially in the Gulf of Mexico region. LGS provides information on well temperatures, reservoir geometry, lateral extents, etc. of resource areas best suitable for development for input into the engineering modeling applications.

Evaluations of Water Permit Requests

LGS has a contract with the Louisiana Department of Natural Resources (LDNR) to evaluate water use permit requests from various sources for various purposes. Unbiased recommendations are made by LGS on permit requests sent for evaluation from LDNR.

Inventory and Digital Infrastructure of Historic Louisiana Geological Map Data

LGS has been awarded a new contract from the US Geological Survey's National Geological and Geophysical Data Preservation Program to fund the proposal *"Inventory and Digital Infrastructure of Historic Louisiana Geological Map Data"*. This is the third year of funding from the USGS program. The task is to inventory the LGS map archives and to index, digitally scan, and catalog the thousands of items into a database with metadata records to help preserve the data and make the collection more accessible. John Snead is the Principal Investigator of the one-year project that also includes Reed Bourgeois, Patrick O'Neill, and Hampton Peele.

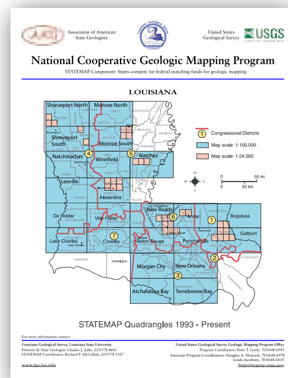


Research and GIS Development of the Base of the Holocene in the Louisiana Coastal Plain and Adjacent Continental Shelf

This is a 2 year (2013-2015), recently funded, project between The Water Institute of the Gulf (TWIG) and LGS with the funds coming from the Louisiana Coastal Protection and Restoration Authority (CPRA) through TWIG. The project involves the preparation of a detailed structural map of the unconformity that forms the base of Holocene sediments within the Louisiana Coastal Zone. During the first year of this project, mapping will cover the Mississippi River Delta region. For the second year, the remainder of the coastal zone and the Louisiana Chenier Plain will be mapped. This unconformity is an important and critical geologic feature because the overlying thickness of typically under-consolidated Holocene sediments is a major factor governing local subsidence rates and depth to solid sediments for the foundation of major structures.

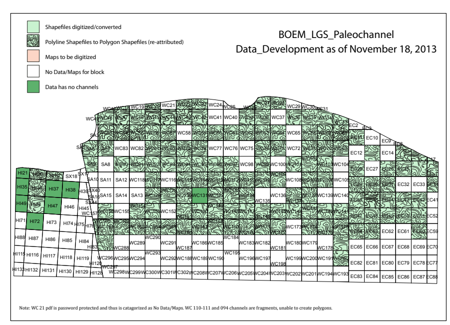
Geologic Mapping

LGS is the only research organization doing geologic mapping in the state of Louisiana. The continuing mapping effort is supported by cooperative agreements with the US Geological Survey under the National Cooperative Geologic Mapping Program approved by the US Congress. The STATEMAP project for fiscal year 2012-2013 involved geologic mapping and compilation of the Natchitoches 30x60 minute quadrangles in the northwestern part of the state. The fiscal year 2013-2014 project will achieve the completion of the 1:100,000 scale coverage of the state with at least draft GIS compilation for all 30x60 minute quadrangles by undertaking the final remaining two, Bastrop and Tallulah, in the northeastern corner of the state. Although LGS has previously mapped some 7.5 minute quadrangles with STATEMAP support in tandem with the geologic compilation of the encompassing 30x60 minute quadrangle, we discontinued this practice in recent years to optimize progress towards the completion of statewide 30x60 minute geologic quadrangle coverage. Beginning in fiscal year 2014-2015 our proposed STATEMAP projects will seek to resume 1:24,000 scale mapping and transition to exclusive focus on field mapping of 7.5 minute quadrangle study areas.



Late Quaternary Stream and Estuarine Systems to Holocene Sea Level Rise on the OCS Louisiana and Mississippi: Preservation Potential of Prehistoric Cultural Resources and Sand Resources

The Louisiana Geological Survey has entered a cooperative agreement from the Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE) to investigate possible sand resources and possible archeological sites in the Louisiana state waters in the Outer Continental Shelf. "Late Quaternary Stream and Estuarine Systems to Holocene Sea Level Rise on the OCS Louisiana and Mississippi: Preservation Potential of Prehistoric Cultural Resources and Sand Resources" is a two year project with Paul Heinrich as Principal Investigator. The project will examine responses of late quaternary stream and estuarine systems to Holocene sea level rise. The objectives of the study are to develop a geophysical and geologic database for the study area, to develop geologic/stratigraphic models, develop a predictive model for paleo-landscape preservation potential, and to evaluate sand resources of paleo-fluvial channel fills within the study area. An understanding of these processes can result in the evaluation and refinement of models used to predict cultural and non fuel mineral resources within deltaic environments. A fully functional Geographic Information System (GIS) will be developed from all collected geospatial data. Robert Paulsell, the project Co-P.I., has coordinated the development of the GIS. Over 118 offshore hazards maps have been digitized resulting in more than 150 shapefiles (Fig x). These data are included in the GIS as well as boring data and seismic track line locations. Nomenclature for these data are being developed as most of the hazards maps have different descriptions for similar geophysical features. These data will be archived with the National Oceanographic Data Center (NODC) and the National Environmental Satellite, Data, and Information Service (NESDIS). The project is expected to be completed by September 30, 2014.



Progress Report on Stream Gaging and Rating Curve Study of Fifty-One Louisiana Streams

Douglas Carlson and Marty Horn

Introduction

Monitoring of streams by stream gaging is used to determine fluctuations of flow. This is important because streams are a natural resource that influences wildlife habitat and associated recreational activities and other economic activities (Shaffer, 2000). Stream gaging information can be used to minimize impacts of droughts and floods, siting of wastewater treatment plants and water supply intakes (Shaffer, 2000), designing bridges, dams, flood control structures and flood plan designation (Shavanda, 2011).

Often stream flow data programs are developed in response to local economic and hydrologic stimuli. Although most of the stations and studies are in response to local needs the resulting data never the less adds up to a wealth of information on streamflow throughout the United States since 1900 (Benson and Carter, 1973). Currently the United States Geological Survey (USGS) notes that there are 8 different reasons for stream gaging:

About 57% of stations are used for determining groundwater contribution to stream flow.

About 52% of stations for determining impact from man-made storage-system or diversions and can be used for estimation of behavior of ungagged systems.

About 39% of stations are collecting data used by water managers for flood control, water supply, and navigation.

About 39% of stations are used for information for flood and water supply forecasting.

About 37% stations provide data used for evaluation of water quality in rivers, lakes, reservoirs, and estuaries.

About 15% of stations provide information that is used for planning and designing of specific projects, for example reservoirs, levees, water treatment facilities, or hydroelectric power plants.

About 10% of stations have long records that are useful for water investigation studies.

About 4% of stations are used for dividing water resources for treaties, compacts and decrees (Wahl et al., 1995)

About 80% of the stations have multiple uses for their data and about 25% have four or more uses enumerated in the categories listed above (Wahl et al., 1995). Only 21% of stations have data used for a single reason. For the 25% of stations with more than 4 reasons for data use 27% have five reasons for use, 8% have six reasons for use and 1.5% have seven or eight of the above reasons for use (Thomas and Wahl, 1993). Louisiana stations often have only a single use for data, 43%, which is far more common than for adjacent states Mississippi 19%, Arkansas 4%, and Texas 4%. (Thomas and Wahl, 1993). It appears that the need of stream gage stations data is somewhat different for Louisiana compared to the United States in general, see in Table 1 (Benson and Carter, 1973).

Stream gaging involves determining discharge which is a multiple of a stream's cross-sectional area times the stream's flow velocity. This involves determining depth of water and water velocity at a number of points across the stream (Shaffer, 2000).

Water level measurements for stream gages come in two types: peak levels (flood crest elevations) and stage as a function of time. These measurements can be made either automatically or manually. For flood crest measurements the automatic system can include a wooden scale or staff inside a pipe that has a few small holes at its base for water to enter. A small amount of cork is placed in the pipe and will adhere to the staff-scale at the highest water level (Chow et al., 1988).

For continuous measurements manual methods of measuring stage can involve use of staff gage observations or sounding devices that signal level when they reach water (Chow et al., 1988), for example an electrical tape with a weight attached to its end. Automatic records have been made by a variety of techniques: systems that sense water level by bubbling a continuous stream of gas (usually carbon dioxide) into water (Chow et al., 1988); another type is a Stevens type system which includes a float counter balance weight and a recording drum and paper (Sanders, 1998).

Rating curves are developed from gage height which is directly measured by the stream gage and discharge which is determined by a variety of techniques profiling stream's width, depth of water, and flow velocity at a number of points across the stream. These curves need to be checked and modified throughout time because river channel shapes and depths could change as time passes. These changes can be a result of either deposition or erosion of sediments on the bottom and sides of the river's channel (Olson and Morris, 2007, USGS, 2013a).

At the present time the USGS is running 242 sites for stream flow in Louisiana (USGS, 2013b). However, most include gage height information, but there is no information on discharge. At the present time discharge is being determined at only 74 sites (USGS, 2013b). Many of the 162 sites that lack discharge results are in the tidal zone and so discharges will not make sense as a normal stream which has a single flow direction. Discharge in a tidal zone will be a function of a combination of stream discharge and tide flow which will yield a complex and confusing rating curve. However, there are still many streams that currently have only gage height information that are not in a tidal zone. It is this set of streams that are the focus of the Louisiana Geological Survey (LGS) study for the development of additional rating curves. These additional sites, 51, will expand the number of streams with rating curves by approximately 70% from the current set of 74 sites. These sites are located throughout Louisiana (Figure 1 and 2, and Appendix A) with a focus over developing shale gas plays: Haynesville of northwest Louisiana, Brown dense in northern Louisiana and Tuscaloosa in central Louisiana towards southeastern Louisiana.

Table 1. Current use of stream gage data (Benson and Carter, 1973).

Reason for stream gage data	Louisiana		United States	
	No. of stations	Percentage of all stations	No. of stations	Percentage of all stations
Assessment of current water conditions	9	10.84	634	7.78
Operation of multi or single purpose storage reservoirs	17	20.48	3075	37.78
Forcasting of flood peaks, low flow or seasonal flow	9	10.84	1147	14.09
Disposal of waste and control of pollution	1	1.20	109	1.34
Water quality data programs for which discharge records are needed	27	32.53	1252	15.38
Compact and legal requirements	4	4.83	891	10.94
Research and special studies	17	20.48	1191	14.63

Total number of stations at the time of Benson and Carter's (1973) study was 83 for Louisiana and 8138 for the United States.

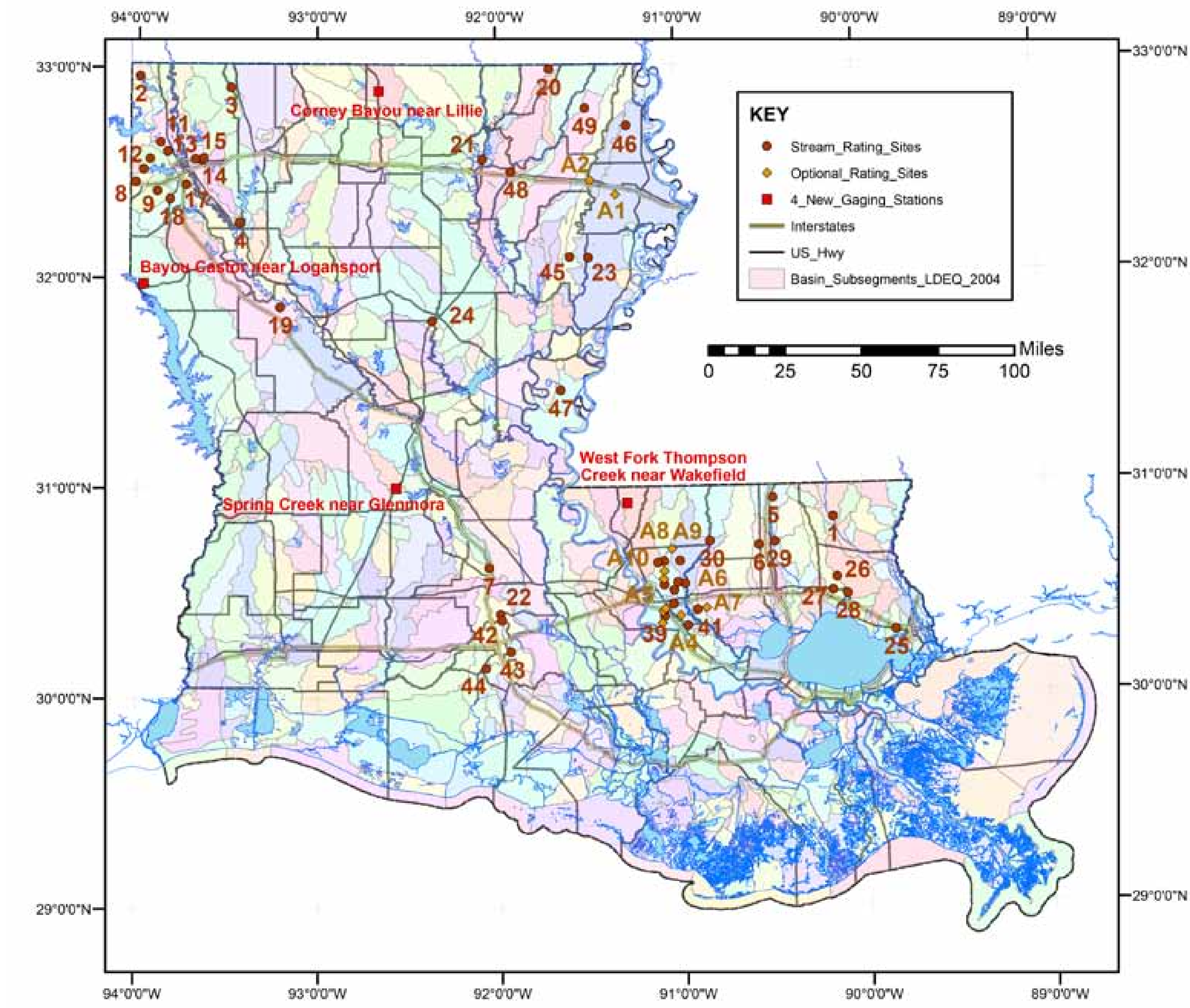


Figure 1. Map of site locations where rating curves are being developed at current USGS stream stage sites throughout Louisiana. The original list of four locations for new gaging sites are shown as red squares and were later dropped due to cost considerations.

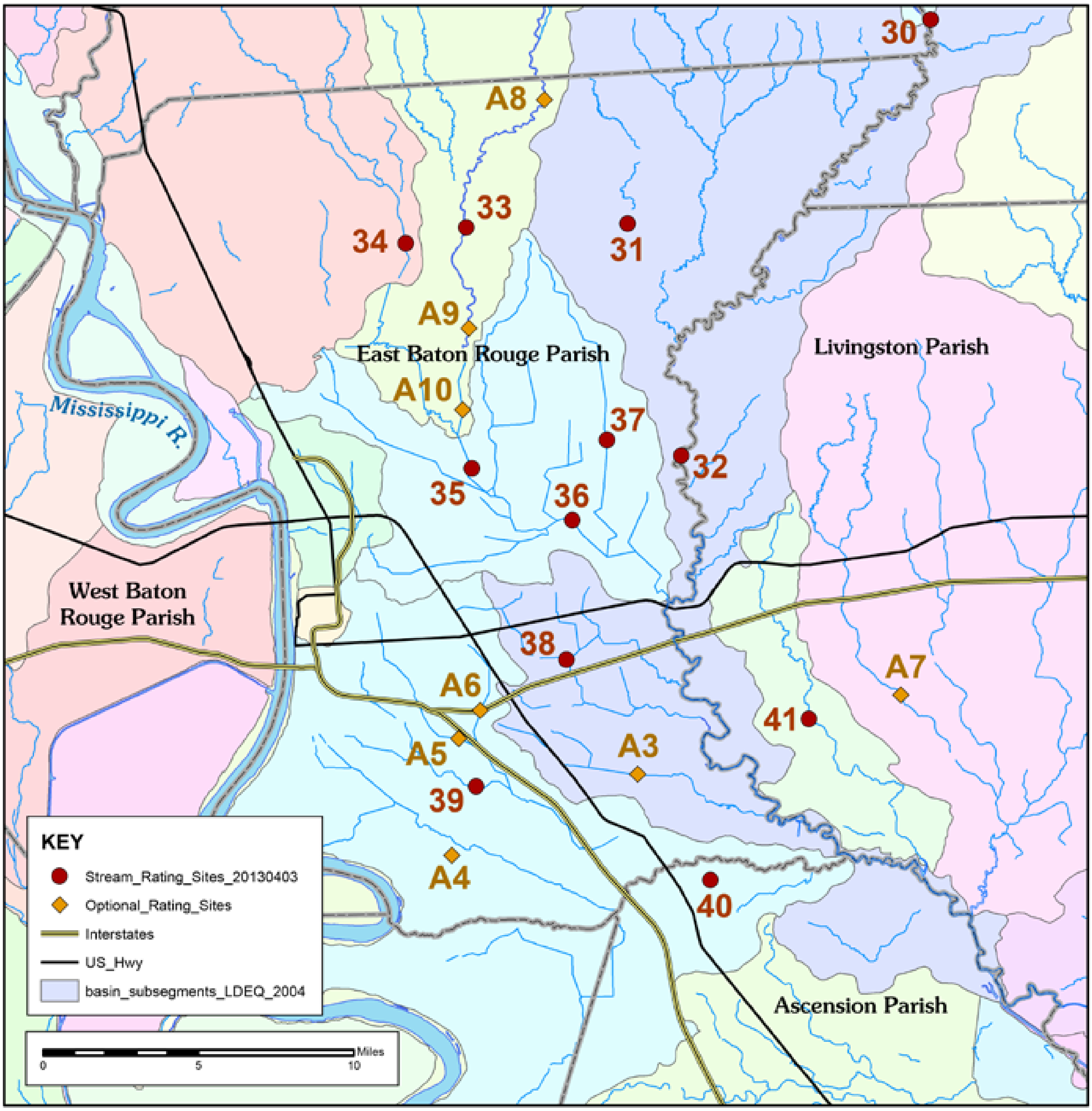


Figure 2. Map of locations where rating curves are being developed in East Baton Rouge and Livingston Parishes at current USGS stream stage sites.

Methods

Use of the River Surveyor for determining stream discharge

One of the instruments used for determination of stream discharge is the River Surveyor S5 ADP (SonTek/YSI Incorp, 2011), hereafter referred to as River Surveyor. This is a boat shaped instrument which is about 2 ft. wide and 3 ft. long (Figure 3). This instrument has been used for most of the measurements of stream discharge in this study, 116 of the first 165 discharge measurements. This instrument was used anytime there is a significant portion of the stream where the depth of water is over 1.5 ft. The other instrument, the Flow Tracker®, was used at many sites particularly for small streams during low flow conditions when the depth of the stream was usually less than 1.5 ft.

The River Surveyor is an acoustic Doppler profiler system, which has four profiling beams and one vertical beam. The four profiling beams are directed off the bow and stern, and off the port and starboard sides of the boat (SonTek/YSI Incorp, 2011). The vertical beam has the lowest frequency, 1 MHz, which allows extension of the depth of measurement while the four profiler beams are 3 MHz, which allow greater sensitivity to the measurement of the Doppler shifts due to moving parcels of water (Son/YSI Incorp., 2011). The River Surveyor has a global positioning (GPS) system which allows the computer to define the exact position of the boat at all times and to provide a record of the profile's position in map coordinates either latitude-longitude or UTM systems, (SonTek/YSI Incorp, 2011). The maximum depth of investigation for the River Surveyor is 16.5 feet for stream velocity and 50 feet for stream discharge (SonTek/YSI Incorp., 2011). The River Surveyor is designed to measure stream velocities between 0.4 mile/hour and 11.25 mile/hour (SonTek/YSI Incorp., 2011).

LGS staff when conducting discharge measurements using the River Surveyor have either two or three individuals involved. These surveys can be conducted either from the banks of a stream with personnel on opposite sides of the stream (Figure 4) or from a bridge deck. For a survey from stream's banks two people on opposite sides of the stream pull the River Surveyor (Figure 4) back and forth across a stream at least twice. The four or more discharge values calculated by the River Surveyor for the four or more trips across the stream are then averaged and that value plus information on stream gage value obtained from the USGS stream gaging webpage is listed for that stream on a given time and date and included in Appendix B as part of the stream's data set for later development of its rating curve.

Figure 3. Above is a close up view of the River Surveyor. Box towards bow end (left) is power source, the tower near stern (right) is global positioning system (GPS) unit used for locating boat on universal grids (latitude-longitude or State Plan Coordinates (UTM).

Use of the Flow Tracker® for determining stream discharge

The second instrument used for determining stream discharge is the Flow Tracker®. For this instrument the mounting pin which measures stream velocity should be orientated parallel to the banks and perpendicular to the tag line across a stream used for position measurements of both depth and lateral positions for sites where there is a determination of flow velocity (SonTek/YSI Incorp, no date). For this study the number of positions used for velocity determination along the tag line is between 12 and 21.

The Flow Tracker® works by sending out an acoustic signal to measure the Doppler shift of a moving parcel of water that is 4 inches from the instrument. The signal bounces off this parcel of water and these rebound signals are recorded at two receivers (SonTek/YSI Incorp, 2009a).

The Flow Tracker® can measure water velocities from 0.007 to 8.9 mph (SonTek/YSI Incorp., 2009a). This range of velocities will with ease include typical velocities observed in this study's examination of 20 sites on small streams, at 39 different times for range discharges of approximately 0.25 cfs to approximately 85 cfs.

Usually the Flow Tracker® requires a depth of water over 1 inches (Shavanda, 2011). However, it appears that the LGS meter needs a depth of water over 2 inches. Due to safety considerations this instrument should be used where the depth of water is less than three feet (Son Tek/YSI Incorp., no date). For this study for practical reasons when wading across the streams depths have been less than 2 ft. (Figure 5). There is really no reason to wade in deeper stream conditions as the River Surveyor is available for deeper stream conditions.

Figure 4. LGS staff measuring stream discharge for Bayou Fountain at Bluebonnet Boulevard. in Baton Rouge on March 7, 2013.

There are three general solution methods that can be used by the Flow Tracker® to determine a stream's discharge: mid-section (which is the default method), mean and Japanese methods. The mid-section method, which is the typical method used by the USGS, is described in greater detail in ISO standards 748 and 9196 (SonTek/YSI, 2009a). Other methods are similar to mid-section except for the mean method area which is defined as a series of trapezoids rather than rectangles in the mid-section method. The Japanese method has velocity determined at every other trapezoid. (SonTek/YSI, 2009a). The 11 or more rectangles-trapezoids for area calculation of a profile are in turn multiplied by velocities at a center of a rectangle to yield discharge in that segment. Then the 11 or more area discharges are summed for the total stream discharge. For solution of discharge through either rectangle or trapezoid there is a need for width of rectangles or trapezoids, depth at the center of a rectangle or a trapezoid, and velocity as measured by the Flower Tracker® at the center of the rectangle or trapezoid. Then all three of these pieces of information for each of the positions is entered into a spreadsheet that solves for discharge for each of the solution techniques using equations as defined in SonTek/YSI Incorp, (2009b) and then these three discharge values are averaged for the stream discharge value that is included in later tables.

Figure 5. LGS staff conducting a Flow Tracker® survey of Beaver Bayou near Wax Road in Baton Rouge, Louisiana on June 20, 2013.

Results

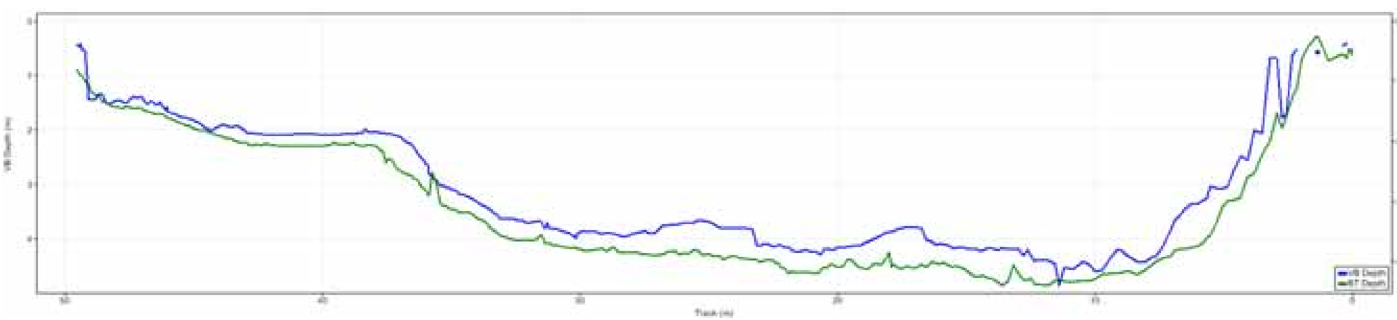
Discharge measurements

The River Surveyor creates a track of the boat in either state plan coordinates or latitude and longitude, river profile (cross-section), and distribution of stream velocity through the area of the stream's cross section. Path is displayed relative to north-south orientation. River cross-sections tend to appear in one of three forms. A typical cross-section in an area where there is a cut bank and point bar where the channel is deep close to one edge (cut bank side) and shallow with a gentle increase in depth on the opposite side of the stream (point bar side) can be seen in Figure 6a. More common cross-section is Figure 6b, which occurs usually in an area with a fairly straight channel and which lies between meander bends within the stream's channel. The last type of channel is a fairly rectangular shaped channel, Figure 6c, which appears to occur most often for small urban streams which are probably channelized for flood control reasons in their urban settings.

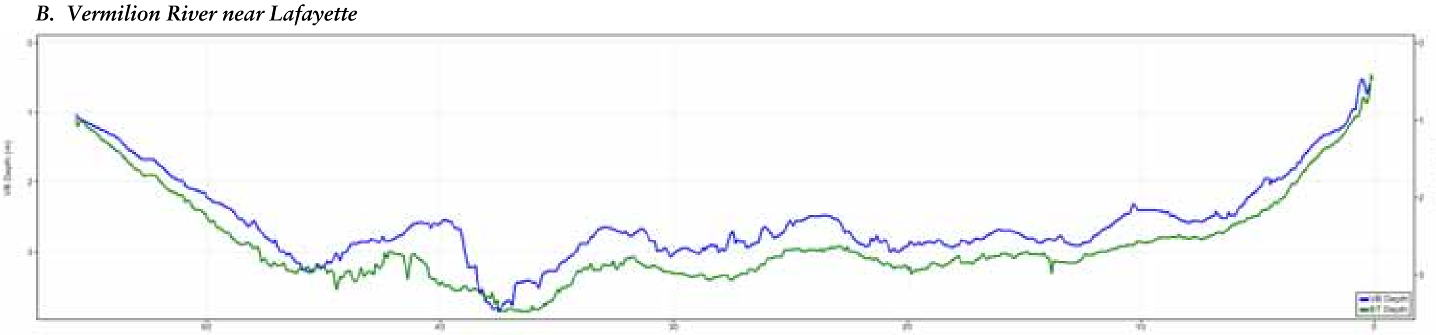
The velocity distributions also come in three general types, which will explain why there are three types of channel cross-sections. Figure 7a is an example of a channel where one side is the cut bank side and the other is a point bar side. The velocity is highest (reds and oranges) on the cut bank side and is lowest (blues and purples) on the point bar side. This all makes sense when you consider erosion is happening on the cut bank side where fastest stream flow occurs and deposition occurs on the point bar side where lowest stream flow occurs (Plummer et al., 1999). In a straight portion of a channel the distribution of stream velocity tends to be highest towards the center (Figure 7b) and lower near the edges, which is to be expected in these areas which tend to have relatively uniform distribution of stream velocity across a stream's channel (Plummer et al., 1999). The distribution of stream velocity is similar in the rectangular stream channel (Figure 7c) where flow velocity like the straight stream segment is highest in the middle and tends to be lower towards the edges of the channel.

Currently 116 discharge values have been determined using the River Surveyor and 49 with the Flow Tracker (Figure 8 and Appendix B). At the current time most of the streams have had one to three measurements of discharge determined, 34 of the 51 sites in the current study (Figure 9). Smaller of sets of sites have four or more discharge observations always completed, 24, or have been dropped from the current study, 9.

A. Vermilion River near Carencro



B. Vermilion River near Lafayette



C. Jones Creek at Old Hammond Hwy, Baton Rouge

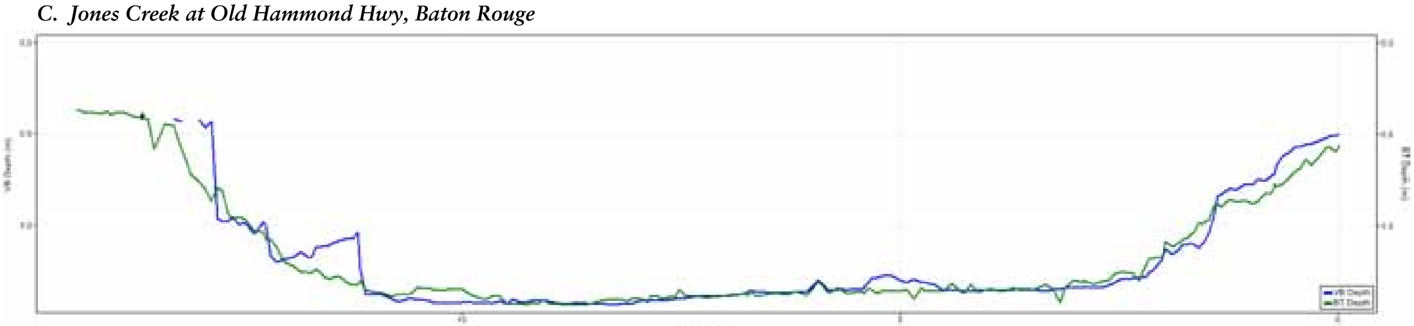
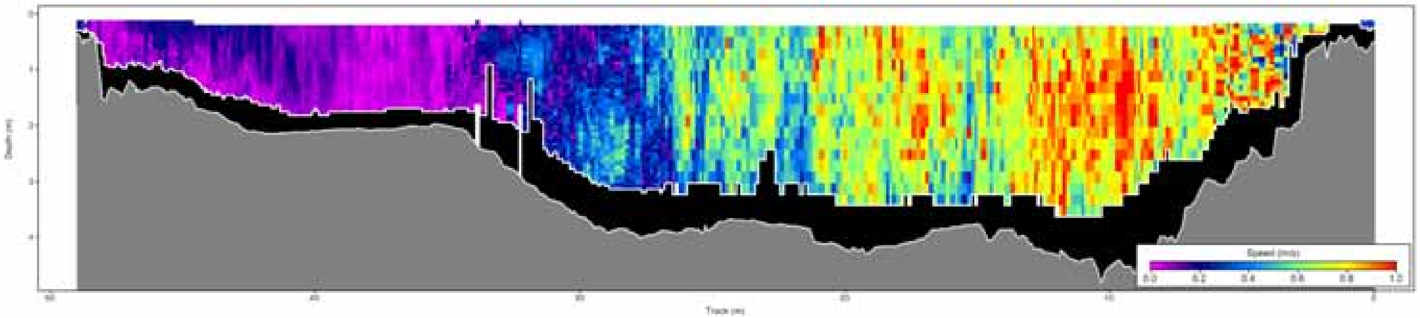
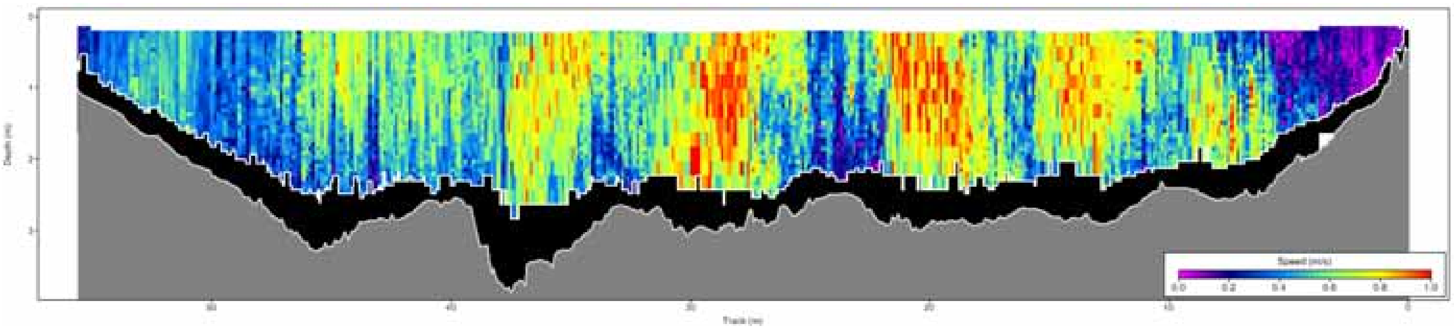


Figure 6. Three typical cross section profiles.

A. Vermilion River near Carencro



B. Vermilion River near Lafayette



C. Jones Creek at Old Hammond Hwy, Baton Rouge

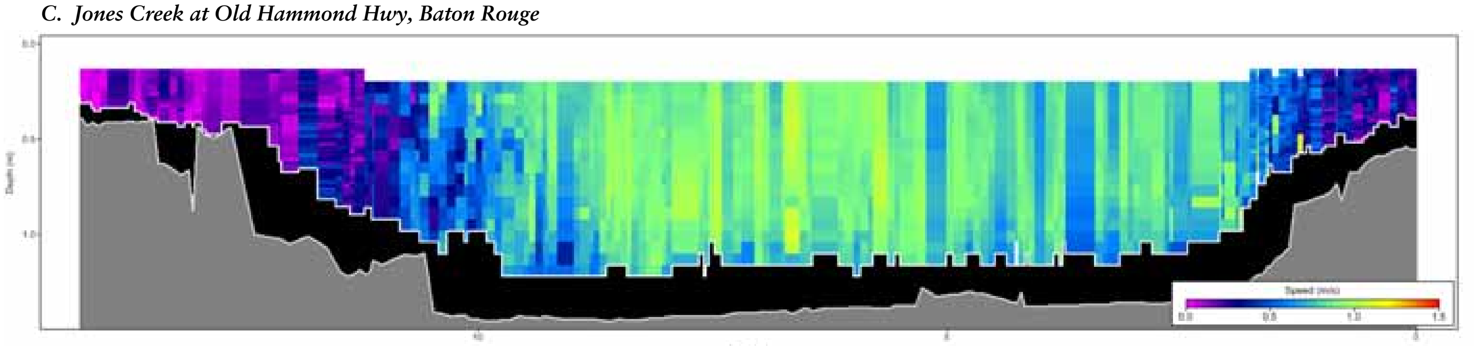


Figure 7. Flow velocity across three examples straight segment, cut-bank point bar, over central change

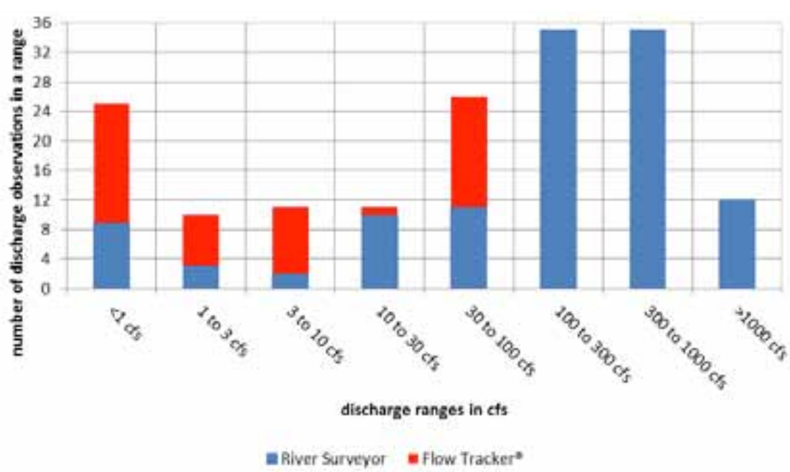


Figure 8. Distribution of stream discharge results as function of which technique was used to determine discharge rates, as of November 7, 2013.

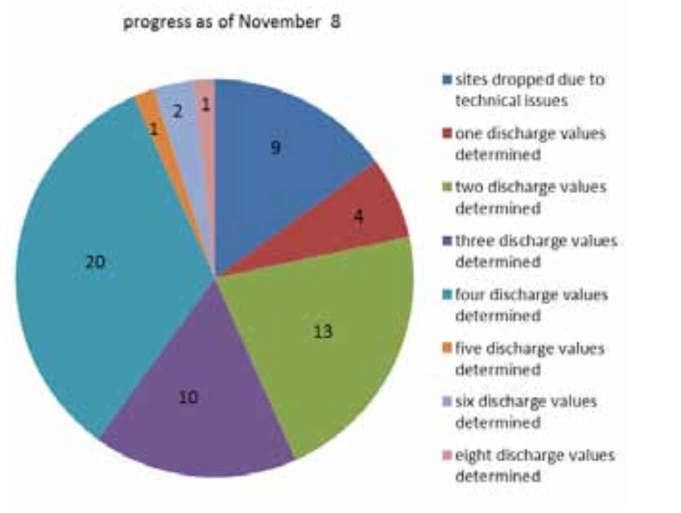


Figure 9. Distribution of sites by number of discharge measurements as of November 8, 2013. Total of 165 values of discharge determined which is about 3.24 per stream site.

Development of Rating Curves

Rating curves are developed by relating measurements of discharge and gage heights to each other (Chow et al, 1988). The rating curve is then used to convert records of water level (gage height) to flow rates (discharges). Rating curves need to be checked periodically to ensure the relationship between discharge and gage height has remained constant or maybe there is a new curve and associated equation. The change could be a result of changes in bed elevation by scouring of sediment or additional deposition (Chow et al., 1988). Ideally the number of observation pairs should be at least 15 and should be distributed uniformly within the range of measurable stream discharge values which for practical reasons will be below large to extreme flood events according to European ISO EN rule 1100-2 (1998, ISO 1100-2:981) (Domeneghetti et al, 2012). For this study there will be an attempt to meet this standard for sites within a day's drive from the LGS office in Baton Rouge, which should include 27 of the 51 stations that are currently within active set of sites being analyzed. Already for 24 of the 27 nearby sites have three to six discharge values already determined. This pace, if continued, in three years should yield 18 to 30 discharge values to be used for this study when it is completed in late 2015. By contrast only 4 of 24 distant sites has three or more discharge values already determined.

Figure 10. Point A5 .Ward Creek at Essen Lane, Baton Rouge, Louisiana on May 9, 2013.

For a number of small and medium size streams it appears that the USGS stream gage is left high and dry on sand bars (Figures 10) or the stilling well bottom is far above the stream surface when stream is running low (Figure 11). These conditions appear to be often occurring for small streams and rare for large streams. The net result is that often the USGS gage height is at the lowest value or close, within an inch for small streams. The average share of time observations are at the lowest value for small streams are 8.21% and for large streams is 0.06%. Results are similar for the average share of observations within one inch of the lowest value where the average for small streams is 33.68% and for large streams is 1.13% For this reason it is necessary when measuring discharge at low stream gage heights that there will be a need to determine how far below the USGS gage's base gage height the stream channel is really at. This will avoid distortions of the rating curve possible by not doing this step, compare results for Clay Cut Bayou (Figures 12 and 13). For this reason for a number of stream gage heights in Appendix B there are two gage height values listed for a single discharge value, second number in brackets is gage height after removing from USGS gage height vertical distance between stilling tower base and top of water surface.

Figure 11. Point A3. Clay Cut Bayou at Antioch Road, Baton Rouge, Louisiana on June 20, 2013.

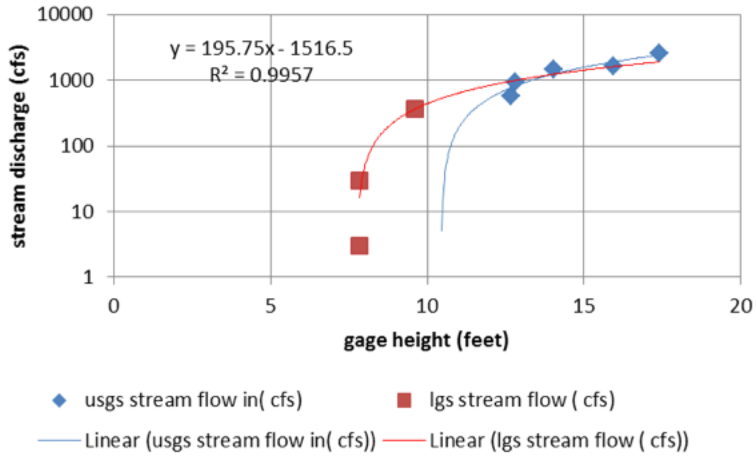


Figure 12. Rating curve using a linear regression equation using USGS gaging heights for Clay Cut Bayou.

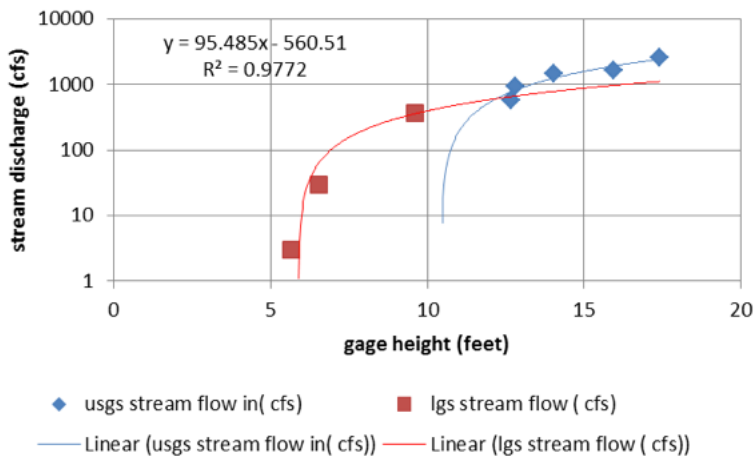


Figure 13. Rating curve using a power function with gage heights modified from USGS gaging heights for Clay Bayou.

Summary

This study includes determining stream discharges at 51 sites and the developing rating curves from discharge and stream gage height results. At the present time results are for the first year of this three year study which at the end of this study will typically include 8 to 15 discharge results that will be used for rating curve development. LGS staff currently working on this project are: Reed Bourgeois, Douglas Carlson, Brian Harder, Marty Horn, Chacko John, Riley Milner, Patrick O'Neill, and Robert Paulsell. Project work started in March of 2013. At the end of the first quarter, March 31, 2013 9 measurements of discharge were completed at 8 streams. At the end of the second quarter, June 30, 2013, 88 measurements of discharge were completed at 41 streams. At the end of the third quarter, September 30, 2013, 120 measurements of discharge were completed at46 streams. Currently as of November 10, 2013 141 measurements of discharge were completed at 49 streams.

Discharge data is being determined using two different instruments, the River Surveyor and the Flow Tracker®. The River Surveyor is used for larger streams where the depth of water is usually over 1.5 feet and often over 10 feet. The Flow Tracker® is used for smaller streams where the depth of water is generally less than 2 feet and over 2 inches. The River Surveyor is a two or three person operation where two people pull the boat with ropes, the boat measures depth and flow velocity, back and forth across the stream/river for at least four trips. The third person when necessary only operates the computer and its software and directs the others who are controlling the boat. When four trips or more are completed, then an average of discharge among the trips is determined for that stream and correlated with observed stage at a nearby USGS gaging site for a single point within a rating curve plot being developed. By contrast the Flow Tracker® is a two man operation where one person reads position along a tag line, depth of water from the staff associated with the Flow Tracker® and the velocity from the Flow Tracker® while the second person records the information. These positions, depths and velocities are entered into a spreadsheet that solves for stream discharge using three techniques and then averaged. The resulting discharge is correlated to a gage height as recorded at a nearby USGS gaging station for a point for the stream rating curve being developed.

At the present time most of the streams have had discharge measured two, three or four times. Currently discharge measurements have ranged from approximately 3,600 cubic feet per second (cfs) for Twelvemile Bayou near Dixie, LA; to less than 0.25 cfs at Paw Paw Bayou near Greenwood, LA., and North Branch of Ward Creek at Jefferson Hwy in Baton Rouge LA. Currently the River Surveyor discharge measurements for larger streams are generally larger than Flow Tracker® discharge measurements for smaller streams. At the present time the average discharge for the 116 measurements made by the river surveyor is 450 cfs, while the average discharge for the 49 measurements made by the Flow Tracker® is 20.6 cfs.

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Appendix A

List of 51 sites LGS staff will be developing a rating curve of discharge as a function of stream level. This set includes 47 USGS gaging sites that currently do not have discharge date being currently available and 4 USAC.

LGS No.	Gaging station-site name	USGS. number	latitude degrees	longitude degrees
1	Bogue Chitto River at Franklinton, LA	02491500	30.84277778	-90.16194444
3	Bodcau Bayou near Sarepta, LA	07349500	32.90500000	-93.48277778
4	Flat River at High Island, LA	07349910	32.26444444	-93.43111111
5	Tangipahoa River near Kentwood, LA	07375300	30.93750000	-90.49027778
7	Bayou Courtableau at Washington, LA	07382500	30.61805556	-92.05555556
8	Cross Bayou at Hwy 80 west of Greenwood, LA	07344425	32.45583333	-94.01444444
9	Paw Paw Bayou near Greenwood	07344450	32.51666667	-93.97222222
10	Shettleworth Bayou near Blanchard, LA	07344460	32.56666667	-93.93666667
11	Twelvemile Bayou near Dixie, LA	07348000	32.64583333	-93.87777778
12	Mc Cain Creek near Blanchard, LA	07348098	32.60194444	-93.83694444
13	Flat River at Shed Road near Bossier City, LA	07349298	32.56138889	-93.64611111
14	Red Chute Bayou at Dogwood Trail near Bossier City	07349849	32.56972222	-93.63472222
15	Willow Chute Bayou at Swan Lake Road, near Bossier City	07349898	32.56527778	-93.68111111
16	Bayou Pierre at Shreveport, LA	07350700	32.44333333	-93.73083333
17	Boggy Bayou north of Spring Ridge, LA	07350985	32.35666667	-93.94583333
18	Gilmer Bayou near Shreveport, LA	07351275	32.41361111	-93.89416667
19	Bayou Pierre near Powhatan, LA	07351755	31.86027778	-93.20611111
20	Bayou Bartholomew, NW of Jones, LA	07364203	32.98472222	-91.69861111
21	Chauvin Bayou near Monroe, LA	07366472	32.55916667	-92.07583333
22	Bayou Lafourche near Alto, LA	07369050	30.39722222	-91.99444444
23	Tensas River south of Newlight, LA	07369649	32.08916667	-91.48972222
24	Little River at Rochelle, LA	07372190	31.79305556	-92.36166667
26	Tchefuncte River near Covington, LA	07375050	30.49444444	-90.16944444
27	Bogue Falaya River near Camp Covington, LA	07375105	30.55638889	-90.14611111
29	Tangipahoa River near Amite, LA	07375430	30.72888889	-90.48416667
30	Amite River at Grangeville, LA	07377150	30.73611111	-90.84166667
31	Little Sandy Creek at Peairs Rd SE of Milldale, LA	07377230	30.64350000	-91.00736111
32	Amite River at Magnolia, LA	07377300	30.53472222	-90.98055556
33	Comite River near Zachary, LA	07377750	30.64305556	-91.09444444
34	White Bayou at State Highway 64 near Zachary, LA	07377780	30.63611111	91.12722222
35	Comite River at Hooper Rd near Baton Rouge, LA	07377870	30.53055556	-91.09361111
36	Comite River at Greenwell Springs Rd near Baton Rouge, LA	07378050	30.50555556	-91.04000000
37	Beaver Bayou at Wax Road, near Baton Rouge, LA	07378100	30.54277778	-91.02055556

LGS Number	Gagging station-site name	USGS. number	latitude degrees	longitude degrees
38	Jones Creek at Old Hammond Hwy near Baton Rouge, LA	07378650	30.44055556	-91.04444444
39	Dawson Creek at Bluebonnet Blvd near Baton Rouge, LA	07379960	30.38222222	-91.09416667
41	Grays Creek near Port Vincent, LA	073801175	30.41083333	-90.91444444
42	Bayou Vermilion near Carencro, LA	07386600	30.36805556	-91.98750000
43	Vermilion River near Lafayette, LA	07386850	30.21888889	-91.93888889
45	Bayou Macon at Como, LA	USACE	32.09222222	-91.59250000
46	Tensas Bayou at Transylvania, LA	USACE	32.71440000	-91.26860000
47	Bayou Cocodrie at Deer Park Monterey, LA	USACE	31.45938900	-91.65090700
49	Big Colewa Bayou at Oak Grove, LA	USACE	32.79890000	-91.49890000
A2	Bayou Macon near Delhi, LA	07370000	32.45777778	-91.47611111
A3	Claycut Bayou at Antioch Road near Baton Rouge, LA	07378722	30.38666667	-91.00722222
A4	Bayou Fountain at Bluebonnet Blvd. near B.R., LA	07378810	30.35027778	-91.10805556
A5	Ward Creek at Essen Lane near Baton Rouge, LA	07379050	30.40472222	-91.10333333
A6	North Branch Ward Creek at Baton Rouge, LA	07379100	30.41777778	-91.09138889
A7	W. Colyell Creek at Joe May Road near Port Vincent, LA	07380185	30.42138889	-90.86472222
A8	Comite River at Pt. Hudson-Pride Road near Milldale, LA	07377600	30.70211111	-91.05119444
A9	Comite River near Baker, LA	07377754	30.59611111	-91.09416667
A10	Comite River at Comite Dr. near Baton Rouge, LA	07377760	30.55808333	-91.09816667

Appendix B

Currently collected discharge results completed as of October 30, 2013 that will be used in the development of stream rating curves.
View Appensix B at https://filestogeaux.lsu.edu/public/download.php?FILE=lgpond/37707hVjkoz

Application of Allostratigraphic Nomenclature by the Louisiana Geological Survey to Geologic Map Units of Quaternary Age

R. P. McCulloh

In the late 20th century, allostratigraphic nomenclature was formulated specifically for application to terraced depositional sequences and similarly related units. This nomenclature was incorporated into the North American Stratigraphic Code originally published in 1983 (North American Commission on Stratigraphic Nomenclature, 1983, 2005). Prior to the advent of allostratigraphic nomenclature, efforts at recognition and mapping of surfaces informally dubbed "the terraces" in the Quaternary outcrop belt of the Louisiana coastal plain had spanned most of the 20th century, and had become a well focused and actively debated research topic by mid century. Depictions by various investigators of the cross-sectional geometry of the depositional sequences underlying the Quaternary terrace surfaces mapped in Louisiana in the 20th century were predominantly of curvilinear unconformable surfaces separating units progressively incised by younger units, in cut-and-fill fashion. Once allostratigraphic nomenclature had become available, it appeared to have obvious utility in Louisiana for making better sense of "the terraces," i.e., for facilitating more systematic classification of the Quaternary units on which they were developed, than previously had been possible.

For example, Gagliano (1963) prepared an interpretive geologic section across the Amite River valley approximately 40 km (25 mi) northeast of Baton Rouge, Louisiana showing an indisputably alloformational configuration of Pleistocene and Holocene units (Figure 1). The dashed lines on his section depict the contacts projected into the shallow subsurface; their essential nature would not have been disputed or debated 50 years ago, nor would it be today, even though a precise rendering of their subsurface disposition would require extensive drilling deeper than the base of Prairie sediments along the line of section. The principal difference between how the units would be viewed now compared to then (apart from the Pliocene vs. Pleistocene age of the "Pre-Prairie" deposits) would involve the potential application of allostratigraphic concepts and nomenclature, which have been formulated and accepted since then, to the units' classification. Allostratigraphic concepts and nomenclature were designed specifically to acknowledge recognition of the particular suite of aspects of the geometry and contacts of these and similar units. The Louisiana Geological Survey (LGS) first began exploring the application of this nomenclature to the mapping of surface Plio–Pleistocene units in the late 1980s (e.g., Autin, 1988), and since then has found it ideally suited to the mapping of Quaternary units generally in Louisiana.

The units for which allostratigraphic nomenclature presently has value to LGS all are situated updip of the hinge zone of northern Gulf basin subsidence in Louisiana, and it seems clear as a matter of empirical observation that these units will not survive long geologically. Miocene Fleming strata presumably once had updip allounits that already have been removed by erosion, and the Pliocene Citronelle and Willis are now partway through such a transition, with remnants persisting in the coastal outcrop belt and on high ridgetops in places updip of it. The complete spectrum shown by coast-parallel exposures of Neogene strata in our state with regard to the preservation of updip allounits shows a clear progression: the younger Pleistocene strata retain pristine allounits; older Pleistocene strata retain relict/remnant allounits; Pliocene strata retain only trace characteristics of remnant allounits; and Miocene strata retain no allounits, as also obtains for older strata. It thus appears that in connection with the gulfward migration of the hinge zone—which Fisk (1944) succinctly diagramed (Figure 2)—the area updip of the present hinge zone where allounit

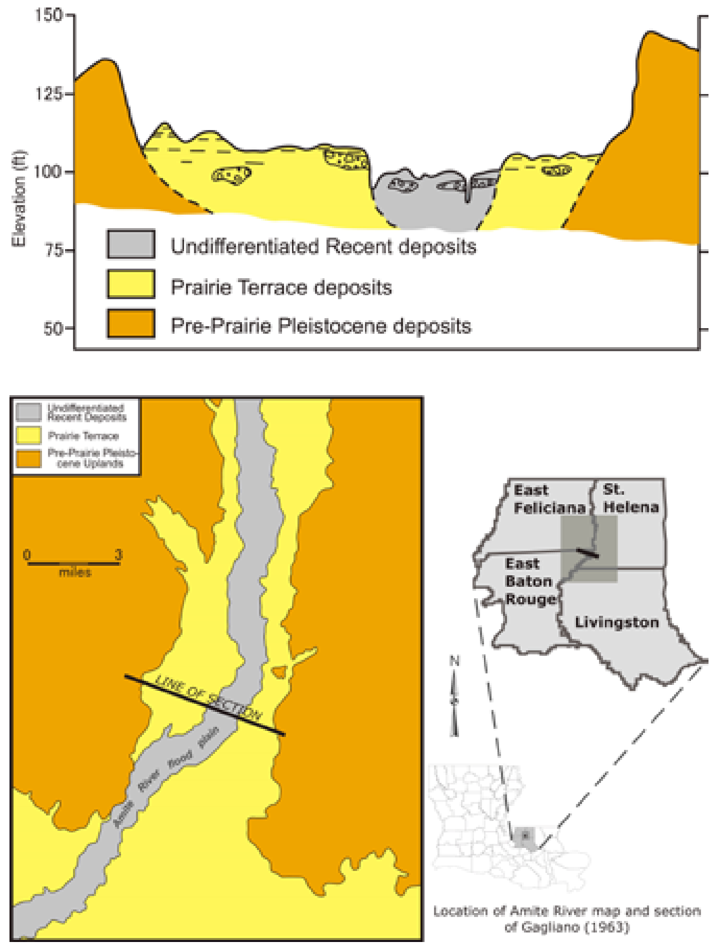

Figure 1. Interpretive geologic strike section across the Amite River valley at the juncture of East Feliciana, St. Helena, and East Baton Rouge parishes, Louisiana showing alloformational configuration of Pleistocene and Holocene units (redrawn and adapted from Gagliano, 1963, his figures 13 and 14).

nomenclature now may be used to advantage ultimately will become uplifted and eroded to such an extent that very little of these lenticular units will survive, and that in a few tens of millions of years they will have disappeared completely, leaving only the downdip portions of the units that lack such attributes. Meanwhile, contemporaneous with the destruction of these presently existing allounits, new strata will continue to be deposited, and new allounits likely will continue to be formed in their updip portions. For the present and foreseeable future, therefore, allounit concepts and nomenclature will continue to offer an effective, indeed essential approach to the understanding and classification of mappable onshore Quaternary units of the Louisiana coastal plain.

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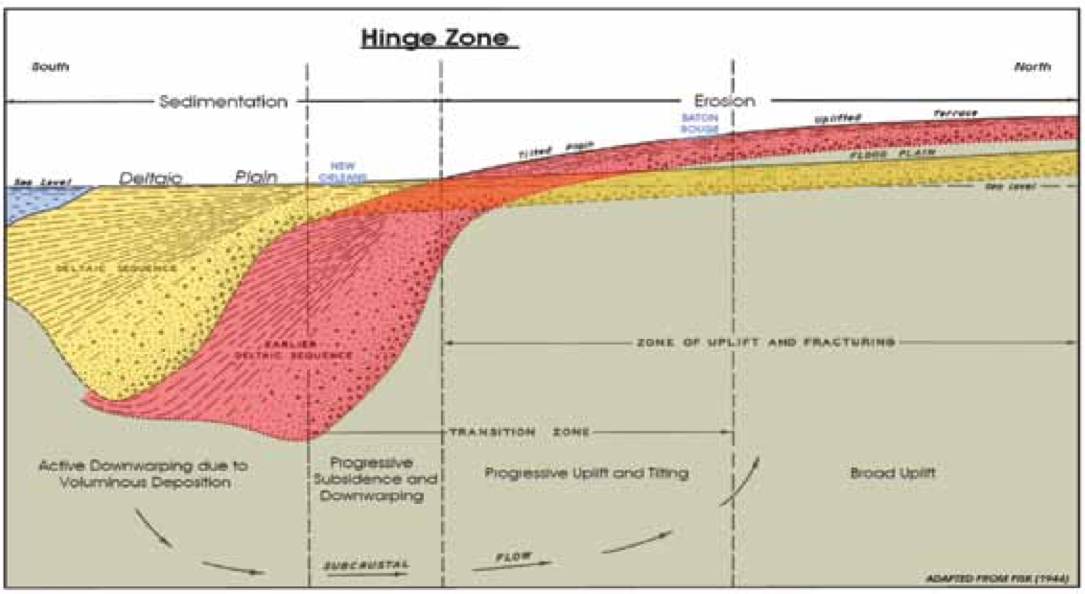

Figure 2. Schematic dip section depicting gulfward migration of the hinge zone of northern Gulf basin subsidence accompanying voluminous deltaic deposition, with alloformational units developed updip via associated uplift and incision (figure 1 of McCulloh et al., 2006, adapted from Fisk, 1944). Only the modern depositional sequence and a single previous sequence were depicted by Fisk for simplicity, whereas numerous such sequences complete with updip allounits in varying stages of erosional destruction populate the Quaternary sedimentary record of Louisiana.

Centennial of Monroe Natural Gas Field a Giant among Louisiana Fields

Douglas Carlson

Introduction

The Monroe Natural Gas Field (MGF) lies in northeast Louisiana. Its center lies approximately 20 miles south of the Arkansas-Louisiana border and 50 miles west of the Mississippi River near Sterlington, Louisiana (Figure 1). The southwest edge of the MGF is approximately 4 miles from the city of Monroe, Louisiana. The MGF is Louisiana's largest natural gas field, here after referred to as a gas field, which lies in parts of Morehouse, Ouachita, and Union Parishes (Figure 1). It is approximately 20 miles across in a east-west direction and 28 miles across in a north-south direction and covers 390 square miles (sqm), 249,600 acres (Fergus, 1935; Department of Conservation, 1937). There have been a large number of wells drilled in this field, more than 10,000 wells have been permitted to draw gas from this field (Washington, 2004). The MGF is a shallow gas field which is located 2,000 to 2,300 feet below the ground surface. The MGF's host rock, Monroe Gas Rock (MGR), is a light colored sandy fossiliferous limestone to a white chalk that is an upper Cretaceous rock that is approximately 70 million years old (Bell and Cattell, 1921). The original gas content of the Monroe Gas Field (MGF) has been determined to be more than 7 trillion cubic feet. Most of this gas has been produced from wells penetrating the Upper Cretaceous MGF during the past century (Zimmerman, 1993).

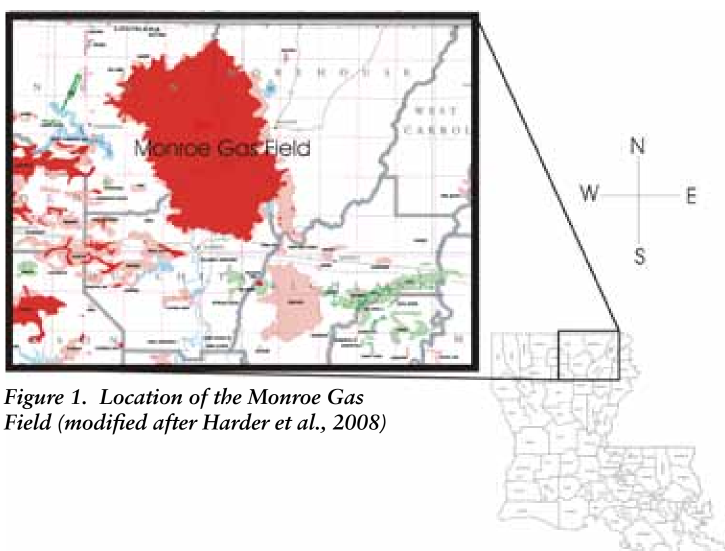

Figure 1. Location of the Monroe Gas Field (modified after Harder et al., 2008)

Development-Production History

Early Rapid Growth

Gas has been reported as present in water wells in the area for many years prior to 1916 (Fergus, 1935; and Department of Conservation, 1937). Between 1901 and 1909 there were a number of exploratory wells drilled for oil in the MGF area. These wells encountered small pockets of gas that would cause blow outs. Many of these were near the Old Breard Shingle Mill on North Riverfront Street in Monroe (Franks and Lambert, 1982). Gas was first discovered and extracted in the Monroe area during 1909, this was before markets were developed to sell and distribute the gas outside of the Monroe area (Bell, 1925; Department of Conservation, 1928; and Wang, 1952). This first well was drilled in Monroe City Park, 1909, that yielded a little gas and salt water at a depth of 1300 to 1500 feet. A year later, 1910, a well was drilled in Forsythe Park, which at 2,350 ft. penetrated a layer containing gas and saltwater (Franks and Lambert, 1982). This was the first well that was drilled into the current host rock which the MGF lies in. Later in 1913 Consolidated Ice Company drilled a well in Monroe to a depth of 3240 feet which yielded salt water and a little gas (Bell, 1925). Between 1913 and 1916 several more wells were drilled in the Monroe area with limited success (Franks and Lambert, 1982). The first commercial production of gas was obtained by Progressive Oil and Gas Company's Spyket no. 1 well in June 28, 1916, which is credited to Louis Lock who was the general manager of this discovery well (Meyer, 1972). This well at 2,275 feet hit a pocket of gas which generated enough pressure to almost blow the drillstem out of the hole. It also generated enough excitement to draw enough sightseers to cause the need for local railway to add special trains to Monroe to see this well. The first well test of this well measured a flow of 2.5 million cubic feet per day (ft^3/day) (Franks and Lambert, 1982). Shortly after this test another well Fisher no. 1 was drilled 2 miles to the north, which produced initially at 5.2 million ft^3/day from a pocket of gas that is at a depth of 2,255 feet. Later Fisher no. 1 rate of production stabilized at 3 million ft^3/day. Several other well were drilled later in 1916 to extend the field to 8 miles in length (Franks and Lambert, 1982).

The size of the proven reservoir for the MGF expanded quickly in the first five years. In 1917 an additional 13 wells were drilled which defined the field's length to be 18 miles and area to be 40 sqm (25,600 acres) (Bell and Cattell, 1921). One of these wells Lieber No. 1 produced an open flow of 21 million ft^3/day (Franks and Lambert, 1982). In 1918 development expanded the field several miles to west and expanded proven reserve area to 75 sqm (48,000 acres) (Bell and Cattell, 1921). These wells are small by today's standards (Figure 2). The great pressure associated with the MGF made it common for blowouts to occur and associated craters around the well, which causes the rig to be swallowed up (Figures 3, 4, and 5). Some of these craters were large, for example, Smith no. 3 by the summer of 1921 generated a crater that had a diameter of 200 feet (Franks and Lambert, 1982). By April of 1920 additional wells expanded proven reserve area to 125 sqm (80,000 acres). Another year of development expanded the MGF several miles to the northwest and increased the proven field size area to 212 sqm. (135,680 acres) (Bell and Cattell, 1921). This is approximately half of the current MGF area of approximately 365 sqm (Zimmerman and Sassen, 1993). By August of 1922 the MGF covered an area of 254 sqm (162,560 acres). Later in September of 1922 additional discoveries expanded the field to an area of 300 sqm (192,000 acres), which makes the field probably the largest in the United States (US) at the time (Stroud and Shayes, 1923). Production increased quickly in the 1920s from approximately 20 billion cubic feet in 1920 to approximately 170 billion cubic feet in 1929 (Figure 6) (Wang, 1951). Although wells

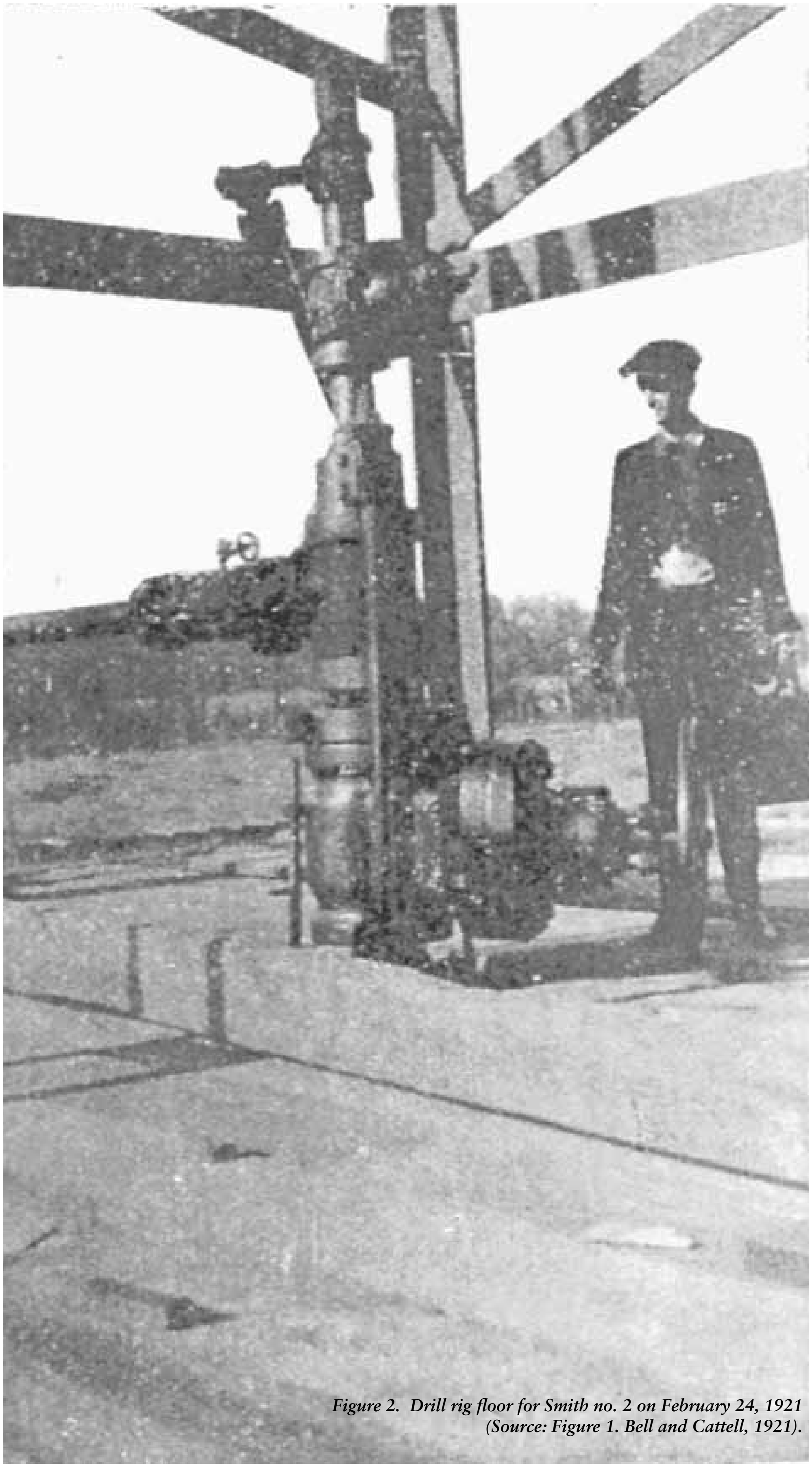

Figure 2. Drill rig floor for Smith no. 2 on February 24, 1921 (Source: Figure 1. Bell and Cattell, 1921).

in the MGF produced at a high rate they were still producing only 24% of capacity, for example, in February of 1921 production rate was 78 million ft^3/day while the full production capacity rate is 325 million ft^3/day (Franks and Lambert, 1982). By 1925 MGF cumulative production had reached 628 billion cubic feet of gas and the available reserves were estimated to be 3.768 trillion cubic feet of gas. Early in the development of the MGF there were many blowouts and a large fraction of gas was wasted (Figures 3,4, and 5). For example, Guthrie no. 1 vented 300 million ft^3/day of gas per day into the atmosphere (Franks and Lambert, 1982).

Within approximately 10 years of the first commercial production of gas estimates of future production and proven available reservoirs were made. In the early 1930s the estimation of available gas was 2.198 trillion cubic feet and estimated production would decrease to 70.8 billion cubic feet/year in 1940, 40.9 billion ft^3/year in 1945, 21.2 billion ft^3/year in 1950, 9.13 billion ft^3/year in 1955 and 2.19 billion ft^3/year in 1960 (Bell, 1925). In reality the decrease of production was far slower than the 1925 estimates. For example, production did not decrease to 70.8 billion ft^3/year until 1967, 27 years later (Figure 6). Production reached 40.9 billion ft^3/year in 1982, 32 years later, 9.13 billion ft^3/year in 1999, 44 years. Production has yet to decline to 2.19 billion ft^3/year even when considering the first nine months of 2013 it MGF is still producing over 2.19 billion cubic feet of gas. Last full year, 2012, production was 4.69 billion ft^3/year (Louisiana Department of Natural Resources, 2013). Advances of exploration and development technology are probably the main reason for the slower than expected rate of production decline.

In terms of exploration the development of geophysical logging instruments allowed for an improved resolution of the extent of the MGR and extent of gas within this formation. The first geophysical logs completed in the MGR are resistivity and spontaneous potential (SP) in 1936 (Schlumberger, 1936), which is only five years after Schlumberger developed SP log and only 9 years after Schlumberger developed resistivity logs (Keys, 1990). By 1953 the currently common 16 inch normal and 64 inch normal resistivity logs were used in the MGF (Schlumberger, 1953). These logs were in common use by 1949 as indicated by normal logs being discussed in Schlumberger (1949) log interpretation manual. In the early 1960s natural gamma and induction logs were introduced among the logs in the MGF (Sclumberger, 1963). Gamma Ray logs were first developed in 1939 (Hilchie, 1979). Induction logs were developed 10 years later in 1949 (Schlumberger, 2013). Later there was the arrival of porosity logs such as sonic logs (Moselye Surveys, 1965) and neturon logs (Schlumberger, 1963), which can be used to directly detect gas and for determination of the porosity values within the MGR. Neutron logs were first developed in 1938 (Buruyakovsky et al., 2012), eight years later in 1946 sonic logs sometimes referred to as acoustic logs were developed (Pike and Duey, 2002).

In addition, a variety of techniques and tools used for finding gas pockets techniques were developed to increase the rate at which gas could be extracted from the MGR. For example, in the late 1940s acidizing wells was done in order to expand fractures in the MGR (Union Producing Company, 1949), both natural and drilling induced, which in turn increases rock permeability that allows for easier and quicker extraction of the gas yielding increased rates of production. It is apparent that MGR is an early site of the use of acidizing of gas wells, because this work was completed within two years of an US patent for acidizing gas wells submitted for consideration in 1947 (Villines 1947).

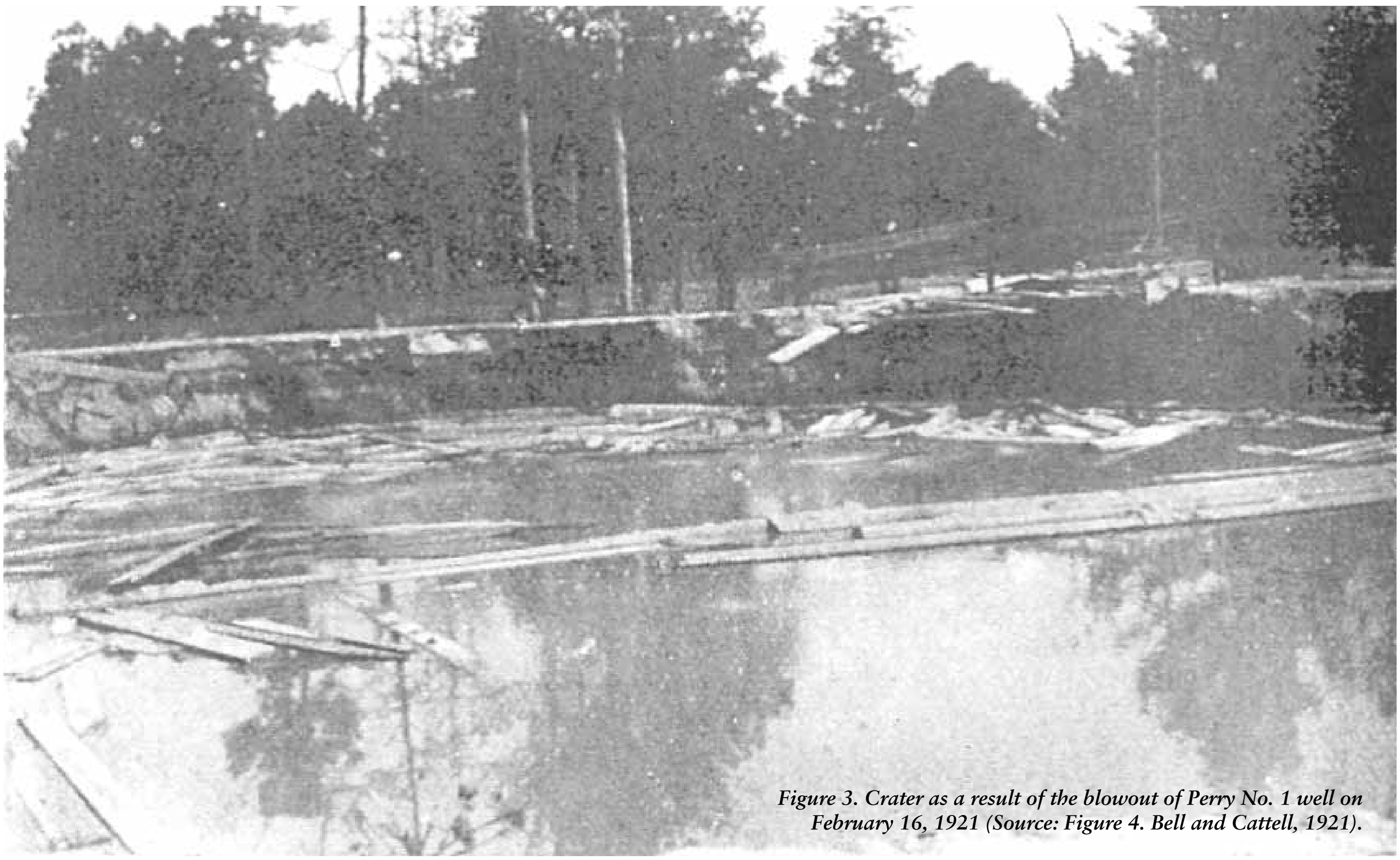

Figure 3. Crater as a result of the blowout of Perry No. 1 well on February 16, 1921 (Source: Figure 4. Bell and Cattell, 1921).

By the mid-1920s the MGF was considered the world's largest gas field. In 1924 largely due to massive production of the Monroe and Caddo Lake fields two "all-inclusive" conservation statutes were passed by the Louisiana legislature. One, was for natural gas and the other for oil. Five years later in 1929 President Hubert Hoover assembled an Oil conservation congress in Colorado Springs, Colorado to address the problem of waste and overproduction and to consider possibility of federal regulations (Franks and Lambert, 1982). In 1929 the Monroe Gas Field was determined to cover 226, 880 acres and included 720 wells producing natural gas. Early development of the MGF was concentrated in the southeastern part of the field. Later on development spread to the north, northwest and west. For example in 1929 development expanded the field 1.5 miles westward and 2 miles northward and northwestward (Wang, 1952).

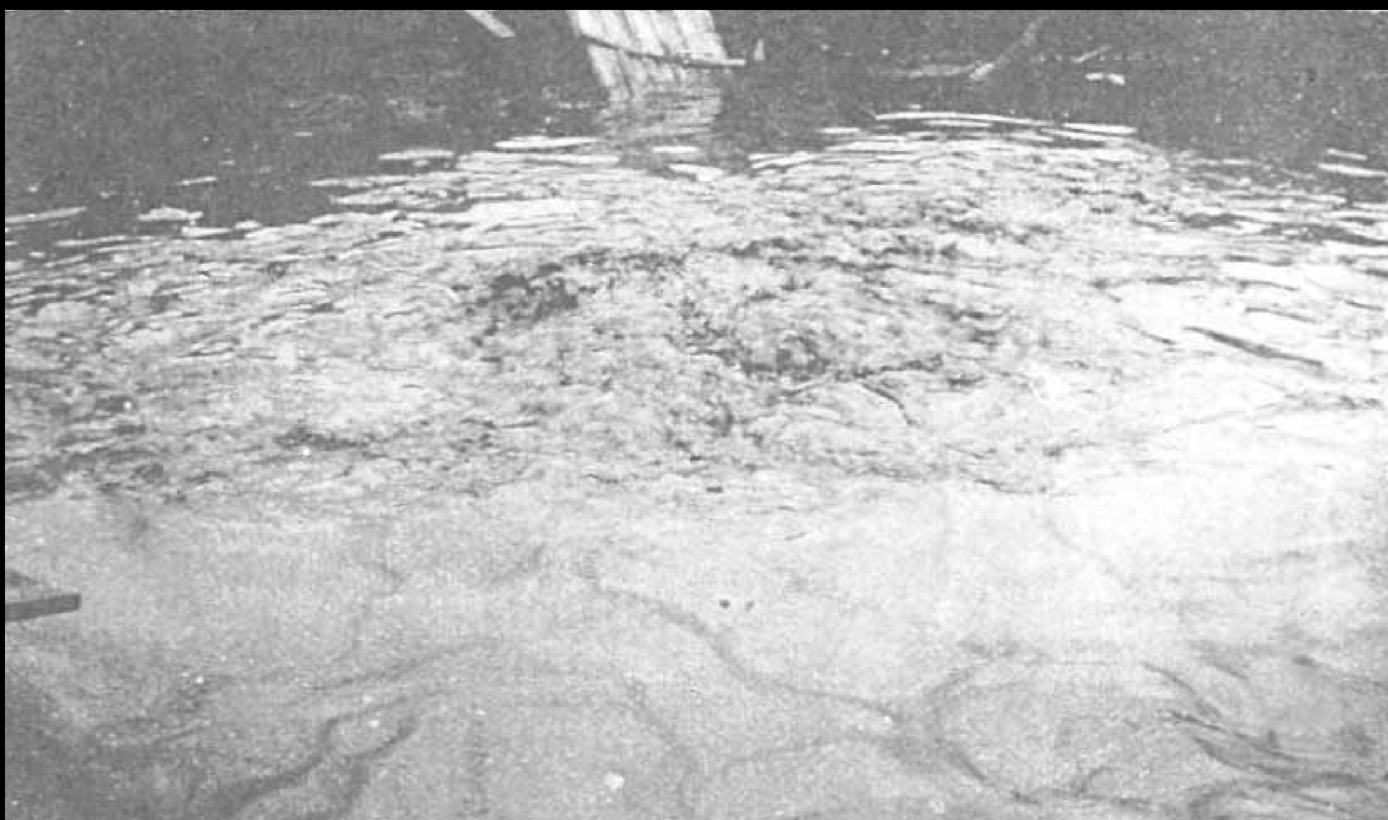

Figure 4. Natural gas bubbling up through water that formed in crater of the blowout of Sandridge No. 1 on March 16, 1921 (Source: Figure 2. Bell and Cattell, 1921).

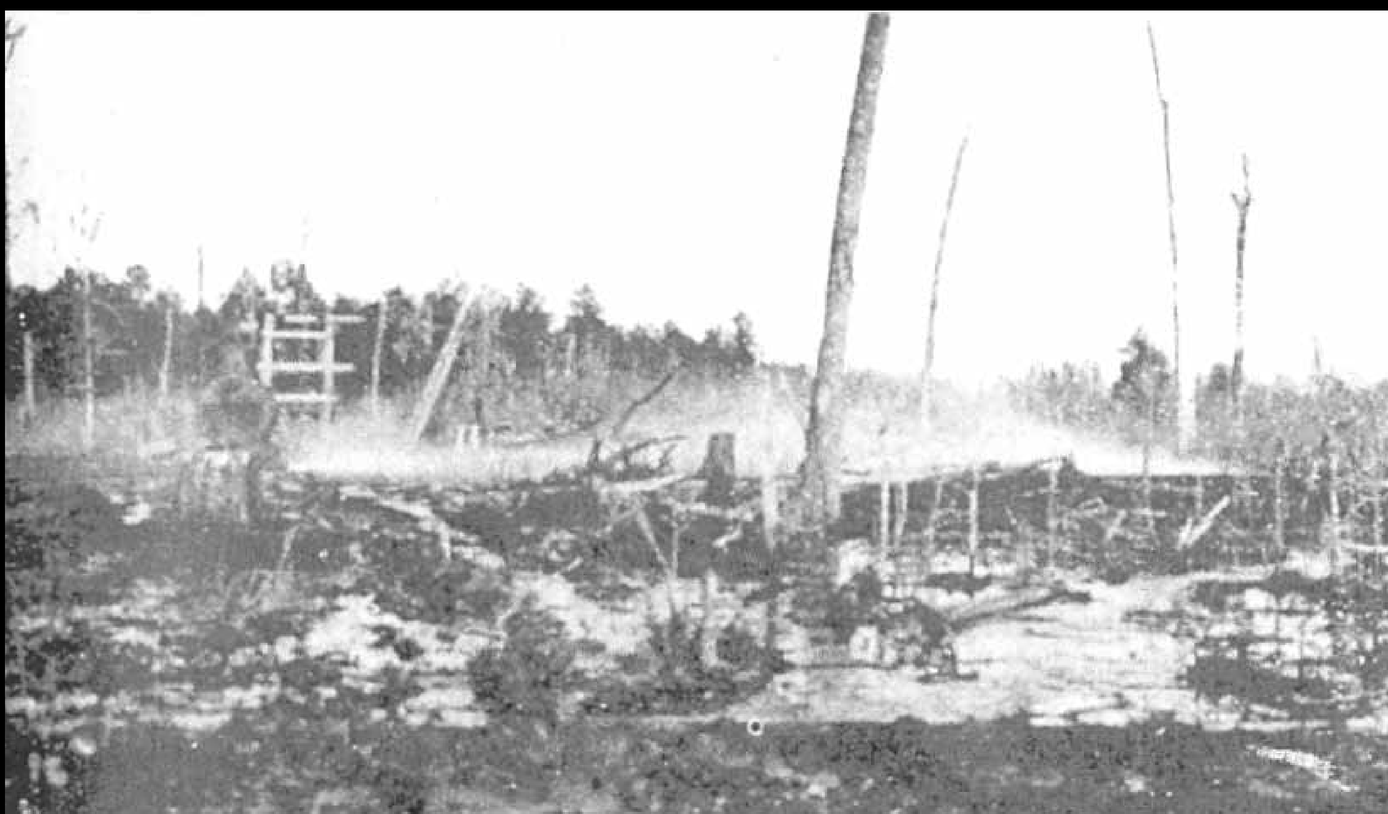

Figure 5. Blowout of natural gas and saltwater from Morehouse No. 2 on March 10, 1921 (Source: Figure 14. Bell and Cattell, 1921)

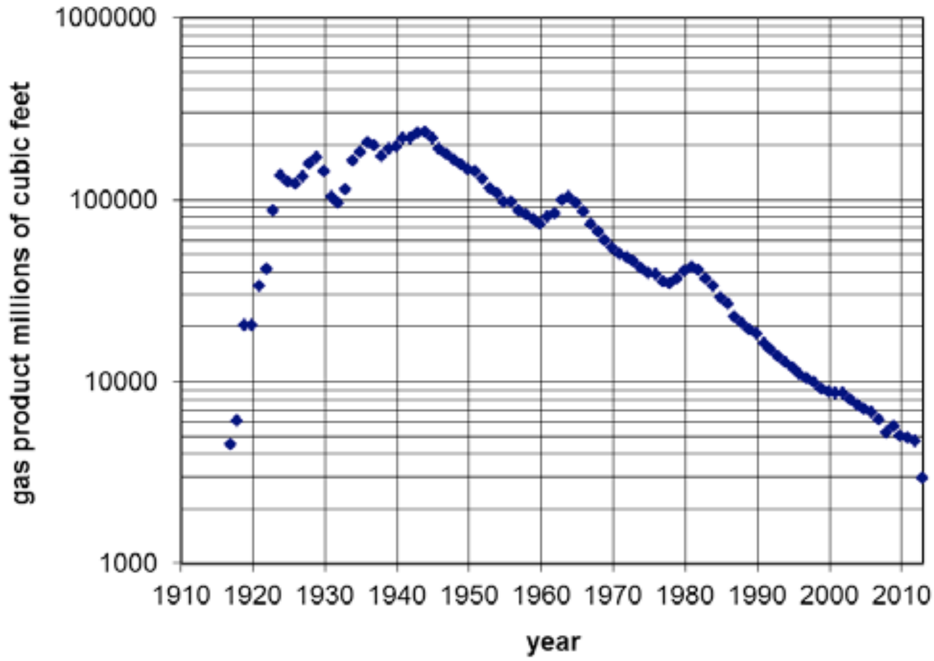

Figure 6. Monroe gas field production from 1916 to 2013, sources of production data are: Department of Conservation, 1937, 1939, 1941, 1943, 1947, 1949, 1951 and 1953; National Oil Scouts & Landman Association, 1954 to 1959; International Oil and Gas Scouts Association and Society of Petroleum Engineers of AIME, 1960 and 1961, International Oil and Gas Scouts Association, 1962; Menefee, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, and 1971; and Sutton, R.T., 1972, 1973, 1974, 1975 and 1976; . Louisiana Department of Natural Resources, 2008a; and Louisiana Department of Natural Resources, 2013b. Production for 2013 is through September only.

Years of Peak Production

As of 1929 the MGF is the largest field in the world in terms of cumulative production which was 1.056 trillion cubic feet of gas (Department of Conservation, 1929). There was a brief decline of production in the early 1930s during the Great Depression which lowered production in 1932 to approximately 100 billion ft^3/year (Figure 6). However, after a low in 1932, production increased significantly throughout the 1930s to nearly 200 billion ft^3/year in 1939. In the early 1930's some abuses still existed in terms of waste and production so the federal government threatened again to intervene, under President Franklin Roosevelt by passing of section 9c of the national industrial recovery act and then a presidential executive order affirmed the right of the federal government to regulate overproduction (Franks and Lambert, 1982). The MGF was still the third largest gas field in terms of production rate in the United States in the early 1930s (Fergus, 1935). Louisiana conservation laws were modified again in 1936 to be similar to New Mexico's which at the time were considered the most advanced (Franks and Lambert, 1982). In 1937 the MGF was responsible for Louisiana being the leading gas producing state in the nation (Department of Conservation, 1937). By 1937 the MGF cumulative production had reached 2.26 trillion cubic feet of gas, and there were 1,136 producing wells (Department of Conservation, 1937). In 1938 the MGF was determined to cover 400 sqm (256,000 acres), which at the time was the third largest field in area after the Amarillo Field in Texas and Hugoton Field in Kansas (National Oil Scouts Association of America, 1939). In 1940 the Louisiana legislature passed one of the most comprehensive oil codes ever enacted, which included production limits which were based on the prevention of waste rather than on "reasonable market demand". This code also protected correlative rights of all co-owners of property, and spacing regulations were included to eliminate unnecessary drilling and the Interstate Oil Compact Commission (IOCC) was authorized to regulate recycling and pressure maintainence programs. A year later in 1941 Louisiana became an active partner in the IOCC (Franks and Lambert, 1982). Production continued to increase to an ultimate peak production in 1944 of approximately 235 billion ft^3/year (Figure 6). By 1951 cumulative production reached 4.91 trillion cubic feet (Wang, 1951), which was approximately two thirds of the cumulative production to the present day. In 1956 after forty years of production the Monroe Gas Field was still the leading producing field in Louisiana and among the top ten fields in the United States for gas production, as well as having the fourth largest proven reserve area (308,400acres) after only Hugoton in Kansas which is 2,239,893 acres, Guymon-Hugston in Oklahoma which is 1,060,934 acres; and Blanco in Colorado-New Mexico which is 625,000 acres (National Oil Scouts and Landman's Association, 1957).

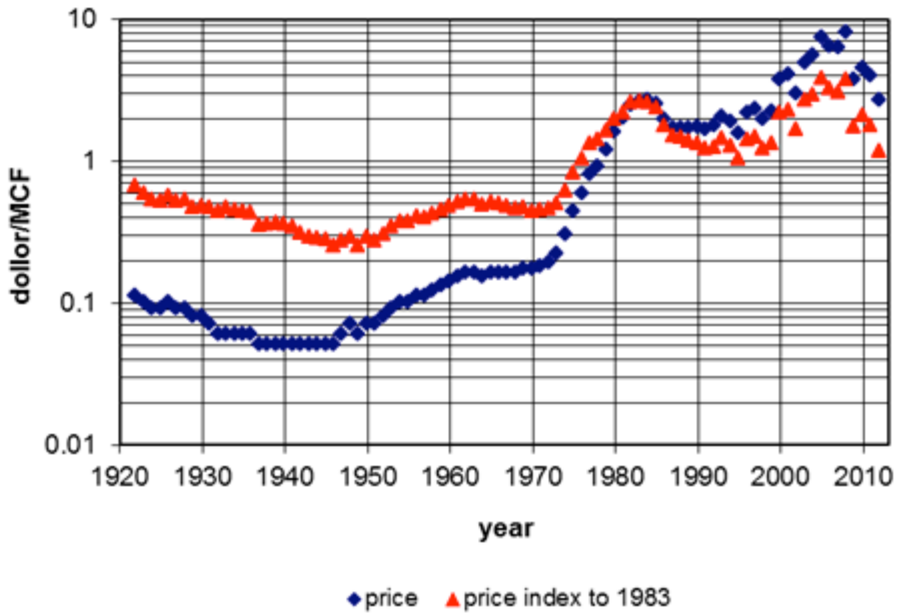

Figure 7. Well head price of natural gas (Energy Information Administration, 2010 and 2013a). MCF is one thousand cubic feet of natural gas.

The Long decline of Production

After the 1944 peak production there was a rapid decrease of production that continued till the early 1960s when production leveled off at approximately75 billion ft^3/year. This rapid production decline was halted and reversed in the early 1960s (Figure 6) as a result of the price of natural gas rising throughout the 1950s (Figure 7). By 1961 MGF proven reserve area dropped to fifth with the addition of Hugoton Texas field, 615,000 acres, above it in size which was added to the 1956 list of gas fields that are larger. Also in 1961 the yearly production of the MGF was the third largest in Louisiana and 13th largest in the nation (International Oil Scouts Association, 1962). Even as late as 1961 MGF cumulative gas production was still third after Panhandle West Field in Texas and Hugoton Field in Kansas (International Oil Scouts Association, 1962). By 1961 MGF cumulative production exceeded 6 trillion cubic feet (Meyer, 1972). After a brief production peak in 1964 gas production continued to decrease till 1978. In 1965 MGF gas production declined to sixth largest field in Louisiana and 15th largest in the nation (International Oil Scouts Association, 1967). Between 1965 and 1970 MGF yearly production decreased by approximately 43%, which caused MGF to drop significantly in field rank in production, yearly production for MGF was 15th rank for onshore fields of Louisiana (Figure 8) and 66th rank in the United States (International Oil Scouts Associations, 1972). In terms of production rank among Louisiana's onshore gas fields MGF remained at 15th rank through 1974. A surprising reversal of rank started in 1975 when MGF moved up to 14th rank among Louisiana's onshore gas fields and continued till 1981 when MGF moved up to 3rd among Louisiana's onshore gas fields (Figure 8). This was a result of this field's vast size which enabled it to move past a series of smaller (in terms of area) salt dome associated fields located in southern Louisiana's Gulf Basin region when increasing prices of gas encouraged increases in drilling activity within the MGF between 1975 and 1981 (Figures 9 and 10). This major increase in drilling activity yielded a third small peak of production that occurred in 1981 at approximately 40 billion cubic ft^3/years. This was probably driven by a major increase in the price in natural gas from approximately \$0.20/1000 ft^3 in 1972 to \$2.00/1000 ft^3 in 1980. After 1981 production continued to decreased to 2012 level of approximately 4.7 billion cubic feet (Figure 6). By 1993 cumulative gas production for the MGF has reached 7.3 trillion cubic feet (Zimmerman and Sassen, 1993). As of the fall of 2013 cumulative production for the MGF has almost reached 7.5 trillion cubic feet.

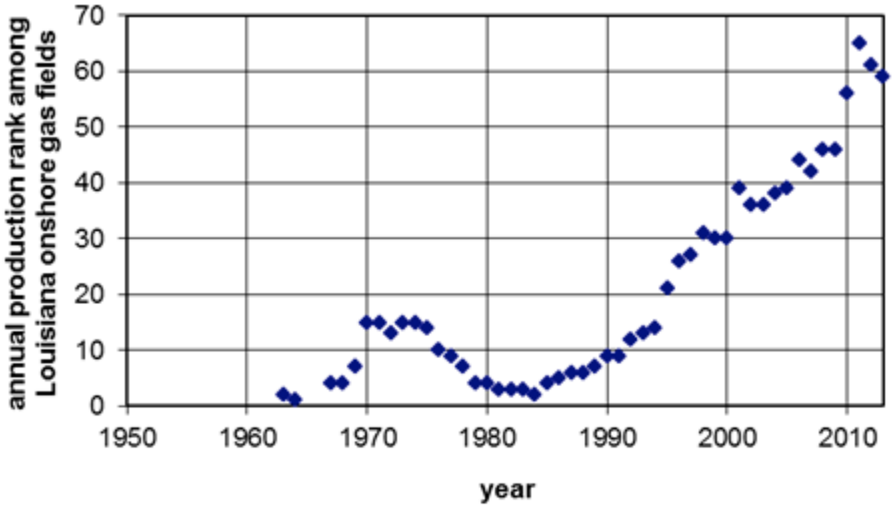

Figure 8. Monroe Gas Field's rank among Louisiana onshore gas fields in terms of annual production.

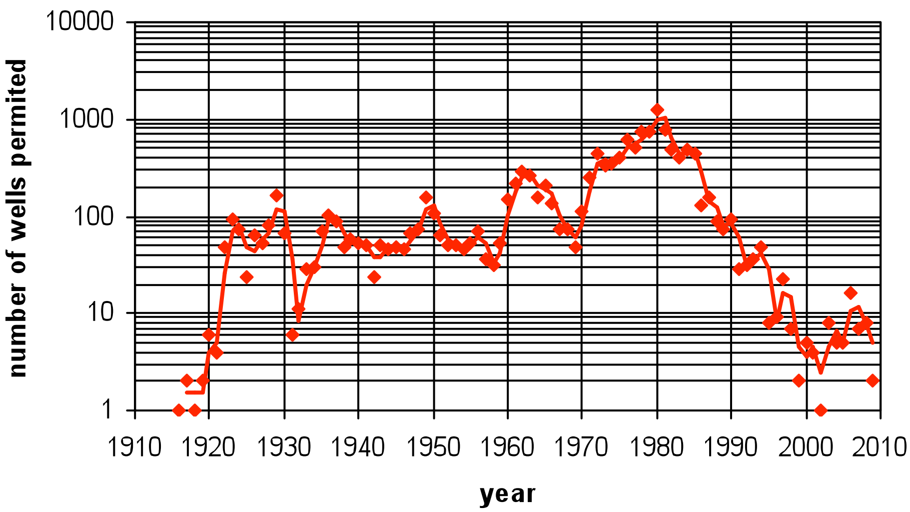

Figure 9. Number of wells permit and then later drilled within the Monroe Gas Field (Source: Louisiana Department of Natural Resources, 2010 and 2013a).

In spite of the major increase in production from 1919 to 1944 and then a decline of production from 1945 to 1972, drilling activity has remained fairly constant as indicated by number of wells permitted and ultimately drilled which has been between 50 and 100 each year (Figure 9). This is probably a result of a fairly constant real price for natural gas between 1922 and 1972 as indicated by the 1983 index price of gas (Figure 7). However, after 1972 drilling activity increased significantly to over 1000 wells permitted per year which were ultimately drilled in 1980 (Figure 9). This is probably a result of the real value of gas increasing by approximately 1000% between 1972 and 1982 (Figure 9).

However, after 10 years of the rapid increase in the number of wells producing gas from approximately 3800 in 1970 to approximately 8500 in 1985 it is clear drilling activity decreased significantly as indicated by only a modest increase in the number of producing wells (Figure 10). In fact between 1985 and 2007 the number of wells producing gas in the MGF has remained roughly constant after 70 years of increases (Figure 10), rapid (1970 to 1985) or slower (1916 to 1969).

Monroe Gas Fields Share of Louisiana & United States Gas Production

In terms of the Monroe Gas Field's share of Louisiana gas production it was over 50% from 1921 to 1941 except for 1931 and 1932 (Figure 11). After the opening of large gas fields in southern Louisiana the MGF's share of all Louisiana production declined rapidly from approximately 56% in 1940 to approximately 9% in 1953. Between 1953 and 1968 MGF share of Louisiana gas production continued to fall from 9% to 1% (Figure 11). The rapid price increase and associated increase in drilling activity within the MGF caused the share of gas production to increase from 1% to 2% between 1970 and 1983 (Figure 11). After 1983 the MGF's share of Louisiana gas production resumed declining from 2% in 1983 to 0.4% in 2009 (Figure 11). Then the opening of the Haynesville gas play south-southeast of Shreveport in 2009 caused a sharp decline in the share of Louisiana gas production from approximately 0.4% in 2010 to 0.2% in 2013 (Figure 11).

The Monroe Gas Field's share of US gas production follows a similar pattern to its share of Louisiana production (Figures 11 and 12). The peak for the share of US production was in 1924 at almost 12% of US production. Between 1924 and 1941 the MGF's share of U.S. gas production was fairly steady, between 8% and 12% (Figure 12). After 1941 the share of US production went through a rapid decline from nearly 8% in 1941 to under 2% by 1951. By 1957 production was under 1% share of US production and it remained till the present (Figure 12). After 1990 MGF share of US gas production was under 0.1% (Figure 12). By 2013 MGF share of U.S. production was down to 0.02%. The introduction of the Haynesville field gas production in 2009 which nearly doubled LA onshore gas production (Energy Information Administration, 2013b; and Louisiana Department of Natural Resources, 2013b) caused a major change in MGF share of Louisiana production. However, the introduction of Haynesville field gas production was less significant for overall US natural gas production. There are three reasons for this relatively smaller impact on fraction of U.S. natural gas production. First, Louisiana's share of U.S. natural gas production has been fairly consistent and at approximately 15%. Second, while the Haynesville production started in 2009, other major gas field production started within a few years of this: Barnett 2001, Fayetteville and Woodford 2007, Bakken, 2009, and Marcellus and Eagle Ford, 2010 (Energy Information Administration, 2013b). Three other U.S. fields have similar if not larger production over the last decade: Barnett January of 2002 to August of 2009 and Marcellus after July of 2012. However, even the interval between September of 2009 and June of 2012 when the Haynesville gas field had the largest natural gas production others Barnett, Fayetteville and Marcellus had rates of production similar to the Haynesville (Energy Information Administration, 2013b). The lead will probably remain for Marcellus for years because its technically recoverable gas resources are approximately 5.5 times that of the second largest field in the U.S., the Haynesville (Energy Information Administration, 2011) .

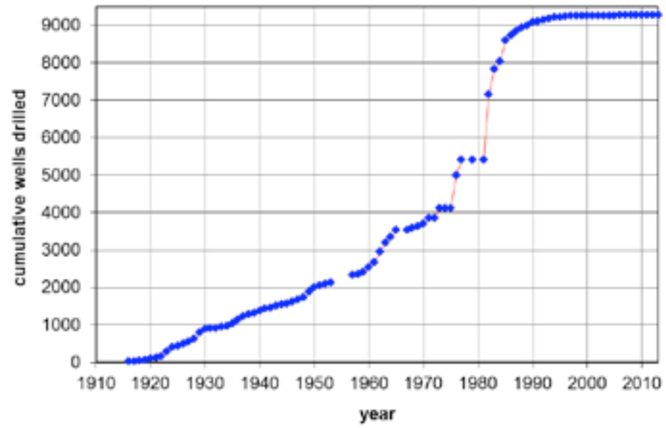

Figure 10. Number of gas producing wells within the Monroe Gas Field (Sources: National Oil Scouts Association of American 1938 to 1939; National Oil Scouts Association and Landmen's Association, 1940 to 1959; Wang, 1952; International Oil and Gas Scouts Association and Society of Petroleum Engineers of AIME, 1960 and 1961, International Oil and Gas Scouts Association, 1962 to 1990; and Louisiana Department of Natural Resources, 2008a and 2013a).

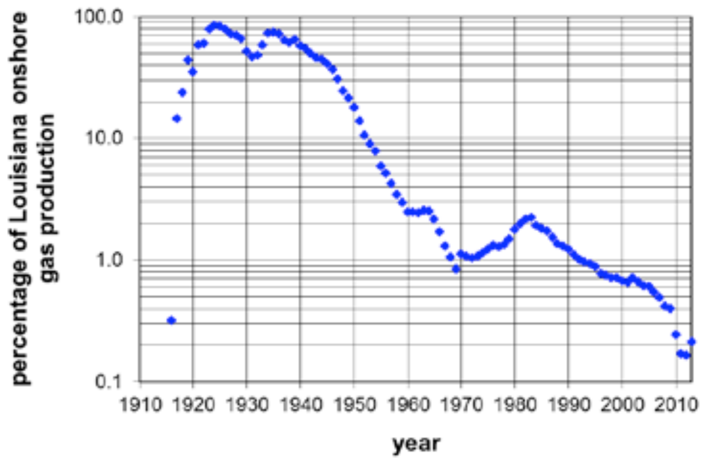

Figure 11. Monroe gas fields share of Louisiana gas production sources of Louisiana gas production data: Anonymous, 1959; DeGolyer and MacNaughton, 1979; and Louisiana Department of Natural Resources 1990, 2008b and 2013b.

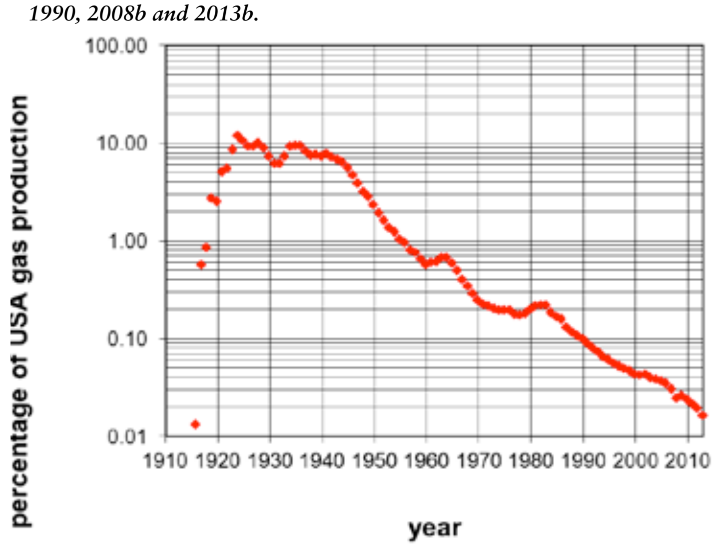

Figure 12. Monroe gas fields share of United States gas production sources of United States gas production data: Anonymous, 1959; DeGolyer and MacNaughton, 1979; and Energy Information Administration, 2008, 2010 and 2013.

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Earth Science Week

Earth Science Week 2013 was celebrated from October 13-19, 2013. This years focus was “Mapping Our World”. At the request of the Louisiana Geological Survey, Governor of Louisiana Bobby Jindal issued a proclamation declaring October 13-19, 2013 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).

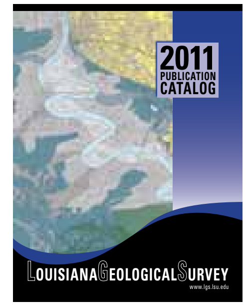

United States of America
State of Louisiana
Governor
Bobby Jindal
Proclamation
EARTH SCIENCE WEEK

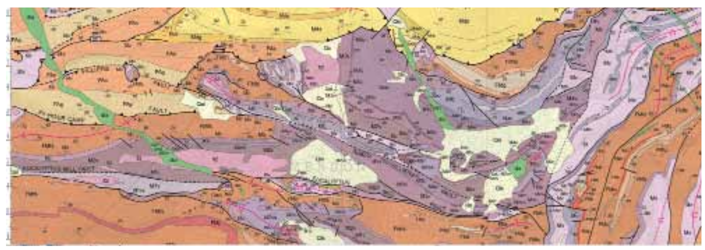
Rock’n In The Swamp

LGS participated in the event titled “Rock’n in the Swamp” organized by the Baton Rouge Parks and Recreation and is a one day educational outreach for schools. The LGS exhibit booth displayed rocks and minerals found in Louisiana and other places and thin sections. Fossil specimens were also displayed. The LGS booth proved to be one of the star attractions for the hundreds of school students and other adults attending the event.

La. Geological Survey’s Publication Catalog Available Online

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. Most maps, atlases, and geological reports are available for order.





LGS Cartographers honored with another map design award

The *Geologic Map of the West-Central Barberton Greenstone Belt, South Africa* was the winner of the **Best Special Purpose Map** category of the 2013 Avenza Map Awards. The map, designed and produced in the LGS Cartographic Section by John Snead, Robert Paulsell, and Hampton Peele, was published in 2012 by the Geological Society of America.

It was the culmination of more than 30 years of research and field investigations by Don Lowe (Max Steineke Professor of Geology at Stanford University), Gary Byler (Fenton Alumni Professor of Geology and Dean of the LSU Graduate School), and Christoph Heubeck (Professor of Geology at Freie Universität Berlin) with funding from the National Science Foundation.

The 2013 Avenza Map Awards recognizes professional and student mapmakers from around the world who use Avenza map design products in the creation of their maps. The various category awards recognize achievement in the art and science of cartography and promote the advancements and innovation made in mapping. It is featured on the Avenza Map Awards Gallery at www. Avenza.com.

Earlier this year, the Barberton map was also recognized by the Cartography and Geographic Information Society’s 40th Annual Map Design Competition as **Best Reference Map of 2012**. The map has now been honored with the most respected map design awards from the mapping professional society and the mapping industry. This is the 8th map design award won by LGS cartographers since 2000.

www.lgs.lsu.edu

LGS Resource Center

The LGS Resource Center consists of a core repository and log library. It is located behind the old Graphic Services building on River Road. Most of our cores are from the Smackover and Wilcox Formations. The core facility has more than 30,000 feet of core from wells mostly in Louisiana. The well log library contains over 50,000 well logs from various parishes in the state. The Core Lab is equipped with climate controlled layout area, microscopes, and a small trim saw. The core and log collections are included as part of the LSU Museum of Natural History as defined by the Louisiana Legislature and is the only one of its kind in Louisiana.The LGS Resource Center is available for use by industry, academia and government agencies, and others who may be interested. Viewing and sampling of cores can be arranged by calling Patrick O'Neill at 225-578-8590 or by email at poneil2@lsu.edu. Please arrange visits two weeks in advance. A list of available cores can be found at the LGS web site (www.lgs.lsu.edu).

Geologists from Formosa Petrochemical Corporation in Taipei, Taiwan, and its subsidiary Neumin Production Company visited the LGS Core Repository for a week in mid-September to do research on Louisiana well cores. From left to right are Karena Chang, Poki Sung, and Yen I-Chin.

Staff Recognition

Brian Harder, Research Associate 5, completed 25 years of service at LGS and was presented with an LSU service award.

John Johnston III, Assistant Director of LGS for over 30 years, retired from full time service at the end of January 2013 and has returned to work part-time on the "Geologic Review" project.

Warren Schulingkamp, Research Associate, retired at the end of September 2013 after six and one half years of service to LGS/LSU.

Louisiana Geological Survey Personnel

Administrative Personnel

Chacko J. John, Ph.D., director and state geologist, professor-research

Patrick O'Neill, research associate, LGS Publications Sales and Resource Center

Basin Research Energy Section

John Johnston, research associate (retired - part time)

Brian Harder, research associate

Reed Bourgeois, computer analyst

Geological Mapping & Minerals Mapping Section

Richard McCulloh, research associate

Paul Heinrich, research associate

Water & Environmental Section

Marty Horn, assistant professor-research

Douglas Carlson, assistant professor-research

Riley Milner, research associate

Cartographic Section

John Snead, cartographic manager (retired - part time)

Lisa Pond, research associate

Robert Paulsell, research associate

R. Hampton Peele, research associate

Staff

Melissa Esnault, administrative coordinator

Jeanne Johnson, accounting technician

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