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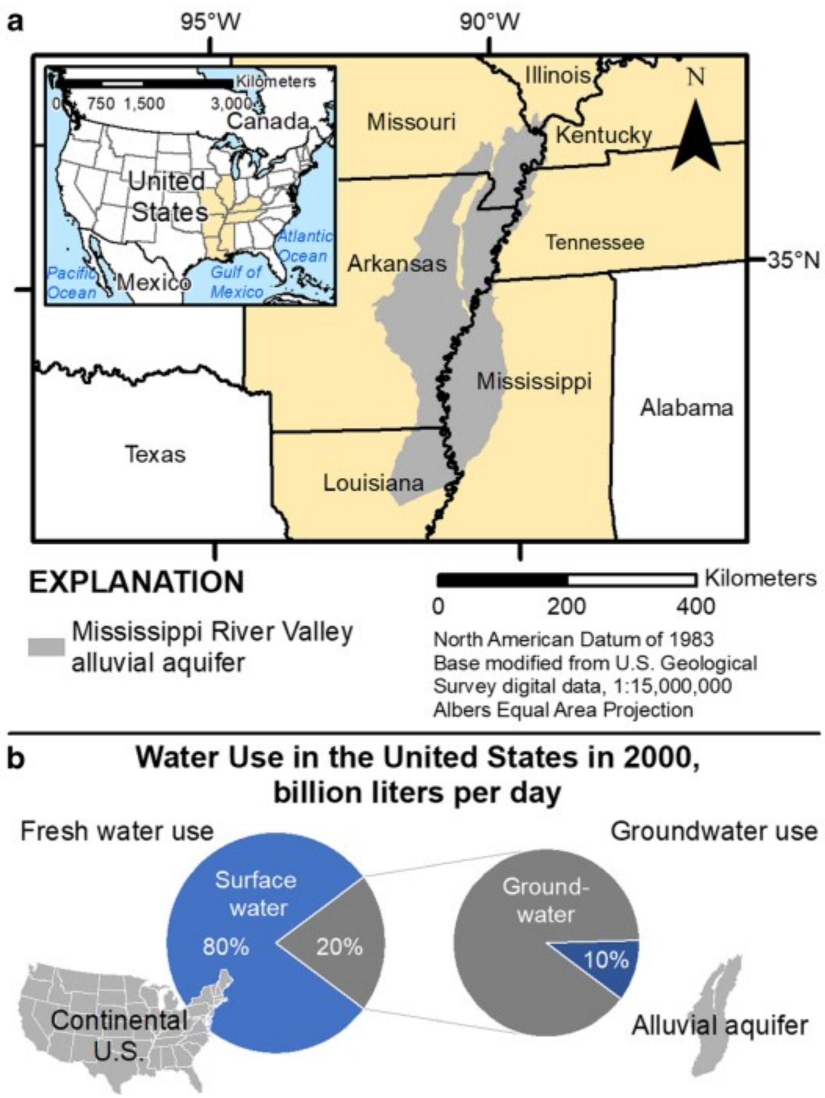
South Texas Geological Society

Volume LXIV

Issue Number Eight



INSIDE THIS ISSUE

Characterizing groundwater and surface-water interaction using hydrograph-separation techniques and groundwater-level data throughout the Mississippi Delta, USA

By: *Courtney D. Killian & William H. Asquith & Jeannie R. B. Barlow & Gardner C. Bent & Wade H. Kress & Paul M. Barlow & Darrel W. Schmitz*

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Volume XLIV Issue No. 8

April 2024

On The Cover

Figure 1 of Killian et al.'s paper on the Mississippi River Valley alluvial aquifer extent which formed the study area

STGS Meeting Notice

Date: April 10th, 2024

Time: Wednesday, 11:30 am

Speaker and Topic: Dr. Wahid Rahman, Organic Facies and Reservoir Characterization of Eagle Ford Shale as Determined by Stratigraphy, Source Rocks, and Oil Geochemistry

Location: Petroleum Club 8620 N New Braunfels Ave #700 San Antonio, TX 78217

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Characterizing groundwater and surface-water interaction using hydrograph-separation techniques and groundwater-level data throughout the Mississippi Delta, USA

President's Message

DEAR STGS MEMBERS,

Spring kicks off the busiest month for STGS this year – we have all sorts of events for you this month, so hang on tight and get ready for a month full of networking and social opportunities.

The Crawfish Boil is Tuesday, April 9 at the Koehler Pavilion in Brackenridge Park, sure to be a fun time full of family, friends, and food! GeoGulf commences the following day, with lots of field trips and short courses in store. We still have our luncheon for April as well, so if you're attending the GeoGulf conference with friends, we would love to have them join us at the luncheon. And don't forget to pull out your eclipse glasses when you watch the eclipse this month!

Our April luncheon will be the last luncheon for the 2023-2024 year, with our annual May dinner closing off this round of meetings. We'd love for you to attend, and I look forward to seeing you all at the next event!

Sincerely,

Alyssa Blaise Balzen, P.G.

STGS President, 2023-2024

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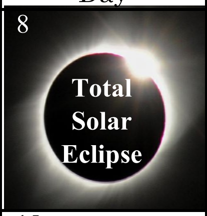
APRIL 2024

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1 EASTER MONDAY April Fool's Day	2	3	4	5	6
7 Geologist's Day	8 	9 **STGS Crawfish Boil 4-8PM** GEO	10 **STGS Luncheon @11:30am** GULF	11 2024	12	13
14	15 Tax Day	16	17	18	19 National Cat Lady Day	20
21 San Jacinto Day	22 	23	24	25	26	27
28	29	30				

STGS AFFILIATES' EVENTS:

SEG SOCIETY OF EXPLORATION GEOPHYSICISTS

- April 9-12—Basic Seismic Interpretation. Virtual. $780.
- April 9-10—Storage of CO_2 in Saline Aquifers. Virtual. $560.

Let's Rock! GEOGULF2024 SAN ANTONIO 10–12 APRIL 2024

Tuesday, April 9, Norris Conference Center

8:00 am–4:00 pm	Short Course 2: TIBCO Spotfire for O&G Professionals (Beginner) with Bryan McDowell (Managing Partner, Sabata Energy Consultants) (Day 1 of 2) Room: MAGNOLIA
12:00 pm–1:00 pm	Short Course Lunch

Wednesday, April 10, Norris Conference Center

7:00 am–6:00 pm	Registration and Check-In in the Norris Center Foyer
7:00 am–6:00 pm	Speaker/Judges Room Open, Break Out Room 1
8:00 am–4:00 pm	Field Trip 3: Building San Antonio: Natural Setting, Water, and Building Resources in the Historic 'Walley of the Missions' Van departs from Norris Conference Center
8:00 am–4:00 pm	Short Course 2 (Day 2 of 2) Room: MAGNOLIA
8:00 am–4:00 pm	Short Course 3 Introduction of Gulf Coast Geothermal Energy with Joseph Batir (Geothermal Lead at Teverra LLC) (Day 1 of 1) Room: Elm
10:00 am–4:00 pm	Exhibitor Setup in Red Oak B Room
12:00 pm–1:00 pm	Short Course Lunches
10:00 pm–2:00 pm	GCAGS Board Meeting (By Invitation Only), Red Oak A Room
2:00 pm–5:00 pm	Poster Session Setup, Red Oak B Room
3:00 pm–5:00 pm	Opening Ceremony and Awards, Red Oak A Room
5:00 pm–8:00 pm	Icebreaker Reception, Exhibits Hall, Red Oak B Room
5:00 pm–8:00 pm	Poster Session, Red Oak B Room

Thursday, April 11, Norris Conference Center

7:00 am–5:00 pm	Registration and Check-In in the Norris Center Foyer Area
7:00 am–8:00 am	Speakers/Poster Presenters/Session Chairs/Committee Volunteers Breakfast, Ballroom A
7:00 am–5:00 pm	Speaker/Judges Room Open, Break Out Room 1
8:00 am–11:30 am	Wildcattin' Ain't Dead Yet: The Next Wave of Prospecting on the Gulf Coast, USA, Magnolia Room
8:00 am–11:30 am	Structure and Geomechanics of the Gulf Coast, Pecan Room
8:00 am–11:30 am	Critical Metals (and Lithium) Exploration Value Chain, Elm Room
8:00 am–5:00 pm	Poster Session, Red Oak B Room
8:00 am–5:00 pm	Exhibits, Red Oak Room B
9:40 am–10:15 am	Conference Break—Visit Exhibit Hall and Poster Session in Red Oak B Room
12:00 pm–1:15 pm	All-Convention Luncheon, Room Red Oak Ballroom A
1:00 pm–2:15 pm	Wildcattin' Ain't Dead Yet: The Next Wave of Prospecting on the Gulf Coast, USA, Magnolia Room
1:00 pm–2:40 pm	Environmental and Geotechnical Technologies and Advancements, Elm Room
1:00 pm–4:55 pm	Geology and Exploration Opportunities of the East Texas Basin, Pecan Room
2:00 pm–2:40pm	PBE Podcast Ballroom A
2:40 pm–3:15 pm	Conference Break—Visit Exhibit Hall in Red Oak B Room, Visit Poster Session in Pecan Room
3:15 pm–4:55 pm	Geology of the Gulf Coast (Part 1), Magnolia Room
3:15 pm–4:55 pm	Emerging Geothermal Energy Resources and Technologies, Elm Room
3:15 pm–4:55 pm	PBE Podcast Ballroom A
6:00 pm–9:00 pm	ROCK and Bowl w/Karaoke, @Pinstack Evening EVENT

Continued on next page…..

Let's Rock! GEOGULF2024 SAN ANTONIO 10–12 APRIL 2024

Friday, April 12, Norris Conference Center

7:00 am–12:00 pm	Registration and Check-In in the Norris Center Foyer
7:00 am–8:00 am	Speakers/Poster Presenters/Session Chairs/Committee Volunteers Breakfast, Ballroom A
7:00 am–5:00 pm	Speaker/Judges Room Open, Break Out Room 1
8:00 am–11:30 am	Eagle Ford and the Austin Chalk: Gifts that Keep on Giving!, Magnolia Room
8:00 am–9:40 am	Geologic Carbon Storage on the Gulf Coast (Bureau of Economic Geology—Gulf Coast Carbon Center), Elm Room
9:40 am–10:15 am	Conference Break—Visit Exhibit Hall and Poster Session in Red Oak B Room
8:00 am–3:15 pm	Exhibits, Red Oak B Room
8:00 am–1:30 pm	Poster Session, Red Oak B Room
10:15 am–11:30 am	ML and AI to Accelerate Gulf Coast Development, Elm Room
10:15 am–11:30 am	Geology of the Gulf Coast (Part 2), Pecan Room
12:00 pm–1:15 pm	FLAG GCSSEPM Luncheon FLAG RED Oak Ballroom A Room
1:00 pm–4:30 pm	New Things to Old Fields in Deepwater Stratigraphic Intervals, Magnolia Room
1:00 pm–4:30 pm	Geology of the Gulf Coast (Part 3), Pecan Room
1:00 pm–4:30 pm	Funding Oil and Gas Ventures: Using your Geo-Logic to Climb the Charts, Elm Room
2:00 pm–2:40pm	PBE Podcast Ballroom A
2:40 pm–3:15 pm	Conference Break
3:10 pm-3:15 pm	Booth Contest Winner Announcement
3:15 pm–4:55 pm	PBE Podcast Ballroom
5:00 pm	End of GeoGulf Conference

Saturday April 13, Norris Conference Center

8:00 am-	Field Trip 1: Laramide Structural Geology near Del Rio, Texas. Vans leave from Norris Center Parking Lot, (2 Days)
8:00 am- 6:00 pm	Field Trip 2: Whiskey from the Rocks: Exploring the Trinity-Edwards Aquifer Systems of Central Texas and How Geology contributed to the History of Whiskey. Vans leave from Norris Parking Lot

Sunday April 14, Norris Conference Center

-7:00 pm	Field Trip 1: Laramide Structural Geology near Del Rio, Texas. Returns to Norris Center Parking Lot (2 Days)

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Please encourage your graduate students to submit their research! Having a student's first paper be published in a state Bulletin is a huge triumph and should be celebrated. Our large audience will help introduce students' names to the scientific community, and is an excellent way to network with potential employers. Please, help us continue our work of sharing new geologic research by encouraging your publishing colleagues to submit their article to the South Texas Geological Society. Thank you.

From the editor,

-Shelby Sckittone

shelbysckittone@yahoo.com

Featured Article

Characterizing groundwater and surface-water interaction using hydrograph-separation techniques and groundwater-level data throughout the Mississippi Delta, USA

Courtney D. Killian[1,2] & William H. Asquith[3] & Jeannie R. B. Barlow[1] & Gardner C. Bent[4] & Wade H. Kress[5] & Paul M. Barlow[6] & Darrel W. Schmitz[2]

Abstract

The Mississippi Delta, a portion of the Mississippi Alluvial Plain (MAP) located in northwest Mississippi (USA), is an area dense with industrial-level agriculture sustained by groundwater-dependent irrigation supplied by the Mississippi River Valley alluvial aquifer. Observed declines in groundwater-level elevations and streamflow, contemporaneous with increases in irrigation, have raised concerns about future groundwater availability and the effects of groundwater withdrawals on streamflow. To quantify the impacts of groundwater withdrawals on streamflow and increase understanding of groundwater and surface-water interaction in the MAP, hydrograph-separation techniques were used to estimate baseflow and identify statistical streamflow trends. The analysis was conducted using the US Geological Survey Groundwater Toolbox open-source software and daily hydrologic data provided by a spatially distributed network of paired groundwater wells and streamgage sites. This study found that statistically significant reductions in stream baseflow occurred in areas with substantial groundwater-level declines. The use of hydrograph-separation and trend analyses to quantify the impacts of groundwater withdrawals and the use of streamflow as a proxy for changes in groundwater availability may be applicable in other altered environments. Characterizing and defining hydrologic relations between groundwater and surface water will help scientists and water-resource managers refine a regional groundwater-flow model that includes the Mississippi Delta, which will be used to aid water-resource managers in future decisions concerning the alluvial aquifer.

Mail: Courtney D. Killian ckillian@usgs.gov

[1] US Geological Survey Lower Mississippi-Gulf Water Science Center, 308 Airport Rd. S, Jackson, MS 39208, USA

[2] Department of Geoscience, Mississippi State University, 108 Hilbun Hall, Mississippi State, MS 39762, USA

[3] US Geological Survey Texas Water Science Center, Science Building MS-1053, Texas Tech University, Lubbock, TX 79409, USA

[4] US Geological Survey New England Water Science Center, Northborough, MA 01532, USA

[5] US Geological Survey Lower Mississippi-Gulf Water Science Center, 640 Grassmere Park #1000, Nashville, TN 37211, USA

[6] US Geological Survey Earth Systems Modeling Branch, Northborough, MA 01532, USA

Introduction

Sustainable agriculture in the United States depends on appropriate management of groundwater resources. Water use in the United States in 2000 (the most recent year for which comprehensive groundwater withdrawal data have been published) was estimated at 1,544.4 billion liters per day (BL/ day) [408 billion gallons per day (Bgal/day)] and freshgroundwater withdrawals comprising about 315.3 BL/ day (83.3 Bgal/day), or approximately 20% of daily water use (Hutson et al. 2004). The majority of groundwater withdrawals were for thermoelectric power supply and irrigation (Hutson et al. 2004; Maupin and Barber 2005). An estimated 34.1 BL/day of groundwater was withdrawn from the Mississippi River Valley alluvial aquifer (alluvial aquifer) alone in the year 2000 (Clark et al. 2011). The alluvial aquifer, located in the south-central United States, is the upper most aquifer underlying the Mississippi Alluvial Plain (MAP) and is the third largest provider of groundwater in the United States (Maupin and Barber 2005). The aquifer is approximately 76,400 km^2 (km^2) [29,500 $mile^2$ (mi^2)] and underlies portions of seven states—Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee; Fig. 1a— (Cushing et al. 1964; Hutson et al. 2004; Clark et al. 2011). Groundwater withdrawals from the alluvial aquifer in 2000 accounted for 10% of all estimated groundwater withdrawals (Fig. 1b) and 2% of all estimated water use in the continental United States (Fig. 1b; Hutson et al. 2004). According to local groundwater modeling studies (Telis 1991; Barlow and Clark 2011; Clark et al. 2011), the current rate of freshwater withdrawals is unsustainable.

The demand for groundwater resources from the alluvial aquifer for agricultural irrigation has resulted in substantial observed declines in groundwater-level elevation over time (Barlow and Clark 2011). Groundwater withdrawals have been cited as a driving factor of streamflow depletion, which has raised concerns for the future of available groundwater resources with local, state, and regional stakeholders (Theis 1940; Barlow and Clark 2011; Barlow and Leake 2012). The quantification of observed environmental changes in groundwater-level elevation and streamflow may be done using many available methods and software tools. Numerical groundwater models simulate groundwater flow and aquifer response to stresses such as groundwater withdrawals and can be useful to increase understanding of complex hydrologic systems (Clark and Hart 2009; Sahoo and Jha 2017). Numerical simulation is an oversimplification of real-world processes and many models fail to accurately represent the interaction of surface water and groundwater.

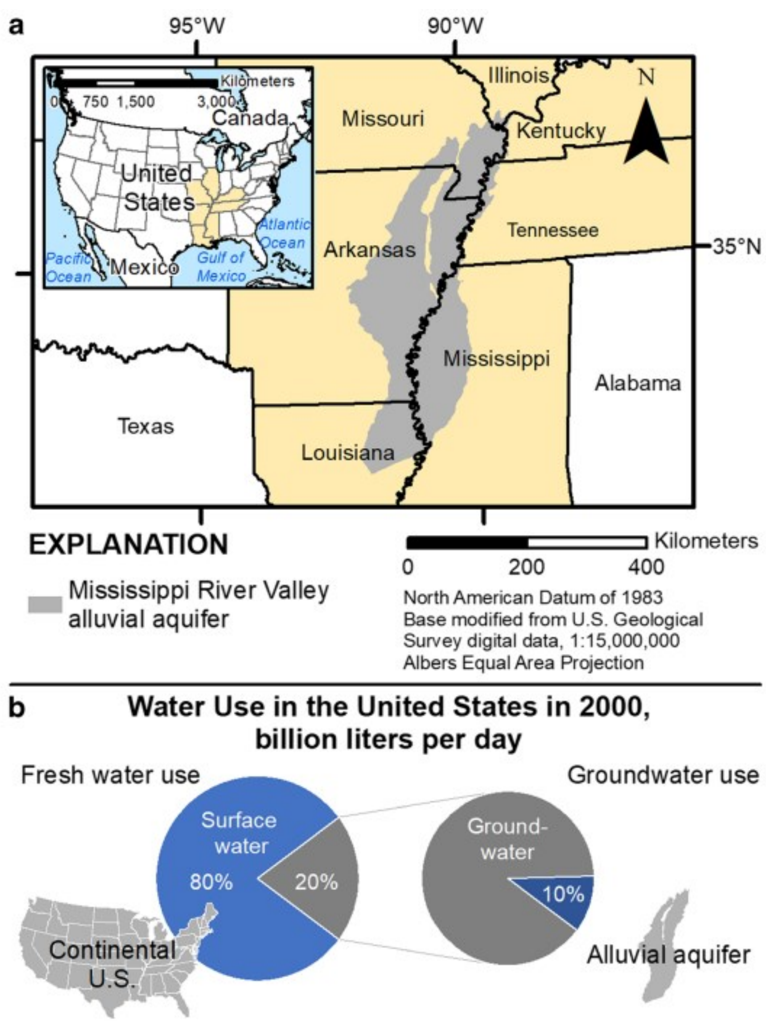


Fig. 1 **a** The Mississippi River Valley alluvial aquifer extent defined in the Mississippi Embayment Regional Aquifer Study (MERAS) model (Clark and Hart 2009; Clark et al. 2011). **b** Water use in 2000 for the continental United States and groundwater withdrawals for the alluvial aquifer

Numerical groundwater modeling may also be expensive in terms of time, money, and computational power. Although there are many examples in the literature of the use of numerical groundwater models to determine the impact of groundwater withdrawals on streamflow, there are comparatively fewer studies that have used statistical evaluations of streamflow and baseflow records to identify groundwater-withdrawal effects; the reader is referred to Wahl and Tortorelli (1997), Burt et al. (2002), McCallum et al. (2013), Abo and Merkel (2015), Juracek (2015), Miller et al. (2015), Juracek and Eng (2017) for examples of the latter. The current understanding of groundwater and surface-water interactions and associated water-resource management issues are documented (Winter 1995; Winter et al. 1998; Sophocleous 2002; Verry 2003; Brodie et al. 2007; Anibas et al. 2011; Barlow and Leake 2012; Barthel and Banzhaf 2015; Yang et al. 2017); however, the complexities of the interactions are not well understood, especially in systems with observed groundwater-level declines.

The purpose of this study was to quantify spatial and temporal trends in streamflow and baseflow at five sites in the Mississippi Delta using four hydrograph-separation methods to determine if observed streamflow and baseflow trends were statistically significant. A spatial correlation of changes in baseflow were compared to measured and modeled groundwater-level elevations as a possible indicator of groundwater-surface water interactions. Such an approach would provide a basic understanding of the impacts of groundwater withdrawals without or prior to the use of expensive numeric groundwater models. Results from the hydrograph-separation and trends analyses were compared to measured and modeled spatial and temporal groundwater-level elevations to identify if statistically significant temporal changes in baseflow occurred in areas with substantial declines in groundwater-level elevation. Quantification of observed declines in streamflow was conducted with the combined use of quantitative hydrograph separation and statistical trend analyses. This study aims to provide a computationally simple means for quantifying temporal changes in streamflow using existing streamflow data to detect potential changes in groundwater-level elevations that will help to improve the understanding of groundwater and surface-water interaction in alluvial settings, a topic of substantial interest by scientists (Theis 1940, 1941; Spalding and Khaleel 1991; Ackerman 1996; Renken 1998; Alley et al. 1999; Burt et al. 2002; Sophocleous 2002; Barlow and Leake 2012; Essaid and Caldwell 2017). Results of this study are anticipated to aid in the development of a decision support tool to help water-resource managers make informed decisions regarding water use.

Study area

This study focused on the Mississippi Delta (Fig. 1a), an area of dense agricultural activity in northwest Mississippi, with known water-level declines in the alluvial aquifer (Boswell et al. 1968; Pennington and Stiles 1994; Ackerman 1996; Renken 1998). The Mississippi Delta covers approximately 18,100 km^2 (7,000 mi^2) of northwest Mississippi and is an area with substantial industrial -scale agriculture that necessitates large volumes of fresh water for irrigation (Arthur 2001). About 98% of the fresh water used for irrigation is supplied by groundwater withdrawn from the alluvial aquifer (Arthur 2001; Barlow and Clark 2011). Groundwater withdrawals from the alluvial aquifer have been rising since the 1930s with a noticeable increase in the 1980s when a majority of agricultural producers switched from surface water to groundwater for irrigation following a drought (Fig. 2; Arthur 2001; Barlow and Clark 2011; Peterson et al. 2015). The alluvial aquifer is composed of Quaternary-age sands and gravel deposited after the Wisconsin glaciation, making it an ideal aquifer with well yields ranging from approximately 1,100– 9,500 L/min (300–2,500 gal/min; Renken 1998; Arthur 2001; Yazoo Mississippi Delta Joint Water Management District, YMD) 2008).

Climate and precipitation are anticipated to have limited effects on groundwater-level elevations and

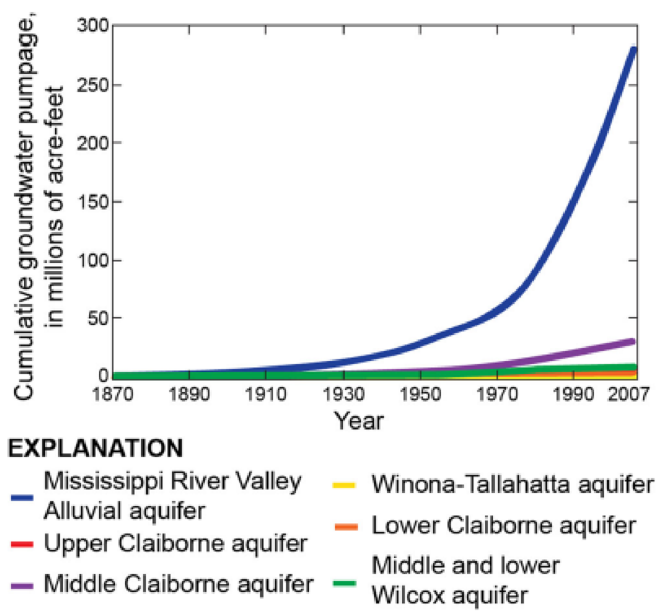


Fig. 2 Groundwater withdrawals from aquifers included in the Mississippi Embayment Regional Aquifer Study model; 1 acre-foot = 1,233.5 m^3; modified from Clark et al. 2011

streamflow in the Mississippi Delta. Groundwater-level elevation and streamflow declines are occurring despite an average increase in precipitation. From 1901 to 2017, the mean annual precipitation for the northern part of the Mississippi Delta was 132 cm [52 in. (in)] with an average increase of about 0.1 cm (0.03 in) per decade (National Oceanic and Atmospheric Administration, NOAA) 2018). The mean annual precipitation for the same time period for the southern part of the Mississippi Delta was 135 cm (53.0 in) with an average increase similar to that of the entire Delta (NOAA 2018). Much of the precipitation received in the MAP is lost to evapotranspiration (about 65%) and runoff (about 29%), leaving about 6% for recharge (Clark and Hart 2009; Kress et al. 2018). Areal recharge rates for the alluvial aquifer have been modeled in several studies (Ackerman 1996; Arthur 2001; Clark and Hart 2009), but few have attempted to calculate actual recharge rates until recently (Reitz et al. 2017; Kress et al. 2018). Most of the recharge to the Mississippi Delta portion of the alluvial aquifer is assumed to be lateral from the Mississippi River to the west and the Bluff Hills to the east (Arthur 2001). The population for the Mississippi Delta decreased by 1% from 1960 to 2017 (Forstall 1995; US Bureau of the Census 2017). While the local population has declined, the global population is rising, and the Mississippi Delta supplies commodities used around the world. Between 1998 and 2007, approximately 1,412 km^2 (349,100 acres) were added to the permitted area for water use in the Mississippi Delta (YMD 2008).

Materials and methods

Quantitative hydrograph separation

Hydrograph separation is a quantitative method to estimate baseflow contributions to streamflow by separating a timeseries of streamflow data into baseflow and surface runoff, the principal components of streamflow. The surface-runoff component of streamflow is assumed to consist of direct precipitation on a stream network, overland flow to the stream channels, and interflow through shallow subsurface deposits that lie above the water table. Surface runoff occurs in greatest proportion during and immediately following precipitation events but can persist through much of a streamflow hydrograph. Streamflow peaks are identified as surface runoff and are calculated as the difference between the total streamflow and baseflow (Wahl and Wahl 1988; Barlow et al. 2014). The baseflow (or groundwater discharge) component of streamflow supplies flow to streams and is assumed to be continuous in certain conditions and enters the stream channel through delayed pathways within the hydrologic system (Meyboom 1961; Fetter 1994; Sloto and Crouse 1996; Sophocleous 2002; Brodie et al. 2007). Baseflow is calculated as the minimum volume of streamflow over a given time period (n) (Barlow et al. 2014).

Four quantitative hydrograph-separation methods were used in this study, the streamflow partitioning (PART) method (Rutledge 1993, 1998), the HYSEP Fixed and HYSEP Local Minimum methods developed by Pettyjohn and Henning (1979) and further discussed by Sloto and Crouse (1996), and the Base Flow Index (BFI) Standard method (Wahl and Wahl 1988, 1995). Each method uses a time series of daily mean streamflow measured at a streamgage. Each method is described in detail in the original documentation reports or papers and all methods are summarized in Barlow et al. (2014). Because baseflow cannot be directly observed or quantified and many of the assumptions are untested, it is unknown which method produces the most accurate results (Halford and Mayer 2000) The results of all methods were compared to assess their general accuracy and reliability, as recommended by Mau and Winter (1996), Sloto and Crouse (1996), Neff et al. (2005), and Eckhardt (2008). Kendall's Tau trend analyses were used to determine statistically significant (α = 0.05) changes in baseflow over time.

Each of the hydrograph-separation methods is based on a number of simplifying assumptions that limit their applicability (Halford and Mayer 2000). Barlow et al. (2014, pp. 3–5) describes these assumptions and limitations and provides guidance on the appropriateness of their use. All hydrograph-separation methods assume that streamflow originates from two sources: surface runoff within the basin and groundwater discharge from a single aquifer. The methods apply to basins dominated by diffuse, uniform aerial recharge that is discharged continuously to the receiving stream network (Rutledge 1998, 2007; Healy 2010; Barlow et al. 2014). It is further assumed that groundwater and surface-water divides are coincident, and that there is no loss of groundwater to the underlying regional flow system or to anthropogenic withdrawals (Rutledge 1998, 2007; Healy 2010). Rutledge (1998 and 2000) suggests that the methods be applied to basins having drainage areas ranging from approximately 2.6 km^2 (1 mi^2) to 1,300 km^2 (500 mi^2). Rutledge (2000) also notes that basins of extremely low relief (approximately less than 1%) increase the duration of surface runoff, which can impact calculations made by the hydrograph-separation methods. As noted by many authors and summarized in Barlow et al. (2014), a number of hydrologic processes and human activities that affect the flow and storage of water within a basin can obscure the surface-runoff and baseflow contributions to a streamflow hydrograph, including snowmelt runoff, drainage from lakes and wetland areas, and streamflow regulation such as occurs at reservoirs, by streamflow diversions, or by wastewater return flows. Because the algorithms that are used by the hydrograph-separation methods cannot differentiate among the various causes of hydrograph fluctuations, they may incorrectly identify snowmelt, reservoir releases, and other sources of water to a stream as groundwater discharge. An example hydrograph of daily estimated baseflow using the hydrograph-separation methods for a 2-month period for the Big Sunflower River streamgage at Sunflower, Miss. (USGS station No. 0728850) is shown in Fig. 3. For the 2-month period, the BFI Standard and PART methods gave the lowest and highest estimated rates of baseflow, respectively, which is consistent with the overall findings of the analysis described in the following. All methods calculate a BFI, or ratio of baseflow to total streamflow, for direct comparison. BFI values can be calculated on daily, monthly, or annual time steps according to the needs of the user.

The Mississippi Delta is instrumented with a spatially distributed network of 11 colocated observation wells and streamgages operated by the US Geological Survey (USGS) in cooperation with the US Army Corps of Engineers (USACE). The network provides continuous data and allows for direct comparison of streamflow with

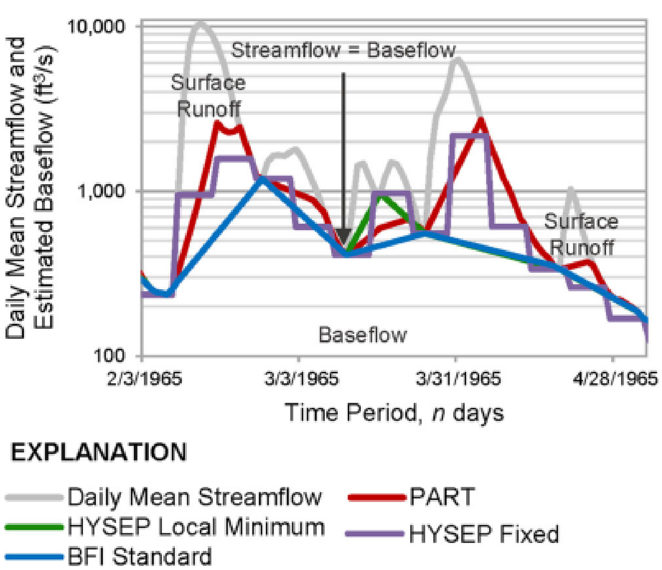


Fig. 3 Example hydrographs showing hydrograph separation by method in cubic feet per second (ft^3/s), 1 ft^3/s = 0.03 m^3/s. The area under each colored line represents the volume of baseflow estimated at a given time

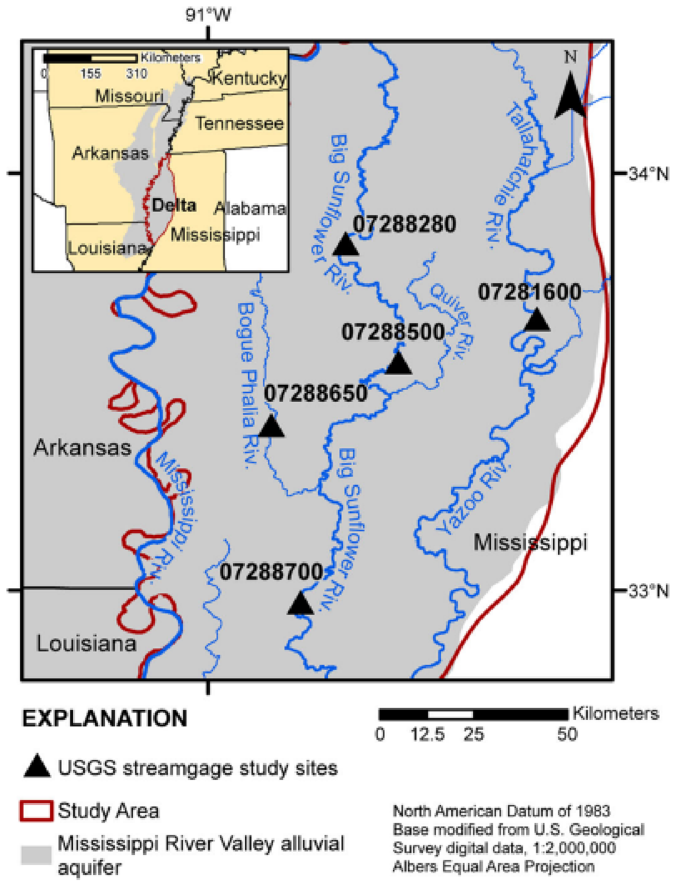


Fig. 4 Map of selected sites from the spatially distributed network of colocated streamgage and groundwater well locations within the Mississippi Delta by USGS

groundwater-level elevations; however, continuous groundwater-level elevation data collection did not begin at the sites until 2014. The groundwater records are not sufficient in length for comparison at this time but are anticipated to be valuable in future scientific studies. Data for this study included daily mean streamflows collected by the USGS and USACE for five of the colocated streamgages (Fig. 4). The five streamgages were selected based on the availability of daily mean streamflow data, period of record, and spatial distribution across the Mississippi Delta (Table 1). Hydrologic data collected by the USGS are publicly available from the USGS National Water Information System (NWIS) web interface (US Geological Survey 2018).

Two of the five selected streamgages had missing daily mean streamflow records. Missing daily mean streamflow records were estimated for the sites using the USGS Streamflow Record Extension Facilitator (SREF; Granato 2009), which uses the Maintenance of Variance-Extension type 1 (MOVE.1) equation in combination with index stations (Hirsch 1982; Granato 2009; Curran 2012). The USGS Get National Water Information System Streamflow (GNWISQ) software was used to retrieve available daily mean streamflow data from NWIS

Table 1 Site information for the five selected USGS streamgage locations used in this study

USGS station No.	Colocated groundwater well (USGS station No.)	River name	Location	Period of record	Drainage area (km^2)
07281600	333904090123801	Tallahatchie	Money, MS	10/01/1995–12/31/2017	13,522
07288280	334956090402201	Big Sunflower	Merigold, MS	10/01/1992–12/31/2017	1,432
07288500	333251090323801	Big Sunflower	Sunflower, MS	10/01/1935–12/31/2017	1,987
07288650	332348090505301	Bogue Phalia	Leland, MS	01/01/1964–12/31/2017	1,254
07288700	325817090464201	Big Sunflower	Anguilla, MS	09/18/2009–12/31/2016	6,680

and format it for use in SREF (Granato 2009). SREF was used to estimate missing daily mean streamflow values for the Bogue Phalia River streamgage near Leland, MS (USGS station No. 07288650) and the Big Sunflower River streamgage near Anguilla, MS (USGS station No. 07288700; Fig. 5). A total of 881 of 19,632 daily mean streamflow values (4.5%) were estimated for the Bogue Phalia River streamgage using the Big Sunflower River streamgage near Sunflower, MS (USGS station No. 07288500) as an index station. Concurrent daily mean streamflows between the Bogue Phalia River streamgage and the Big Sunflower River streamgage near Sunflower, MS had an R^2 of 0.847 (Fig. 5a). A total of 2,090 of 2,662 daily mean streamflows (78.5%) were estimated for the Big Sunflower River streamgage near Anguilla, MS using two index stations: The Big Sunflower River streamgage near Sunflower, MS (R^2 = 0.890; Fig. 5b) and the Big Sunflower River streamgage near Merigold, MS (USGS station No. 07288280; R^2 = 0.832; Fig. 5c). Streamflow record extension was not used to extend records prior to the initial streamflow collection date because of insufficient index stations and the highly altered environment.

The hydrograph-separation methods used in this analysis are part of the overall functionality of the USGS Groundwater Toolbox (Barlow et al. 2017). Continuous daily mean streamflow data are available from NWIS (US Geological Survey 2018) and the USACE (US Army Corps of Engineers 2018), and missing streamflow estimates were calculated using SREF (Granato 2009) and are available from Killian and Asquith (2019). Daily mean streamflow data and calculated baseflow estimates were analyzed by climatic year (April 1st to March 31st). A partition length of n = 5 days and a turning point test factor of 0.9 were used for the BFI Standard method for all records analyzed. Data for this hydrograph-separation analysis are available from Killian and Asquith (2019). The Groundwater Toolbox also facilitates the calculation of Kendall's Tau measure of rank correlation, which was used to identify trends in the data by estimating the magnitude of monotonic change with time (Kendall 1938, 1975; Wahl and Wahl 1988; Wahl and Tortorelli 1997). Baseflow trends were recognized as statistically significant for each n-day low flow period of analysis when the null hypothesis was rejected at the 95% confidence (such

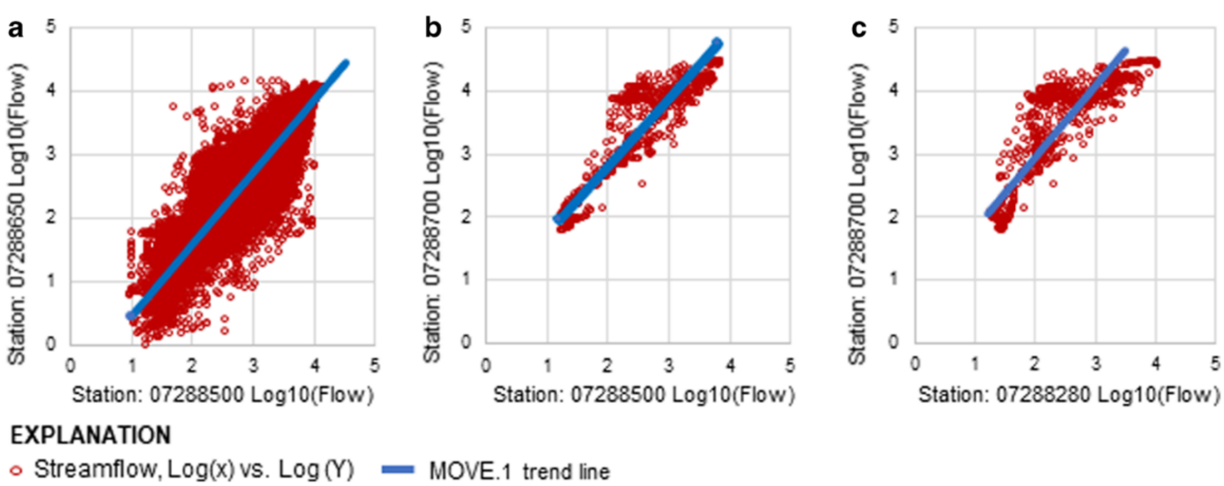


Fig. 5 Streamflow relation using SREF software computations (Granato 2009) between the Big Sunflower River at Sunflower, MS (USGS station No. 07288500) and **a** the Bogue Phalia River near Leland, MS (USGS station No. 07288650) and **b** the Big Sunflower River near Anguilla, MS (USGS station No. 07288700) and **c** between the Big Sunflower River at Merigold, MS (USGS station No. 07288280) and the Big Sunflower River near Anguilla, MS

as p value of 0.05 or less) and if Kendall's Tau was trending to +1 or –1 (Fig. 7b; Wahl and Tortorelli 1997; Helsel and Hirsch 2002).

Generalization of groundwater-level elevations

To quantify groundwater-level elevation changes systematically in the study area, available groundwater-level elevation data needed to be normalized for space and time because of the spatial and temporal variability of the observations. The majority of the groundwater-level elevation observations were made in the spring and fall months, but such practice was not uniform throughout the period of record. A grid of the study area was created at a 4.5-km (km) spacing; the grid nodes are not coincident with actual wells. Statistical processing (timeseries regression) of the observational groundwater-level elevation data surrounding each grid node was made to estimate the water levels at specific or strategic points in time to give estimates throughout the grid for year M and again for a year N. Groundwater-level elevation changes can readily be computed from years M to N in a geographic information system.

For this study, time-series regressions were based on the generalized additive model (GAM) algorithms (Hastie and Tibshirani 1986, 1990; Wood 2017, 2018). These were used to quantify temporal changes in groundwater-level elevation for a given data set in which a data set that included all observations at wells within a set radial distance from a grid node. The GAM is analogous to a linear regression but incorporates additive smoothing functions and can be used to identify trends (Hastie and Tibshirani 1986, 1990; Wood 2017, 2018) and provides a more rigorous framework for trend estimation than available in the lowess and loess functions (Cleveland 1979; Cleveland et al. 1992) in R (R Development Core Team 2018). Further, temporal data density within the alluvial aquifer was considered insufficient for autoregressive–moving-average type modeling. Extensive testing (not reported here) showed that the GAM had sufficient robustness against outliers in water-level elevations. All available groundwater-level elevation observation data between 1980 and 2016 for the study area in the NWIS database were used, which included more than 3,300 wells and almost 28,000 groundwater-level measurements (US Geological Survey 2018). These data included copious quantities of measurements from local water-resource authorities (YMD 2008) in the region.

Generalized groundwater-level elevation observations were estimated using GAMs, based on the algorithms of Wood (2018), for April 10th of each year for each grid node (4.5 km spacing). April 10th of each year was selected because of the large number of groundwater-level elevation observations made on or immediately before that day as part of other data-collection efforts by local water-resource authorities (YMD 2008). Early April is also prior to the start of irrigation season and is generally a period of approximate maximum water-level recovery in the alluvial aquifer from the previous irrigation season (Snipes et al. 2005). The GAM estimates for each grid node also include the upper and lower 90th-percentile prediction limits.

For each grid node, a GAM was created using an 8-km search radius and included up to 300 nearby wells publicly available from NWIS (Fig. 6; US Geological Survey 2018). A lower limit of 10 groundwater measurements from nearby wells was needed to estimate groundwater-level elevations over time for the specified node. If less than ten measurements were available, no estimate was calculated for the node. If the number of measurements exceeded 100, then an attempt was made to estimate first-order seasonality using paired cosine and sine trigonometric functions for which a cyclical year had 2 times π radians (Fig. 6, grid node 298). If the p-value for both trigonometric terms was greater than 0.005, then the GAM was fitted using only the smooth on the date of measurement (Fig. 6, grid node 299). From the gridded estimates, quantification of changes between 1980 and 2016 thus reflect generalized groundwater-level elevation change across the Delta.

An example groundwater-level elevation estimated hydrograph for grid node 0918 based on a GAM using nearby (8-km radius) groundwater-well observations is shown in Fig. 7. For node 0918, 122 wells are included with 713 measurements in aggregate. The measurements for the neighboring wells are also shown, and highlights that many observation wells have solitary measurements, especially around 1980. Figure 7 also shows that some monitoring network wells are nearby as evidence by the twice-yearly measurements. The figure does not highlight the difference in well construction nor is such information used in the statistical modeling.

Several representations of the same GAM are shown (Fig. 7). The continuous month over month predictions of the GAM are depicted by the sinusoidal, light blue line for which the troughs and peaks occur around December and May, respectively. Of primary importance to this study are the April 10th predictions for each year. These have been connected to form the darker solid blue line with the corresponding 90thpercentile

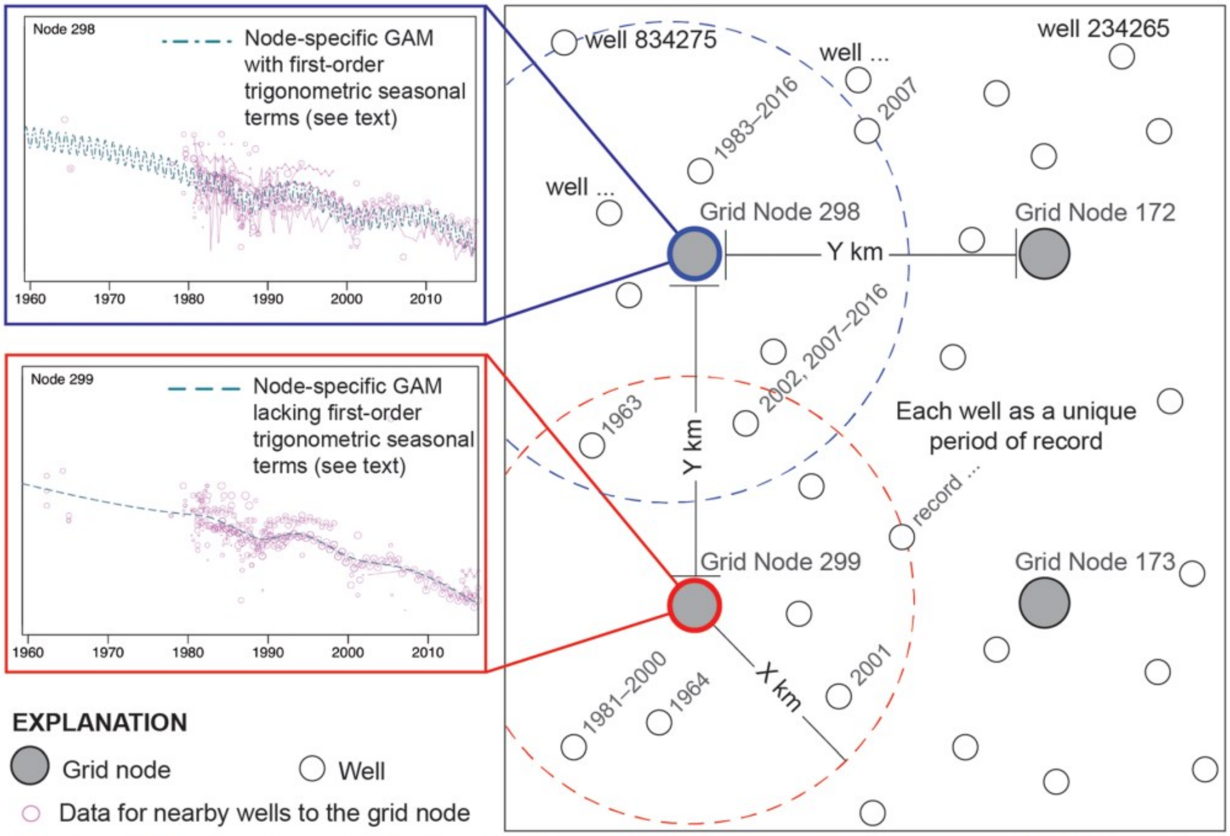


Fig. 6 Diagram of two GAM nodes with associated hydrographs of groundwater-level elevation observations from wells within the search radius. Dates indicate available records from NWIS (US Geological Survey 2018) at each well identified

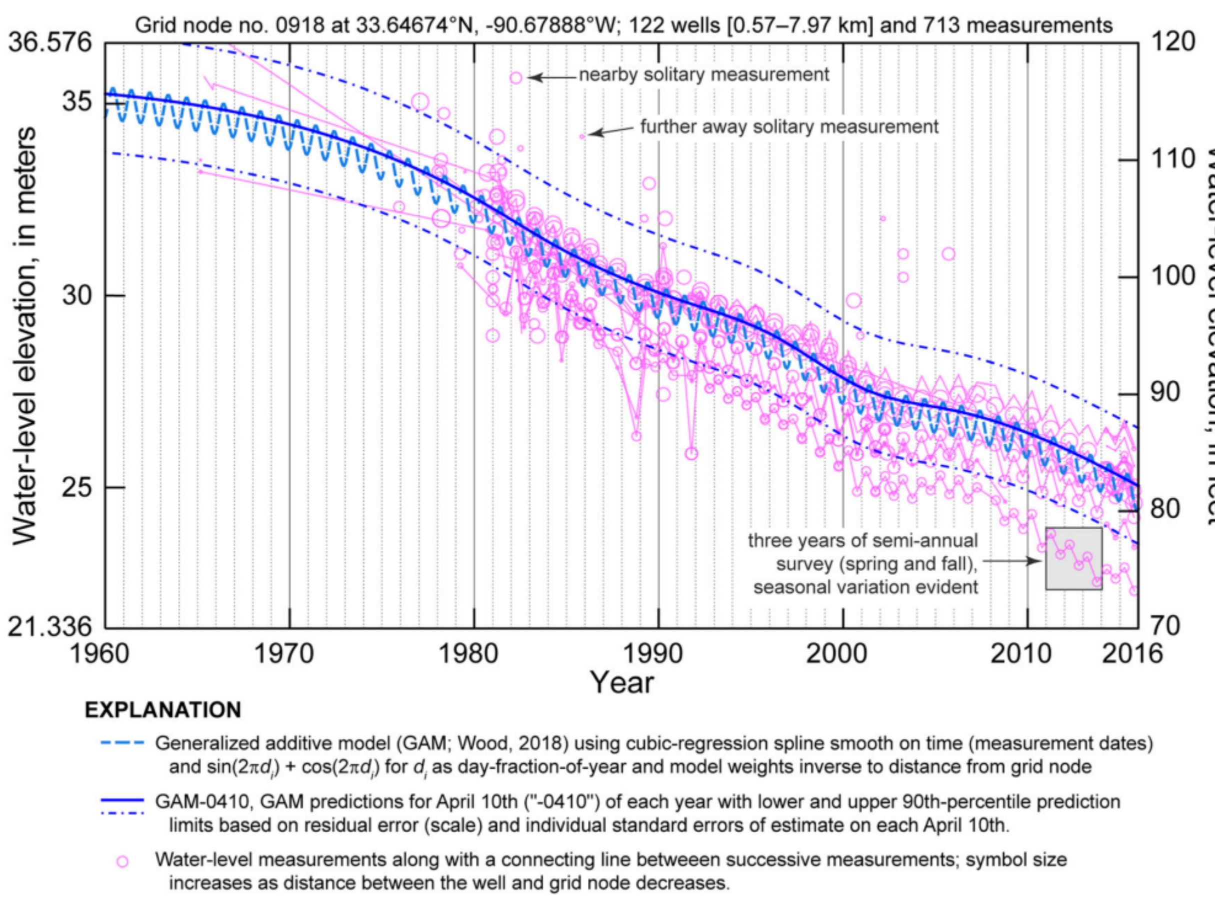


Fig. 7 Example hydrograph of groundwater-level elevation for grid node 0918 showing measurements from radially-neighboring wells with fitted generalized additive model

prediction limits (not confidence limits; see Helsel and Hirsch 2002). The overall curvature (not the parametric seasonality) of the GAM for the time period shown is controlled by the smooth term that uses only the date of the measurement. The smooth within a GAM is a type of cross validated regression spline estimated during the construction of the GAM. The figure indicates that generalization of water levels for each year of interest at this grid node is possible. For the remainder of the nodes, generally unsupervised predictions were made using the other and node-specific GAMs. However, substantial review of GAM results for about 100 grid nodes scattered throughout the study area was done, and the authors conclude that this statistical approach for normalizing for space and time is reliable for the data available for the alluvial aquifer.

Results

Hydrograph separation and trend analyses

The degree of groundwater contribution to streamflow, indicated by the average annual base flow index (BFI), varied temporally and spatially among the five study sites. Baseflow contribution to streamflow in the Tallahatchie River at Money, MS (USGS station No. 07281600, Fig. 8a graph A; Table 2) was moderate to high (average annual BFI = 0.805) and varied seasonally. Groundwater contribution to streamflow in the Big Sunflower River at Merigold, MS (USGS station No. 07288280, Fig. 8a, graph B; Table 2), the most upstream study site, was moderate to low (average annual BFI = 0.366), and the degree of BFI contribution varied between high- and low-flow events. Baseflow contributions to streamflow decreased over time (average annual BFI = 0.563 for 1936–1979 and average annual BFI = 0.418 for 1980– 2016) in the Big Sunflower River at Sunflower, MS (USGS station No. 07288500, Fig. 8a graph C; Table 2). The decrease in BFI and the increasing variability between high- and lowflow events after the 1980s is contemporaneous with increased groundwater withdrawals for irrigation (Fig. 3).

Baseflow contributions to streamflow decrease over time in the Bogue Phalia River (USGS station No. 07288650, Fig. 8a, graph D; Table 2), which corresponds to increases in groundwater withdrawals from the alluvial aquifer (Fig. 3). Hydrograph separation results for the Big Sunflower River near Anguilla, MS (USGS station No. 07288700, Fig. 8a, graph E; Table 2), the most downstream site on the Big Sunflower River, varied but there was a slight increase in baseflow contribution over time; however, the period of record for data at this site is short—less than 10 years in length. Statistically significant declines in baseflow occurred at the Big Sunflower River at Sunflower and Bogue Phalia River sites for most hydrograph-separation methods over most *n* -day periods of analysis. For example, Kendall's Tau values for the 1-day through 30-day analysis periods for the Big Sunflower River at Sunflower were approximately −0.65 (Fig. 8b, graph C); however, the trends became less significant (trended to 0) for the 60 to 365-day analysis periods. There were no statistically significant declines in baseflow in the Big Sunflower River at Merigold and Tallahatchie River sites. The Big Sunflower River streamgage near Anguilla showed an increase in baseflow contribution to streamflow over longer analysis periods (60–365 days) with statistically significant changes for the 365-day time period and no statistically significant change in baseflow over shorter periods (1–30 days). The streamflow record for the Big Sunflower River near Anguilla is for the shortest period of time (2009–2016) and may be insufficient for a trend analysis, so results for this site should be taken with caution.

Generalized groundwater-level elevation change

A well-defined region of persistent groundwater-level elevation declines is located near the middle of the study area (Fig. 9). The estimated groundwater-level decline based on the difference between April 10, 1980 and April 10, 2016 ranges from approximately zero to more than 12 m. The area of largest decline (~12 m) is located along the middle reaches of the Big Sunflower River. Groundwater-level elevations have been generally stable on both the eastern and western margins of the study area. This observation is consistent with the persistent flow within the Tallahatchie River that flows near the Bluff Hills and Mississippi River, which may act as areas of recharge for the study area (Arthur 2001; Barlow and Clark 2011). The flow persistency is associated with the substantial surface-water input into the study area from upstream or the headwaters of the rivers. The southern fifth of the study area also shows that groundwater-level elevations have been relatively stable.

Discussion

Ranges in estimates from the individual hydrograph separation methods at each study site were consistent with findings from previous baseflow separation studies by Neff et al. (2005) and Eckhardt (2008). PART and HYSEP Fixed methods tend to estimate higher baseflow than the HYSEP Local Minimum and BFI Standard methods. Results should be interpreted with caution

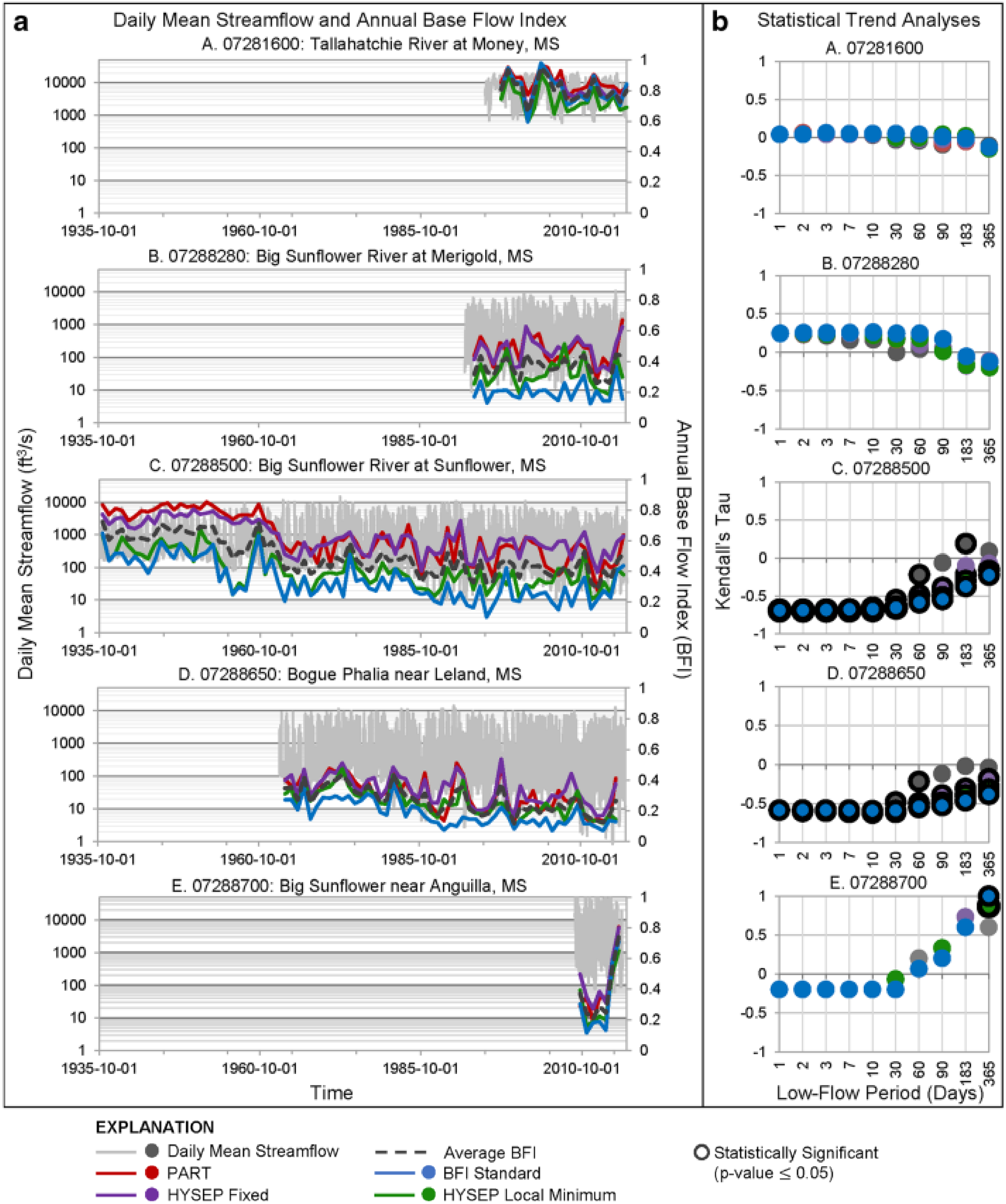
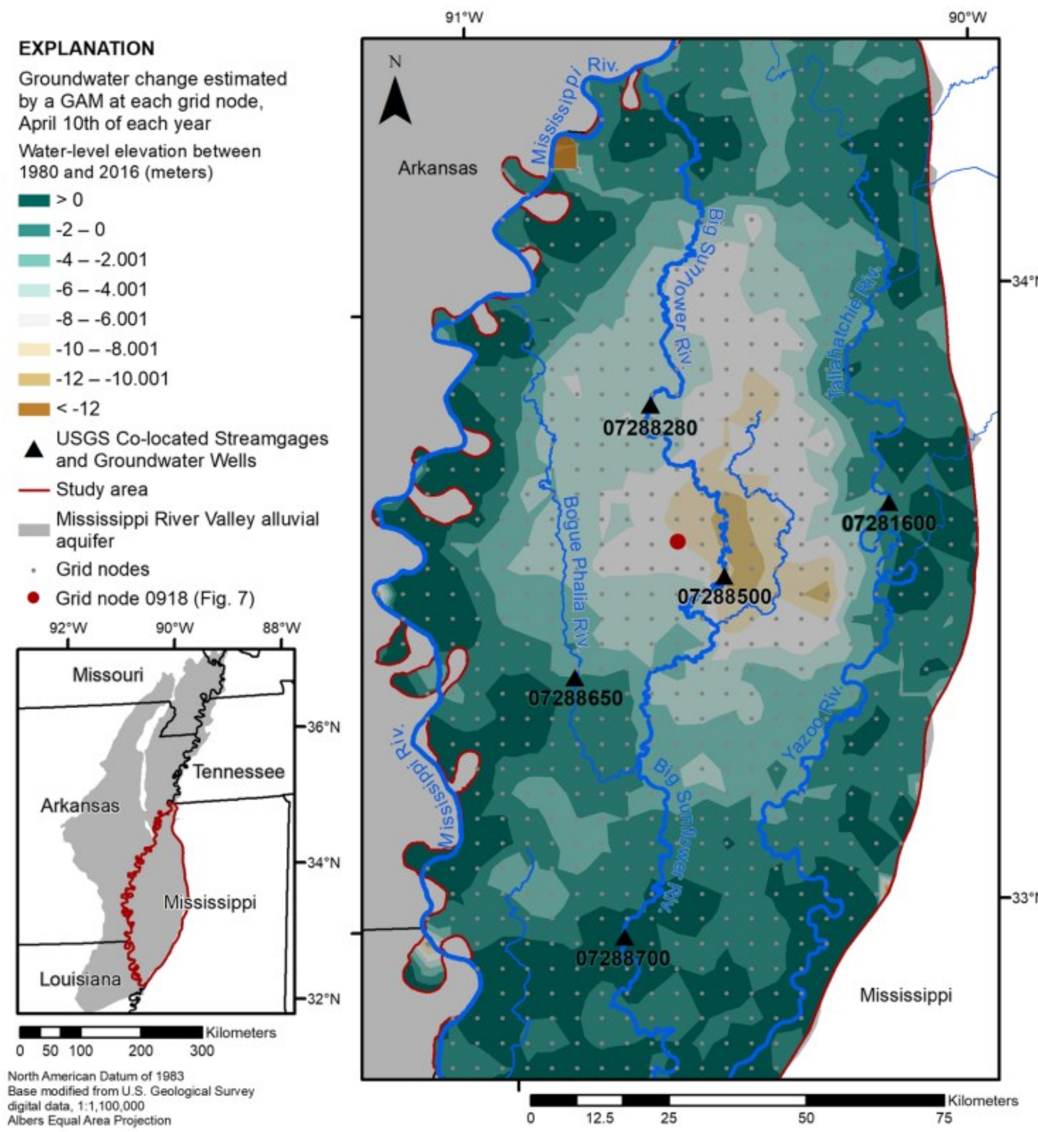


Fig. 8 **a** Daily mean streamflow (ft^3/s) and annual mean baseflow time series by streamgage, 1 $ft^3/s = 0.03\ m^3/s$. **b** Results of the Kendall's Tau trend analyses for baseflow results by streamgage

because the Mississippi Delta is heavily influenced by anthropogenic factors including streamflow-control structures and alterations in landscape to accommodate agriculture. Results from the Big Sunflower River streamgage near Anguilla may be uninformative because of the relatively short period of streamflow record. The Tallahatchie River streamgage also exceeds the recommended drainage basin size of 1,300 km^2 (500 mi^2) for hydrograph separation and is downstream of streamflow-control structures (Rutledge 1998, 2000; Barlow et al. 2014). The colocated groundwater-observation wells will prove useful for studies such as this in the future as additional data are collected.

The degree of changes in groundwater-level elevation corresponded to changes of baseflow contribution to streamflow both spatially and temporally at the five study sites. Baseflow results for the Big Sunflower River at Merigold and Tallahatchie River streamgages showed no statistically significant change ($\alpha = 0.05$), which is consistent with the relatively small decline in nearby groundwater level elevations (−2 to −4 m [m], Fig. 9). Statistically significant changes in baseflow were observed at the Big Sunflower River streamgage at Sunflower, which showed substantial declines in the nearby generalized groundwater level elevation estimates (−8 to −12 m). An increase in baseflow contribution over time has occurred at the Big Sunflower River streamgage near Anguilla, which is consistent with increases in the nearby groundwater-level elevation (>0 m) as shown in YMD (2008) and Clark et al. (2011). Although there was a statistically significant decrease in baseflow contribution at the Bogue Phalia River site, estimated nearby groundwater-level elevations have declined relatively little (−2

Fig. 9 Estimated groundwater - level elevation change measured as the difference between April 10, 1980 and April 10, 2016 using the generalized additive (statistical) model for each grid node as described in the text



and −4 m). This might suggest that the stream is in good connection with the aquifer and is thus sensitive to relatively minor changes in groundwater level elevations because of the low baseflow contribution or reflect upstream effects as the river crosses areas with larger decline (Fig. 9). It is possible that the Tallahatchie River streamgage shows a similar groundwater and surface water interaction scenario, but the streamgage could be in an area with less groundwater extraction and may have hydrogeologic controls conducive to aquifer recharge. Results of this study are intended to aid in refining the existing Mississippi Embayment Regional Aquifer Study model by increasing current understanding of groundwater and surface-water interactions and reducing model uncertainty to allow for improved estimates of groundwater surface water exchange parameters such as streambed conductance and recharge. Conclusions This study utilized existing groundwater-level elevation and streamflow datasets to quantify changes in baseflow contribution to streamflow at five sites in the Mississippi Delta to define groundwater-level elevation changes over a 26-year time period across the study area. Areas with little or no statistically significant ($\alpha = 0.05$) changes in streamflow and baseflow were observed in areas with little relative change in groundwater-level elevation. Baseflow characterization techniques and analysis of groundwater-level elevation data suggest that decreases in baseflow are a result of groundwater-level elevation declines within in the alluvial aquifer that underlies the Mississippi Delta. Groundwater-level elevation declines within the alluvial aquifer are contemporaneous with increases in groundwater withdrawals from the alluvial aquifer. This research demonstrates that baseflow contributions to streamflow calculated from streamflow data may be used as a proxy for changes in groundwater level elevation over time in alluvial settings. To further evaluate the approach, streamflow should be analyzed on seasonal or decadal scales to identify if observed trends are maintained.

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Hydrogeology Journal (2019) 27:2167–2179
https://doi.org/10.1007/s10040-019-01981-6

STGS Board Member Candidates –*President Elect*

The President Elect is a two year commitment; the first year as president elect the member attends executive meetings and shadows the president but is not part of the voting body. The following year the member assumes the president role and becomes a member of the voting body.

Troy Tittlemier

M.S. Geology Consulting Geologist
Active STGS Member
Host of The PBE Podcast
President of MSSK, an oil and gas operating company
Co-Inventor of U.S Patent #11,396,622

Professional Experience:

Senior Geologist and Business Development Manager at Trey Resources
CEO of The MagmaChem Research Institute
Adjunct Geology Professor for The University of Texas Permian Basin

Jack Sackrider, P.G.

Project Geologist, Westward Environmental, Inc.
B.A. Geography, The University of Texas at Austin
B.A. Geology, The University of Texas at San Antonio

Professional Organizations:
STGS
The Texas Board of Professional Geoscientists (P.G. #12456)
The Arizona Board of Technical Registration (P.G. #73931)
The North Carolina Board for Licensing of Geologists (P.G. #2851)
The South Carolina Board of Registration for Geologists (P.G. #2869)
The Society for Mining, Metallurgy & Exploration (SME #04311091)
Industrial Minerals & Aggregates Division Committee Nominations
Geology of Industrial Minerals Steering Committee (2022 – 2025)
Technical Committee Chair (2024 – 2025)Program Committee Vice Chair (2024 – 2025)
Young Scientists Award Committee Member (2024 – 2025)
Scholarship Committee (2024 – 2026)
The Society of Exploration Geophysicists (SEG #586475)

Professional Experience:
Project Geologists, Westward Environmental, Inc. (2013 – Present)
Geologic Consultant, with a focus in Environmental and Economic Geology as it relates to construction aggregate, industrial minerals, and associated industries. As a Professional Geologists licensed in the great state of Texas, he has performed an array of tasks, primarily related to geologic exploration, modeling and calculations of economic aggregate reserves; Geologic Assessments over the Edwards Aquifer; and sensitive recharge feature training of mine and quarry staff. Mr. Sackrider also volunteers his experience with industry and the community through organizations such as SME and educational events like the Texas Hydro-Geo Workshop.

STGS Board Member Candidates – *Vice President*

The Vice President serves a one year term and is part of the voting body, and is responsible for recruiting speakers for luncheons, handles speakers' travel arrangements, secures the venue for meetings, and introduces the speaker at the luncheon or meeting. The VP is expected to fill in if the president is absent.

JR Rodriguez

Current:

Geologist/Owner, Marmot Energy, LLC

B.S. Geology, Texas A&M University

Professional Organizations:

STGS – Member

AAPG – Member

Professional Experience:

Independent/Consulting Geologist

Ricochet Energy, Sr. Geologist

Killam Oil Co., Geologist

Halliburton Energy Services, Sr. Wireline Engineer

Tyler Quade

University of Texas at San Antonio - M.S. Geosciences

Texas A&M University Kingsville - B.S. Geosciences

Waters Petroleum - Geologist, North Slope, Alaska

Ageron Energy - Contract Geologist

Windridge Oil & Gas - Geologist

Past VP STGS

Past AAPG Delegate

STGS Board Member Candidates – *Secretary*

The Secretary is a one year term. They are responsible for attending all executive meetings, keeping a record of all discussions held during executive meetings, and distributing these records to all executive offices the next day. The Secretary is a member of the voting body.

Mike Younger

President, Pineridge Resources, Inc.

B.S. Geology, Illinois State University

M.S. Geology, University of Texas at Arlington

Professional Organizations:

STGS – AAPG Delegate 2013-2015; Secretary 2009-2010; Editor, 2006-2008

AAPG-CPG #5666

Professional Experience:

President, Pineridge Resources, Inc.

Senior Geologist, BlackBrush Oil and Gas, LP

Petroleum Geologist, Swift Energy

Staff Geologist, Bass Enterprises Production Co.

Yvette Counts

Senior Geologist, Formerly at EOG Resources

M.S. Geology, University of Teas at Arlington

B.S Geology, University of Texas at Arlington

Professional Organizations:

STGS - 2022 - Present

AAPG - 1999 - Present

Professional Experience:

EOG Resources - Geological Specialist, 2017 - 2023

EOG Resources - Senior Geologist, 2012 - 2017

EOG Resources - Geologist II, 2008 - 2012

Rosewood Resources - Development / Exploration Geologist, 2006 - 2008

Rosewood Resources - Operations Geologist, 2004 - 2005

Rosewood Resources - Geotech, 2003 - 2004

STGS Board Member Candidates – *Treasurer*

The Treasurer term is a three year commitment. During the first year the treasurer shadows the previous treasurer to learn the role. The next two years the treasurer becomes part of the voting body and handles all payments to STGS, makes payments as directed by the executive officers, assembles a financial report for each executive meeting, and maintains financial records for tax and audit purposes.

Jason Besancheney

Senior property tax consultant (oil & gas), American Ad Valorem
B.S. Geology, Texas A&M Corpus Christi
M.S. Geology, University of Texas at San Antonio

Memberships and licenses:
Senior property tax consultant, TDLR# 3647
Texas Board of Professional Geoscientists, GIT-560
South Texas Geological Society
Texas Oil & Gas Association

Rykley Crowe

Petroleum Geoscientist, Hurd Enterprises, Ltd.
B.S. Geology, Centenary College of Louisiana
Geology, University of Texas at San Antonio
Professional Organizations:
AAPG – 2013-Present, House of Delegates 2020-2023
STGS – 2017-Present, Scholarship Committee, 2023-Present
HGS – 2015-Present

Professional Experience:
Hurd Enterprises, Ltd. – Petroleum Geoscientist, 2019-Present
Hurd Enterprises, Ltd. – Geology Intern, 2018-2019
Anderson Oil and Gas – Geology Intern, 2014-2017

STGS Board Member Candidates – *AAPG Delegate*

Steven Shirley

Education:

University of Oklahoma MS Geology

Louisiana State University BS Geology

Work:

Chevron/Unocal 1990 - 2018
Champlin/Union Pacific 1985 - 1990
Joined AAPG in 1982

Past Service:

HGS Executive Director, 2016 - 2018
AAPG GEVO Comm. 2014 - 2020
HGS Treasurer, 1996 - 1997
HoD Committee, Delegate, 1992 - 1997
HoD Committee, Alternate, 1991 - 1992
ACE Organizing Committee,
Sponsorship Co-Chair, 2016 - 2017

Past Awards:

2017/04/02 - AAPG Certificate of Merit
2014/07/01 - AAPG Certificate of Merit

Troy Tittlemier

M.S. Geology
Consulting Geologist

Active STGS Member

Host of The PBE Podcast

President of MSSK, an oil and gas operating company

Co-Inventor of U.S Patent #11,396,622

Professional Experience:

Senior Geologist and Business Development Manager at Trey Resources

CEO of The MagmaChem Research Institute

Adjunct Geology Professor for The University of Texas Permian Basin

STGS Board Member Candidates – *Editor*

The Editor position is a one year commitment. They are responsible for creating a bulletin PDF each month during the fiscal year, distributes this bulletin to all paid members, and uploads it to the organization's website. It isn't too late to throw your name in the hat, if you or anyone you know is interested in being editor, contact any board member in the back of this bulletin.

Shelby Sckittone

Natural Resource Specialist –Bandera County River Authority & Groundwater District. B.A. Geology, University of Texas at San Antonio, 2019. STGS Editor 2020-2024.
STGS member 2020-present.

Professional Organizations:

STGS, GSA, AEG, Master Naturalist, Alamo Area Chapter.

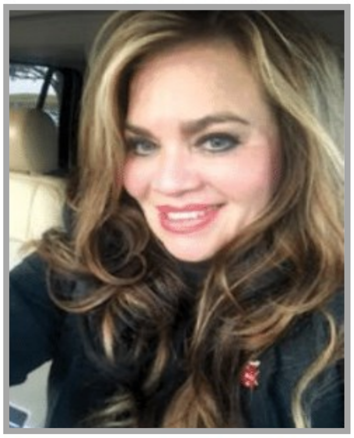
Professional Experience:

Natural Resource Specialist for Bandera County River Authority & Groundwater District. Texas Parks & Wildlife Volunteer. Texas Waters Specialist. Master Naturalist. UTSA Student Geological Society board member, 2018-2020. Texas Hydro-Geo Attendee 2017, 2019, and module presenter 2023.

STGS Board Member Candidates – *Executive Committee*

The Executive Committee term is one year. Two candidates hold this position each year, and they are responsible for attending all executive meetings and aiding the officers in decision-making.

Margaret P. Graham



MARGARETP.GRAHAM, Founder and President of MPG Petroleum, Inc., graduated from Trinity University, San Antonio, Texas. Class of 1979,with a Bachelor of Arts in Geology. Since graduation Ms. Graham has continuously been engaged in the Upstream Oil and Gas Sector and has developed a very broad range of expertise.

Ms. Graham founded MPG Petroleum, Inc. in 1985and early on diversified into the Contract Operations business beginning with 38 oil wells. The experience gained in Production Operations proved invaluable, including but not limited to Oil Well Workover, Oil Sales, Joint Interest Billing Accounting, Revenue Disbursement, and Regulatory filing. Operations began in the Somerset Field and continued soon after into the Leming Field where Ms. Graham was involved in the field's early development. Subsequent focus was on prospect generation in deeper targets spanning Central and Southwest Texas to the Texas Gulf Coast. Today, MPG is engaged in highly proprietary, deep exploration work and has developed a very large portfolio of conventional and unconventional prospects, targeting world-class sized oil and gas reserves. MPG's team of Geoscientists and Engineers are +40 years experienced, having worked in major basins domestically and internationally.

Prior to forming MPG Petroleum, Inc. Ms. Graham served as Exploration Geologist for Tesoro Petroleum. Her first prospect was drilled at age 23 and resulted in a new field discovery in the Magnolia Beach Field. She was next assigned a reconnaissance study of the Maverick Basin. This work was an early precursor to the Eagle Ford Shale Play, as well as the Pearsall, Glen Rose and James Lime plays of Maverick County. Ms. Graham assisted with the early work in the deep, tight, Wilcox gas play, eventually leading to the Bob West Field discovery. Prior to joining Tesoro Petroleum, Ms. Graham served as Geological Technician to Gulf Energy and was trained as a well-site Geologist. Ms. Graham also served as a Geological Consultant to Rio Exploration and to Durst Energy Corporation prior to forming MPG Petroleum, Inc. Serving as 1997–1998 Chairman of the Southwest Chapter of the American Petroleum Institute, other professional affiliations are the South Texas Geological Society, the San Antonio Geophysical Society, the Society of Petroleum Engineers, the Society of Professional Earth Scientists and the American Association of Petroleum Geologists.

STGS Board Member Candidates – *Executive Committee*

The Executive Committee term is one year. Two candidates hold this position each year, and they are responsible for attending all executive meetings and aiding the officers in decision-making.

C. Elmo Brown

Retired, Kerrville TX

BA Geology, University of Texas at Austin

MS Geology program, University of Texas at Austin

Teaching Certification, Metropolitan State University of Denver

Author on two publications, Editor on one publication

Professional Organizations

STGS

AAPG, Distinguished Service & Public Service Awards, Committee Member, House Delegate

RMS-AAPG, Board Member including President, Certificate of Merit from AAPG

RMAG, President's, Distinguished Service & Honorary Membership Awards, President, 1st VP, Treasurer, Secretary, Committee Chair

Denver Well Log Society

Professional Experience:

The Discovery Group, Senior Geological Advisor

Voyager Exploration, Exploitation Geologist

Independent/Consulting Geologist

Placid Oil Company, Staff Geologist

Candidates

STGS Board Member Candidates – *Executive Committee*

The Executive Committee term is one year. Two candidates hold this position each year, and they are responsible for attending all executive meetings and aiding the officers in decision-making.

Geary Schindel

Education:

West Virginia University (BS - Geology -1981)

Western Kentucky University (MS - Physical Geography -1984)

Professional Organizations:

National Speleological Society (fellow, past president, and life member) (1975 to present)

Geological Society of America (fellow and life member) (1985 to present)

National Ground Water Association (1985 to present)

Texas Cave Management Association (1999 to present

South Texas Geological Society, (2000 to present)(past VP)

Professional Geologist

Texas (PG 0911) and Pennsylvania (PG 3042G)

Tennessee, Alabama, and Kentucky (PG's are retired)

Employment:

Karst Works, Inc. (President) (1988 to present)

Edwards Aquifer Authority (Director of Aquifer Science and Karst Initiatives, Chief Technical Officer, Senior Hydrogeologist) (1999 to 2022)

Texas State University (Adjunct Instructor - groundwater) (2022)

University of Texas - San Antonio (Adjunct Instructor - groundwater) (2016 and 2017)

Eckenfelder, Brown and Caldwell (Director of Karst Hydrology, Director of Karst Initiatives, Senior Project Manager), (1990 to 1999)

ATEC Associates, Inc. (Environmental Service Manager/Hydrogeologist) (1988 to 1990)

Kentucky Division of Water, (Groundwater Branch Manager/Section Supervisor) (1985 to 1988)

Mammoth Cave National Park (Research Assistant) (1982 to 1984)

Roger Andrade, P.G.

San Antonio College

St. Mary's University

AAPG Member # 742878

NGWA Member # 4013378

SAWS 1991 – 2005

EAA 2005 -Present

STGS Board VP 2022-2024

CoSA Storm Water Management Advisory Board (SWMAB) 2023 - 2025

Honorary membership is the highest honor which the Society may confer on a member. Nominees for Honorary membership must be voting members of the Society who have distinguished themselves in their services to the Society and to their profession. They must be sponsored by three (3) voting members in good standing in a written recommendation to the Board of Directors. On approval of such recommendation by the Board, nominees will be presented to the voting membership. Election to this high honor shall be by an affirmative vote of two thirds (2/3) of the voting members of the Society who cast ballots.

Honorary Membership Candidate: Geary M. Schindel, P.G

Geary was born in 1957 in Washington D.C. and was raised in Wheaton, Maryland, a D.C. suburb. Geary had an early interest in geology after digging up a piece of quartz in the playground in 1st grade. At age 12, he read a book on caves and visited Mammoth Cave while on vacation with his family – at that point, he knew he wanted to be a geologist. At age 14, he joined a Boy Scout Explorer Post that specialized in caving and canoeing, and he was hooked. At 15, he was riding his bike to Great Falls of the Potomac which had great exposures of shist, quartz, pegmatite dikes, and an old gold mine. At 16, he was organizing caving and rock climbing trips to West Virginia with his friends. He joined the National Speleological Society (NSS) at 17 and became active in the local caving club (grotto). He attended Montgomery College in Rockville, Maryland for his first two years. He then took a year off college and worked as a laborer on a tunnel boring machine (TBM) where his primary job seemed to be working a shovel as a pilot – as in, pile it here and pile it there. He also worked a jackleg drilling blast holes, installing roof bolts, helping load and wire explosives, mucking out the tunnel and starting all over again.

While Geary was helping remove a jammed catwalk on the TBM, he and the foremen were knocked to the ground by a lightning strike on the TBM transformers. The electricity ran along the pipping and rail lines and killed all the power in the tunnel. After they picked themselves off the ground, he could look down the drift and see light entering the shaft. He wasn't sure if that was "The Light At The End Of The Tunnel" or just the light entering the tunnel. At that point, he decided he had made enough money and headed off to West Virginia University to finish his studies in geology and graduated in 1981. While at school, he met his future wife, Sue at the local grotto meeting and they were married in 1980.

Geary went on to graduate school at Western Kentucky University (WKU) in Bowling Green, Kentucky. WKU had a very active karst research program directed by Dr. Nick Crawford. Geary gained experience in collecting water sampling, dye tracing, mapping caves, and servicing field instruments. He also worked at Mammoth Cave National Park under Dr. James Quinlan. At Mammoth Cave, Geary was part of a team of four that were tasked with mapping caves under the sinkhole plain adjacent to Mammoth Cave.

Mapping caves was a fun but difficult job, the caves they were working on were very dynamic and the entrance series of one cave could flood to the ceiling in a matter of a few minutes to hours after a heavy rain. Mapping trips involved belly crawling through mud wearing a wet suit and dragging ropes and rappelling gear, survey equipment, etc. The team mapped miles of virgin caves - most of which have never been revisited. Trips usually lasted 20 to 25 hours and if the weather was stable, they would do two to three trips a week. All for $4.25 an hour.

After graduating from WKU in 1984, Geary was hired as Geologist Chief and Supervisor for the newly formed Groundwater Section of the Kentucky Division of Water in Frankfort. He was tasked with hiring the staff and developing the first comprehensive Groundwater Protection Strategy for the state of Kentucky. He was promoted to Branch Manager as the program expanded.

Geary was lured away by the private sector and moved to Nashville, Tennessee where he was the Environmental Division Manager for ATEC Associations. Most of this work involved property assessments, underground storage tank removals, soil and groundwater evaluation and remediation, sinkhole evaluation and tracer testing.

Geary later went to work for Eckenfelder Inc., also located in Nashville as the Director of Karst Hydrology and Senior Project Manager. Most of the work at Eckenfelder Inc. involved both RCRA and CERCLA projects including the manager of a Remedial Investigation (RI) for a National Priority List Superfund site. Geary also worked on numerous groundwater investigations including permitting of landfills, tracer testing, and groundwater monitoring. Eckenfelder was later acquired by Brown and Caldwell, Inc.

Geary was hired as the Chief Technical Officer (CTO) at the Edwards Aquifer Authority (EAA) in April 1999 where he was tasked with creating the research program for the EAA. Over the following 23 years, Geary served as the CTO, Director of Aquifer Sciences, and Senior Hydrogeologist. Under his direction, the EAA developed an extensive data collection program including water quality, rainfall, and aquifer water level data. He also led efforts to develop the EAA's regional groundwater modeling efforts, overseeing the contract with U.S. Geological Survey and leading the Groundwater Modeling Advisory Panel, set up the EAA's highly successful Distinguished Lecture Series, and directed numerous tracer tests and co-wrote technical reports.

Geary has led more than 100 field trips of the Edwards Aquifer and also appeared on numerous television news programs and newspaper articles. He has assisted numerous BS, MS, and Ph.D. students with their research on the Edwards and Trinity aquifers. In 2012, he created the Texas Hydro Geo Workshop at Cave Without a Name which has brought together students, professors, and practitioners for a weekend each fall.

Geary has also served as the Program Chair for the STGS, served seven years as the National Speleological Society's (NSS) Administrative Vice President where he was in charge of the NSS's conservation, education, annual convention, and cave preserves. He also served for five years as the NSS's President during the Covid Pandemic.

Geary retired in May 2022 from the EAA but still consults as president of Karst Works, Inc. which specializes in tracer testing and environmental services in karst. Over the years, Geary has worked in more than 30 states and numerous countries. His vacation time is spent visiting karst landscapes, having visited more than 25 countries in North and South America and Europe. Over the years, Geary has also been an adjunct Instructor at UT San Antonio and Texas State University. He has done contract work for the World Bank, been an invited speaker at an UNESCO conference in Bosnia working on Transboundary Aquifer issues, and an invited workshop instructor on applied karst science with the University of Belgrade and University of Birmingham in U.K. Geary has held Professional Geologist licenses in Texas, Kentucky, Tennessee, Alabama, and Pennsylvania and continues to explore caves in the Texas Hill Country in his spare time.

Honorary membership is the highest honor which the Society may confer on a member. Nominees for Honorary membership must be voting members of the Society who have distinguished themselves in their services to the Society and to their profession. They must be sponsored by three (3) voting members in good standing in a written recommendation to the Board of Directors. On approval of such recommendation by the Board, nominees will be presented to the voting membership. Election to this high honor shall be by an affirmative vote of two thirds (2/3) of the voting members of the Society who cast ballots.

Honorary Membership Candidate: Kenneth R. Helm

Ken Helm is honored with Honorary Membership for his outstanding leadership in the South Texas Geological Society. Through his work on the STGS Scholarship Committee, his contributions to the geology students of South Texas have been enormous.

Ken Helm has been actively engaged in the Geosciences and the Oil and Gas Industry for 43 years. He graduated Cum Laude from Duke University with a BS in Geology and an MA in Geoscience from Binghamton University. He is a Texas Professional Geoscientist (PG #5012) and an AAPG Certified Petroleum Geologist (#4131).

He began his career with Pennzoil Exploration & Production Co. as a geologist working the Wilcox trend of South Texas. This was followed by over 10 years as a consulting geologist including four years as the "South Texas geologist in Pennsylvania". Ken and his family moved to San Antonio in 1999 when he joined the staff of Hurd Enterprises where he continued to generate and drill Wilcox prospects. In 2019, he joined Ruckus Energy to provide seismic interpretation on the Central Basin Platform in the Permian Basin. He is currently a consulting geoscientist providing services and generating prospects for several San Antonio oil and gas companies. While working for a large exploration and production company, a small independent company and as a consulting geoscientist, he has been a proven hydrocarbon finder. He has also authored papers and given presentations to the geoscience community.

Ken has faithfully provided the South Texas Geological Society (STGS) with outstanding service since his arrival in San Antonio. He has served as the Advertising Chair for the STGS Bulletin, on the Executive Committee and as a Delegate to the AAPG House of Delegates. He has been active in various conventions that were held in San Antonio, including serving as the General Chairman of the 2011 SEG Convention. Ken served as the Golf Tournament Chairman at the 2004 and 2017 San Antonio GCAGS conventions and, as usual, used his organizational skills to make them enjoyable to all who participated and profitable for GCAGS. He received the GCAGS Distinguished Service Award in 2019.

Probably Ken's most long-lasting contribution to the geoscience community in Central and South Texas is his tireless service on the Scholarship Committee of the STGS. He has helped to raise thousands of dollars for the STGS Scholarship Fund. During his sixteen years of overseeing the Fund's investments, its assets have increased approximately 40%, not including the scholarships awarded to students. His stewardship of the investment of the Fund's assets has provided long-term fund stability and scholarships for worthy local geoscience students. His service on the San Antonio Energy Coalition, which has raised nearly $400,000, has helped to fund the scholarship programs of nine San Antonio area oil & gas professional societies that cover the entire spectrum of our business including the local SIPES chapter and the San Antonio Geophysical Society. In this way Ken has helped many San Antonio area college students fund their education with generous scholarships. This contribution to our industry will live on in the students that he has helped.

Ken is honored to be recognized by the STGS Board and members with an Honorary Membership. More importantly, he shares this honor with his wife, Donna Weidemann, whose help, support and patience over our years in San Antonio made this all possible.

73rd Annual GCAGS Meeting
AND

GEOGULF2024
SAN ANTONIO
10-12 APRIL 2024
Norris Conference Center

SCHOOL OF ROCK EXPERT GEOSCIENCE WITH A SOUNDTRACK

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Our "**School of ROCK, Expert Geoscience with a Soundtrack"** themed conference will be one of the most relevant conferences in the Gulf Coast. "GEOGULF 2024" will be the 73rd Annual Meeting of the Gulf Coast Association of Geologic Societies and the Annual Gulf Coast AAPG Section Meeting. We will continue advancing subsurface exploration and research by expert professionals, young professionals and outstanding students. The technical program and vendor exhibits will encompass all subjects necessary for a prosperous future. Potential sessions include petroleum exploration (onshore, offshore, conventional and unconventional), critical minerals, AI/Data, hydrology, environmental/engineering and subsurface storage. The audience includes multinational corporations, small companies and independents. We anticipate meeting with 300-500 attendees. We are also planning unique events that should provide extra opportunities to be recognized. Publicity for Sponsors will be on our website, at the venue and via an unprecedented media presence.

POTENTIAL TECHNICAL SESSIONS

- Petroleum Exploration with Case Studies of Fields, Plays and Basins along the Gulf Coast
    - Onshore
    - Offshore
    - Conventional
    - Unconventional
    - Caribbean, Mexico
- Critical Minerals
- AI/Data Science and its Future with Geosciences
- Environmental Geology and Engineering
- Carbon Capture and Sequestration
- Seismic Imaging and Data Analytics

CONFERENCE HIGHLIGHTS

- Geologic Field Trips
- Short Courses
- Technical Sessions
- Networking Events

Please consider supporting this non-profit event that supports local geological communities! Sponsorship information below.

GENERAL SPONSORSHIP LEVELS

LEVEL	AMOUNT	Transactions Ad	Complimentary Registrations to Entire Convention	Complimentary Passes to All-Convention Luncheon	Company Logo on Scrolling PowerPoint	Company Logo in Convention Program Book	Company Logo on Signs at Registration and Exhibit Hall Entrance	Announcement on LinkedIN
Diamond	25,000+	2-page Composite Landscape, bleed, color	5	4	Listed as "DIAMOND"			
Emerald	20,000+	2 Page Portrait, bleed, color	4	3	Listed as "EMERALD"			
Platinum	15,000+	Portrait full page, bleed, color	3	2	Listed as "PLATINUM"			
Gold	10,000+	Portrait full page with margins	2		Listed as "GOLD"			
Silver	5,000+	Landscape ½ page with margins	1		Listed as "SILVER"			
Bronze	2,500+	Portrait ¼ page			Listed as "BRONZE"			
Copper	1,000+	Logo only			Listed as "COPPER"			
Patron	500+	Name only			Name as "PATRON"			
Friend	100+	Name only			Name as "FRIEND"			

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Best themed Rock/Music booth wins Dr. Shaley's Fender Guitar

Booth Pricing: $1,500

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- **1 full registration ticket 3 guest pass are included**

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Society of Independent Professional Earth Scientists (SIPES)

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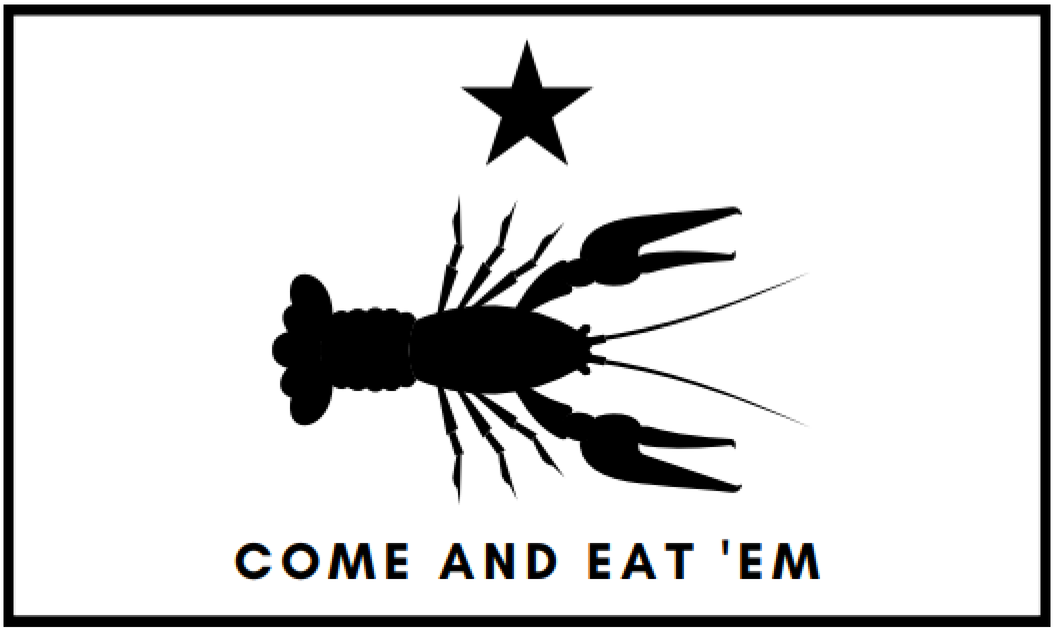

TUESDAY APRIL 9, 2024

TIME: 4 -8 PM

WHERE: KOEHLER PAVILION AT BRACKENRIDGE PARK

Crawfish sourced and cooked by
Chef Pieter Sypesteyn of NOLA Restaurant

SAVE THE DATE! MAY 9, 2024 Energy Professionals Hiring Event

9 MAY 2024 - IN PERSON Job Fair - 1000-1400 CDT - HOUSTON - NRG PARK - ROOM TBD

You are cordially invited to attend the “ENERGY PROFESSIONALS HIRING EVENT” hosted by the Society of Petroleum Engineers – Gulf Coast Section. We strive to provide a platform for experienced upstream and energy professionals and industry companies to e-meet and create value for both sides.

JOB SEEKERS

Welcome to the SPE Spring 2024 Energy Professional Hiring Event! This event provides job seekers opportunities to meet with potential energy industry hiring companies in upstream oil and gas and renewables.

Event registration is PREFERRED (though walk-ins are welcome), and a resume/CV must be submitted at least 48 hours before the event. Various Event entry times are available for registration to allow job seekers ample time to meet with companies. Job seeker qualifications include:

QUALIFICATIONS:

Be an active member of either SPE or any professional collaborative organization (click here for a summary of participating collaborative organizations). Provide proof of active membership.

And possess a university degree equivalent to a 4-year bachelor’s degree in engineering or applied sciences or a 4-year degree in a field other than science or engineering and technical experience working in the energy sector and projects.

Or possess a 2-year science or engineering degree and technical experience working in the energy sector and projects.

https://www.spegcs.org/hiring-event/

SPEAKER: Wahid Rahman, Ph.D.

TOPIC: Organic Facies and Reservoir Characterization of Eagle Ford Shale as Determined by Stratigraphy, Source Rocks, and Oil Geochemistry

WHEN: Wednesday, April 10th, 11:30AM

WHERE: Petroleum Club, Suite #700

Dr. Wahid Rahman

BIOGRAPHY

Dr. Wahid Rahman is currently working as the Director of Geoscience and Laboratories at Impac Exploration Services, Houston Texas. Dr. Rahman has previously worked as Sr. Staff Scientist/Program Coordinator for CWQMN (Continuous Water Quality Monitoring Network) at Texas Commission on Environmental Quality (TCEQ), Austin, Texas; as Director of Research at Geoscience and Petroleum Research (GPR) Inc., Houston, Texas; as Chief Geochemist at Paladin Geological Services, Edmond, OK; as Geological Adviser at Ossidiana Energy, Denver, CO; Staff Geochemist at Pioneer Natural Resources, Irving, Texas; and as Sr. Geochemist at Devon Energy, Oklahoma City, OK. Dr. Rahman has 20+ years of industry, academic, and research experience in the field of geochemistry, petroleum systems analysis, basin modeling, environmental and aqueous geochemistry, and geology. He worked on most of the North American onshore unconventional and conventional petroleum plays/basins. Dr. Rahman's research interest includes organic geochemistry, basin modeling, environmental geochemistry, isotope geochemistry, surface geochemistry, conventional and unconventional resource play evaluation, HC migration pathway analysis, thermal maturity of organic matter (OM) and hydrocarbons (oil and gas), relationship between OM maturity versus Gas-to-Oil Ratio (GOR), pressure gradient, kerogen/OM density, brine water geochemistry to understand reservoir continuity, production allocation, reservoir geochemistry, and water resistivity (Rw), oil (So), gas (Sg) and water saturation (Sw). Wahid has over 50 conference presentations, papers, and peer reviewed journals (with more than 750 citations) in the field of geochemistry, environmental geochemistry, and geology. He received his Ph.D. in Organic Geochemistry from Southern Illinois University, Carbondale, IL; M.S. in Geology from Auburn University, Auburn, AL; M.S. and B.S. in Geology from University of Dhaka, Dhaka, Bangladesh.

Meeting Speaker

Organic Facies and Reservoir Characterization of Eagle Ford Shale as Determined by Stratigraphy, Source Rocks, and Oil Geochemistry

Wahid Rahman, Ph.D.

Director Geoscience, Impac Exploration Services, Houston, Texas

Abstract:

The source of the Cenomanian to Santonian petroleum systems across East and South Texas has been attributed to the Eagle Ford Shale play. However, little effort has been made to distinguish the relationship between the depositional settings, organic facies, oil families, and lithostratigraphic characteristics of the source rock. This study finds that there are significant variations in stratigraphy, reservoir type, and produced hydrocarbon chemistry between the South Texas Eagle Ford and the so-called East Texas Eagle Ford. The South Texas Lower Eagle Ford Shale reservoir facies is dominated by organic-rich, relatively low clay, foraminfera-rich, coccolith mudstones/marlstones, whereas the superficially equivalent source rocks in East Texas have a much more dominant terrestrial influence. In a regional reservoir modeling study at the confluence of East Texas and South Texas on the San Marcos Arch, the interplay of these depositional systems had to be accounted for to achieve reliable results. The model included analysis of cores from multiple counties combining detailed stratigraphic facies descriptions and petrophysical data from the base of the Austin Chalk to the Buda Formation. Source rock data is available from approximately 118 wells throughout this interval between the Austin Chalk and Buda. The dataset includes TOC, pyrolysis, and vitrinite reflectance data. Based on TOC analyses across the entire trend, the average TOC of the East Texas and South Texas Eagle Ford is 3.43%. Pyrolysis data and visual kerogen descriptions clearly show the South Texas Eagle Ford contains primarily Type II algae-rich oil prone kerogen. In contrast, the East Texas Eagle Ford contains type II kerogen with terrestrially derived mixed kerogen from the northeast. Thermal maturity in the Eagle Ford play area varies systematically with structure independent of the depositional systems from early oil generation to dry gas trending northwest to southeast. Produced oil geochemistry data from 70 oils include bulk molecular compositions, pristane/nC_{17}, Phytane/nC_{18}, Pristane/Phytane, C_{13} to C_{20} isoprenoids, saturate and aromatic carbon isotope compositions, sterane and hopane ratios. The geochemical data suggest that the oils from the South Texas Eagle Ford and East Texas Eagle Ford plays are generated from two distinct types of organofacies. One type is dominantly carbonate mudstone sourced in South Texas, and the other type is siliciclastic marine shale sourced in East Texas.

Future Speakers

May 16th ……………………………..…… Neil Bockoven

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AAPG Liaison	Tom Ewing	210-494-4526	tewing@frontieraexploration.com	
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