Nutrient and Sediment Monitoring of the Lower San Jacinto River

Final Report

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Abbreviations

$\delta^{15}N_{NO3}$	delta nitrogen-15/nitrogen-14 of nitrate
$\delta^{18}O_{NO3}$	delta oxygen-18/oxygen-16 of nitrate
µm	micron(s)
‰	per mil (parts per thousand)
A	area
ADCP	acoustic Doppler current profiler
ADVM	acoustic Doppler velocity meter
ASTM	American Society for Testing and Materials
CDT	Central Daylight Time
CST	Central Standard Time
dB	decibel(s)
EDI	equal discharge increments
ft/s	feet per second
ft^3/s	cubic feet per second
LED	light emitting diode
mg/L	milligrams per liter
mi^2	square mile(s)
mm	millimeter(s)
nm	nanometer(s)
NWIS	National Water Information System
NWQL	National Water Quality Laboratory
per mil	parts per thousand
QC	quality control
RPD	relative percent difference
$\overline{SCB}$	mean sediment corrected backscatter
Std.	standard
T&M	techniques and methods
TCEQ	Texas Commission on Environmental Quality
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey
UV	ultraviolet
V	velocity

Executive Summary

From 2018-2021, the U.S. Geological Survey, in cooperation with the Galveston Bay Estuary Program, conducted a project to collect sediment and nutrient data in freshwater inflow entering Galveston Bay from the San Jacinto River. This project aimed to continue data collection efforts started in 2011 to improve our understanding of freshwater inflow, and nutrient and sediment variability in inflow, from the San Jacinto River to Galveston Bay.

An acoustic Doppler velocity meter was installed at U.S. Geological Survey streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas” to collect velocity and backscatter data. The data collected from these discharge measurements will be used to develop an index-velocity rating that will provide five-minute streamflow data. Nutrient, suspended sediment, and isotope samples were also collected over a range of hydrologic conditions. These data can help characterize nutrients and sediment in the lower San Jacinto River and be used in future assessments on the variability of freshwater inflow into Galveston Bay.

Acoustic backscatter data from the acoustic doppler velocity meter were collected concurrently with water-quality samples to assess the feasibility of estimating a continuous record of suspended-sediment concentrations in the San Jacinto River. Due to limitations associated with the use of two acoustic doppler velocity meters and the small size of the dataset, additional data are needed to develop preliminary regressions. However, acoustic backscatter and discharge data continue to be collected by the acoustic doppler velocity meter and can potentially be used for future development of surrogate models for suspended-sediment concentrations.

The results from this project provide a high-quality dataset that can serve as the foundation for future assessments of nutrient and sediment inputs in freshwater inflow from the San Jacinto River into Galveston Bay. Data collected as part of this project will be used by the U.S. Geological Survey in planned studies in cooperation with the Texas Water Development Board. Future data collection efforts will focus on expanding a calibration dataset for surrogate models, collecting data over the entire range of hydrologic conditions observed in the lower reaches of the San Jacinto River, and expanding the dataset to obtain a better understanding of nitrate sources.

Introduction

The delivery of freshwater inflow plays an important role in the ecological productivity of bays and estuaries. Freshwater inflows into estuaries maintain salinity regimes and circulation patterns and deliver nutrients and sediments necessary to sustain the health of coastal ecosystems (Copeland, 1966; Longley, 1994). In Texas, the delivery of freshwater into estuaries is often affected by diversions and impoundments constructed for the purpose of providing flood control and water supplies. This results in efforts to define appropriate environmental flows that can sustain sound ecological environments in estuaries while allowing for human needs (Houston Advanced Research Center, 2020). Due to the variable and complex nature of estuaries on the Texas coast, defining environmental flows is a complicated process, often driven by system-specific conditions (Montagna and others, 2011), requiring both spatially and temporally distributed data on streamflow, nutrient, and sediment inputs over a range of hydrologic conditions.

Previous research conducted by the U.S. Geological Survey (USGS) in the Trinity River, the largest freshwater inflow to Galveston Bay, characterized and quantified freshwater volume, suspended sediment, and nutrients entering the estuary from the lower reaches of the Trinity River and developed a suspended sediment surrogate model to estimate suspended-sediment concentrations at 15-minute intervals (Lucena and Lee, 2017). The findings from this study improved the understanding of the processes driving the delivery of nutrients and sediment in freshwater inflow from the Trinity River to Galveston Bay. However, the Trinity River only provides a portion of freshwater inflows into Galveston Bay, resulting in the need to characterize the remaining sources of freshwater inflows to fully understand nutrient and sediment delivery into the estuary.

The San Jacinto River is the second largest inflow into Galveston Bay. The ability to accurately estimate the loads of sediment and nutrients entering Galveston Bay from the San Jacinto River watershed depends on accurate estimates of freshwater inflow and the concentrations of suspended sediment and nutrients associated with that inflow. Population and water demand are projected to continue to increase rapidly in the San Jacinto River watershed (Texas Water Development Board, 2019), underscoring the need for accurate streamflow, nutrient, and sediment load data. Available data on sediment and nutrient loads in the lower reaches of the San Jacinto River are scant, and all USGS streamflow gaging stations in the watershed are located upstream from Lake Houston. To obtain better estimates of the nutrients and sediment entering Galveston Bay from San Jacinto River, in 2011, the USGS, in cooperation with Galveston Bay Estuary Program, collected nutrient and sediment samples in the lower reaches of the San Jacinto River. Due to drought conditions, these samples did not capture high flow events, when most of the sediment and nutrient loads are transported to the estuary, limiting the findings from this project. This project aimed to continue data collection efforts to improve our understanding of freshwater inflow, and nutrient and sediment variability in inflow, from the San Jacinto River to Galveston Bay.

Project Significance and Background

Purpose and Scope

The purpose of this project was to establish datasets that can be used to improve our understanding of the variability of nutrient and sediment concentrations in freshwater inflow from the San Jacinto River into Galveston Bay. An index-velocity meter was installed at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas”, to obtain velocity data for future development of a discharge rating in the lower reaches of the San Jacinto River. Data from this index-velocity meter also were used to conduct a preliminary assessment on the potential for developing regression models based on surrogate parameters, such as acoustic backscatter. A dataset was also produced from nutrient and suspended-sediment samples collected in the lower San Jacinto River to assess variability in sediment and nutrient concentrations and sources over a range of hydrologic conditions.

Description of Study Area

The San Jacinto River, with a drainage area of approximately 3,200 mi^2, is the second largest watershed that drains into Galveston Bay. The upper San Jacinto River watershed is divided into two subwatersheds upstream from Lake Houston: the East Fork San Jacinto River and the West Fork San Jacinto River. The West Fork of the San Jacinto River feeds Lake Conroe in North Montgomery County, Texas, and then flows through the urbanized eastern side of the Greater Houston area into Lake Houston. The East Fork of the San Jacinto River has its headwaters in Walker County, Texas, just north of the Sam Houston National Forest and flows through Liberty and Montgomery Counties before its confluence with the West Fork in Lake Houston (Fig. 1). Below Lake Houston, the San Jacinto flows in one main channel and astronomical tides control daily flow patterns. This project is focused on USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas” (Fig. 1) which is the lowermost USGS streamflow gaging station on the San Jacinto River and is located approximately four river miles downstream from the Lake Houston spillway.

Figure 1. Map showing San Jacinto River watershed and the location of USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.”

Methods

Installation of the ADVM

Amendment 3 of the original contract between TCEQ and USGS modified this study to install an acoustic doppler velocity meter (ADVM) at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.” Application of the index-velocity method for computing continuous records of discharge has become increasingly common, especially since the introduction of low-cost ADVMs in 1997. Computing discharge using the index-velocity method differs from the traditional stage-discharge method by separating velocity and area into two ratings—the index velocity rating and the stage-area rating. The outputs from each of these ratings, mean channel velocity (*V*) and cross-sectional area (*A*), are then multiplied together to compute a discharge. For the index velocity method, *V* is a function of such parameters as stream velocity, stage, cross-stream velocity, and velocity head, and *A* is a function of stage and cross-section shape. The index-velocity method can be used at locations where stage-discharge methods are used, but it is especially appropriate when more than one specific discharge can be measured for a specific stage (Levesque and Oberg, 2012), such as for tidally-affected waterways like the lower San Jacinto River. USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas” had been previously equipped with a gagehouse and a stage sensor. The addition of an ADVM will allow the USGS to compute the streamflow at this site at 5-minute intervals once an index-velocity rating is developed. Continuation of the rating development beyond this project and future operation and maintenance of this station will be funded by the Harris County Flood Control District.

Streamflow Measurements

Discrete discharge measurements were made at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas” over a range of hydrologic conditions to evaluate temporal variability of streamflow and start building a dataset for the development of an index-velocity rating. Discharge measurements were made using an acoustic Doppler current profiler (ADCP) following standard USGS protocols as described in Mueller and Wagner (2009).

Water-Quality and Suspended Sediment Sampling

From October 2018–March 2021, 11 discrete water quality samples were collected over a range of hydrologic conditions at the San Jacinto River site. Samples were analyzed for suspended sediment concentration, total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite, nitrite, ammonia, total phosphorus, orthophosphate, dissolved organic carbon, total organic carbon, and ultraviolet (UV)-absorbing organic constituents. A sand-fine separation was done to determine the amounts of sand-sized suspended sediment (greater than 0.0625 and less than or equal to two millimeters [mm]) and fine-sized suspended sediment (less than or equal to 0.0625 mm) (Guy, 1969). Amendment 2 of the original Joint Funding Agreement modified this study to include the analysis of nitrogen and oxygen isotopes of nitrate. If nitrate concentrations were determined to be above

0.060 milligrams per liter (mg/L), samples were analyzed for the delta nitrogen-15/nitrogen-14 ($\delta^{15}N$) and delta oxygen-18/oxygen-16 ($\delta^{18}O$) of nitrate.

Water quality samples were collected in accordance with guidelines described in the USGS National Field Manual (U.S. Geological Survey, variously dated). Suspended-sediment samples were collected in accordance with USGS methods described in Edwards and Glysson (1999). During the collection of water quality and sediment samples, a multiparameter water quality sonde was used in the field to measure the dissolved oxygen concentration, pH, specific conductance, water temperature, and turbidity. Water quality and suspended-sediment samples were collected from a boat by either the equal discharge increment (EDI) or the multiple grab sample method (Edwards and Glysson, 1999; U.S. Geological Survey, variously dated). When measured mean water velocity exceeded 1.5 feet per second (ft/s), EDI samples were collected using a cable-suspended US DH–2 sampler after dividing a cross-section into five sections, each representing equal volumes of stream discharge. The EDI method allowed the collection of an isokinetic depth-integrated sample that represents the discharge-weighted concentrations of the stream cross-section being sampled. When the measured mean water velocity was less than 1.5 ft/s, non-isokinetic grab samples were collected at the center of five equal width sections using a weighted bottle sampler (U.S. Geological Survey, variously dated). Of the 11 collected samples, two were collected with the EDI method.

Water quality and suspended-sediment samples for each vertical were composited in a polyethylene churn splitter and sub-samples for unfiltered constituents were transferred into sample bottles while mixing at a constant rate. Water quality samples for dissolved nutrients analysis were filtered using a 0.45-micron (μm) pore size capsule filter and decanted into sample bottles. Samples for isotopic analysis were filtered through two filters with pore sizes of 0.45 μm and 0.20 μm.

Analytical Methods

Samples for suspended-sediment concentration, sand-fine separation analysis, and full particle-size distribution analysis were shipped to the USGS Kentucky Water Science Center Sediment Laboratory in Louisville, Kentucky. Methods for sediment sample analyses are documented in Guy (1969). Samples for nutrient analysis were preserved, chilled, and shipped overnight to the National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Samples were analyzed for nutrients and sediment using USGS-approved methods. The analysis method and method detection level for each constituent are provided in Table 1. Water quality data are stored in the National Water Information System (NWIS) database in accordance with USGS protocols.

Table 1. Analytes measured, sample treatment and preservation, analytical methods, and reporting limits for samples collected at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.”

Constituent	Sample treatment and preservation method(s)	Analyzing laboratory	Analytical method(s)	Method number	Method detection limit (mg/L)	Analytical Method Reference
Ammonia	0.45 µm filter	USGS NWQL, Lakewood, CO	Salicylate-hypochlorite reaction and colorimetry, discrete analyzer	USGS I-2522-90	0.01	Fishman (1993)
Nitrite	0.45 µm filter	USGS NWQL, Lakewood, CO	Diazotization and colorimetry, discrete analyzer	USGS I-2540-90	0.001	Fishman (1993)
Nitrate plus nitrate	0.45 µm filter	USGS NWQL, Lakewood, CO	Enzymatic reduction, Griess Reaction colorimetry, automated discrete analyzer	USGS I-2547-11	0.04	Patton and Kryskalla (2011)
Total nitrogen	H_2SO4	USGS NWQL, Lakewood, CO	Alkaline-persulphate digestion and colorimetry, continuous flow analyzer	USGS I-4650-03	0.05	Patton and Kryskalla (2003)
Total Kjeldahl nitrogen	H_2SO4	USGS NWQL, Lakewood, CO	Semi-automated block digestion and colorimetry, continuous flow analyzer	USGS I-2515-91	0.07	Patton and Truitt (2000)
Orthophosphate	0.45 µm filter	USGS NWQL, Lakewood, CO	Phosphomolybdate formation and colorimetry, discrete analyzer	USGS I-2601-90	0.004	Fishman (1993)
Total phosphorus	H_2SO4	USGS NWQL, Lakewood, CO	Acid-persulphate digestion and colorimetry, continuous flow analyzer	USEPA 365.1	0.004	United States Environmental Protection Agency (1993)
Total organic carbon	None	USGS NWQL, Lakewood, Colo.	High-temperature combustion	Std. Methods 5310B	0.7	Rice and others (2017)

Constituent	Sample treatment and preservation method(s)	Analyzing laboratory	Analytical method(s)	Method number	Method detection limit (mg/L)	Analytical Method Reference
Dissolved Organic carbon	H_2SO4, 0.45 µm filter	USGS NWQL, Lakewood, CO	High-temperature combustion	Standard Method 5310B	0.23	Rice and others (2017)
Ultraviolet absorbing organic constituents - 254 nm	None	USGS NWQL, Lakewood, CO	UV absorption by spectrophotometer	Standard Method 5910	0.005	Rice and others (2017)
$\delta^{15}N$	0.45 µm filter, 0.20 µm filter, frozen	USGS RISL, Reston, VA	Conversion of nitrate to nitrous oxide and mass spectrometry	USGS T&M 10-C17	-1.8	Coplen and others (2012)
$\delta^{18}O$	0.45 µm filter, 0.20 µm filter, frozen	USGS RISL, Reston, VA	Conversion of nitrate to nitrous oxide and mass spectrometry	USGS T&M 10-C17	-27.9	Coplen and others (2012)
Suspended-sediment less than or equal to 0.062 mm, sieve diameter	None	Sediment Lab-USGS Kentucky Science Center, Louisville, KY	Wet sieve	ASTM D3977-97	1	Guy (1969)
Suspended-sediment concentration	None	Sediment Lab-USGS Kentucky Science Center, Louisville, KY	Evaporation of material from sediment size analysis	ASTM D3977-97	1	Guy (1969)

Quality Control

To ensure proper interpretation of water quality data, quality control (QC) information is needed to estimate the bias variability that results from sample collection, sample processing, transportation, and laboratory analysis (Mueller and others, 2015). QC samples were collected as described in USGS (variously dated) and analyzed by the same laboratories and methods as the environmental samples.

Replicates

Split replicates were collected and prepared by dividing a single volume of water into multiple samples to provide a measure of the variability of sample processing and analysis. A total of three field split replicates were collected as part of this project. Replicate samples were compared by computing relative percent differences (RPD. The larger the RPD, the greater the variability in sample-replicate pairs. RPDs for each analyte and replicate sample pair were calculated by the following equation (Crain, 2006):

$$RPD = \frac{|S_1 - S_2|}{\frac{S_1 + S_2}{2}} x\ 100$$

where,

S_1 = the concentration in the environmental sample, in milligrams per liter

S_2 = the concentration in the replicate sample, in milligrams per liter

If the RPD of replicate samples was within 20%, then the data from the environmental samples were determined to meet the precision objectives of the project.

Field and Equipment Blanks

A field blank consists of deionized water that is taken to the field and poured into the sample container. Field blanks are not routinely required but are used to assess the contamination from field sources such as airborne materials, containers, and preservatives. One field blank was collected as part of this project.

Equipment blanks test the amount of potential contamination to water samples from equipment used to collect or process the samples. It consists of a sample of reagent water that is poured into or over a sampling device, compositing container, or filtering apparatus. The equipment blank is collected in the same type of container as the environmental sample, preserved in the same manner and analyzed for the same parameter. One equipment blank was collected as part of this project. The analysis of field and equipment blanks should yield values lower than the reporting limit.

Acoustic Backscatter Data Collection

Although ADVMs are primarily used to measure water velocity, the acoustic backscatter measured by ADVMs makes them useful for computing suspended-sediment concentrations in streams. Acoustic backscatter increases as more particles are suspended in the water, reflecting the acoustic pulse emitted by the ADVM (Wood and Teasdale, 2013; Landers and others, 2016). Regression equations that contain acoustic backscatter, turbidity, or streamflow can be used to compute suspended-sediment concentrations at a high temporal resolution (typically every 15 minutes), providing an advantage over discrete suspended-sediment concentration samples.

Acoustic backscatter data was collected from a temporarily mounted ADVM (prior to the installation of the ADVM at the San Jacinto River site) or from the permanently mounted ADVM. The raw measured acoustic backscatter data for each cell in the sample volume requires corrections for beam spreading and for acoustic attenuation as the sound signal is transmitted through the water and sediment (Landers and others, 2016). Raw measured acoustic backscatter (as signal-to-noise-ratio) for each cell was corrected and averaged using methods described in Landers and others (2016). Data corrections produce a sediment corrected backscatter value, which is determined for each measurement in the dataset.

Before the permanent installation of the ADVM in August 2020, a SonTek SL-1500 ADVM was temporarily installed in the San Jacinto River at the time of sampling. Even though care was taken to install the ADVM at in the same location and depth for every sample to reduce variability in velocity and backscatter readings, the location and position of the ADVM in the water column varied slightly during each deployment. The permanent installation of SonTek SL-1500 (3G) ADVM at a fixed location provides more comparable readings among samples. Because the permanent installation of an ADVM requires a sampled zone appropriate for the entire range of hydrologic conditions, the configuration of each ADVM was also different. The configuration of each ADVM is included (Table 2). Due to limited comparability between ADVM models and sampling locations, the acoustic backscatter data was separated into two datasets, one for each ADVM.

Table 2. Configuration of ADVM meters installed at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Parameter	Temporary SL-1500	Permanent SL-1500 (3G)
Frequency (megahertz)	1.5	1.5
Blanking distance (meters)	3.05	2.00
Cell size (meters)	3.05	1.80
Number of cells	5	10

Results and Observations

Installation of the ADVM

An ADVM was installed at the USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas" on August 19, 2020. This ADVM was installed in accordance with USGS standards and practices and with additional assistance from the Harris County Flood Control District. The data from this ADVM, including velocity data, are available on the NWIS website[1]. This stream gage may be a useful tool in future assessments of freshwater inflow and sediment and nutrient loading from the San Jacinto River into Galveston Bay. Photos of the installation are included in Figs. 2 and 3.

Streamflow, Nutrients, and Suspended Sediment

A total of 11 nutrient and sediment samples were collected as part of this project. Samples were collected at flows ranging from -1,650 to 36,900 cubic feet per second (ft^3/s). Results from measured streamflow measurements, field properties, and nutrient concentrations are included in Tables 3 and 4.

Results from field replicate samples, field blanks, and equipment blanks are included in Tables 5 and 6. Replicate variability was less than 20% for most parameters in all samples. For a sample collected on September 24, 2020, the relative percent difference was 28.6% for suspended sediment smaller than 0.0625 mm and 96.8% for suspended-sediment concentration. An error during sample mixing while pouring from the churn into sample bottles could have caused suspended-sediment results to be higher in the

[1] waterdata.usgs.gov/nwis/uv?site_no=08072050

environmental sample than in the replicate sample. If a higher amount of sediment was removed from the churn for the environmental sample, then the replicate sample results are likely erroneous as well. Because of data quality concerns, sediment results from these samples were rejected as they did not meet criteria established for this project.

Field blank and equipment blank results were below the laboratory reporting level for all parameters and met the quality assurance criteria established for this project.

Figure 2. USGS personnel installing the ADVM at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.”

Figure 3. USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Table 3. Results from field properties measured at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas”, October 2018 – March 2021.

Sample Date	Sample Time	Time Zone	Discharge, instantaneous, cubic feet per second	Dissolved oxygen, water, unfiltered, milligrams per liter	pH, water, unfiltered, field, standard units	Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	Temperature, water, degrees Celsius	Turbidity, water, unfiltered, monochrome near infrared LED light source, 780-900 nm, detection angle 90 +-2.5 degrees, formazin nephelometric units
10-18-2018	11:45	CDT	1,650	7.5	7.6	221	22.4	15
12-12-2018	13:00	CST	23,400	10.9	6.8	99	11.9	100
05-10-2019	12:15	CDT	36,900	--	--	--	--	--
06-25-2019	11:00	CDT	9,630	7.5	7.6	196	28.5	28
08-20-2019	11:00	CDT	-1,410	7.9	8.1	218	31.9	13
03-18-2020	10:00	CDT	-292	9.5	8.5	352	20.9	12
06-18-2020	10:45	CDT	-121	5.8	7.8	277	30.3	18
07-22-2020	09:30	CDT	-1,650	4.8	7.4	226	30.2	12
09-24-2020	09:15	CDT	11,100	7.9	7.7	256	24.8	20
11-03-2020	11:15	CST	1,110	11.4	8.6	2,560	19.7	5.3
03-04-2021	09:45	CST	-21	10.8	7.6	240	13.6	46

Table 4. Results from nutrient and sediment samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas", October 2018 – March 2021.

Sample Date	10/18/2018	12/12/2018	5/10/2019	6/25/2019	8/20/2019	3/18/2020	6/18/2020	7/22/2020	9/24/2020	11/3/2020	3/4/2021
Sample Time	11:45	13:00	12:15	11:00	11:00	10:00	10:45	9:30	9:15	11:15	9:45
Discharge, instantaneous, cubic feet per second	1,650	23,400	36,900	9,630	-1,410	-292	-121	-1,650	11,100	1,110	-21
Absorbance, 254 nm, water, filtered, absorbance units per centimeter	0.169	0.34	0.326	0.328	0.171	0.176	0.186	0.2	0.165	0.147	0.281
Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as nitrogen	0.18	0.01	0.08	<0.01	<0.01	0.04	0.05	0.09	0.09	0.03[n]	<0.02
Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	0.89	0.81	0.79	0.75	0.94	0.56	0.76	0.85	1	0.89	0.78
Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	0.276	0.193	0.245	0.384	<0.040	0.713	<0.040	0.152	0.060[n]	0.248	1.22
Nitrite, water, filtered, milligrams per liter as nitrogen	0.044	0.005	0.011	0.002[n]	<0.001	0.013	0.006	0.026	0.017	0.101	0.005

Sample Date	10/18/2018	12/12/2018	5/10/2019	6/25/2019	8/20/2019	3/18/2020	6/18/2020	7/22/2020	9/24/2020	11/3/2020	3/4/2021
Orthophosphate, water, filtered, milligrams per liter as phosphorus	0.13	0.039	0.06	0.121	0.114	0.066	0.076	0.138	0.122	0.106	0.211
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	0.18	0.15	0.15	0.19	0.15	0.13	0.14	0.19	0.23	0.16	0.3
Organic carbon, water, filtered, milligrams per liter	4.96	7.54	6.67	7.57	5.61	5.72	6.14	6.07	5.1	5.07	6.39
Organic carbon, water, unfiltered, milligrams per liter	7.5	--	10.6	10.4	8.1	8.1	9	7.8	8.3	7	9.8
Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters	100	98	95	92	96	94	96	95	--	84	89
Suspended sediment concentration, milligrams per liter	18	122	104	30	18	24	28	23	--	54	55

n, below the reporting level but at or above the detection level--, no data

Table 5. Results from replicate sample pairs collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Parameter Name	5/10/2019			9/24/2020			3/4/2021		
	Environmental Sample	Replicate Sample	RPD	Environmental Sample	Replicate Sample	RPD	Environmental Sample	Replicate Sample	RPD
Absorbance, 254 nm, water, filtered, absorbance units per centimeter	0.326	0.299	8.6	0.165	0.161	2.5	0.281	0.246	13.3
Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as nitrogen	0.08	0.08	0.0	0.09	0.09	0.0	<0.02	<0.02	--
Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	0.79	0.78	1.3	1.0	0.92	8.3	0.78	0.82	5.0
Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	0.245	0.248	1.2	0.060	0.062	3.3	1.22	1.29	5.6
Nitrite, water, filtered, milligrams per liter as nitrogen	0.011	0.012	8.7	0.017	0.017	0.0	0.005	0.005	0.0
Orthophosphate, water, filtered, milligrams per liter as phosphorus	0.060	0.059	1.7	0.122	0.123	0.8	0.211	0.223	5.5
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	0.15	0.16	6.5	0.23	0.23	0.0	0.30	0.31	3.3
Organic carbon, water, filtered, milligrams per liter	6.67	6.61	0.9	5.10	5.15	1.0	6.39	6.4	0.2
Organic carbon, water, unfiltered, milligrams per liter	10.6	10.9	2.8	8.3	8.7	4.7	9.8	9.9	1.0

Parameter Name	5/10/2019			9/24/2020			3/4/2021		
	Environmental Sample	**Replicate Sample**	**RPD**	**Environmental Sample**	**Replicate Sample**	**RPD**	**Environmental Sample**	**Replicate Sample**	**RPD**
Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters	95	91	4.3	88	66	28.6	89	90	1.1
Suspended sediment concentration, milligrams per liter	104	98	5.9	69	24	96.8	55	57	3.6

--, no data

Table 6. Results from blank samples collected to detect and quantify bias in samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Parameter name	Equipment Blank	Field Blank
	6/4/2018	7/22/2020
Absorbance, 254 nm, water, filtered, absorbance units per centimeter	<0.005	<0.005
Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as nitrogen	<0.01	0.01n
Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	--	<0.07
Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	<0.040	<0.040
Nitrite, water, filtered, milligrams per liter as nitrogen	<0.001	0.002n
Orthophosphate, water, filtered, milligrams per liter as phosphorus	<0.004	<0.004
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	<0.004	<0.02
Organic carbon, water, filtered, milligrams per liter	<0.23	0.42n
Organic carbon, water, unfiltered, milligrams per liter	<0.7	<0.7
Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters	--	--
Suspended sediment concentration, milligrams per liter	--	--

n, below the reporting level but at or above the detection level

--, sample not collected

Variability of nutrient and sediment concentrations over the range of hydrologic conditions sampled during this project are shown in Figures 4 through 7.

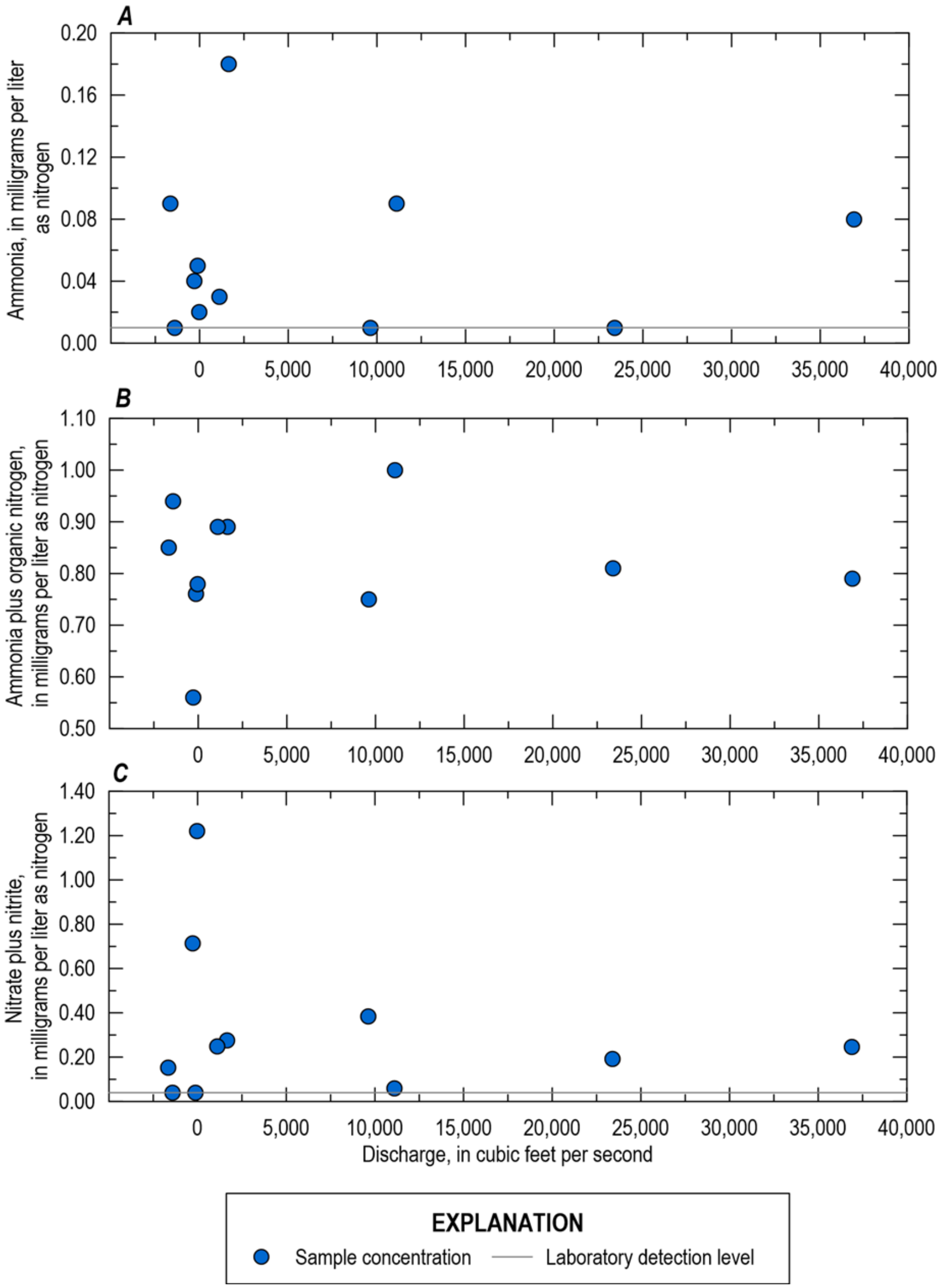

Figure 4. Concentrations of ammonia (A), ammonia plus organic nitrogen (B), and nitrate plus nitrite (C) with their associated discharges for samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas" from 2018-2021.

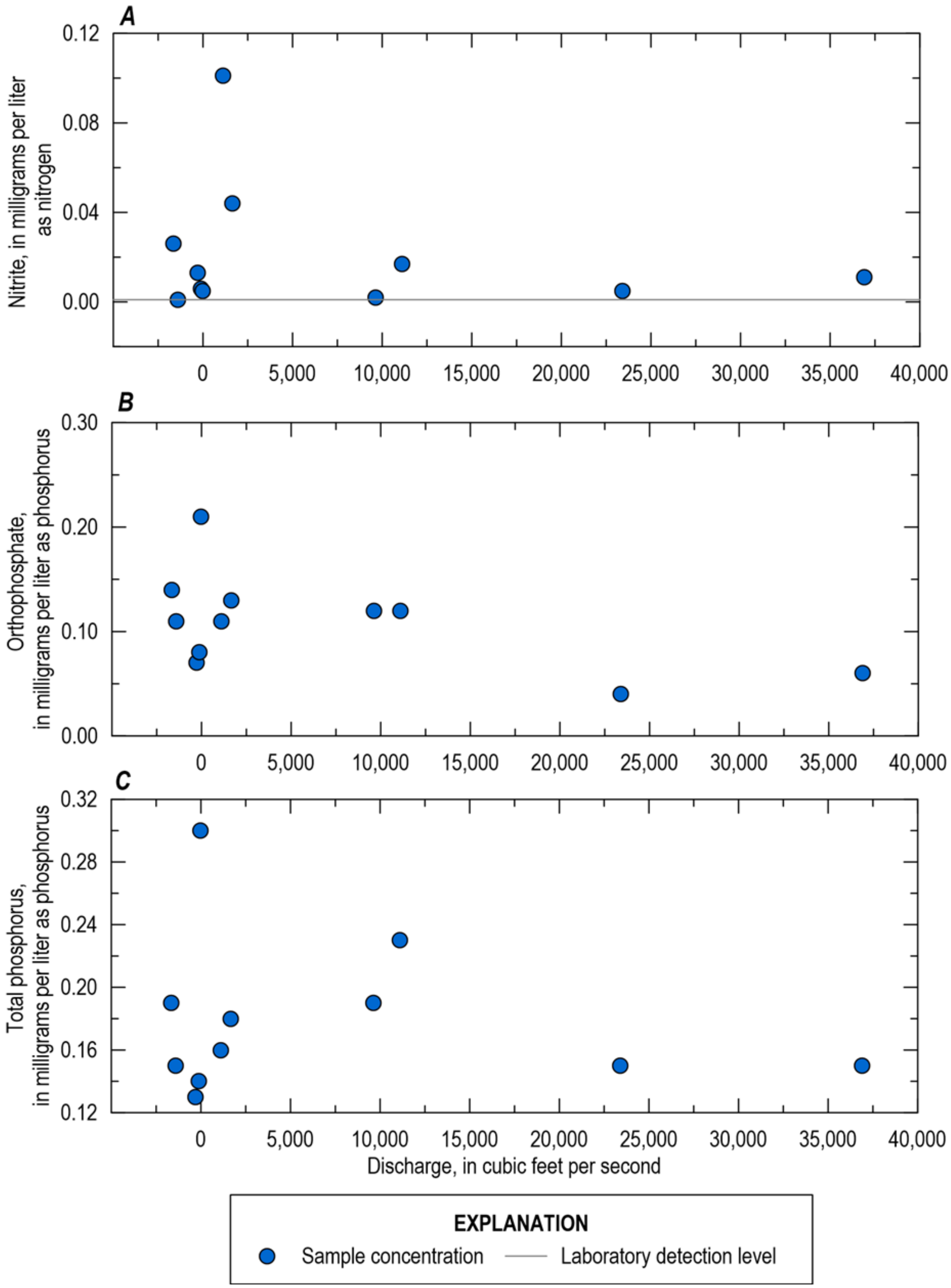

Figure 5. Concentrations of nitrite (A), orthophosphate (B), and total phosphorus (C) with their associated discharges for samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas" from 2018-2021.

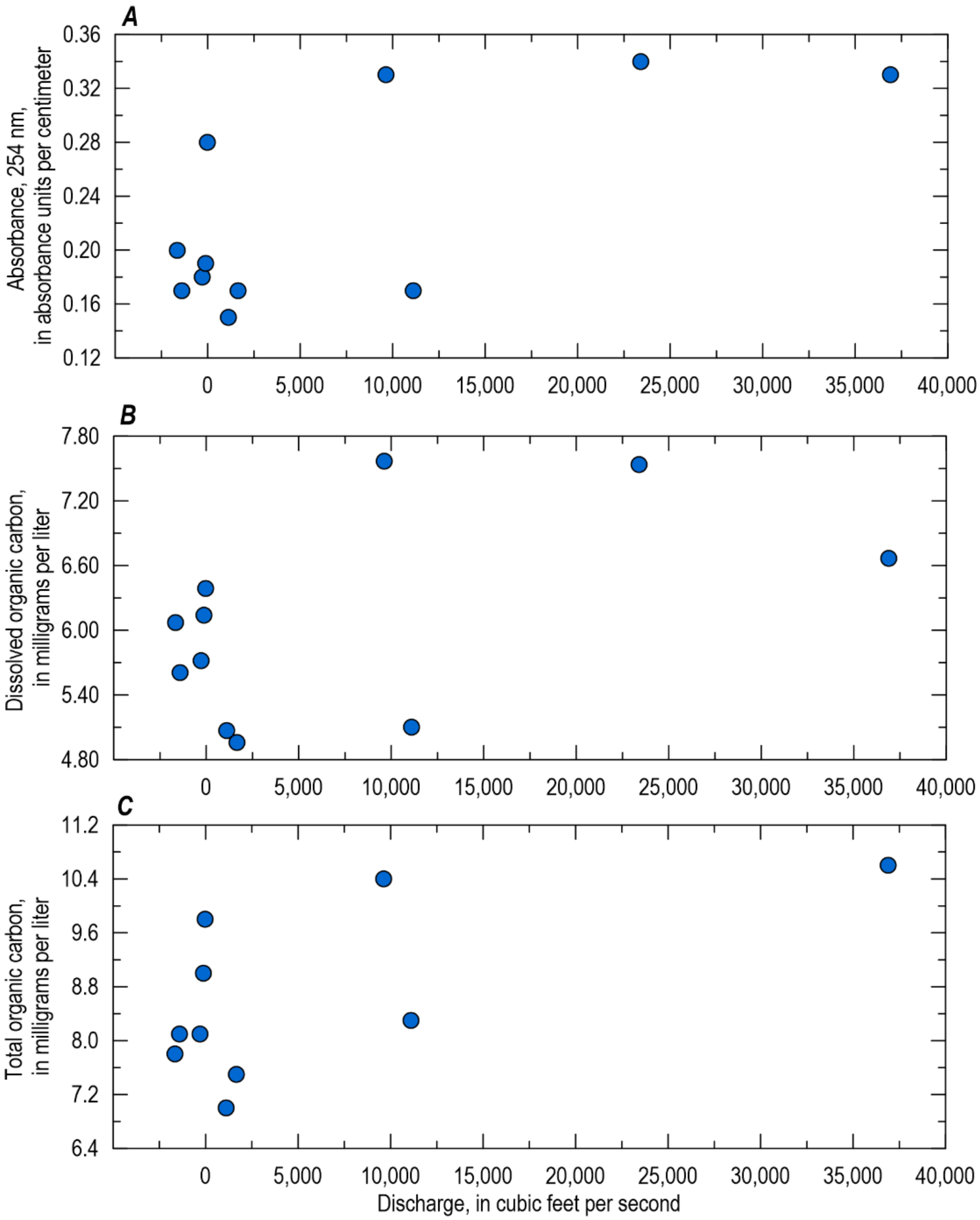

Figure 6. Results of absorbance at 254 nm (A), dissolved organic carbon (B), total organic carbon (C), with their associated discharges from samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas" from 2018-2021.

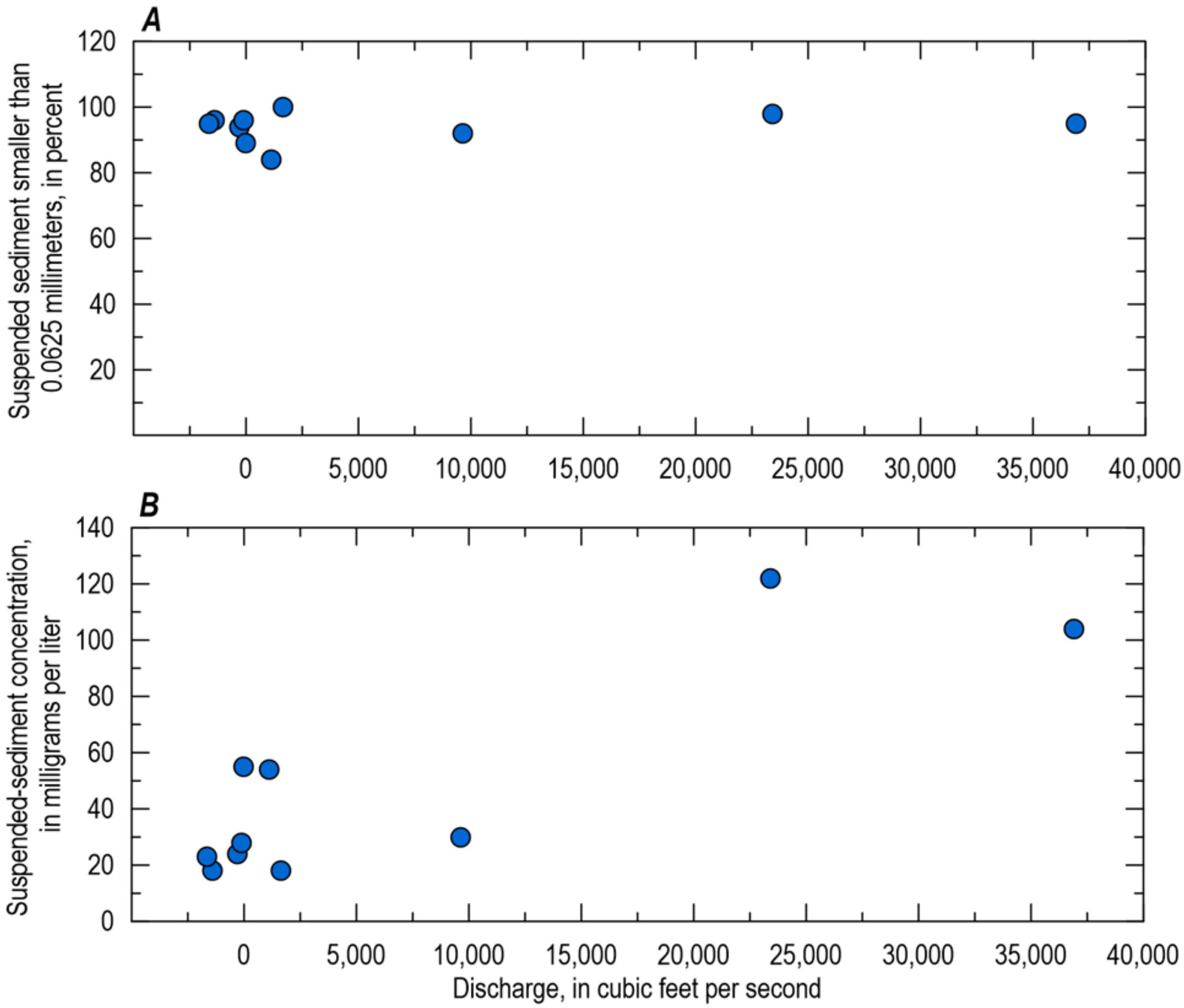

Figure 7. Results of suspended-sediment smaller than 0.0625 mm (A) and suspended-sediment concentrations (B) from samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas" from 2018-2021.

Acoustic Backscatter

Acoustic backscatter, as signal-to-noise ratio, was measured by the ADVM during sample collection. The dataset consists of a total of nine observation pairs. Backscatter data are not available for the sample collected June 18, 2020, due to a manufacturer's defect on the SL-1500 (3G) ADVM which required a major repair. Suspended-sediment data also are not available for the sample on September 24, 2019, due to data quality concerns (see the Quality Control section).

Upon evaluation of acoustic backscatter data, it was discovered that during some periods, particularly those with low suspended-sediment concentrations, the water corrected backscatter increased with the range of the ADVM. Because this is not physically possible, use of this data in calculations would have resulted in erroneous estimates of sediment attenuation. During these periods, acoustic backscatter in the outer cells may have been erroneous because it could not be distinguished from the instrument noise floor (Landers and others, 2016; Wood and Teasdale, 2013). USGS will continue evaluating other potential reasons for this issue and explore additional solutions, such as evaluating ADVM configuration and reducing cell size. When this occurred in this project, the cells were discarded from the calculation of sediment attenuation. Only cells along the decreasing trend of the line, representing data corrected for beam spreading and acoustic absorption by water, were used to calculate sediment attenuation.

Mean sediment corrected backscatter ($\overline{SCB}$) from samples collected as part of this project ranged from 52.7 to 73.2 decibels (dB). Suspended-sediment concentrations ranged from 18 to 122 mg/L (Table 7). In general, $\overline{SCB}$ increased slightly with suspended-sediment concentrations (Fig. 8), a pattern consistent with the acoustic theory associated with the acoustic index method (Landers and others, 2016). However, because a reduced number of suspended-sediment samples were collected to allow for the installation of the permanent ADVM, the dataset available for this preliminary evaluation has various limitations. For five out of the nine samples, the suspended-sediment concentrations were relatively low (<30 mg/L), resulting in a dataset that does not entirely represent the variability in suspended-sediment concentrations observed at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.” The range of $\overline{SCB}$ since installation of the permanent ADVM was 43.6 to 103.7 dB, also a range that is not entirely represented in this dataset. Another limitation of this dataset is that because two ADVMs with different configurations were used for backscatter measurements, data from each ADVM must be evaluated separately, resulting in smaller datasets inappropriate for establishing statistical relations.

Table 7. Suspended-sediment concentration and mean sediment corrected backscatter observation pairs from samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Instrument used	Sample sate	Suspended sediment concentration, milligrams per liter	log10 of suspended sediment concentration	$\overline{SCB}$, in decibels
Temporarily mounted ADVM	10-18-2018	18	1.26	61.0
	12-12-2018	122	2.09	63.2
	05-10-2019	104	2.02	73.2
	06-25-2019	30	1.48	70.5
	08-20-2019	18	1.26	52.7
	03-18-2020	24	1.38	68.7
Permanent ADVM	06-18-2020	28	1.45	--
	07-22-2020	23	1.36	70.7
	09-24-2020	--	1.84	72.3
	11-03-2020	54	1.73	65.9
	03-04-2021	55	1.74	65.9

--, no data

For acoustic surrogates, to ensure the technique has been applied appropriately, a review that includes an assessment of the theoretical soundness, the adequacy of the model calibration dataset, and the quality of the regression model and regression diagnostic is required (Landers and others, 2016). The limitations in the dataset developed for this project require that additional data be collected to fully determine if a regression model can be developed using backscatter and suspended-sediment concentration data. In particular, data collected at backscatter levels below 50 dB, between 55 and 60 dB, and above 75 dB are needed. The USGS will continue collecting these data in cooperation with the Texas Water Development Board and the Harris County Flood Control District. If, upon collection of additional samples, it is determined that backscatter data are not appropriate to use as a surrogate for suspended-sediment concentrations in a regression model at this location, the potential of using other variables (or a combination of variables) from the index-velocity meter, such as discharge, may be evaluated. The dataset collected as part of this project will be used in any future evaluations of ADVM derived data as a surrogate for suspended-sediment concentrations.

Isotope Data

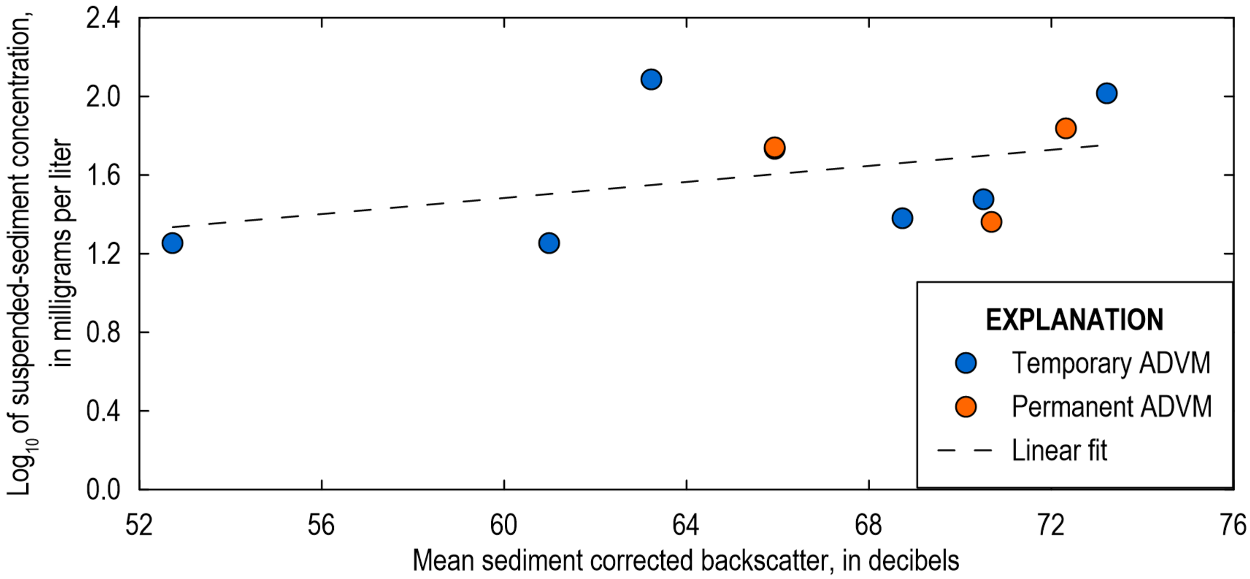

Figure 8. Graph showing the relation between mean sediment corrected backscatter and the $\log_{10}$ of suspended sediment concentration at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Stable isotopes of nitrate have been used as environmental tracers for examining sources of nitrate (Chang and others, 2002; McSwain and others, 2014). Isotopic analysis of nitrate can aid in distinguishing atmospheric and synthetic fertilizer sources from organic fertilizer (animal manure) and septic sources. Isotopic analyses can also provide information on geochemical influences on nitrate in surface water, such as denitrification.

A total of eight samples were collected for isotopic analysis. Of the eight samples, only five had nitrate concentrations over 0.06 mg/L as nitrogen, the minimum concentration needed in a sample to complete this analysis while maintaining a reasonable level of uncertainty. Results from isotope samples are included in Table 8. Values for $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ ranged from +5.58 to +16.72 parts per thousand (‰) and 1.44 to +17.68‰, respectively.

Table 8. Results from isotopic analysis of nitrogen and oxygen isotopes of nitrate in samples collected at USGS streamflow gaging station "08072050 San Jacinto River near Sheldon, Texas."

Date	Season	Hydrologic condition	Nitrate, in milligrams per liter as N	delta nitrogen-15/nitrogen-14 of nitrate, water, filtered, per mil	delta oxygen-18/oxygen-16 of nitrate, water, filtered, per mil
05-10-2019	Spring	Stormflow	0.234	5.58	17.68
08-20-2019	Summer	Baseflow	<0.0398[a]	--	--
03-18-2020	Winter	Baseflow	0.700	16.72	11.62
06-18-2020	Spring	Baseflow	<0.039[a]	--	--
07-22-2020	Summer	Baseflow	0.126	6.84	0.35
09-24-2020	Autumn	Stormflow	0.043[a]	--	--
11-03-2020	Autumn	Baseflow	0.147	10.30	-1.44
03-04-2021	Winter	Baseflow	1.215	10.11	5.81

--, no data

a, nitrate result too low for isotopic analysis

Common fields of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values derived from typical source signatures, as defined by Kendall and others (2007), are displayed in Figure 9. Boxes outlined in the graph indicate likely sources of nitrate, assuming there has been minimal cycling of nitrogen. Source identification is affected by various factors. If mixing between water from two or more nitrate sources occurs, isotope values may plot between the typical source boxes. For example, after a rain event, nitrate from precipitation and natural soil may mix, causing values to plot outside the source boxes. Additionally, in situ microbial transformation processes, such as denitrification, can cause the values of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ to increase through the loss of ^{14}N and ^{16}O due to fractionation, complicating source determination (Kendall and others, 2007). The results from $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$collected as part of this project and their potential sources of nitrogen are shown in Figure 9. Four of the five samples plotted inside defined isotope source boxes as defined by Kendall and others (2007). Three of these samples fell within the manure and septic waste source box. One sample, collected on July 22, 2020, fell within the nitrification of soil nitrogen source box.

Due to an unexpected small number of isotope samples that had nitrate concentrations high enough (greater than 0.06 mg/L) for isotope analysis, seasonal variability comparisons cannot be made as not all seasons are represented in baseflow samples. The USGS will continue collecting isotope samples in a future project in cooperation with the Texas Water Development Board to expand this dataset and have the ability to assess seasonal variability of nitrate sources in the lower San Jacinto River.

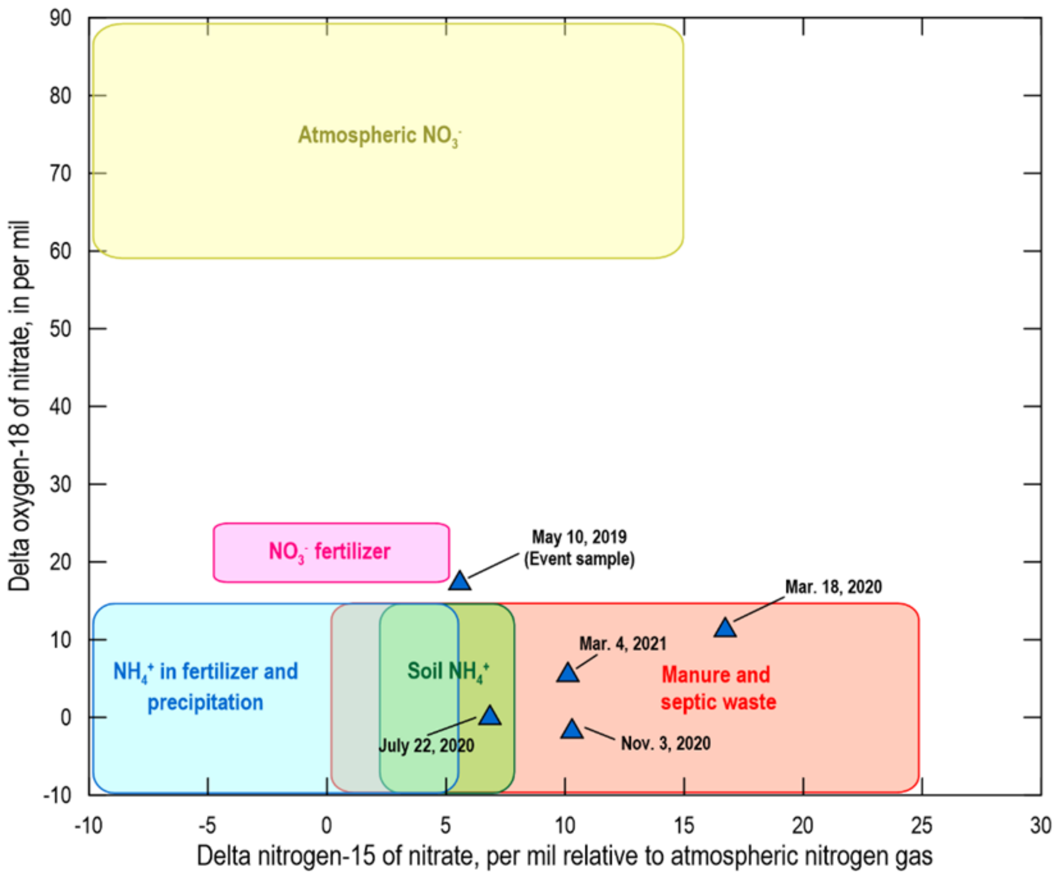

Figure 9. Nitrogen-15 and oxygen-18 isotope results and potential sources of nitrogen from samples collected at USGS station "08072050 San Jacinto River near Sheldon, Texas."

Discussion

Future Considerations and Lessons Learned

The original objectives of this project were affected by a lack of high-flow events on the San Jacinto River. Flow events of various magnitudes would have provided a more representative dataset of hydrologic conditions. However, the samples collected still include a range of high-flow events that should be useful for future research to obtain a better understanding of freshwater inflow and nutrient and sediment input from the San Jacinto River into Galveston Bay.

Due to limited sampling opportunities resulting from a lack of high-flow events, the scope of the project was changed to allow for the installation of the ADVM at USGS streamflow gaging station “08072050 San Jacinto River near Sheldon, Texas.” This streamgage, which will provide streamflow data at 5-minute intervals upon development of an index-velocity rating, will continue to be an essential tool in future assessments of freshwater inflow into Galveston Bay. The nutrient, sediment, and isotope data collected as part of this project will also serve as the foundation for future assessments of nutrient and sediment variability in freshwater inputs from the San Jacinto River into Galveston Bay.

In the future, the USGS will continue collecting these streamflow and water quality data in cooperation with the Harris County Flood Control District and the Texas Water Development Board with the purpose of continuing to improve our understanding of freshwater inflows into Galveston Bay. Future data collection efforts will focus on expanding a calibration dataset for surrogate models, collecting data over the entire range of hydrologic conditions observed in the lower reaches of the San Jacinto River, and expanding the dataset to obtain a better understanding of nitrate sources.

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Appendix A. Conversion Factors

Inch/Pound to International System of Units (SI)

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
Area		
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
cubic foot (ft^3)	0.02832	cubic meter (m^3)
Flow rate		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (˚C) may be converted to degrees Fahrenheit (˚F) as follows:

˚F=(1.8×˚C)+32

Temperature in degrees Fahrenheit (˚F) may be converted to degrees Celsius (˚C) as follows:

˚C=(˚F-32)/1.8

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 ˚C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).