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Determination of Freshwater Inflow Volume from the Trinity River into Galveston Bay, May 2014 – August 2015

U.S. Department of the Interior
U.S. Geological Survey

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Introduction

The movement of water into and throughout the shallow estuaries and bays along the Texas Gulf Coast are governed by a number of factors, including freshwater inflows, prevailing winds, and tidal currents. Periods of high flow in streams and rivers flowing into a coastal ecosystem are usually caused by local rainfall or releases from upstream reservoirs made in response to rainfall upstream in the basin (Galveston Bay Estuary Program, 2002). Heavy rainfall and resultant flooding can increase sediment erosion and nutrient runoff into coastal rivers and consequently increase sediment and nutrient input into estuaries and bays. Galveston Bay is typical of the estuary systems in Texas in many ways, with extensive nutrient and sediment loading possible during periods of runoff.

Nutrient and sediment loading into Galveston Bay from freshwater sources are not well understood. Improving our understanding of nutrient and sediment loading into Galveston Bay requires more accurate streamflow estimates. Traditional methods of streamflow gaging utilize stage-discharge relationships. In tidally affected areas, these methods are not appropriate as a particular stream stage can be associated to more than one discharge. Instead, velocity-index methods, which account for this variability, are used to compute discharge (Dunn and others, 1997).

In a previous study with the Texas Water Development Board, the United Stated Geological Survey (USGS) found that discharge at the lower reaches of the Trinity River differs from the flow at upstream stations. Due to the lack of a continuous stream gaging station in the lower portion of the watershed, the discharge data from upstream stations are currently being used by other agencies as input in models to predict freshwater inflows and nutrient and sediment loads from the Trinity River into Galveston Bay. In order to estimate inflows into the bay more accurately, a stream gaging station, using the index-velocity method to account for tidal flow, is needed in the lower reaches of the Trinity River.

The USGS, in cooperation with the Basin and Bay Area Stakeholder Committee and the Texas Water Development Board, developed a study to determine tidally affected discharge on the lower reaches of the Trinity River using the index velocity method and evaluate the variability of nutrient and sediment concentration entering Galveston Bay over a range of hydrologic conditions. Additionally, the study intends to investigate possible correlations between in situ field measurements of acoustic backscatter and discrete nutrient and sediment concentrations.

Description of Study Area

Galveston Bay is a shallow estuary in southeastern Texas; the Trinity River watershed is the largest contributing area to the bay. The Trinity River watershed extends from Galveston Bay northwestward to the Dallas/Fort Worth area draining an area of approximately 2,120

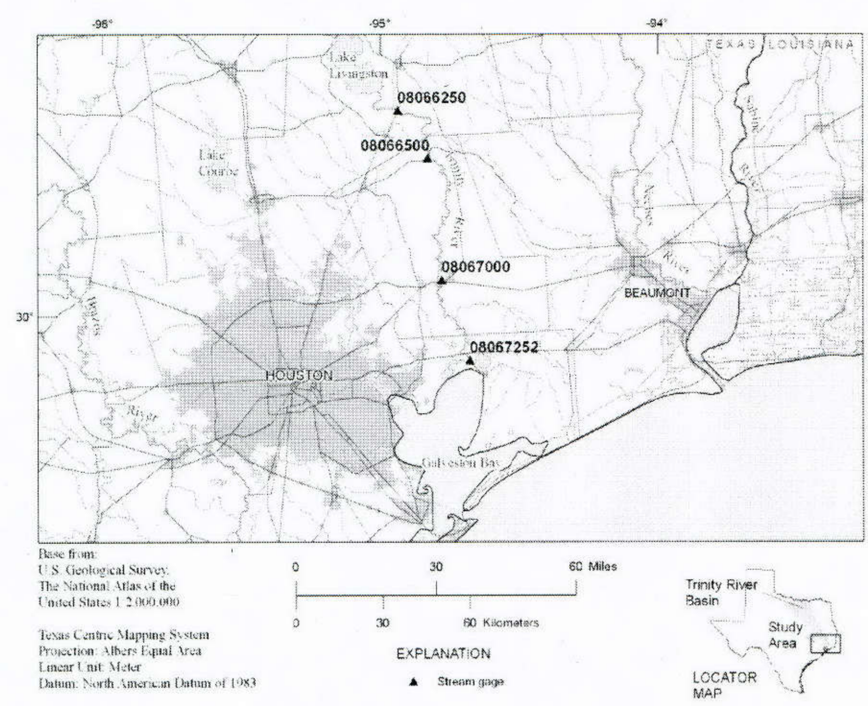

Figure 1. Location of stream gaging stations in the Trinity River basin, Texas

mi^2 with an annual discharge of approximately 200 billion gallons (Galveston Bay Estuary Program, 2011), contributing more than 50% of the average total inflow to Galveston Bay. The river is regulated by several reservoirs; Lake Livingston in southeast Texas is the largest and separates the upper and lower watersheds of the Trinity River system (Figure 1).

Project Methodology

Site Selection

The USGS streamflow gaging station, 08067252 Trinity River at Wallisville, Tex. was selected for sample collection and velocity meter installation. This station is the closest existing USGS streamflow gaging station to the entrance of Galveston Bay on the Trinity River. Three streamflow gaging sites are located upstream, between Lake Livingston and station 08067252 (Table 1). These sites are: 08066250 Trinity River nr Goodrich, Tex., 08066500 Trinity River at Romayor, Tex., and 08067000 Trinity River at Liberty, Tex. (Fig. 1). These sites are currently active and have historical streamflow data that can be used for comparative purposes.

Table 1. Attributes of streamgages in the Trinity River below Lake Livingston, listed in downstream order.

[NAD 27, North American Datum 1927; mi^2, square miles]

Site identification number	Streamgage name	Latitude (NAD 27)	Longitude (NAD 27)	Contributing drainage area (mi^2)
8066250	Trinity Rv nr Goodrich, Tex.	30°34'19"	94°56'55"	16,844
8066500	Trinity Rv at Romayor, Tex.	30°25'30"	94°51'02"	17,186
8067000	Trinity Rv at Liberty, Tex.	30°03'27"	94°49'05"	17,468
8067252	Trinity Rv at Wallisville, Tex.	29°48'44"	94°43'52"	17,796

Installation and Operation of Index Velocity meter

Application of the index velocity method for computing continuous records of discharge has become increasingly common, especially since the introduction of low-cost acoustic Doppler velocity meters (ADVMs) in 1997. Presently, the index velocity method is being used to compute discharge records for approximately 500 gaging stations operated and maintained by the U.S. Geological Survey (Levesque and Oberg, 2012).

An index velocity meter was installed at the streamflow gaging station 08067252 in accordance with USGS standards (Levesque and Oberg, 2012) and with additional assistance and in kind services from the United Sates Army Corps of Engineers. The installation consists of a SonTek Argonaut SL1500, bolted to a Cupronickel 2" diameter pipe that is pinned in place to a steel bracket that is welded onto the stream bulkhead at the gage location, as shown in Figure 2.

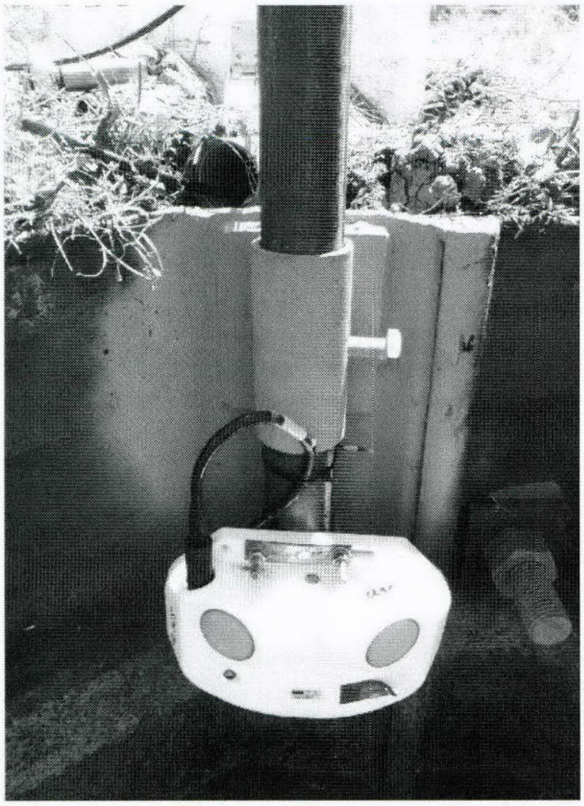

Figure 2. Sontek Argonaut SL 1500 installed at USGS streamflow gaging station 08067252 Trinity River at Wallisville, Tex

Power is provided by a marine battery charged by a 30 watt solar panel installed above the gage house. The data is averaged over a 10 minute interval and recorded every 15 minutes by a Sutron SatLink2-V2 Data Collection Platform (DCP), and then transmitted via a Helical antenna to the GOES satellite, to a downlink at the USGS office for display on the web and storage in the USGS NWIS database. The completed installation is shown in figure 3.

Figure 3. USGS index-velocity gaging station 08067252 Trinity River at Wallisville, Tex.

The index velocity rating at station 08067252 was developed following standard USGS methods described in Levesque and Oberg (2012). This method is different from the traditional stage-discharge measurement 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 parameters such as stream velocity, stage, cross-stream velocity, and velocity head, and A is a function of stage and cross-section shape (Levesque and Oberg, 2012).

To calibrate the index velocity rating, discharge measurements were collected at the gage between May 2014 and June 2015. The measurements were collected using an acoustic Doppler current profiler (ADCP) as described in Mueller and others (2013). A total of 47 discharge measurements were collected at the gage, 32 during baseflow conditions and 16 during storm events when discharge on the Trinity River exceeded 10,000 cfs. Of the 32 baseflow measurements, 19 are from a set of hourly measurements encompassing a complete tidal cycle (four of the 24 expected measurements during the tidal cycle were lost due to equipment malfunction).

A standard cross-section surveyed in September 2009 by the USGS was used to develop the Stage-Area rating after being re-surveyed and validated on August 2015. Index velocity data from the ADVM and measured discharge were used to develop an ordinary least squares regression model to predict mean velocity. This rating, combined with the stage-area rating, was used to develop a continuous record of discharge at station 08067252 from May 2014 forward.

Hydrologic Monitoring

Water Quality Sampling

Physical water-quality properties (water temperature, specific conductance, pH, dissolved oxygen concentration, and turbidity) were measured at the sampling sites using a water-quality multi-probe instrument at the time of sampling. Discrete water-quality samples were routinely collected and analyzed for nutrients (Table 2) and suspended sediment concentration.

Table 2. Nutrient constituents measured at station 08067252 and reporting limits.

Analyte	Unit	Reporting Limit	Reporting Limit Type*
Nitrogen, ammonia	mg/L	0.01	DLDQC
Nitrogen, nitrite	mg/L	0.001	DLDQC
Nitrogen, nitrite + nitrate	mg/L	0.04	DLDQC
Total nitrogen (NH3+NO2+NO3+Organic), unfiltered	mg/L	0.05	DLDQC
Phosphorus, phosphate, ortho	mg/L	0.004	DLDQC
Phosphorus	mg/L	0.004	DLDQC

*DLDQC= Lowest concentration that with 90%confidence will be exceeded no more than 1% of the time when a blank sample is measured (≤1% false positive risk).

Water-quality samples were collected and processed following standard USGS sampling methods as described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Samples were collected using a polytetrafluoroethelyene bottle within each of five vertical sections to capture variability of constituent concentration within the river cross-section. The location of each vertical section was determined based on discharge and water velocity. When water velocities exceeded 1.5 ft/s, the cross section was divided using the equal discharge increment (EDI) method. The EDI method is an isokinetic method that allows the collection of a discharge-weighted sample that represents the flow passing through the cross section. It requires collecting a series of samples, each representing equal volumes of stream discharge (United States Geological Survey, variously dated). When water velocities were lower than 1.5 ft/s samples were collected at multiple verticals along the cross section using a flow-weighted sampler.

Water-quality sample verticals were composited in a polyethylene churn splitter from which sub-samples for whole-water analysis were drawn. The churn splitter was used to allow for subsamples to be drawn while maintaining a uniform distribution of suspended material in the composite sample (Darrell and others, 1999). Dissolved nutrient samples were filtered using a 0.45-micron pore-sized filter that was pre-rinsed with deionized water. Total nutrient samples were preserved using 1-milliliter of 4.5N sulfuric acid.

Sample Analysis

All nutrient samples were chilled and shipped overnight to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado for analysis. Methods for nutrient analysis are documented in Fishman (1993), U.S. Environmental Protection Agency (1993; method 365.1), and Patton and Kryskalla (2003, 2011). Suspended-sediment samples were shipped to the USGS Kentucky Water Science Center Sediment Laboratory in Louisville, Kentucky and analyzed for suspended-sediment concentration and particle-size with methods described in Guy (1969) and Mathes and others (1992). The data for samples gathered during this study are stored in the USGS NWIS database and can be accessed online (U.S. Geological Survey, 2015).

Quality Control

Quality-control information is needed to estimate variability that results from sample collection, sample processing, transportation, and laboratory analysis in order to ensure proper interpretation of water-quality data (Crain, 2006). Quality-control (QC) samples for this study were collected and processed as described in the USGS "National Field Manual for the Collection of Water-Quality Data" (variously dated) and analyzed by the same laboratories using the same methods as the environmental samples. 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. Split replicate samples were compared by computing relative percent differences (RPD); the larger the RPD, the greater the variability in sample-replicate pairs. RPD's for each analyte was calculated by using the following equation (Crain, 2006):

$$RPD = \frac{|S_1 - S_2|}{(S_1 + S_2)/2}\ x\ 100 \quad (1)$$

where,

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

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

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

Project Results

Index Velocity Rating

An index velocity rating was developed using a dataset of 47 discharge measurements ranging from -1,630 cfs to 21,600 cfs collected between May 2014 and June 2015. The results of the ordinary least squares regression (Fig. 4) developed to predict mean velocity utilizing the index-velocities measured by the ADV are shown in Table 3. The coefficient of determination (R^2) for the regression, which indicates the proportion of the variance that is predicted by the independent variable, is 0.99. The slope of the regression is 0.98. When an index velocity rating slope is less than one, index velocity tends to be measured in a region of the channel where it is near to, but a little more than the measured mean velocity (Levesque and Oberg, 2012).

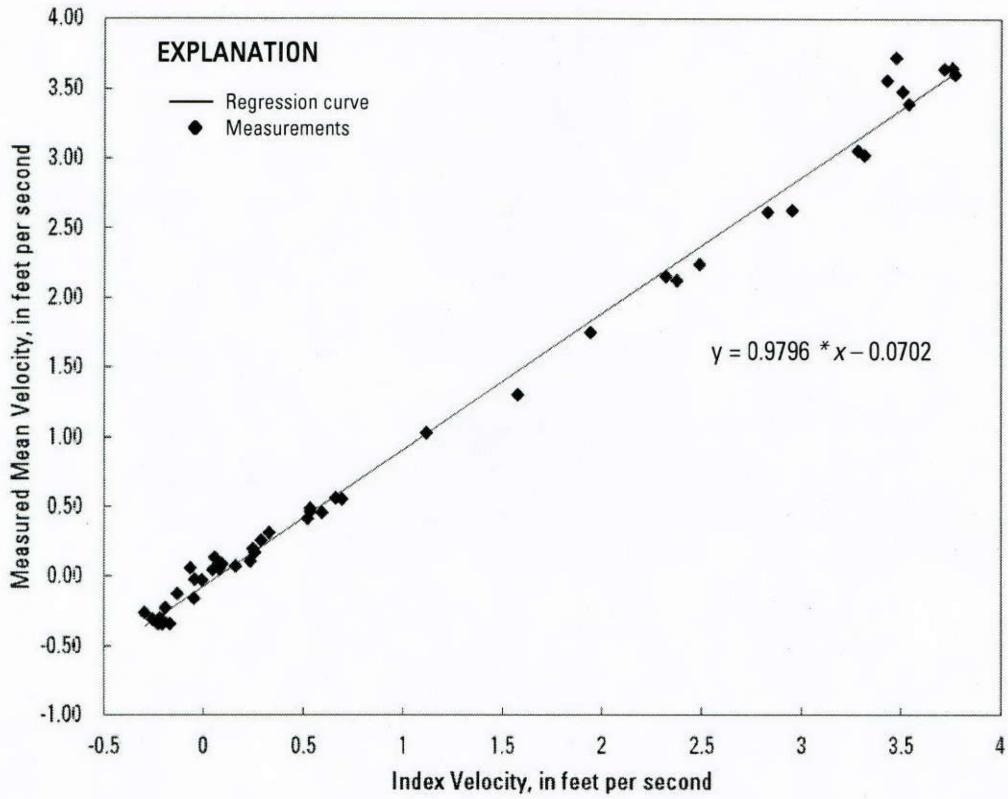

Figure 4. Linear index velocity rating.

Table 3. Results of simple linear regression used in index-velocity rating.

[R-square, coefficient of determination (also R2); ANOVA, analysis of variance; df, degrees of freedom; SS, sum of squares; MS, mean square; F, F-test statistic; P-value, probability value for the regression coefficient; Lower 95%, lower value for 95% confidence interval; Upper 95%, upper value for 95% confidence interval]

Regression statistics						
R-square	0.9943					
Adjusted R-square	0.9941					
Standard Error	0.1099					
Observations	47					
ANOVA						
	df	**SS**	**MS**	**F**	**Significance F**	
Regression	1	94.111	94.111	7787.9	<2.2 E -16	
Residual	45	0.544	0.012			
Total	46	94.655				
	Coefficients	**Standard Error**	**t value**	**P-Value**	**Lower 95 %**	**Upper 95%**
Intercept	-0.0702	0.0203	-3.459	0.0012	-0.1111	-0.0293
Vi	0.9796	0.0111	88.249	<2 E -16	0.9573	1.0020

The index velocity regression was evaluated with residual and Quantile-Quantile probability plots (Q-Q plot). Homoscedasticity, the assumption of equal variance along the regression line, can be evaluated with a residual plot (Figure 5A). In a residual plot, homoscedasticity exhibits a random pattern equally distributed around zero instead of a defined trend. A Q-Q plot (Figure 5B) is used to evaluate the assumption that errors are normally distributed. If the quantiles of the theoretical and data distributions agree, the plotted points will fall on or near the *y=x* line. Points that do not fall near the *y=x* line can result from chance variation or a deviation from normal distribution (Chambers and others, 1983).

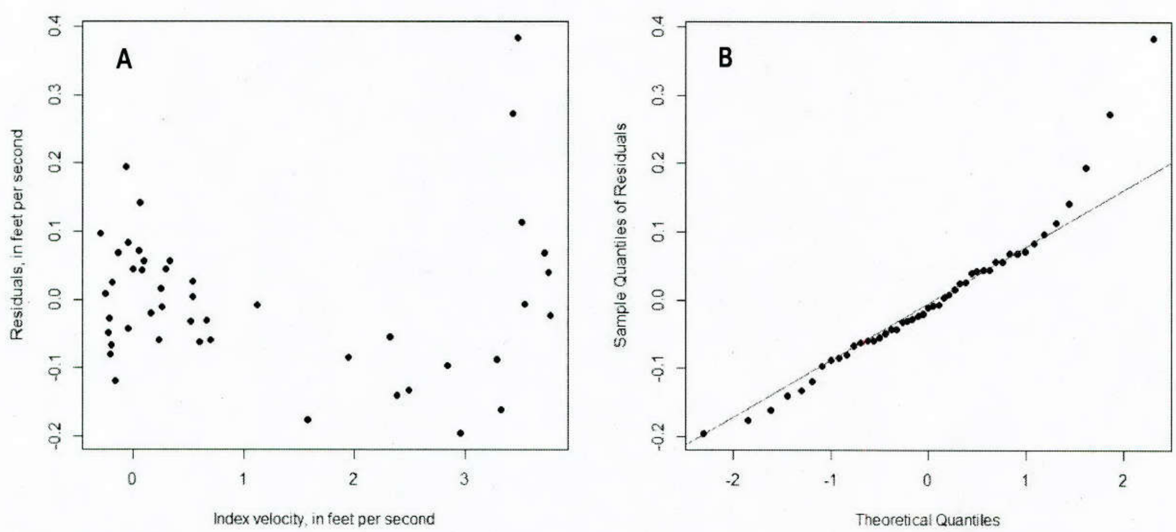

Figure 5. Plots of (A) regression residuals with index velocity and (B) and Quantile-Quantile probability for residuals.

Discharge for measured data points was calculated by multiplying the mean velocity predicted by the index-velocity rating with the area provided by the stage-area rating. Figure 6 shows the observed versus predicted values of the model with a majority of the data points being on or near the $y=x$ line.

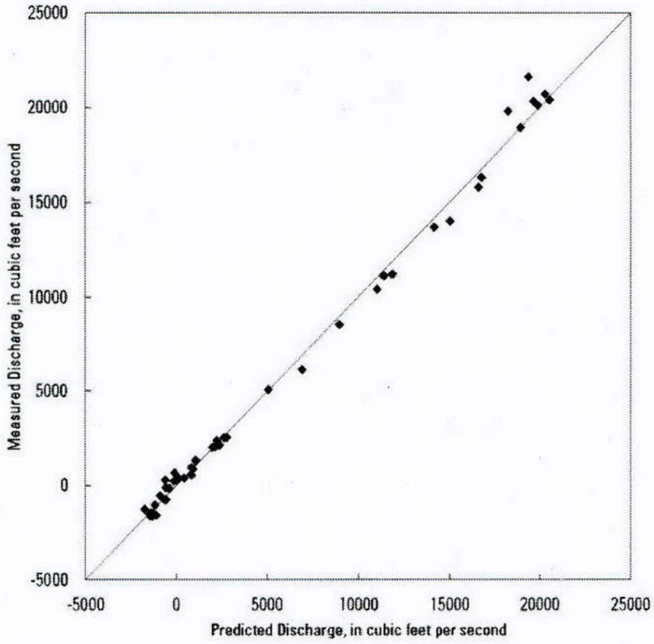

Figure 6. Plot showing measured discharge versus predicted discharge and 1:1 line.

Discharge was then calculated from index-velocity and stage data collected since the ADVM was installed at station 08067252. A continuous record of discharge was created and plotted with sites 08066500 and 08067000, located upstream of 08067252 in the Trinity River. The hydrographs for all three stations are shown in figure 7.

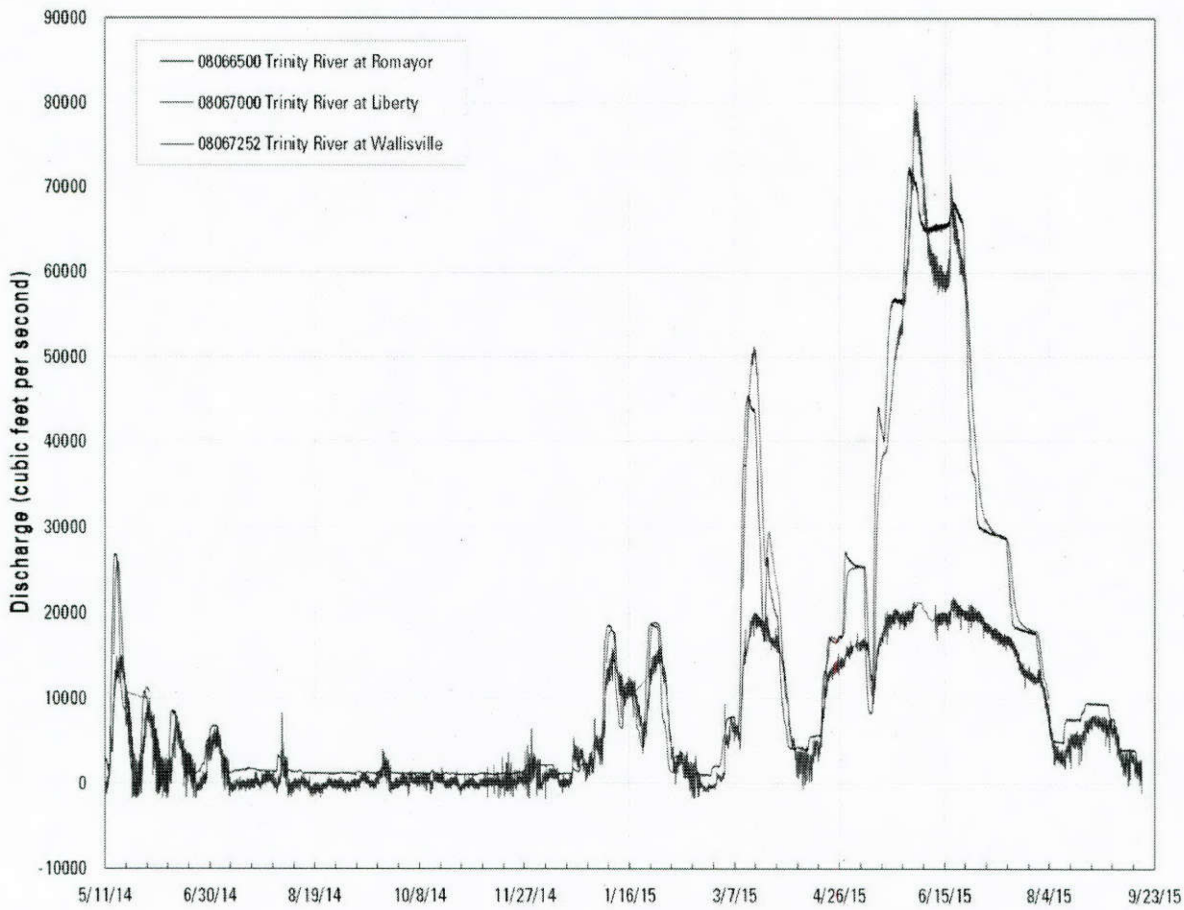

Figure 7. Hydrographs of stations 08066500 Trinity River at Romayor, Tex., 08067000 Trinity River at Liberty, Tex., and 08067252 Trinity River at Wallisville, Tex. from May 2014 to September 2015.

Water Quality and Sediment Data

A total of 33 water quality samples were collected at site 08067252 between May 2014 and August 2015. Sampling occurred approximately twice a month and during events when discharge on the Trinity River exceeded 10,000 cfs. A total of 16 samples were collected during 4 storm events for this project. Physical water quality and nutrient data collected are shown in tables 4 and 5.

Suspended sediment concentration, including sand/fine break concentration, and bed material data are presented in tables 4 and 5. Bed material samples were collected only when a moving bed condition was indicated by the Acoustic Doppler Current Profiler. Bed sediment samples were collected for 9 event samples throughout the study. USGS is still awaiting results from the lab for the 3 samples collected in May 2015.

Table 4. Field parameters collected at Trinity River at Wallisville, Tex.

Date (dd/mm/yyyy)	Time (hhmm)	Discharge, instantaneous (cfs)	Dissolved oxygen, water, unfiltered (mg/l)	pH, water, unfiltered, field (standard units)	Specific conductance, water, unfiltered (uS/cm at 25 °C)	Temperature, water (°C)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +-2.5 degree (FNU)
5/16/2014	1135	14000	7.0	7.6	390	22.2	110
6/19/2014	1240	2040	5.8	7.9	373	29.9	13
7/8/2014	1200	921	7.4	8.2	408	31.4	9.0
7/30/2014	1145	238	5.8	7.8	396	32.1	2.9
8/6/2014	1113	N/A	4.5	7.6	377	30.6	8.9
8/26/2014	1138	269	7.5	8.2	380	32.5	2.7
9/10/2014	1213	539	6.9	8.1	428	31.0	5.9
9/22/2014	1400	2370	4.7	7.5	341	27.8	15
10/10/2014	1146	366	6.8	7.8	382	27.8	6.8
10/15/2014	1227	859	5.5	7.6	387	26.2	10
11/3/2014	1124	405	7.7	7.9	389	22.3	7.5
11/17/2014	1127	674	8.6	7.6	433	15.0	9.1
12/12/2014	1135	1290	10.0	8.0	419	16.3	8.6
1/7/2015	1222	13700	10.5	7.6	383	10.7	80
1/12/2015	1129	11100	10.6	7.5	366	8.8	32
1/14/2015	1312	10400	11.0	7.4	349	8.9	33
1/16/2015	1106	11200	11.6	7.8	395	8.8	30
1/20/2015	1220	8540	11.0	7.7	399	10.5	22
1/23/2015	1142	6120	10.2	7.6	307	11.0	25
1/29/2015	1214	14100	11.2	7.8	419	11.6	42
2/15/2015	1520	256	13.4	8.2	409	15.7	12
3/12/2015	1210	16300	10.5	7.6	351	11.5	130
3/16/2015	1214	20100	9.4	7.3	357	13.7	70
3/20/2015	1224	19800	8.9	7.4	359	15.8	40
4/3/2015	1055	5060	6.9	7.2	323	21.3	28
5/4/2015	1250	15800	9.0	7.5	336	23.5	45
5/18/2015	1300	18900	5.5	7.3	307	24.8	50
5/22/2015	1145	20400	4.8	7.2	316	24.4	55
5/30/2015	1130	22200	4.3	7.1	276	25.3	54
6/10/2015	1415	21600	4.3	7.5	281	28.0	47
6/26/2015	1257	20300	4.8	7.4	328	29.2	24
7/16/2015	1259	17800	6.5	7.7	338	30.2	28
8/5/2015	1220	5820	6.5	7.9	361	31.0	16
	Minimum	238	4.3	7.1	276	8.8	2.7
	Maximum	22200	13.4	8.2	433	32.5	130
	Median	9470	7.4	7.6	373	23.5	25

N/A -- No discharge measurement due to equipment failure

Table 5. Nutrient data collected at Trinity River at Wallisville, Tex.

Date (dd/mm/yyyy)	Time (hhmm)	Ammonia, water, filtered, as nitrogen (mg/l)	Nitrate plus nitrite, water, as nitrogen (mg/l)	Nitrite, water, filtered, as nitrogen (mg/l)	Orthophosphate, water, filtered, as phosphorus (mg/l)	Phosphorus, water, unfiltered, milligrams per liter as phosphorus (mg/l)	Total nitrogen (nitrate + nitrite + ammonia + organic-N), water, unfiltered, analytically determined (mg/l)
5/16/2014	1135	0.03	0.645	0.021	0.016	0.274	1.64
6/19/2014	1240	0.02	<0.040	<0.001	0.034	0.091	0.77
7/8/2014	1200	0.01	<0.040	<0.001	0.039	0.088	0.63
7/30/2014	1145	<0.01	<0.040	0.003	0.034	0.082	0.60
8/6/2014	1113	0.11		0.008	0.049		
8/26/2014	1138	<0.01	<0.040	<0.001	0.033	0.077	0.60
9/10/2014	1213	<0.01	<0.040	<0.001	0.053	0.111	0.62
9/22/2014	1400	0.04	0.057	0.015	0.069	0.139	0.86
10/10/2014	1146	<0.01	<0.040	<0.001	0.047	0.102	0.69
10/15/2014	1227	0.03	0.074	0.03	0.048	0.095	0.59
11/3/2014	1124	<0.01	<0.040	<0.001	0.024	0.076	0.61
11/17/2014	1127	0.02	<0.040	0.001	0.018	0.067	0.56
12/12/2014	1135	0.01	<0.040	<0.001	0.014	0.081	0.68
1/7/2015	1222	0.08	0.103	0.007	0.012	0.222	1.16
1/12/2015	1129	0.03	0.156	0.007	0.025	0.112	0.88
1/14/2015	1312	0.03	0.161	0.006	0.030	0.116	0.90
1/16/2015	1106	0.03	0.229	0.007	0.021	0.113	1.05
1/20/2015	1220	0.01	0.299	0.007	0.022	0.101	1.06
1/23/2015	1142	<0.01	0.239	0.006	0.025	0.108	0.94
1/29/2015	1214	0.01	0.239	0.008	0.048	0.153	1.39
2/15/2015	1520	<0.01	0.110	0.007	0.006	0.107	1.15
3/12/2015	1210	0.07	0.583	0.008	0.015	0.266	1.64
3/16/2015	1214	0.02	0.522	0.006	0.018	0.266	1.41
3/20/2015	1224	0.01	0.506	0.006	0.023	0.167	1.43
4/3/2015	1055	0.02	0.400	0.012	0.087	0.19	1.27
5/4/2015	1250	0.01	0.779	0.002	0.064	0.172	1.54
5/18/2015	1300	0.03	0.731	0.005	0.080	0.197	1.37
5/22/2015	1145	0.03	0.674	0.007	0.080	0.176	1.37
5/30/2015	1130	0.02	0.532	0.006	0.090	0.227	1.24
6/10/2015	1415	0.02	0.287	0.014	0.100	0.237	1.06
6/26/2015	1257	0.02	0.234	0.005	0.093	0.167	0.83
7/16/2015	1259	<0.01	0.156	0.001	0.075	0.123	0.83
8/5/2015	1220	<0.01	<0.040	<0.001	0.042	0.107	0.69
	Minimum	<0.01	<0.040	<0.001	0.006	0.067	0.56
	Maximum	0.11	0.779	0.03	0.100	0.274	1.64
	Median	0.02	0.263	0.007	0.034	0.1145	0.92

N/A – Samples not able to be analyzed by the lab.

Table 6. Suspended sediment data collected at Trinity River at Wallisville Tex.

Date (dd/mm/yyyy)	Time (hhmm)	Suspended sediment concentration (mg/l)	Suspended sediment, sieve diameter (% <0.0625mm)
5/16/2014	1135	453	86
6/19/2014	1240	17	94
7/8/2014	1200	14	95
7/30/2014	1145	7	61
8/6/2014	1113	9	100
8/26/2014	1138	5	100
9/10/2014	1213	6	100
9/22/2014	1400	19	100
10/10/2014	1146	8	100
10/15/2014	1227	11	100
11/3/2014	1124	9	93
11/17/2014	1127	10	N/A
12/12/2014	1135	9	90
1/7/2015	1222	380	53
1/12/2015	1129	65	85
1/14/2015	1312	65	83
1/16/2015	1106	84	80
1/20/2015	1220	38	92
1/23/2015	1142	39	97
1/29/2015	1214	197	N/A
2/15/2015	1520	17	N/A
3/12/2015	1210	359	N/A
3/16/2015	1214	346	N/A
3/20/2015	1224	244	N/A
4/3/2015	1055	49	96
5/4/2015	1250	225	49
5/18/2015	1300	201	57
5/22/2015	1145	236	49
5/30/2015	1130	169	47
6/10/2015	1415	185	37
	Minimum	5	
	Maximum	453	
	Median	44	

N/A -- Size analysis was not performed

Table 7. Bed material data collected at Trinity River at Wallisville, Tex.

Date	Begin time	Bed sediment, fall diameter (deionized water)	Bed sediment, fall diameter (deionized water)	Bed sediment, fall diameter (deionized water)	Bed sediment, fall diameter (deionized water)	Bed sediment, fall diameter (deionized water)	Bed sediment, sieve diameter	Bed sediment, sieve diameter	Bed sediment, sieve diameter	Bed sediment, sieve diameter	Bed sediment, sieve diameter	Bed sediment, sieve diameter
mm/dd/yyyy	hhmm	% <0.002 mm	% <0.004 mm	% <0.008 mm	% <0.016 mm	% <0.031 mm	% <0.0625 mm	% <0.125 mm	% <0.25 mm	% <0.5 mm	% <1 mm	% <2 mm
5/16/2014	1135	1	1	1	1	2	2	7	60	100		
1/7/2015	1222	3	4	4	4	4	5	9	65	98	100	
1/29/2015	1214	2	2	2	2	2	18	24	66	99	100	
3/12/2015	1210	11	11	12	13	15	16	24	64	99	100	
3/16/2015	1214	8	9	9	10	12	15	18	41	96	99	100
3/20/2015	1224	11	13	13	13	15	19	21	52	95	100	

Relative percent differences (RPD) were calculated to compare replicate samples. The RPD's for the nutrient and suspended sediment data are shown in table 7. All RPDs were below 20%.

Table 8. Relative percent difference for replicate samples collected at Trinity River at Wallisville, Tex.

Date	Time	RDP for Ammonia, water, filtered, as nitrogen	RPD for Nitrate plus nitrite, water, as nitrogen	RPD for Nitrite, water, filtered, as nitrogen	RPD for Orthophosphate, water, filtered, as phosphorus	RPD for Phosphorus, water, unfiltered, milligrams per liter as phosphorus	RPD for Total nitrogen	RPD for Suspended Sediment Concentration
(mm/dd/yyyy)	(hhmm)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
7/30/2014	1146	0.0	0.0	0.0	0.0	2.5	0.0	0.0
12/12/2014	1136	0.0	0.0	0.0	0.0	1.2	0.0	10.5
6/10/2015	1416	0.0	2.4	0.0	6.2	0.0	0.0	N/A

Preliminary Surrogate Investigation

The primary purpose of an ADVM is to measure water velocity, but it has been found that quality control measures provided by the instrument are useful to monitor suspended-sediment transport (Wood, 2014). As the instrument emits an acoustic pulse into the water and measures the Doppler-shifted frequency of the pulse as it bounces off acoustic reflectors (typically assumed to be primarily sediment particles), the strength of the returned pulse (backscatter) is also measured as it returns to the instrument along the beam path (Wood and Teasdale, 2013). As a result, the backscatter measurement can potentially be related to suspended-sediment concentration and measured variables can be used to estimate concentration and load on a real-time basis.

The suspended-sediment samples collected at the Trinity River gaging station are being used to develop a relation between suspended sediment concentration and ADVM backscatter. A number of factors affect acoustic backscatter readings, including transmission losses due to absorption by water, absorption or attenuation by sediment, and beam spreading. Thus, acoustic backscatter data must be corrected prior to assessing potential correlations with suspended sediment concentration in the water column. These corrections are being done using the Surrogate Analysis and Index Developer (SAID) Tool developed by the USGS (*http://water.usgs.gov/osw/SALT/SAID/index.html*). The tool processes acoustic parameters to be used as predictor variables using a constant spatial suspended sediment concentration method. The corrected backscatter data was used to develop a preliminary ordinary least squares regression model to predict suspended sediment concentrations. Preliminary assessments have shown a potential correlation at Trinity River at Wallisville, Tex (Figure 8), but additional data needs to be included in the model to confirm the relation. This effort is being continued through additional support of Texas Water Development Board.

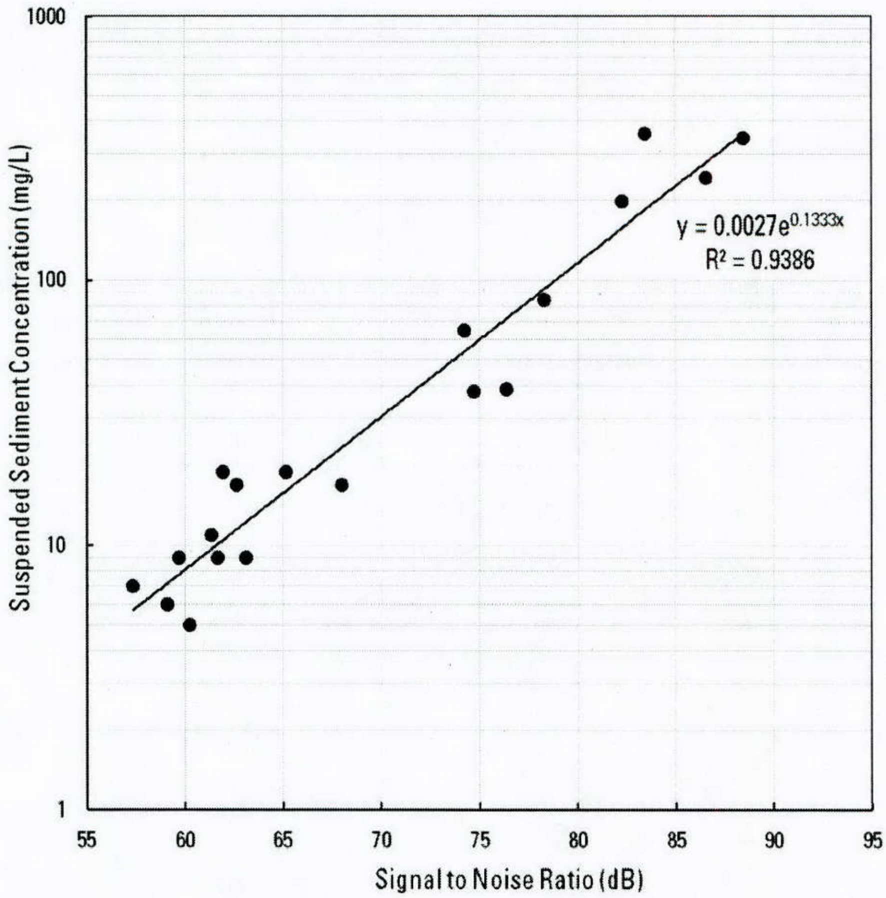

Figure 8. Preliminary regression of suspended sediment concentration on acoustic backscatter data.

Project Conclusions

USGS developed an index velocity rating for station 08067252 that provides a real-time continuous record of flow at the lower reaches of the Trinity River. Real-time data can be found in the USGS NWIS online database (*http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08067252*). This record, ranging from May 2014 to present, shows that flow at the lower reaches of the Trinity River follow a similar trend to the upstream stations until it attains a discharge of approximately 20,000 cfs. This appears to be the maximum discharge at this station even when higher flows are observed upstream on the Trinity River. The route and destination of the unaccounted flow between stations 08067000 and 08067252 is currently unknown.

In addition to providing discharge data, calibration of the acoustic Doppler velocity meter (using backscatter data) holds promise for estimating sediment and nutrient concentrations in the Trinity River. Preliminary assessments have shown a potential correlation at Trinity River at Wallisville, Tex., but additional data needs to be included in the model to confirm the relation. Developing a model that predicts suspended sediment concentration with acoustic backscatter would provide a continuous real-time record of suspended sediment concentrations and loads into Trinity Bay.

Further research is needed to understand the hydrology of the Trinity River delta and account for the missing discharge between stations 08067000 Trinity River at Liberty, Tex. and 08067252 Trinity River at Wallisville, Tex. The Trinity River delta is a complex system of wetlands, channels, and lakes that could be playing a role in the hydrology of the lower portions of the watershed and influencing the water quality of Galveston Bay inflows. Determining the route and destination of the unaccounted flow during storm events may be useful for improving hydrodynamic and water quality models and develop a more accurate understanding of the volume and water quality of inflows entering the Galveston Bay ecosystem.

References

Crain, A.S., 2006, Concentrations, and estimated loads and yields of nutrients and suspended sediment in the Little River Basin, Kentucky, 2003-04: U.S. Geological Survey Scientific Investigations Report 2006-5204, 31 p.

Chambers, J. M., Cleveland, W. S., Kleiner, B., and Tukey, P. A. (1983), *Graphical Methods for Data Analysis*, Belmont, CA: Wadsworth International Group.

Darrell, L.C., Majedi, B.F., Lizarraga, J.S., and Blomquist, J.D., 1999, Nutrient and suspended-sediment concentrations, trends, loads, and yields from the nontidal part of the Susquehanna, Potomac, Patuxent and Choptank Rivers, 1985–96: U.S. Geological Survey Water-Resources Investigations Report 98-4177, 38 p.

Dunn, D.D., Solis, R.S., and Ockerman, D.J., 1997, Discharge measurements in tidally affected channels during a hydrographic estuarine survey of Sabine Lake, Texas: U.S. Geological Survey Fact Sheet FS-157-97, 6 p.

Edwards, T.K., and Glysson, G.D., 1998, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap.C2, 80 p.

Galveston Bay Estuary Program, 2002, The State of the Bay— A characterization of the Galveston Bay ecosystem (2d ed.): Publication GPEP-T7, chapters 5– 6.

Galveston Bay Estuary Program, 2011, The State of the Bay— A characterization of the Galveston Bay ecosystem (3d ed.): Publication SFR-101/10, chapters 5– 6.

Guy, Harold P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chapter C1, 58 p.

Levesque, V.A., and Oberg, K.A., 2012, Computing discharge using the index velocity method: U.S. Geological Survey Techniques and Methods 3-A23, 148p.

Mathes, W.J , Sholar, C.J., and George, J.R., 1992, Quality-assurance plan for analysis of fluvial sediment: U.S. Geological Survey Open-File Report 91–467, 31 p., accessed May 4, 2008, at *http://pubs.er.usgs.gov/usgspubs/ofr/ofr91467*.

Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A,, and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p., *http://dx.doi.org/10.3133/tm3A22*.

Patton, C. J., and Kryskalla, J. R., 2011, Colorimetric determination of nitrate plus nitrite in water by enzymatic reduction, automated discrete analyzer methods: U.S. Geological Survey Techniques and Methods, book 5, chap. B8

Patton, C.J., Kryskalla. J.R., 2003, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory: Evaluation of Alkaline Persulfate Digestion as an Alternative to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water, Water-Resources Investigations Report 03-4174, 33p.

Terrio, P.J., 1995, Water-quality assessment of the Upper Illinois River Basin in Illinois, Indiana, and Wisconsin—Nutrients, dissolved oxygen, and fecal-indicator bacteria in surface water, April 1987 through August 1990: U.S. Geological Survey Water-Resources Investigations Report 95–4005, 79 p.

U.S. Environmental Protection Agency, 1993, Methods for the determination of inorganic substances in environmental samples: Cincinnati, Ohio, Environmental Monitoring Systems Laboratory, EPA/600/R–93/100, 79 p.

U.S. Geological Survey, 2015, National Water Information System (NWISWeb) [for Texas] data available on the World Wide Web: at http://waterdata.usgs.gov/tx/nwis/nwis.

U.S. Geological Survey [variously dated], National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chapters A1–A9, accessed February 22, 2015 at *http://pubs.water.usgs.gov/twri9A*.

Wood, M.S., 2014, Estimating suspended sediment in rivers using acoustic Doppler meters: U.S. Geological Survey Fact Sheet 2014-3038, 4 p.,*http://dx.doi.org/10.3133/fs20143038*.

Wood, M.S., and Teasdale, G.N., 2013, Use of surrogate technologies to estimate suspended sediment in the Clearwater River, Idaho, and Snake River, Washington, 2008–10: U.S. Geological Survey Scientific Investigations Report 2013-5052, 30 p.