# Appendix 2.33. Model Archive Summary for Suspended-Sediment Concentration at U.S. Geological Survey site 07144100; Little Arkansas River near Sedgwick, Kansas, during October 2014 through December 2019

This model archive summary summarizes the suspended-solids concentration model developed to compute hourly or daily suspended-sediment concentration. Model development methods follow U.S. Geological Survey (USGS) guidance from Office of Surface Water/Office of Water Quality Technical Memoranda and USGS Techniques and Methods, book 3, chap. C4 (Rasmussen and others, 2009).

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## Site and Model Information

Site Number: 07144100

Site Name: Little Arkansas River near Sedgwick, Kansas

Location: Latitude 37°52'59", longitude 97°25'27" referenced to North American Datum of 1927, in NE 1/4 NW 1/4 NW 1/4 sec.15, T.25 S., R.1 W., Sedgwick County, Kansas; hydrologic unit 11030012.

Equipment: A Sutron Satlink II High Data Rate Collection Platform and a Design Analysis Water Log H350/355 nonsubmersible pressure transducer transfers real-time stage and water-quality data via satellite. The primary reference gage is a Type-A wire-weight gage located on the downstream bridge handrail. Check-bar elevation is 33.614 feet. The orifice is enclosed in a well-screen and attached to a concrete pier on the left downstream side of the bridge. Gage height was measured during October 2014 through December 2019. A YSI 6600 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved oxygen, and turbidity (a YSI Model 6026 [September 1998 through December 2006] and YSI Model 6136 [July 2004 through March 2015]) sensors collected data during April 1998 through March 2015. A YSI EXO2 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved organic matter sensors collected data during September 2014 through December 2019. A YSI 620 (2014 through December 2015). A YSI EXO2 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved organic matter sensors collected data during September 2014 through December 2019. A Hach Nitratax monitor collected nitrate data during March 2012 through December 2019.

Date model was developed: June 1, 2020

Model calibration data period: October 16, 2014 through December 11, 2019

## **Model Data**

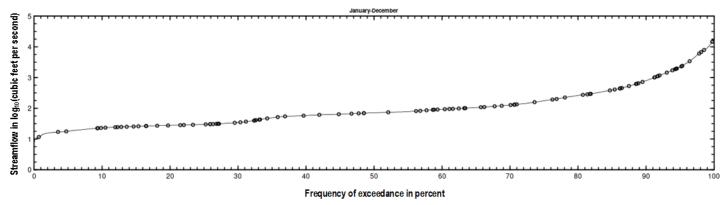
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated individually and in combination. Potential explanatory variables included streamflow, water temperature, specific conductance, pH, dissolved oxygen, YSI EXO2 turbidity, nitrate, and fluorescent dissolved organic matter. Seasonal components (sine and cosine variables) also were evaluated as explanatory variables.

The regression model is based on 108 concomitant values of discretely collected suspended-solids concentration and continuously measured turbidity during October 2014 through December 2019. Discrete samples were collected over a range of streamflow and turbidity conditions. No samples had concentrations that were below laboratory detection limits. Summary statistics and the complete model-calibration dataset are provided below. Outliers and influential points were identified using studentized residuals, DFITS, Cook's D (Cook, 1977), and leverage. Outliers in previously published versions of this model (Christensen and others, 2003; Rasmussen and others, 2016) were examined and retained in the dataset if there were no clear issues, explanations, or conditions that would cause a result to be invalid for model calibration. One sample (collection date January 18, 2018) was not representative of the dataset and exceeded Cook's D and DFITS outlier criteria and was removed from the model dataset to avoid erroneous inflation of model-computed values at the upper range of surrogate relations. Removing data points based only on outlier criteria may only overestimate the certainty of the model.

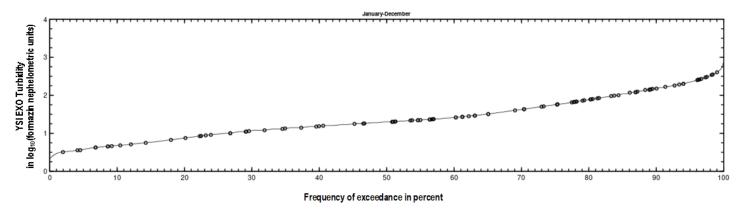
## **Suspended-Sediment Concentration**

Discrete samples were collected from the downstream side of the bridge or instream within 50 feet of the bridge using equal-width-increment, multi-vertical, single vertical or grab-dip methods following U.S. Geological Survey (variously dated) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging from 4 to 22 samples per year with a FISP US DH–95 or D–95 with a Teflon bottle, cap, and nozzle depth-integrating sampler, a DH–81 with a Teflon bottle, cap, and nozzle hand sampler or a grab sample with a Teflon bottle depending on sample location. Samples were analyzed for suspended-solids concentration by the USGS Iowa Sediment Laboratory following standard methods (Guy, 1969).

# Suspended-Sediment Concentration Samples Plotted on Streamflow Duration Curve



# Suspended-Sediment Concentration Samples Plotted on YSI EXO Turbidity Duration Curve



## **Continuous Data**

Concomitant turbidity values were time interpolated. If no concomitant continuous data were available within 2 hours of sample collection, the sample was not included in the dataset.

# **Model Development**

Ordinary least squares regression analysis was done using R (version 4.0.0) programming language (R Core Team, 2020) to relate discretely collected suspended-solids concentration to turbidity and other continuously measured data. The distribution of residuals was examined for normality and plots of residuals (the difference between the measured and model-calculated values) compared to model-computed suspended-solids concentration were examined for homoscedasticity (departures from zero did not change substantially over the range of model-calculated values). Previously published explanatory variables were also strongly considered for continuity; however, the best explanatory variable(s) were ultimately selected.

Turbidity was selected as the best predictor of suspended-sediment concentration based on residual plots, high coefficient of determination ( $R^2$ ), and low model standard percentage error (MSPE). Turbidity was positively correlated with suspended-sediment concentration because turbidity measures light scattered by particulates in water.

# **Model Summary**

Summary of final suspended-solids concentration regression analysis at USGS site number 07144100:

Suspended-solids concentration-based model:

 $\log_{10}(SSC) = 1.13 \times \log_{10}(TBY) + 0.0959$ 

where,

 $log_{10} = logarithm$  base 10; SSC = suspended-sediment concentration, in milligrams per liter (mg/L); and TBY = turbidity, in formazin nephelometric units (FNU)

The log-transformed model may be retransformed to original units so that SSC can be calculated directly. The retransformation introduces a bias in the calculated constituent. This bias may be corrected using Duan's bias correction factor (BCF; Duan, 1983). For this model, the calculated BCF is 1.08. The retransformed model, accounting for BCF is:

 $SSC = 1.347 \times TBY^{1.13}$ 

# Model Statistics, Data, and Plots

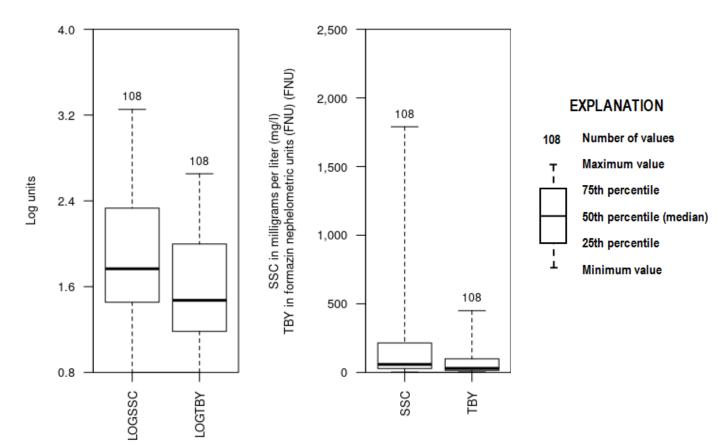
Model

LOGSSC = + 1.13 \* LOGTBY + 0.0959

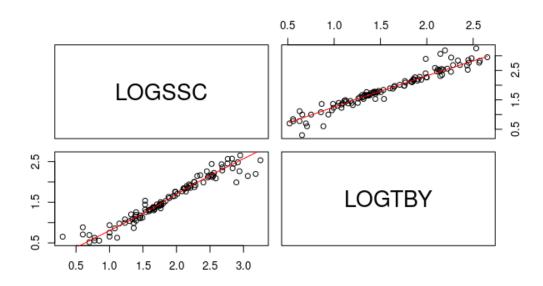
#### **Variable Summary Statistics**

	LOGSSC	SSC	LOGTBY	TBY
Minimum	0.301	2.0	0.519	3.3
1st Quartile	1.450	28.5	1.180	15.3
Median	1.770	58.5	1.470	29.7
Mean	1.880	197.0	1.580	76.9
3rd Quartile	2.330	215.0	2.000	99.6
Maximum	3.250	1790.0	2.650	450.0
1st Quartile Median Mean 3rd Quartile	1.450 1.770 1.880 2.330	28.5 58.5 197.0 215.0	1.180 1.470 1.580 2.000	15.3 29.7 76.9 99.6





**Exploratory Plots** 



## **Basic Model Statistics**

Number of Observations	108
Standard error (RMSE)	0.164
Average Model standard percentage error (MSPE)	38.5
Coefficient of determination (R <sup>2</sup> )	0.935
Adjusted Coefficient of Determination (Adj. R <sup>2</sup> )	0.934
Bias Correction Factor (BCF)	1.08

# **Explanatory Variables**

	Coefficients	Standard Error	t value	Pr(> t )
(Intercept)	0.0959	0.0482	1.99	4.93e-02
LOGTBY	1.1300	0.0289	39.00	1.00e-64

## **Correlation Matrix**

	Intercept	E.vars
Intercept	1.000	-0.945
E.vars	-0.945	1.000

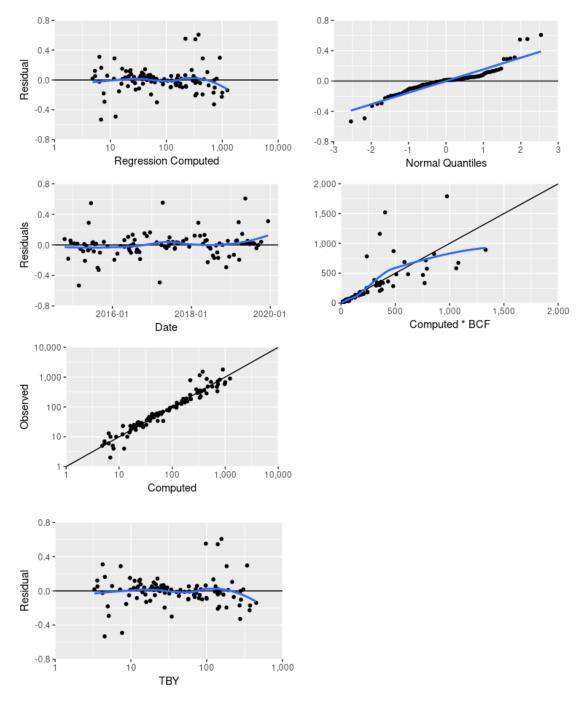
## **Outlier Test Criteria**

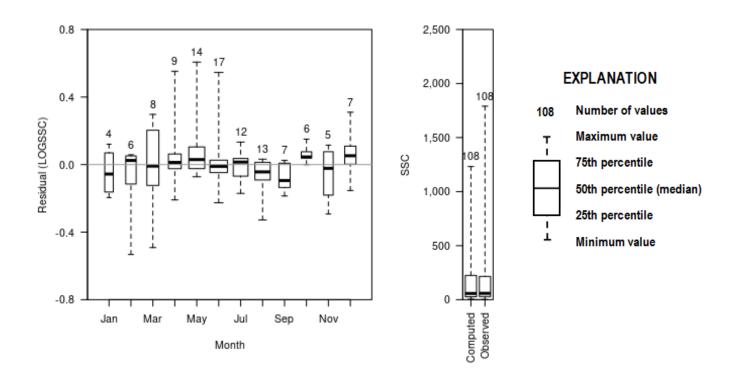
Leverage Cook's D DFFITS 0.0556 0.1944 0.2722

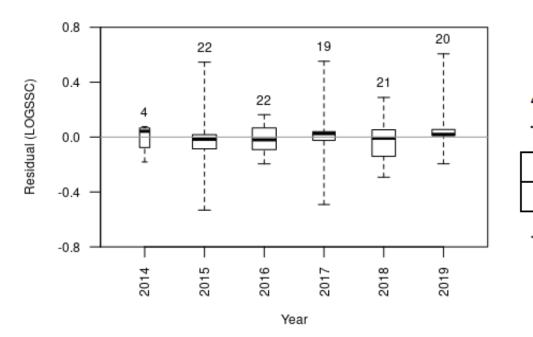
# **Flagged Observations**

	LOGSSC	Estimate	Residual	Standard	Studentized	Leverage	Cook's	DFFITS
				Residual	Residual	0-	D	_
2/25/2015 11:20	0.301	0.833	-0.532	-3.32	-3.49	0.0359	0.205	-0.673
5/27/2015 11:50	2.94	2.65	0.289	1.79	1.81	0.024	0.0393	0.283
6/17/2015 10:40	3.06	2.52	0.546	3.37	3.55	0.0194	0.113	0.5
8/27/2015 10:40	2.53	2.85	-0.328	-2.04	-2.07	0.0327	0.0701	-0.38
3/14/2017 9:50	0.602	1.09	-0.491	-3.04	-3.17	0.0243	0.115	-0.5
4/11/2017 10:50	2.89	2.34	0.552	3.4	3.59	0.0146	0.0858	0.437
3/6/2018 9:40	1.36	1.07	0.289	1.79	1.81	0.0251	0.0412	0.29
6/1/2018 10:50	2.77	2.99	-0.226	-1.41	-1.42	0.0399	0.0413	-0.289
11/19/2018 11:00	0.602	0.895	-0.293	-1.82	-1.84	0.0329	0.0563	-0.339
3/14/2019 13:30	3.25	2.96	0.297	1.85	1.88	0.0379	0.0677	0.372
5/15/2019 12:30	3.18	2.57	0.607	3.75	4.01	0.0213	0.153	0.591
12/11/2019 11:10	1.11	0.804	0.31	1.93	1.96	0.0374	0.0726	0.386

## **Statistical Plots**

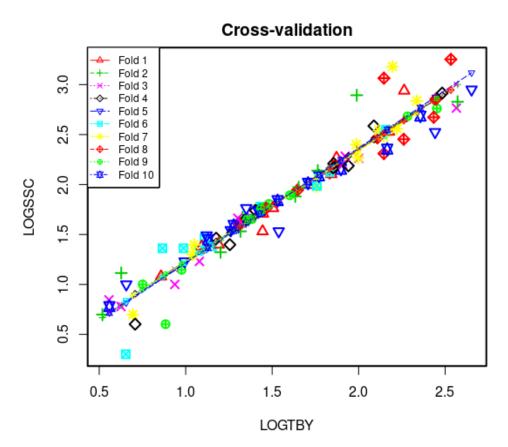




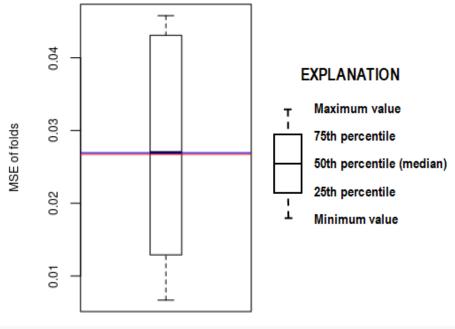


# EXPLANATION 4 Number of values T Maximum value 1 75th percentile 50th percentile (median) 25th percentile Minimum value

## **Cross Validation**



Minimum MSE of folds: 0.00667 Mean MSE of folds: 0.02700 Median MSE of folds: 0.02700 Maximum MSE of folds: 0.04580 (Mean MSE of folds) / (Model MSE): 1.01000



Red line - Model MSE

Blue line - Mean MSE of folds

# **Model-Calibration Dataset**

vioue	-calibration	Dalasel							
	Date	LOGSSC	LOGTBY	SSC	TBY	Computed LOGSSC	Computed SSC	Residual	Normal Quantiles
1	10/16/2014	1.67	1.33	47	21.3	1.6	42.7	0.0758	0.947
2	11/19/2014	0.699	0.695	5	4.95	0.88	8.2	-0.181	-1.29
3	12/9/2014	1	0.751	10	5.64	0.944	9.5	0.0562	0.779
4	12/15/2014	1.34	1.08	22	12	1.31	22.3	0.0282	0.392
5	1/14/2015	0.699	0.519	5	3.3	0.681	5.19	0.0177	0.175
6	2/11/2015	1.08	0.857	12	7.2	1.06	12.5	0.0154	0.104
7	2/25/2015	0.301	0.653	2	4.5	0.833	7.36	-0.532	-2.54
8	3/11/2015	1.15	0.976	14	9.47	1.2	17.1	-0.0518	-0.63
9	4/6/2015	1.23	1.08	17	12	1.31	22.3	-0.0837	-0.779
10	4/16/2015	1.58	1.3	38	20.2	1.57	40	0.0111	0.0116
11	4/22/2015	2.31	2.15	204	140	2.52	357	-0.209	-1.55
12	5/5/2015	2.01	1.71	103	51	2.02	114	-0.0107	-0.222
13	5/20/2015	2.68	2.36	484	228	2.76	617	-0.0718	-0.717
14	5/27/2015	2.94	2.26	870	183	2.65	484	0.289	1.55
15	6/10/2015	2.12	1.83	131	68	2.16	158	-0.0473	-0.547
16	6/17/2015	3.06	2.15	1160	140	2.52	357	0.546	1.98
17	6/29/2015	1.66	1.36	46	23.2	1.64	46.8	0.0261	0.367
18	7/6/2015	1.65	1.35	45	22.3	1.62	44.9	0.0345	0.468
19	7/13/2015	2.15	1.9	142	79	2.24	187	-0.0858	-0.81
20	7/20/2015	1.64	1.36	44	23	1.63	46.4	0.0103	-0.0348
21	8/3/2015	1.84	1.53	69	34	1.82	72.2	0.0141	0.0812
22	8/17/2015	1.53	1.54	34	34.5	1.83	73.4	-0.3	-1.83
23	8/27/2015	2.53	2.44	335	277	2.85	770	-0.328	-1.98
24	9/8/2015	1.98	1.76	95	57	2.08	129	-0.1	-0.947
25	10/14/2015	1.46	1.18	29	15	1.42	28.7	0.0388	0.521
26	11/17/2015	1.71	1.45	51	28	1.73	58	-0.022	-0.318
27	1/19/2016	1.53	1.44	34	27.8	1.73	57.6	-0.195	-1.47
28	2/16/2016	1.4	1.26	25	18	1.51	35.2	-0.115	-1.02
29	3/16/2016	1.38	1.15	24	14.2	1.4	26.9	-0.0154	-0.27
30	4/20/2016	2.17	1.86	149	72.7	2.2	170	-0.024	-0.367
31	4/21/2016	2.4	1.99	252	97	2.34	236	0.0626	0.876
32	5/26/2016	2.84	2.34	688	217	2.73	584	0.105	1.06
33	5/31/2016	2.48	2.15	301	140	2.52	357	-0.0401	-0.443
34	6/7/2016	2.1	1.84	127	69.5	2.18	162	-0.0715	-0.688
35	6/17/2016	2.47	2.11	293	128	2.48	323	-0.00913	-0.175
36	6/21/2016	2.76	2.45	577	283	2.86	791	-0.103	-0.984
37	6/28/2016	1.94	1.65	88	44.3	1.95	97.4	-0.0104	-0.198
38	7/6/2016	2.59	2.09	386	123	2.45	307	0.133	1.29
39	7/13/2016	1.97	1.65	94	45	1.96	99.1	0.0109	-0.0116
40	7/25/2016	1.78	1.43	60	27	1.71	55.7	0.0664	0.911
41	8/11/2016	2.26	2	183	100	2.35	244	-0.0912	-0.843
42	8/16/2016	1.88	1.63	76	43	1.94	94.1	-0.0591	-0.659
43	8/29/2016	2.27	2	185	99.2	2.35	242	-0.0824	-0.748
44	9/7/2016	1.99	1.76	97	57.3	2.08	130	-0.0942	-0.876
45	9/13/2016	2.35	2.17	226	146	2.54	375	-0.186	-1.35
46 47	10/24/2016	1.36	0.988	23	9.72	1.21	17.6	0.151	1.41
47 48	11/15/2016	1.46 1	1.11 0.656	29 10	12.8	1.35	24	0.115	1.1
48 49	12/14/2016 2/14/2017		0.656 1.04	10 20	4.53 10.9	0.837 1.27	7.43 20	0.163 0.0332	1.47 0.443
49 50	2/14/2017 3/14/2017	1.3 0.602	0.884	20	7.65	1.27	20 13.4	0.0332 -0.491	0.443 -2.18
50 51	3/30/2017	2.86	2.45	4 717	280	2.86	780	-0.491	-2.18 -0.128
52	3/30/2017 4/11/2017	2.80	2.45 1.99	717	280 97.5	2.80	237	-0.00297 0.552	-0.128 2.18
53	4/11/2017 5/1/2017	2.69	2.18	338	150	2.54	386	-0.0236	-0.342
22	5/1/201/	2.33	2.10	220	120	2.55	200	-0.0250	-0.342

54       5/15/2017       1.77       1.45       59       2.17       159       -0.443       0.575         55       5/31/2017       1.67       7       4.45       59       2.17       58       0.4413       0.575         56       6/3/2017       1.66       1.3       46       20       1.56       39.7       0.8981       1.02         57       6/13/2017       1.53       1.32       34       22.8       1.63       45.9       0.8253       0.342         59       7/13/2017       1.53       1.32       34       22.7       1.58       41.3       -0.8566       -0.602         61       8/2/2017       1.74       1.43       55       2.5.8       1.71       55.2       0.8322       0.6417         63       8/39/2017       1.6       1.31       40       20.5       1.58       40.8       0.6252       0.638         65       10/15/2017       1.33       28       1.35       1.37       25.4       0.60764       0.984         67       12/12/2017       0.778       0.526       6       4.22       0.802       6.8       -0.224       -0.392         68       1/3/2018       0.845										
56 $6/5/2017$ 1.60       1.6       78       40       1.9       86.7 $-0.0981$ $-0.246$ 57 $6/13/2017$ 1.65       1.36       45       22.8       1.63       45.9 $0.0981$ $1.062$ 58 $6/28/2017$ 1.74       1.13       1.48       64 $30.27$ $1.58$ 41.3 $-0.4986$ $-0.4026$ 61 $8/2/2017$ 1.74       1.43       55       2.68 $1.717$ 55.2 $0.8322$ $-0.4628$ 62 $8/16/2017$ 1.74       1.43       55       2.68 $1.717$ $55.2$ $0.8322$ $0.417$ 63 $8/30/2017$ 1.54 $1.26$ $55.7$ $0.0252$ $0.631$ 65 $1/1/5/2017$ $1.38$ $1.09$ $24$ $12.44$ $0.332$ $25.4$ $0.0282$ $0.663$ 67 $1/3/2018$ $0.845$ $0.556$ 7 $3.6$ $0.724$ $5.72$ $0.121$ $0.132$ $1.63$ 7 $1.40$ $0.52$ $1.12$ $1.28$ $0.26.6$ $0.131$ $1.6$										
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59       7/13/2017       1.61       1.48       64       30.2       1.77       63.3       0.0388       0.494         60       7/31/2017       1.53       1.32       34       20.7       1.58       41.3       -0.0596       -0.6622         61       8/2/2017       1.6       1.31       40       20.5       1.58       44.8       0.0229       -0.468         62       8/36/2017       1.6       1.31       40       20.5       1.52       35.7       0.0229       0.318         65       10/17/0217       1.48       1.26       35       18.2       1.52       35.7       0.0252       0.318         67       12/12/2017       0.778       0.626       6       4.22       0.802       6.86       -0.621       -0.998         67       12/12/2017       0.452       0.731       0.872       5.7       0.121       1.19         68       1/31/2018       0.845       0.556       7       3.6       0.242       5.72       0.121       1.19         69       3/62/2018       1.36       0.865       23       7.36       0.6       0.118       1.15         70       3/2/2018       1.4       1										
60       7/31/2017       1.53       1.32       34       20.7       1.58       41.3       -0.06023       -0.6024         61       8/2/2017       1.74       1.43       1.9       25       15.5       1.44       29.8       -0.0423       -0.6468         62       8/16/2017       1.74       1.43       55       26.8       1.58       40.8       0.0229       0.2349         63       8/30/2017       1.64       1.31       40       20.5       1.58       40.8       0.0229       0.318         64       9/6/2017       1.54       1.26       35       1.37       25.4       0.0562       0.633         66       1/15/2017       1.45       1.13       28       1.35       1.37       25.4       0.0764       0.984         67       1.21/2018       0.778       0.626       6       4.22       0.802       6.86       -0.821       1.63         70       3/2/2018       1.44       1.05       25       11.2       1.28       0.289       1.63         70       3/2/2018       1.49       1.12       31       31.2       1.28       0.6       0.131       0.0434         72       5/2/2018										
61 $8/2/2017$ 1.41.192515.51.4429.8 $-0.4033$ $-0.468$ 62 $8/16/2017$ 1.741.435526.81.7155.2 $0.0322$ $0.417$ 63 $8/30/2017$ 1.61.314020.51.5235.7 $0.0252$ $0.631$ 65 $10/17/2017$ 1.381.021321.321.5235.7 $0.0252$ $0.633$ 66 $11/15/2017$ 1.451.13281.371.3725.4 $0.0764$ $0.984$ 67 $12/12/2017$ 0.778 $0.626$ 64.22 $0.802$ $6.86$ $-0.0241$ $-0.392$ 68 $1/31/2018$ 0.485 $0.556$ 73.6 $0.724$ $5.72$ $0.121$ $1.19$ 70 $3/22/2018$ 1.441.052511.21.2828.6 $0.118$ $1.15$ 71 $4/18/2018$ 1.591.283913.21.3624.8 $0.131$ $1.24$ 73 $5/9/2018$ 1.591.283918.91.5437.3 $0.653$ $0.748$ 74 $5/23/2018$ 1.771.575833.672.991060 $-0.226$ $-1.63$ 75 $6/1/2018$ 2.772.575833.672.991360 $-0.121$ $-1.19$ 78 $6/26/2018$ 2.21.9115980.92.25192 $-0.0486$ $-0.575$ 79 $7/19/2018$ 2.772.575833.67										
63       8/30/2017       1.6       1.31       40       20.5       1.52       35.7       0.0249       0.294         64       9/6/2017       1.54       1.26       35       18.2       1.52       35.7       0.0252       0.318         65       10/17/2017       1.45       1.13       228       13.5       1.33       25.4       0.0764       0.984         67       12/12/2017       0.78       0.626       6       4.22       0.802       6.86       -0.0241       -1.19         69       3/6/2018       1.36       0.865       23       7.33       1.07       12.8       0.289       1.63         70       3/22/2018       1.4       1.06       25       11.2       1.28       20.6       0.131       0.034         71       3/5/9/2018       1.59       1.28       39       18.9       1.54       37.3       0.653       0.748         75       6/1/2018       2.17       1.85       147       71.1       2.19       166       -0.0192       -0.226         76       6/26/2018       2.19       1.59       1.58       32       1.8       67.4       -0.0316       -0.417         76 <td></td>										
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107         10/9/2019         1.76         1.44         57         27.2         1.72         56.2         0.0399         0.547										
108         12/11/2019         1.11         0.627         13         4.24         0.804         6.88         0.31         1.83										
	108	12/11/2019	1.11	0.627	13	4.24	0.804	6.88	0.31	1.83

#### Definitions

SSC: Suspended sediment concentration (SSC) in mg/L (80154) TBY: Turbidity in FNU (63680)

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