Appendix 25. Model Archival Summary for Suspended-Sediment Concentration at Station 06887500; Kansas River at Wamego, Kansas

This model archival summary summarizes the suspended-sediment concentration (SSC) model developed to compute 15-minute SSC from July 19, 2012 onward. This model supersedes all previous models.

Site and Model Information

Site number: 06887500
Site name: Kansas River at Wamego, Kansas
Location: Lat 39°11'54", long 96°18'19" referenced to North American Datum of 1927, in SW 1/4 NW 1/4 SE 1/4 sec.9, T.10 S., R.10 E., Pottawatomie County, KS, Hydrologic Unit 10270102.

Equipment: An YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance, dissolved oxygen, pH, turbidity, and chlorophyll was installed from August 2012 through May 2014. From June 2014 to the present (2015) a Xylem YSI EXO2 water-quality monitor equipped was installed with sensors for water temperature, specific conductance, dissolved oxygen, pH, turbidity, and chlorophyll. The monitor is housed in a 4-inch diameter galvanized steel pipe. Readings from the water-quality monitor are recorded every 15 minutes and transmits data by way of satellite, hourly.

Date model was created: October 15, 2015

Model calibration data period: July 19, 2012 – June 29, 2015

Model application date: July 19, 2012 onward

Model-Calibration Dataset

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the National Water Information System (NWIS) database. Linear regression models were developed using the open-source software package "R." Explanatory variables selected as inputs to linear regression were physicochemical properties: specific conductance, pH, water temperature, dissolved oxygen, turbidity, chlorophyll fluorescence, and streamflow. Seasonal components (sine and cosine variables) were also evaluated as explanatory variables in the models to determine if seasonal changes affected the model. All combinations of physicochemical properties and a seasonal component were evaluated to determine which combinations produced the best models.

The final selected regression model is based on 48 concurrent measurements of SSC concentration, and turbidity (Turb) collected from July 19, 2012 through June 29, 2015. Samples were collected throughout the range of continuously observed hydrologic conditions. No samples were below laboratory detection limits. Summary statistics and the complete model-calibration dataset are provided below. Studentized residuals from the final model were inspected for values greater than 3 or less than negative 3. Values outside of that range are considered potential outliers and are investigated. Six samples collected during icy conditions were found to have erroneously high sand fractions, and were removed from the dataset (November 19, 2012, December 17, 2012, January 14, 2013, December 16, 2013, January 13, 2014, and February 10, 2014). No other potential outliers were found to have errors in collection, processing, or analysis, therefore they were retained.

Suspended Sediment Sampling Details

Cross-section samples are typically collected either from the downstream side of the bridge or instream within 100 feet of the bridge. The equal-width-increment (EWI) method is used, and samples typically are composited for analysis. Cross-section samples are collected every 2 weeks from March through October, once a month from November through February, and during selected runoff events. A FISP US DH-95, D-95, or D-96A1 depth integrating sampler is used from the bridge; and a DH-81 or DH-95 hand sampler is used for boat samples. Samples are analyzed for SSC concentration at the USGS Sediment Laboratory in Iowa City, Iowa.

Model Development

Regression analysis was done using R by examining Turb, streamflow, and other continuously measured data as explanatory variables for estimating SSC concentration. A variety of models that predict SSC, $(SSC)^2$, $\sqrt{SSC}$ and models that predict $\log_{10}(SSC)$ were evaluated. The distribution of residuals was examined for normality, and plots of residuals (the difference between the measured and computed values) as compared to computed SSC were examined for homoscedasticity (meaning that their departures from zero did

not change substantially over the range of computed values). This comparison lead to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}$(SSC).

Turb was selected as the best predictors of SSC based on residual plots, relatively high adjusted coefficient of determination (adjusted R^2) and relatively low model standard percentage error (*MSPE*), prediction error sum of squares (PRESS), and Mallow's C_p. Values for all of the afore mentioned statistics and metrics were computed for various models and are included below along with all relevant sample data and more in-depth statistical information.

Model Summary

Summary of final regression analysis for SSC concentration at site number 06887500.

SSC concentration-based model:

$$\log_{10}(SSC) = 0.969 \times \log_{10}(Turb) + 0.461$$

where

SSC = suspended-sediment concentration in milligrams per liter (mg/L); and,

Turb = turbidity in formazin nephelometric units (FNU)

Turbidity makes physical and statistical sense as explanatory variables for SSC.

The log-transformed model may be retransformed to the 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). For this model, the calculated BCF is 1.21. The retransformed model, accounting for BCF is:

$$SSC = Turb^{0.969} + 3.50$$

Previous Models

Start year	End year	Model
2000	2005	$\log_{10}(SSC) = 0.910 \times \log_{10}(Turb) + 0.271$

Suspended-Sediment Concentration Record

The SSC record is computed using this regression model and stored at the National Real-Time Water Quality (NRTWQ) Web site. Data are computed at 15-minute intervals. The complete water-quality record can be found at http://nrtwq.usgs.gov/ks.

Remarks

None

R Output for Suspended Sediment; 06887500; Kansas River at Wamego, KS

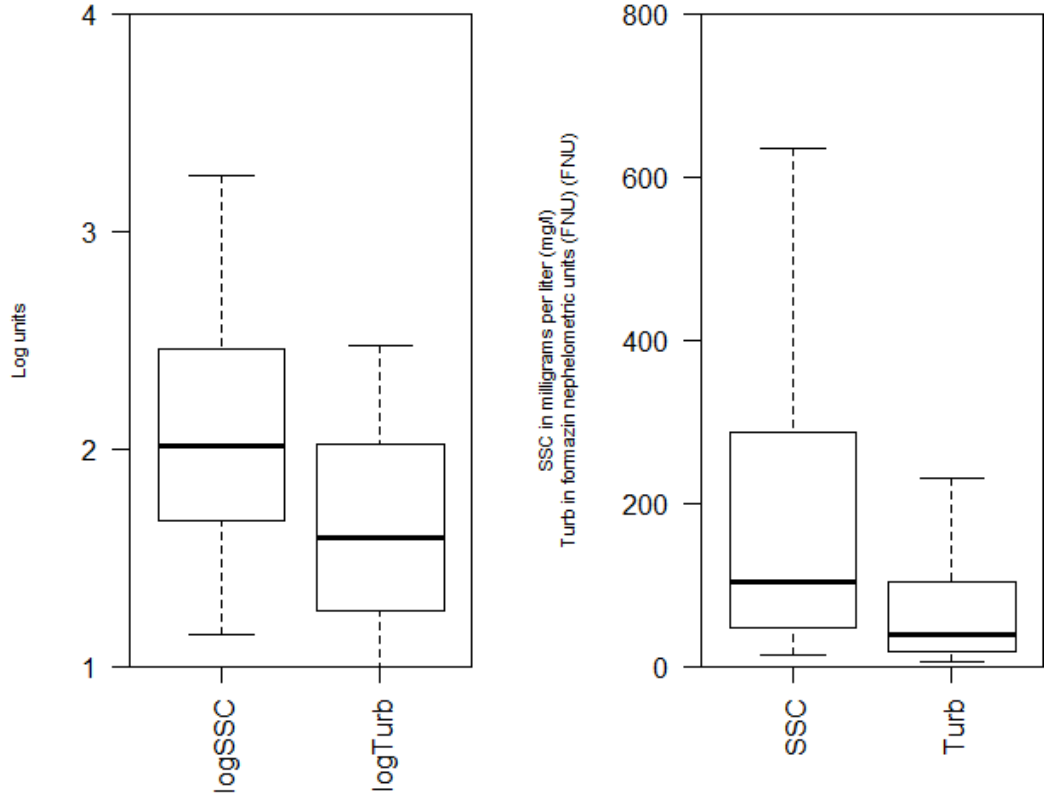
Model Form

logSSC = + 0.969 * logTurb + 0.461

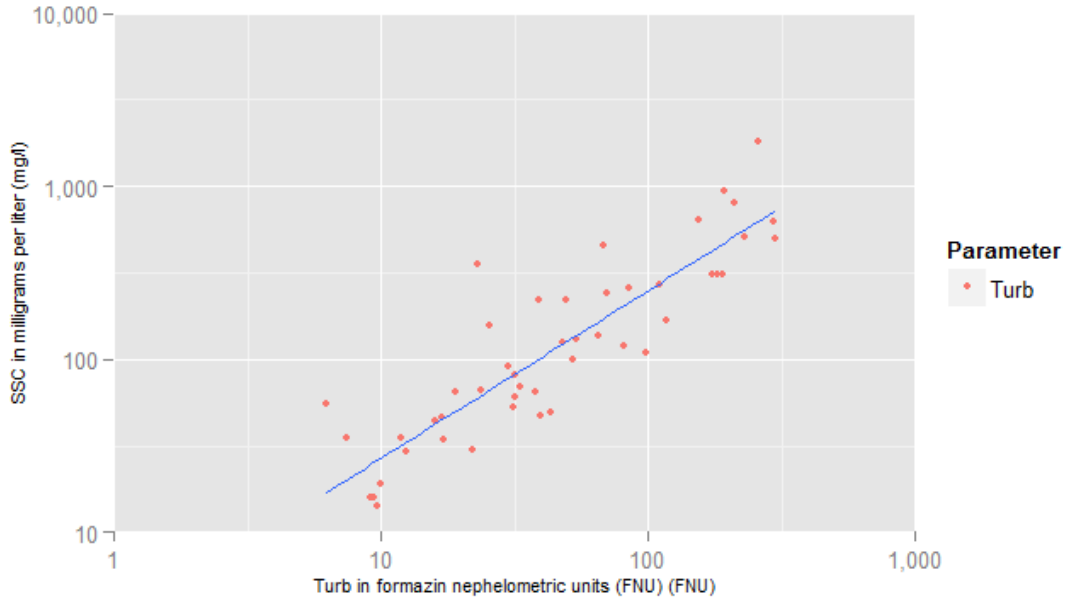
Variable Summary Statistics

	logSSC	logTurb	SSC	Turb
Minimum	1.15	0.792	14.0	6.2
1st Quartile	1.67	1.260	46.5	18.0
Median	2.02	1.590	104.0	39.2
Mean	2.05	1.640	226.0	76.1
3rd Quartile	2.46	2.020	287.0	104.0
Maximum	3.26	2.480	1800.0	299.0

Box Plot(s) of sample data



Exploratory Plot



Model Calibration

Basic Data

Number of Observations	48
Standard error (RMSE)	0.248
Upper Model standard percentage error (MSPE)	77.2
Lower Model standard percentage error (MSPE)	43.6
Coefficient of determination (R^2)	0.781
Adjusted Coefficient of Determination (Adj. R^2)	0.776
Bias Correction Factor (BCF)	1.21

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(>|t|)
(Intercept)	0.461	0.1290	3.57	8.54e-04
logTurb	0.969	0.0757	12.80	9.36e-17

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.961
E.vars	-0.961	1.000

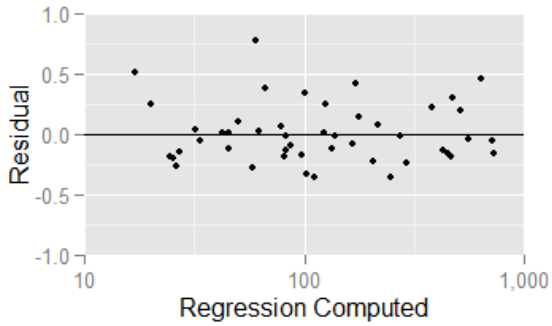
Test Criteria

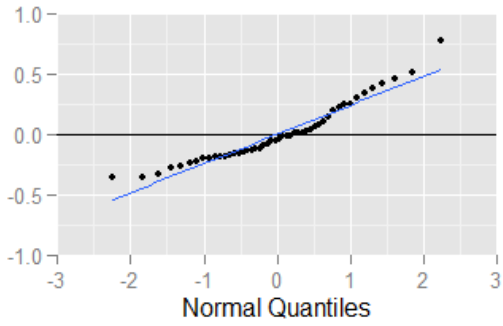
Leverage	Cook's D	DFFITS
0.0625000	0.1055971	0.2886751

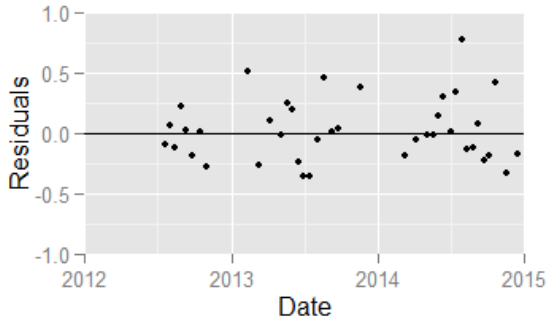
Flagged Observations

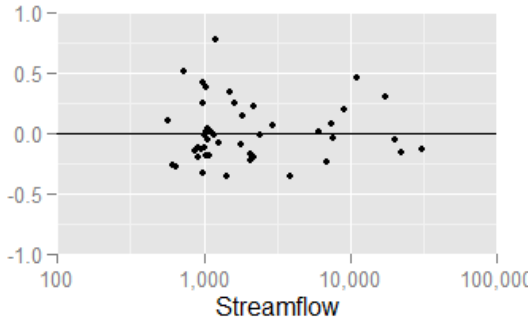
	logSSC	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
2/11/2013 8:20	1.740	1.228	0.51230	2.1590	2.2520	0.08724	0.222700	0.69630
6/3/2013 8:50	2.903	2.710	0.19340	0.8049	0.8017	0.06436	0.022280	0.21030
8/5/2013 7:30	2.800	2.851	-0.05119	-0.2154	-0.2132	0.08493	0.002153	-0.06494
8/19/2013 9:30	3.255	2.800	0.45570	1.9100	1.9680	0.07696	0.152000	0.56840
3/10/2014 8:20	1.204	1.388	-0.18390	-0.7653	-0.7618	0.06382	0.019960	-0.19890
6/11/2014 9:00	2.974	2.673	0.30050	1.2470	1.2550	0.05969	0.049390	0.31630
7/28/2014 10:00	2.549	1.779	0.76960	3.1420	3.5070	0.02791	0.141700	0.59420
4/6/2015 8:50	1.544	1.304	0.24050	1.0070	1.0070	0.07555	0.041420	0.28780
5/18/2015 10:30	2.693	2.858	-0.16510	-0.6952	-0.6913	0.08601	0.022740	-0.21210
6/1/2015 8:00	2.708	2.748	-0.04039	-0.1685	-0.1667	0.06953	0.001061	-0.04558

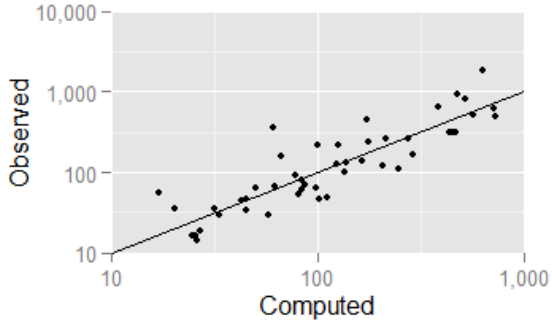
Statistical Plots

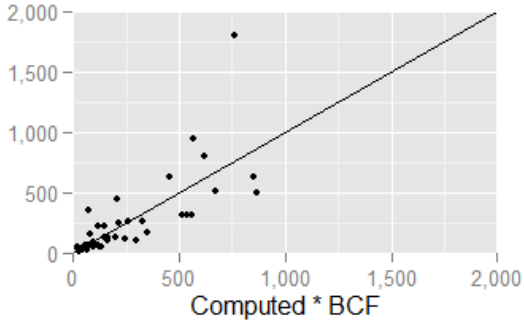


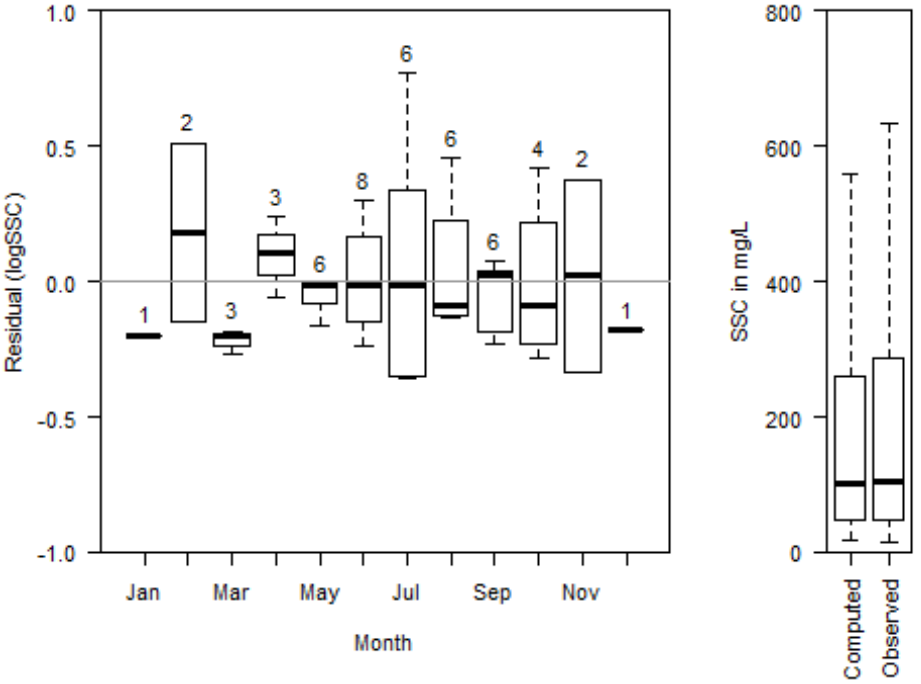


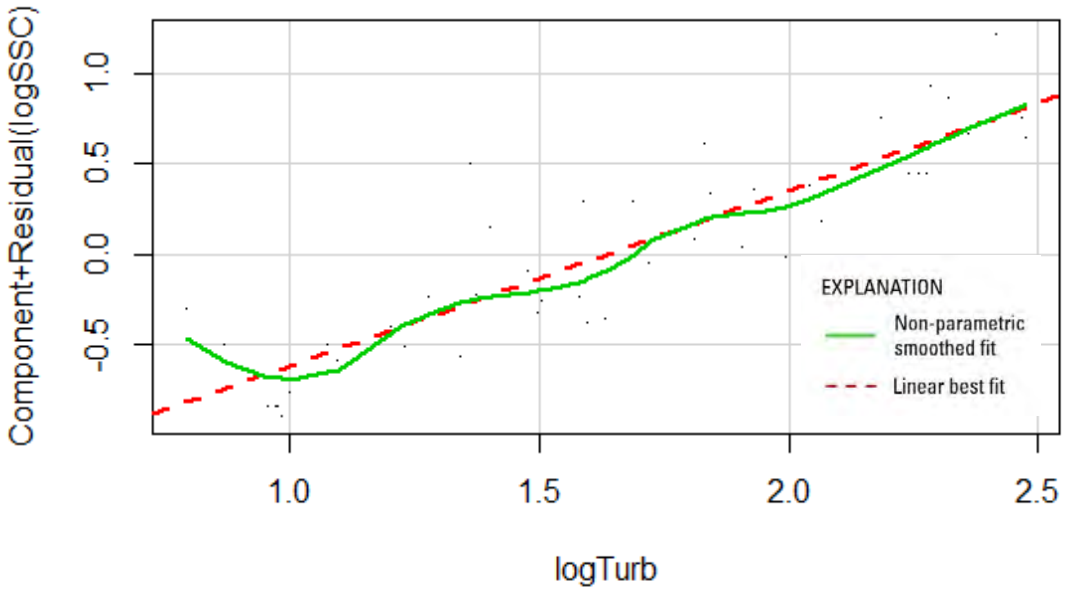









Residual (logSSC)
1.0
0.5
0.0
-0.5
-1.0
1
2
3
3
6
8
6
6
6
4
2
1
Jan
Mar
May
Jul
Sep
Nov
Month
SSC in mg/L
800
600
400
200
0
Computed
Observed


Component+Residual(logSSC)
1.0
0.5
0.0
-0.5
1.0
1.5
2.0
2.5
logTurb
EXPLANATION
Non-parametric smoothed fit
Linear best fit

Models considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logSSC ~ logTurb	1	0.2484	78.05	77.58	-0.3312	3.103	1	± 60
logSSC ~ Turb	1	0.309	66.03	65.29	23.58	4.871	1	± 77
logSSC ~ logQ	1	0.3864	46.89	45.74	61.67	7.433	1	± 100
logSSC ~ logTurb + cos2DY	2	0.249	78.42	77.46	0.9311	3.257	1.518	± 61
logSSC ~ Turb + logTurb	2	0.2503	78.21	77.24	1.361	3.248	5.284	± 61
logSSC ~ Q + logTurb	2	0.2508	78.11	77.14	1.551	3.177	1.738	± 61
logSSC ~ Turb + logTurb + cos2DY	3	0.2501	78.71	77.26	2.353	3.395	5.549	± 61
logSSC ~ Q + logTurb + cos2DY	3	0.2514	78.5	77.04	2.774	3.334	1.745	± 61
logSSC ~ Q + Turb + logTurb	3	0.2514	78.5	77.03	2.779	3.263	2.452	± 61
logSSC ~ Q + Turb + logTurb + cos2DY	4	0.25	79.22	77.29	3.341	3.372	2.574	± 61
logSSC ~ logQ + Turb + logTurb + cos2DY	4	0.2518	78.92	76.96	3.946	3.451	3.578	± 61
logSSC ~ Turb + logTurb + sin2DY + cos2DY	4	0.252	78.89	76.93	3.993	3.461	6.093	± 61
logSSC ~ Q + Turb + logTurb + sin2DY + cos2DY	5	0.2521	79.36	76.9	5.07	3.439	2.59	± 61
logSSC ~ Q + logQ + Turb + logTurb + cos2DY	5	0.2528	79.25	76.78	5.286	3.466	6.581	± 62
logSSC ~ logQ + Turb + logTurb + sin2DY + cos2DY	5	0.2539	79.07	76.57	5.654	3.522	3.611	± 62
logSSC ~ Q + logQ + Turb + logTurb + sin2DY + cos2DY	6	0.255	79.39	76.38	7	3.531	6.581	± 62

Data

	Date	logSSC	logTurb	SSC	Turb	Computed logSSC	Computed SSC	Residual	Normal Quantiles
1	2012-07-19	1.845	1.524	70	33.4	1.936	104.1	-0.0913	-0.183
2	2012-07-30	1.954	1.479	90	30.1	1.893	94.14	0.0616	0.516
3	2012-08-13	1.531	1.233	34	17.1	1.655	54.44	-0.123	-0.236
4	2012-08-27	2.803	2.188	635	154	2.579	457.5	0.224	0.845
5	2012-09-10	1.82	1.375	66	23.71	1.792	74.72	0.0273	0.4
6	2012-09-24	1.724	1.496	53	31.33	1.909	97.87	-0.185	-0.845
7	2012-10-15	1.663	1.23	46	17	1.652	54.14	0.0104	0.29
8	2012-10-29	1.477	1.342	30	22	1.761	69.49	-0.284	-1.44
9	2013-02-11	1.74	0.7924	55	6.2	1.228	20.38	0.512	1.84
10	2013-03-11	1.146	0.9845	14	9.65	1.414	31.28	-0.268	-1.31
11	2013-04-08	1.806	1.279	64	19	1.699	60.29	0.107	0.639
12	2013-05-06	2.427	2.041	267	110	2.438	330.3	-0.0112	0.13
13	2013-05-20	2.338	1.69	218	49	2.098	150.9	0.241	1
14	2013-06-03	2.903	2.322	800	210	2.71	617.8	0.193	0.772
15	2013-06-17	2.223	2.067	167	116.7	2.462	349.7	-0.24	-1.19
16	2013-07-01	2.033	1.993	108	98.5	2.391	296.8	-0.358	-2.24
17	2013-07-15	1.69	1.633	49	43	2.043	133	-0.352	-1.84
18	2013-08-05	2.8	2.468	631	294	2.851	855.8	-0.0512	-0.026
19	2013-08-19	3.255	2.415	1800	260	2.8	759.8	0.456	1.61
20	2013-09-09	1.643	1.204	44	16	1.627	51.05	0.0166	0.345
21	2013-09-23	1.544	1.076	35	11.9	1.502	38.32	0.0418	0.458
22	2013-11-18	2.199	1.404	158	25.33	1.82	79.65	0.379	1.31
23	2014-03-10	1.204	0.9576	16	9.07	1.388	29.46	-0.184	-0.772
24	2014-04-07	1.462	1.097	29	12.5	1.523	40.19	-0.0606	-0.0781
25	2014-05-05	2.117	1.732	131	53.99	2.138	165.8	-0.0211	0.0781
26	2014-05-19	1.908	1.505	81	32	1.918	99.89	-0.00987	0.183
27	2014-06-02	2.386	1.845	243	70	2.248	213.2	0.138	0.704
28	2014-06-11	2.974	2.284	941	192.5	2.673	567.9	0.3	1.09
29	2014-06-30	2.093	1.679	124	47.79	2.087	147.3	0.00636	0.236
30	2014-07-14	2.338	1.591	218	39	2.002	121	0.337	1.19
31	2014-07-28	2.549	1.362	354	23	1.779	72.55	0.77	2.24

32	2014-08-11	1.785	1.505	61	32	1.918	99.89	-0.133	-0.345
33	2014-08-25	2	1.72	100	52.5	2.127	161.3	-0.127	-0.29
34	2014-09-08	2.408	1.932	256	85.42	2.331	258.5	0.0769	0.576
35	2014-09-22	2.079	1.909	120	81.17	2.31	246.1	-0.231	-1.09
36	2014-10-06	2.487	2.279	307	190	2.668	560.7	-0.18	-0.704
37	2014-10-20	2.654	1.831	451	67.8	2.234	206.7	0.42	1.44
38	2014-11-17	1.672	1.597	47	39.5	2.007	122.5	-0.335	-1.61
39	2014-12-15	1.813	1.58	65	38	1.991	118	-0.178	-0.639
40	2015-01-12	1.204	0.9713	16	9.36	1.401	30.37	-0.197	-0.921
41	2015-02-09	1.279	1	19	10	1.429	32.38	-0.15	-0.458
42	2015-03-09	1.204	0.9759	16	9.46	1.406	30.69	-0.202	-1
43	2015-04-06	1.544	0.8704	35	7.42	1.304	24.25	0.24	0.921
44	2015-05-04	2.134	1.813	136	65	2.216	198.4	-0.0829	-0.13
45	2015-05-18	2.693	2.475	493	298.8	2.858	869.2	-0.165	-0.576
46	2015-06-01	2.708	2.362	510	230	2.748	674.7	-0.0404	0.026
47	2015-06-15	2.49	2.26	309	181.8	2.649	537.3	-0.159	-0.516
48	2015-06-29	2.494	2.243	312	175	2.633	517.8	-0.139	-0.4

Definitions and National Water Information System (parameter code)

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