

Appendix 26. Model Archival Summary for Suspended-Sediment Concentration at Station 06892350; Kansas River at De Soto, 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: 06892350

Site name: Kansas River at De Soto, Kansas

Location: Lat 38°59'00", long 94°57'52" referenced to North American Datum of 1927, in NE 1/4 SE 1/4 SE 1/4 sec.28, T.12 S., R.22 E., Leavenworth County, KS, Hydrologic Unit 10270104.

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 51 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. One sample, June 11, 2014, was found to have potential errors in collection and processing, and has been removed from the dataset. 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 led to the conclusion that the most appropriate and reliable model would be one that estimated $\log_{10}(\text{SSC})$.

Turb was as the best predictor 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 Mallows' C_p . Values for all of the aforementioned 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 06892350.

SSC concentration-based model:

$$\log_{10}(\text{SSC}) = 0.942 \times \log_{10}(\text{Turb}) + 0.441$$

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 1.12. The retransformed model, accounting for BCF is:

$$SSC = \text{Turb}^{0.942} + 3.09$$

Previous Models

Start year	End year	Model
2000	2005	$\log_{10}(\text{SSC}) = 0.904 \times \log_{10}(\text{Turb}) + 0.264$

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 06892350; Kansas River at De Soto, KS

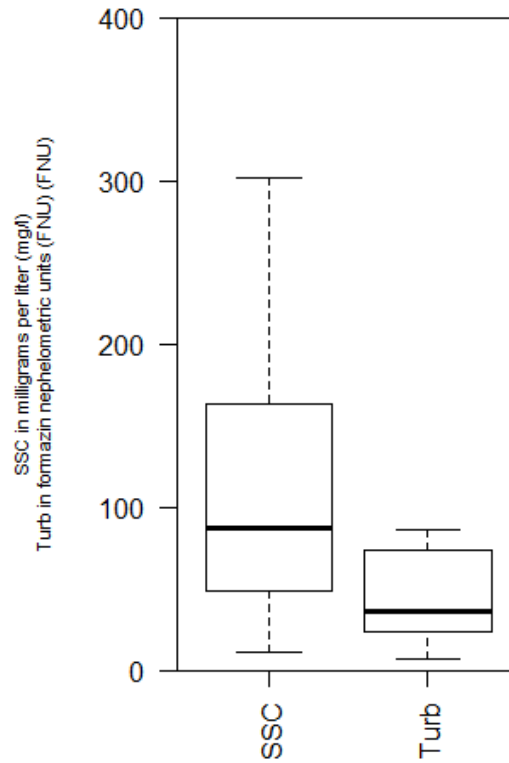
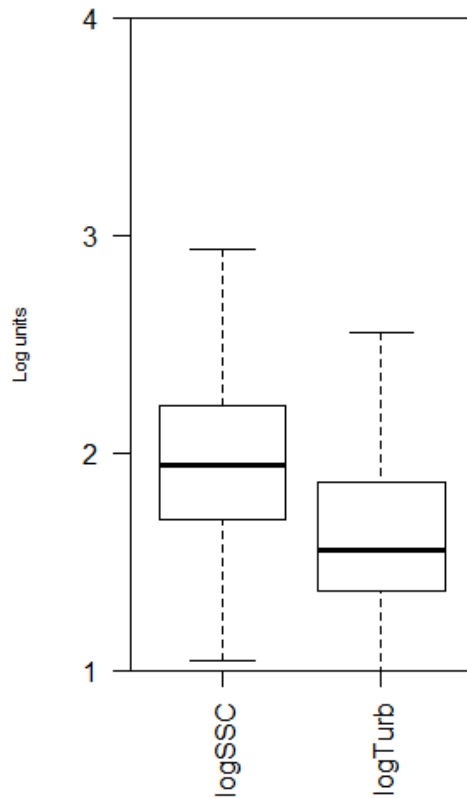
Model Form

$$\log\text{SSC} = + 0.942 * \log\text{Turb} + 0.441$$

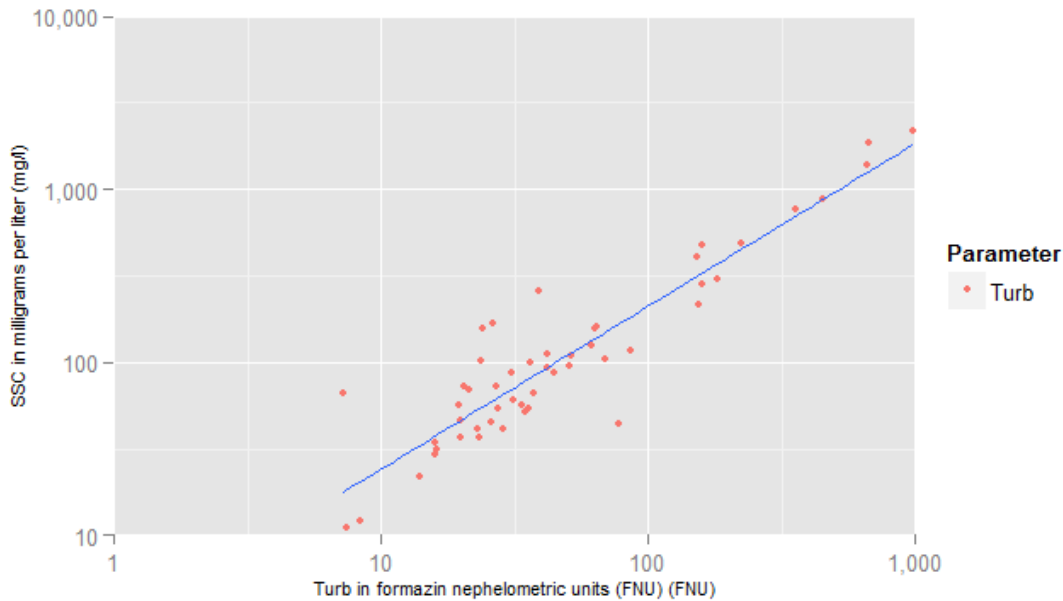
Variable Summary Statistics

	logSSC	logTurb	SSC	Turb
Minimum	1.04	0.858	11	7.21
1st Quartile	1.66	1.360	46	23.00
Median	1.94	1.550	87	35.80
Mean	2.02	1.680	243	108.00
3rd Quartile	2.22	1.890	167	78.00
Maximum	3.34	2.990	2190	982.00

Box Plot(s) of sample data



Exploratory Plot



Model Calibration

Basic Data

Number of Observations	51
Standard error (RMSE)	0.202
Upper Model standard percentage error (MSPE)	59.2
Lower Model standard percentage error (MSPE)	37.2
Coefficient of determination (R^2)	0.847
Adjusted Coefficient of Determination (Adj. R^2)	0.844
Bias Correction Factor (BCF)	1.12

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.441	0.0999	4.41	5.62e-05
logTurb	0.942	0.0571	16.50	1.24e-21

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.959
E.vars	-0.959	1.000

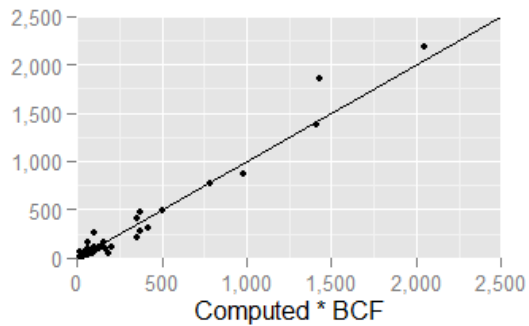
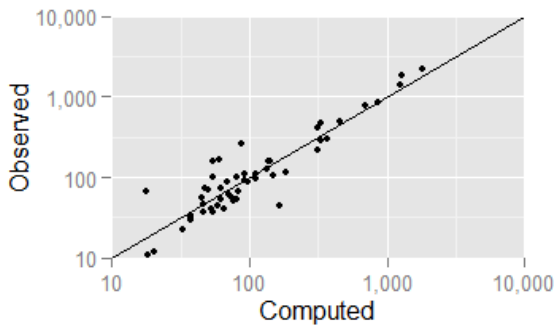
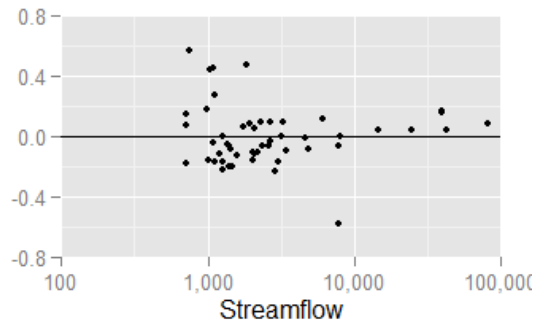
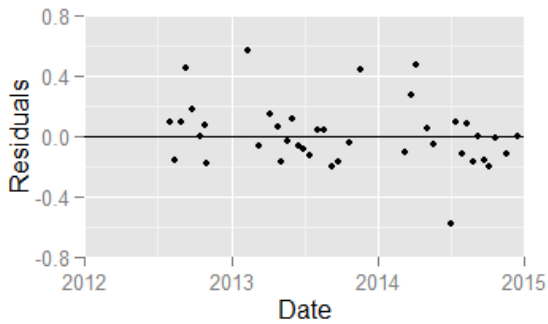
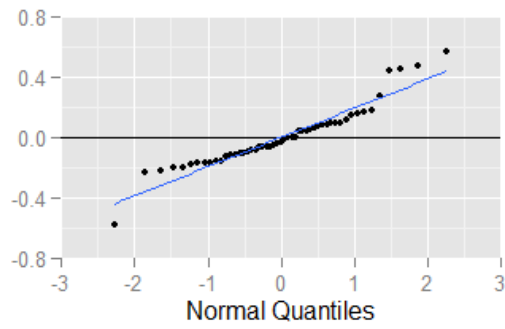
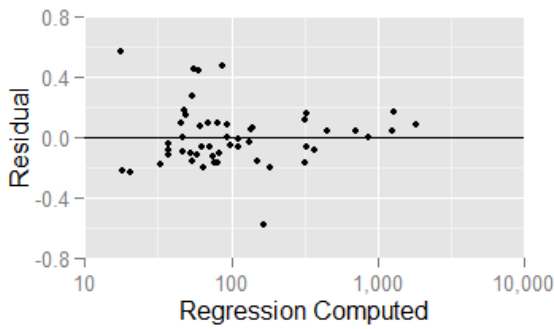
Test Criteria

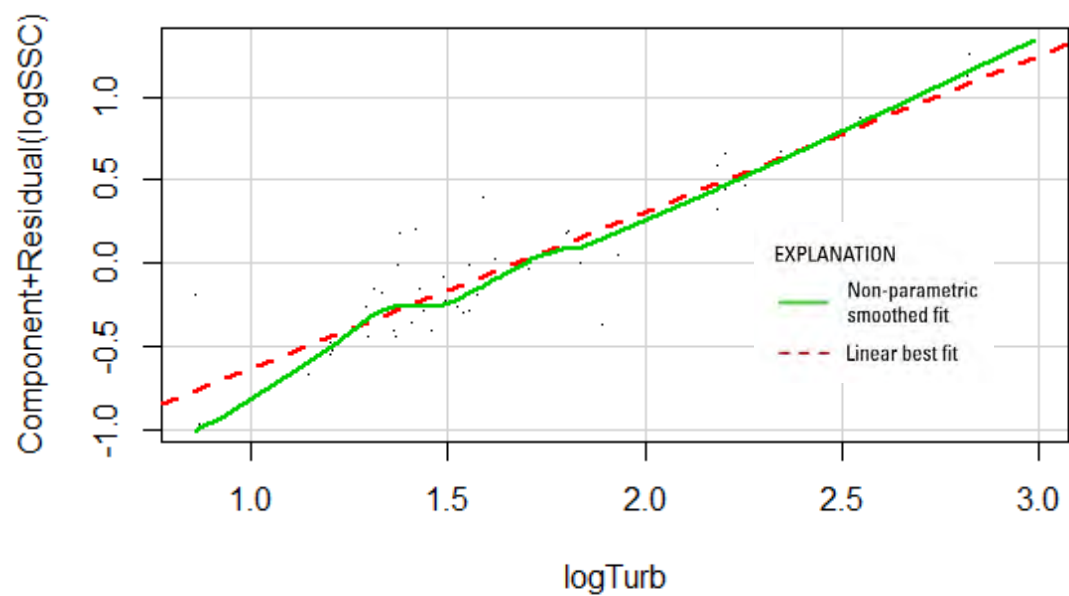
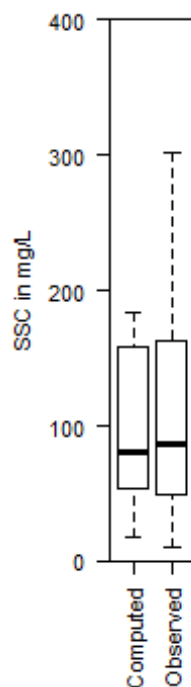
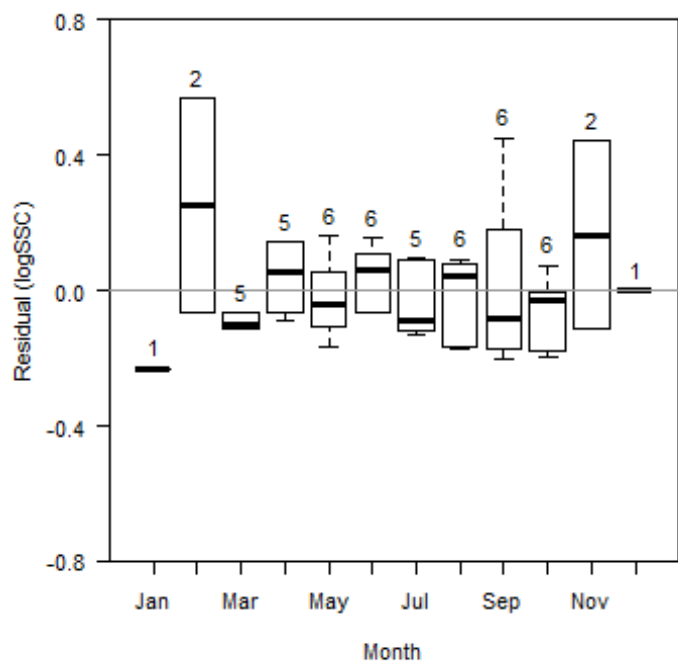
Leverage	Cook's D	DFFITS
0.05882353	0.10558284	0.28005602

Flagged Observations

	logSSC	Estimate	Residual	Standard Residual	Studentized Residual	Residual Leverage	Cook's D	DFFITS
9/10/2012 12:10	2.193	1.741	0.451800	2.267000	2.37200	0.02667	7.042e-02	0.392600
2/11/2013 10:35	1.820	1.249	0.570300	2.933000	3.19700	0.07334	3.404e-01	0.899400
8/5/2013 11:30	3.140	3.100	0.040290	0.213200	0.21110	0.12450	3.230e-03	0.079580
8/19/2013 10:00	2.885	2.845	0.040440	0.208800	0.20680	0.08078	1.916e-03	0.061300
11/18/2013 14:00	2.223	1.780	0.442400	2.218000	2.31400	0.02484	6.264e-02	0.369400
4/7/2014 11:40	2.415	1.940	0.475000	2.376000	2.49900	0.02020	5.818e-02	0.358900
6/30/2014 12:20	1.643	2.224	-0.580200	-2.906000	-3.16200	0.02330	1.008e-01	-0.488400
9/8/2014 12:40	2.939	2.940	-0.001329	-0.006921	-0.00685	0.09569	2.534e-06	-0.002228
1/12/2015 11:30	1.079	1.310	-0.231100	-1.183000	-1.18800	0.06518	4.881e-02	-0.313800
3/9/2015 12:20	1.041	1.260	-0.218500	-1.123000	-1.12600	0.07187	4.880e-02	-0.313300
5/18/2015 15:30	3.270	3.106	0.163100	0.863600	0.86130	0.12580	5.365e-02	0.326700
6/6/2015 19:50	3.340	3.260	0.080110	0.432200	0.42860	0.15800	1.753e-02	0.185700

Statistical Plots





Models considered

Model Formula	Number of Variables	Standard Error	R2	Adjusted R2	Cp	PRESS	VIF	MSPE
logSSC ~ logTurb	1	0.202	84.73	84.42	1.235	2.161	1 ± 48	
logSSC ~ Turb	1	0.3013	66.01	65.32	60.35	5.383	1 ± 75	
logSSC ~ logQ	1	0.333	58.48	57.63	84.13	5.863	1 ± 84	
logSSC ~ Turb + logTurb	2	0.2012	85.16	84.54	1.86	2.193	3.482 ± 48	
logSSC ~ Q + logTurb	2	0.2015	85.11	84.49	2.034	2.159	1.933 ± 48	
logSSC ~ logTurb + cos2DY	2	0.2024	84.97	84.35	2.459	2.214	1.538 ± 48	
logSSC ~ Q + logQ + logTurb	3	0.1992	85.76	84.85	1.985	2.411	3.674 ± 47	
logSSC ~ Q + logTurb + cos2DY	3	0.2022	85.32	84.38	3.377	2.221	1.941 ± 48	
logSSC ~ logQ + Turb + logTurb	3	0.2023	85.31	84.37	3.4	2.302	3.759 ± 48	
logSSC ~ Q + logQ + logTurb + sin2DY	4	0.2002	85.91	84.69	3.499	2.492	3.674 ± 48	
logSSC ~ Q + logQ + logTurb + cos2DY	4	0.2002	85.91	84.68	3.501	2.482	3.714 ± 48	
logSSC ~ Q + logQ + Turb + logTurb	4	0.2012	85.77	84.54	3.932	2.6	6.297 ± 48	
logSSC ~ Q + logQ + logTurb + sin2DY + cos2DY	5	0.2013	86.07	84.52	5.002	2.568	3.714 ± 48	
logSSC ~ Q + logQ + Turb + logTurb + sin2DY	5	0.2023	85.93	84.37	5.437	2.703	6.299 ± 48	
logSSC ~ Q + logQ + Turb + logTurb + cos2DY	5	0.2025	85.91	84.34	5.5	2.644	6.386 ± 48	
logSSC ~ Q + logQ + Turb + logTurb + sin2DY + cos2DY	6	0.2036	86.07	84.17	7	2.751	6.388 ± 49	

Data

0	Date	logSSC	logTurb	SSC	Turb	Computed logSSC	Computed SSC	Residual	Normal Quantiles
1	2012-07-30	1.934	1.488	86	30.79	1.843	78.28	0.0912	0.687
2	2012-08-13	1.568	1.371	37	23.5	1.733	60.69	-0.165	-0.887
3	2012-08-27	2	1.556	100	36	1.907	90.71	0.0927	0.75
4	2012-09-10	2.193	1.38	156	24	1.741	61.91	0.452	1.64
5	2012-09-24	1.857	1.314	72	20.59	1.679	53.58	0.179	1.23
6	2012-10-15	1.663	1.301	46	20	1.667	52.13	-0.00397	0.0981
7	2012-10-26	1.863	1.431	73	27	1.79	69.17	0.0738	0.511
8	2012-10-29	1.342	1.146	22	14	1.521	37.25	-0.178	-1.23
9	2013-02-11	1.82	0.8579	66	7.21	1.249	19.94	0.57	2.27
10	2013-03-11	1.785	1.495	61	31.28	1.85	79.46	-0.0644	-0.197
11	2013-04-08	1.839	1.332	69	21.5	1.696	55.81	0.143	0.962
12	2013-04-25	2.204	1.81	160	64.61	2.147	157.4	0.0575	0.456
13	2013-05-06	2.336	2.188	217	154	2.502	356.8	-0.166	-0.962
14	2013-05-20	2.097	1.788	125	61.4	2.126	150	-0.0288	0
15	2013-06-03	2.609	2.184	406	152.9	2.499	354.3	0.11	0.887
16	2013-06-17	2.453	2.204	284	160	2.518	369.9	-0.0643	-0.147
17	2013-07-01	2.48	2.258	302	181	2.568	415.4	-0.0881	-0.402
18	2013-07-15	1.748	1.526	56	33.6	1.879	85	-0.131	-0.75
19	2013-08-05	3.14	2.822	1380	663.3	3.1	1412	0.0403	0.298
20	2013-08-19	2.885	2.551	768	356	2.845	785.8	0.0404	0.35
21	2013-09-09	1.613	1.459	41	28.75	1.815	73.39	-0.202	-1.47
22	2013-09-23	1.732	1.554	54	35.84	1.905	90.33	-0.173	-1.04
23	2013-10-21	1.531	1.204	34	16	1.575	42.25	-0.0439	-0.049
24	2013-11-18	2.223	1.422	167	26.4	1.78	67.72	0.442	1.47
25	2014-03-10	1.613	1.362	41	23	1.724	59.47	-0.111	-0.568
26	2014-03-24	2.009	1.376	102	23.75	1.737	61.3	0.272	1.34
27	2014-04-07	2.415	1.591	260	39	1.94	97.81	0.475	1.86
28	2014-05-05	2.193	1.803	156	63.57	2.14	155	0.0532	0.402
29	2014-05-19	1.94	1.648	87	44.5	1.994	110.8	-0.0545	-0.0981
30	2014-06-30	1.643	1.892	44	78	2.224	188	-0.58	-2.27
31	2014-07-14	1.756	1.294	57	19.67	1.66	51.32	0.096	0.817
32	2014-07-28	1.653	1.411	45	25.75	1.77	66.15	-0.117	-0.687
33	2014-08-11	2.045	1.621	111	41.8	1.968	104.4	0.0769	0.568

34	2014-08-25	1.716	1.539	52	34.6	1.891	87.38	-0.175	-1.13
35	2014-09-08	2.939	2.652	868	449	2.94	977.8	-0.00133	0.197
36	2014-09-22	2.013	1.839	103	69	2.173	167.4	-0.161	-0.817
37	2014-10-06	2.068	1.936	117	86.33	2.265	206.8	-0.197	-1.34
38	2014-10-20	2.041	1.711	110	51.4	2.053	126.9	-0.0116	0.049
39	2014-11-17	1.462	1.204	29	16	1.575	42.25	-0.113	-0.626
40	2014-12-15	1.968	1.623	93	41.99	1.97	104.9	-0.00176	0.147
41	2015-01-12	1.079	0.9227	12	8.37	1.31	22.94	-0.231	-1.86
42	2015-02-09	1.732	1.439	54	27.5	1.797	70.38	-0.0647	-0.247
43	2015-03-09	1.041	0.8692	11	7.4	1.26	20.43	-0.218	-1.64
44	2015-03-23	1.568	1.301	37	20	1.667	52.13	-0.0985	-0.456
45	2015-04-06	1.491	1.206	31	16.07	1.577	42.42	-0.0858	-0.35
46	2015-04-20	1.982	1.708	96	51	2.05	125.9	-0.0675	-0.298
47	2015-05-04	1.82	1.574	66	37.49	1.924	94.24	-0.104	-0.511
48	2015-05-18	3.27	2.829	1860	674.5	3.106	1435	0.163	1.13
49	2015-06-07	3.34	2.992	2190	982.5	3.26	2045	0.0801	0.626
50	2015-06-15	2.692	2.348	492	223	2.653	505.6	0.0385	0.247
51	2015-06-29	2.674	2.204	472	160	2.518	369.9	0.156	1.04

Definitions and National Water Information System (parameter code)

SSC: Suspended sediment concentration (SSC) in mg/L (80154)

Turb: Turbidity in FNU (63680)