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 oxygen, turbidity, and fluorescent 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

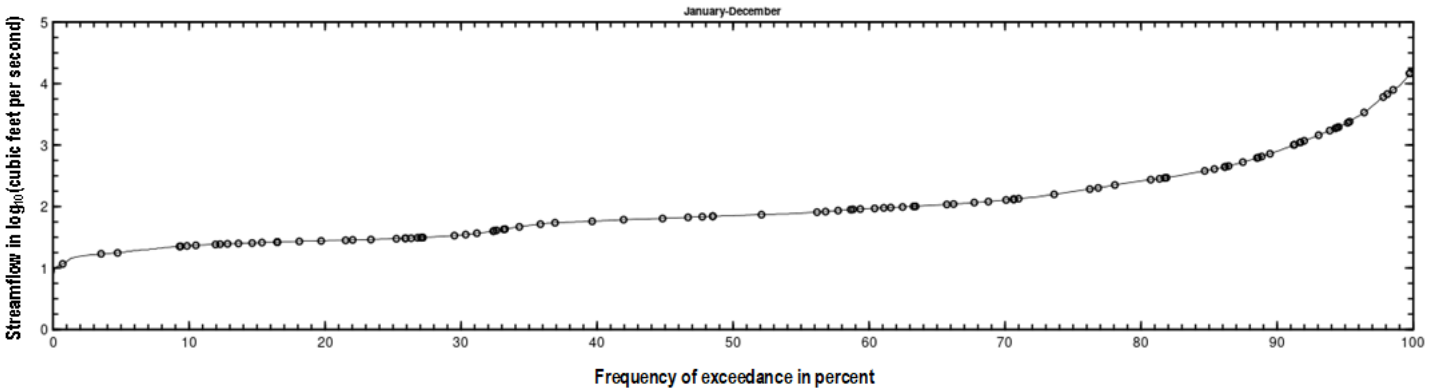
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated 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.

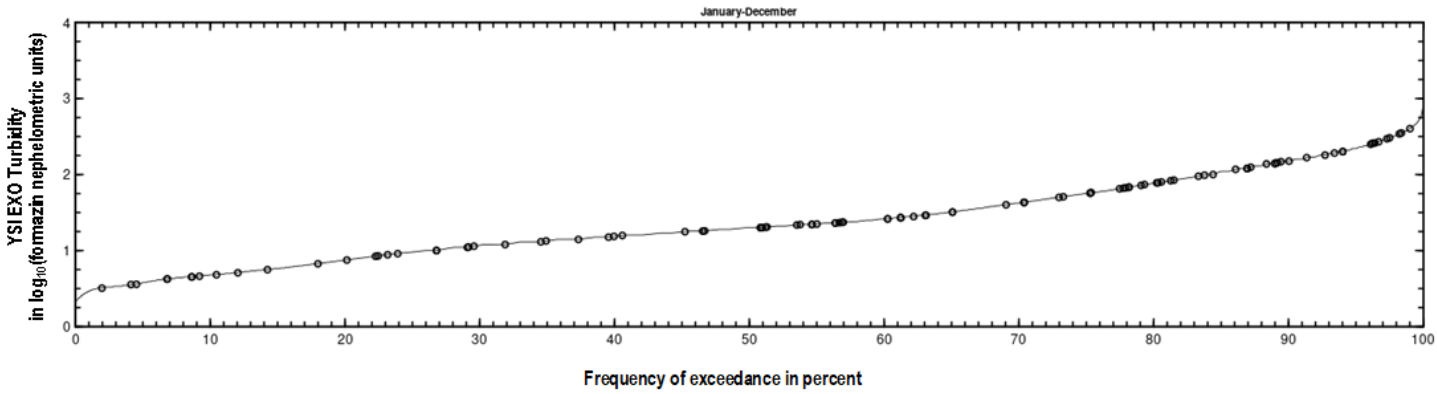
Suspended-Sediment Concentration

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 concenration 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

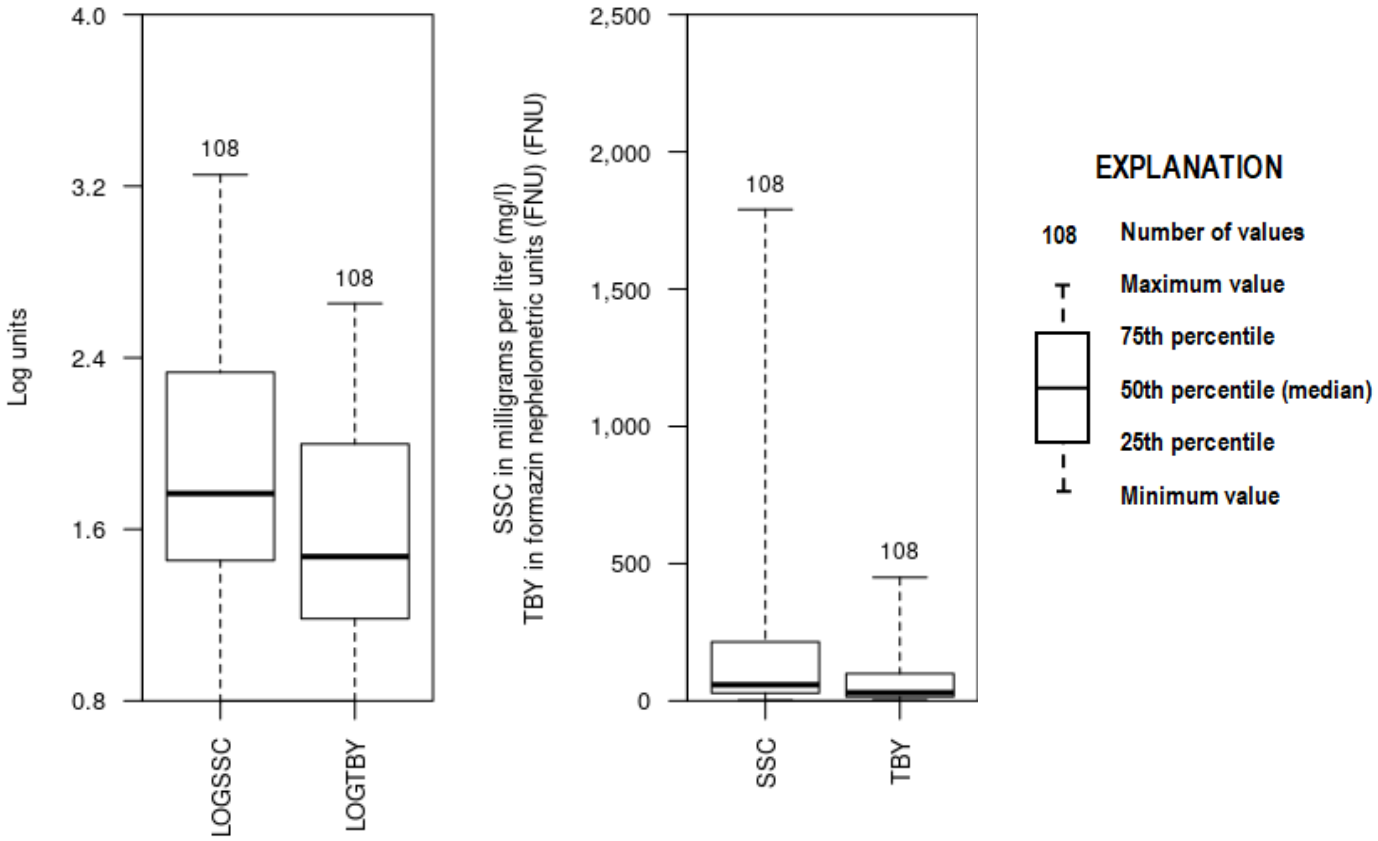
Model

LOGSSC = + 1.13 * LOGTBY + 0.0959

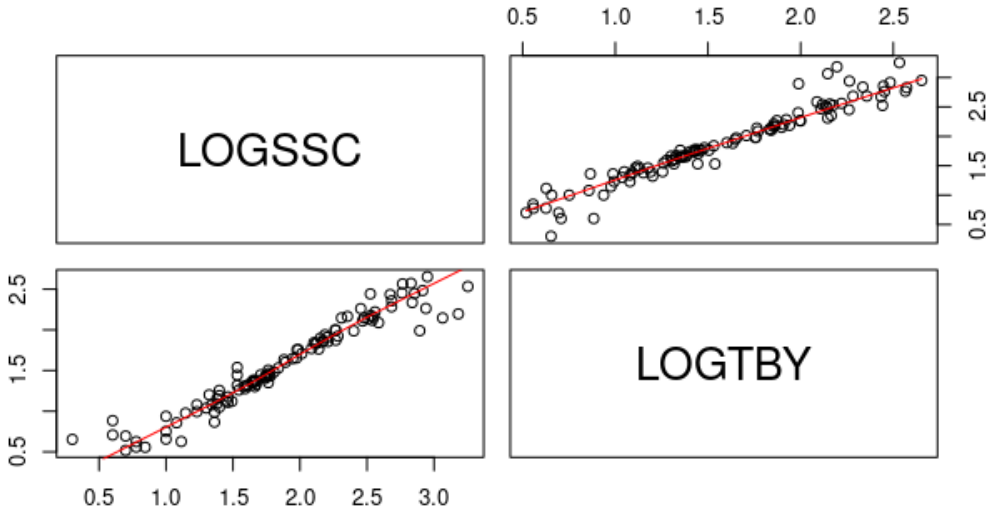
Variable Summary Statistics

	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

Box Plots



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^2)	0.935
Adjusted Coefficient of Determination (Adj. R^2)	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

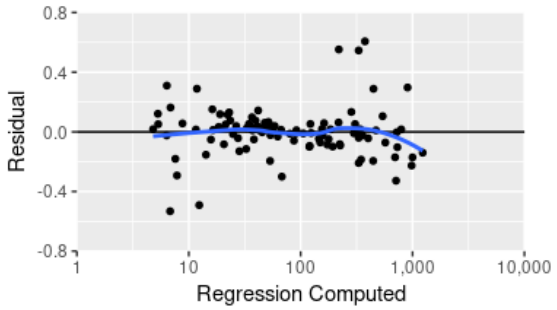
Outlier Test Criteria

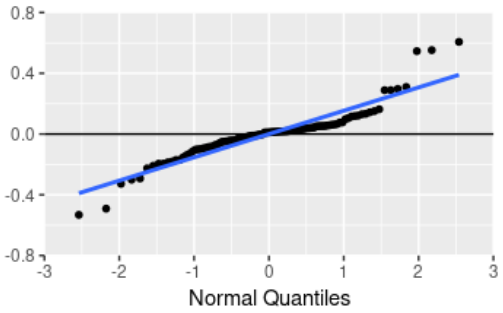
Leverage	Cook's D	DFFITS
0.0556	0.1944	0.2722

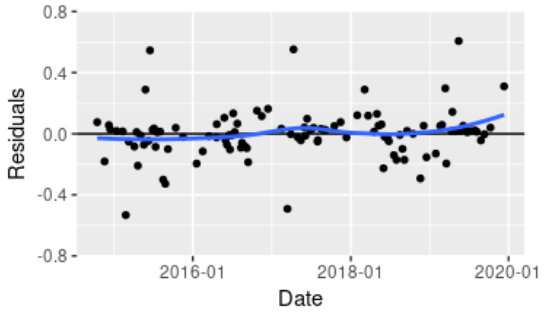
Flagged Observations

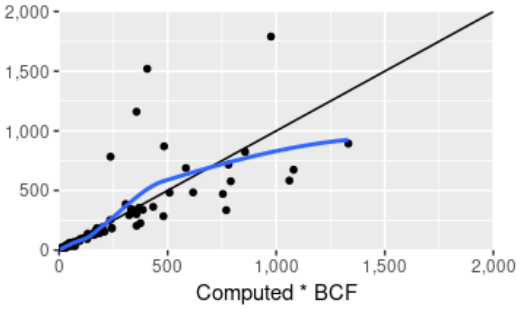
	LOGSSC	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
2/25/2015 11:20	0.301	0.833	-0.532	-3.32	-3.49	0.0359	0.205	-0.673
5/27/2015 11:50	2.94	2.65	0.289	1.79	1.81	0.024	0.0393	0.283
6/17/2015 10:40	3.06	2.52	0.546	3.37	3.55	0.0194	0.113	0.5
8/27/2015 10:40	2.53	2.85	-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

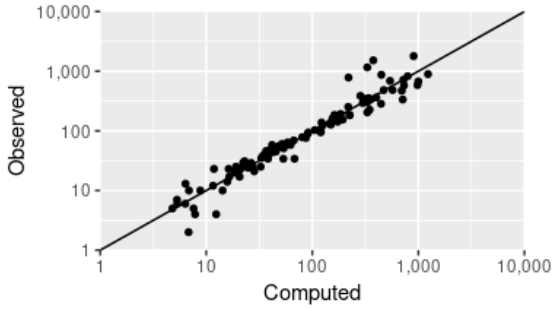
Statistical Plots

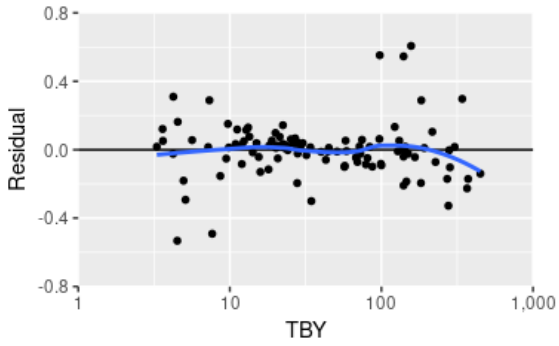


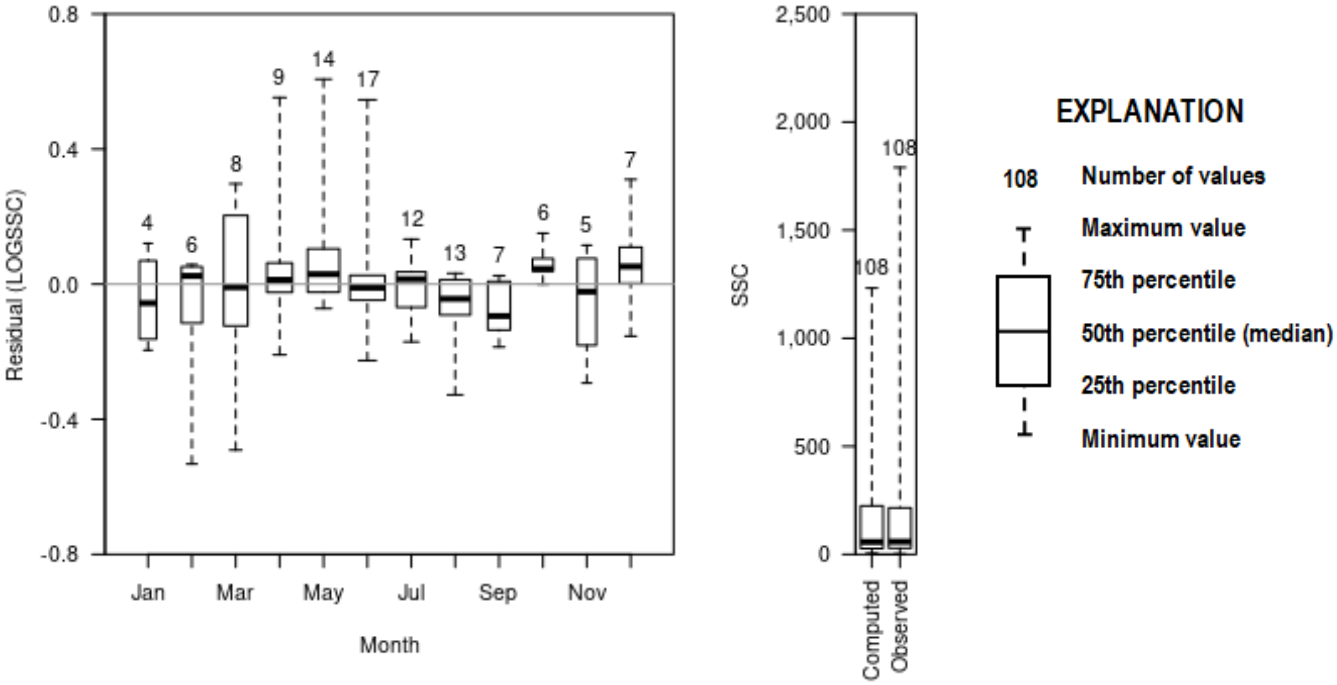


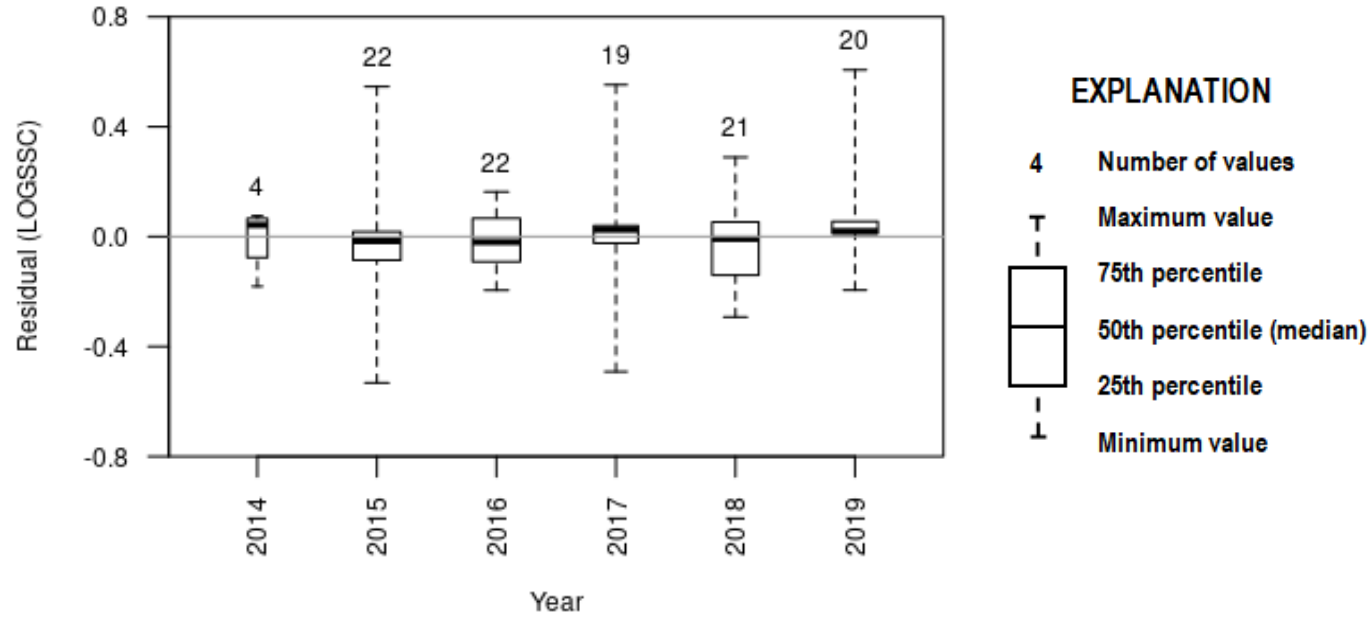




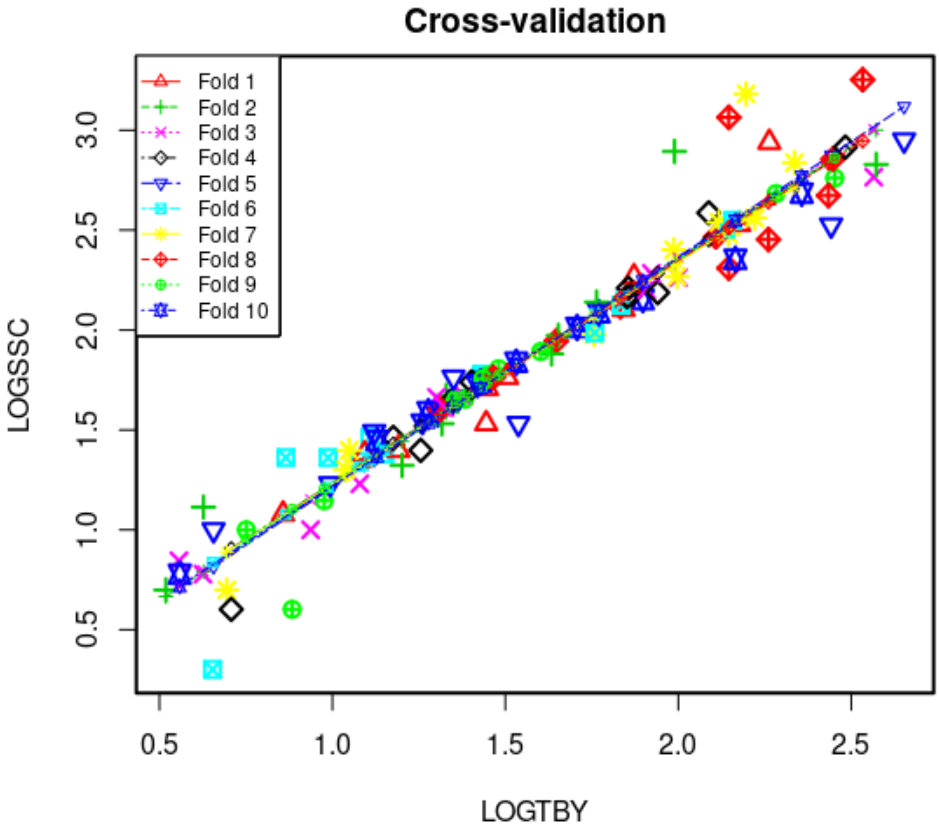





Residual (LOGSSC)
0.8
0.4
0.0
-0.4
-0.8
4
6
8
9
14
17
12
13
7
6
5
7
Jan
Mar
May
Jul
Sep
Nov
Month
SSC
2,500
2,000
1,500
1,000
500
0
108
108
Computed
Observed
EXPLANATION
108 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value


Residual (LOGSSC)
0.8
0.4
0.0
-0.4
-0.8
4
22
22
19
21
20
2014
2015
2016
2017
2018
2019
Year
EXPLANATION
4 Number of values
Maximum value
75th percentile
50th percentile (median)
25th percentile
Minimum value

Cross Validation

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             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
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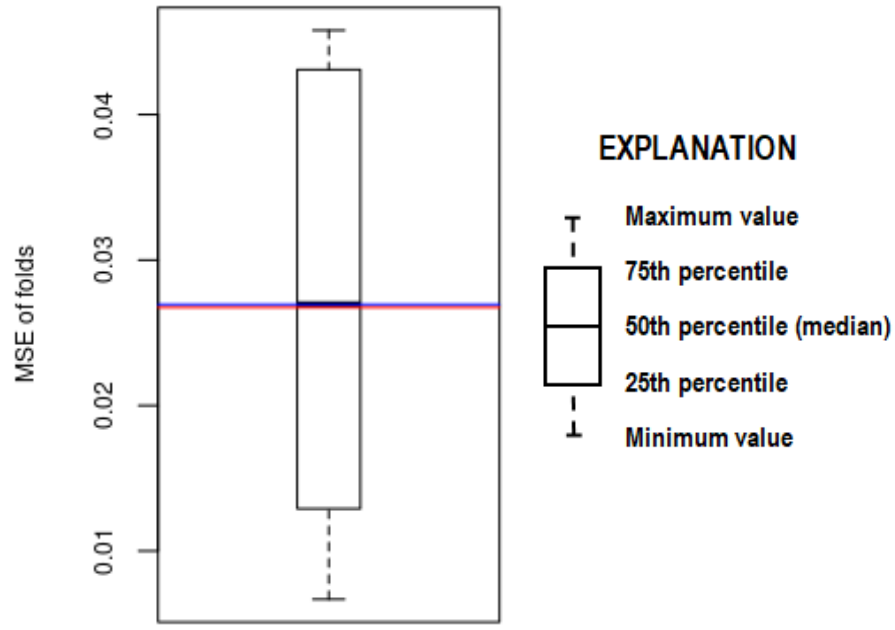


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Red line - Model MSE

Blue line - Mean MSE of folds
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Model-Calibration Dataset

	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	10/24/2016	1.36	0.988	23	9.72	1.21	17.6	0.151	1.41
47	11/15/2016	1.46	1.11	29	12.8	1.35	24	0.115	1.1
48	12/14/2016	1	0.656	10	4.53	0.837	7.43	0.163	1.47
49	2/14/2017	1.3	1.04	20	10.9	1.27	20	0.0332	0.443
50	3/14/2017	0.602	0.884	4	7.65	1.09	13.4	-0.491	-2.18
51	3/30/2017	2.86	2.45	717	280	2.86	780	-0.00297	-0.128
52	4/11/2017	2.89	1.99	783	97.5	2.34	237	0.552	2.18
53	5/1/2017	2.53	2.18	338	150	2.55	386	-0.0236	-0.342

54	5/15/2017	2.12	1.83	133	68.3	2.17	159	-0.0432	-0.494
55	5/31/2017	1.77	1.45	59	28	1.73	58	0.0413	0.575
56	6/5/2017	1.89	1.6	78	40	1.9	86.7	-0.0124	-0.246
57	6/13/2017	1.66	1.3	46	20	1.56	39.7	0.0981	1.02
58	6/28/2017	1.65	1.36	45	22.8	1.63	45.9	0.0253	0.342
59	7/13/2017	1.81	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	-0.0506	-0.602
61	8/2/2017	1.4	1.19	25	15.5	1.44	29.8	-0.0423	-0.468
62	8/16/2017	1.74	1.43	55	26.8	1.71	55.2	0.0322	0.417
63	8/30/2017	1.6	1.31	40	20.5	1.58	40.8	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	1.38	1.09	24	12.4	1.33	23.1	0.0502	0.63
66	11/15/2017	1.45	1.13	28	13.5	1.37	25.4	0.0764	0.984
67	12/12/2017	0.778	0.626	6	4.22	0.802	6.86	-0.0241	-0.392
68	1/31/2018	0.845	0.556	7	3.6	0.724	5.72	0.121	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	1.05	25	11.2	1.28	20.6	0.118	1.15
71	4/18/2018	1.23	0.993	17	9.85	1.22	17.8	0.0131	0.0348
72	5/2/2018	1.49	1.12	31	13.2	1.36	24.8	0.13	1.24
73	5/9/2018	1.59	1.28	39	18.9	1.54	37.3	0.053	0.748
74	5/23/2018	1.74	1.4	55	25.3	1.68	51.6	0.0611	0.843
75	6/1/2018	2.77	2.57	583	367	2.99	1060	-0.226	-1.63
76	6/6/2018	2.17	1.85	147	71.1	2.19	166	-0.0192	-0.294
77	6/20/2018	1.76	1.51	58	32	1.8	67.4	-0.0316	-0.417
78	6/26/2018	2.2	1.91	159	80.9	2.25	192	-0.0486	-0.575
79	7/19/2018	2.95	2.65	893	450	3.09	1330	-0.14	-1.1
80	7/31/2018	2.67	2.43	471	272	2.84	754	-0.171	-1.19
81	8/16/2018	2.09	1.77	122	58.9	2.09	134	-0.00782	-0.151
82	8/28/2018	2.19	1.94	154	87.2	2.29	209	-0.0988	-0.911
83	9/6/2018	2.83	2.57	674	373	3	1080	-0.171	-1.24
84	9/18/2018	1.67	1.38	47	24	1.65	48.7	0.0188	0.222
85	10/16/2018	2.51	2.14	322	137	2.51	348	-0.00018	-0.0812
86	11/19/2018	0.602	0.708	4	5.1	0.895	8.48	-0.293	-1.72
87	12/4/2018	2.54	2.12	346	131	2.49	331	0.0525	0.688
88	12/17/2018	1	0.937	10	8.65	1.15	15.4	-0.154	-1.15
89	1/29/2019	1.32	1.2	21	15.9	1.45	30.6	-0.13	-1.06
90	2/19/2019	0.778	0.559	6	3.62	0.727	5.76	0.0515	0.659
91	2/27/2019	2.27	1.87	185	74.5	2.21	175	0.058	0.81
92	3/14/2019	3.25	2.53	1790	341	2.96	976	0.297	1.72
93	3/19/2019	2.45	2.26	284	182	2.65	481	-0.195	-1.41
94	4/11/2019	2.28	1.92	192	83.7	2.27	200	0.0171	0.151
95	4/16/2019	1.76	1.35	58	22.4	1.62	45.1	0.143	1.35
96	5/1/2019	2.92	2.48	823	304	2.9	857	0.0163	0.128
97	5/15/2019	3.18	2.2	1520	157	2.57	406	0.607	2.54
98	5/23/2019	2.55	2.16	354	144	2.53	367	0.0178	0.198
99	6/5/2019	2.14	1.76	138	58	2.09	132	0.0528	0.717
100	6/12/2019	1.74	1.42	55	26.3	1.7	53.9	0.0424	0.602
101	6/24/2019	2.68	2.28	482	192	2.67	509	0.0101	-0.0579
102	7/10/2019	2.21	1.86	162	71.7	2.19	168	0.0189	0.246
103	7/30/2019	1.61	1.32	41	21.1	1.59	42.2	0.0211	0.27
104	8/7/2019	1.76	1.47	58	29.2	1.75	60.8	0.0133	0.0579
105	8/26/2019	2.56	2.22	363	166	2.6	434	-0.0433	-0.521
106	9/11/2019	1.65	1.38	45	24.1	1.66	49	-0.00284	-0.104
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

Definitions

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