

Appendix 3. Model Archive Summary for Suspended-Sediment Concentration at U.S. Geological Survey Site 07182390, Neosho River at Neosho Rapids, Kansas, during January 1, 2010, through September 24, 2015

This model archive summary summarizes the suspended-sediment concentration (SSC) model developed to compute hourly or daily SSC during January 1, 2010, through September 24, 2015. This model supersedes all prior models used during this period. The methods used follow U.S. Geological Survey (USGS) guidance as referenced in relevant Office of Surface Water/Office of Water Quality Technical Memoranda and USGS Techniques and Methods, book 3, chapter C4, and the policy and guidance for approval of surrogate regression models for computation of time series SSCs and loads (Rasmussen and others, 2009; U.S. Geological Survey, 2016).

Site and Model Information

Site number: 07182390

Site name: Neosho River at Neosho Rapids, Kansas

Location: Lat 38°22'05", long 96°00'00" referenced to North American Datum of 1927, in SW 1/4 NW 1/4 sec.29, T.19 S., R.13 E., Lyon County, Kans., hydrologic unit 11070201, on right upstream side of bridge, 0.75 mile west of the intersection of Kansas Highway 130 and South Street at Neosho Rapids, and at mile 370.7.

Equipment: A YSI 6600 water-quality monitor equipped with sensors for water temperature, specific conductance, and turbidity (YSI model 6136 turbidity sensor). The YSI 6600 water-quality monitor was in operation during August 11, 2009, through November 11, 2015.

Date model was developed: January 16, 2020

Model calibration data period: June 17, 2009, through September 24, 2015

Model Data

All data were collected using USGS protocols (Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010; U.S. Geological Survey, variously dated) and are stored in the National Water Information System (NWIS) database (<https://doi.org/10.5066/F7P55KJN>; U.S. Geological Survey, 2020). Explanatory variables were evaluated individually and in combination. Potential explanatory variables included streamflow, water temperature, specific conductance, and turbidity. Seasonal components also evaluated as explanatory variables.

The regression model is based on 42 concurrent measurements of discretely collected SSC samples and continuously measured turbidity during June 17, 2009, through September 24, 2015. Discrete samples were collected over a range of streamflows and turbidity conditions. No samples had concentrations below laboratory detection limits. Identification of potential outliers included any values that exceeded the Cook's D test (Cook, 1977) and any point for which the studentized residual was greater than 3 or less than -3 . None of the samples in this dataset were deemed outliers or removed from the model calibration dataset.

Suspended-Sediment Sampling Details

Discrete samples were collected from the downstream side of the bridge or instream within 150 feet of the bridge using equal-width-increment, multiple vertical, single vertical, or grab-dip methods following U.S. Geological Survey (2006) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging from 4 to 10 samples per year with a Federal Interagency Sediment Project U.S. DH-48, DH-77 TM, DH-81, DH-95, and D-95, with a Teflon bottle, cap, and nozzle, D-96, with a plastic bag, Teflon collar, and nozzle depth-integrating sampler or a grab sample depending on sample location. Samples were analyzed for SSC, loss on ignition, and occasionally five-point grain size by the USGS Sediment Laboratory in Iowa City, Iowa.

Continuous Data

Continuously monitored turbidity was measured using a YSI 6600 model 6136 turbidity sensor installed during August 11, 2009, to November 11, 2015 (U.S. Geological Survey, 2018). Concomitant turbidity values were time interpolated. If continuous data were not available (2 or more hours of specific conductance values bracketing the sample collected time were missing) because of fouling, changes in equipment, or unsuitable site conditions, then the field monitor turbidity value measured during sampling was substituted. If neither concomitant continuous data nor field monitor data were available, the sample was not included in the dataset. The range of continuous turbidity data of the YSI model 6136 sensor (in formazin nephelometric units) was as follows: maximum 1,540; minimum 1.70; mean 68.4; median 31.0.

Model Development

Ordinary least squares regression analysis was done using R programming language (R Core Team, 2019) to relate discretely collected SSC 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 calculated SSC 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) was ultimately selected.

Turbidity was selected as the best predictors of logarithm base 10 (\log_{10}) (SSC) based on residual plots, relatively high coefficient of determination (R^2), and relatively low model standard percentage error (MSPE).

Model Summary

Summary of final SSC regression analysis at site 07182390:
SSC-based model:

$$\log_{10}(SSC) = 1.07 \times \log_{10}(Turb6136) + 0.16$$

where

SSC = suspended-sediment concentration, in milligrams per liter, and

$Turb6136$ = turbidity, YSI model 6136, in formazin nephelometric units.

The use of turbidity as an explanatory variable is appropriate physically and statistically. Turbidity makes sense physically because suspended sediment is composed of particles that scatter light in water. The relation between turbidity and SSC can vary given varying concentrations of organic suspended particles that increase turbidity but are not included in the SSC analysis.

The log-transformed model may be retransformed to the original units to calculate SSC directly. A bias is introduced in the calculated constituent during retransformation and may be corrected using the Duan's bias correction factor (BCF; Duan, 1983). The calculated BCF is 1.05 for this model and the formula for the retransformed model accounting for BCF is as follows:

$$SSC = 1.52 \times Turb6136^{1.07}$$

Suspended-Sediment Concentration Record

The SSC record that is being used in this regression model is stored at the National Real-Time Water Quality (NRTWQ) website (<https://nrtwq.usgs.gov/ks>).

Previously Published Model

$$\log_{10}(SSC) = 1.06 \times \log_{10}(Turb) + 0.17$$

Model author: Foster (2014)

Model data period: June 17, 2009, through September 27, 2012

Model Statistics, Data, and Plots

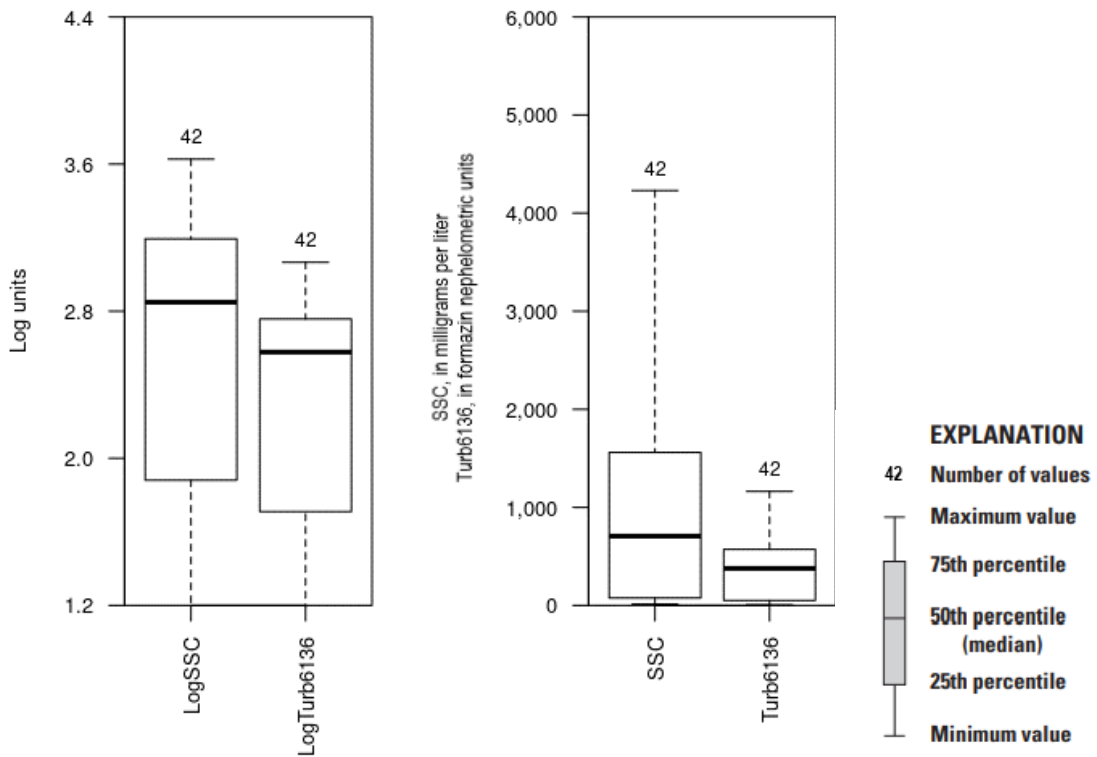
Model

$$\text{Log}(SSC) = + 1.07 * \text{Log}(Turb6136) + 0.16$$

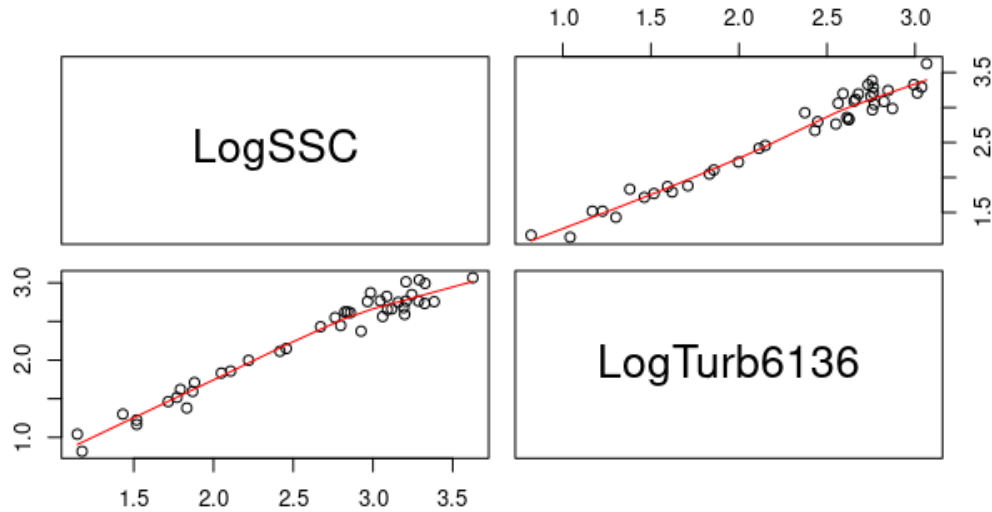
Variable Summary Statistics

	LogSSC	SSC	LogTurb6136	Turb6136
Minimum	1.15	14	0.82	6.6
1st Quartile	1.88	76	1.71	51.3
Median	2.85	707	2.58	378.0
Mean	2.60	911	2.27	374.0
3d Quartile	3.19	1560	2.76	572.0
Maximum	3.63	4230	3.07	1160.0

Box Plots



Exploratory Plots



Basic Model Statistics

Number of Observations	42
Standard error (RMSE)	0.137
Average Model standard percentage error (MSPE)	32.1
Coefficient of determination (R^2)	0.962
Adjusted Coefficient of Determination (Adj. R^2)	0.961
Bias Correction Factor (BCF)	1.05

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	0.16	0.0793	2.02	5.02e-02
LogTurb6136	1.07	0.0336	32.00	4.19e-30

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.964
E.vars	-0.964	1.000

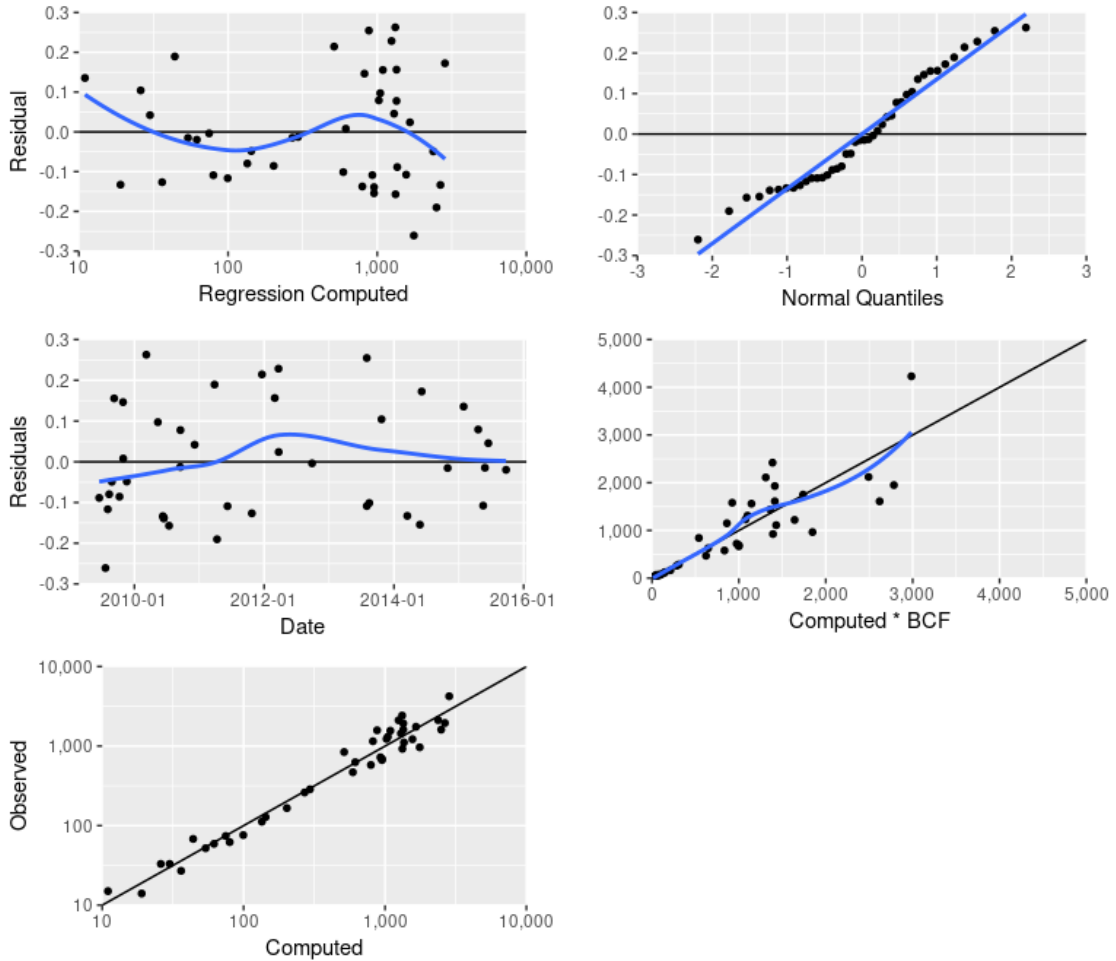
Outlier Test Criteria

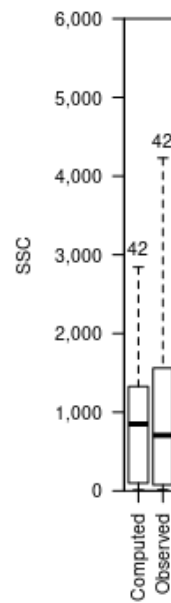
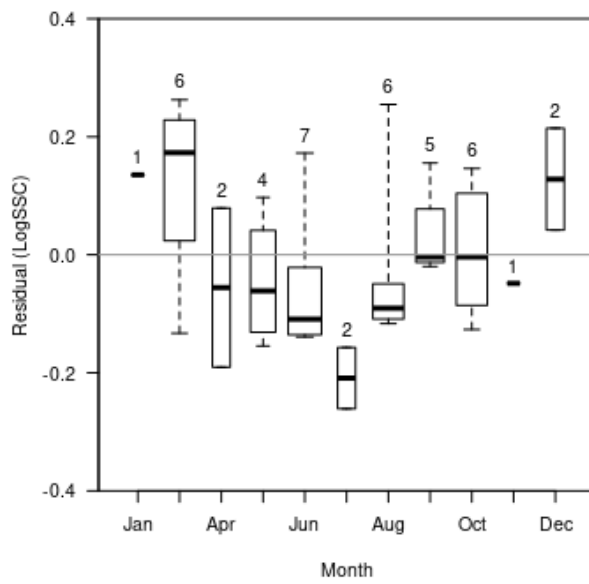
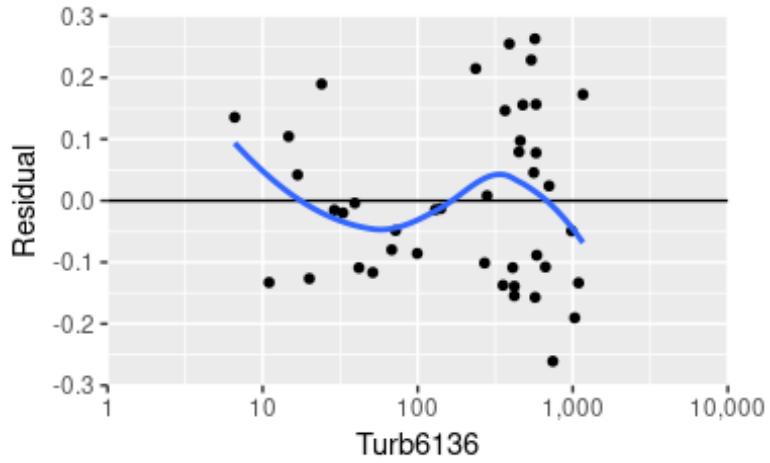
Leverage	Cook's D	DFFITS
0.143	0.194	0.436

Flagged Observations

	LogSSC Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
7/22/2009 14:30	2.98	3.25	-0.261	-1.95	-2.02	0.0452	0.0897
1/28/2015 14:20	1.18	1.04	0.135	1.07	1.07	0.1510	0.1020

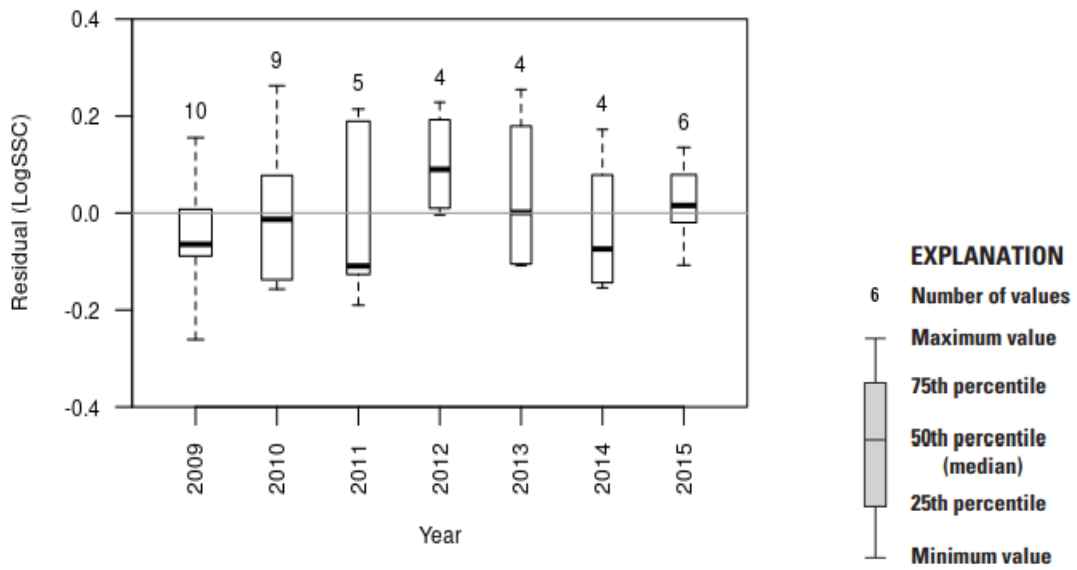
Statistical Plots



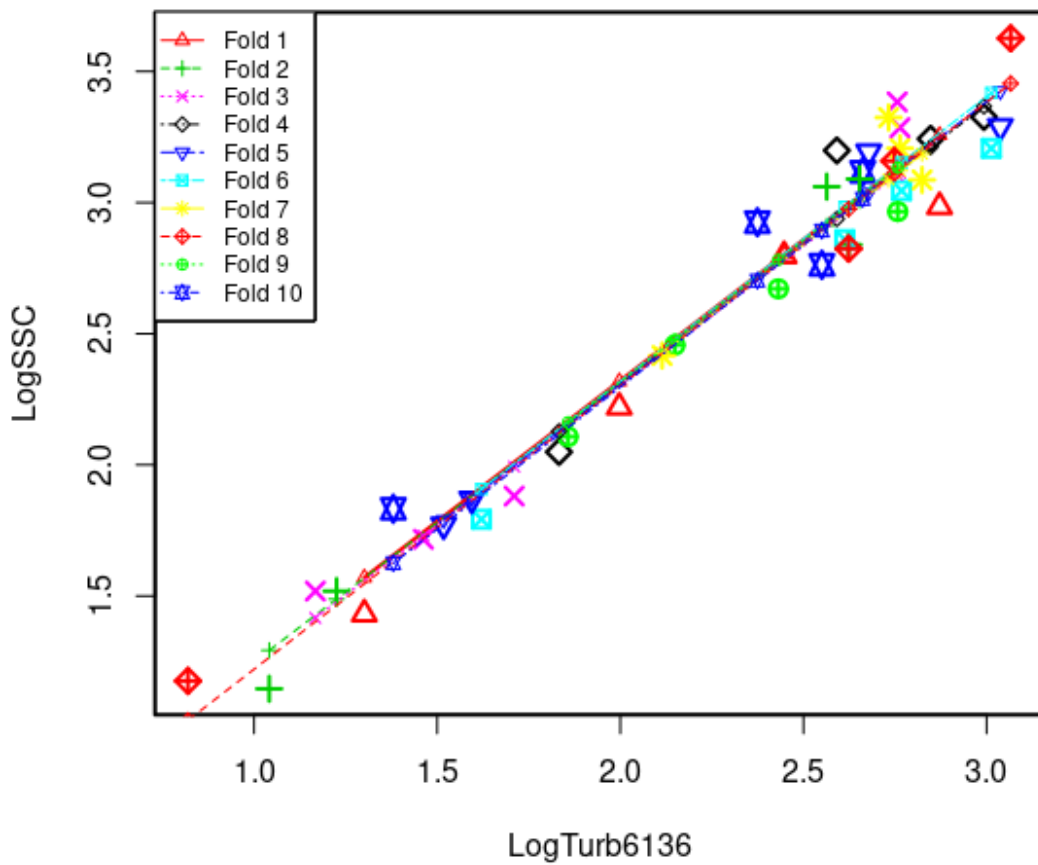


EXPLANATION

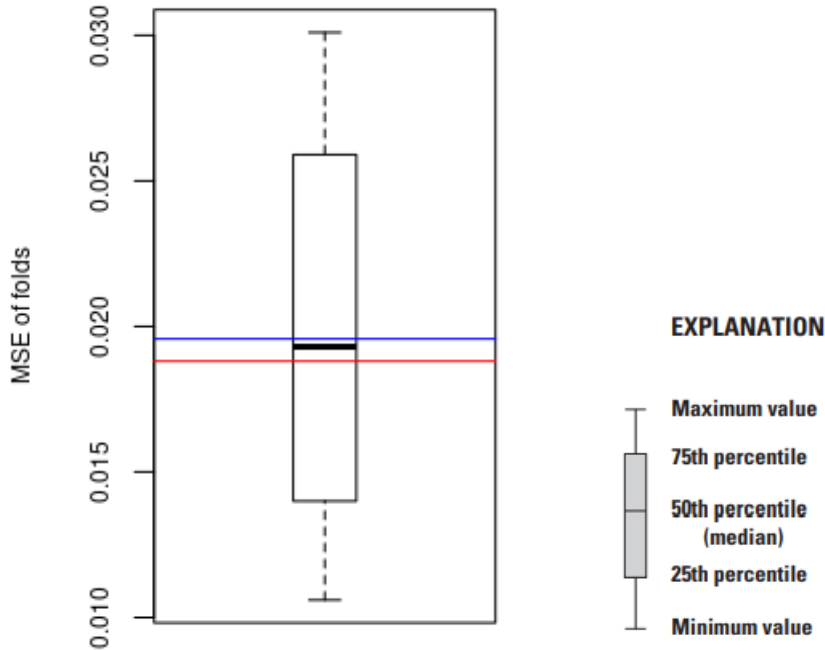
- 6 **Number of values**
- Maximum value
- 75th percentile
- 50th percentile (median)
- 25th percentile
- Minimum value



Cross Validation



Minimum mean squared error (MSE) of folds: 0.0106
 Mean MSE of folds: 0.0196
 Median MSE of folds: 0.0193
 Maximum MSE of folds: 0.0301
 (Mean MSE of folds) / (Model MSE): 1.0400



Red line - Model MSE

Blue line - Mean MSE of folds

Model-Calibration Dataset

	Date	LogSSC	LogTurb6136	SSC	Turb6136	Computed LogSSC	Computed SSC	Residual	Normal Quantiles	Censored Values
0										
1	2009-06-17	3.05	2.77	1110	586	3.13	1430	-0.0886	-0.396	--
2	2009-07-22	2.98	2.87	965	744	3.25	1850	-0.261	-2.19	--
3	2009-08-04	1.88	1.71	76	51.3	2	104	-0.117	-0.747	--
4	2009-08-12	2.05	1.83	112	68	2.13	141	-0.0798	-0.271	--
5	2009-08-27	3.33	2.99	2120	983	3.38	2490	-0.0492	-0.209	--
6	2009-09-09	3.19	2.68	1560	477	3.04	1140	0.156	0.915	--
7	2009-10-09	2.22	2	166	99.3	2.31	212	-0.0857	-0.333	--
8	2009-10-29	3.06	2.56	1150	366	2.91	862	0.146	0.828	--
9	2009-10-30	2.8	2.45	627	280	2.79	646	0.00791	0.209	--
10	2009-11-19	2.11	1.86	128	72	2.16	150	-0.0484	-0.149	--
11	2010-03-09	3.38	2.76	2420	570	3.12	1390	0.263	2.19	--
12	2010-05-13	3.12	2.66	1310	459	3.02	1100	0.0973	0.598	--
13	2010-06-15	2.84	2.62	691	420	2.98	999	-0.139	-1.23	--
14	2010-06-16	2.76	2.55	579	355	2.9	834	-0.137	-1.11	--
15	2010-06-10	3.29	3.04	1950	1090	3.42	2780	-0.134	-1.01	--

16	2010-07-15	2.97	2.76	924	572	3.12	1390	-0.157	-1.54	--
17	2010-09-16	2.46	2.15	286	141	2.47	309	-0.0129	0.0892	--
18	2010-09-17	3.21	2.76	1610	580	3.13	1410	0.0777	0.461	--
19	2010-12-06	1.52	1.23	33	16.8	1.48	31.5	0.0419	0.333	--
20	2011-03-28	1.83	1.38	68	24	1.64	46.1	0.189	1.23	--
21	2011-04-11	3.21	3.01	1610	1030	3.4	2620	-0.19	-1.78	--
22	2011-06-09	1.79	1.62	62	41.8	1.9	83.7	-0.109	-0.671	--
23	2011-10-24	1.43	1.3	27	20	1.56	37.9	-0.127	-0.828	--
24	2011-12-20	2.93	2.37	842	237	2.71	540	0.214	1.37	--
25	2012-03-01	3.29	2.76	1930	580	3.13	1410	0.156	1.01	--
26	2012-03-22	3.32	2.73	2110	540	3.1	1310	0.228	1.54	--
27	2012-03-23	3.24	2.85	1750	703	3.22	1740	0.0239	0.271	--
28	2012-09-27	1.87	1.59	74	39.3	1.87	78.4	-0.00391	0.149	--
29	2013-08-01	2.86	2.61	722	410	2.97	974	-0.109	-0.598	--
30	2013-08-01	3.2	2.59	1580	390	2.94	923	0.255	1.78	--
31	2013-08-15	2.67	2.43	469	270	2.77	622	-0.101	-0.461	--
32	2013-10-23	1.52	1.17	33	14.7	1.41	27.3	0.104	0.671	--
33	2014-03-17	1.15	1.04	14	11	1.28	20	-0.133	-0.915	--
34	2014-05-27	2.82	2.62	667	420	2.98	999	-0.154	-1.37	--
35	2014-06-06	3.63	3.07	4230	1160	3.45	2990	0.172	1.11	--
36	2014-10-30	1.72	1.46	52	29	1.73	56.6	-0.0153	-0.0297	--
37	2015-01-28	1.18	0.82	15	6.6	1.04	11.5	0.135	0.747	--
38	2015-04-20	3.09	2.65	1230	450	3.01	1080	0.0792	0.528	--
39	2015-05-18	3.09	2.82	1220	667	3.19	1640	-0.108	-0.528	--
40	2015-06-16	3.16	2.75	1440	560	3.11	1360	0.0456	0.396	--
41	2015-05-28	2.42	2.11	261	130	2.43	283	-0.0147	0.0297	--
42	2015-09-24	1.77	1.52	59	32.9	1.79	64.8	-0.0198	-0.0892	--

Definitions

Adj R²: Adjusted coefficient of determination

BCF: Bias correction factor

DFFITS: Studentized difference in fits

Log: logarithm base 10

MSE: Mean squared error

MSPE: Model standard percentage error

R²: Coefficient of determination

RMSE: Root mean square error

SSC: Suspended-sediment concentration, in milligrams per liter (80154)

Turb6136: Turbidity, in formazin nephelometric units (63680)

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References Cited

- Cook, R.D., 1977, Detection of influential observations in linear regression: *Technometrics*, v. 19, no. 1, p. 15–18. [Also available at <https://doi.org/10.2307/1268249>.]
- Duan, N., 1983, Smearing estimate—A nonparametric retransformation method: *Journal of the American Statistical Association*, v. 78, no. 383, p. 605–610. [Also available at <https://doi.org/10.1080/01621459.1983.10478017>.]
- Foster, G.M., 2014, Relations between continuous real-time turbidity data and discrete suspended-sediment concentration samples in the Neosho and Cottonwood Rivers, east-central Kansas, 2009–2012: U.S. Geological Survey Open-File Report 2014–1171, 20 p., accessed September 2019 at <https://doi.org/10.3133/ofr20141171>.
- R Core Team, 2019, R—A language and environment for statistical computing: Vienna, Austria, R Foundation for Statistical Computing, accessed September 2019 at <https://www.Rproject.org/>.
- Rasmussen, T.J., Bennett, T.J., Stone, M.L., Foster, G.M., Graham, J.L., and Putnam, J.E., 2014, Quality-assurance and data-management plan for water-quality activities in the Kansas Water Science Center, 2014: U.S. Geological Survey Open-File Report 2014–1233, 41 p., accessed September 2019 at <https://doi.org/10.3133/ofr20141233>.
- Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler, A.C., 2009, Guidelines and procedures for computing time-series suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data: U.S. Geological Survey Techniques and Methods, book 3, chap. C4, 54 p. [Also available at <https://doi.org/10.3133/tm3c4>.]
- Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A7, 45 p., accessed September 2019 at <https://doi.org/10.3133/tm3A7>.
- Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p., accessed September 2019 at <https://doi.org/10.3133/tm3A8>.
- U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water Resources Investigations, book 9, chap. A4 [variously paged]. [Also available at <https://pubs.water.usgs.gov/twri9A4/>.]
- U.S. Geological Survey, 2016, Policy and guidance for approval of surrogate regression models for computation of time series suspended-sediment concentrations and loads: U.S. Geological Survey, Office of Water Quality Technical Memorandum 2016.10, 40 p., accessed November 20, 2020, at <https://water.usgs.gov/admin/memo/SW/sw.2016.07+wq.2016.10.pdf>.
- U.S. Geological Survey, 2018, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 2017 at <https://doi.org/10.5066/F7P55KJN>.
- U.S. Geological Survey, 2020, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 2020, at <https://doi.org/10.5066/F7P55KJN>.

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, chaps. A1–A9 [variously paged]. [Also available at <https://water.usgs.gov/owq/FieldManual/>.]

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods, book 1, chap. D3, 51 p. [Also available at <https://doi.org/10.3133/tm1D3>.]