Appendix 2.5. Model Archive Summary for Total Suspended Solids Concentration at U.S. Geological Survey site 07144100; Little Arkansas River near Sedgwick, Kansas, during February 2016 through December 2019

This model archive summary summarizes the total suspended solids model developed to compute hourly or daily total suspended solids. 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 February 2015 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 – 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: February 25, 2015 through December 11, 2019

Model Data

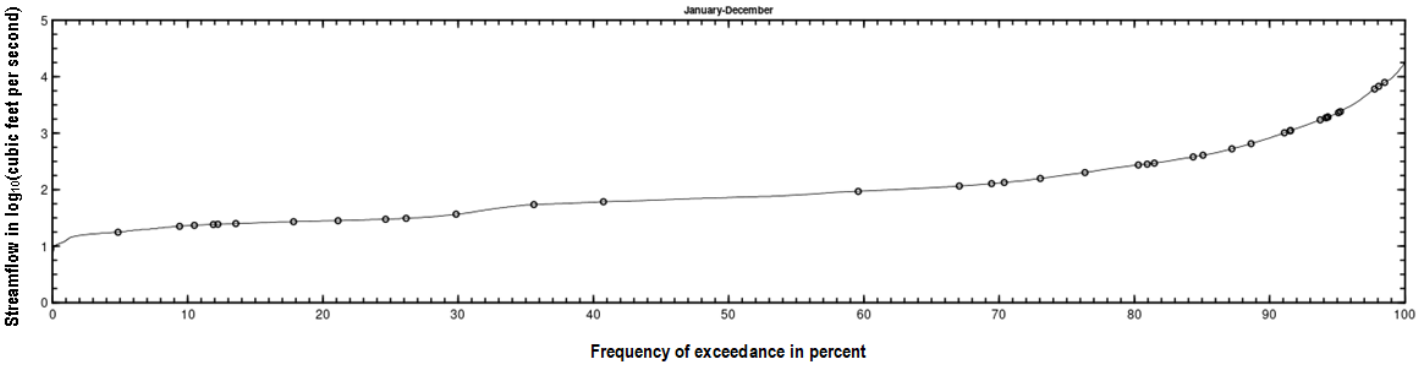
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated 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 40 concomitant values of discretely collected total suspended solids and continuously measured turbidity during February 2015 through December 2019. Discrete samples were collected over a range of streamflow and turbidity conditions. Two samples had concentrations that were below the minimum reporting level (<15 mg/L) and a Tobit regression model was developed to compute estimates of TSS using the absolute maximum likelihood estimation approach (Hald, 1949; Cohen, 1950; Tobin, 1958; Helsel and others, 2020). Summary statistics and the complete model-calibration dataset are provided below. Outliers and influential points were identified using methods described in Rasmussen and others (2009), including leverage and Cook's distance (Cook's D; Cook, 1977) values. 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. All samples were retained in the dataset.

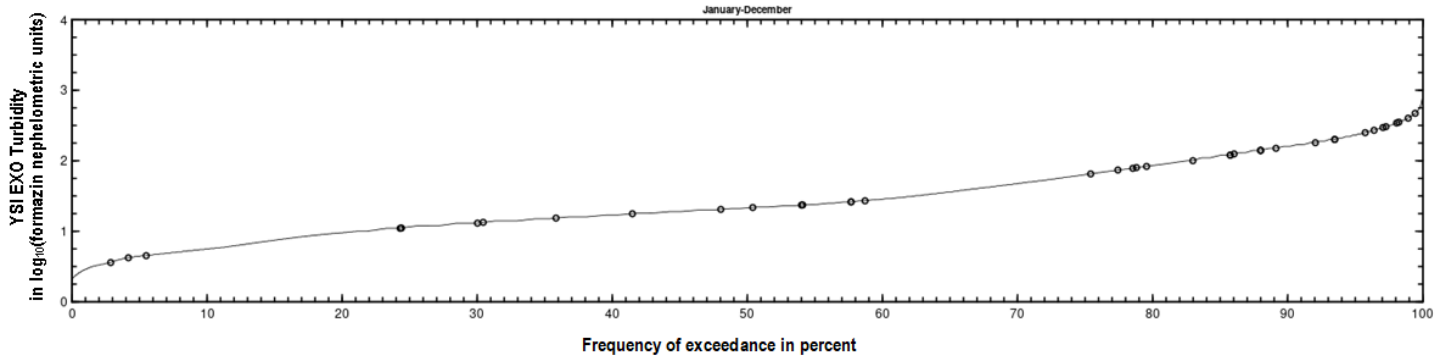
Total Suspended Solids

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 7 to 9 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 total suspended solids by the Wichita Municipal Water and Wastewater Laboratory in Wichita, Kansas, or the USGS National Water Quality Laboratory according to standard methods (American Public Health Association and others, 1995).

Total Suspended Solids Samples Plotted on Streamflow Duration Curve



Total Suspended Solids Samples Plotted on YSI EXO Turbidity Duration Curve



Continuous Data

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

Model Development

Tobit regression models were developed using absolute maximum likelihood estimation methods using the *smwrQW* (v.0.7.9) package in R (version 4.0.0) programming language (R Core Team, 2020).

Turbidity was selected as the best predictor of total suspended solids based on residual plots, a larger pseudo coefficient of determination (pseudo R^2) and a low estimated residual standard error (*RSE*). Turbidity was positively correlated with total suspended solids because turbidity measures light scattered by particulates in water.

Model Summary

Summary of final total suspended solids regression analysis at USGS site number 07144410:

Total suspended solids-based model:

$$\log_{10}(TSS) = 0.9478 \times \log_{10}(TBY) + 0.2936$$

where,

$\log_{10}$ = logarithm base 10;
TSS = total suspended solids, 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 TSS 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). Extracted model residuals used for BCF computation included censored residuals that were replaced by their expected values. For this model, the calculated BCF is 1.05. The retransformed model, accounting for BCF is:

$$TSS = 2.0644 \times TBY^{0.9478}$$

Model Statistics, Data, and Plots

Model

LOGTSS = 0.9478 * LOGTBYEXO + 0.2936

Variable Summary Statistics

	TSS	TBYEXO
Minimum	<15	3.6
1st Quartile	41	21.62
Median	115.545	90.33
Mean	194	129.5
3rd Quartile	261	191.67
Maximum	928	479.1

Explanatory Variables

Coefficients:

	Estimate	Std. Error	z-score	p-value
(Intercept)	0.2936	0.08416	3.488	0.001
logTBYEXO	0.9478	0.04363	21.725	0.000

Basic Model Statistics

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Estimated residual standard error (Unbiased) = 0.154
Distribution: normal
Number of observations = 40, number censored = 2 (5 percent)

Loglik(model) = 18.06 Loglik(intercept only) = -36.94
  Chi-square = 110, degrees of freedom = 1, p-value = <0.0001

Computation method: AMLE

Pseudo R-squared: 0.9382

  AIC: -30.12
  BIC: -25.05
```

Outlier Test Criteria

leverage	cooksD
0.0750	0.7056

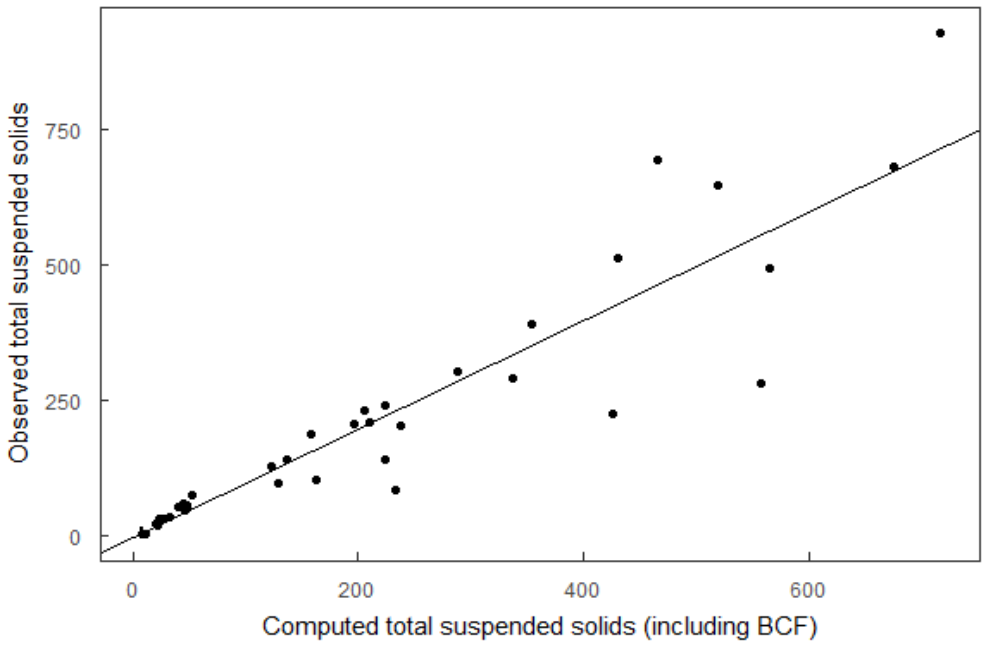
Flagged Observations

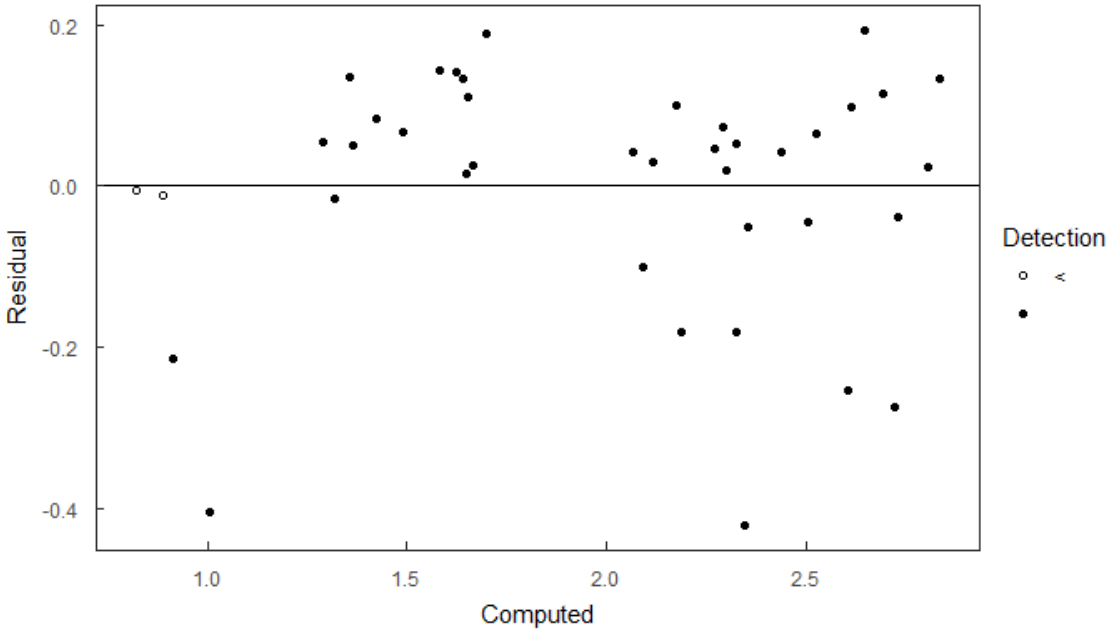
	logTSS	ycen	yhat	resids	leverage	cooksD
1	0.6021	FALSE	1.0054	-0.40337	0.09509	3.98E-01
2	0.699	FALSE	0.9127	-0.2137	0.10901	1.32E-01
25	1.1761	TRUE	0.8208	-0.00434	0.12403	6.41E-05
38	2.9675	FALSE	2.834	0.133504	0.07787	3.44E-02
40	1.1761	TRUE	0.888	-0.01102	0.11292	3.67E-04

95% Confidence Intervals

	2.5 %	97.5 %
(Intercept)	0.1286066	0.4585145
logTBYEXO	0.8622852	1.0332968

Plots

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Detection
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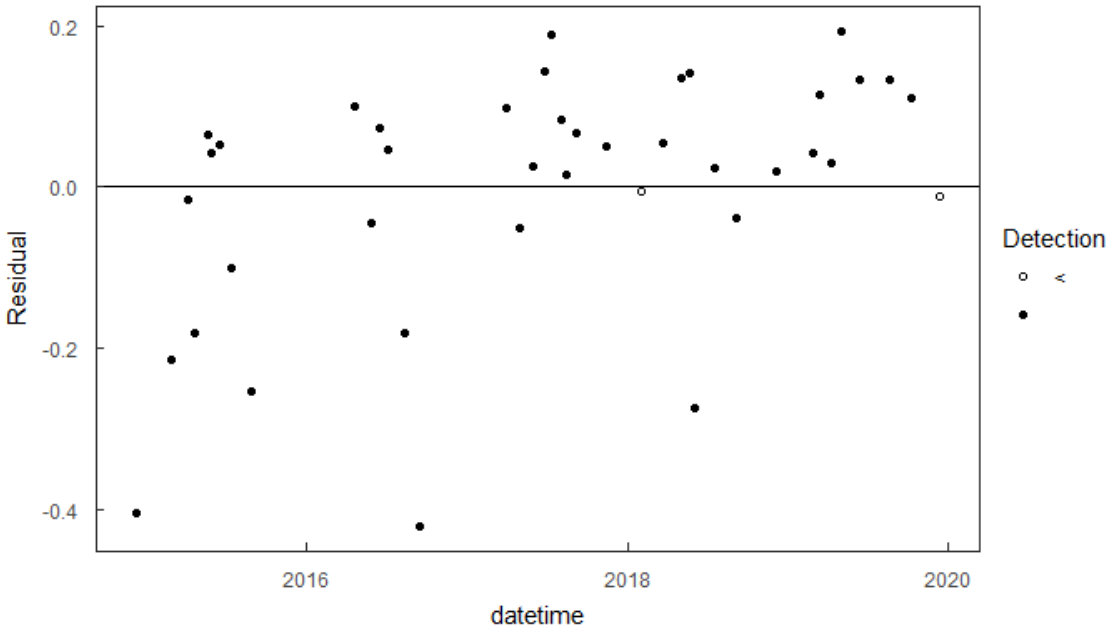
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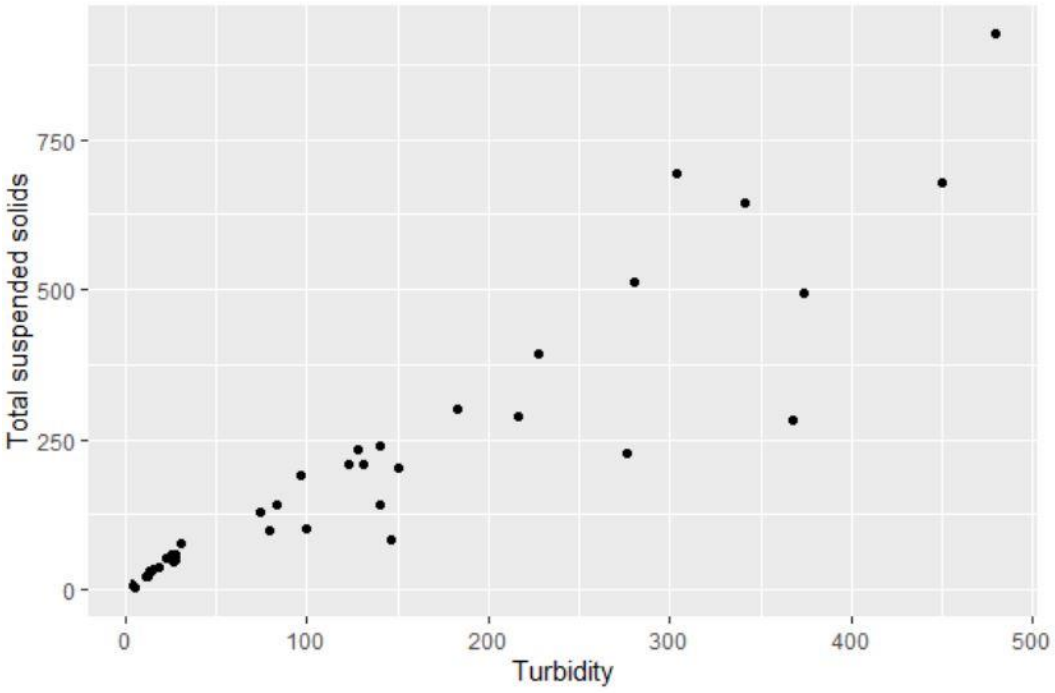

Model-Calibration Dataset

	datetime	logTSS	logTBYEXO	TSS	TBYEXO	Computed logTSS	Computed TSS
1	12/9/2014 10:45	0.602	0.751	4	5.64	1.005	10.63
2	2/25/2015 11:20	0.699	0.653	5	4.5	0.913	8.59
3	4/6/2015 12:35	1.3	1.079	20	12	1.316	21.76
4	4/22/2015 14:30	2.15	2.146	140	140	2.328	223.28
5	5/20/2015 13:15	2.59	2.357	392	227.5	2.528	353.76
6	5/27/2015 11:50	2.48	2.263	302	183.33	2.439	288.31
7	6/17/2015 10:40	2.38	2.146	240	140	2.328	223.28
8	7/13/2015 12:30	1.99	1.898	98	79	2.092	129.82
9	8/27/2015 10:40	2.35	2.442	226	276.67	2.608	425.84
10	4/21/2016 11:30	2.28	1.987	189	97	2.177	157.7
11	5/26/2016 12:10	2.46	2.336	290	216.67	2.507	337.77
12	6/17/2016 12:10	2.37	2.108	232	128.33	2.292	205.61
13	7/6/2016 11:15	2.32	2.088	208	122.5	2.273	196.74
14	8/11/2016 11:35	2.01	2	102	100	2.189	162.31
15	9/13/2016 11:15	1.92	2.165	84	146.25	2.346	232.72
16	3/30/2017 13:45	2.71	2.447	513	280	2.613	430.7
17	5/1/2017 11:00	2.31	2.176	202	150	2.356	238.37
18	5/31/2017 10:50	1.69	1.447	49	28	1.665	48.57
19	6/28/2017 10:00	1.72	1.357	53	22.76	1.58	39.9
20	7/13/2017 9:40	1.89	1.481	77	30.24	1.697	52.25
21	8/2/2017 9:50	1.51	1.191	32	15.52	1.422	27.76
22	8/16/2017 11:00	1.66	1.428	46	26.8	1.647	46.6
23	9/6/2017 10:10	1.56	1.26	36	18.22	1.488	32.32
24	11/15/2017 10:50	1.41	1.129	26	13.47	1.364	24.27
25	1/31/2018 10:10	<1.18	0.556	<15	3.6	0.821	6.95
26	3/22/2018 10:50	1.34	1.049	22	11.18	1.287	20.35
27	5/2/2018 10:00	1.49	1.121	31	13.21	1.356	23.83
28	5/23/2018 10:40	1.76	1.403	58	25.27	1.623	44.06
29	6/1/2018 10:50	2.45	2.565	282	367.45	2.725	557.25
30	7/19/2018 11:30	2.83	2.653	680	449.7	2.808	674.84
31	9/6/2018 12:00	2.69	2.572	493	373.4	2.732	565.8

32	12/4/2018 11:25	2.32	2.118	209	131.13	2.301	209.86
33	2/27/2019 10:40	2.11	1.872	129	74.47	2.068	122.74
34	3/14/2019 13:30	2.81	2.533	645	341.35	2.695	519.67
35	4/11/2019 10:50	2.15	1.922	140	83.65	2.116	137.05
36	5/1/2019 13:10	2.84	2.483	693	304.18	2.647	465.88
37	6/12/2019 10:50	1.77	1.419	59	26.25	1.639	45.69
38	8/20/2019 11:40	2.97	2.68	928	479.1	2.834	716.58
39	10/9/2019 11:50	1.76	1.435	58	27.23	1.654	47.31
40	12/11/2019 11:10	<1.18	0.627	<15	4.24	0.888	8.11

Definitions

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TSS: Total suspended solids in mg/L (00530)
TBYEXO: Turbidity in FNU (63680)
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