Appendix 1.5. Model Archive Summary for Total Suspended Solids Concentration at U.S. Geological Survey site 07143672; Little Arkansas River at Highway 50 near Halstead, Kansas, during March 2017 through October 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 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).

Site and Model Information

Site Number: 07143672

Site Name: Little Arkansas River at Highway 50 near Halstead, Kansas

Location: Latitude 38°01'43", longitude 97°32'25" referenced to North American Datum of 1927, in NW 1/4 NE 1/4 NE 1/4 sec.28, T.23 S., R.2 W., Harvey 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 guardrail. Check-bar elevation is 33.396 feet. The orifice tube is enclosed in 1.25-inch steel conduit trenched into the ground down to the edge of water, where the orifice emerges from the bank and culminates in a 2-inch open-end orifice tethered to a steel fencepost near the left edge of water. Gage height was measured during May 1998 through December 2019. A YSI 6600 water-quality monitor equipped with water temperature, specific conductance, pH, dissolved oxygen, and turbidity (a YSI Model 6026 [December 1998 through December 2006] and YSI Model 6136 [July 2004 through December 2017]) sensors collected data during May 1998 through December 2017. 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 January 2017 through December 2019. A Hach Nitratax monitor collected nitrate data during February 2017 through December 2019.

Date model was developed: June 1, 2020

Model calibration data period: March 30, 2017 through October 8, 2019

Model Data

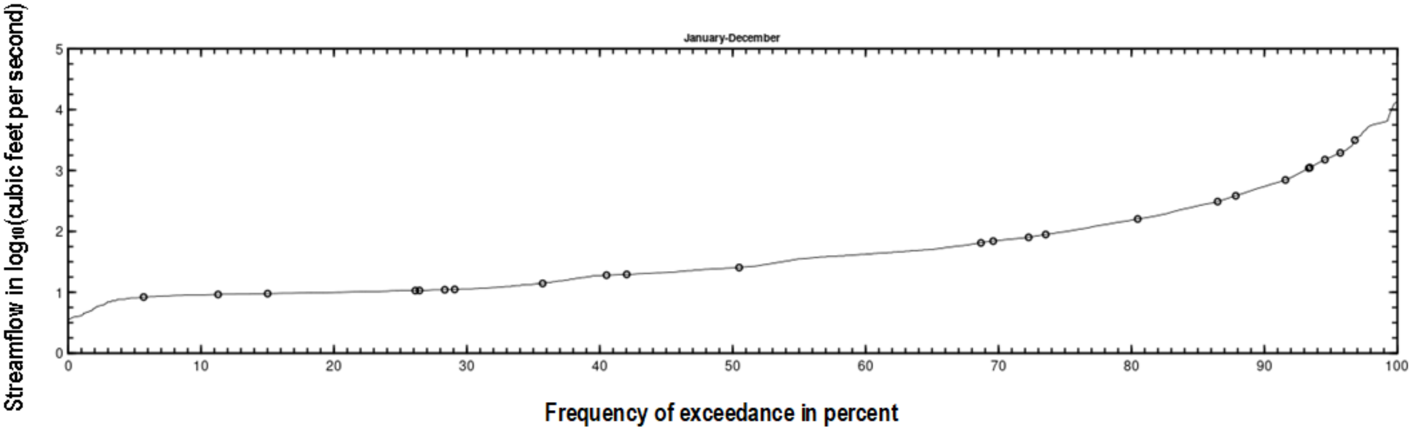
All data were collected using USGS protocols (U.S. Geological Survey, variously dated; Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010) and are stored in the National Water Information System (NWIS) database (U.S. Geological Survey, 2021). Explanatory variables were evaluated 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 24 concomitant values of discretely collected total suspended solids and continuously measured turbidity during March 2017 through October 2019. Discrete samples were collected over a range of streamflow and turbidity conditions. One sample had a concentration that was below the minimum reporting level (<15 mg/L) and a Tobit regression model was developed to compute estimates of total suspended solids 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.

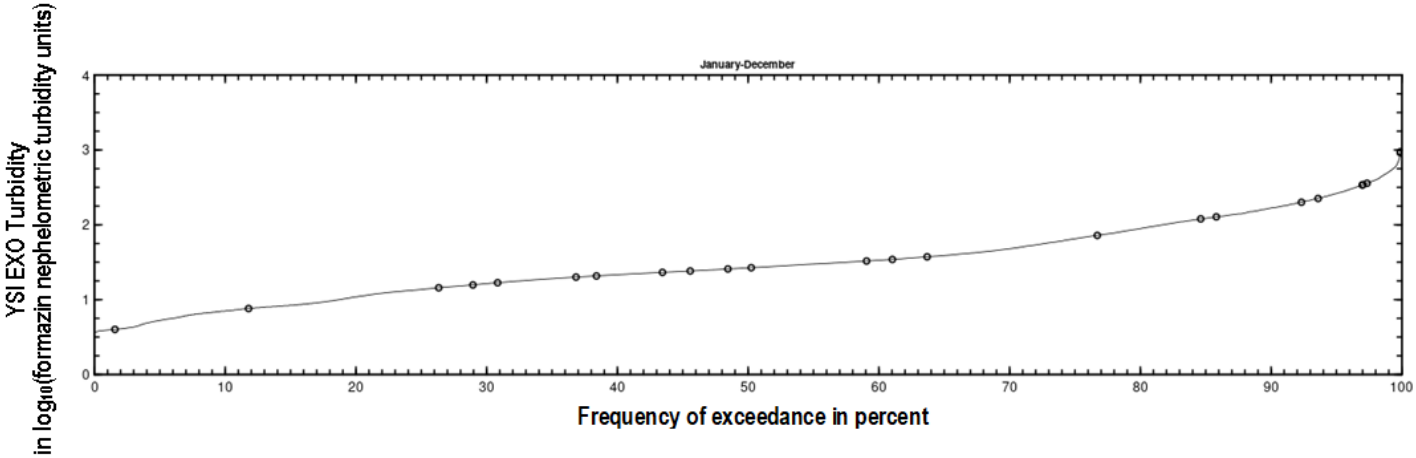
Total Suspended Solids

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 2 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 07143672:

Total suspended solids-based model:

$$\log_{10}(TSS) = 1.0175 \times \log_{10}(TBY) + 0.2545$$

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 1.04. The retransformed model, accounting for BCF is:

$$TSS = 1.8687 \times TBY^{1.0715}$$

Model Statistics, Data, and Plots

Model

LOGTSS = + 1.0175 * LOGTBY + 0.2545

Variable Summary Statistics

```
                    TSS   TBYEXO
       Minimum      <15        4
  1st Quartile     44.5    22.62
        Median       78    35.32
          Mean    352.1   176.83
  3rd Quartile      336   214.04
       Maximum     2790  1038.43
```

Explanatory Variables

```
Coefficients:
            Estimate Std. Error z-score p-value
(Intercept)   0.2545    0.08001   3.181  0.0039
logTBYEXO     1.0175    0.04137  24.592  0.0000
```

Basic Model Statistics

```
Estimated residual standard error (Unbiased) = 0.1198
Distribution: normal
Number of observations = 24, number censored = 2 (8.3 percent)

Loglik(model) = 15.85 Loglik(intercept only) = -25.33
  Chi-square = 82.37, degrees of freedom = 1, p-value = <0.0001

Computation method: AMLE

Pseudo R-squared: 0.9705

  AIC: -25.71
  BIC: -22.18
```

Outlier Test Criteria

```
leverage   cooksD
  0.1250   0.7145
```

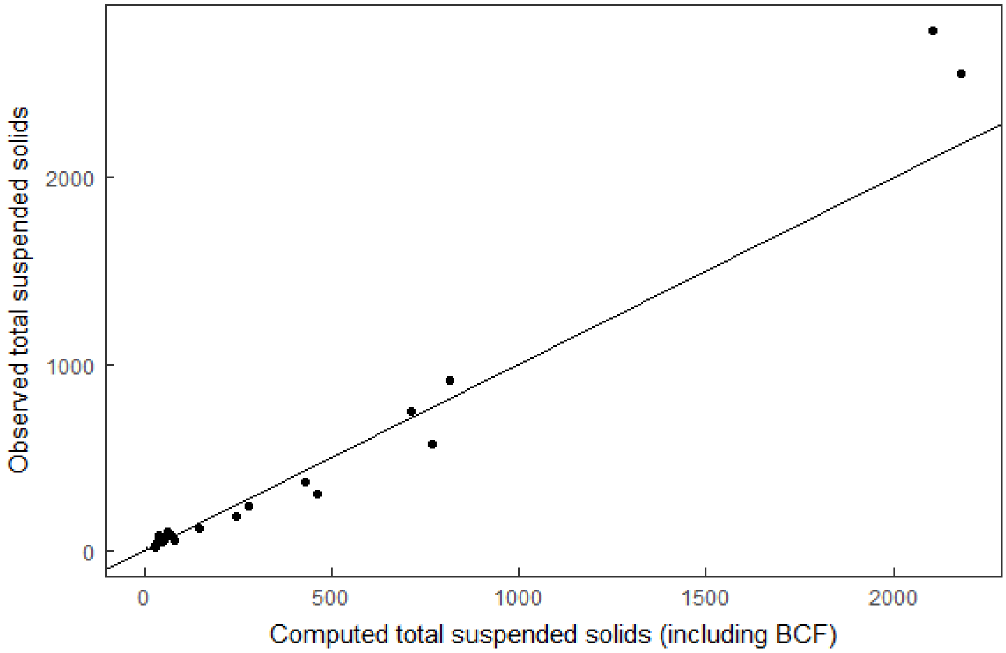
Flagged Observations

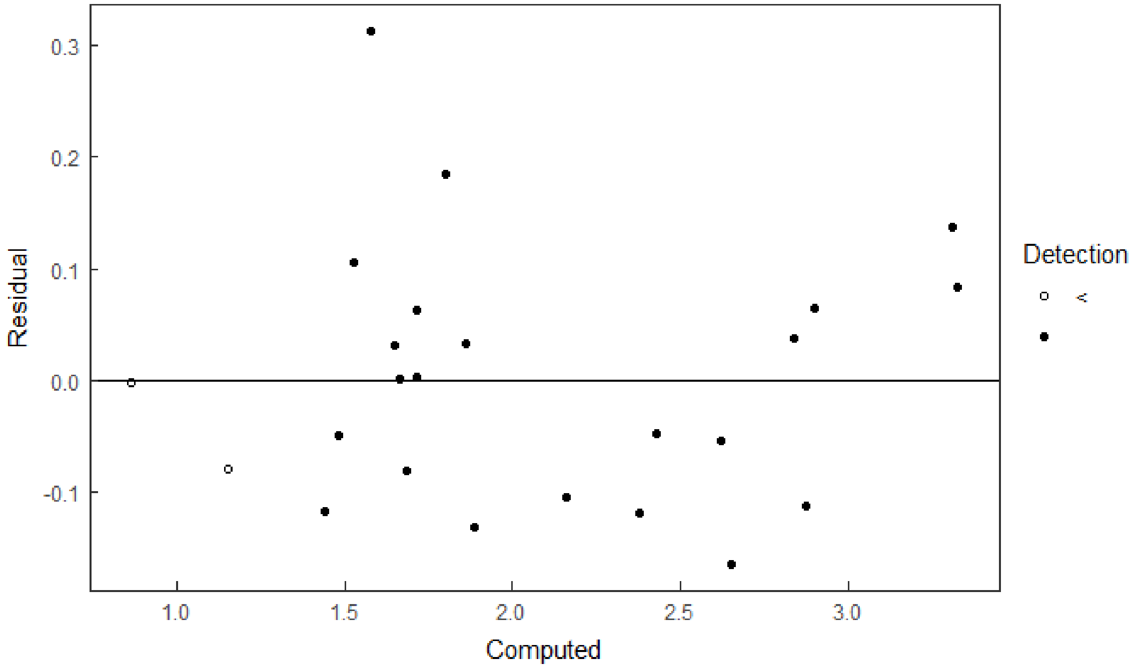
```
         logTSS     ycen     yhat    resids  leverage       cooksD
     10   1.176     TRUE   0.8671  -0.00173    0.1795     2.77E-05
     19   3.407    FALSE   3.3237  0.083723    0.1954     7.37E-02
     21   3.446    FALSE   3.3086  0.136969    0.1918     1.92E-01
```

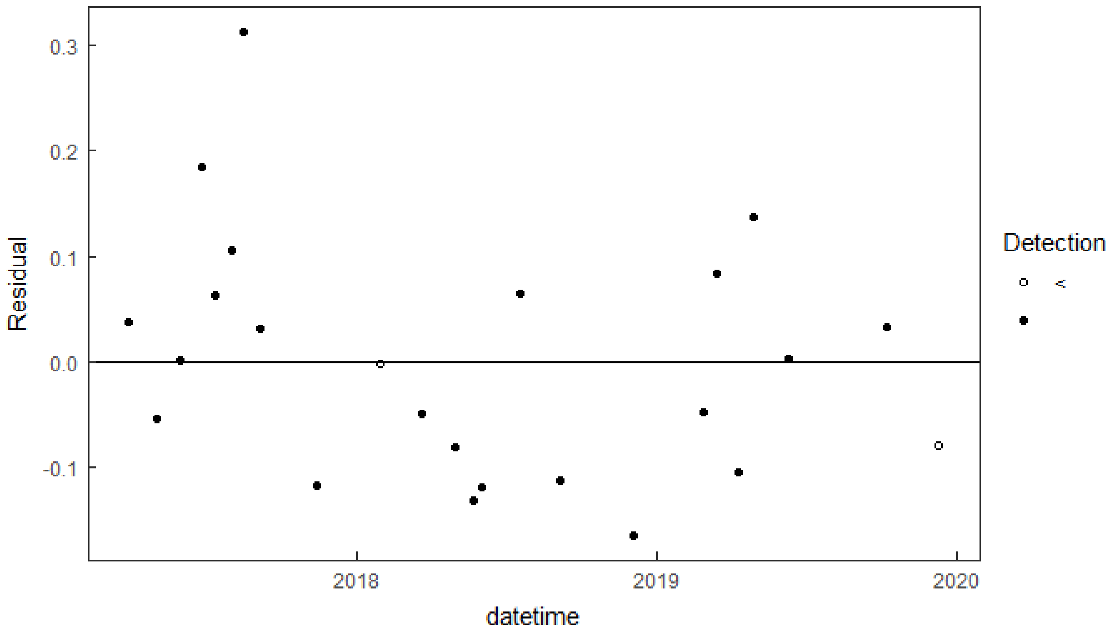
95% Confidence Intervals

```
                 2.5 %    97.5 %
(Intercept) 0.09771927 0.4113532
logTBYEXO   0.93639545 1.0985823
```

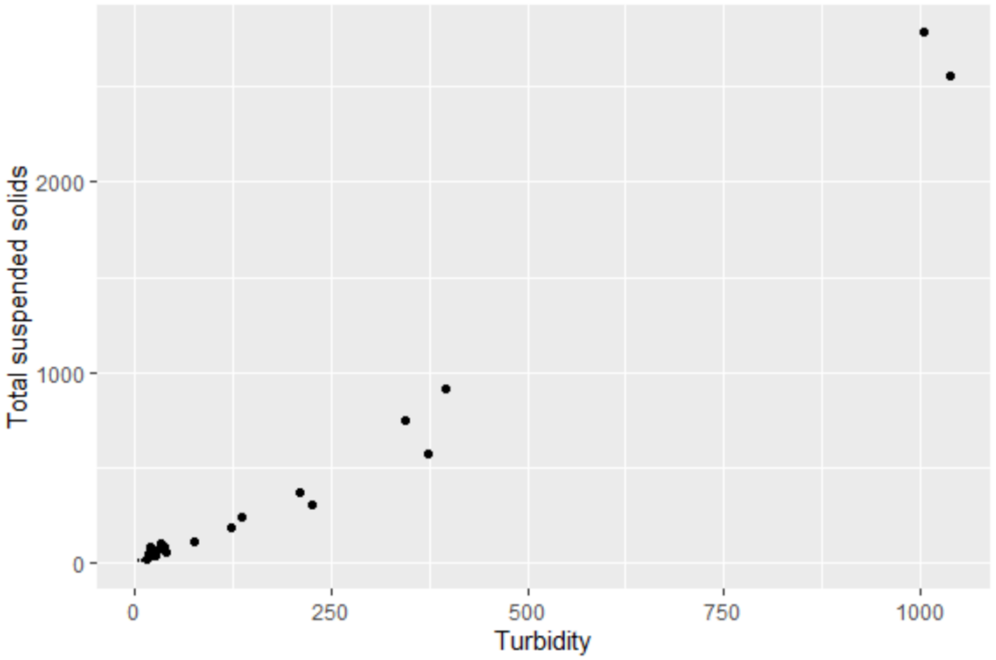
Plots


Observed total suspended solids
2000
1000
0
0
500
1000
1500
2000
Computed total suspended solids (including BCF)


Residual
0.3
0.2
0.1
0.0
-0.1
1.0
1.5
2.0
2.5
3.0
Computed
Detection
<



Residual
0.3
0.2
0.1
0.0
-0.1
2018
2019
2020
datetime
Detection
○ <
●



Total suspended solids
2000
1000
0
0
250
500
750
1000
Turbidity

Model-Calibration Dataset

```
               datetime logTSS logTBYEXO    TSS TBYEXO Computed_logTSS Computed_TSS
   1    3/30/2017 10:30   2.88     2.538    750    345           2.837       710.79
   2     5/3/2017 10:15   2.56     2.322    366    210           2.617       428.91
   3    5/30/2017 12:10   1.66     1.383     46   24.2           1.662        47.52
   4    6/27/2017 10:35   1.98     1.517     96   32.9           1.798        65.06
   5     7/12/2017 9:40   1.78     1.436     60   27.3           1.715        53.73
   6     8/1/2017 10:25   1.63     1.252     43   17.8           1.528        34.91
   7    8/17/2017 10:05   1.89     1.302     78     20           1.579        39.29
   8      9/5/2017 9:50   1.68     1.371     48   23.5           1.649        46.16
   9   11/14/2017 10:30   1.32     1.164     21   14.6           1.439        28.46
  10    1/30/2018 10:00  <1.18     0.602    <15      4           0.867         7.62
  11    3/21/2018 10:10   1.43     1.205     27     16           1.481        31.31
  12     5/1/2018 11:10    1.6     1.404     40   25.4           1.683        49.93
  13     5/22/2018 9:35   1.76     1.605     57   40.3           1.888         79.9
  14      6/2/2018 9:20   2.26     2.088    182  122.4           2.379       247.71
  15    7/18/2018 10:20   2.96     2.596    912  394.8           2.896       815.25
  16     9/6/2018 10:00   2.76     2.572    573  373.4           2.872       770.41
  17    12/3/2018 11:05   2.49     2.354    306  226.2            2.65        462.5
  18    2/26/2019 11:40   2.38     2.136    240  136.8           2.428       277.32
  19    3/14/2019 10:20   3.41     3.016   2560 1038.4           3.324       2181.1
  20    4/10/2019 12:00   2.06     1.874    114   74.8           2.161       150.04
  21    4/29/2019 13:05   3.45     3.002   2790 1003.7           3.309      2106.89
  22    6/11/2019 10:10   1.72     1.434     52   27.2           1.713        53.51
  23    10/8/2019 10:10   1.89     1.577     78   37.7           1.859        74.78
  24   12/10/2019 11:30  <1.18     0.881    <15    7.6           1.151        14.65
```

Definitions

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

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