Prepared in cooperation with the U.S. Army Corps of Engineers

Suspended-Sediment Concentrations and Loads During an Operational Drawdown of Fall Creek Lake, Oregon, Winter 2013–14

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Data Release

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg), or metric ton
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datum

Vertical coordinate information is referenced to, North American Vertical Datum of 1988 (NAVD 88)].
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)].
Elevation, as used in this report, refers to distance above the vertical datum.

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Suspended-Sediment Concentrations and Loads During an Operational Drawdown of Fall Creek Lake, Oregon, Winter 2013-14

By Liam N. Schenk and Heather M. Bragg

Introduction

The U.S. Army Corps of Engineers (USACE) has been performing operational drawdowns of Fall Creek Lake since 2011 to allow endangered juvenile salmonids to pass freely through the dam to comply with requirements in the 2008 Biological Opinion (BiOp). The drawdowns involve lowering the lake water level to the lake bed, creating a fluvial environment characterized by large amounts of sediment being transported through the dam and into Fall Creek and the Middle Fork Willamette River. Water year 2014 is the second year the USGS has monitored turbidity and suspended sediment at this site, approximately 1 mile below the dam at Fall Creek Lake. USGS monitoring activities for WY 2014 started in November 2013 and ended in March 2014.

Purpose and Scope

This report presents results of the winter 2013–14 drawdown sediment-transport study conducted in cooperation with the USACE. The USGS assessed turbidity and streamflow as possible surrogates for SSC at one project site, *Fall Creek Outflow* (USGS station 14151000, fig. 1). The resulting simple linear or multiple linear regressions were used to calculate continuous (15-minute) SSC values; these values were then used, with continuous streamflow, to compute instantaneous and daily suspended-sediment loads (SSL) at the project sites.

Description of the Study Area

Fall Creek Lake is located in the Middle Fork Willamette River watershed in west-central Oregon, on the fringe of the Willamette Valley Foothills and the Western Cascades Lowlands and Valleys (fig. 1). The lake is a flood control reservoir operated by the USACE, encompassing 1,820 acres at full pool (elevation 830 ft). The watershed is predominately forested (91 percent of total acreage, fig.1) with the exception of developed areas in the foothills, including some pasture and rangeland (Natural Resources Conservation Service, 2006). The watershed extends eastward into the High Cascades physiographic subprovince, and the elevation ranges from 454 ft in the city of Springfield to approximately 6,500 ft in the High Cascades.

Methods

Data Collection and Sample Analysis

Data were collected using USGS protocols and are stored in USGS NWIS databases U.S. Geological Survey, 2015). The turbidity sensor, a McVann self-cleaning sensor installed on a Hydrolab DS-5x datasonde, was deployed in November 2013 and retrieved in March 2014, resulting in approximately a 4-month deployment period. In addition to the Hydrolab, a Campbell Scientific OBS-500 turbidity sensor was deployed to provide backup turbidity data in the event the Hydrolab became excessively fouled. Equal Width Increment (EWI) samples were collected from a cableway approximately 300 ft upstream from the monitoring station. In addition to EWI samples, an ISCO pump sampler was installed on the right edge of water at the gage house with the pump tubing attached to the deployment pipe that housed the sonde. Grab samples were also collected using a 3-liter bottle attached to an extension pole to collect samples as close to the turbidity sensor as possible. Samples were analyzed at USGS Cascade Volcano Observatory sediment lab for suspended-sediment concentration (SSC, in milligrams/liter) and percent finer than 63microns.

EWI samples were used to calculate box coefficients for the SSC of the pump samples and grab samples to correct for cross–sectional variation. Box coefficients were calculated one of two ways. When two pump samples were collected bracketing the begin and end time of an EWI sample, the average SSC of the pump samples was time-adjusted to the mean time of the EWI sample and divided by the EWI SSC. If only one pump or grab sample collected, that sample SSC was divided into the corresponding EWI sample, and the result was used as the box coefficient. Box coefficients were combined and averaged according to hydrologic conditions at the time of sample collection (pre-drawdown, drawdown, etc.) and were then applied to samples that were collected in those conditions.

Methods for Assigning Turbidity and Streamflow

To assign turbidity values to discrete SSC samples, continuous (15-minute) turbidity data were averaged over the period of EWI sample collection. Turbidity values were averaged starting with the data value immediately before the start of the EWI sampling and ending with the data value immediately after the end of the EWI sampling. Pump samples that were collected on a 15-minute mark were assigned the corresponding turbidity value. For pump samples that were not collected on a 15-minute mark, the two turbidity values before and after the sample were averaged.

Streamflow values were averaged to match with SSC sample times, starting with the 15-minute data value before the mean time of the sample. For samples times that occurred on a 15-minute mark, single unit values of streamflow were used.

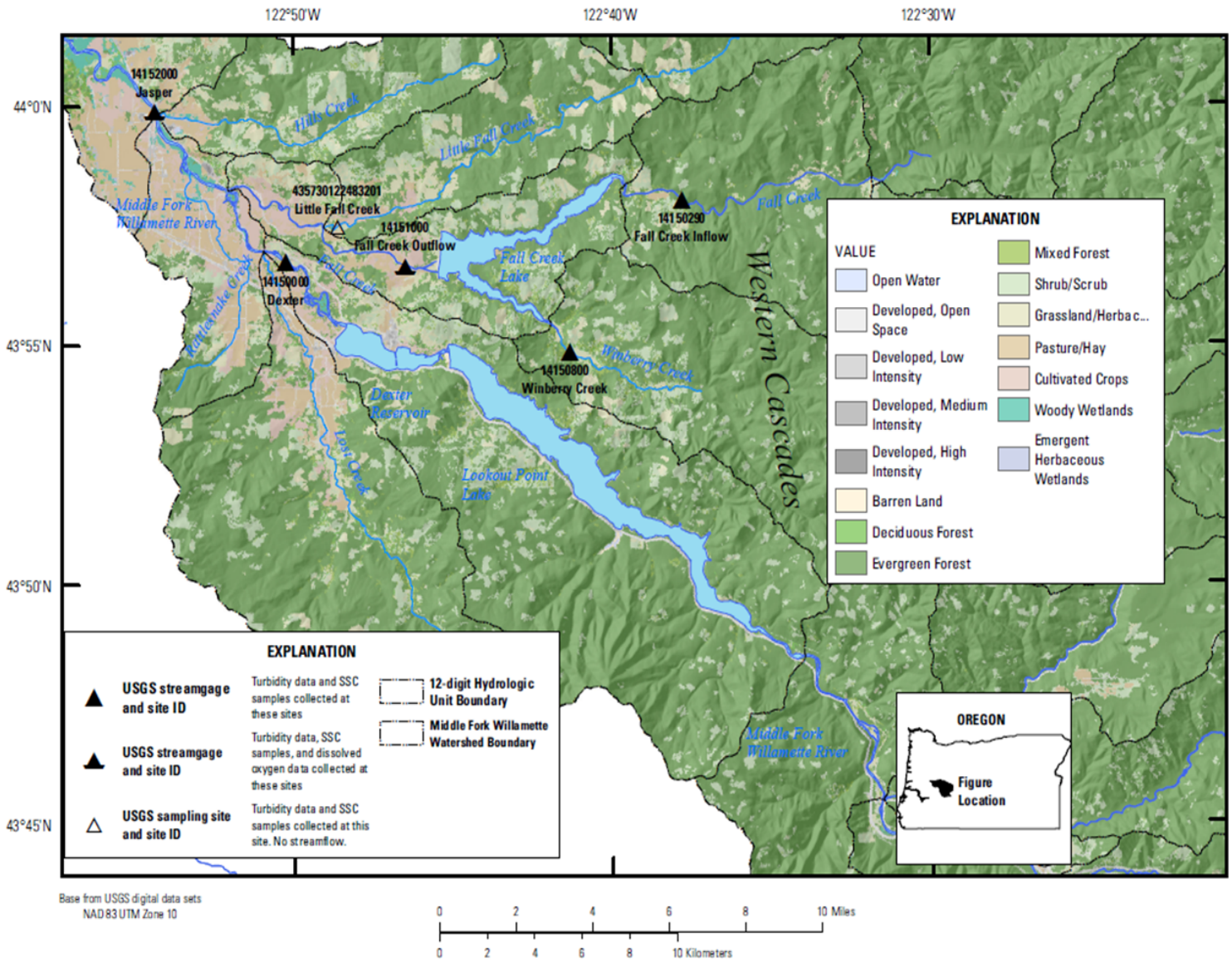

Figure 1. Location of study area and monitoring stations, Middle Fork Willamette River Basin, Oregon.

Model Development

All three types of samples (EWI, pump, and grab) were evaluated for use in SSC regressions. Regression analysis was performed using the Excel spreadsheet program from the TM3, chapter 4 publication (Rasmussen and others, 2009). Turbidity and streamflow were examined together as explanatory variables for estimating SSC. Different combinations of untransformed and log10-transformed data were also evaluated for both single linear regression and multiple linear regression models.

Results

Based on the turbidity-SSC model results, three regression models were used for the project period to estimate instantaneous SSC.

Model Period 1 – Pre-drawdown

The first model applied to the project period, from 11/14/13 17:15 to 12/08/13 08:30, was based on 14 concurrent measurements of turbidity and SSC samples. Of the 14 samples, 2 were EWI samples, and 12 were pump samples with concentrations adjusted by box (cross-section) coefficients (Edwards and Glysson, 1999). Samples were collected over the range of the hydrograph for the pre-drawdown period, up until the onset of increasing turbidity associated with the drawdown.

Log10-transformed turbidity was selected as the best explanatory variable for this model period (11/14/13—12/08/13) on the basis of adjusted R^2, residual plots, model standard percentage errors (MSPE), probability plot correlation coefficients (PPCC), and prediction-error sum of squares (PRESS) statistics. Residual plots for evaluating variance, normality, homoscedasticity, and curvature are provided (fig. 2). For log10-transformed models, estimated values were multiplied by a calculated retransformation bias correction factor (BCF) (Duan, 1983). Ninety-percent prediction intervals are also provided for evaluating uncertainty of the estimates (fig. 3).

<u>Pre-Drawdown Model Summary</u>

Model Period: 11/14/13 17:15 to 12/08/13 08:30

Equation: $\mathbf{\log(SSC) = -0.0426 + 0.758\log(TB)}$

SSC = Suspended-sediment concentration, in milligrams per liter

TB = Turbidity, in formazin nephelometric units (FNU)

Number of measurements = **14**

MSPE = **+37.46 and –27.25 %**

Adj r^2: **0.82**

Duan BCF: **1.04**

PPCC: **0.99**

PRESS: **0.33**

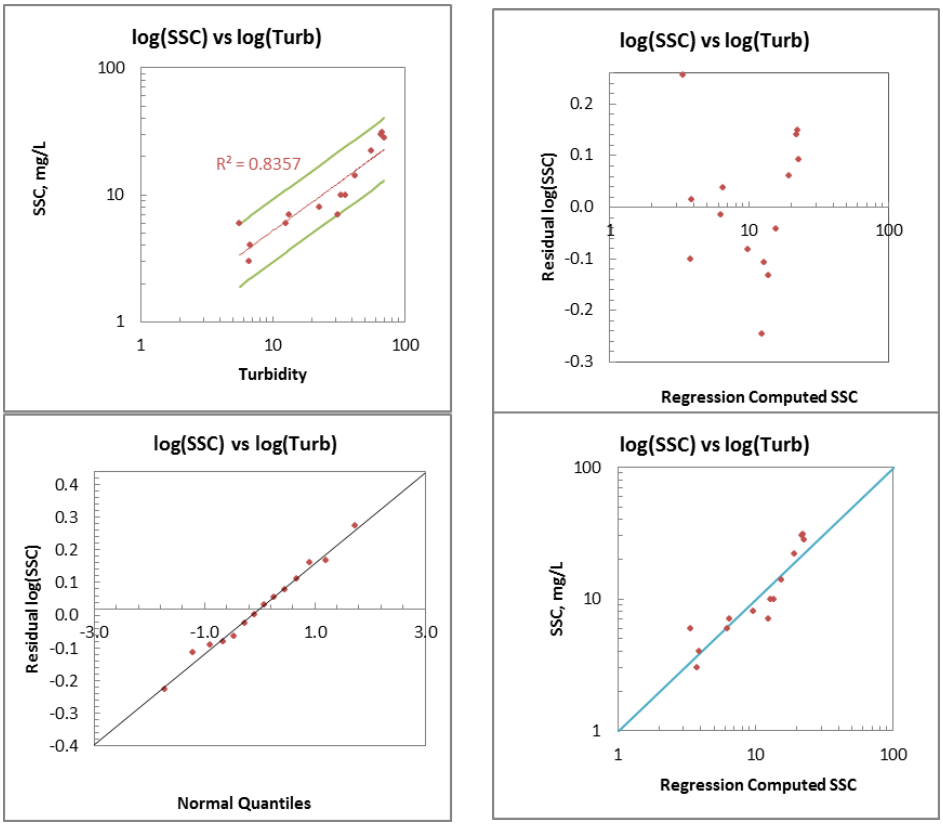

Figure 2. Pre-drawdown model analyses for Fall Creek below Winberry Creek, USGS station 14151000

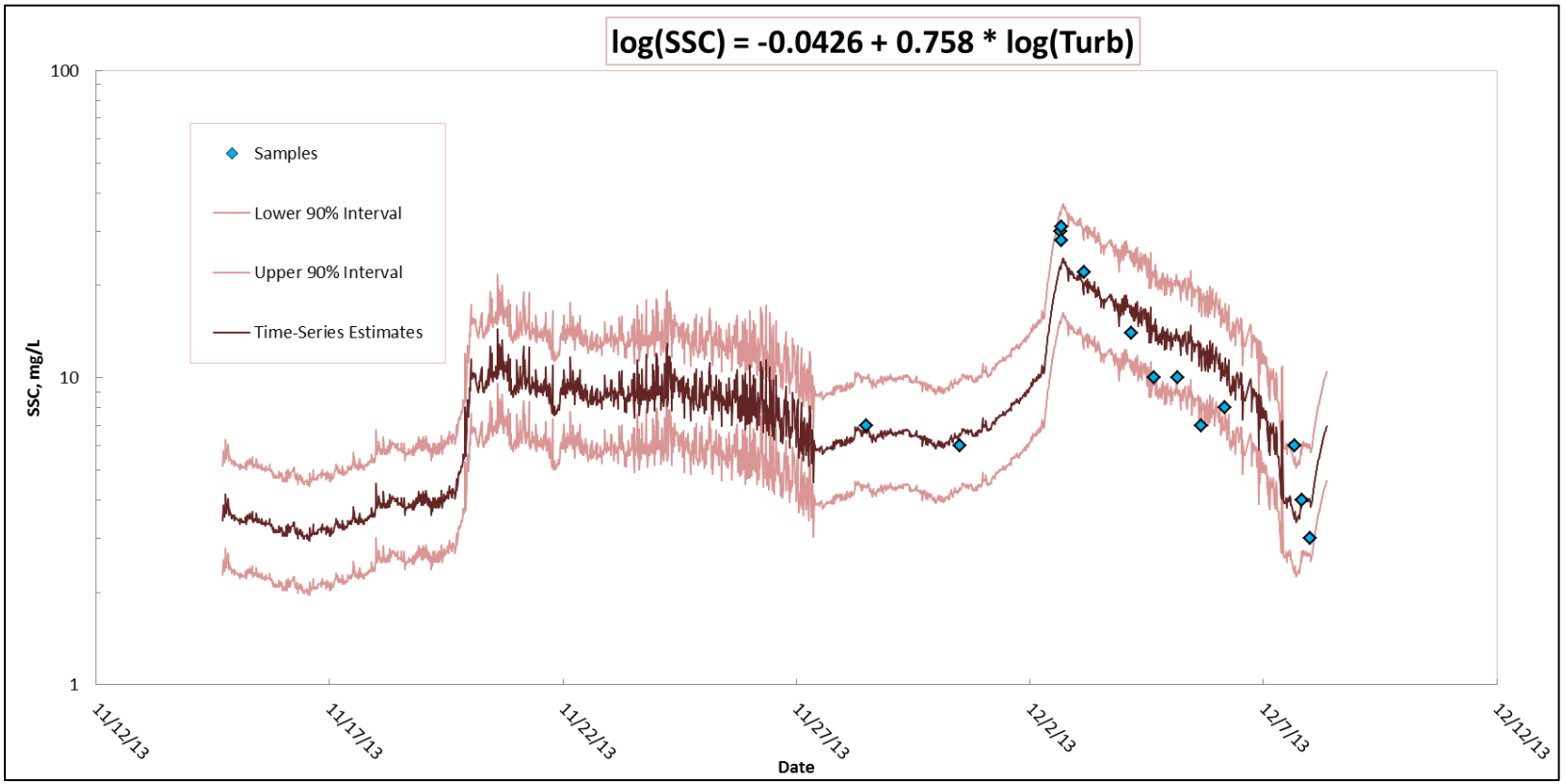

Figure 3. Pre-drawdown suspended sediment concentration (SSC) time series and 90 percent confidence intervals for Fall Creek below Winberry Creek, USGS station 14151000

Model Period 2 – Drawdown

The second model, applied to the project period from 12/08/13 08:45 to 12/13/13 19:45, was based on 37 concurrent measurements of turbidity and a combination of EWI, grab, and pump samples during the drawdown which lasted for 6 days. These samples were considered to represent hydrologic conditions that were different from pre-drawdown conditions based on high SSC concentrations, decreasing values of percent fines indicating a coarsening of the sediment load (fig. 4), and low to moderate streamflow when the samples were collected. Turbidity data were deleted from 12/13/13 to 12/18/13 due to extreme sensor fouling, and several samples at the end of the drawdown could not be paired with turbidity data. To estimate daily concentrations of SSC, unit values on 12/13 and 12/18 were used, but daily mean SSC values were calculated for 12/14–12/17/13 (4 days), for which no turbidity data are available. Three pump samples were collected on each of the 4 days, and the SSC concentrations were averaged to obtain a mean daily SSC value (table 1).

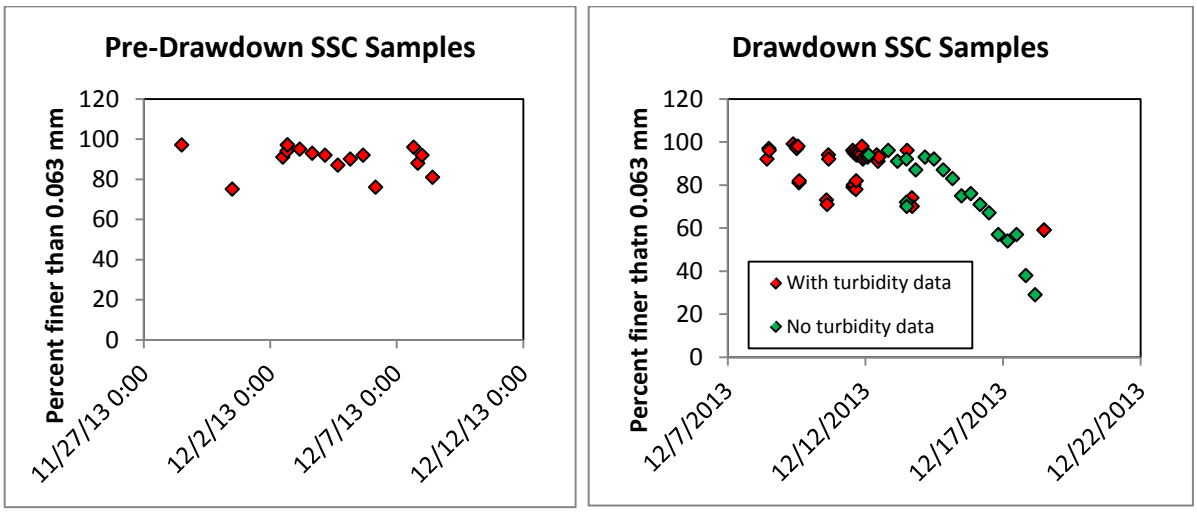

Figure 4. Percent-fines plots of pre-drawdown and drawdown samples

Table 1. Mean daily SSC values for full days with missing turbidity data

[mg/L = milligrams per liter]

Date	Number of Pump samples	Mean daily SSC calculated from pump samples (mg/L)
12/14/2013	3	653
12/15/2013	3	931
12/16/2013	3	667
12/17/2013	3	275

Sub-freezing temperatures persisted for much of the 6 days of the drawdown period, making use of depth-integrated samplers and the pump sampler impossible due to freezing and ice-clogged sampling equipment. Only grab samples could be collected during the coldest conditions. When weather conditions improved, a grab sample was collected after an EWI sample to calculate the box coefficient. Box coefficient results showed that the grab samples were biased low, so it was necessary to apply a large coefficient to adjust the concentrations of those samples.

Nineteen of the SSC samples in the calibration dataset were EWI, 5 samples were grabs, and 13 were pump samples. The pump sample concentrations were adjusted using a box coefficient of 1.16 or 0.95 based on the timing of sample collection.

An untransformed multiple linear regression with turbidity and streamflow as explanatory variables was selected as the best-fit model for the drawdown period on the basis of adjusted R^2, residual plots, MSPE, PPCC, and PRESS statistics. Residual plots for evaluating variance, normality, homoscedasticity, and curvature are provided (fig. 5), as well as 90-percent prediction intervals for evaluating uncertainty of the estimates (fig. 6).

To transition between the pre-drawdown and drawdown models, unit values of SSC were interpolated from the end of model period 1 beginning on 12/08/13 08:45 and ending on 12/08/13 11:30, a total of 12 unit values . Unit values of SSC computed using model 2 begin on 12/08/13 11:45.

<u>Drawdown Model Summary</u>

Model Period: 12/08/13 11:45 to 12/13/13 19:45

Equation: $\boldsymbol{SSC = 441 + 1.98(TB) - 0.521(Q)}$

SSC = Suspended-sediment concentration, in milligrams per liter

TB = Turbidity, in formazin nephelometric units (FNU)

Q = Streamflow, in cubic feet per second

Number of measurements = **37**

Adj r^2: **0.86**

Model standard percentage error (MSPE) = **+15.52 and -15.52 %**

PPCC: **0.99**

PRESS: **495,528**

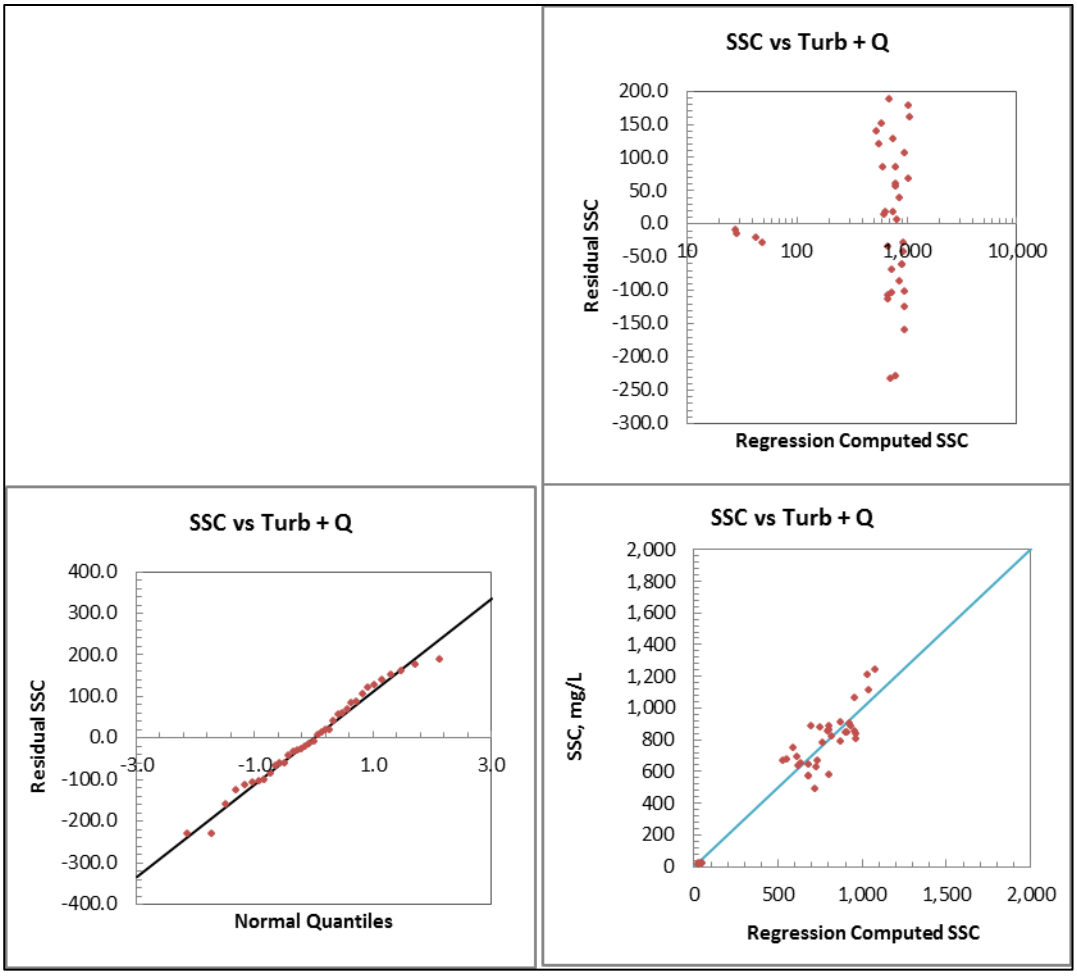

Figure 5. Drawdown model analyses for Fall Creek below Winberry Creek, USGS station 14151000

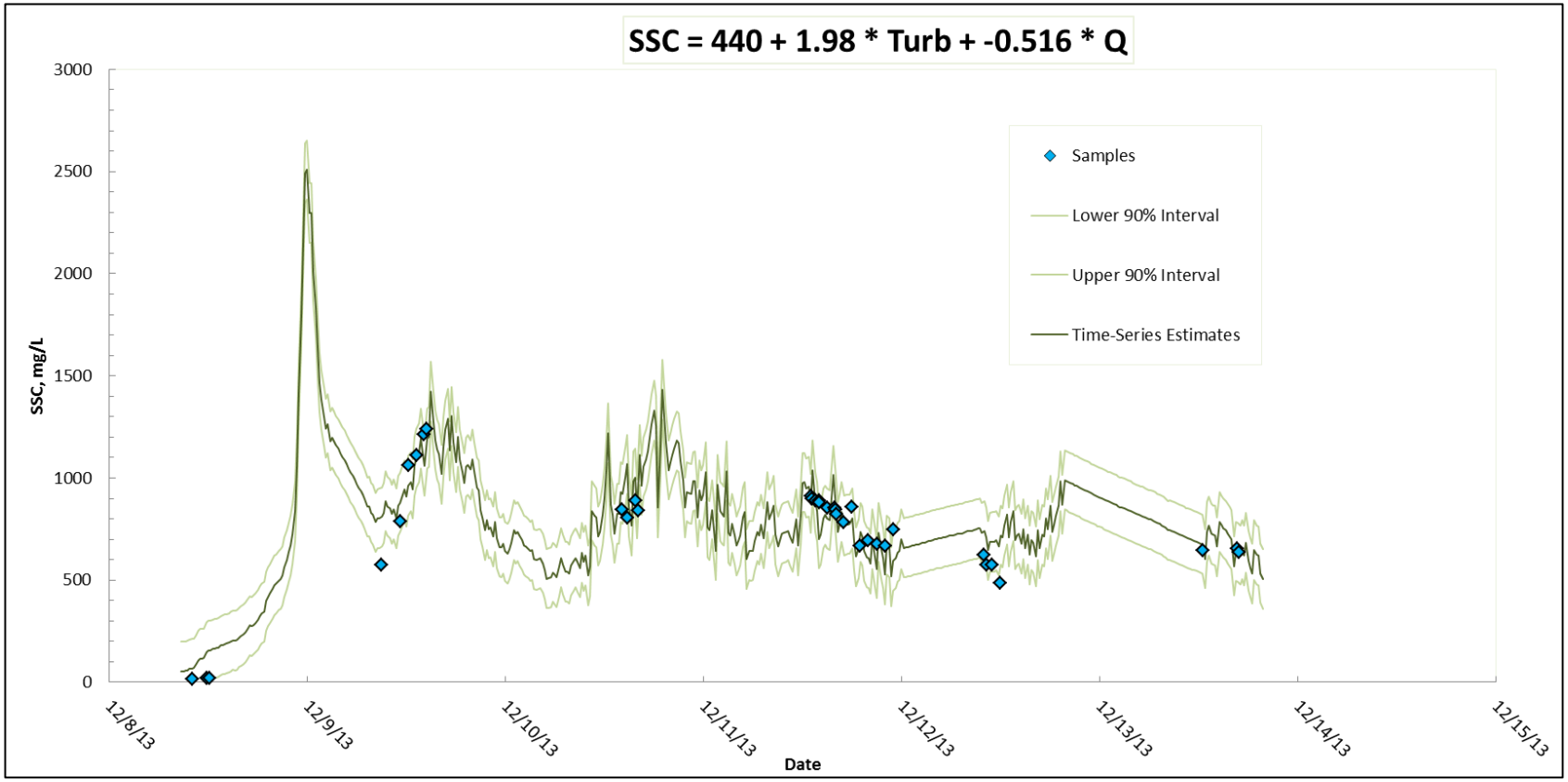

Figure 6. Drawdown suspended sediment concentration (SSC) time series and 90-percent prediction intervals for Fall Creek below Winberry Creek, USGS station 14151000

Turbidity data were deleted from 12/13/13 20:00 to 12/18/13 10:15 due to extreme sensor fouling. Unit values on 12/13 and 12/18 were used to calculate daily values of SSC, but daily mean SSC values were calculated for 12/14 to 12/17/13 (4 days) when no turbidity data are available. Three pump samples were collected on each of the 4 days, and the SSC concentrations were averaged to obtain a mean daily SSC value (table 1).

Model Period 3 – Post Drawdown

The third model was applied to the period from 12/18/13 10:45 to 03/28/14 00:45. Preliminary assumptions were that the hydrologic conditions would have returned to pre-drawdown conditions after the effects of the drawdown subsided. However, analysis of percent fines of samples collected after the drawdown showed that there was still sand-sized material in transport well after the drawdown subsided (fig. 7). Although the sand content was not as high as in samples collected during the drawdown, the average percent fines values for post drawdown samples was 78% (n=10) compared to 90% (n=17) for the pre-drawdown samples. As such, samples collected between 12/18/13 and 03/28/14 were evaluated separately to represent post-drawdown conditions.

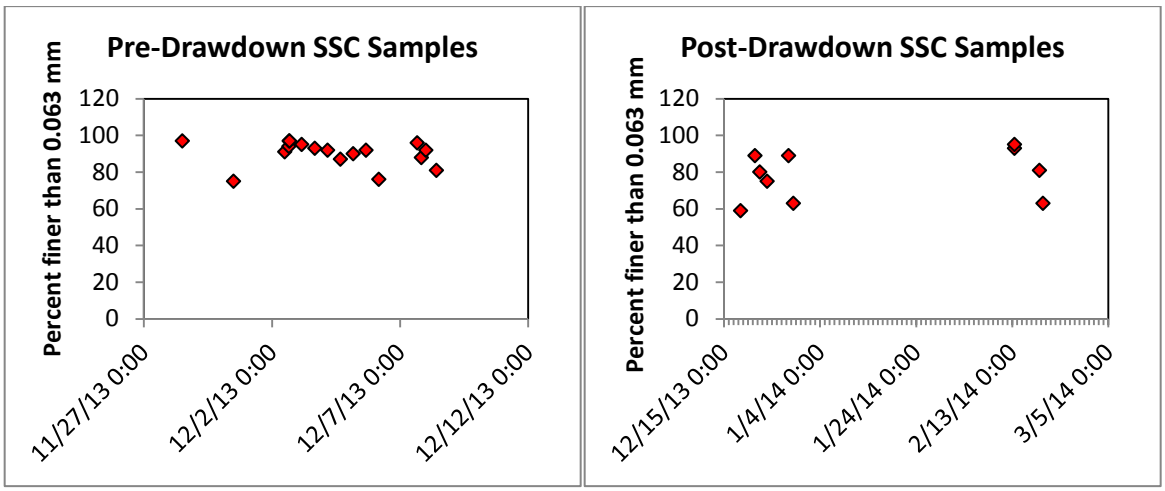

Figure 7. Percent fines of samples collected during pre-drawdown and post-drawdown conditions

A multiple linear regression model with Log10-transformed turbidity and streamflow as explanatory variables was selected as the best-fit model for the post-drawdown period on the basis of adjusted R^2, residual plots, MSPE, PPCC, and PRESS statistics. Streamflow in the month of February approached channel capacities and was very high compared to that during the rest of the project period. These high streamflows and the high sand content of the samples likely led to a large coefficient for the streamflow variable in the model, which resulted in high values for computed SSC in the month of February. Residual plots for evaluating variance, normality, homoscedasticity, and curvature are provided in figure 8, and 90-percent prediction intervals for evaluating uncertainty of the estimates are shown in figure 9.

<u>Post-Drawdown Model Summary</u>

Model Period: 12/18/13 10:30 to 03/28/13 00:45

Equation: $\log(SSC) = -0.558 + 0.854\log(TB) + 0.392\log(Q)$

SSC = Suspended-sediment concentration, in milligrams per liter

TB = Turbidity, in formazin nephelometric units (FNU)

Q = Streamflow, in cubic feet per second

Number of measurements = **10**

Adj r^2: **0.80**

Model standard percentage error (MSPE) = **+65.90 and -39.72 %**

PPCC: **0.97**

PRESS: **0.70**

Duan BCF**: 1.09**

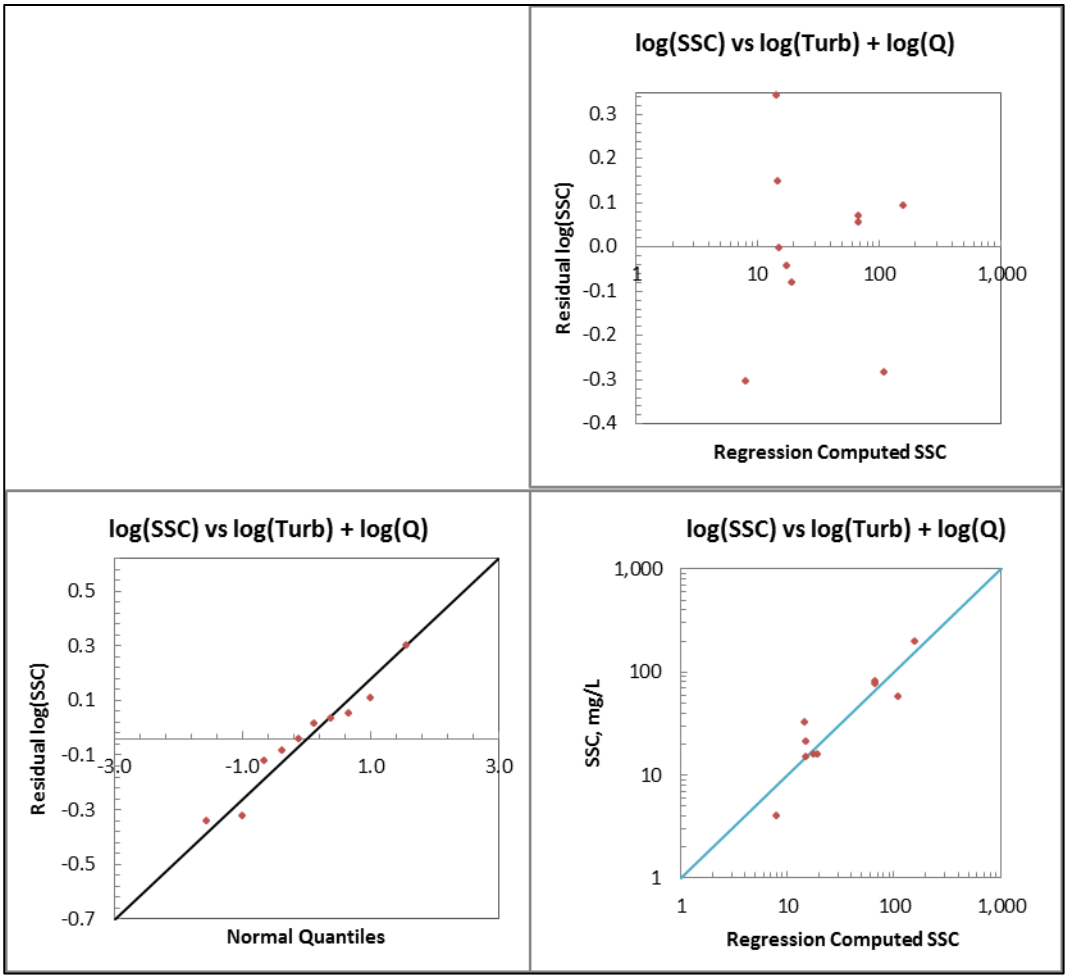

Figure 8. Post-drawdown model analyses for Fall Creek below Winberry Creek, USGS 14151000

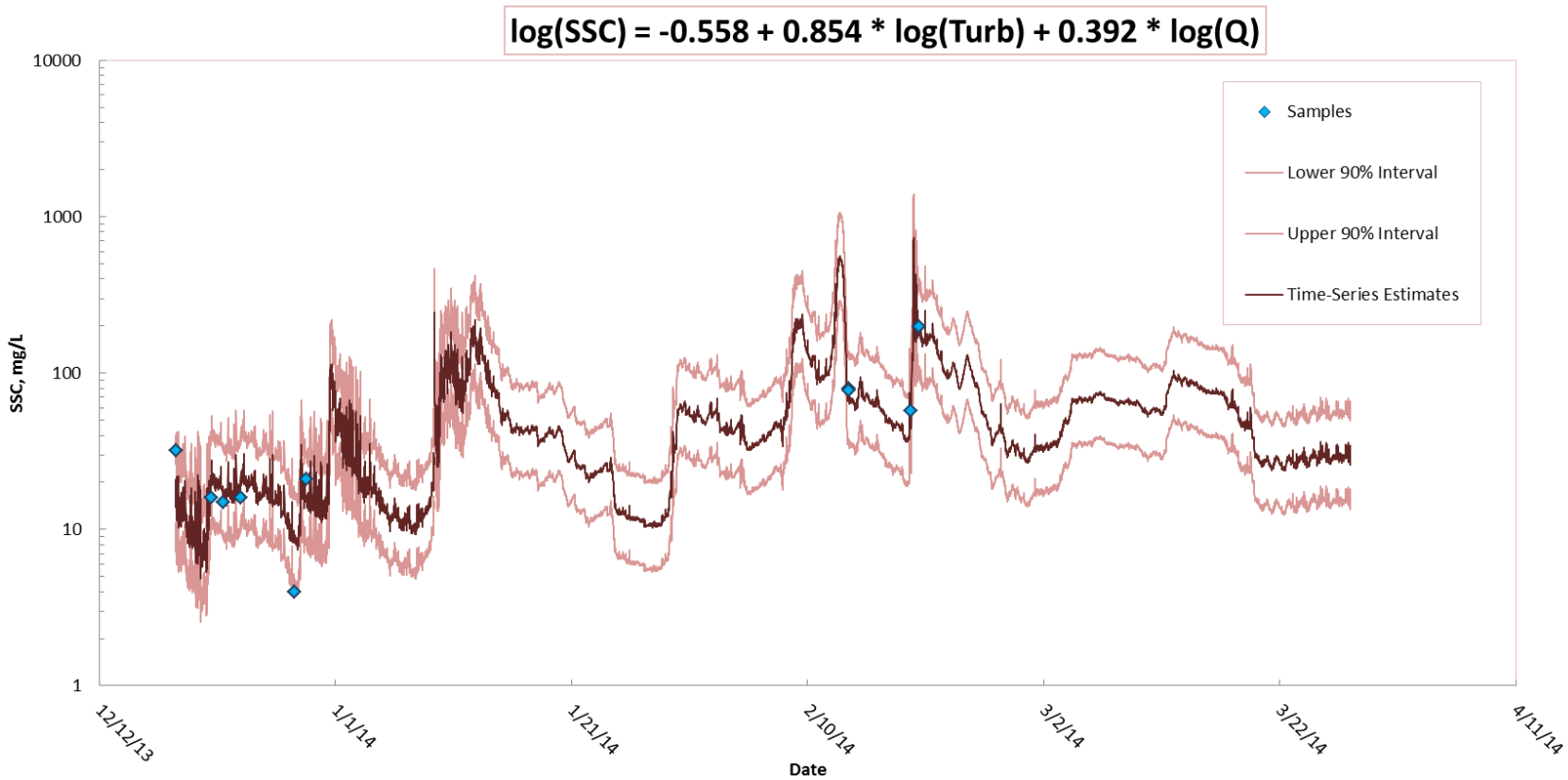

Figure 9. Post-drawdown suspended sediment concentration (SSC) time series and 90 percent confidence intervals for Fall Creek below Winberry Creek, USGS 14151000

Suspended Sediment Loads

Unit values of computed SSC were paired with instantaneous streamflow values to calculate instantaneous suspended-sediment loads. For the 4 days in December 2013 when turbidity data were lost due to fouling, the estimated daily average SSC was multiplied by the daily mean streamflow (in cubic feet per second) and a conversion factor to obtain daily values of suspended-sediment load in tons. The total suspended-sediment load calculated during the drawdown (12/08/13–12/13/13) was approximately 3,300 tons. Monthly totals of suspended sediment load in tons for the WY 2014 drawdown are shown in table 2.

Table 2. Total suspended-sediment loads at Fall Creek below Winberry Creek, USGS station 14151000, water year 2014

Month	Total monthly suspended-sediment load in tons
November[1]	333
December	5,530
January	3,920
February	13,140
March[2]	4,660

[1] November monthly total calculation based on suspended-sediment loads from 11/14/13 to 11/30/13

[2] March monthly total calculation based on suspended-sediment loads from 03/01/14 to 03/27/14

References Cited

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: Techniques of Water-Resources Investigations of the U.S. Geological Survey, book 3, chap. C2, 89 p.

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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, 52 p.

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