Appendix 2. Model Archive Summary for Streamflow Regression Model to Estimate Suspended Sediment Concentration at U.S. Geological Survey Site Number 07017610; Big River below Bonne Terre, Missouri

This model archive summary describes the secondary suspended sediment concentration (SSC) model developed to compute real-time SSC using real-time streamflow data from October 1, 2018, to present. This model supersedes all previous secondary models used. The methods used follow U.S. Geological Survey (USGS) guidance as referenced in relevant Office of Surface Water/Office of Water Quality Technical Memoranda (USGS, 2016) and Rasmussen and others (2009). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Site and Model Information

Site number: 07017610

Site name: Big River below Bonne Terre, Missouri

Location: Latitude 37°57′54.9″, longitude 90°34′28.2″, referenced to North American Datum of 1983, in St. Francois County, Missouri, hydrologic unit 07140104, on downstream left wingwall of State Highway E, approximately 3 miles north of Bonne Terre, Missouri.

Equipment: The streamgage was equipped with a data collection platform that stored data from the pressure transducer that measured stage at 15-minute intervals. Data were transmitted

hourly via satellite telemetry to the USGS National Water Information System (NWIS; USGS, 2023).

Model number: 07017610.SSC.WY18.2

Date model was created: April 28, 2023

Model-calibration data period: November 28, 2018, to September 10, 2021

Model application date: October 1, 2018, to present

Computed by: Kendra M. Markland

Reviewed by: Jessica Garrett

Approved by: Dan Christensen

Model Data

All data were collected using USGS protocols and are stored in the NWIS database (USGS, 2023). The turbidity regression model is based on 40 measurements of suspended sediment concentration and streamflow collected from November 28, 2018, through September 10, 2021. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration data are provided. Studentized residuals from the final model were inspected for outliers; no outliers were excluded from the model.

Sediment Data

Traditional cross-sectional sampling methods were used to collect suspended sediment samples during base-flow and stormflow conditions. During base-flow conditions, suspended sediment samples were collected approximately 40 feet upstream from the bridge by wading the stream and using the equal-width increment (EWI) method (USGS, 2006). A US DH-81 sampler

was used. Samples were collected at each equally spaced location (vertical) with a consistent transit rate (vertical speed). The samples at each vertical were composited into one or more sampling bottles. If the minimum mean stream velocity was less than 1.5 feet per second, the sample was collected using grab sample methodology because of the lack of isokinetic conditions (USGS, 2006). Streamflow measurements were collected in the same location as the sediment sample.

During stormflow event sampling, measurements and samples were collected from the downstream side of the bridge deck on Highway E using the same EWI method. Samples were collected across the hydrologic event, targeting the rising limb, peak, and falling limb when possible. Streamflow was measured nearest to the peak as possible. Depending on stream conditions, either a US DH–95 or US DH–2 sampler was used. USGS personnel operated the sampler, which was attached to a reel and cable mechanism mounted on a vehicle. The sampler was raised and lowered at a constant speed according to the transit rate, which is calculated from the maximum stream velocity and depth. Samples were analyzed in the USGS Central Midwest Water Science Center Sediment Laboratory in Rolla, Missouri.

Surrogate Data

A pressure transducer measured stream stage at 15-minute intervals. Data were transmitted hourly via satellite telemetry to NWIS (USGS, 2023). Streamflow measurements were obtained every 4–6 weeks and during selected stormflow events using an acoustic Doppler current profiler. This information was used to maintain the stage-streamflow relation following standard USGS methods and techniques (Rantz and others, 1982; Oberg and others, 2005; Turnipseed and Sauer, 2010; Mueller and others, 2013).

Model Development

Outliers were identified in the dataset by reviewing data for erroneous entries and errors in sampling or laboratory methods. Forty discrete suspended sediment samples were collected and used in the development of the secondary streamflow-derived regression model. Graphing nontransformed SSC against streamflow values identified a suitable relation between the two properties. Streamflow-derived regression models tend to have greater uncertainty than turbidity-derived regression models (Rasmussen and others, 2009). Inspection of the data and residual plots identified no outliers. The 40 data pairs were used to calibrate the secondary SSC-streamflow model, with both variables being log-transformed. Regression analysis was done using R (version 4.1.3; R Core Team, 2022). For periods when instantaneous turbidity was not available, a gap-fill framework was used by computing SSC using a secondary regression model based on instantaneous streamflow. Suspended sediment concentrations computed using the streamflow-derived model (approximately 42 percent of the record) were flagged as estimated values.

Model Summary

Secondary streamflow regression model for calculation of SSC:

$$SSC = 0.1592 \times Q^{0.953},$$

where

SSC is suspended sediment concentration, in milligrams per liter; and

Q is instantaneous streamflow, in cubic feet per second.

The model information is as follows:

- number of calibration measurements=40;
- adjusted coefficient of determination=0.80;
- root mean squared error=0.38; and
- bias-correction factor=1.38.

Previous model for October 2011 through September 2013 (Barr, 2016):

$$SSC = 0.3341 \times Q^{0.8148}$$

Suspended-Sediment Concentration Record

The SSC record computed using this regression model as the secondary model, as well as the daily loads, are available in NWIS (USGS, 2023).

Model Statistics, Data, and Plots

Definitions

SSC: Suspended sediment concentration (SSC) in milligrams per liter (parameter code 80154)

Q: Streamflow, in cubic feet per second (parameter code 00060)

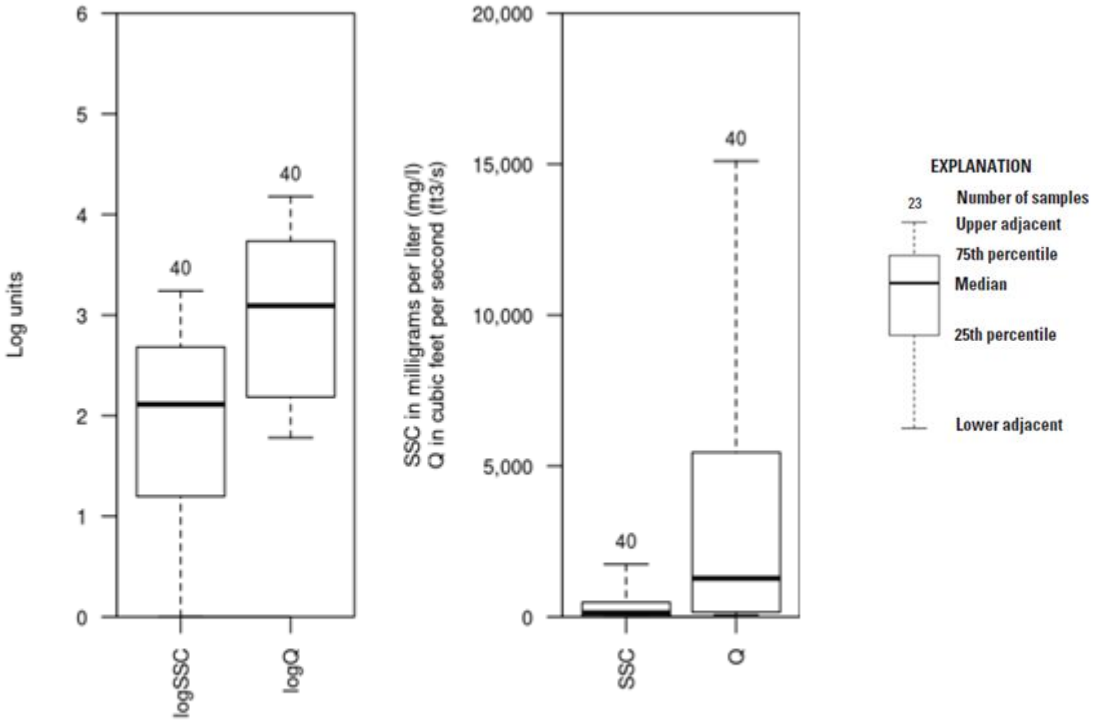
Model

$$SSC = 0.1592 \times Q^{0.953}$$

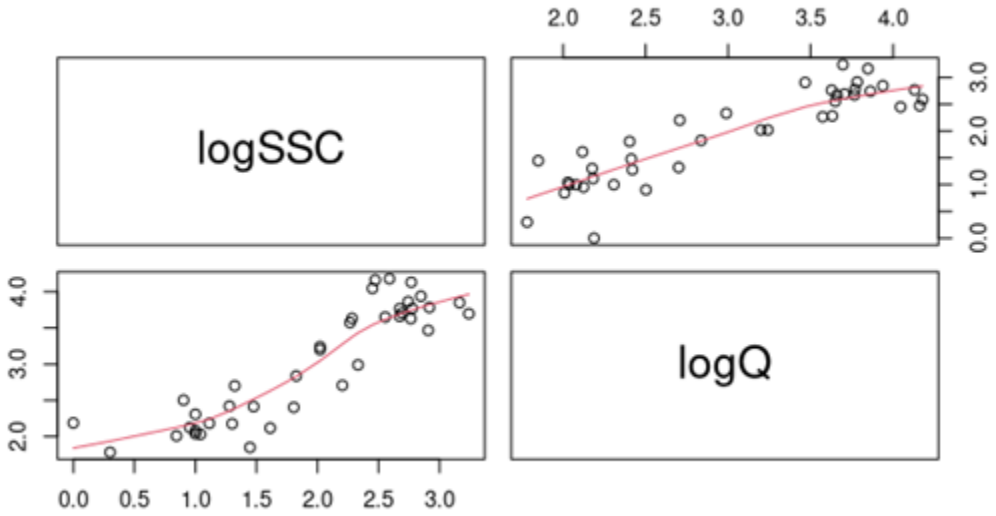
Variable summary statistics.

Statistic	logSSC	SSC	logQ	Q
Minimum	0.00	1	1.78	60.5
1st Quartile	1.20	16	2.18	153
Median	2.11	133	3.09	1,280
Mean	1.94	299	3.02	3,440
3rd Quartile	2.68	482	3.74	5,450
Maximum	3.24	1,740	4.18	15,100

Box Plots


Log units
6
5
4
3
2
1
0
40
40
logSSC
logQ
SSC in milligrams per liter (mg/l)
Q in cubic feet per second (ft3/s)
20,000
15,000
10,000
5,000
0
40
40
SSC
Q
EXPLANATION
23
Number of samples
Upper adjacent
75th percentile
Median
25th percentile
Lower adjacent

Exploratory Plots



The x- and y-axis labels for a given bivariate plot are defined by the intersecting row and column labels.

Basic model statistics.

Statistic	Value
Observations	40
Root mean square error (RMSE)	0.378
Average model standard percentage error (MSPE)	98.6
Coefficient of determination (R^2)	0.804
Adjusted coefficient of determination (Adj. R^2)	0.799
Bias correction factor (BCF)	1.38

Explanatory variables.

	Coefficients	Standard error	t value	**Pr(>|t|)**
(Intercept)	-0.938	0.2380	-3.94	0.000340
logQ	0.953	0.0764	12.50	0.000000000

Correlation matrix.

	Intercept	E.vars
Intercept	1.000	-0.968
E.vars	-0.968	1.000

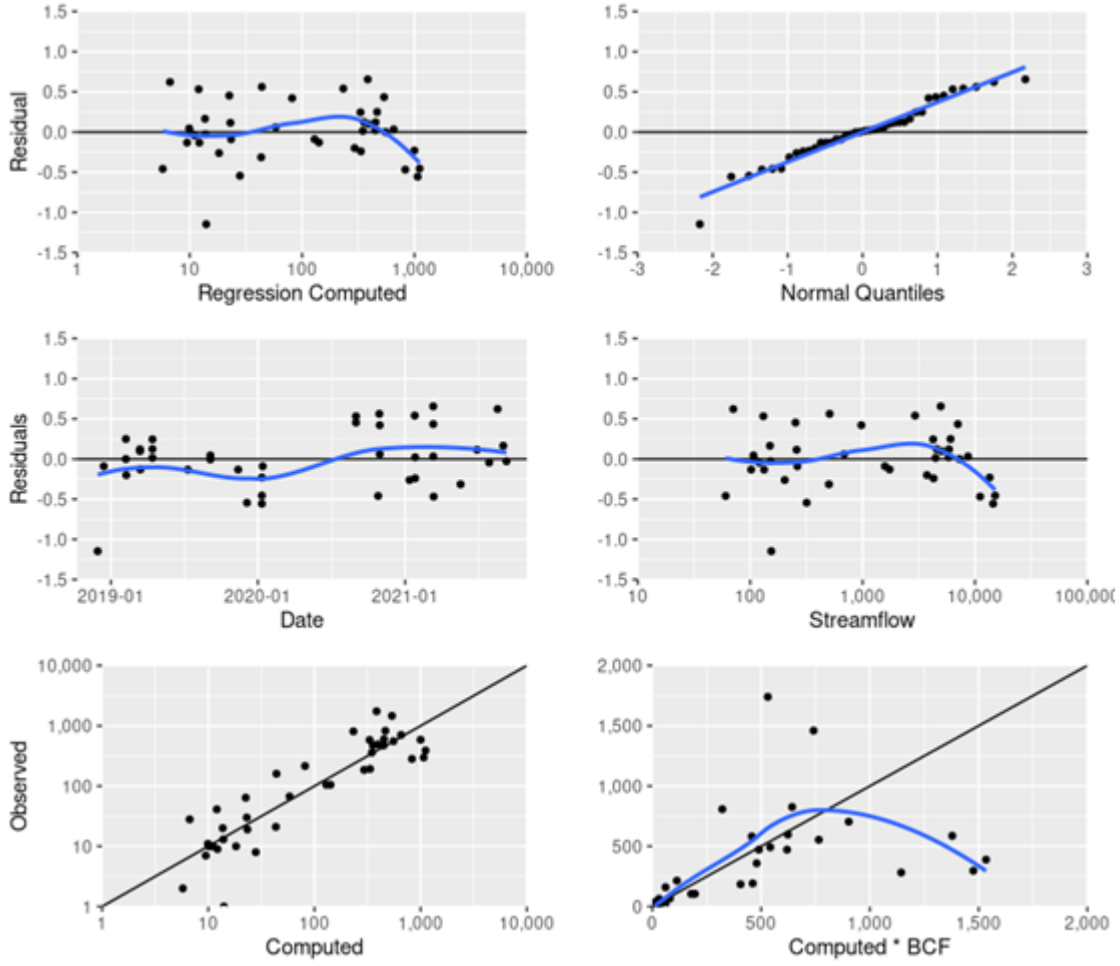
Outlier test criteria.

	Test criteria
Leverage	0.150
Cook's D	0.194
DFFITS	0.447

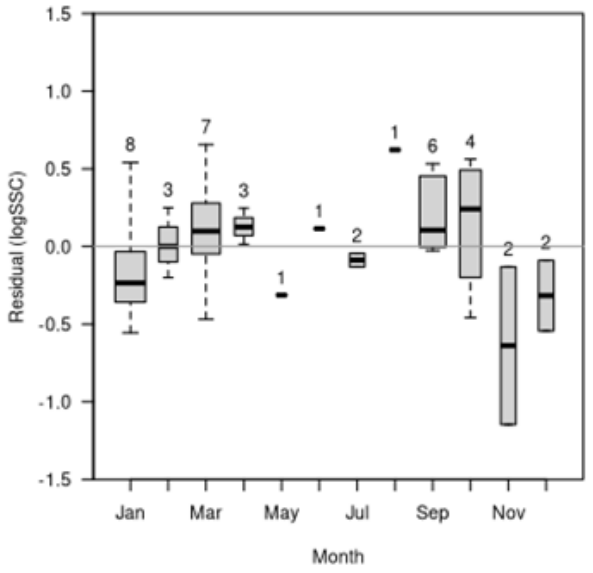
Flagged observations.

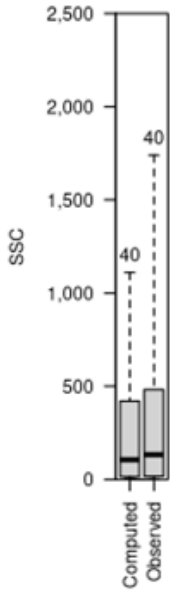
datetime	logSSC	CooksD	DFFITS	Leverage	Studentized residual
11/29/2018 8:00	0.00	0.2730	-0.845	0.0532	-3.56
1/11/2020 10:34	2.47	0.0992	-0.454	0.0782	-1.56
8/19/2021 11:15	1.45	0.1300	0.523	0.0808	1.76

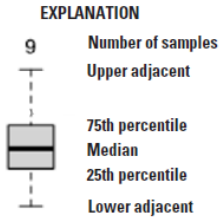
Statistical Plots

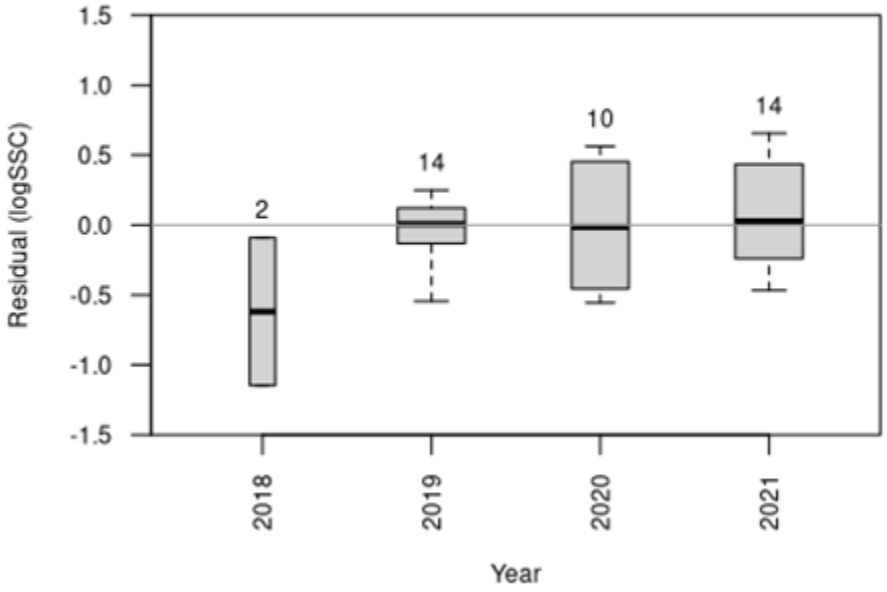


The blue line shows the locally estimated scatterplot smoothing (LOESS). The black dots correspond to observed values. The black line represents the 1:1 line.

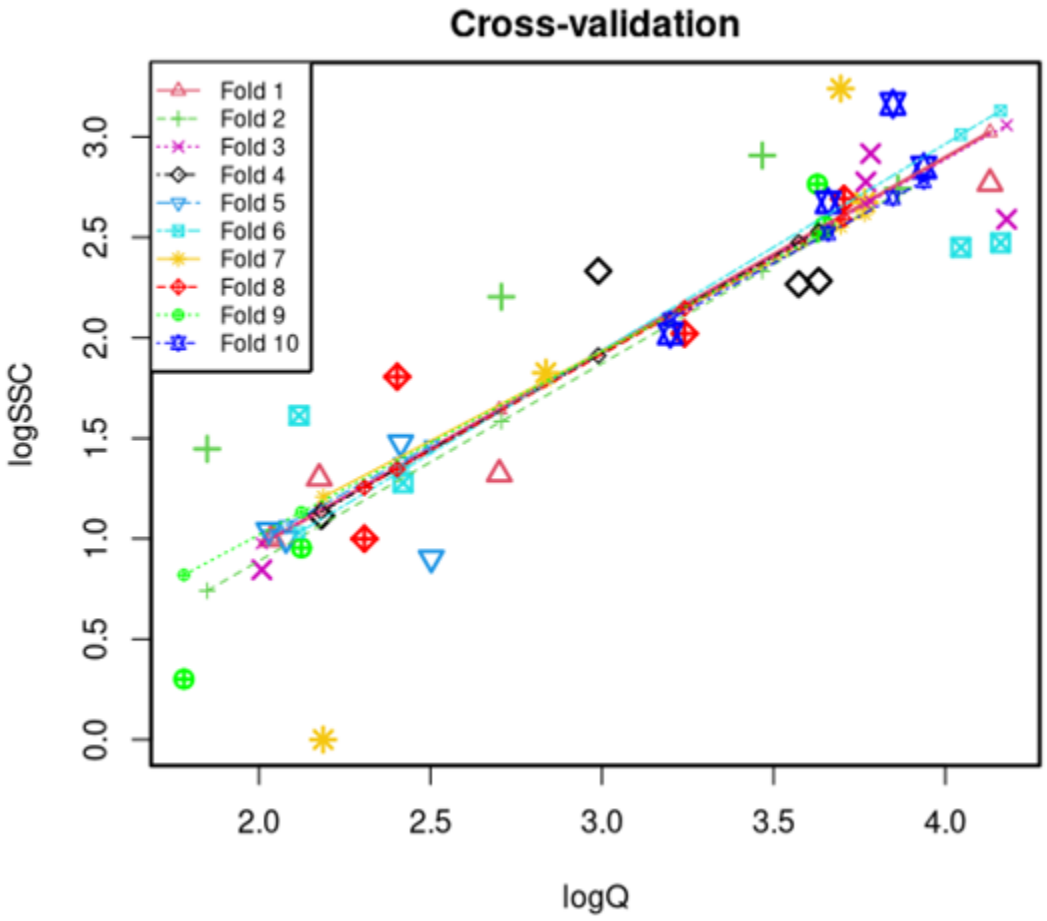

Residual (logSSC)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
8
3
7
3
1
1
2
1
6
4
2
2
Jan
Mar
May
Jul
Sep
Nov
Month


SSC
2,500
2,000
1,500
1,000
500
0
40
40
Computed
Observed


EXPLANATION
9
Number of samples
Upper adjacent
75th percentile
Median
25th percentile
Lower adjacent


Residual (logSSC)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2
14
10
14
2018
2019
2020
2021
Year

Cross Validation



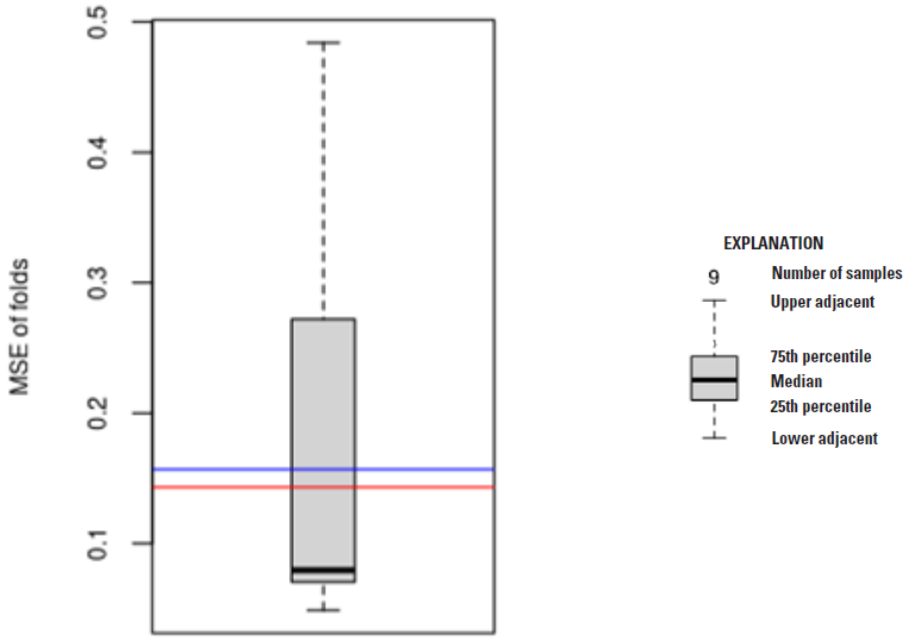
Fold – equal partition of the data (10 percent of the data).

Large symbols – observed value of a data point removed in a fold.

Small symbols – recomputed value of a data point removed in a fold.

Recomputed regression lines – adjusted regression line with one fold removed

Statistic	Value
Minimum mean square error (MSE) of folds	0.0487
Mean MSE of folds	0.1570
Median MSE of folds	0.0796
Maximum MSE of folds	0.4840
(Mean MSE of folds)/(Model MSE)	1.1000



Red line – Model mean square error (MSE)
Blue line – Mean MSE of folds

Model-calibration dataset.

Date	Time	Q	SSC	logQ	logSSC	Computed logSSC	Computed SSC
11/29/2018	8:00	154	1	2.187521	0	1.15	19.4
12/14/2018	12:00	263	19	2.419956	1.278754	1.37	32.3
2/7/2019	12:20	6,060	826	3.782473	2.91698	2.67	642
2/7/2019	16:40	7,280	554	3.862131	2.74351	2.74	765
2/8/2019	10:25	3,740	185	3.572872	2.267172	2.47	406
3/14/2019	10:52	5,070	492	3.705008	2.691965	2.59	542
3/14/2019	13:59	5,870	597	3.768638	2.775974	2.65	623
3/15/2019	10:22	1,740	105	3.240549	2.021189	2.15	196
4/14/2019	7:25	4,240	582	3.627366	2.764923	2.52	457
4/14/2019	8:54	4,560	472	3.658965	2.673942	2.55	490
4/14/2019	10:04	4,460	359	3.649335	2.555094	2.54	480
7/11/2019	11:00	133	9	2.123852	0.954243	1.09	16.9

9/5/2019	12:30	109	10	2.037426	1	1	13.9
9/5/2019	13:00	107	11	2.029384	1.041393	0.996	13.7
11/13/2019	9:30	102	7	2.0086	0.845098	0.976	13.1
12/5/2019	9:30	318	8	2.502427	0.90309	1.45	38.7
1/11/2020	9:00	13,500	587	4.130334	2.768638	3	1,380
1/11/2020	10:34	14,500	297	4.161368	2.472756	3.03	1480
1/11/2020	12:13	15,100	389	4.178977	2.58995	3.05	1530
1/13/2020	12:34	1,580	105	3.198657	2.021189	2.11	178
9/1/2020	12:00	131	41	2.117271	1.612784	1.08	16.6
9/1/2020	16:05	253	64	2.403121	1.80618	1.35	31.1
10/26/2020	11:00	60.5	2	1.781755	0.30103	0.76	7.96
10/29/2020	12:30	509	160	2.706718	2.20412	1.64	60.6
10/30/2020	3:05	975	215	2.989005	2.332438	1.91	113
10/30/2020	15:10	686	67	2.836324	1.826075	1.77	80.5
1/12/2021	11:30	203	10	2.307496	1	1.26	25.2
1/25/2021	12:30	2,930	808	3.466868	2.907411	2.37	321
1/26/2021	3:15	5,830	472	3.765669	2.673942	2.65	619
1/26/2021	9:20	4,280	192	3.631444	2.283301	2.52	461
3/11/2021	19:35	4,960	1740	3.695482	3.240549	2.58	531
3/11/2021	21:00	7,040	1460	3.847573	3.164353	2.73	741
3/12/2021	0:15	8,660	704	3.937518	2.847573	2.82	903
3/12/2021	21:00	11,100	282	4.045323	2.450249	2.92	1140
5/19/2021	10:00	502	21	2.700704	1.322219	1.64	59.8
6/29/2021	11:35	259	30	2.4133	1.477121	1.36	31.8
7/29/2021	11:25	120	10	2.079181	1	1.04	15.3
8/19/2021	11:15	70.7	28	1.849419	1.447158	0.825	9.23
9/2/2021	12:00	150	20	2.176091	1.30103	1.14	18.9
9/10/2021	10:45	152	13	2.181844	1.113943	1.14	19.1

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