Appendix J

Northeast Lakeshore TMDL

Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids

Development of Calibration and Validation Dataset to Support TMDL Development for Total Phosphorus and Total Suspended Sediment

Prepared By Wisconsin Department of Natural Resources Bureau of Water Quality

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Content

1 Streamflow and Water Quality Monitoring

Stream discharge and load estimates are necessary for the calibration and validation of watershed models. This document summarizes the methods and results of the stream discharge, total phosphorus (TP) loads, and total suspended solids (TSS) loads that were used to calibrate and validate the SWAT watershed model developed in support of the Northeast Lakeshore Total Maximum Daily Load (TMDL).

1.1 Monitoring summary

The length of stream flow, water chemistry, and load data varied per site but generally occurred in 2016 – 2019 for the Ahnapee and the Silver Creek tributary, 2017 – 2019 for locations in the Twin, Kewaunee, and Manitowoc watersheds, and 2018 – 2019 for locations in the Sheboygan and Pigeon watersheds. Due to expansion of the study area over time, the sites in the northern project area were generally monitored longer than sites in the southern project area. This monitoring effort resulted in WDNR developing continuous discharge records for 18 locations, 17 of which also had total phosphorus (TP) and total suspended solid (TSS) loads estimated. Additionally, WDNR developed loads at 5 USGS gaging stations, resulting in a total of 23 locations with TP/TSS load and 24 locations with streamflow. Additionally, there were 17 sites monitored for water chemistry only. A map of all monitoring sites is shown in Figure 1 with additional site detail in Table 1. Total nitrogen loads (TN) were also calculated from this monitoring effort but are detailed in a separate report.

1.2 Site Selection

The NE Lakeshore TMDL is made up of many independent watersheds, all of which drain to lake Michigan. In general, flow and chemistry monitoring locations were selected to be in the lower reaches of these watersheds so they 1) represented a majority of the watershed area, and 2) maximized the area that was calibrated and validated in the SWAT watershed model. Additional monitoring locations were also placed before major confluences within the same watershed or to better characterize the water quality within the main stem of a river. This approach resulted in approximately 84% of the NE Lakeshore TMDL area draining to a load monitoring location

After the general location for a monitoring site was chosen, the precise flow monitoring location was chosen to maximize the criteria listed below. These site criteria helped to take advantage of the best locally available conditions for developing a stable stage-discharge relationship. Because of these flow location criteria, some monitoring sites have a have a flow monitoring location that is upstream of their associated chemistry monitoring location.

1) Ensure that backwater from lake Michigan or downstream confluence would not affect the stage-discharge relationship.
2) Near by a road crossing or foot bridge for high flow measurements.
3) Stream cross section has relatively uniform flow, defined to a main channel, and stable banks.
4) Stable downstream controls. Downstream controls often consisted of a riffle (section control) during baseflow conditions and stream banks or bridge abutments (channel control) at high flows.

1.3 Sampling approach

1.3.1 Water level

The length of record for water level data varied per site but was primarily monitored between 2016 – 2019 in the Ahnapee and the Silver Creek tributary, 2017 – 2019 for locations in the Twin, Kewaunee, and Manitowoc Watersheds, and 2018 – 2019 for locations in the Sheboygan and Pigeon watersheds. The period of flow record varies per site due to effects from ice and water level logger malfunction or loss. Figure 2 displays the duration of water level monitoring at each site. The water level loggers were programmed to provide continuous readings at 1-hour intervals. These 1-hour readings provided the basis for the continuous discharge records.

1.3.2 Flow measurements

Flow measurements were taken throughout the duration of the water level monitoring period, as described in the previous section. An effort was made to measure flow at a variety of flow conditions (baseflow to high flow) throughout the monitoring period. The number of flow measurements used for rating curve development varied from 7 to 22 per site, with a median of 15. Table 2 provides a list of the flow and stage measurements at each site. Figure 2 visualizes the frequency and timing of the flow measurements.

1.3.3 Chemistry Sampling

Chemistry monitoring was conducted for TP and TSS at the 23 sites used for load estimation. In addition, 21 of these sites were also monitored TN. However, the NE

Lakeshore TMDL addresses only phosphorus and sediment impaired waters so this report does not focus on the nitrogen data. Load estimates for TN were made as part of a separate study and are described in "Nitrogen Report". The monitoring effort also included 17 additional sites that were monitored for water chemistry only. See Table 1 for additional detail about the monitoring activities and chemistry parameters at each site.

Chemistry sampling occurred on a bi-weekly to monthly basis, year-round. The length of chemistry sampling varied per site but primarily matched the period of water level monitoring as described in water level section above. The duration and frequency of chemistry sampling data at sites used for load estimation is displayed in figures 3a, 3b, and 3c.

1.4 Installation and maintenance of water level loggers

Instream water level loggers were installed near flow monitoring locations in a relatively calm and deep location, which helps to increase the accuracy of their readings. To install the water level logger, a rebar was first securely placed into the stream bed. Next, the logger was placed into a PVC housing using and secured with hose clamps. The PCV housing was then securely hose clamped to the rebar. Data from the water level loggers was downloaded in the spring and fall of each year.

An elevation survey of the water level logger was conducted 1) after the initial installation and 2) both immediately before and after each data download. Results of the elevation survey ensure that water level logger maintained its position in the water column throughout time or provided the information to adjust for any elevation change that may have occurred after a data download or due to movement of the rebar from the stream.

Elevation surveys made use of two permanent benchmarks at each site. Benchmarks were made on permanent structures and often consisted of a small mark on a bridge railing or abutment. These benchmarks served as "known" elevations and were used to reference the elevation of the water level logger over time.

The water level logger setup was visually inspected during each site visit for chemistry or flow sampling. If the elevation of a logger set up was noticeably different due to movement of the rebar, then an elevation survey was conducted as soon as possible, and the rebar secured into the streambed again.

2 Discharge Data Processing

2.1 Water Level Processing and QC

2.1.1 Barometric Compensation

Because the instream water level loggers are actually recording pressure (rather than water level), data processing must occur to adjust these pressure readings into water level data. The instream water level loggers were non-vented, meaning they account for both water pressure and barometric pressure. Therefore, the raw instream pressure data was adjusted to account for water pressure only. The adjustment was made by subtracting the hourly barometric pressure from each hourly instream measurement (Equation 1).

Equation 1

$$Pressure_{final} = Pressure_{initial} - Pressure_{baro}$$

Where $Pressure_{final}$ represents water pressure, $Pressure_{initial}$ represents water pressure plus barometric pressure, and $Pressure_{baro}$ represents barometric pressure. Barometric pressure data was sourced from data within the same geographic region. For stream sites within the northern project area, barometric pressure data was retrieved from one of two pressure loggers were hung in a tree by WDNR at two of the stream monitoring locations for this purpose. For sites in the Sheboygan basin, barometric pressure retrieved from the NOAA monitoring station at the Sheboygan County Airport.

2.1.2 Conversion of Water Pressure to Water Level

After the instream pressure data was adjusted to remove barometric pressure, the hourly water density was calculated with Equation 2.

Equation 2

$$\rho = 0.0624 \times \left(\frac{(999.84 + (16.945 \times T) - (0.008 \times T^2) - (4.65 \times 10^{-5} \times T^3) + (1.06 \times 10^{-7} \times T^4) - (2.81 \times 10^{-10} \times T^5))}{(1 + (0.0624 \times T))} \right)$$

Where ρ represents the density of freshwater (lb per cubic ft), and T represents the water temperature (degrees Celsius). Hourly temperature readings were also recorded by the water level loggers.

Lastly, instream pressure was converted to stage (water level) with Equation 3.

Equation 3.

$$stage = \frac{Pressure_{final}}{\rho}$$

Where $stage$ represents the height (ft) of the water above the pressure sensor, $Pressure_{final}$ represents water pressure (lb per square ft) and ρ represents the density of freshwater (lb per cubic ft).

2.1.3 Elevation Adjustment

If the elevation survey indicated that the water level logger moved by more than 0.02 ft, then an adjustment was made to the raw stage data. Adjustments were mostly commonly made due to the pressure logger being placed at a slightly different elevation after a data download. If the elevation change was due to an event other than a data download, then the location of the adjustment within the timeseries was made using the following techniques 1) closely inspecting the hourly stage data for obvious movements, 2) overlaying timeseries stage data from similar sites during the same time period, 3) using a draft rating curve to identify when stage-flow pairs began deviating from the initial stage-flow relationship. If the location for the stage adjustment could not be found with the following techniques then the adjustment was presumed to have occurred during the last high flow event, which was often spring melt.

2.1.4 Ice Affected Stage Data

Water level data collected by WDNR from ice affected periods was removed from the discharge record and not used for load estimation. All WDNR flow monitoring sites were significantly prone to affects of ice on the water level data. During ice affected periods, it was not possible to produce a consistent relationship between water level and flow as the ice would haphazardly raise the water level data, but without an associated increase in flow. Because of this, ice affected periods were easily identifiable in the stage data and cross checked against timing of ice effected periods at the nearest USGS gage.

2.1.5 Flow Measurement Processing and QC

During base flow conditions, stream flow measurements were made with a handheld flow meter and wading rod, which require the operator to be in the stream while conducting the measurement. During high flow conditions, an acoustic doppler current profiler (ADCP) was used to collect flow data. This instrument allows for the operator to safely collect flow data while outside of the stream, such as while standing on a bridge crossing. In contrast to handheld flow meters, the ADCP requires the user to traverse the stream cross section multiple times to obtain a reliable flow measurement. Cross sections were repeated approximately 10 times for each flow measurement. Prior to use for rating curve development, the cross section of each measurement was inspected in the USGS program QRev version 3.43. Cross sections were removed from the overall measurement if a considerable portion of the was cross section went undetected by the ADCP, as compared to the other cross sections in the measurement. Final flow values from the ADCP were obtained from the QRev program.

3 Stage-Discharge Rating Curves

3.1 Rating Curve Methods

The development of stage-discharge rating curves took place after careful inspection of the stage data and flow measurements for each site. Prior to rating curve development, flow measurements were paired with a stage value sourced from the water level loggers that occurred within ±30 minute of the flow measurement. In some instances, a stage value from the water level logger was unavailable; however, a stage reading was available from a staff gage with a known elevation (in relation to the water level logger). In these instances, stage data was sourced from the staff gage and the flow-stage pair was still useful for rating curve development.

At all flow monitoring sites, the flow-stage pairs were fit using an exponential curve, as described in Rantz (1982).
Equation 4.

$$Q = C\ (stage - e)^N$$

In this equation, the parameters that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N) that respectively relate to the scale and resistance (to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019).

The offset (e) will equal to elevation of zero flow for the lowest unique segment of the rating curve (Rantz, 1982). For sites with multiple downstream controls across flow conditions (eg. section control at low flow, and channel control at high flow), the offsets may be unique for each control, resulting in a segmented rating curve (Hamilton et al. 2019).

In addition to offsets resulting in a stage that is equal to the elevation of zero flow (for the lowest segment of the rating curve), they are also useful for rating curve extrapolation. The correct offset value will result in a rating curve that plots as straight line on a log-log scale (Rantz, 1982).

The offset value was uniquely selected for each site by plotting the raw stage value against the discharge value on a log – log scale. A range of stage offsets was then applied to the raw stage values and added to the original plot. An example of this method is shown in Figure 4. Using this method, the offset values can be readily identified by finding the dataset that produces the straightest line (Hamilton et al. 2019). If the offset is too low the pairs will plot in a concave up pattern, or if too high the pairs will plot in a concave down pattern (Rantz, 1982). If the offset could not produce a straight line at all sections of the rating curve, then a break point was inserted, and two separate equations were used. A site with a break point in the rating curve represents a change in the downstream control. For example, from a section control at low flows to channel control at high flows. For sites with a break point, the upper stage - discharge pairs were then reassessed to ensure they plotted in a straight line with the current offset. If not, another set of offset values were tested until a straight line was produced. While separate offsets result in a segment rating curve, it is known that separate offsets may be needed for each unique control at a given site (Hamilton et al. 2019).

Once the proper offset was selected, the pairs of offset stage and flow were fit to an exponential curve using a nonlinear regression (nls) in R. Stage– discharge pairs used in rating curve development are shown in Table 2. Equations of the resulting exponential curves are shown in Table 3. Rating curves are visualized in Appendix 8.1. The equations in Table 3 were used to convert the continuous water level data into continuous discharge data (Appendix 8.2).

3.2 Assessment of Rating Curve Fit

The shape of a rating curve is dependent on the shape of the channel that controls the flow. Therefore, one way a rating curve can be assessed is by comparing the slope (N) of the curve to typical values of channel shape. Hamilton et al. (2019) states that slope parameters should fall between 1.5 and 3. Indeed, most slope parameters for the rating curves in the NE Lakeshore TMDL fall within this range (Table 3). Additionally, it is generally stated that a rating curve should be extrapolated no more than twice as high as the greatest measured discharge (Rantz, 1982), and most flow extrapolations for site within the NE Lakeshore were within this range (Table 3).

A visual review of the rating curves produced for sites in the NE Lakeshore TMDL (Appendix 8.1) indicates that the stage-discharge rating curves produced a reliable discharge record across most flow conditions. However, at some sites, uncertainty does increase at higher flows due to a lack of flow measurements.

4 Site-Specific Flux Models

Continuous daily fluxes were estimated for both TP and TSS at each site in the monitoring network where samples were taken at a frequency of less than 14 days. Flux computation was performed with a modified version of the methods that are associated with U.S. Geological Survey Fluxmaster and LOADEST software programs (Schwarz, Hoos, Alexander, & Smith, 2006). The purpose of these methods is to estimate constituent concentrations at a given site when water quality sampling frequency is insufficient for estimating continuous long-term flux. The methods are most effective for constituents that have a strong relationship with discharge and exhibit cyclic variation with season (e.g., sediment concentration is often greatest with snowmelt events in late Spring). Additionally, a time variable allows concentrations to vary, linearly or quadratically, over the sampling period.

4.1 Modifications to LOADEST model

The first purpose of modifying the Fluxmaster/LOADEST method was to rectify issues with marginal sample sizes for most sites in the monitoring network. Since the development of these tools, new statistical methods have become available that allow model coefficients to vary by a grouping factor (e.g., a monitoring site). Using each monitoring site as a grouping factor, a single model per constituent can be fitted without the loss of degrees of freedom that would result from multiple independent models for each site using the regression methods implemented in Fluxmaster/LOADEST. The modeling framework chosen for model fitting was an implementation of linear mixed-effects models in the R programming language for statistical computing (R Core Team, 2020)—the library used in R software was the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). Most of the same methods were used by adapting computer code from the rloadest R package (Runkel & De Cicco, 2017), except when model fitting was performed using lme4.

The second purpose of modifying the Fluxmaster/LOADEST method was based on initial findings that quickflow (the combination of surface runoff and shallow aquifer water yield) was a better predictor of TP and TSS than total discharge. To calculate quickflow for each site, we applied a baseflow separation routine based on wavelet transform (Nathan & McMahon, 1990) that is available in an R package called EcoHydRology. The recommended parameters (filter parameter = 0.925, passes = 3) were used. In model fitting for both TSS and TP, quickflow was always used instead of total discharge. All quickflow values were translate by a value of positive 0.01 to prevent the log transformation of zero values during dry periods when baseflow accounted for all flow. Constituent concentration models were fitted using quickflow, however flux estimates were calculated by multiplying concentration predictions by total discharge.

4.2 Model Selection

The rloadest R package provides a convenience function that fits 9 different models that are different permutations of discharge, season, and time as fixed-effect co-variates, then selects the best performing model as the one with the lowest AIC. Structuring these models as mixed-effect models using the lmer package in R allows more permutations of model coefficients. A mixed-effect model allows coefficients to vary by grouping factor, usually referred to as a "random effects". In a mixed-effects model, coefficients that do not vary by grouping factor are referred to as "fixed effects". Therefore, the 9 different models used by the rloadest package can be expanded to 30 with different permutations of discharge (i.e., quickflow), season, and time as both fixed effects and random effects (

Table 3. parameter values for the stage-discharge rating curves. All curves were fit to an exponential model with the equation $Q = C$ (
that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N). These parameters
(to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019)

). In cases where random effects were fitted, the coefficients were allowed to vary for each monitoring site. The intercept of all model permutations was allowed to vary by monitoring site.

Two models (one for TSS, and one for TP) were selected that predicted constituent concentrations across all monitoring sites. These models were selected by permuting through all combinations of fixed and random effects for quickflow, season, and time, then selecting those with the minimum AIC (

Table 3. parameter values for the stage-discharge rating curves. All curves were fit to an exponential model with the equation $Q = C$ (
that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N). These parameters
(to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019)
). The model selected for TSS (model 8d in

Table 3. parameter values for the stage-discharge rating curves. All curves were fit to an exponential model with the equation $Q = C$ (
that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N). These parameters
(to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019)
) can be described by the following equation:

Equation 1

$$\ln(\boldsymbol{\rho}_m) = \beta_0 + [\beta_f] * \begin{bmatrix} \ln(\boldsymbol{Q_m}) \\ \ln(\boldsymbol{Q_m^2}) \\ \boldsymbol{T_m} \\ \sin(2\pi \boldsymbol{T_m}) \\ \cos(2\pi \boldsymbol{T_m}) \end{bmatrix} + \gamma_0 + [\gamma_{f,m}] * \begin{bmatrix} \ln(\boldsymbol{Q_m}) \\ \ln(\boldsymbol{Q_m^2}) \\ \sin(2\pi \boldsymbol{T_m}) \\ \cos(2\pi \boldsymbol{T_m}) \end{bmatrix} + \boldsymbol{e}_m$$

In the above equation, m is a monitoring site, $\boldsymbol{\rho}$ is a matrix of TSS concentrations, $\boldsymbol{Q}$ is a matrix of quickflow paired with $\boldsymbol{\rho}$, $\boldsymbol{T}$ is a matrix of decimal time numbers paired with $\boldsymbol{\rho}$, β is a fixed-effect coefficient, γ is a random-effect coefficient, and $\boldsymbol{e}$ is residual error. The model selected for TP (model 8e in

Table 3. parameter values for the stage-discharge rating curves. All curves were fit to an exponential model with the equation $Q = C$ (
that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N). These parameters
(to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019)
) is exactly the same structure except with the inclusion of a random effect for $\boldsymbol{T}$:

Equation 2

$$\ln(\boldsymbol{\rho}_m) = \beta_0 + [\beta_f] * \begin{bmatrix} \ln(\boldsymbol{Q_m}) \\ \ln(\boldsymbol{Q_m^2}) \\ \boldsymbol{T_m} \\ \sin(2\pi \boldsymbol{T_m}) \\ \cos(2\pi \boldsymbol{T_m}) \end{bmatrix} + \gamma_0 + [\gamma_{f,m}] * \begin{bmatrix} \ln(\boldsymbol{Q_m}) \\ \ln(\boldsymbol{Q_m^2}) \\ \boldsymbol{T_m} \\ \sin(2\pi \boldsymbol{T_m}) \\ \cos(2\pi \boldsymbol{T_m}) \end{bmatrix} + \boldsymbol{e}_m$$

The coefficients for both fixed effects and random effects are listed in Table 3.

4.3 Flux Estimation

To estimate flux for a given day, the estimated constituent concentrations from Equation 1 and Equation 2, must first be re-transformed from natural log to real space, then multiplied by the average daily discharge for each day. In the process of transforming back to real space, systemic biases in the predictions can occur due to heterscedasticity in the linear model. A common approach to reduce bias in estimates is to multiply each concentration prediction by a bias-correction factor (BCF). The BCF that is used in the LOADEST model is a function of the residual standard error (SE) of the model (Runkel, Crawford, & Cohn, 2004):

Equation 3

$$BCF = \exp\left(\frac{SE^2}{2}\right)$$

Residual error varies for each monitoring site, and therefore site-specific biases can be resolved by calculation a BCF for each monitoring site, m.

Equation 4

$$BCF_m = \exp\left(\frac{SE_m^2}{2}\right)$$

As mentioned in Section 4.1, the benefit of using a mixed-effect model is that coefficients are allowed to vary by grouping factors without the same reduction in degrees of freedom that would result in independent regression models fit for each group. However, there is some disagreement among statisticians about the interpretation of degrees of freedom associated with each group fit in a mixed-effects model. Therefore, the denominator in the equation used to calculate the SE of the residuals for each monitoring site, m, is subject to interpretation:

Equation 5

$$SE = \sqrt{\frac{\sum_i e_{i,m}^2}{d.f.}}$$

We tested multiple different calculations for degrees of freedom for each monitoring site, including sample size, sample size minus the number of fixed effects, and sample size minus the number of the total of fixed and random effects. We found that simply using the sample size as the degrees of freedom for each monitoring site provided an appropriate balance of bias correction across sites (a list of BCFs can be found by site in Table 2). For those monitoring sites where the number of samples are limited, the flux predictions should be used with caution, paying closest attention to the overall bias of predictions.

4.4 Assessment of Fit

For each constituent, TSS and TP, a single mixed-effect model was fitted that included samples across all monitoring sites. However, the flux estimates, and associated characterization of model fit, will likely be used site-by-site. Therefore, all observed (sample concentration multiplied by mean daily flow on the date the sample was taken) and simulated fluxes were first separated out by site before calculating performance statistics (i.e., error is characterized as $\boldsymbol{e}_m$ from Equation 1 and Equation 2). Performance statistics for both TSS and TP for each site are shown in Table 2.

In addition to quantitative performance statistics, visualizations can also aid in diagnosing problems in flux models (Hirsch, 2014). Systemic biases are apparent when model residuals are plotted against estimations and each of the covariates, discharge, time, and season. Biases can also be diagnosed when samples occur in a frequency that does not align with natural variation—boxplots of the variation between sample concentrations and estimates are useful for testing differences in these distributions. Similarly, these biases are apparent if boxplots are created for values of discharge on sampled days versus all daily discharge values. Simple scatterplots showing observed versus simulated for both concentration and flux, can also be useful. All these plots (Figure 4. An example of a stage-discharge pairs trialed with a variety of offsets and plotted on a log-log scale. When the offset is too small, the dataset is concave up, when the offset is too large, the data set is concave down. The proper offset results in a dataset that plots in a straight line. In this example, an offset of 1.7 ft was chosen for this site.

Figure 1) in a standardized format (Hirsch, 2014) is a quick way to assess an individual site-specific flux model. Finally, time-series plots (Figure 2) showing continuous daily flux estimates along with sampled flux (sample concentration multiplied by daily mean discharge), can reveal specific times when large errors occurred. All these plots are available in Appendix 8.1.

5 References

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6 Tables

Table 1. Stream monitoring stations within the NE Lakeshore TMDL and corresponding monitoring activity. Single asterisk (*) indicates an active USGS stream gage and corresponding WDNR long term trend chemistry monitoring location. Double asterisk (**) indicates a former USGS gage with chemistry sampling by The Nature Conservancy.

Map ID	DNR Station ID	Official WDNR Station Name	Monitoring Activity	Lat	Long	Chem Parameters
1	153161	Ahnapee River at CTH H Forestville	Chemistry	44.74771	-87.53657	TP.TSS.TN.DOP.NO3.NH4.
2	153027	Ahnapee River at CTH J Forestville	Flow	44.690487	-87.48718	
3	153221	Stony Creek at Rosewood Rd	Chemistry	44.682715	-87.403246	TP.TSS.TN.
4	10044953	Ahnapee River at Washington Road	Chemistry	44.646654	-87.466835	TP.TSS.TN.DOP.NO3.NH4.
5	10020779	Silver Creek-200 Feet Below Dam 100 Feet Above Bridge In Breumerville Park Off Willow Drive.	Chemistry and Flow	44.607872	-87.47118	TP.TSS.TN.
6	10029954	Kewaunee River at Hillside Road	Chemistry and Flow	44.554382	-87.6594	TP.TSS.TN.
7	313038	*Kewaunee River DS Cth F at Bruemmer Park	Chemistry and Flow	44.458455	-87.556113	TP.TSS.TN.DOP.NO3.NH4.
8	10008204	East Twin River - Hwy J	Chemistry	44.40017	-87.614555	TP.TSS.TN.
9	10009857	Neshota River - Neshota River at Highway Bb	Chemistry	44.32781	-87.765686	TP.TSS.TN.
10	363268	Black Creek - Hwy Bb	Chemistry	44.327159	-87.753061	TP.TSS.TN.
11	10039193	Devils River at Hwy R	Chemistry	44.29954	-87.774185	TP.TSS.TN.
12	10008207	East Twin River - East Twin River - Steiners Corners	Chemistry and Flow	44.221325	-87.62305	TP.TSS.TN.DOP.NO3.NH4.
13	10029482	West Twin River at CTH V	Chemistry and Flow	44.19673	-87.66574	TP.TSS.TN.DOP.NO3.NH4.
14	10011680	Molash Creek - Molash Cr. at Hwy O	Chemistry	44.180996	-87.53468	TP.TSS.TN.
15	10016958	Branch River - Cty J - 07600 Ft Upstream From Bridge	Chemistry	44.17445	-87.864034	TP.TSS.TN.
16	363313	Branch River - Above Branch River Rd	Flow	44.142666	-87.764684	
17	363299	Branch River at N Union Rd (2)	Chemistry	44.13478	-87.76542	TP.TSS.TN.
18	10016717	Mud Creek - Hilltop Road	Chemistry and Flow	44.124354	-87.959677	TP.TSS.TN.
19	363069	*Manitowoc River at Cth Jj(Michigan Ave)	Chemistry and Flow	44.106068	-87.71607	TP.TSS.TN.DOP.NO3.NH4.
20	10020782	Manitowoc River-300 Feet Above Upper Cato Falls At Clark Mills Sportsman Club.	Flow	44.09386	-87.889946	
21	83100	Manitowoc River - North Branch River View Rd	Chemistry	44.08121	-88.05002	TP.TSS.TN.
22	363228	Silver Creek at Cth Ls (Bi Sur)	Chemistry and Flow	44.062298	-87.6599	TP.TSS.TN.
23	10042875	Killsnake River at County Rd Y	Flow	44.058507	-88.108398	
24	363291	Killsnake River at Lemke Road	Chemistry	44.044681	-88.053125	TP.TSS.TN.
25	10013310	Mud Creek- Hwy 151	Chemistry	44.036556	-87.93849	TP.TSS.TN.

26	363375	Manitowoc River South Branch at Lemke Road	Chemistry and Flow	44.033656	-88.063028	TP.TSS.TN.
27	83062	Pine Creek at Quarry Rd Bridge	Chemistry	44.008274	-88.111589	TP.TSS.TN.
28	10020831	Pine Creek - 200 Feet Downstream From Cth T	Chemistry	43.954803	-88.06232	TP.TSS.TN.DOP.NO3.NH4
29	363368	Point Creek at Centerville Road Near Newton WI	Flow	43.969216	-87.731402	
30	363225	Point Creek at CTH LS	Chemistry	43.962032	-87.708916	TP.TSS.TN.
31	10031811	Fischer Creek 400ft W of LS	Chemistry	43.937252	-87.72307	TP.TSS.TN.
32	10008233	Centerville Creek - Site #1 Lakeshore Dr	Chemistry	43.91613	-87.72584	TP.TSS.TN.
33	603296	Sevenmile Creek at CTH LS	Chemistry	43.853861	-87.741103	TP.TSS.TN.
34	603295	Pigeon River at Cth A -And River Rd	Chemistry and Flow	43.833854	-87.817365	TP.TSS.TN.
35	40857005	**Otter Creek at Willow Rd	Chemistry and Flow	43.78889	-87.92139	TP.TSS
36	603051	Pigeon River at Mill Road	Chemistry and Flow	43.784653	-87.73548	TP.TSS.TN.DOP.NO3.NH4.
37	10039440	Sheboygan River at Palm Tree Rd	Chemistry and Flow	43.814335	-88.16465	TP.TSS.TN.
38	10016139	Sheboygan R. - Hwy 57 Crossing	Chemistry and Flow	43.887588	-87.94962	TP.TSS.TN.
39	40854592	**Fisher Creek at Howards Grove, WI	Chemistry and Flow	43.825	-87.8333	TP.TSS
40	603095	*Sheboygan River - at Sth 28 Sheboygan-Esslingen Park	Chemistry and Flow	43.740273	-87.75094	TP.TSS.TN.DOP.NO3.NH4.
40	10049358	Mullet River at Sumac Road	Chemistry and Flow	43.72144	-87.88001	TP.TSS.TN.
41	603304	Onion River at Ourtown Rd 5m Bi	Chemistry and Flow	43.696884	-87.820616	TP.TSS.TN.
43	603291	Black River at Indian Mound Rd	Chemistry	43.690687	-87.712423	TP.TSS.TN.
44	10030656	Sucker Creek - Sucker Brook Lane	Chemistry	43.423668	-87.83834	TP.TSS.TN.
45	463070	Sauk Creek at Mink Ranch Rd (Bi)	Chemistry and Flow	43.412524	-87.880507	TP.TSS.TN.

Table 2. Flow and stage pairs used for rating curve development.

Station Name	Date	Flow Source	Stage (ft) raw	Stage (ft) after offset	Flow (cfs)
Ahnapee - CTH J	8/4/2016	Flow Meter	1.81	0.11	12.72
Ahnapee - CTH J	8/21/2016	Flow Meter	2.18	0.48	38.19
Ahnapee - CTH J	9/8/2016	Flow Meter	1.9	0.2	24.89
Ahnapee - CTH J	9/13/2016	Flow Meter	2.06	0.36	39.76
Ahnapee - CTH J	11/14/2016	Flow Meter	1.84	0.14	16.65
Ahnapee - CTH J	4/20/2017	Flow Meter	2.85	1.15	139.6
Ahnapee - CTH J	6/2/2017	Flow Meter	1.88	0.18	13.97
Ahnapee - CTH J	6/26/2017	Flow Meter	2.14	0.44	50.43
Ahnapee - CTH J	6/29/2017	Flow Meter	2.03	0.33	34.94
Ahnapee - CTH J	7/17/2017	Flow Meter	2.04	0.34	34.87
Ahnapee - CTH J	8/10/2017	Flow Meter	1.92	0.22	15.09
Ahnapee - CTH J	9/11/2017	Flow Meter	1.81	0.11	5.58
Ahnapee - CTH J	2/28/2018	Flow Meter	2.48	0.78	77.72
Ahnapee - CTH J	4/25/2018	ADCP	3.92	2.22	237
Ahnapee - CTH J	7/9/2018	Flow Meter	1.85	0.15	9.46
Ahnapee - CTH J	8/20/2018	Flow Meter	1.71	0.01	1.01
Ahnapee - CTH J	8/28/2018	Flow Meter	2.5	0.8	90.29
Ahnapee - CTH J	3/21/2019	ADCP	4.83	3.13	300
Ahnapee - CTH J	3/26/2019	ADCP	3.79	2.09	199
Ahnapee - CTH J	4/5/2019	Flow Meter	2.49	0.79	66.07
Branch - Branch River Rd	6/14/2017	Flow Meter	2.66	1.66	113.6
Branch - Branch River Rd	6/23/2017	ADCP	6.64	5.64	1302.5
Branch - Branch River Rd	6/30/2017	Flow Meter	2.71	1.71	127.8
Branch - Branch River Rd	7/18/2017	Flow Meter	1.93	0.93	46.05
Branch - Branch River Rd	8/2/2017	Flow Meter	1.75	0.75	29.75
Branch - Branch River Rd	9/6/2017	Flow Meter	1.63	0.63	19.68
Branch - Branch River Rd	4/23/2018	ADCP	4.81	3.81	591
Branch - Branch River Rd	4/24/2018	ADCP	4.96	3.96	639.6
Branch - Branch River Rd	5/4/2018	ADCP	8.13	7.13	3002.9
Branch - Branch River Rd	5/8/2018	ADCP	3.77	2.77	363.4
Branch - Branch River Rd	8/17/2018	Flow Meter	1.41	0.41	14.34
Branch - Branch River Rd	3/20/2019	ADCP	4.55	3.55	527.9
East Twin River at Steiners Corners Rd.	6/29/2017	Flow Meter	2.39	1.89	108.2
East Twin River at Steiners Corners Rd.	7/11/2017	Flow Meter	1.07	0.57	29.07
East Twin River at Steiners Corners Rd.	7/14/2017	Flow Meter	1.37	0.87	49.14
East Twin River at Steiners Corners Rd.	7/19/2017	Flow Meter	1	0.5	26.77
East Twin River at Steiners Corners Rd.	8/2/2017	Flow Meter	0.94	0.44	21.73

East Twin River at Steiners Corners Rd.	4/23/2018	ADCP	6.47	5.97	687
East Twin River at Steiners Corners Rd.	4/24/2018	ADCP	6.38	5.88	671
East Twin River at Steiners Corners Rd.	5/4/2018	ADCP	7.48	6.98	1107
East Twin River at Steiners Corners Rd.	5/8/2018	ADCP	5.22	4.72	360
East Twin River at Steiners Corners Rd.	3/21/2019	ADCP	6.66	6.16	771
East Twin River at Steiners Corners Rd.	3/26/2019	ADCP	5.51	5.01	452
East Twin River at Steiners Corners Rd.	4/5/2019	ADCP	3.67	3.17	194
Kewaunee - Hillside Rd	11/15/2017	Flow Meter	1.45	0.25	3.26
Kewaunee - Hillside Rd	4/24/2018	ADCP	5.47	4.27	660
Kewaunee - Hillside Rd	4/25/2018	ADCP	4.62	3.42	454
Kewaunee - Hillside Rd	6/19/2018	Flow Meter	2.17	0.97	48.66
Kewaunee - Hillside Rd	7/24/2018	Flow Meter	1.3	0.1	1.31
Kewaunee - Hillside Rd	8/20/2018	Flow Meter	1.28	0.08	1.37
Kewaunee - Hillside Rd	8/28/2018	Flow Meter	1.76	0.56	13.85
Kewaunee - Hillside Rd	8/14/2019	Flow Meter	1.71	0.51	14.21
Kewaunee - Hillside Rd	9/25/2019	ADCP	3.37	2.17	206
Kewaunee - Hillside Rd	9/26/2019	ADCP	2.66	1.46	94
Killsnake - CTH Y	6/23/2017	ADCP	5.06	4.86	200.5
Killsnake - CTH Y	6/30/2017	Flow Meter	3.41	3.21	70.69
Killsnake - CTH Y	7/3/2017	Flow Meter	2.11	1.91	29.93
Killsnake - CTH Y	7/6/2017	Flow Meter	1.66	1.46	20.69
Killsnake - CTH Y	7/14/2017	Flow Meter	1.38	1.18	13.96
Killsnake - CTH Y	7/19/2017	Flow Meter	1.31	1.11	12.31
Killsnake - CTH Y	8/2/2017	Flow Meter	1.06	0.86	7.04
Killsnake - CTH Y	9/20/2017	Flow Meter	0.81	0.61	3.53
Killsnake - CTH Y	4/23/2018	ADCP	3.95	3.75	113
Killsnake - CTH Y	5/4/2018	ADCP	6.56	2.06	2328.78
Killsnake - CTH Y	8/20/2018	Flow Meter	0.44	0.24	4.78
Killsnake - CTH Y	3/20/2019	ADCP	3.23	3.03	100.2
Manitowoc - Leist Rd	6/23/2017	ADCP	3.45	2.95	1150
Manitowoc - Leist Rd	7/3/2017	ADCP	3.48	2.98	1137
Manitowoc - Leist Rd	7/6/2017	ADCP	3.26	2.76	949
Manitowoc - Leist Rd	7/18/2017	Flow Meter	2.23	1.73	382.3
Manitowoc - Leist Rd	8/2/2017	Flow Meter	1.38	0.88	100.5
Manitowoc - Leist Rd	8/14/2017	Flow Meter	1.43	0.93	111
Manitowoc - Leist Rd	9/20/2017	Flow Meter	1.07	0.57	35.72
Manitowoc - Leist Rd	4/23/2018	ADCP	3.15	2.65	1008
Manitowoc - Leist Rd	5/4/2018	ADCP	4.01	3.51	1631
Manitowoc - Leist Rd	5/8/2018	ADCP	5.06	4.56	2783
Manitowoc - Leist Rd	6/25/2018	ADCP	2.87	2.37	801
Manitowoc - Leist Rd	8/20/2018	Flow Meter	0.92	0.42	27.08
Manitowoc S. Branch - Lemke Rd	6/13/2017	ADCP	2.52	2.52	135.6
Manitowoc S. Branch - Lemke Rd	6/23/2017	ADCP	3.32	3.32	240.8

Manitowoc S. Branch - Lemke Rd	7/3/2017	ADCP	3.01	3.01	119.5
Manitowoc S. Branch - Lemke Rd	7/6/2017	ADCP	2.61	2.61	100.4
Manitowoc S. Branch - Lemke Rd	7/14/2017	Flow Meter	1.63	1.63	71.4
Manitowoc S. Branch - Lemke Rd	7/19/2017	Flow Meter	1.34	1.34	64.9
Manitowoc S. Branch - Lemke Rd	8/2/2017	Flow Meter	1.14	1.14	51.1
Manitowoc S. Branch - Lemke Rd	9/20/2017	Flow Meter	0.46	0.46	20.4
Manitowoc S. Branch - Lemke Rd	4/23/2018	ADCP	3.15	3.15	228
Manitowoc S. Branch - Lemke Rd	4/30/2018	ADCP	2.92	2.92	237.4
Manitowoc S. Branch - Lemke Rd	5/4/2018	ADCP	3.71	3.71	423
Manitowoc S. Branch - Lemke Rd	5/8/2018	ADCP	4.45	4.45	573
Manitowoc S. Branch - Lemke Rd	5/21/2018	ADCP	2.83	2.83	159
Manitowoc S. Branch - Lemke Rd	5/29/2018	Flow Meter	1.4	1.4	77
Manitowoc S. Branch - Lemke Rd	6/21/2018	ADCP	3.03	3.03	255.1
Manitowoc S. Branch - Lemke Rd	8/20/2018	Flow Meter	0.2	0.2	13.8
Manitowoc S. Branch - Lemke Rd	3/20/2019	ADCP	4.74	4.74	624.8
Mud - Hilltop Rd	6/15/2017	Flow Meter	2.87	1.77	91.5
Mud - Hilltop Rd	6/23/2017	ADCP	4.31	3.21	427.6
Mud - Hilltop Rd	6/30/2017	Flow Meter	2.79	1.69	75.5
Mud - Hilltop Rd	7/19/2017	Flow Meter	2.14	1.04	20.19
Mud - Hilltop Rd	8/2/2017	Flow Meter	1.6	0.5	3.94
Mud - Hilltop Rd	8/8/2017	Flow Meter	1.97	0.87	18.51
Mud - Hilltop Rd	4/24/2018	ADCP	3.55	2.45	216.9
Mud - Hilltop Rd	8/20/2018	Flow Meter	1.21	0.11	0.1
Mullet - Sumac Rd	4/20/2018	Flow Meter	1.79	1.04	149.26
Mullet - Sumac Rd	7/13/2018	Flow Meter	0.93	0.18	18.56
Mullet - Sumac Rd	8/7/2018	Flow Meter	1.04	0.29	19.14
Mullet - Sumac Rd	8/28/2018	ADCP	3	2.25	400.4
Mullet - Sumac Rd	8/29/2018	ADCP	3.33	2.58	449.4
Mullet - Sumac Rd	8/30/2018	ADCP	2.43	1.68	271.3
Mullet - Sumac Rd	8/31/2018	ADCP	2	1.25	207
Mullet - Sumac Rd	10/17/2018	ADCP	1.32	0.57	94.4
Mullet - Sumac Rd	11/8/2018	ADCP	1.54	0.79	119.86
Mullet - Sumac Rd	3/19/2019	ADCP	2.6	1.85	312.7
Mullet - Sumac Rd	3/22/2019	ADCP	2.2	1.45	235.4
Mullet - Sumac Rd	3/25/2019	ADCP	1.84	1.09	168.5
Mullet - Sumac Rd	3/28/2019	ADCP	1.72	0.97	148.6
Mullet - Sumac Rd	4/4/2019	ADCP	1.5	0.75	108.6
Mullet - Sumac Rd	5/14/2019	ADCP	1.28	0.53	64.9
Mullet - Sumac Rd	5/15/2019	ADCP	1.49	0.74	106.9
Mullet - Sumac Rd	5/21/2019	ADCP	1.51	0.76	89.8
Mullet - Sumac Rd	10/2/2019	ADCP	4.6	3.85	959.9
Mullet - Sumac Rd	10/3/2019	ADCP	3.27	2.52	467.1
Mullet - Sumac Rd	10/8/2019	ADCP	2.01	1.26	178

Mullet - Sumac Rd	10/9/2019	ADCP	1.93	1.18	168.1
Onion - Ourtown Rd	5/2/2018	Flow Meter	1.2	0.75	56.6
Onion - Ourtown Rd	7/16/2018	Flow Meter	0.69	0.24	12.4
Onion - Ourtown Rd	8/28/2018	ADCP	3.4	2.95	661.2
Onion - Ourtown Rd	8/29/2018	ADCP	3.96	3.51	868.6
Onion - Ourtown Rd	8/30/2018	ADCP	4.18	3.73	988.8
Onion - Ourtown Rd	8/31/2018	ADCP	3.68	3.23	794.4
Onion - Ourtown Rd	10/17/2018	ADCP	1.37	0.92	103.9
Onion - Ourtown Rd	11/8/2018	ADCP	2.21	1.76	306.1
Onion - Ourtown Rd	3/19/2019	ADCP	3.2	2.75	615.6
Onion - Ourtown Rd	3/22/2019	ADCP	2.45	2	410.2
Onion - Ourtown Rd	3/25/2019	ADCP	1.99	1.54	265.2
Onion - Ourtown Rd	3/28/2019	ADCP	1.69	1.24	170.8
Onion - Ourtown Rd	4/4/2019	ADCP	1.37	0.92	107.5
Onion - Ourtown Rd	5/10/2019	ADCP	1.42	0.97	95.3
Onion - Ourtown Rd	5/14/2019	ADCP	1.22	0.77	60.6
Onion - Ourtown Rd	8/28/2019	Flow Meter	1.23	0.78	56.6
Onion - Ourtown Rd	9/27/2019	ADCP	1.17	0.72	71.3
Onion - Ourtown Rd	10/2/2019	ADCP	4.99	4.54	1481.3
Onion - Ourtown Rd	10/3/2019	ADCP	5.92	5.47	2070.9
Onion - Ourtown Rd	10/8/2019	ADCP	2.33	1.88	374.6
Onion - Ourtown Rd	10/9/2019	ADCP	1.89	1.44	249.1
Pigeon - CTH A and River Rd	4/27/2018	Flow Meter	2.41	1.21	43.45
Pigeon - CTH A and River Rd	5/2/2018	Flow Meter	2.13	0.93	29.63
Pigeon - CTH A and River Rd	7/13/2018	Flow Meter	1.36	0.16	3.85
Pigeon - CTH A and River Rd	8/28/2018	ADCP	5.22	4.02	253
Pigeon - CTH A and River Rd	8/29/2018	ADCP	7.49	6.29	683.3
Pigeon - CTH A and River Rd	8/30/2018	ADCP	6.86	5.66	515.2
Pigeon - CTH A and River Rd	8/31/2018	ADCP	5.43	4.23	260.9
Pigeon - CTH A and River Rd	3/19/2019	ADCP	5.46	4.26	253.4
Pigeon - CTH A and River Rd	3/25/2019	ADCP	3.87	2.67	145.3
Pigeon - CTH A and River Rd	3/28/2019	ADCP	3.22	2.02	100.7
Pigeon - CTH A and River Rd	4/4/2019	ADCP	2.56	1.36	58.4
Pigeon - CTH A and River Rd	5/10/2019	ADCP	2.67	1.47	56.5
Pigeon - CTH A and River Rd	5/14/2019	ADCP	2.07	0.87	30.6
Pigeon - CTH A and River Rd	5/21/2019	ADCP	2.72	1.52	64.2
Pigeon - CTH A and River Rd	9/27/2019	ADCP	2.01	0.81	28.5
Pigeon - CTH A and River Rd	10/2/2019	ADCP	8.66	7.46	1154
Pigeon - CTH A and River Rd	10/8/2019	ADCP	3.08	1.88	97.4
Pigeon - CTH A and River Rd	10/9/2019	ADCP	2.8	1.6	72.6
Pigeon - Mill Rd	4/27/2018	Flow Meter	2.09	1.14	77.6
Pigeon - Mill Rd	7/13/2018	Flow Meter	1.22	0.27	7
Pigeon - Mill Rd	8/7/2018	Flow Meter	1.25	0.3	9.5

Pigeon - Mill Rd	8/28/2018	ADCP	3.88	2.93	524.5
Pigeon - Mill Rd	8/29/2018	ADCP	5.31	4.36	1011.3
Pigeon - Mill Rd	8/30/2018	ADCP	5.02	4.07	837.6
Pigeon - Mill Rd	8/31/2018	ADCP	3.79	2.84	460.9
Point - Centerville Rd	4/24/2018	ADCP	2.77	1.27	46.1
Point - Centerville Rd	5/4/2018	ADCP	5.07	3.57	238
Point - Centerville Rd	7/10/2018	Flow Meter	1.57	0.07	0.71
Point - Centerville Rd	8/8/2018	Flow Meter	1.6	0.1	0.83
Point - Centerville Rd	10/17/2018	Flow Meter	2.1	0.6	14.08
Point - Centerville Rd	11/19/2018	Flow Meter	1.95	0.45	7.27
Point - Centerville Rd	3/20/2019	ADCP	3.27	1.77	80.1
Point - Centerville Rd	3/26/2019	ADCP	2.54	1.04	34.1
Point - Centerville Rd	4/5/2019	ADCP	2.13	0.63	15.9
Point - Centerville Rd	6/5/2019	Flow Meter	2.05	0.55	12.46
Sauk - Mink Ranch Rd	4/20/2018	Flow Meter	2.69	1.99	78.91
Sauk - Mink Ranch Rd	5/2/2018	Flow Meter	1.53	0.83	14.83
Sauk - Mink Ranch Rd	7/13/2018	Flow Meter	0.77	0.07	0.1
Sauk - Mink Ranch Rd	8/28/2018	ADCP	6.18	5.48	749.7
Sauk - Mink Ranch Rd	8/29/2018	ADCP	6.5	5.8	817.3
Sauk - Mink Ranch Rd	8/30/2018	ADCP	4.38	3.68	367.4
Sauk - Mink Ranch Rd	8/30/2018	ADCP	4.09	3.39	301
Sauk - Mink Ranch Rd	8/31/2018	ADCP	3.46	2.76	191.5
Sauk - Mink Ranch Rd	8/31/2018	ADCP	3.29	2.59	162
Sauk - Mink Ranch Rd	10/17/2018	Flow Meter	1.55	0.85	15.24
Sauk - Mink Ranch Rd	11/8/2018	ADCP	2.57	1.87	76.6
Sauk - Mink Ranch Rd	3/19/2019	ADCP	3.05	2.35	140.1
Sauk - Mink Ranch Rd	3/22/2019	ADCP	2.75	2.05	98.6
Sauk - Mink Ranch Rd	3/25/2019	ADCP	2.31	1.61	57.7
Sauk - Mink Ranch Rd	3/28/2019	ADCP	2.06	1.36	41.5
Sauk - Mink Ranch Rd	4/4/2019	ADCP	1.57	0.87	20.8
Sauk - Mink Ranch Rd	5/14/2019	ADCP	1.56	0.86	12.9
Sauk - Mink Ranch Rd	8/28/2019	Flow Meter	0.97	0.27	2.08
Sauk - Mink Ranch Rd	10/8/2019	ADCP	2.5	1.8	63.4
Sauk - Mink Ranch Rd	10/9/2019	ADCP	2.25	1.55	46.6
Sheboygan - HWY 57	5/2/2018	Flow Meter	2.18	1.68	369.2
Sheboygan - HWY 57	7/16/2018	Flow Meter	0.81	0.31	60.7
Sheboygan - HWY 57	8/14/2018	ADCP	0.64	0.14	17.3
Sheboygan - HWY 57	8/28/2018	ADCP	2.15	1.65	377.8
Sheboygan - HWY 57	8/29/2018	ADCP	3.07	2.57	727.8
Sheboygan - HWY 57	8/30/2018	ADCP	2.8	2.3	636
Sheboygan - HWY 57	8/31/2018	ADCP	2.68	2.18	577.5
Sheboygan - HWY 57	10/17/2018	ADCP	2.56	2.06	557
Sheboygan - HWY 57	10/19/2018	ADCP	1.91	1.41	351.3

Sheboygan - HWY 57	11/8/2018	ADCP	1.68	1.18	268.5
Sheboygan - HWY 57	3/19/2019	ADCP	4.93	4.43	1570.8
Sheboygan - HWY 57	3/22/2019	ADCP	4.5	4	1305.6
Sheboygan - HWY 57	3/25/2019	ADCP	3.06	2.56	755.1
Sheboygan - HWY 57	3/28/2019	ADCP	2.1	1.6	443.5
Sheboygan - HWY 57	4/4/2019	ADCP	1.77	1.27	341.2
Sheboygan - HWY 57	5/10/2019	ADCP	1.22	0.72	129.8
Sheboygan - HWY 57	9/27/2019	ADCP	1.51	1.01	247.2
Sheboygan - HWY 57	9/27/2019	ADCP	1.56	1.06	246.3
Sheboygan - HWY 57	10/2/2019	ADCP	3.5	3	919.3
Sheboygan - HWY 57	10/3/2019	ADCP	3.73	3.23	1045.5
Sheboygan - HWY 57	10/8/2019	ADCP	2.82	2.32	687.7
Sheboygan - HWY 57	10/9/2019	ADCP	2.88	2.38	746.9
Sheboygan - Palm Tree Rd	3/22/2019	ADCP	3.3	2.7	220.8
Sheboygan - Palm Tree Rd	3/25/2019	ADCP	2.72	2.12	165.9
Sheboygan - Palm Tree Rd	3/28/2019	ADCP	2.48	1.88	142.6
Sheboygan - Palm Tree Rd	4/4/2019	ADCP	2.13	1.53	112.4
Sheboygan - Palm Tree Rd	5/14/2019	ADCP	1.51	0.91	49.2
Sheboygan - Palm Tree Rd	9/27/2019	ADCP	1.97	1.37	98
Sheboygan - Palm Tree Rd	10/2/2019	ADCP	3.91	3.31	377.4
Sheboygan - Palm Tree Rd	10/3/2019	ADCP	4.79	4.19	653.5
Sheboygan - Palm Tree Rd	10/8/2019	ADCP	3.83	3.23	331
Sheboygan - Palm Tree Rd	10/9/2019	ADCP	3.58	2.98	251.5
Silver - CTH LS	6/20/2017	Flow Meter	1.64	0.84	12.52
Silver - CTH LS	7/4/2017	Flow Meter	1.6	0.8	7.08
Silver - CTH LS	7/18/2017	Flow Meter	1.27	0.47	2.66
Silver - CTH LS	8/1/2017	Flow Meter	1.17	0.37	1.63
Silver - CTH LS	8/15/2017	Flow Meter	1.19	0.39	1.78
Silver - CTH LS	8/29/2017	Flow Meter	1.07	0.27	0.94
Silver - CTH LS	10/23/2017	Flow Meter	1.25	0.45	1.64
Silver - CTH LS	11/17/2017	Flow Meter	1.23	0.43	1.6
Silver - CTH LS	2/28/2018	Flow Meter	1.89	1.09	48.27
Silver - CTH LS	4/24/2018	ADCP	2.27	1.47	100.4
Silver - CTH LS	5/4/2018	ADCP	2.64	1.84	162
Silver - CTH LS	6/6/2018	Flow Meter	1.19	0.39	1.76
Silver - CTH LS	7/3/2018	Flow Meter	1.14	0.34	3.52
Silver - CTH LS	7/3/2018	Flow Meter	1.21	0.41	3.53
Silver - CTH LS	7/10/2018	Flow Meter	0.97	0.17	0.87
Silver - CTH LS	7/24/2018	Flow Meter	1.17	0.37	3.89
Silver - CTH LS	8/8/2018	Flow Meter	0.99	0.19	1.24
Silver - CTH LS	8/22/2018	Flow Meter	0.99	0.19	0.86
Silver - CTH LS	9/4/2018	Flow Meter	2.03	1.23	67.18

Silver - CTH LS	9/19/2018	Flow Meter	1.3	0.5	5.61
Silver - CTH LS	10/3/2018	Flow Meter	1.56	0.76	17.64
Silver - CTH LS	10/17/2018	Flow Meter	1.65	0.85	21.42
Silver - CTH LS	10/30/2018	Flow Meter	1.54	0.74	10.54
Silver - CTH LS	11/19/2018	Flow Meter	1.51	0.71	12.42
Silver - CTH LS	3/20/2019	ADCP	2.76	1.96	178
Silver - Willow Dr	5/24/2016	Flow Meter	0.37	0.37	5.61
Silver - Willow Dr	8/4/2016	Flow Meter	0.72	0.72	22.07
Silver - Willow Dr	8/21/2016	Flow Meter	1.38	1.38	99.85
Silver - Willow Dr	9/8/2016	Flow Meter	0.54	0.54	13.13
Silver - Willow Dr	9/13/2016	Flow Meter	0.74	0.74	19.23
Silver - Willow Dr	10/7/2016	Flow Meter	0.67	0.67	14.96
Silver - Willow Dr	11/14/2016	Flow Meter	0.65	0.65	13.88
Silver - Willow Dr	4/20/2017	Flow Meter	1.62	1.62	125.3
Silver - Willow Dr	6/2/2017	Flow Meter	0.69	0.69	16.66
Silver - Willow Dr	6/26/2017	Flow Meter	0.91	0.91	32.77
Silver - Willow Dr	6/29/2017	Flow Meter	0.76	0.76	25.13
Silver - Willow Dr	7/13/2017	Flow Meter	0.41	0.41	6.09
Silver - Willow Dr	7/17/2017	Flow Meter	0.49	0.49	9.7
Silver - Willow Dr	9/11/2017	Flow Meter	0.31	0.31	1.89
Silver - Willow Dr	9/25/2017	Flow Meter	0.25	0.25	0.94
Silver - Willow Dr	4/25/2018	ADCP	3.01	3.01	495
Silver - Willow Dr	8/20/2018	Flow Meter	0.09	0.09	0.43
Silver - Willow Dr	8/28/2018	Flow Meter	0.61	0.61	13.83
Silver - Willow Dr	3/21/2019	ADCP	2.86	2.86	461
Silver - Willow Dr	8/14/2019	Flow Meter	0.88	0.88	28.14
Silver - Willow Dr	9/25/2019	ADCP	2.24	2.24	260
Silver - Willow Dr	9/26/2019	ADCP	1.89	1.89	156
West Twin - CTH V	6/14/2017	Flow Meter	1.03	0.4	91.72
West Twin - CTH V	6/23/2017	ADCP	3.03	2.4	1196
West Twin - CTH V	7/11/2017	Flow Meter	0.86	0.56	44.53
West Twin - CTH V	7/19/2017	Flow Meter	0.76	0.46	35.07
West Twin - CTH V	9/6/2017	Flow Meter	0.68	0.38	27.18
West Twin - CTH V	10/18/2017	Flow Meter	0.86	0.56	44.24
West Twin - CTH V	3/27/2018	Flow Meter	1.02	0.39	83.58
West Twin - CTH V	4/12/2018	Flow Meter	1.33	0.7	188.8
West Twin - CTH V	4/23/2018	ADCP	3.7	3.07	1674
West Twin - CTH V	4/24/2018	ADCP	3.04	2.41	1269
West Twin - CTH V	5/4/2018	ADCP	5.57	4.94	3290
West Twin - CTH V	6/19/2018	ADCP	2.47	1.84	848.8
West Twin - CTH V	3/21/2019	ADCP	2.69	2.06	1068

Table 3. parameter values for the stage-discharge rating curves. All curves were fit to an exponential model with the equation $Q = C\ (stage - e)^N$ In this equation, the parameters that define the relationship between discharge (Q) and stage are a coefficient (C), an offset (e), and an exponent (N). These parameters respectively relate to the scale and resistance (to flow) of the channel, the control elevation, and the shape of the control (Hamilton et al. 2019)

		Lower Equation				Upper Equation					
Station ID	Station name	coefficient (C)	stage offset - ft (e)	slope (N)	flow break point - cfs	coefficient (C)	stage offset - ft (e)	slope (N)	max flow measured (cfs)	max flow extrapolated (cfs)	percent extrapolation
153027	Ahnapee - CTH J	102.28	1.7	0.97					300	431	30%
10008207	East Twin - Steiners Corners Rd	54.92	0.5	1.09	255	5.64	0.5	2.71	1107	3237	66%
10029954	Kewaunee - Hillside Rd	51.84	1.2	1.76					660	1277	48%
10020779	Silver - Willow Dr	41.24	0	2.27					495	855	42%
10029482	West Twin - CTH V	91.71	0.3	1.5	45	371.31	0.63	1.37	3290	4880.2	33%
363313	Branch - Branch River Rd	45.81	1	1.93	1295	2.9	1	3.54	3003	3018.1	1%
10042875	Killsnake - CTH Y	9.07	0.2	1.95	198	593.94	4.5	1.89	2329	2592	10%
363375	Manitowoc S. Branch - Lemke Rd	49.52	0	0.94	111	12.43	0	2.55	625	761	18%
10016717	Mud - Hilltop Rd	20.68	1.1	2.6					427	1317	68%
363228	Silver - CTH LS	34.75	0.8	2.49					178	620	71%
363368	Point - Centerville Rd	32.1	1.5	1.58					238	499	52%
10020782	Manitowoc - Leist Rd	131.54	0.5	2.01					2783	3284	15%
10049358	Mullet - Sumac Rd	147.66	0.75	1.21	490	76	0.75	1.88	960	1253	23%
603304	Onion - Ourtown Rd	107.02	0.45	1.73					2071	2074	0%
603295	Pigeon - CTH A and River Rd	38.22	1.2	1.33	4.42	5.08	1.2	2.69	1154	1313	12%
603051	Pigeon - Mill Rd	75.88	0.95	1.74					1011	1039	3%
463070	Sauk - Mink Ranch Rd	24.93	0.7	2					817	2995	73%
10016139	Sheboygan - HWY 57	219.32	0.5	1.31					1570	1589	1%
10039440	Sheboygan - Palm Tree Rd	64.22	0.6	1.25	237	15.61	0.6	2.62	654	792	17%

Table 1 Permutations of fixed and random effects that were tested during model selection, where Q is discharge and T is decimal time. FE refers to fixed effect, and RE refers to random effect. For example, model 1a has one fixed effect, discharge, and model 1b has one random effect, also discharge, but the discharge coefficient is allowed to vary by site. The AIC is listed for both the Total Suspended Solids (TSS) and Total Phosphorus (TP) models. The model that was selected based on minimum AIC is denoted by an asterisk.

Model		AIC_{TSS}	AIC_{TP}	Q		Q^2		T		T^2		cos/sin(T)	
				FE	RE	FE	RE	FE	RE	FE	RE	FE	RE
1	a	6264	5524	•									
	b	6064	5129	•	•								
2	a	5987	5227	•		•							
	b	5834	4899	•	•	•	•						
3	a	6248	5534	•				•					
	b	6049	5139	•	•			•					
	c	6050	5132	•	•			•	•				
4	a	6080	5315	•								•	
	b	5831	4797	•	•							•	
	c	5704	4586	•	•							•	•
5	a	5964	5237	•		•		•					
	b	5815	4910	•	•	•	•	•					
	c	5820	4913	•	•	•	•	•	•				
6	a	5720	4917	•		•						•	
	b	5518	4460	•	•	•	•					•	
	c	5372	4238	•	•	•	•					•	•
7	a	6039	5327	•				•				•	
	b	5787	4809	•	•			•				•	
	c	5785	4801	•	•			•	•			•	
	d	5670	4598	•	•			•				•	•
	e	5678	4583	•	•			•	•			•	•
8	a	5660	4929	•		•		•				•	
	b	5459	4473	•	•	•	•	•				•	
	c	5462	4460	•	•	•	•	•	•			•	
	d	**5323***	4249	•	•	•	•	•				•	•
	e	5333	**4233***	•	•	•	•	•	•			•	•
9	a	5676	4946	•		•		•		•		•	
	b	5475	4489	•	•	•	•	•		•		•	
	c	5510	4561	•	•	•	•	•	•	•	•	•	
	d	5339	4266	•	•	•	•	•				•	•
	e	5361	4256	•	•	•	•	•	•	•	•	•	•

Table 2 Performance statistics for site-specific flux models where n is the number of samples, BCF is the bias-correction factor (fluxes calculated using back-transformed log concentration were multipled by this BCF), PBIAS is percent bias, and NSE is Nash-Sutcliffe Efficiency.

Monitoring Station	n		BCF		PBIAS[1]		NSE		R^2	
	TSS	TP	TSS	TP	TSS	TP	TSS	TP	TSS	TP
Ahnapee River	60	60	1.23	1.08	-5.8	-13.1	0.53	0.79	0.72	0.8
Branch River	57	57	1.30	1.06	22.1	4.1	0.28	0.8	0.82	0.88
East Twin River	56	56	1.20	1.05	-5.4	-7.4	0.67	0.93	0.78	0.94
Fisher Creek (USGS)	-	110	-	1.25	-	1.2	-	0.65	-	0.74
Kewaunee River at Hillside Road	18	18	1.53	1.07	8.9	-7.2	-1.73	0.88	0.06	0.9
Kewaunee River (USGS)	100	129	1.19	1.14	-0.5	-11.7	0.79	0.9	0.8	0.96
Killsnake River	51	51	1.42	1.05	1.5	-2.3	0.86	0.99	0.91	0.99
Manitowoc River (USGS)	291	317	1.29	1.11	-6.9	-6.1	-0.8	0.62	0.22	0.67
Manitowoc River South Branch	43	43	1.52	1.07	-1.4	5.5	-0.64	0.81	0.3	0.88
Mud Creek	53	53	1.34	1.05	32.1	-0.9	-0.24	0.95	0.93	0.97
Mullet River	31	41	1.25	1.04	32.2	5	-1.09	0.72	0.89	0.92
Onion River	34	42	1.67	1.08	17.7	11.7	-1.16	0.61	0.39	0.8
Otter Creek (USGS)[2]	730	896	1.47	1.21	-1.6	-16.6	0.3	0.67	0.55	0.7
Pigeon River at CH A	36	46	1.22	1.06	20.2	9.4	-0.73	0.88	0.45	0.93
Pigeon River at Mill Road	7	13	1.21	1.07	139.6	13.3	-3.62	0.78	0.99	0.97
Point Creek	9	9	1.46	1.07	169.1	29.9	-4.87	0.85	0.97	0.99
Sauk Creek	36	46	1.43	1.08	-15.5	-26.9	0.97	0.81	1	0.98
Sheboygan River at Hwy 57	35	44	1.12	1.03	18.8	-3.2	-1.26	0.8	0.75	0.86
Sheboygan River (USGS)	345	377	1.22	1.12	-10.3	-1.7	0.56	0.81	0.57	0.81
Sheboygan River at Palm Tree Rd	21	24	1.15	1.04	-18.8	-4	-0.27	0.75	0.27	0.78
Silver Creek at Willow Dr	69	69	1.30	1.09	-7.9	-13.5	0.64	0.86	0.64	0.9
Silver Creek at CH LS	46	48	1.51	1.13	-20.8	-9.6	0.6	0.93	0.61	0.96
West Twin River at CTH V	52	52	1.42	1.09	0.1	1.7	0.55	0.87	0.79	0.91

[1] Negative values indicate under-prediction

[2] A model was fitted for Otter Creek to provide additional samples to the overall model. However, because the frequency of sampling is nearly daily, interpolation between samples likely provides a better estimate of flux.

Table 3 Mixed-effect model coefficients for Total Suspended Solids (TSS) and Total Phosphorus (TP). Model coefficients are associated with the co-variates in the top row, which correspond to those described in Equation 1 and Equation 2. Table cells with a value of “N” have negligible values.

	Intercept		$ln(Q^2)$		$ln(Q)$		$cos(2\pi T)$		$sin(2\pi T)$		T	
Monitoring Station	**TSS**	**TP**	**TSS**	**TP**	**TSS**	**TP**	**TSS**	**TP**	**TSS**	**TP**	**TSS**	**TP**
Fixed effects	**1.83**	**-2.19**	**0.22**	**0.15**	**0.04**	**0.02**	**-0.80**	**-0.50**	**-0.31**	**-0.39**	**-0.03**	**-0.01**
Ahnapee River	-0.117	-0.734	-0.107	-0.038	-0.010	N	0.037	0.015	0.066	0.250	-	-0.009
Branch River	-0.081	-0.400	0.101	0.051	0.007	0.007	0.011	0.031	0.043	-0.012	-	0.004
East Twin River	-0.153	-0.598	0.045	0.039	0.010	0.009	0.110	0.003	0.001	-0.002	-	0.002
Fisher Creek (USGS)	-	0.732	-	0.006	-	-0.004	-	0.077	-	-0.044	-	0.005
Kewaunee River at Hillside Road	-0.115	0.296	-0.093	0.010	-0.013	-0.002	-0.187	0.053	-0.063	0.016	-	0.002
Kewaunee River (USGS)	-0.310	-0.239	0.098	0.092	0.012	0.009	0.047	0.294	0.001	0.235	-	0.009
Killsnake River	0.782	0.391	-0.274	-0.043	-0.019	-0.007	0.119	-0.041	-0.017	-0.015	-	-0.003
Manitowoc River (USGS)	0.900	0.239	-0.036	-0.014	-0.012	-0.005	-0.032	0.004	0.058	0.036	-	-0.002
Manitowoc River South Branch	0.654	0.402	-0.215	-0.064	-0.033	-0.012	-0.239	-0.168	0.033	-0.087	-	-0.007
Mud Creek	0.129	0.225	-0.117	-0.057	-0.017	-0.006	-0.202	-0.117	-0.044	-0.067	-	-0.005
Mullet River	-0.655	-0.627	0.211	0.008	0.017	0.004	-0.123	-0.090	-0.049	-0.020	-	-0.003
Onion River	-0.109	0.220	0.059	-0.017	0.012	-0.001	0.075	-0.064	-0.055	-0.114	-	N
Otter Creek (USGS)[1]	0.073	-0.279	0.127	0.174	0.038	0.026	0.710	0.524	0.127	0.223	-	0.023
Pigeon River at CH A	-0.202	0.070	0.083	0.009	0.008	0.002	-0.016	-0.032	-0.022	-0.099	-	0.002
Pigeon River at Mill Road	-0.010	0.177	0.109	-0.029	0.010	-0.004	0.029	-0.096	0.009	-0.093	-	-0.002
Point Creek	-0.184	0.092	0.148	0.019	0.013	0.002	-0.009	0.056	-0.005	0.001	-	0.003
Sauk Creek	0.415	0.863	-0.100	-0.096	0.001	-0.010	0.249	-0.146	0.010	-0.182	-	-0.005
Sheboygan River at Hwy 57	-0.265	-0.046	-0.058	-0.053	-0.015	-0.007	-0.280	-0.111	-0.045	0.013	-	-0.007
Sheboygan River (USGS)	0.425	-0.099	0.092	0.035	0.001	N	0.091	0.142	0.170	0.186		0.002
Sheboygan River at Palm Tree Rd	-0.204	0.040	-0.252	-0.032	-0.022	-0.004	-0.168	-0.083	-0.109	-0.031		-0.004
Silver Creek at Willow Dr	-0.450	-0.334	-0.055	-0.035	-0.013	-0.004	-0.282	-0.198	-0.048	-0.077		-0.007
Silver Creek at CH LS	-0.313	0.057	0.108	-0.018	0.012	-0.002	0.014	-0.081	-0.016	-0.081		-0.002
West Twin River at CTH V	-0.207	-0.450	0.127	0.053	0.016	0.010	0.045	0.030	-0.045	-0.036		0.005

7 Figures

Figure 1. Map of stream monitoring sites in the NE Lakeshore TMDL and corresponding monitoring activities. Site numbers correspond to the Map ID column in table 1.

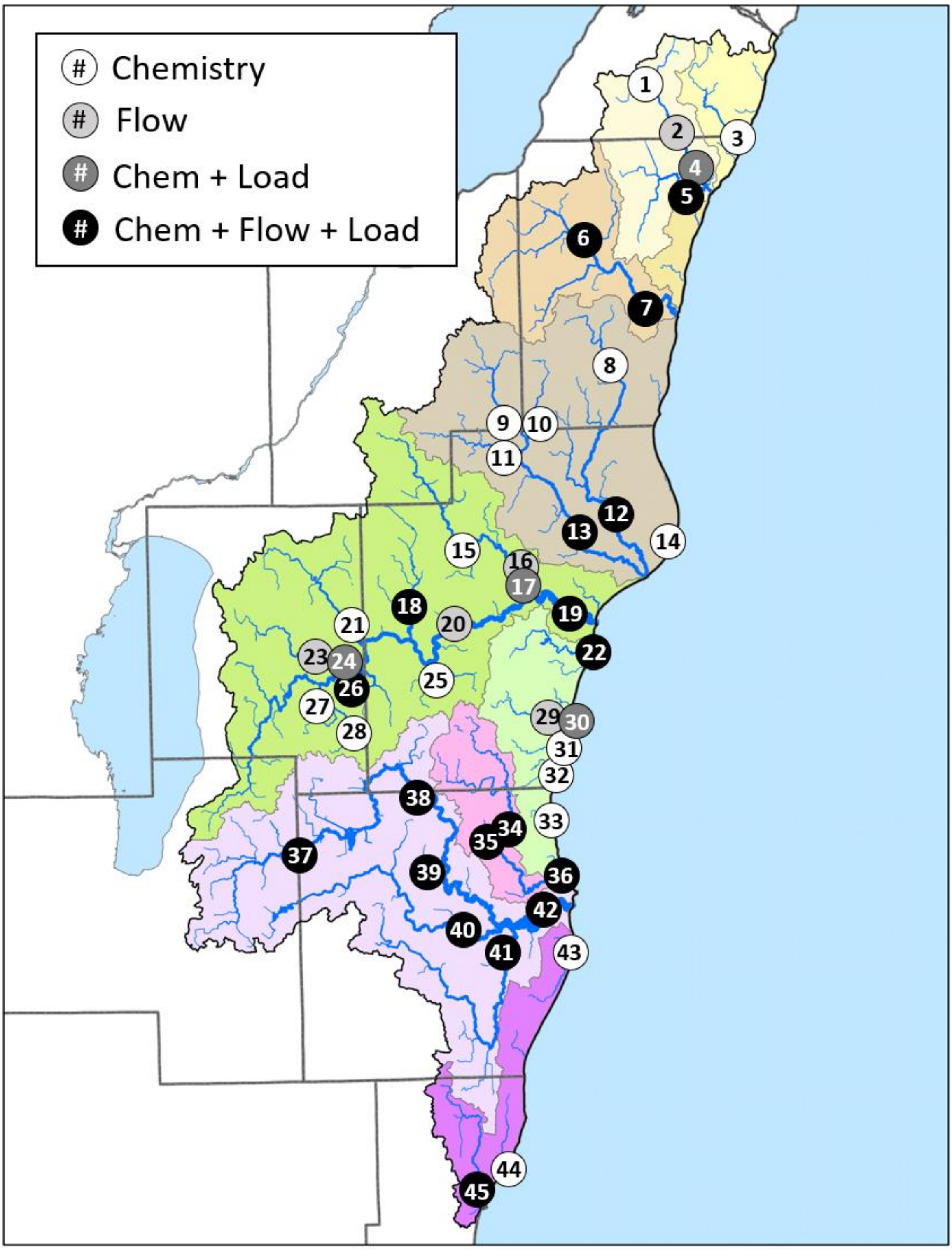


Figure 2.
Locations and time periods with flow data. Black dots indicate flow data. Red dots indicate flow measurements. At USGS sites, more flow data may exist than what is shown in this figure. Flow measurements (red dots) are not shown for the USGS sites.

Figure 3a. Kewaunee model area. Frequency and duration of water chemistry monitoring data for sites with TP and TSS load estimates.

Figure 3b. Manitowoc model area. Frequency and duration of water chemistry monitoring data for sites with TP and TSS load estimates.

Figure 3c. Sheboygan model area. Frequency and duration of water chemistry monitoring data for sites with TP and TSS load estimates.

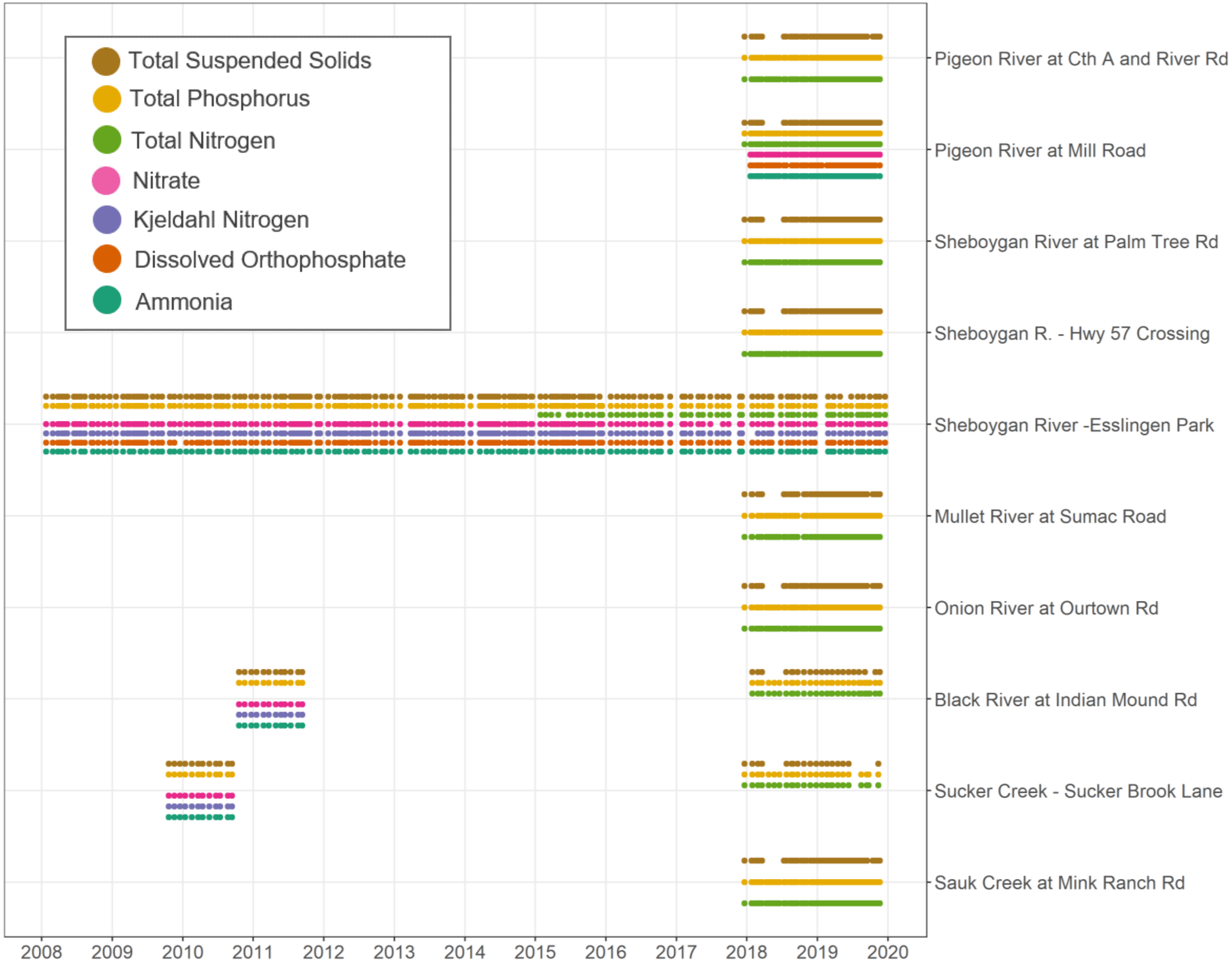


Figure 4. An example of a stage-discharge pairs trialed with a variety of offsets and plotted on a log-log scale. When the offset is too small, the dataset is concave up, when the offset is too large, the data set is concave down. The proper offset results in a dataset that plots in a straight line. In this example, an offset of 1.7 ft was chosen for this site.

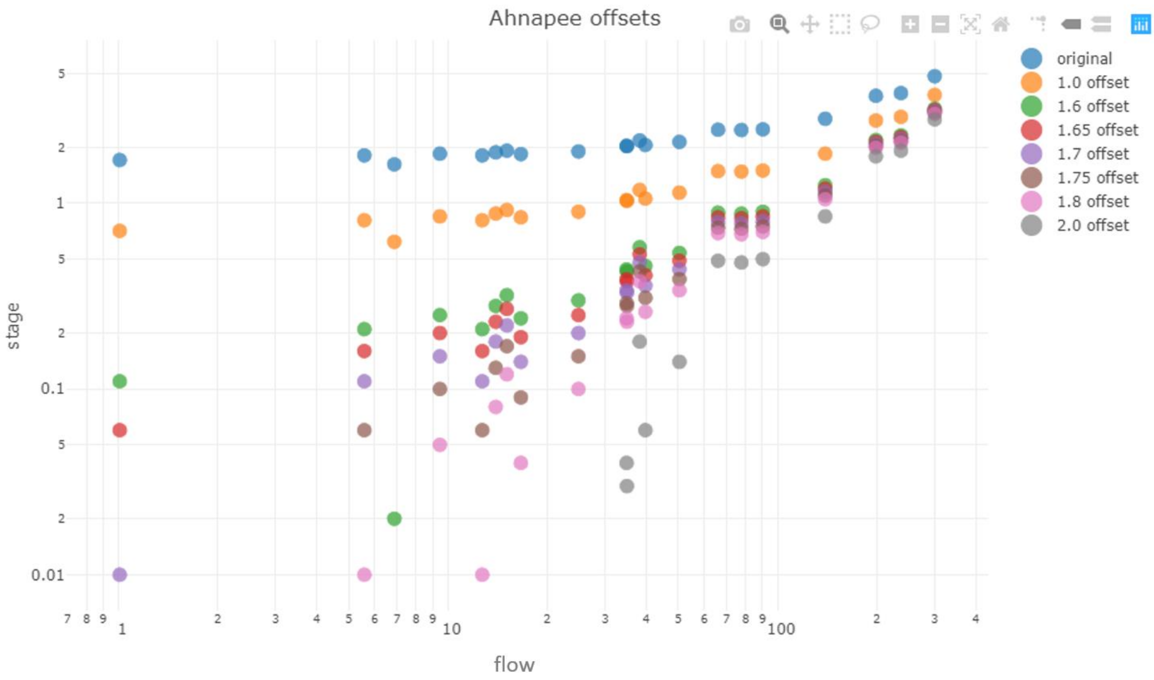
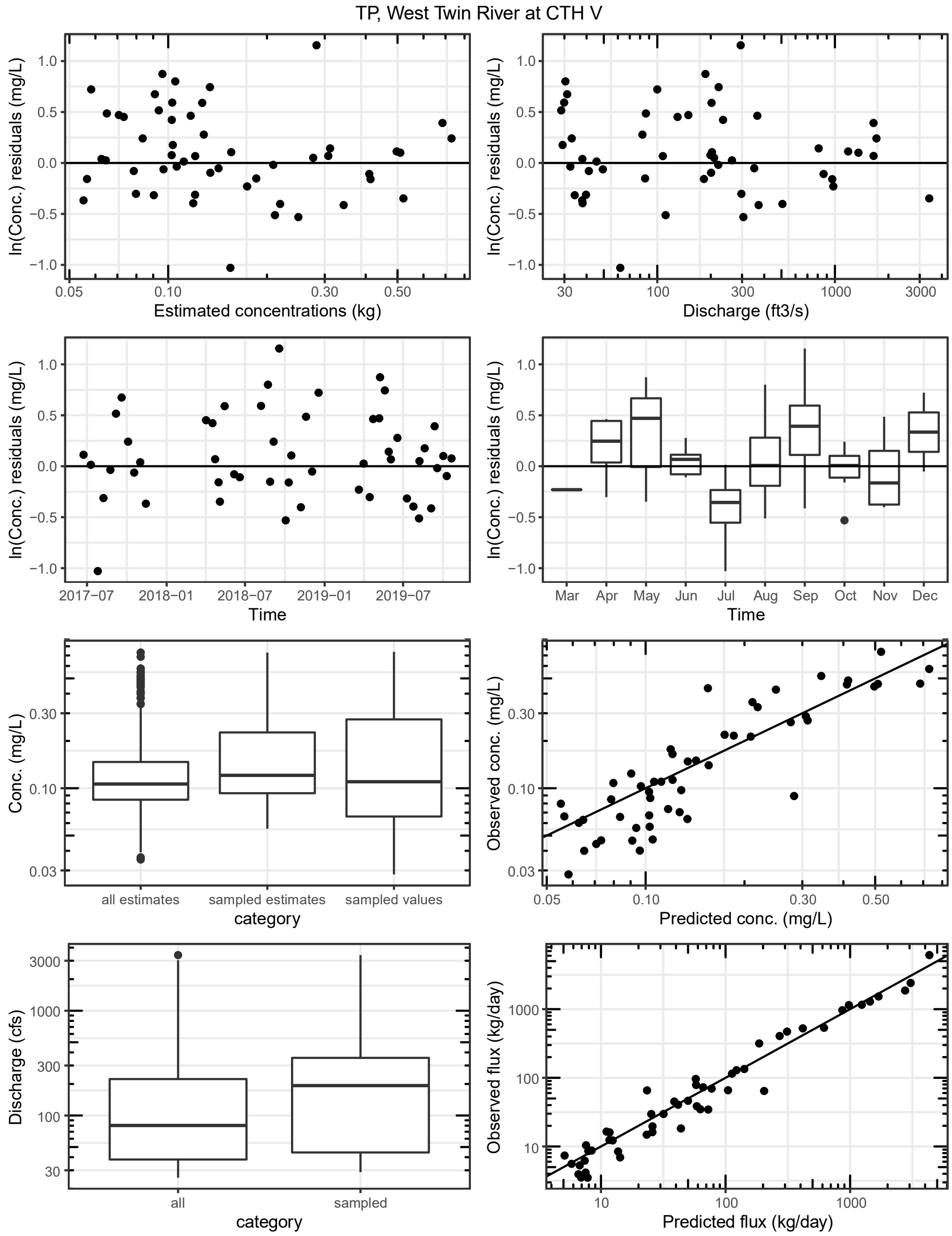


Figure 1 Example of a composite diagnostic plot (Hirsch, 2014) for rapid assessment of model error at individual sites.



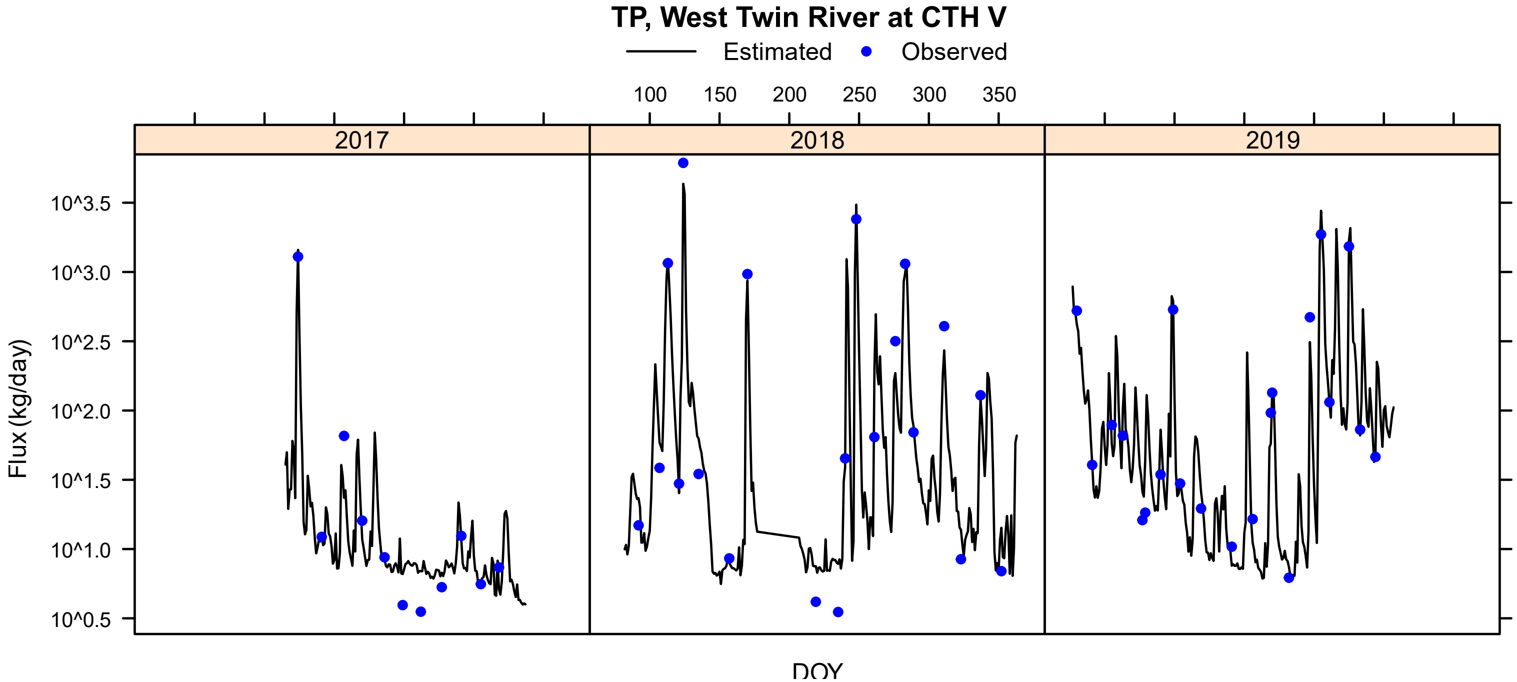


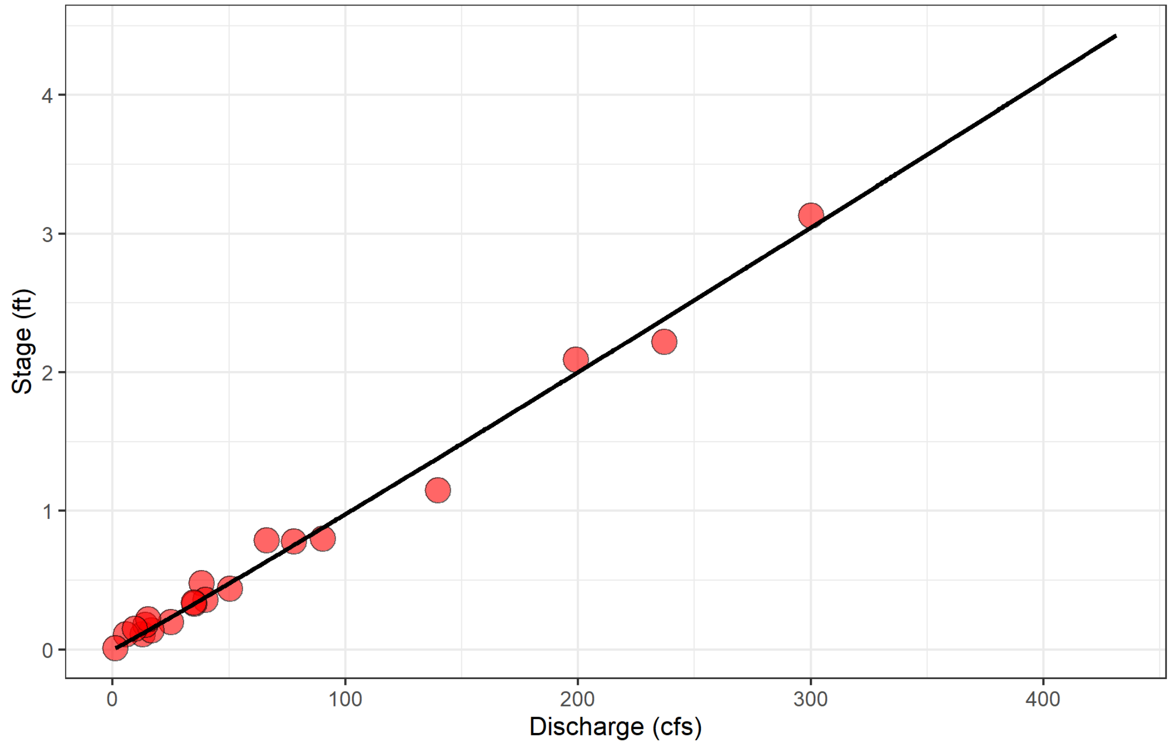
Figure 2 Example of a time-series plot by day-of-year (DOY) showing continuous estimated total phosphorus (TP) flux as black lines and observed flux (sample multiplied by mean daily discharge) on sample days as blue dots.

8 Appendices

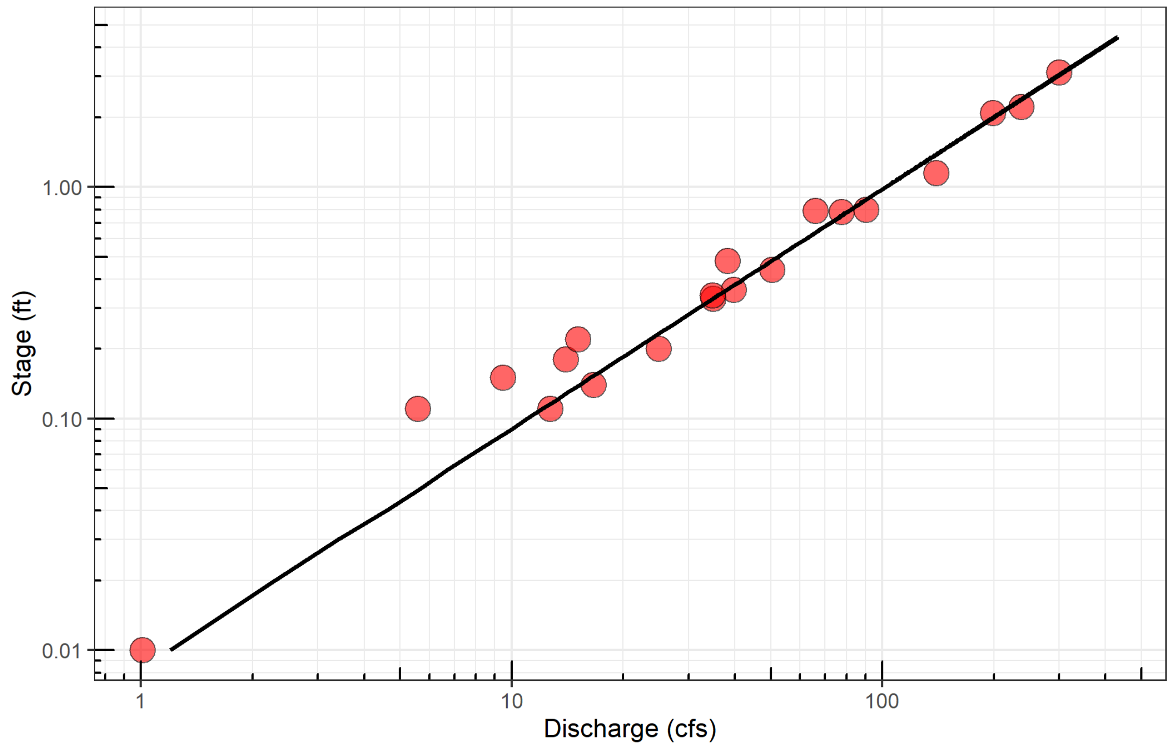
8.1 Stage – Discharge Rating Curves

Ahnapee - CTH J

Standard axis

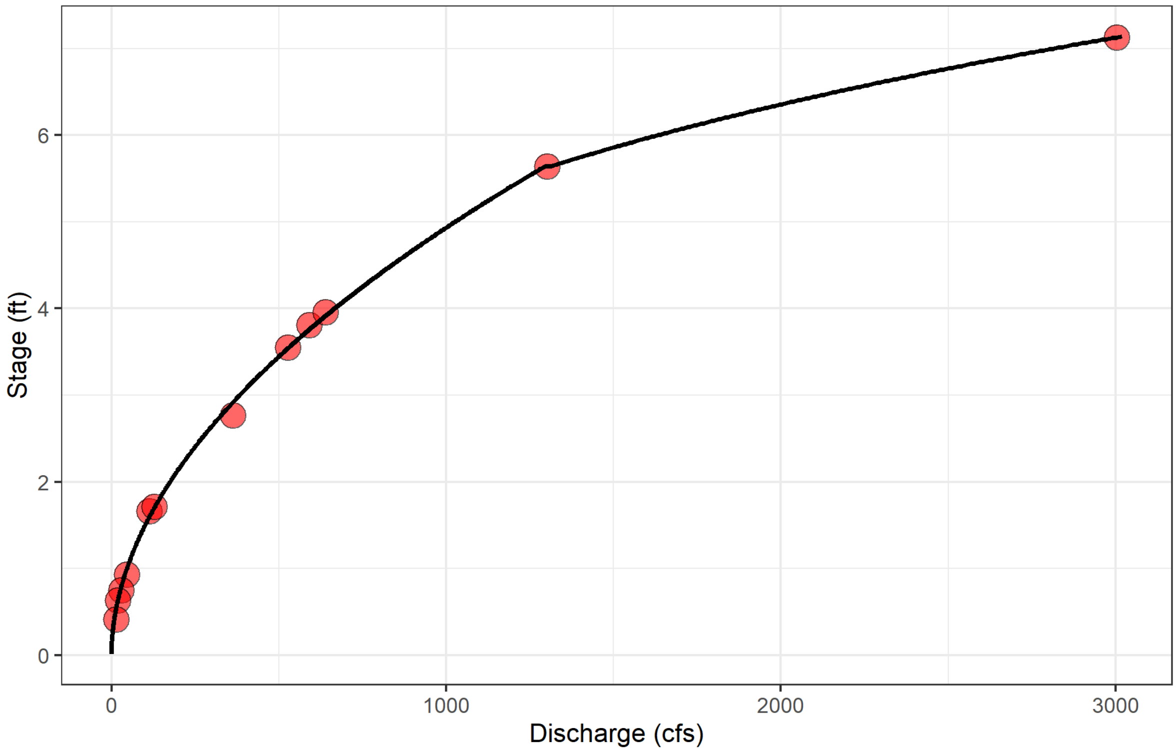


Log-Log axis

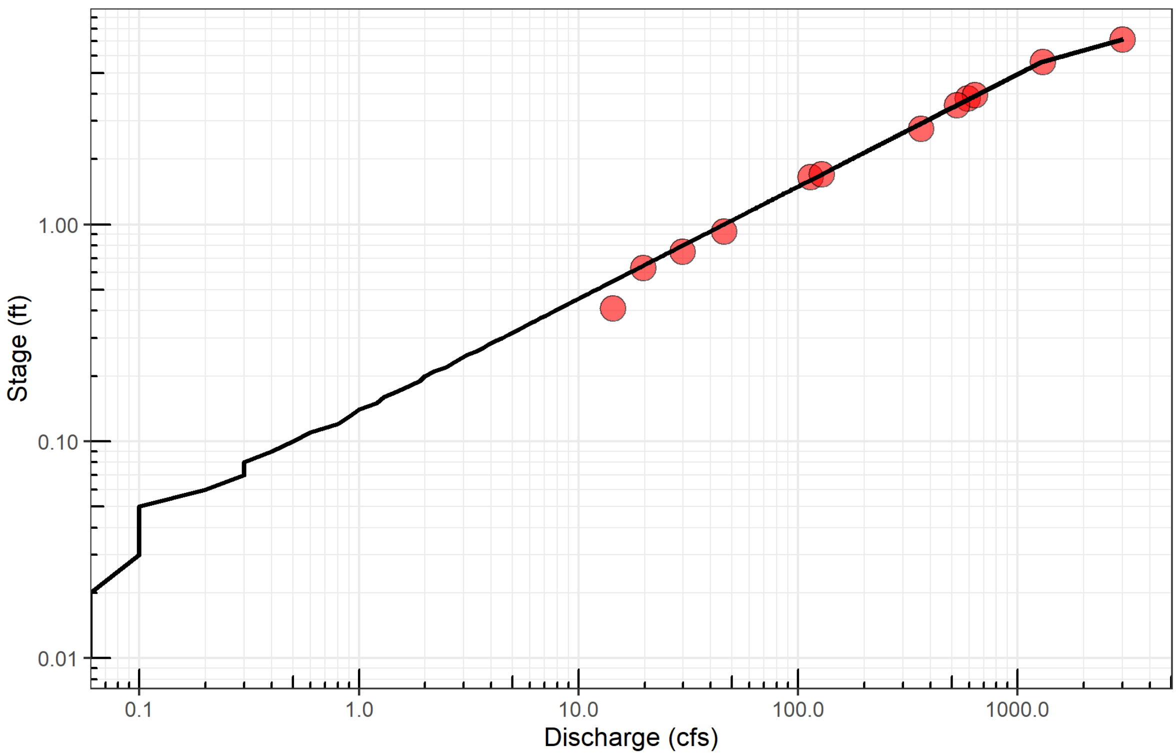


Branch - Branch River Rd

Standard axis

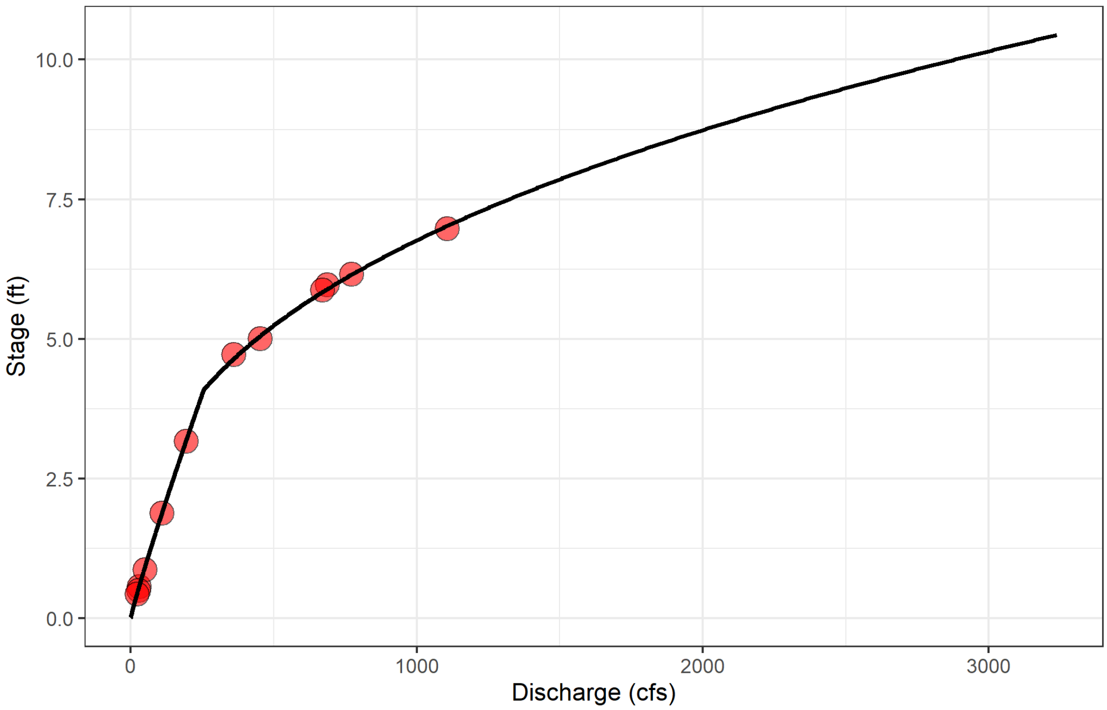


Log-Log axis

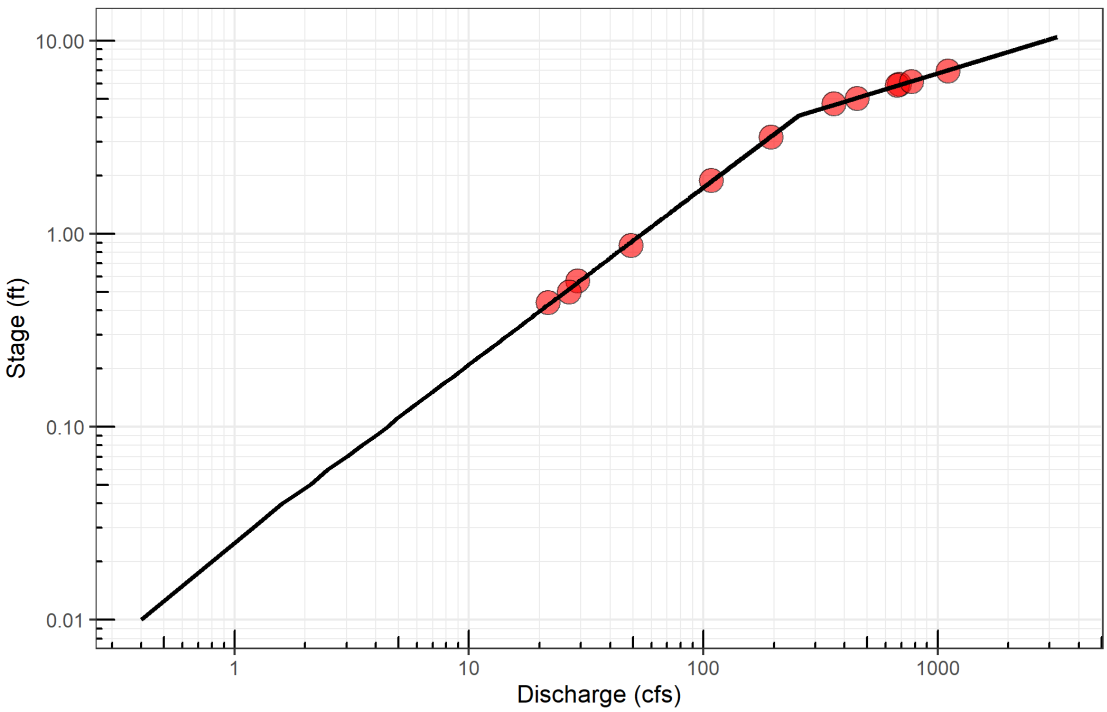


East Twin - Steiners Corners Rd

Standard axis

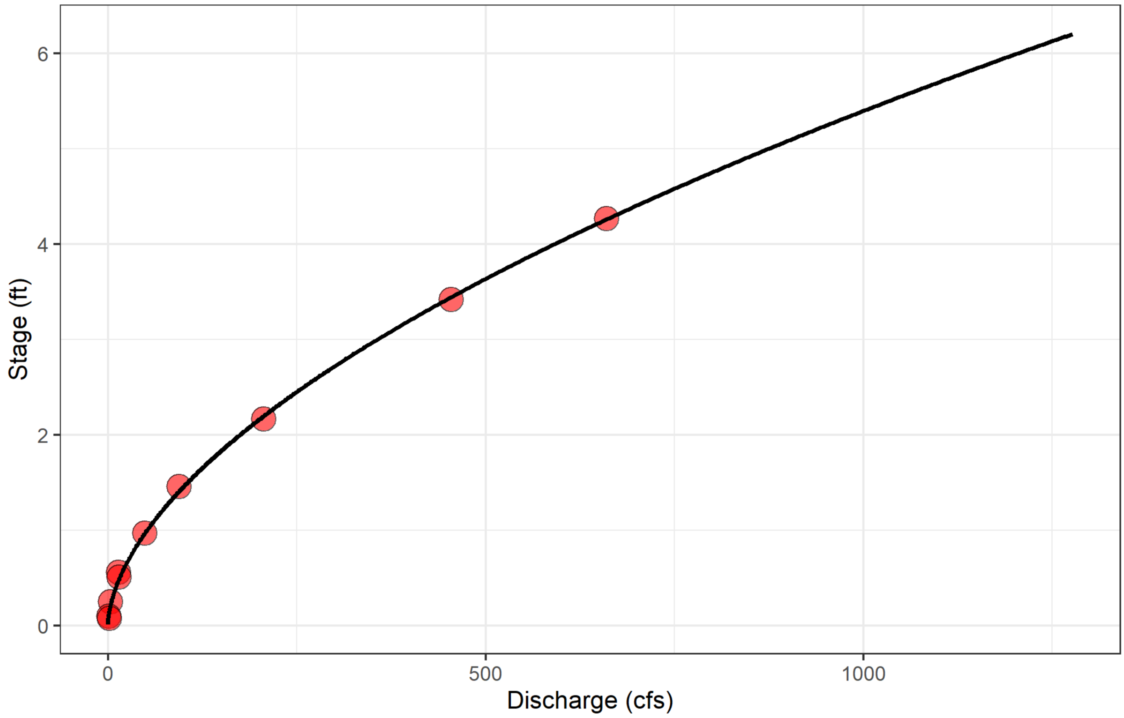


Log-Log axis

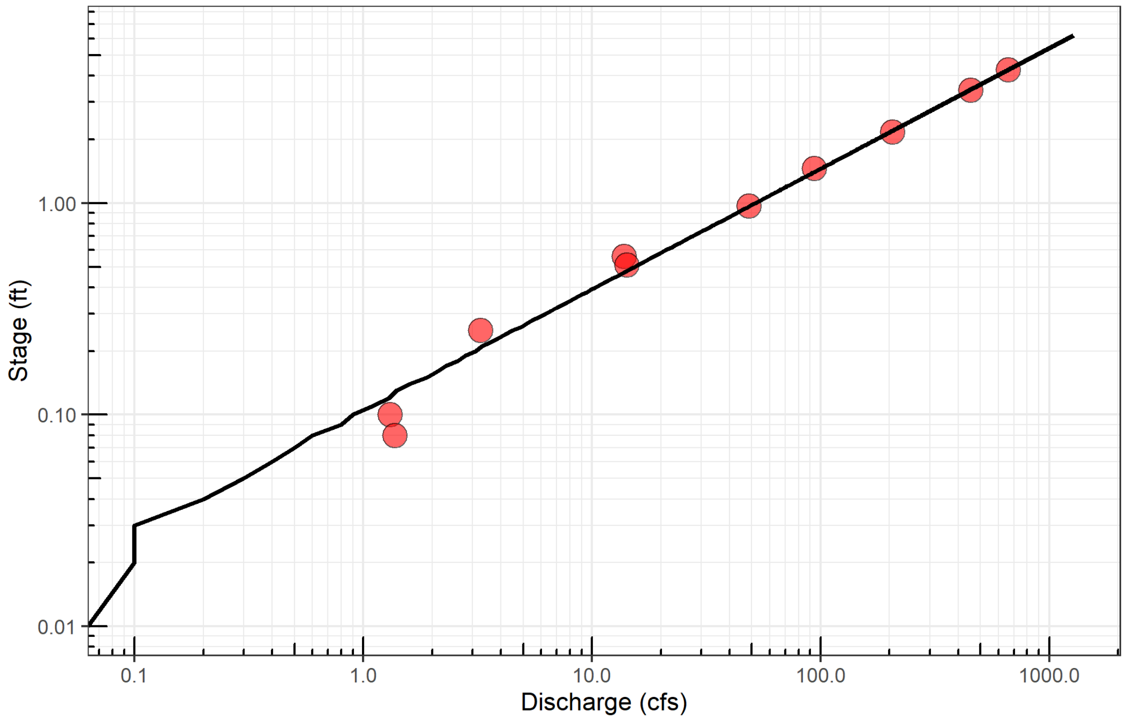


Kewaunee - Hillside Rd

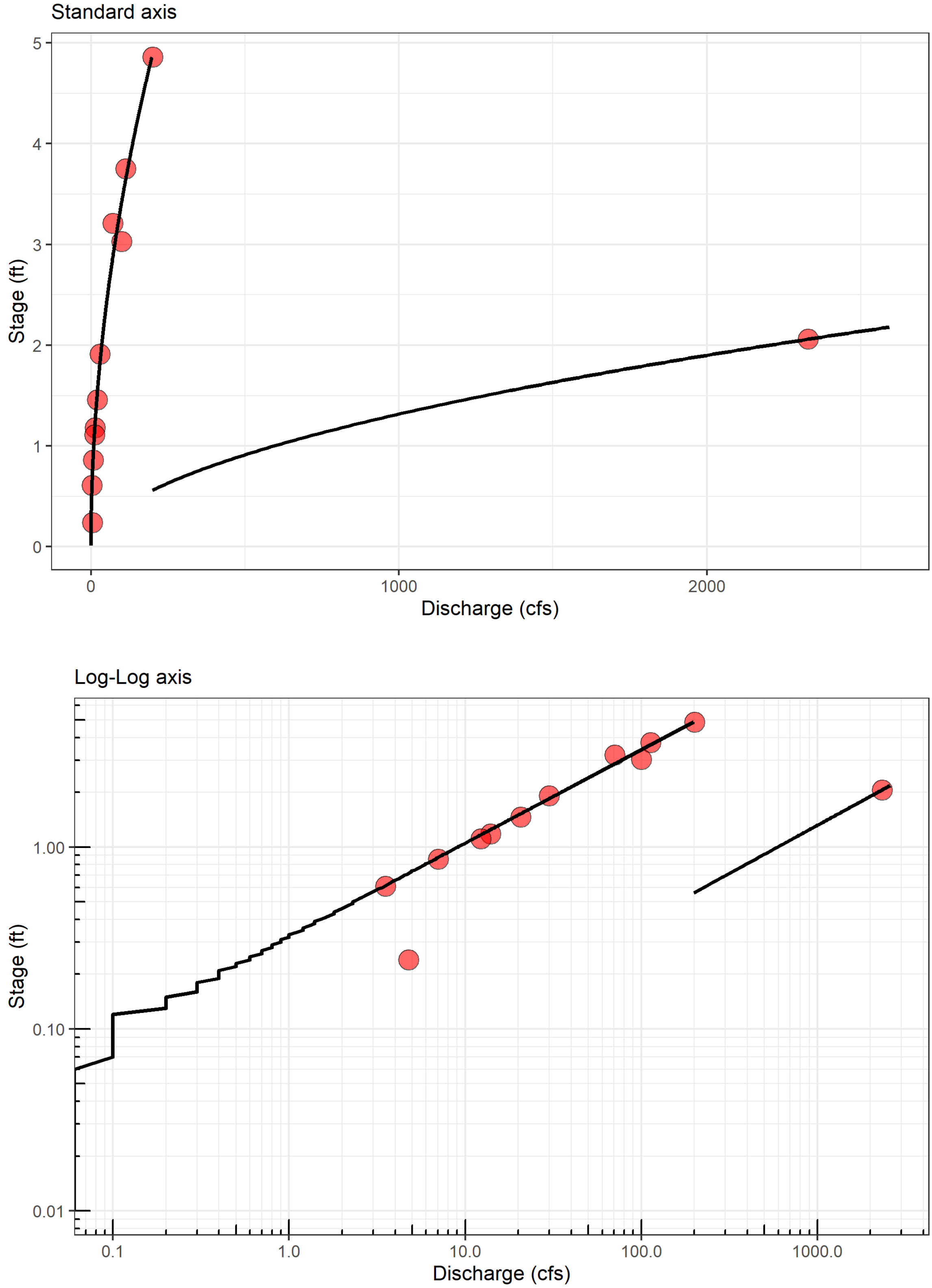
Standard axis



Log-Log axis

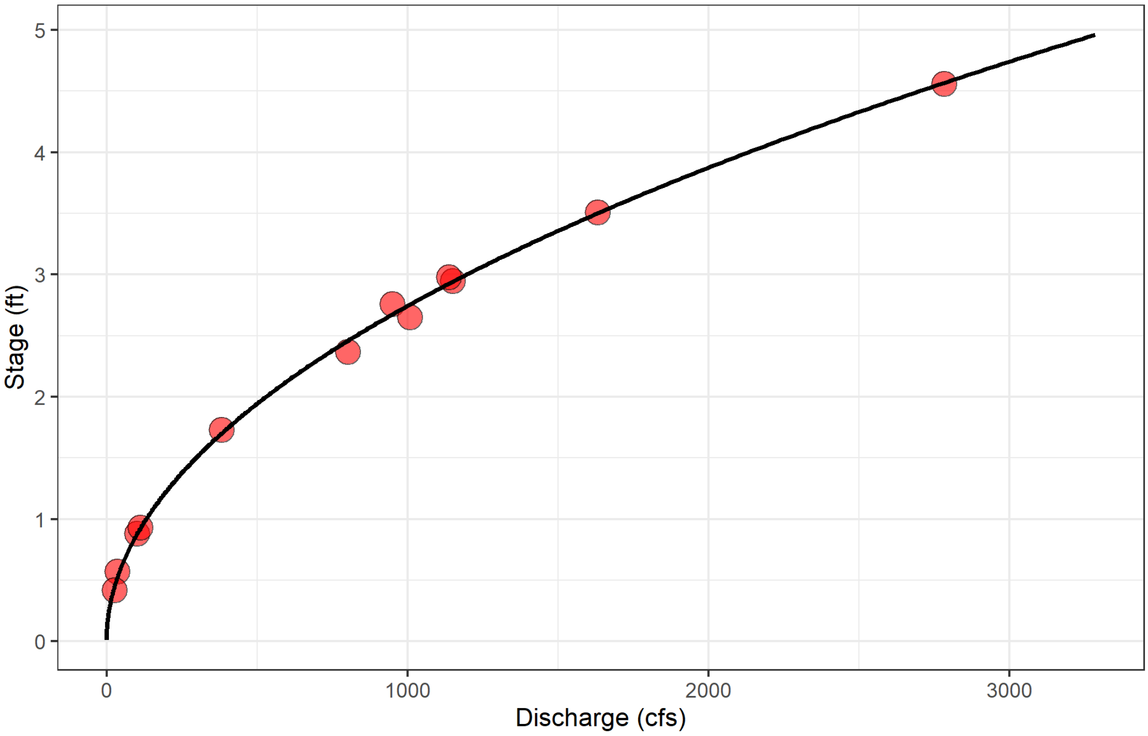


Killsnake - CTH Y

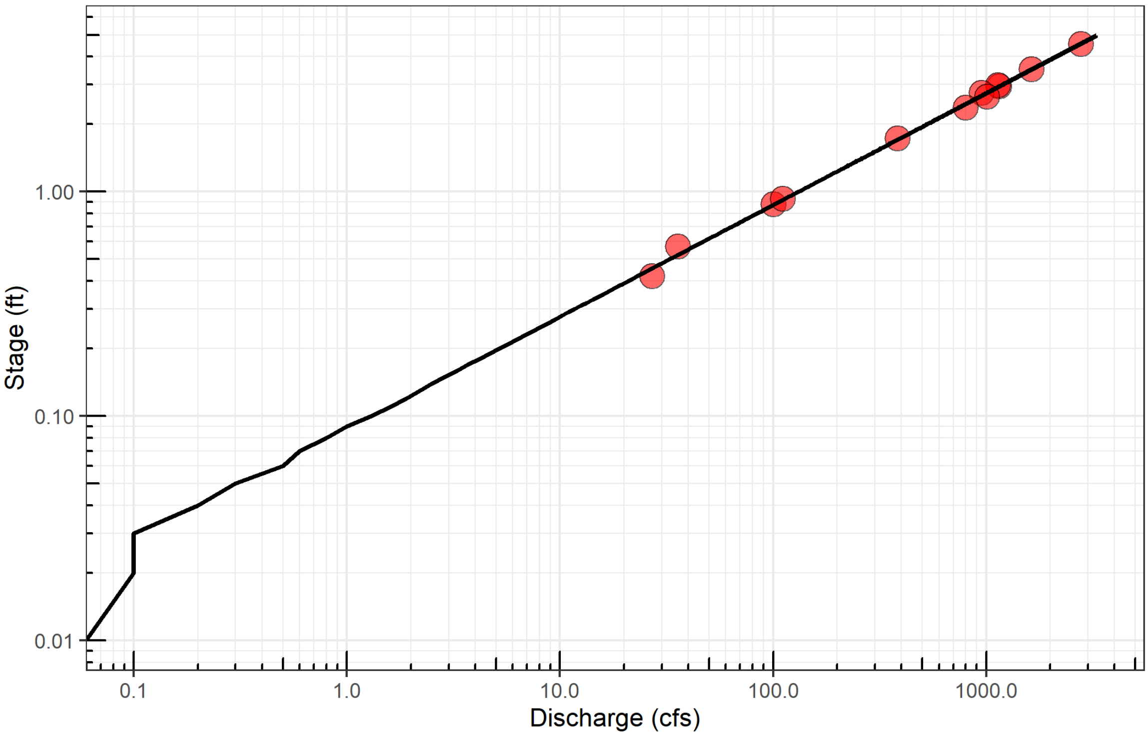


Manitowoc - Leist Rd

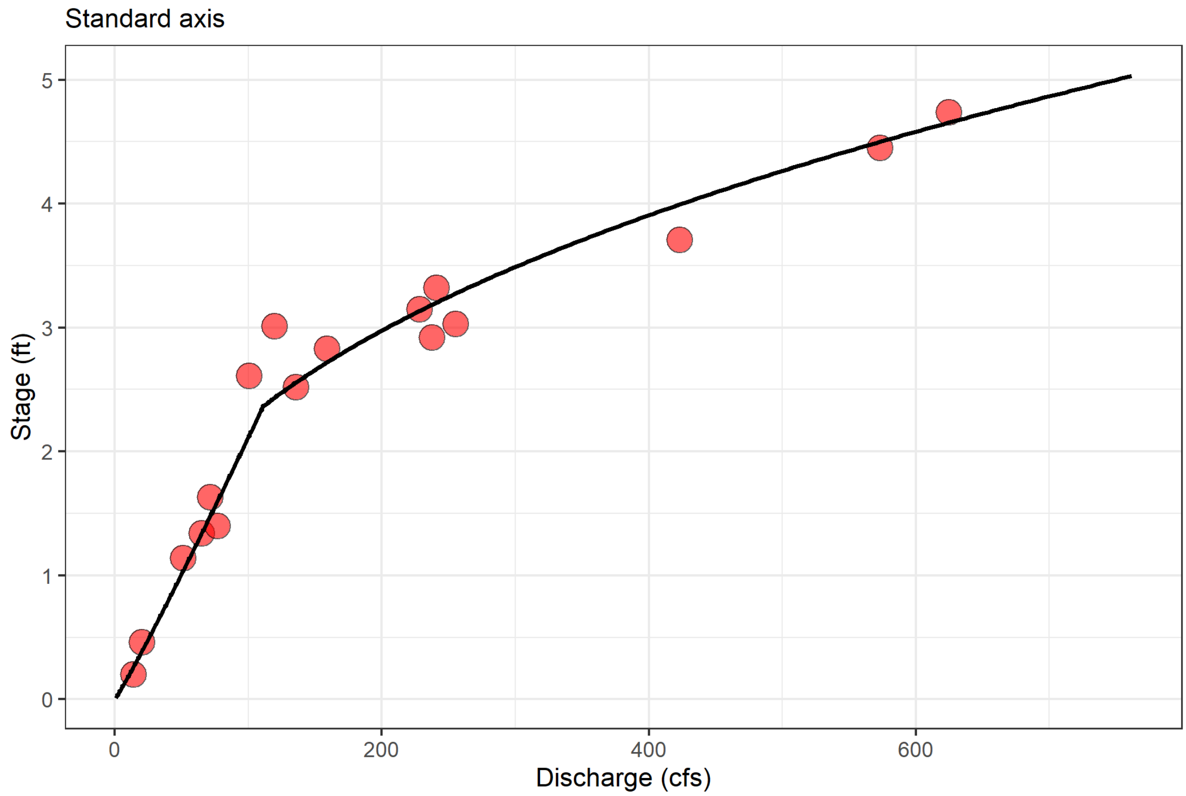
Standard axis

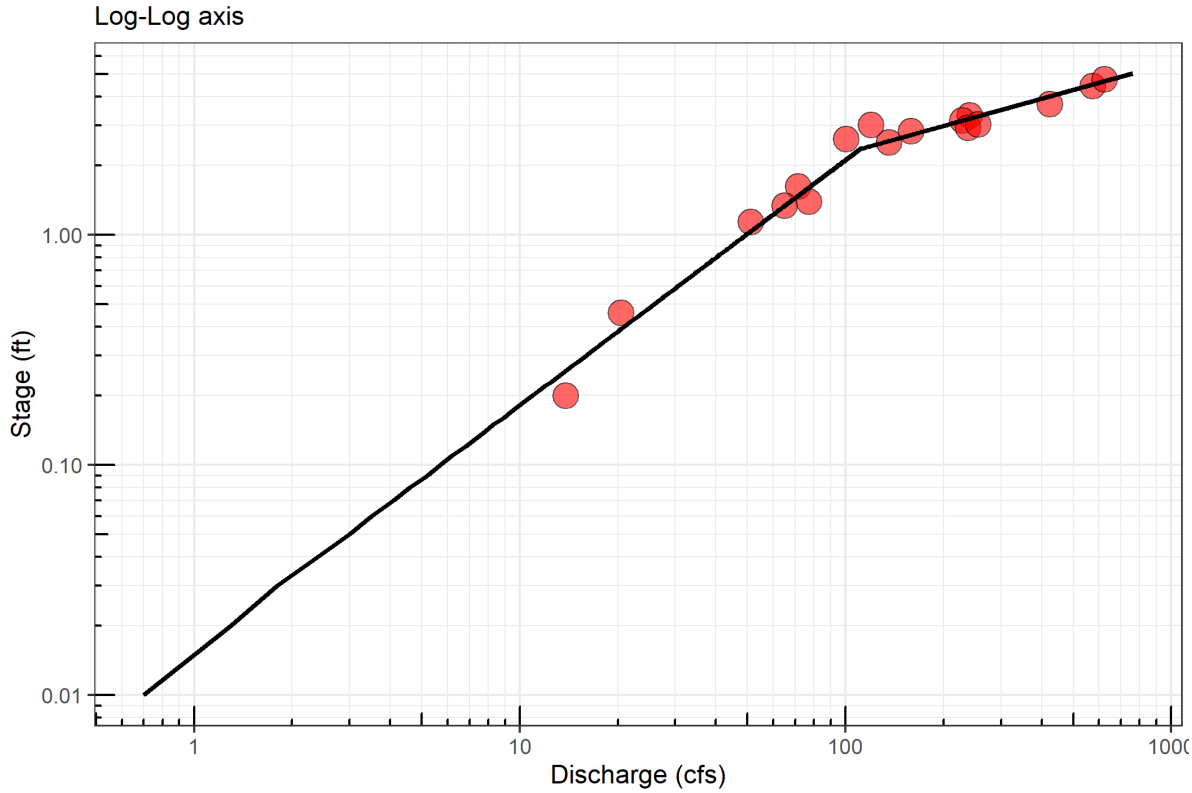


Log-Log axis



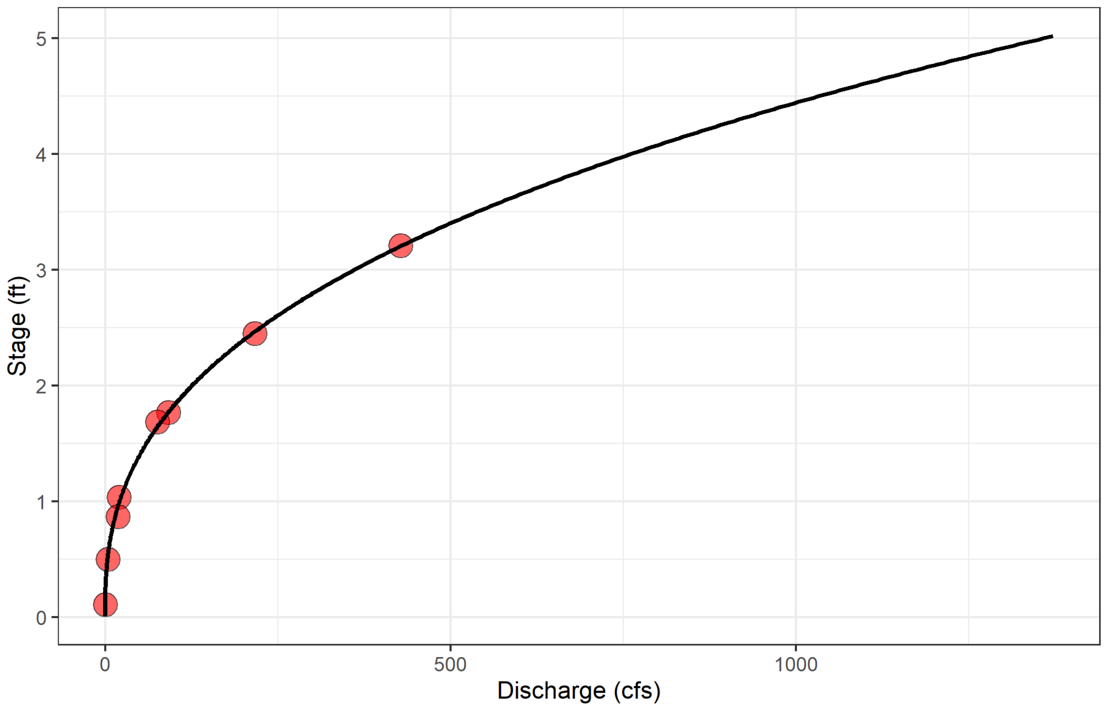
Manitowoc S. Branch - Lemke Rd



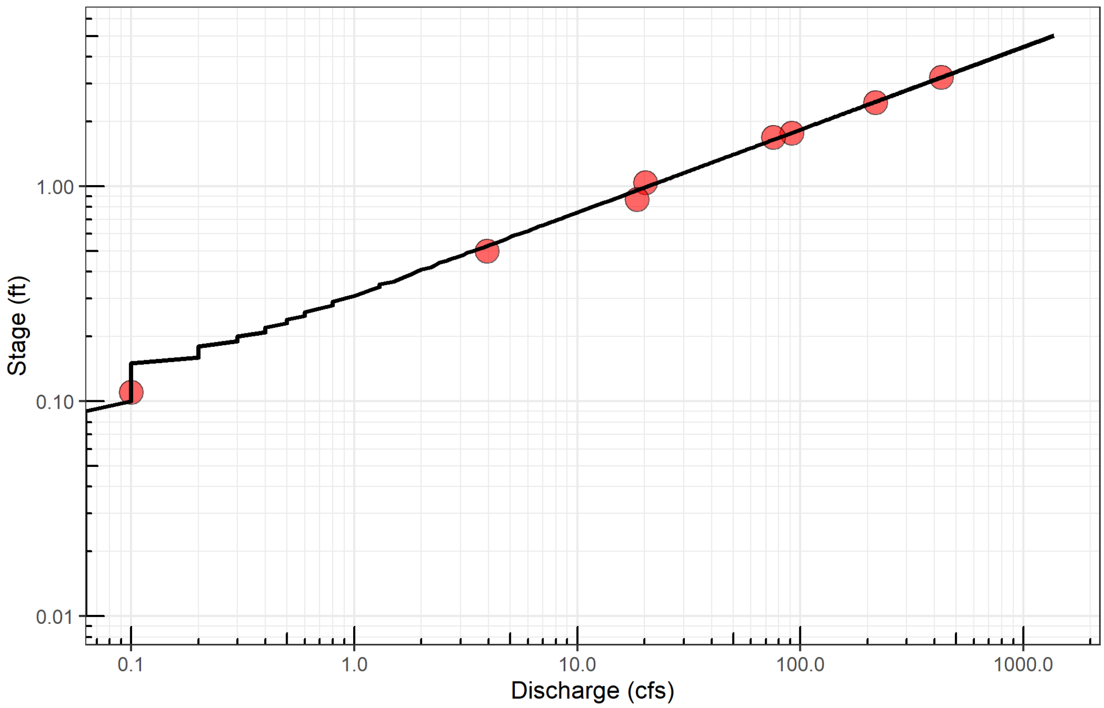


Mud - Hilltop Rd

Standard axis

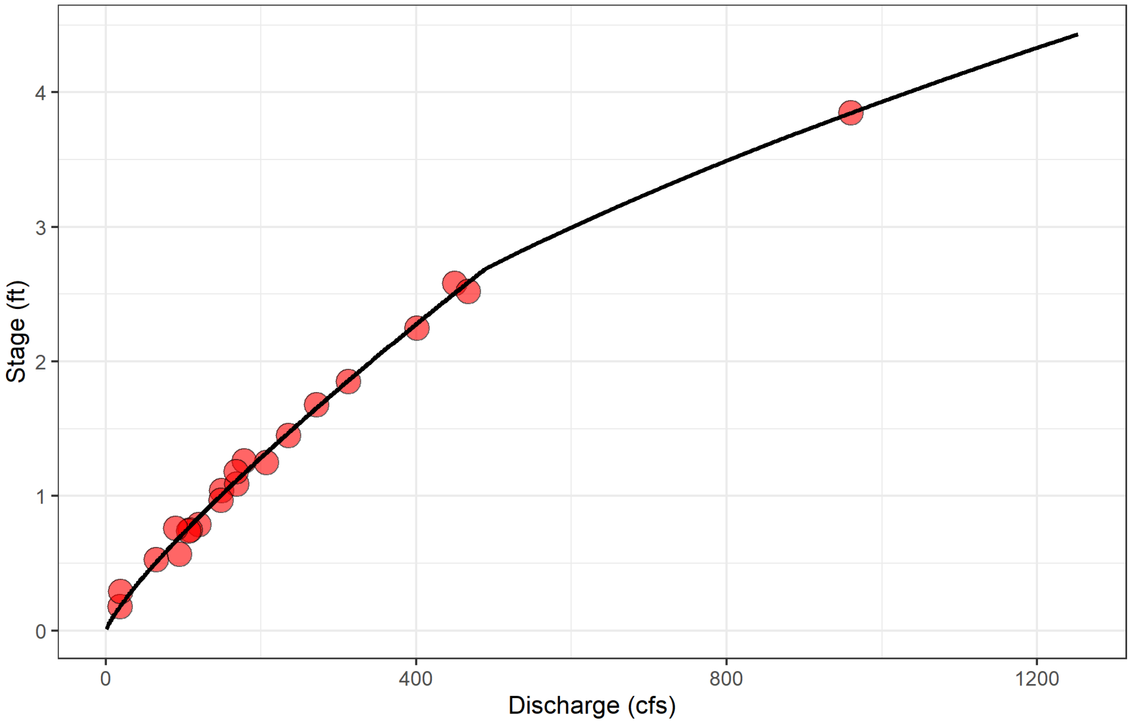


Log-Log axis

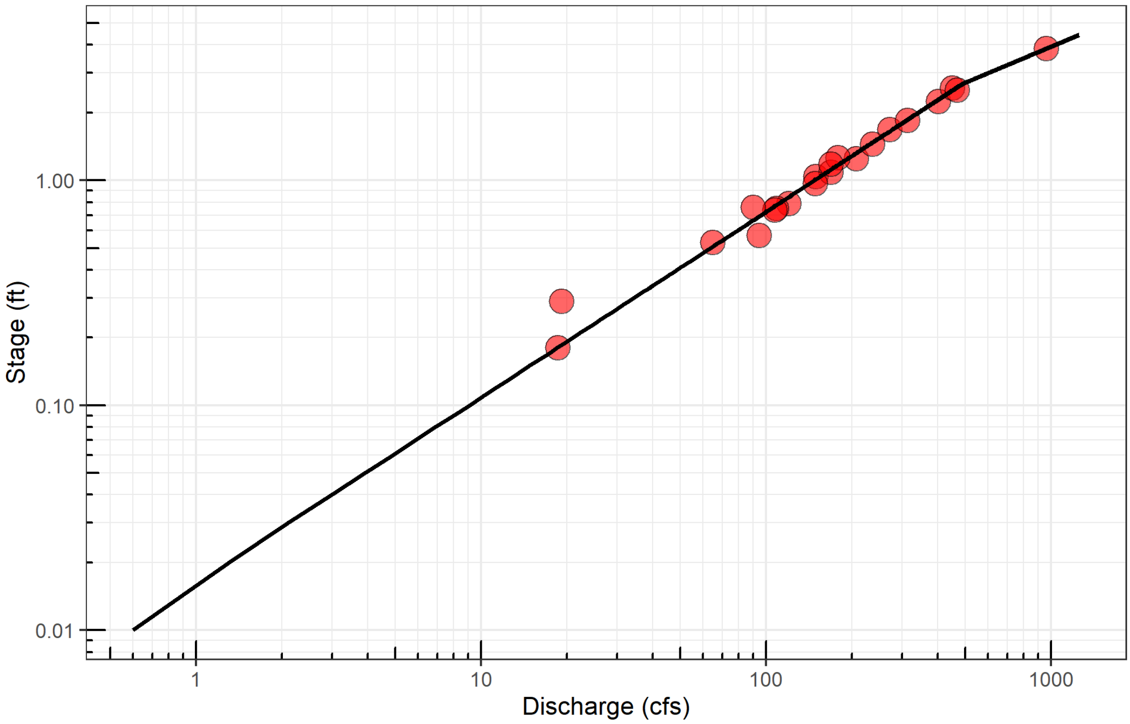


Mullet - Sumac Rd

Standard axis

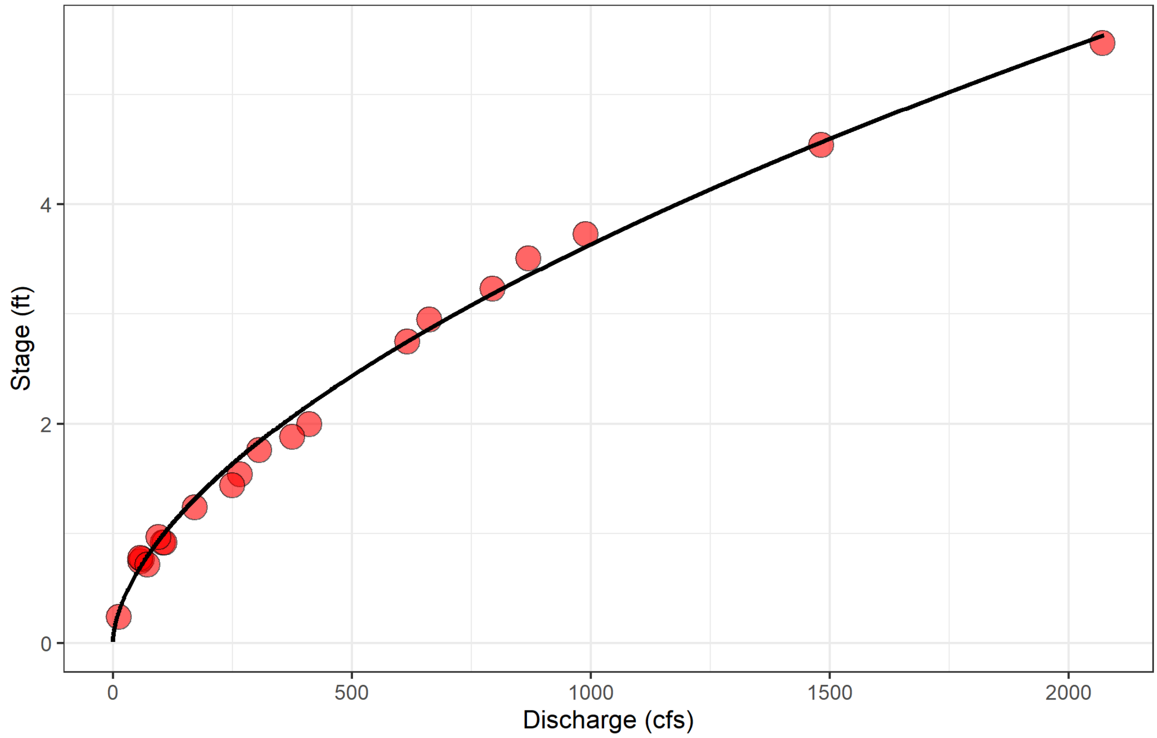


Log-Log axis

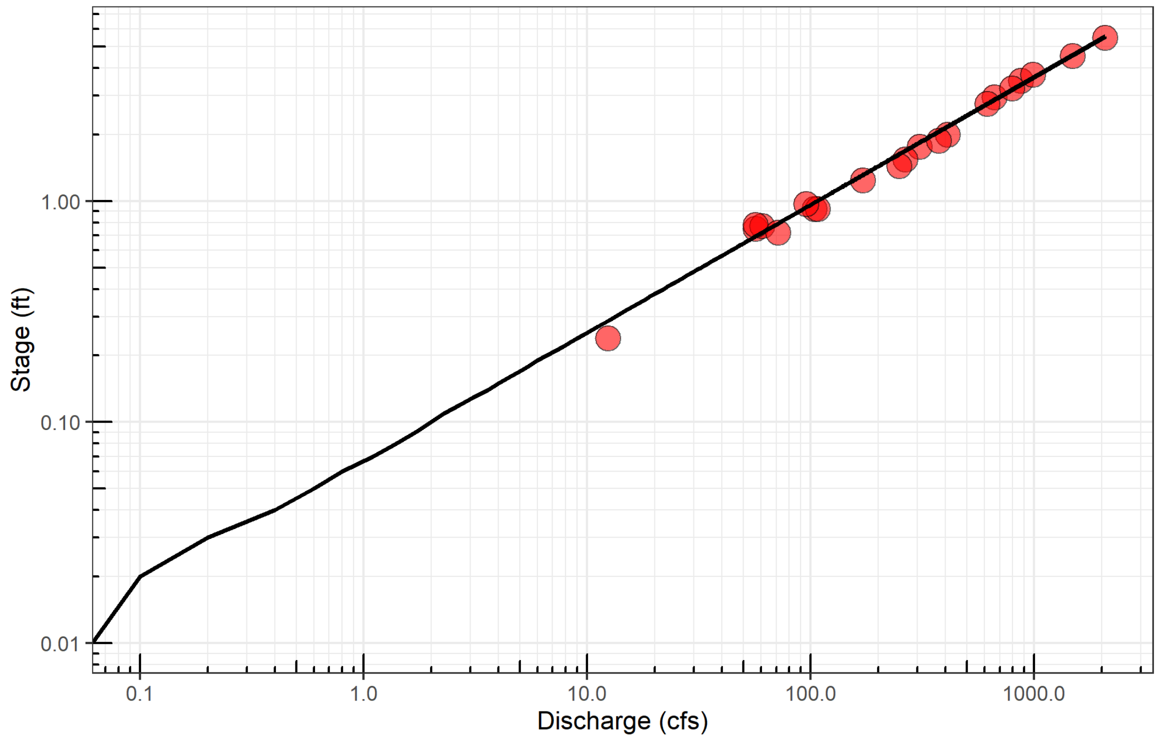


Onion - Ourtown Rd

Standard axis

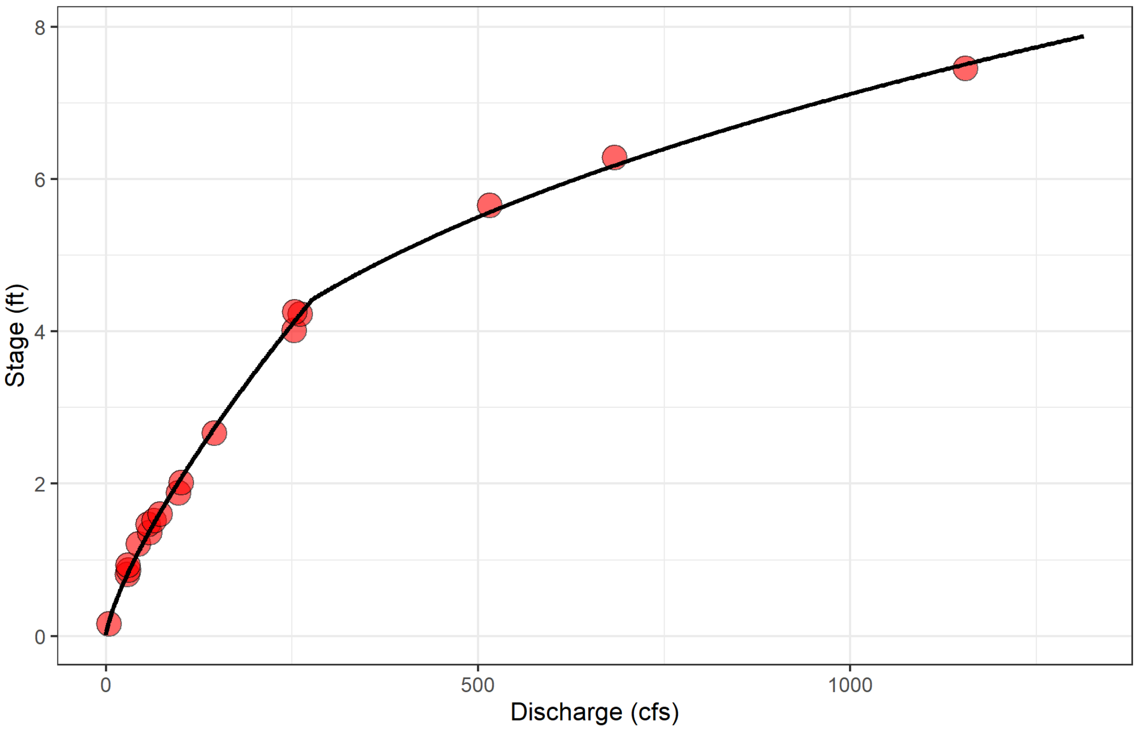


Log-Log axis

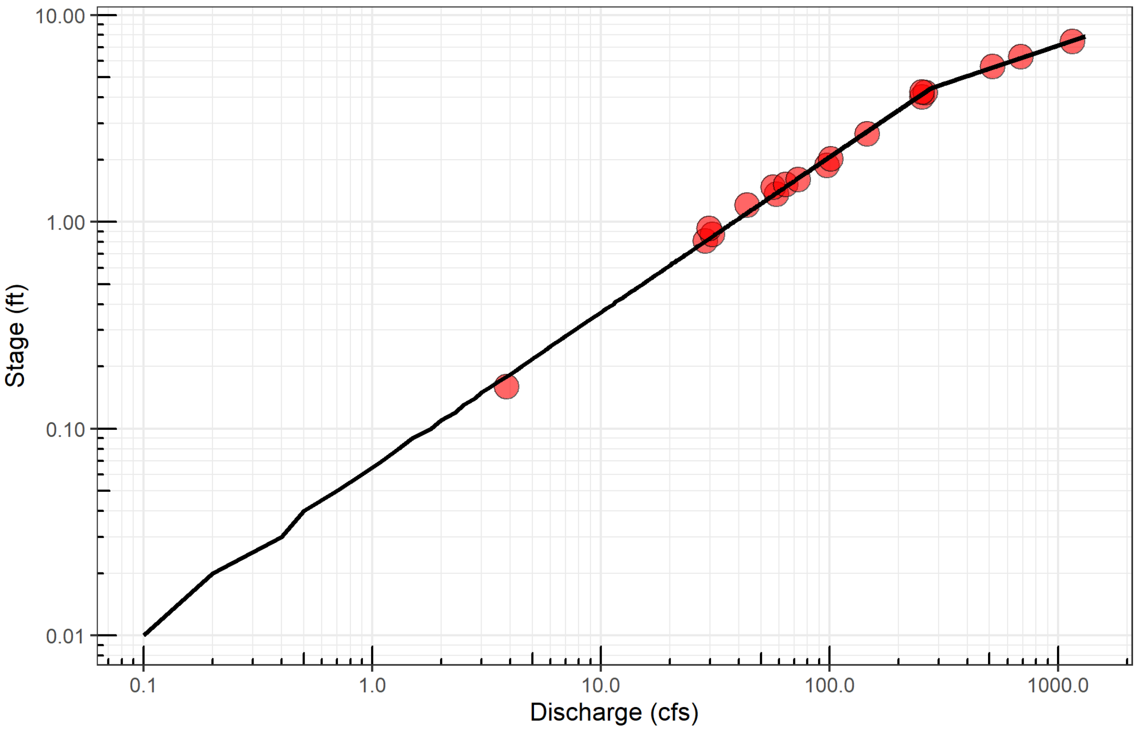


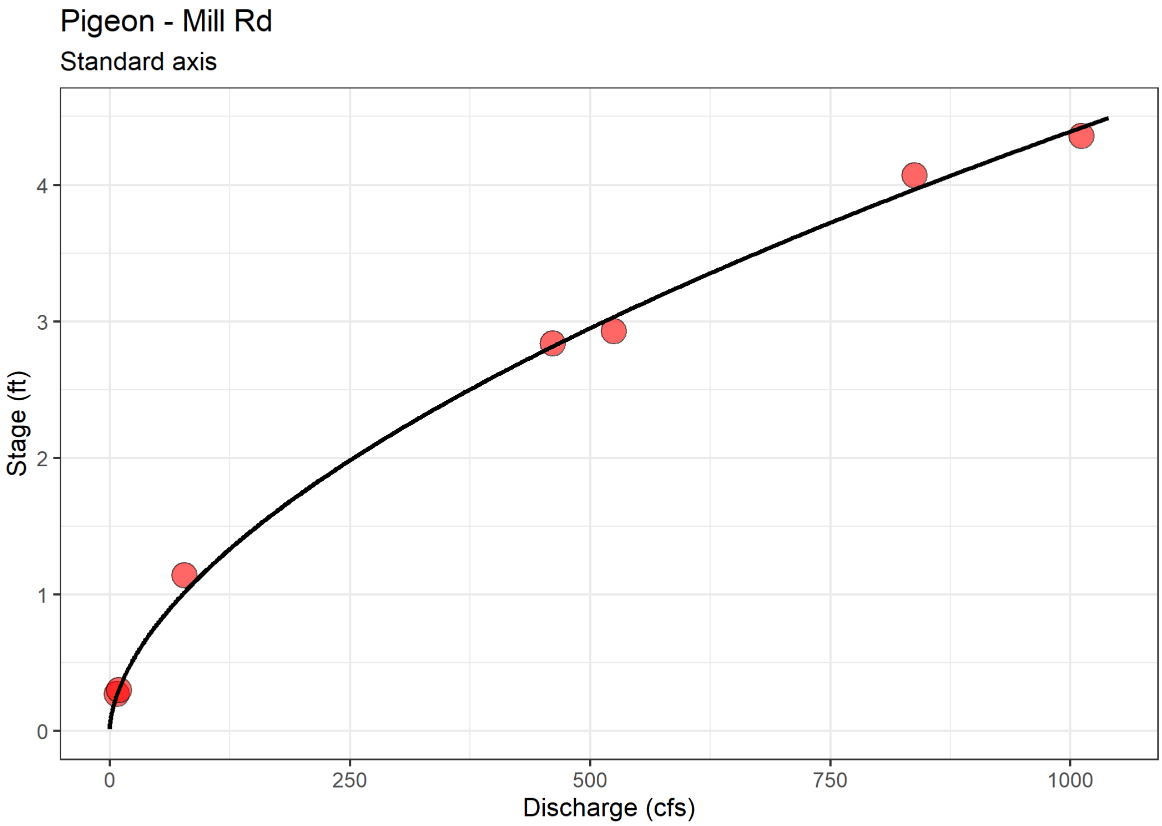
Pigeon - CTH A and River Rd

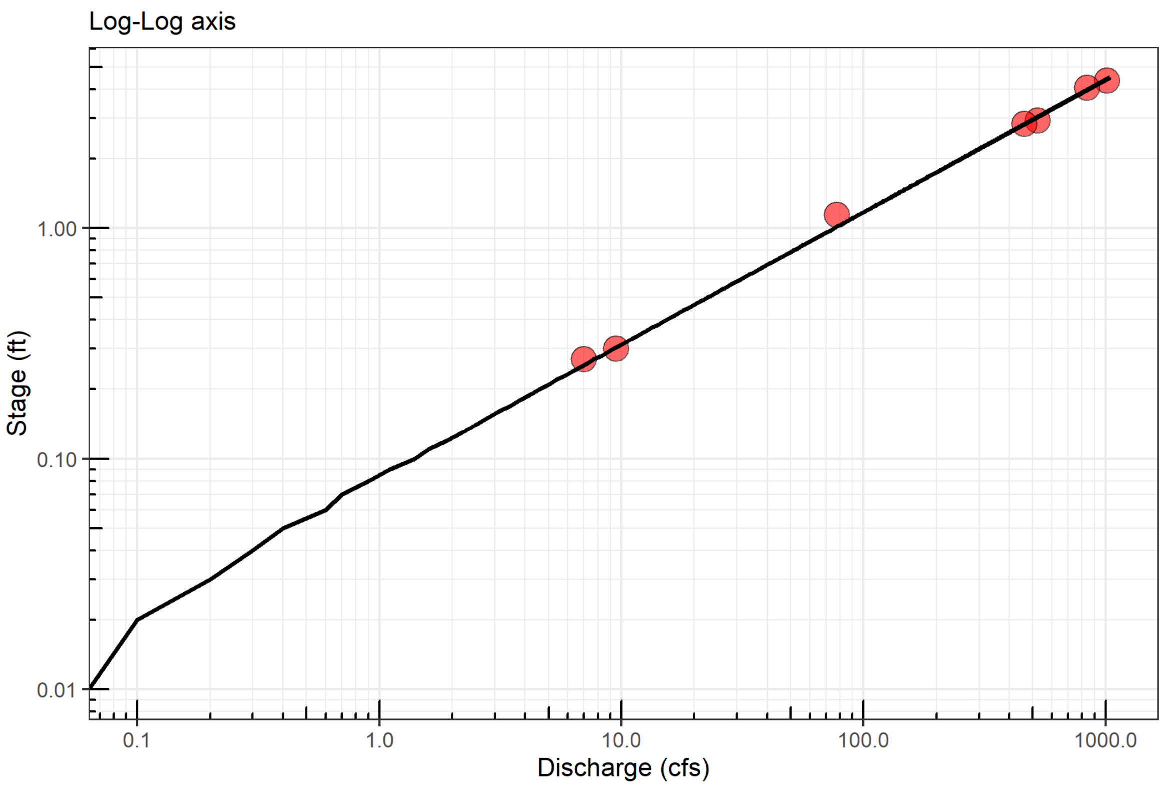
Standard axis



Log-Log axis

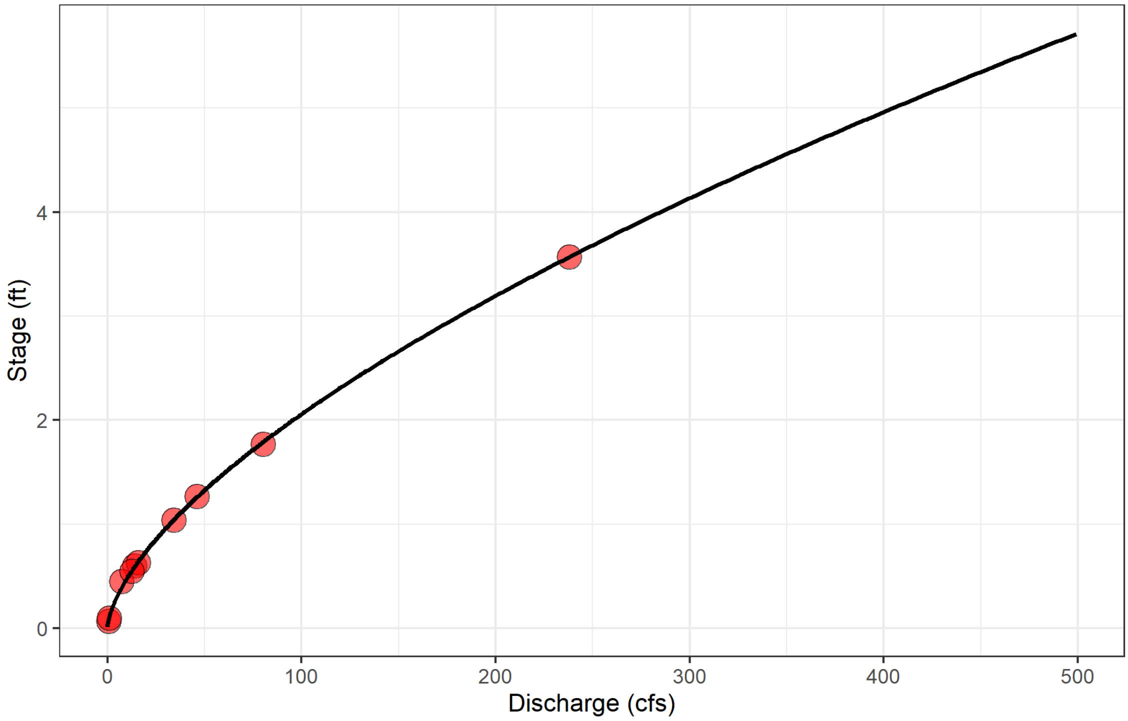



Pigeon - Mill Rd
Standard axis
Stage (ft)
0
1
2
3
4
0
250
500
750
1000
Discharge (cfs)

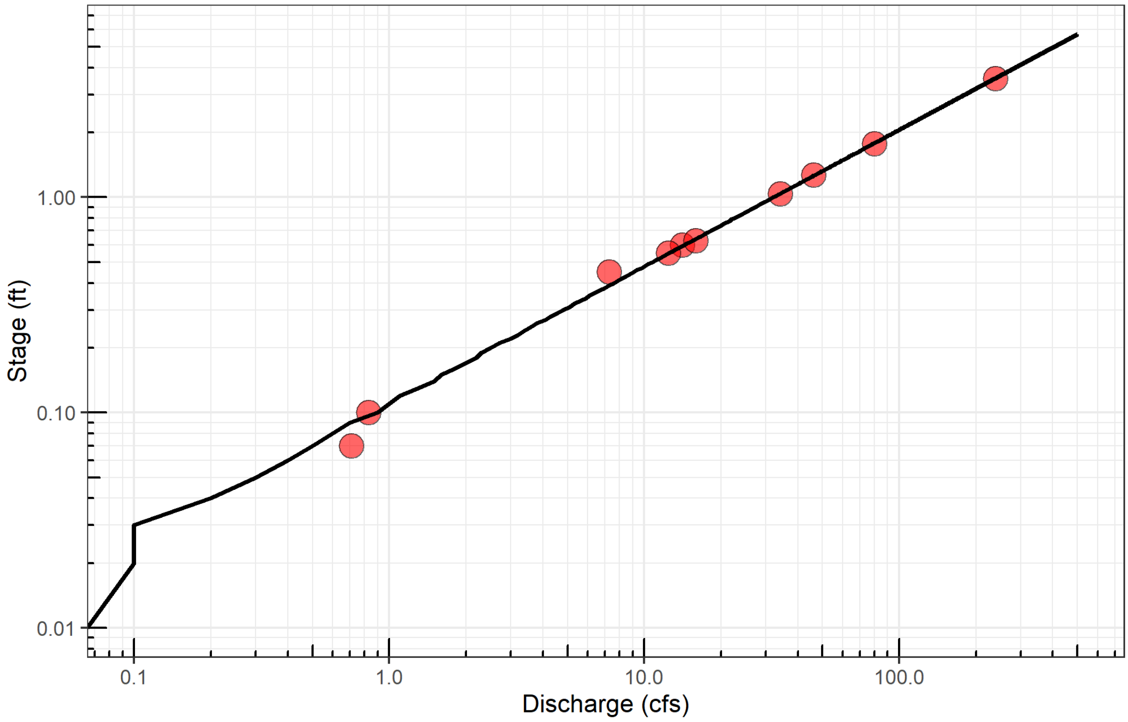

Log-Log axis
Stage (ft)
0.01
0.10
1.00
0.1
1.0
10.0
100.0
1000.0
Discharge (cfs)

Point - Centerville Rd

Standard axis

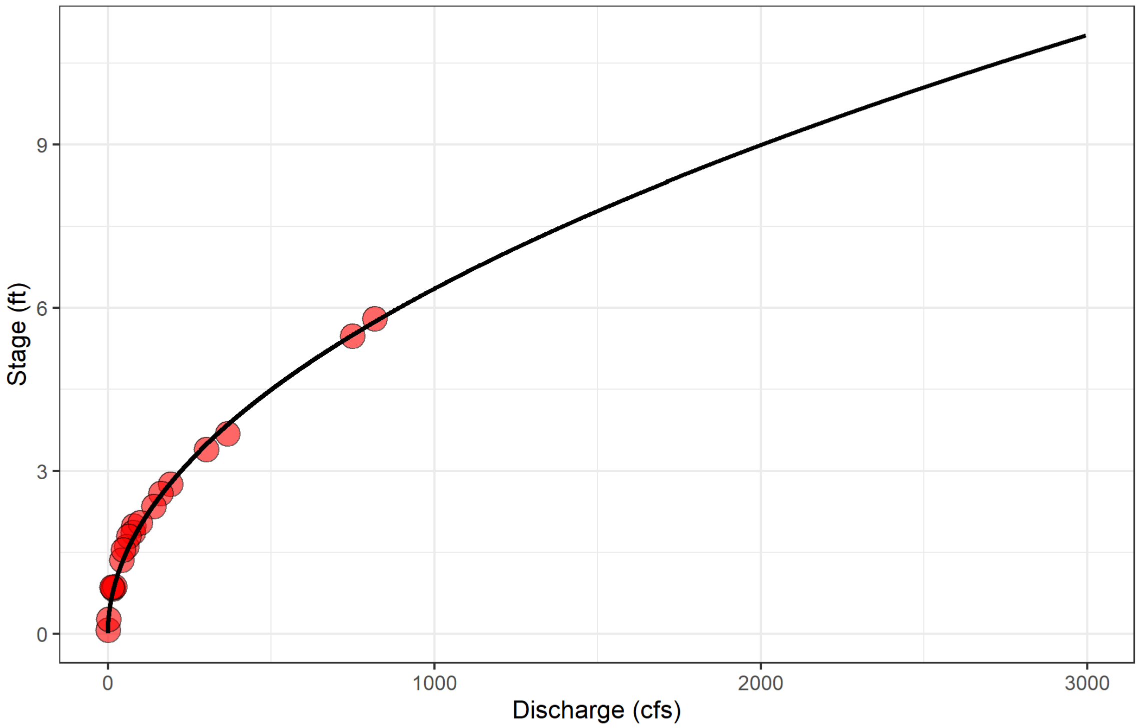


Log-Log axis

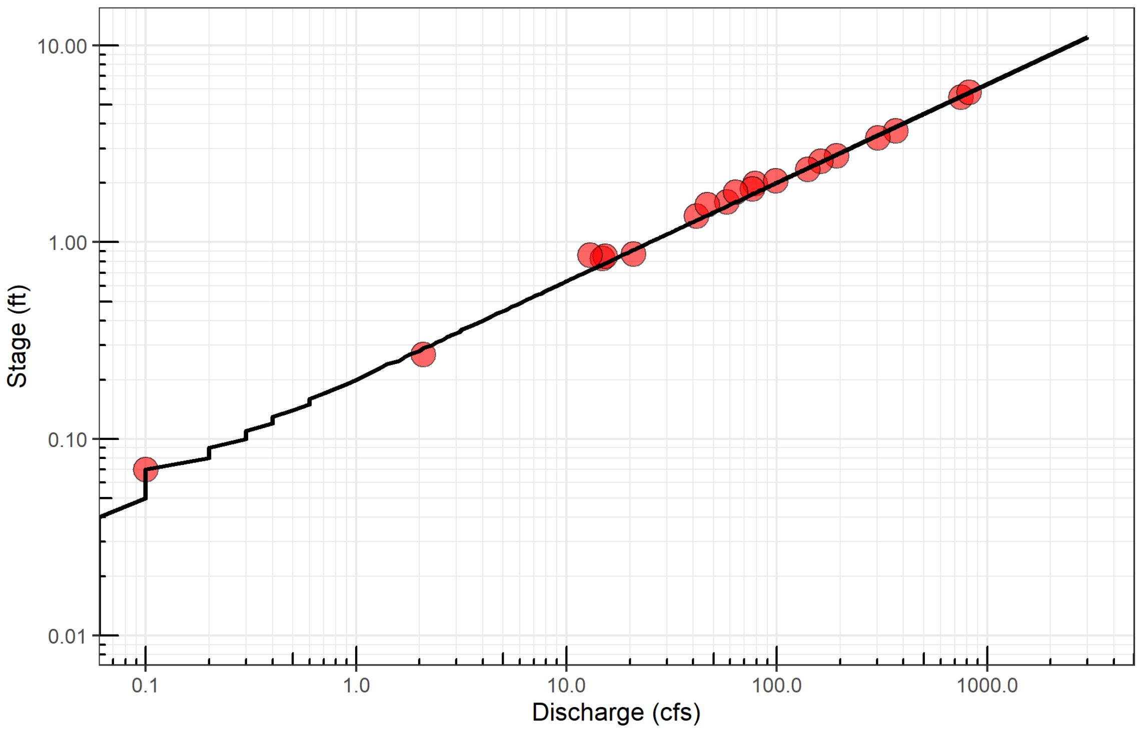


Sauk - Mink Ranch Rd

Standard axis

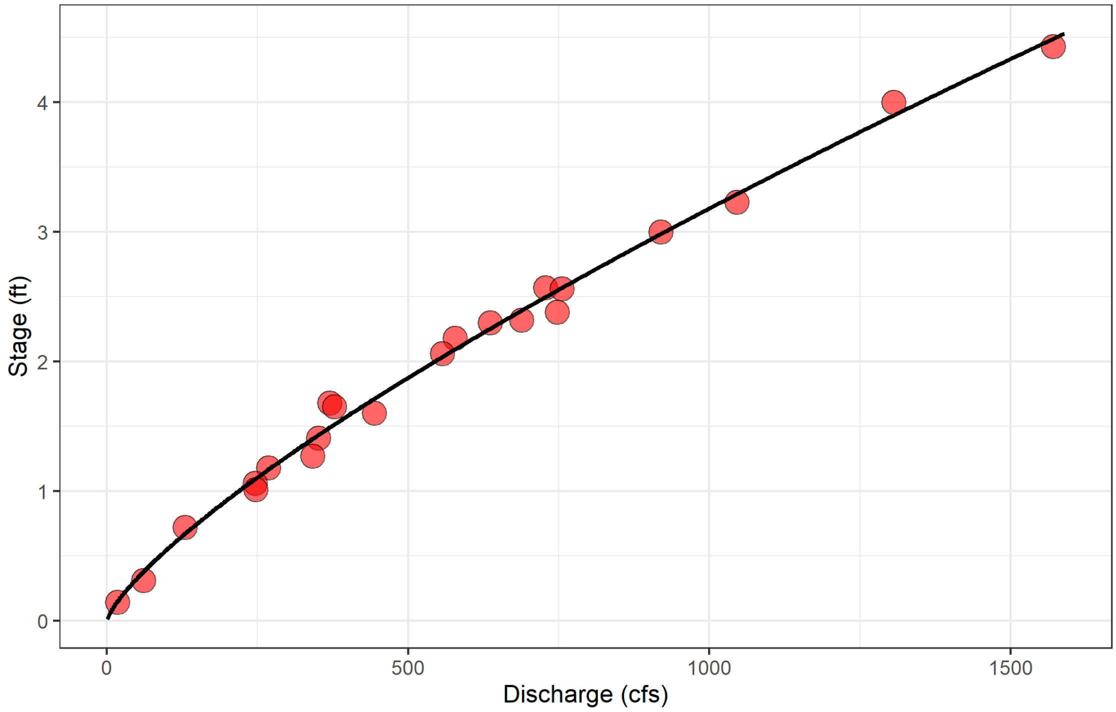


Log-Log axis

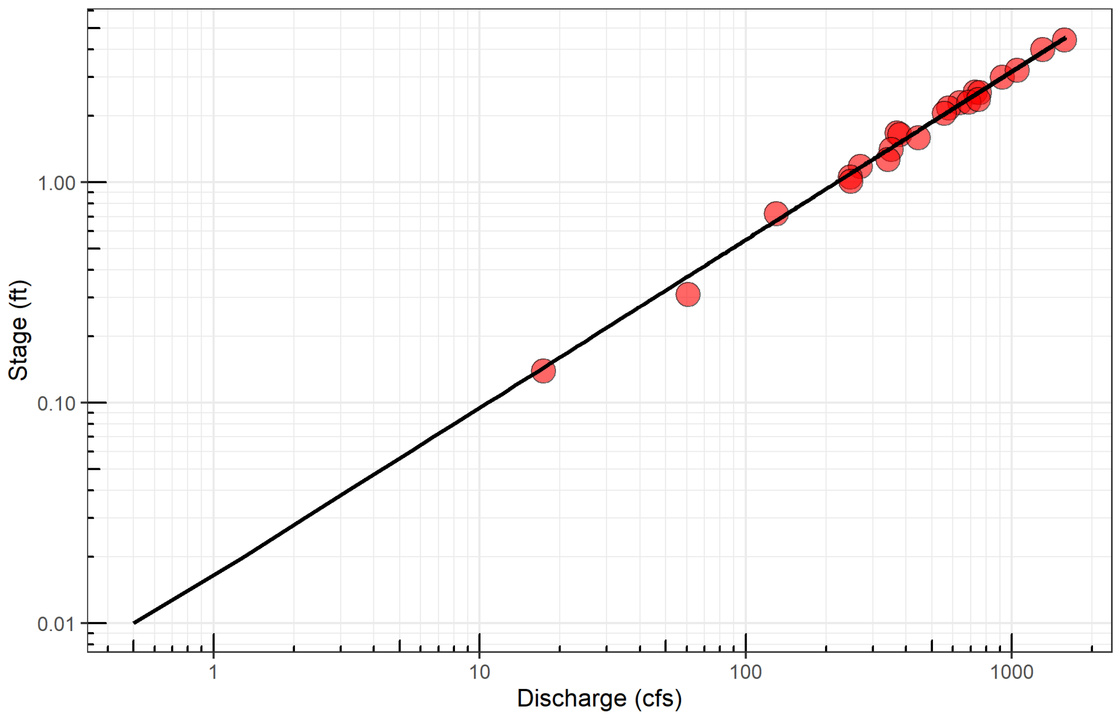


Sheboygan - HWY 57

Standard axis

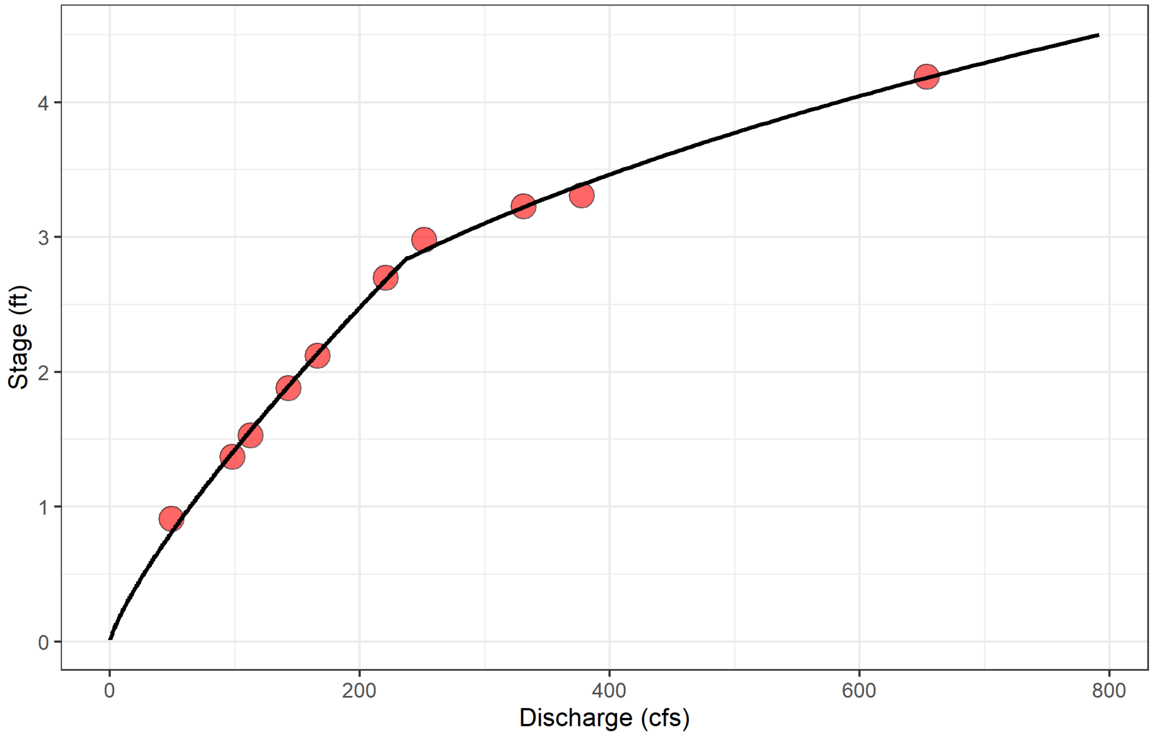


Log-Log axis

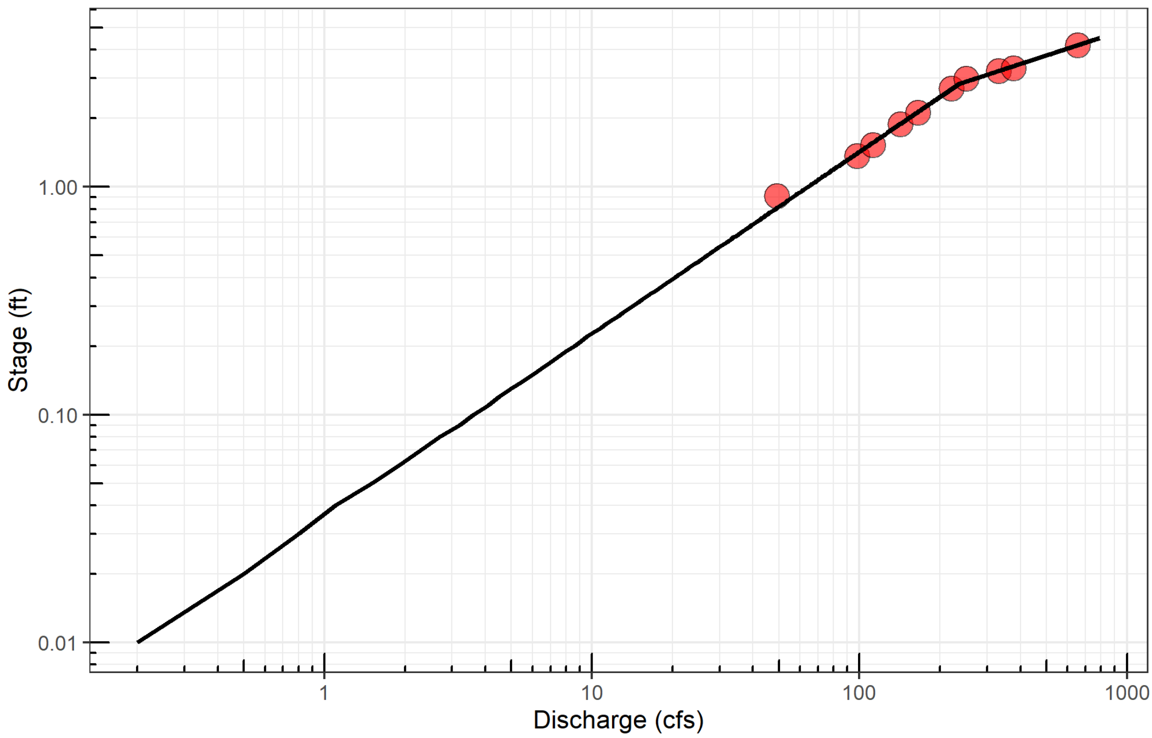


Sheboygan - Palm Tree Rd

Standard axis

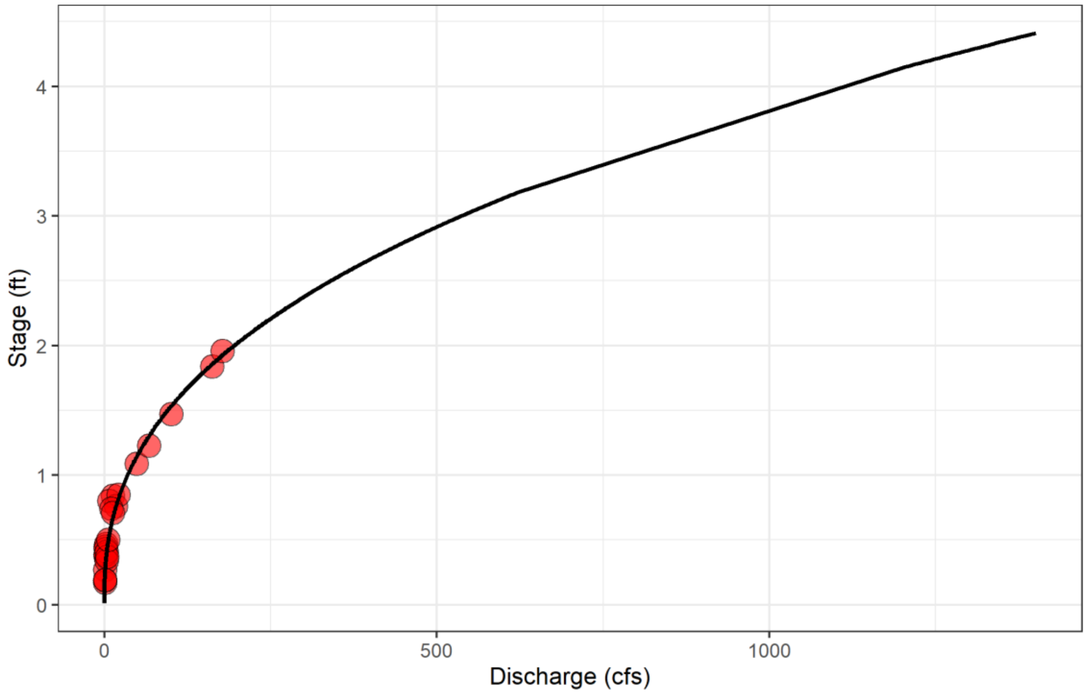


Log-Log axis

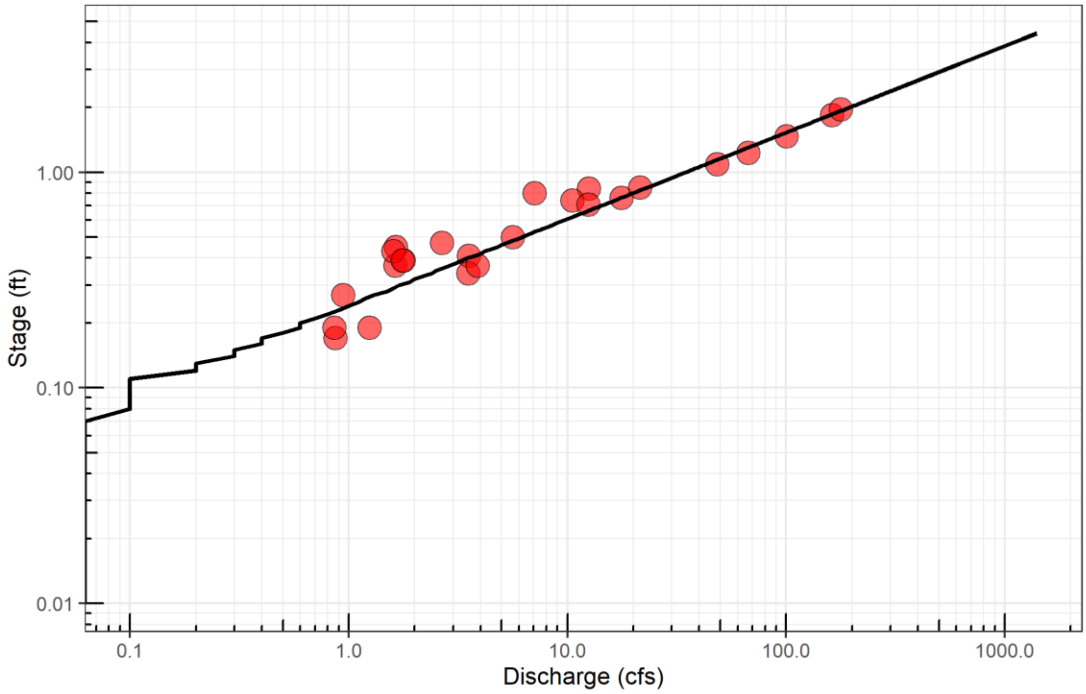


Silver - CTH LS

Standard axis

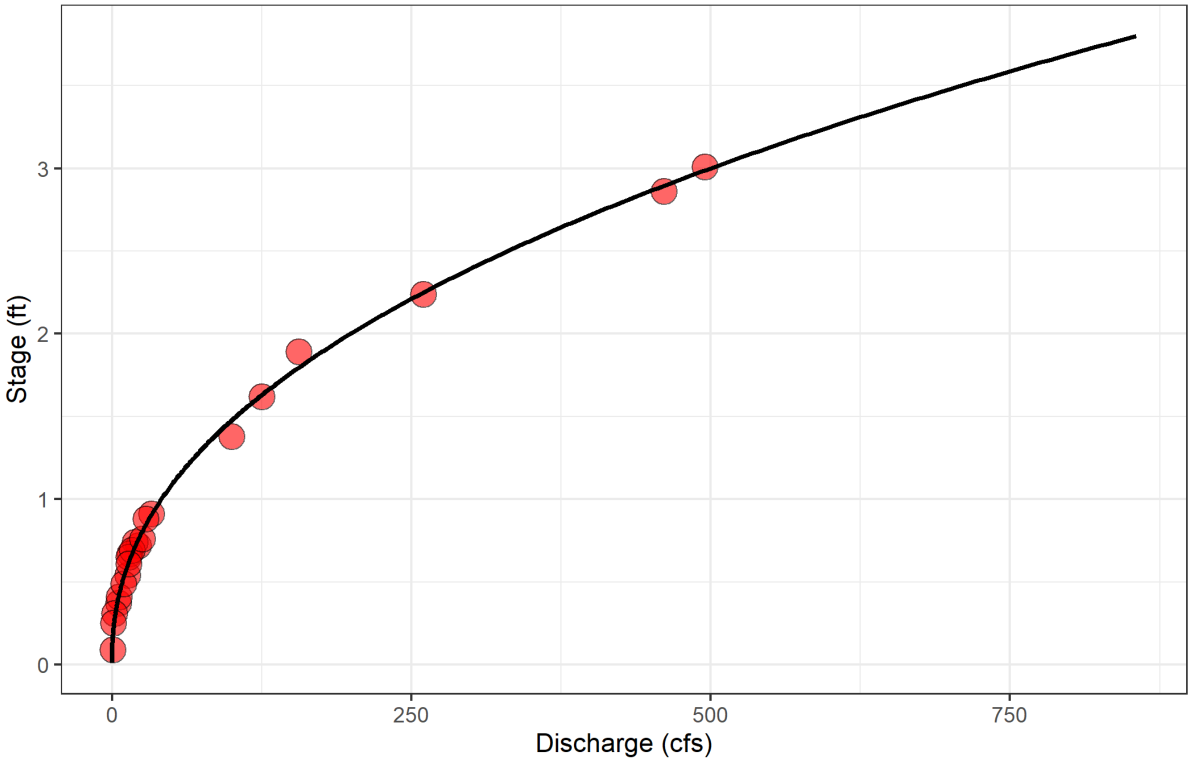


Log-Log axis

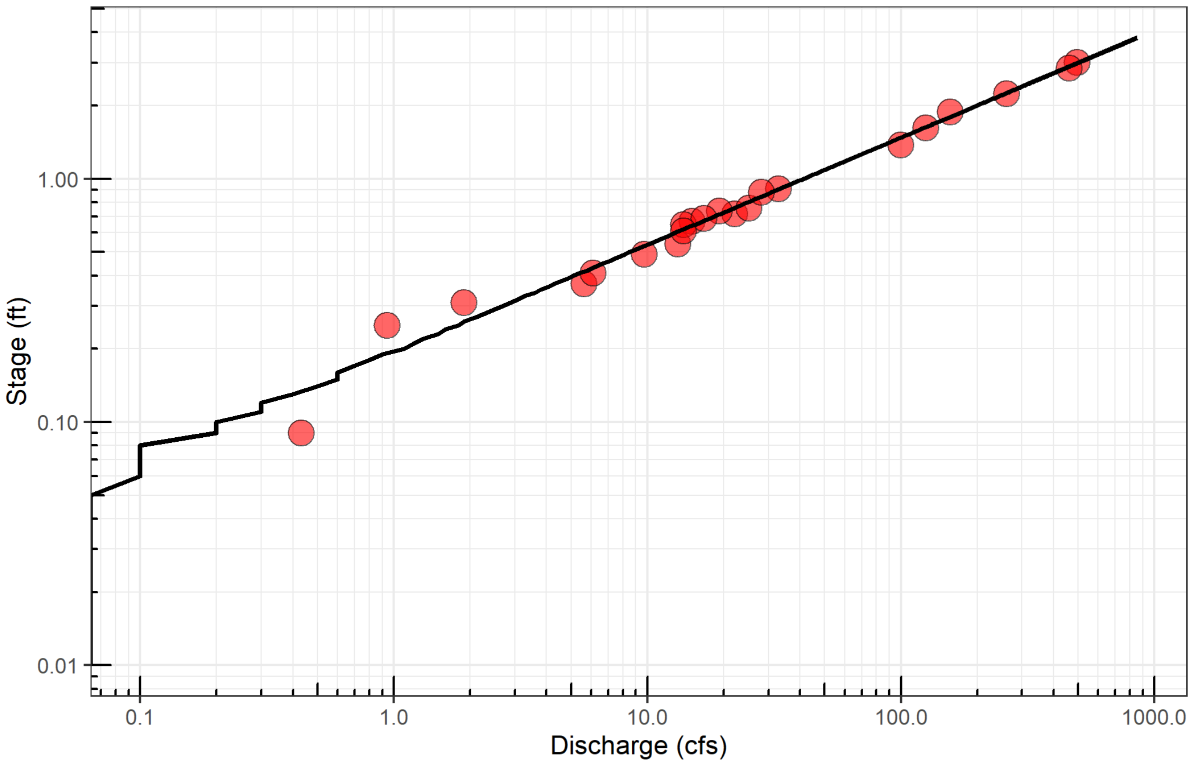


Silver - Willow Dr

Standard axis

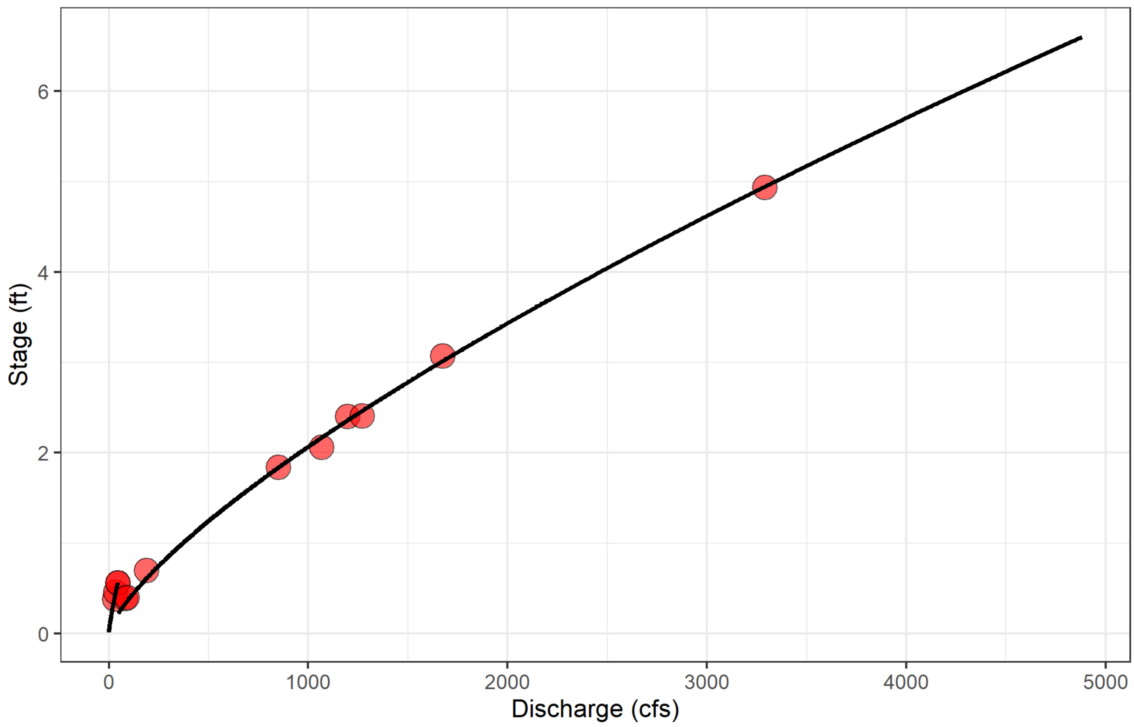


Log-Log axis

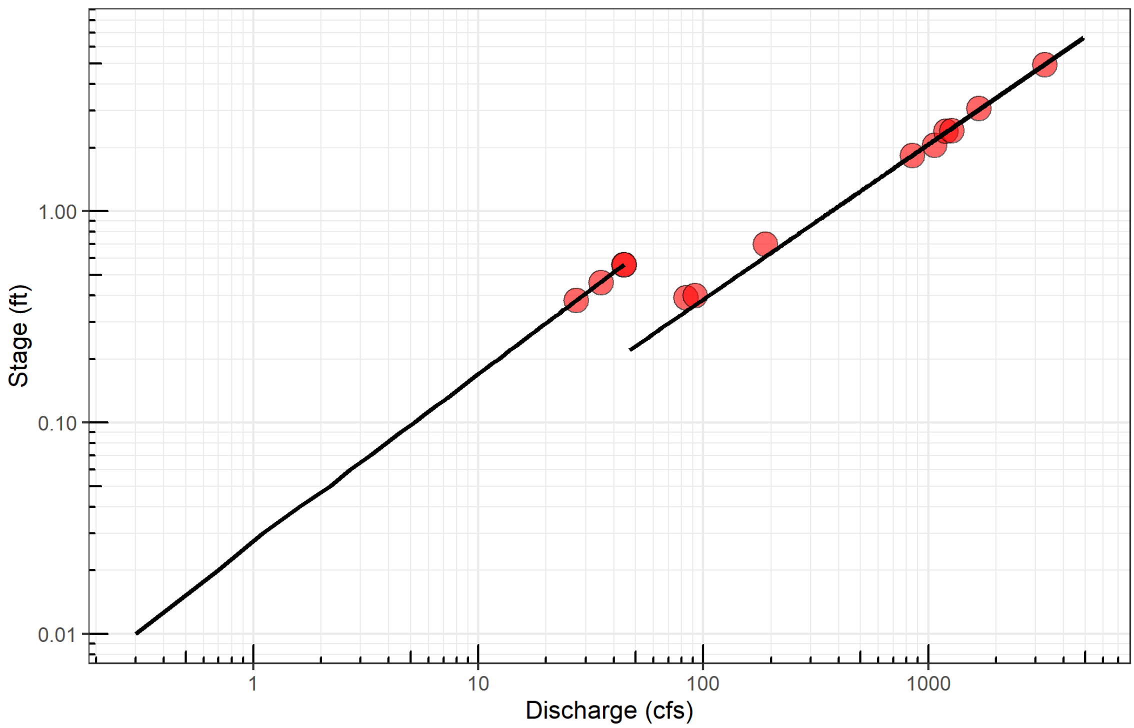


West Twin - CTH V

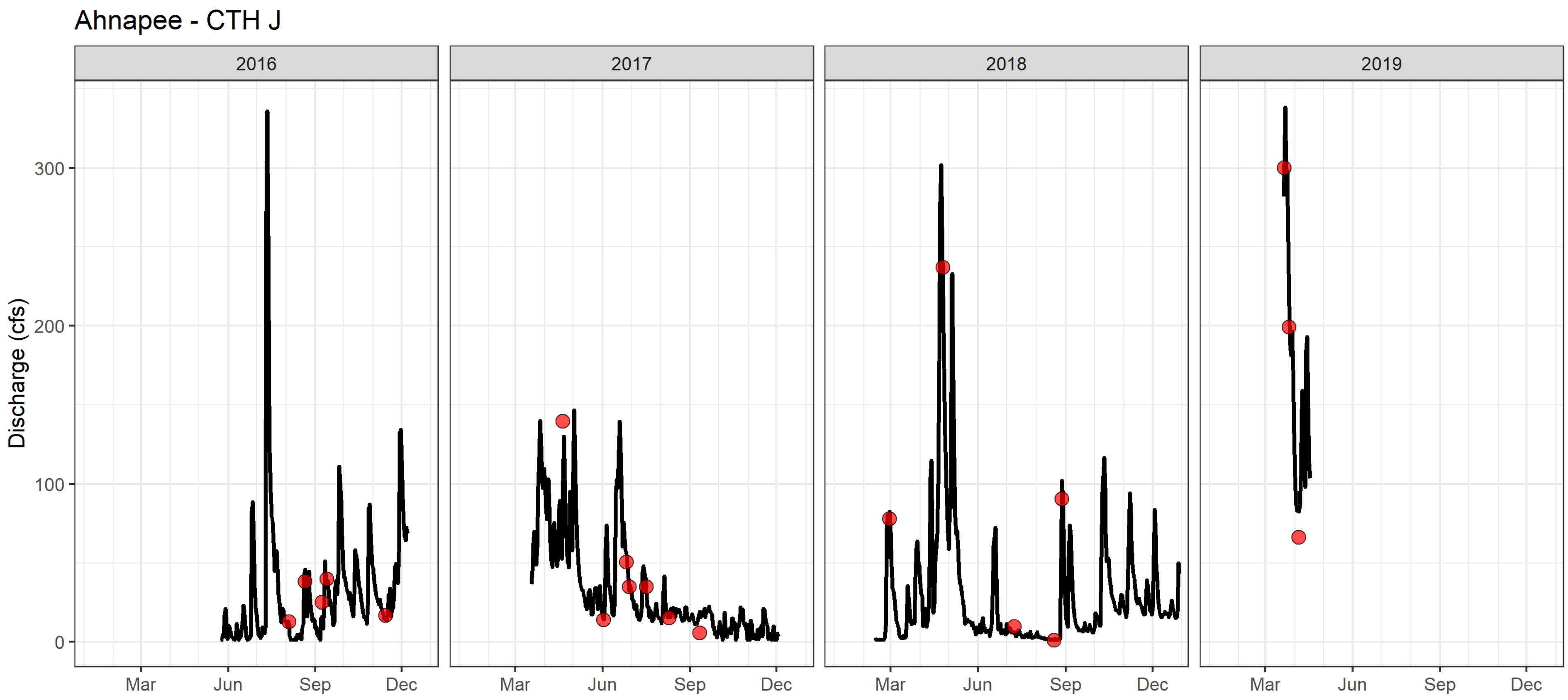
Standard axis



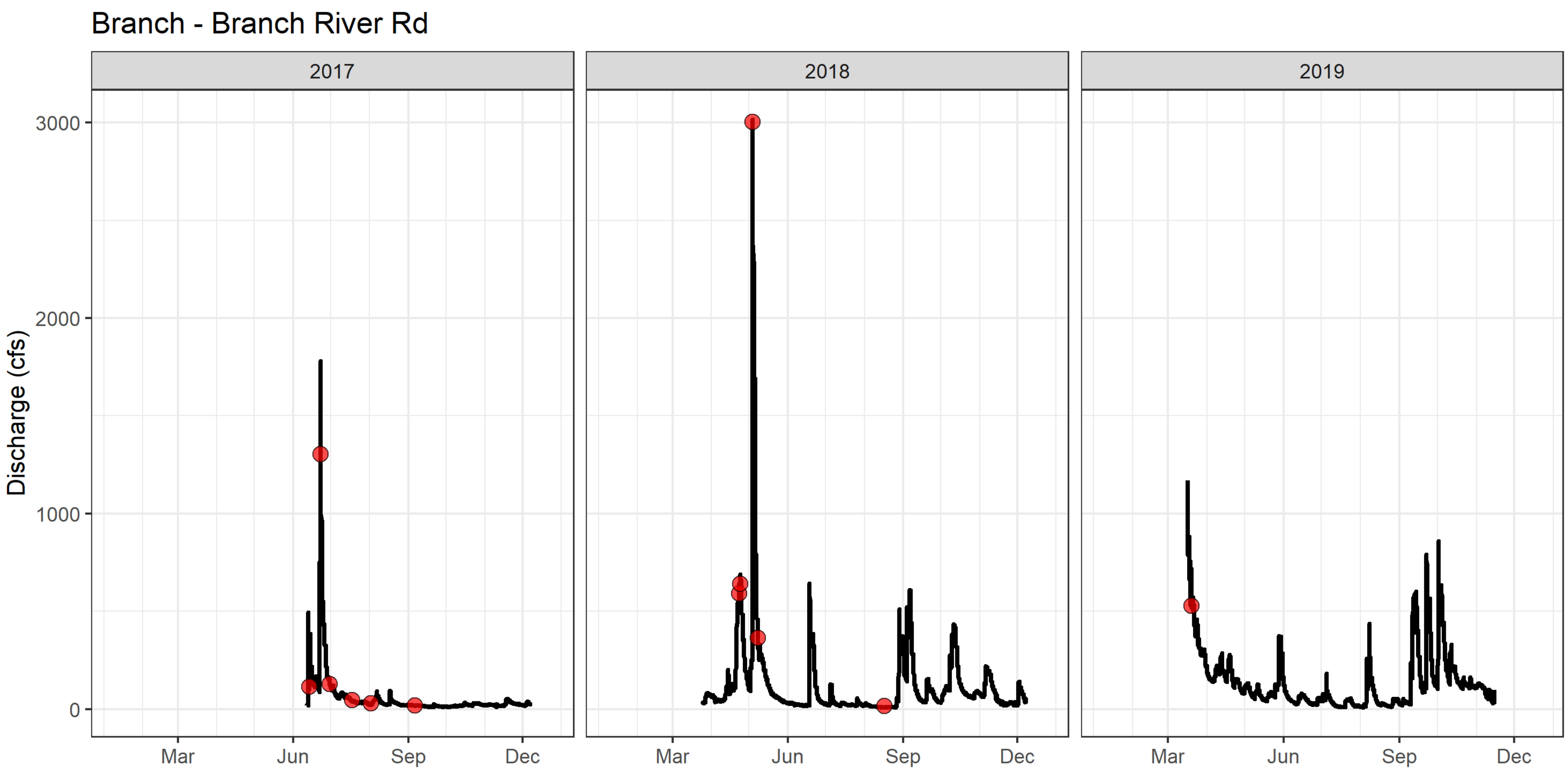
Log-Log axis



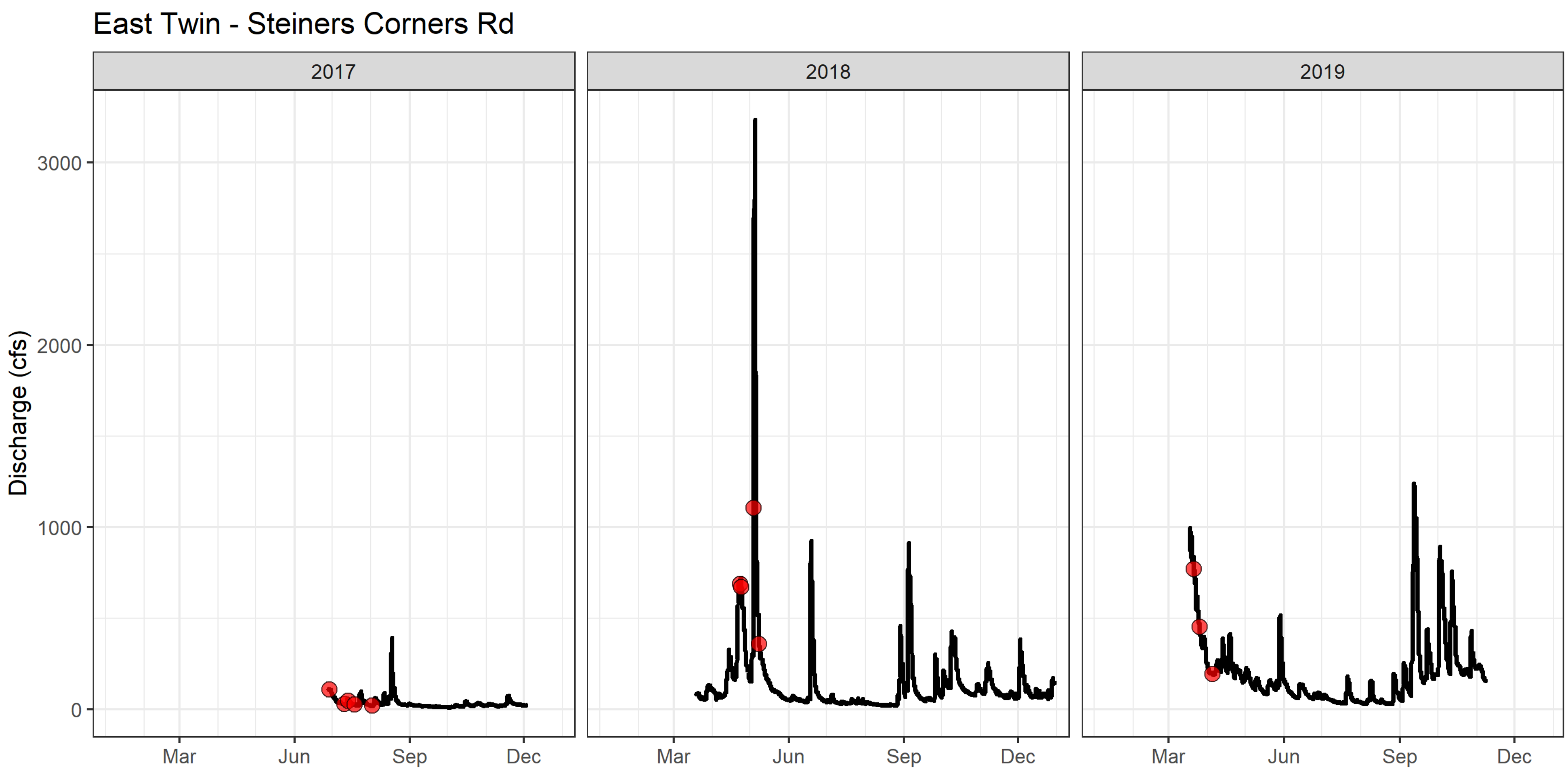
8.2 Continuous Discharge Records

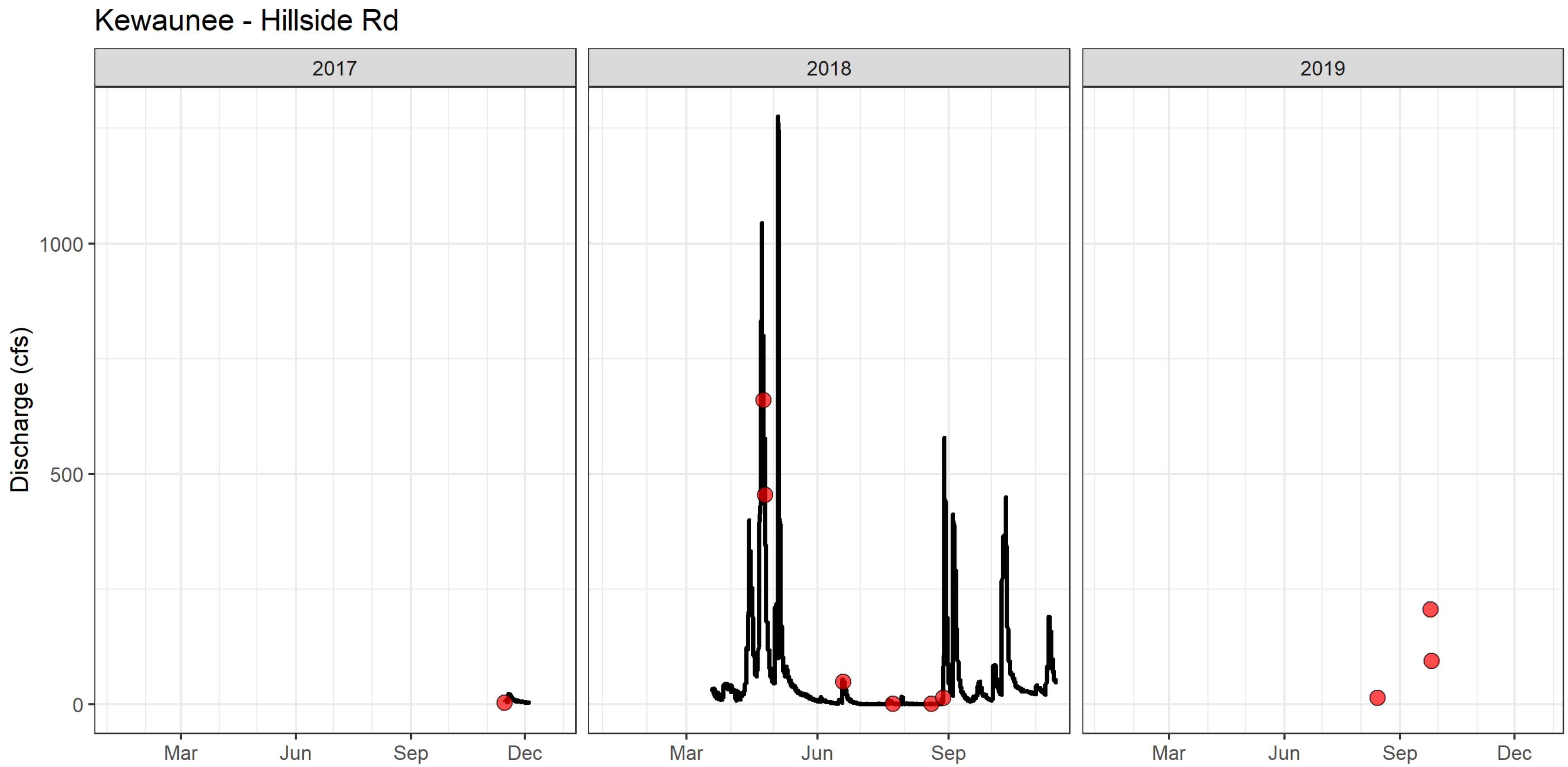


Ahnapee - CTH J
2016
2017
2018
2019
Discharge (cfs)
300
200
100
0
Mar
Jun
Sep
Dec



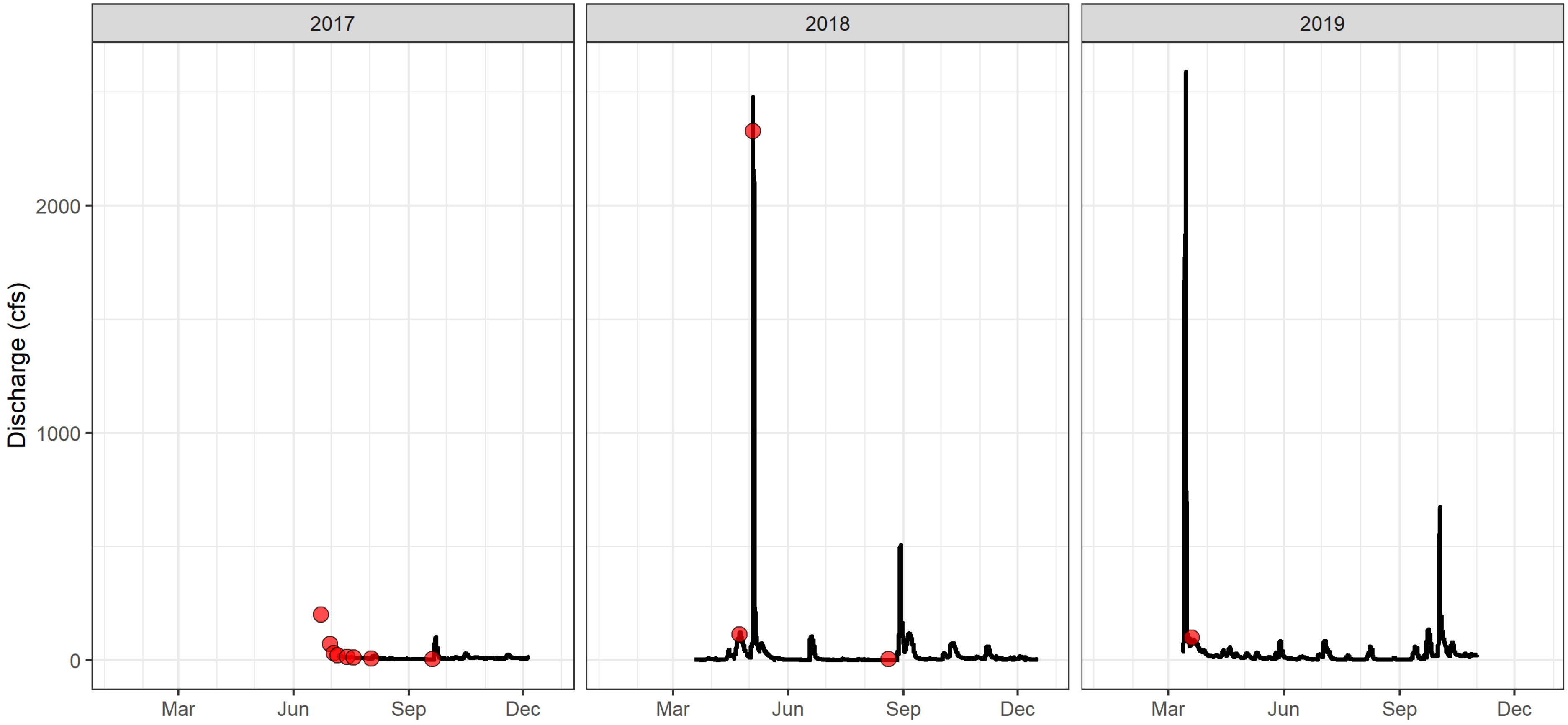
Branch - Branch River Rd
2017
2018
2019
Discharge (cfs)
3000
2000
1000
0
Mar
Jun
Sep
Dec


East Twin - Steiners Corners Rd
2017
2018
2019
Discharge (cfs)
3000
2000
1000
0
Mar
Jun
Sep
Dec

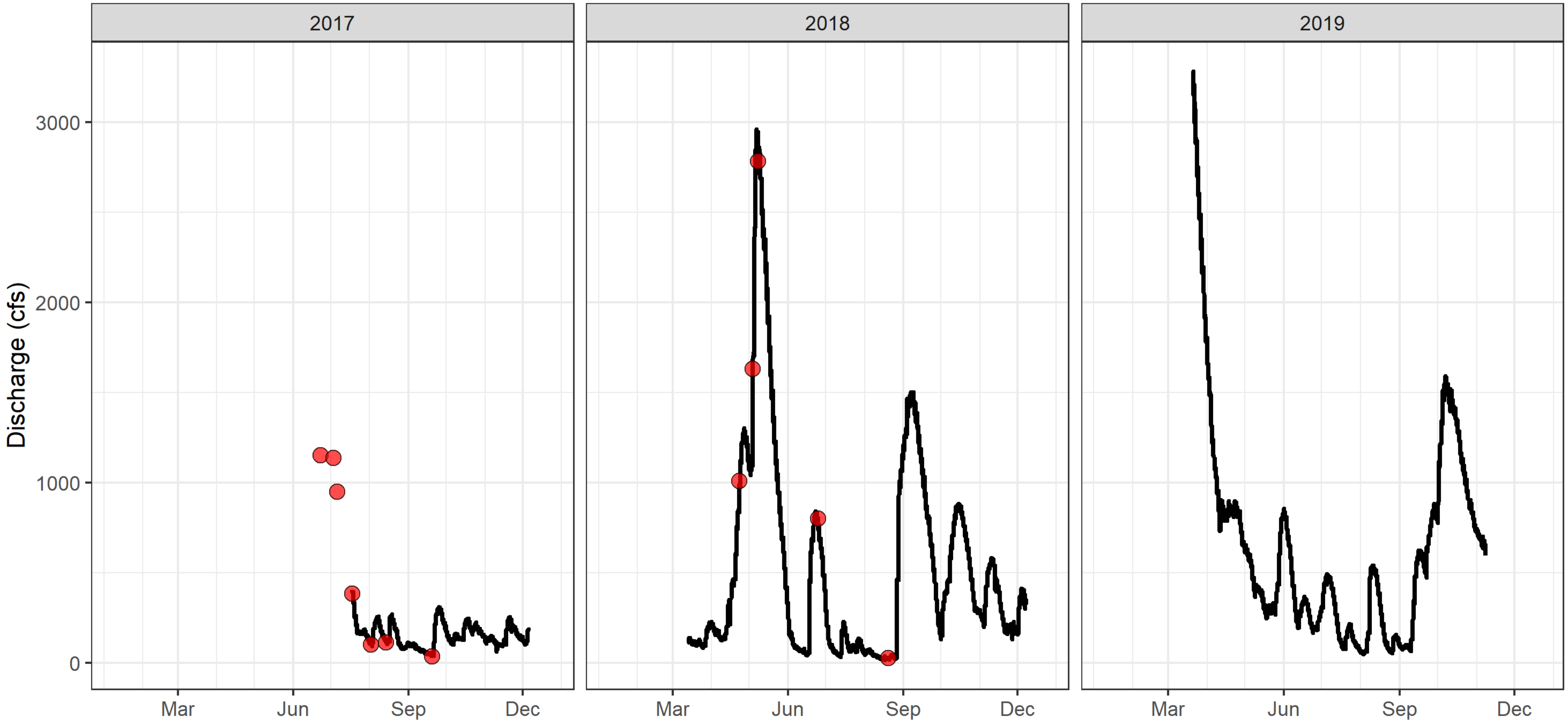


Kewaunee - Hillside Rd
2017
2018
2019
Discharge (cfs)
1000
500
0
Mar
Jun
Sep
Dec

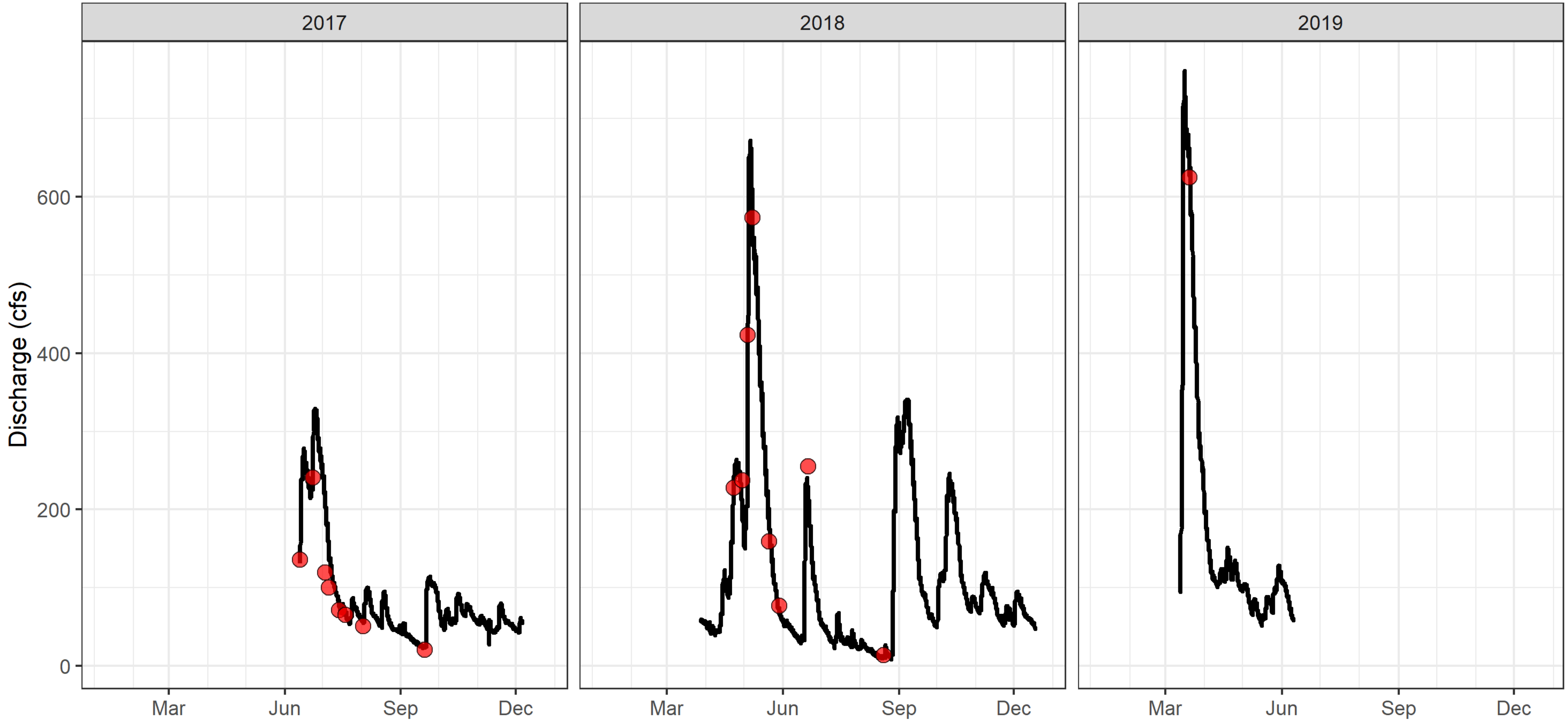
Killsnake - CTH Y

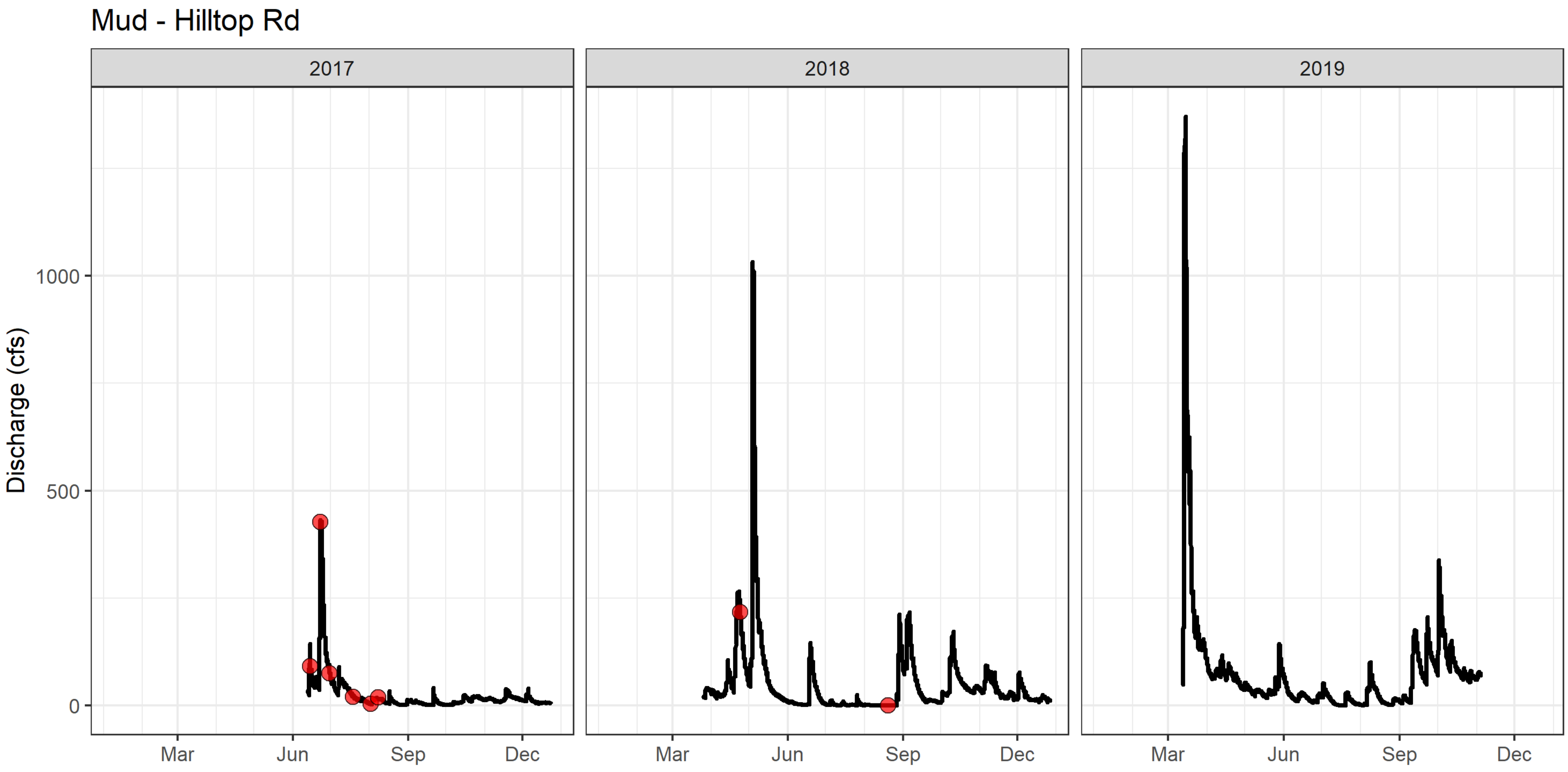


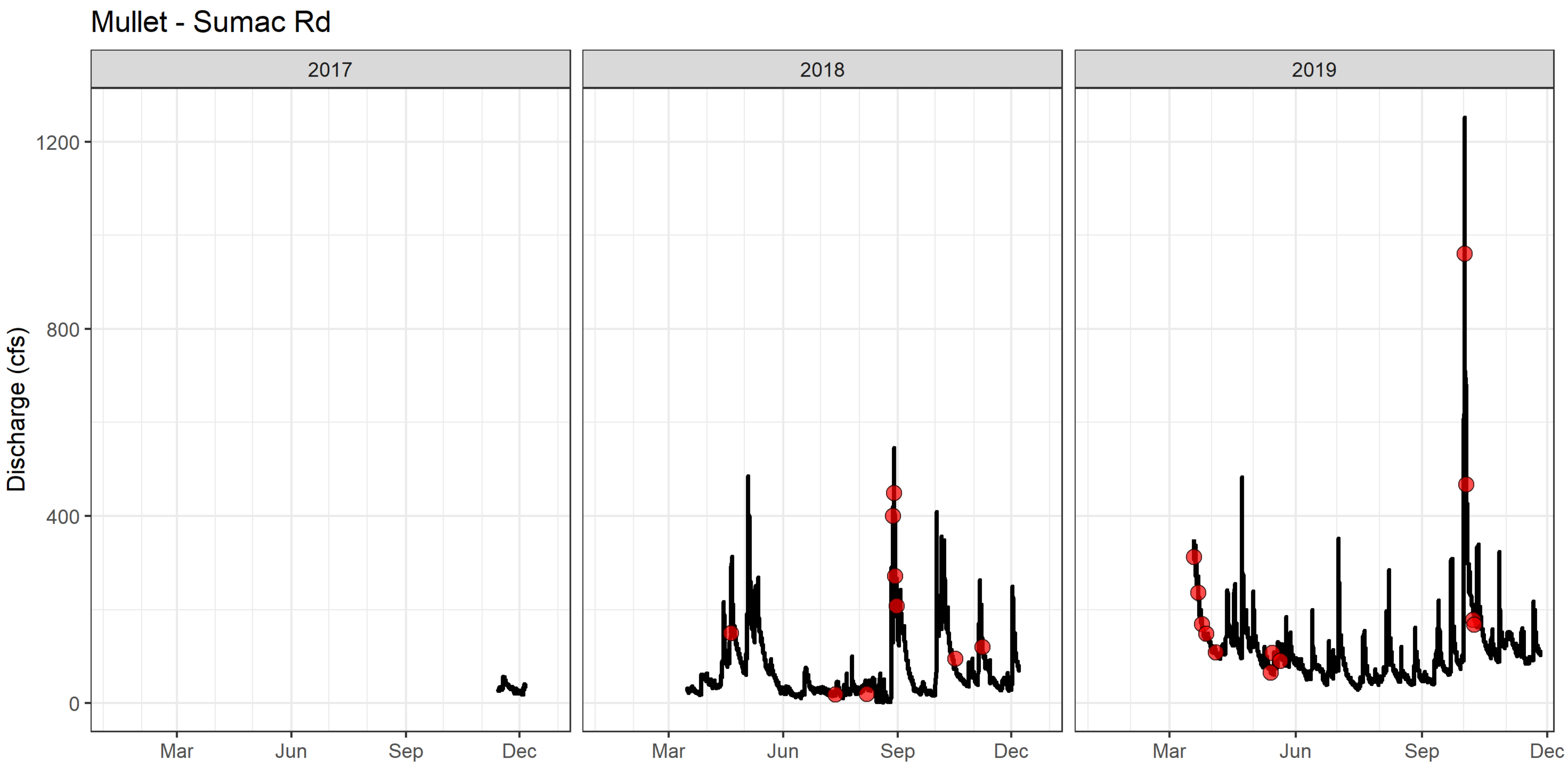
Manitowoc - Leist Rd

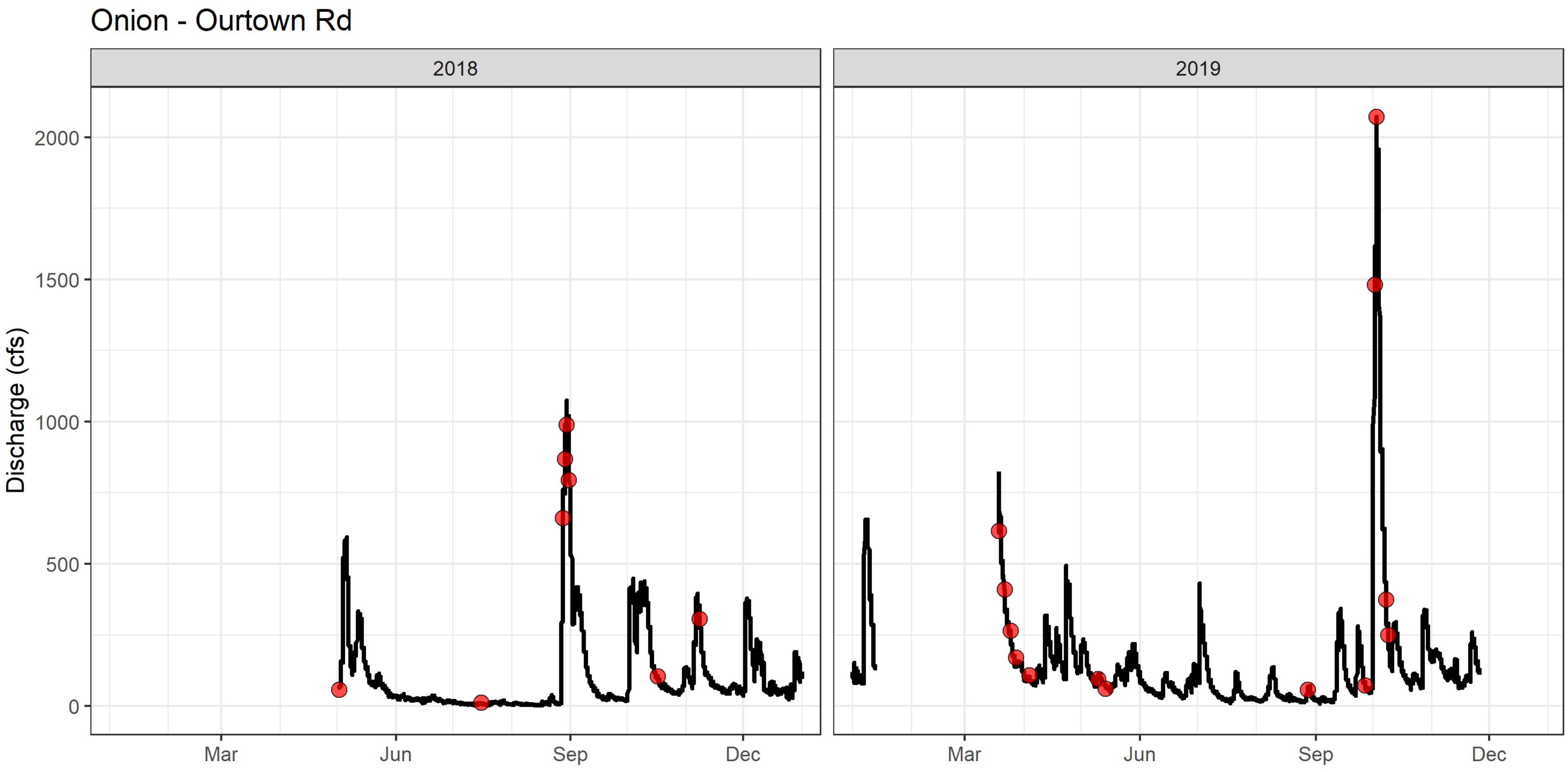


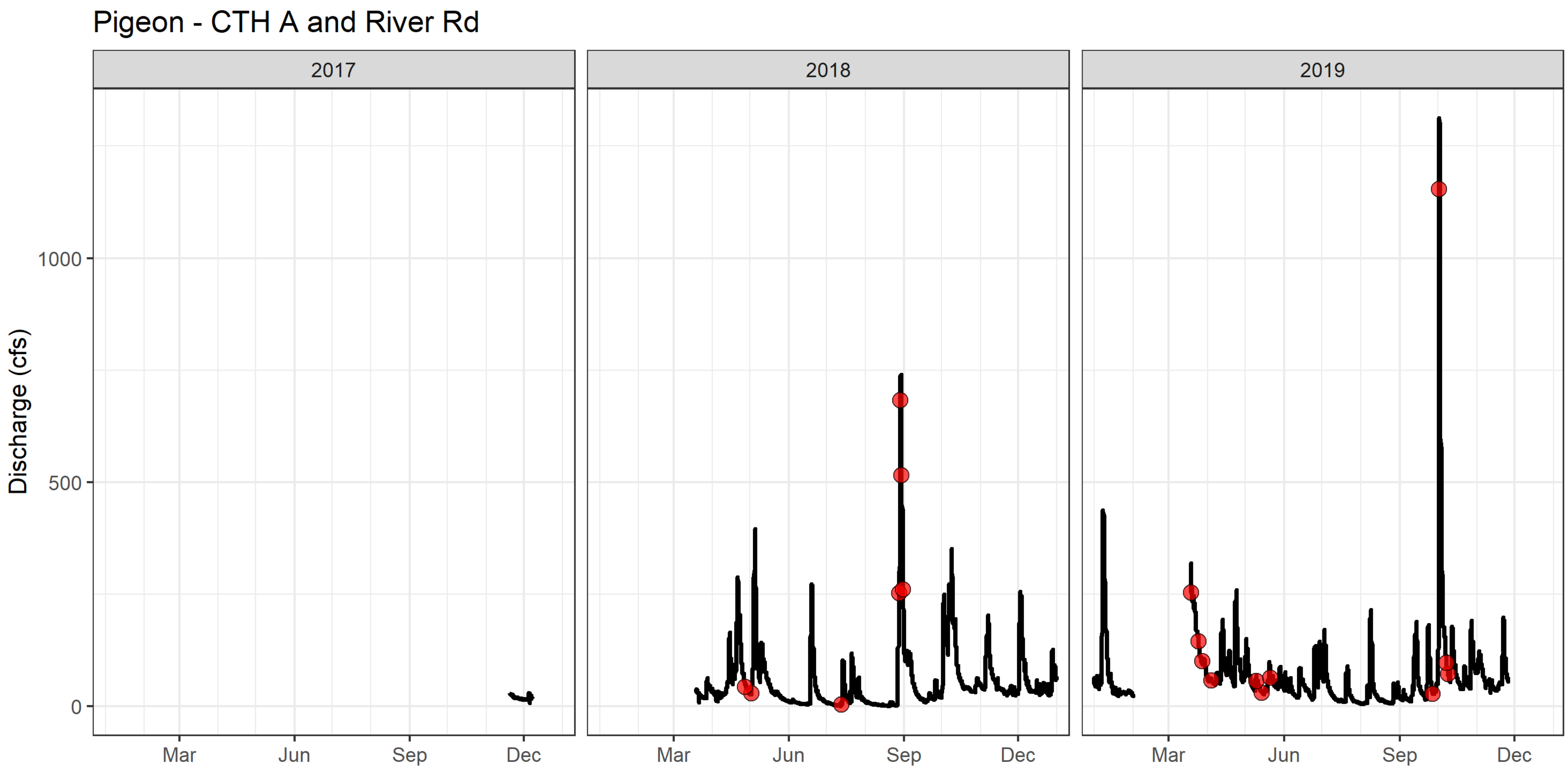
Manitowoc S. Branch - Lemke Rd

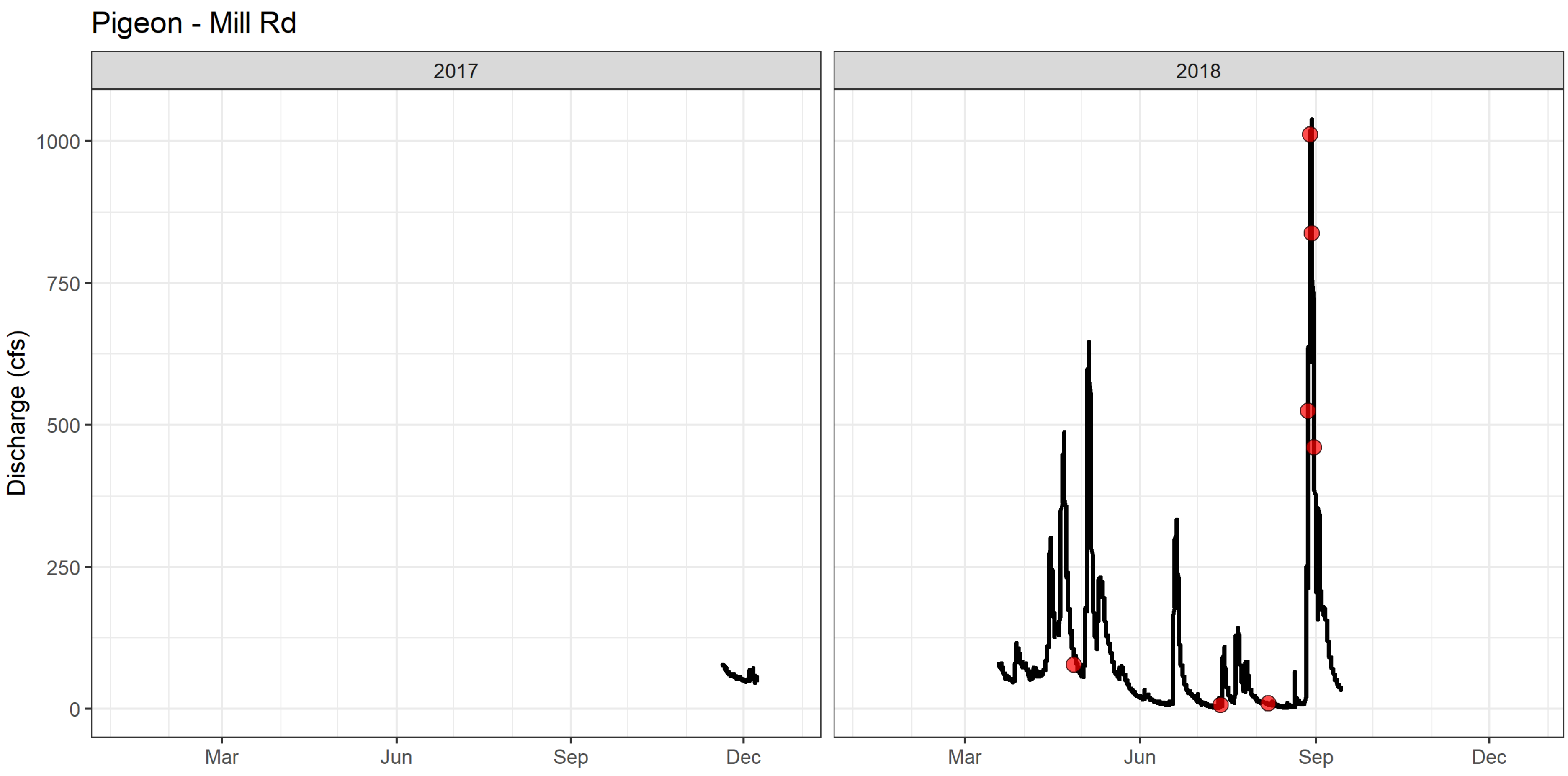



Mud - Hilltop Rd
2017
2018
2019
Discharge (cfs)
1000
500
0
Mar
Jun
Sep
Dec


Mullet - Sumac Rd
2017
2018
2019
Discharge (cfs)
1200
800
400
0
Mar
Jun
Sep
Dec

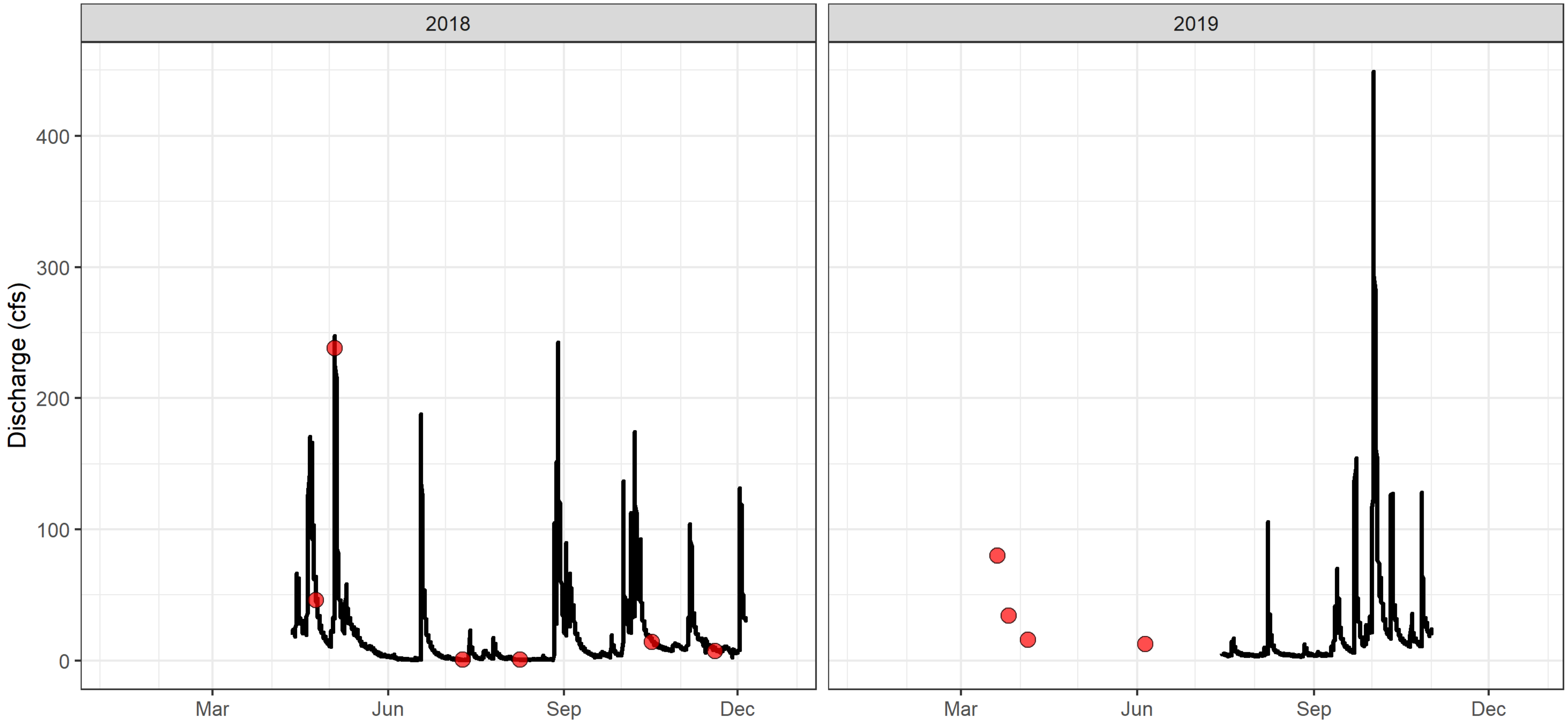

Onion - Ourtown Rd
2018
2019
Discharge (cfs)
2000
1500
1000
500
0
Mar
Jun
Sep
Dec
Mar
Jun
Sep
Dec

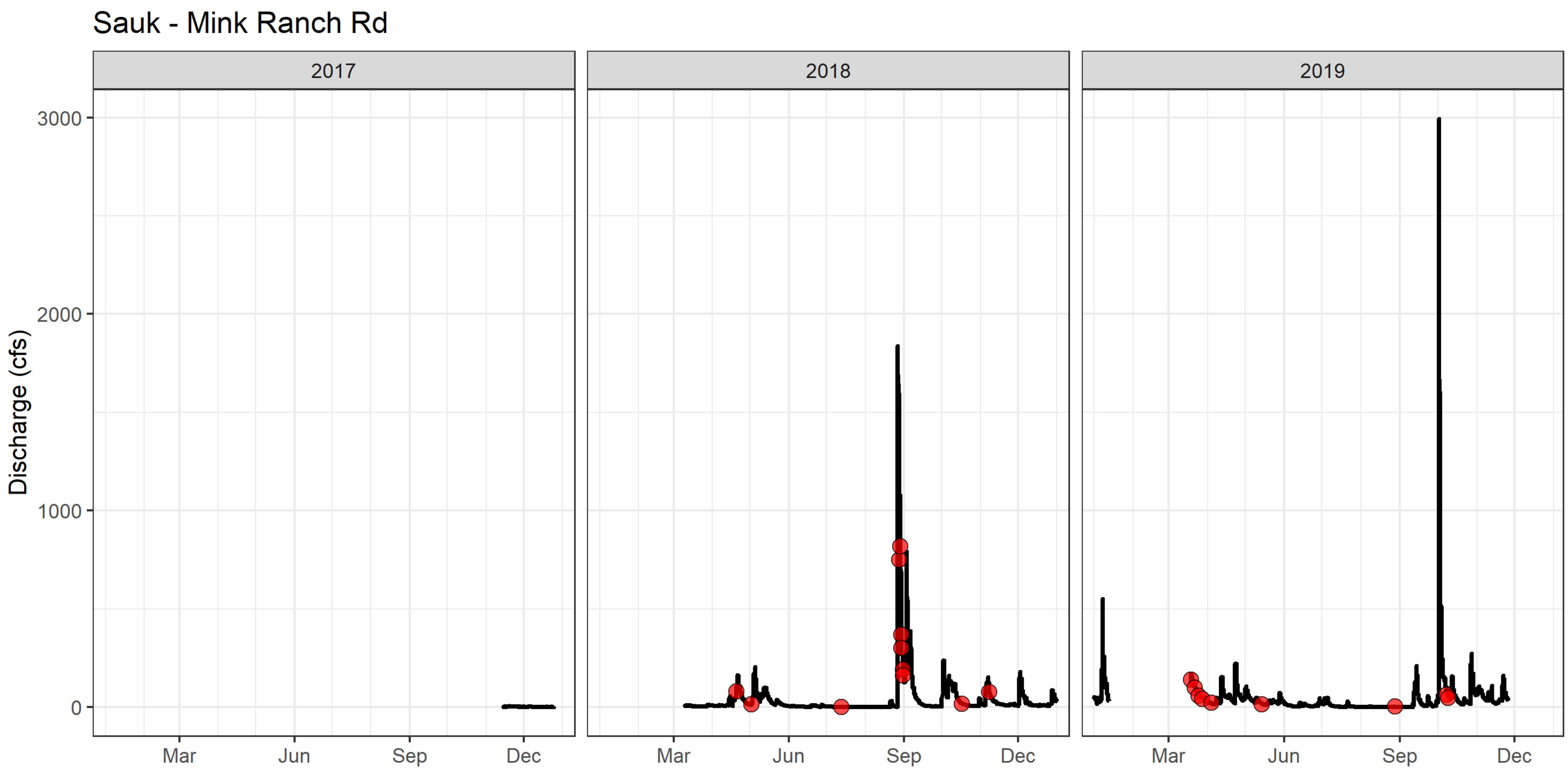

Pigeon - CTH A and River Rd
2017
2018
2019
Discharge (cfs)
1000
500
0
Mar
Jun
Sep
Dec



Pigeon - Mill Rd
2017
2018
Discharge (cfs)
1000
750
500
250
0
Mar
Jun
Sep
Dec

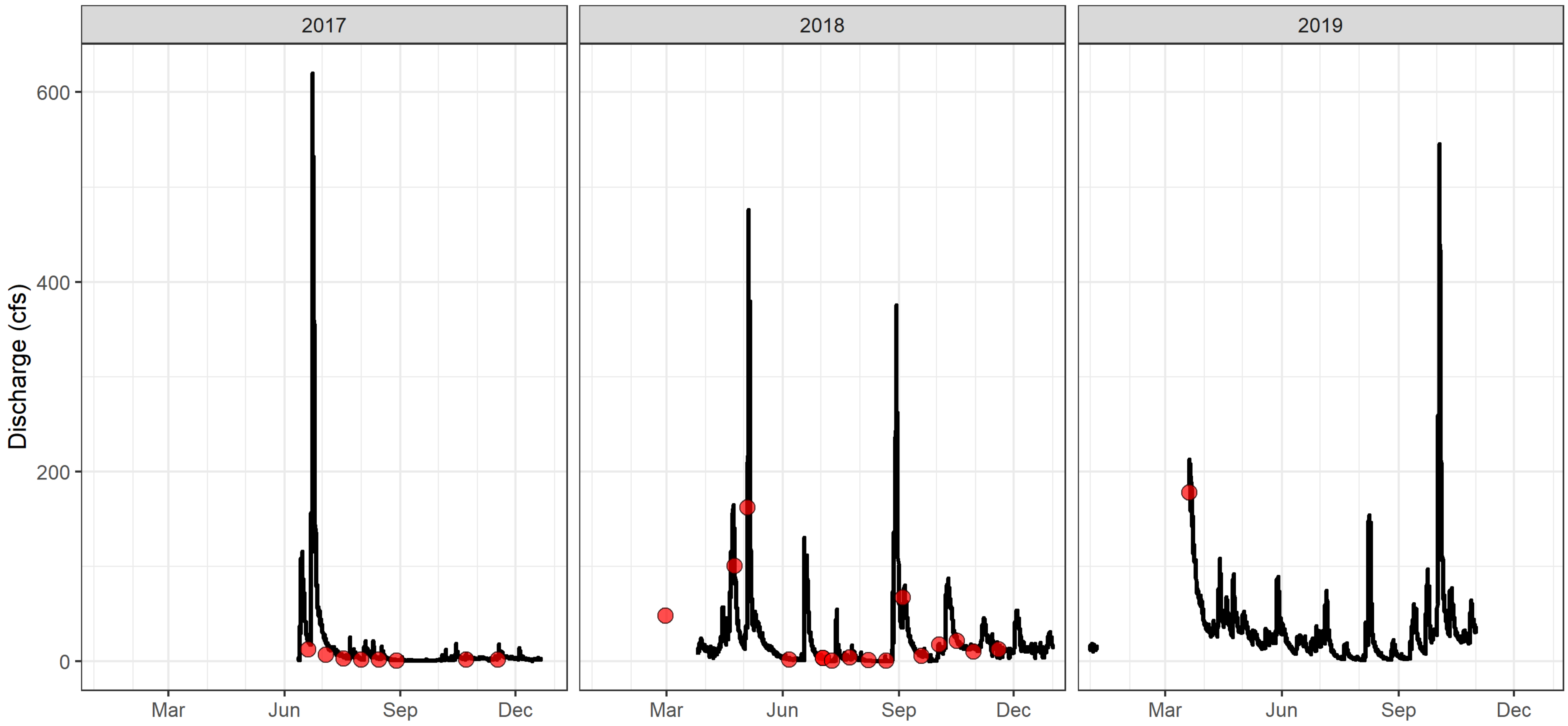
Point - Centerville Rd

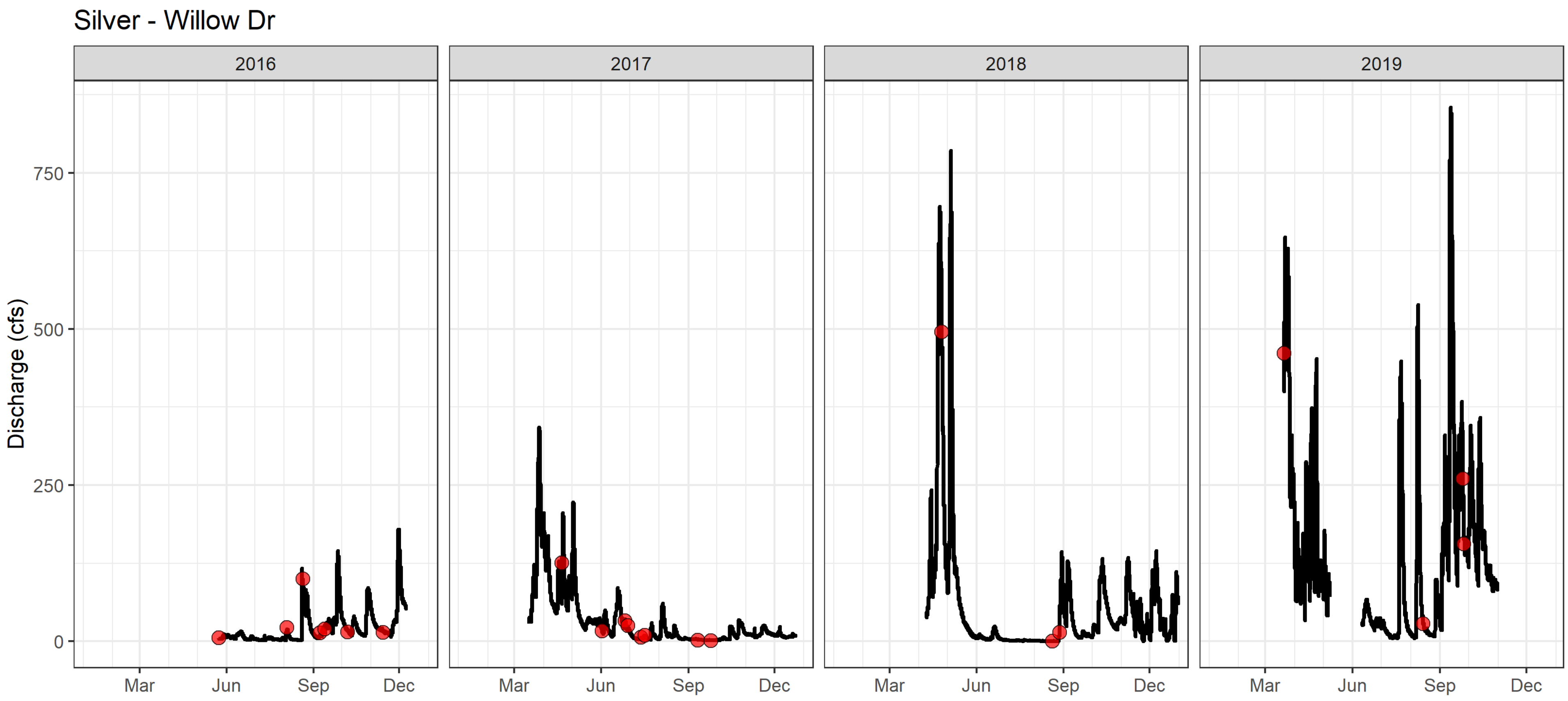




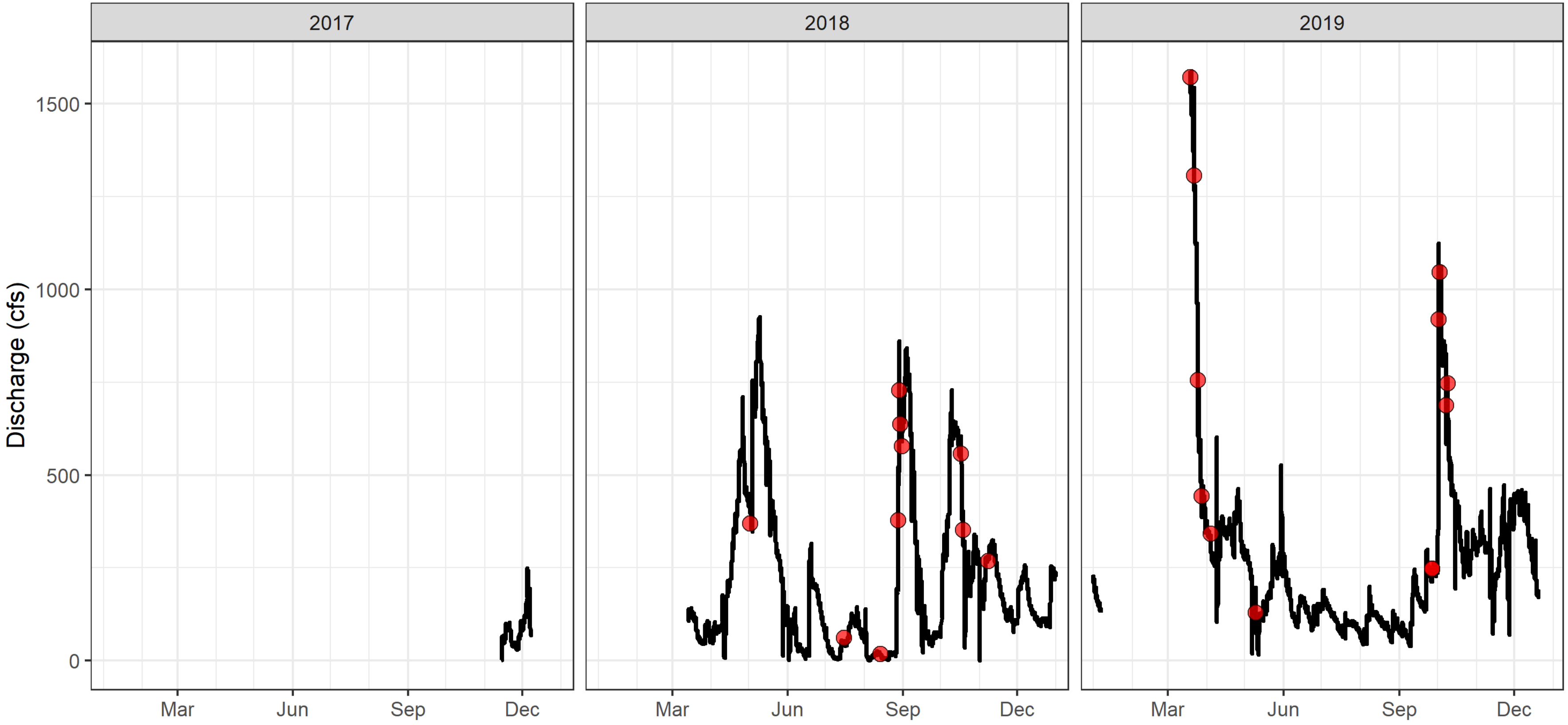
Sauk - Mink Ranch Rd
2017
2018
2019
Discharge (cfs)
3000
2000
1000
0
Mar
Jun
Sep
Dec

Silver - CTH LS

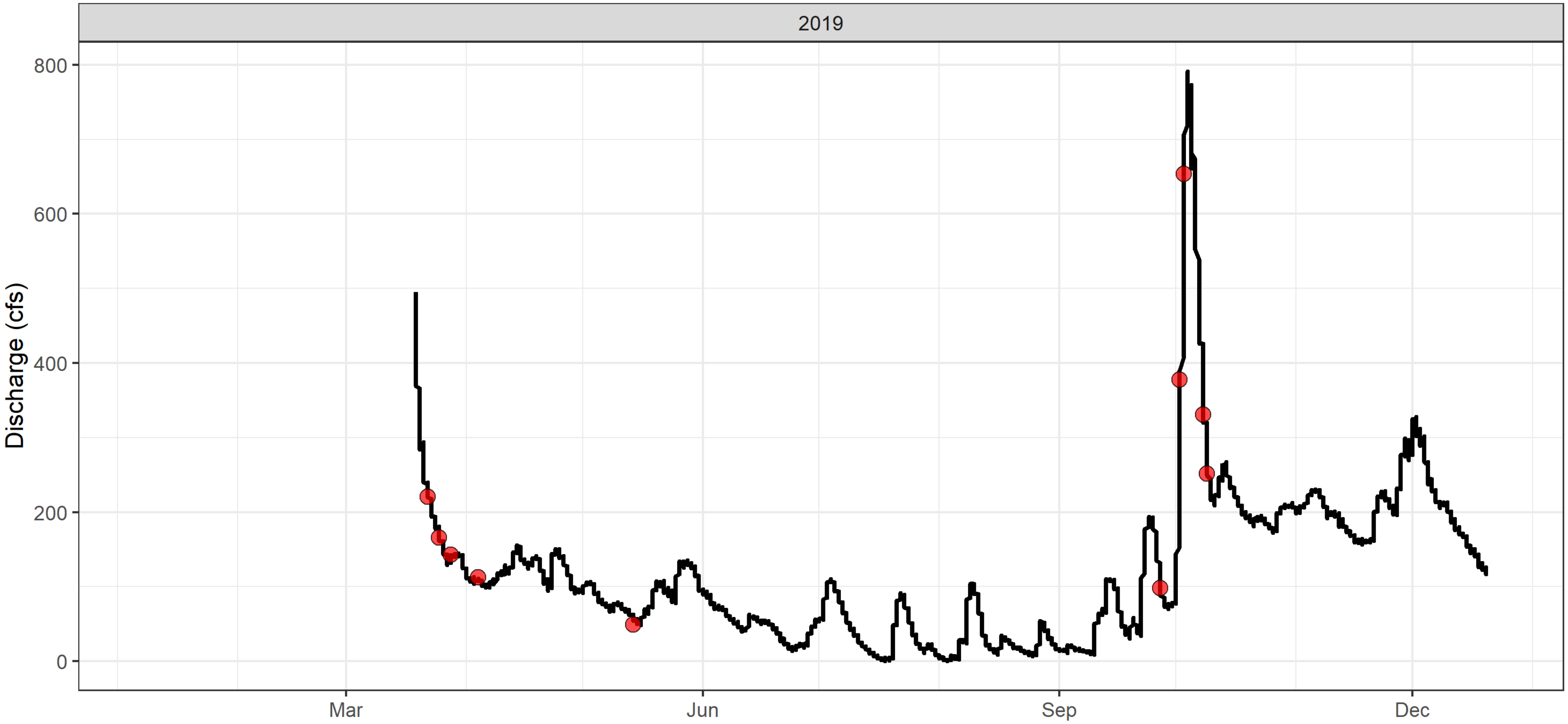



Silver - Willow Dr
2016
2017
2018
2019
Discharge (cfs)
750
500
250
0
Mar
Jun
Sep
Dec

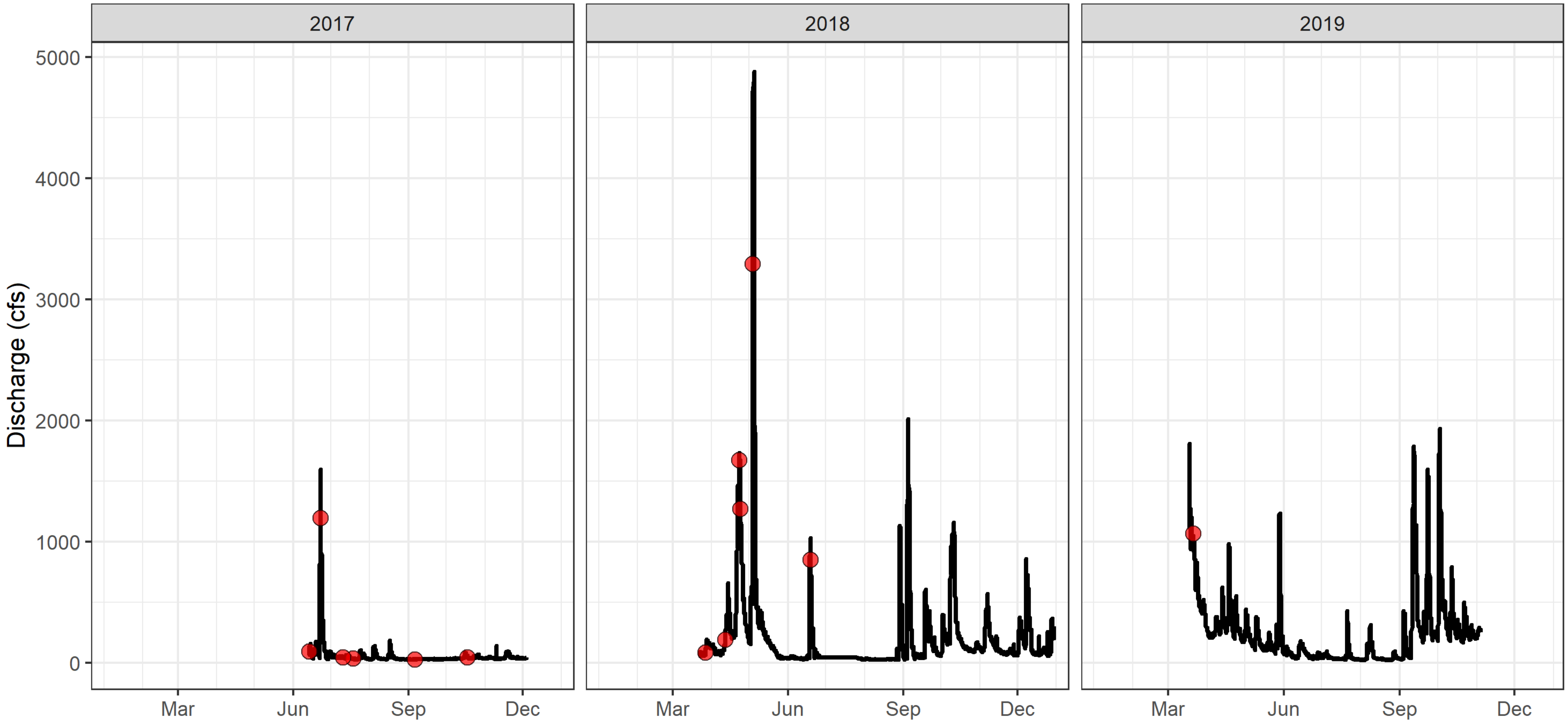
Sheboygan - HWY 57



Sheboygan - Palm Tree Rd



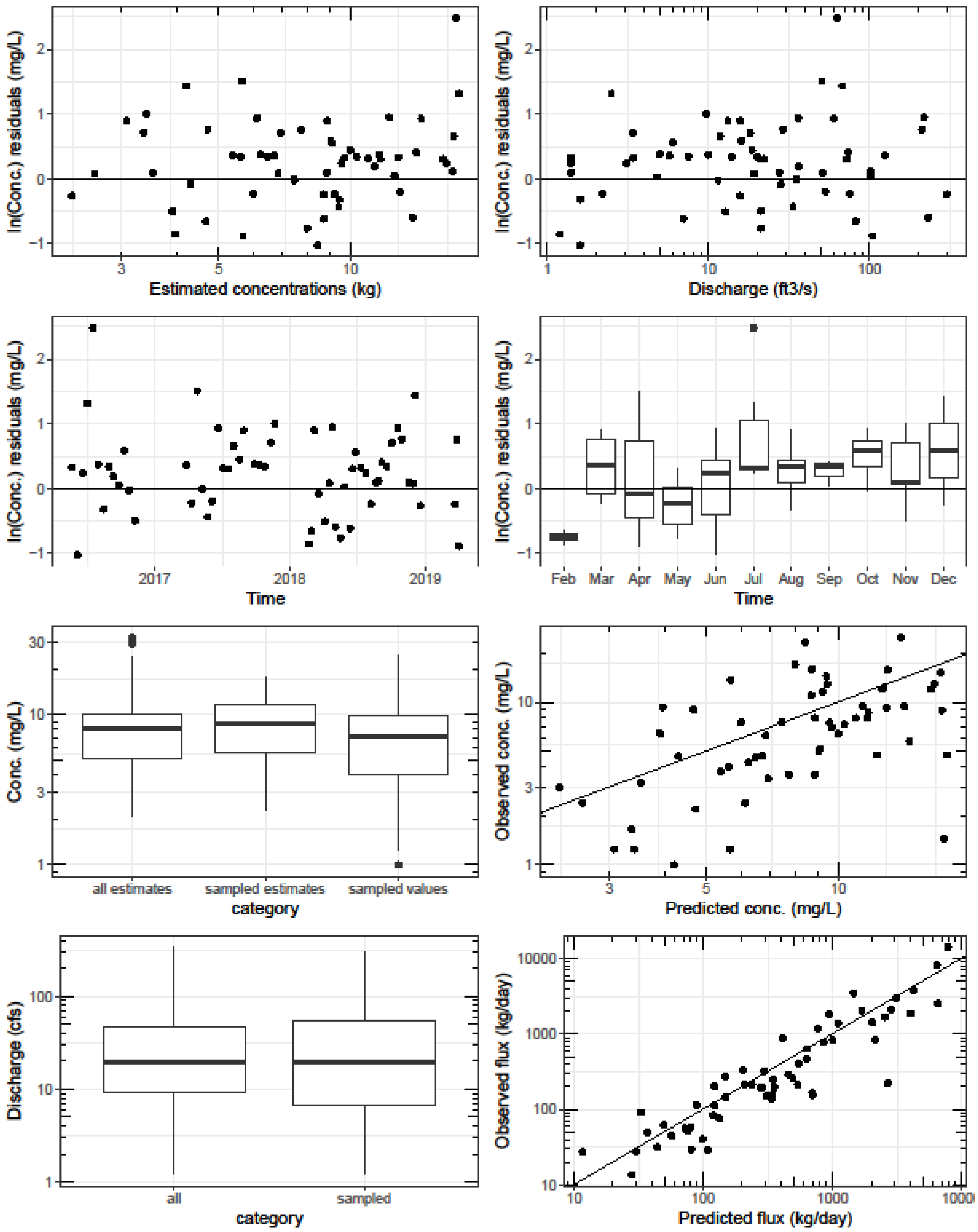
West Twin - CTH V

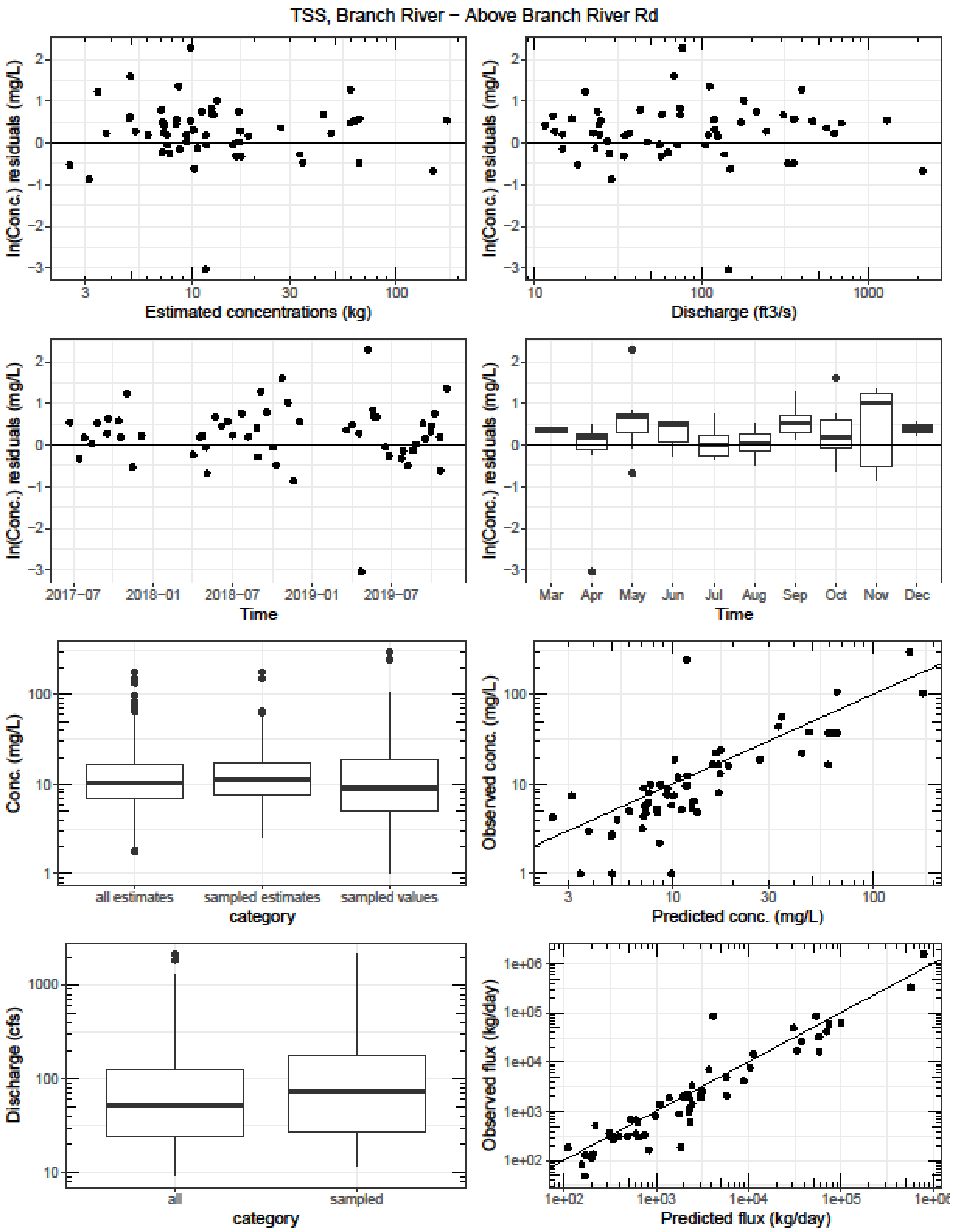


Flux Model Visual Diagnostics

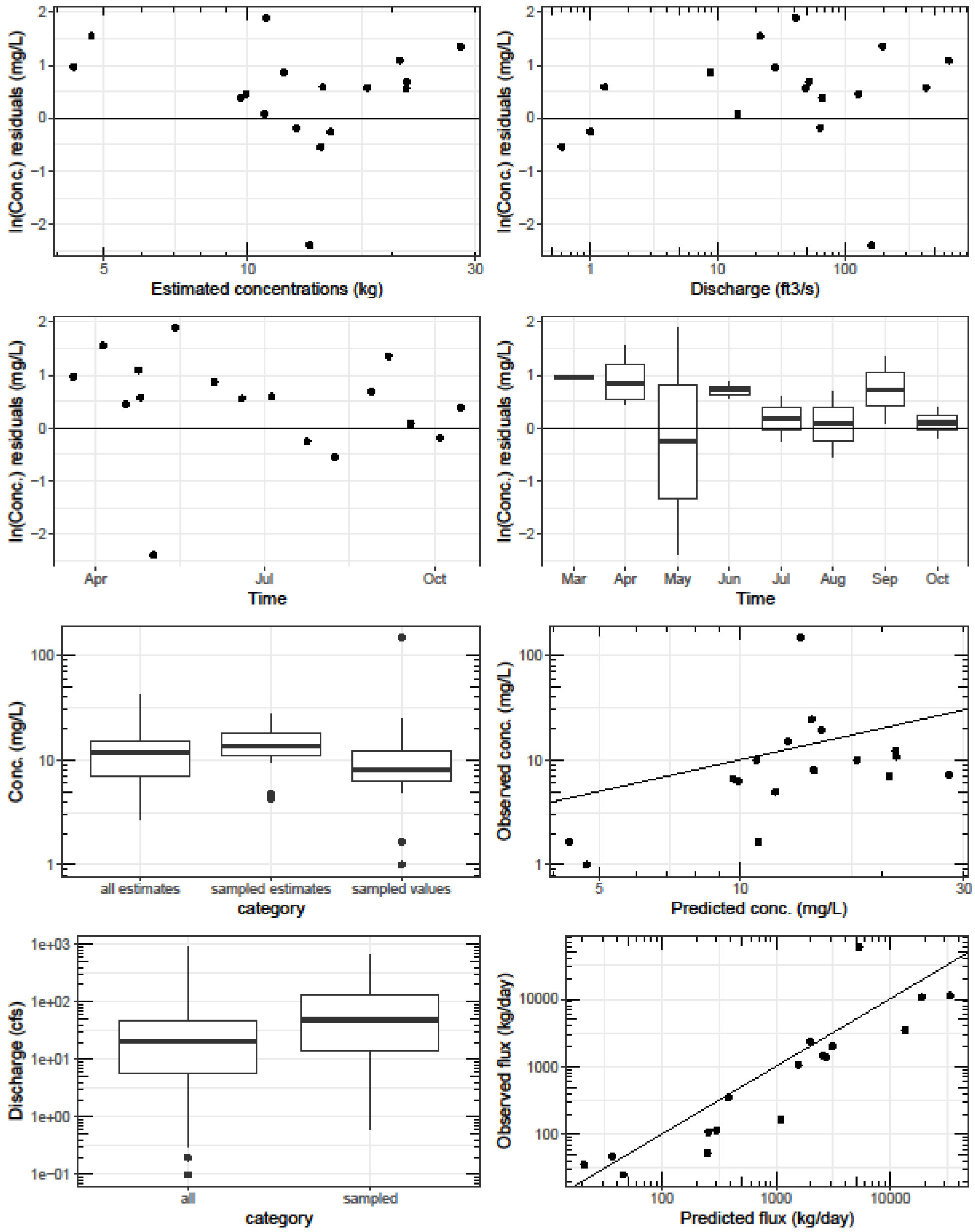
8.2.1 Total Suspended Solids Composite Plots

TSS, Ahnapee River at CTH J Forestville

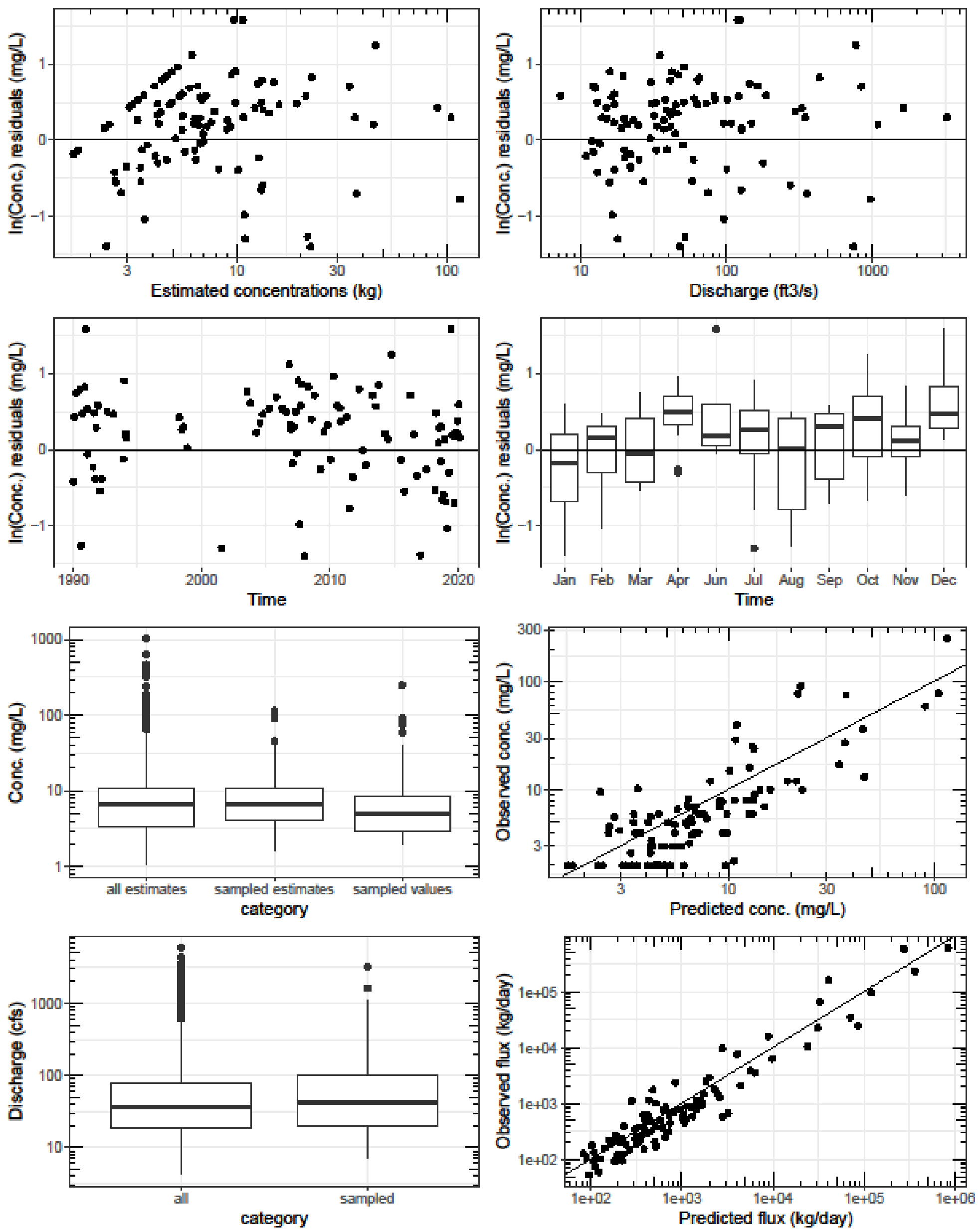


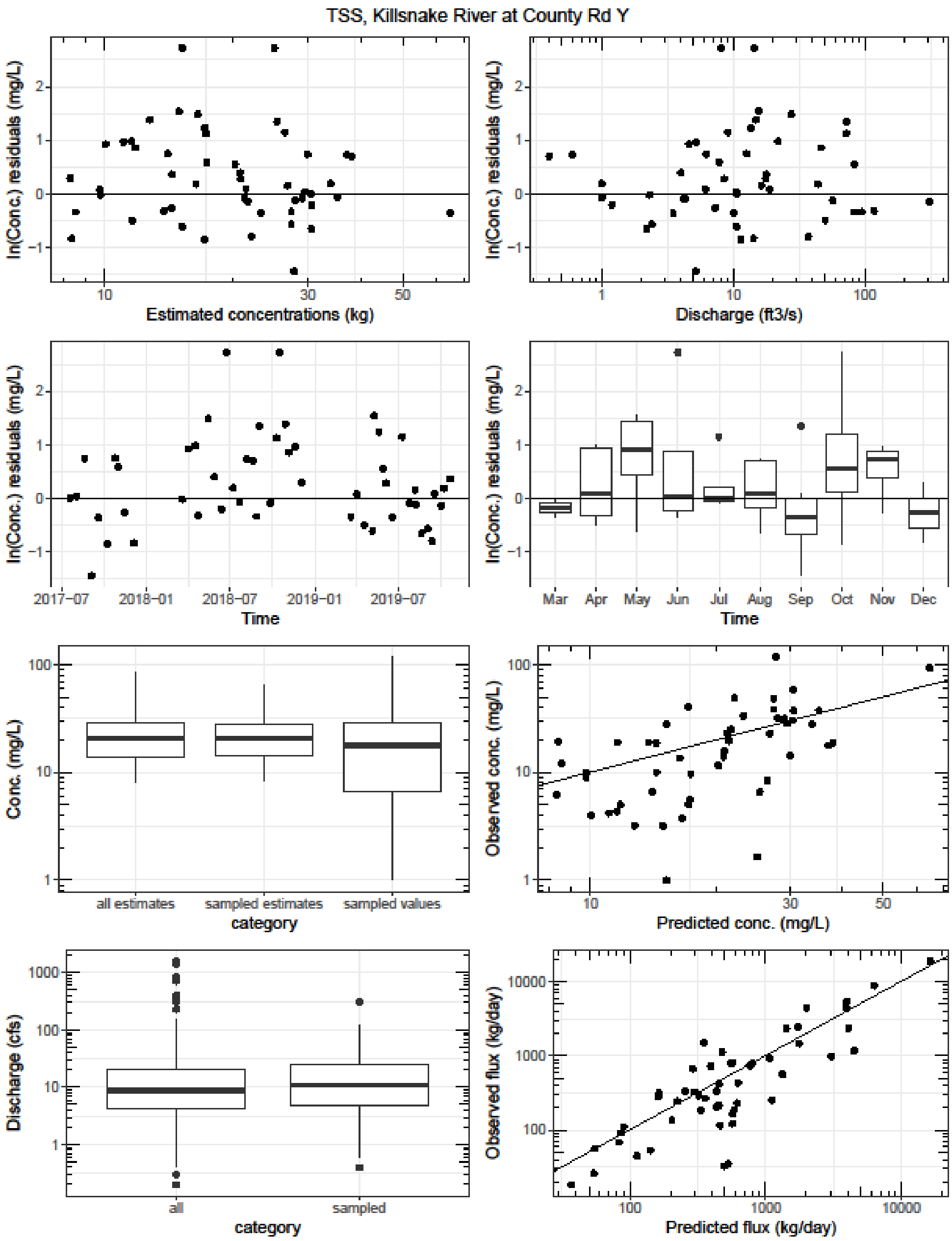

TSS, Branch River − Above Branch River Rd
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2017−07
2018−01
2018−07
2019−01
2019−07
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

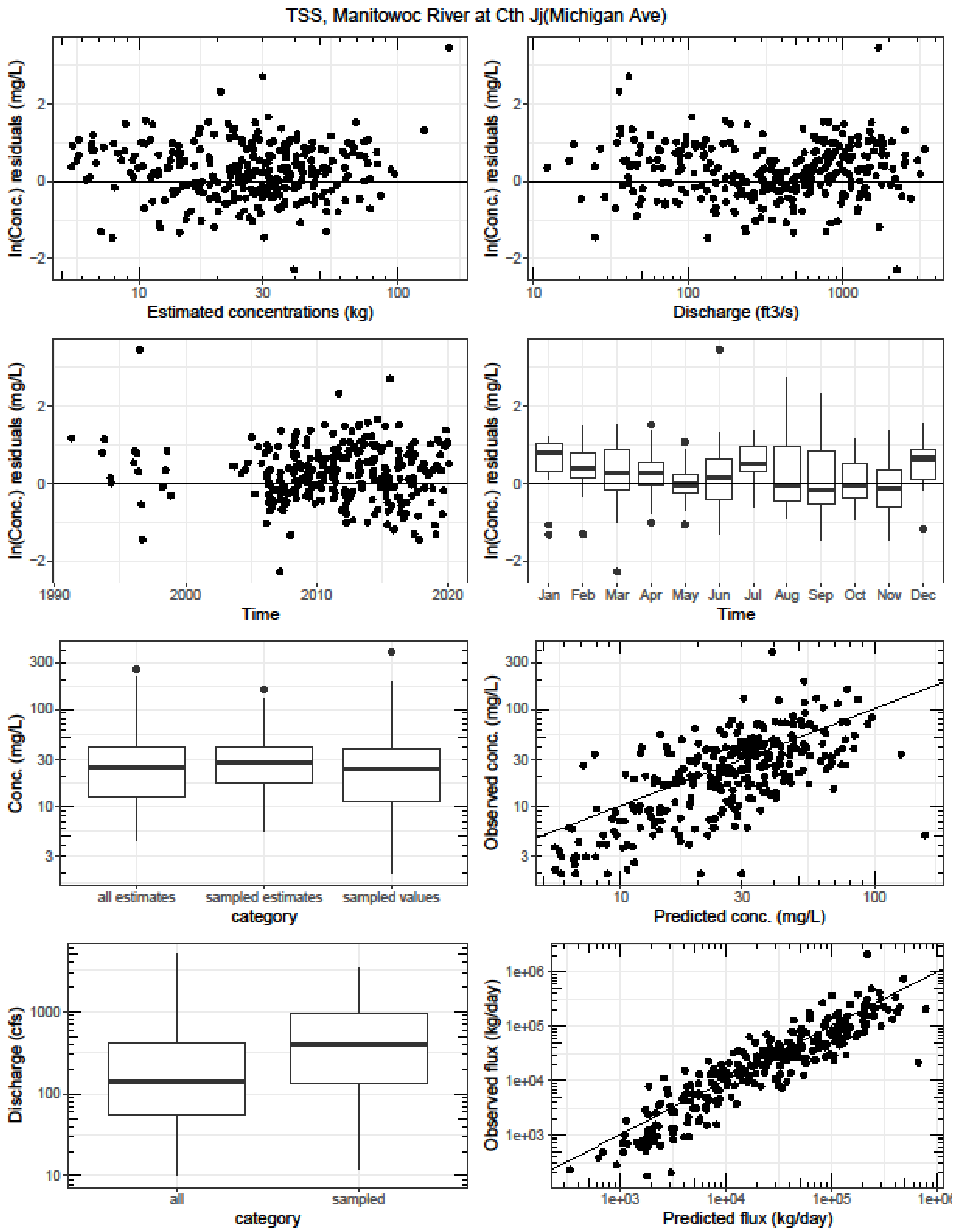
TSS, Kewaunee River at Hillside Road

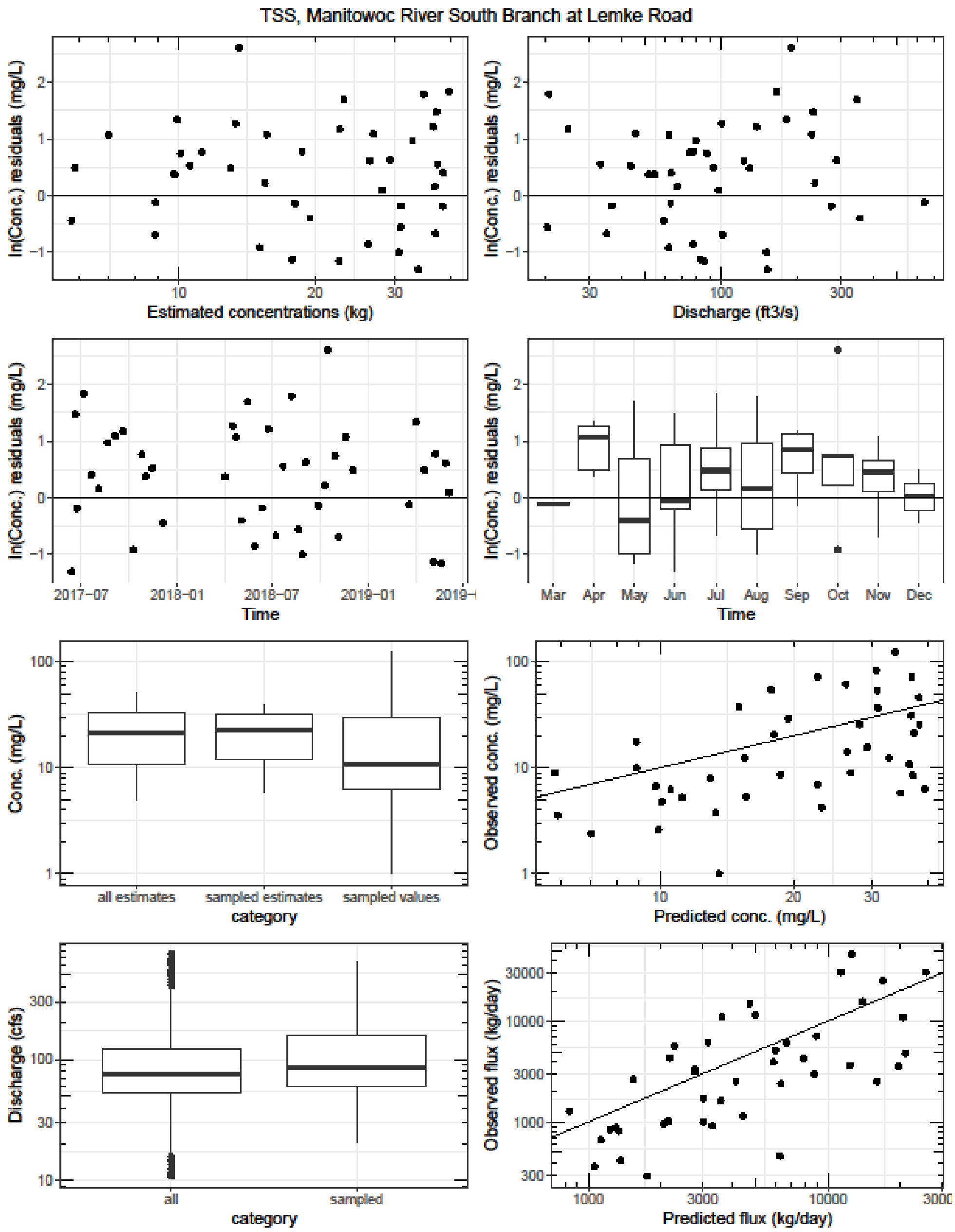


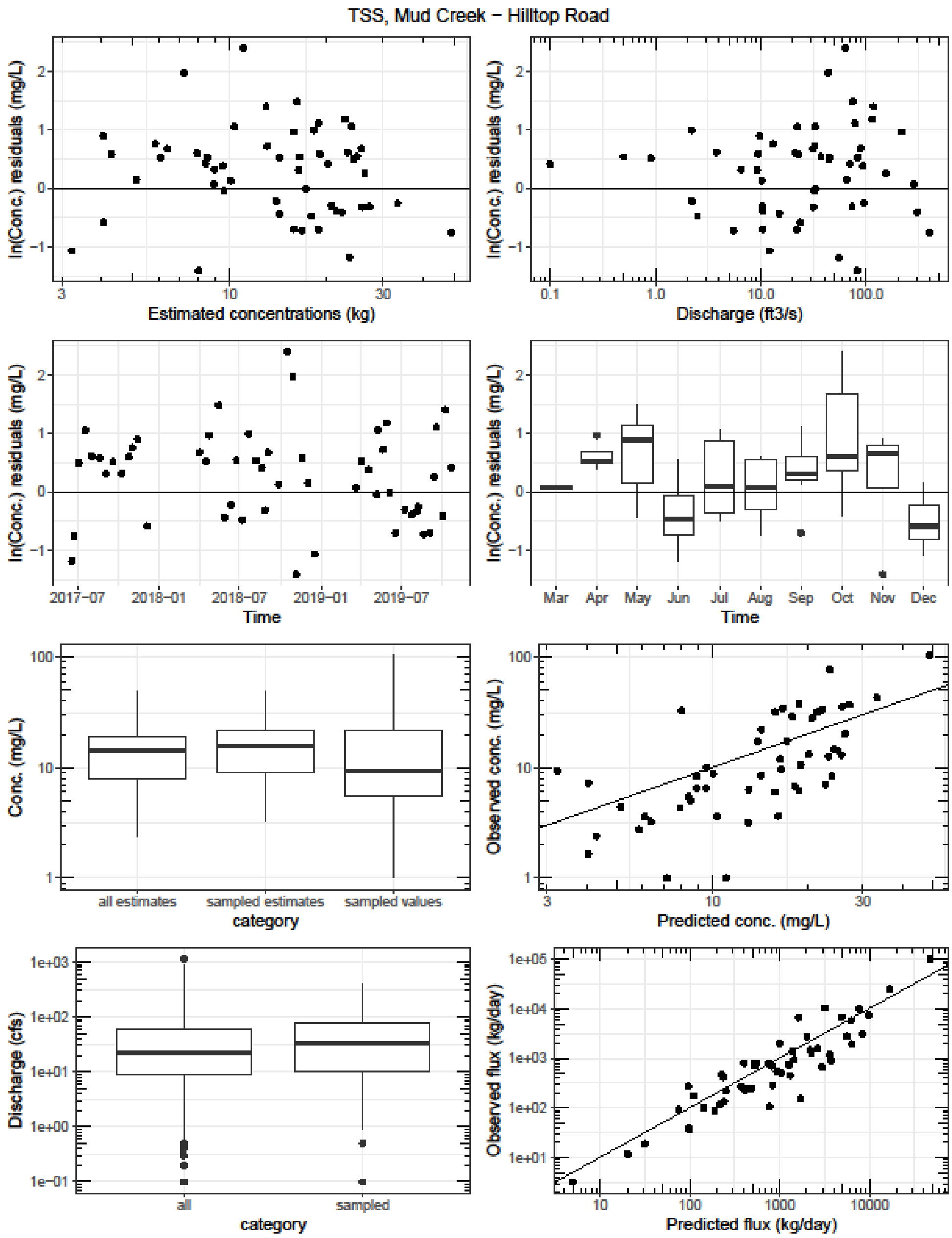
TSS, Kewaunee River DS Cth F at Bruemmer Park

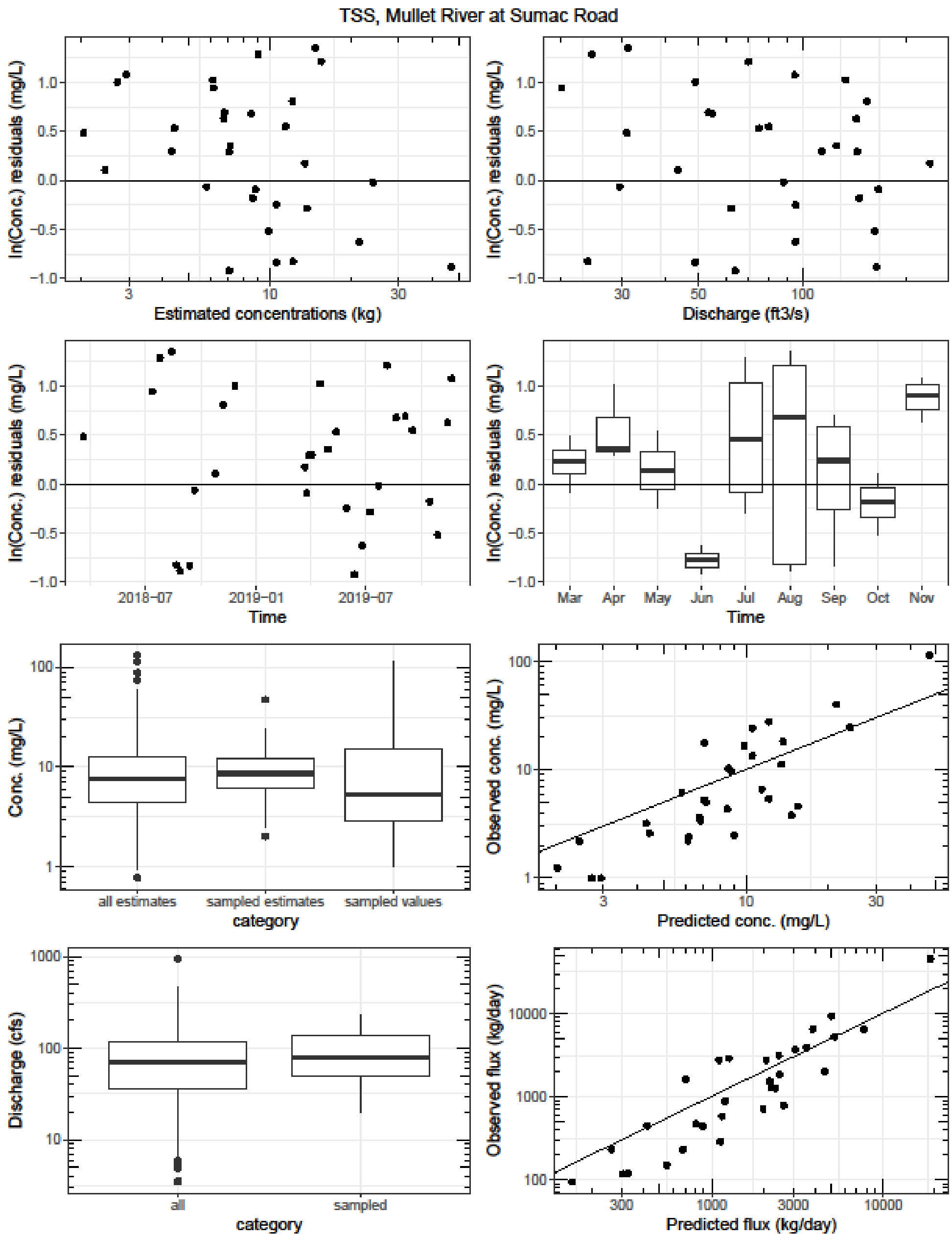


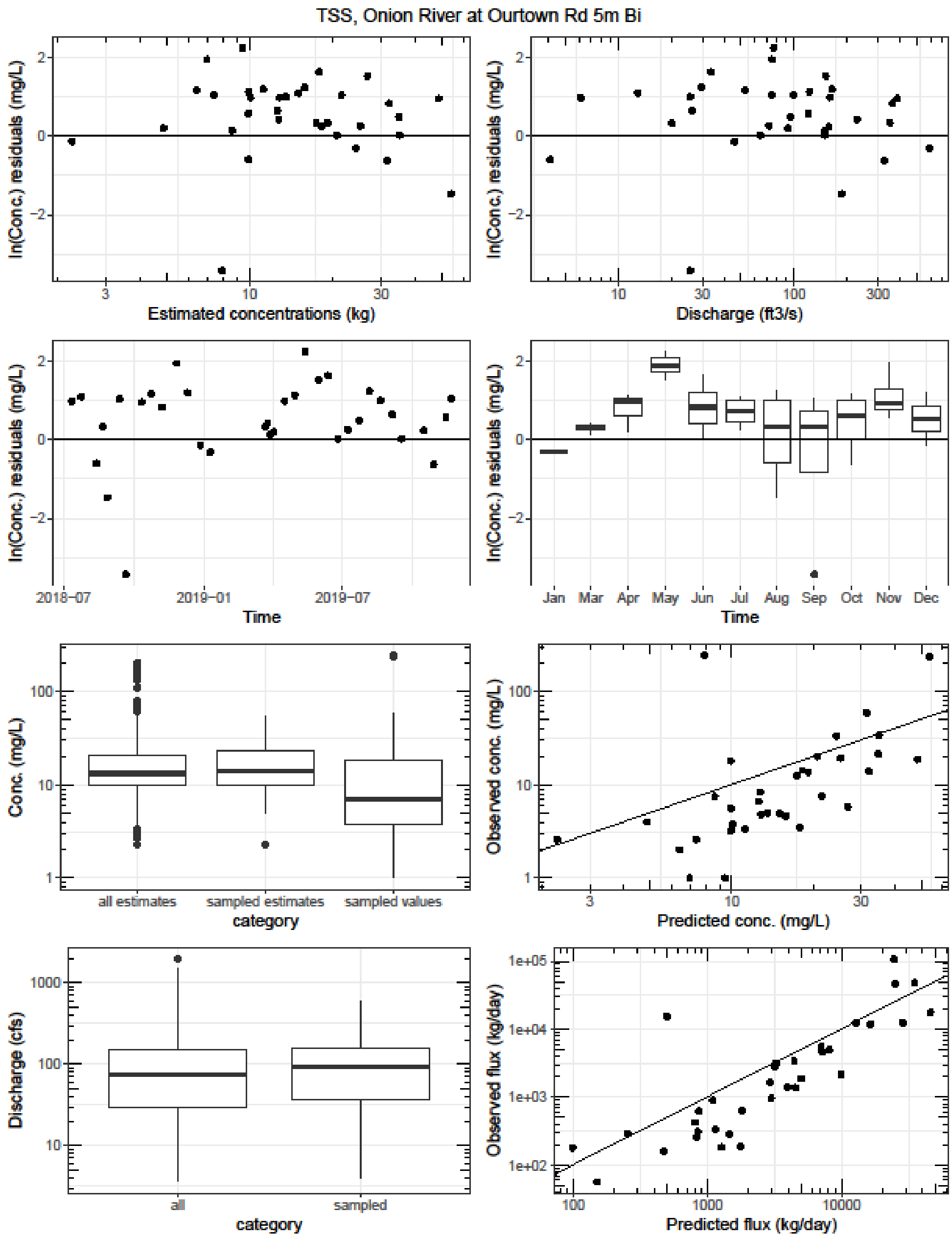

TSS, Killsnake River at County Rd Y
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2017−07
2018−01
2018−07
2019−01
2019−07
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TSS, Manitowoc River at Cth Jj(Michigan Ave)
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TSS, Manitowoc River South Branch at Lemke Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

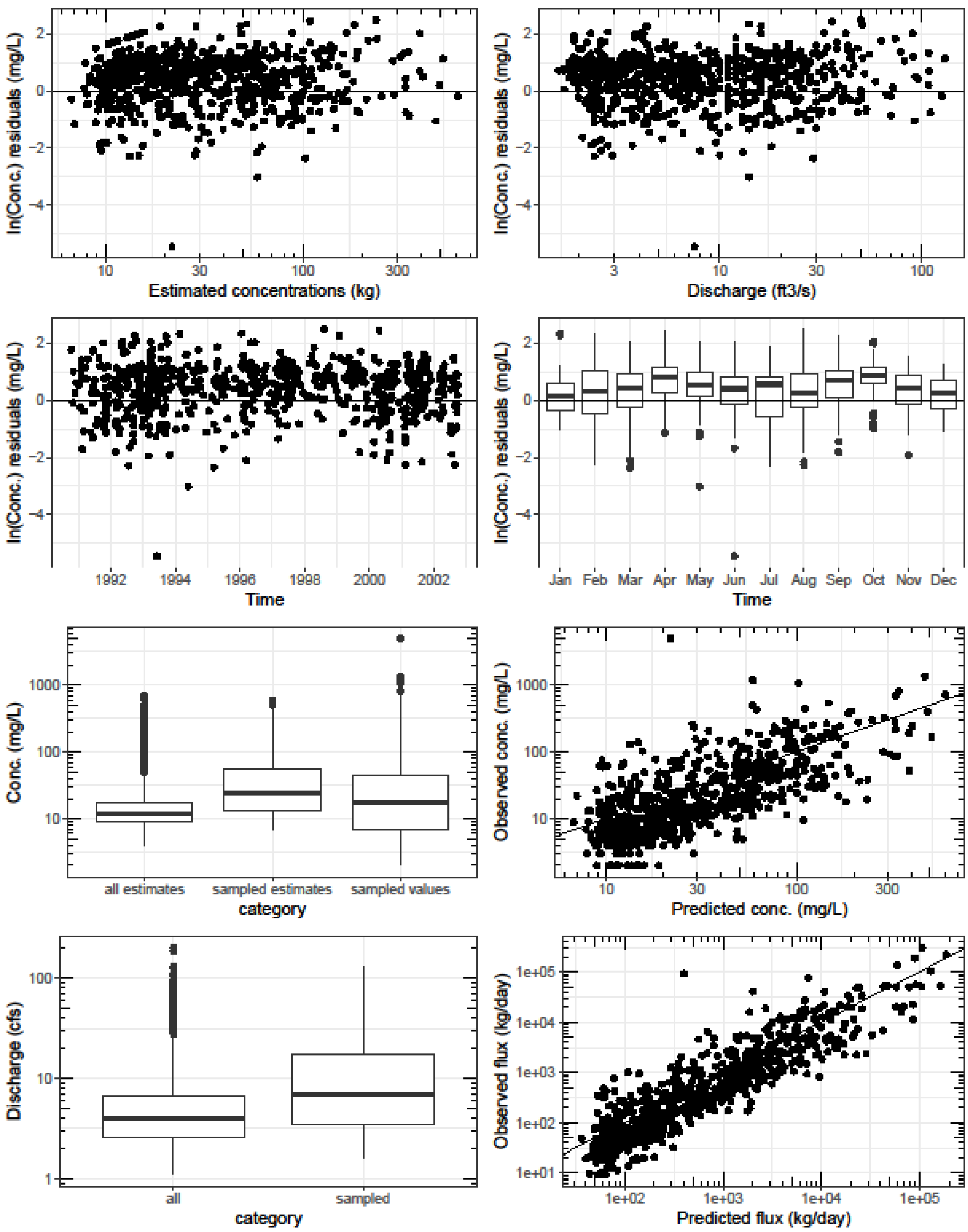

TSS, Mud Creek − Hilltop Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

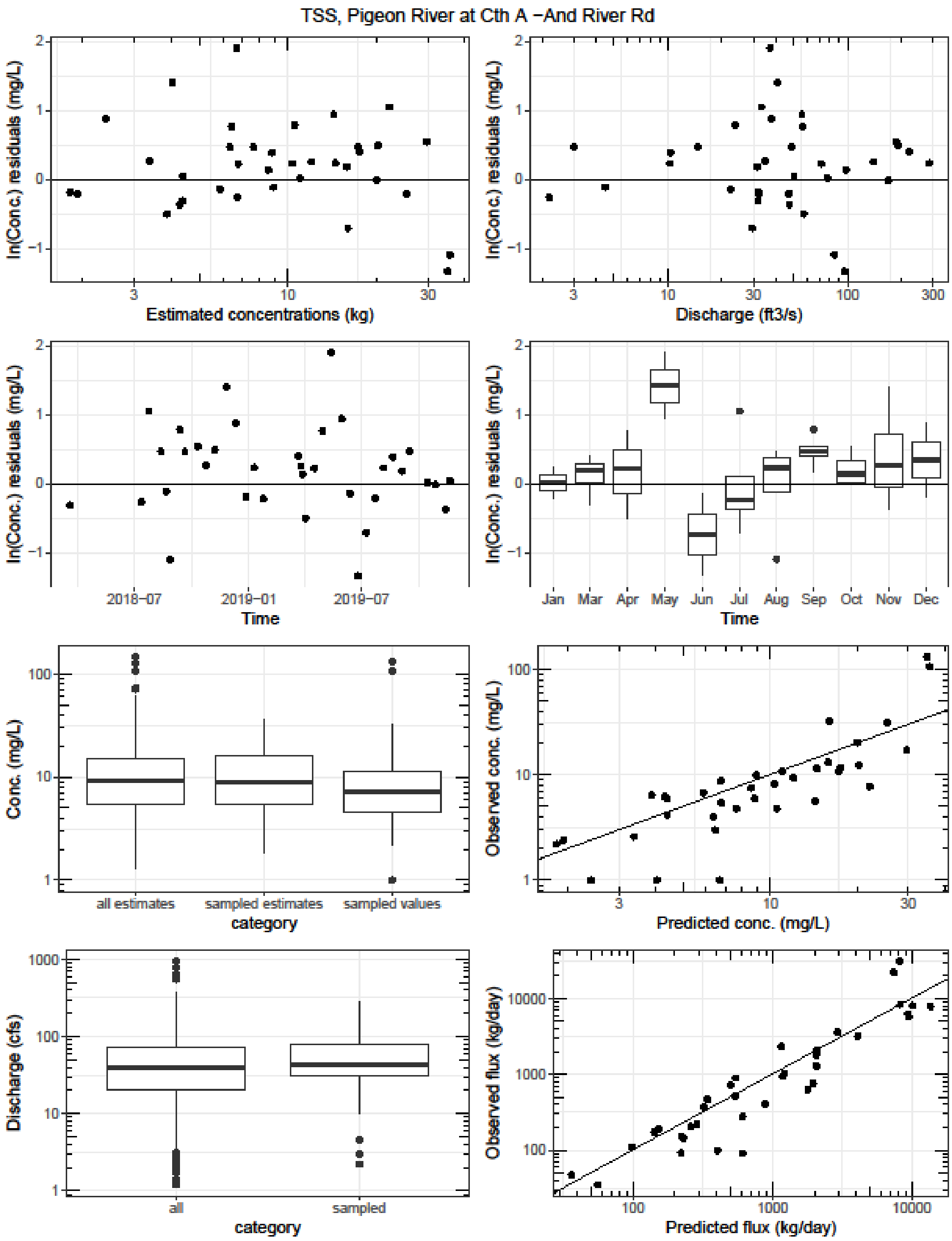

TSS, Mullet River at Sumac Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2018−07
2019−01
2019−07
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

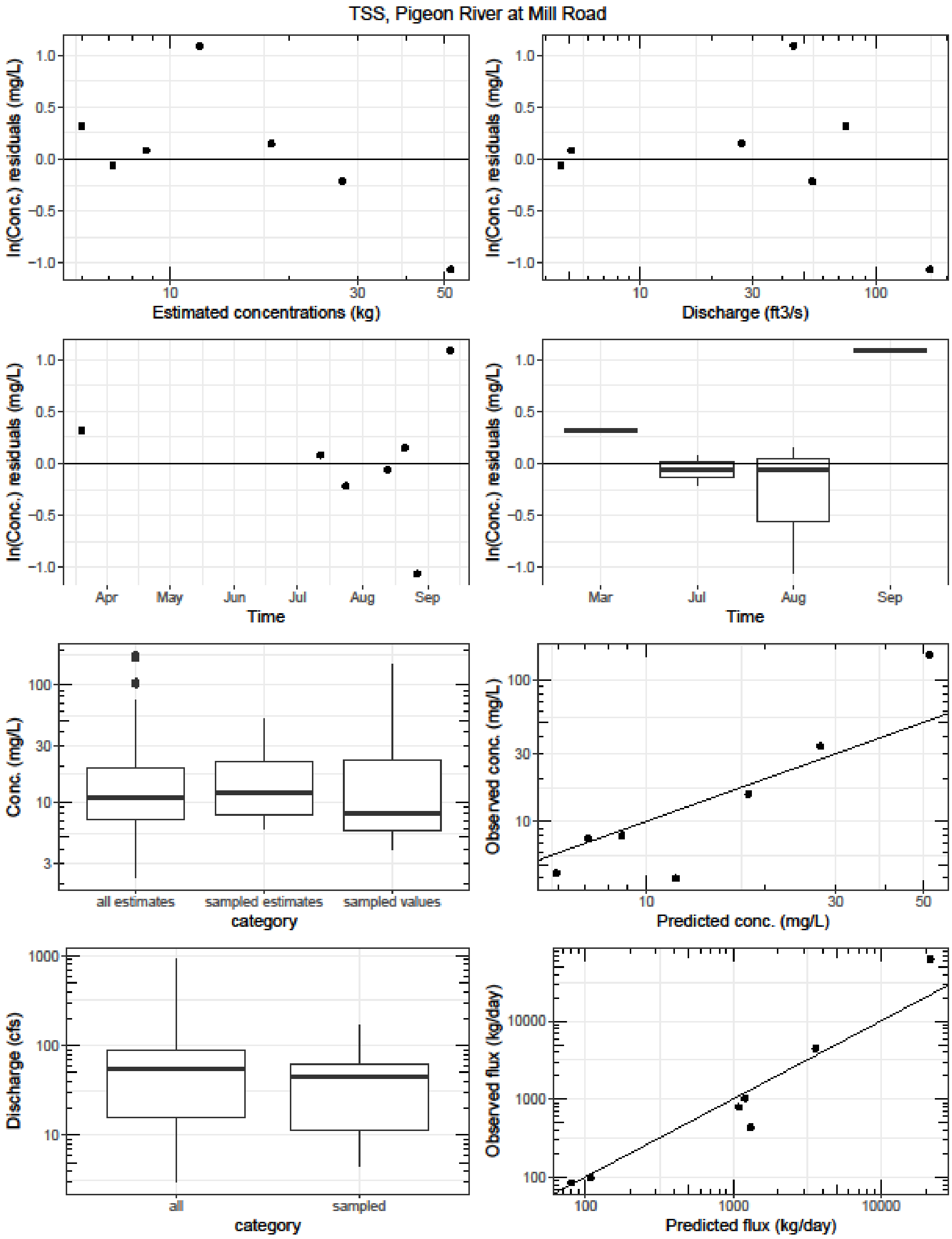


TSS, Onion River at Ourtown Rd 5m Bi
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2018−07
2019−01
2019−07
Jan Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

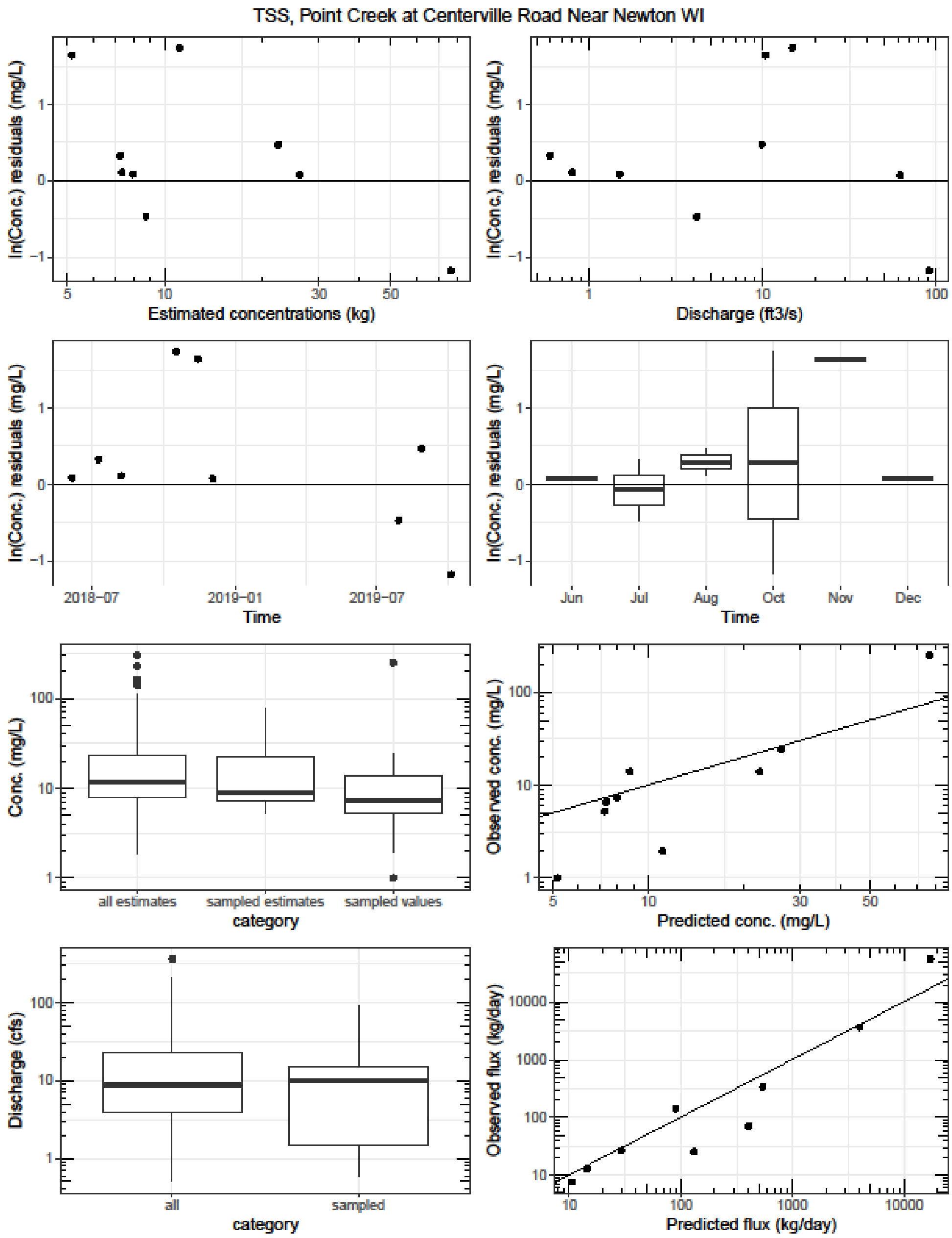
TSS, Otter Creek at Willow Rd Near Plymouth WI



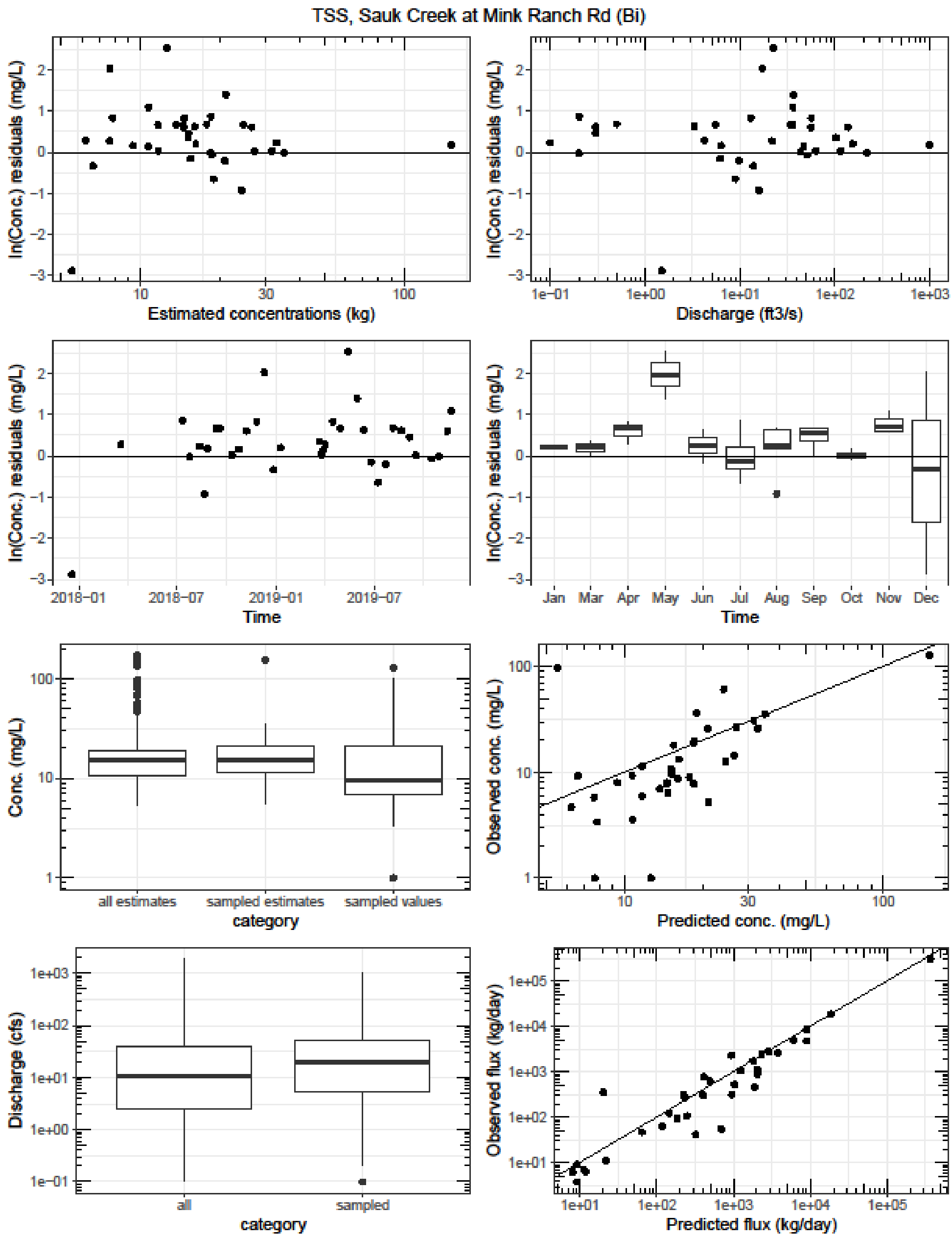

TSS, Pigeon River at Cth A −And River Rd
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2018−07
2019−01
2019−07
Jan
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

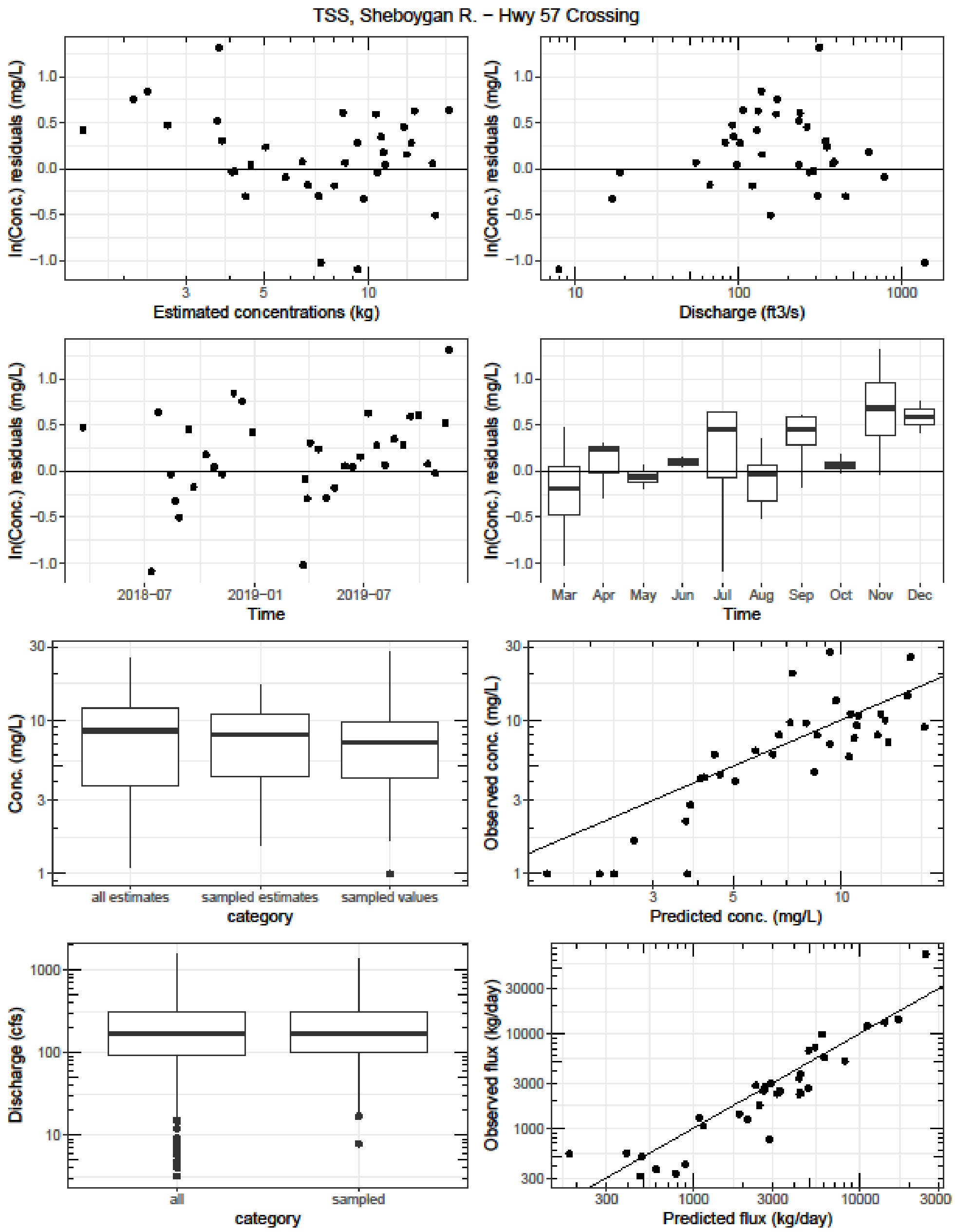


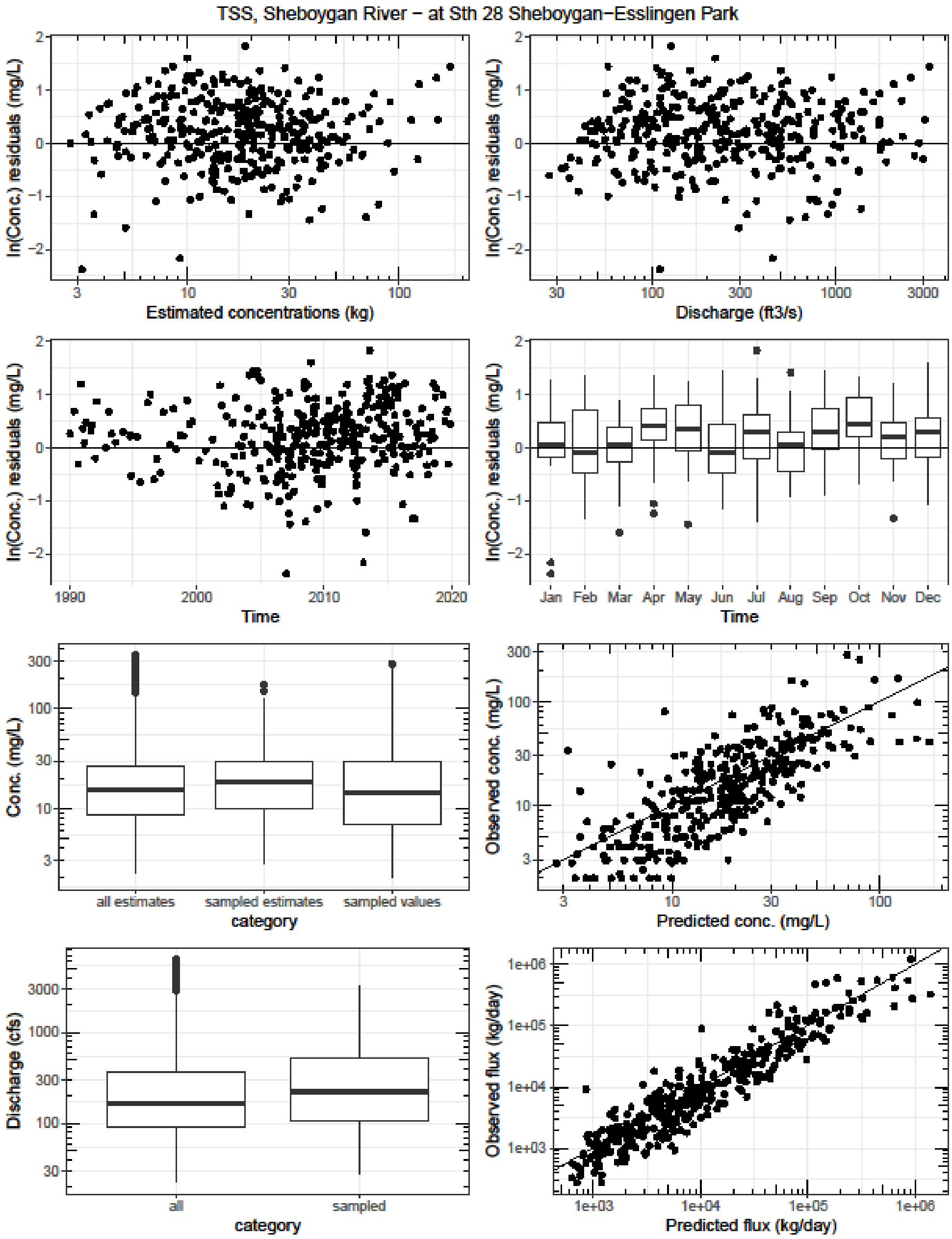
TSS, Pigeon River at Mill Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Apr
May
Jun
Jul
Aug
Sep
Mar
Conc. (mg/L)
category
all estimates
sampled estimates
sampled values
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

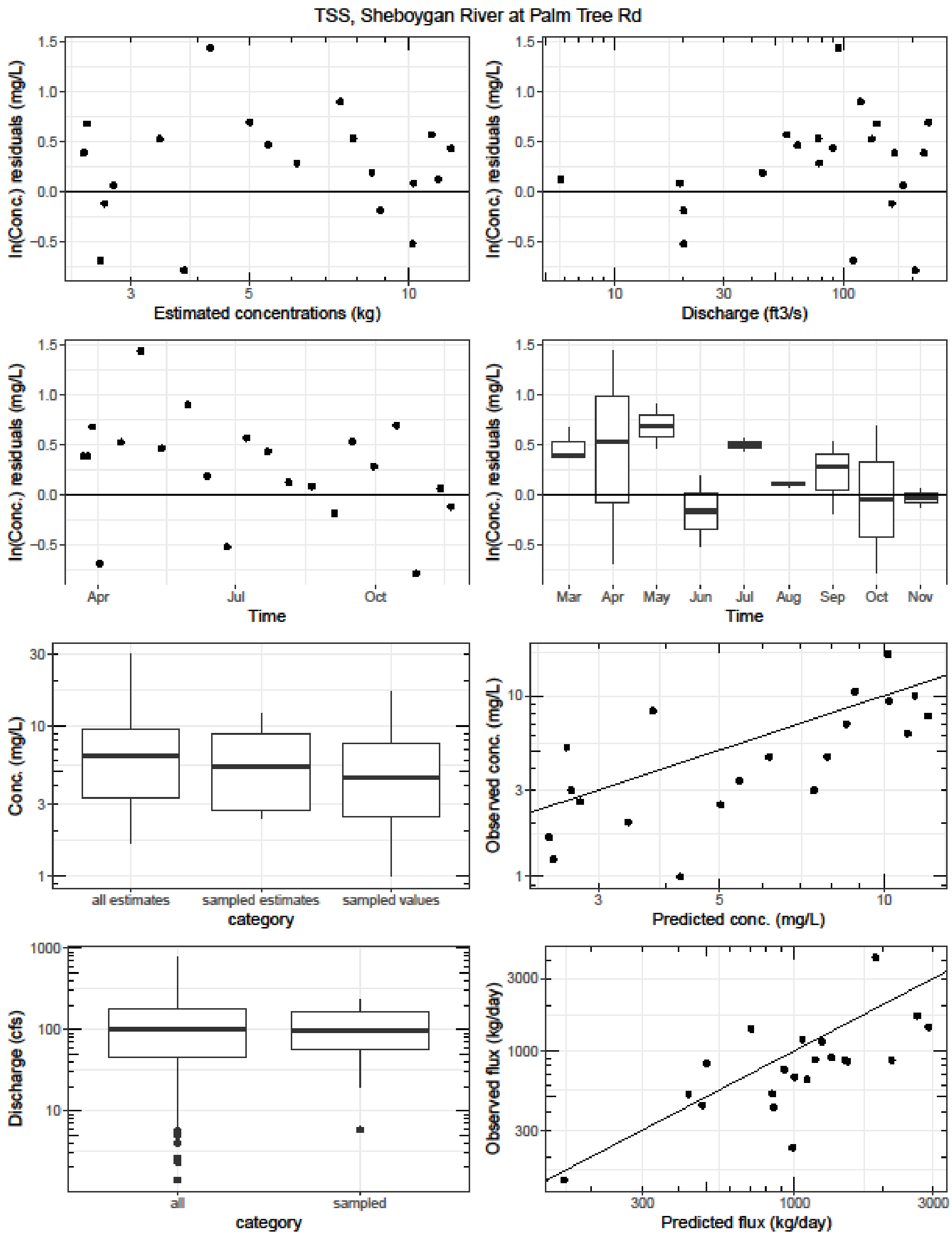


TSS, Point Creek at Centerville Road Near Newton WI
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2018−07
2019−01
2019−07
Jun
Jul
Aug
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TSS, Sauk Creek at Mink Ranch Rd (Bi)
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

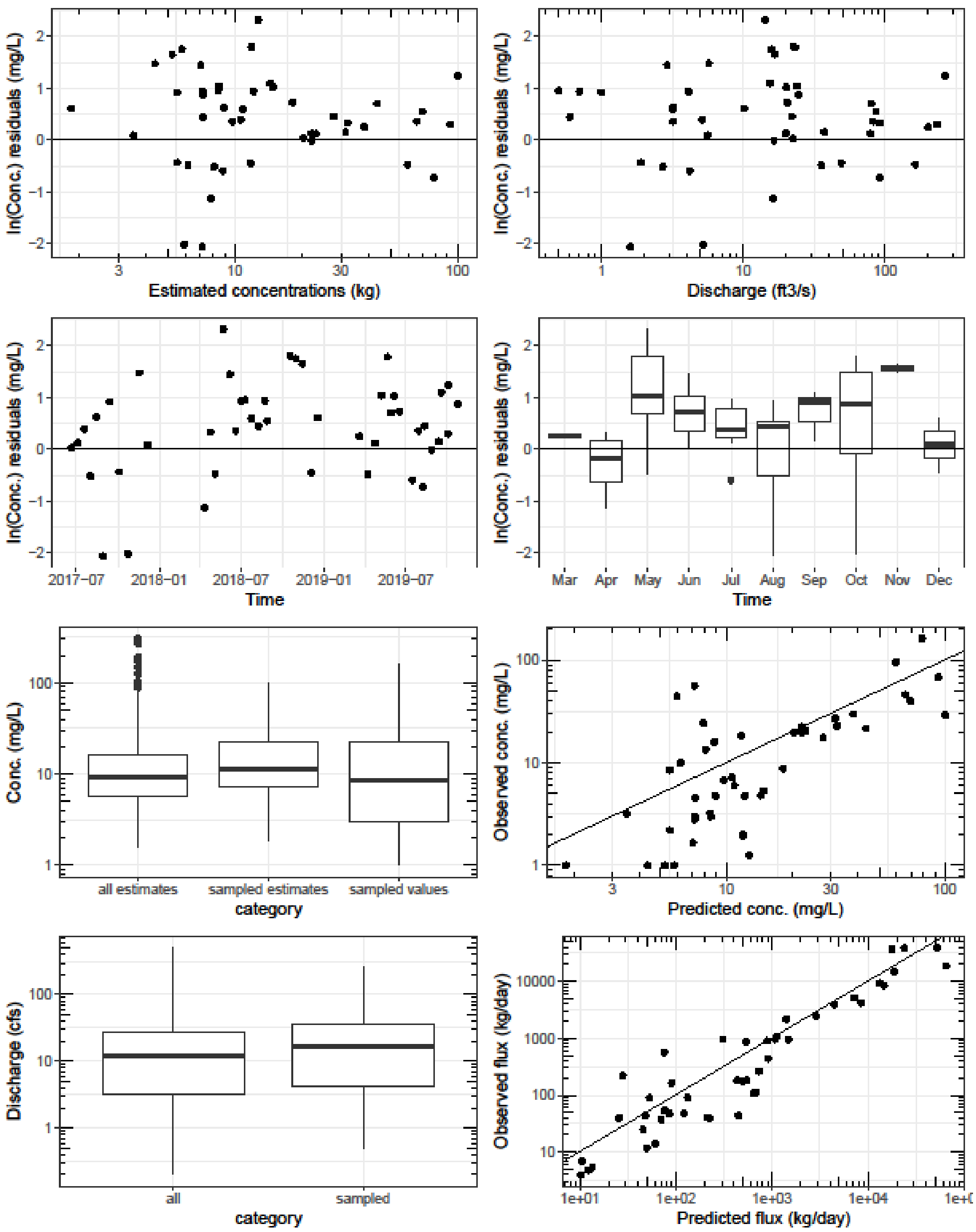

TSS, Sheboygan R. – Hwy 57 Crossing
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Conc. (mg/L)
category
all estimates
sampled estimates
sampled values
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2018−07
2019−01
2019−07


TSS, Sheboygan River − at Sth 28 Sheboygan−Esslingen Park
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

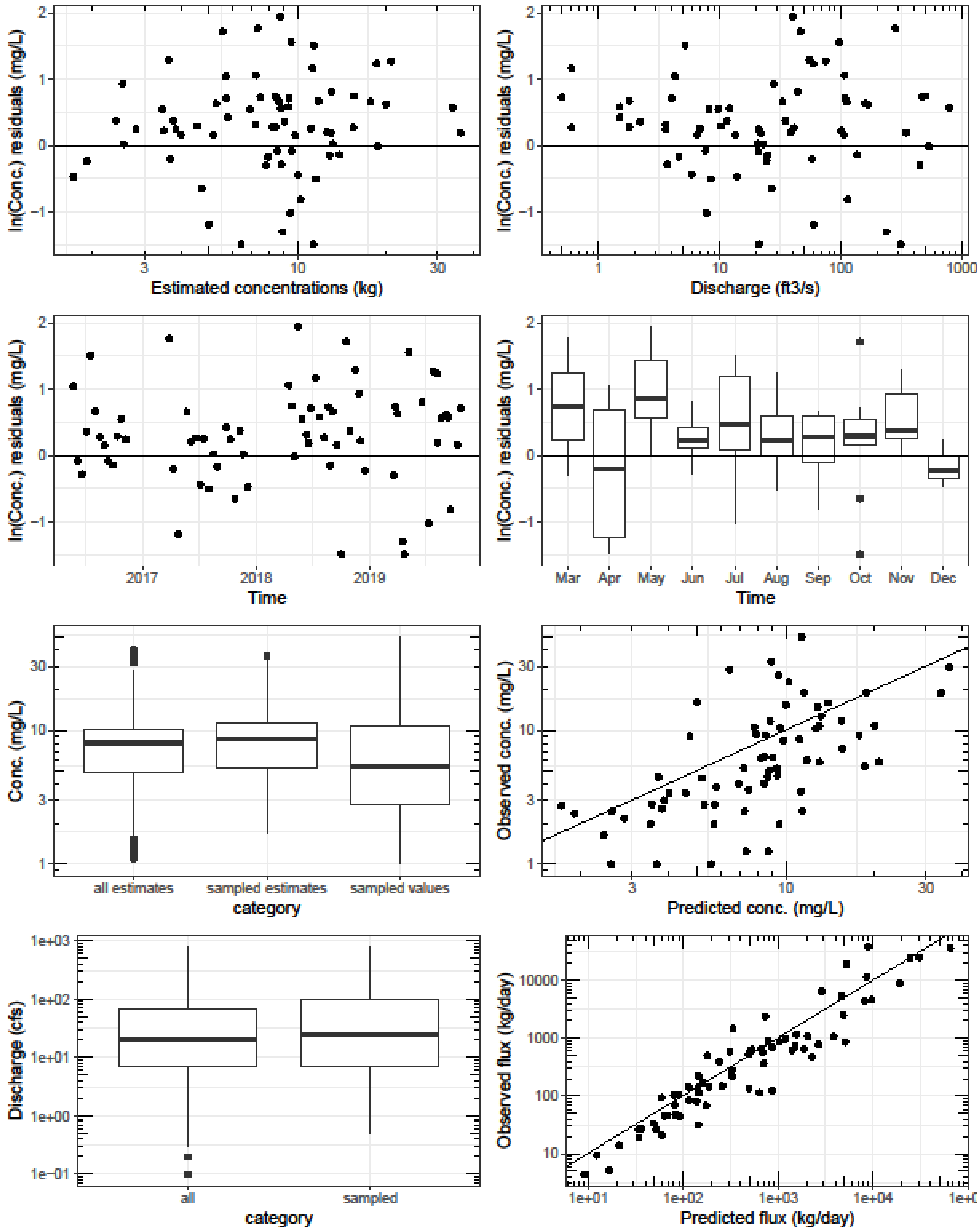


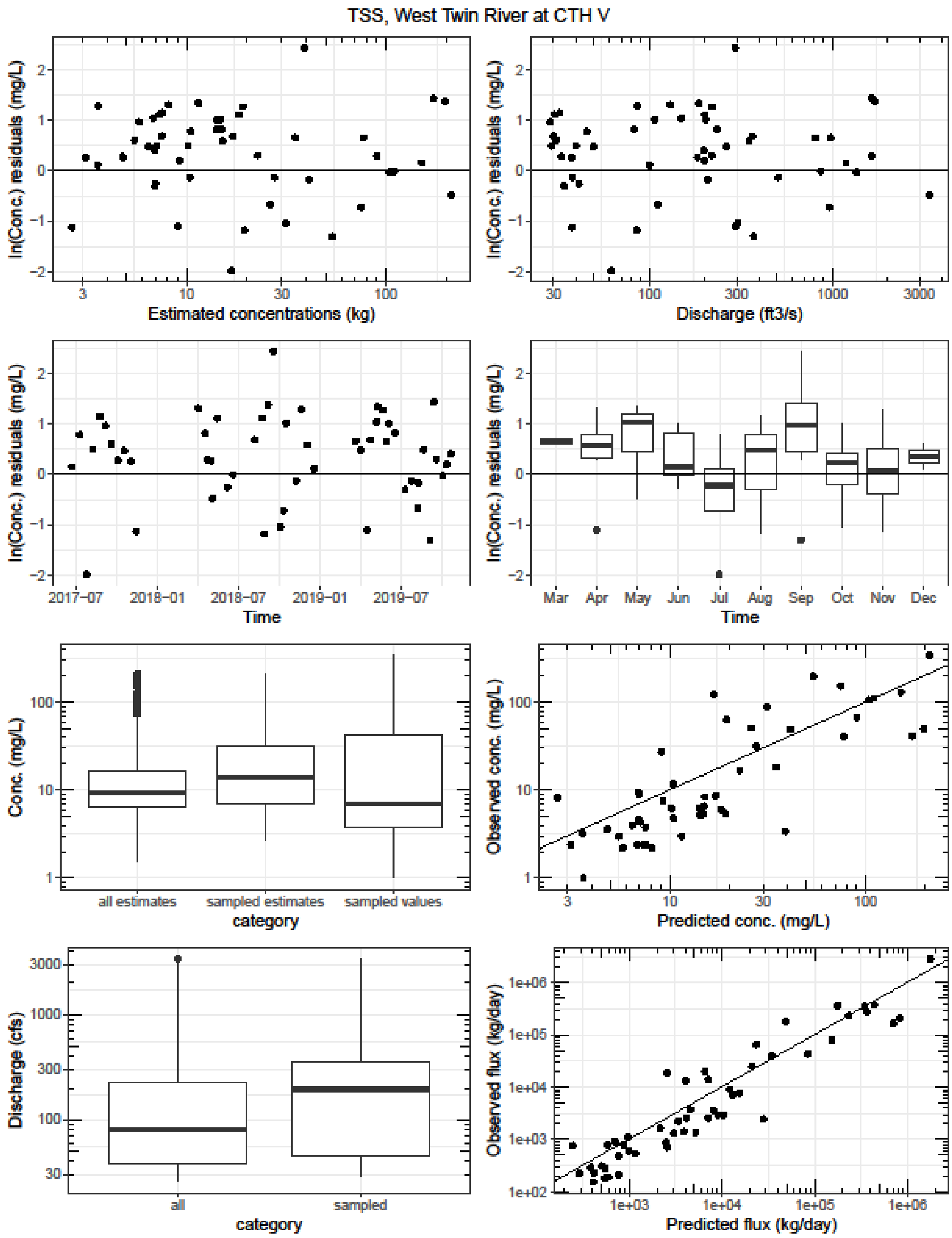
TSS, Sheboygan River at Palm Tree Rd
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Apr
Jul
Oct
Mar
May
Jun
Aug
Sep
Nov
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

TSS, Silver Creek at Cth Ls (Bi Sur)

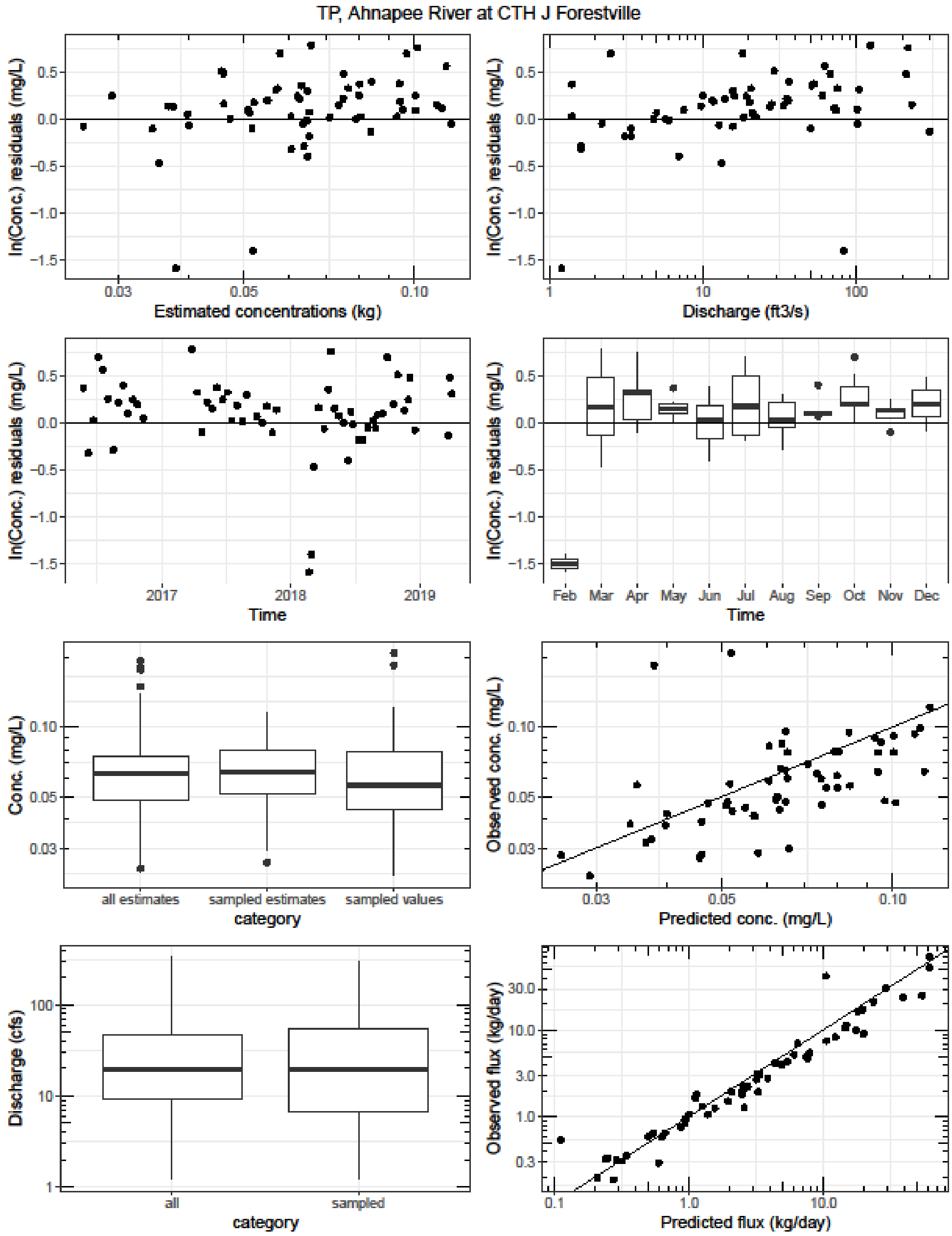


TSS, Silver Creek−200 Feet Below Dam 100 Feet Above Bridge In Breumerville Park Off Willow Drive.

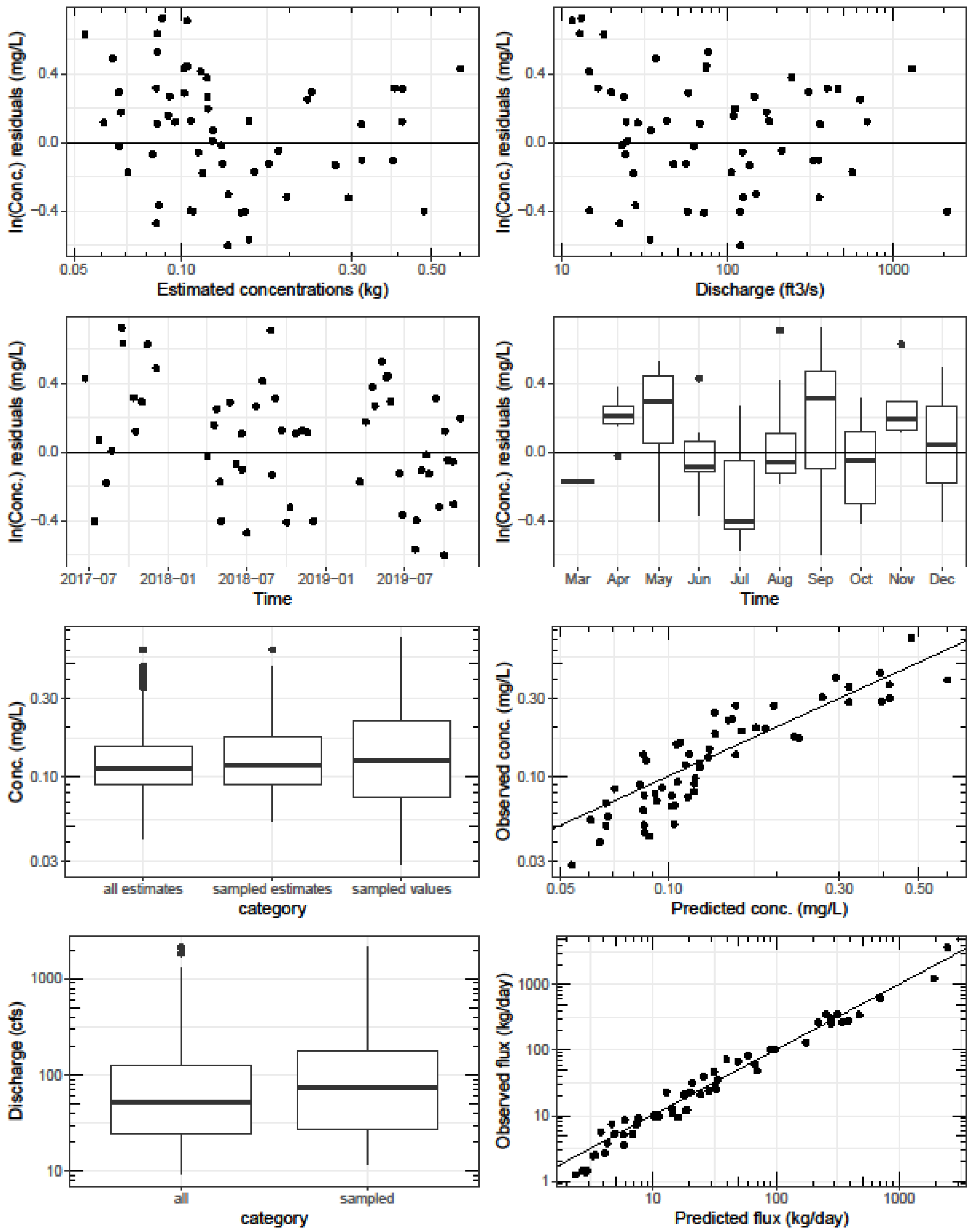


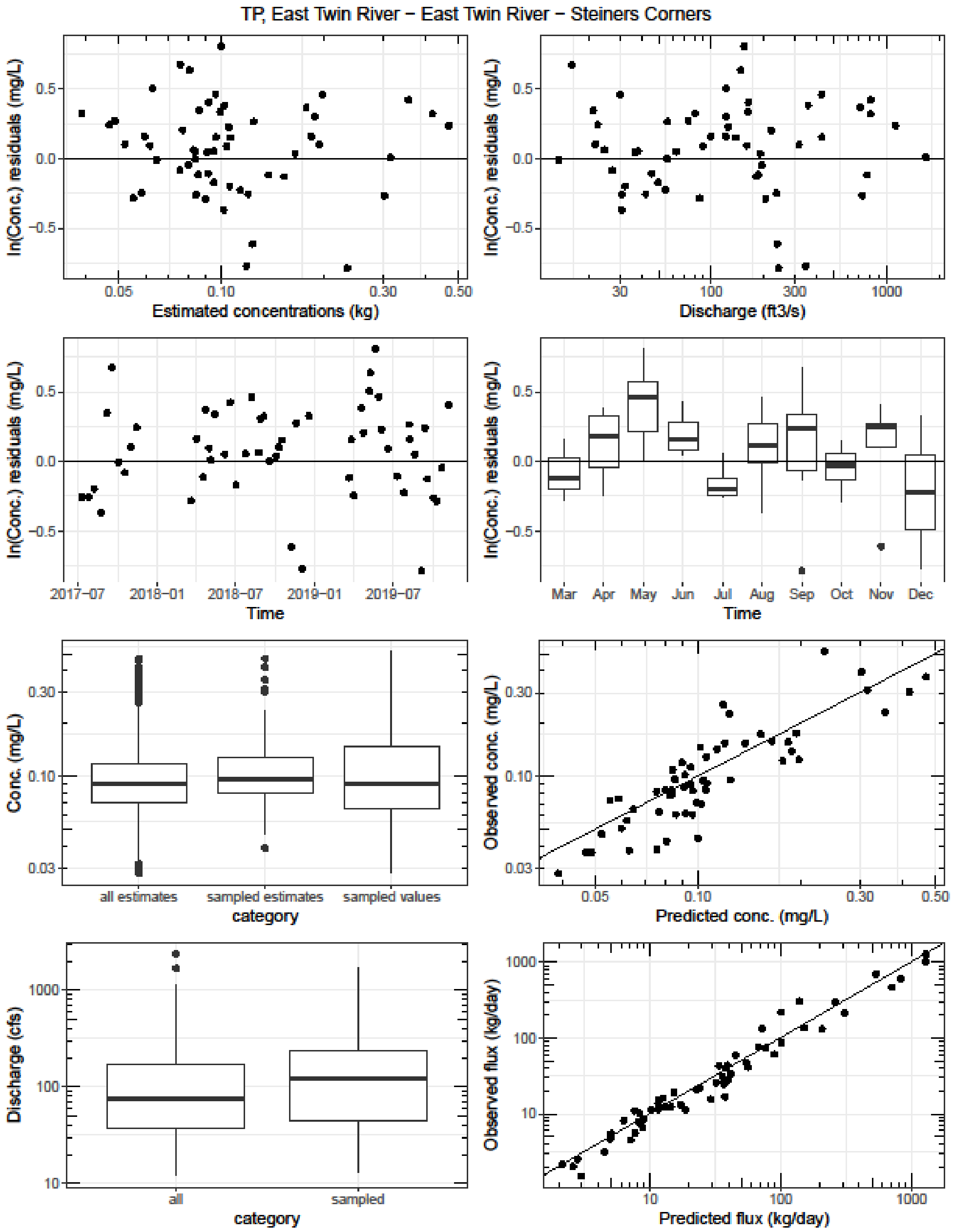

TSS, West Twin River at CTH V
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2017-07 2018-01 2018-07 2019-01 2019-07
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

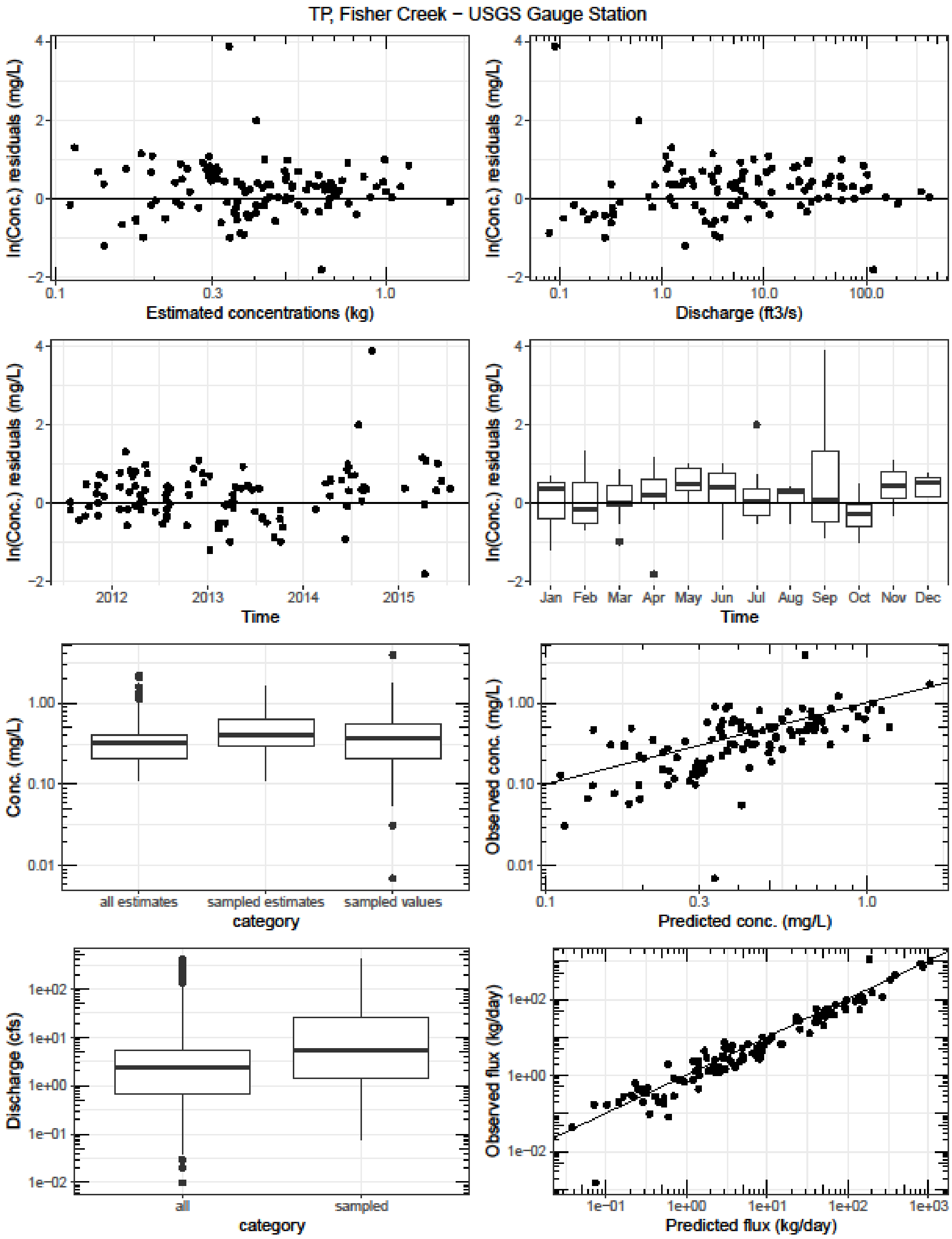
8.2.2 Total Phosphorus Composite Plots

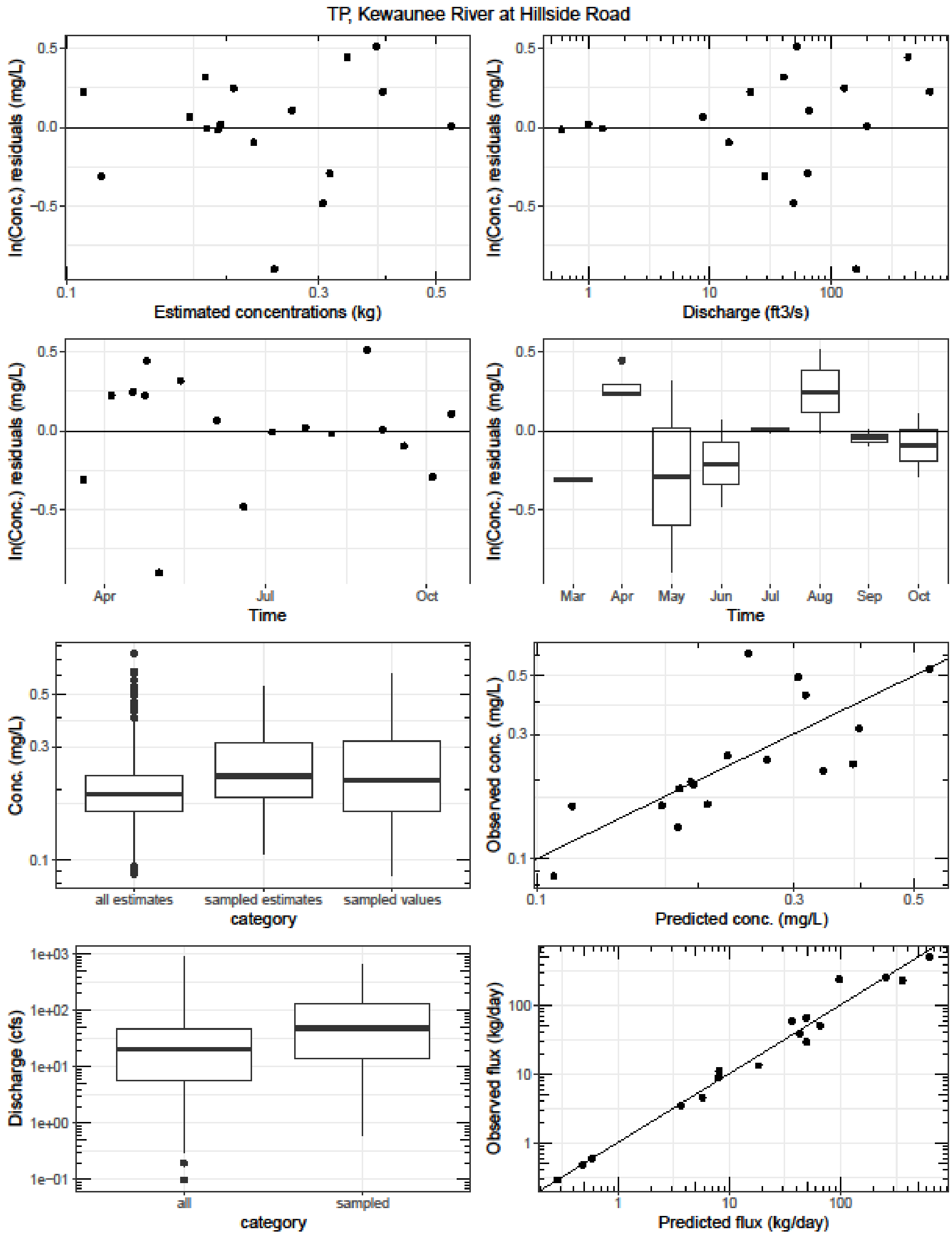


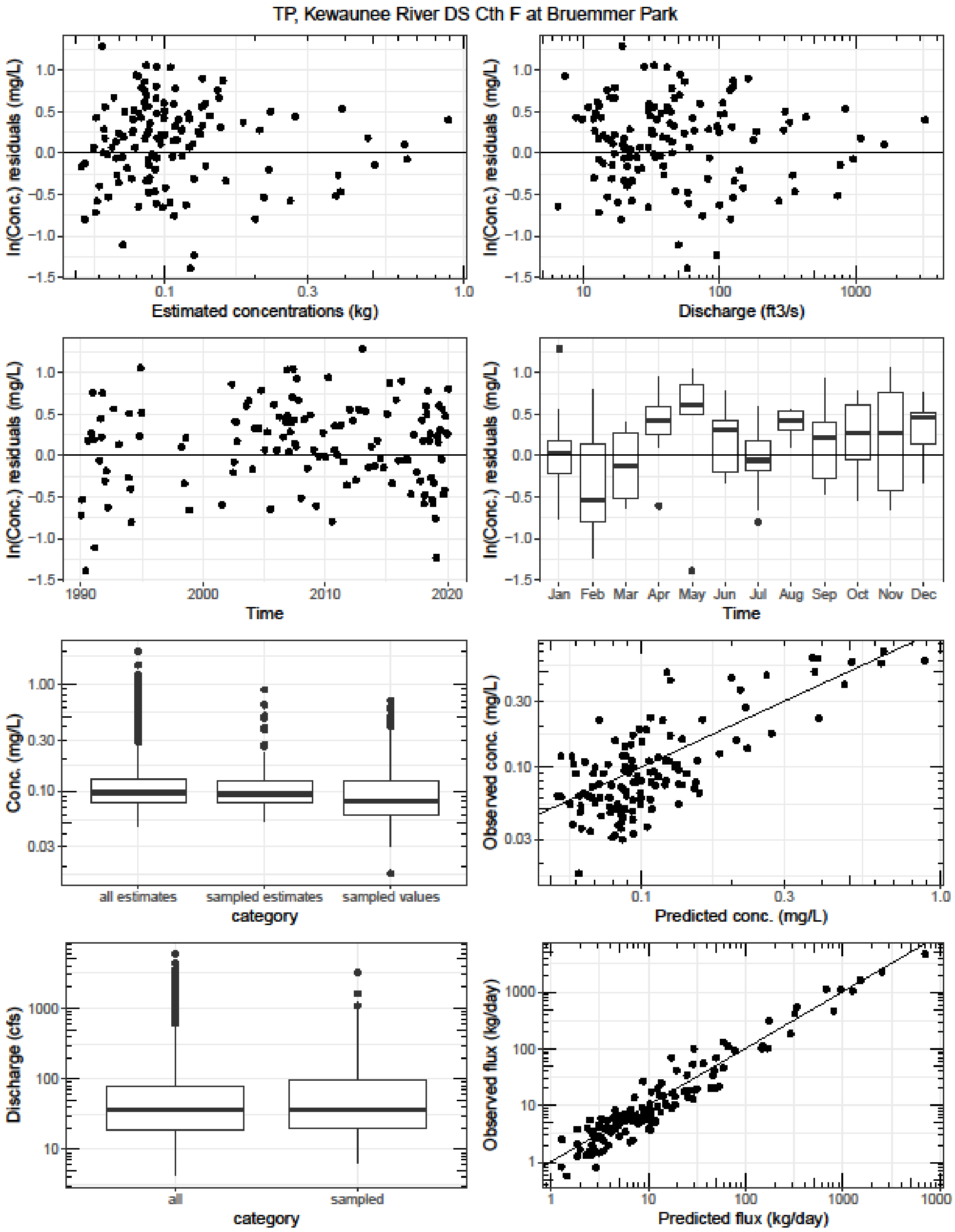
TP, Branch River − Above Branch River Rd



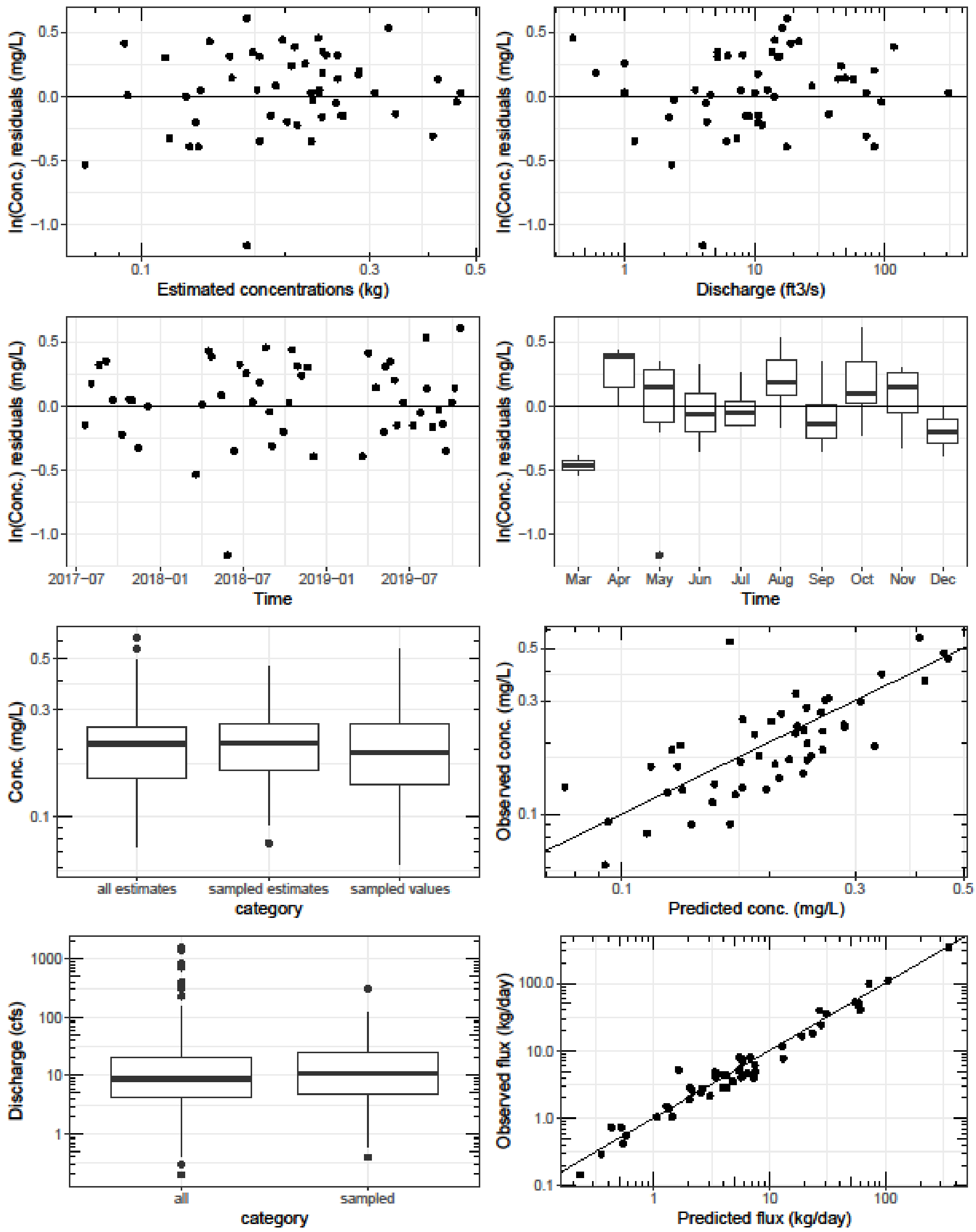

TP, East Twin River – East Twin River – Steiners Corners
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

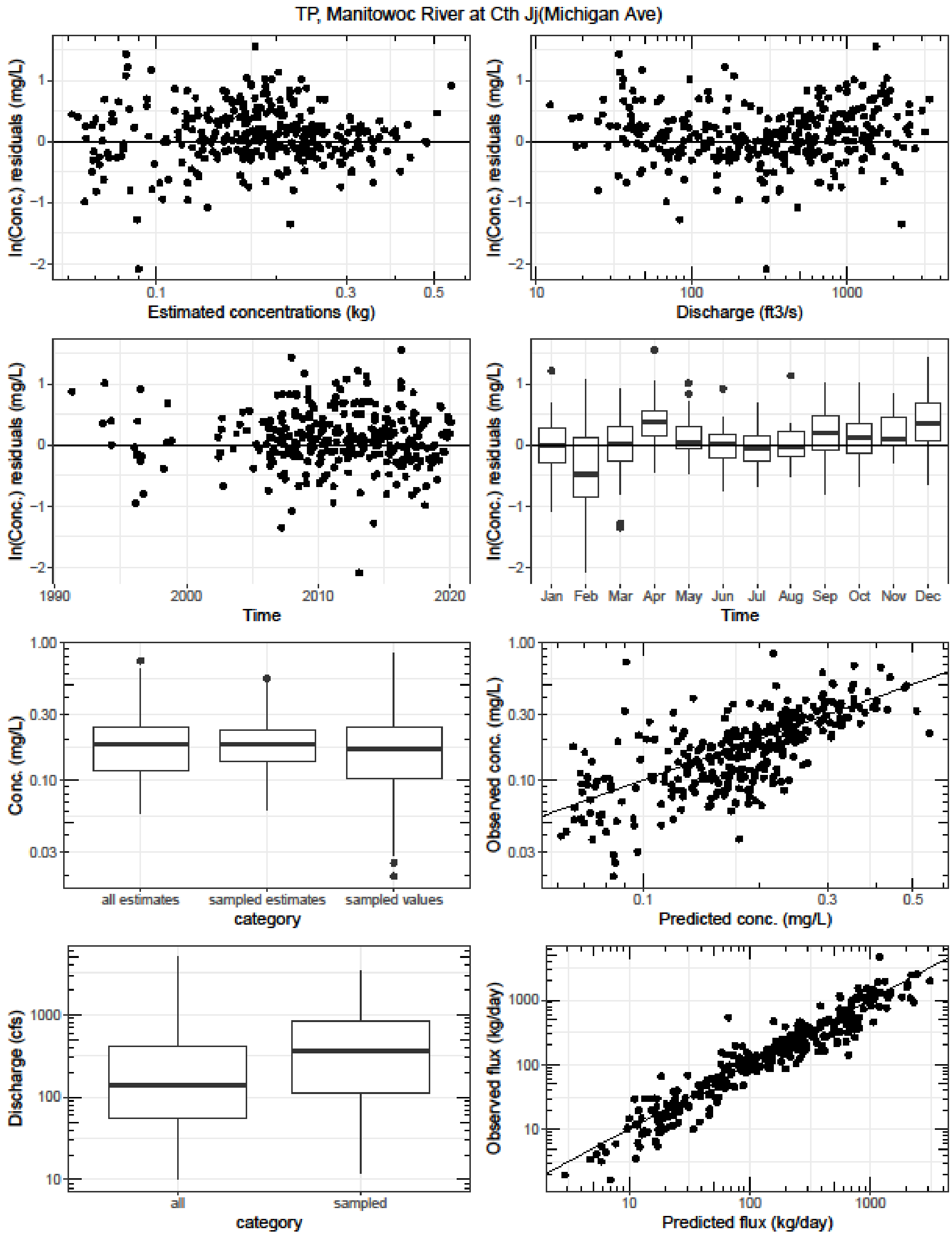

TP, Fisher Creek − USGS Gauge Station
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

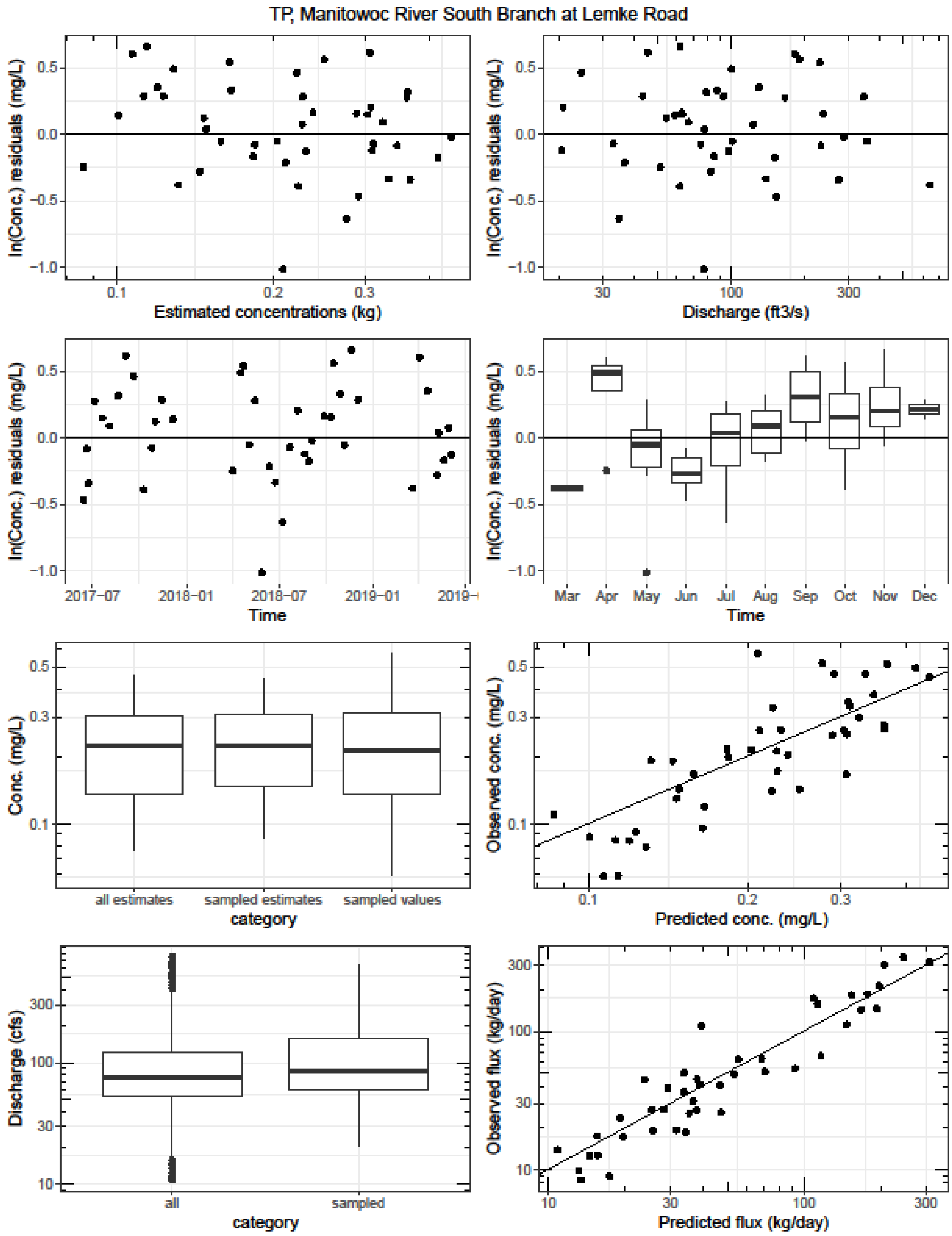

TP, Kewaunee River at Hillside Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TP, Kewaunee River DS Cth F at Bruemmer Park
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

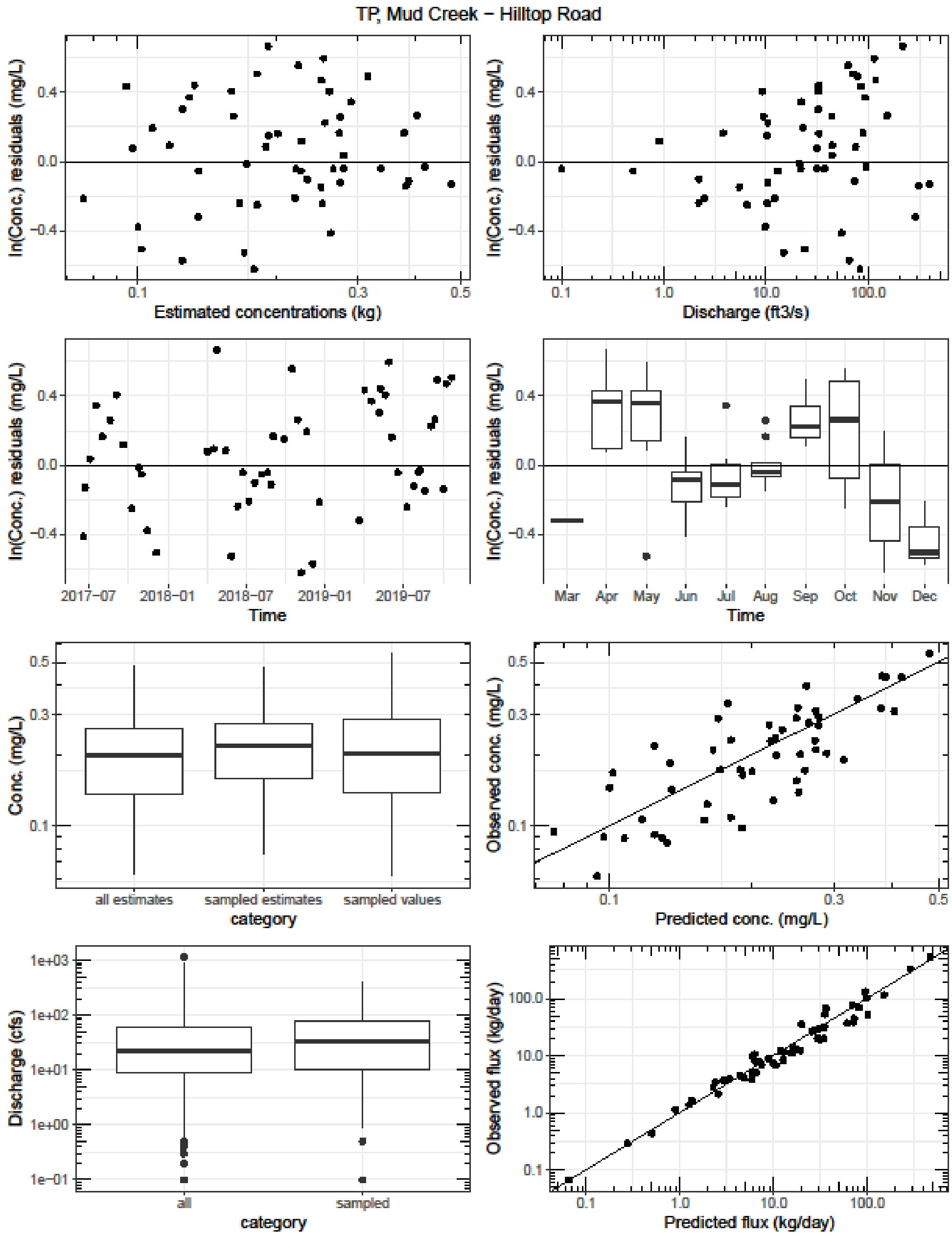
TP, Killsnake River at County Rd Y

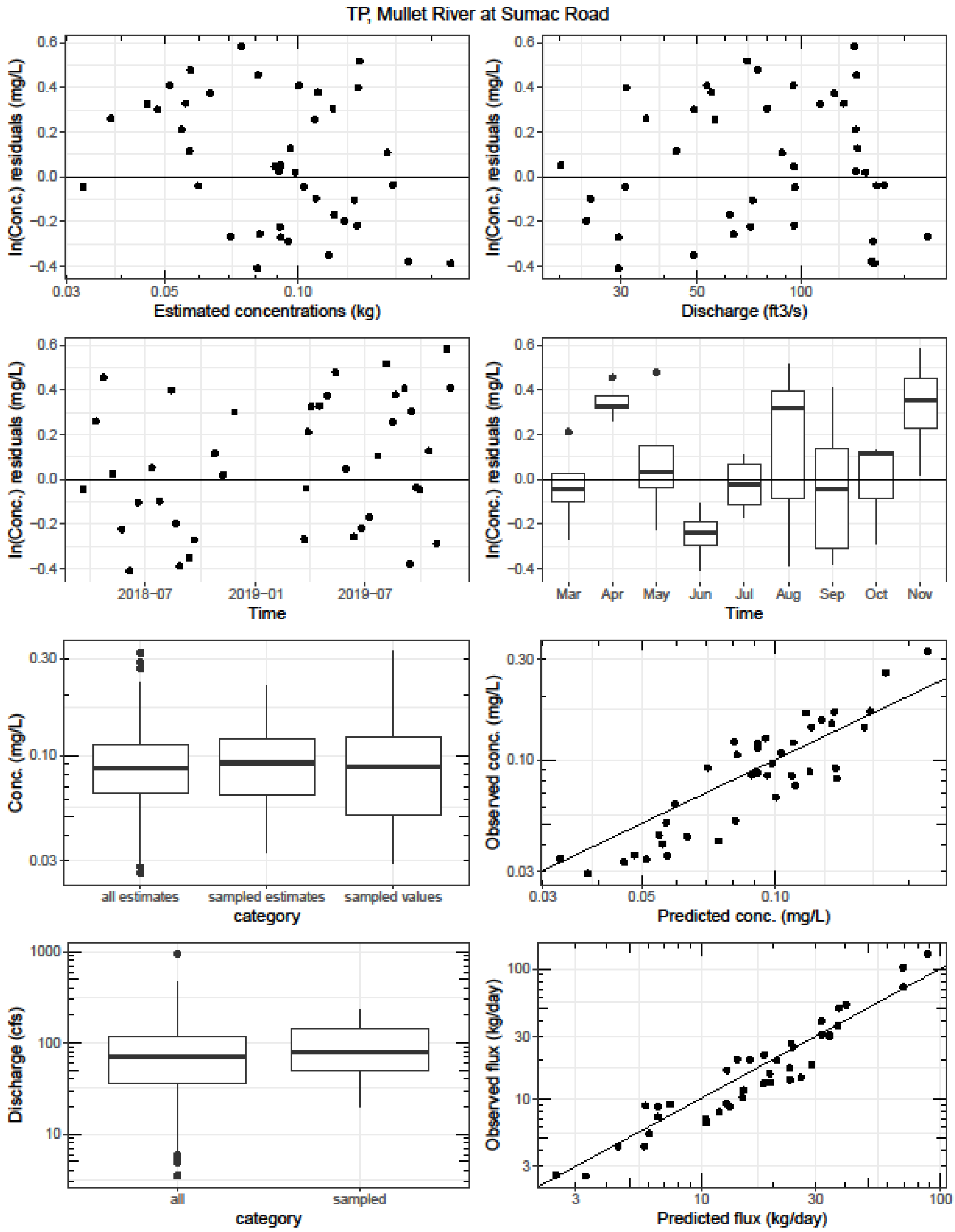


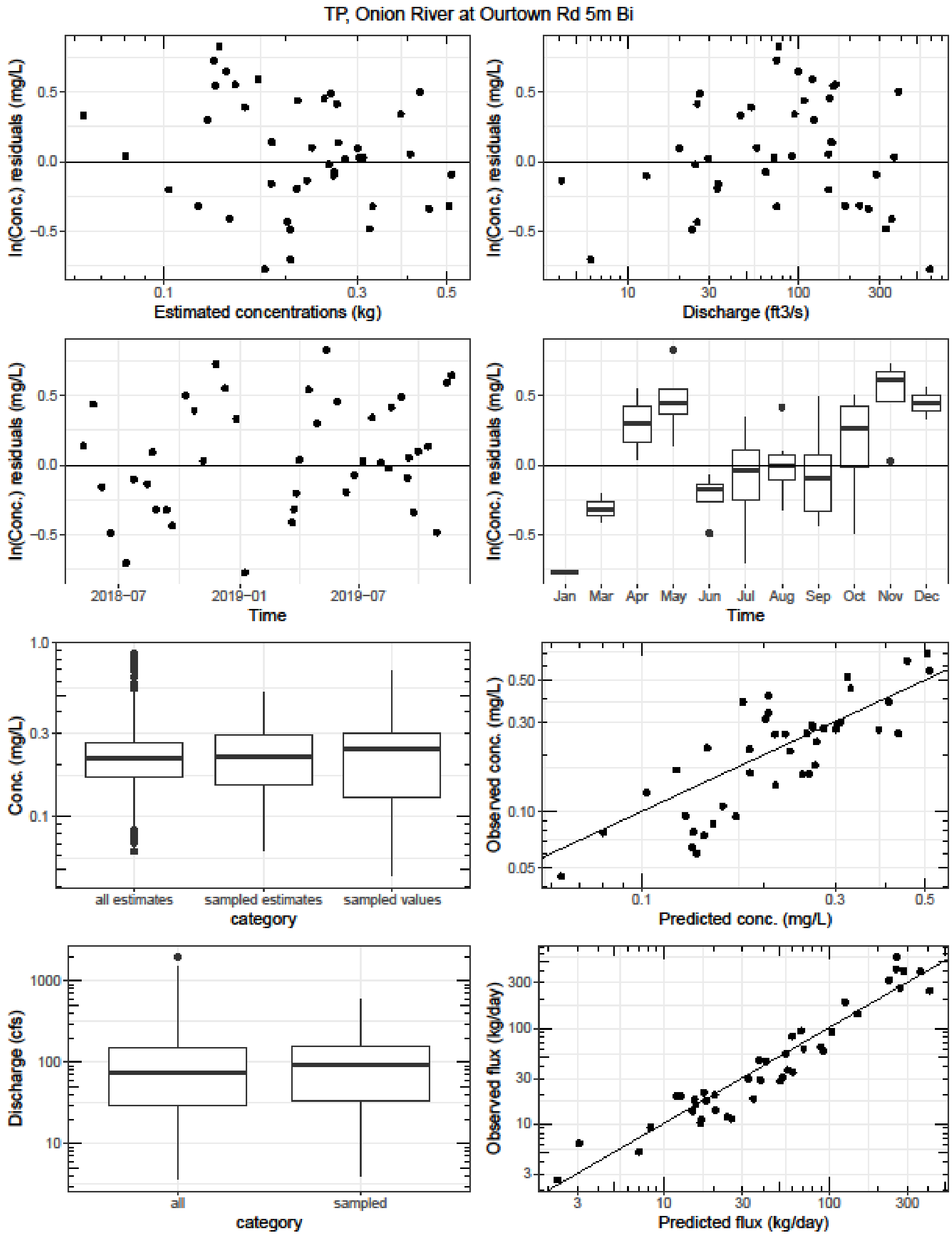

TP, Manitowoc River at Cth Jj(Michigan Ave)
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)



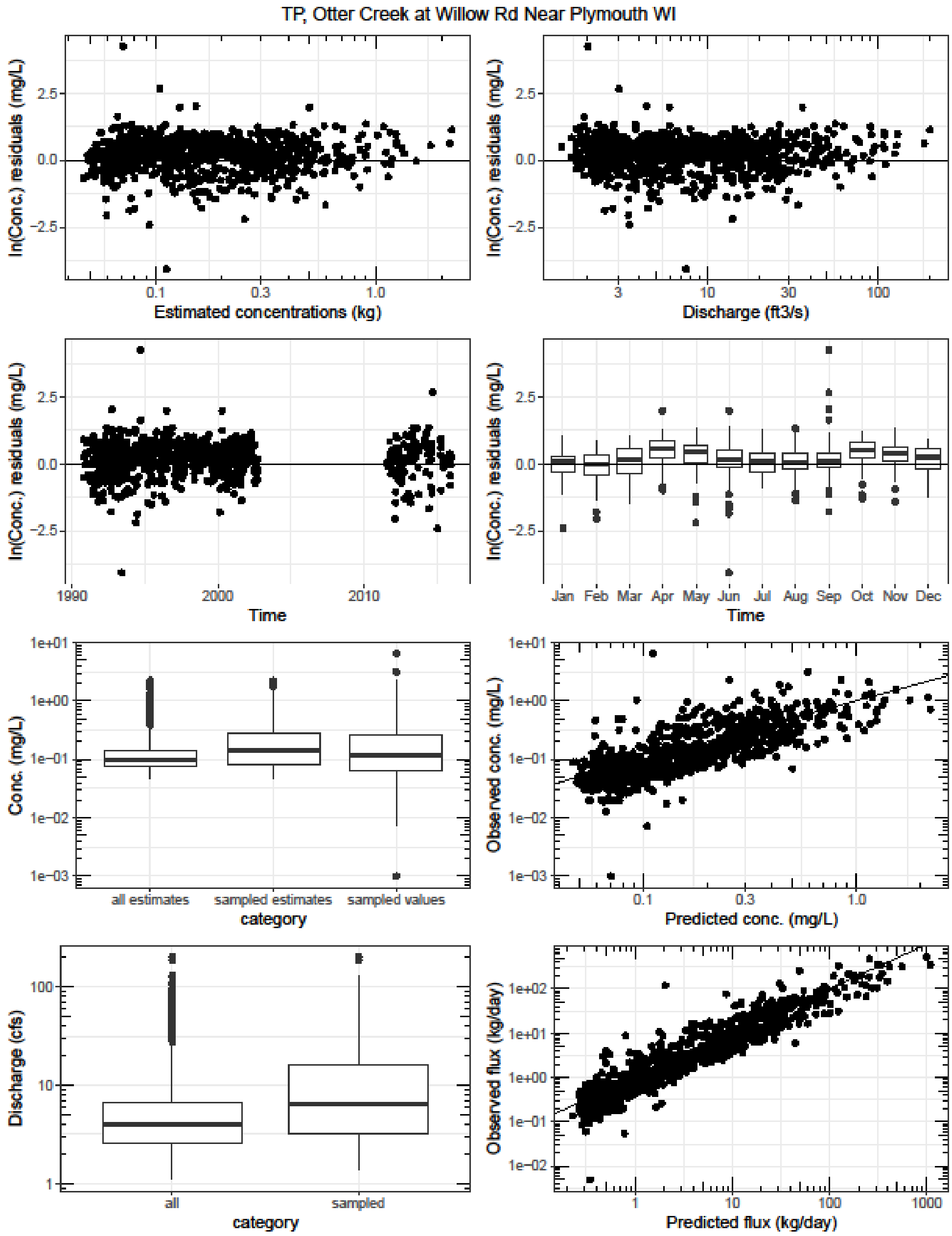
TP, Manitowoc River South Branch at Lemke Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
0.1
0.2
0.3
Discharge (ft3/s)
30
100
300
Time
2017−07
2018−01
2018−07
2019−01
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TP, Mud Creek – Hilltop Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
2017−07
2018−01
2018−07
2019−01
2019−07
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TP, Mullet River at Sumac Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Conc. (mg/L)
category
all estimates
sampled estimates
sampled values
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

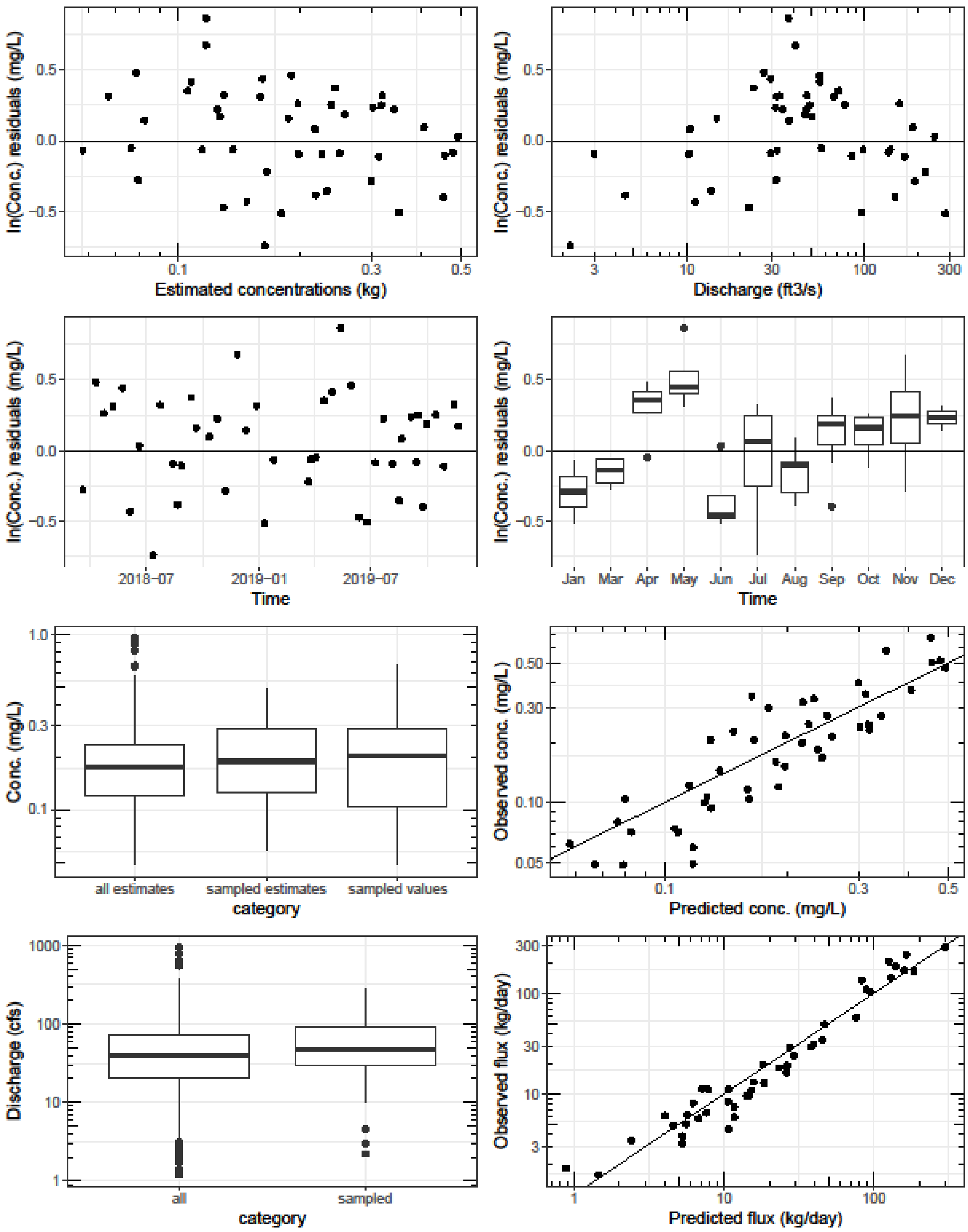


TP, Onion River at Ourtown Rd 5m Bi
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2018−07
2019−01
2019−07
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

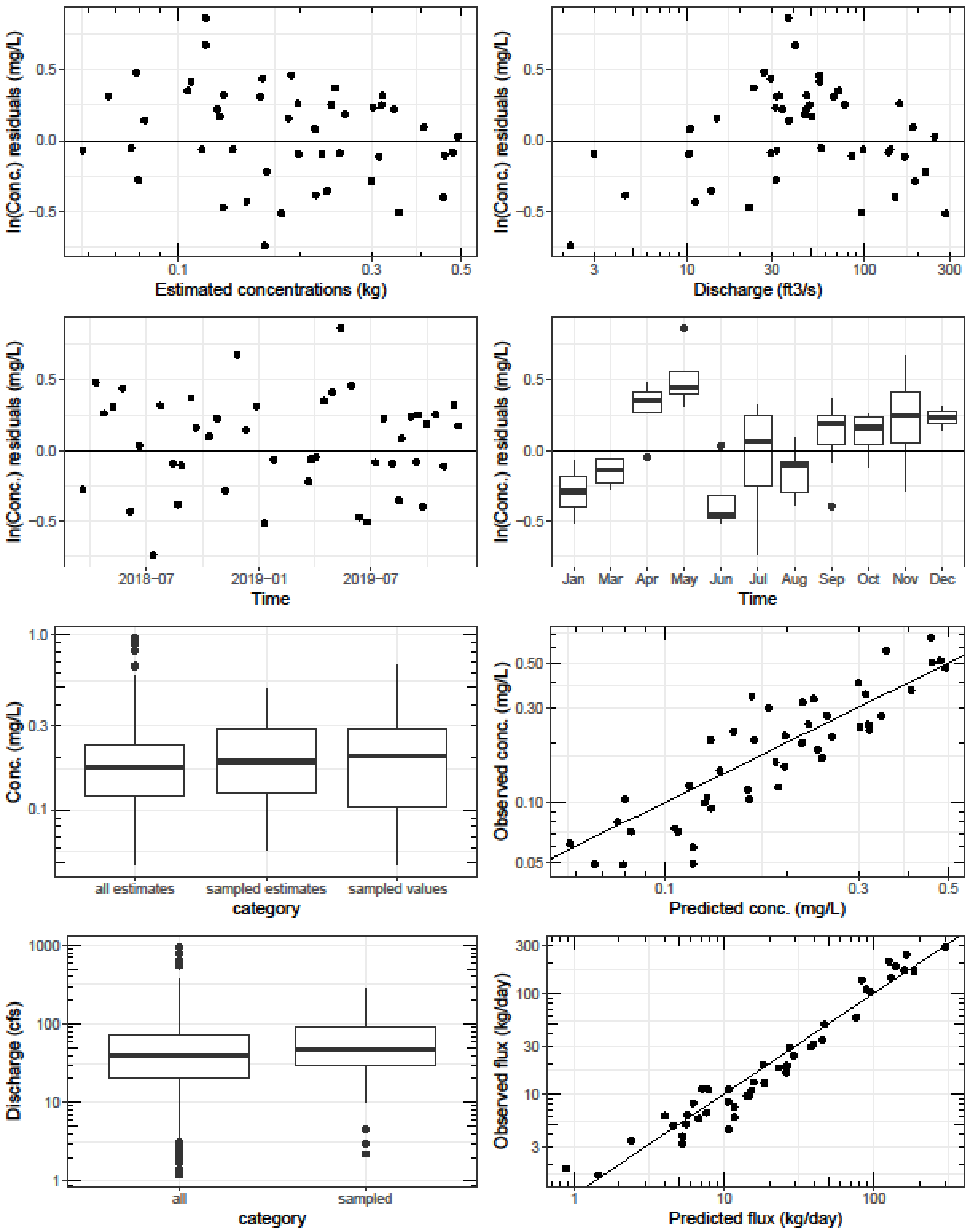


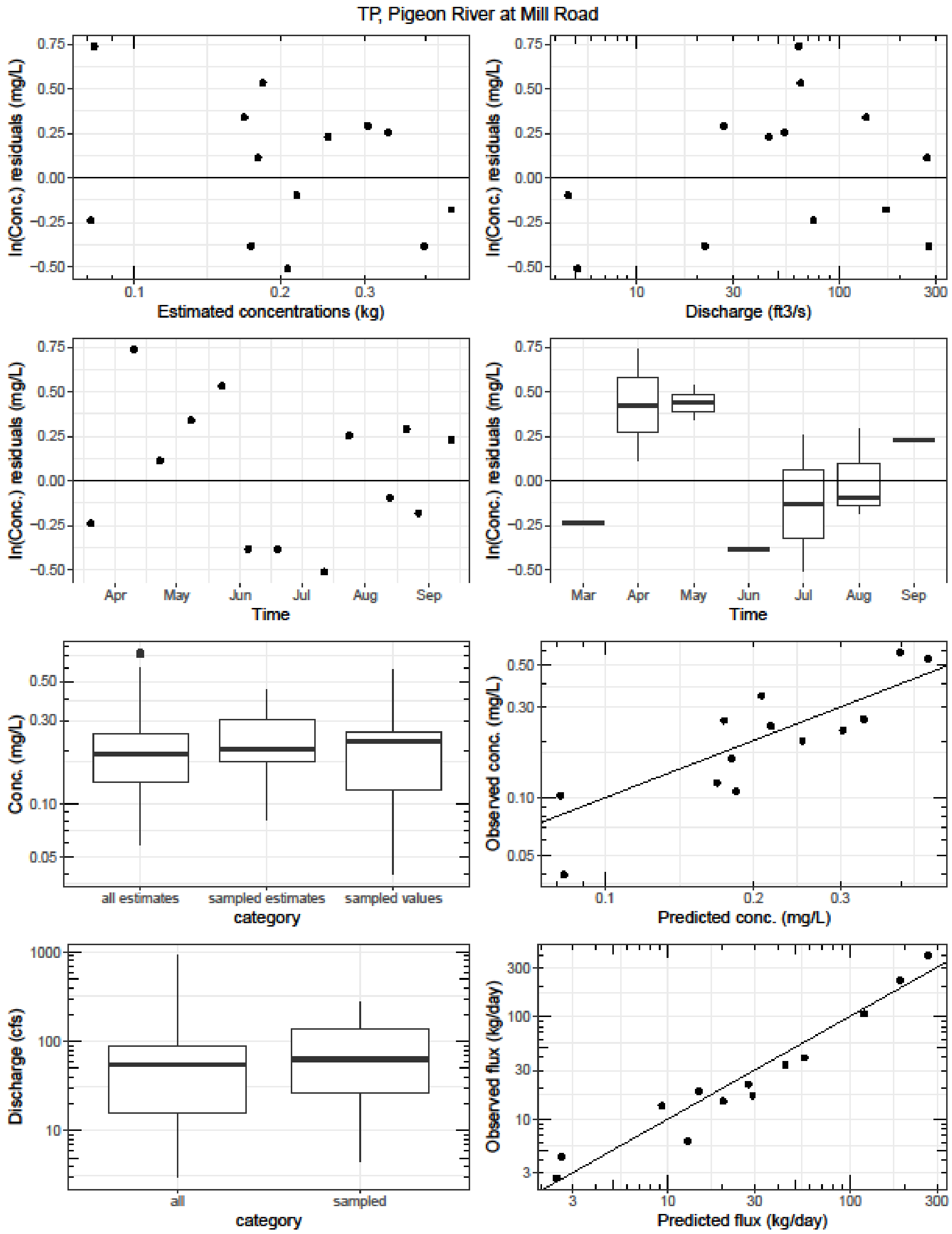
TP, Otter Creek at Willow Rd Near Plymouth WI
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

TP, Pigeon River at Cth A −And River Rd

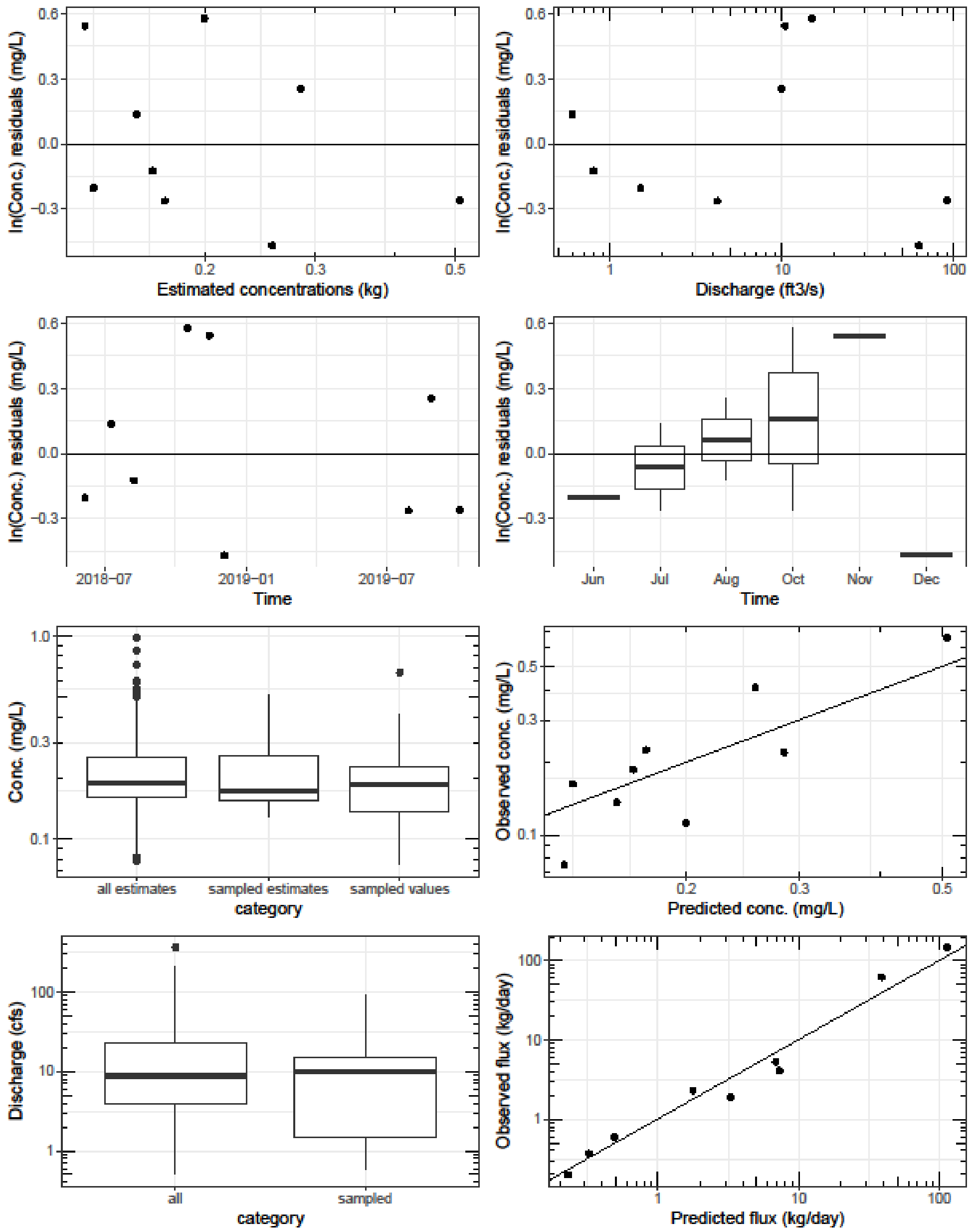


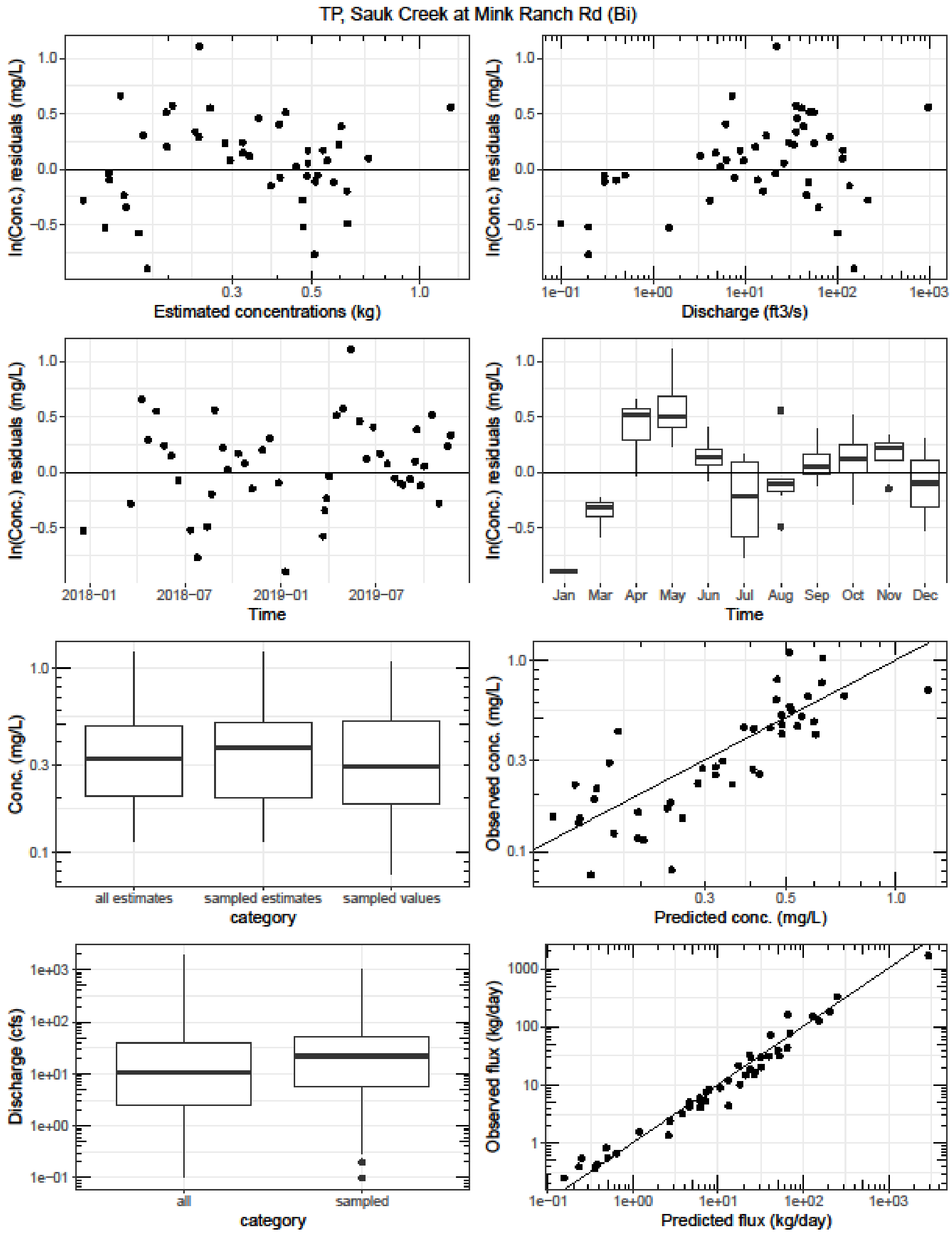
TP, Pigeon River at Cth A −And River Rd



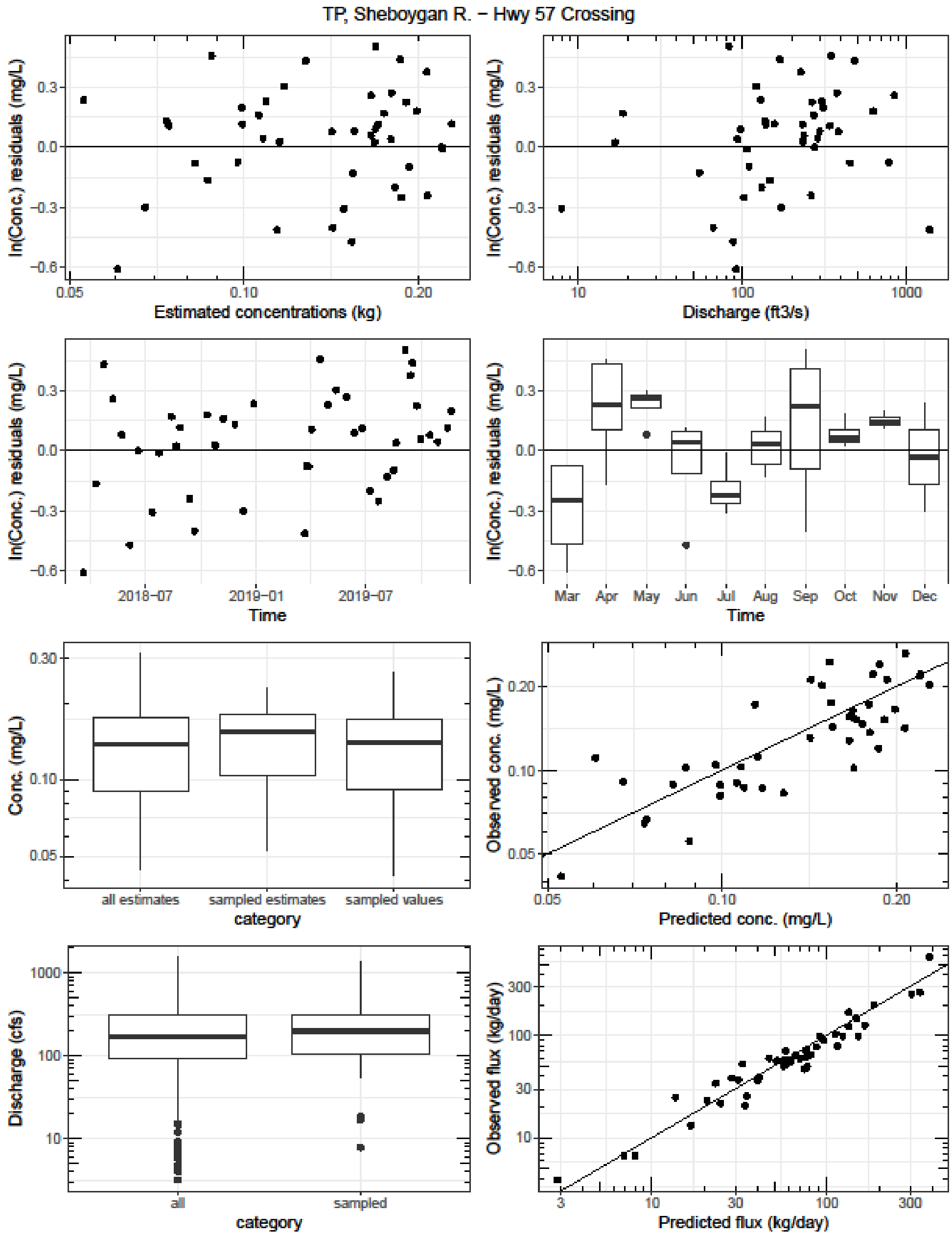

TP, Pigeon River at Mill Road
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Apr
May
Jun
Jul
Aug
Sep
Mar
Conc. (mg/L)
category
all estimates
sampled estimates
sampled values
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

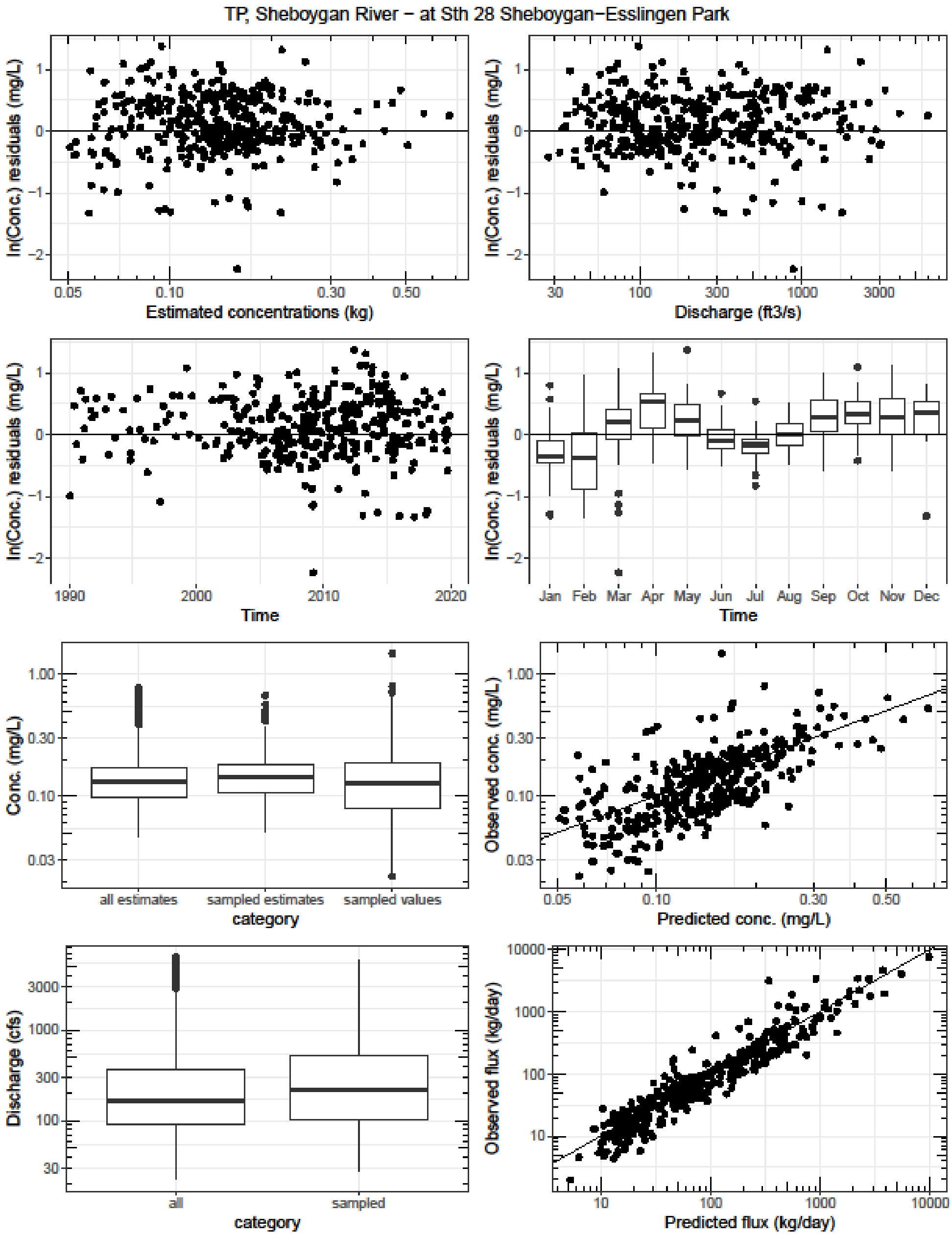
TP, Point Creek at Centerville Road Near Newton WI

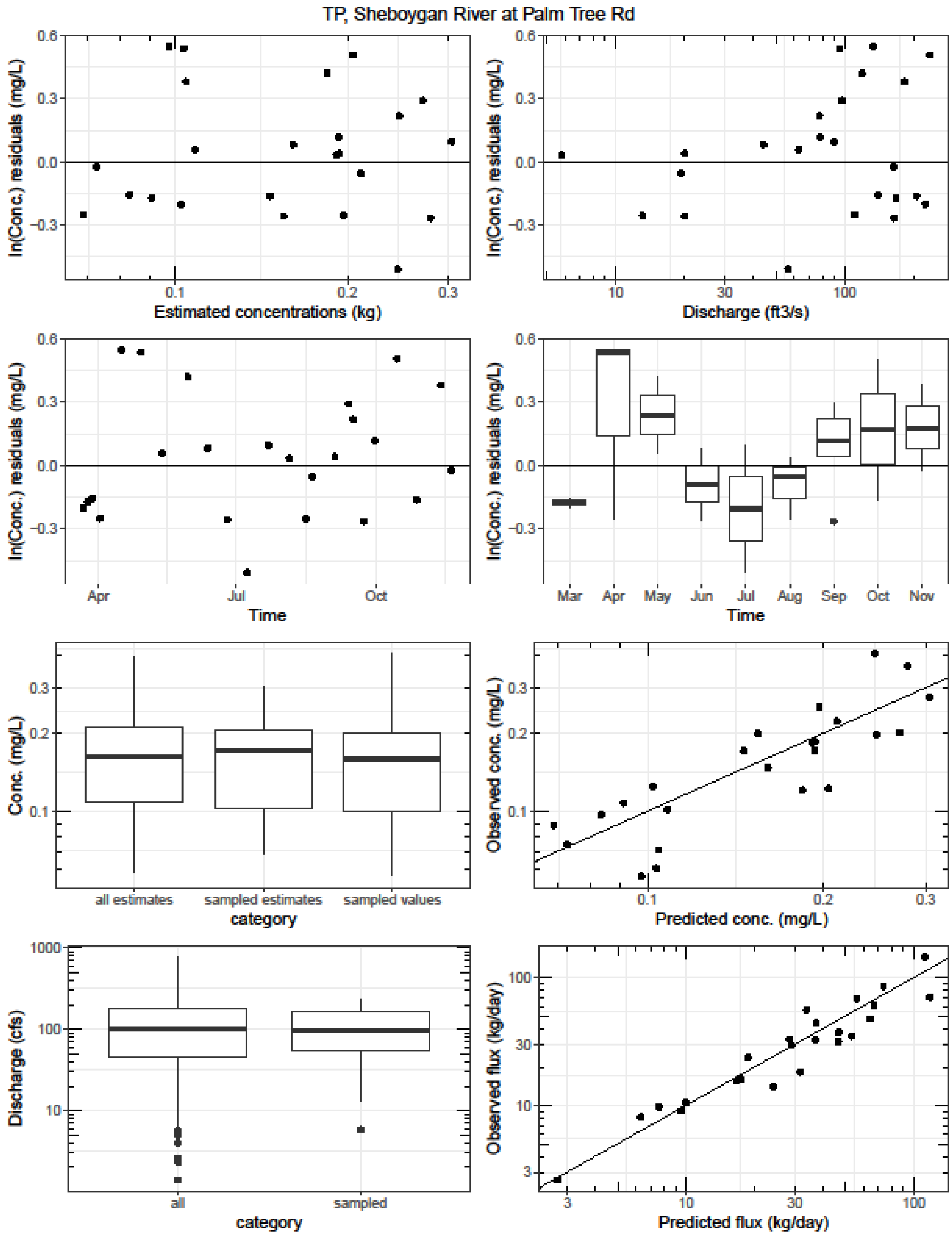




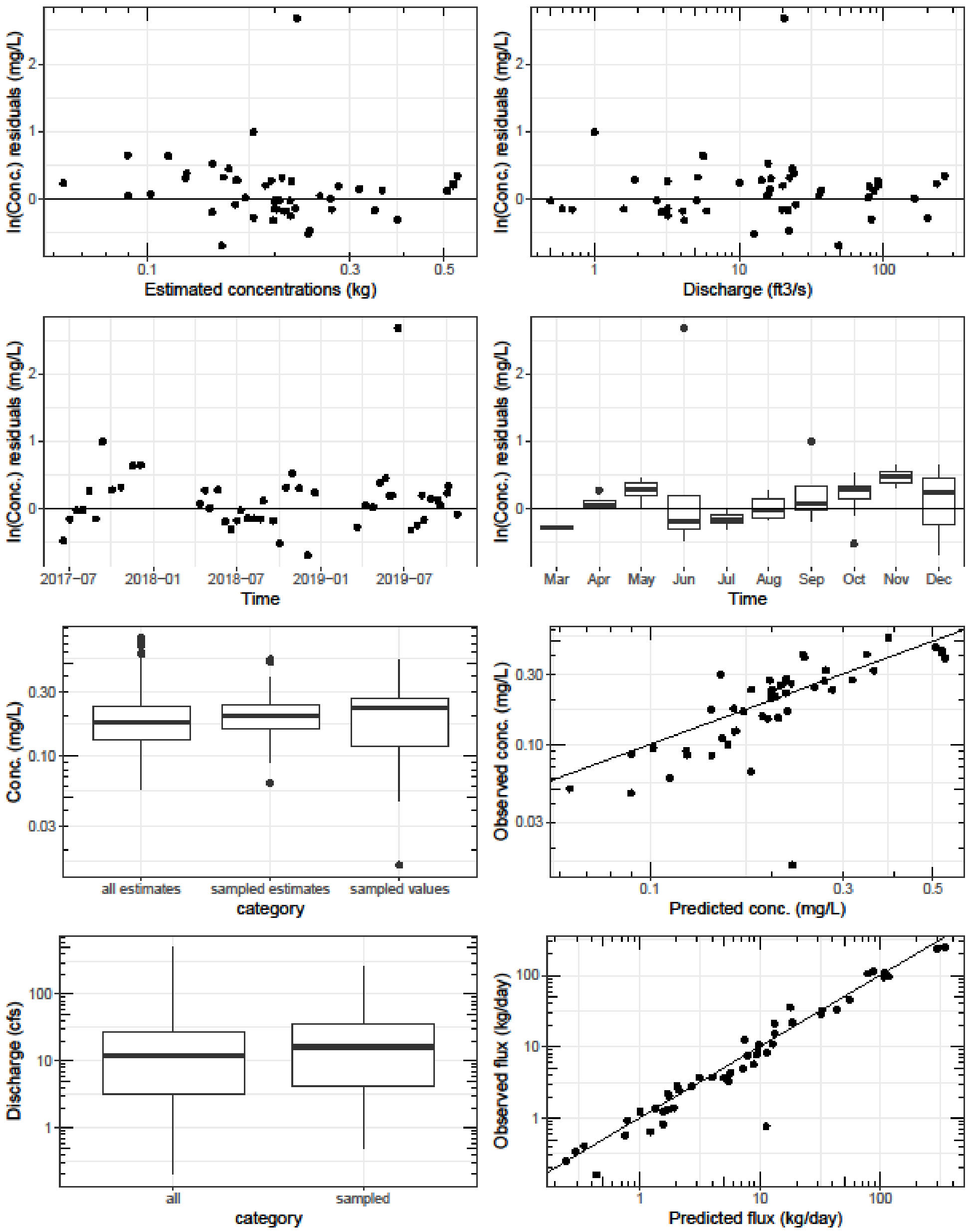
TP, Sauk Creek at Mink Ranch Rd (Bi)
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)


TP, Sheboygan R. – Hwy 57 Crossing
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2018−07 2019−01 2019−07
Conc. (mg/L)
all estimates sampled estimates sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all sampled
Observed flux (kg/day)
Predicted flux (kg/day)

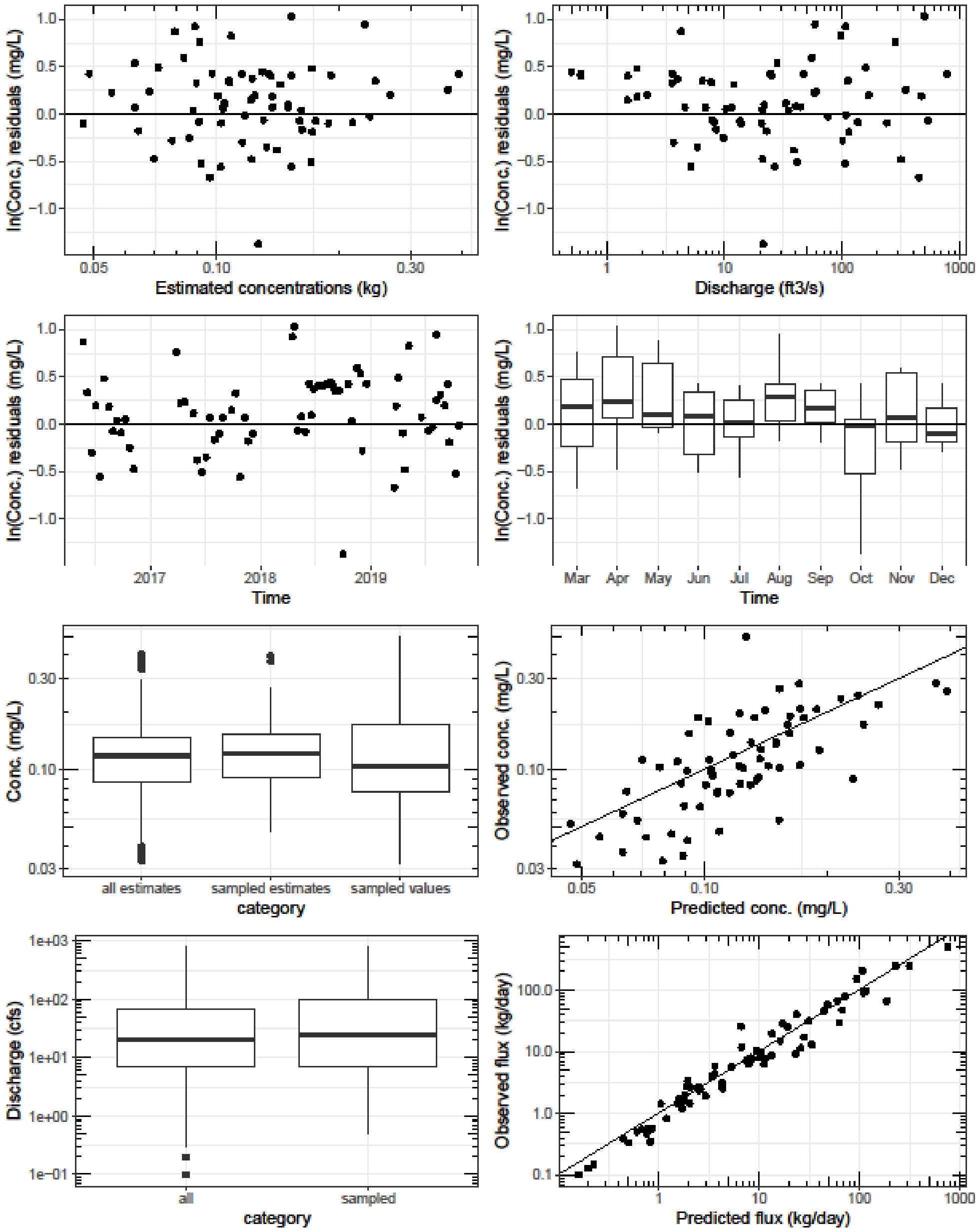

TP, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

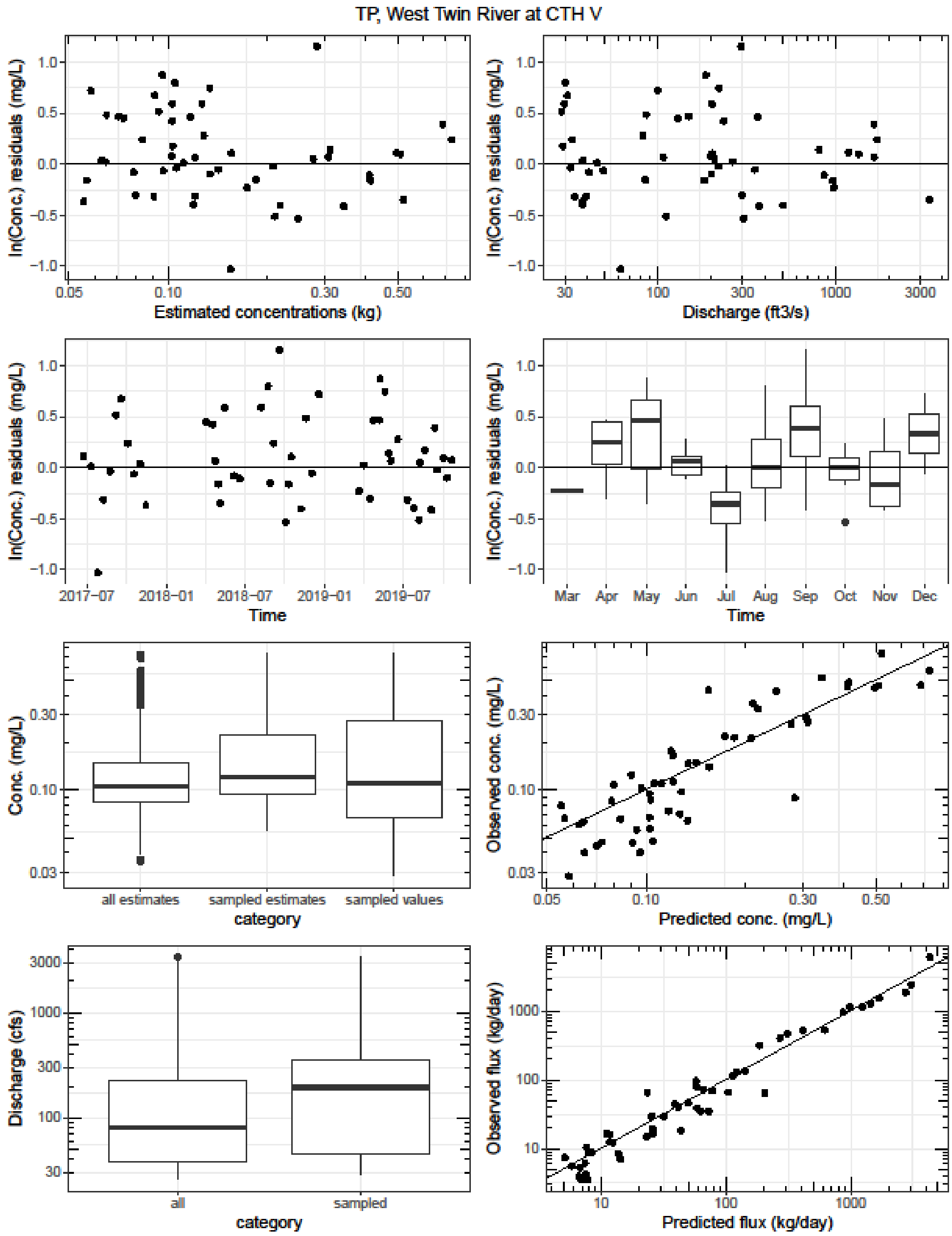

TP, Sheboygan River at Palm Tree Rd
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Apr
Jul
Oct
Mar
May
Jun
Aug
Sep
Nov
Conc. (mg/L)
category
all estimates
sampled estimates
sampled values
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

TP, Silver Creek at Cth Ls (Bi Sur)

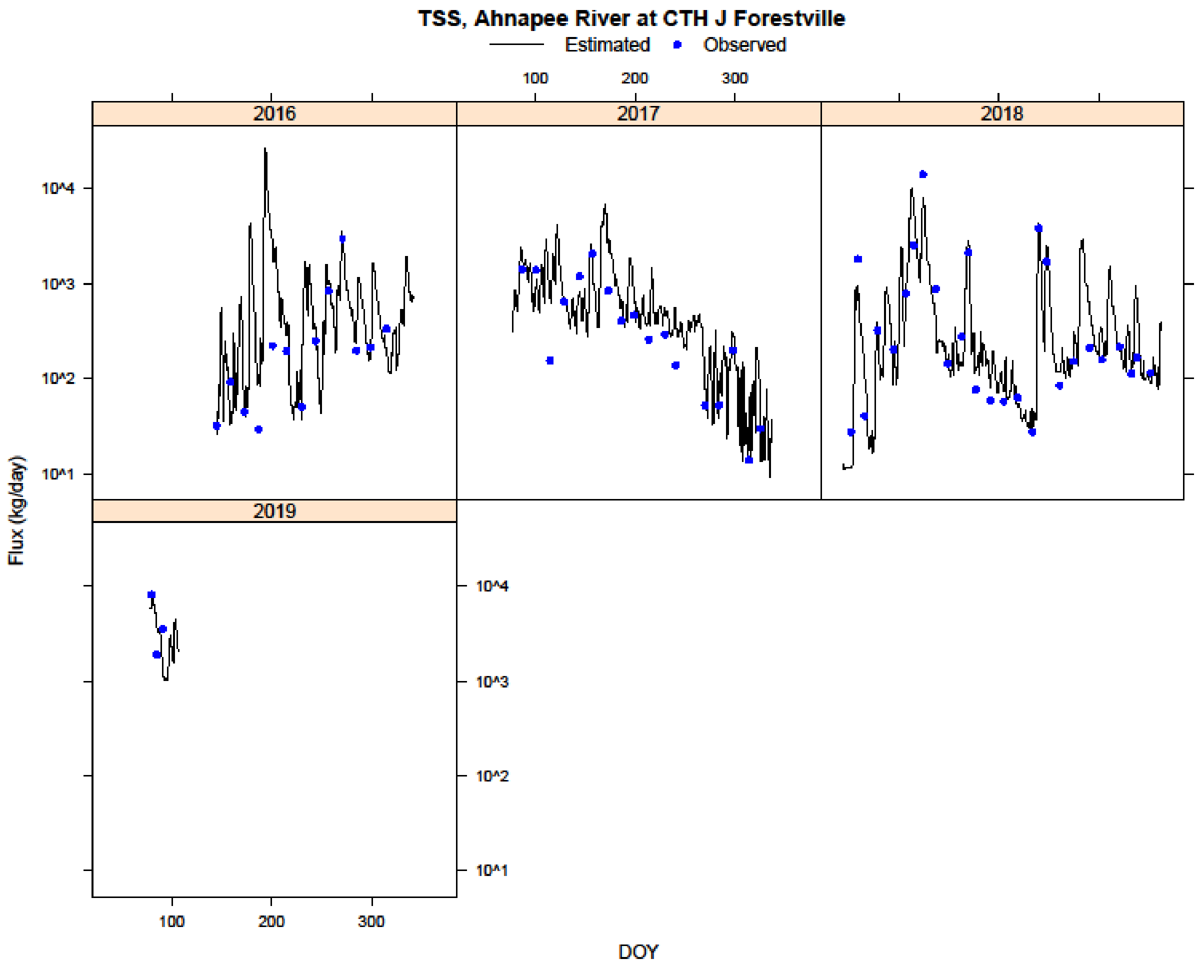


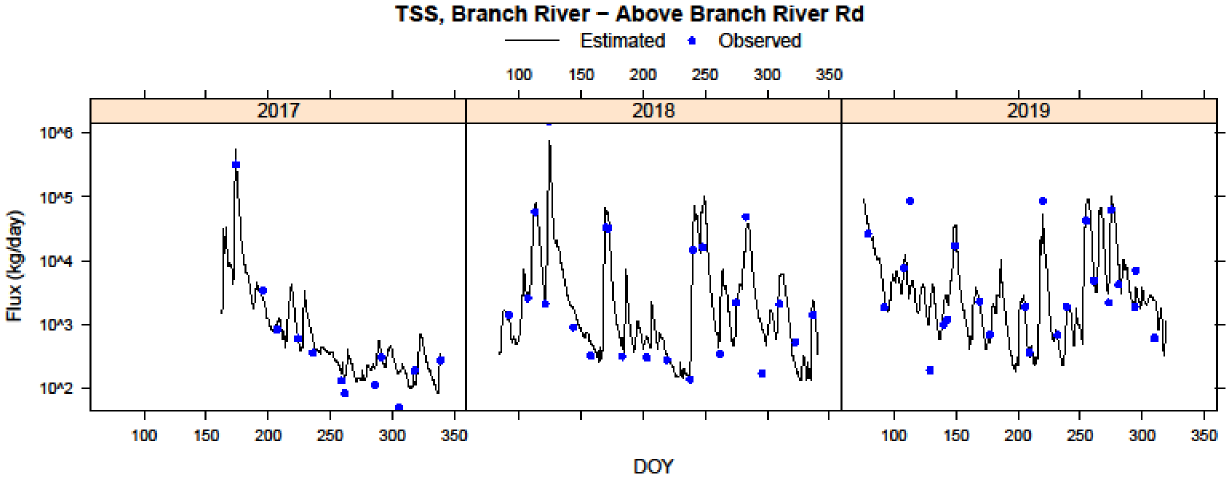
TP, Silver Creek−200 Feet Below Dam 100 Feet Above Bridge In Breumerville Park Off Willow Drive.

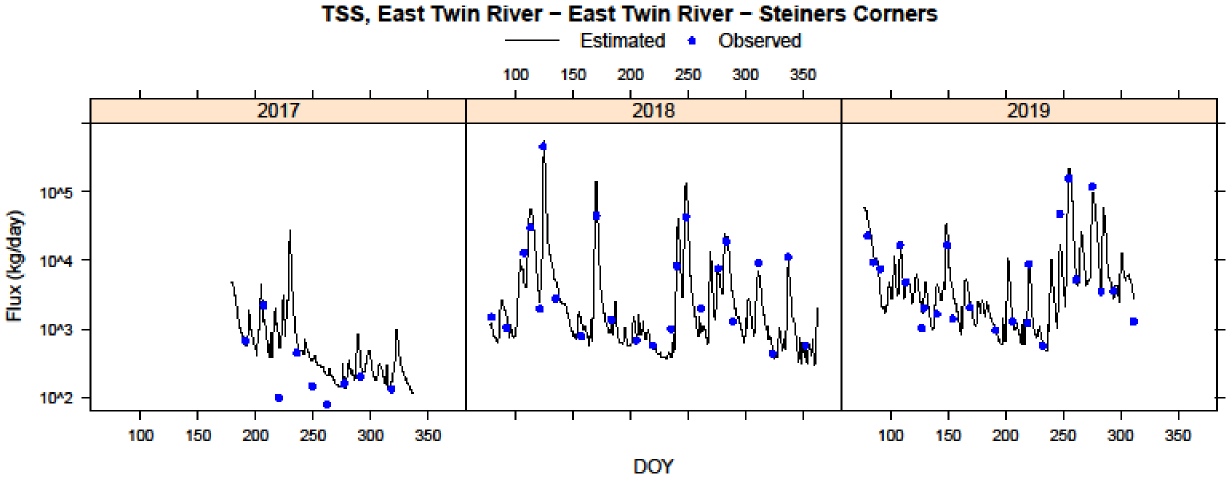


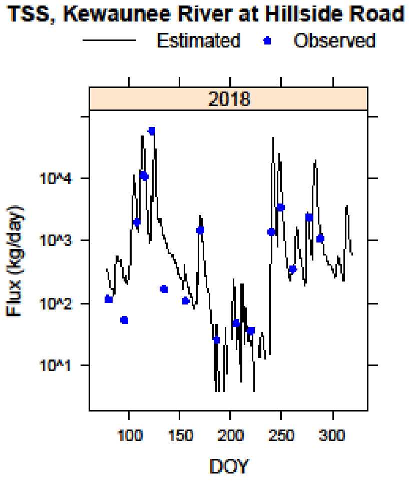

TP, West Twin River at CTH V
ln(Conc.) residuals (mg/L)
Estimated concentrations (kg)
Discharge (ft3/s)
Time
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Conc. (mg/L)
all estimates
sampled estimates
sampled values
category
Observed conc. (mg/L)
Predicted conc. (mg/L)
Discharge (cfs)
all
sampled
Observed flux (kg/day)
Predicted flux (kg/day)

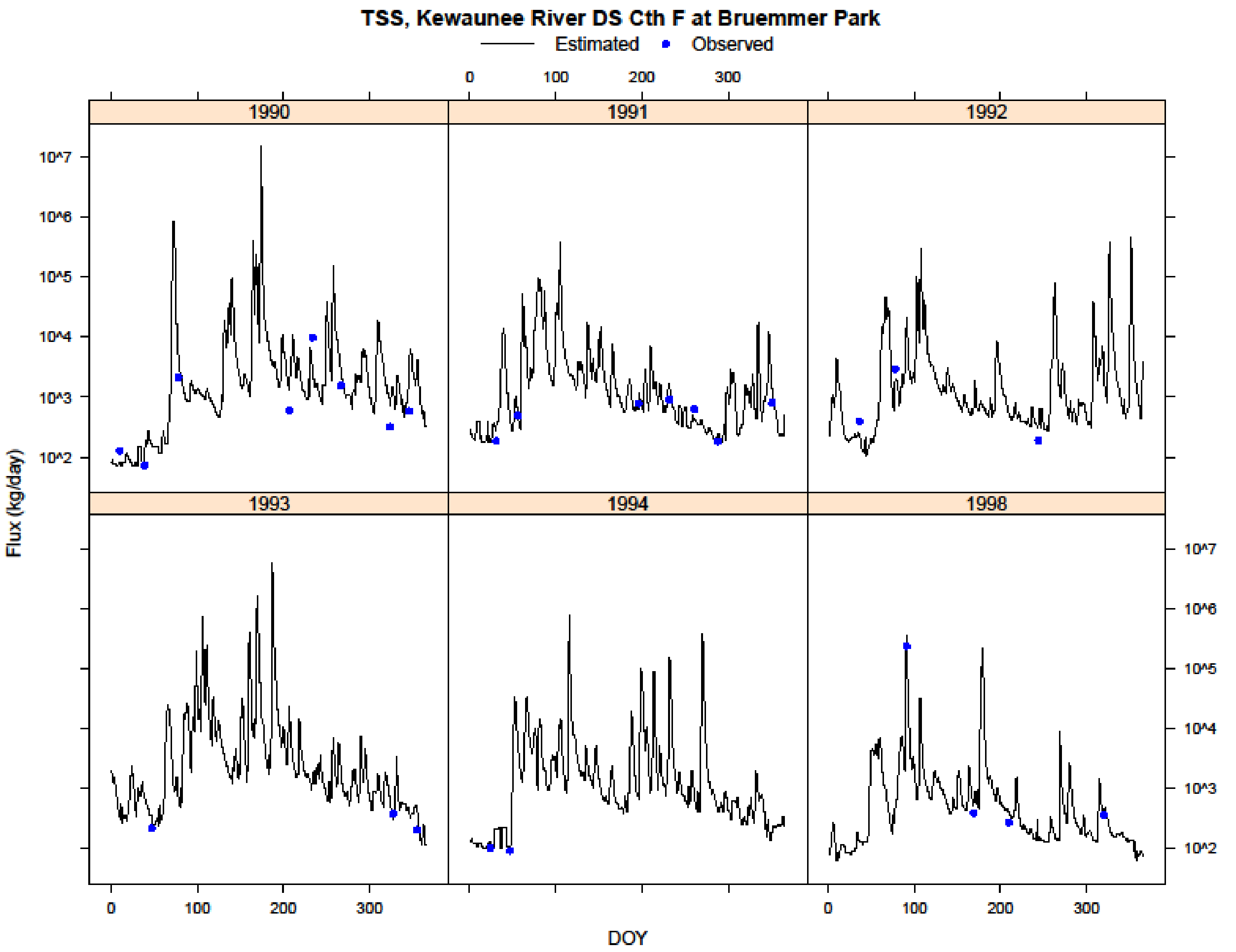
8.2.3 Total Suspended Solids Time-Series Plot

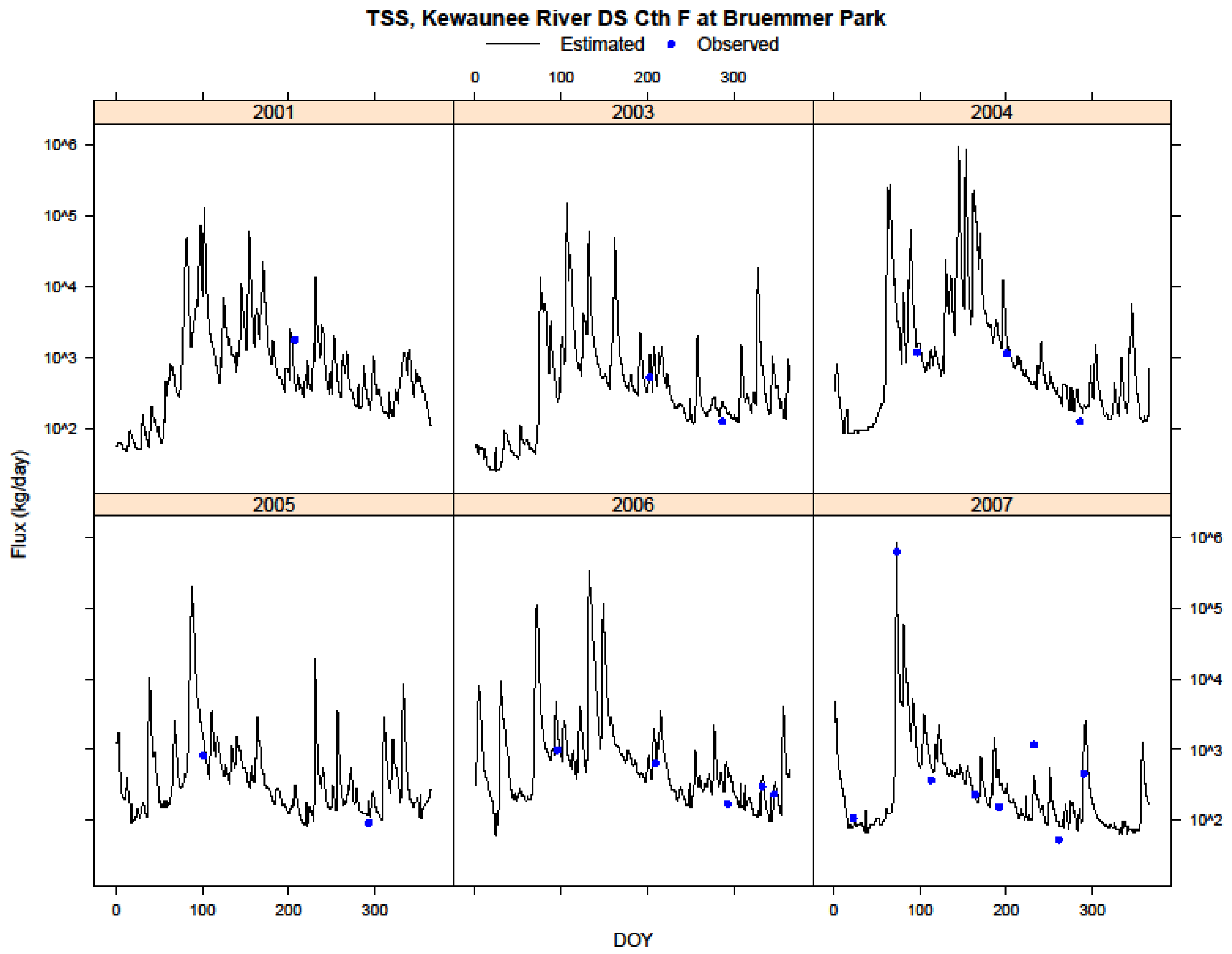

TSS, Ahnapee River at CTH J Forestville
Estimated
Observed
2016
2017
2018
2019
10^4
10^3
10^2
10^1
100
200
300
Flux (kg/day)
DOY

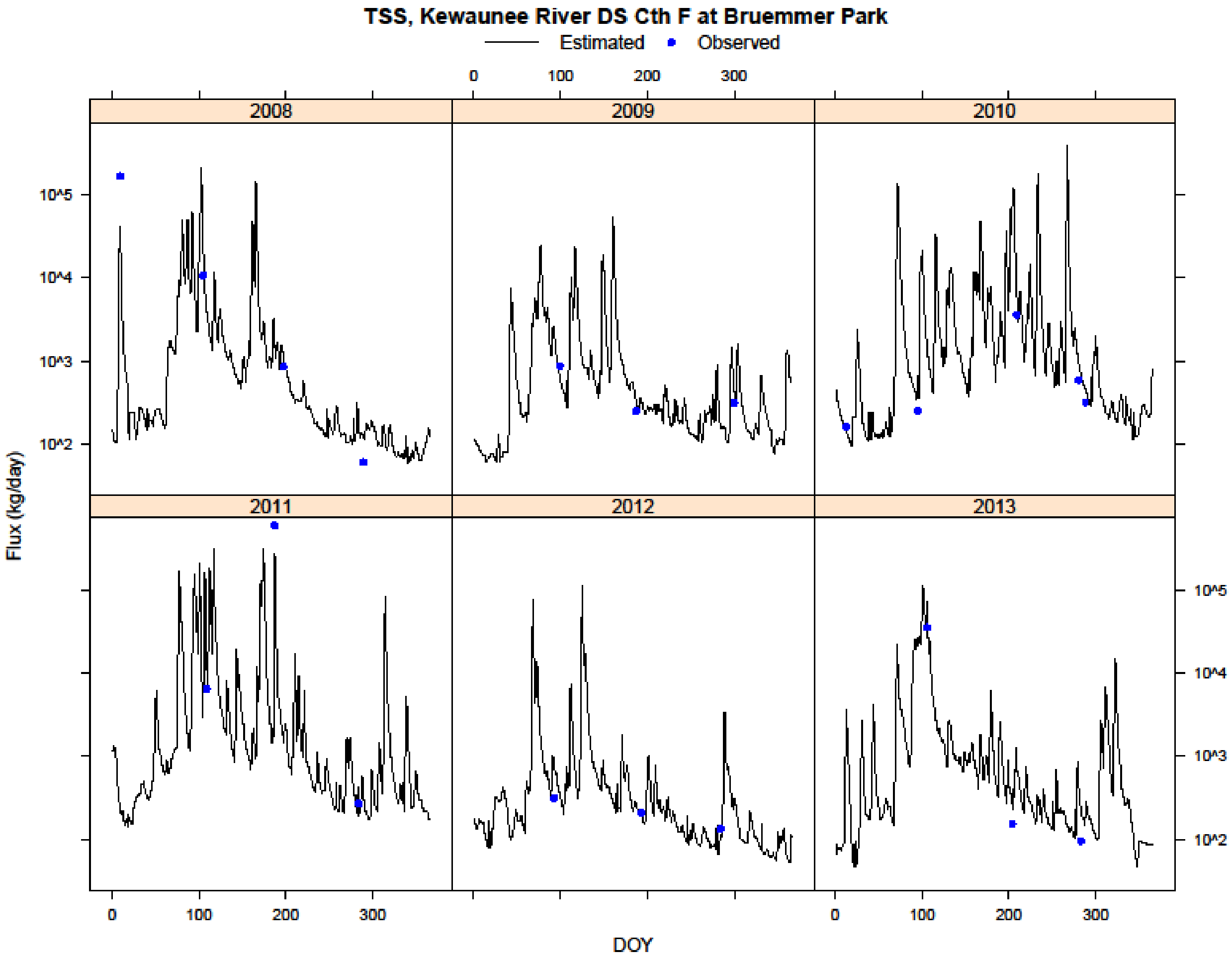

TSS, Branch River – Above Branch River Rd
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^6
10^5
10^4
10^3
10^2
100
150
200
250
300
350
DOY

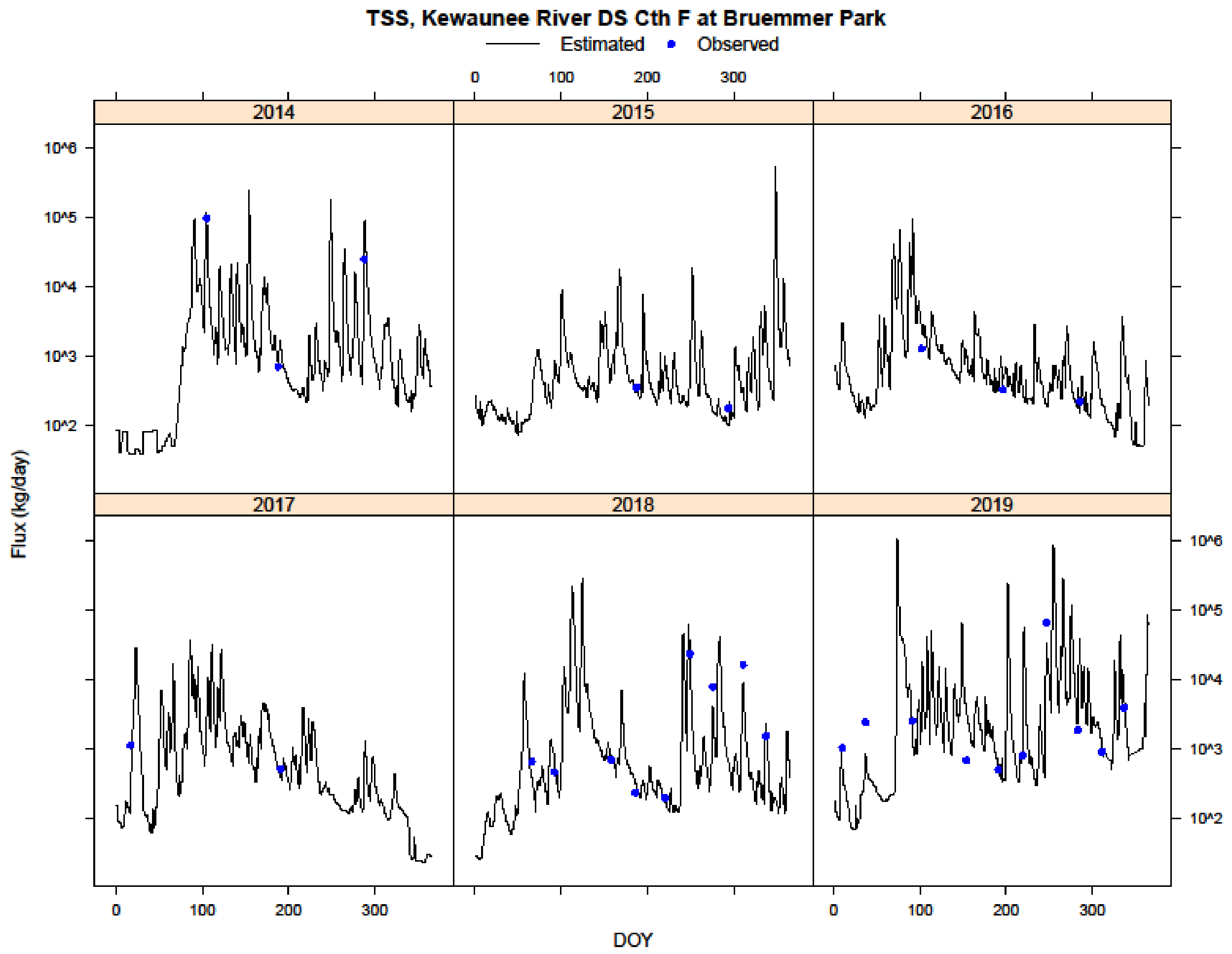

TSS, East Twin River – East Twin River – Steiners Corners
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
100 150 200 250 300 350
DOY


TSS, Kewaunee River at Hillside Road
Estimated
Observed
2018
Flux (kg/day)
10^4
10^3
10^2
10^1
100
150
200
250
300
DOY

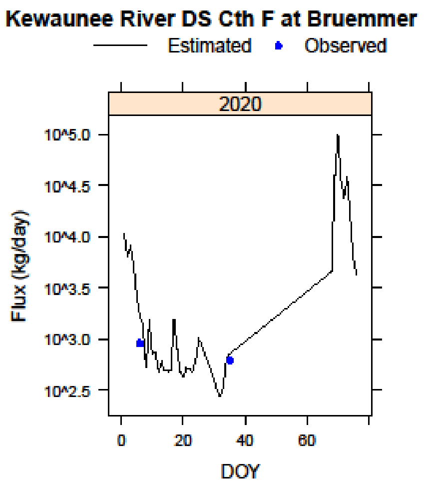

TSS, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
1990
1991
1992
1993
1994
1998
Flux (kg/day)
10^7
10^6
10^5
10^4
10^3
10^2
0
100
200
300
DOY


TSS, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2001
2003
2004
2005
2006
2007
Flux (kg/day)
10^6
10^5
10^4
10^3
10^2
0
100
200
300
DOY

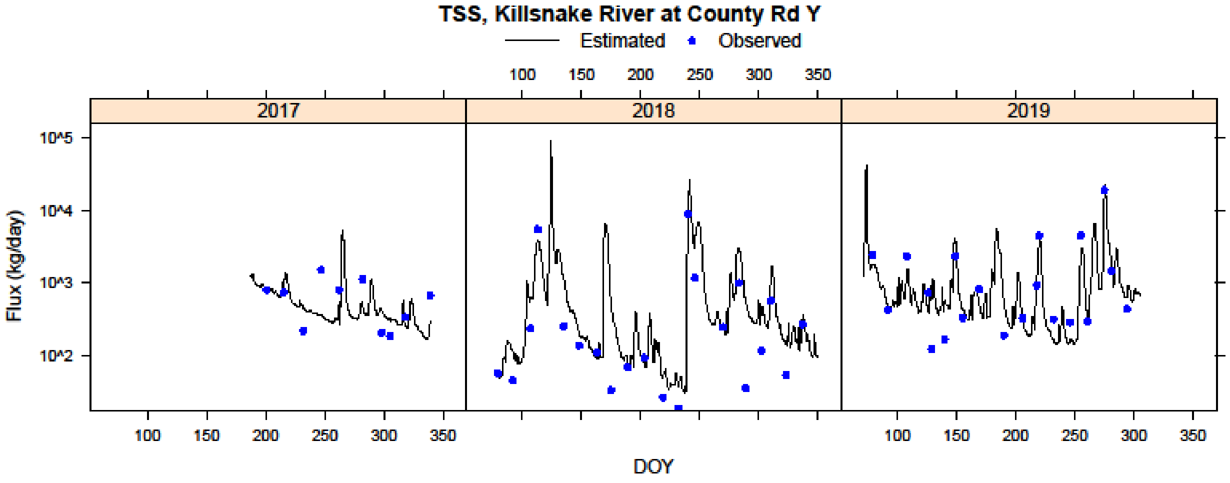

TSS, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2008
2009
2010
2011
2012
2013
Flux (kg/day)
DOY
10^5
10^4
10^3
10^2
0
100
200
300

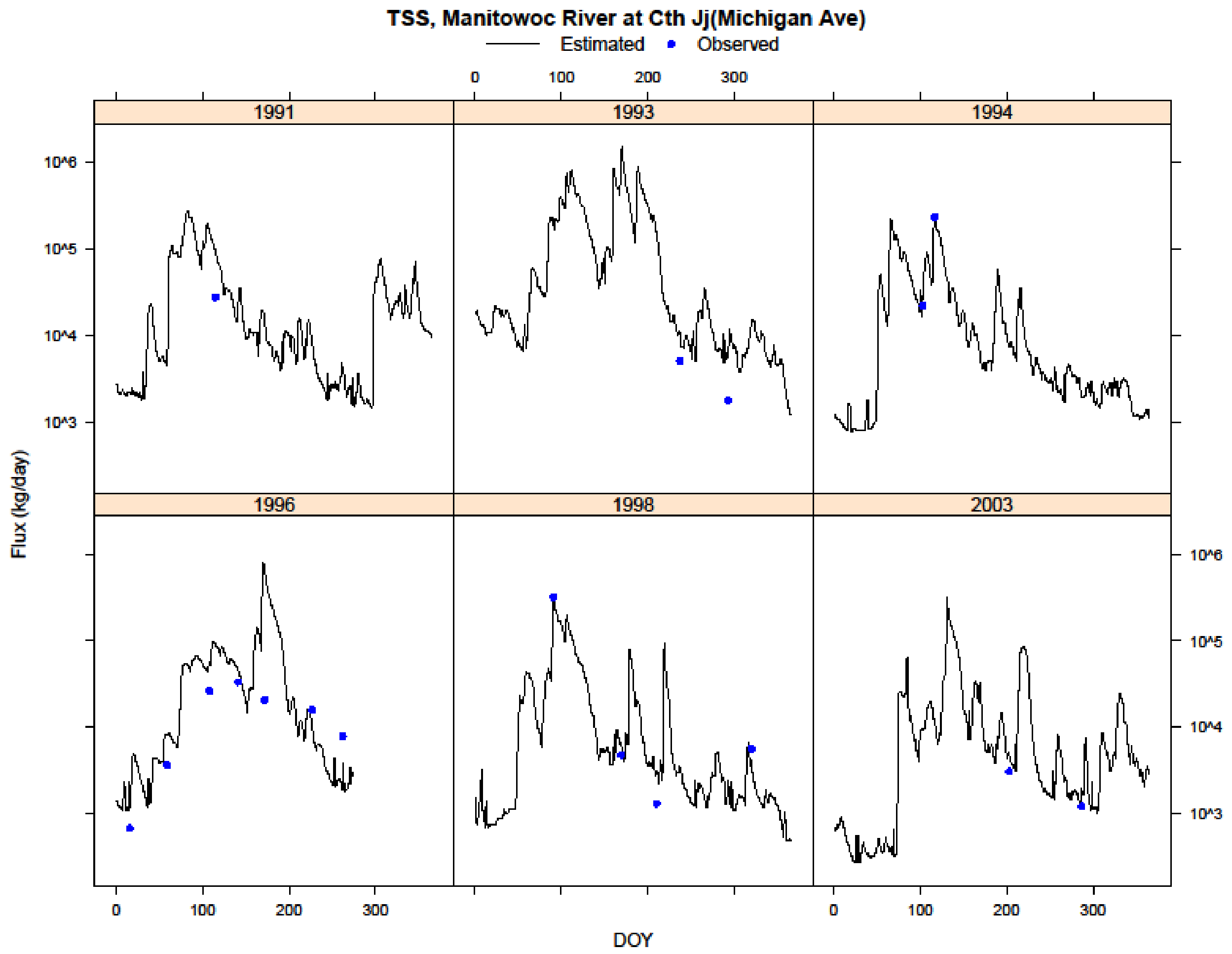


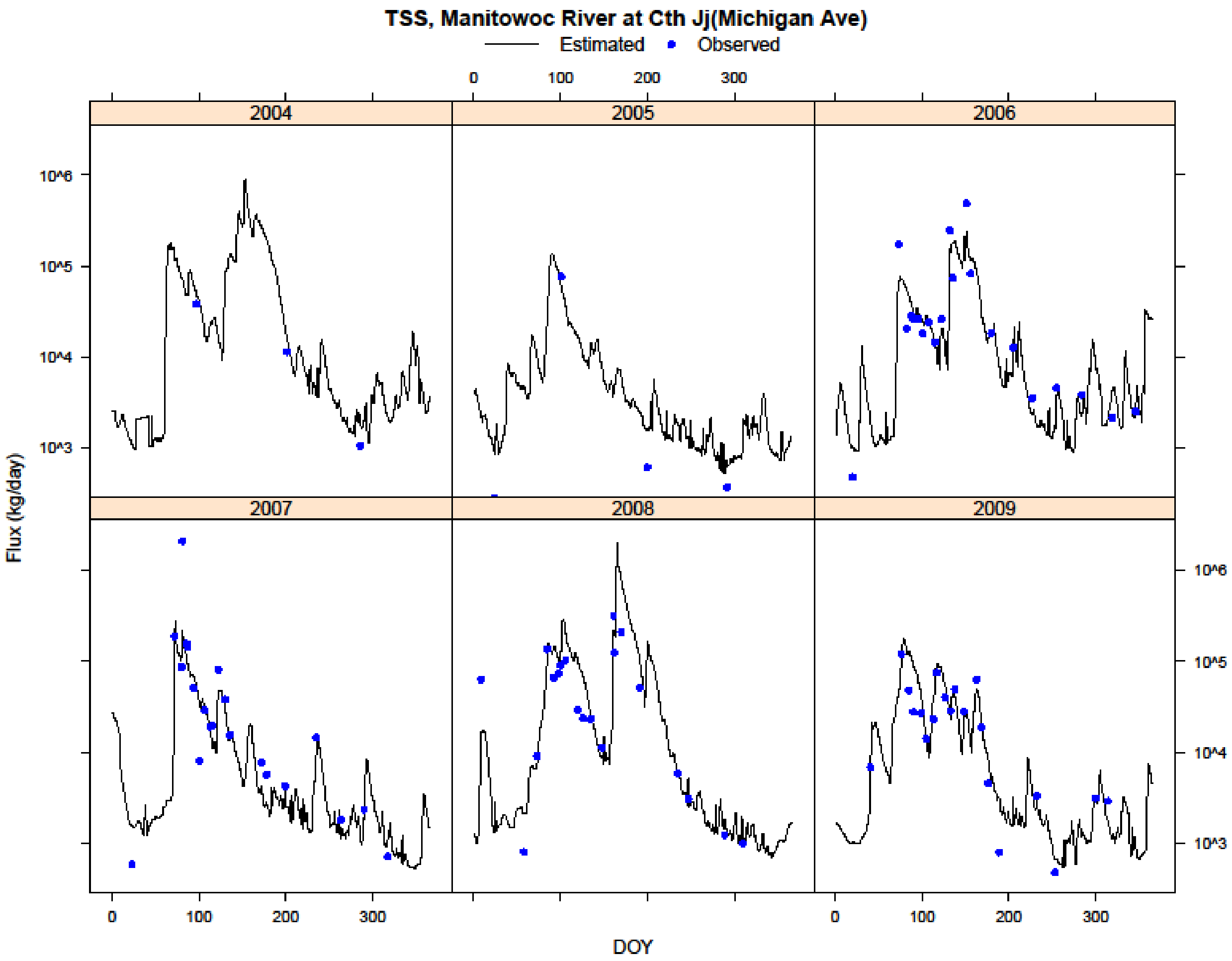
TSS, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2014
2015
2016
2017
2018
2019
10^6
10^5
10^4
10^3
10^2
Flux (kg/day)
0
100
200
300
DOY

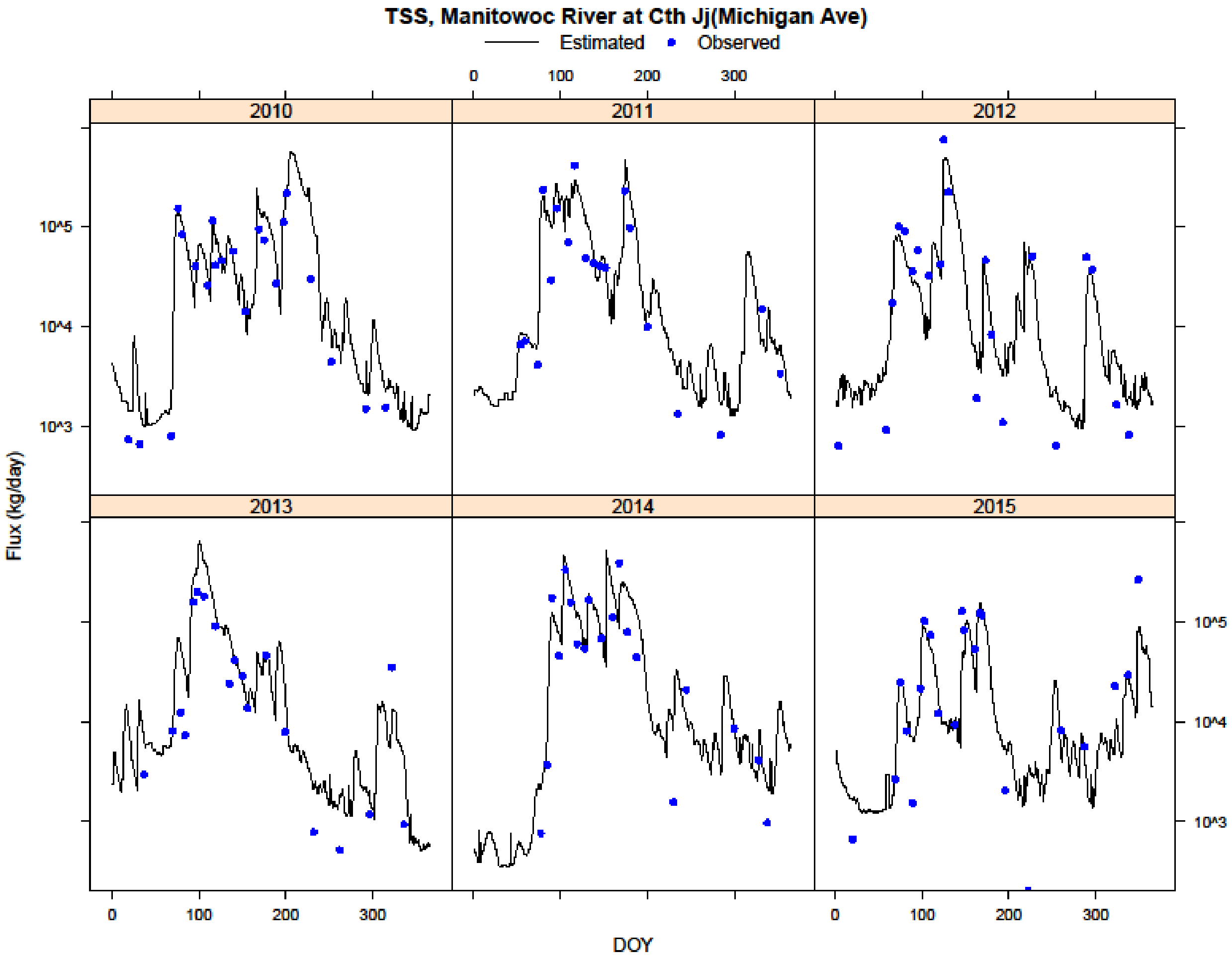


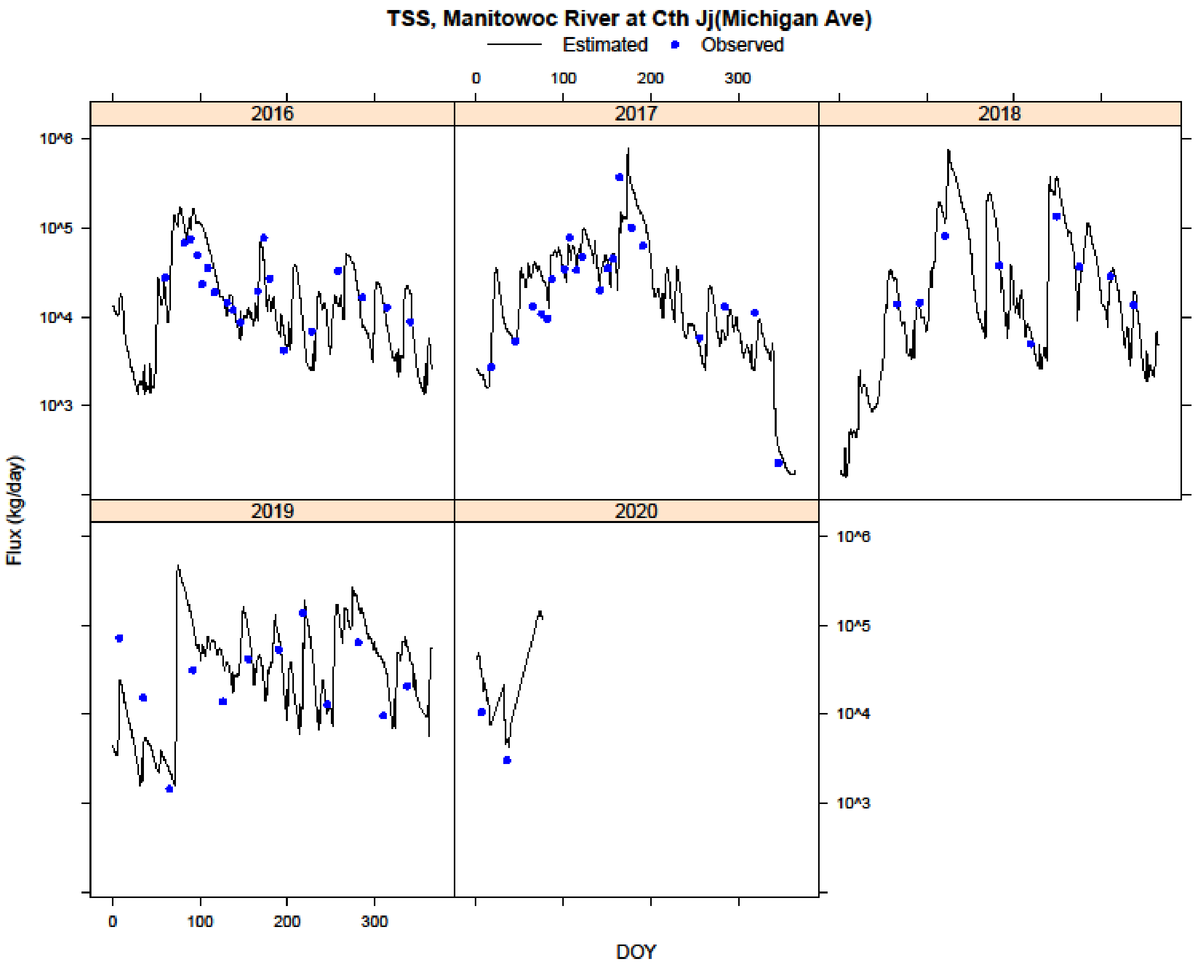
Kewaunee River DS Cth F at Bruemmer
Estimated
Observed
2020
10^5.0
10^4.5
10^4.0
10^3.5
10^3.0
10^2.5
Flux (kg/day)
0
20
40
60
DOY

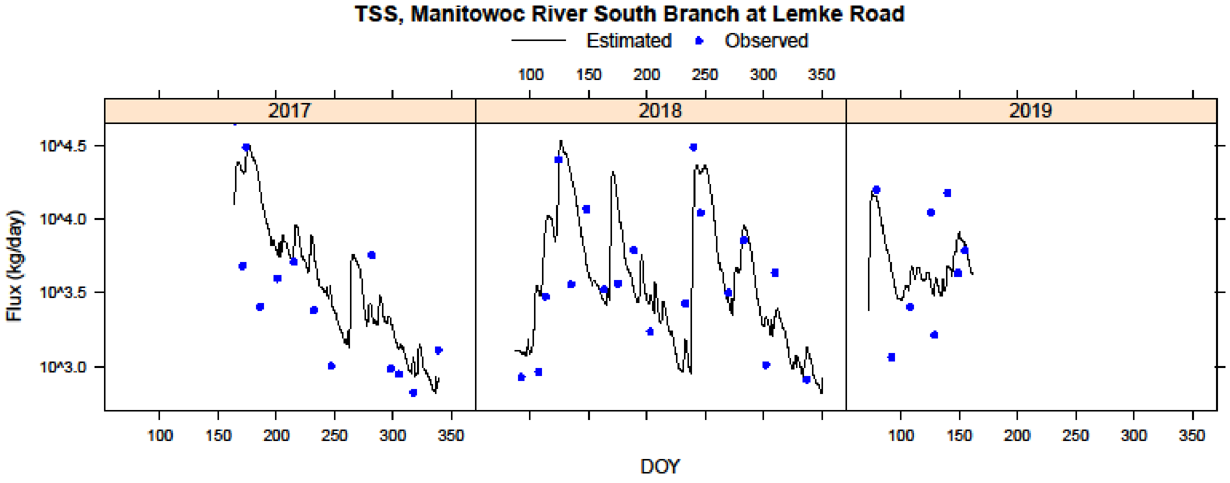

TSS, Killsnake River at County Rd Y
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
100
150
200
250
300
350
DOY

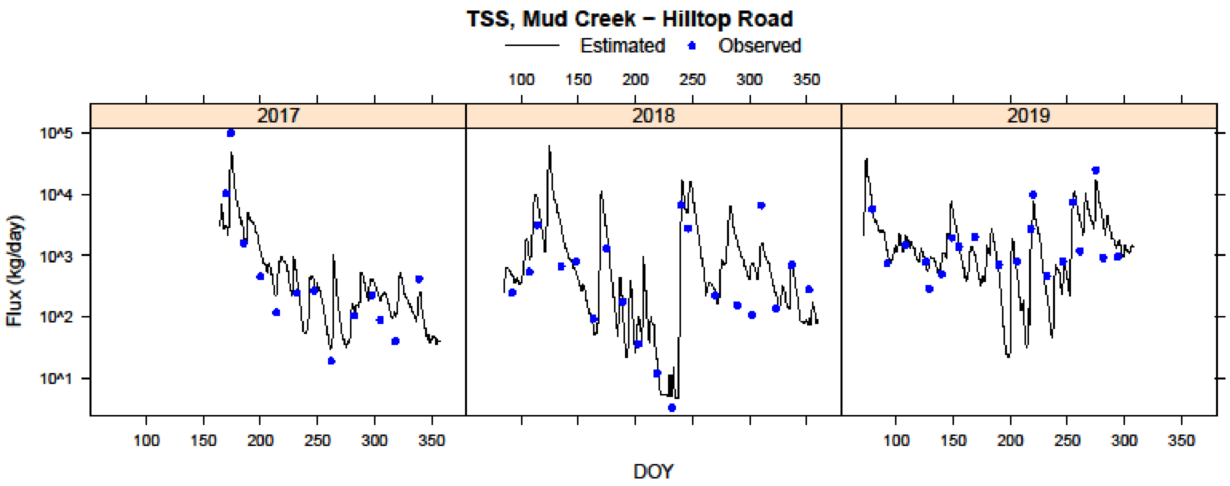

TSS, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
1991
1993
1994
1996
1998
2003
10^6
10^5
10^4
10^3
0
100
200
300
Flux (kg/day)
DOY


TSS, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2004
2005
2006
2007
2008
2009
Flux (kg/day)
DOY
10^6
10^5
10^4
10^3
0
100
200
300

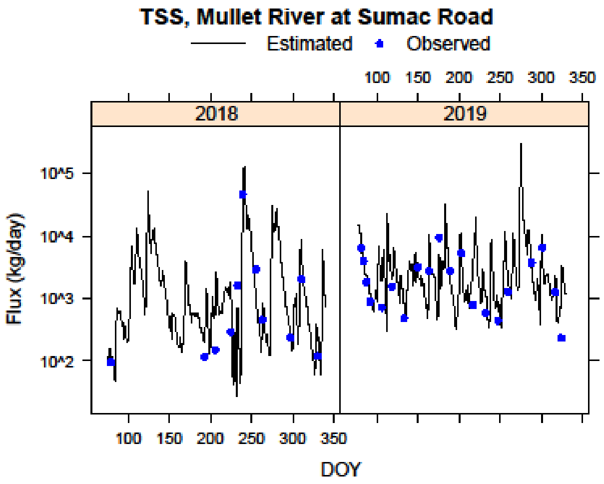

TSS, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2010
2011
2012
2013
2014
2015
Flux (kg/day)
10^5
10^4
10^3
0
100
200
300
DOY


TSS, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2016
2017
2018
2019
2020
Flux (kg/day)
10^6
10^5
10^4
10^3
0
100
200
300
DOY

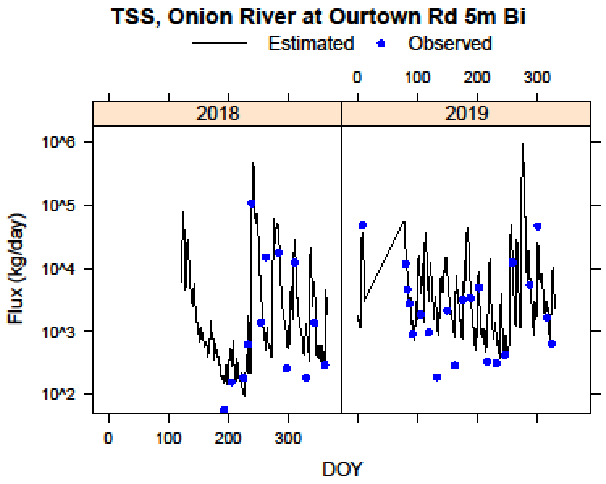

TSS, Manitowoc River South Branch at Lemke Road
Estimated
Observed
2017
2018
2019
10^4.5
10^4.0
10^3.5
10^3.0
Flux (kg/day)
100
150
200
250
300
350
DOY



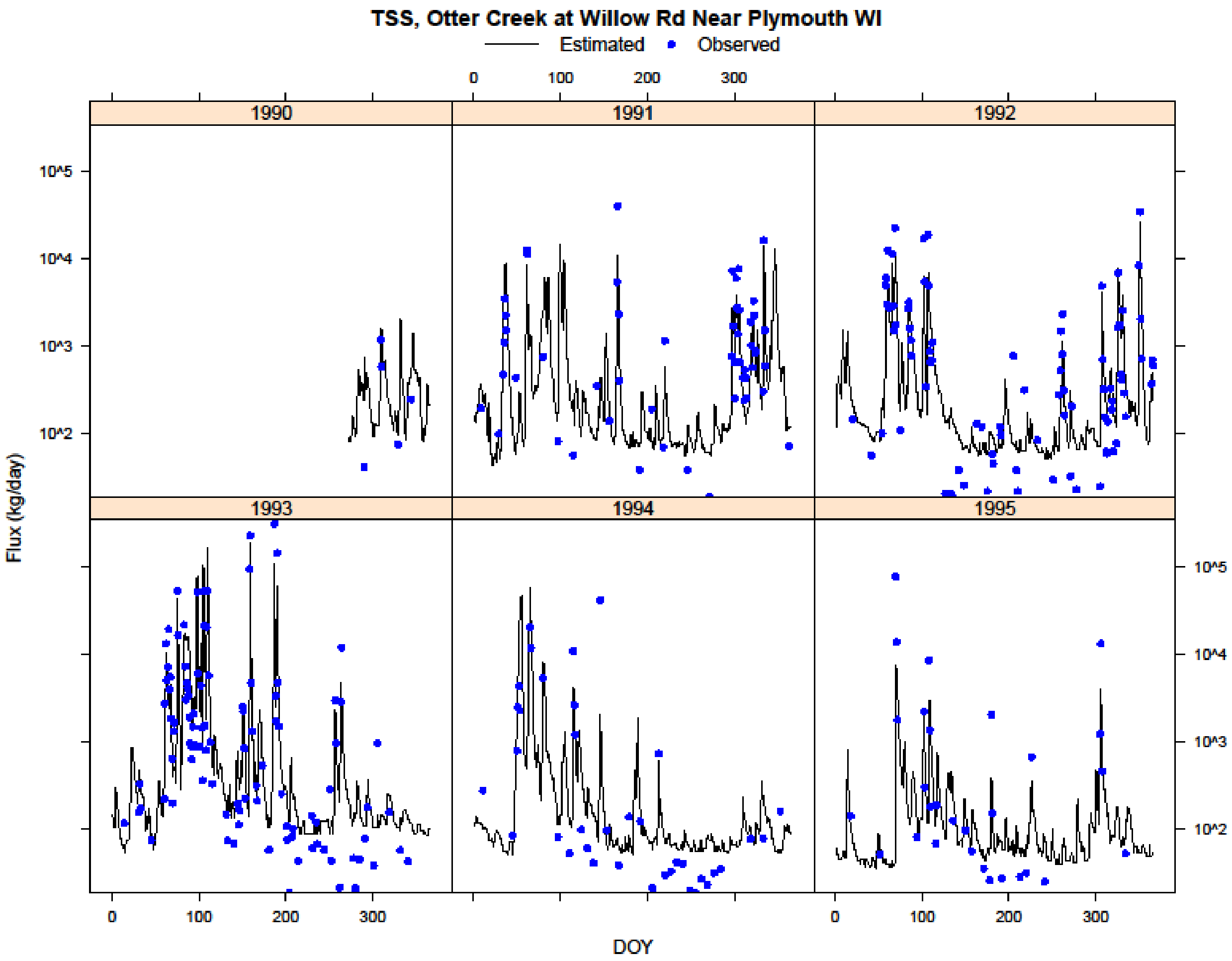
TSS, Mud Creek – Hilltop Road
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
10^1
100
150
200
250
300
350
DOY

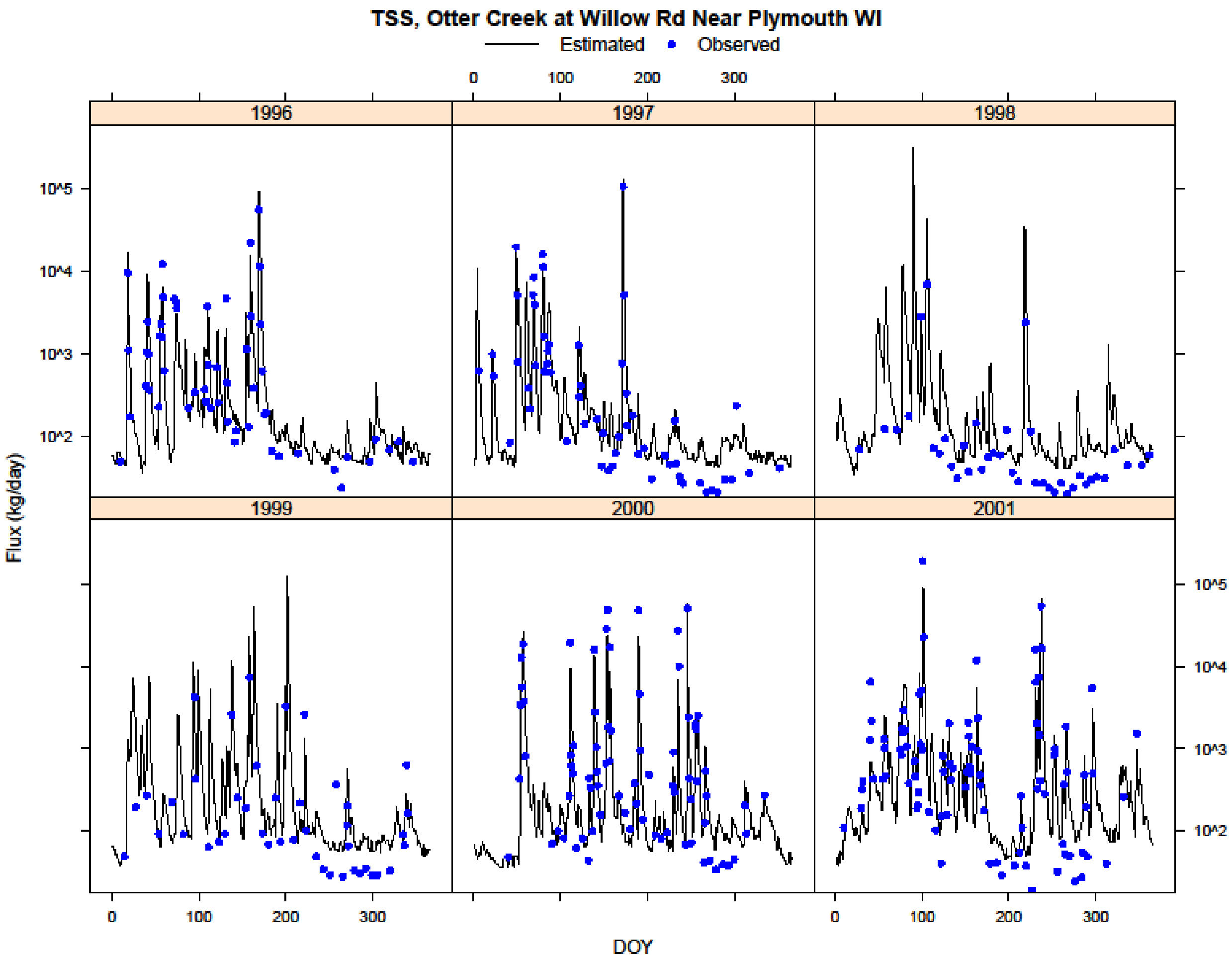


TSS, Mullet River at Sumac Road
Estimated
Observed
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
100 150 200 250 300 350
DOY

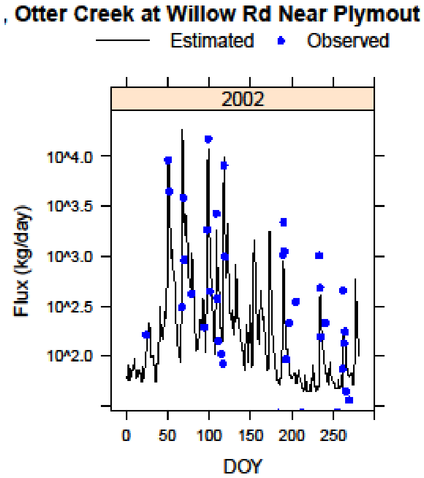


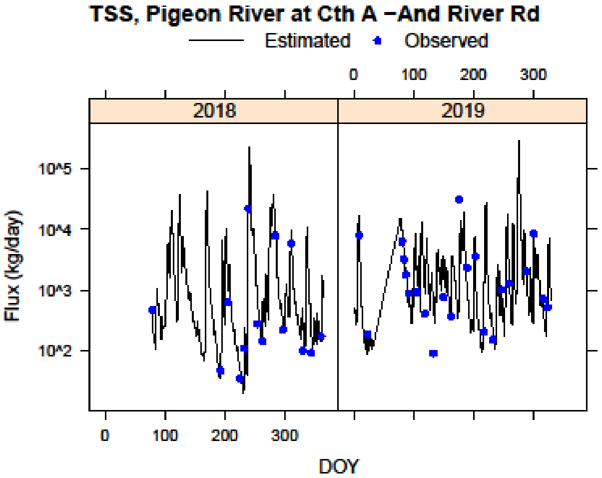
TSS, Onion River at Ourtown Rd 5m Bi
Estimated
Observed
2018
2019
Flux (kg/day)
10^6
10^5
10^4
10^3
10^2
0 100 200 300
DOY

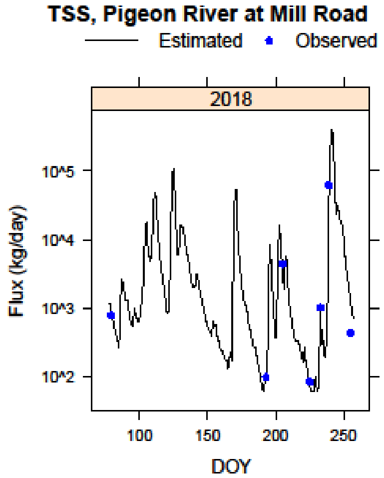

TSS, Otter Creek at Willow Rd Near Plymouth WI
Estimated
Observed
1990
1991
1992
1993
1994
1995
Flux (kg/day)
DOY
10^5
10^4
10^3
10^2
0
100
200
300

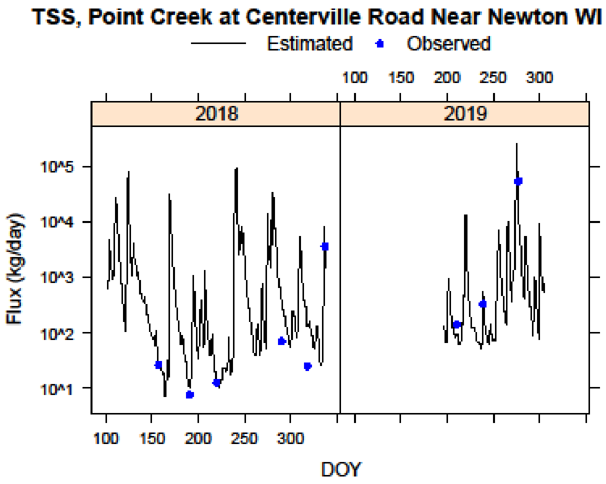


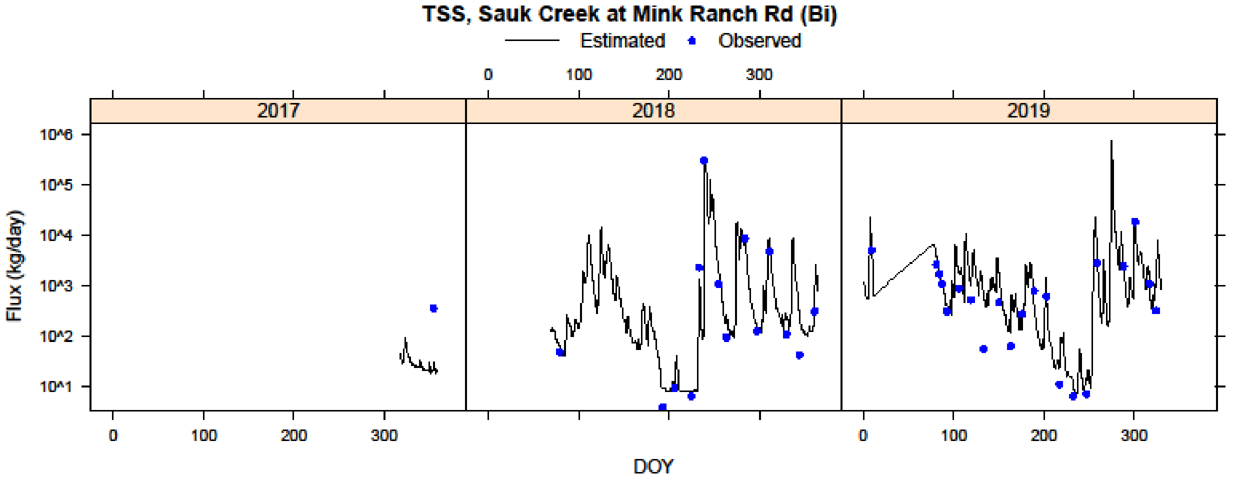
TSS, Otter Creek at Willow Rd Near Plymouth WI
Estimated
Observed
1996
1997
1998
1999
2000
2001
Flux (kg/day)
10^5
10^4
10^3
10^2
0
100
200
300
DOY

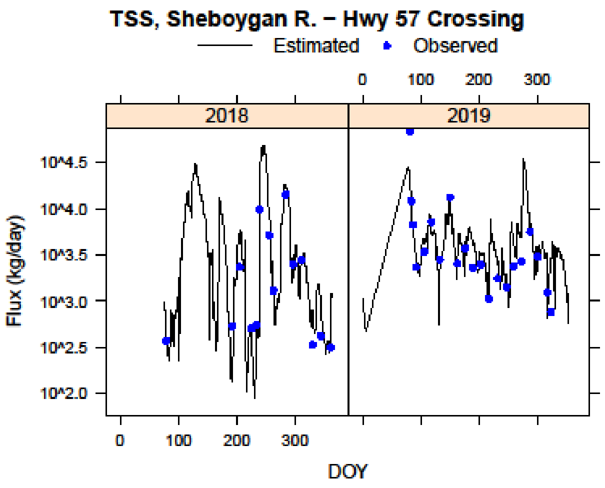

, Otter Creek at Willow Rd Near Plymout
Estimated
Observed
2002
Flux (kg/day)
10^4.0
10^3.5
10^3.0
10^2.5
10^2.0
0
50
100
150
200
250
DOY

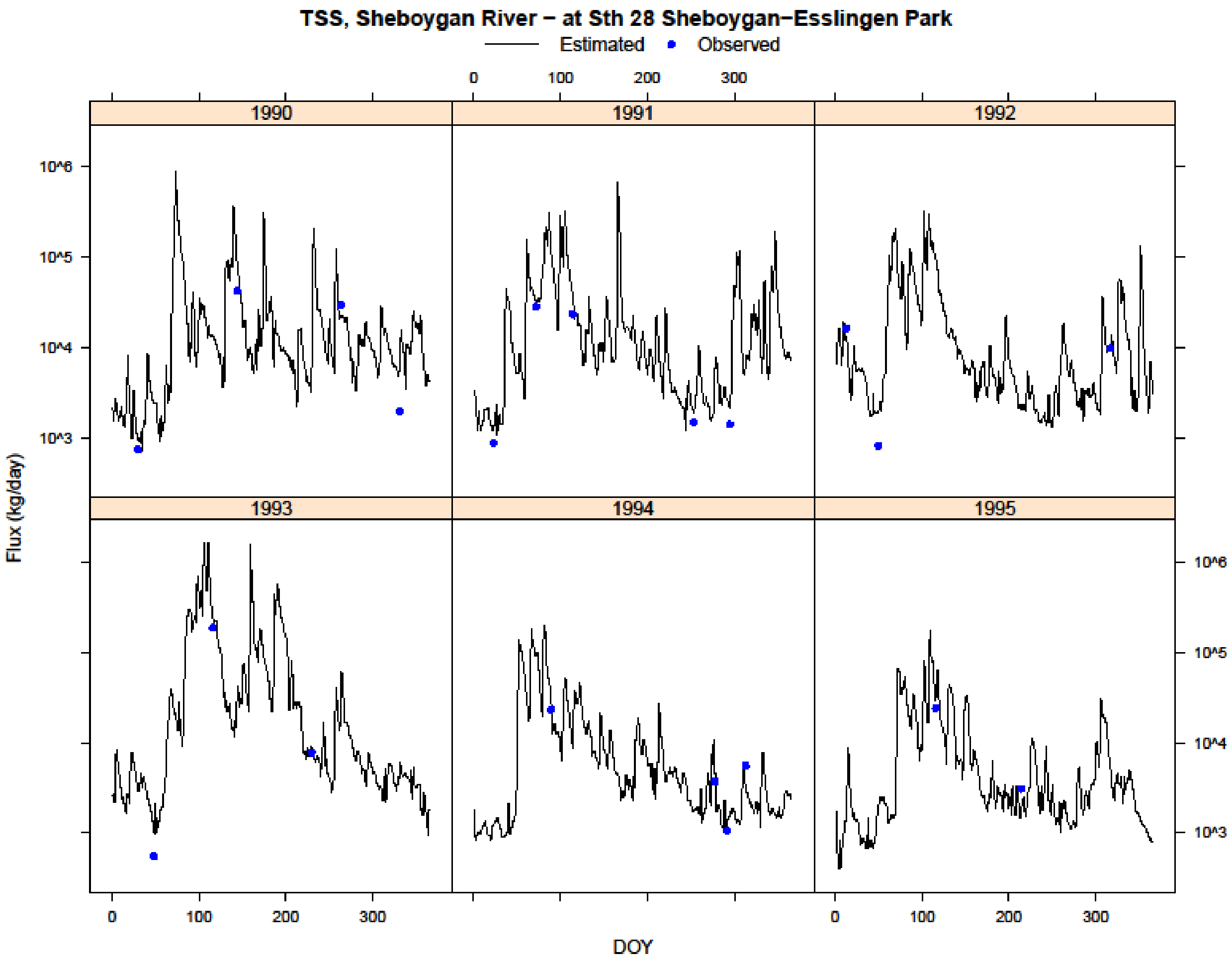

TSS, Pigeon River at Cth A –And River Rd
Estimated
Observed
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
0
100
200
300
DOY

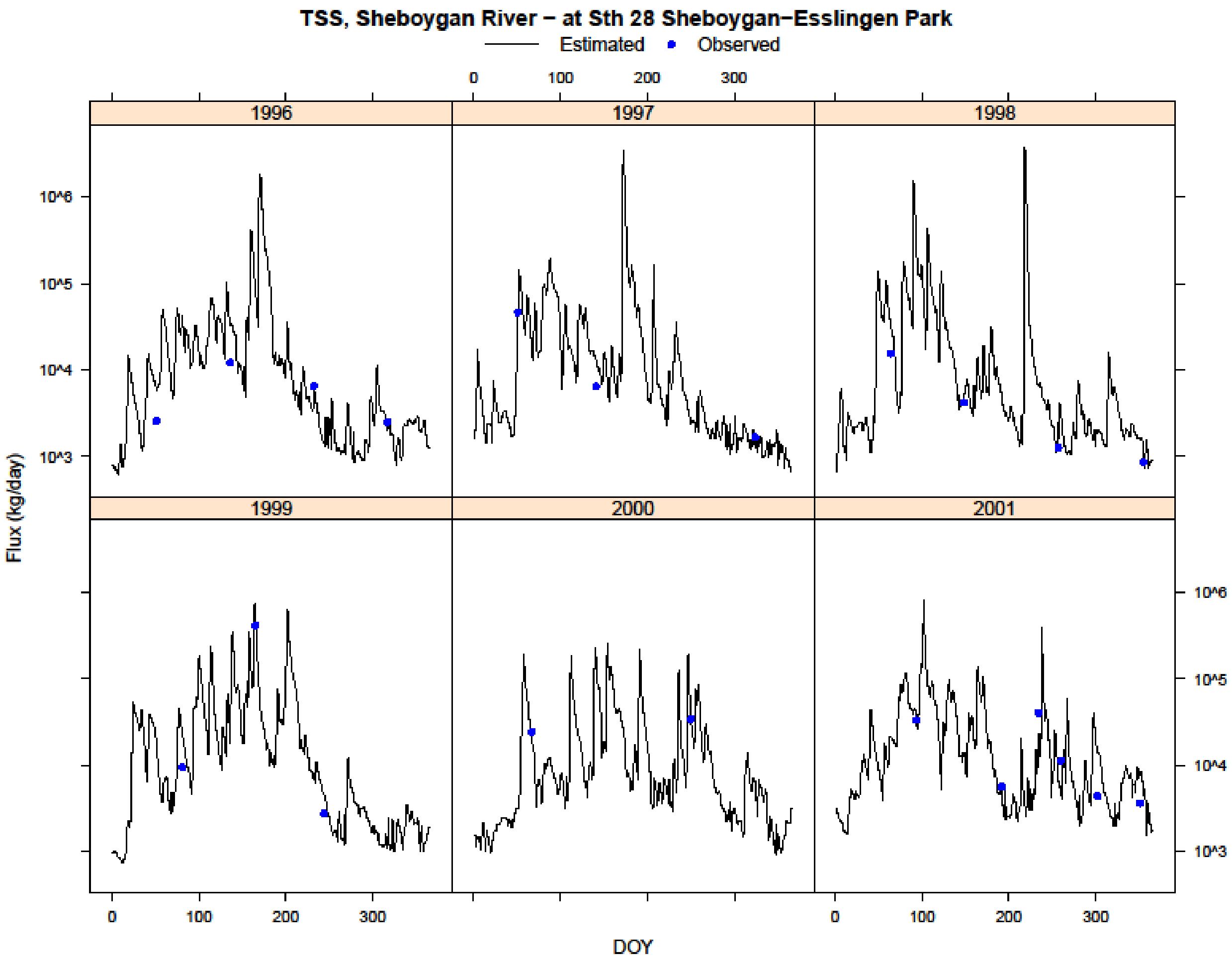

TSS, Pigeon River at Mill Road
Estimated
Observed
2018
Flux (kg/day)
10^5
10^4
10^3
10^2
100
150
200
250
DOY


TSS, Point Creek at Centerville Road Near Newton WI
Estimated
Observed
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
10^1
100
150
200
250
300
DOY

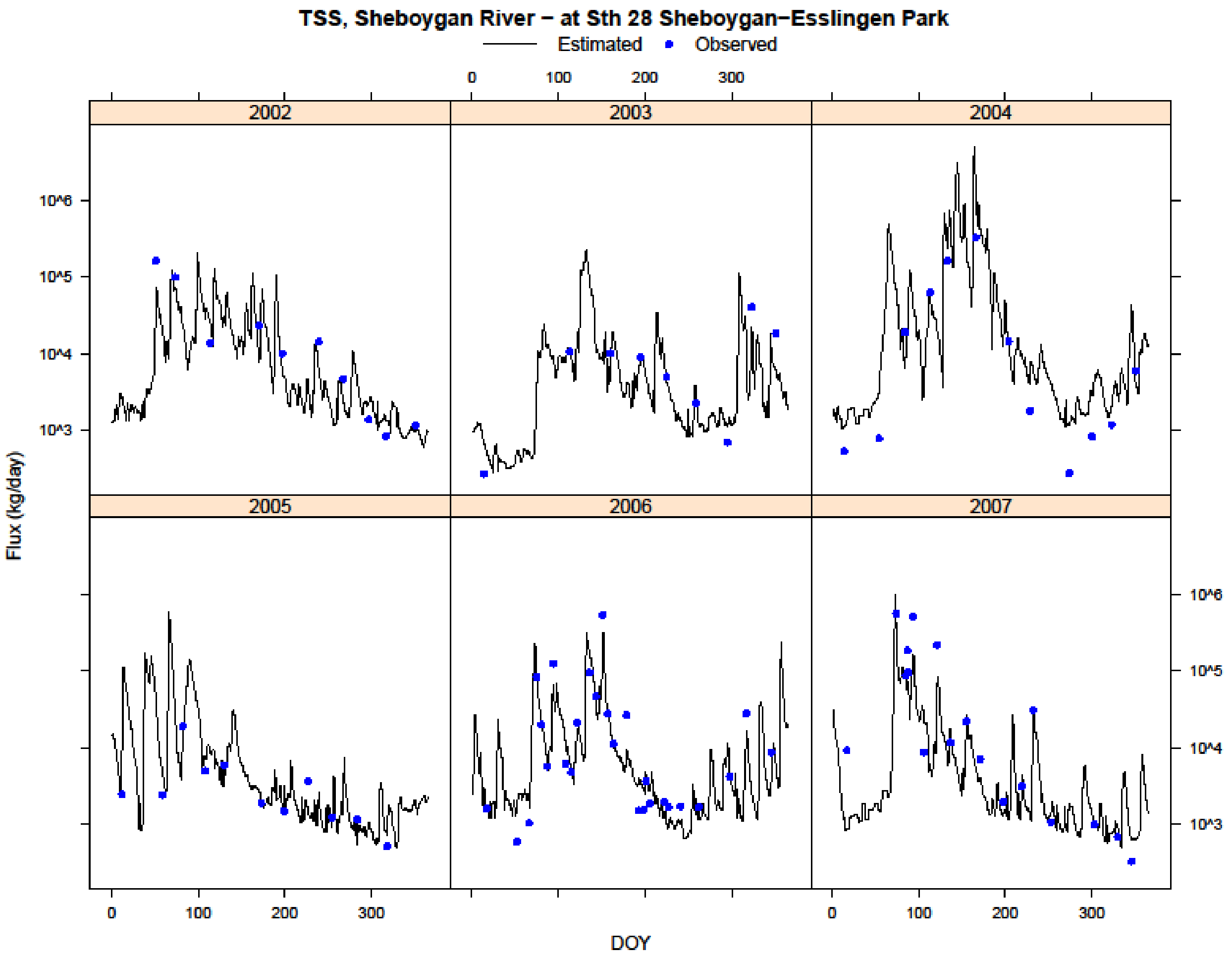

TSS, Sauk Creek at Mink Ranch Rd (Bi)
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^6
10^5
10^4
10^3
10^2
10^1
0
100
200
300
DOY


TSS, Sheboygan R. – Hwy 57 Crossing
Estimated
Observed
2018
2019
Flux (kg/day)
10^4.5
10^4.0
10^3.5
10^3.0
10^2.5
10^2.0
0
100
200
300
DOY

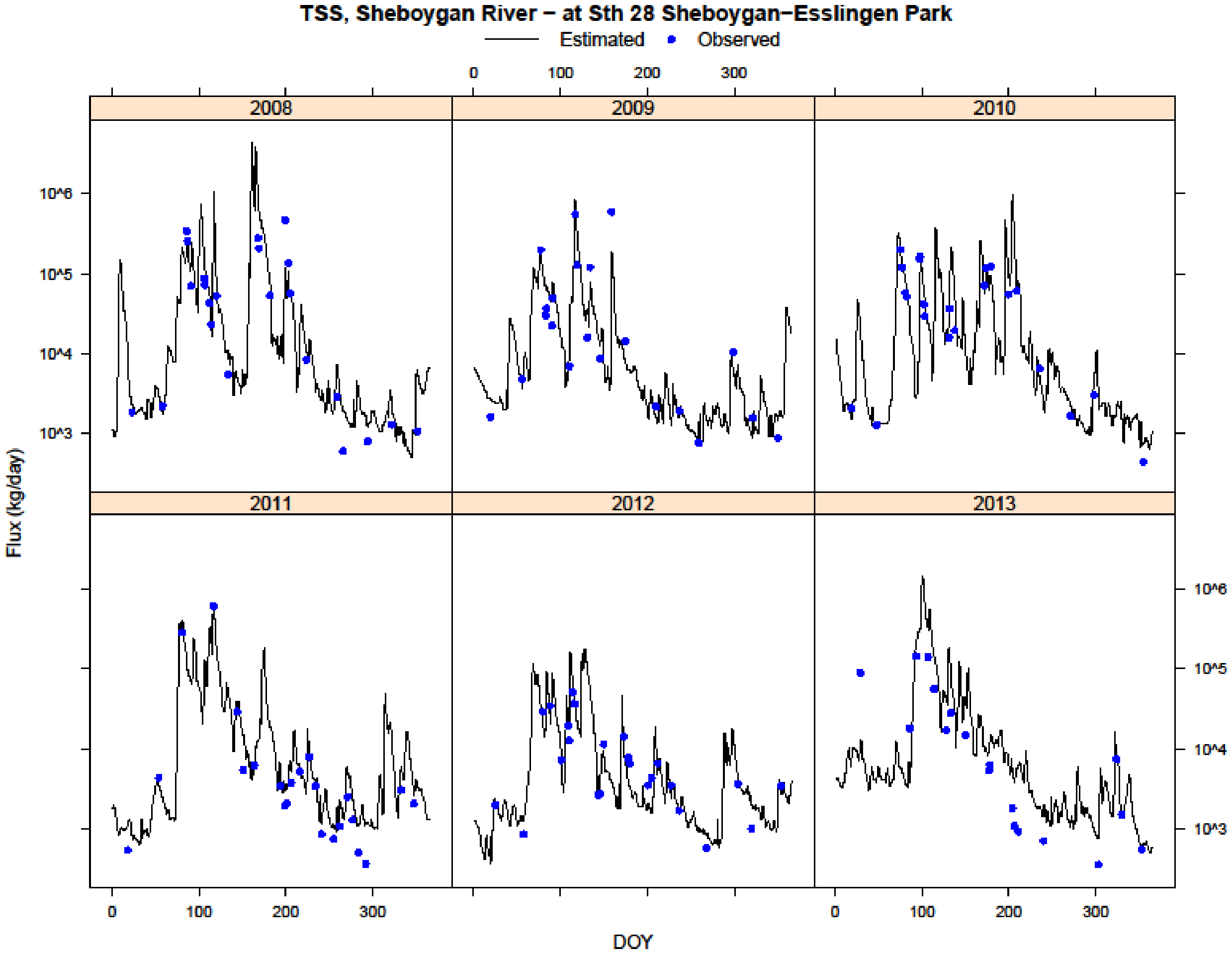

TSS, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
1990
1991
1992
1993
1994
1995
10^6
10^5
10^4
10^3
Flux (kg/day)
0
100
200
300
DOY



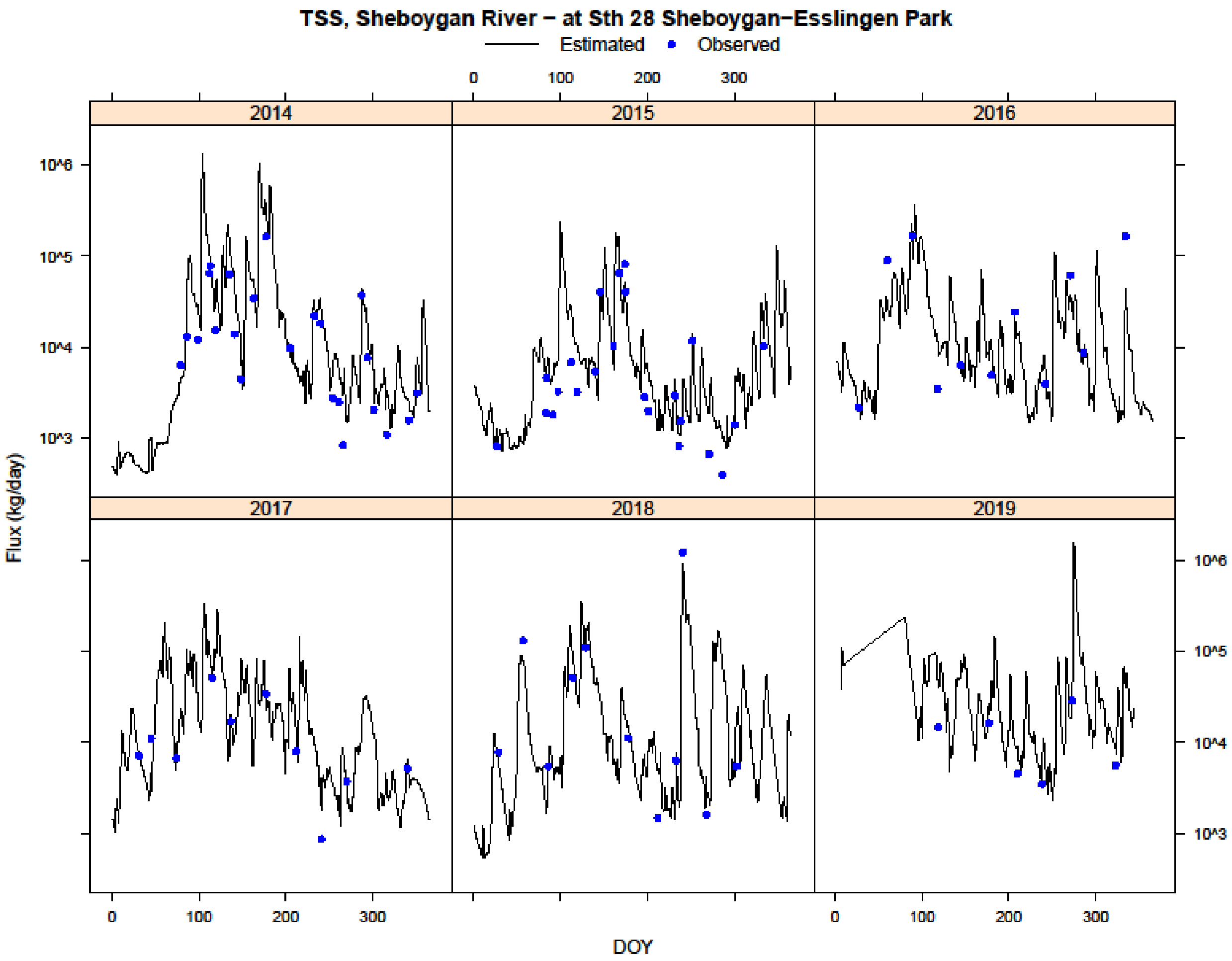
TSS, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
1996
1997
1998
1999
2000
2001
Flux (kg/day)
10^6
10^5
10^4
10^3
DOY
0
100
200
300

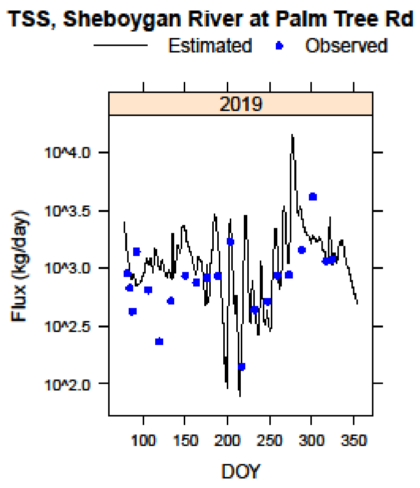


TSS, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
2002
2003
2004
2005
2006
2007
10^6
10^5
10^4
10^3
0
100
200
300
Flux (kg/day)
DOY

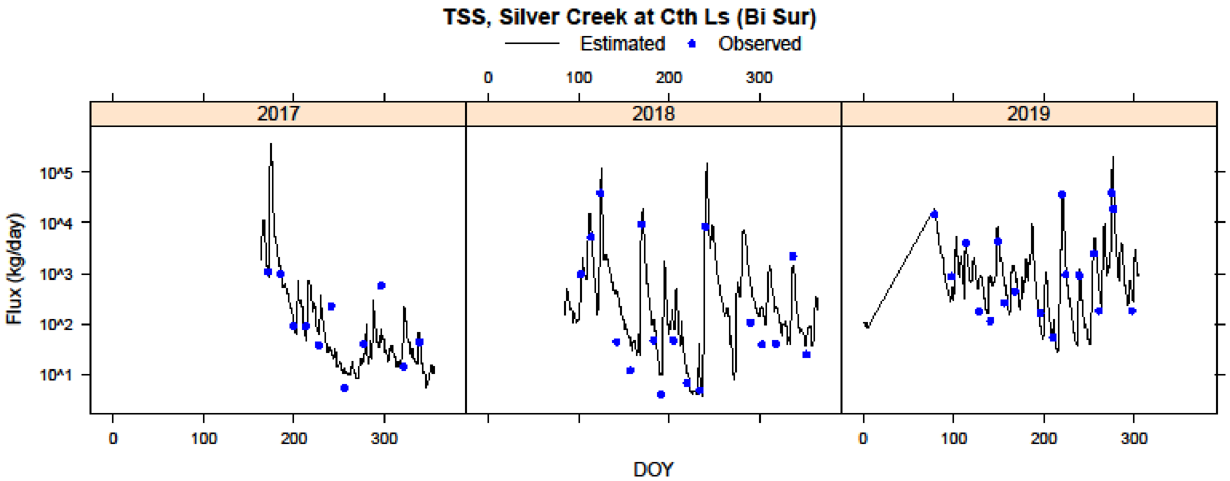


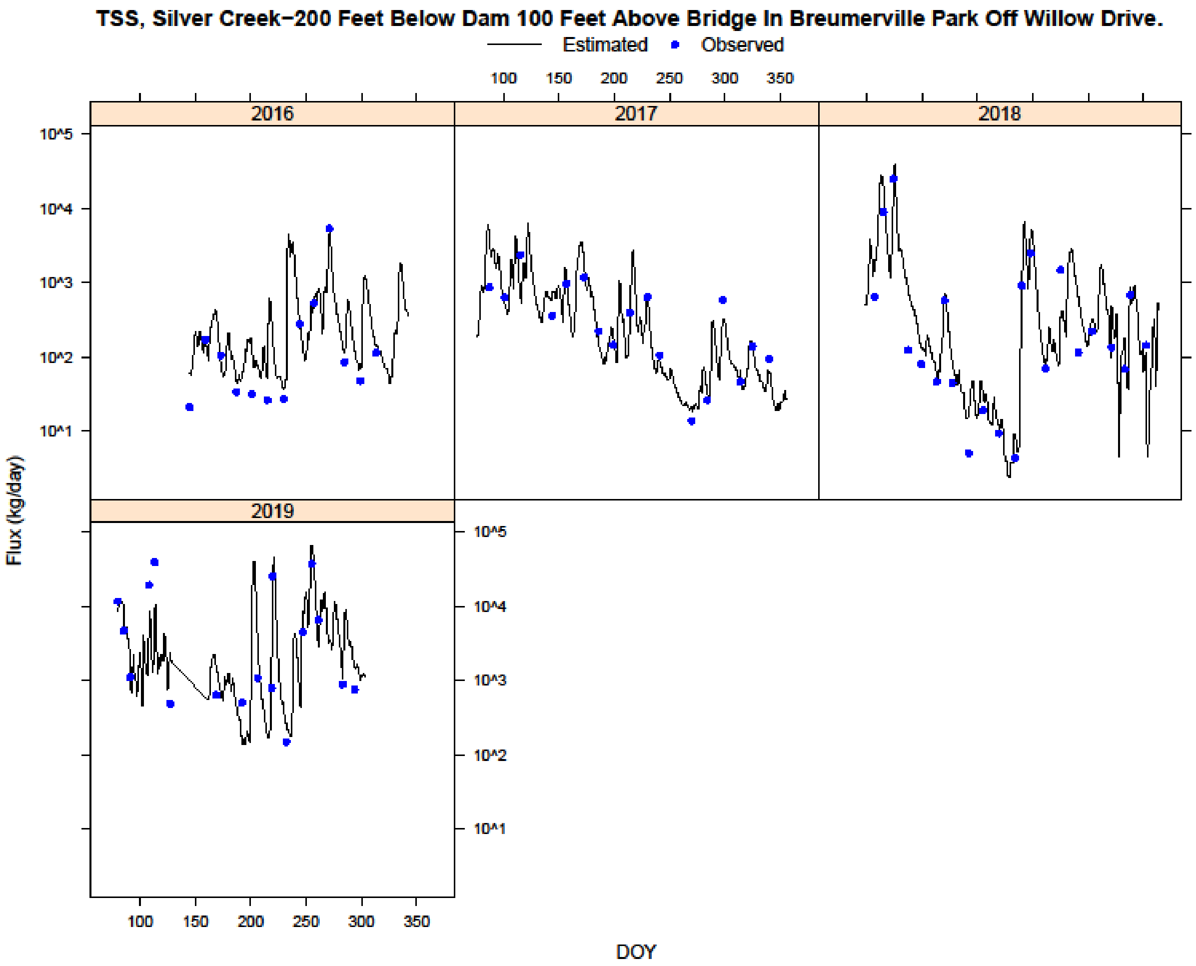
TSS, Sheboygan River − at Sth 28 Sheboygan−Esslingen Park
Estimated
Observed
2008
2009
2010
2011
2012
2013
Flux (kg/day)
DOY
10^6
10^5
10^4
10^3
0
100
200
300


TSS, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
2014
2015
2016
2017
2018
2019
Flux (kg/day)
10^6
10^5
10^4
10^3
0
100
200
300
DOY

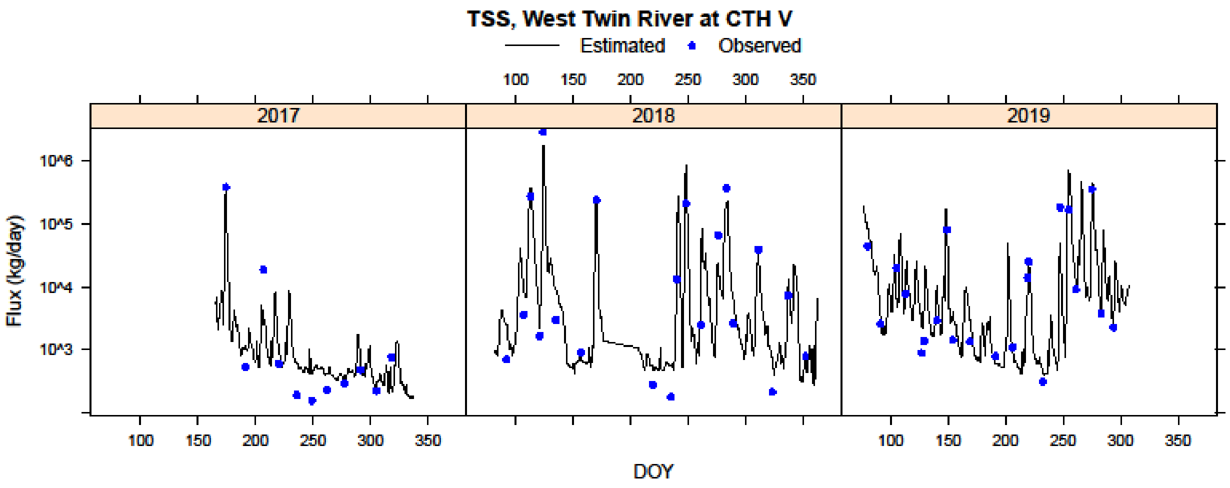


TSS, Sheboygan River at Palm Tree Rd
Estimated
Observed
2019
10^4.0
10^3.5
10^3.0
10^2.5
10^2.0
Flux (kg/day)
100
150
200
250
300
350
DOY

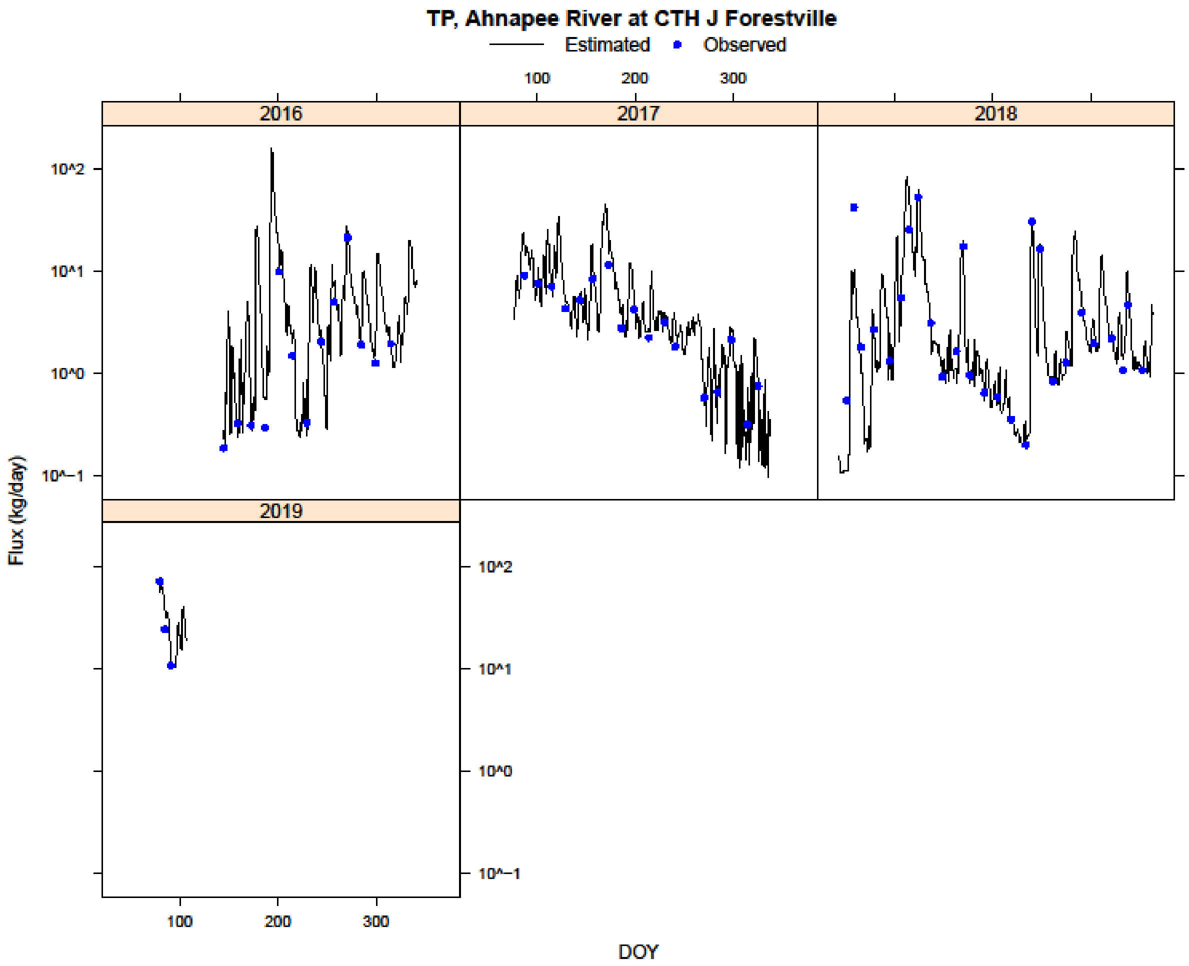

TSS, Silver Creek at Cth Ls (Bi Sur)
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^5
10^4
10^3
10^2
10^1
0
100
200
300
DOY

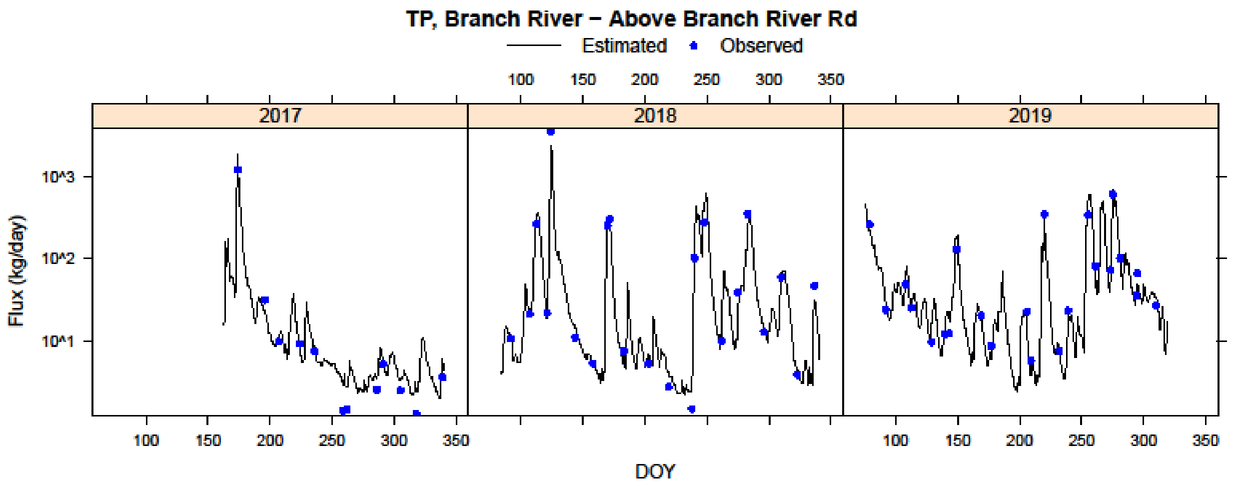


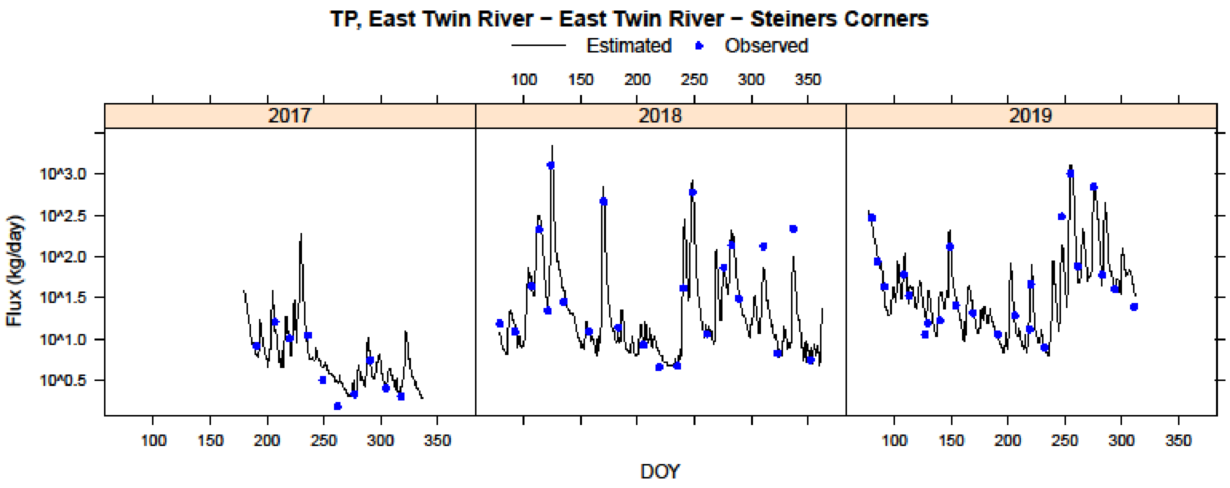
TSS, Silver Creek−200 Feet Below Dam 100 Feet Above Bridge In Breumerville Park Off Willow Drive.
Estimated
Observed
2016
2017
2018
2019
10^5
10^4
10^3
10^2
10^1
100
150
200
250
300
350
Flux (kg/day)
DOY

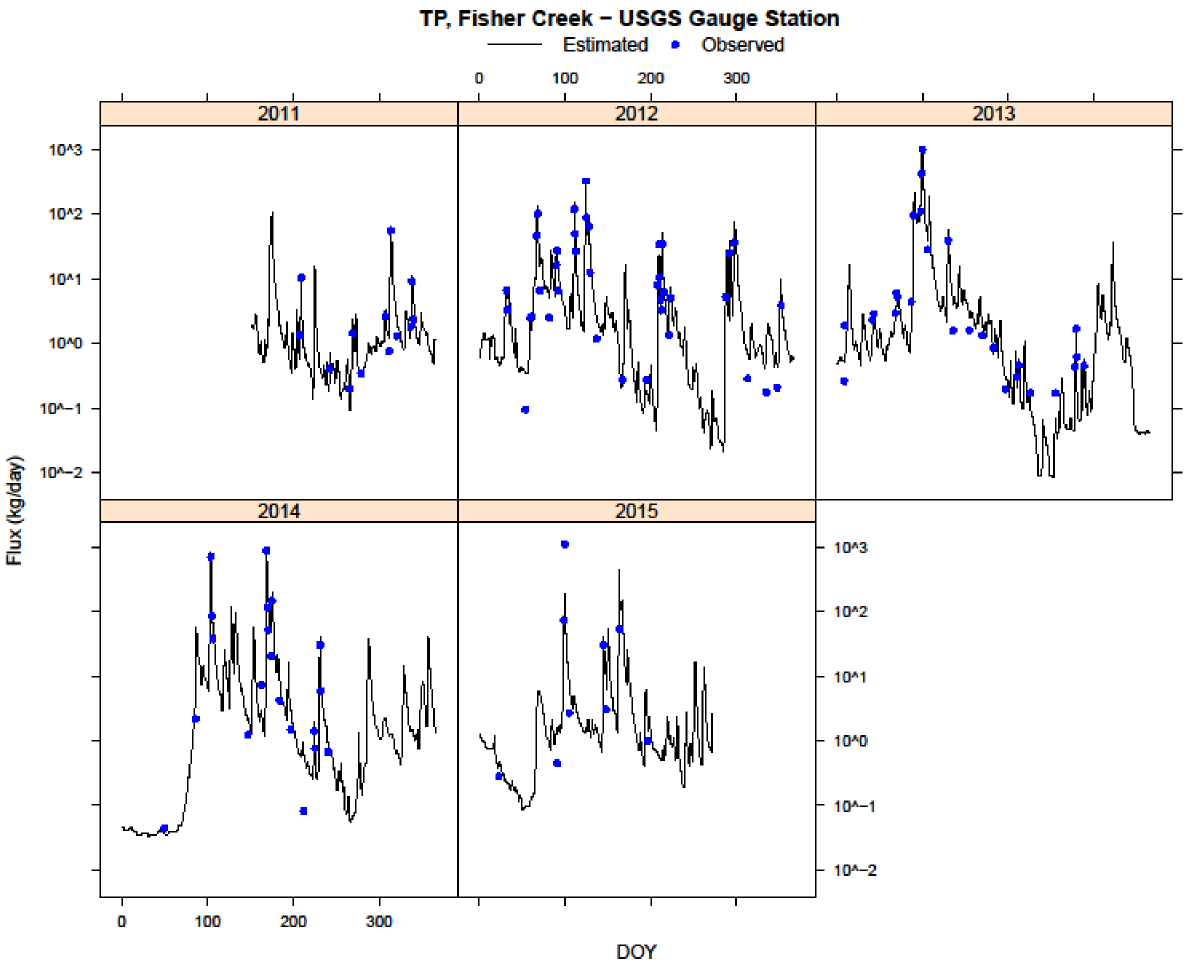

TSS, West Twin River at CTH V
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^6
10^5
10^4
10^3
100
150
200
250
300
350
DOY

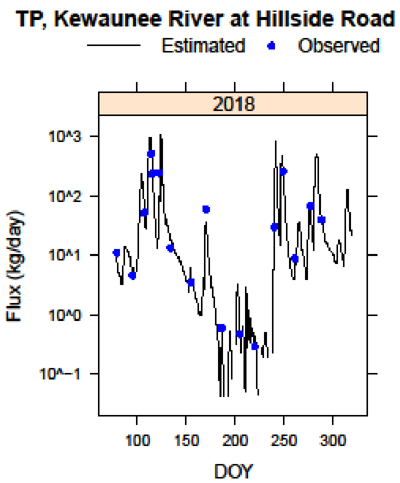
8.2.4 Total Phosphorus Time-Series Plots

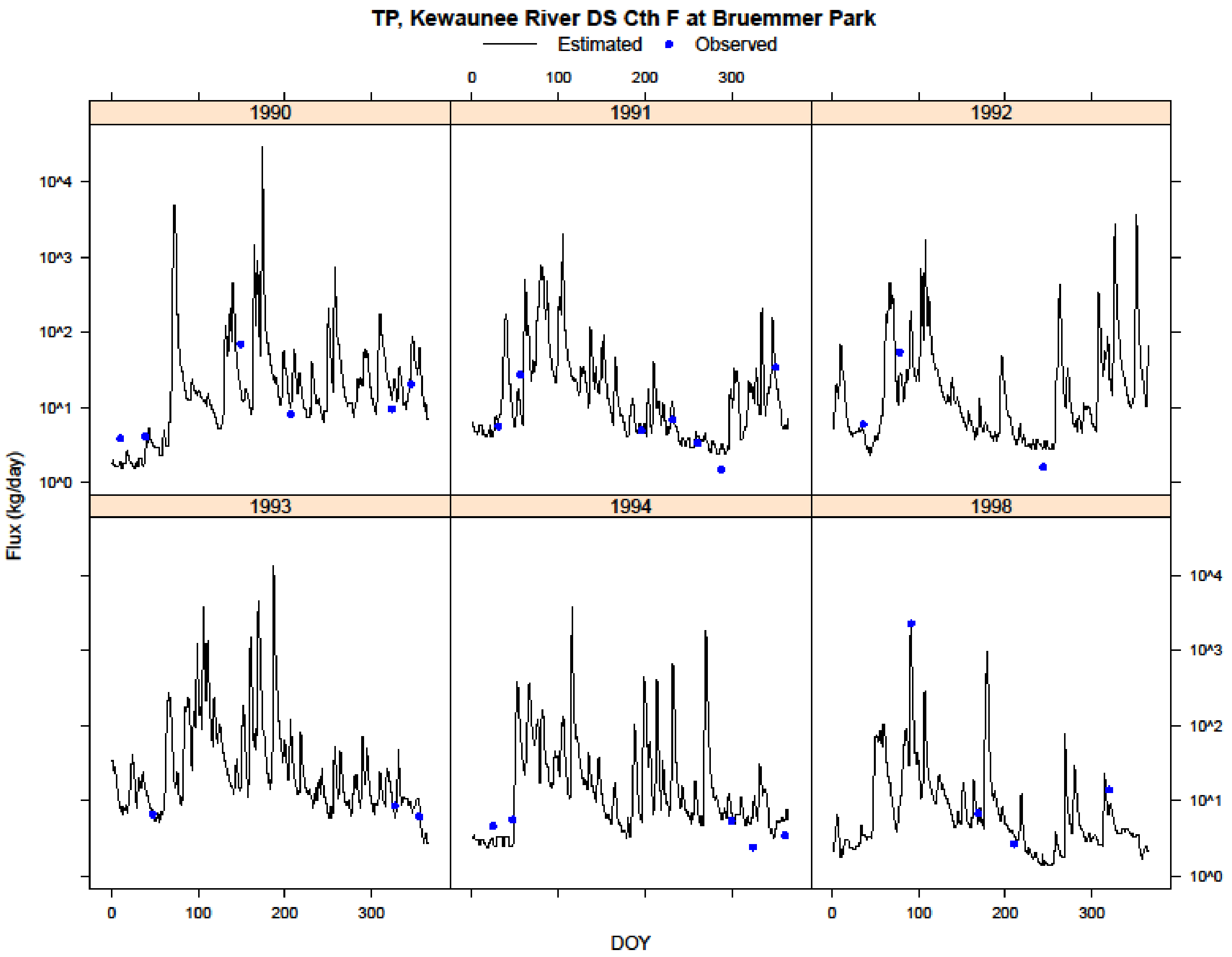

TP, Ahnapee River at CTH J Forestville
Estimated
Observed
2016
2017
2018
2019
Flux (kg/day)
10^2
10^1
10^0
10^−1
100
200
300
DOY


TP, Branch River – Above Branch River Rd
Estimated
Observed
2017
2018
2019
10^3
10^2
10^1
Flux (kg/day)
100
150
200
250
300
350
DOY

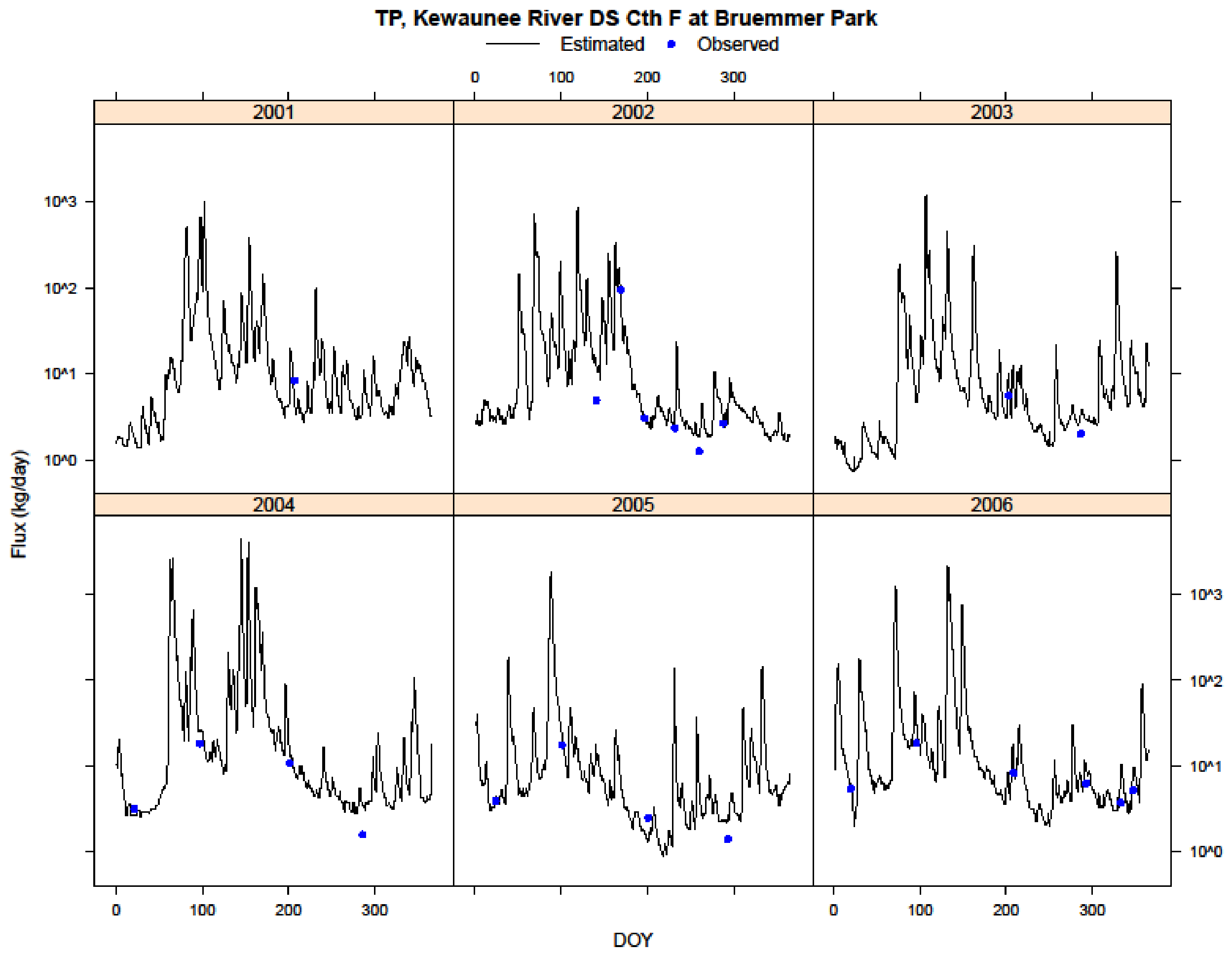

TP, East Twin River – East Twin River – Steiners Corners
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
100
150
200
250
300
350
DOY


TP, Fisher Creek – USGS Gauge Station
Estimated
Observed
2011
2012
2013
2014
2015
Flux (kg/day)
10^3
10^2
10^1
10^0
10^−1
10^−2
0
100
200
300
DOY

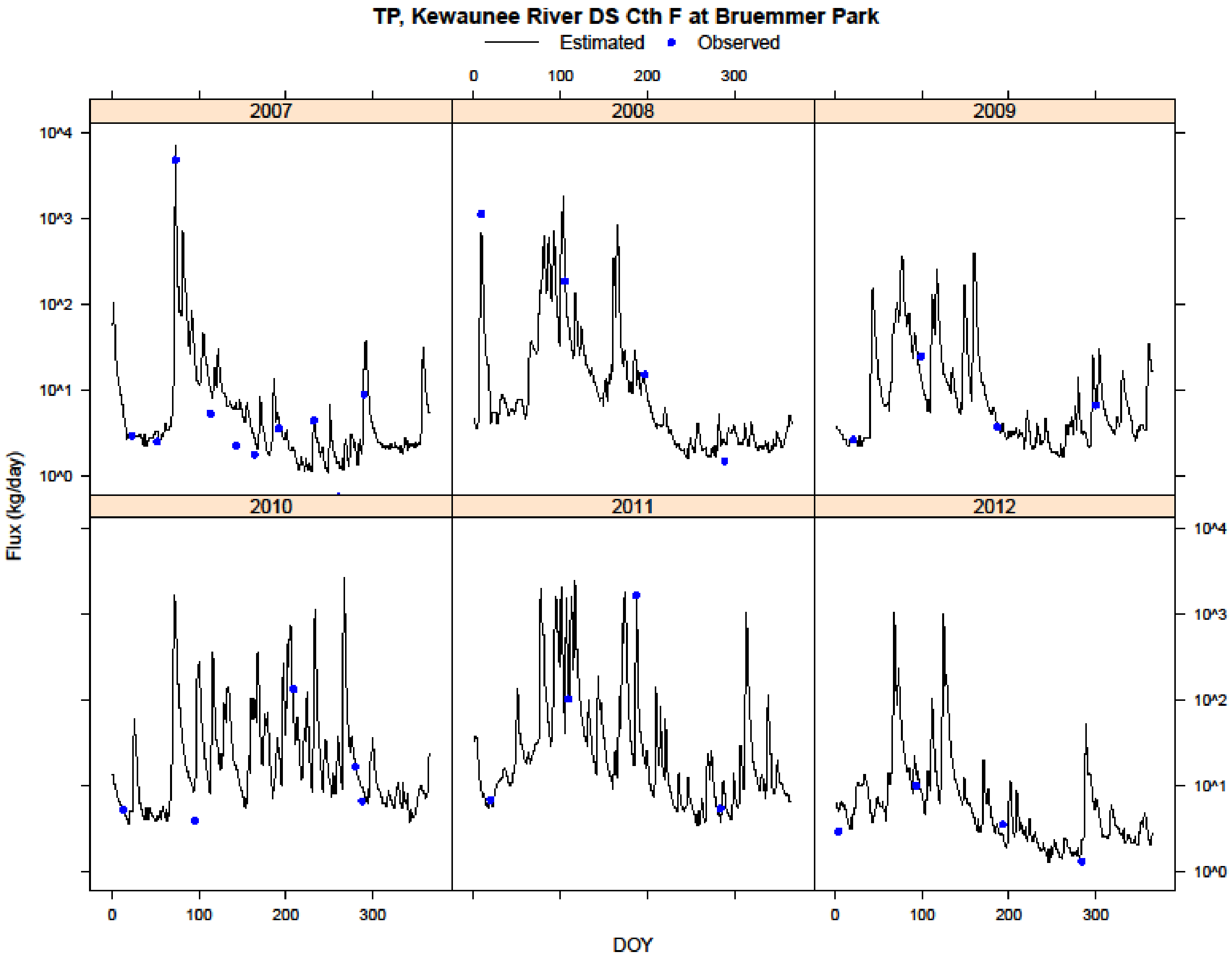

TP, Kewaunee River at Hillside Road
Estimated
Observed
2018
10^3
10^2
10^1
10^0
10^−1
Flux (kg/day)
100
150
200
250
300
DOY

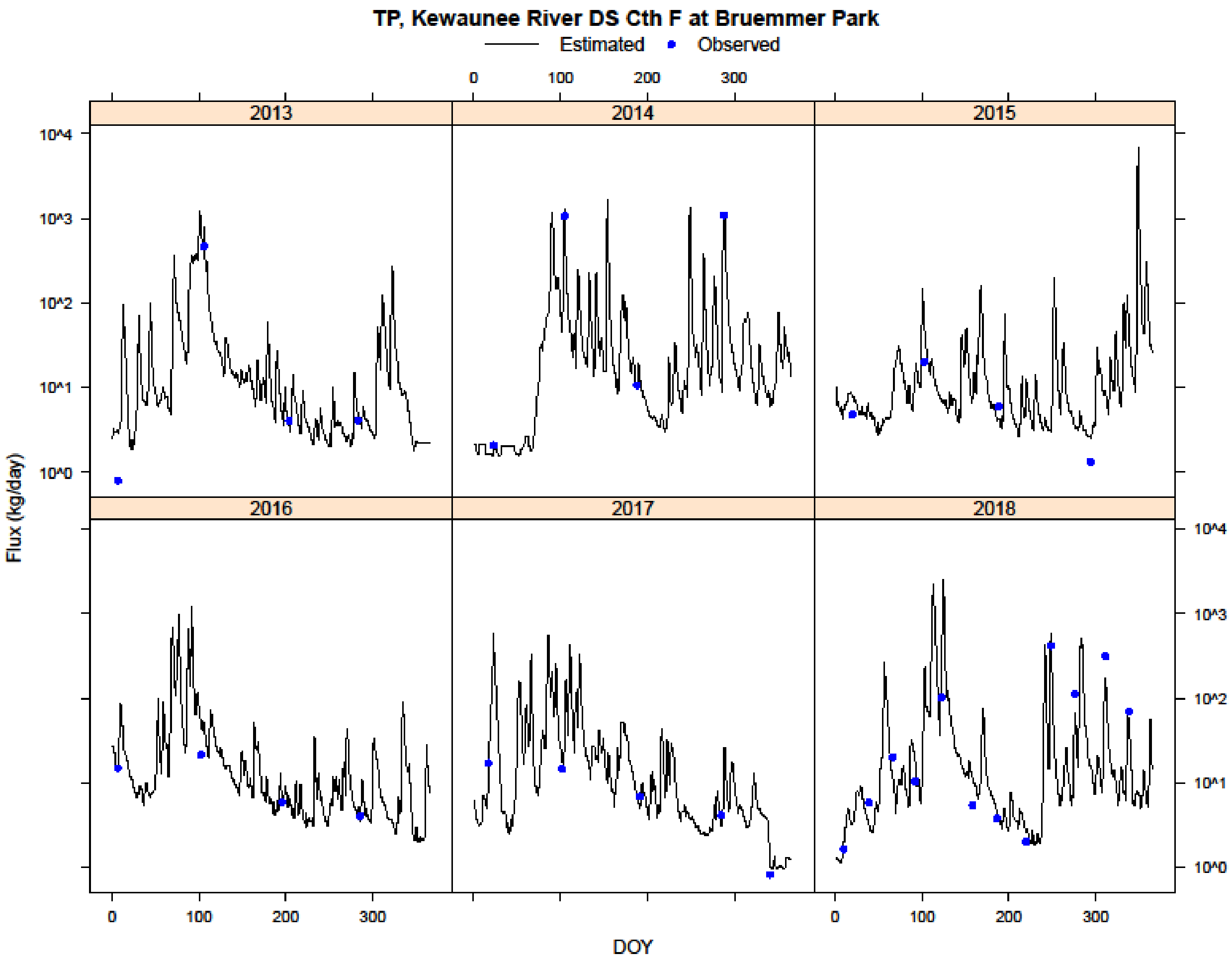


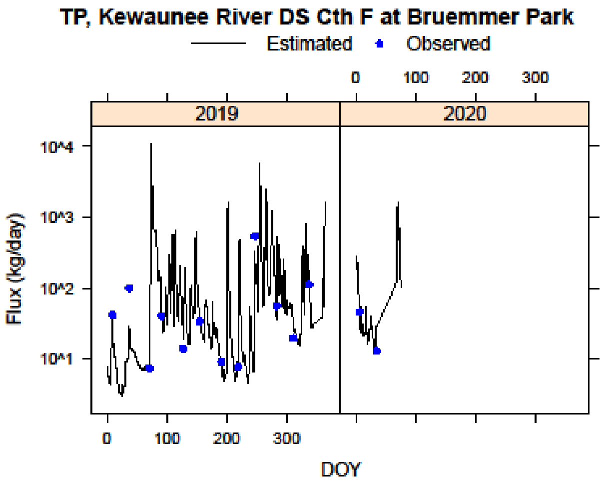
TP, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
1990
1991
1992
1993
1994
1998
Flux (kg/day)
DOY
10^0
10^1
10^2
10^3
10^4
0
100
200
300



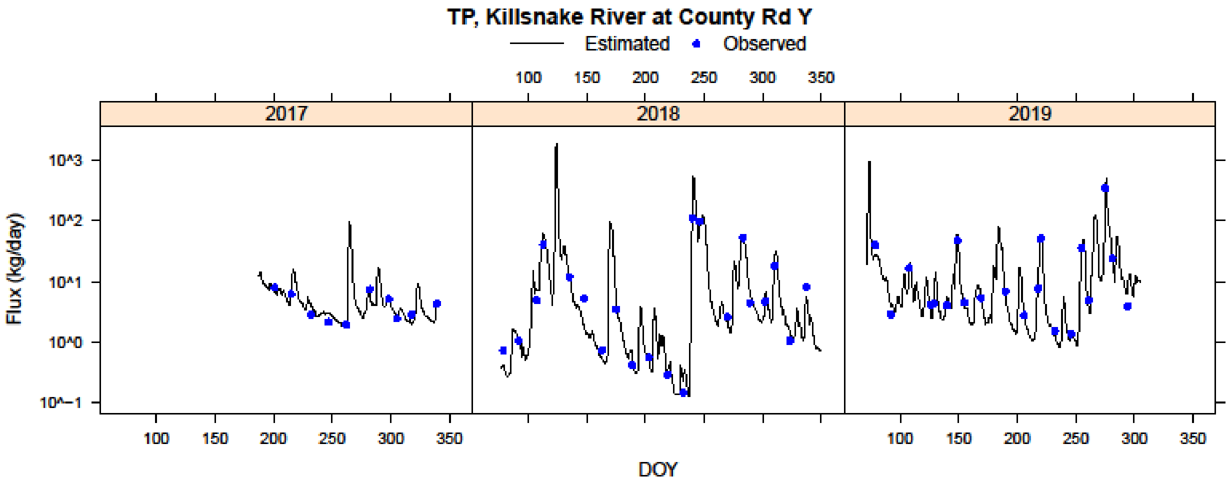
TP, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2001
2002
2003
2004
2005
2006
10^3
10^2
10^1
10^0
0
100
200
300
Flux (kg/day)
DOY

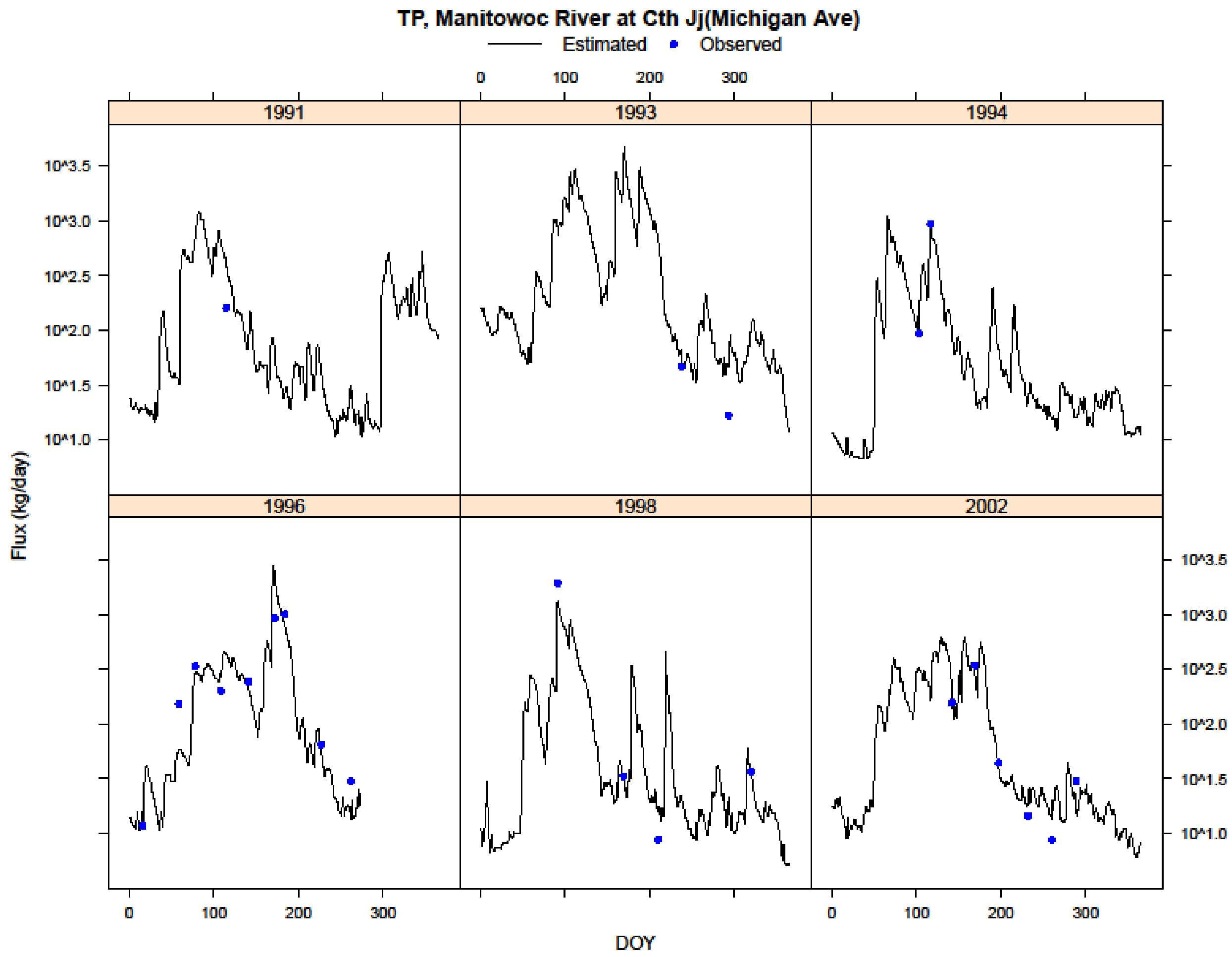

TP, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2007
2008
2009
2010
2011
2012
Flux (kg/day)
DOY
10^4
10^3
10^2
10^1
10^0
0
100
200
300


TP, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2013
2014
2015
2016
2017
2018
Flux (kg/day)
10^0
10^1
10^2
10^3
10^4
0
100
200
300
DOY

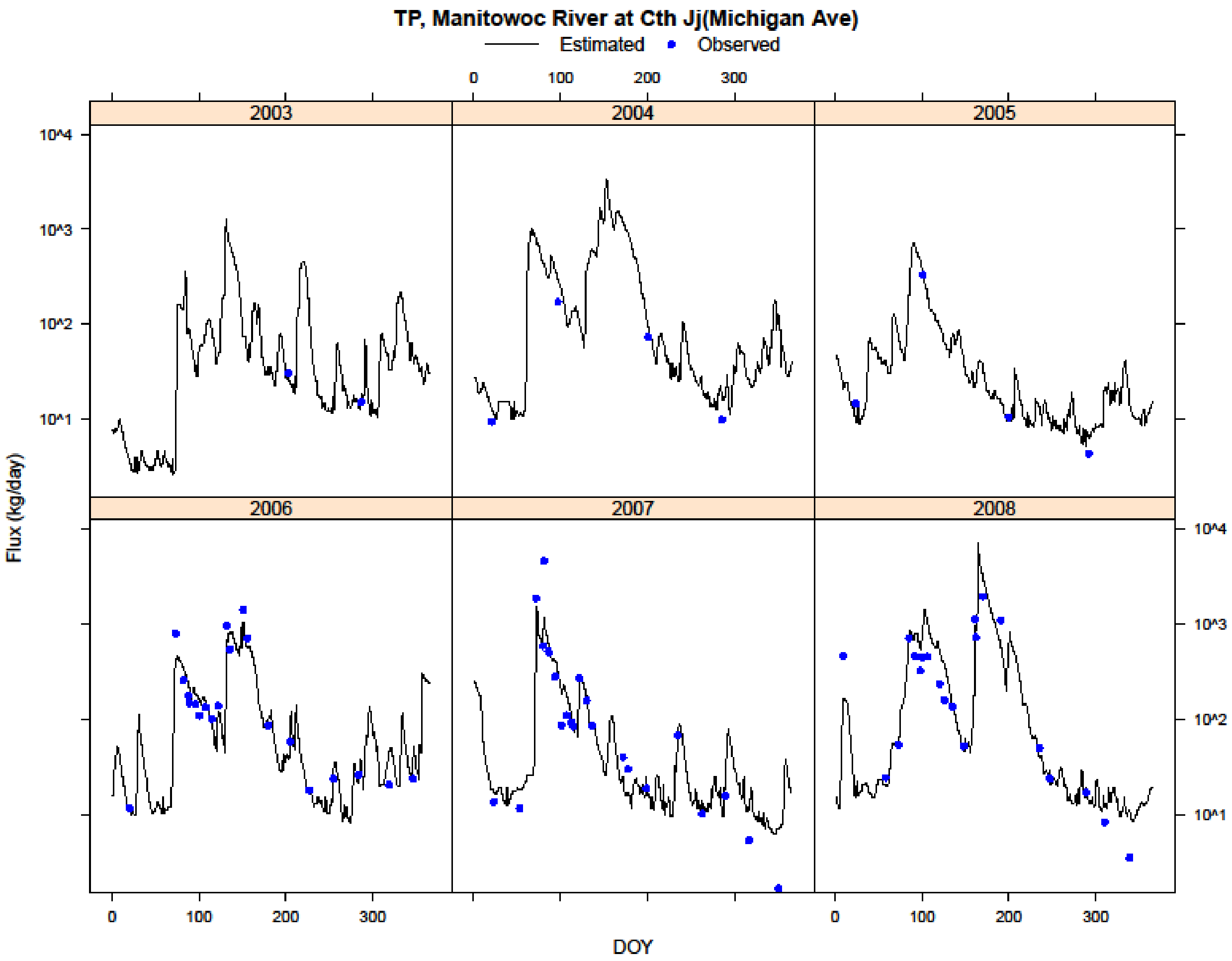


TP, Kewaunee River DS Cth F at Bruemmer Park
Estimated
Observed
2019
2020
Flux (kg/day)
10^4
10^3
10^2
10^1
0
100
200
300
DOY

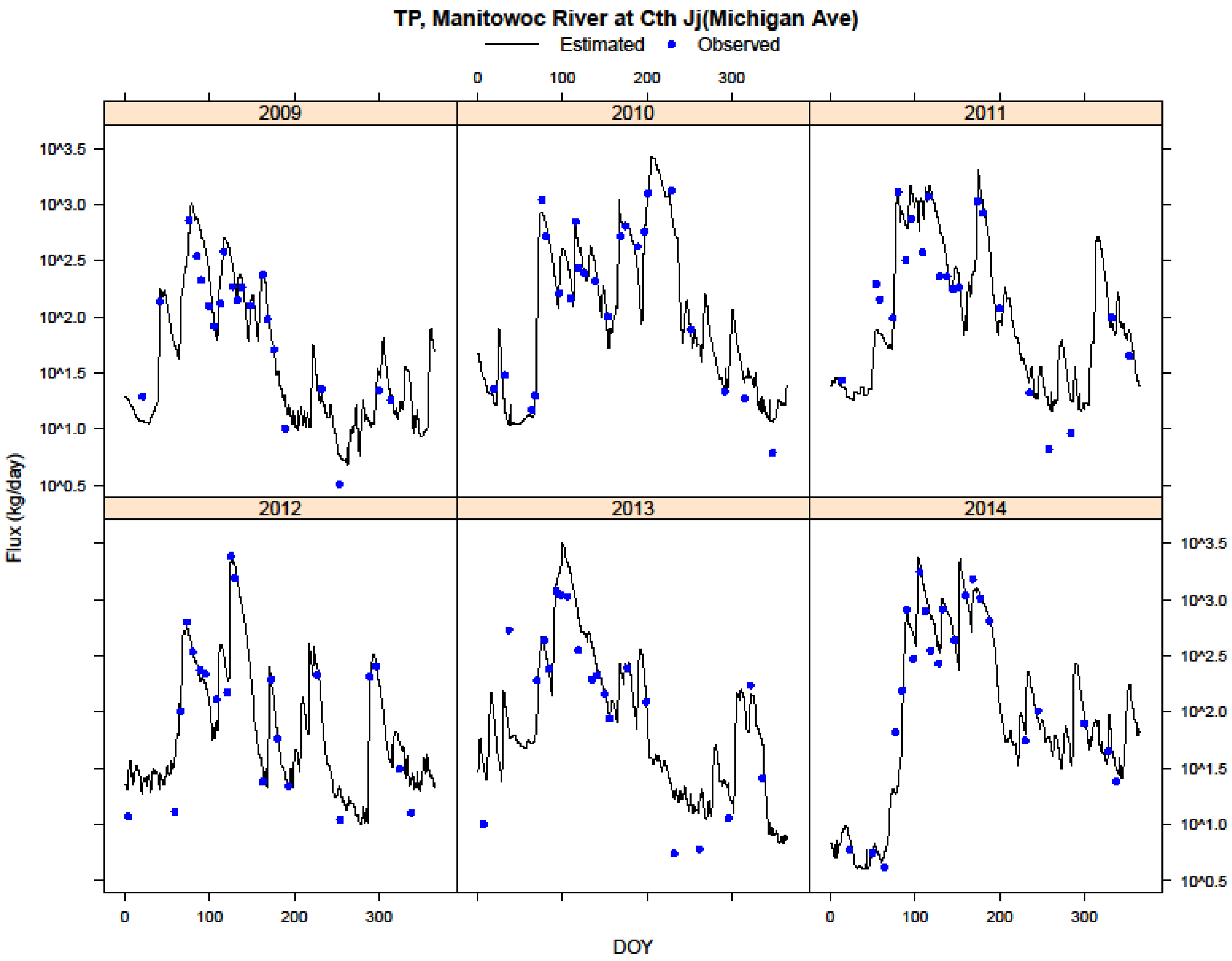

TP, Killsnake River at County Rd Y
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
10^−1
100
150
200
250
300
350
DOY



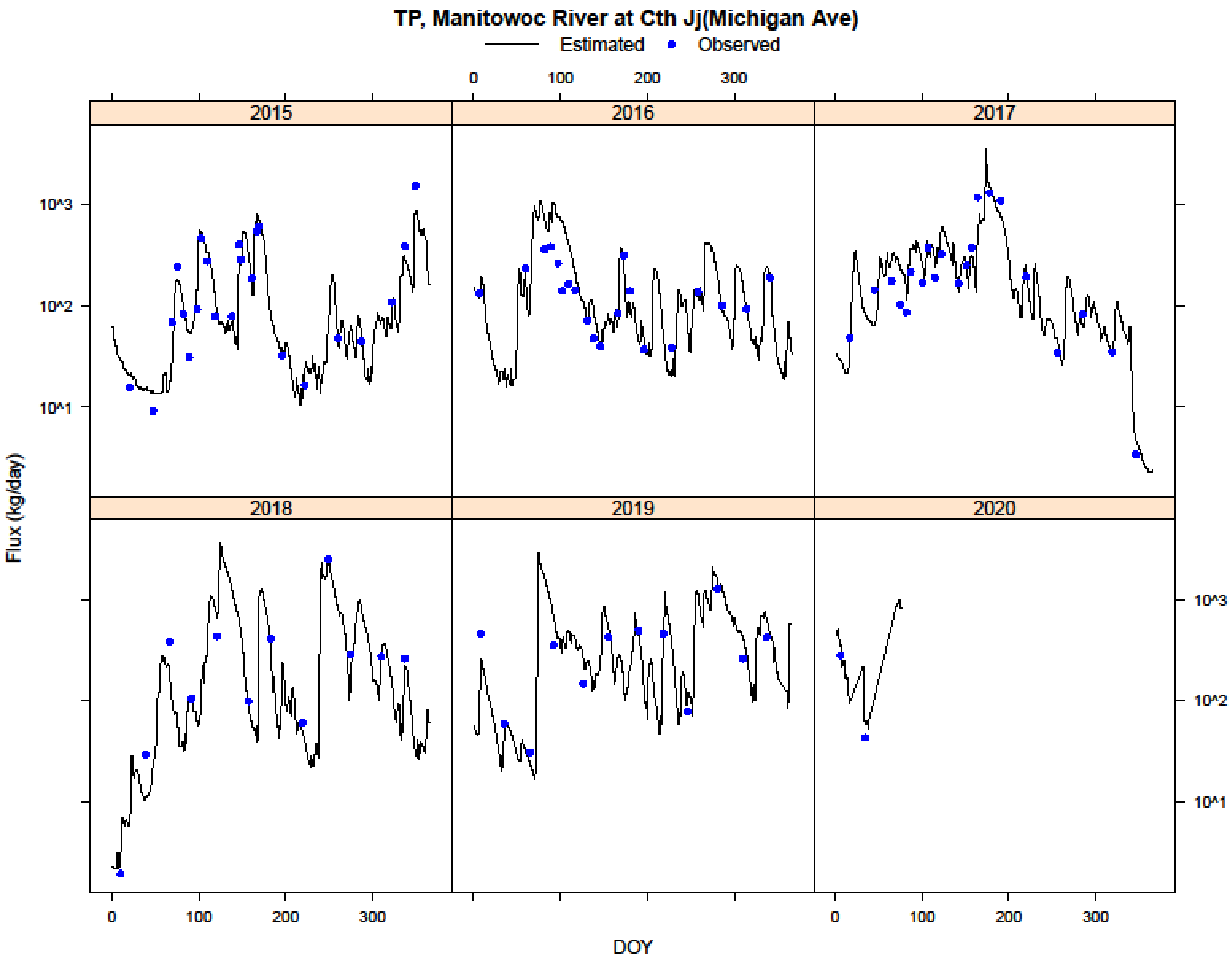
TP, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
1991
1993
1994
1996
1998
2002
Flux (kg/day)
10^3.5
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
0
100
200
300
DOY

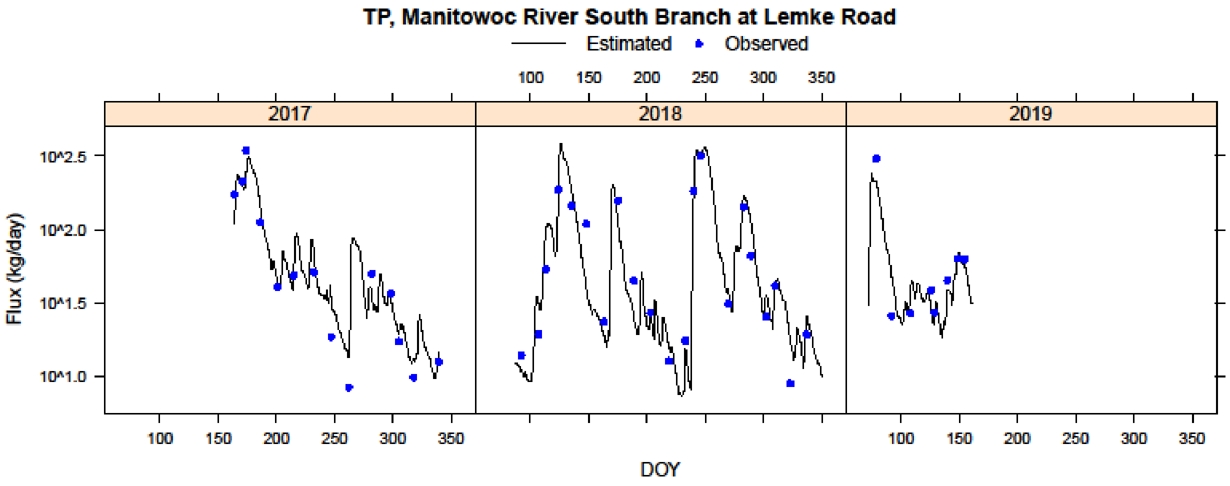


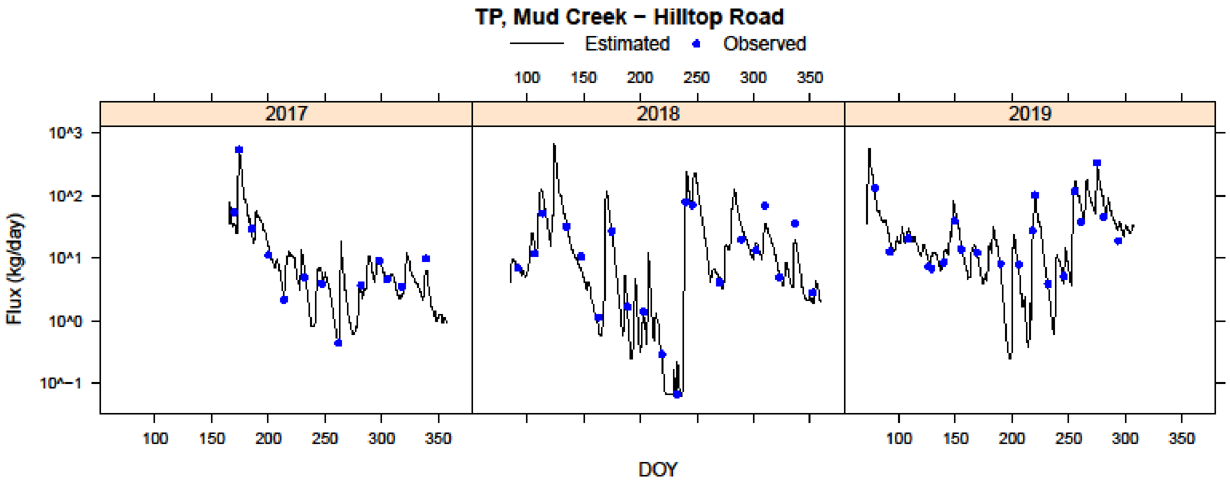
TP, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2003
2004
2005
2006
2007
2008
10^4
10^3
10^2
10^1
0
100
200
300
Flux (kg/day)
DOY



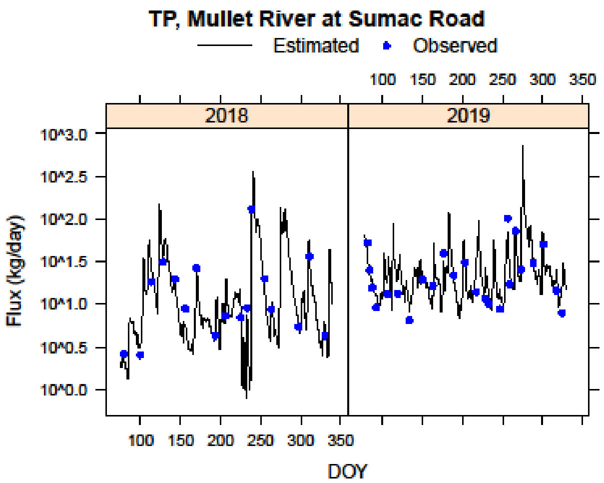
TP, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2009
2010
2011
2012
2013
2014
Flux (kg/day)
DOY
10^3.5
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
0
100
200
300

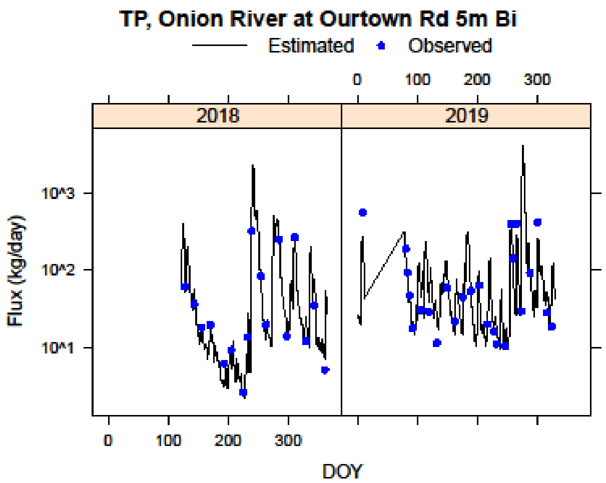

TP, Manitowoc River at Cth Jj(Michigan Ave)
Estimated
Observed
2015
2016
2017
2018
2019
2020
Flux (kg/day)
10^1
10^2
10^3
0
100
200
300
DOY

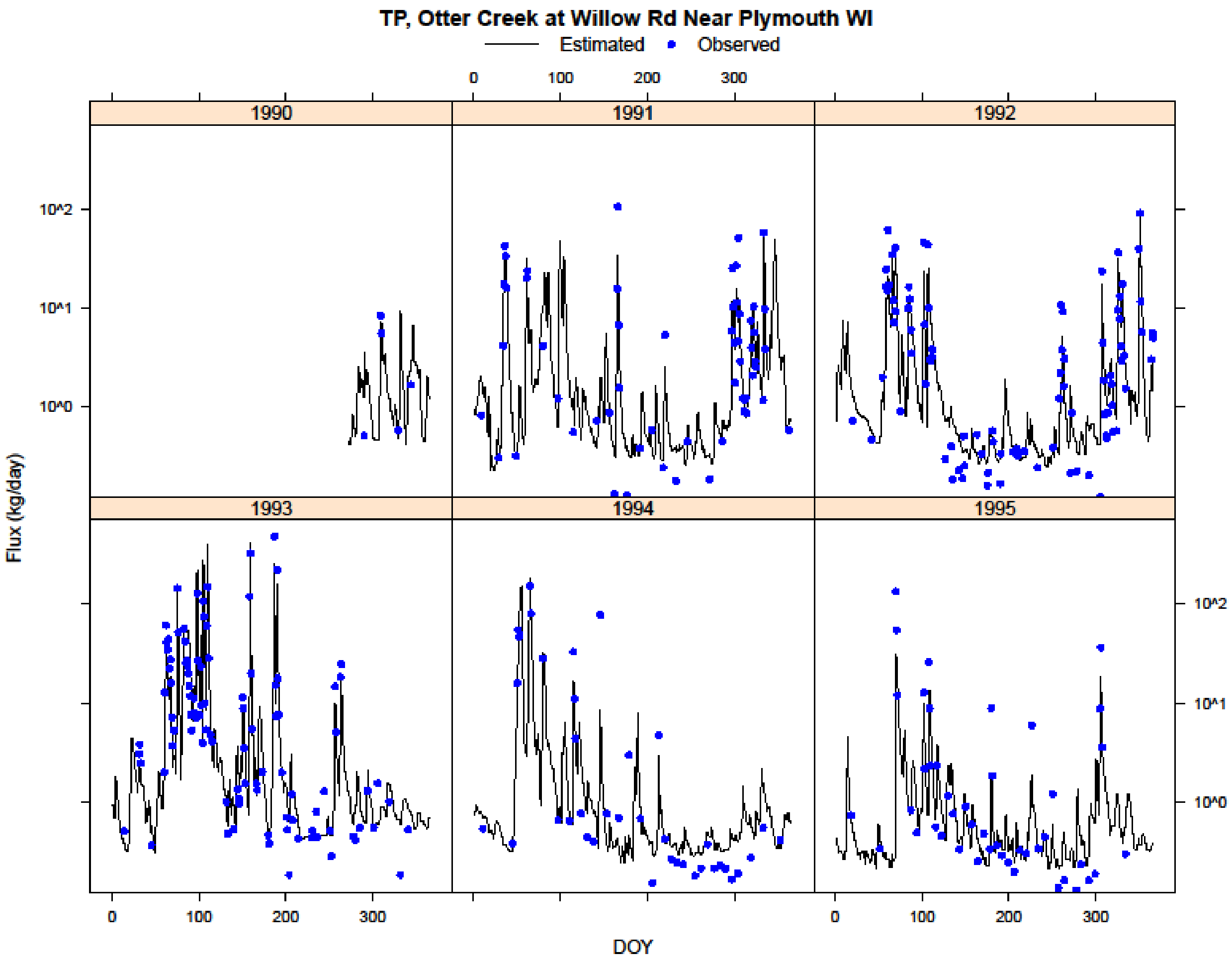

TP, Manitowoc River South Branch at Lemke Road
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^2.5
10^2.0
10^1.5
10^1.0
100
150
200
250
300
350
DOY



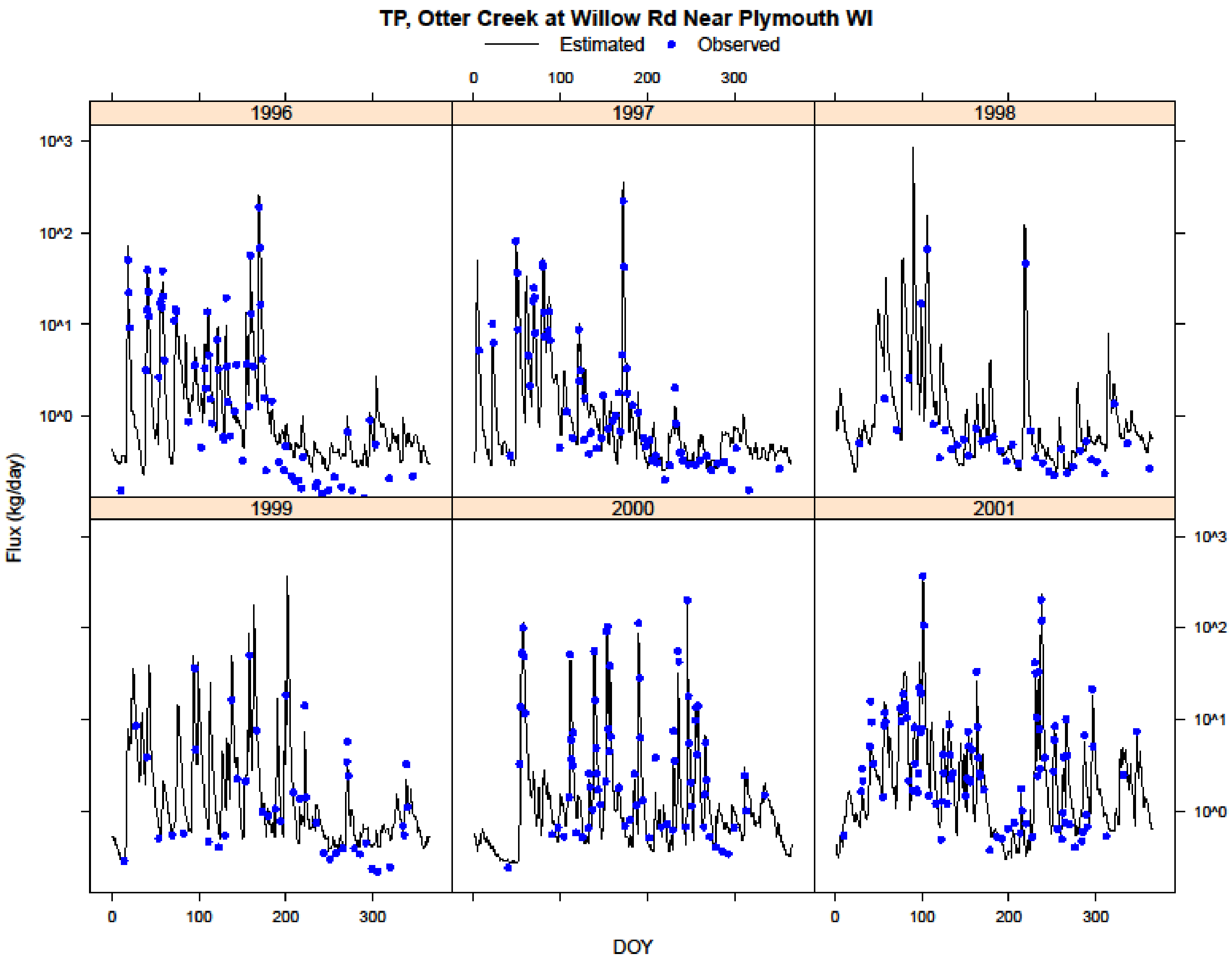
TP, Mud Creek – Hilltop Road
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
10^−1
100
150
200
250
300
350
DOY


TP, Mullet River at Sumac Road
Estimated
Observed
2018
2019
Flux (kg/day)
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
10^0.0
100 150 200 250 300 350
DOY

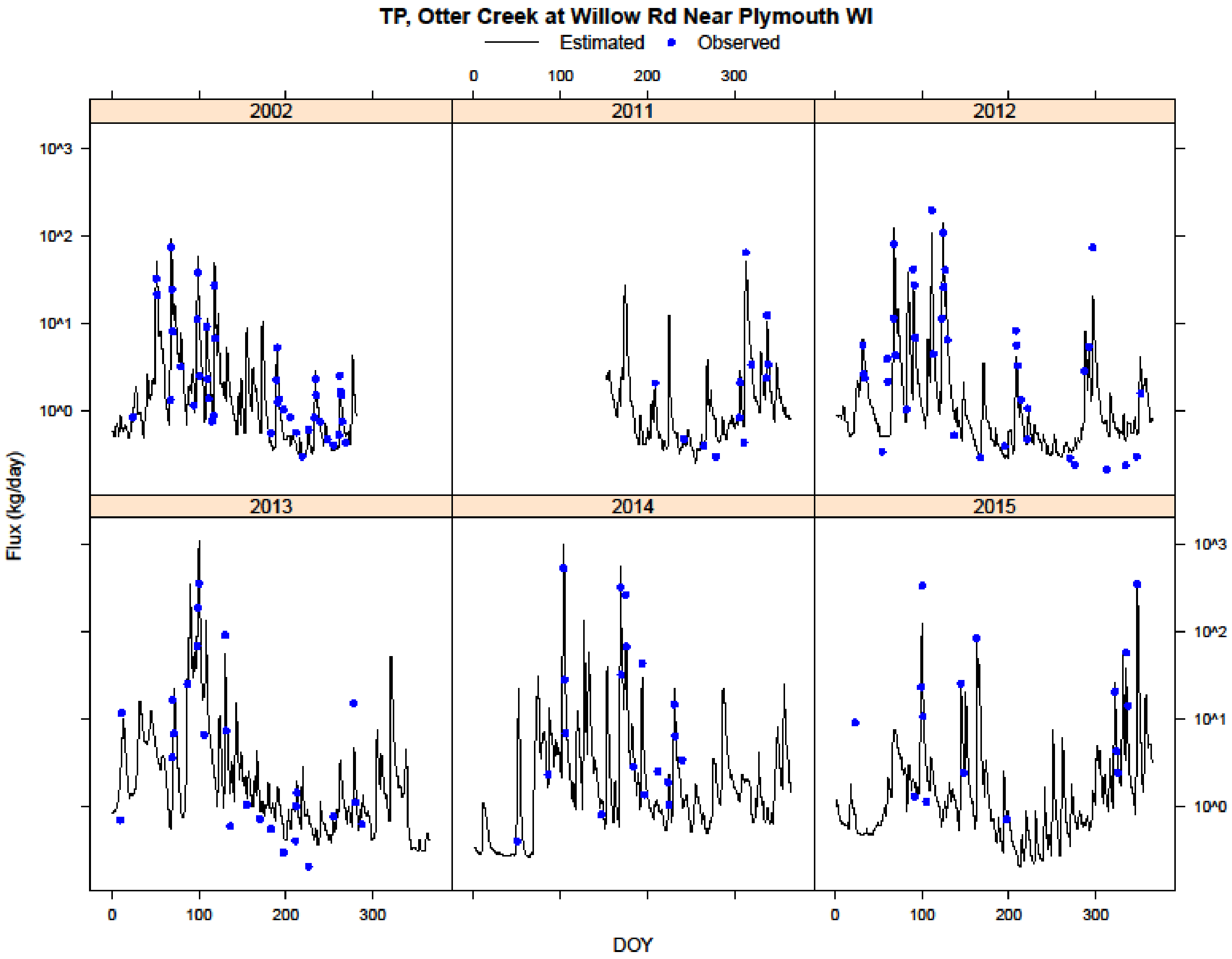

TP, Onion River at Ourtown Rd 5m Bi
Estimated
Observed
2018
2019
Flux (kg/day)
10^3
10^2
10^1
0 100 200 300
DOY



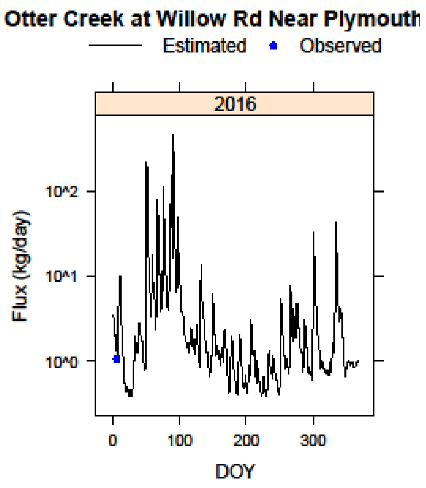
TP, Otter Creek at Willow Rd Near Plymouth WI
Estimated
Observed
1990
1991
1992
1993
1994
1995
0
100
200
300
10^0
10^1
10^2
Flux (kg/day)
DOY

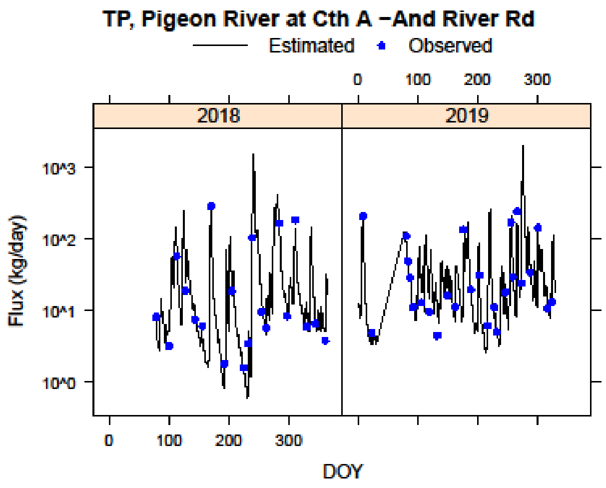


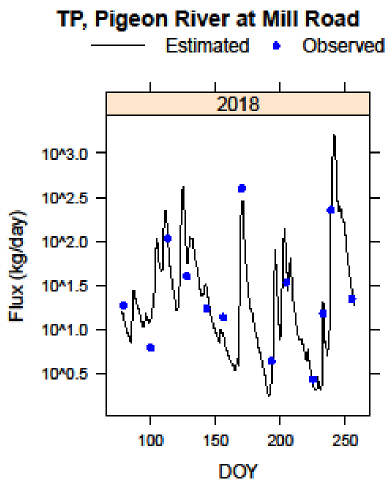
TP, Otter Creek at Willow Rd Near Plymouth WI
Estimated
Observed
1996
1997
1998
1999
2000
2001
Flux (kg/day)
DOY
10^3
10^2
10^1
10^0
0
100
200
300

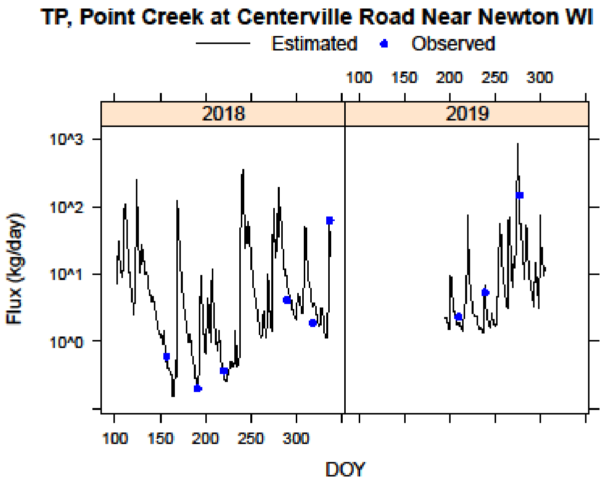


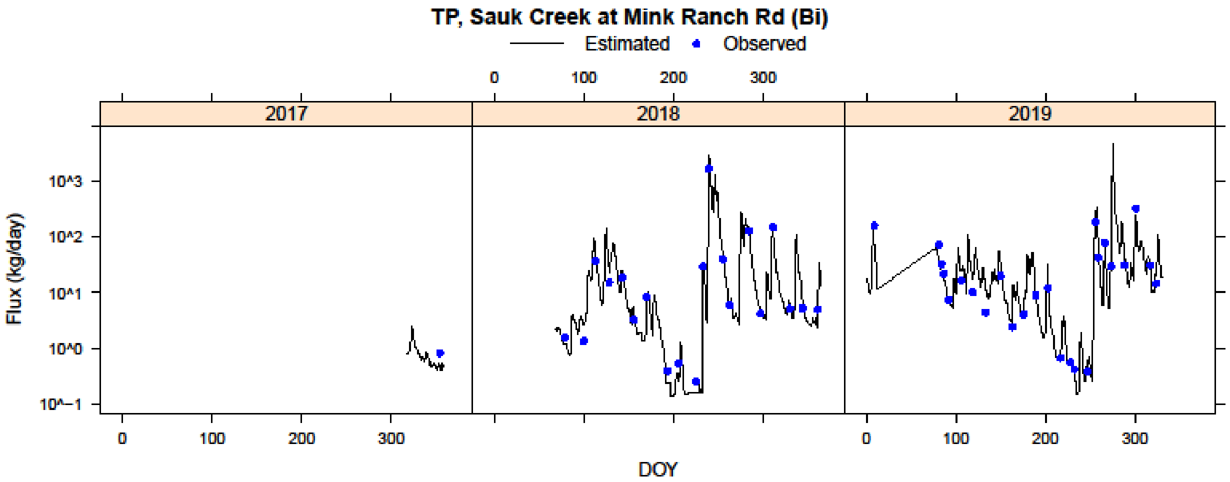
TP, Otter Creek at Willow Rd Near Plymouth WI
Estimated
Observed
2002
2011
2012
2013
2014
2015
10^3
10^2
10^1
10^0
0
100
200
300
Flux (kg/day)
DOY

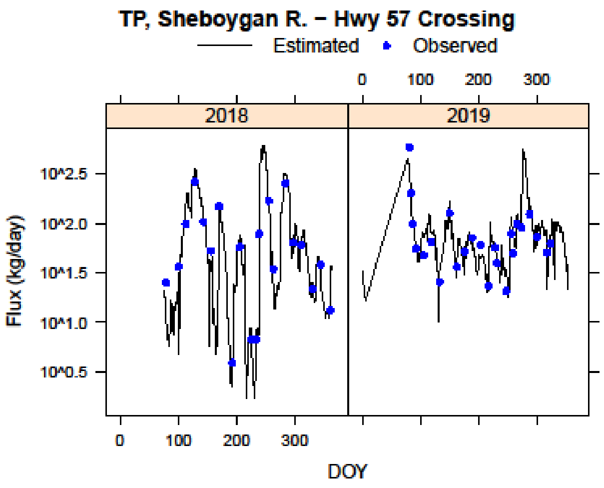

Otter Creek at Willow Rd Near Plymouth
Estimated
Observed
2016
Flux (kg/day)
10^2
10^1
10^0
0
100
200
300
DOY


TP, Pigeon River at Cth A −And River Rd
Estimated
Observed
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
0
100
200
300
DOY

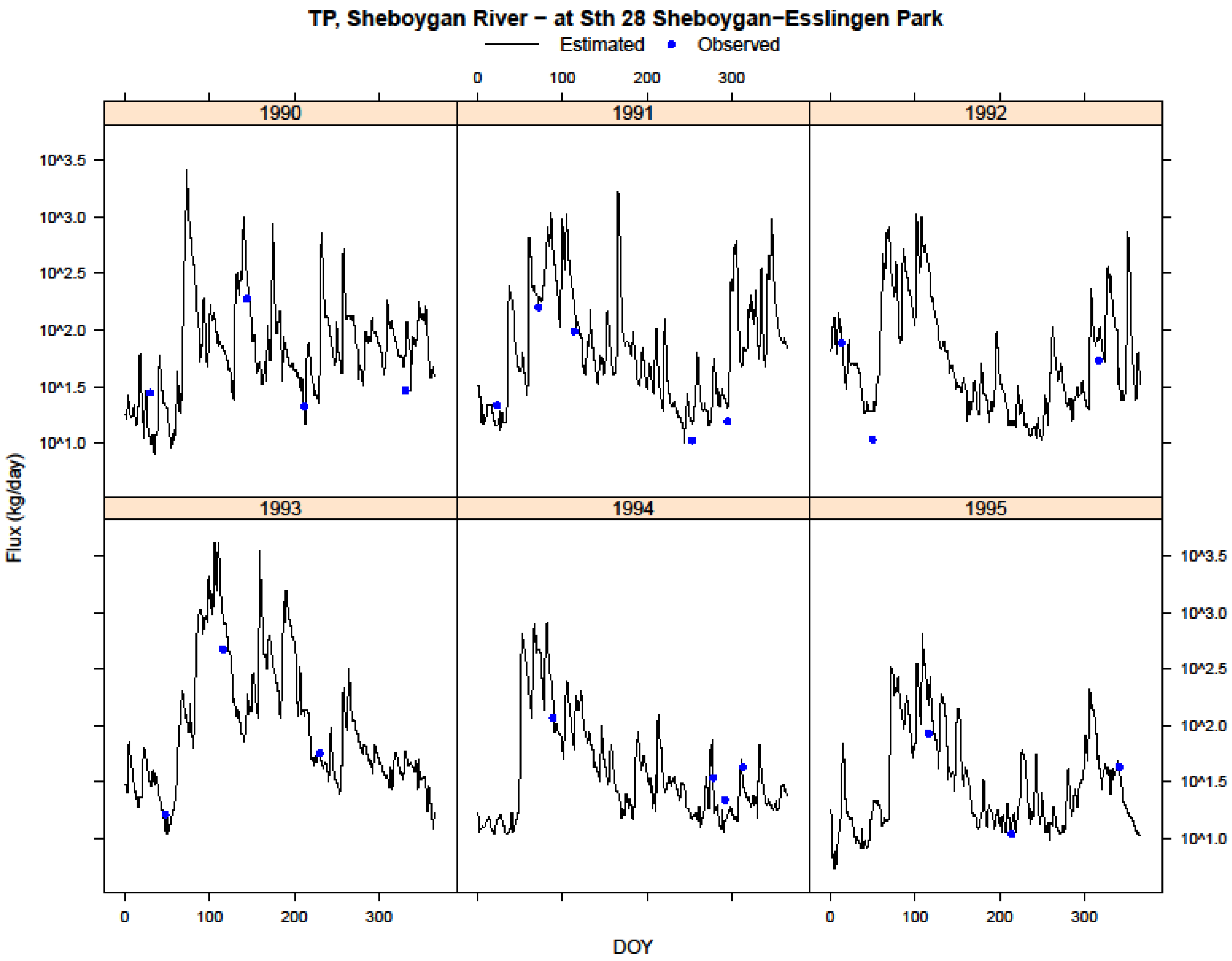

TP, Pigeon River at Mill Road
Estimated
Observed
2018
Flux (kg/day)
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
100
150
200
250
DOY


TP, Point Creek at Centerville Road Near Newton WI
Estimated
Observed
2018
2019
10^3
10^2
10^1
10^0
Flux (kg/day)
100
150
200
250
300
DOY

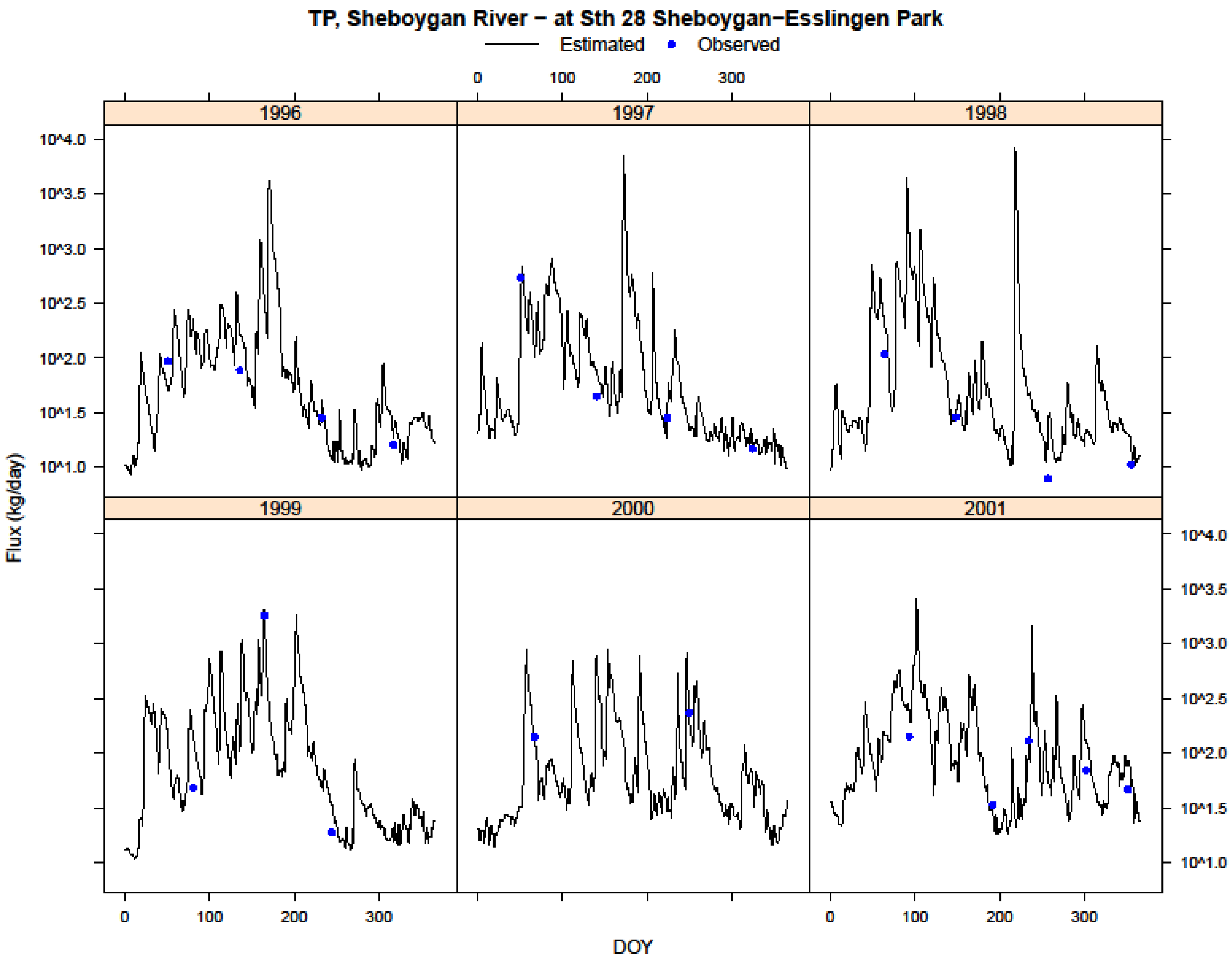

TP, Sauk Creek at Mink Ranch Rd (Bi)
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
10^−1
0
100
200
300
DOY



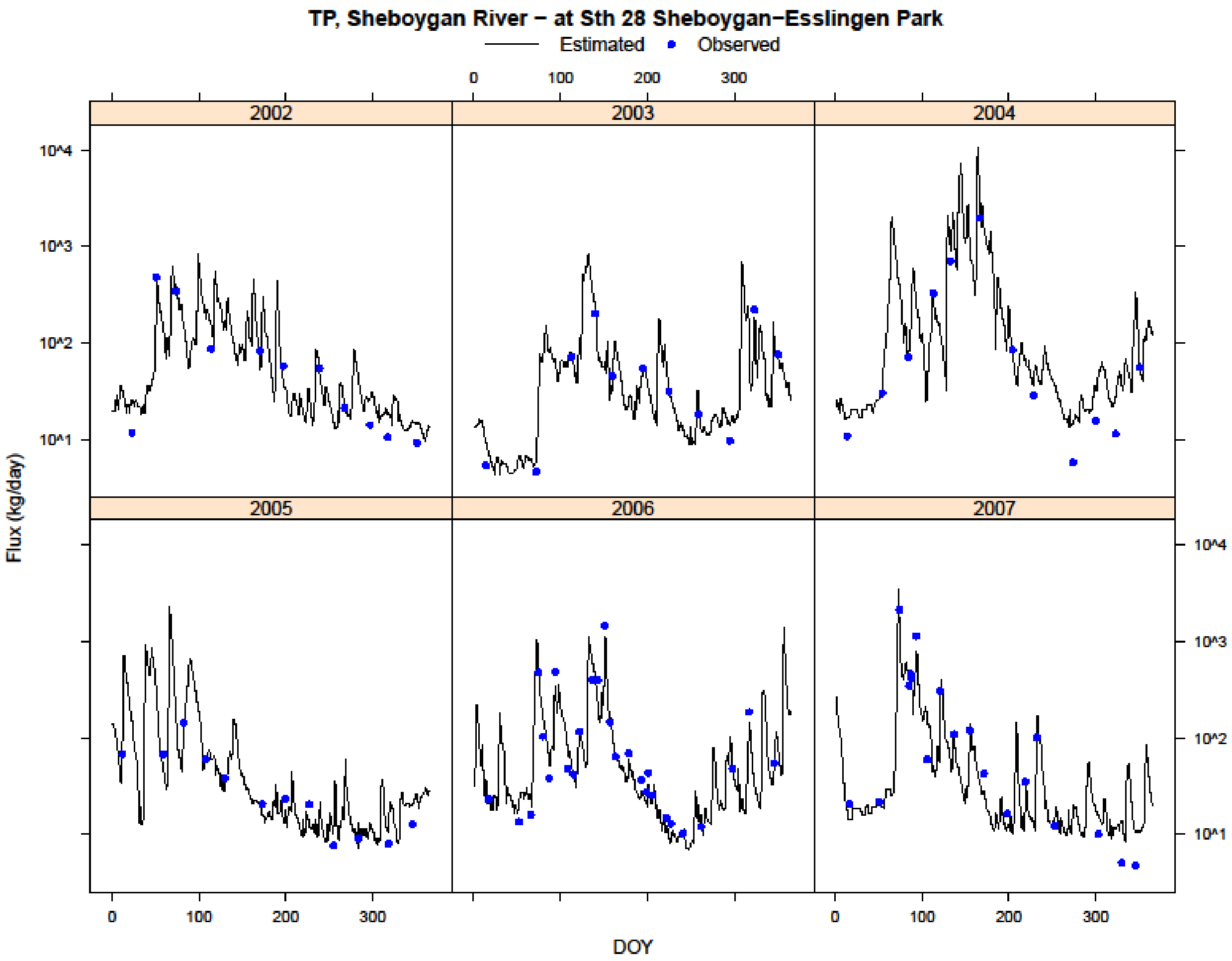
TP, Sheboygan R. – Hwy 57 Crossing
Estimated
Observed
2018
2019
Flux (kg/day)
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
0
100
200
300
DOY



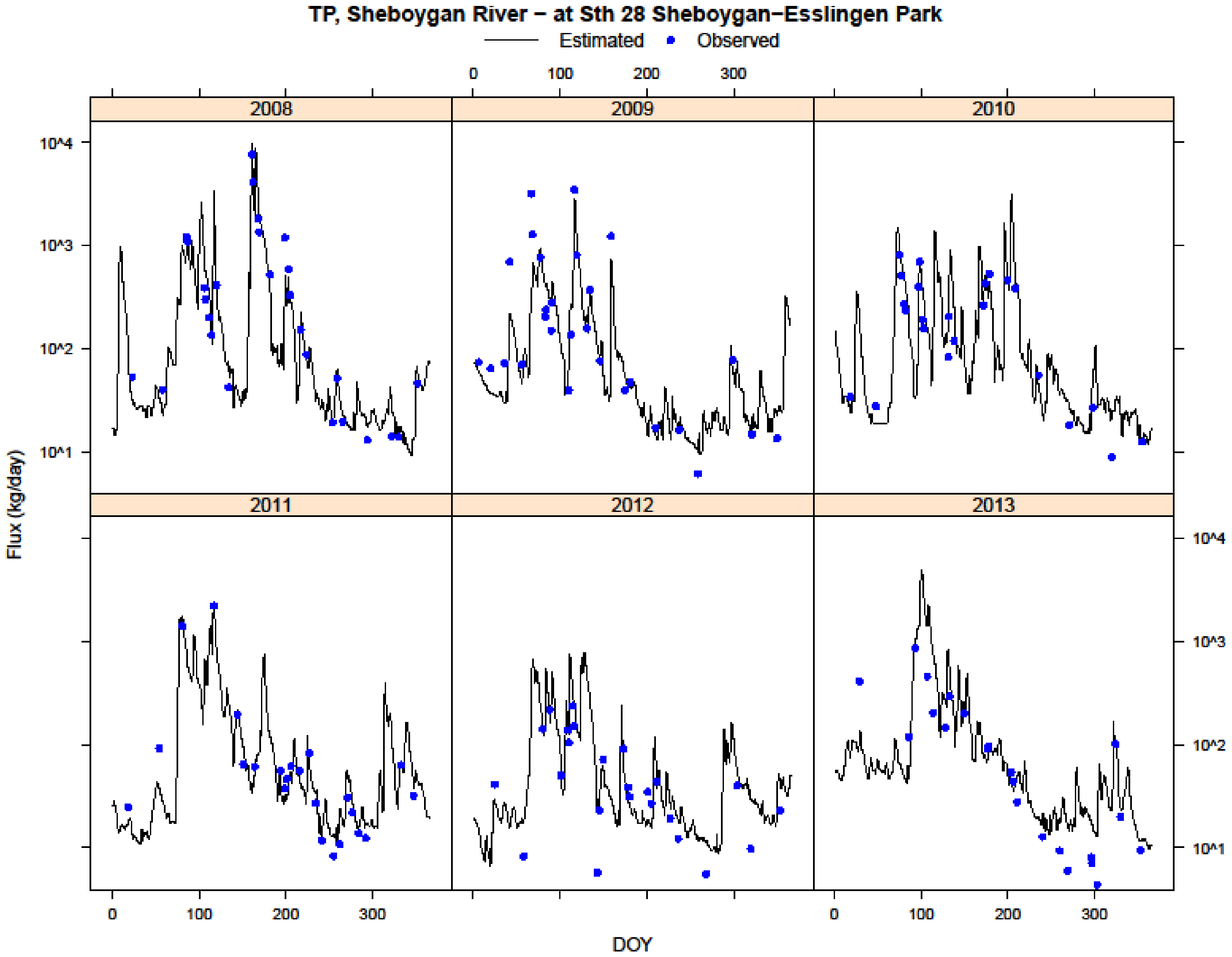
TP, Sheboygan River − at Sth 28 Sheboygan−Esslingen Park
Estimated
Observed
1990
1991
1992
1993
1994
1995
10^1.0
10^1.5
10^2.0
10^2.5
10^3.0
10^3.5
0
100
200
300
Flux (kg/day)
DOY



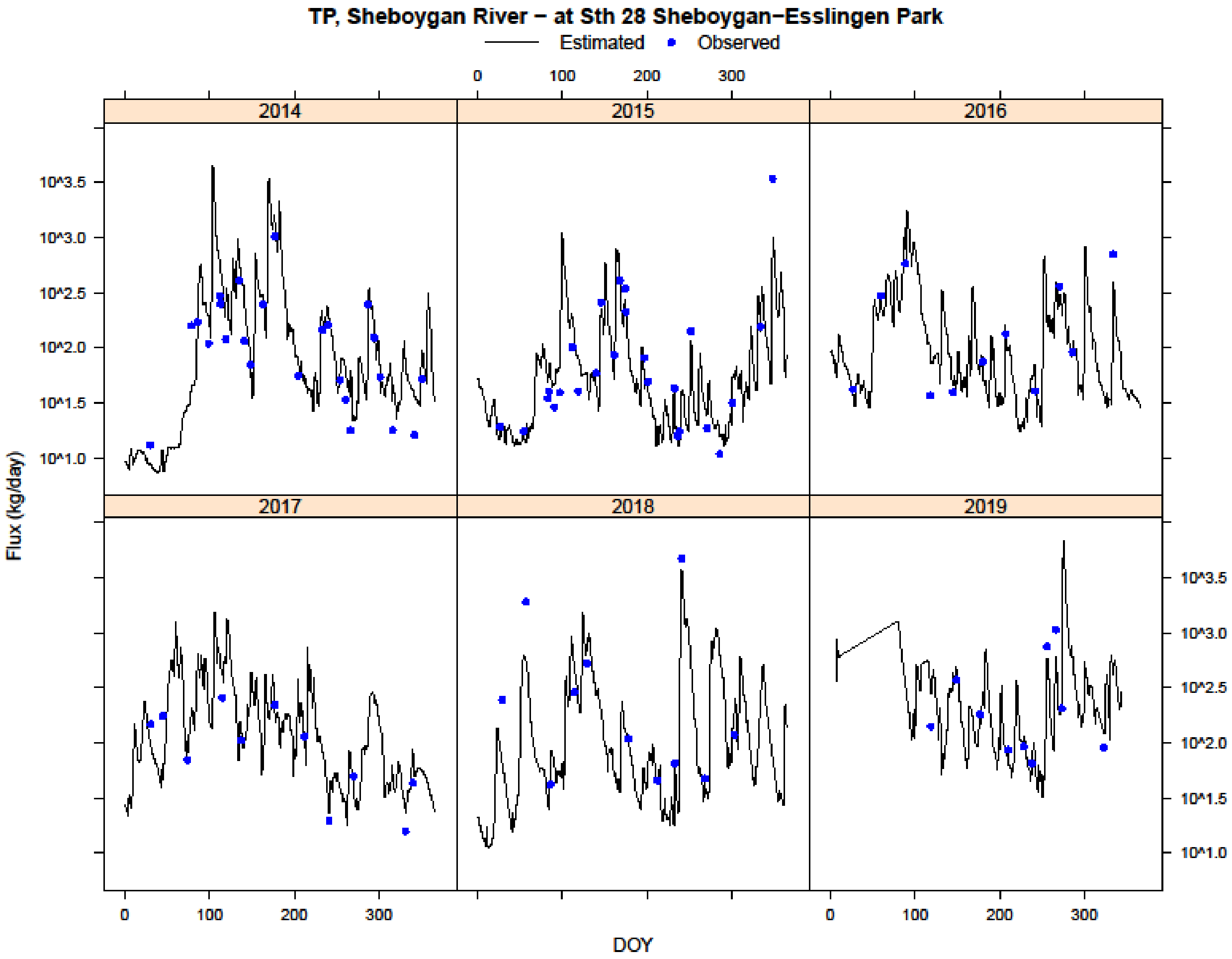
TP, Sheboygan River − at Sth 28 Sheboygan−Esslingen Park
Estimated
Observed
1996
1997
1998
1999
2000
2001
10^4.0
10^3.5
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
0
100
200
300
Flux (kg/day)
DOY



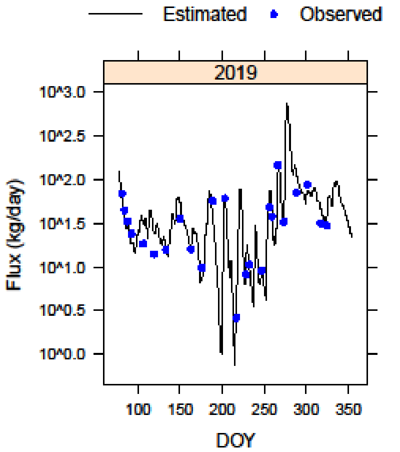
TP, Sheboygan River − at Sth 28 Sheboygan−Esslingen Park
Estimated
Observed
2002
2003
2004
2005
2006
2007
10^4
10^3
10^2
10^1
Flux (kg/day)
0
100
200
300
DOY

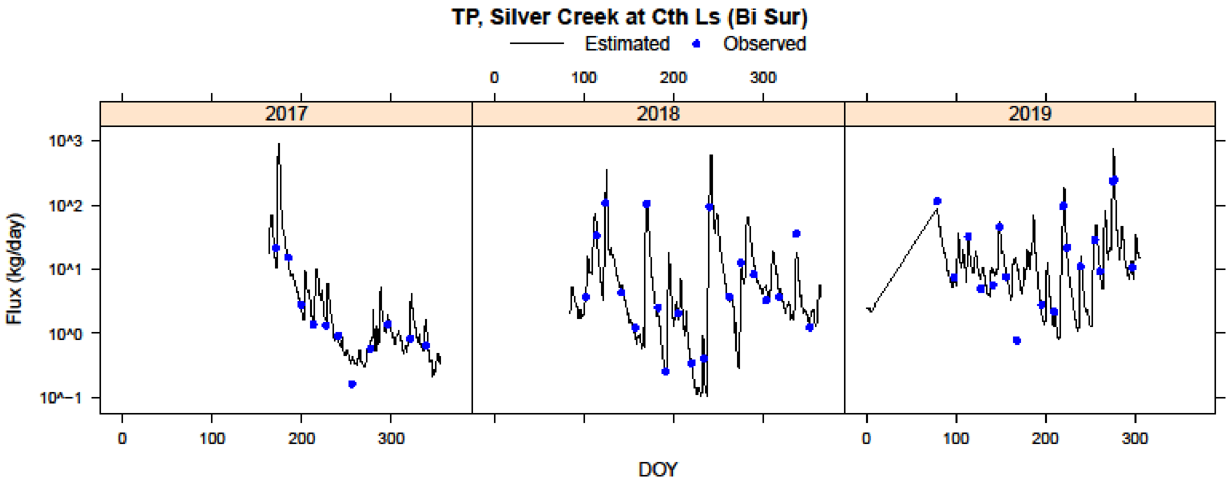


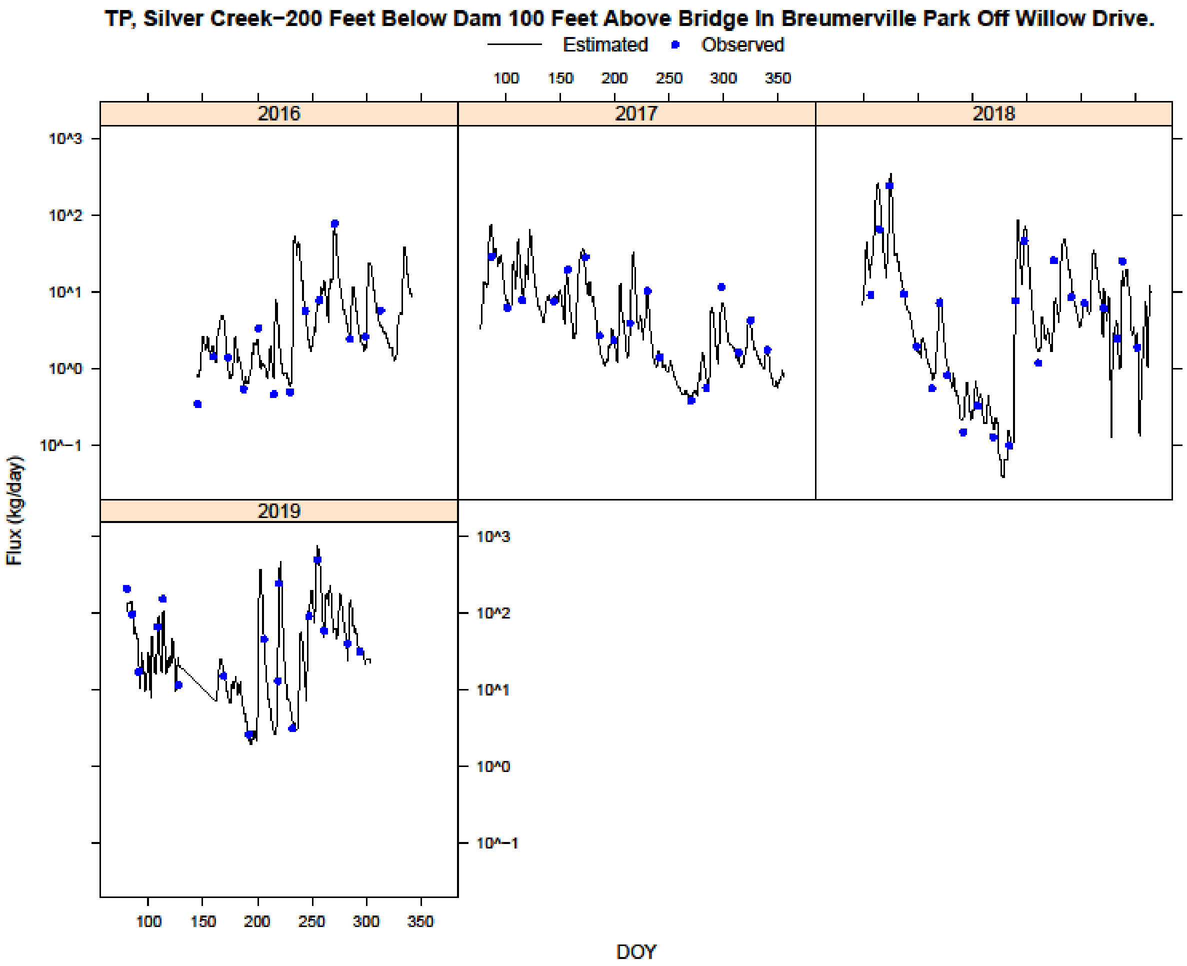
TP, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
2008
2009
2010
2011
2012
2013
Flux (kg/day)
DOY
10^4
10^3
10^2
10^1
0
100
200
300


TP, Sheboygan River – at Sth 28 Sheboygan–Esslingen Park
Estimated
Observed
2014
2015
2016
2017
2018
2019
Flux (kg/day)
10^3.5
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
0
100
200
300
DOY

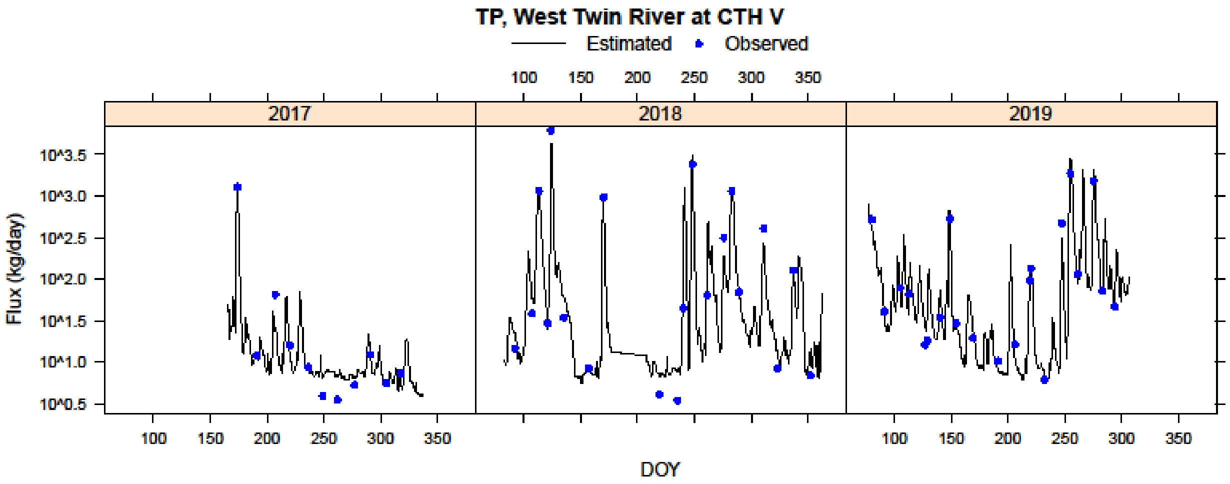
TP, Sheboygan River at Palm Tree Rd




TP, Silver Creek at Cth Ls (Bi Sur)
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
10^-1
0
100
200
300
DOY



TP, Silver Creek−200 Feet Below Dam 100 Feet Above Bridge In Breumerville Park Off Willow Drive.
Estimated
Observed
2016
2017
2018
2019
Flux (kg/day)
10^3
10^2
10^1
10^0
10^−1
100
150
200
250
300
350
DOY



TP, West Twin River at CTH V
Estimated
Observed
2017
2018
2019
Flux (kg/day)
10^3.5
10^3.0
10^2.5
10^2.0
10^1.5
10^1.0
10^0.5
100
150
200
250
300
350
DOY