Stantec

Technical Memo

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File:	Lake Mallalieu Desktop Analysis	Date:	October 11, 2022

REFERENCE: LAKE MALLALIEU DESKTOP ANALYSIS

BACKGROUND DATA

The dam below Little Falls Lake has experienced multiple breach events in recent years that have released sediment and nutrients downstream into Willow River, and ultimately Lake Mallalieu. These releases of sediment and nutrients are believed to have increased in frequency and magnitude during the period from the initial dam drawdown and breach in 2015 up to the completion of the new dam in 2020. Sediment deposition during these breach events is thought to be the cause of a recent increase in siltation, aquatic plant growth, and algal blooms in Lake Mallalieu, and subsequently an overall decrease in water quality and clarity. A better understanding of stream and lake conditions pre- and post-dam breach events will help understand potential water quality, biological, and navigational impacts from upstream releases of sediment to Lake Mallalieu. Stantec was contracted by the Lake Mallalieu Association (Association) to perform a desktop analysis of sediment and nutrient transport to Lake Mallalieu during this time period using publicly available stream gage data and aerial imagery. This analysis will help the Association better understand potential changes to the system before and after alterations to the Little Falls Dam.

A timeline of events was generated using various news stories and local knowledge to capture the streamflow, sediment, and phosphorus regimes under dammed conditions and breach conditions (Figure *1*). For the purposes of this analysis, the “breach period” will refer to September 1, 2015 through September 1, 2018 and March 24, 2019 through April 8, 2019. This breach period accounts for the time when the dam was purposefully breached during the design phase of the new dam (2015-2018) and the short time window when the dam construction site breached (Spring 2019). The “dam period” will refer to all dates that fall outside of the breach period.

Reference: **Lake Mallalieu Desktop Analysis**

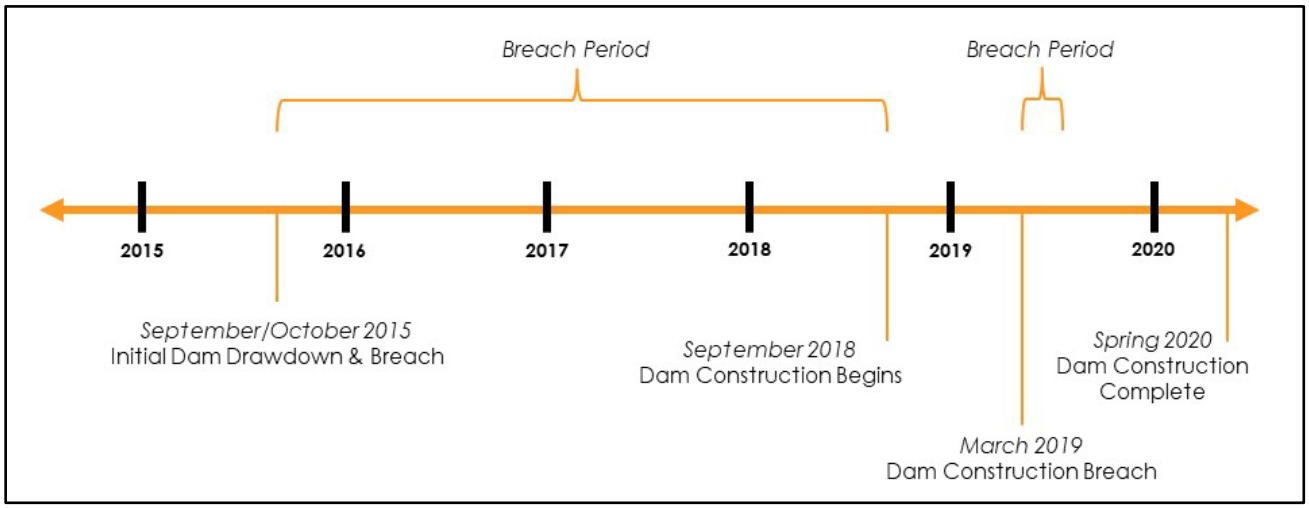

Figure 1. *Timeline of Little Falls Dam events.*

USGS STREAM GAGE DATA ANALYSIS

The United States Geological Survey (USGS) stream gage ID 0534172 (Willow River @ Willow R State Park Nr Burkhardt, WI) is located on the Willow River approximately 0.4 miles downstream of the outlet of Little Falls Lake and approximately 2 miles upstream from Lake Mallalieu. Gage data were used in this analysis to evaluate flow and sediment, and phosphorus delivery to Lake Mallalieu via the Willow River stream channel. While it is outside of the scope or practical limitations of this study to assess in-stream pollutant loading dynamics, it is likely (and assumed from here forward) that fluctuations in sediment and phosphorus delivery in the stream channel are ultimately reflected in the downstream receiving water, Lake Mallalieu, over time.

Data has been collected from USGS stream gage ID 0534172 from 1998 to present (2022). The gage has collected three parameters relevant to this study: (1) streamflow from 1998 to present, (2) total suspended sediment (TSS) from 2013 to 2020 and (3) total phosphorus (TP) from 2012 to 2020. Streamflow, pollutant concentrations, and pollutant loads were all evaluated because they can provide more meaningful information in the context of one another. Pollutant loads represent the total mass of a pollutant delivered to a specific location over a period of interest and are calculated using the pollutant concentration and the total volume of water delivered. Pollutant loads are useful in assessing watershed contributions over a period of time whereas pollutant concentrations have direct implication for organisms and represent a snapshot of conditions in the stream. Table 1 below provides the subset of date ranges used for this analysis for each parameter of interest.

Reference: **Lake Mallalieu Desktop Analysis**

Table 1. Parameters and date ranges used in this analysis.

Parameter	Start Date	End Date
Discharge (cfs)	October 1, 2012	September 30, 2020
Total Phosphorus (lbs/day)	October 1, 2012	September 30, 2020
Total Phosphorus (mg/L)	October 1, 2012	September 30, 2020
Total Suspended Sediment (Tons/day)	October 1, 2013	September 30, 2020
Total Suspended Sediment (mg/L)	October 1, 2013	September 30, 2020

Streamflow

Figure 2 shows a timeseries of daily mean streamflow (cubic feet per second, cfs), daily TP load (pounds per day), and daily TSS load (tons per day) for the period of interest in this analysis, with dam breach periods highlighted in dark grey. Streamflow varied over time and there was no initial observed difference in streamflow during the dammed period versus the breach period. The highest daily TP and TSS loads for the period of interest were observed during the breach period.

Reference: **Lake Mallalieu Desktop Analysis**

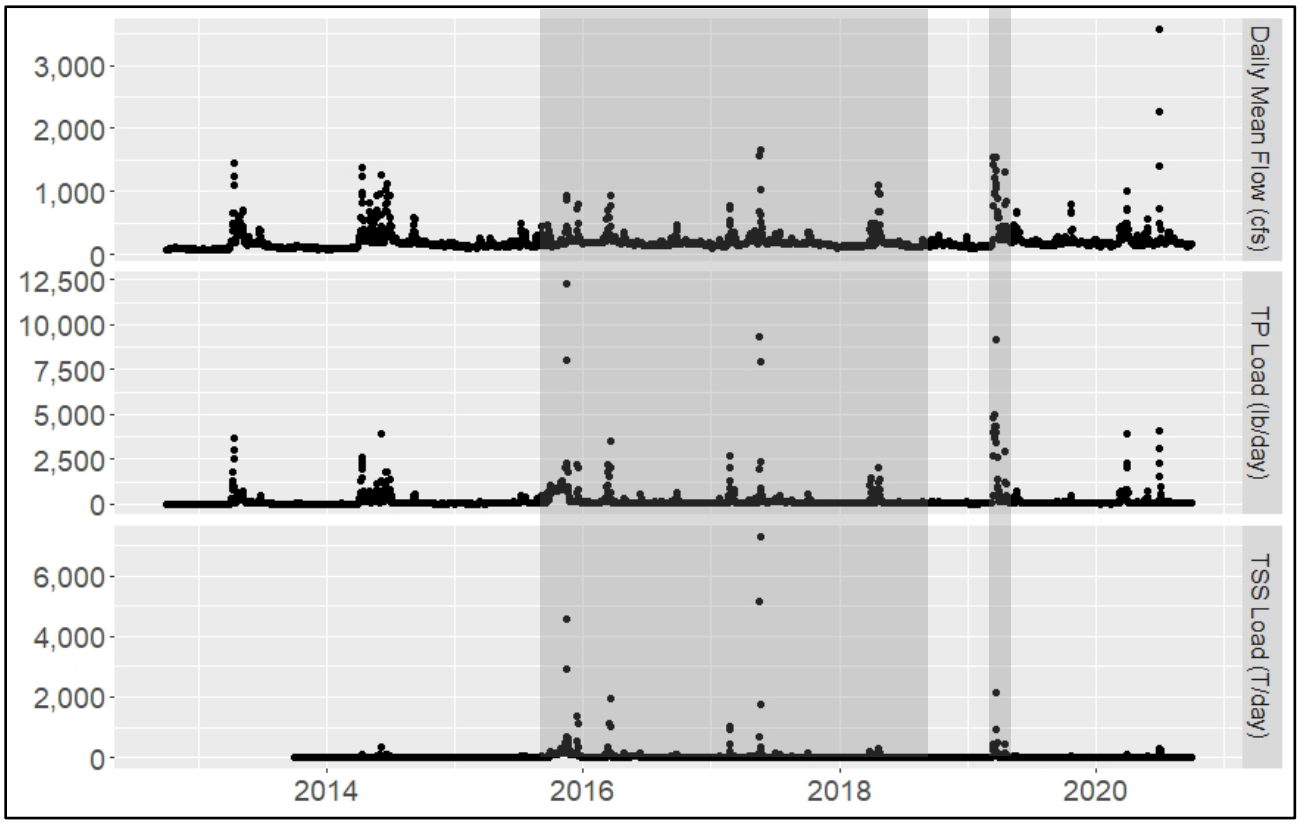

Figure 2. Timeseries of daily mean flow (cfs), TP load (lbs/day), and TSS load (T/day) for the time period used in this analysis, October 1, 2012 through September 30, 2020, with breach periods highlighted in dark grey.

Flow duration curves were used to compare streamflow regimes for the breach period and the dammed period to assess how similar flow conditions were during the two periods (Figure 3). Flow duration curves illustrate how frequently a given stream flow event occurs by expressing the percent of time that a flow is exceeded. For example, often very low flows are exceeded a high percentage of the time, whereas very high flows are rarely exceeded. The flow duration curves during both the breach and dammed periods are similar, suggesting that streamflow conditions and hydrologic response during both periods are largely the same. The similar flow regime between the breach and dammed periods provides a basis for comparison of pollutant loads and concentrations across the two periods.

Reference: **Lake Mallalieu Desktop Analysis**

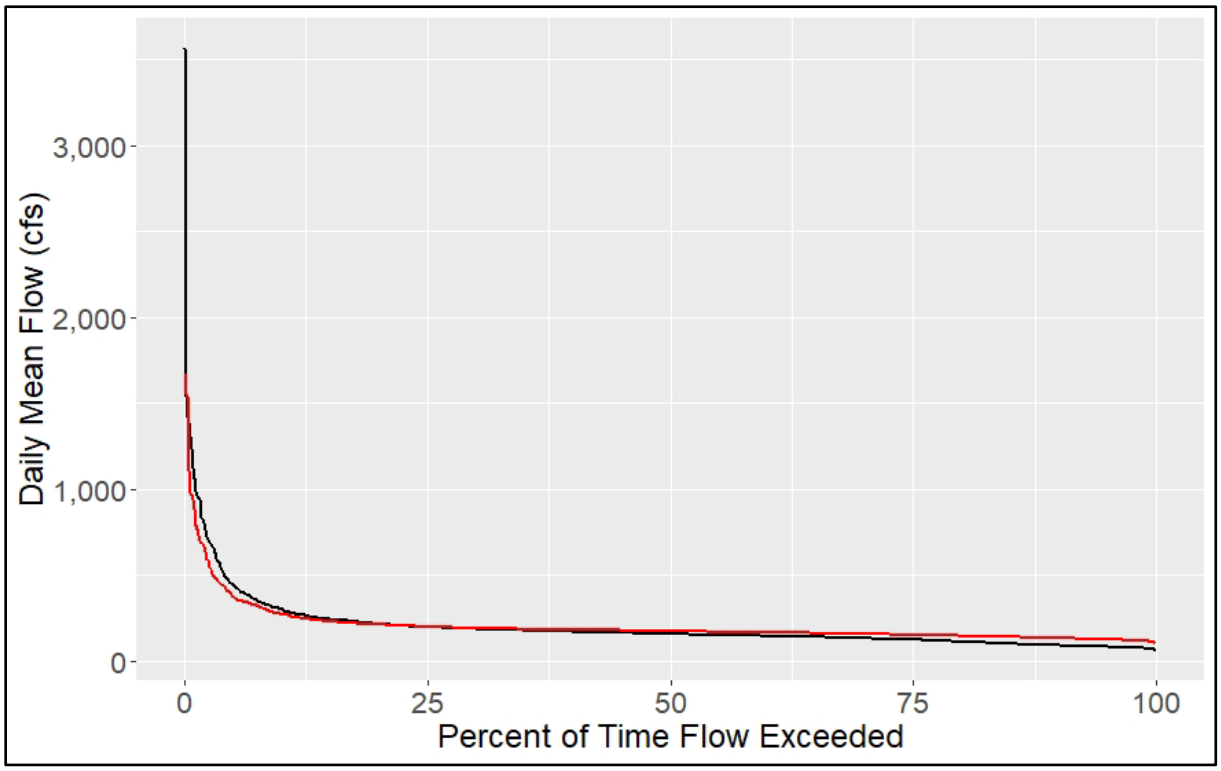

Figure 3. Flow Duration Curves for the dammed period (black) and the breach period (red).

Sediment

Table 2 summarizes the median TSS load in tons per month and tons per day during the dammed period versus the breach period. Comparison of cumulative pollutant loads over the dam period and the breach period would provide misleading results given that the two periods are not the same length of time; evaluating pollutant loading based on median monthly and median daily loads normalizes the values for comparison. Median monthly and daily TSS loads were higher during the breach period than the dammed period. The median monthly and daily TSS loads were over 4 and 3 times higher, respectively, during the breach period than the dammed period.

Reference: **Lake Mallalieu Desktop Analysis**

Table 2. Median monthly and median daily TSS loads for the dammed and breach periods.

Time Period	Median Monthly TSS Load (T/month)	Median Daily TSS Load (T/day)
Dammed Period	103.9	2.57
Breach Period	447.3	9.40

Figures 4 and 5 compare TSS concentration and load across streamflow and flow duration. TSS concentrations are highest during the breach period (Figure 4). High TSS concentrations were observed during low flows during the breach period, compared to the dammed period where high concentrations were not typically observed during low flows. Many of the high concentrations observed during low flows occurred after the initial dam breach in September through November 2015 (see blue scatter points in Figure 4A). The highest TSS loads during the period of interest were observed during the breach period and occurred across various flow conditions (Figure 5).

Reference: **Lake Mallalieu Desktop Analysis**

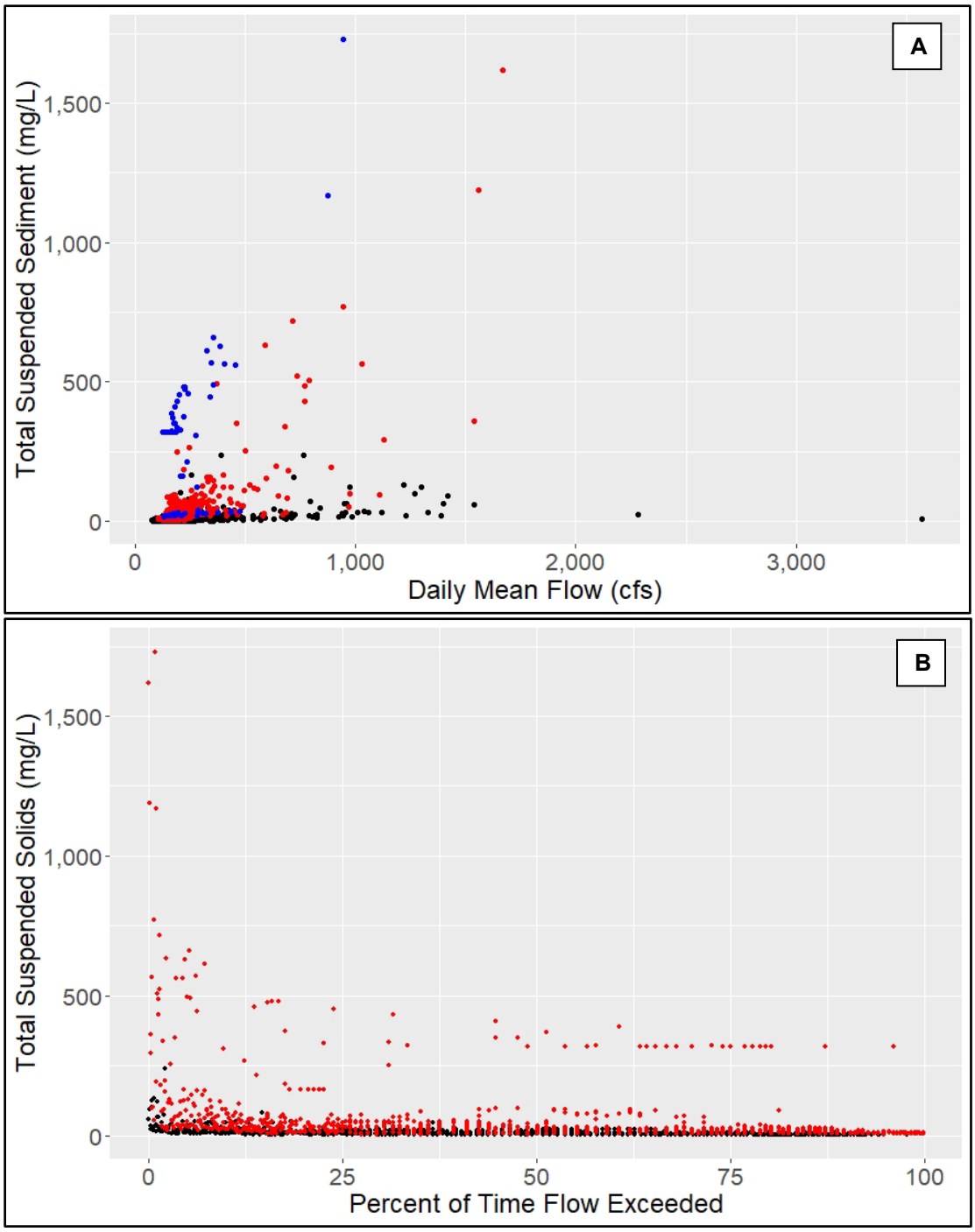

Figure 4. Total suspended solids concentrations versus (A) streamflow and (B) flow duration for dammed (black) and breach (red) periods. Blue points in A are samples taken between September 1 and November 30, 2015.

Reference: **Lake Mallalieu Desktop Analysis**

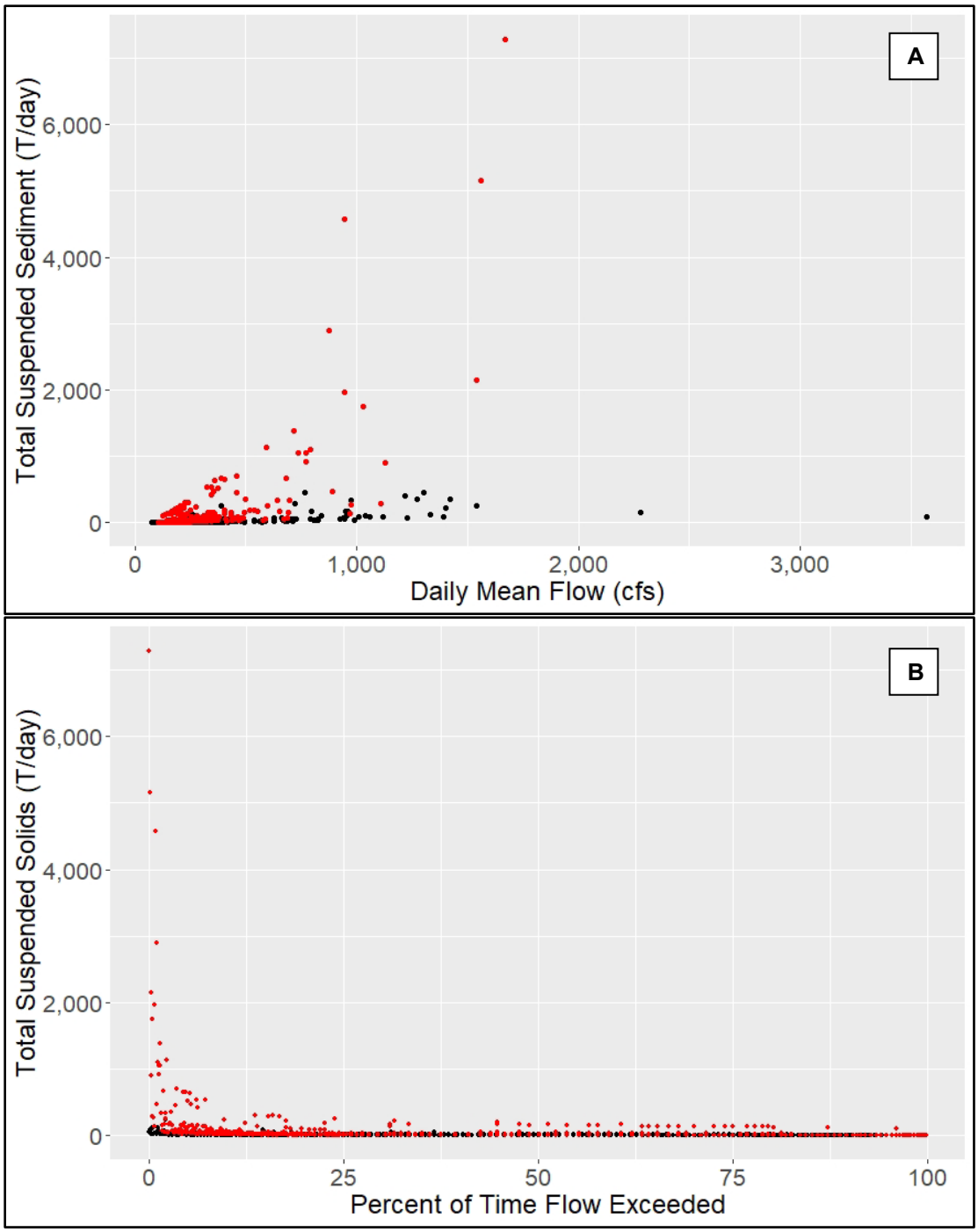

Figure 5. Total suspended solids load versus (A) streamflow and (B) flow duration for dammed (black) and breach (red) periods.

Total Phosphorus

Table 3 summarizes the median TP load in pounds per month and pounds per day during the dammed period and the breach period. Median monthly and daily TP loads were highest during the breach period.

Table 3. Median monthly and median daily TP loads for the dammed and breach periods.

Time Period	**Median Monthly TP Load (lbs/month)**	**Median Daily TP Load (lbs/day)**
Dammed Period	1,507.2	46.9
Breach Period	3,332.3	82.4

Figures 6 and 7 compare TP concentration and load across streamflow and flow duration. Many of the highest observed TP concentrations occurred during the breach period (Figure 6). Like TSS, high TP concentrations were observed during low flows during the breach period, compared to the dammed period where high concentrations were not typically observed during low flows. Many of the high concentrations observed during low flows occurred after the initial dam breach in September through November 2015 (see blue scatter points in Figure 6A). The highest TP loads during the period of interest were observed during the breach period and occurred across various flow conditions (Figure 7).

Reference: **Lake Mallalieu Desktop Analysis**

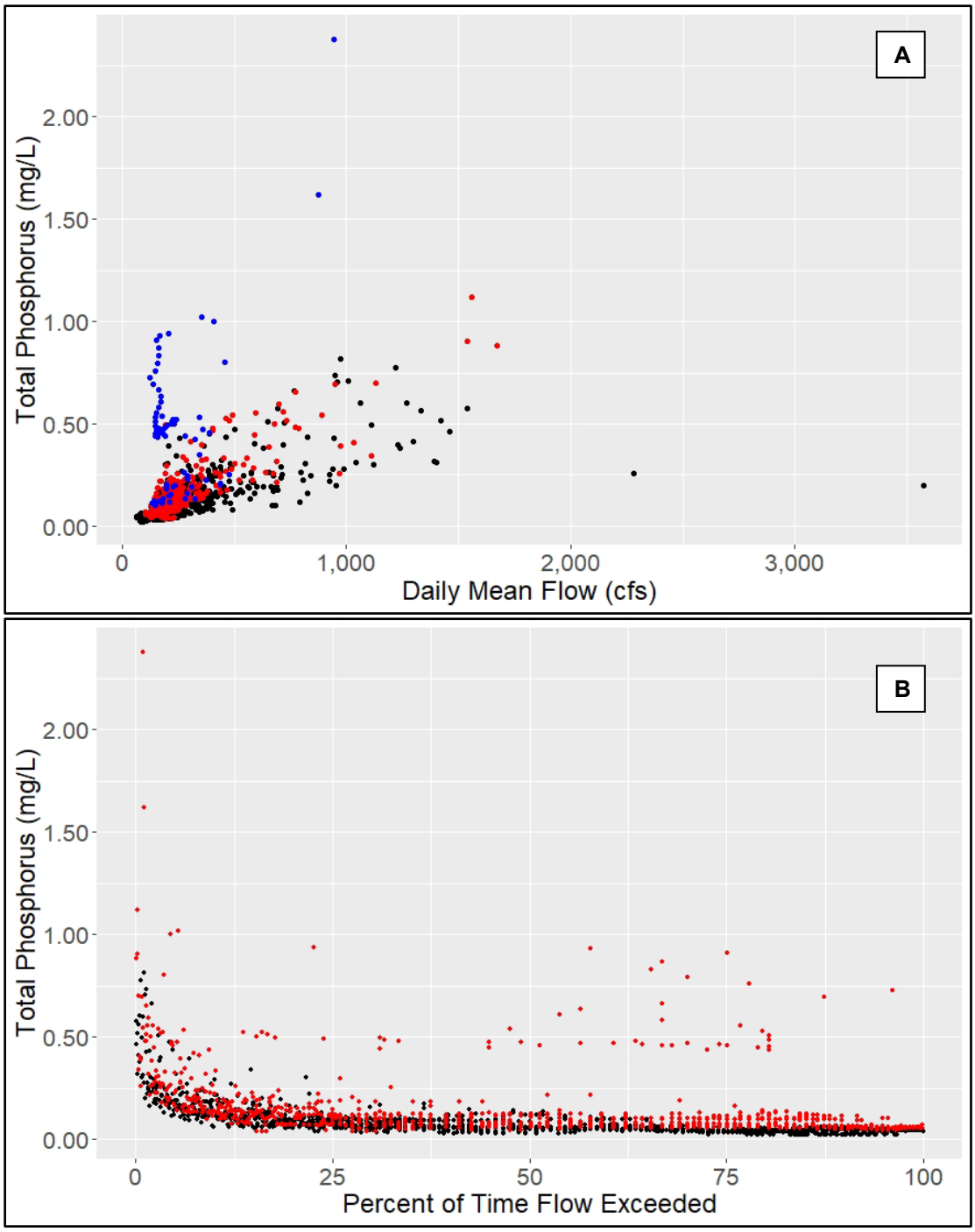

Figure 6. Total phosphorus concentrations versus (A) streamflow and (B) flow duration for dammed (black) and breach (red) periods. Blue points in A are samples taken between September 1 and November 30, 2015.

Reference: **Lake Mallalieu Desktop Analysis**

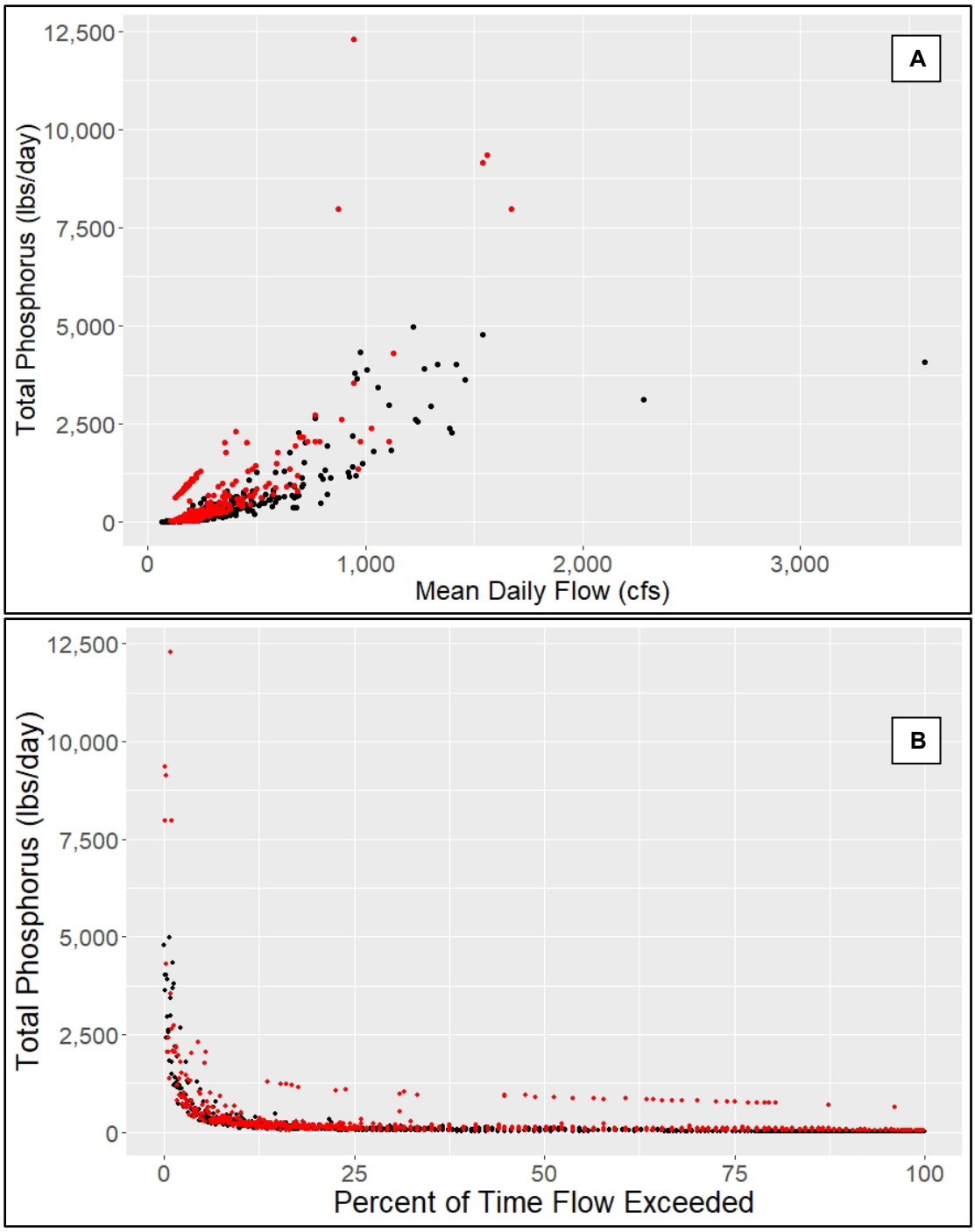

Figure 7. Total phosphorus load versus (A) streamflow and (B) flow duration for dammed (black) and breach (red) periods.

Reference: **Lake Mallalieu Desktop Analysis**

AERIAL IMAGERY ANALYSIS

Publicly available aerial imagery was reviewed for coverage and resolution prior to analysis. A determination was made to use Google Earth Pro imagery due to the high resolution of imagery, image capture date, and length of record. Table 4 below summarizes the available imagery from Google Earth Pro and the corresponding mean daily streamflow on that date.

For this comparison, 10/11/2014 was selected as an appropriate pre-breach image and 8/12/2021 as the post-breach image. Both dates had a mean daily streamflow in the 75th percentile and had high resolution imagery. The long record of aerial imagery demonstrates typical lake level conditions in Lake Mallalieu, likely in part due to the dam-controlled nature of the reservoir. However, the streamflow percentile was calculated so that any variability caused by differences in streamflow magnitude from the Willow River could be accounted for during comparison.

Table 4. Summary of aerial imagery available from Google Earth. Streamflow percentile was calculated across the entire USGS streamflow record that had corresponding sediment and phosphorus data. Rows in grey denote imagery during the dam period whereas rows in white denote imagery during the breach period. Images selected for analysis are denoted by an asterisk (*).

Date	Image Quality	Daily Streamflow (cfs)	Daily Streamflow Percentile
9/26/2012	High	84.7	5%
9/15/2013	High	107	25%
10/11/2014*	High	166	75%
8/11/2015	High	134	25%
3/11/2016	High	595	99%
5/21/2016	High	166	75%
4/5/2017	High	174	75%
4/28/2018	High	342	95%
5/14/2018	High	177	75%
10/25/2019	High	667	99%
6/2/2020	Medium	201	90%
10/9/2020	High	145	50%
8/12/2021*	High	181	75%

Assessing changes in the extent and magnitude of sediment delivery from aerial imagery in this region is challenging. Confounding factors such as tree cover, turbid water, shadowing, and narrow stream channels and braiding at the mouth of the Willow River made meaningful comparison across the entire length of the Willow River downstream to Lake Mallalieu impractical. In addition, an aerial imagery approach can only capture sedimentation that is presented at the surface and not subsurface accumulation. As such, the imagery comparison was performed at the mouth of the Willow River for a 1,000-foot diameter area of interest (AOI) in a region deemed viable for comparison given the aforementioned constraints. Areas of landforms (i.e., terrestrial landscapes) were hand delineated from the aerial imagery for each year, and the total area of landforms within the AOI during 2014 and 2021 were compared. This analysis estimated that landforms within the AOI comprised 4.2 acres in 2014 and 10.1 acres in 2021, representing an increase in landforms within the AOI of 240%. The results of this process are demonstrated in (Figure *8*).

Reference: **Lake Mallalieu Desktop Analysis**

Figure 8. Comparison of 2014 and 2021 land area at the mouth of the Willow River. Land area was compared within a 1,000-foot diameter circle for demonstration. Note that the displayed aerial imagery in both images is from 2021.

KEY ASSUMPTIONS & LIMITATIONS

The following is a list of key assumptions and limitations for this analysis:

- Streamflow, sediment, and phosphorus measurements at USGS site 05341752 are suitable for comparison under both the breach and dam periods.
- In channel dynamics (i.e., deposition and resuspension) of sediment and nutrients within the Willow River channel is outside the scope of this effort, and therefore has not been assessed.
- Changes in the extent and magnitude of sediment and phosphorus loading can only be quantified for within the stream channel of the Willow River based on USGS site 05341752. The proportion of these loads that are ultimately delivered to Lake Mallalieu is unknown.
- In some cases, the timing of major events at the Little Falls Dam site is approximate. For example, the initial 2015 drawdown began in September 2015 but the breach did not occur until October 2015.

Although not technically breach conditions, September 2015 was included in the breach period due to the initial alteration to flow conditions.

- Delineating terrestrial areas in aquatic environments based on aerial imagery carries implicit error. Factors such as algae/aquatic plant growth, shadows from adjacent vegetation, shadow effects, and highly turbid water present significant challenges for accurately parsing out terrestrial environments from aquatic environments.

SUMMARY OF FINDINGS

Below is a bulleted summary of findings from this analysis.

- Streamflow regimes between the breach and dammed period are similar and suitable for comparing pollutant concentrations and loads.
- Many of the highest observed concentrations of TSS and TP were sampled during the breach period and across various flow conditions.
- High concentrations of TSS and TP at low flows were observed during the breach period but were not common during the dammed period. Many of these high concentrations were sampled during the initial dam breach in September-November 2015.
- The highest TSS and TP monthly and daily loads were observed during the breach period. Median monthly TSS loads were approximately four times higher during the breach period than the dam period, and median monthly TP loads were approximately two times higher during the breach period than the dam period.
- Comparison of aerial imagery under similar flow conditions at the mouth of the Willow River to Lake Mallalieu showed a 240% increase in landforms from 2014 to 2021.

Reference: **Lake Mallalieu Desktop Analysis**

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