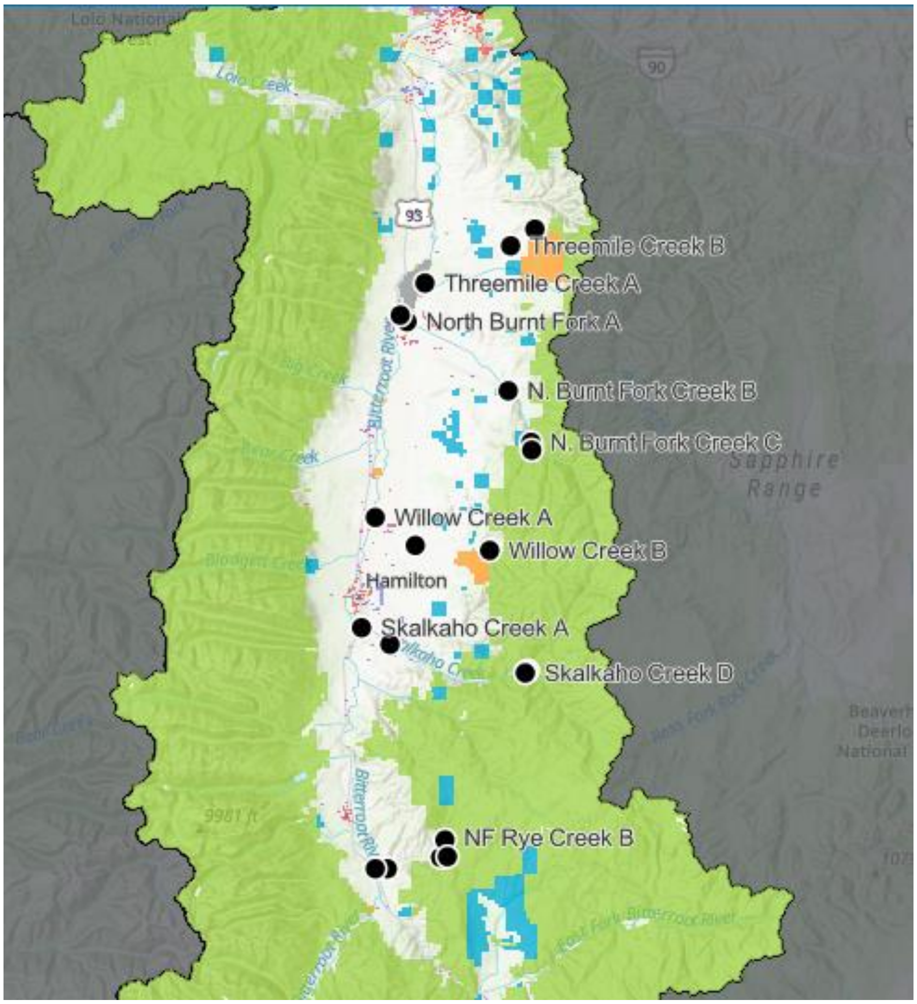
Bitterroot River Protection Association 2018-23 Water Quality Data Analysis
MSU Student Project



Authors:

Olivia Lynch, Montana State University Undergraduate Student

Bridget Warrenfeltz, MSU Extension Water Quality, Research Associate

Dr. Adam Sigler, Extension Water Quality Specialist & Assistant Professor in Land Resources and Environmental Sciences Department, MSU

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Forward and Acknowledgements

This work was conducted as part of a one semester Montana State University undergraduate research course, led by Dr. Adam Sigler with support from Bridget Warrenfeltz. Olivia Lynch was the undergraduate student assigned to the Bitterroot program for the course.

This work was conducted in consultation with the Bitterroot River Protection Association representatives Michael Howell and Chris Clancy.

Fall 2024 was the initial pilot of this course, with the intention to produce useful data summaries for volunteer monitoring programs while simultaneously providing hands on student learning opportunities.

This work was supported by funding from Montana Department of Environmental Quality (MDEQ).

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Introduction

Watershed Description

The Bitterroot Watershed is located in southwestern Montana. The watershed covers 2,900 square miles and is characterized by a wide valley floor surrounded by the rugged Bitterroot and Sapphire Mountains. The Bitterroot River meanders through the Bitterroot Valley, providing various benefits such as recreation, irrigation, groundwater recharge that feeds domestic water supplies, etc. The headwaters are formed by the East and West Fork Bitterroot River that converge near has Conner, Montana to form the mainstem Bitterroot. The mainstem flows north through the Bitterroot Valley until its confluence with the Clark Fork River near Missoula. The valley has a arid climate with 12 inches of rainfall per year and stream flow is dominated by snowmelt runoff from the surrounding mountains. Water management for irrigated agriculture plays a significant role in the hydrology of the watershed, through diversions and conveyance systems that interact in complex ways with the Bitterroot River and tributaries (Appendix B; Bitterroot Watershed Restoration Plan, 2019).

Project Description

The Bitterroot River Protection Association's (BRPA) Sapphire Front Project started in 2017 and focuses on the water quality in tributaries that flow west from the Sapphire Front mountains into the Bitterroot River. Sample sites for this project are located on five tributaries: Rye Creek, Skalkaho Creek, Willow Creek, North Burnt Fork Creek, and Threemile Creek. Rye Creek is listed as two separate tributaries in the BRPA sampling and analysis plan (SAP), so that document references six tributaries, but we have treated them as a single tributary because they confluence before meeting the Bitterroot mainstem. The BRPA SAP states that one monitoring station has been located on each creek near the mouth, and a second station has been positioned near the Forest Service boundary (Figure 2; Howell, 2024). Each tributary has data for more than two sites because site have been relocated over time due to changing access conditions and in order to better meet monitoring objectives. A key factor is the influence of irrigation canals and ditches that cross the tributaries with complex water mixing conditions that complicate interpretation of data downstream. A summary of some known intersections between irrigation conveyances and the five tributaries is provided in Appendix B and must be considered for interpreting the data presented in this report.

The 2024 BRPA Sample and Analysis Plan (SAP) includes goals and objectives that describe the purpose of the monitoring project (Figure 1). These goals provided the focus for our analyses and data interpretations.

Goal	Objective	Data Analysis
Goal # 1 is to determine current conditions of nutrients and in situ field measurements on six tributaries along the Sapphire Front.	To measure nutrients and discharge on six tributaries along the Sapphire Front to evaluate nutrient concentrations from Forest Service land and agricultural land.	Compare nutrient concentrations to the recommended ranges of nitrogen and phosphorus that protect beneficial uses.
	Document the general condition of each location by taking photographs upstream, across and downstream during each sampling	Photos taken over time can be compared to identify any significant alteration to the environment in the area of the sampling
Goal # 2 is to quantify nutrient loads in tributaries at the mountain-valley transition and at the confluence with the Bitterroot to distinguish forest versus agriculture/residential land use.	Characterize tributary nutrient loads by collecting water samples for nutrientanalysis and measuring discharge at two locations on each tributary.	Combined nutrient concentration data with flow data to determine the total nutrient loaddelivered to the river by each stream. The data can be used in subsequent years to evaluate how nutrient loads differ from yearto year.

Figure 1. BRPA Goals and Objectives. *This figure is Table 4 from the BRPA SAP (Howell, 2024) and outlines the organization's goals, objectives, and data analysis.*

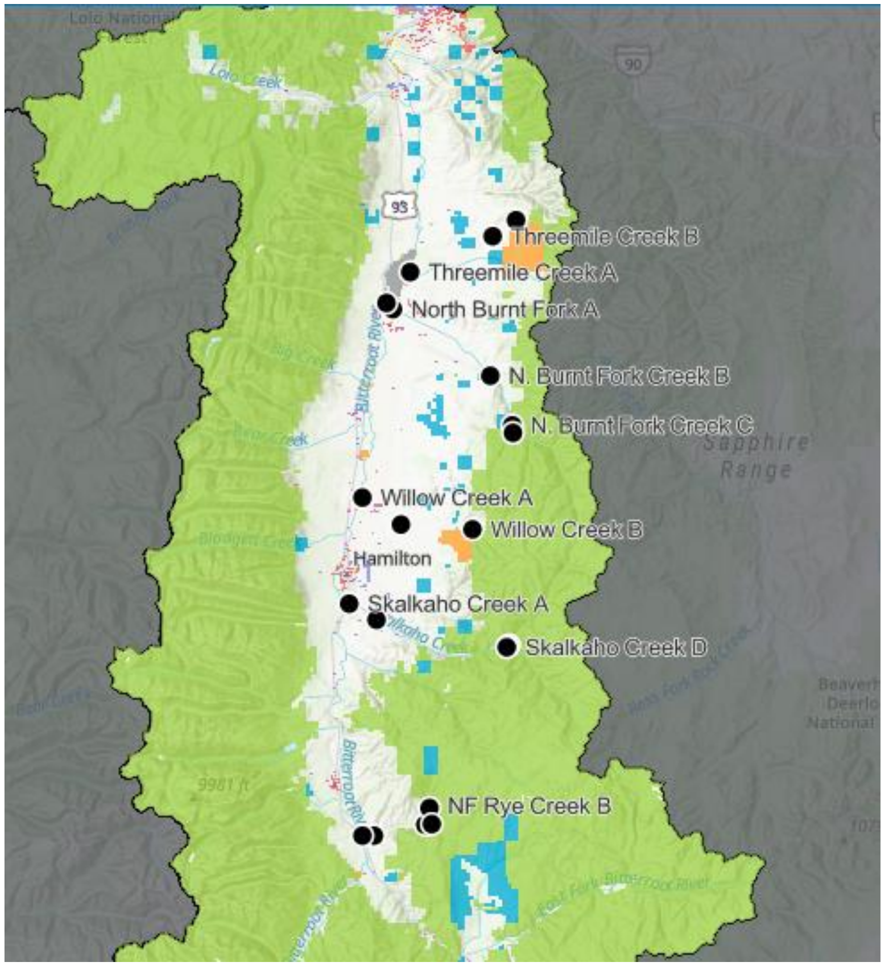

Figure 2. Sample Site Map. *This map shows locations of Bitterroot Protection Association sample sites. Some sites are not shown as they're closely grouped but can be viewed as interactive map via this link.* https://sscmsu.maps.arcgis.com/apps/mapviewer/index.html?webmap=271fc8c282884ac7ad207dacc250bd20

Methods

Data Sources

Monitoring for this project was conducted by the BRPA, following the methods outlined in their annual SAPs (Howell, 2024). The BRPA program leaders conduct quality assurance and data compilation each year and work with MDEQ to upload data to MDEQ's MT-eWQX, which links to a national database for the long-term storage of volunteer data and associated metadata. The data for this report was downloaded from the National Water Quality Exchange (WQX) database through the national water quality portal (Water Quality Portal, 2021).

Data Curation and Analysis

Data was curated and assessed for errors that may have occurred in the collection or upload process. A list of corrections necessary to be made in the WQX database were identified in partnership with BRPA program representatives and are inventoried in Appendix C. Types of corrections included site naming and coordinate issues, all of which were manually corrected in the data downloaded from WQX before making the plots in this report. All plots in this report are correct based on the best information at the time of publication.

Primary data plotting for visualization was conducted in Excel. A series of Excel worksheets were used to track raw data, inventory sample sites and analytes, and clean and plot the data. For plots presented in this report, quality control results for blanks and duplicates were removed. Nutrient concentrations in WQX were reported in both units of milligrams and micrograms per liter and were all converted to mg/L prior to analysis. Some additional analysis to calculate nutrient loads was conducted in R Statistical software. All Excel files and R related files supporting this report are available through a website hosted by MSUEWQ (MSUEWQ, 2024).

Loads were calculated for all days on which nutrient concentration and discharge measurements were available at the same site. Sites were identified for one upstream and one downstream location on each tributary where the most consistent years of data were available (Figure 3), and those loads were plotted. Nutrient concentrations for total nitrogen (TN) and total phosphorus (TP) are interpreted relative to the MDEQ Circular 12A document (MDEQ, 2013). The Circular 12A thresholds are not currently in effect, but the science behind them is reliable, so they are used here for reference. When the thresholds were in place, they were only applicable for growing season months, which extend from July to September. Concentrations for nitrate-N are interpreted relative to the 0.1 mg/L threshold identified by MDEQ for a general value above which nuisance algae may be expected (MDEQ, 2013).

Flow data from sites maintained by USGS and DNRC was assessed for potential supplemental inclusion. However, all USGS gage sites are located on the mainstem Bitterroot rather than the study site tributaries. DNRC has one site located on North Fork Burnt Fork Creek, but the gauge was established in 2024 making the data irrelevant for the data period assessed here (2018 to 2023).

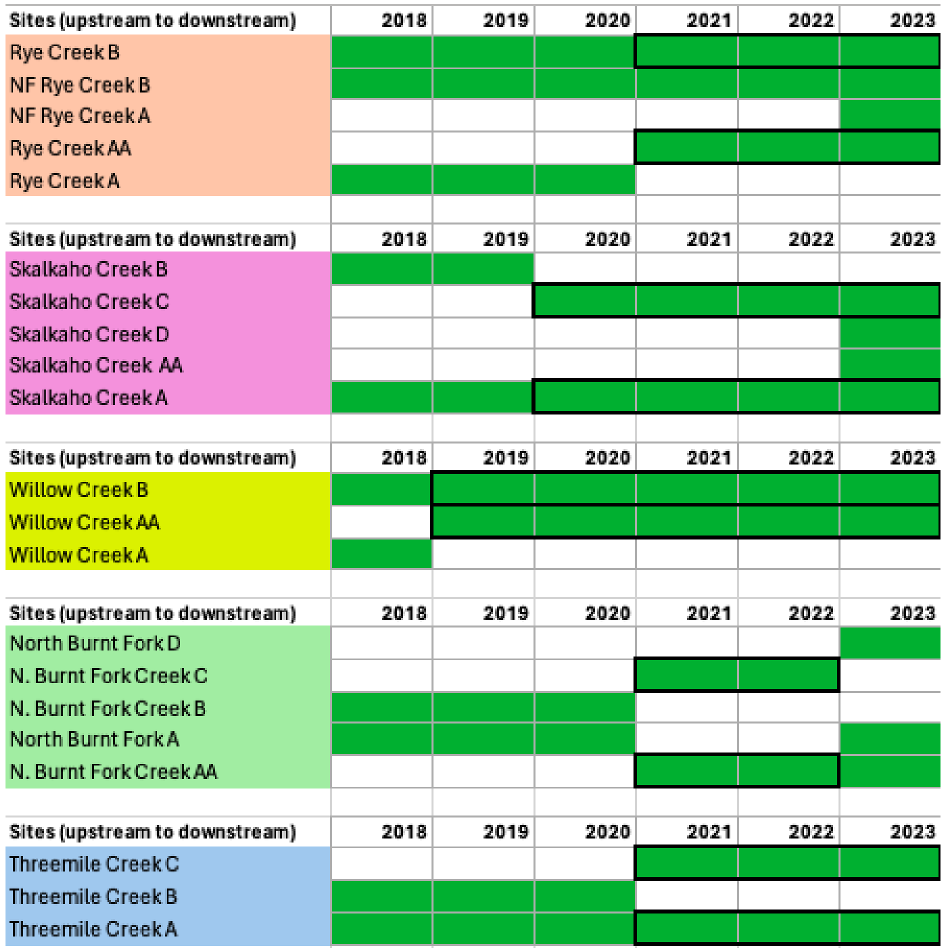

Figure 3. Site list indicating years sampled. The green boxes represent the years each site was sampled, and the black outlines represent the upstream and downstream sites with the most consistent overlapping flow and nutrient data which were used to calculate and plot nutrient loads.

Results

Total Nitrogen (TN)

Total Nitrogen (TN) concentrations range from 0.0382 mg/L to 1.09 mg/L across all sample sites and dates (Figure 4). With the exception of two outlier points, concentrations are consistently below the 0.3 mg/L threshold (DEQ Circular 12A) at headwaters sites and generally increase downstream.

For Rye Creek, TN concentrations range from 0.087 mg/L to 1.09 mg/L and mean concentrations range from 0.1322 mg/L on Rye Creek B to 0.473 mg/L on NF Rye Creek A. The only sites with a portion of TN concentrations exceeding the threshold are NF Rye Creek A (50% of samples) and Rye Creek B (25% of samples). All concentrations for the remaining sites fall below the threshold. Two of the three sites that are relatively close to the Forest Service boundary (Rye Creek B and NF Rye Creek B) have low concentrations, but the third site (NF Rye Creek A) has concentrations exceeding the threshold. The two sites downstream on the mainstem of Rye Creek (Rye Creek AA and Rye Creek A) have concentrations progressively increasing from the upstream mainstem site. BRPA contributors note that by late summer, Rye Creek A is largely East Fork Bitterroot River water that enters Rye Creek upstream of the sampling site (See Appendix B for details).

For Skalkaho Creek, TN concentrations range from 0.04 mg/L to 0.19 mg/L and mean concentrations range from 0.067 mg/L on Skalkaho Creek D to 0.19 mg/L on Skalkaho Creek A. All concentrations are below the threshold and there are no outlier concentrations. Mean concentrations increase slightly moving downstream, starting with Skalkaho Creek B's mean of 0.0825 mg/L and ending with Skalkaho Creek A's mean of 0.19 mg/L. BRPA contributors note that Skalkaho Creek is intersected by irrigation conveyance water from the Bitterroot River, such that relatively low nutrient water from the river is added to the creek upstream from the Skalkaho A site (See Appendix B for details).

For Willow Creek, TN concentrations range from 0.0438mg/L to 0.67 mg/L and mean concentrations range from 0.081 mg/L on Willow Creek B to 0.3 mg/L on Willow Creek AA. Mean concentrations increase notably from upstream Willow Creek B within the forest (0.081 mg/L), to downstream Willow Creek AA below more diverse land use (0.3 mg/L). Median TN concentration for Willow Creek AA and Willow Creek A are equal to the 0.3 mg/L threshold, but Willow Creek AA has outliers reaching as high as 0.67 mg/L. BRPA contributors note that irrigation water from the Bitterroot River intersects Willow Creek upstream from the Willow Creek A site (See Appendix B for details).

For North Burnt Fork Creek, TN concentrations range from 0.038 mg/L 0.439 mg/L and mean concentrations range from 0.054 mg/L to 0.257 mg/L. Mean concentrations increase notably from upstream N. Burnt Fork Creek B to downstream North Burnt Fork A. N. Burnt Fork Creek B lies within the forest boundary and has a mean concentration of 0.054 mg/L, while North Burnt Fork A is downstream from more diverse land use and has a mean concentration of 0.257 mg/L. None of the mean concentrations extend beyond the threshold, but there are outliers from North Burnt Fork A and N. Burnt Fork Creek AA above the threshold at 0.4 mg/L and 0.439 mg/L respectively. BRPA contributors note that irrigation water from Lake Como enters North Burnt Fork Creek upstream from sites A and AA (See Appendix B for details).

For Threemile Creek, TN concentrations range from 0.05 mg/L to 0.792 mg/L and mean concentrations range from 0.07 mg/L to 0.5 mg/L. Threemile Creek C has an outlier above the threshold, but all other concentrations are below the threshold. There is a large increase in TN concentrations from Threemile Creek B to Threemile Creek A. Threemile Creek B lies within the forest boundary and has a mean concentration of 0.07 mg/L, while Threemile Creek A is downstream from more diverse land use and has a mean concentration of 0.5 mg/L. BRPA contributors note that Threemile Creek receives a lot of water from Lake Como via the Big Ditch (See Appendix B for details).

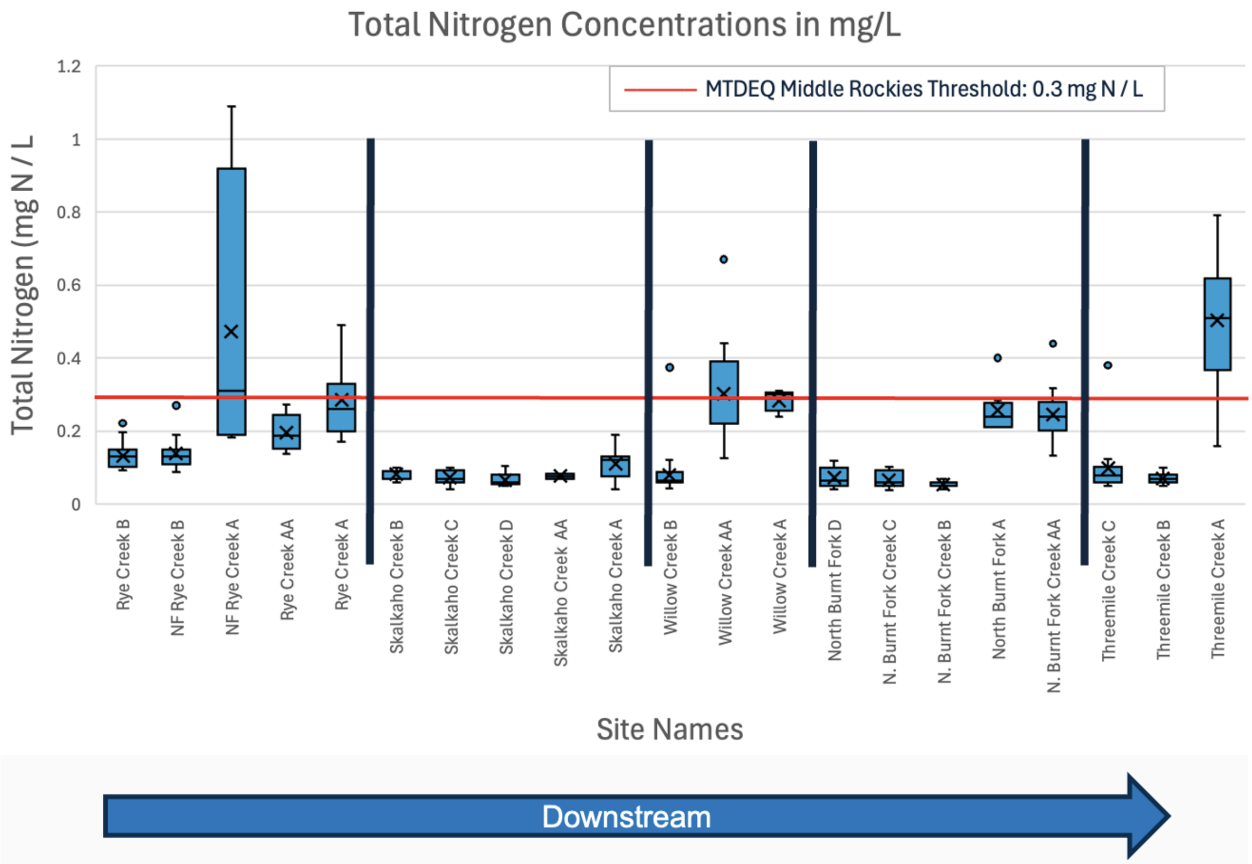

Figure 4: Total Nitrogen Concentrations. *The y axis is the concentration of total nitrogen. Sites are organized from upstream to downstream within tributary, moving from left to right. Tributaries are organized based on location of confluence with the mainstem Bitterroot, from upstream to downstream, moving from left to right. Boxes indicate the interquartile range of data (25th to 75th percentile), the horizontal line within the box is the median, and the X symbol indicates the mean concentration. Whiskers extend to the farthest point within 1.5 times the interquartile range from the interquartile box and points beyond the whiskers are considered outliers. The red line is the MDEQ Middle Rockies TN threshold of 0.3 mg/L (DEQ Circular 12A).*

Nitrate-N

Nitrate and Nitrite concentrations range from 0.002 mg/L to 0.72 mg/L across all sample sites and dates (Figure 5). With the exception of one outlier, concentrations are consistently below the 0.1 mg/L threshold (DEQ Circular 12A) at headwaters sites and generally increase downstream.

For Rye Creek*, nitrate-N concentrations range from 0.002 mg/L to 0.72 mg/L and mean concentrations range from 0.007 mg/L to 0.26 mg/L. NF Rye Creek B has an outlier above the threshold, but no other concentrations exceed the threshold. There is a large increase in mean nitrate-N concentrations from NF Rye Creek B (0.02 mg/L) to NF Rye Creek A (0.26 mg/L), which both lie within the forest boundary. Other than NF Rye Creek A, upstream sites near the forest boundary generally have lower TN concentrations than downstream sites.

For Skalkaho Creek*, nitrate-N concentrations range from 0.02 mg/L to 0.11 mg/L and mean concentrations range from 0.01 mg/L to 0.05 mg/L. All values except for one at Skalkaho A are below the threshold. There are no outliers present. Nitrate-N mean concentrations slightly decrease from upstream downstream from Skalkaho Creek B (0.05 mg/L) to Skalkaho Creek AA (0.01 mg/L). The one exception is Skalkaho Creek A, which has a median of 0.03 mg/L and is the furthest downstream of the Skalkaho sample sites.

For Willow Creek*, nitrate-N concentrations range from 0.09 mg/L to 0.16 mg/L and mean concentrations range from 0.02 mg/L to 0.08 mg/L. Mean concentrations increase from upstream to downstream. No means exceed the threshold, but the maximum concentration for Willow Creek AA is 0.16 mg/L and 25% of values for Willow Creek A exceed the 0.1 mg/L threshold.

For North Burnt Fork Creek*, nitrate-N concentrations range from 0.003 mg/L to 0.16 mg/L and mean concentrations range from 0.007 mg/L to 0.05 mg/L. Concentrations generally decrease from upstream to downstream until the most downstream site where concentrations increase. The most upstream site (North Burnt Fork D) has a mean of 0.02 mg/L, followed by progressive decrease moving downstream until North Burnt Fork A where the mean is 0.01 mg/L. The furthest downstream site (N. Burnt Fork Creek AA) has the highest mean on the tributary at 0.05 mg/L.

For Threemile Creek*, nitrate-N concentrations range from 0.004 mg/L to 0.48 mg/L and mean concentrations range from 0.02 mg/L on Threemile Creek C to 0.25 mg/L on Threemile Creek A, with a notable increase at the lower site. More than 75% of samples at the downstream site (Threemile Creek A) exceed the threshold of 0.1 mg/L. Conversely, the upstream sites (Threemile Creek C and Threemile Creek B) are far below the threshold with a highest concentration at 0.05 mg/L.

** Irrigation water mixes with all five tributary streams, which complicates interpretation of data for downstream sites and relationships between data at upstream and downstream sites. See Appendix B for details.*

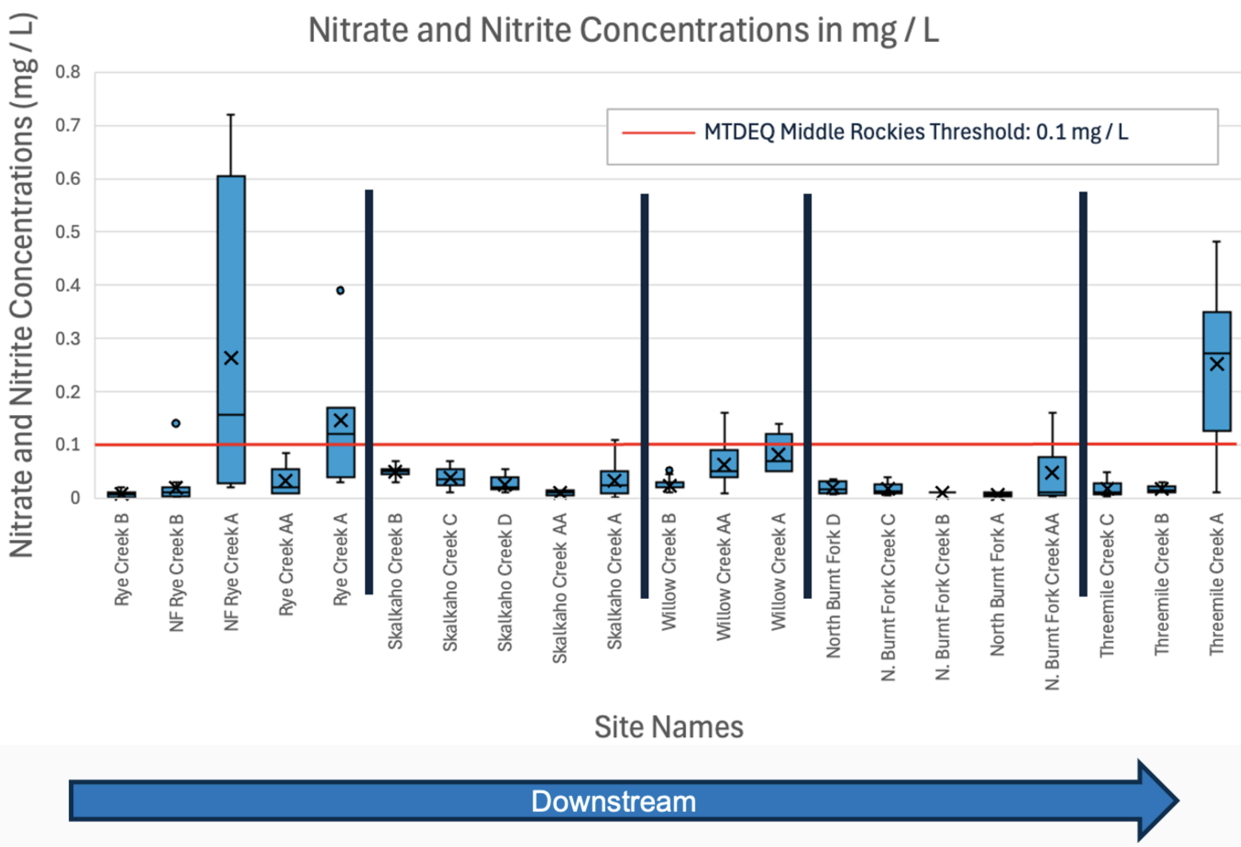

Figure 5: Nitrate/Nitrite Concentrations. *The y axis is the concentration of nitrate and nitrite Sites are organized from upstream to downstream within tributary, moving from left to right. Tributaries are organized based on location of confluence with the mainstem Bitterroot, from upstream to downstream, moving from left to right. Boxes indicate the interquartile range of data (25th to 75th percentile), the horizontal line within the box is the median, and the X symbol indicates the mean concentration. Whiskers extend to the farthest point within 1.5 times the interquartile range from the interquartile box and points beyond the whiskers are considered outliers. The red line is the MDEQ Middle Rockies* total nitrogen *threshold of 0.1 mg*/L (DEQ Circular 12A).

Total Phosphorus (TP)

TP concentrations range from 0.001 mg/L to 0.484 mg/L across all sample sites and dates (Figure 6). In contrast to TN where upstream sites have concentrations consistently below thresholds, upstream concentrations of TP for both Rye and Threemile are above the 0.03 mg/L threshold. Rye Creek has the most consistently high concentrations, Skalkaho has the most consistently low concentrations, and the remaining three creeks show a general pattern of increasing concentrations moving downstream. BRPA contributors note that both Threemile Creek and Rye Creeks are locally recognized to have significant sediment loads in the upper watersheds, which is relevant for phosphorus due to strong sediment-phosphorus association. Threemile Creek may be due to some natural factors and Rye Creek has influence from historic road and logging practices.

On Rye Creek*, TP concentrations range from 0.01 mg/L to 0.11 mg/L and mean concentrations range from 0.02 mg/L to 0.05 mg/L. All sample sites have at least some values above the threshold. The highest concentration is on NF Rye Creek A, with the maximum reaching 0.11 mg/L and more than 50% of observations above the threshold of 0.03 mg/L. Upstream, Rye Creek B's mean TP concentration is above the threshold at 0.034 mg/L.

On Skalkaho Creek*, TP concentrations range from 0.001 mg/L to 0.04 mg/L and mean concentrations range from 0.003 mg/L to 0.01 mg/L. The concentrations seem to increase as the sites move from upstream to downstream, with a large leap from Skalkaho Creek C's mean of 0.003 mg/L to Skalkaho Creek D's mean of 0.01 mg/L. Most site concentrations are below the threshold, apart from Skalkaho Creek D's maximum value that exceeds the threshold that lands at 0.04 mg/L.

On Willow Creek*, TP concentrations range from 0.003 mg/L to 0.1 mg/L and mean concentrations range from 0.01 mg/L to 0.06 mg/L. There's a large increase in TP mean concentration from Willow Creek B to Willow Creek AA. Willow Creek B lies within the forest boundary and has a mean concentration of 0.01 mg/L, while Willow Creek AA lies on the diversely used valley floor and has a mean concentration of 0.06 mg/L. An extremely high TP concentration outlier of 0.484 mg/L was recorded on Willow Creek AA. The concentration was caused by a culvert flood on the tributary and was omitted due to its strong outlier effect on the figure.

On North Burnt Fork Creek*, TP concentrations range from 0.009 mg/L to 0.07 mg/L and mean concentrations range from 0.01 mg/L to 0.05 mg/L. All observations for the three most upstream sites are below the threshold. Downstream, both North Burnt Fork A and North Burnt Fork Creek AA's mean concentrations are above the threshold at 0.05 mg/L and 0.04 mg/L, respectively.

On Threemile Creek*, TP concentrations range from 0.03 mg/L to 0.15 mg/L and mean concentrations range from 0.04 mg/L to 0.1 mg/L. All three sample sites have means above the threshold of 0.03 mg/L, with TP means increasing from upstream to downstream. Threemile Creek A has the highest median concentration across all sites on all tributaries at 0.1 mg/L and has concentrations ranging up to 0.145 mg/L.

** Irrigation water mixes with all five tributary streams, which complicates interpretation of data for downstream sites and relationships between data at upstream and downstream sites. See Appendix B for details.*

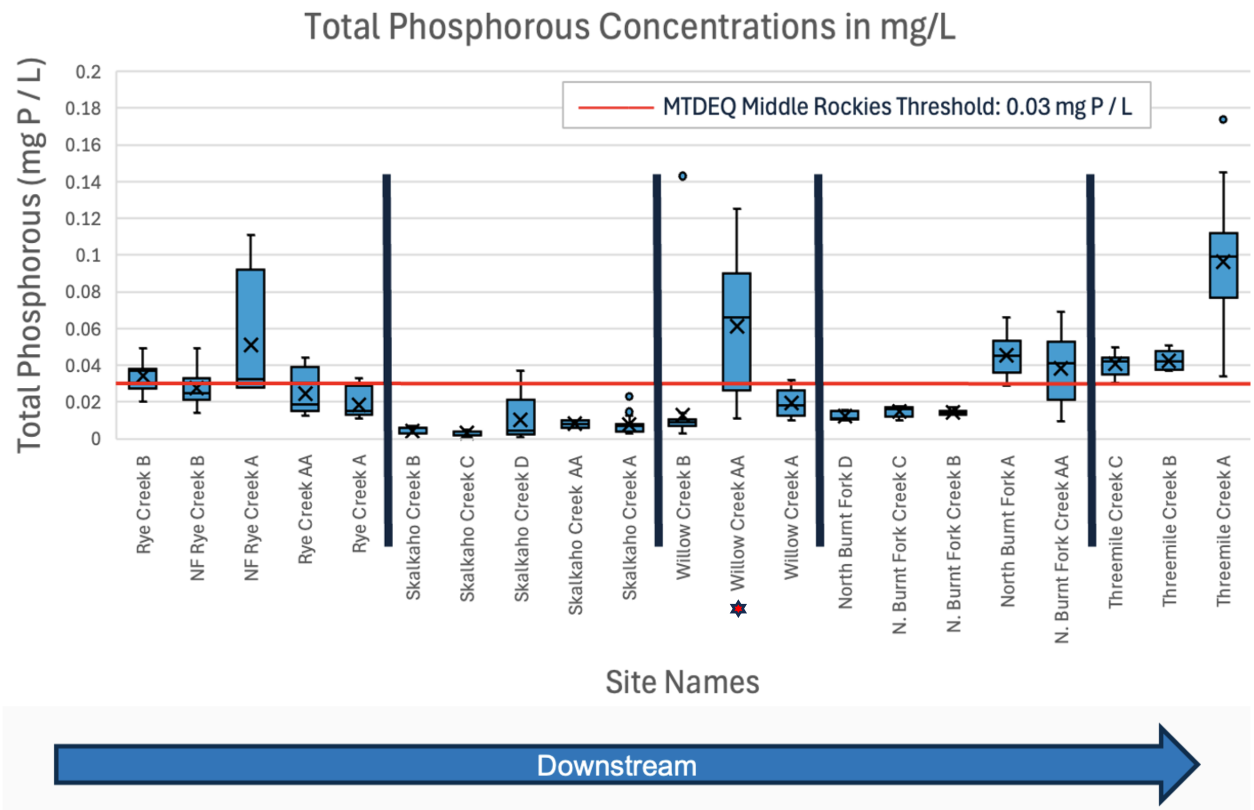

Figure 6: Total Phosphorous Concentrations. *The y axis is the concentration of total phosphorous. Sites are organized from upstream to downstream within tributary, moving from left to right. Tributaries are organized based on location of confluence with the mainstem Bitterroot, from upstream to downstream, moving from left to right. Boxes indicate the interquartile range of data (25th to 75th percentile), the horizontal line within the box is the median, and the X symbol indicates the mean concentration. Whiskers extend to the farthest point within 1.5 times the interquartile range from the interquartile box and points beyond the whiskers are considered outliers. The red line is the MDEQ Middle Rockies total phosphorous threshold of 0.03 mg/L (DEQ Circular 12A). *A strong outlier of 0.484 mg/L was measured on Willow Creek AA on 8/18/22. The outlier heavily skewed the graph and was omitted.*

Nutrient Loads

Across all three nutrient parameters, Threemile A (downstream site) has higher loads than Threemile C (upstream site; Figure 7). This pattern of consistently higher loads at downstream sites was not observed across all tributaries (Appendix A, Figures A1-A5).

Nitrate-N load ranged from 0.06 kg/day to 0.36 kg/day at the upstream site and 0.07 kg/day to 4.57 kg/day at the downstream site (Table 1). The difference between downstream and upstream loads, the load contributions attributable to the stream reach between sites, ranged from 2.34 kg/day to 4.5 kg/day (Table 1). The average load at the upstream site was 0.22 kg/day and the average difference between sites was 3.41 kg/day (Table 1).

Total nitrogen load ranged from 0.21 kg/day to 2.65 kg/day at the upstream site and 1.13 kg/day to 11.32 kg/day at the downstream site (Table 2). The difference between downstream and upstream loads, the load contributions attributable to the stream reach between sites, ranged from 0.86 kg/day to 10.7 kg/day (Table 2). The average load at the upstream site was 1.17 kg/day and the average difference between sites was 5.14 kg/day (Table 2).

Total phosphorus load ranged from 0.11 kg/day to 0.92 kg/day at the upstream site and 0.24 kg/day to 1.91 kg/day at the downstream site (Table 3). The difference between downstream and upstream loads, the load contributions attributable to the stream reach between sites, ranged from 0.05 kg/day to 1.47 kg/day (Table 3). The average load at the upstream site was 0.41 kg/day and the average difference between sites was 0.67 kg/day.

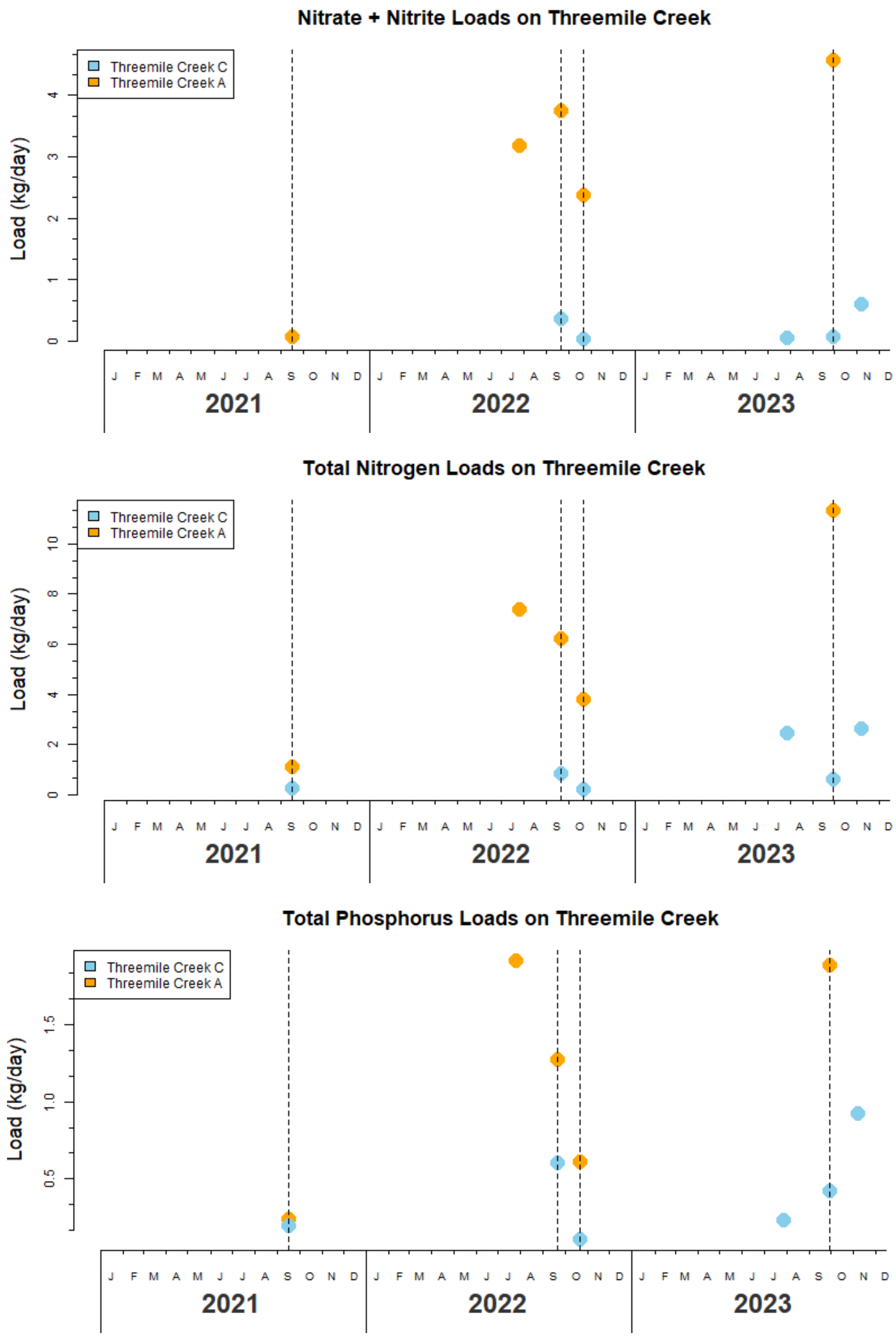

Figure 7. Upstream and downstream nutrient loads on Threemile Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. Threemile Creek C (blue dots) is the upstream site, and Threemile Creek A (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites. (Note: Nitrate concentration was not sampled at Threemile Creek C on Sept 2021, so load could not be calculated and is not shown on the plot.)*

Date	Threemile C Load	Threemile A Load	Load Difference
9/16/21	--**	0.07	--
7/25/22	--*	3.18	--
9/21/22	0.36	3.75	3.39
10/21/22	0.03	2.37	2.34
7/28/23	0.06	--*	--
9/29/23	0.07	4.57	4.5
11/7/23	0.6	--*	--
Average	**0.22**	**2.79**	**3.41**

Table 1. Upstream vs. downstream nitrate-N loads. *Nitrate-N load in kg/day for dates with concentration and flow observations on the same day for the upstream site (Threemile A), the downstream site (Threemile C), and the change in load between the two sites (Difference). *Note that flow was not measured at Threemile C on 25 July 2022 or at Threemile A on 28 July 2023 and 7 November 2023. **Note that nitrate-N concentration was n*ot measured on *16 September 2021, so load could not be calculated.*

Date	Threemile C Load	Threemile A Load	Load Difference
9/16/21	0.27	1.13	0.86
7/25/22	--*	7.37	--
9/21/22	0.83	6.22	5.39
10/21/22	0.21	3.83	3.62
7/28/23	2.44	--*	--
9/29/23	0.62	11.32	10.7
11/7/23	2.65	--*	--
Average	**1.17**	**5.97**	**5.14**

Table 2. Upstream vs. downstream total nitrogen loads. *Total nitrogen load in kg/day for dates with concentration and flow observations on the same day for the upstream site (Threemile A), the downstream site (Threemile C), and the change in load between the two sites (Difference). *Note that flow was not measured at Threemile C on 25 July 2022 or at Threemile A on 28 July 2023 and 7 November 2023, so load could not be calculated.*

Date	Threemile C Load	Threemile A Load	Load Difference
9/16/21	0.19	0.24	0.05
7/25/22	--*	1.91	--
9/21/22	0.61	1.27	0.66
10/21/22	0.11	0.61	0.5
7/28/23	0.23	--*	--
9/29/23	0.42	1.89	1.47
11/7/23	0.92	--*	--
Average	**0.41**	**1.18**	**0.67**

Table 3. Upstream vs. downstream total phosphorus loads. *Total phosphorus load in kg/day for dates with concentration and flow observations on the same day for the upstream site (Threemile A), the downstream site (Threemile C), and the change in load between the two sites (Difference). *Note that flow was not measured at Threemile C on 25 July 2022 or at Threemile A on 28 July 2023 and 7 November 2023, so load could not be calculated.*

Discussion

In general, tributaries show relatively low concentrations of nutrients near the Forest Service boundary and increasing concentration at sites further downstream with an increasing diversity and intensity of human land use. However, patterns are different for phosphorus and nitrogen. Exceptions to the expected pattern of increasing nutrient concentrations at sites further downstream are likely primarily caused by mixing of tributary flow with low nutrient irrigation ditch water.

Concentrations of TP are elevated above threshold concentrations near the Forest Service boundary on Rye Creek and Threemile creek. Phosphorus is typically associated with sediment, so an assessment of sediment erosion patterns upstream of these sites could provide insights about causes. While Threemile Creek has TP concentrations starting above the threshold at the forest boundary, the concentrations also increase notably downstream to produce the highest median concentration across all sites on all tributaries. BRPA contributors note that Threemile Creek has had quite a bit of study due to the sediment loads and that a large NRCS bank stabilization project was aimed at controlling sediment input and erosion, but that success was limited. Threemile Creek and North Burnt Fork Creek show the clearest increases in TP concentrations moving from the forest boundary downstream, indicating opportunities for phosphorus loading reduction in the lower elevation sections of these tributaries.

For nitrogen, four of the five tributaries show clear increases in concentration from the upstream sites to downstream sites. Threemile Creek shows the most pronounced increase in TN from relatively low values at the forest boundary to values at the downstream site that almost all exceed the threshold and have the highest median concentration across all tributaries and sites. North Burnt Creek also shows a clear increase in TN concentrations between the upstream and downstream sites, with most downstream samples below the threshold. Willow Creek and Rye Creek both show increases from clearly below the threshold at the upstream site to observations closer to and above the threshold at the downstream most sites. Skalkaho Creek is the only tributary with no TN concentrations above the threshold.

A compelling aspect of the study design for the Saphire Front Project is the pairing of upstream sites near the forest boundary with downstream sites near the confluence with the Bitterroot River. In the simplest application of this design, concentration and flow values are measured on the same day at both the upstream and downstream locations on a tributary. The load at the upstream site is attributed to the forest and the difference between the upstream and downstream load is attributed to the land area between the sites. In practice, concentration and flow measurements were sometimes made on adjacent days for the same sites and for the different sites on the same tributary. This precludes the use of date to align values for analysis. While additional work could be done to pair measurement values from adjacent days and to assess the required assumption that concentration and flow were relatively stable across days, that was beyond the scope of analysis for this report. With the limited number of load values available for paired sites on the same day, we were not able to make strong conclusions about differences in load on tributaries. Follow up work to pair data collection across days could extract more information from this dataset. For data collection moving forward, increasing emphasis on collection of concentration and flow data at both sites on each tributary on the same day would make future analysis easier and more robust. Future data analysis would also benefit from a more detailed assessment of irrigation canal/ditch water mixing with stream flow where the conveyances intersect.

Conclusion

Data collection under the Saphire Front Project provides useful insights about where likely nutrient impairment exists on the five tributaries included. Nutrient loss at the forest boundaries is generally low apart from Rye Creek and Threemile Creek, where sediment erosion rate assessments could provide more insights. Phosphorus observations on Threemile, North Burnt Fork, and Willow Creeks all show opportunities for phosphorus reduction in the lower portions of the watersheds. All tributaries show relatively low nitrogen at forest boundary and increases moving downstream. Four of the five tributaries (Rye, Willow, North Burnt, and Threemile) show pronounced nitrogen concentration increases with downstream concentrations near or exceeding the threshold. Only Skalkaho Creek does not show any nitrogen values above the threshold at any site.

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Appendices

Appendix A – Load calculations

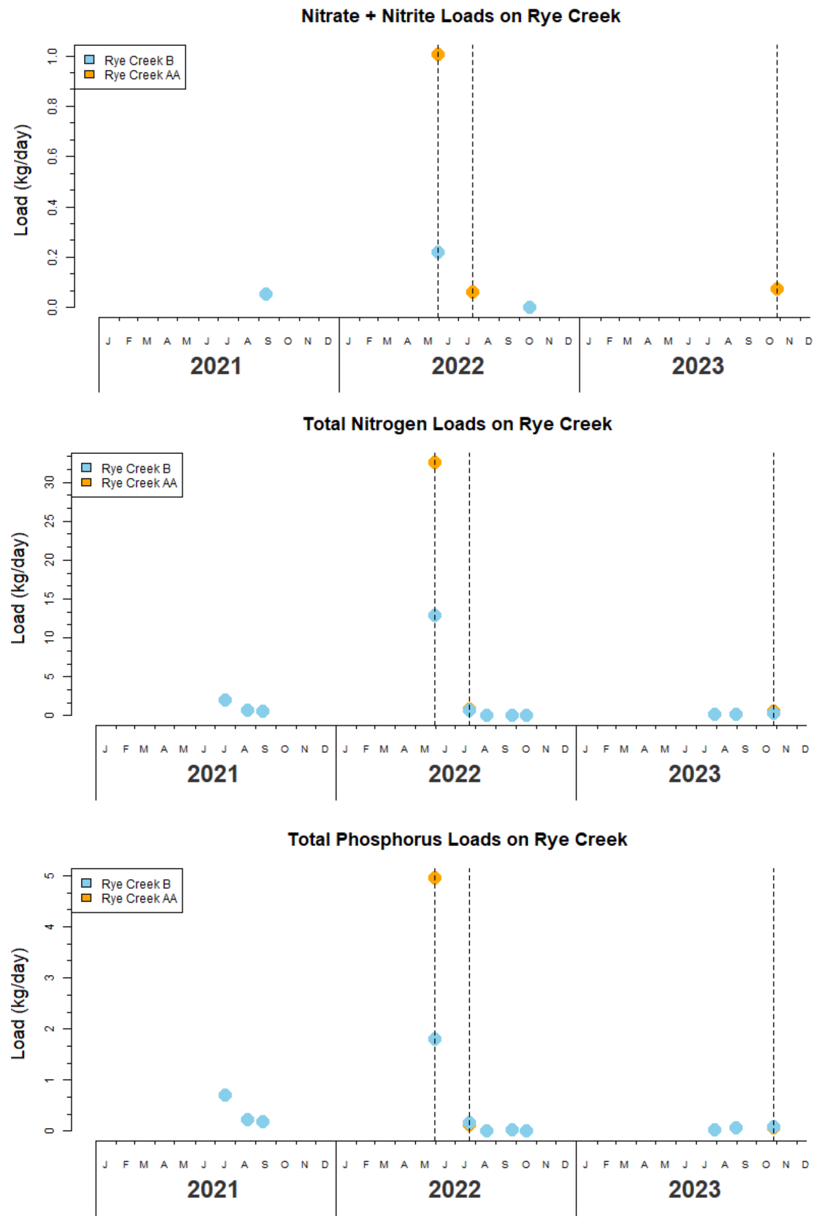
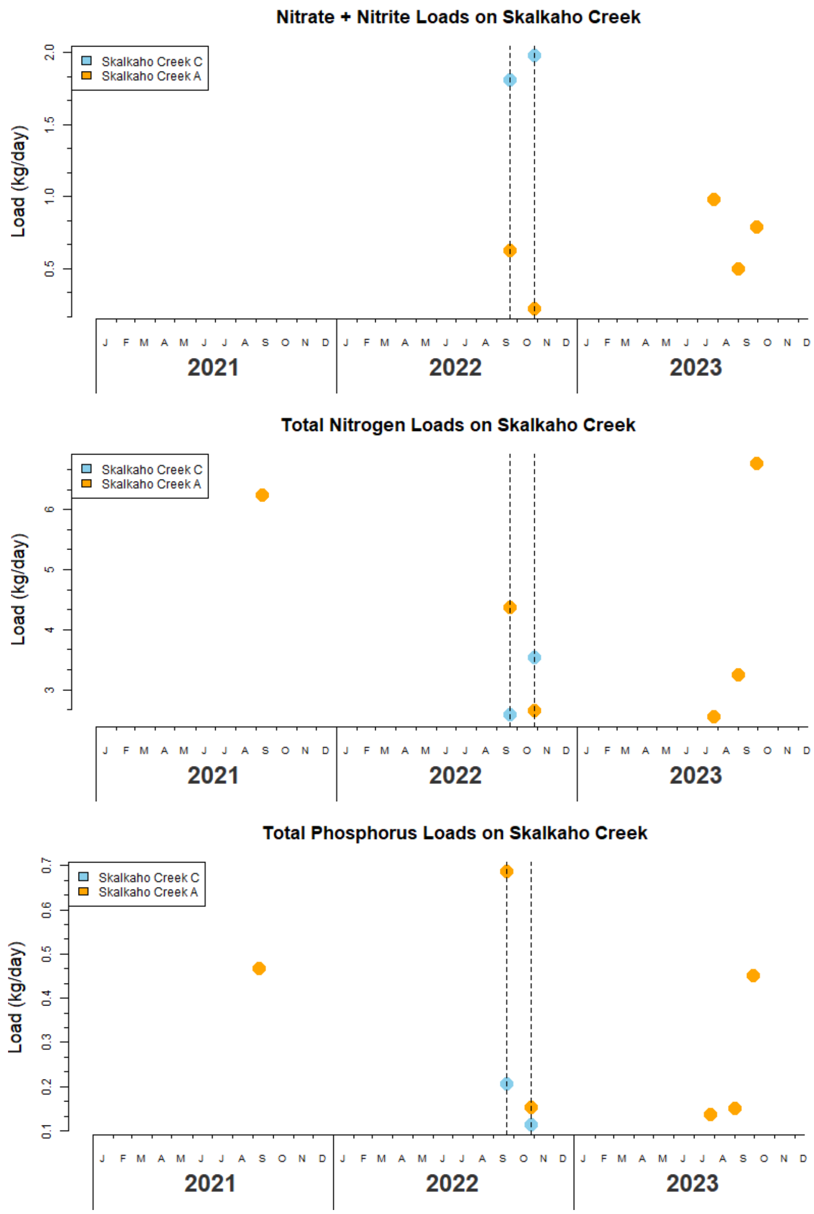
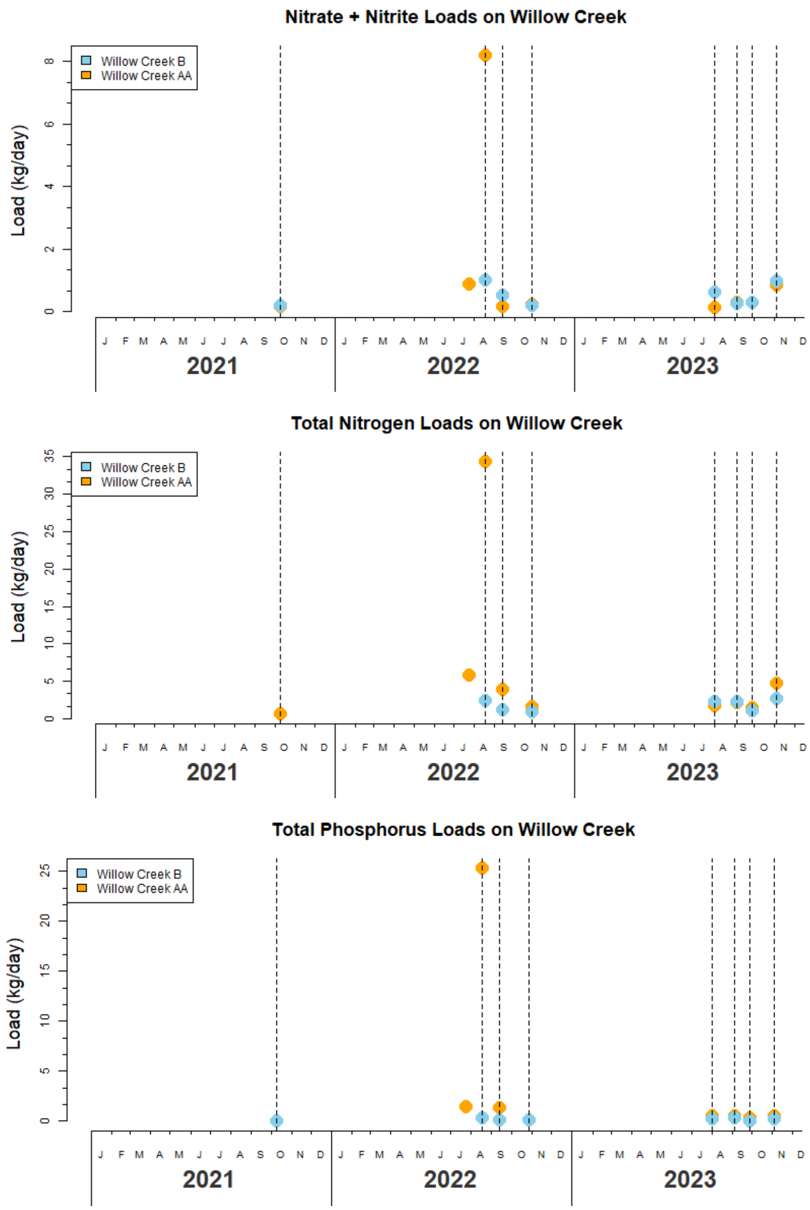


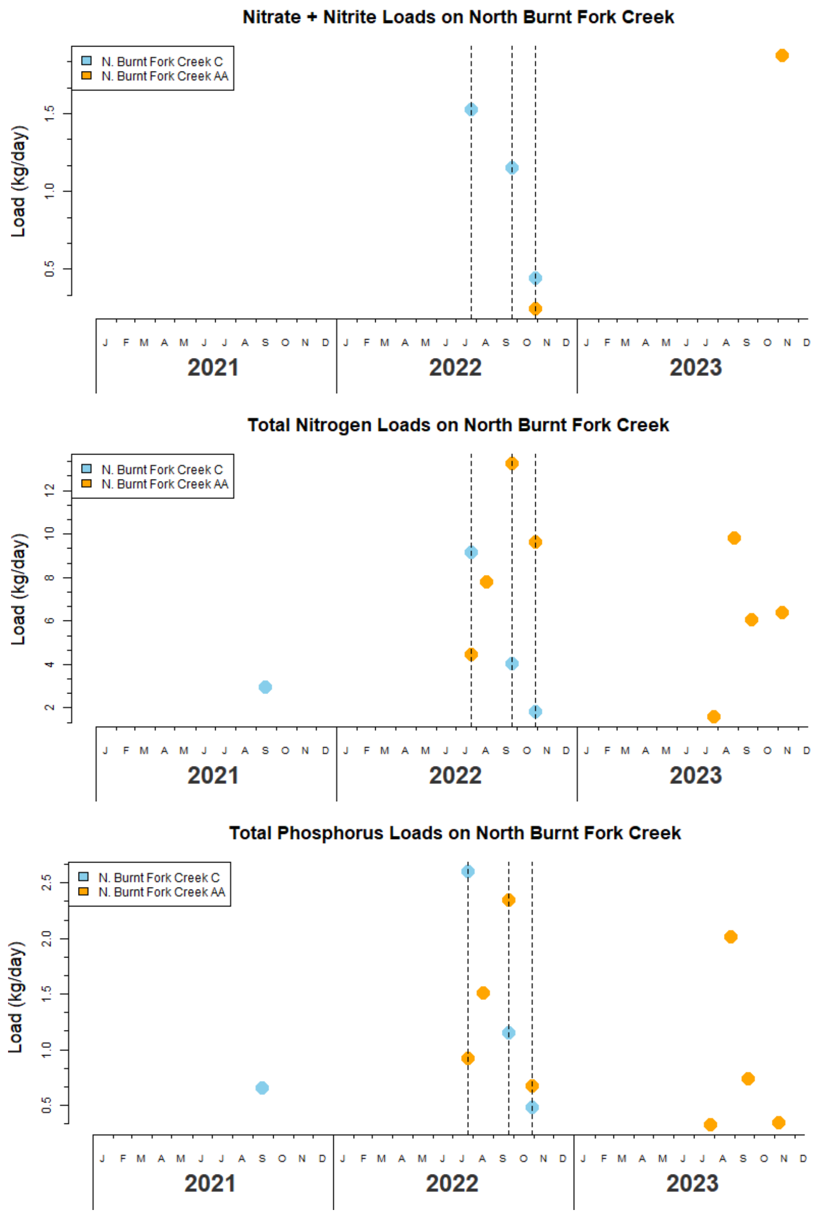
Figure 1A. Upstream and downstream nutrient loads on Rye Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. Rye Creek B (blue dots) is the upstream site, and Rye Creek AA (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites. (Note: Nitrate concentrations on Rye Creek B for July 2022 and October 2023 sampling dates were below detection, so load could not be calculated and is not depicted on the plot. Orange points depicting TN and TP load for Rye Creek AA on July 2022 and October 2023 are hidden behind the blue points.)*



Figures 2A. Upstream and downstream nutrient loads on Skalkaho Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. Skalkaho Creek C (blue dots) is the upstream site, and Skalkaho Creek A (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites.*



Figures 3A. Upstream and downstream nutrient loads on Willow Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. Willow Creek B (blue dots) is the upstream site, and Willow Creek AA (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites.* (Note: *Orange points depicting nitrate, TN, and TP loads for Willow Creek AA on Oct 2021, Oct 2022, and Aug-Nov 2023 are hidden behind blue points. Total nitrogen concentration for Willow Creek B was below detection on Oct 2021 sampling date, so load could not be calculated and is not shown on the plot.)*



Figures 4A. Upstream and downstream nutrient loads on North Burnt Fork Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. N. Burnt Fork Creek C (blue dots) is the upstream site, and N. Burnt Fork Creek AA (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites. (Note: Nitrate concentrations for N. Burnt Fork Creek AA were below detection on July 2022 and Sept 2022 sampling dates, so load could not be calculated and is not shown on the plot.)*

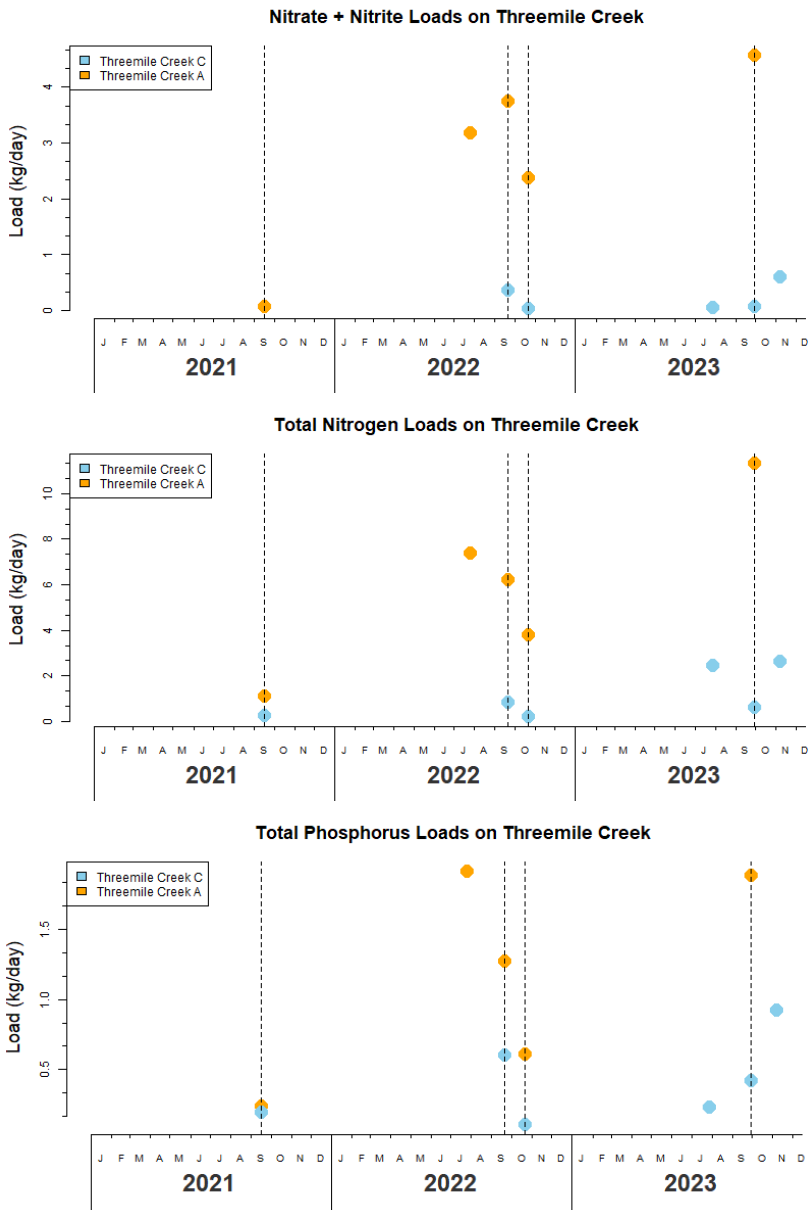


Figure 5A. Upstream and downstream nutrient loads on Threemile Creek. *Load in kg/day is on the y axis, and the time period of data collection on the x axis. Threemile Creek C (blue dots) is the upstream site, and Threemile Creek A (orange dots) is the downstream site. The vertical dashed lines represent days where concentration and flow measurement data were available for the upstream and downstream site to calculate nutrient loads and facilitate calculation of difference in load between sites. (Note: Nitrate concentration was not sampled at Threemile Creek C on Sept 2021, so load could not be calculated and is not shown on the plot.)*

Appendix B – Canal/Ditch interactions with stream

This appendix is a summary prepared by Chris Clancy on 12/14/2024.

A complex network of irrigation ditches exists on the east side of the Bitterroot River The 5 watersheds that are sampled by the Bitterroot Sapphire Front project are all impacted by irrigation diversions. Diversion of water out of the streams is common which affects the quantity of water in the streams. Also, the mixing of water from ditches that carry Bitterroot River and Lake Como water likely has more of an effect on water chemistry. These large ditches, five from the Bitterroot River, one from Lake Como and a smaller ditch from the East Fork Bitterroot River intersect some of the Sapphire Front streams and, at times, will mix the ditch water with the creek water. This affects the water chemistry downstream in the creek. The water from the Bitterroot River and Lake Como generally has a lower specific conductance than the creeks in the Sapphire Front and likely has different nutrient values too.

This table reflects my observations about some of the points of intersection between these large ditches and the streams of the Sapphire Front. Generally, the ditches may siphon water under the stream, carry water over the creek in a flume or mix water with the creek and structures allow this mixed water to flow both downstream in the ditch and stream. In most cases, some mixing occurs but it can be relatively minor in the case of flumes and siphons. However, sometimes the ditch companies need to "waste" ditch water down the creek, in which case there is more ditch water in the creek than usual. As said earlier, it is complicated.

Appendix B - Table 1. The five streams studied in the Sapphire Front and what I recall from the locations where these ditches intersect them. This list is not complete. I have not seen some of the crossings and lateral ditches off the main ditches probably also cross the streams.

Stream	Ditch and Source of Water	Notes About Intersection	Location of Intersection
Rye Creek	Name unknown from East Fork Bitteroot River	The terminus of this ditch empties into Rye Creek and carries water through most of the summer	45.9647 N -114.123 W
Skalkaho Creek	Big Ditch (Lake Como)	Crosses Skalkaho Creek In a siphon that can drain water into creek	46.181 N -114.080 W
	Hedge Ditch (Bitterroot R.)	Crosses Skalkaho Creek In a siphon that can drain water into creek	46.2039 N -114.127 W
	Republicsn Ditch (Bitterroot R.)	Crosses Skalkaho Creek In a siphon that can drain water into creek	46.211 N -114.145 W
Willow Creek	Big Ditch (Lake Como)	Have not seen, appears to be a flume over the creek.	46.295 N -114.033 W
	Hedge Ditch (Bitt. R.)	Appears to mix with creek	46.298 N -114.079 W
	Republican Ditch (Bitt. R)	Appears to mix with creek	46.309 N -114.102 W
	Corvallis Canal (Bitt. R.)	Mixes with Creek	46.309 N -114.111 W
Burnt Fork	Big Ditch (Lake Como)	Complicated, large structure	46.496 N -113.994 W
	Supply Ditch (Bitt. R.)	Appears to mix with creek	46.521 N -114.073 W
Threemile Creek	Big Ditch (Lake Como)	Complicated, large structure	46.593 N -113.945 W
	Supply Ditch (Bitt. R.)	Appears to mix with creek	46.562 N -114.047 W

Appendix C - List of corrections to be made in WQX:

1. Site names for Threemile A and C should be swapped (Only site names are incorrect; Site ID's are correct and should remain the same)
    1. MTVOLWQM_WQX-SF-THREEMILECR-C
        1. Current MonitoringLocationName: Threemile Creek A
        2. Correct MonitoringLocationName: Threemile Creek C
    2. MTVOLWQM_WQX-SF-THREEMILECR-A
        1. Current MonitoringLocationName: Threemile Creek C
        2. Correct MonitoringLocationName: Threemile Creek A
2. Rye Creek site names are incorrect
    1. MTVOLWQM_WQX-SF-NFRYECR-A
        1. Current MonitoringLocationName: North Rye Creek A
        2. Correct MonitoringLocationName: NF Rye Creek A
    2. MTVOLWQM_WQX-SF-RYECR-A
        1. Current MonitoringLocationName: NF Rye Creek A
        2. Correct MonitoringLocationName: Rye Creek A
3. Unit issues for field parameters from Skalkaho Creek C on 8/19/2020,
    1. Barometric pressure, DO, pH, SC, water temp, and TDS all have units of NTUs
    2. The ResultIdentifier codes and correct units are as follows:
        1. STORET-972885993 (BP), Correct unit: mmHg
        2. STORET-972885994 (DO), Correct unit: mg/L
        3. STORET-972885995 (pH), Correct unit: none
        4. STORET-972885996 (SC), Correct unit: uS/cm
        5. STORET-972885998 (wat temp), Correct unit: degrees C
        6. STORET-972885997 (TDS), Correct unit: mg/L
4. Data entered at wrong sites on N. Burnt Fork Creek, Skalkaho Creek, and Willow Creek (these have implications for the following feilds: MonitoringLocationName, MonitoringLocationIdenifier, and ActivityIdentifier)
    1. Data from 2018-2020 at N. Burnt Fork Creek AA should be entered under N. Burnt Fork A
    2. Data from 2020 at Skalkaho B should be entered under Skalkaho C
    3. Data from 2020 at Willow Creek A should be entered under Willow Creek AA
5. Location coordinates for Willow Creek B and Willow Creek AA should be flipped