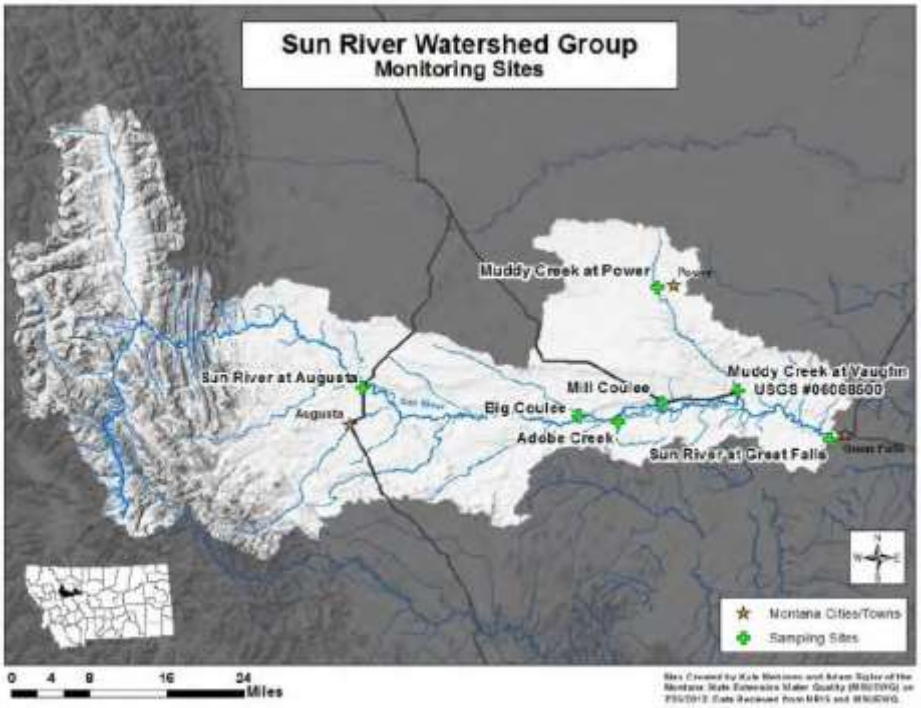
Sun River Watershed Group

Volunteer Monitoring Program

Nutrient Data Summary



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Acknowledgements

The following analysis was conducted by MSU Extension Water Quality (MSUEWQ) with funding support from the Montana Department of Environmental Quality (MDEQ) and with statistical assistance from Jennifer Weeding with Treasure State Analytics. Data was collected by the Sun River Watershed group, coordinated by Alan Rollo with field work conducted by Rai Hahn and students of Fairfield High School. Short bios for Alan and Rai are available on the MSUEWQ programs page.

Analysis summary

Water quality data used in this analysis were collected according to the specifications in the Sun River Quality Assurance Project Plan (Sigler, et al. 2012) and subsequent sampling and analysis plans. All data included in this analysis are available through the MSUEWQ Data Hub (MSUEWQ, 2019). This data was emailed to Sigler by Alan Rollo in May of 2017 and was formatted by Sigler for entry into the MSUEWQ Data Hub (file names in Appendix 1).

Concentration summaries organized by nutrient are presented in the section titled "Nutrient Boxplots and Summaries." Tables with accompanying summary statistics are presented on the following page in the "Nutrient Summary Tables" section. MDEQ nutrients standards for Total Nitrogen (TN) and Total Phosphorus (TP) for the Northwest Glaciated Plains (Appendix 3), where study sites are located, are included reference but a detailed assessment of concentrations exceeding the threshold was not conducted.

Analysis of concentrations and trends over time are organized by site and by nutrient parameter in sections named for each site followed by the word "Summary." Initial assessment of the data revealed relatively consistent seasonal patterns in concentrations for most site/nutrient combinations (Appendix 2). This means that a lot of the variability in nutrient concentration across time is related to conditions associated with season. This means that accounting for season of data collection in analysis could result in more robust statistics. Data was divided into three seasons for analysis based on three dates described below and trends were assessed individually for each season at each site for each nutrient parameter.

High flow – Starting on May 1 based on an inflection point in the median daily discharge at the USGS gage on the Sun River near Great Falls (Appendix 3).

Growing season – Starting on June 16th, which is the first date of the year that the MDEQ nutrient criteria for wadable streams apply for the sites on the Sun and tributaries, which fall within the Northwest Glaciated Plains ecoregion. Growing season ends on September 30th, which is the last day that the MDEQ nutrient standards for wadable streams apply (Appendix 4).

Base flow – is the period from October 1 to April 30 that is not high flow or growing season based on the definitions above.

Trend analysis was conducted using linear regression of nutrient concentration versus date, with accounting for season based on the date ranges above. Slope and p values are included for each site, for each parameter, for each season. The slope is the change in concentration (mg/L or ppm) per year. Lines are drawn on the plots if an increasing or decreasing trend is statistically significant, using a p value threshold of 0.1 (alpha value). This means that if there is a line on the plot, the relationship is significant and there is less than a 10% chance that the trend is not real.

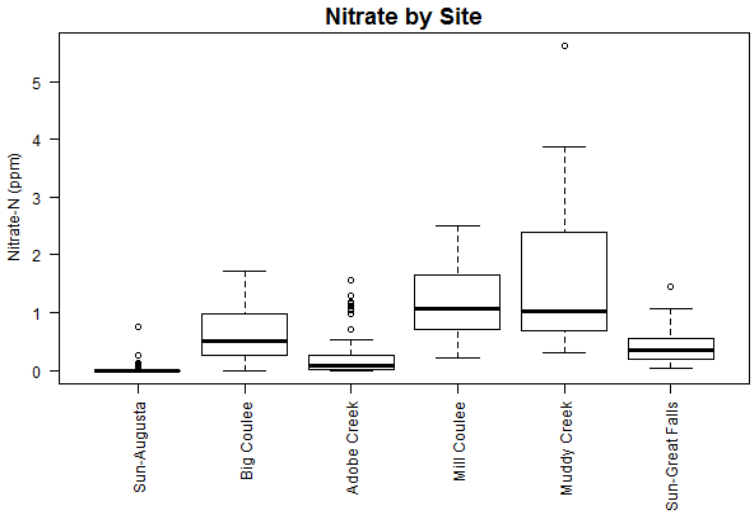
Table 1. Site IDs, names, and coordinates.

#	Site ID 2017 SAP	Site Name 2017 SAP	Site ID 2012 QAPP	Latitude	Longitude
1	SUN-SUNR50	Sun River near Augusta	SR-AG	47.547861	-112.366250
2	SUN-DUCKC01	Big Coulee near Simms	BC-SM	47.516972	-111.887306
3	SUN-ADBEC01	Adobe Creek near Ft Shaw	AC-200	47.510583	-111.800611
4	SUN-MILCU01	Mill Coulee near Sun River	ML-200	47.540611	-111.705806
5	SUN-MUDYC57	Muddy Creek at Vaughn	MC-VHN	47.561056	-111.538306
6	SUN-SUNR56	Sun River at Great Falls	SR-GF	47.492028	-111.334361

Results

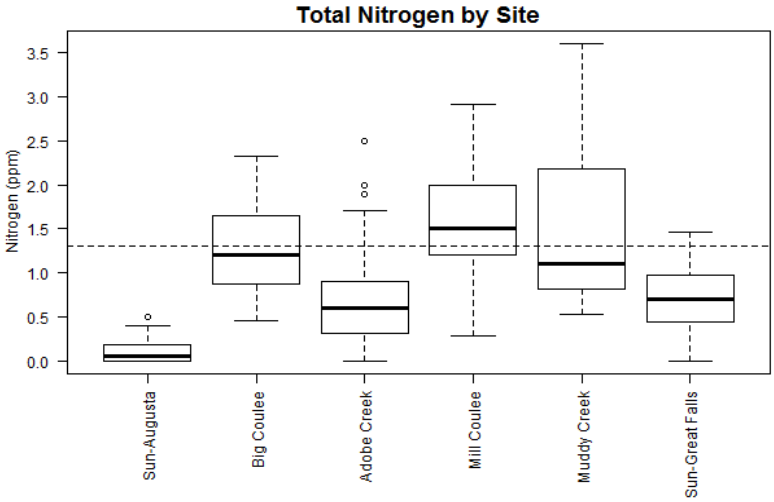
Nitrate Summary

- At the most upstream site (Augusta), most (58/76) of the nitrate concentrations are below detection (0.01 ppm).
- The highest observed nitrate concentrations are on Muddy Creek.
- Both the Muddy Creek and Mill Coulee sites consistently have the highest nitrate concentrations (median around 1 ppm).
- There is not an aquatic life standard for nitrate in Montana. The drinking water standard for nitrate is 10 ppm.



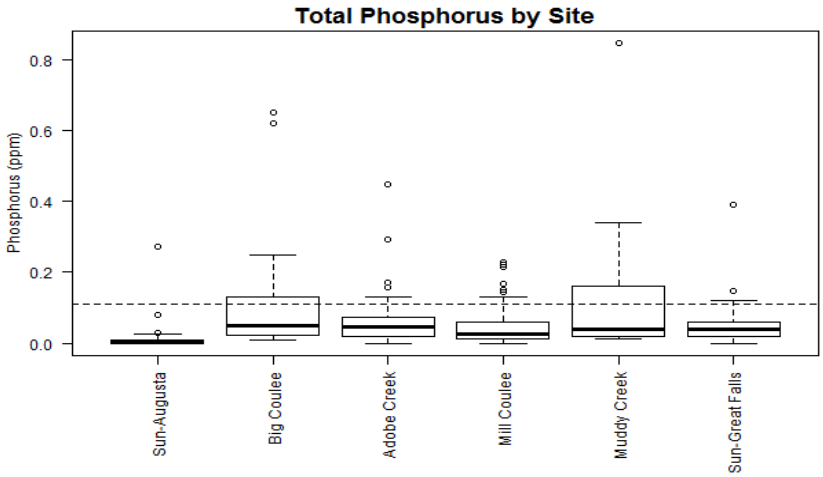
Total Nitrogen Summary

- At the most upstream site (Augusta), almost half (26/58) of the total nitrogen concentrations are below detection (0.05 ppm).
- Big Coulee, Mill Coulee, and Muddy Creek regularly have total nitrogen concentrations above the total nitrogen standard of 1.3 ppm for the Northwest Glaciated Plains wadeable streams, but it is important to note that the standard only applies between June 16th and September 30th.



Total Phosphorus Summary

- For all of the sites, most of the total phosphorus concentrations are below the 0.11 ppm standard for the Northwest Glaciated Plains wadeable streams, which apply between June 16th and September 30th.



Nutrient Summary Tables

Nitrate							
Site	**#**	**# ND**	**Min**	**Avg**	**Med**	**Max**	**Trends**
Sun-Augusta	76	58	ND	0.02	ND	0.76	
Big Coulee	58	1	ND	0.64	0.50	1.72	
Adobe Creek	65	13	ND	0.26	0.08	1.56	
Mill Coulee	60	0	0.21	1.18	1.07	2.51	
Muddy Creek	82	0	0.31	1.55	1.02	5.61	
Sun-Great Falls	79	0	0.03	0.43	0.36	1.45	Grow↓

Total Nitrogen							
Site	#	# ND	Min	Avg	Med	Max	Trends
Sun-Augusta	58	26	ND	0.10	0.06	0.50	
Big Coulee	51	0	0.46	1.25	1.20	2.33	Grow↓ High↓
Adobe Creek	63	8	ND	0.71	0.60	2.50	
Mill Coulee	54	0	0.29	1.56	1.50	2.91	
Muddy Creek	23	0	0.53	1.50	1.10	3.60	
Sun-Great Falls	63	5	ND	0.69	0.70	1.46	Grow↓

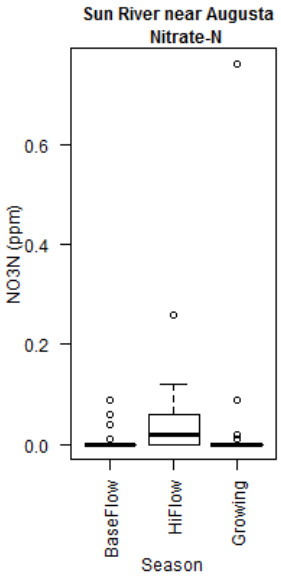
Total Phosphorus							
Site	**#**	**# ND**	**Min**	**Avg**	**Med**	**Max**	**Trends**
Sun-Augusta	74	22	ND	0.01	ND	0.27	
Big Coulee	60	0	0.01	0.10	0.05	0.65	Grow↓
Adobe Creek	65	1	ND	0.06	0.05	0.45	Grow↓ High↓
Mill Coulee	59	3	ND	0.05	0.03	0.23	
Muddy Creek	29	0	0.01	0.11	0.04	0.85	
Sun-Great Falls	78	1	ND	0.05	0.04	0.39	Grow↓ Base↓

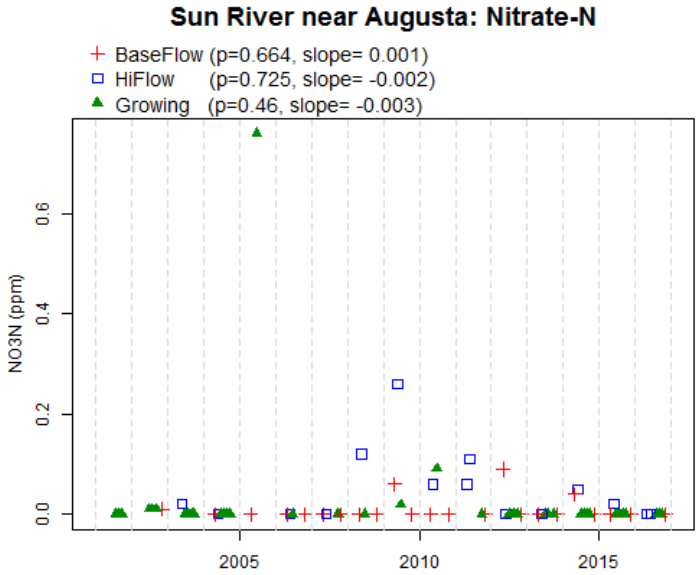
Sun Near Augusta

Nitrate

Nitrate concentrations are relatively consistent across seasons, with the highest concentrations detected during high flow.

The high number of samples below the detection limit (58/76) make it impossible to statistically assess the trend in nitrate concentration over time at this site.

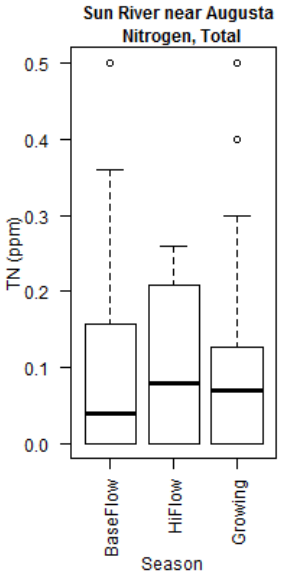


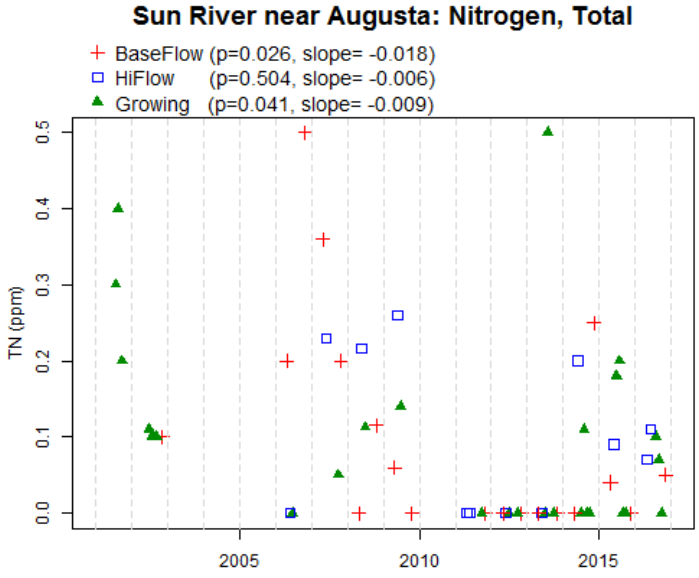


Total Nitrogen

Total nitrogen is relatively consistent across seasons.

The high number of samples below the detection limit (26/58) make it challenging to statistically assess the trend in total nitrogen concentration over time at this site. High numbers of non-detects are the reason that no significance is indicated during the growing season even though the p value is less than 0.1.

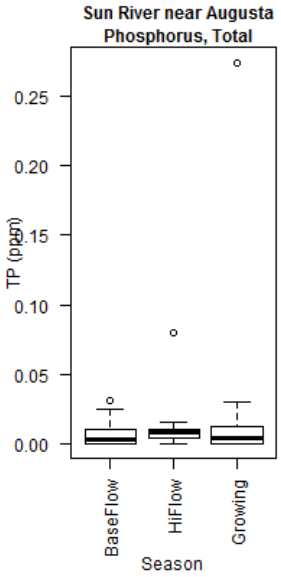


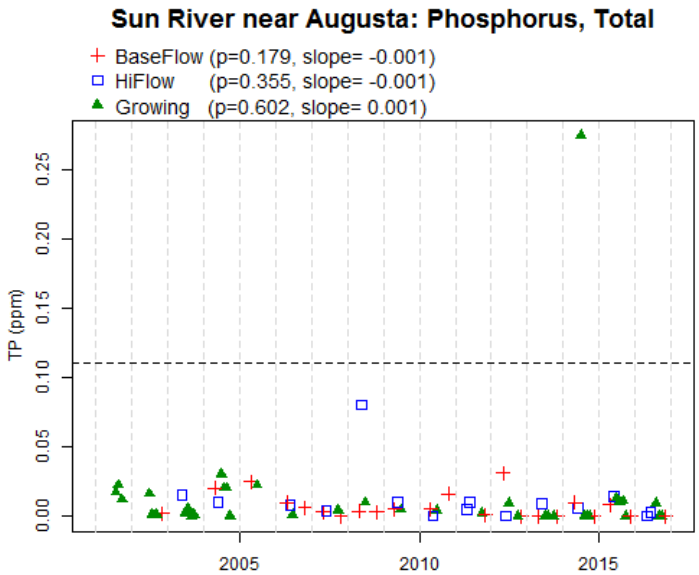


Total Phosphorus

Total phosphorus is relatively consistent across seasons.

The high number of samples below the detection limit (22/74) make it challenging to statistically assess the trend in total phosphorus concentration over time at this site.



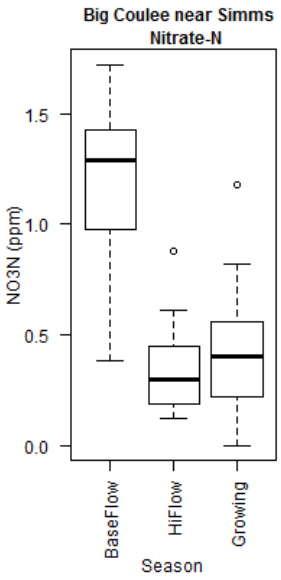


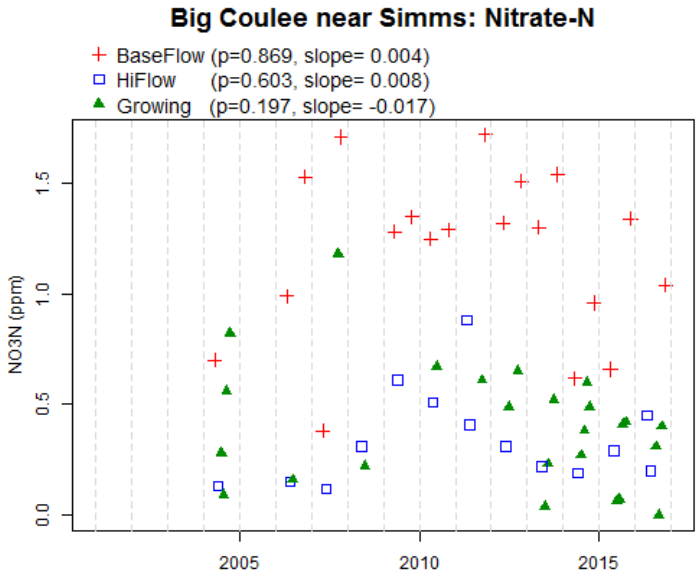
Big Coulee

Nitrate

Nitrate concentrations are highest during baseflow at this site.

There are no significant trends in nitrate concentration over time at this site.

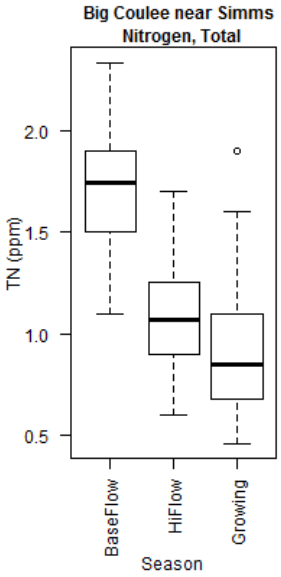


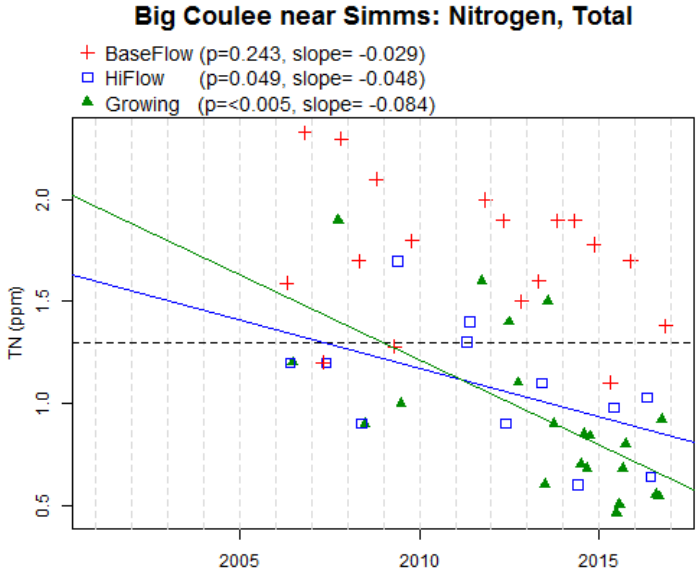


Total Nitrogen

Total nitrogen concentrations are highest during baseflow and are primarily attributed to nitrate.

Over the sampling period, there is a statistically significant decrease in total nitrogen concentration during high flow of 0.048 ppm per year and a decrease during the growing season of 0.084 ppm per year.

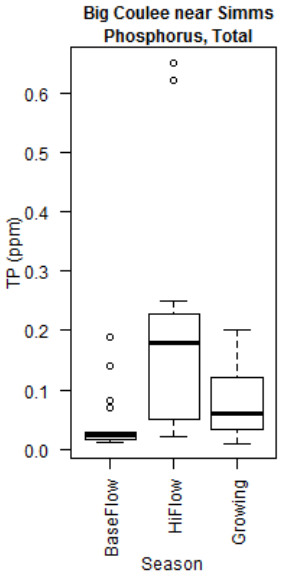


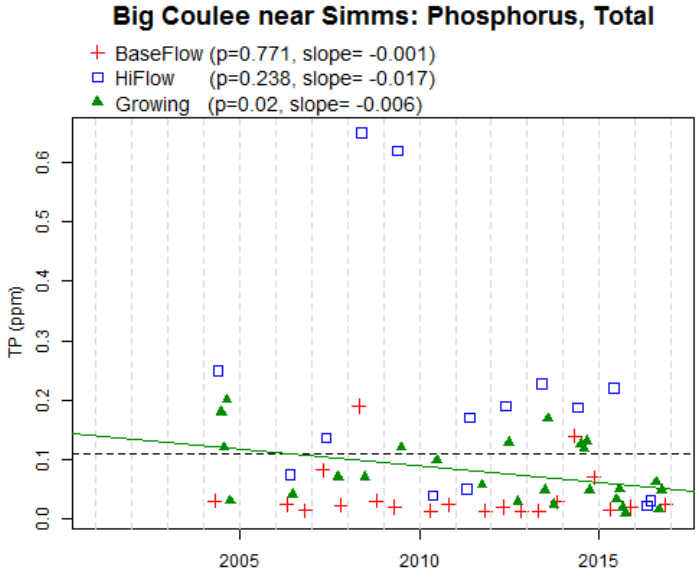


Total Phosphorus

Total phosphorus concentrations are highest during high flow.

Over the sampling period, there is a statistically significant decrease in total phosphorus concentration during the growing season of 0.006 ppm per year.

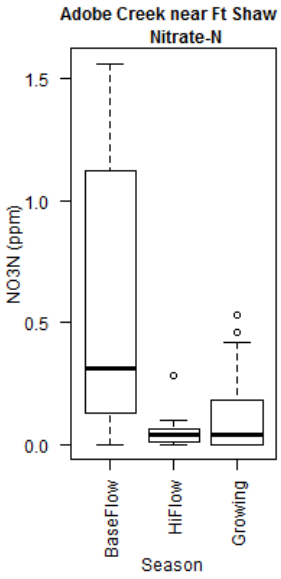


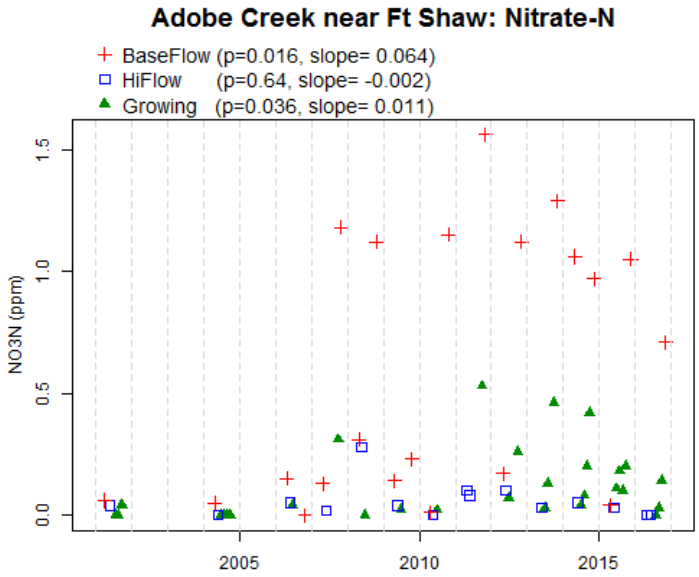


Adobe Creek

Nitrate

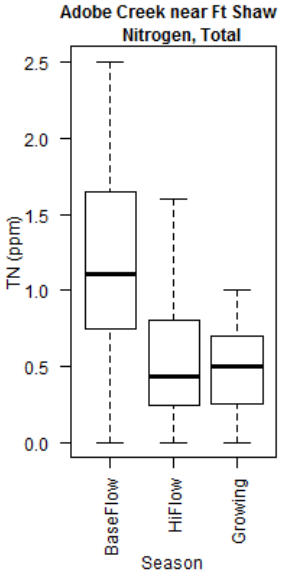
Nitrate concentrations are highest during baseflow at this site.
There are no significant trends in nitrate concentration over time at this site.
There is a pattern of higher nitrate concentrations during some portions of baseflow and not others, which is worth further assessment.

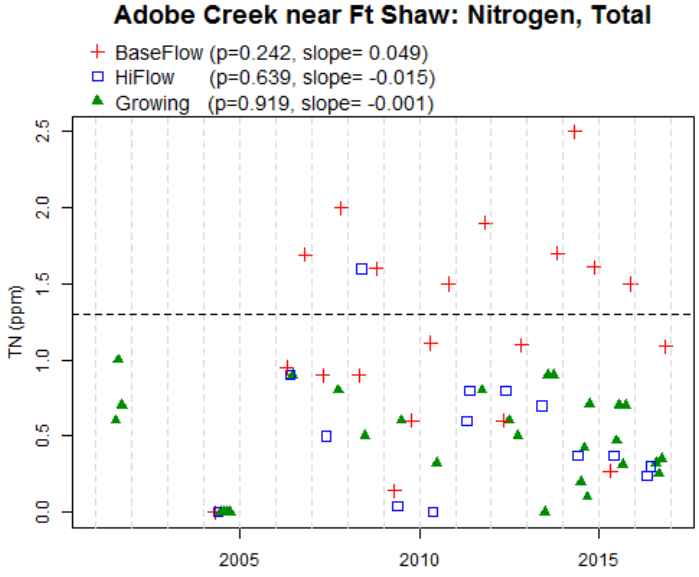




Total Nitrogen

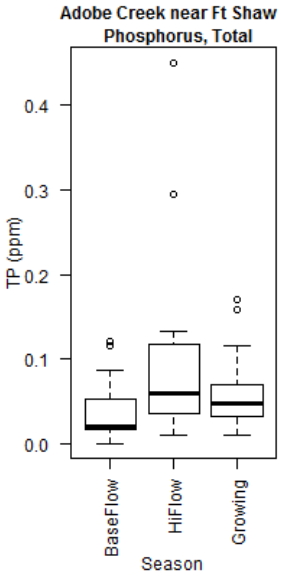
Total nitrogen concentrations are highest during baseflow and are largely attributed to nitrate.
There are no significant trends in total nitrogen concentration over time at this site.

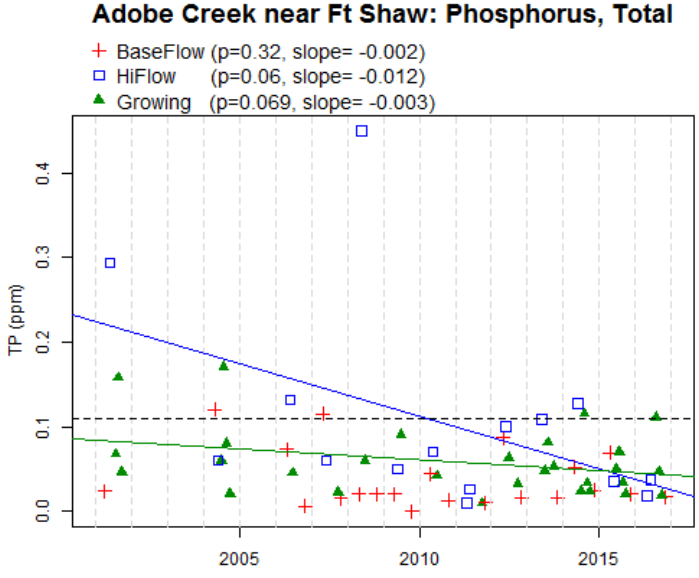




Total Phosphorus

Total phosphorus concentrations are highest during high flow.
Over the sampling period, there is a statistically significant decrease in total phosphorus concentration during high flow of 0.012 ppm per year and during the growing season of 0.003 ppm per year.



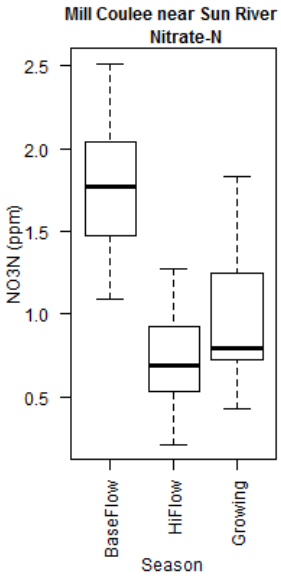


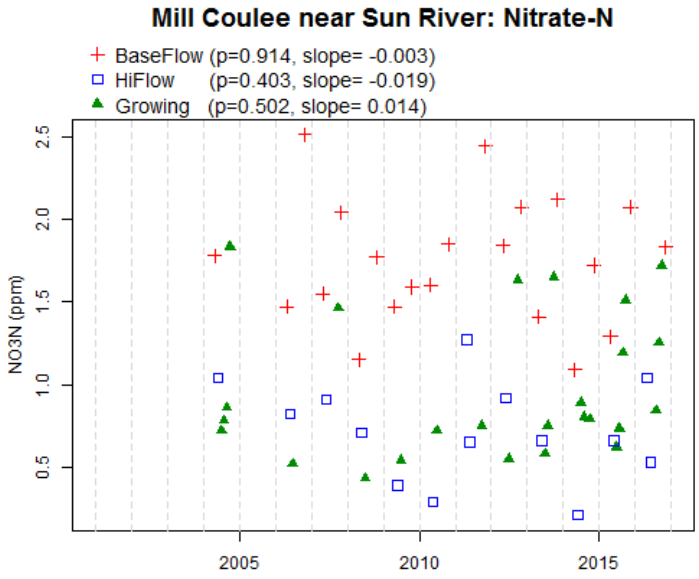
Mill Coulee

Nitrate

Nitrate concentrations are highest during baseflow at this site.

There are no significant trends in nitrate concentration over time at this site.

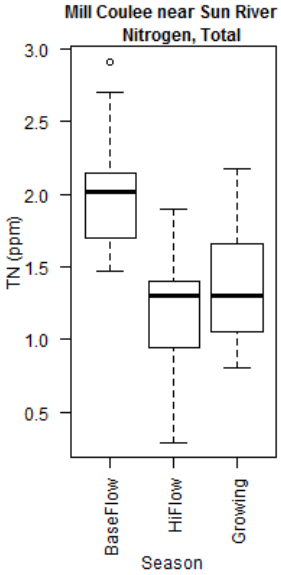


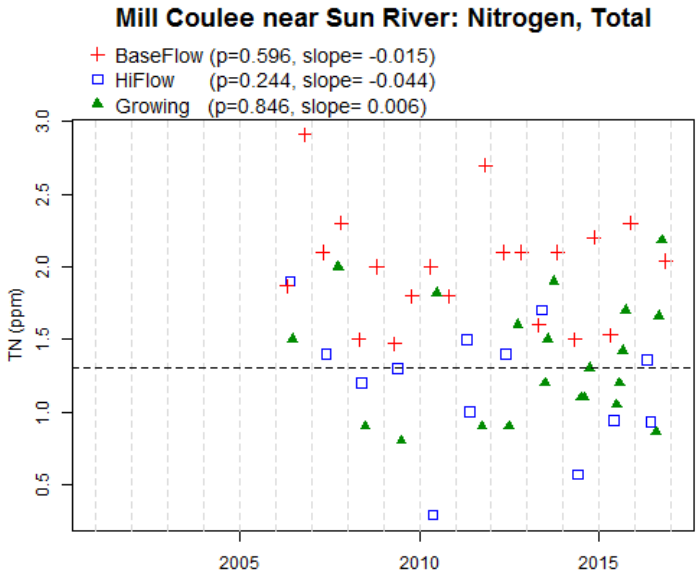


Total Nitrogen

Total nitrogen concentrations are highest during baseflow and are primarily attributed to nitrate.

There are no significant trends in total nitrogen concentration over time at this site.

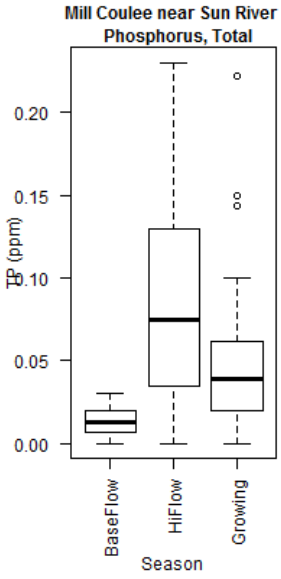


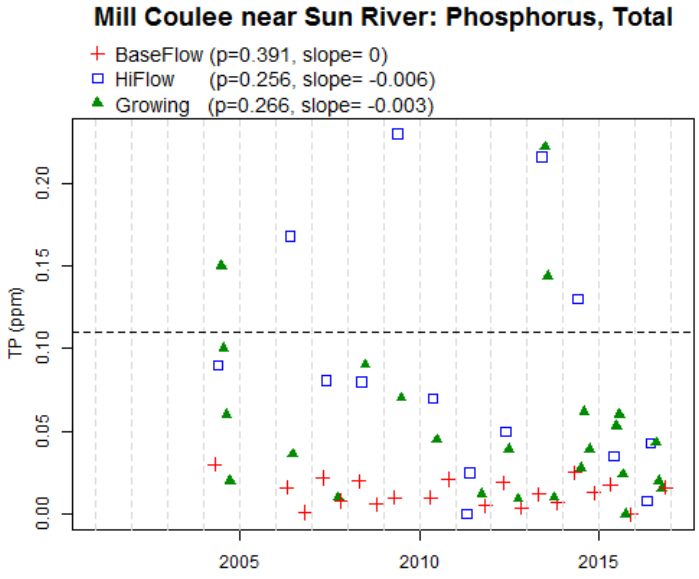


Total Phosphorus

Total phosphorus concentrations are highest during high flow.

There are no significant trends in total phosphorus concentration over time at this site.



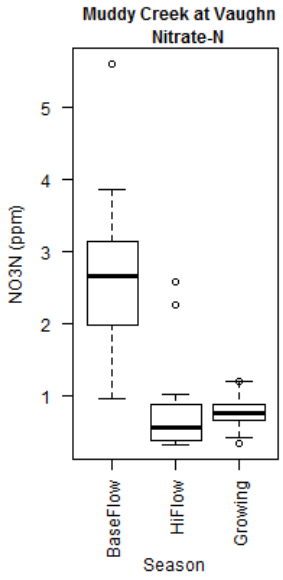


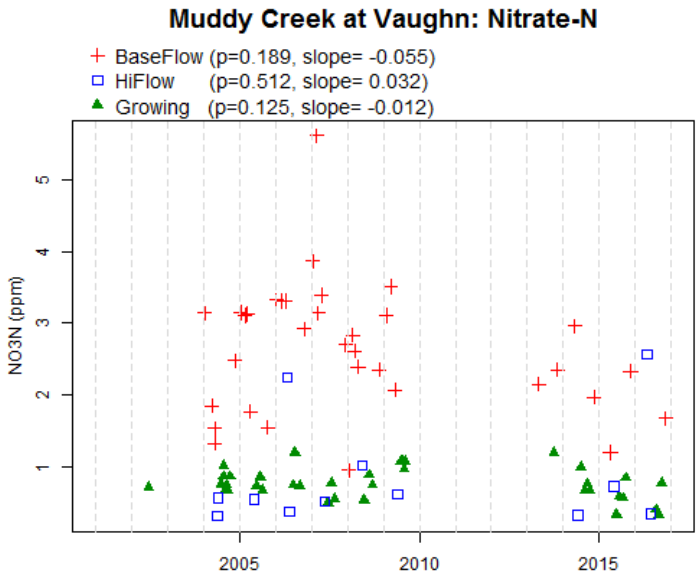
Muddy Creek

Nitrate

Nitrate concentrations are highest during baseflow at this site.

There are no significant trends in nitrate concentration over time at this site.

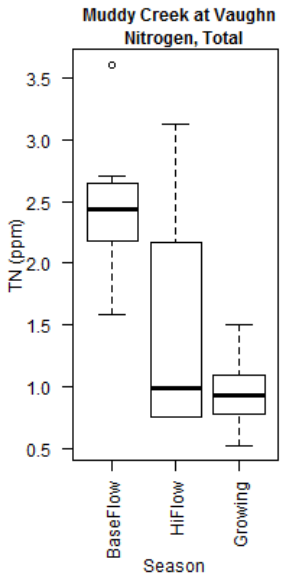


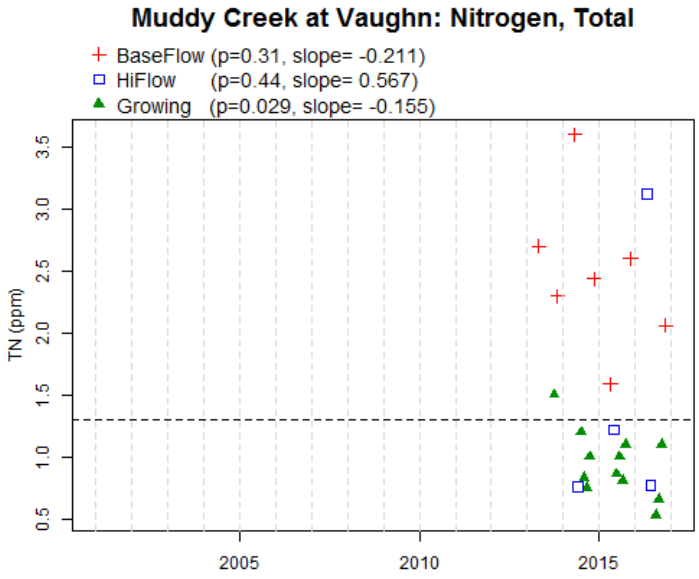


Total Nitrogen

Total nitrogen concentrations are highest during baseflow and are primarily attributed to nitrate.

The short time period of data at this site makes statistical assessment of trends challenging. The short data period is the reason for no indication of significance in trend even though the p value during the growing season is less than 0.1.

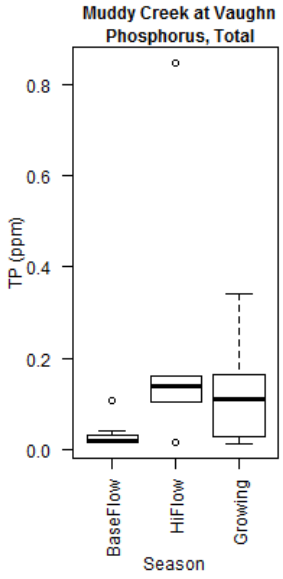


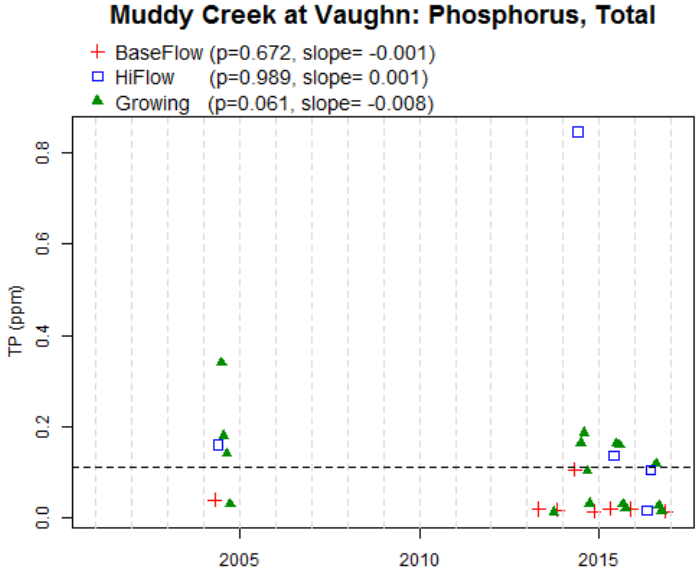


Total Phosphorus

Total phosphorus is lower during baseflow than high flow and growing season at this site.

Sparse data for total phosphorus at this site make statistical assessment of trends challenging. Sparse data is the reason for no indication of significance even though the p value for the growing season is less than 0.1.



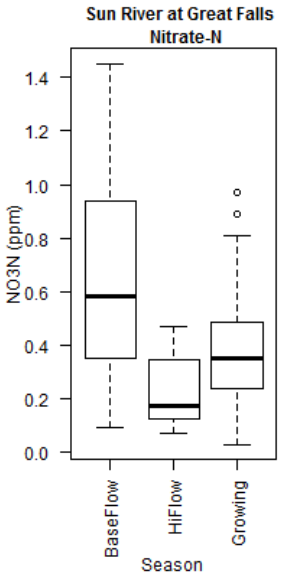


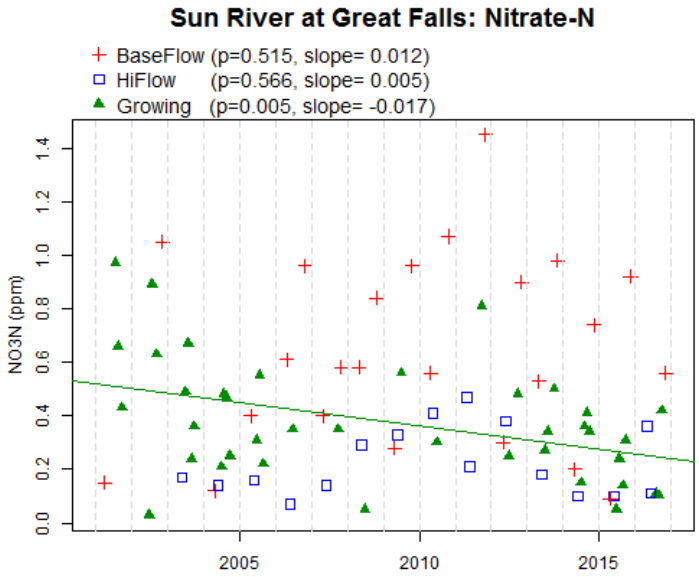
Sun at Great Falls

Nitrate

Nitrate concentrations are highest during baseflow at this site.

Over the sampling period, there is a statistically significant decrease in nitrate concentration during the growing season of 0.017 ppm per year.

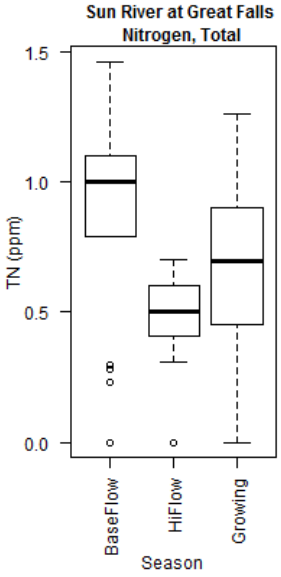


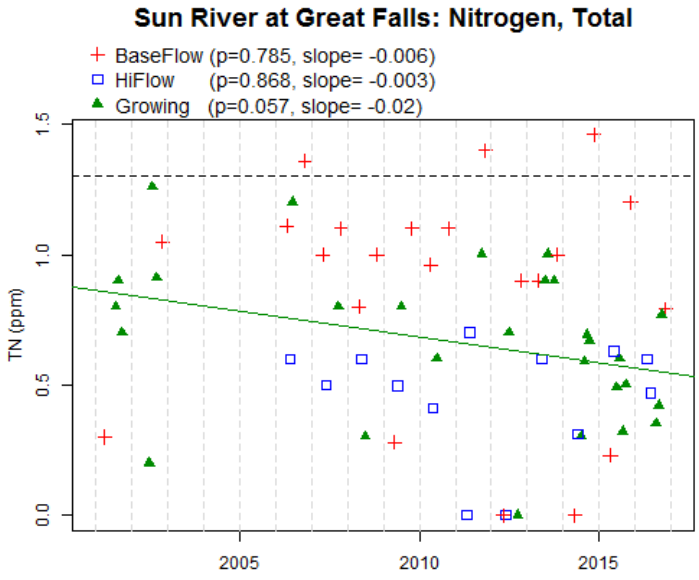


Total Nitrogen

Total nitrogen concentrations are highest during baseflow and are primarily attributed to nitrate.

Over the sampling period, there is a statistically significant decrease in total nitrogen concentration during the growing season of 0.02 ppm per year.

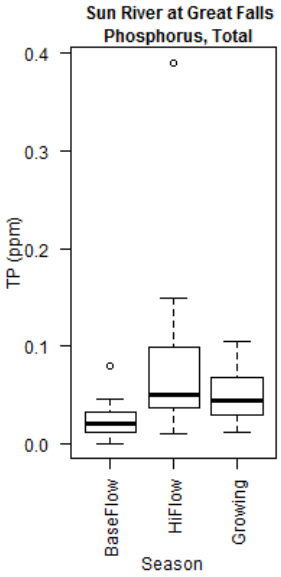


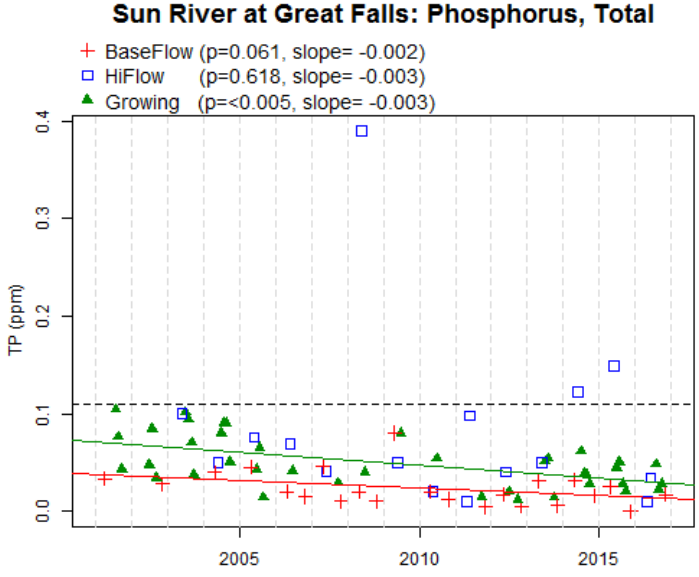


Total Phosphorus

Total phosphorus is lower during baseflow than high flow and growing season at this site.

Over the sampling period, there is a statistically significant decrease in total phosphorus concentration during the growing season of 0.003 ppm per year and during baseflow of 0.002 ppm per year.





References

MDEQ Circular DEQ-12A; Montana Base Numeric Nutrient Standards. https://deq.mt.gov/Portals/112/Water/WQPB/Standards/PDF/NutrientRules/CircularDEQ12A_July2014_FINAL.pdf

MSUEWQ Data Hub. 2019. Online at: https://django.msu.montana.edu/msuewq/

NMLE package; Linear and Nonlinear Mixed Effects Models; https://cran.r-project.org/web/packages/nlme/nlme.pdf

Sigler, Adam; Torie Bunn, Alan Rollo. 2012. Sun River Quality Assurance Project Plan. Version 1.0 September 19th, 2012. Online at: http://waterquality.montana.edu/vol-mon/images-files/FINALSunQAPPwAppendices_%202012-11-01.pdf

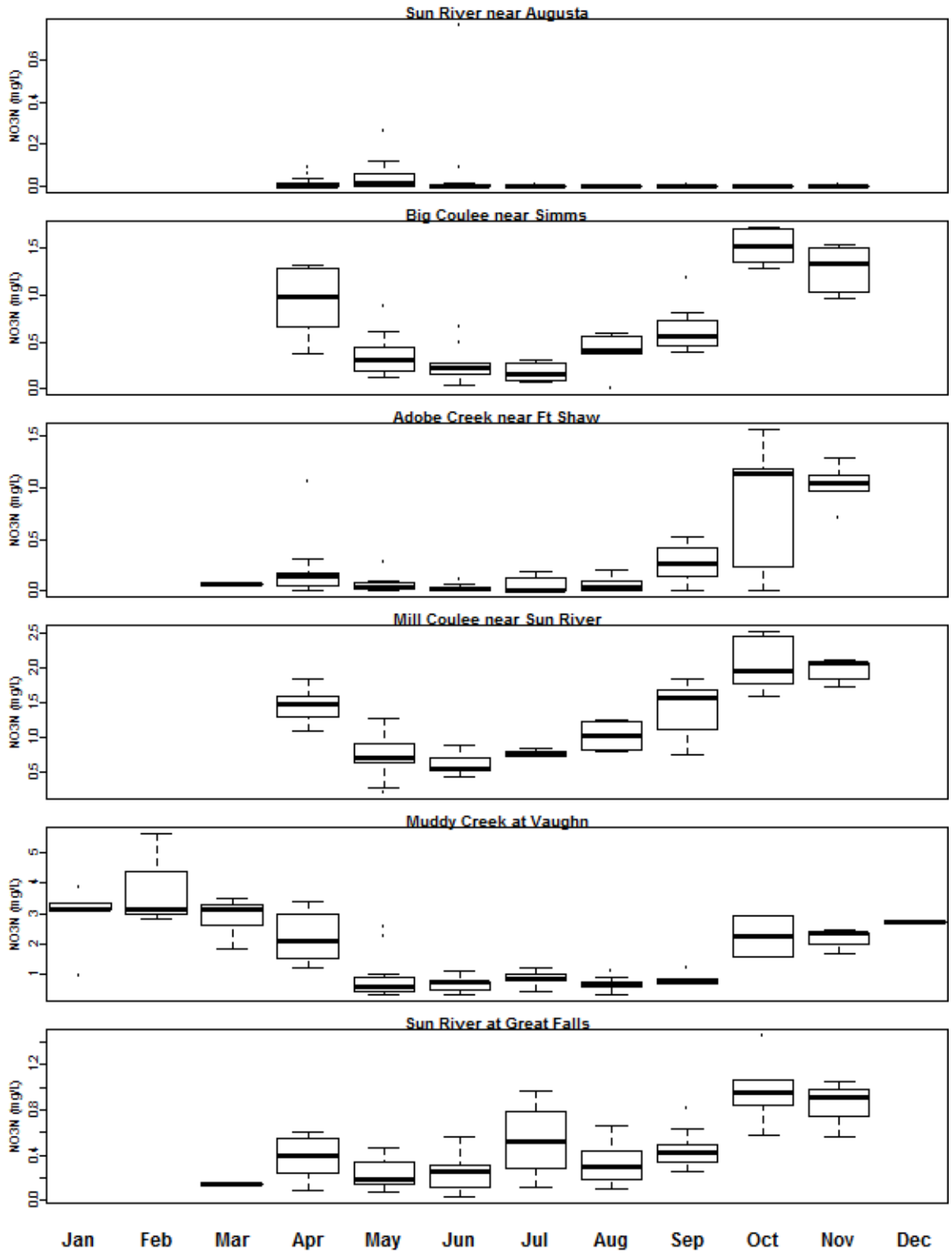
USGS Gage Data; Discharge at USGS gate 06089000 for Sun River near Vaughn MT; https://waterdata.usgs.gov/mt/nwis/uv?site_no=06089000

Appendix 1 – File names Alan Rollo emailed to Adam Sigler

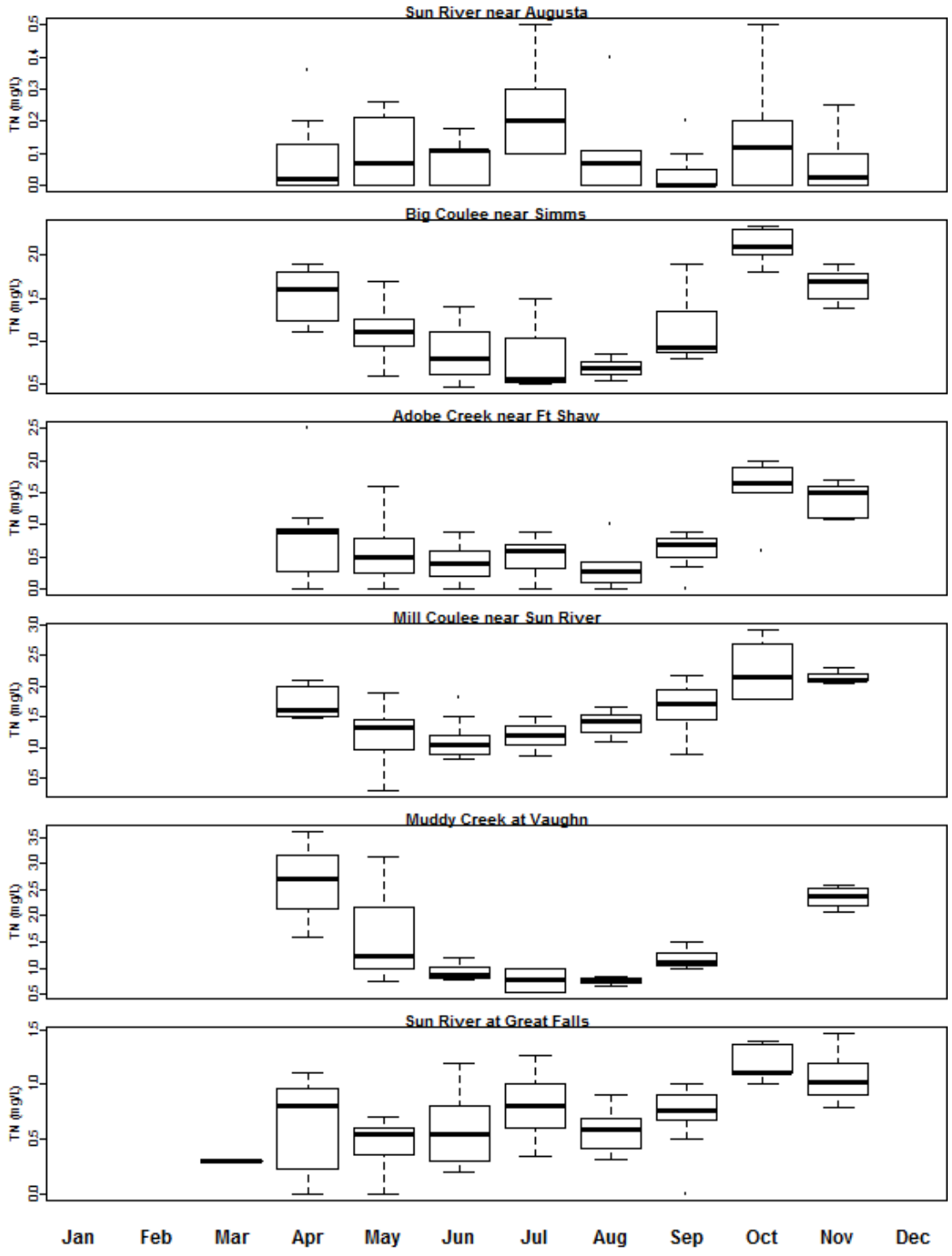
Supplemental Table 1. Sun River Sample Sites and File Names			
#	Site ID	Site Name	Name of file emailed by Alan Rollo
1	SUN-SUNR50	Sun River near Augusta	Sun River at Augusta_2001-2016_2017-5-30 UPDATED.xlsx
2	SUN-DUCKC01	Big Coulee near Simms	Big Coulee 2017 updated.xlsx
3	SUN-ADBEC01	Adobe Creek near Ft Shaw	Adobe Creek_2001-2016_ 2017-6-2 updated.xlsx
4	SUN-MILCU01	Mill Coulee near Sun River	Mill Coulee 2017 updated.xlsx
5	SUN-MUDYC57	Muddy Creek	Muddy Creek @ Vaughn_2004-2017_2017-6-2 updated.xlsx
6	SUN-SUNR56	Sun River at Great Falls	Sun River at Great Falls_2001-2016_ 2017-5-29 updated.xlsx

Appendix 2 – Seasonal fluctuations in nutrient concentrations

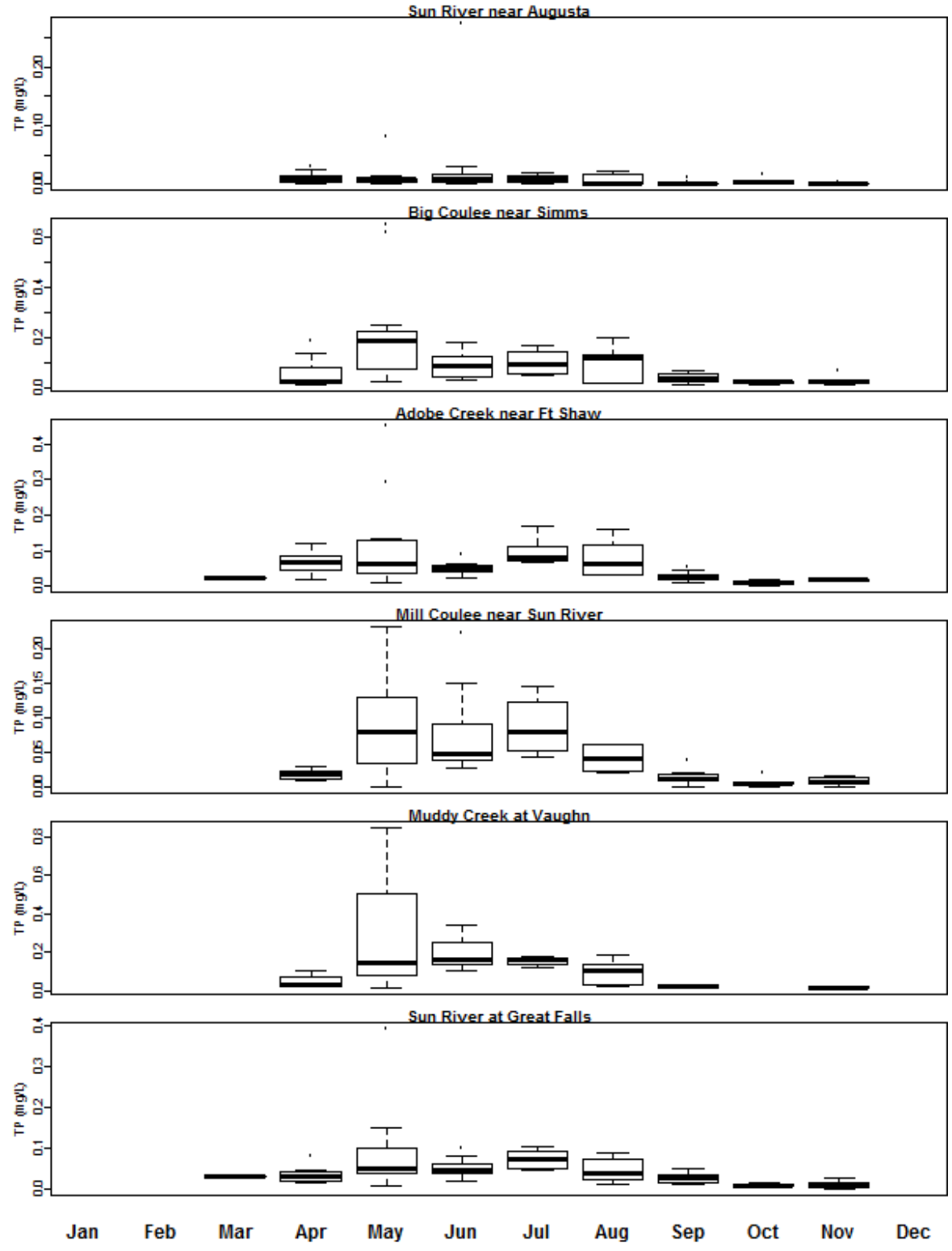
Nitrate concentrations by month for each site



Total Nitrogen concentrations by month for each site



Total Phosphorus concentrations by month for each site



Appendix 3 – MDEQ Nutrient Standards

MDEQ Circular 12A

Table 12A-1. Base Numeric Nutrient Standards for Wadeable Streams in Different Montana Ecoregions. If standards have been developed for level IV ecoregions (subcomponents of the level III ecoregions) they are shown in italics below the applicable level III ecoregion. Individual reaches are in the continuation of this table.

			Numeric Nutrient Standard[4]	
Ecoregion[1,2] (level III or IV) and Number	Ecoregion Level	Period When Criteria Apply[3]	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)
Northern Rockies (15)	III	July 1 to September 30	25	275
Canadian Rockies (41)	III	July 1 to September 30	25	325
Idaho Batholith (16)	III	July 1 to September 30	25	275
Middle Rockies (17)	III	July 1 to September 30	30	300
Absaroka-Gallatin Volcanic Mountains (17i)	IV	July 1 to September 30	105	250
Northwestern Glaciated Plains (42)	III	June 16 to September 30	110	1300
Sweetgrass Upland (42l), Milk River Pothole Upland (42n), Rocky Mountain Front Foothill Potholes (42q), and Foothill Grassland (42r)	IV	July 1 to September 30	80	560
Northwestern Great Plains (43) and Wyoming Basin (18)	III	July 1 to September 30	150	1300
River Breaks (43c)	IV	See Endnote 5	See Endnote 5	See Endnote 5
*Non-calcareous Foothill Grassland (43s), Shields-Smith Valleys (43t), Limy Foothill Grassland (43u), Pryor-Bighorn Foothills (43v), and Unglaciated Montana High Plains (43o)**	IV	July 1 to September 30	33	440

*For the Unglaciated High Plains ecoregion (43o), criteria only apply to the polygon located just south of Great Falls, MT.

[1] See Endnote 1

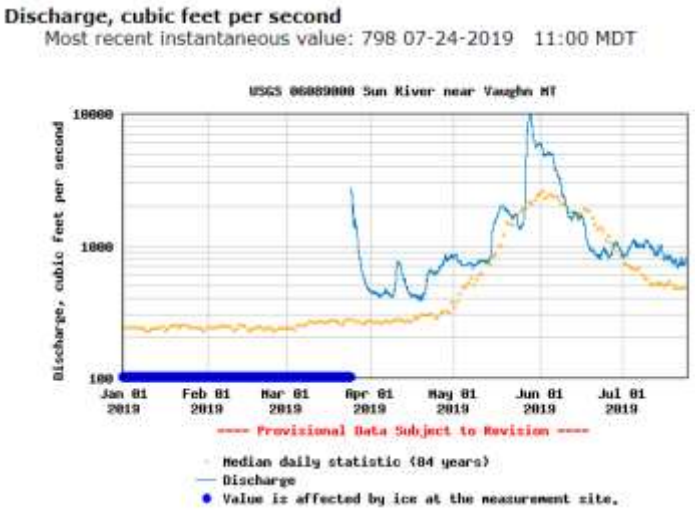
[2] See Endnote 2

[3] See Endnote 3

[4] See Endnote 4

Appendix 4 – Sun River median daily discharge

Discharge at USGS gate 06089000 for Sun River near Vaughn MT. The period of record median daily values show an inflection point on May 1st. which was selected for the beginning of peak flow. Clear from the 2019 data, runoff notably diverges from median behavior in individual years, so more detailed analysis accounting for daily runoff would likely provide useful insights.



Appendix 5 – Statistical analysis details

Trend analysis was conducted in R statistical software using the gsl function within the Linear and Nonlinear Mixed Effects Models (nlme) package. This linear model fit uses generalized least squares and allows for errors to be correlated and/or have unequal variances. A statistical test allowing for unequal variance was selected because the variance in the data was different among seasons and across time for many of the site/parameter combinations.

NMLE package; Linear and Nonlinear Mixed Effects Models; https://cran.r-project.org/web/packages/nlme/nlme.pdf