Upper Missouri River Water Quality Report 2022: from Lewis & Clark, Broadwater and Cascade Counties, MT

Prepared for:

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Water quality collection station at the Missouri River looking upstream of Craig.

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Acknowledgements

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Executive Summary

In 2016, the Upper Missouri Watershed Alliance (UMOWA) began collecting water quality (WQ) data at seven sites on the Upper Missouri River between Wolf Creek and Cascade. These sites were chosen to coincide with long-term macroinvertebrate monitoring sites that were established in 2015 by Montana Biological Survey. 2022 marked the 7th consecutive year that WQ samples have been collected. WQ samples were typically collected seasonally in spring (April/May), summer (July) and fall (late-September/October) to coincide with pre-, post- and during irrigation periods.

The goals of the project are: 1) to continue to collect seasonal baseline WQ data as it may affect benthic macroinvertebrate, algae and plant communities and 2) to collect baseline information for total suspended solids (TSS), total dissolved solids (TDS) and nutrients (Total Nitrogen, TN; inorganic nitrogen, NN; total phosphorus, TP) to allow for spatially and temporal robust comparisons of water quality in the Upper Missouri River. WQ samples have not been analyzed for recoverable metals since 2016, because then, these metals were recovered in low (often non-detectable) levels (except an Arsenic (AS) spike during the spring below Little Prickly Pear Creek) suggesting that they pose, little to no acute or chronic threat to the Missouri River.

The water quality data collected in 2022 has reinforced some of the seasonal and spatial trends observed since 2016 but has also indicated a reverse of the increasing trend of TN and NN concentration levels in the Missouri River below Holter. Additional tributary sites sampled for WQ upstream of Canyon Ferry Reservoir revealed some very high levels of TP and TN entering the Missouri River upstream of Townsend.

During the fall sampling period of 2022, TN concentration levels at 4 sites and TP levels at 6 of the 7 monitoring sites below Holter Dam exceeded the old, recommended standards set by MDEQ.

Across all monitoring years, nutrient concentrations (TN and TP) were the highest in 2018 and 2019 compared to 2016, 2017, or 2020-2022. This increase was most apparent during June and October. Inorganic nitrogen (NN) concentrations have remained at very low concentrations below Holter since 2019, and the MDEQ numeric nutrient standards for TN, and (with MO Cascade) for TP.

Nutrient levels in 2022, particularly total nitrogen (TN), were lower downstream of Holter Dam than in previous years, except an unexpected spike below the Dearborn River. Lower mean discharge and no large flushing flows in 2021 and 2022 did not provide the lower Missouri River below Canyon Ferry with a large nutrient pulse that occurred from 2017 to 2020. The Missouri River upstream of Canyon Ferry exceeded the old MDEQ nutrient thresholds for both Total Nitrogen (TN) and TP in May, but these nutrients are being utilized within the reservoir. The tributaries contributing these excess nutrients are Deep, Dry and Greyson Creeks for all 3 evaluated (NN, TN, TP) with Deep Creek being the biggest contributor of TP with over 5 times the concentration that was historically 'allowed' by MDEQ. Nutrient levels in the mainstem Missouri River have been trending upward over the first 4 study years, most notably in the Fall samples, while below tributaries,

concentrations have been somewhat mediated by the inflows; this rising trend has stabilized in 2020. October 2017 was really at the forefront of the increasing trends in nutrient concentrations during the previous sampling periods.

It is evident that high nutrient loads entering Canyon Ferry are the biggest threat that the Upper Missouri River is facing at present. When we started this project, no sites that we sampled in 2016 during any season exceeded the old numeric nutrient standards or screening values set by MDEQ, but now most monitoring sites are surpassing these thresholds routinely in the fall and oftentimes in the spring as well (UMOWA 2022). It is critical that UMOWA continue to monitor the Missouri River water quality into 2023 to see if nutrient concentrations continue to stabilize below impairment levels or continue an upward trajectory when a 'normal' flushing flow streamflow pattern occurs.

1.0 Introduction

The 2.8-mile reach of the Missouri River from Holter Dam to Little Prickly Pear Creek is listed as impaired for aquatic life by Montana Department of Environmental Quality (MDEQ) due to sedimentation/siltation, increased total nitrogen and phosphorus concentrations (likely caused by grazing in riparian zones, municipal point source discharges and caused by on-site treatment systems (septic systems) and flow regime alterations from upstream impoundments (MDEQ 2016). The 20.9-mile reach of the Missouri River from Little Prickly Pear Creek to Sheep Creek is listed as impaired for aquatic life due to increased arsenic concentrations, increased total nitrogen concentrations due to grazing in riparian zones, impacts from hydro-structure flow regulation/modification, and sedimentation/siltation caused by irrigated crop production and natural sources (USEPA 2020). Similar impairments are listed for the next Missouri River section from Sheep Creek to the Sun River (USEPA 2020). Nutrient levels in the mainstem Missouri River had been trending upward over the first 4 study years (2016-2019), most notably in the Spring and Fall samples, while the past 2 years nutrient concentrations have leveled off (UMOWA 2022) while below tributaries, concentrations are somewhat mediated by the inflows (UMOWA 2021).

In 2016, the Aquatic Resources Committee of the Upper Missouri Watershed Alliance (UMOWA) decided to fund the collection of water quality data on a periodic and consistent basis to monitor the health of the Upper Missouri River between Holter Dam and Cascade. Samples were collected concurrently with macroinvertebrate samples being collected by Montana Biological Survey (Stagliano 2019) to determine if any correlations can be drawn between water chemistry and aquatic insect communities. The overall goals of the project were to 1) establish baseline water quality data as it may affect benthic macroinvertebrate and aquatic plant communities, and 2) collect baseline information about total suspended/dissolved solids and nutrients to allow for spatial and temporal comparisons of water quality. To get an idea of river assessment conditions, WQ data will be compared against previous DEQ nutrient standards (discontinued in 2021) for wadable streams in the ecoregion. In 2017, analysis of metal concentrations was eliminated from the project goals. The 2018-2022 WQ sampling focused on nutrient concentrations as well as total suspended/dissolved solids concentrations.

From our 7 years of collecting and analyzing spatial and temporal WQ data, it has become clear that most of the nutrient issues on the Missouri River below Holter Dam are not originating from local sources but are being cycled through one or more of the upstream reservoirs and must be addressed at their sources. Therefore, in 2021 we sampled WQ nutrient data at 8 new Missouri River or Canyon Ferry tributaries that are on the 303(d) Impaired Waters List with nutrients: TN, TP and/or NN, listed as at least one cause of Aquatic Life impairment (MDEQ Appendix A 2020).

2.0 Methods

2.1 Sample Site Selection

Water quality samples were collected seasonally from seven sites between Wolf Creek and the town of Cascade (**Table 1, Figure 1**). These sites coincide with monitoring sites that have been sampled for macroinvertebrates by Montana Biological Survey since 2015. The sites were chosen to be spatially representative of the upper Missouri River and integrate the influence of the three major tributaries (Little Prickly Pear Creek, Dearborn River and Sheep Creek) on water quality.

Station ID	Site Name	Latitude	Longitude
MO_LPPC_US	Missouri River U/S Little Prickly Pear	47.02281	-112.01527
MO_LPPC_DS	Missouri River D/S Little Prickly Pear	47.02345	-112.01523
MO_CRAIG	Missouri River U/S Craig	47.05415	-111.96701
MO_DEAR_US	Missouri River U/S Dearborn River	47.12819	-111.91174
MO_DEAR_DS	Missouri River D/S Dearborn River	47.12791	-111.9109
MO_HARDY	Missouri River U/S Sheep Creek (Hardy Bridge: cover photo)	47.16781	-111.83366
MO_CASCADE	Missouri River @ Cascade FAS	47.28062	-111.69113

Figure 1. WQ Sampling sites are denoted by blue triangles. Black dots are towns.

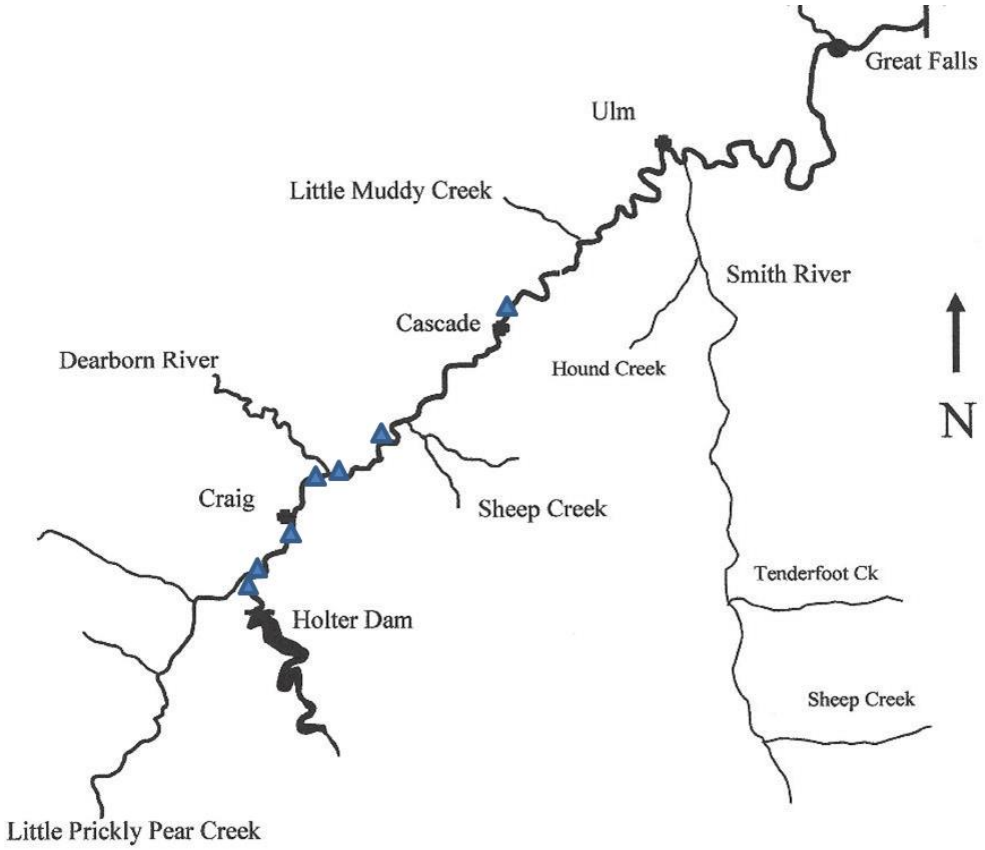
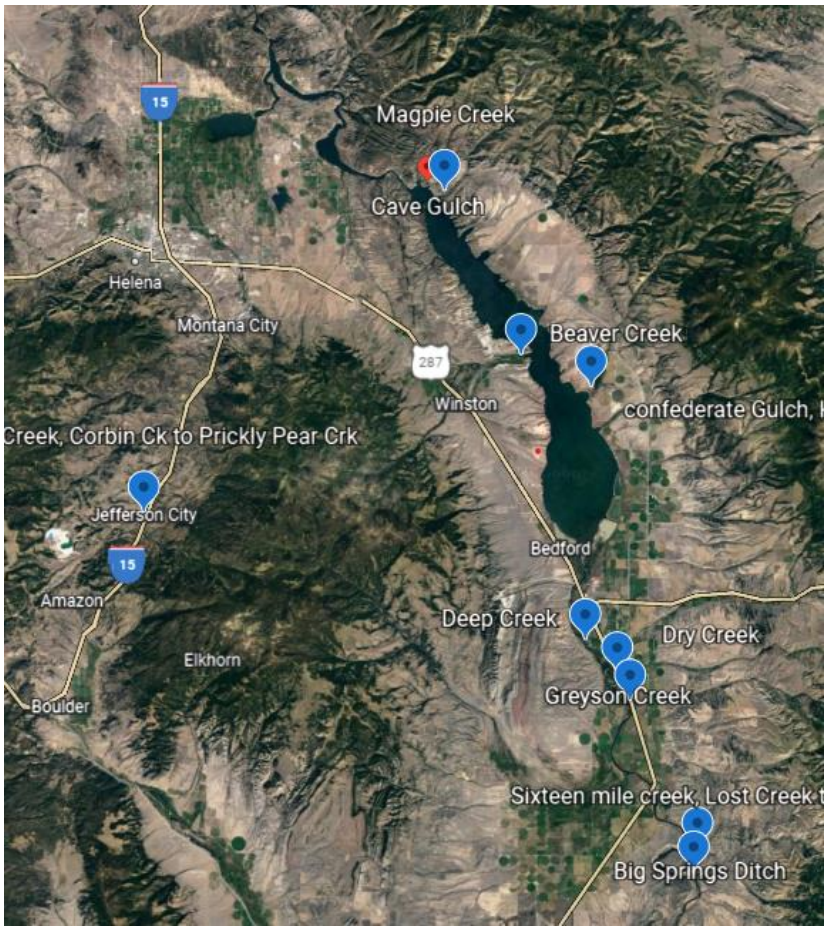


Table 2. *Tributary streams and Missouri River locations upstream of Canyon Ferry sampled for WQ in 2022.*

Station ID	Agency	Site Name	Latitude	Longitude	Parameters to Collect**
MO_Beaver	UMOWA	Beaver Creek, headwaters to mouth, sample D/S of HWY 12	46.5134	-111.5995	WQS (added 2021)
MO_DeepCR	UMOWA	Deep Creek D/S of HWY 12	46.28603	-111.4996	WQS (added 2021)
MO_DryCreek	UMOWA	Dry Creek upstream of HWY 12	46.24361	-111.4509	WQS (added 2021)
MO_Greyson	UMOWA	Greyson Creek D/S of HWY 12	46.26329	-111.4842	WQS (added 2021)
MO_Townsend	UMOWA	Missouri River bridge in Townsend	46.33527	-111.5325	WQS (added 2021)

WQS=Water quality samples (TSS, TDS, NO2+3, TP, TN)

Map 2. WQ Sampling sites upstream of Holter Reservoir (some from 2021) are denoted by blue drops.

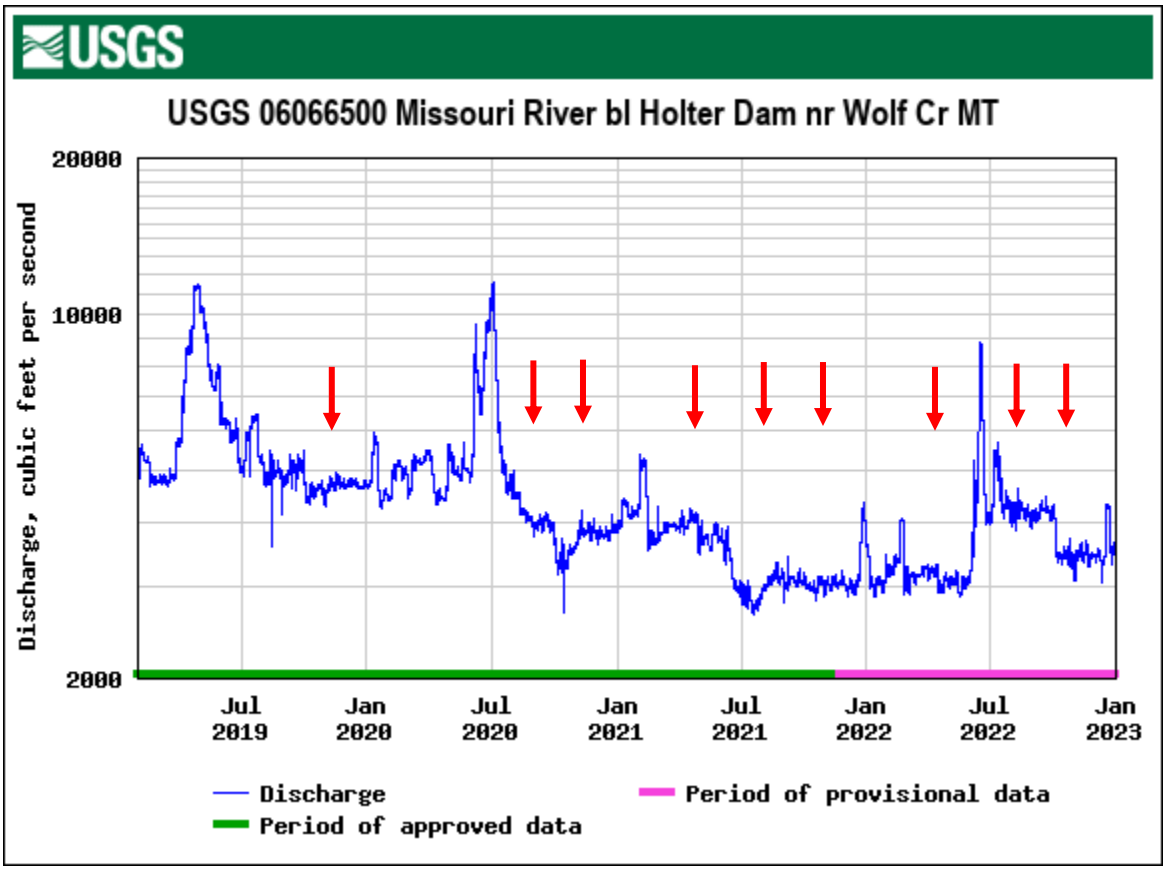


2.2 Sample Timing

Samples were collected seasonally on the Mainstem Missouri River to examine temporal changes in water quality through the year, especially related to the summer irrigation and the growing season. In 2022, seasonal samples were collected on May 5th (May 8th for tributaries), July 18th and September 21st (**Figure 2**). WQ samples collected in 2021 captured data during some of the

lowest annual discharge reported in the last decade; there wasn't even a spring pulse. While 2022 provided a more normal discharge pattern with a below average spring pulse (~8,200 cfs) in mid-June of 2022 (**Figure 2**).

Figure 2. Discharge below Holter Dam from Jan 2019-2023. Red arrows represent sampling dates.



2.3 Sampling Methods

Water quality samples were collected in sterilized bottles provided by Energy Laboratories Inc. At the time of sample collection, water bottles were held upstream of the collector and each bottle and lid were triple rinsed with ambient river water prior to collecting the final sample. Total nitrogen (TN) samples were collected in 250 mL HDPE bottles and kept on ice until analyzed. Total phosphorus (TP) and inorganic nitrogen (nitrate and nitrite, NN) samples were collected in 250 mL HDPE bottles, preserved with sulfuric acid and nitric acid, respectively, and kept on ice until analyzed. Total suspended solids (TSS) and total dissolved solids (TDS) samples were collected in 1000 mL HDPE bottles and kept on ice until analyzed. All water samples were submitted to Energy Laboratories Inc. in Helena, MT within 24 hours of collection.

2.4 Quality Assurance – Field Blanks and Duplicates

During each seasonal sampling, one field duplicate of a sample was collected to ensure the quality of the sampling procedure and the accuracy of the lab analysis. Field duplicates consist of an extra set of sample bottles filled with the same water from the same sampling site. Field duplicates were collected, handled, and stored in the same way as the routine samples for laboratory shipment. In theory, a duplicate sample should yield results identical to the other sample taken at the same site at the same time. Collecting and analyzing duplicate samples ensures that the sampling and analysis process is consistently accurate.

Field blanks consist of an extra set of sample bottles filled with deionized (DI) water and transported with the other samples in the field. Field blanks were prepared in the field at the same time as the routine samples and handled and analyzed in the same way as the routine samples. In theory, field blank samples should be clean of all contaminants. Collecting and analyzing field blank samples ensures that the sampling and analysis processes are free of contaminants.

2.5 Water Quality Analysis

Energy Laboratories Inc. in Helena, MT analyzed all water quality samples. Energy Laboratories Inc. routinely processes 1,000's of WQ samples for MDEQ, USEPA and other agencies, and has been proven to provide laboratory data of very high accuracy and consistency. This summer Energy Labs failed to supply us with a Field Blank during the visits and Duplicate sample bottles for the Summer Sampling Period.

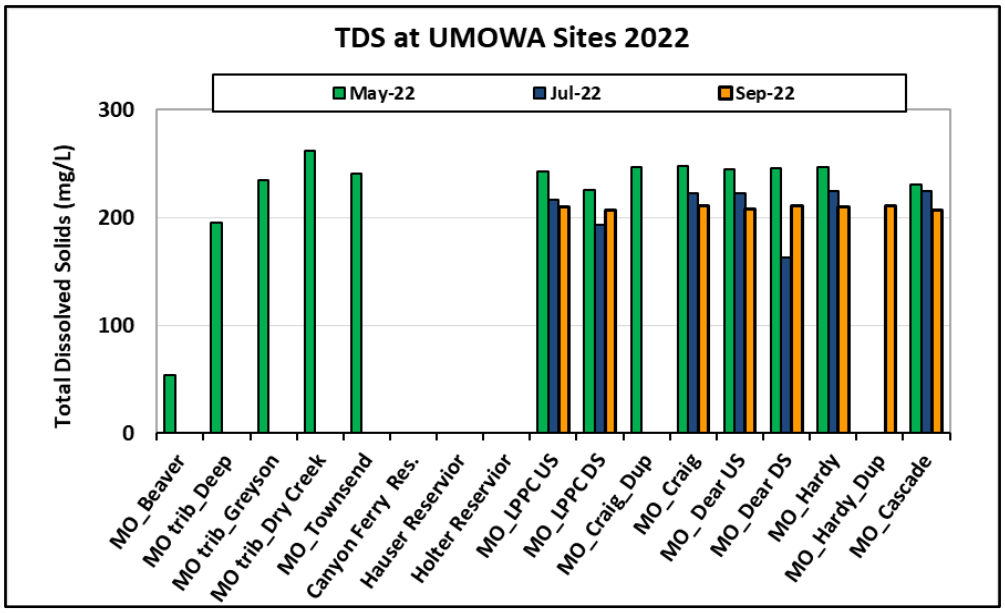
3.0 Results for 2022

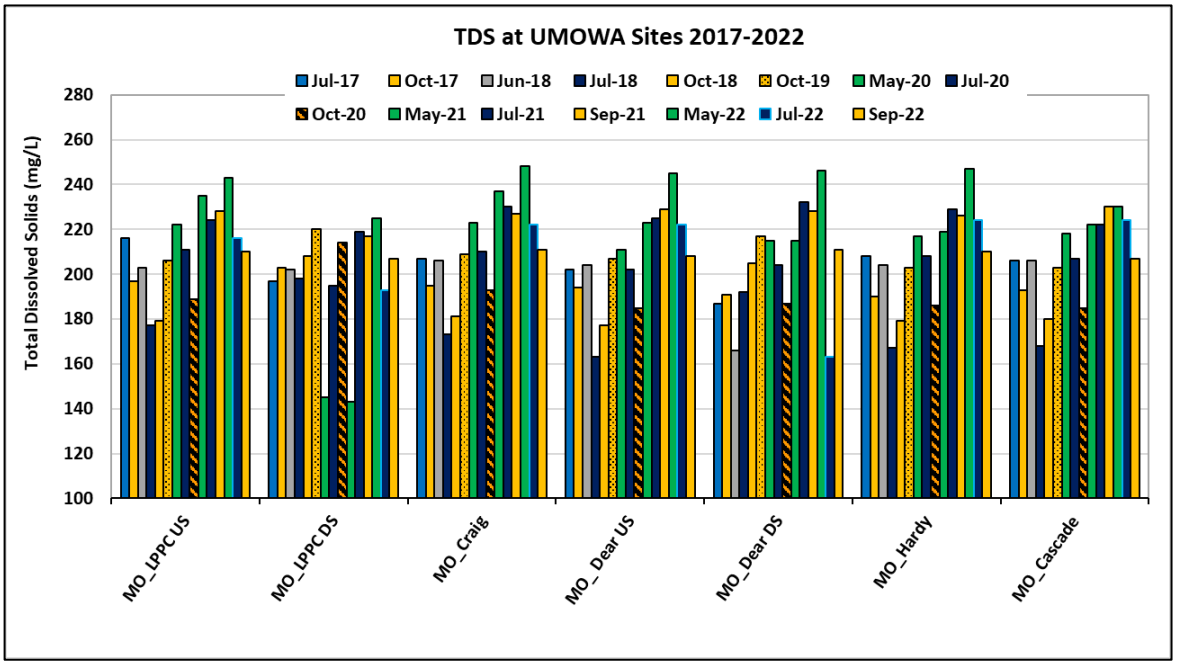
Four tributary sites proposed for sampling this year (Beaver, Dry, Deep and Greyson Creeks) were visited in early-May prior to run-off; we sampled the mainstem Missouri River in Townsend during this period as well (**Table 2, Map 2**). Results were interpreted relative to previously established MDEQ numeric WQ standards within the ecoregion. MDEQ established these numeric water quality criteria to control limits on pollutant levels in Montana's wadable rivers and streams. Numeric nutrient criteria had not yet been developed for the mainstem Missouri River (a non-wadable river), and wadable stream nutrient thresholds have been discontinued in 2021 in favor of narrative criteria. Circular 12A (MDEQ 2014) provides the discontinued threshold numeric nutrient standards of 0.3 mg/L for total nitrogen (TN) concentrations and 0.03 mg/L for total phosphorus (TP) concentrations. The screening value of 0.1 mg/L for inorganic nitrogen concentrations was provided via personal communication with MDEQ staff. Screening values and numeric nutrient standards are represented as horizontal lines on the graphs. A table of all 2016-2022 WQ results is available in Appendix A.

3.1 Total Dissolved Solids

In 2022, Total Dissolved Solid (TDS) concentrations averaged 216 mg/L across all sites and seasons and ranged from 54 mg/l at Beaver Cr. to 262 mg/L (Dry Creek); no distinct spatial trends were noted below Holter Dam except overall lower concentrations at the Missouri River below Little Prickly Pear Creek (MO_LPPC_DS) and at Cascade (**Figure 3**). The Missouri River at Townsend had similar TDS levels to below Holter in May 2022. Seasonally, May 2022 samples had the highest TDS levels downstream of Holter Dam and September samples had the lowest TDS, except at the sites located below tributaries (MO_LPPC_DS, MO_DEAR_DS) which dipped below Fall levels in the summer visit (**Figure 3**). In 2018, TDS concentrations averaged 187 mg/L across all sites and ranged between 162 and 208 mg/L; the lowest TDS levels across all years were reported in July 2018, while the highest levels were reported in Spring 2022 (**Figure 3**).

Figure 3. *Total Dissolved Solid levels across the UMOWA sites in 2022 (top) and 2017-2022 (bottom). Sites arranged upstream to downstream.*

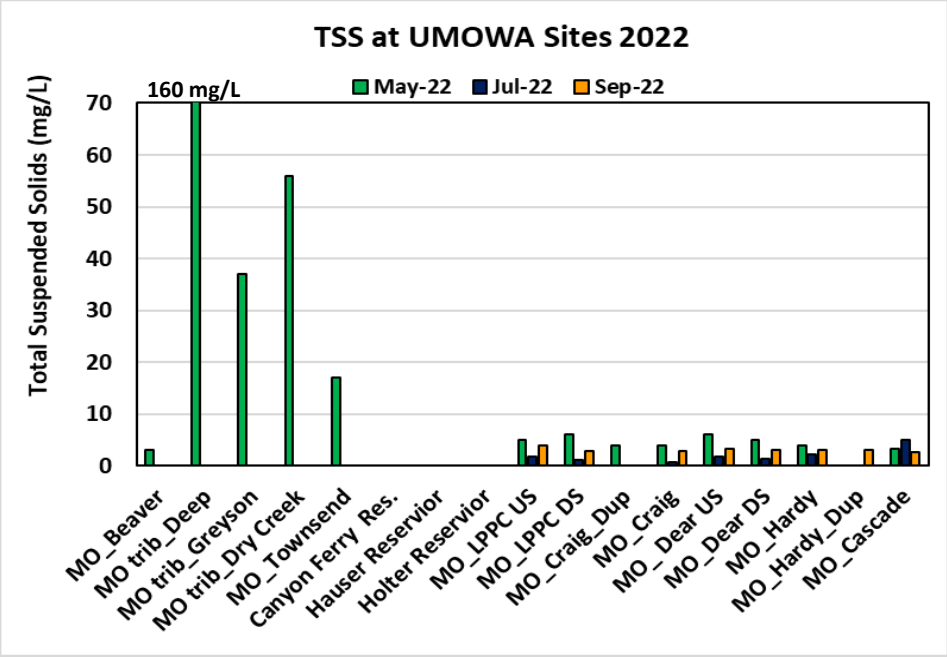


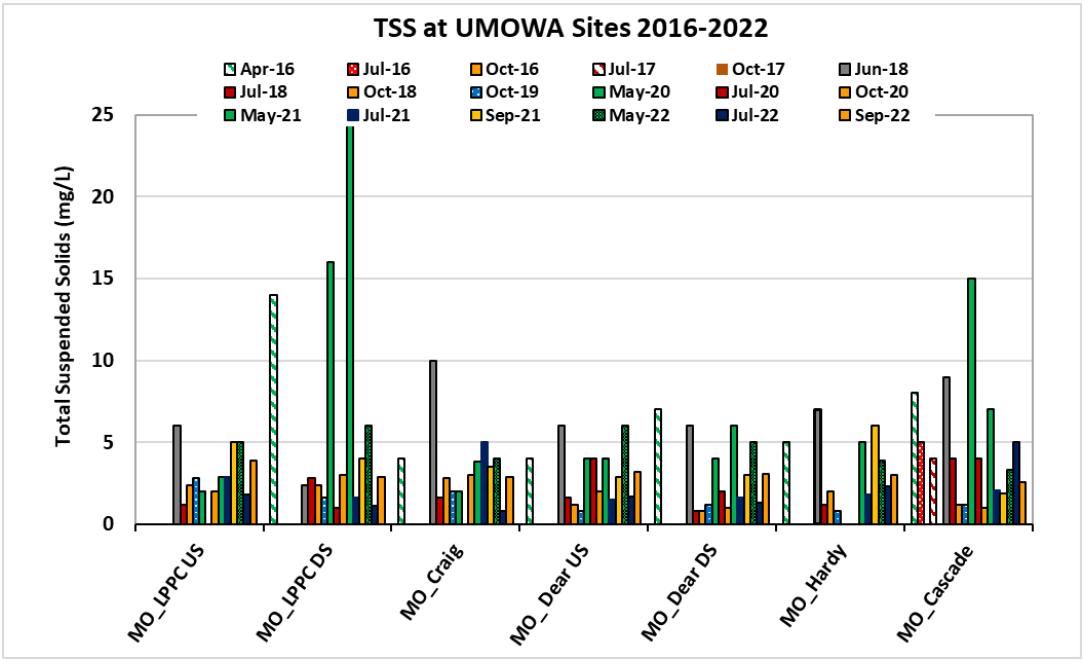


3.2 Total Suspended Solids

In 2022, Total suspended solids (TSS) concentrations ranged between 0.8 to 160 mg/L and averaged 12.5 mg/L across all sites and seasons; downstream of Holter Reservoir, average TSS values were 3.3 mg/l across all sites and seasons (**Figure 4**). Most of the tributaries upstream of Canyon Ferry had substantially higher TSS values than below Holter Res. with Deep Creek reporting an "off the chart" value of 160 mg/l (**Figure 4**). The highest TSS values reported downstream of Holter in 2022 were reported from the samples taken downstream of Little Prickly Pear Creek (6.0 mg/l) and downstream of the Dearborn River during those streams' high-flow May period (**Figure 4**). The Missouri River at Hardy Bridge has reported non-detectable TSS levels during all seasons in 2020 and from July 2016 to Oct 2017, but this year and 2021 had more sites at detectable levels (**Figure 4**).

Figure 4. *Total Suspended Solids (TSS) across the UMOWA sites in 2022 (top) and 2016-2022 (bottom). Sites arranged upstream to downstream.*

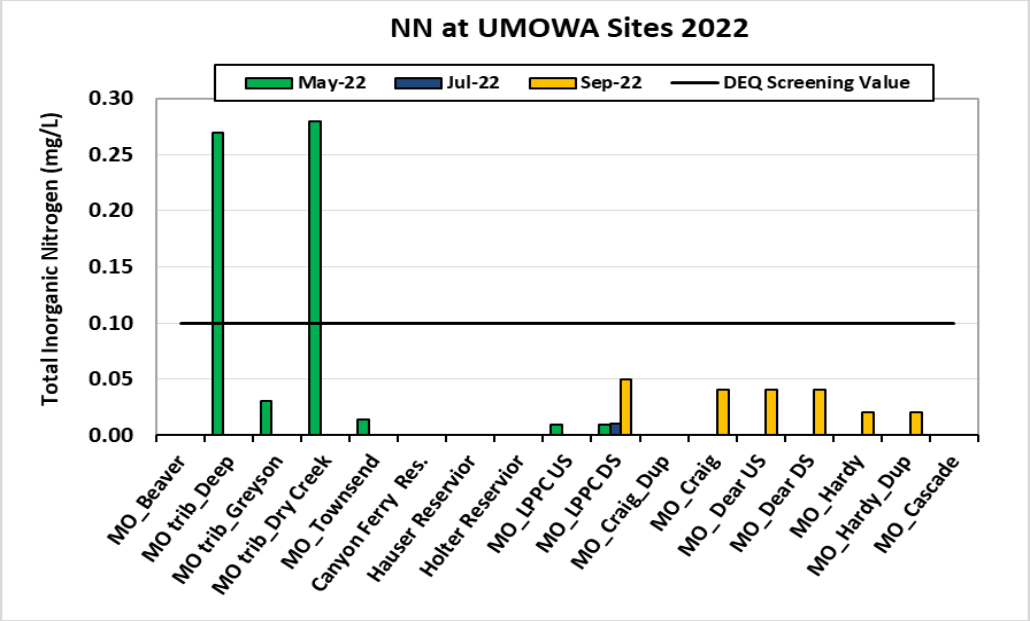


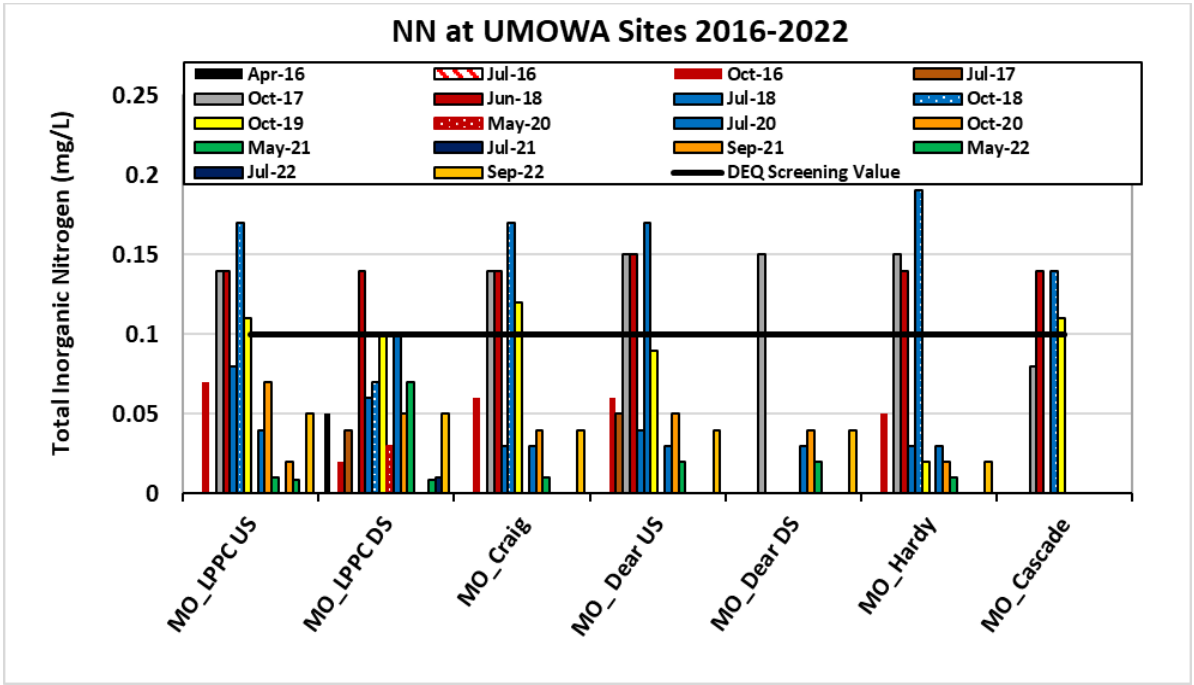


3.3 Inorganic Nitrogen

In 2022, Total Inorganic Nitrogen (NN) concentrations ranged between 0.0 and 0.28 mg/L and averaged 0.02 mg/L across all sites and seasons: with 2 detectable sample levels downstream of Holter Dam in May and July, while in September, all sites downstream of Little Prickly Creek had detectable levels except Cascade. No sites below Holter approached the MDEQ screening value during any season, while upstream of Canyon Ferry, 2 sites had values exceeding this level in May (**Figure 5**). The highest NN values between 2016 and 2022 were reported from samples during the Oct. 2018 sampling and lowest during the May 2020 period where all sites except below Little Prickly Pear and all seasons at Cascade in 2020 reported non-detectable levels (**Figure 5**).

Figure 5. *Total Inorganic Nitrogen (NN) levels across the UMOWA sites in 2022 (top) and 2016-2022 (bottom). Sites arranged upstream to downstream*

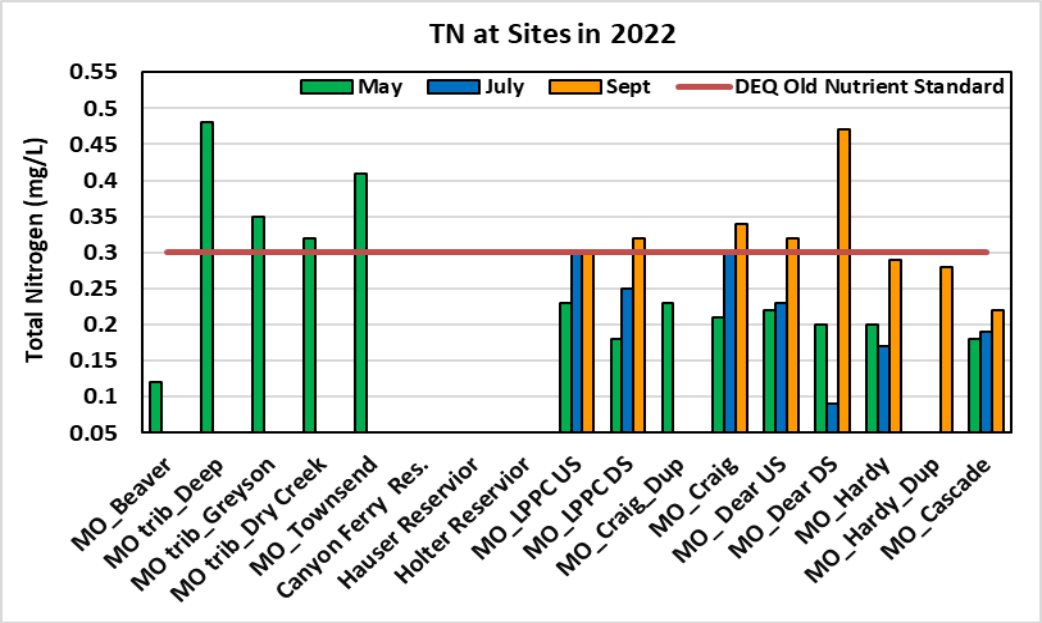




3.4 Total Nitrogen

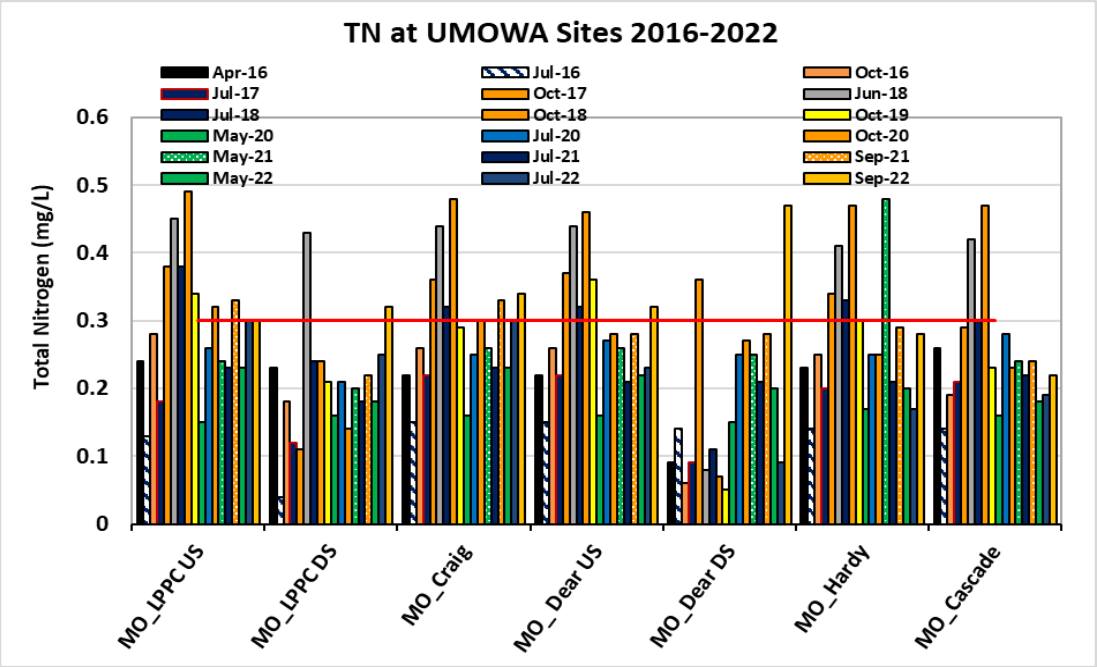
In 2022, Total Nitrogen (TN) concentrations ranged between 0.09 mg/l (MO_DEAR_DS in July) to 0.48 mg/L (MO_trib Deep Creek in May) and averaged 0.26 mg/L (± 0.08 SE) across all sites and seasons; 4 of the 7 sites downstream of Holter exceeded the MDEQ old nutrient standard for wadable streams in September, while upstream of Canyon Ferry 4 of 5 sites exceeded the 0.3 mg/l threshold in May (**Figure 6**). Elevated TN concentrations from Deep, Dry and Greyson Creek tributaries increase the TN concentrations at the mainstem Missouri River near Townsend to levels exceeding 0.3 mg/l (**Figure 6**). Hardy Creek approached but did not exceed the 0.3 mg/l threshold in the Fall 2022 samples while the Cascade site remained well below this level during all seasons (**Figure 6**). The high levels of TN at the Missouri R. downstream of the Dearborn River (MO_DEAR_DS) may reflect insufficient mixing with the mainstem and we are likely sampling almost all Dearborn River water because of the new channel configuration (**Figure 6**).

Figure 6. *Total Nitrogen (TN) levels across the UMOWA sites in 2022. Sites arranged upstream to downstream.*



October 2017 was the 1st sample period of this study where Missouri River samples began exhibiting elevated TN levels and Oct 2018 was the sampling period with the highest concentrations of TN reported over the course of the 7 year study (**Figure 7**). All sites have reported an overall lower TN concentration during the lower annual discharge years of 2019-2022 (**Figure 7**). Two downstream sites (Cascade and Hardy) haven't exceeded TN 'impairment threshold' levels since Oct 2018 (except for May 2021) (**Figure 7**).

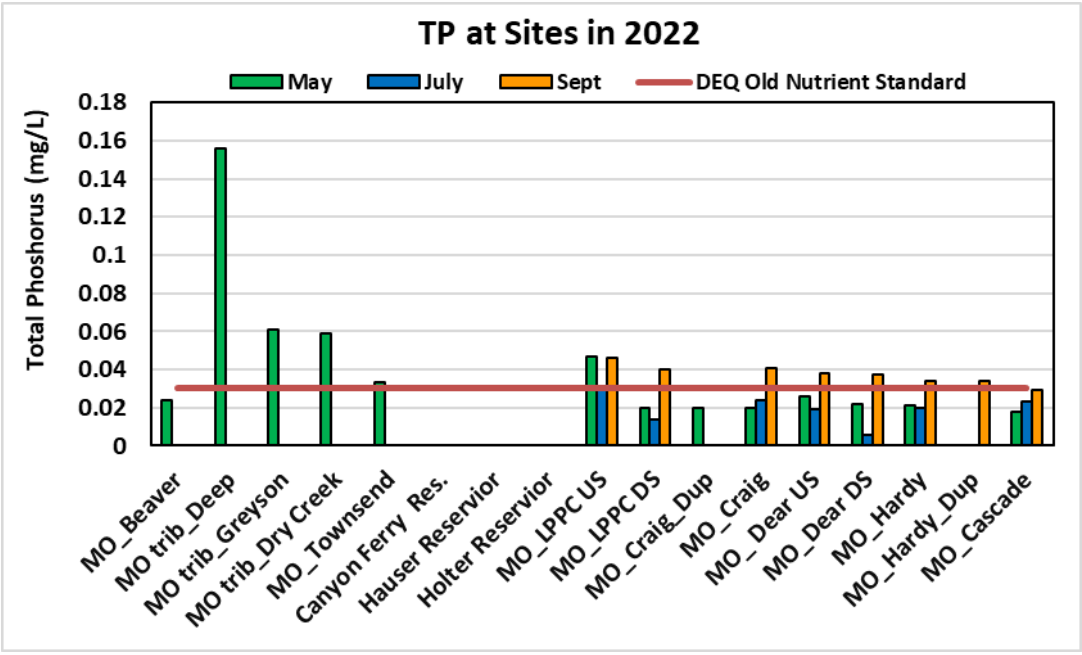
Figure 7. *Total Nitrogen (TN) levels across the UMOWA mainstem sites 2016-2022. Sites arranged upstream to downstream.*



3.5 Total Phosphorus

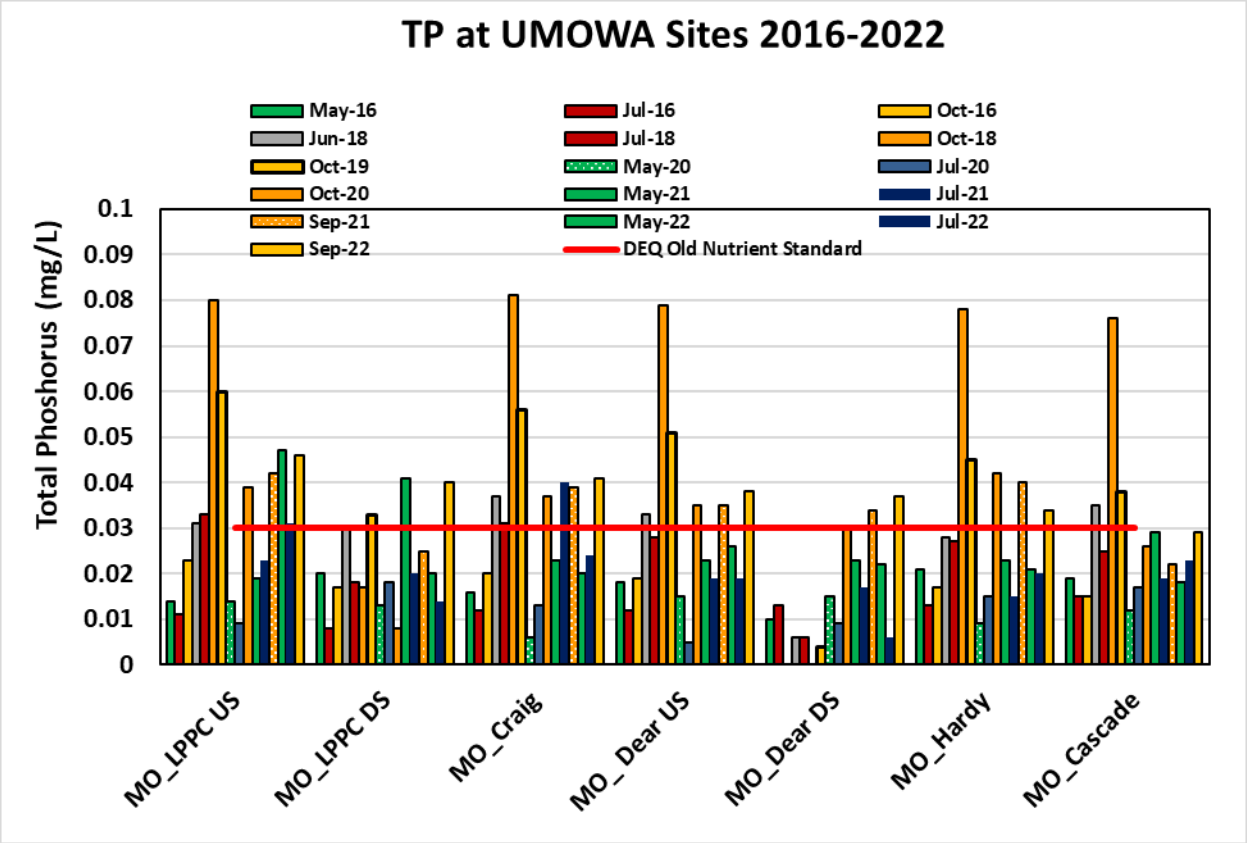
In 2022, Total phosphorus (TP) concentrations ranged between 0.006 (MO_DEAR_DS in July) to 0.156 mg/L (MO_trib Deep Creek in May) and averaged 0.034 mg/L across all sites and seasons; 4 of the 5 sites sampled in upstream of Canyon Ferry (May) and 6 of the 7 sites sampled in late-September (d/s Holter Reservoir) reported values exceeding the MDEQ old nutrient standard threshold (**Figure 8**). In May, Deep Creek reported very elevated TP levels (5x the old nutrient standard) while Greyson and Dry Creek had concentrations 2 times these levels (**Figure 8**).

Figure 8. *Total Phosphorus levels across the UMOWA sites in 2022.*



Elevated TP concentrations exceeding the old MDEQ standard were reported below Holter Res. during all the Fall sampling (Sept/October) 2018 through 2022 at 5 of the 7 total sample sites (**Figure 9**). Cascade is the only mainstem site that hasn't reported a TP value exceeding 0.03 mg/l concentration level since Oct 2019 (**Figure 9**).

Figure 9. *Total Phosphorus levels across the UMOWA sites during 2016-2022.*



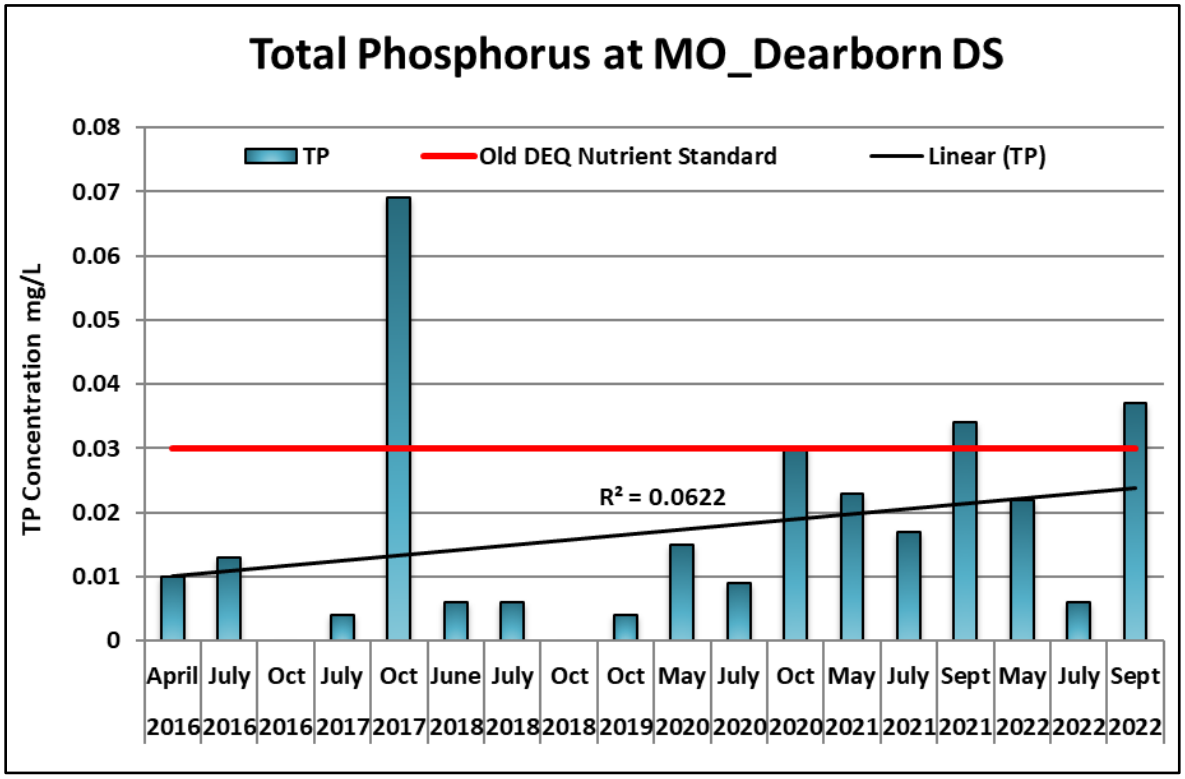
4.0 Discussion

4.1 Spatial Trends

When comparing Missouri River upstream sites closer to Holter Dam to downstream sites, no strong trends were observed for any of the measured WQ parameters in 2022, except below the tributaries where solids and nutrient concentrations tended to be diluted. When nutrient levels were exceeding the old MDEQ numeric nutrient thresholds, they are generally elevated from upstream of Little Prickly Pear Creek (LPPC) all the way downstream to Cascade, usually with only slight decreases in the concentration levels (**Figures 5, 7 & 8**). We see this dilution in 2022 with TP concentrations, where upstream of LPPC is >0.03 mg/l and downstream all to Cascade TP is <0.03 mg/l (**Figure 8**). There were no documented "big spikes or dips" between sites unless a tributary comes in and dilutes levels down for a kilometer or 2 km until full mixing occurs, then

nutrient levels go right back up. There were a couple of notable exceptions: with TN this year (Fall 2022) at MO_DEAR_DS, concentrations jumped from 0.32 upstream to 0.47 mg/l downstream. And the Missouri River samples taken below Little Prickly Pear Creek and the Dearborn River reported reduced nutrient levels below MDEQ nutrient standards in all seasons, except June 2018 and Oct 2017. During October 2016, 2018, 2019 and July of 2022, the MO_DEAR_DS site yielded exceptionally low and/or non-detectable TP concentrations (**Figure 9 & 10**). Although, concentrations of all three nutrient parameters (NN, TN and TP) are increasing in the Missouri River below the Dearborn site (MO_DEAR_DS) since 2019 indicating that declining Dearborn River flows are offering less of a dilution effect (**Figure 10**). The high TN and TP concentrations that we documented in some of the tributaries upstream of Canyon Ferry Reservoir in 2021 and 2022 are elevating readings 'locally' in the Missouri River but are likely being utilized within the reservoir and are not spiraling downstream to our sites below Holter Reservoir (**Figure 8**).

Figure 10. *Total Phosphorus levels at the Missouri d/s of the Dearborn River from 2016-2022.*



4.2 Seasonal Trends

Total dissolved solids (TDS) concentrations were the highest ever reported in May 2022 for six of the seven sites; only the Missouri River at Cascade reported levels in the spring similar to the previous years (**Figure 4**). This is likely due to early run-off from LPPC and some dilution effects, but this was not seen below the Dearborn River. The Missouri River below LPPC reported a high spike in TSS in May of 2020 and 2021. It is unclear as to what extent natural and anthropogenic sources (fertilizers, pesticides, etc.) are contributing to elevated TDS concentrations during the

June run-off period (Total Nitrogen is also very elevated during this period). But elevated readings of TDS were also reported at all sites in Fall of 2019, especially below the tributaries. Overall, in 2022, nutrient levels were greater in September than in May or July; TP was significantly higher in September than May (T-test, p=0.001) or July (T-test, p=0.025). Total nitrogen, and total phosphorus concentrations increased between July and September for six of the seven sites (the one exception was the TP levels at MO_CRAIG as described in 4.1).

4.3 Yearly Trends

Total dissolved solids (TDS) concentrations have been higher in 2022, 2021 and 2020 than reported in 2016-2019 (**Figure 4**). This could be related to lower discharge and the concentrating effect of lower river volumes (**Figure 2, Appendix A**). TSS concentrations reached their highest levels in May 2020 and 2021, but they were similar between Fall 2018 and 2019. TSS concentrations were zero (i.e., at non detectable levels) at all sites between July 2016 and October 2017, except at the Cascade site, which exhibited moderate concentrations during July of all years. TSS concentrations has been correlated with or a contributor to higher nutrient levels. The TP levels have been steadily increasing across the years (since the large spike of Oct 2017) at the Missouri d/s of the Dearborn River, the last 3 years (2020-2022) the Fall TP concentrations have been increasing above the 0.03mg/l old impairment threshold (**Figure 10**).

5.0 Conclusions

This water quality study has established a comprehensive baseline dataset in the upper Missouri River over seven different water discharge years (2016-2022) and has elucidated several spatial and temporal trends. The 2022 water quality downstream of Holter Reservoir has been trending towards lower nutrient concentrations (TN, TP, and NN) across all seasons compared to October 2017-2019 when the overwhelming trends observed were substantial increases in inorganic nitrogen (NN), total nitrogen (TN), and total phosphorus (TP) concentrations to levels exceeding old MDEQ nutrient standards (UMOWA 2021). Nutrient exceedances in 2018 and 2019 were reported from the furthest upstream site all the way down to Cascade, except at sites below the tributaries, Little Prickly Pear Creek and the Dearborn River were somewhat insulated from these increasing nutrient trends, but some seasonal increases are being documented (MO_DEAR_DS).

During September 2022 sampling, 4 and 6 of the 7 long-term sites exceeded the old MDEQ nutrient standard values for TN and TP concentrations, respectively. Zero sites exceeded the MDEQ recommended screening value for NN. It appears that TN levels have declined in 2020 and 2021 after nutrient concentrations exceeding the MDEQ nutrient standards and screening values, across most sites, have occurred during the Fall sampling of 2017, 2018 and 2019. Warmer September temperatures and lower discharge in 2020 and 2021 with numerous sunny days may be one explanation for lower TN levels, as a longer growing season means that aquatic plants would be utilizing more nutrients than they would if water temperatures had dropped earlier in autumn.

Although we have observed fewer nutrient levels in 2022 (TN, NN) with concentrations exceeding the recommended levels set by MDEQ, elevated TP levels at 6 of the 7 sites in the fall is still a cause for concern. Higher nutrient levels are causally linked to the excessive aquatic plant and algae growth and are among the biggest threats that the Upper Missouri River is currently facing. In terms of nutrients and aquatic plant growth, weed growth in 2021 and 2022 may not have exploded as one might have expected with the low steady flows and warm temperatures. Due to UMOWA's water quality collections, we have a pretty good explanation for why this is the case; nutrient levels, particularly total phosphorus (TP), were lower downstream of Holter Dam than in previous years. Lower mean discharge and no flushing flows in 2021 did not provide the lower Missouri River below Canyon Ferry with a large nutrient pulse as occurred in 2017-2020. The Missouri River upstream of Canyon Ferry still exceeded the old MDEQ nutrient thresholds for both Total Nitrogen (TN) and TP in May (2022) and July (2021), but these nutrients are being utilized within the reservoir. The tributaries contributing these excess nutrients are Deep, Dry and Greyson Creeks for all three nutrients--NN, TN, TP, with Deep Creek the biggest contributor of TP with over 5 times the concentration that was historically 'allowed' by MDEQ. It is critical that UMOWA continue to monitor water quality parameters in 2023 to see if these nutrient concentrations continue to reach old impairment levels. Additionally, focused watershed BMP measures (riparian vegetation buffers, cattle fencing, etc.) should be evaluated for tributaries upstream of Canyon Ferry to alleviate non-point source nutrient additions to the ecosystem.

6.0 References

MDEQ 2020. Appendix A: Impaired Waters. (2020). Available at: http://deq.mt.gov/Portals/Impaired Waters2020

Montana DEQ 2014. Planning Prevention and Assistance Division, Water Quality Planning Bureau, Water Quality Standards Section. 2014. DEQ Circular-12A Montana Base Numeric Nutrient Standards. Helena, MT: Montana Dept. of Environmental Quality.

Stagliano, D. 2015. UMOWA Baseline Macroinvertebrate Monitoring Report 2015 for the Upper Missouri River, MT. Report to the Upper Missouri River Alliance.

Stagliano, D. 2018. UMOWA Baseline Summary Macroinvertebrate Monitoring Report for 2015-2017 for the Upper Missouri River, MT. Report to the Upper Missouri River Alliance.

UMOWA 2022. Baseline Water Quality Report 2021 for the Upper Missouri River, MT. Report to the Upper Missouri River Alliance and MDEQ. Prepared by D. Stagliano, MBS.

UMOWA 2021. Baseline Water Quality Report 2020 for the Upper Missouri River, MT. Report to the Upper Missouri River Alliance and MDEQ. Prepared by D. Stagliano, MBS.

APPENDIX A. WATER QUALITY RAW DATA FROM 2016-2022

Appendix A. Sites Highlighted in yellow are in exceedance of the old DEQ nutrient standards for wadable streams (prior to 2021).

Sample Site	Year	Sample Period	TDS (mg/L)	TSS (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
MO_LPPC_US	2016	April	NA	0	0	0.24	0.014
MO_LPPC_DS	2016	April	NA	14	0.05	0.23	0.02
MO_Craig	2016	April	NA	4	0	0.22	0.016
MO_Dearborn US	2016	April	NA	4	0	0.22	0.018
MO_Dearborn DS	2016	April	NA	7	0	0.09	0.01
MO_Hardy Creek	2016	April	NA	5	0	0.23	0.021
MO_Cascade	2016	April	NA	8	0	0.26	0.019
MO_LPPC_US	2016	July	NA	0	0	0.13	0.011
MO_LPPC_DS	2016	July	NA	0	0	0.04	0.008
MO_Craig	2016	July	NA	0	0	0.15	0.012
MO_Dearborn US	2016	July	NA	0	0	0.15	0.012
MO_Dearborn DS	2016	July	NA	0	0	0.14	0.013
MO_Hardy Creek	2016	July	NA	0	0	0.14	0.013
MO_Cascade	2016	July	NA	5	0	0.14	0.015
MO_LPPC_US	2016	October	NA	0	0.07	0.28	0.023
MO_LPPC_DS	2016	October	NA	0	0.02	0.18	0.017
MO_Craig	2016	October	NA	0	0.06	0.26	0.02
MO_Dearborn US	2016	October	NA	0	0.06	0.26	0.019
MO_Dearborn DS	2016	October	NA	0	0	0.06	0
MO_Hardy Creek	2016	October	NA	0	0.05	0.25	0.017
MO_Cascade	2016	October	NA	0	0	0.19	0.015
MO_LPPC US	2017	July	216	0	0	0.18	0.013
MO_LPPC DS	2017	July	197	0	0.04	0.12	0.016
MO_Craig	2017	July	207	0	0	0.22	0.012
MO_Dearborn US	2017	July	202	0	0.05	0.22	0.012
MO_Dearborn DS	2017	July	187	0	0	0.09	0.004
MO_Hardy Creek	2017	July	208	0	0	0.2	0.012
MO_Cascade	2017	July	206	4	0	0.21	0.014
MO_LPPC US	2017	October	197	0	0.14	**0.38**	**0.068**
MO_LPPC DS	2017	October	203	0	0	0.11	0.016
MO_Craig	2017	October	195	0	0.14	**0.36**	**0.068**
MO_Dearborn US	2017	October	194	0	0.15	**0.37**	**0.067**
MO_Dearborn DS	2017	October	191	0	0.15	**0.36**	**0.069**
MO_Hardy Creek	2017	October	190	0	0.15	**0.34**	**0.063**
MO_Cascade	2017	October	193	0	0.08	0.29	**0.055**

Appendix A. Continued.

Sample Site	Year	Sample Time	TDS (mg/L)	TSS (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
MO_LPPC US	2018	June	203	6	0.14	**0.45**	**0.031**
MO_LPPC DS	2018	June	202	2.4	0.14	**0.43**	**0.03**
MO_Craig	2018	June	206	10	0.14	**0.44**	**0.037**
MO_Dearborn US	2018	June	204	6	0.15	**0.44**	**0.033**
MO_Dearborn DS	2018	June	166	6	0	0.08	0.006
MO_Hardy Creek	2018	June	204	7	0.14	**0.41**	0.028
MO_Cascade	2018	June	206	9	0.14	**0.42**	**0.035**
MO_LPPC US	2018	July	177	1.2	0.08	**0.38**	**0.033**
MO_LPPC DS	2018	July	198	2.8	0.06	0.24	0.018
MO_Craig	2018	July	173	1.6	0.03	**0.32**	**0.031**
MO_Dearborn US	2018	July	163	1.6	0.04	**0.32**	0.028
MO_Dearborn DS	2018	July	192	0.8	0	0.11	0.006
MO_Hardy Creek	2018	July	167	1.2	0.03	**0.33**	0.027
MO_Cascade	2018	July	168	4	0	0.3	0.025
MO_LPPC US	2018	October	179	2.4	0.17	**0.49**	**0.08**
MO_LPPC DS	2018	October	208	2.4	0.07	0.24	0.017
MO_Craig	2018	October	181	2.8	0.17	**0.48**	**0.081**
MO_Dearborn US	2018	October	177	1.2	0.17	**0.46**	**0.079**
MO_Dearborn DS	2018	October	205	0.8	0	0.07	0
MO_Hardy Creek	2018	October	179	2	0.19	**0.47**	**0.078**
MO_Cascade	2018	October	180	1.2	0.14	**0.47**	**0.076**
MO_LPPC US	2019	October	206	2.8	0.11	**0.34**	0.06
MO_LPPC DS	2019	October	220	1.6	0.1	0.21	**0.033**
MO_Craig	2019	October	209	2	0.12	0.29	**0.056**
MO_Dearborn US	2019	October	207	0.8	0.09	**0.36**	**0.051**
MO_Dearborn DS	2019	October	217	1.2	0	0.05	0.004
MO_Hardy Creek	2019	October	203	0.8	0.02	0.3	**0.045**
MO_Cascade	2019	October	203	1.2	0.11	0.23	**0.038**
MO_LPPC US	2020	May	222	2.0	0	0.15	0.014
MO_LPPC DS	2020	May	145	16.0	0.03	0.16	0.013
MO_Craig	2020	May	223	2.0	0	0.16	0.006
MO_Dearborn US	2020	May	211	4.0	0	0.16	0.015
MO_Dearborn DS	2020	May	215	4.0	0	0.15	0.015
MO_Hardy Creek	2020	May	217	0.0	0	0.17	0.009
MO_Cascade	2020	May	218	15.0	0	0.16	0.012
MO_LPPC US	2020	July	211	0.0	0.04	0.26	0.009
MO_LPPC DS	2020	July	195	1.0	0.10	0.21	0.018
MO_Craig	2020	July	210	0.0	0.03	0.25	0.013
MO_Dearborn US	2020	**July**	202	4.0	0.03	0.27	0.005
MO_Dearborn DS	2020	**July**	204	2.0	0.03	0.25	0.009
MO_Hardy Creek	2020	**July**	208	0.0	0.03	0.25	0.015
MO_Cascade	2020	**July**	207	4.0	0	0.28	0.017
MO_LPPC US	2020	October	189	2	0.07	**0.32**	**0.039**
MO_LPPC DS	2020	October	214	3	0.05	0.14	0.008
MO_Craig	2020	October	193	3	0.04	0.3	**0.037**
MO_Dearborn US	2020	October	185	2	0.05	0.28	**0.035**
MO_Dearborn DS	2020	October	187	1	0.04	0.27	0.03
MO_Hardy Creek	2020	October	186	0	0.02	0.25	**0.042**
MO_Cascade	2020	October	185	1	0	0.23	0.026

Appendix A. Continued

Sample Site	Year	Sample Period	TDS (mg/L)	TSS (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
MO_LPPC US	2021	May	235	2.9	0.01	0.24	0.019
MO_LPPC DS	2021	May	143	26.0	0.07	0.2	**0.041**
MO_upstream Craig	2021	May	237	3.8	0.01	0.26	0.023
MO_Dearborn US	2021	May	223	4.0	0.02	0.26	0.023
MO_Dearborn DS	2021	May	215	6.0	0.02	0.25	0.023
MO_Hardy Creek	2021	May	219	5.0	0.01	**0.48**	0.023
MO_Cascade	2021	May	222	7.0	ND	0.24	0.029
MO_LPPC US	2021	July	224	2.9	ND	0.23	0.023
MO_LPPC DS	2021	July	219	1.6	ND	0.18	0.02
MO_upstream Craig	2021	July	230	5	ND	0.23	**0.04**
MO_Dearborn US	2021	July	225	1.5	ND	0.21	0.019
MO_Dearborn DS	2021	July	232	1.6	ND	0.21	0.017
MO_Hardy Creek	2021	July	229	1.8	ND	0.21	0.015
MO_Cascade	2021	July	222	2.1	ND	0.22	0.019
MO_LPPC US	2021	Sept	228	5	0.02	**0.33**	**0.042**
MO_LPPC DS	2021	Sept	217	4	0.02	0.22	0.025
MO_upstream Craig	2021	Sept	227	3.5	ND	**0.33**	**0.039**
MO_Dearborn US	2021	Sept	229	2.9	ND	0.28	**0.035**
MO_Dearborn DS	2021	Sept	228	3.0	ND	0.28	**0.034**
MO_Hardy Creek	2021	Sept	226	6	ND	0.29	0.040
MO_Cascade	2021	Sept	230	1.9	ND	0.24	0.022
		Hauser Reservior			**Holter Reservior**		
PPC trip_Spring Creek	2021	July	508	8	0.18	**0.31**	**0.045**
			Canyon Ferry Reservior				
MO trib_Sixteenmile Cr.	2021	July	292	8	ND	0.21	0.012
MO trib_Big Springs Ditch	2021	July	248	5	**0.25**	**0.32**	0.021
MO trib_Dry Creek	2021	July	215	**15**	**0.15**	**0.57**	**0.056**
MO trib_Greyson Cr.	2021	July	196	**104**	0.01	**0.41**	**0.157**
MO trib_Deep Cr.	2021	July	219	**33**	ND	0.20	**0.041**
MO_Townsend	2021	July	210	9	0.07	**0.35**	**0.04**
MO trib_Magpie Cr.	2021	July	426	**16**	ND	0.07	0.013

Appendix A. Continued.

Sample Site	Year	Sample Period	TDS (mg/L)	TSS (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
MO_LPPC US	2022	May	243	5.0	0.009	0.23	**0.047**
MO_LPPC DS	2022	May	225	6.0	0.009	0.18	0.02
MO_Craig	2022	May	247	3.9	ND	0.23	0.02
MO_Craig_DUP	2022	May	248	4.0	ND	0.21	0.02
MO_Dearborn US	2022	May	245	6.0	ND	0.22	0.026
MO_Dearborn DS	2022	May	246	5.0	ND	0.2	0.022
MO_Hardy Creek	2022	May	247	3.9	ND	0.2	0.021
MO_Cascade	2022	May	230	3.3	ND	0.18	0.018
MO_Beaver	2022	May	54	3.0	ND	0.12	0.024
MO_Deep	2022	May	195	**161.0**	**0.27**	**0.48**	**0.156**
MO_Greyson	2022	May	234	**37.0**	0.03	**0.35**	**0.061**
MO_Dry	2022	May	262	**56.0**	**0.28**	**0.32**	**0.059**
MO_TOWNSEND	2022	May	240	17.0	0.014	**0.41**	**0.033**
MO_LPPC US	2022	July	216	1.8	ND	0.3	**0.031**
MO_LPPC DS	2022	July	193	1.1	0.01	0.25	0.014
MO_upstream Craig	2022	July	222	0.8	ND	0.3	0.024
MO_Dearborn US	2022	July	222	1.7	ND	0.23	0.019
MO_Dearborn DS	2022	July	163	1.3	ND	0.09	0.006
MO_Hardy Creek	2022	July	224	2.3	ND	0.17	0.02
MO_Cascade	2022	July	224	5	ND	0.19	0.023
MO_LPPC US	2022	Sept	210	3.9	0.05	**0.3**	**0.046**
MO_LPPC DS	2022	Sept	207	2.9	0.05	**0.32**	**0.04**
MO_upstream Craig	2022	Sept	211	2.9	0.04	**0.34**	**0.041**
MO_Dearborn US	2022	Sept	208	3.2	0.04	**0.32**	**0.038**
MO_Dearborn DS	2022	Sept	211	3.1	0.04	**0.47**	**0.037**
MO_Hardy Creek	2022	Sept	210	3	0.02	0.29	**0.034**
MO_Hardy Creek_DUP	2022	Sept	211	3	0.02	0.28	**0.034**
MO_Cascade	2022	Sept	207	2.6	ND	0.22	0.029