



Clark Fork River Nutrient Water Quality Status and Trends Report, 1998–2022



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EXECUTIVE SUMMARY

This Nutrient Water Quality Status and Trends Report for the Clark Fork River was completed for the Clark Fork River Water Quality Monitoring Committee (CFRWQMC) under contract with Montana Department of Environmental Quality (DEQ) and Avista. This report presents an analysis of the latest dataset, including the fifth five-year monitoring period and twenty-five years of nutrient monitoring in the basin spanning the years 1998–2022. The report provides background and details of the monitoring program and summarizes nutrient reduction activities that have taken place in the Clark Fork River basin of Montana in recent years. The primary purpose of this report is to address the following Clark Fork River water quality monitoring program objectives:

1. Evaluate time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries,
2. Evaluate time trends for benthic algae chlorophyll-*a* in the Clark Fork River,
3. Monitor compliance with established summer nutrient and benthic algae chlorophyll-*a* target levels in the Clark Fork River, and
4. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River.

Additionally, this report summarizes efforts in the Clark Fork River basin in Montana to reduce point source and nonpoint source nutrient loading to the Clark Fork River and its tributaries.

The time trends analysis for nutrient constituents was conducted on data from 12 long-term monitoring stations in the Clark Fork River basin extending from the headwaters at the Clark Fork River confluence with Silver Bow Creek to the Clark Fork River below Cabinet Gorge Dam. Nutrients evaluated include total nitrogen as N (TN), total soluble inorganic nitrogen as N (TSIN), total phosphorus as P (TP), and soluble reactive phosphorus as P (SRP). The time trends analysis for benthic algae included seven monitoring stations in the upper and middle Clark Fork River, extending from the Clark Fork River at Deer Lodge, to the Clark Fork River above the Flathead River. Time trends analysis for benthic algae evaluated mean and maximum benthic chlorophyll-*a*. The analyses were completed for the summer season months of July, August, and September from data collected between 1998–2022.

Before conducting the time trend analysis and loading evaluation, data reduction activities were completed for the DEQ-provided dataset and the data were reviewed for quality control purposes. Additionally, nutrient concentration data were regressed against flow utilizing a Local Polynomial Regression (LOESS) method to remove variation in concentration related to stream discharge. A two-sided nonparametric Mann-Kendall trend test (significance level = 0.1) was then used to evaluate trends in the LOESS residuals for each site-parameter combination, which is consistent with past project methodology and accepted statistical methods. TN, TSIN, TP, and SRP were evaluated with the Seasonal Mann-Kendall test and chlorophyll-*a* trends were evaluated using the Mann-Kendall test.

This report also assesses exceedance rates from State of Montana numeric nutrient water quality standards for Clark Fork River monitoring stations in the upper and middle Clark Fork River. Exceedance

of numeric nutrient standards for the Clark Fork River were evaluated and compared over three time periods: 1998 to 2007, 2008 to 2017, and 2018 to 2022.

Additionally, nutrient loading estimates for TP and TN were estimated and compiled for the Clark Fork River into Lake Pend Oreille with March–November data from monitoring Station CFR-30, Clark Fork River below Cabinet Gorge Dam, in Idaho, from 1998–2022. Nutrient loadings were evaluated using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (version 3.10).

The 1998–2022 Clark Fork River nutrient and chlorophyll-*a* time trends analysis detected 29 statistically significant decreasing trends and two statistically significant increasing trends among the 62 site-parameter combinations analyzed. Findings of the time trends analysis are tabulated, summarized, and displayed graphically in Section 6 and **Attachment C** of this report.

The following are conclusions based on the results presented in this report:

1. Over the 1998–2022 evaluation period, SRP, TN, and TSIN exhibited statistically significant decreasing trends at about 42% of monitored sites. Between 50 and 60% of sites had no significant trends detected and only 15% had statistically significant increasing trends for these parameters.
2. TP stands out (as it did in 2017) for having the most sites exhibiting statistically significant decreasing trends (eight sites). No statistically significant increasing TP trends were identified, and only four sites had no statistically significant trend detected.
3. By site, CFR-18 (below Missoula) and CFR-22 (at Huson) had the most decreasing nutrient trends, with statistically significant decreasing trends for all four nutrient parameters. CFR-12 (at Bonita) had three statistically significant decreasing trends, whereas the remaining sites all had one or two statistically significant decreasing nutrient trends (except CFR-25, which had none).
4. A total of four statistically significant decreasing benthic chlorophyll-*a* trends were identified (two for mean and two for maximum) among the seven stations for which these concentrations were calculated. No statistically significant increasing trends were identified. Compared to the previous trend analysis (1998–2017), there were a total of three fewer decreasing trends. The number of decreasing trends on the middle reach is notably lower in the 2022 dataset compared to the 2017 dataset, whereas the number of decreasing trends remained constant on the upper reach over the same period.
5. Only two statistically significant increasing trends were identified among all monitored parameters, one at CFR-25 (TSIN) and one at CFR-28 (TN). The CFR-25 trend is potentially an artifact of a short-lived spike in TSIN that occurred from approximately 2016 to 2018 and may not be representative of an actual long-term trend. However, the CFR-28 trend appears to be a real upward trend as confirmed by visual evaluation of time series data. The reason for the upward TN trend at CFR-28 is not clear but could be related to non-point source nutrient loading associated with population growth along the Clark Fork River and in the Flathead watershed, or potential changes in nutrient loading and cycling in Thompson Falls Reservoir.
6. Analysis of the current dataset found that previously identified increasing TP and SRP trends at station CFR-2.5 are no longer statistically significant.
7. Spatially, decreasing trends in the 2022 dataset are most heavily concentrated in the upper and middle reaches of the Clark Fork River, with fewer decreasing trends identified in the lower reach.

8. Factors contributing to decreasing trends in the upper and middle reaches of the Clark Fork River are likely to include upgrades to the City of Deer Lodge’s wastewater treatment system between 2017 and 2022 and continuing positive effects of previously completed improvements to the City of Butte and City of Missoula wastewater treatment systems. Continuing non-point source reduction activities are also likely to be a contributing factor.
9. Numeric nutrient standard exceedance rates for TN are relatively low, with most samples collected during the 2018–2022 period being below the standard. The exception is at CFR-2.5 with a TN standard exceedance rate of 74% during the 2018–2022 period, which is down 26% from the 1998–2007 baseline period. Exceedance rates for TP and chlorophyll-*a* are also relatively low on the middle reach. However, exceedance rates remain high for TP and chlorophyll-*a* on the upper reach, where many samples from 2018–2022 remained elevated above standards. High exceedance rates on the upper reach are consistent with historical issues and could also be related to increased housing development trends in this area.
10. Change in the rate of numeric nutrient standard exceedances between 1998–2007 and 2018–2022 was variable among monitored parameters. TN exhibited a 22–44% decrease in the rate of exceedances at all but one of the stations evaluated (CFR-25, +2%), whereas TP exceedance rates changed by -14 to +10% at the stations evaluated. The majority of chlorophyll-*a* mean and maximum exceedance rates decreased by about 10–70%, although two middle reach stations saw a 10% increase in chlorophyll-*a* maximum exceedance rates. Overall, changes in exceedance rates do not consistently track with changes in statistical trends.
11. Nutrient loading from the Clark Fork River to Lake Pend Oreille varies from year to year and is proportional to the volume of inflow from the watershed. Generally, in years when inflow greater than the annual average, the TP load exceeds the allocated target load of 259,500 kilograms per year of Montana-Idaho Border Agreement. The estimated TP load exceeded the allocated target load six times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012, 2014, and 2018 but there has been no short-term TP load exceedance during the monitoring period.

The following recommendations are made to the CFRWQMC to further assess nutrient water quality status in future studies or as part of the next 5-year trends analysis:

1. Basin-wide nutrient water quality monitoring should continue into the future so that cumulative, long-term impacts of nutrient reduction activities can be evaluated. The nutrient water quality monitoring program should continue to regularly assess the status and trends of water quality in the Clark Fork River basin so that planners and managers may better direct and focus nutrient reduction efforts in the Clark Fork River basin.
2. Consider application of piecewise trend analysis to the dataset or testing for trends over different periods within the overall project dataset. For instance, trends could be evaluated separately for 1998–2008 (early project period with different data collection methods and fewer nutrient reduction activities) and the period after 2008 when data collection was more standardized and nutrient reduction activities were underway. Comparing the early and late period trends could provide better insight into the efficacy of nutrient reduction activities.
3. Compile and tabulate basin-wide nutrient loads from permitted point sources and estimates of non-point source contributions.
4. Estimate summer and/or annual nutrient loads at select stations in the upper and middle river.
5. Review and evaluate stream discharge changes and other hydrologic factors and assess their potential effect on nutrient and chlorophyll-*a* levels.

6. Assess changes in nitrogen to phosphorus ratios at select monitoring stations throughout the river.
7. Summarize available summertime temperature and dissolved oxygen data since these parameters interact with algae levels to affect habitat quality. Where little data exist, add some stations with temperature and dissolved oxygen monitors.
8. Collaborate with the Idaho Department of Environmental Quality to evaluate effects of estimated annual nutrient loading to Lake Pend Oreille on water quality in the lake.

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 - Electronic Report Files and Maps

ACRONYMS

AFDM	Ash-free Dry Mass
ARM	Administrative Rules of Montana
BNR	Biological Nutrient Removal
°C	Celsius
CFRWQMC	Clark Fork River Water Quality Monitoring Committee
cfs	Cubic feet per second
DEQ	Montana Department of Environmental Quality
DO	Dissolved Oxygen
DQI	Data quality indicators
DQO	Data quality objectives
EDD	Electronic Data Deliverable
EPA	Environmental Protection Agency (U.S.)
g/m ²	Grams per square meter
hm ³ /year	Cubic hectometers per year
IDEQ	Idaho Department of Environmental Quality
LOWESS	Locally Weighted Scatterplot Smoothing
MDL	Method Detection Limit
mg/L	Milligrams per liter
mg/m ²	Milligrams per square meter
mg/m ³	milligrams per cubic meter
MT-eWQX	Montana EQUIS Water Quality Exchange
mV	Millivolts
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RC	Result Condition
SAP	Sampling and Analysis Plan
SC	Specific Conductance
SRP	Soluble Reactive Phosphorus
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPN	Total Persulfate Nitrogen
TSIN	Total Soluble Inorganic Nitrogen
µg/L	Micrograms per liter
µS/cm	MicroSiemens per centimeter
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
VNRP	Voluntary Nutrient Reduction Program

1.0 INTRODUCTION

This Nutrient Water Quality Status and Trends Report for the Clark Fork River is a joint effort sponsored by the Montana Department of Environmental Quality (DEQ) and Avista. The report has been prepared on behalf of the Clark Fork River Water Quality Monitoring Committee (CFRWQMC) to evaluate the completion of the fifth five-year nutrient water quality monitoring period over 25 years of nutrient monitoring in the Clark Fork River basin by the program for the years 1998–2022. The CFRWQMC is currently managed by DEQ and includes as members Idaho Department of Environmental Quality (IDEQ), Avista, City of Missoula, and the University of Montana. A map of the project area and monitoring locations is included as **Attachment A**.

This report is the result of decades of collaboration between public, private, and nonprofit entities working together to reduce nutrient impacts to the Clark Fork River and to methodically monitor the progress. A comprehensive Clark Fork River basin-wide nutrient water quality monitoring program was started in 1998 and continues today under the direction of the CFRWQMC. The nutrient water quality monitoring program was established by the Clark Fork-Pend Oreille Basin Management Plan (Basin Management Plan; EPA 1993), which was prepared by the states of Montana, Idaho, and Washington, in conjunction with the U.S. Environmental Protection Agency (EPA) Regions 8 and 10. The Basin Management Plan was based on studies mandated by U.S. Congress because of citizen concerns regarding increased aquatic weeds and algae in the Clark Fork River and Pend Oreille Lake.

The Basin Management Plan was adopted in 1993 and was last updated in 2007. The plan focuses efforts on controlling eutrophication and associated water use impairments that were identified as the most important interstate water quality problems. The goal of the Basin Management Plan is to restore and protect designated beneficial water uses. The Basin Management Plan further identifies water quality objectives and emerging new water quality challenges.

To that end, this report is intended to meet priority water quality monitoring program objectives including:

1. Evaluate time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributary streams,
2. Evaluate time trends for benthic algae chlorophyll-*a* in the Clark Fork River,
3. Monitor compliance with established summer nutrient and benthic algae chlorophyll-*a* target levels in the Clark Fork River,
4. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River.

Additionally, this report provides a summary of recent and ongoing nutrient point source and non-point source reduction activities in the Clark Fork River basin in Montana.

The time trends analysis for nutrient constituents was conducted on monitoring program data collected during 1998–2022 from 12 long-term monitoring stations in the Clark Fork River basin, extending from the river's headwaters at Silver Bow Creek to the Clark Fork River below Cabinet Gorge Dam. The time trends analysis was completed for the summer season months of July, August, and September.

Project sponsors DEQ and Avista contracted with HydroSolutions Inc (HydroSolutions) to complete this Nutrient Water Quality Status and Trends Report for the Clark Fork River. Work was authorized under DEQ contract number 224049, signed on June 25, 2024, and Avista contract number R-43494 Work Authorization No. 3 signed on April 12, 2022.

2.0 BACKGROUND

The Clark Fork River drains about 22,000 square miles including most of Montana west of the Continental Divide. The Clark Fork River is a vital resource and critical lifeline for human and aquatic communities living in its basin. According to the 2020 US Census, the Clark Fork River basin in Montana has a population of about 369,000 people. The basin contains 334 named streams with a total of over 5,200 miles in stream length, has five major dams, and supports over 350,000 irrigated acres (USGS 2015). The Clark Fork River has long-term average annual flow of almost 22,000 cubic feet per second (cfs) leaving Montana (USGS 2025). The Clark Fork River provides water to support a wide array of beneficial uses, including drinking water, irrigation, industry, hydro-electric power generation, and recreation. It also supports a diverse assemblage of aquatic life including several threatened and endangered species.

The upper Clark Fork River from headwaters to the former Milltown Dam has undergone major restoration and cleanup efforts to remove contaminated heavy metals sediments that washed downstream from mine tailings. EPA Superfund Program, DEQ and the Montana Natural Resource Damage Program have undertaken large scale restoration efforts in the upper Clark Fork River to restore streambeds, streambanks, and the floodplain. For these many reasons the Clark Fork River is considered a critical resource that multiple citizen and watershed groups, businesses, municipalities, and state and federal agencies work together to monitor, protect, and improve.

2.1 HISTORY

The current monitoring program on the Clark Fork River is a continuation of a program that was initially developed in 1998 by the Tri-State Water Quality Council (Council). The Council was established in 1993 as a partnership of citizens, businesses, industry, tribes, government, and environmental groups with the goal of collaboratively addressing the problem of excess nutrients and algae, as identified in the Basin Management Plan (EPA 1993). One of the first tasks of the Council was to create a Monitoring Committee to oversee and implement a long-term, basin-wide monitoring strategy. The monitoring program was started in 1998 and continues today. The Council disbanded in 2012 and DEQ assumed the overall responsibility for administering the monitoring program in the Clark Fork basin in Montana. Today, former members of the Council, including DEQ, Avista, City of Missoula, University of Montana, and IDEQ collaborate as the CFRWQMC and continue monitoring and data collection efforts for the Clark Fork River.

Currently, DEQ manages the CFRWQMC water quality monitoring program in Montana. In addition, Avista's Water Resources Technical Advisory Committee (WRTAC) serves in an advisory capacity. WRTAC is a subcommittee that was formed during the relicensing process in 1999 to advise the Clark Fork Settlement Agreement Management Committee in making decisions about how to spend Avista's protection, mitigation, and enhancement measure funding to offset effects from operation of Noxon Rapids Dam and Cabinet Gorge Dam on the Clark Fork River.

The 2018-2022 monitoring program represents the second five-year monitoring program managed by the CFRWQMC. The Council managed the previous five-year monitoring programs since their beginning in 1998. Consistent data collection and management, a rigorous data quality assurance oversight process, and methodical data review and validation completed through the life of the program provides the basis for statistical analysis of water quality time trends for the Clark Fork River. This nutrient time

trends analysis report builds on the efforts of the monitoring committee to incorporate data collected in the 2018-2022 monitoring period.

2.2 PURPOSE

In order to improve water quality and to work to achieve objectives identified in the Basin Management Plan (EPA 2007), the Council established four primary water quality management goals and seven associated water quality monitoring program objectives for the Clark Fork-Pend Oreille basin. This report both provides a means to evaluate effectiveness of certain management goals and fulfills a number of program monitoring objectives. This report builds on previously completed Clark Fork River water quality trends reports (Tri-State Water Quality Council 2009, HydroSolutions 2018) to assess the status of water quality in the Clark Fork River. This report will be used by state agencies and the CFRWQMC to evaluate effectiveness of nutrient reduction activities in the Clark Fork River basin and help guide future management decisions.

The following management goals were identified by the Council and conform to specific basin management goals originally identified in the Basin Management Plan:

- Control nuisance algae in the Clark Fork River by reducing nutrient concentrations,
- Protect Lake Pend Oreille water quality by maintaining or reducing current rates of nutrient loading from the Clark Fork River,
- Reduce near-shore eutrophication in Lake Pend Oreille by reducing nutrient loading from local sources, and
- Improve Pend Oreille River water quality through macrophyte management and tributary non-point source controls.

The Council established seven priority water quality program monitoring objectives for the Clark Fork-Pend Oreille basin. These monitoring objectives are:

1. Evaluating time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries,
2. Evaluating time trends for benthic algae chlorophyll in the Clark Fork River,
3. Monitoring compliance with established summer nutrient and benthic algae chlorophyll target levels in the Clark Fork River,
4. Estimating nutrient loading rates to Lake Pend Oreille from the Clark Fork River,
5. Evaluating time trends for benthic algae chlorophyll densities in near-shore areas of Lake Pend Oreille,
6. Evaluating time trends for Secchi transparency in Lake Pend Oreille,
7. Evaluating time trends for nutrient concentrations in the Pend Oreille River.

The CFRWQMC has adopted monitoring objectives numbers one through four. The purpose of this report is to evaluate these four objectives, including nutrient water quality and chlorophyll-*a* levels and identify time trends in the program's dataset. The other monitoring objectives continue to be evaluated by others, primarily IDEQ and Washington Department of Ecology through separate monitoring programs.

2.3 NUTRIENT STANDARDS

Because the Clark Fork mainstem was determined to be impaired by nutrients, the Clean Water Act required that a Total Maximum Daily Load analysis be performed. Hence, the Council helped enact the

Clark Fork River Voluntary Nutrient Reduction Program (VNRP) to reduce nutrient loading to the river (Environmental Quality Council 1999). The VNRP included instream nutrient target concentrations for the mainstem Clark Fork River June 21 to September 21. In 2002, the state of Montana subsequently adopted the VNRP targets as nutrient standards for TP, TN, and mean and maximum benthic algal chlorophyll-*a* in the Administrative Rules of Montana (ARM) 17.30.631, the first numeric nutrient standards in the state. The EPA accepted the VNRP targets as TMDLs for the river.

Today, nutrient standards for the Clark Fork River monitoring program fall under two authorities. For Silver Bow Creek at Opportunity, the standards are listed in DEQ Department Circular DEQ-12A. This circular contains information pertaining to the base numeric nutrient standards for Wadeable Streams (§75-5-301(2), MCA) and their implementation. Silver Bow Creek is located within the Middle Rockies ecoregion, thus the standards apply from July 1 to September 30, and are as follows:

- Total Phosphorus as P: 30 µg/L,
- Total Nitrogen as N: 300 µg/L.

For the mainstem Clark Fork River from below the Warm Springs Creek confluence (N46°11'17", W112°46'03") to the confluence with the Blackfoot River (N46°52'19", W113°53'35"), ARM 17.30.631(2)(a) applies. The numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll-*a*, applicable from June 21 to September 21, are as follows:

- Total Phosphorus as P: 20 µg/L,
- Total Nitrogen as N: 300 µg/L,
- (Summer mean) - Benthic 100 mg/square meter algal chlorophyll-*a*,
- (Maximum) - Benthic 150 mg/square meter algal chlorophyll-*a*.

For the mainstem Clark Fork River from the confluence with the Blackfoot River (N46°52'19", W113°53'35") to the confluence with the Flathead River (N47°21'45", W114°46'43"), ARM 17.30.631(2)(b) applies. The numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll-*a*, applicable from June 21 to September 21, are as follows:

- Total Phosphorus as P: 39 µg/L,
- Total Nitrogen as N: 300 µg/L,
- (Summer mean) - Benthic 100 mg/square meter algal chlorophyll-*a*,
- (Maximum) - Benthic 150 mg/square meter algal chlorophyll-*a*.

These nutrient standards are used as a benchmark by the CFRWQMC to evaluate water quality monitoring data collected by the program each year during annual data reporting activities.

2.4 NUTRIENT LOAD AGREEMENT

On the lower Clark Fork River, nutrient loads were established by The Montana and Idaho Border Nutrient Load Memorandum of Agreement (Tri-State Water Quality Council 2001) in 2002 to protect Lake Pend Oreille from accelerated cultural eutrophication. The Border Agreement, which was also championed by the Council, directs the completion of an annual nutrient loading analysis and developed nutrient loadings to protect water quality in the open waters of Lake Pend Oreille from the mouth of the Clark Fork River to the Long Bridge (Highway 95). Nutrient targets established in Section VII of the Border Agreement include:

- An area-weighted euphotic-zone average concentration of 7.3 micrograms per liter (µg/L) TP for Lake Pend Oreille,
- Total TP loading to Lake Pend Oreille of 328,651 kilograms per year (kg/year),

- TP loading from Montana of 259,500 kg/year, as measured at the Clark Fork River at the Montana/Idaho state line, below Cabinet Gorge Dam,
- TP loading from Lake Pend Oreille watershed in Idaho of 69,151 kg/year,
- Greater than 15:1 TN to TP ratio.

The Border Agreement established short-term and long-term exceedances of the nutrient load targets. The Border Agreement states that an exceedance of the nutrient targets exists when either of the following conditions are documented:

- (a) A short-term exceedance of the nutrient targets consisting of three consecutive years of TP load increases at the border that are above the targets by greater than 10%,
- (b) A long-term exceedance of the nutrient targets consisting of a ten-year average TP concentration in the lake greater than 7.3 µg/L.

Avista completes annual estimates of nutrient loading from the Clark Fork River to Lake Pend Oreille. These estimates are compared to the nutrient targets in the Border Agreement to evaluate short-term exceedances of the targets. Other nutrient targets are evaluated by IDEQ.

3.0 NUTRIENT REDUCTION ACTIVITIES

The Council was a catalyst for nutrient reduction activities in the Clark Fork River basin through the creation of the Basin Management Plan and the VNRP. The VNRP was a landmark agreement in place from 1998 to 2008 to reduce nutrient discharges in the upper and middle Clark Fork River. The agreement was a commitment to reduce nutrient discharge into the river between three municipal wastewater treatment plants (Butte, Deer Lodge, and Missoula) and one industrial discharger (Smurfit-Stone). In addition, Missoula County connected over 3,000 septic systems to a piped sewer system for treatment, and municipalities banned phosphate containing laundry detergents (McDowell 2000). Additional information on this significant program can be found in a final report prepared by the Council (2009). The report is a comprehensive account of the nutrient reduction activities implemented during the VNRP and their impacts.

The following sections provide a summary of recent point and non-point nutrient reduction activities that have taken place in the Clark Fork River basin. DEQ compiled these activities and their descriptions for this report.

3.1 POINT SOURCE NUTRIENT REDUCTION ACTIVITIES

Point sources are those that release nutrients from discrete conveyances, such as discharge pipes at factories or wastewater treatment plants. Notable point source reduction activities occurring in the Clark Fork River basin since 2017 include improvements to wastewater treatment facilities in the communities of Deer Lodge, Plains, Thompson Falls, and Polson. Error! Reference source not found. contains a table describing noteworthy point source nutrient reduction activities that have occurred in the Clark Fork River basin since 1998.

3.2 NON-POINT SOURCE NUTRIENT REDUCTION ACTIVITIES

Non-point nutrient sources include those that come from a large area and diffuse sources (grazing, timber harvest, abandoned mine lands, irrigation, recreation, and septic systems). Non-point source nutrient reduction activities are typically implemented through land, soil, and water conservation practices.

Each year, the state of Montana receives funding from EPA through Section 319 of the Clean Water Act to distribute throughout the state to groups interested in implementing projects to reduce non-point source pollution. DEQ publishes an interactive map that details restoration projects funded by the 319 Grant Program. This interactive map offers a current and detailed visual display of non-point source nutrient reduction activities in the Clark Fork River Basin. The interactive map can be accessed online through DEQ's website (Montana DEQ n.d.). The program funded approximately 34 different projects within the Clark Fork River basin in the 2017–2022 period. Most of the projects (nutrient reduction activities) included streambank restoration, mine reclamation, revegetation projects, and implementation and education of best management practices for agriculture and grazing. The scope of these activities varied in scale from watershed-wide to discrete reaches of stream. **Attachment B** contains a table summarizing non-point source nutrient reduction activities funded through the 319 Grant Program that have occurred generally since the last trends report. The activities are distributed across the entire basin, and do not necessarily represent a comprehensive list. Projects are typically funded through a variety of sources.

4.0 MONITORING PROGRAM

The Council initiated and coordinated a Clark Fork-Pend Oreille basin-wide monitoring program. The Council's Monitoring Committee directed and oversaw a consistent water quality monitoring program, which consisted of a dedicated network of state agencies including DEQ, IDEQ, and Washington Department of Ecology; industry and business partners including Avista, Plum Creek Timber Company, Montana Rail Link; the City of Missoula; the University of Montana; and a technical consultant. The U.S. Forest Service and EPA also provided regular funding and other assistance for the monitoring program. Generally, the monitoring program consisted of measuring field parameters and collecting water quality samples at monitoring locations on the Clark Fork River and selected tributaries, Lake Pend Oreille, and the Pend Oreille River within the Clark Fork-Pend Oreille watershed of western Montana, northern Idaho, and northeastern Washington. Key to the program was developing and maintaining a consistent set of methods, sample stations, sampling personnel, and data quality control measures. Dedicated long-term monitoring stations were established and divided among the multiple organizations and agencies that formed the Council's Monitoring Committee. Under the direction of the Council, the monitoring program was consistently completed beginning in 1998 and on an annual basis until 2012.

Clark Fork River water quality monitoring is now managed at the state level by the CFRWQMC. Many members that served with the Council now serve on the CFRWQMC. The CFRWQMC has carried over many of the same monitoring protocols to direct their efforts to maintain consistent long-term water quality monitoring objectives. Separate project-specific sampling programs and associated quality assurance project plans (QAPPs) have been developed as guidance for the individual participants of the sampling program. These plans are collectively managed by the CFRWQMC and published through DEQ. Program QAPPs provide a consistent and scientifically rigorous approach to data collection and management that facilitates achievement of program objectives, provides framework for conducting the activity, establishes the guidelines for reviewing analytical results, and assures quality data. Program sampling and analysis plans (SAPs) are developed for each activity to provide structure and define who, what, where, when, and the protocols for accomplishing the monitoring activity. Program QAPPs and SAPs are regularly reviewed and updated by members of the CFRWQMC at an annual meeting.

The following list summarizes relevant Clark Fork River water quality monitoring program activities completed for use in this report. The Clark Fork River water quality monitoring program included:

- Clark Fork River Monthly Monitoring (monthly monitoring): Avista collected monthly nutrient samples and measured field parameters at three lower Clark Fork River stations in July, August, and September. Monthly monitoring and nutrient data collection at Station 30 (below Cabinet Gorge Dam) occurred monthly, from March through November,
- Clark Fork River Peak Flow Monitoring (peak flow monitoring): Avista collected nutrient samples at Station 30 (below Cabinet Gorge Dam) during spring runoff. This consisted of six sampling events spread over about a one-month period during the rising limb of the hydrograph and at the peak, typically in May and June,
- Clark Fork River Summer Nutrient Monitoring (summer monitoring): The Clark Fork Coalition and University of Montana collected nutrient samples and field constituents in summer months (July-September) at eight Clark Fork River stations, one station on Silver Bow Creek, and one Station on the lower Flathead River (not included in this trends report),
- Clark Fork River Benthic Algae Monitoring (benthic algae monitoring): The University of Montana collected summer benthic algae samples for chlorophyll-*a* and ash-free dry mass at seven Clark Fork River sites in August and September.

4.1 MONITORING NETWORK

The locations selected for water quality monitoring provide distributed spatial coverage for evaluating the effects of point and non-point pollution sources and the influences of major population centers and tributary inflows. Although numerous monitoring stations have been sampled through the course of the monitoring program, consistent data collection has occurred at twelve locations from 1998 to present.

Data generated from sampling at these twelve locations are selected for inclusion in this trends report. This design provides for a cost effective and scientifically rigorous assessment of nutrient inputs and effects throughout the watershed.

Monitoring stations are distributed throughout the upper, middle, and lower reaches of the Clark Fork River watershed. The upper Clark Fork River extends from the headwaters at Silver Bow Creek to the confluence with the Blackfoot River, upstream of Missoula. The middle Clark Fork River extends from the confluence with the Blackfoot River to the confluence with the Flathead River. The lower Clark Fork River in Montana extends downstream from the confluence with the Flathead River to below Cabinet Gorge Dam. Note the monitoring stations include eleven stations on the Clark Fork River and one station on Silver Bow Creek. Collectively these stations are referred to as “Clark Fork River Stations” in this report. The twelve Clark Fork River nutrient monitoring stations included in this report are listed in **Table 4-1** and are shown on the map in **Attachment A**. Also shown in **Table 4-1** are the river reach, the paired USGS stream gaging station, and monitoring type for each monitoring station.

Reach	Station ID	Monitoring Station Name	USGS Gage Number	Monitoring Type
Upper CFR	CFR-2.5	Silver Bow Creek at Opportunity	12323600 Silver Bow Creek at Opportunity	SN6
	CFR-07	CFR below Warm Springs Creek	12323800 CFR at Galen	SN6
	CFR-09	CFR at Deer Lodge	12324200 CFR at Deer Lodge	P2, SN6
	CFR-10	CFR above Little Blackfoot River	12324200 CFR at Deer Lodge	P2, SN6
	CFR-12	CFR at Bonita	12331800 CFR near Drummond	P2, SN6
Middle CFR	CFR-15.5	CFR above Missoula	12340500 CFR above Missoula	P2, SN6
	CFR-18	CFR below Missoula	12340500 CFR above Missoula	P2, SN6
	CFR-22	CFR at Huson	12353000 CFR below Missoula	P2, SN6
	CFR-25	CFR above Flathead	12354500 CFR at St. Regis	P2, SN6
Lower CFR	CFR-28	CFR below Thompson Falls	12389000 CFR near Plains	N3
	CFR-29	CFR at Noxon Bridge	12391400 CFR below Noxon Rapids Dam	N3
	CFR-30	CFR below Cabinet Gorge Dam	12391950 CFR below Cabinet Gorge Dam	N15

Notes:

CFR	Clark Fork River
SN6	Summer monitoring for nutrient and field constituents, six samples collected in July, August, and September
P2	Periphyton collected in August and September by University of Montana Watershed Health Clinic
N3	Monthly monitoring for nutrients and field constituents, three monthly samples collected in July, August, and September
N15	Monthly monitoring for nutrients and field constituents, nine monthly samples (excludes December, January, and February) and six peak flow samples for nutrients and field constituents

4.2 MONITORED CONSTITUENTS

The current monitoring program consists of the collection of the following nutrient constituents, benthic algae data, and field parameter measurements. Additional nutrient constituents such as total Kjeldahl nitrogen (TKN) have been included in the past but are no longer part of the current program. Selected metals constituents have also been monitored in past years but are no longer part of the current monitoring program.

Nutrient Constituents

- Total (persulfate) nitrogen (TPN), or total nitrogen (TN) in $\mu\text{g/L}$ (monitored from 2009–present),
- Total Kjeldahl nitrogen (TKN) in $\mu\text{g/L}$, (monitored from 1998–2008),
- Soluble nitrate and nitrite as N ($\text{NO}_2 + \text{NO}_3$ as N), or also called inorganic nitrogen as N (dissolved) in $\mu\text{g/L}$,
- Soluble ammonia nitrogen as N ($\text{NH}_3 + \text{NH}_4$ as N), or also called total ammonia nitrogen as N (dissolved) in $\mu\text{g/L}$,
- Total phosphorus (TP), or phosphate-phosphorus as P in $\mu\text{g/L}$,
- Soluble reactive phosphorus (SRP), or Orthophosphate as P in $\mu\text{g/L}$.

Benthic Algae (or periphyton)

- Benthic algae samples were analyzed for chlorophyll-*a* in milligrams per square meter (mg/m^2) and ash-free dry mass (AFDM) in grams per square meter (g/m^2).

Field Parameters

- Water temperature in degrees Celsius ($^{\circ}\text{C}$),
- Dissolved oxygen (DO) in milligrams per liter (mg/L),
- pH (standard units),
- Oxidation reduction potential (ORP) in millivolts (mV),
- Specific conductance (SC) in microSiemens per centimeter ($\mu\text{S/cm}$),
- Total dissolved solids (TDS) in mg/L ,
- Turbidity in Nephelometric Turbidity Units (NTU).

Stream flow (cfs) and river stage (feet) data recorded by the USGS are also part of the data used in this report.

4.3 SAMPLING AND ANALYTICAL METHODS

Specific methods of sample collection, preservation, and handling currently followed by each of the monitoring program activities can be found in the CFRWQMC program QAPP (Montana DEQ 2018). Sampling and analytical methods are consistent with DEQ Water Quality Planning Bureau water quality monitoring standard operating procedures (Montana DEQ 2013). All nutrient analyses were performed by state-certified laboratories using EPA-approved analytical methods. Details of these methods can be found in Standard Methods for the Examination of Water and Wastewater, 20th Ed (APHA/AWWA/WEF 1998) and in the laboratories' quality assurance plans which are part of the respective monitoring activity QAPPs.

Throughout the history of the monitoring program, various analytical methods and detection limits have been applied to generate the dataset used in this report. **Table 4-2** summarizes the constituents,

analytical methods, and detection limits of the nutrient and chlorophyll-*a* analyses used to generate the source data.

Table 4-2. Summary of analytical constituents, analytical methods, and detection limits for the Clark Fork River Monitoring Program, 1998–2022		
Constituent	Analytical Method(s)	Range of Detection Limits
Ammonia nitrogen (NH ₃ +NH ₄ as N)	350.1, 4500-NH ₃ (H), SM 4500-NH ₃ (G)	10 µg/L
Nitrate + Nitrite (NO ₂ +NO ₃ as N)	353.2, 353.3, 4500-NO ₃ (I)	2-20 µg/L
Kjeldahl nitrogen (TKN)	351.1, 351.2	100 µg/L
Nutrient-nitrogen (TPN) or Total Nitrogen (TN)	4500-N (C)	10-100 µg/L
Orthophosphate (SRP)	365.1, 365.3, 4500-P-G, 4500-P (F)	1-4 µg/L
Phosphate-phosphorus or Total Phosphorus (TP)	365.2, 365.3, 365.4, 4500-P-H, 4500-P (B)	1-8 µg/L
Algal chlorophyll- <i>a</i> (chl- <i>a</i>)	(University of Montana Watershed Health Clinic 2009), A 10200H	0.1-7 mg chl- <i>a</i> /m ²
Algal ash-free dry mass (AFDM)	(University of Montana Watershed Health Clinic 2009), A 10300 C (5)	0.01-0.8 g/m ²

Notes:

- 1 Detection Limits shown are equivalent to the lower reporting limits in the dataset used
- 2 Analytical Methods reference: (APHA/AWWA/WEF 1998)
- 3 µg/L micrograms per liter
- 4 UM-WHC University of Montana Watershed Health Clinic
- 5 The range of detection limits for the algal parameters is due to different sampling methods that sample different size areas. The limit of detection (LOD) for hoop samples 0.01 mg/m² chlorophyll-*a*, 0.01 g/m² AFDM; template samples 0.4 mg/m² chlorophyll-*a*, 0.4g/m² AFDM. The limit of required quantitation (LORQ) is about 10 times these levels. In the past DEQ used the LORQ as the LOD but now uses both.

Detection limits shown in **Table 4-2** are based on laboratory lower reporting limits recorded in the source data. Laboratory lower reporting limits were established by the laboratories for each constituent as the lowest concentration that could be reliably measured within specified limits of precision and accuracy during routine laboratory operating conditions. Method detection limits (MDLs) are calculated by the laboratories and are a value less than the lower reporting limit. MDLs were not consistently provided by the laboratories in the dataset provided by DEQ. Constituents detected at greater than the MDL but less than the lower reporting limit indicate the presence of the analyte, but the concentration is not accurately quantified. Therefore, those results in the database were qualified as an estimated value and were used in the trends analysis. Lower reporting limits for each monitored constituent met project required quantitation limits for Clark Fork River monitoring activities established in the QAPP.

Note that the range of detection limits for the algal parameters is due to different sampling methods that sample different size areas. The laboratory limit of detection (LOD) for hoop samples is 0.01 mg/m² chlorophyll-*a*, 0.01 g/m² AFDM; template samples 0.4 mg/m² chlorophyll-*a*, 0.4g/m² AFDM. The laboratory limit of required quantitation is about 10 times these levels.

Table 4-3 details the current approved analytical methods and minimum lower reporting limit concentrations (referred to as project required quantitation limit) necessary to effectively evaluate the project data to the project objectives, as determined in the most recent project QAPP (Montana DEQ

2018). Note the methods and limits apply generally to data collected during the recent five-year monitoring cycle. Not all of the data included in the trends analysis conform to these limits, however all data used were reviewed through a quality assurance quality control process and approved for this use.

Table 4-3. Current monitoring program analytical methods and detection limits			
Analyte	Method	Alternate Method	Project Required Quantitation Limit
Total Phosphorus (TP)	SM 4500-P-H	SM 4500-P(B) &(F)	2 µg/l
Total Persulfate Nitrogen (TPN)	SM 4500-N (C)	SM 4500-N (C)	50 µg/l
Nitrate + Nitrite-Nitrogen (NO ₂ +NO ₃ -N)	SM 4500-NO ₃ (I)	SM 4500-NO ₃ (F)	2 µg/l
Total Ammonia-Nitrogen (NH ₃ +NH ₄ -N)	SM 4500-NH ₃ (H)	SM 4500-NH ₃ (G)	10 µg/l
Soluble Reactive Phosphorus (SRP)	SM 4500-P-G	SM 4500-P (F)	2 µg/l
Chlorophyll- <i>a</i> <i>hoop vs template</i>	A 10200H		0.1 vs 4 mg/m ²
Ash-Free Dry Mass <i>hoop vs template</i>	A 10300 C (5)		0.1 vs 4 g/ m ²

Source: (Montana DEQ 2018)

4.4 DATA QUALITY ASSURANCE

The program's water quality data undergoes rigorous quality assurance/quality control (QA/QC) review and reporting as directed by the program QAPP (Montana DEQ 2018) prior to final approval and upload. The QA/QC procedures include a review of documentation associated with sampling and measurement and laboratory analytical results to verify data quality. It also includes a review of the data quality objectives (DQOs) and data quality indicators (DQIs) as outlined in the program QAPP. Documentation of this review is provided by the CFRWQMC in an annual report.

Data generated through this program are submitted annually to DEQ as an electronic data deliverable (EDD) file that is uploaded to the Montana EQUIS Water Quality Exchange (MT-eWQX). Data from MT-eWQX is submitted to EPA's data warehouse, the National Water Quality Portal. Data uploaded through this QA/QC process form the basis for the dataset used in this report. The data quality assurance processes assure the data can be used for the intended program purposes, including this water quality trends report.

5.0 DATA ANALYSIS METHODS

This section describes the methods used in this report including methods to reduce the raw dataset into a usable format, statistical analysis methods used to assess trends in the data, and methods used to estimate nutrient loading. The data reduction methods, statistical methods, and loading evaluation methods are consistent with previous work (Tri-State Water Quality Council 2009, Suplee, et al. 2012, HydroSolutions 2018) and were approved by DEQ.

5.1 DATA REDUCTION

The dataset used in this report was retrieved by DEQ from the Water Quality Portal (WQP) and provided electronically to HydroSolutions. DEQ extracted all available nutrient data from the Clark Fork River monitoring program and other sources at the same monitoring stations through 2022. DEQ had previously removed all data prior to 1998 for inconsistencies in data and laboratory MDL or lower reporting limit reporting (HydroSolutions 2018).

The 1998–2017 dataset was reduced and analyzed by HydroSolutions, as described in the previous trends analysis report (HydroSolutions 2018). Data covering the period from 2018–2022 was reduced into a similar format and incorporated into the overall 1998–2022 dataset. The following provides a list of data reduction activities that were completed on the 2018–2022 dataset:

1. Data associated with sampling stations on tributaries including the Bitterroot River, Flathead River, and Thompson River were removed. Data from the Thompson River (CFR-27.5) was analyzed as part of a previous trends report, but data collection at that station has ceased since that time.
2. Quality control duplicate and blank sample data were removed.
3. Extreme outliers were removed at the direction of DEQ (this applied to two values in the 1998–2012 dataset and was addressed in previous reports). There were no extreme outliers identified by DEQ in the 2018–2022 dataset.
4. Data collected in months other than July, August, and September were removed.
5. Variations in nomenclature were harmonized prior to analysis. For example, total phosphorous is also reported as phosphate-phosphorous and total nitrogen is also reported as nutrient-nitrogen.
6. Results reported as non-detect were assigned a quantity one-half the lower reporting limit reported in the database.
7. TN concentrations were calculated by summing concentrations of TKN and $\text{NO}_2 + \text{NO}_3$ as N collected concurrently at each monitoring station for the years 1998–2008 (this was completed as part of the previous trends analysis).
8. TSIN concentrations were calculated by summing concentrations of nitrate and nitrite ($\text{NO}_2 + \text{NO}_3$ as N) and ammonia ($\text{NH}_3 + \text{NH}_4$ as N) collected concurrently at each monitoring station for the 2018–2022 dataset. The TSIN concentration values from 2018–2022 were then merged with all previously generated TSIN concentration values.
9. Where multiple sample results at one station existed within a calendar month, the results were averaged to provide a single monthly value.
10. Monthly average stream flow at USGS gaging stations identified in **Table 4-1** were extracted from the USGS National Water Information System and paired to respective monitoring stations.

11. Monthly average stream flow data provided by Avista for Noxon Rapids Dam was paired with site CFR-29 after September 2014, when USGS gage 12391400 CFR below Noxon Rapids Dam was taken out of service.
12. Chlorophyll-*a* mean and maximum values were calculated from samples identified as Chlorophyll-*a*, Composite for Weighted Average in the WQX database.

Reduced datasets are provided electronically in **Attachment 1**.

5.2 STATISTICAL TREND ANALYSES

Based on review of literature (Helsel and Hirsch 2002) and previous work (Suplee, et al. 2012, HydroSolutions 2018), and consultation with DEQ, the nonparametric Mann-Kendall trend test was selected as the appropriate method to detect trends in the selected dataset. The R statistical programming language was used to run the trends analysis (R Core Team 2024). Prior to execution of the time trends analysis, code was written in R to format the data into a usable format. This process consisted of cleaning, transforming, and pre-processing the reduced dataset into consistent and usable formats. The *rkt* package for R (Marchetto 2024) was used to calculate time-series trend analyses for each parameter of interest using the Mann-Kendall and Seasonal Mann-Kendall tests.

The time trend analyses employed two-sided tests with significance level α ; also known as the false positive rate, of 0.1 and a null hypothesis, H_0 , that there was no trend in the series. An α value of 0.1 means that there is at most a 10% chance of a false positive (trend identified when one does not exist) in the results. When using a false positive rate of 0.1, results with a reported p-value less than 0.1 exhibit a statistically significant trend in the data. The direction of the trend is indicated by the Mann-Kendall statistic score (S), with positive values indicating an increasing trend and negative values indicating a decreasing trend.

Previous work concluded that discharge influenced total monthly nutrient levels at all sites (Suplee, et al. 2012). Consistent with Suplee's work, previously completed site by site analysis has shown that total nutrients are influenced by mean monthly summer discharge (or stream flow). Observation of the data indicate that TN concentrations generally decrease with increasing stream flow, while TP concentrations generally increase with increasing stream flow. Dissolved constituents (TSIN and SRP) generally followed similar patterns as the total nutrients.

Because of this concentration-discharge relationship, nutrient concentration data were first regressed against flow utilizing a Local Polynomial Regression (LOESS) (Helsel, Hirsch and Ryberg, et al. 2020). Consistent with current statistical guidance (Helsel, Hirsch and Ryberg, et al. 2020) and that of DEQ, this study assessed time nutrient trends for TN, TSIN, TP, and SRP with the Seasonal Mann-Kendall trend test on flow-adjusted concentrations (residuals from the LOESS regression) against time. This method is able to distinguish time trends in water quality beyond those due to variation caused by time changes in discharge, and to correct for seasonality (Hirsch, Slack and Smith 1982, Hirsch, Slack and Smith 1982, Suplee, et al. 2012). For this study, the Seasonal Mann-Kendall test with a period of three, for the months of July, August, and September, accounted for monthly trends within the dataset.

Previous analyses in the area determined chlorophyll-*a* concentrations were not clearly tied to discharge (Suplee, et al. 2012). Therefore, no flow adjustment was made prior to the time trends analysis of chlorophyll-*a*. This study assessed time trends of the mean and maximum annual chlorophyll-*a* values with the Mann-Kendall trend test on concentration against time.

5.3 EVALUATION OF NUMERIC NUTRIENT STANDARDS EXCEEDANCE COMPARISON

This section describes the method used to assess attainment or exceedance of State of Montana numeric nutrient water quality standards for Clark Fork River monitoring stations in the upper and middle Clark Fork River over time.

Attainment or exceedance of numeric nutrient standards for the Clark Fork River were evaluated for the complete dataset 1998–2022. This 25-year dataset was broken into three periods: 1998–2007, 2008–2017, and 2018–2022. The two latter datasets were evaluated against the initial (1998–2007) dataset for the purpose of comparing the initial period when nutrient reduction activities were just beginning to later periods when nutrient reduction activities were underway.

For each period, individual sample results (i.e. not the averaged and flow-adjusted dataset used for trends analysis) for TN, TP, mean chlorophyll-*a*, and maximum chlorophyll-*a* were tabulated and compared to numeric standards. The number of samples exceeding the numeric standard was tabulated and computed into a percentage for both time periods. Results of this comparison are presented in **Section 7.0**. This analysis does not constitute a Clean Water Act beneficial use assessment but may assist DEQ in updating nutrient related beneficial assessments for specific segments of the Clark Fork River.

5.4 NUTRIENT LOADING ESTIMATION METHOD

Clark Fork River nutrient loading (TP and TN) into Lake Pend Oreille is evaluated on an annual basis using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (currently version 4.0) (USACE 2019). The FLUX32 model is one of three USACE models that comprise the BATHTUB Eutrophication model (Walker 1999). The model uses grab-sample nutrient concentrations, corresponding discharge measurements, and complete discharge records to calculate annual nutrient loading. The FLUX32 model provides six methods to synthesize the discharge-nutrient concentration relationship from individual sample records and impute them onto the entire flow record. The model imputes individual sample results onto the complete annual discharge record through stratification of the discharge record and regression analysis for each stratification.

Method 6, Regression Applied to Individual Flows, described in the Border Agreement Technical Guidance document (Tri-State Water Quality Council 2001), has been used in previous Tri-State Water Quality Council and CFRWQMC Clark Fork River annual water quality reports and in five-year nutrient water quality trend reports. Method 6 is used here for historical consistency and because the method generally provides a low error relative to other methods. Method 6, Regression Applied to Individual Flows, is defined by Walker (1999).

For the loading analysis, the model converts nutrient concentrations from micrograms per liter ($\mu\text{g/L}$) to milligrams per cubic meter (mg/m^3) and discharge values from cubic feet per second (cfs) to cubic hectometers per year (hm^3/year).

Data stratification of the input flows and nutrient concentrations serves to 1) adjust for differences in the frequency distribution of sampled and unsampled flow regimes, 2) reduce or eliminate biases associated with some calculation methods and/or sampling program designs, and 3) reduce the standard error variances of the mean loading estimate (USACE 2019). The number of stratified discharge regimes calculated by the model is limited by the number of sample results available to impute onto the complete discharge record. Typically, nutrient data is stratified in the model into two groups based on flow: samples collected at flows less than the annual mean daily flow, and samples collected at greater

than the annual mean daily flow. For each stratum, a regression equation is applied to estimate a daily load for each flow regime. The sum of daily loads provides the annual estimate. In some instances when the typical data stratification yields a large standard of error (i.e. more than 30%) the model is run with unstratified data, which can provide for a better statistical fit with a lower standard of error, and a corresponding tighter 95% confidence interval.

Consistent with previous work, nutrient loads are estimated using a synthesized annual hydrograph of mean daily discharge from U.S. Geological Survey (USGS) station 12392000, Clark Fork River at Whitehorse Rapids. This station operated during water years 1929 to 2014 and is no longer operational. It was located about 2.75 miles downstream of the active USGS station 12391950, Clark Fork River below Cabinet Gorge Dam. The USGS documented that about 600 cfs continuous groundwater inflow contributes to the river via seepage around Cabinet Gorge Dam (USGS 2025). Thus, to account for this seepage and to maintain consistency with previous work, 600 cfs is added to the published average daily discharge flow record at USGS station 12391950 for use in the model. Nutrient loading results are presented in **Section 8.0**.

6.0 NUTRIENT WATER QUALITY TIME TREND RESULTS

This section presents results of the time trends analysis of TN, TSIN, TP, SRP, mean chlorophyll-*a*, and maximum chlorophyll-*a* for each of the twelve monitoring stations in the Clark Fork River 1998–2022 dataset. **Table 6-1** summarizes results of the trend tests including trend direction and relative significance by monitoring station. The following is an explanation of the results reported in **Table 6-1**:

Numerical Results

p-value = The risk to reject H_0 (null hypothesis of no trend present) while it is true (represented as a decimal in the results, can also be represented as a percentage).

S = The statistical value representing the monotonic dependence of y on x ; in this case the statistic represents the tendency of the constituent values to decrease or increase as time progresses; where the seasonal Mann-Kendall test is implemented, the S statistic is represented by S' which is equal to the sum of the S statistic for each season.

Interpretation

Null hypothesis, H_0 : there is no trend in the series

Alternate hypothesis, H_a : there is a trend in the series

If $p > 0.1$ then H_0 cannot be rejected (a trend is not detected)

If $p < 0.1$ then reject H_0 , and accept H_a (a trend is detected)

Trend Direction

If $p > 0.1$, then a trend is not detected

If $p < 0.1$ and If $S < 0$, then decreasing trend

If $p < 0.1$ and If $S > 0$, then increasing trend

Trend Magnitude

As in previous trend reports, the magnitude of trends were ranked based on guidance in USGS publication “Statistical Methods in Water Resources,” (Helsel and Hirsch 2002). Interpretation of the presence and magnitude and of a significant trend, evaluated at a significance level of $\alpha=0.1$ was interpreted as follows:

Marginally Significant: $0.05 < p \leq 0.1$

Significant: $0.01 < p \leq 0.05$

Highly Significant: $p < 0.01$

A graphical display of trend results is presented in the maps provided in **Attachment C**. Each map symbolically represents the trend findings for a single constituent at each monitoring station. Symbology for each monitoring station falls into one of three categories, 1) not sampled, 2) no significant trend detected, and 3) trend detected. For all stations where a trend was detected, the stations are symbolized with graduated arrows, with the direction and size of the symbol indicating the direction and significance of the trend calculated.

6.1 TREND RESULTS BY MONITORING STATION

Results of the seasonal Mann-Kendall trend test for TN, TSIN, TP, SRP, and Mann-Kendall trend test for maximum and mean benthic chlorophyll-*a* stations in the Clark Fork River 1998–2022 dataset are presented in **Table 6-1** and on **Figure 6-1**. Detailed output and plots from the statistical analysis routine are provided in **Attachment D**.

Table 6-1. Results and findings of seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP, mean benthic chlorophyll-<i>a</i>, and maximum benthic chlorophyll-<i>a</i> for $\alpha = 0.1$ at all monitoring stations, 1998–2022					
Nutrient	<i>p</i> – value (Two-tailed)	Interpretation	S, S'^A	Trend Direction (if significant)	Change in Trend (Previous to Current Report) ^B
Monitoring Station CFR-2.5, Silver Bow Creek at Opportunity					
TN	0.000	Highly Significant	-445	Decreasing	
TSIN	0.000	Highly Significant	-425	Decreasing	
TP	0.4583	Not Significant	-56		Increasing → None
SRP	0.1648	Not Significant	98		Increasing → None
Monitoring Station CFR-07, Clark Fork River below Warm Springs Creek					
TN	0.0475	Significant	-148	Decreasing	None → Decreasing
TSIN	0.1491	Not Significant	-108		
TP	0.0820	Marginally Significant	-130	Decreasing	None → Decreasing
SRP	0.3669	Not Significant	-64		
Monitoring Station CFR-09, Clark Fork River at Deer Lodge					
TN	0.2002	Not Significant	-96		
TSIN	0.1086	Not Significant	120		
TP	0.0029	Highly Significant	-222	Decreasing	
SRP	0.1402	Not Significant	-104		
Mean Chlorophyll- <i>a</i>	0.6572	Not Significant	-20		
Maximum Chlorophyll- <i>a</i>	0.8335	Not Significant	-10		
Monitoring Station CFR-10, Clark Fork River above Little Blackfoot River					
TN	0.1345	Not Significant	-112		
TSIN	0.9248	Not Significant	-8		
TP	0.0299	Significant	-162	Decreasing	
SRP	0.0101	Significant	-177	Decreasing	
Mean Chlorophyll- <i>a</i>	0.2244	Not Significant	-53		
Maximum Chlorophyll- <i>a</i>	0.3383	Not Significant	-42		
Monitoring Station CFR-12, Clark Fork River at Bonita					
TN	0.0391	Significant	-154	Decreasing	None → Decreasing
TSIN	0.7771	Not Significant	-22		
TP	0.0647	Marginally Significant	-138	Decreasing	
SRP	0.0498	Significant	-138	Decreasing	None → Decreasing
Mean Chlorophyll- <i>a</i>	0.0235	Significant	-98	Decreasing	
Maximum Chlorophyll- <i>a</i>	0.0422	Significant	-88	Decreasing	

Table 6-1. Results and findings of seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP, mean benthic chlorophyll-*a*, and maximum benthic chlorophyll-*a* for $\alpha = 0.1$ at all monitoring stations, 1998–2022

Nutrient	<i>p</i> – value (Two-tailed)	Interpretation	S, S ^A	Trend Direction (if significant)	Change in Trend (Previous to Current Report) ^B
Monitoring Station CFR-15.5, Clark Fork River above Missoula					
TN	0.1819	Not Significant	-100		
TSIN	0.1416	Not Significant	-110		Decreasing → None
TP	0.3384	Not Significant	-72		Decreasing → None
SRP	0.0048	Highly Significant	-198	Decreasing	
Mean Chlorophyll- <i>a</i>	0.9627	Not Significant	3		
Maximum Chlorophyll- <i>a</i>	0.3873	Not Significant	38		
Monitoring Station CFR-18, Clark Fork River below Missoula					
TN	0.0000	Highly Significant	-458	Decreasing	
TSIN	0.0000	Highly Significant	-436	Decreasing	
TP	0.0000	Highly Significant	-374	Decreasing	
SRP	0.0000	Highly Significant	-320	Decreasing	
Mean Chlorophyll- <i>a</i>	0.0016	Highly Significant	-136	Decreasing	
Maximum Chlorophyll- <i>a</i>	0.0142	Significant	-106	Decreasing	
Monitoring Station CFR-22, Clark Fork River and Huson					
TN	0.0048	Highly Significant	-190	Decreasing	None → Decreasing
TSIN	0.0581	Marginally Significant	-128	Decreasing	None → Decreasing
TP	0.000	Highly Significant	-326	Decreasing	
SRP	0.0001	Highly Significant	-251	Decreasing	
Mean Chlorophyll- <i>a</i>	0.5128	Not Significant	-29		Decreasing → None
Maximum Chlorophyll- <i>a</i>	0.6568	Not Significant	-20		Decreasing → None
Monitoring Station CFR-25, Clark Fork River above Flathead					
TN	0.6370	Not Significant	36		
TSIN	0.0261	Significant	166	Increasing	
TP	0.3250	Not Significant	-74		Decreasing → None
SRP	0.2461	Not Significant	-82		
Mean Chlorophyll- <i>a</i>	0.2823	Not Significant	-47		
Maximum Chlorophyll- <i>a</i>	0.141	Not Significant	-64		Decreasing → None
Monitoring Station CFR-28, Clark Fork River below Thompson Falls					
TN	0.0104	Significant	177	Increasing	
TSIN	0.4926	Not Significant	49		
TP	0.0518	Marginally Significant	-137	Decreasing	
SRP	0.6795	Not Significant	-22		
Monitoring Station CFR-29, Clark Fork River at Noxon Bridge					
TN	0.2285	Not Significant	82		Increasing → None
TSIN	0.0098	Highly Significant	-178	Decreasing	
TP	0.7817	Not Significant	-20		

Table 6-1. Results and findings of seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP, mean benthic chlorophyll-*a*, and maximum benthic chlorophyll-*a* for $\alpha = 0.1$ at all monitoring stations, 1998–2022

Nutrient	<i>p</i> – value (Two-tailed)	Interpretation	S, S' ^A	Trend Direction (if significant)	Change in Trend (Previous to Current Report) ^B
SRP	0.7625	Not Significant	-16		
Monitoring Station CFR-30, Clark Fork River below Cabinet Gorge Dam					
TN	0.1029	Not Significant	113		
TSIN	0.0151	Significant	-171	Decreasing	
TP	0.0085	Highly Significant	-185	Decreasing	
SRP	0.1755	Not Significant	-90		Decreasing → None

^A S or S' represent the tendency of the constituent values to decrease or increase over time with positive values indicative of an increasing trend and negative values a decreasing trend. See text for details (Section 6.0).

^B Change in trend compared to trend in previous report. E.g. “None → Decreasing” indicates no significant trend detected in 1998–2017 but 1998–2022 trend is significant and decreasing. Blank cell indicates no change in trend compared to 1998–2017.

6.2 SUMMARY OF TRENDS

Trend direction and magnitude at each monitoring station is summarized on **Figure 6-1** and trend analysis results are also presented on maps in **Attachment C** for all analyzed constituents at all monitoring stations. Additionally, **Figure 6-2** and **Figure 6-3** graphically depict the number of sites with decreasing, increasing, and not significant trends identified in both the 2013–2017 and 2018–2022 datasets.

Nutrients

The 1998–2022 nutrient trend analysis (TSIN, TN, TP, SRP) identified a total of 25 statistically significant trends among the four nutrient parameters and 12 nutrient monitoring sites (totaling 48 site-parameter combinations). Of these 25 statistically significant trends, two were increasing and 23 were decreasing (**Table 6-1** and **Table 6-2**). Compared to the previous trend analysis (1998–2017), there were two additional decreasing trends, three fewer increasing trends, and one additional no trend identified in the 1998–2022 dataset (**Figure 6-2**). Thus, for nutrients in the 2022 data, about half of the 48 site-parameter combinations were found to have significant trends, and of those significant trends, the vast majority exhibited decreasing concentration over time.

For SRP, TN, and TSIN, about 42% of sites had statistically significant decreasing trends, between 0 to 10% of sites had statistically significant increasing trends, and between 50 and 60% of sites had no significant trend detected (**Table 6-2**). TP stands out (as it did in 2017) for having the most sites exhibiting statistically significant decreasing trends (eight sites or about 67%). There were no sites with a statistically significant increasing TP trend, and only four sites (or about 33%) had no significant TP trend detected.

Table 6-2. Summary of 1998–2022 nutrient trends by parameter

	Number of Sites with Trend				Percent of Sites with Trend		
	Not Sig.	Decreasing	Increasing	Total	Not Sig.	Decreasing	Increasing
TN	6	5	1	12	50	42	8
TSIN	6	5	1	12	50	42	8
TP	4	8	0	12	33	67	0
SRP	7	5	0	12	58	42	0

By site, CFR-18 and CFR-22 had the most decreasing nutrient trends, with statistically significant decreasing trends for all four nutrient parameters (**Figure 6-1**). CFR-12 had three statistically significant decreasing trends, whereas the remaining sites all had one or two statistically significant decreasing trends (except CFR-25, which had none). Of the two total statistically significant increasing trends detected, one was associated with CFR-25 (TSIN) and one with CFR-28 (TN).

Spatially, decreasing trends in the 2022 dataset are most heavily concentrated in the upper and middle reaches of the Clark Fork River, with fewer decreasing trends identified in the lower reach (**Figure 6-1, Attachment C**). Specifically, the upper reach exhibited an average rate of two decreasing trends per monitoring site and the middle reach exhibited a rate of 2.25 decreasing trends per site, whereas the lower reach had a rate of 1.3 decreasing trends per site. The spatial distribution of trends in the 2022 analysis is similar to the distribution in the 2017 analysis, except that the number of decreasing trends in the upper reach increased by about 70% between 2017 and 2022.

Period	Reach	Not Sig.	Decreasing	Increasing	Decreasing trends per site in reach
1998–2022	Lower	7	4	1	1.33
	Middle	6	9	1	2.25
	Upper	10	10	0	2
1998–2017	Lower	5	5	2	1.7
	Middle	5	10	1	2.5
	Upper	12	6	2	1.2

Mean and Maximum Benthic Chlorophyll-*a*

A total of four statistically significant decreasing trends were identified (two for mean and two for maximum) among the seven stations for which mean and maximum benthic chlorophyll-*a* concentrations were calculated. No statistically significant increasing trends were identified (**Table 6-4, Figure 6-1, Figure 6-3**). Compared to the previous trend analysis (1998–2017), there were a total of three fewer decreasing trends (two less for maximum and one less for mean), and three more no trends identified.

	Number of Sites with Trend				Percent of Sites with Trend		
	Not Sig.	Decreasing	Increasing	Total	Not Sig.	Decreasing	Increasing
Max	5	2	0	7	71	29	0
Mean	5	2	0	7	71	29	0

By site, CFR-12 and CFR-18 each had two statistically significant decreasing trends for mean and maximum chlorophyll-*a*. Sites CFR-9, CFR-10, CFR-15.5, CFR-22, and CFR-25 had no significant chlorophyll-*a* trends.

Spatial distribution of trends is summarized in **Table 6-5**. The absolute number and rate of decreasing trends per site on the middle reach is notably lower in 2022 compared to 2017, whereas the number and rate of decreasing trends remained constant on the upper reach over the same period.

Period	Reach	Not Sig.	Decreasing	Increasing	Decreasing trends per site in reach
1998–2022	Middle	6	2	0	0.50
	Upper	4	2	0	0.67
1998–2017	Middle	3	5	0	1.25
	Upper	4	2	0	0.67

Reach	Station ID	TN	TSIN	TP	SRP	Chl-a Mean	Chl-a Max
Upper	CFR-2.5	↓	↓	●	●	□	□
	CFR-07	↓	●	↓	●	□	□
	CFR-09	●	●	↓	●	●	●
	CFR-10	●	●	↓	↓	●	●
	CFR-12	↓	●	↓	↓	↓	↓
Middle	CFR-15.5	●	●	●	↓	●	●
	CFR-18	↓	↓	↓	↓	↓	↓
	CFR-22	↓	↓	↓	↓	●	●
	CFR-25	●	↑	●	●	●	●
Lower	CFR-28	↑	●	↓	●	□	□
	CFR-29	●	↓	●	●	□	□
	CFR-30	●	↓	↓	●	□	□

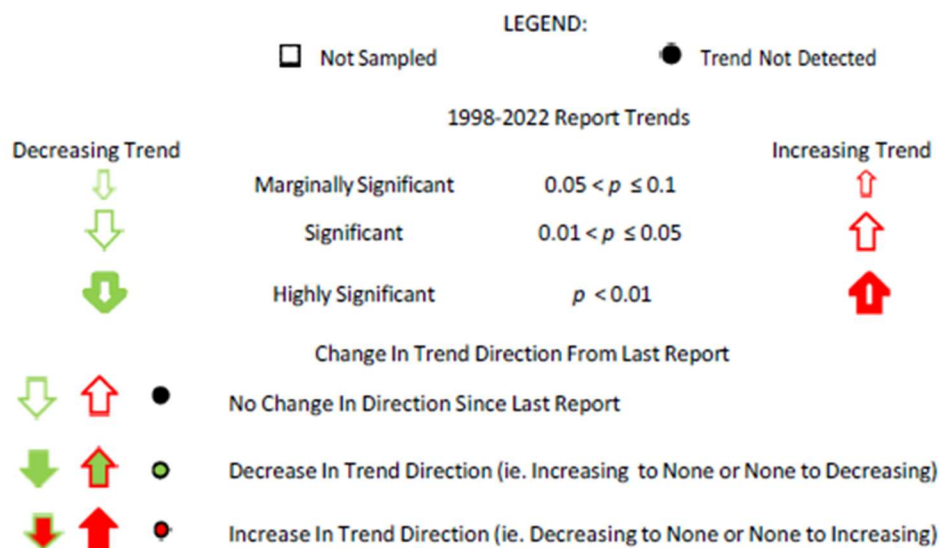


Figure 6-1. Summary of nutrient and chlorophyll-*a* trends for the Clark Fork River dataset, 1998–2022, with respective significance levels. Note: SRP was not collected at CFR-28 or CFR-29 from 2008–2012.

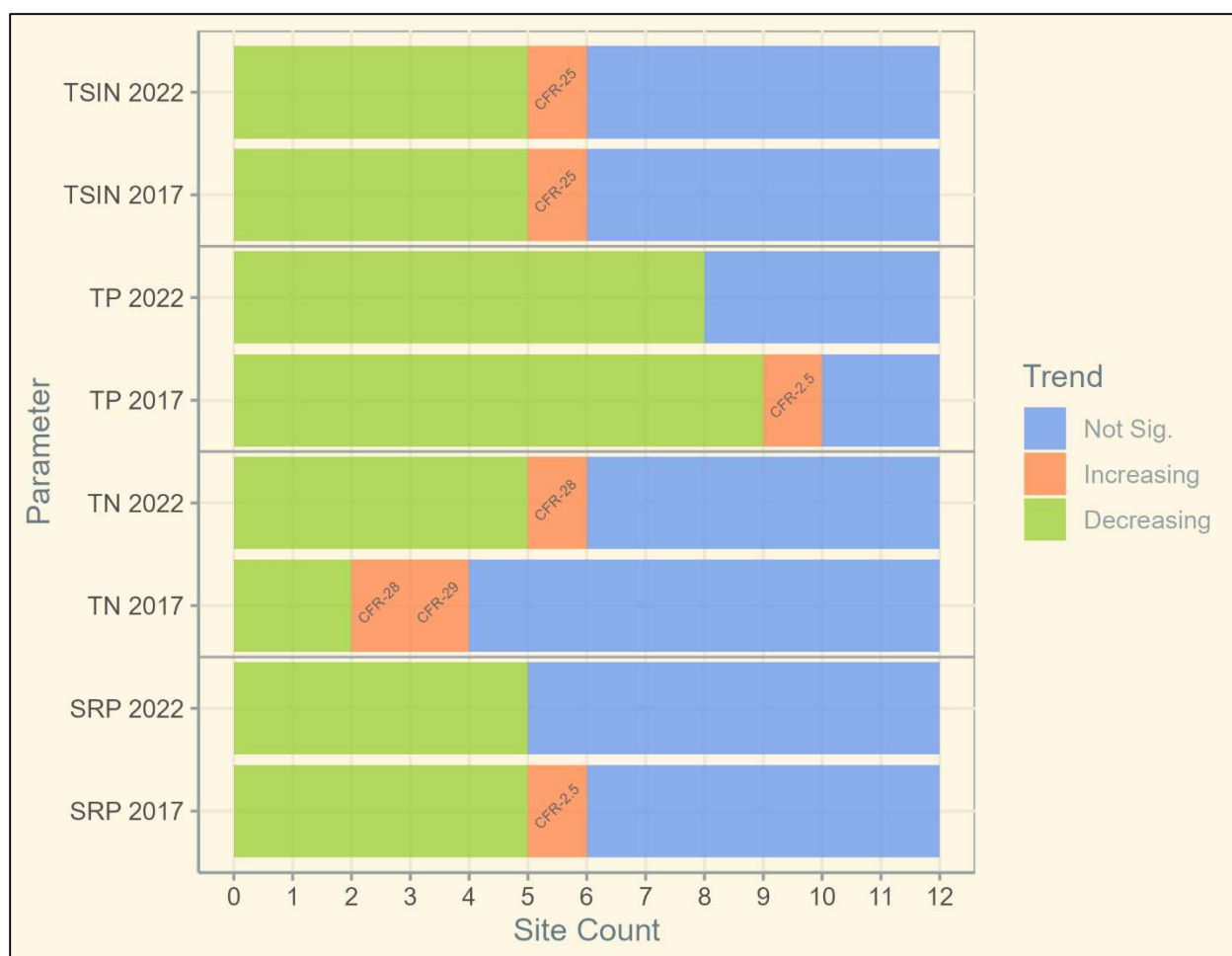


Figure 6-2. Count of sites exhibiting decreasing, increasing, and not statistically significant trends for nutrient parameters based on analysis of both 2017 and 2022 datasets. Increasing trends labeled with site ID.

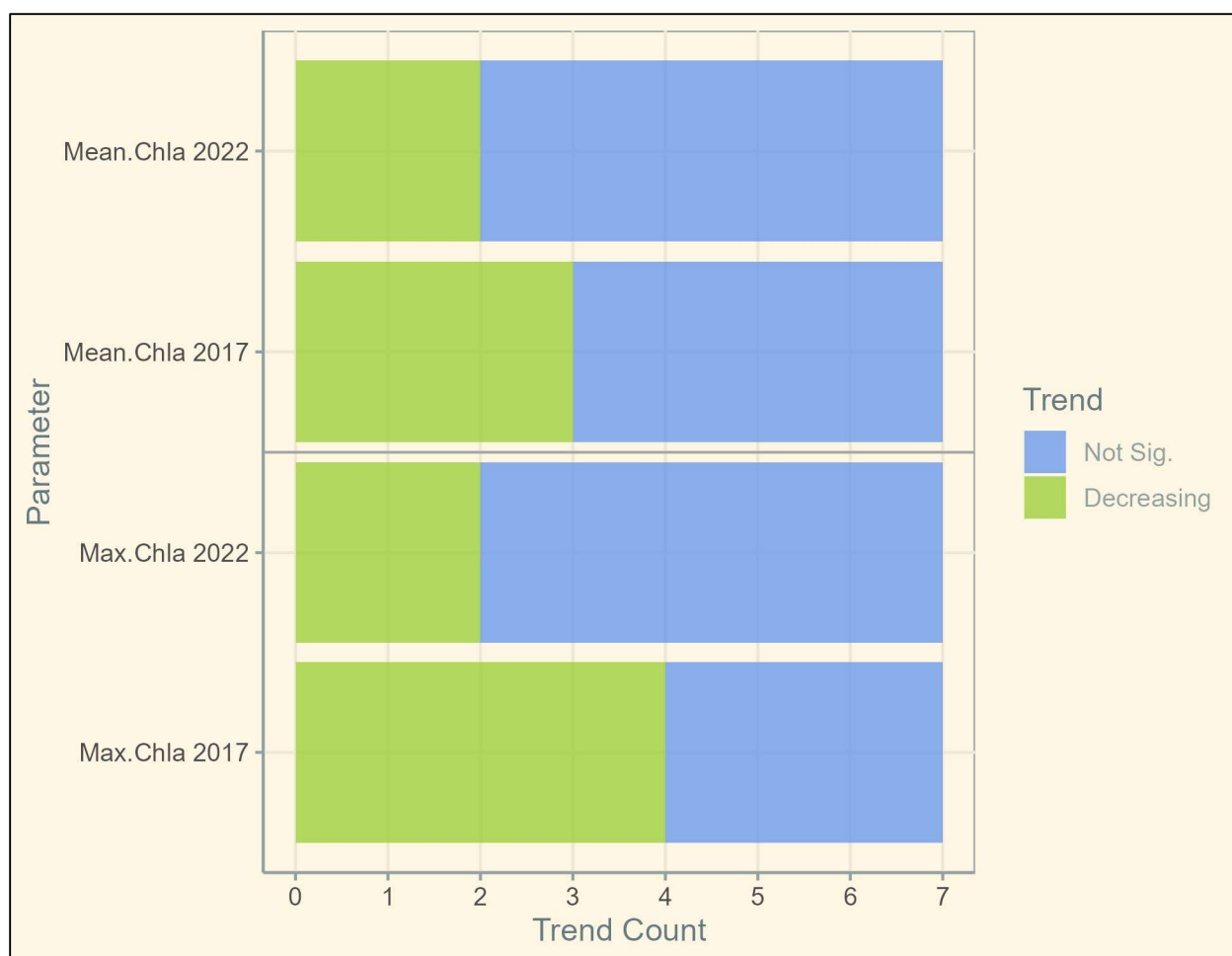


Figure 6-3. Comparison of 2017 and 2022 trend count by type for algal chlorophyll-*a* mean and maximum.

6.3 DISCUSSION

The nutrient time trends analysis provides a means by which to evaluate the effectiveness of nutrient reduction activities in the basin. Since the effectiveness of point source nutrient reduction activities are more straightforward to evaluate than non-point source nutrient reduction activities, they are the focus of this discussion.

Multiple point source nutrient reduction activities have taken place in the upper Clark Fork River and its headwaters since the trend monitoring program was initiated. This discussion focuses on reduction activities implemented since 2017; previously completed reduction activities are cataloged in **Attachment B** and are discussed in detail in previous reports.

In the current trend analysis, a large number of significant, downward trends in nutrient concentrations were identified in both the upper and middle reaches of the Clark Fork River. In the upper reach of the Clark Fork River, the total number of downward trends increased from 6 in 2017 to 10 as of 2022. Factors contributing to these decreasing trends are likely to include improvements made to the City of Deer Lodge’s wastewater treatment system between 2017 and 2022, as well as continuing positive

effects of previously completed improvements to the City of Butte’s wastewater treatment system (**Attachment B**).

Notably, increasing trends for TP and SRP detected at CFR-2.5 (Silver Bow Creek) in 2017 have reverted to no significant trend in the 2022 analysis. The reason for this variability in trend direction over the last two monitoring cycles is not clear. Improvements to Butte’s wastewater treatment system may have contributed to stabilizing instream phosphorus levels.

The middle reach of the Clark Fork River had one less decreasing trend detected in 2022 compared to 2017, but overall, the middle reach continued to show a tendency towards decreasing nutrient trends in the current analysis. Middle reach stations CFR-18 (below Missoula) and CFR-22 (at Huson) are the only two stations in the monitoring program that exhibited statistically significant decreasing trends for all four nutrient parameters in the 2022 analysis. These trends may be related to ongoing effects of improvements to the City of Missoula’s wastewater treatment system completed over the previous two decades (**Attachment B**), continuing non-point source reduction activities in this reach, and downstream effects of recent point source improvements made along the upper reach (noted previously).

One of the only two statistically significant increasing trends identified in the 2022 analysis was identified for TSIN at station CFR-25 (above Flathead) in the middle reach. This increasing trend was also identified in the 2017 dataset. Visual inspection of both the time series and residual plots for TSIN at this station (**Attachment D**) suggest there was a modest uptick in TSIN concentration from about 2016 to 2018, but since about 2019 the range of values has returned to near the baseline of previous decades. Thus, it is possible that this upward trend detection is an artifact of a short-lived anomaly in TSIN that occurred from approximately 2016 to 2018 and may not be representative of the actual long-term trend at the site. Data from the next five-year monitoring period will help to clarify whether or not this is the case.

Water quality and hydrology of the lower reach is heavily influenced by the inflow from the Flathead River and three hydroelectric dams at Thompson Falls, Noxon Rapids, and Cabinet Gorge. In the 2022 analysis, this reach exhibited the lowest rate of statistically significant downward trends of the three reaches, with a total of four significant decreasing trends. Compared to the 2017 analysis, the lower reach had two fewer decreasing trends and one less increasing trend and has thus more or less maintained the status quo since the previous monitoring period. Notably, the only relatively large-scale nutrient reduction activity implemented in the lower reach watershed between 2018 and 2022 was improvement of the City of Polson’s wastewater treatment system, which is on the Flathead River. Wastewater improvements at both Plains and Thompson Falls came online in 2023 and may positively affect lower reach nutrient trends in the future.

TN at station CFR-28 (at Noxon) in the lower reach is the second of two statistically significant increasing trends identified in the 2022 analysis. This trend was also identified in the previous analysis. Visual examination of the residual and nutrient time series for this station (**Attachment D**) corroborate the appearance of a gradual upward TN trend from about 2005 to 2019 followed by a spike in 2020 and then a return to pre-spike concentrations in 2021 and 2022. Thus, visual evaluation is consistent with a real upward trend through at least 2020, which has been consistently detected by statistical trend analysis. The reason for this upward trend is not clear but could be related to non-point source nutrient loading associated with population growth along the Clark Fork River and in the Flathead watershed over the last few decades, or potential changes in nutrient loading and cycling in Thompson Falls Reservoir.

7.0 NUMERIC NUTRIENT STANDARDS EXCEEDANCE RATE EVALUATION

This section presents an evaluation of the rate of numeric nutrient standard (NNS) exceedances for TN, TP, and chlorophyll-*a* summer mean and maximum. For each parameter, the exceedance rate has been tabulated and compared across three time periods, specifically 1998–2007, 2008–2017, and 2018–2022.

7.1 TOTAL NITROGEN

Results of the numeric nutrient standards exceedance rate comparisons for TN are shown in **Table 7-1** and **Figure 7-1**. The table shows the number of samples collected and the number of samples that exceeded the numeric nutrient standard applicable to the site. The total number of samples exceeding standards dropped from 52% in the 1998–2007 period to 31% in the 2008–2017 to 19% in 2018–2022, resulting in a drop of 33% between the 1998–2007 and 2018–2022 analysis periods.

The TN exceedance rate for all stations except CFR-25 (above Flathead) experienced a drop of more than 20% between the 1998–2007 and 2018–2022 periods. Station CFR-25 exhibited a decrease in exceedance rate between 1998–2007 and 2008–2017 but increased during the 2018–2022 time period resulting in a 2% overall increase between the 1998–2007 time period and the 2018–2022 period. This trend generally aligns with the results of the time trend analysis for station CFR-25 presented previously.

Station CFR-9 (at Deer Lodge) had shown a modest increase in TN exceedances from 1998–2007 to 2008–2018 but has since dropped substantially in 2018–2022, resulting in a decrease of 26% from the 1998–2007 period to the 2018–2022 period.

The most substantial decrease in TN exceedance rate occurred at station CFR-18 (below Missoula) with a 46% decrease from the 1998–2007 to 2018–2022 time periods, closely followed by stations CFR-7 (below Warm Springs), CFR-10 (above Little Blackfoot), and CFR-12 (at Bonita), each of which dropped by 44%.

In comparison to the initial time period of 1998–2007, the most recent period of 2018–2022 has shown a greater decrease in exceedance rates than the 2008–2017 period for all stations apart from CFR-18 and CFR-25.

Table 7-1. Summary of Clark Fork River total nitrogen numeric nutrient standard exceedance 1998–2022											
Station	TN Numeric Nutrient Standard (NNS): 300 µg/l (all sites)										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N ¹	N > NNS	% > NNS	N	N > NNS	% > NNS		N	N > NNS	% > NNS	
CFR-2.5	77	77	100%	72	72	100%	0%	27	20	74%	-26%
CFR-7	77	39	51%	72	25	35%	-16%	30	2	7%	-44%
CFR-9	49	34	69%	71	51	72%	2%	30	13	43%	-26%
CFR-10	77	52	68%	72	30	42%	-26%	30	7	23%	-44%
CFR-12	49	25	51%	72	16	22%	-29%	29	2	7%	-44%
CFR-15.5	49	11	22%	72	2	3%	-20%	28	0	0%	-22%
CFR-18	76	38	50%	71	2	3%	-47%	28	1	4%	-46%

Table 7-1. Summary of Clark Fork River total nitrogen numeric nutrient standard exceedance 1998–2022											
Station	TN Numeric Nutrient Standard (NNS): 300 µg/l (all sites)										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N ¹	N > NNS	% > NNS	N	N > NNS	% > NNS		N	N > NNS	% > NNS	
CFR-22	76	24	32%	72	3	4%	-27%	20	0	0%	-32%
CFR-25	50	4	8%	72	2	3%	-5%	31	3	10%	2%
Total	580	304	52%	64	6	203	31%	253	48	19%	-33%

Notes: 1. N - number of samples analyzed

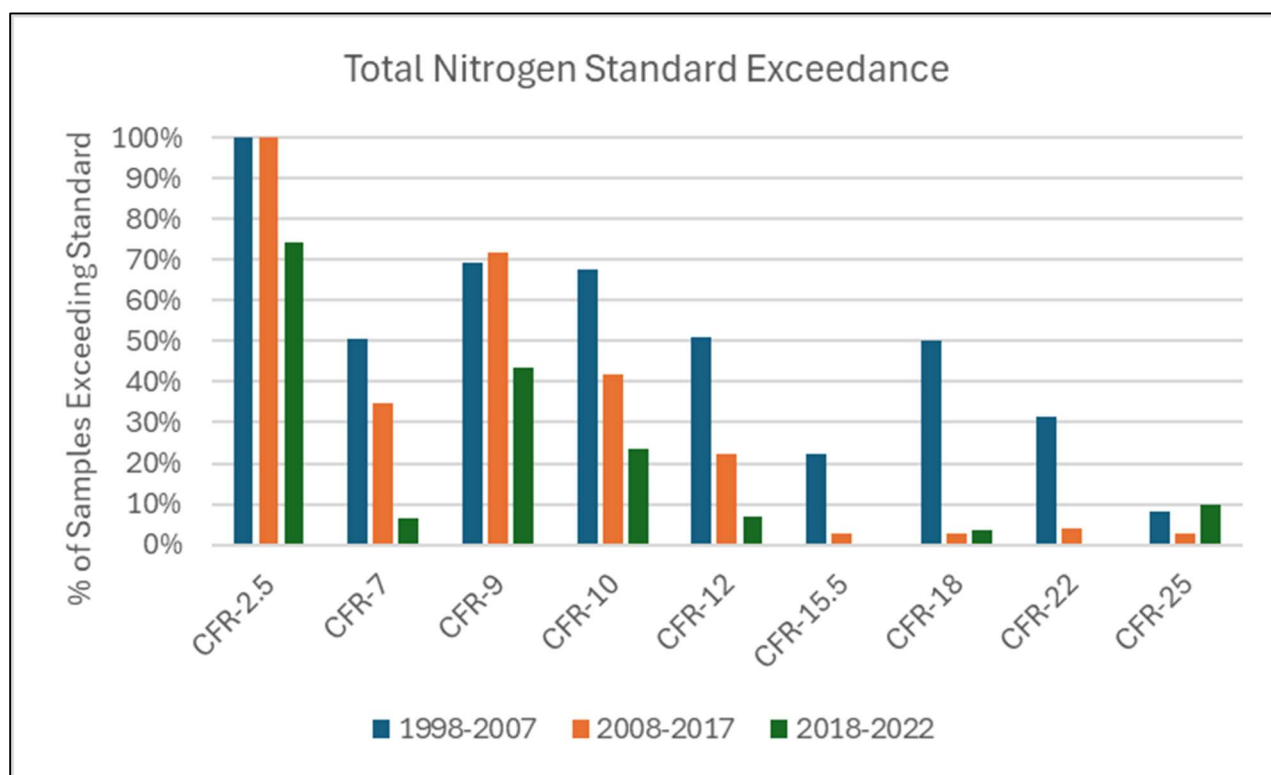


Figure 7-1. Percent samples exceeding Total Nitrogen numeric nutrient standard in Clark Fork River

7.2 TOTAL PHOSPHORUS

Results of the numeric nutrient standards assessment for are shown in **Table 7-2** and on **Figure 7-2**. Exceedance rates for TP have not changed dramatically throughout the monitoring period with the current period overall exceedance rate being 3% lower than the rate in 1998–2007. The 2018–2022 exceedance rate is notably higher in upper reach stations compared to lower reach stations, which could be a reflection of population growth trends in this area.

The greatest decrease in exceedance rate between the 1998–2007 and the 2018–2022 time period occurred at station CFR-18 (-14%), whereas the greatest increase was at station CFR-25 (+10%). Four of the nine stations evaluated exhibited increases in the TP standard exceedance rate between the initial and current periods. Overall, changes in TP exceedance rates over time do not consistently track with statistical trends and have no clear correlation with river reach.

Table 7-2. Summary of Clark Fork River total phosphorus numeric nutrient standard exceedance 1998–2022											
Station	TP Numeric Nutrient Standard (NNS): 30 µg/l CFR-2.5, 20 µg/l CFR-7 to CFR-12, and 39 µg/l CFR 15.5 to CFR-25										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N ¹	N > NNS	% > NNS	N	N > NNS	% > NNS		N	N > NNS	% > NNS	
CFR-2.5	78	78	100%	71	71	100%	0%	27	25	93%	-7%
CFR-7	78	64	82%	72	72	100%	18%	28	23	82%	0%
CFR-9	50	23	46%	72	47	65%	19%	29	15	52%	6%
CFR-10	78	64	82%	72	66	92%	10%	29	22	76%	-6%
CFR-12	49	32	65%	72	49	68%	3%	29	20	69%	4%
CFR-15.5	50	4	8%	72	2	3%	-5%	29	3	10%	2%
CFR-18	77	19	25%	72	2	3%	-22%	28	3	11%	-14%
CFR-22	77	3	4%	72	1	1%	-3%	20	0	0%	-4%
CFR-25	50	0	0%	72	0	0%	0%	29	3	10%	10%
Total	587	287	49%	647	310	48%	-1%	248	114	46%	-3%
Notes: 1. N - number of samples analyzed											

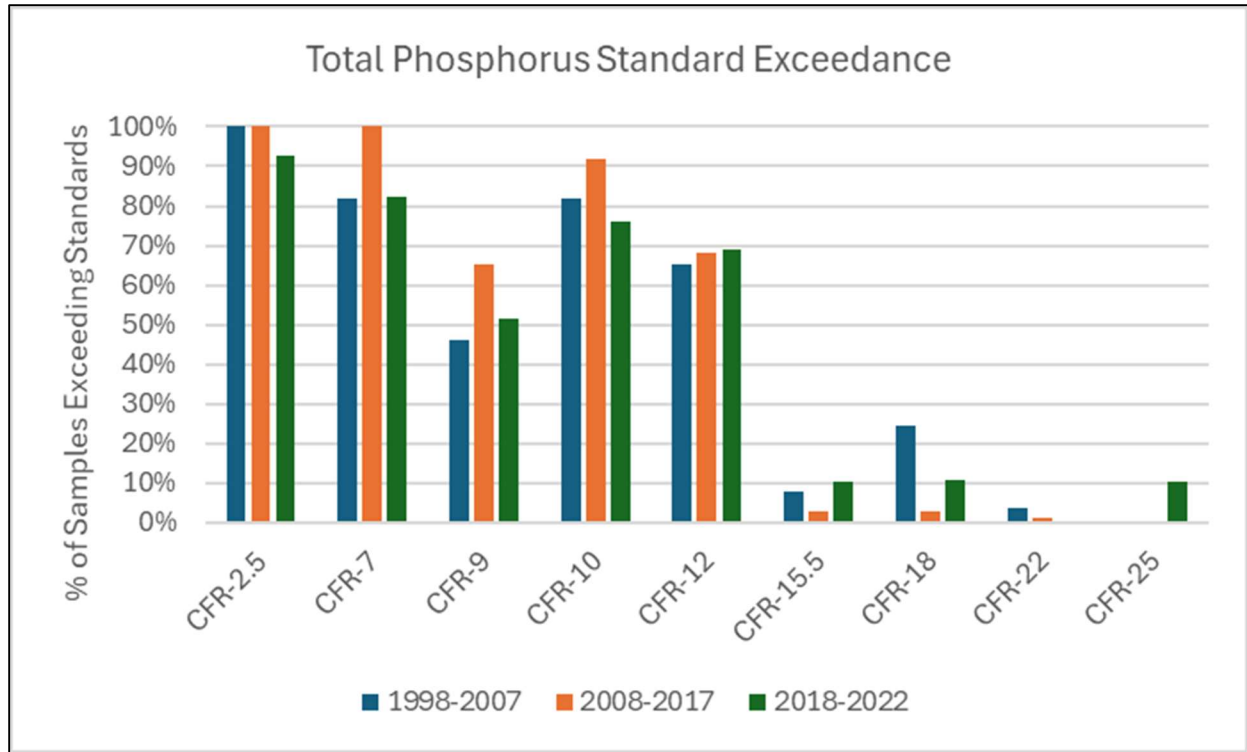


Figure 7-2. Percent samples exceeding Total Phosphorus numeric nutrient standard in Clark Fork River

7.3 CHLOROPHYLL-*a* SUMMER MEAN

Results of the numeric nutrient standards assessment for chlorophyll-*a* summer mean are shown in **Table 7-3** and on **Figure 7-3**. The rate of chlorophyll-*a* summer mean numeric standard exceedances decreased at six of the seven stations between the initial and current monitoring periods. The remaining station, CFR-25, did not exceed the numeric standard during any period over the 25-year project period and thus exhibits no change in exceedance rate. The two stations with the greatest decrease in the rate of chlorophyll-*a* summer mean exceedances are CFR-12 and CFR-18, with decreases of 70% each, whereas most other stations showed a decreasing exceedance rate on the order of 10–30%.

Despite the overall downward trend of chlorophyll-*a* summer mean exceedance rates over time, the most recent data for upper reach stations CFR-9 and CFR-10 still show a majority of samples exceeding the standard with 80% and 60% exceedance rates, respectively. In contrast, middle reach stations have lower exceedance rates, a pattern similar to that observed for TP.

Table 7-3. Summary of Clark Fork River chlorophyll-<i>a</i> summer mean numeric nutrient standard exceedance 1998–2022											
Station	Chlorophyll- <i>a</i> Summer Mean Numeric Nutrient Standard (NNS): 100 mg/m ²										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N ¹	N > NNS	% > NNS	N	N > NNS	% > NNS		N	N > NNS	% > NNS	
CFR-9	10	10	100%	10	9	90%	-10%	5	4	80%	-20%
CFR-10	10	9	90%	10	6	60%	-30%	5	3	60%	-30%
CFR-12	10	9	90%	10	7	70%	-20%	5	1	20%	-70%
CFR-15.5	10	5	50%	10	1	10%	-40%	5	2	40%	-10%
CFR-18	10	9	90%	10	4	40%	-50%	5	1	20%	-70%
CFR-22	10	3	30%	10	0	0%	-30%	5	1	20%	-10%
CFR-25	10	0	0%	10	0	0%	0%	5	0	0%	0%
Total	70	45	64%	70	27	39%	-26%	35	12	34%	-30%
Notes: 1. N - number of samples analyzed											

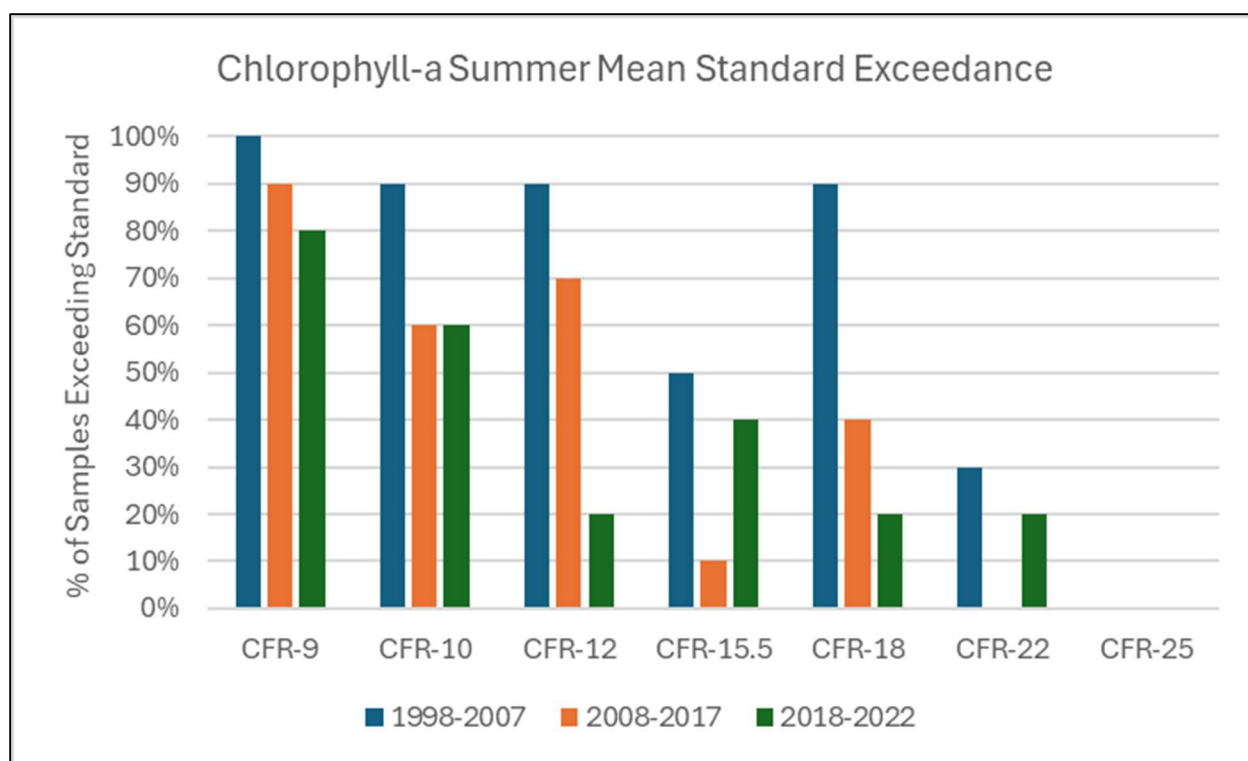


Figure 7-3. Percent samples exceeding chlorophyll-*a* summer mean numeric nutrient standard in Clark Fork River

7.4 CHLOROPHYLL-*a* SUMMER MAXIMUM

Results of the numeric nutrient standards assessment for chlorophyll-*a* summer maximum are shown in **Table 7-4** and on **Figure 7-4**. The overall rate of standards exceedances for the chlorophyll-*a* summer maximum has decreased by 20% from the initial 1998–2007 time period to the most recent 2018–2022 time period. However, on a station-by-station basis, there have been increasing, decreasing, and steady exceedance rates. Specifically, between the initial and most recent periods, the exceedance rate decreased at three of the seven stations (CFR-10, CFR-12, and CFR-18). Two stations (CFR-9 and CFR-25) exhibited no change in exceedance rate and two stations (CFR-15 and CFR-22) exhibited a 10% increase in exceedance rate compared to the initial period.

Similar to TP and mean chlorophyll-*a*, absolute exceedance rates for the 2018–2022 period are highest in the upper reach (stations CFR-9 and CFR-10) but lower in the middle reach.

Table 7-4. Summary of Clark Fork River chlorophyll- <i>a</i> summer maximum numeric nutrient standard exceedance 1998–2022											
Station	Chlorophyll- <i>a</i> Summer Maximum Numeric Nutrient Standard (NNS): 150 mg/m²										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N > NNS		% > NNS	N > NNS		% > NNS		N > NNS		% > NNS	
	N¹	NNS	NNS	N	NNS	NNS		N	NNS	NNS	
CFR-9	10	8	80%	10	9	90%	10%	5	4	80%	0%
CFR-10	10	7	70%	10	3	30%	-40%	5	2	40%	-30%
CFR-12	10	8	80%	10	6	60%	-20%	5	1	20%	-60%

Table 7-4. Summary of Clark Fork River chlorophyll-<i>a</i> summer maximum numeric nutrient standard exceedance 1998–2022											
Station	Chlorophyll- <i>a</i> Summer Maximum Numeric Nutrient Standard (NNS): 150 mg/m ²										
	1998–2007			2008–2017			Change in % (‘98–‘07 vs ‘08–‘17)	2018–2022			Change in % (‘98–‘07 vs ‘18–‘22)
	N ¹	N > NNS	% > NNS	N	N > NNS	% > NNS		N	N > NNS	% > NNS	
CFR-15.5	10	1	10%	10	0	0%	-10%	5	1	20%	10%
CFR-18	10	9	90%	10	5	50%	-40%	5	1	20%	-70%
CFR-22	10	1	10%	10	0	0%	-10%	5	1	20%	10%
CFR-25	10	0	0%	10	0	0%	0%	5	0	0%	0%
Total	70	34	49%	70	23	33%	-16%	35	10	29%	-20%

Notes: 1. N - number of samples analyzed

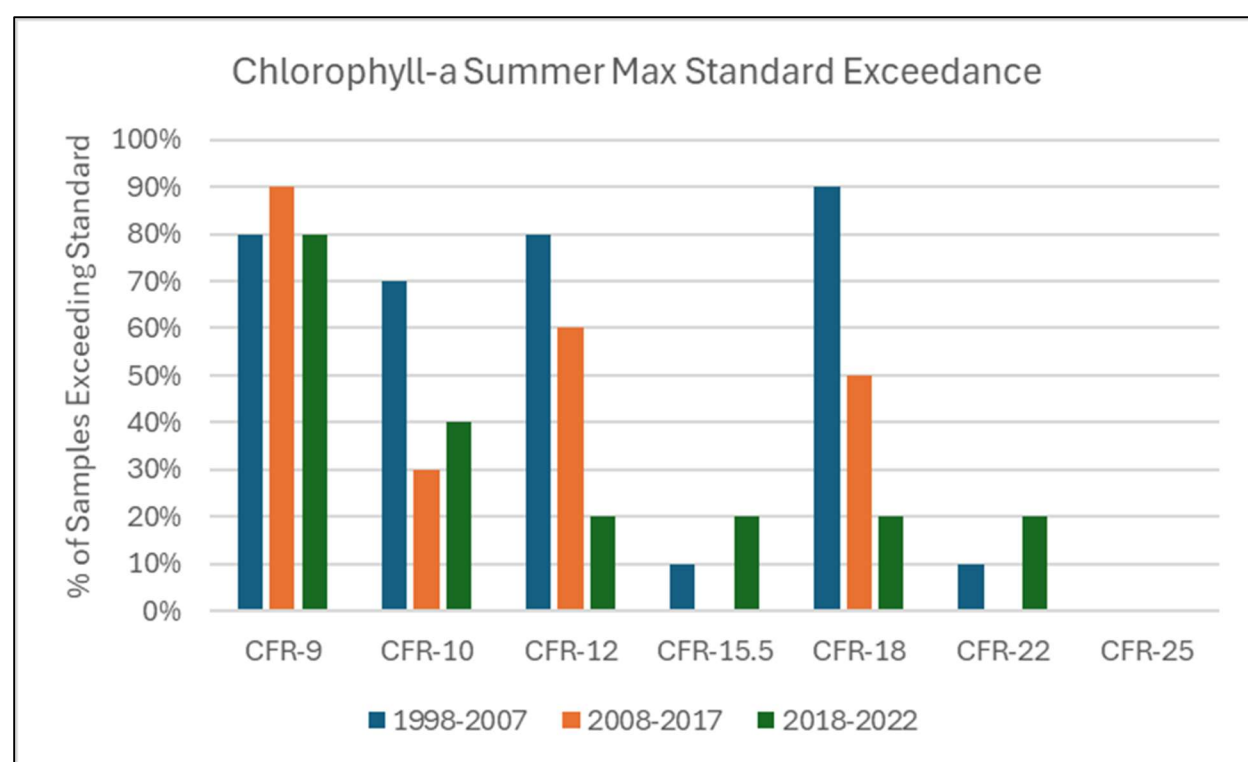


Figure 7-4. Percent samples exceeding chlorophyll-*a* summer maximum numeric nutrient standard in Clark Fork River

8.0 NUTRIENT LOADING RESULTS

The nutrient loading results presented in this report are a compilation of previously completed work reported in annual Clark Fork River nutrient loading estimate memorandums. The memorandums were prepared by HydroSolutions for Avista. Nutrient loading estimates for TP and TN to Lake Pend Oreille from the Clark Fork River from 1998–2022 are presented below in **Table 8-1**. Charts of annual nutrient loads are provided in **Attachment E**.

Table 8-1. Estimated total phosphorus and total nitrogen loads to Lake Pend Oreille from the Clark Fork River 1998–2022

Year	Daily Mean Flow Rate		Inflow Volume		TP Loading		TN Loading	
	CFS	% of Average	hm ³	ac-ft x 1000	Kg x 1000	lbs x 1000	Kg x 1000	lbs x 1000
1998	19,627	89%	17,530	14,212	170.2	375.2	1,955	4,311
1999	22,534	103%	20,125	16,316	229.0	504.9	3,055	6,734
2000	18,584	85%	16,644	13,493	122.8	270.7	1,900	4,189
2001	11,505	52%	10,276	8,331	90.9	200.4	1,535	3,384
2002	23,158	106%	20,683	16,768	235.4	519.0	2,525	5,567
2003	17,576	80%	15,697	12,726	179.2	395.1	2,882	6,354
2004	17,695	81%	15,847	12,847	139.7	308.0	1,848	4,075
2005	17,869	81%	15,959	12,938	159.2	351.1	1,813	3,997
2006	22,417	102%	20,021	16,231	285.1	628.6	3,401	7,498
2007	18,661	85%	16,667	13,512	158.8	350.2	2,587	5,704
2008	23,101	105%	20,689	16,773	307.6	678.2	4,050	8,928
2009	19,484	89%	17,402	14,108	215.4	474.8	2,482	5,471
2010	17,996	82%	16,072	13,030	150.4	331.5	2,254	4,969
2011	32,491	148%	29,018	23,525	528.1	1,164.4	4,842	10,676
2012	26,219	119%	23,481	19,036	312.0	687.8	3,966	8,743
2013	19,535	89%	17,447	14,144	148.9	328.2	2,279	5,025
2014	25,598	117%	22,799	18,483	260.5	574.3	3,720	8,200
2015	17,764	81%	15,865	12,862	132.3	291.6	2,179	4,803
2016	18,752	85%	16,794	13,615	141.2	311.3	2,355	5,193
2017	26,461	121%	23,633	19,160	258.5	569.8	3,347	7,379
2018	27,473	125%	24,537	19,892	441.1	972.4	4,291	9,460
2019	18,109	83%	16,174	13,112	248.3	547.5	2,577	5,681
2020	21,969	100%	19,675	15,951	170.3	375.4	2,655	5,853
2021	17,956	82%	16,035	12,999	139.5	307.6	1,994	4,396
2022	22,880	104%	20,378	16,521	158.8	350.0	2,414	5,321

Notes:

CFS - cubic feet per second

lbs -- pound mass

TP - Total Phosphorus

ac-ft - acre feet

hm³ - cubic hectometer

Kg - Kilogram

TN - Total Nitrogen

Average of mean daily flow rate at USGS gaging station 12392000 Clark Fork at Whitehorse Rapids near Cabinet Idaho for published record 1929-2013 (21,950 CFS)

Bolded TP loading values indicate exceedance of the allocated target load of 259,500 kilograms per year

Nutrient load estimates of TP and TN from the Clark Fork River to Lake Pend Oreille varies from year to year and are related to the mean annual discharge and total volume of inflow from the watershed. As expected, nutrient loads increase with increased mean annual discharge. According to loading

estimates, the annual TP load has exceeded the allocated target load of 259,500 kilograms per year six times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012, 2014, and 2018. In each of these cases, the mean annual discharge was greater than the long-term mean annual discharge. The largest nutrient loads occurred in 2011, which corresponds to the largest mean annual discharge for the period analyzed.

The Border Agreement identifies a short-term exceedance as three consecutive years greater than 110% of the target load. No short-term TP load exceedances have been identified since monitoring began in 1998. Nutrient loading targets have not been established for Clark Fork River TN loading to Lake Pend Oreille.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 SUMMARY AND CONCLUSIONS

The following are conclusions based on the results presented in this report:

1. Over the 1998–2022 evaluation period, SRP, TN, and TSIN all exhibited statistically significant decreasing trends at about 42% of monitored sites. Between 50 and 60% of sites had no significant trends detected and there were only two instances of statistically significant increasing trends for these parameters.
2. TP stands out (as it did in the previous report) for having the most sites exhibiting statistically significant decreasing trends (eight sites). No statistically significant increasing TP trends were identified, and only four sites had no statistically significant trend detected.
3. By site, CFR-18 (below Missoula) and CFR-22 (at Huson) had the most decreasing nutrient trends, with statistically significant decreasing trends for all four nutrient parameters. CFR-12 (at Bonita) had three statistically significant decreasing trends, whereas the remaining sites all had one or two statistically significant decreasing nutrient trends (except CFR-25, which had none).
4. A total of four statistically significant decreasing benthic chlorophyll-*a* trends were identified (two for mean and two for maximum) among the seven stations for which these concentrations were calculated. No statistically significant increasing trends were identified. Compared to the previous trend analysis (1998–2017), there were a total of three fewer decreasing trends. The number of decreasing trends on the middle reach is notably lower in the 2022 dataset compared to the 2017 dataset, whereas the number of decreasing trends remained constant on the upper reach over the same period.
5. Only two statistically significant increasing trends were identified among all monitored parameters, one at CFR-25 (TSIN) and one at CFR-28 (TN). The CFR-25 trend is potentially an artifact of a short-lived spike in TSIN that occurred from approximately 2016 to 2018 and may not be representative of an actual long-term trend. However, the CFR-28 trend appears to be a real upward trend as confirmed by visual evaluation of time series data. The reason for the upward TN trend at CFR-28 is not clear but could be related to non-point source nutrient loading associated with population growth along the Clark Fork River and in the Flathead watershed, or the hydroelectric dam at Thompson Falls.
6. Analysis of the current dataset found that previously identified increasing TP and SRP trends at station CFR-2.5 are no longer statistically significant.
7. Spatially, decreasing trends in the 2022 dataset are most heavily concentrated in the upper and middle reaches of the Clark Fork River, with fewer decreasing trends identified in the lower reach.
8. Factors contributing to decreasing trends in the upper and middle reaches of the Clark Fork River are likely to include upgrades to the City of Deer Lodge’s wastewater treatment system between 2017 and 2022 and continuing positive effects of previously completed improvements to the City of Butte and City of Missoula wastewater treatment systems. Continuing non-point source reduction activities are also likely to be a contributing factor.
9. Numeric nutrient standard exceedance rates for TN are relatively low, with most samples collected during the 2018–2022 period being below the standard. The exception is at CFR-2.5 with a TN standard exceedance rate of 74% during the 2018–2022 period, which is down 26%

from the 1998–2007 baseline period. Exceedance rates for TP and chlorophyll-*a* are also relatively low on the middle reach. However, exceedance rates remain high for TP and chlorophyll-*a* on the upper reach, where many samples from 2018–2022 remained elevated above standards. High exceedance rates on the upper reach are consistent with historical issues and could also be related to increased housing development trends in this area.

10. Change in the rate of numeric nutrient standard exceedances between 1998–2007 and 2018–2022 was variable among monitored parameters. TN exhibited a 22–44% decrease in the rate of exceedances at all but one of the stations evaluated (CFR-25, +2%), whereas TP exceedance rates changed by -14 to +10% at the stations evaluated. The majority of chlorophyll-*a* mean and maximum exceedance rates decreased by about 10–70%, although two middle reach stations saw a 10% increase in chlorophyll-*a* maximum exceedance rates. Overall, changes in exceedance rates do not consistently track with changes in statistical trends.
11. Nutrient loading from the Clark Fork River to Lake Pend Oreille varies from year to year and is proportional to the volume of inflow from the watershed. Generally, in years when inflow is greater than the annual average, the TP load exceeds the Montana-Idaho Border Agreement allocated target load of 259,500 kilograms per year. The estimated TP load exceeded the allocated target load six times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012, 2014, and 2018 but there has been no short-term TP load exceedance during the monitoring period.

9.2 RECOMMENDATIONS

The following recommendations are made to the CFRWQC to further assess nutrient water quality status in future studies or as part of the next 5-year trends analysis:

1. Basin-wide nutrient water quality monitoring should continue into the future so that cumulative, long-term impacts of nutrient reduction activities can be evaluated. The nutrient water quality monitoring program should continue to regularly assess the status and trends of water quality in the Clark Fork River basin so that planners and managers may better direct and focus nutrient reduction efforts in the Clark Fork River basin.
2. Consider application of piecewise trend analysis to the data set or testing for trends over different periods within the overall project dataset. For instance, trends could be evaluated separately for 1998 to 2008 (early project period with different data collection methods and fewer nutrient reduction activities) and the period after 2008 when data collection was more standardized and nutrient reduction activities were underway. Comparing the early and late period trends could provide better insight into the efficacy of nutrient reduction activities.
3. Compile and tabulate basin-wide nutrient loads from permitted point sources and estimates of non-point source contributions.
4. Estimate summer and/or annual nutrient loads at select stations in the upper and middle river.
5. Review and evaluate stream discharge changes and other hydrologic factors and assess their potential effect on nutrient and chlorophyll-*a* levels.
6. Assess changes in nitrogen to phosphorus ratios at select monitoring stations throughout the river.
7. Summarize available summertime temperature and dissolved oxygen data since these parameters interact with algae levels to affect habitat quality. Where little data exist, add some stations with temperature and dissolved oxygen monitors.

8. Collaborate with IDEQ to evaluate effects of estimated annual nutrient loading to Lake Pend Oreille on water quality in the lake.

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