Clark Fork River Nutrient Water Quality Status and Trends Report, 1998—2012

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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 under contract with Montana DEQ and Avista Corporation. This report provides background, history, and details of nutrient reduction activities that have taken place in the Clark Fork River basin of Montana, including a map that spatially shows locations of nutrient reduction activities. This report describes elements of the long-term water quality monitoring program that has occurred in the basin to evaluate the nutrient reduction activities, and the quality control steps taken to assure data collected in the monitoring program are sound and able to be used for the intended purpose. The primary purpose of this report is to address the following Clark Fork River water quality monitoring program objectives:

1. Evaluate temporal trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries
2. Evaluate temporal trends for periphyton (algal biomass as measured by benthic algal chlorophyll-*a* and ash free dry mass concentrations) standing crops in the Clark Fork River
3. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River

The temporal trends analysis for nutrient constituents was conducted on data from thirteen 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. Nutrient constituents included 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 temporal trends analysis for periphyton included seven monitoring stations in the upper and middle Clark Fork River, extending from the Clark Fork River near Deer Lodge, to the Clark Fork River above the Flathead River. Temporal trends analysis for periphyton evaluated mean and maximum benthic chlorophyll-*a.* The analyses were completed for the summer season months of July, August, and September from data collected from 1998–2012. Nutrient loading analysis evaluated TP and TN loading rates to Lake Pend Oreille from the Clark Fork River with year-round data at monitoring Station CFR-30, Clark Fork River below Cabinet Gorge Dam, in Idaho, from 1998–2012.

Prior to conducting the temporal trend analysis and loading evaluation, data reduction activities were completed on the DEQ provided dataset and reviewed for quality assurance. The nonparametric Mann-Kendall trend test was used to detect trends in the reduced data. The temporal trend analyses employed two-sided tests with significance level of alpha=0.1 and a null hypothesis, H_0, that no trend was present in the series. Nutrient concentration data were first regressed against flow utilizing the locally weight scatterplot smoothing (LOWESS) method. Consistent with current statistical guidance (Helsel and Hirsch 2002), and that of DEQ, temporal nutrient trends for TN, TSIN, TP and SRP were assessed with the seasonal Mann-Kendall trend test on flow-adjusted concentrations (residuals from the LOWESS regression) against time. Temporal trends of mean and maximum annual chlorophyll-*a* values were assessed with the Mann-Kendall trend test on concentration against time. TP and TN nutrient

loading was evaluated using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (version 3.10).

The results of the Clark Fork River nutrient and chlorophyll-*a* temporal trends analysis, 1998—2012, found that some discernable trends were present with varying degrees of significance and direction within the analyzed dataset. Findings of the trends analysis are tabulated and provided graphically for all analyzed constituents at all monitoring stations. Trends found in the Clark Fork River temporal nutrient trends analysis are also described by the magnitude or level of significance, and vary from marginally significant to highly significant (Helsel and Hirsch 2002).

Based on the findings of this report we conclude that:

- Overall, TN and TSIN concentrations appear to be holding steady in the Clark Fork River. No trends were detected in TN and TSIN concentrations at eleven of the thirteen monitoring stations. Highly significant decreasing trends in TN and TSIN were found at Station CFR-18, Clark Fork River below Missoula. In the lower Clark Fork River a marginally significant increasing trend in TN was found at monitoring Station CFR-28, Clark Fork River below Thompson Falls, and a marginally significant decreasing trend in TSIN was found at monitoring Station CFR-29, Clark Fork River at Noxon.
- Summertime TP concentrations have been generally declining since 1998 in the upper and middle Clark Fork River above the confluence with the Flathead River. Significant to highly significant decreasing trends in TP concentrations were found at six monitoring stations in the Clark Fork River in the approximately 160 mile reach from Garrison to Paradise, Montana, in the upper and middle reaches of the river. Summertime TP concentrations appear to be holding steady in the lower Clark Fork River. No trends in TP concentrations were found at any lower Clark Fork River monitoring station.
- Summertime SRP concentrations appear to be on the rise since 1998 in the upper and lower Clark Fork River. Increasing trends in SRP concentrations were found at four monitoring stations, including CFR-2.5, Silver Bow Creek at Opportunity; CFR-09, Clark Fork River at Deer Lodge; CFR-28, Clark Fork River below Thompson River; and CFR-29, Clark Fork River at Noxon. The only decreasing trend in SRP was found at CFR-18, Clark Fork River below Missoula.
- Summertime nutrient concentrations have been declining since 1998 in the Clark Fork River below Missoula. Highly significant decreasing trends were found for TN, TSIN, and TP; and a significant decreasing trend for SRP was found at Station CFR-18, Clark Fork River below Missoula.
- Algal trends are holding steady in the Clark Fork River upstream of Missoula. No trends were detected in summertime mean or maximum chlorophyll-*a* at four monitoring stations upstream of Missoula. Algal concentrations have been declining since 1998 in the Clark Fork River below Missoula. A highly significant decreasing trend was found in mean summertime chlorophyll-*a*, and significant decreasing trend in maximum summertime chlorophyll-*a* was found at Station CFR-18, Clark Fork River below Missoula. Algal concentrations have been declining in the Clark Fork River above the Flathead River, at Station CFR-25.
- Nutrient loading from the Clark Fork River to Lake Pend Oreille varies year to year and is proportional to the volume of inflow from the watershed. Generally in years when inflow is in excess of the annual average, the TP load exceeds the allocated target load of 259,500 kilograms per year of the Montana-Idaho Border Agreement. The estimated TP load exceeded the allocated target load four times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, and 2012. All of the exceedances have occurred in the last seven years, including the last two consecutive years. TN loads were also evaluated, but no target load exists.

TABLE OF CONTENTS

1.0 Introduction 1-1
2.0 Background 2-1
2.1 History 2-1
2.2 Nutrient Reduction Activities 2-2
2.2.1 Point Source Nutrient Reduction Activities 2-3
2.2.2 Non-Point Source Nutrient Reduction Activities 2-3
2.3 Purpose 2-8
3.0 Monitoring Program 3-1
3.1 Monitoring Network 3-2
3.2 Monitored Constituents 3-2
3.3 Sampling and Analytical Methods 3-3
3.4 Data Quality Assurance 3-4
4.0 Data Analysis Methods 4-1
4.1 Data Reduction 4-1
4.2 Statistical Trend Analyses 4-2
4.3 Nutrient Loading Estimation Method 4-3
5.0 Nutrient Water Quality Temporal Trend Results 5-1
5.1 Total Nitrogen 5-1
5.2 Total Soluble Inorganic Nitrogen 5-2
5.3 Total Phosphorus 5-3
5.4 Soluble Reactive Phosphorus 5-4
5.5 Chlorophyll-*a* 5-5
5.6 Summary of Trends 5-6
5.7 Discussion 5-9
6.0 Nutrient Loading Results 6-1
7.0 Conclusions 7-1
8.0 References 8-1

LIST OF TABLES

Table 3-1 Clark Fork River Watershed Monitoring Stations included in the Nutrient Trends Report
Table 3-2 Summary of Analytical Constituents, Analytical Methods, and Detection Limits for the Clark Fork River Monitoring Program
Table 4-1 Sample Population Count (N) and Number of Values with Sample Result Conditions (RC) of the Clark Fork River Nutrient Trends Analysis Dataset 1998—2012
Table 5-1 Seasonal Mann-Kendall Trend Test Results for Total Nitrogen at α=0.1 for all monitoring stations 1998–2012
Table 5-2 Seasonal Mann-Kendall Trend Test Results for Total Soluble Inorganic Nitrogen at α=0.1 for all monitoring stations 1998–2012
Table 5-3 Seasonal Mann-Kendall Trend Test Results for Total Phosphorus at α=0.1 for all monitoring stations 1998–2012
Table 5-4 Seasonal Mann-Kendall Trend Test Results for Soluble Reactive Phosphorus at α=0.1 for all monitoring stations 1998–2012
Table 5-5 Mann-Kendall Trend Test Results for Mean Benthic Chlorophyll-*a* at α=0.1 for all monitoring stations 1998–2012
Table 5-6 Mann-Kendall Trend Test Results for Maximum Benthic Chlorophyll-*a* at α=0.1 for all monitoring stations 1998–2012
Table 6-1 Estimated Total Phosphorus and Total Nitrogen Loads to Lake Pend Oreille from the Clark Fork River, 1998–2012, includes Annual Daily Mean Flow Rate, and Annual Inflow Volume

ATTACHMENTS

Attachment A Map of Nutrient Reduction Activities in Clark Fork River Basin
Attachment B Map of Clark Fork River Water Quality Monitoring Network
Attachment C Clark Fork River, 1998–2012, Temporal Trend Findings Maps
- Attachment C-1: 1998–2012 Temporal Trend Findings for Total Nitrogen at Clark Fork River Monitoring Stations
- Attachment C-2: 1998–2012 Temporal Trend Findings for Total Soluble Inorganic Nitrogen at Clark Fork River Monitoring Stations
- Attachment C-3: 1998–2012 Temporal Trend Findings for Total Phosphorus at Clark Fork River Monitoring Stations
- Attachment C-4: 1998–2012 Temporal Trend Findings for Soluble Reactive Phosphorus at Clark Fork River Monitoring Stations
- Attachment C-5: 1998–2012 Temporal Trend Findings for Mean Chlorophyll-*a* at Clark Fork River Monitoring Stations
- Attachment C-6: 1998–2012 Temporal Trend Findings for Maximum Chlorophyll-*a* at Clark Fork River Monitoring Stations

Attachment D Charts of Estimated Nutrient Loading from the Clark Fork River 1998—2012

ELECTRONIC ATTACHMENTS

Attachment E Electronic Data Compilation of Clark Fork River Nutrient Water Quality Status and Trends Report

- Electronic File of Dataset Used in Temporal Trends Analysis
- Electronic File of Dataset Used in Nutrient Loading Evaluation and FLUX Files
- Electronic Files of Kendall Trend Test Results
- Electronic Files of FLUX32 Results
- Electronic Report Files and Maps

ACRONYMS

AFDM	Ash-free Dry Mass
ARM	Administrative Rules of Montana
BNR	Biological Nutrient Removal
CFRWQMC	Clark Fork River Water Quality Monitoring Committee
DEQ	Montana Department of Environmental Quality
DO	Dissolved Oxygen
EPA	Environmental Protection Agency (U.S.)
ERFO	Emergency Relief for Federally Owned Roads
IDEQ	Idaho Department of Environmental Quality
LOWESS	Locally Weighted Scatterplot Smoothing
MDL	Method Detection Limit
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
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
VNRP	Voluntary Nutrient Reduction Program

1.0 INTRODUCTION

Montana Department of Environmental Quality (DEQ) and Avista Corporation (Avista) contracted with HydroSolutions Inc (HydroSolutions) to complete a Nutrient Water Quality Status and Trends Report for the Clark Fork River. Work was authorized under Montana Department of Environmental Quality (DEQ) contract number 213015, signed on December 3, 2012, and included three contract modifications (Modification 1, Modification 2, and Modification 3). Avista contract number R-39018, Work Authorization number 2, was signed on July 23, 2013, and amended on February 21, 2014.

This report was completed for the Clark Fork River Water Quality Monitoring Committee (CFRWQMC), which is comprised of DEQ, Avista, City of Missoula, University of Montana, and Idaho Department of Environmental Quality (IDEQ). Previous water quality trends reports for the Clark Fork River were prepared following completion of programmatic water quality monitoring in each of the five year increments from 1998–2002 and 2003–2007 (Tri-State Water Quality Council 2004) (Tri-State Water Quality Council 2009). This Nutrient Water Quality Status and Trends report was prepared following completion of programmatic water quality monitoring from 2008–2012.

The scope of work for this report was defined in the DEQ contract documents for DEQ contract number 213015 and Modifications 1 to 3. Under this contract, the Contractor was to complete a Nutrient Water Quality Status and Trends Report for the Clark Fork River. The scope of work specified that:

- The contractor shall "organize data and conduct seasonal and flow-weighted Locally Weighted Scatterplot Smoothing (LOWESS) regression techniques to determine if temporal trends exist at any sites that are part of the Clark Fork River Water Quality Monitoring Program in Montana and at the Cabinet Gorge site in Idaho"
- Montana DEQ shall provide guidance about statistical significance levels, how to handle non-detects, and must provide approval of statistical software used
- Trends shall be assessed for summer month chemical concentrations and year-round loading
- The DEQ project manager shall provide a final list of sites for inclusion in the trends analysis
- Trends analysis parameters shall include total nitrogen as N (TN), total soluble inorganic nitrogen as N (TSIN), total phosphorus as P (TP), soluble reactive phosphorus as P (SRP), and benthic chlorophyll-*a*
- Nutrient loading for TP and TN shall be assessed only at the Cabinet Gorge station where the Clark Fork River enters Idaho
- The final deliverable shall be a stand-alone report that describes potential shifts in nutrient producing or reduction activities in the basin along with long-term water quality trends analysis

The temporal trends analysis for nutrient constituents was conducted on monitoring program data, 1998–2012, from thirteen, long-term monitoring stations in the Clark Fork River basin, extending from the headwaters at Silver Bow Creek to the Clark Fork River below Cabinet Gorge Dam. The temporal trends analysis was completed for the summer season months of July, August, and September. The original scope of work specified that DEQ would provide spreadsheets or databases of all applicable water quality data. This was later changed in Modification 2 requiring completion of certain data reduction activities in the contract. These included:

- Retrieving discharge data from U.S. Geological Society (USGS) monitoring locations and pairing appropriate discharge and water quality data

- Compiling data from DEQ sources: including calculation of TN as the sum of total Kjeldahl nitrogen (TKN) and soluble nitrate and nitrite as N (NO2+NO3 as N) and TSIN as the sum of soluble ammonia nitrogen as N (NH_3+NH_4 as N) and NO2+NO3 as N
- Computing average monthly concentrations and flow conditions for each site prior to conducting trend analysis

In accordance with the scope of work, DEQ provided a summary list of nutrient reduction activities that have occurred in the Clark Fork River basin to supplement and enhance the interpretation of the trends analysis. DEQ also provided project oversight and quality control throughout all project activities including approval of data reduction methods, station selection, dataset quality assurance review, and statistical program and methods approval.

This report provides a temporal trend analysis of nutrient water quality in the Clark Fork River basin during July, August, and September, for the dataset years 1998–2012. This report describes:

- The purpose of completing a trends analysis
- The programmatic monitoring program that gathered, compiled, and stored the water quality dataset used in the analysis
- The data reduction and statistical methods used
- The results and findings, summary, and discussion of the temporal trends analysis
- The results and findings of estimated annual nutrient loading from the Clark Fork River into Lake Pend Oreille
- Conclusions of the Nutrient Water Quality Status and Trends Report for the Clark Fork River

2.0 BACKGROUND

The Clark Fork River drains about 22,000 square miles including most all 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 2010 US Census, the Clark Fork River basin in Montana has a population of about 339,800 people, contains 334 named streams with over 5,000 miles in stream length, has five major dams, and supports over 350,000 irrigated acres (National Atlas 2013). The Clark Fork River has long-term average annual flow of almost 22,000 cubic feet per second (CFS) leaving Montana (USGS 2014). The Clark Fork River provides a source of water for drinking and irrigation, support for industrial and forestry processing activities, multiple hydro-electric generation facilities, a means to treat and dispose water, many opportunities for commerce and recreation, and diverse habitats for multiple ecological communities including several threatened and endangered species. The upper Clark Fork River from headwaters to the former Milltown Dam is undergoing major restoration and cleanup efforts to remove contaminated heavy metals sediments that washed downstream from mine tailings. Restoration is part of Superfund and the Montana Natural Resource Damage Program, and includes projects to restore streambeds, streambanks, and the floodplain in the upper Clark Fork River. 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 have all worked together to monitor, protect, and improve.

2.1 HISTORY

The Tri-State Water Quality Council (Council) was a partnership of citizens, businesses, industry, tribes, government, and environmental groups working together to improve and protect water quality throughout the Clark Fork-Pend Oreille watershed. In 1993, the states of Montana, Idaho, and Washington, in conjunction with the U.S. Environmental Protection Agency (EPA) Regions 8 and 10, released the Clark Fork-Pend Oreille Watershed Management Plan (Watershed Management Plan) that was formed based on studies mandated by Congress under Section 525 of the Amendments to the 1987 Clean Water Act. The mandate was a direct result of the concerns of citizens regarding increased aquatic vegetation and attached algae in the Clark Fork River and Lake Pend Oreille. The main objectives of the study were to characterize water quality concerns, identify sources of the concern, and recommend actions for maintaining and enhancing water quality throughout the watershed. The findings and recommendations were reported back to Congress and formed the basis for the Watershed Management Plan, adopted in 1993 (EPA 1993) and last updated in 2007 (EPA 2007).

The Clean Water Act is the primary federal law in the United States governing water pollution. It established the objective of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The formation of the Council was a direct result of the Watershed Management Plan (EPA 1993). One of the first tasks of the Council was to create a Monitoring Committee that would oversee and implement a long-term, basin-wide monitoring strategy. The monitoring program was started in 1998 and continues today, despite the closing of the Council, which ceased operations in October 2012. The Watershed Management Plan focused efforts on controlling eutrophication and associated water use impairments that were identified as the most important interstate water quality problems. The goal of the Watershed Management Plan is to restore and protect designated beneficial water uses. The Watershed Management Plan further identifies water quality objectives and emerging new water quality challenges.

2.2 NUTRIENT REDUCTION ACTIVITIES

The Council was a catalyst for nutrient reduction activities in the Clark Fork River basin through the Watershed Management Plan and creation of the Clark Fork River Voluntary Nutrient Reduction Program (VNRP). The VNRP was a landmark 1998 agreement to reduce nutrient pollution in the upper and middle Clark Fork River. The agreement allocated nutrient discharge into the river between three municipal wastewater treatment plants (Butte, Deer Lodge, and Missoula), one industrial discharger (Smurfit-Stone) and Missoula County, which is responsible for septic systems discharges (McDowell 2000).

As part of the VNRP, the Council championed target nutrient concentrations for the Clark Fork River. The state of Montana in 2002, subsequently adopted the VNRP targets as nutrient standards for TP, TN, and mean and maximum benthic algal chlorophyll-*a* concentrations in the Administrative Rules of Montana (ARM) 17.30.631, the first, and currently only, nutrient standards in the state. The standards are applicable in the mainstem Clark Fork River below Warm Springs Creek to the confluence with the Flathead River during the summertime months from June 21 to September 21. The VNRP also established target concentrations for soluble nutrient constituents (TSIN and SRP), which continue today.

The Council also assisted in brokering the Montana and Idaho Border Nutrient Load Memorandum of Agreement (Border Agreement) in 2002, through developing and advocating recommended nutrient targets and apportioning nutrient loads to Lake Pend Oreille. Nutrient targets established in the Border Agreement were developed to maintain water quality in the open waters of Lake Pend Oreille from the mouth of the Clark Fork River to the Long Bridge (Highway 95). The Border Agreement apportioned nutrient loading of 259,500 kilograms per year TP from Montana (as measured at Clark Fork River below Cabinet Gorge Dam) into Lake Pend Oreille. The Border Agreement established a short-term exceedance of the targets as three consecutive years of TP load increases at the border that are above the targets by greater than 10%. A long-term exceedance of the Border Agreement targets is defined as a ten year average total phosphorus concentration in Lake Pend Oreille greater than 7.3 micrograms per liter (µg/L).

The following sections list recent point and non-point nutrient reduction activities that have taken place in the Clark Fork River basin during and since the VNRP. These activities were compiled and provided by DEQ. A map showing the general location of each nutrient reduction activity in the Clark Fork River basin is provided in **Attachment A**.

2.2.1 Point Source Nutrient Reduction Activities

The following point source nutrient reduction activities were compiled by DEQ.

Nutrient Source	Action Taken
Basin wide	Phosphate laundry detergent ban enacted in 1989
Missoula wastewater facility	Upgraded and expanded the facility biological nutrient removal (BNR), and fermenter; 2004–2005. Launched a pilot project to irrigate 1.6 acres of poplar trees with treated effluent in 2009.

Deer Lodge wastewater facility	Replaced old leaking sewer lines; slipped lined sewer lines in 2009; developed a land application system for effluent to reduce direct July–September discharge to the river to zero (Note: Reductions occurred only up to 2008, as facility returned temporarily to direct discharge in 2008). In the process of designing a new facility.
Smurfit-Stone Container corporation	Reduced nutrient additions to treatment systems; no direct discharge to river July-August (used storage ponds). The paper mill operated along the banks of the Clark Fork River for over 50 years and processed up to 25 million gallons of water per day during peak production. The mill was closed in 2010.
Hamilton wastewater treatment plant	Upgraded facility (headworks, flow meters, transfer switch for generator, computer system), added a dissolved air floatation unit, upgraded the return activated sludge pumps, and added a screw press in 2010.
Stevensville wastewater	Replaced unlined polishing lagoons with a UV disinfection as a final clarifier in 2011.
Missoula County	Connected thousands of existing home septic system to the central sewer.
Butte wastewater facility	Constructed stormwater detention basins to reduce stormwater overflow to the sanitary sewers; reduced industrial loads; grew sod with effluent in summer (Note: New membrane bioreactor facility planned to be operational by 2015); Updated facilities headworks, and installed influent and effluent Parshall flumes, and two vertical turbine effluent pumps for sod farm in 2011.

2.2.2 Non-Point Source Nutrient Reduction Activities

The following non-point source nutrient reduction activities were compiled by DEQ. The listed activities are distributed across the entire basin, but do not necessarily represent a comprehensive list. All projects are sponsored by individual organizations, but are typically funded through a variety of sources. Non-point source nutrient reduction activities include projects to reduce sediment (e.g. bank stabilization, channel restoration, and mine reclamation). The premise is that a reduction in sediment loads will also reduce nutrient loads to the Clark Fork River, and that the projects together, will have a cumulative effect in improving water quality.

Date	Waterbody/Project Name	Project Sponsor or Organization
1993–2013	Clark Fork River Basin (Various Waterbodies)	Plum Creek Timber Co.
Activity Description: Best Management Practices have been applied to improve roads and reduce sediment delivery. Range management plans and riparian monitoring have been applied to the lands that are leased by Plum Creek. Approximately 500,000 acres of company land has been sold to conservations groups such as The Nature Conservancy, United States Forest Service, Montana Fish Wildlife and Parks, and others over the last 20 years.		
2007–2012	Upper Clark Fork River/Milltown Dam Removal	Environmental Protection Agency

Date	Waterbody/Project Name	Project Sponsor or Organization
Activity Description: Excavation of reservoir sediments took place between 2007 and 2009. Over 2,330,000 tons of sediment was removed by train cars for relocation and disposal at the Anaconda Region Water Waste and Soils Operable Unit. Another 230,000 tons of sediment was removed from the spillway area and contained outside of the 100-year floodplain. The river channel was redirected and re-graded before stream bank stabilization and revegetation took place (2009–2012). A total of 34,050 plants were installed over five phases.		
2013	Peterson Creek/Upper Clark Fork Tributary Restoration	Watershed Restoration Coalition
Activity Description: Livestock were fenced out of three miles of Peterson Creek, a tributary to the Clark Fork mainstem near Deer Lodge.		
2003	Thompson River (upper)/Thompson River Riparian Restoration (Lower Clark Fork)	Plum Creek Timber Co.
Activity Description: Revegetation occurred along two acres of treated plots in the riparian area and 4,000 conifers were planted in other riparian zones. As of 2009, 83% of the vegetation has survived.		
2010	Big Rock Creek/Big Rock Creek Road Rehabilitation (Thompson River Drainage, Lower Clark Fork)	Montana Fish Wildlife and Parks
Activity Description: A segment of the road was moved out of the floodplain after it was washed out in 2008. The two undersized culverts were replaced with a new bridge. Within the washed-out area, approximately 100 meters of stream was reclaimed and some excess eroding banks were sloped back.		
2011	Little McCormick Creek/Ninemile Watershed TMDL Implementation 2008 (Lower Clark Fork)	Trout Unlimited
Activity Description: Channel restoration occurred on 2,600 feet of Little McCormick Creek to reduce sediment erosion. Little McCormick Creek flows into Ninemile Creek.		
2012	St. Louis Creek/Ninemile TMDL Implementation (Lower Clark Fork)	Trout Unlimited
Activity Description: Mine waste was removed from St. Louis Creek, a tributary to Ninemile Creek. The project reduced sediment erosion.		
2005	Daisy Creek/Daisy Creek Stream Rehabilitation (Lower Clark Fork)	United States Forest Service
Activity Description: A trail and a culvert were removed from Daisy Creek and the channel was reconstructed with 800 feet of the channel being relocated into the historic channel and seeded.		
2007	Crow Creek/Crow Creek Restoration (Lower Clark Fork)	United States Forest Service
Activity Description: Crow Creek was unstable due to a power line corridor. Over 670 linear feet of the channel was reshaped and vegetated.		
2007	Cooper Gulch & Chipmunk Creek / Cooper & Chipmunk Culvert Replacement (Bridges) (Lower Clark Fork)	United States Forest Service
Activity Description: Two culverts along Cooper Gulch and Chipmunk Creek were undersized and causing sedimentation and instability. They were replaced with free-spanning concrete bridges. The stream was also modified by placing large rocks within the channel to help prevent erosion during high flow. The stream banks were also lined with rip rap to ensure stability.		
2008	Prospect Creek/Old Wilkes Creek Bridge Abutment Removal (Lower Clark Fork)	United States Forest Service

Date	Waterbody/Project Name	Project Sponsor or Organization
Activity Description: Bridge abutments of an abandoned bridge were removed and banks were sloped back and protected by rootwad revetments. This reduced the potential for roadbed washout and sediment input.		
2008	Crow Creek/Prospect Creek/Crow Creek Restoration Project (Lower Clark Fork)	Lower Clark Fork Watershed Group
Activity Description: Channel restoration occurred in Crow Creek, a tributary to Prospect Creek. The project reduced sediment erosion, and therefore likely reduced nutrient pollution.		
2009	Prospect Creek/Prospect Creek Riparian Re-Forestation (Lower Clark Fork)	Lower Clark Fork Watershed Group
Activity Description: Twentyfive hundred trees were planted in the riparian area of Prospect Creek for stabilization, stream shade, and large woody debris recruitment.		
2009	Prospect Creek/YPL Riparian Revegetation (Lower Clark Fork)	Green Mountain Conservation District
Activity Description: Revegetation took place along Prospect Creek at seven sites next to the Yellowstone Pipe Line. Approximately 7,000 individual plants were installed.		
2007	Graves Creek/Graves Creek Restoration (Cox/Newby) (Lower Clark Fork)	Lower Clark Fork Watershed Group
Activity Description: An eroding glacial terrace received a larger woody debris structure, and soil lifts to prevent further erosion and to encourage pool development		
1997	Beaver Creek/Beaver 301 (ERFO) (Lower Clark Fork)	United States Forest Service
Activity Description: Erosion issues along Beaver Creek threatened to reroute the creek over the road. For prevention, various rock and wood structures were used to stabilize the channel for approximately 1,300 linear feet.		
2006	Vermilion River/Upper Vermilion Bank Stabilization (Lower Clark Fork)	United States Forest Service
Activity Description: Channel stabilization work was done after a road was washed out. The channel was narrowed in areas that had over widened, and log veins were installed to help pool formation. Some revegetation work was done. The entire project reach was approximately 300 feet in length.		
2001	Trout Creek/Trout Creek Restoration (Morkert)	Trout Creek Watershed Council
Activity Description: A section of Trout Creek on private property had high banks and little vegetation. Fascines were added to the bank and revegetation was implemented.		
2009	Marten Creek/Marten Creek -Smith (Lower Clark Fork)	United States Forest Service
Activity Description: Riparian logging caused channel instability, widening, aggradation, and increased lateral migration. Then in 2008 the spring runoff caused major erosion at two sites. Fifty feet and over 1,000 feet were treated with rock and wood structures to restore the reach to a naturally functioning channel at the lower and upper sites, respectively.		
2006	Pilgrim Creek/Pilgrim Creek Railroad Bridge (Lower Clark Fork)	United States Forest Service and Green Mountain Conservation District
Activity Description: A reach was reshaped after the removal of an abandoned bridge and its piers covering approximately 150 feet of channel. Features were added, and shrubs and conifers were planted. Rock stabilization was added after a beaver dam affecting erosion was removed.		

Date	Waterbody/Project Name	Project Sponsor or Organization
2006	Pilgrim Creek/ Reishus Restoration (Lower Clark Fork)	Green Mountain Conservation District
Activity Description: A Pilgrim Creek reach was defined as a braided channel with eroding terraces with poor aquatic habitat and riparian vegetation. This was due to riparian vegetation being removed in the 1980s. After the initial reconstruction of 1,200 feet of channel, several modifications were made a few years later and structures added. These additions helped with the success of the project.		
2007	West Fork Pilgrim Creek/West Fork Pilgrim Creek Restoration (Lower Clark Fork)	United States Forest Service
Activity Description: This stream had mass wasting upstream of a bridge on a USFS road. The stream was reconstructed and routed through 200 feet of new channel and 800 feet of historic channel, and structures were added to increase stability. A large woody debris revetment and footer rocks were added to the mass wasting site. Revegetation efforts were made in the disturbed area.		
2002 +	East Fork Bull River/Stein - East Fork Bull River (Lower Clark Fork)	Clark Fork – Pend Oreille Conservancy
Activity Description: Two full-scale channel stabilization/reconstruction projects were completed along a section of the East Fork of Bull River located on private property, along with a multiyear revegetation project.		
1999	Berray Creek/Berray Creek Restoration (Lower Clark Fork)	United States Forest Service
Activity Description: A Wetland along Berray Creek was unstable due to logging in the area. Concern that the channel would bypass the wetland and deposit directly into the Bull River led to structures such as pre-vegetated coir matting, large rootwad revetments, and large riprap as a back fill to be added at the erosion point to stabilize it. Approximately 1,800 linear feet were addressed by this project		
2001	Bull River/McDowell Bank Stabilization and Revegetation (Lower Clark Fork)	Bull River Watershed Council
Activity Description: Eroding banks along the Bull River on private land received rock and large woody debris revetments for stabilization. The upper eroding bank was over 200 linear feet and the lower eroding bank was over 400 linear feet. The banks were seeded and vegetated.		
2002	Snake Creek/SN-6 Snake Creek Restoration	United States Forest Service
Activity Description: Undersized culverts along Snake Creek resulted in backfilling, gully erosion, and road failures. The culverts and the road prism were removed, and grade control structures (rock and log weirs) were added. About 150 shrubs and trees were planted in 2003.		
2003	South Fork Bull River/SFBR Slide Restoration (Lower Clark Fork)	Bull River Watershed Council and Green Mountain Conservation District
Activity Description: The South Fork of Bull River was affected by a landslide in the early 1990s which impacted the channel stability, structure, and riparian vegetation. Structures were added to restore about 120 meters of the channel to a single thread with the proper dimensions. Pre- and post-construction sediment samples show a 190% decrease in fine sediment contribution from the slide.		
2006	Bull River/Dabronski Bridge Removal (Lower Clark Fork)	United States Forest Service
Activity Description: An outdated bridge on USFS land caused an erosion problem by acting as a constriction point. The bridge was replaced with a new foot bridge, and the channel was reshaped to resemble above and below stream reaches. Seeding was done on disturbed areas.		

Date	Waterbody/Project Name	Project Sponsor or Organization
2008	East Fork Bull River/EFBR Slide Restoration (Lower Clark Fork)	United States Forest Service
Activity Description: A mass waste site was providing chronic fine sediment loads to the East Fork of Bull River at all flows due to surfacing groundwater. Nine hundred linear feet of the channel was reconstructed and structures were added to control grade and stabilize banks. Revegetation efforts were made after the construction.		
1997	Elk Creek/Elk Creek (Heron)	Elk Creek Watershed Council
Activity Description: Thirty-five sites along the East Fork and mainstem of Elk Creek were reconstructed for channel stability. Primarily rootwad revetments were used, and some revegetation efforts took place after construction.		
2000	West Fork Elk Creek/West Fork Elk Creek Stabilization (Lower Clark Fork)	Elk Creek Watershed Council
Activity Description: Six sites along the West Fork Elk Creek were identified as having erosion problems, including: unstable banks, unstable overflow channels, deteriorating pond diversion, and an eroding bridge abutment. Various measures were taken to stabilize the stream.		
2001	Elk Creek/Hollinshead Workshop	Natural Resource Conservation Service
Activity Description: Landowners were concerned about floodwaters from Elk Creek and a nearby wetland area reaching their house. Seven Hundred linear feet of bank near the house was vegetated with willow and alder.		
2008	Elk Creek/Elk Creek Restoration Project (Lower Clark Fork)	Lower Clark Fork Watershed Group
Activity Description: This project provided channel restoration and bank stabilization on roughly 1,000 linear feet of Elk Creek.		
2013	East Fork Elk Creek/East Fork Elk Creek Springer Bank Stabilization (Lower Clark Fork)	Lower Clark Fork Watershed Group
Activity Description: This project provided riparian renovation to reduce sediment. Work was completed on the East Fork of Elk Creek which flows into Elk Creek.		
2010	East Fork Blue Creek/Scotchman Mine Tailings Cleanup (Lower Clark Fork)	Green Mountain Conservation District
Activity Description: An abandoned mine tailing site (200-500 cubic yards) was reclaimed near the East Fork of Blue Creek. The tailings pile was steep, unstable, and was only a few feet away from the stream. The tailings were removed to a capped and sealed repository site downstream. Structures were used to prevent the channel from washing out the nearby road after tailings were removed. Roadwork was done in the area, including converting a part of the repaired road that was used for construction to a trail. A ford repair on private property was done, and French drains with rock lined ditches were added to one section where springs would run over the road.		

2.3 PURPOSE

In order to achieve the water quality goals and objectives identified in the Watershed 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 watershed. The purpose of this report is to provide the means to evaluate effectiveness of stated water quality management goals and respond directly to long-term monitoring program objectives. This report builds on a previously completed Clark Fork River water quality trends report (Tri-State Water Quality Council 2009) and provides 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 are identified by the Council:

- 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
- Improve Pend Oreille River water quality through macrophyte management and tributary non-point source controls

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

1. Evaluate temporal trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries
2. Evaluate temporal trends for periphyton (algal biomass as measured by benthic algal chlorophyll-*a* and ash free dry weight concentrations) standing crops in the Clark Fork River
3. Monitor summer nutrient and periphyton target levels in the Clark Fork River
4. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River
5. Evaluate temporal trends for periphyton densities in near-shore areas of Lake Pend Oreille
6. Evaluate temporal trends for Secchi depth transparency in Lake Pend Oreille
7. Evaluate temporal trends for nutrient concentrations in the Pend Oreille River

The purpose of this report is to evaluate nutrient water quality and chlorophyll-*a* levels and temporal trends in the Clark Fork River. This report does not address monitoring objectives five, six, and seven; therefore, the monitoring program described below includes only information pertinent to monitoring activities associated with the Clark Fork River, located primarily in Montana.

3.0 MONITORING PROGRAM

The Council coordinated a Clark Fork-Pend Oreille basin-wide monitoring program. Consistent water quality monitoring was completed by the Council's Monitoring Committee, which consisted of a dedicated network of state agencies including DEQ, IDEQ, and Washington Department of Ecology; industry and business partners including Avista and Plum Creek Timber Company; 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. 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. Dedicated long-term monitoring stations were established and divided among the multiple organizations and agencies that formed the Council's Monitoring Committee. The monitoring program was consistently completed beginning in 1998 and on an annual basis thereafter.

The Council's stated monitoring objectives were achieved under separate project-specific sampling programs and associated quality assurance project plans (QAPPs), but were managed inclusively by the Council's Monitoring Committee. The QAPPs were regularly reviewed and updated by the Council's Monitoring Committee. The QAPP provided a consistent and scientifically acceptable approach to data collection and management that facilitated achievement of program objectives, provided the framework for conducting the activity, and provided the guidelines for reviewing analytical results to assure quality data. A sampling and analysis plan (SAP) was developed for each activity to provide the structure and protocol of the activity, defining what, where, when, and the protocols for accomplishing the monitoring activity. Over the monitoring period, elements of the SAP were merged into the QAPP.

Currently the Council is not available to coordinate basin-wide monitoring, so monitoring is now managed separately, at the state level. Clark Fork River monitoring is managed by the CFRWQMC. The CFRWQMC have developed SAPs and QAPPs to guide their efforts, to determine which elements are consistent with long-term water quality monitoring completed by the Council.

The following list summarizes the general water quality monitoring program completed for the Clark Fork River beginning in 1998. Specific monitoring activities and locations varied through the years. The nutrient and periphyton data collected through this program provided the dataset and basis for completing this report. The Clark Fork River water quality monitoring program included:

- Clark Fork River Monthly Monitoring (monthly monitoring): Monthly collection of nutrient and heavy metals samples and field measurements at three lower Clark Fork River stations and monthly collection of nutrient samples and field measurements in the Thompson River near its mouth completed January through December
- Clark Fork River Peak Flow Monitoring (peak flow monitoring): Collection of nutrient and heavy metals samples at the Clark Fork River below Cabinet Gorge Dam during spring peak flow conditions completed in six sampling events over about a one-month period, May to June
- Clark Fork River Summer Nutrient Monitoring (summer nutrient monitoring): Collection of summer nutrient samples and field measurements at nine Clark Fork River and tributary stations completed during ten sampling events, June through September, during the nutrient regulatory period

- Clark Fork River Periphyton Monitoring: Collection of summer algae standing crop samples at seven Clark Fork River stations, completed twice, once in August and once in September

3.1 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. This design provides for a cost effective and scientifically-based 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. Clark Fork River nutrient monitoring stations included in this report are listed in **Table 3-1** and shown on the map in **Attachment B**. Also shown in **Table 3-1** are the river reach, the paired USGS stream gaging station, and monitoring type for each monitoring station.

Table 3-1 Clark Fork River Watershed Monitoring Stations included in the Nutrient Trends Report

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	SN10
	CFR-07	CFR below Warm Springs Creek	12323800 CFR at Galen	SN10
	CFR-09	CFR at Deer Lodge	12324200 CFR at Deer Lodge	P2, SN10
	CFR-10	CFR above Little Blackfoot River	12324200 CFR at Deer Lodge	P2, SN10
	CFR-12	CFR at Bonita	12331800 CFR near Drummond	P2, SN10
Middle CFR	CFR-15.5	CFR above Missoula	12340500 CFR above Missoula	P2, SN10
	CFR-18	CFR below Missoula	12340500 CFR above Missoula	P2, SN10
	CFR-22	CFR at Huson	12353000 CFR below Missoula	P2, SN10
	CFR-25	CFR above Flathead	12354500 CFR at St. Regis	P2, SN10
Lower CFR	CFR-27.5	Thompson River near mouth	12389500 Thompson River	N12
	CFR-28	CFR below Thompson Falls	12389000 CFR near Plains	NM12
	CFR-29	CFR at Noxon Bridge	12391400 CFR below Noxon Rapids Dam	NM12
	CFR-30	CFR below Cabinet Gorge Dam	12391950 CFR below Cabinet Gorge Dam	NM18

Notes:

CFR	*Clark Fork River*
SN10	*Summer nutrient and field constituents, 10 samples during 3 months in summer*
P2	*Periphyton collected in August and September by University of Montana Watershed Health Clinic*
N12	*Nutrient and field constituents, 12 monthly samples by technical consultant (site sponsored by Plum Creek)*
NM12	*Nutrient, metal and field constituents, 12 monthly samples by technical consultant (SRP monitored from 1998—2007)*
NM18	*Nutrient, metal and field constituents, 12 monthly samples and 6 peak flow samples by Avista and technical consultant*

3.2 Monitored Constituents

The monitoring program consists of the collection of the following nutrient constituents, periphyton data, and field parameter measurements. Monitored constituents differ between monitoring activities and individual monitoring stations. Select metals constituents were also monitored at lower Clark Fork River stations.

Nutrient Constituents

- Total (persulfate) nitrogen (TN), or nutrient nitrogen (monitored from 2009–2012)
- Total Kjeldahl nitrogen (TKN) (monitored from 1998–2008)
- Soluble nitrate and nitrite as N (NO_2+NO_3 as N), or inorganic nitrogen as N (dissolved)
- Soluble ammonia nitrogen as N (NH_3+NH_4 as N), or total ammonia nitrogen as N (dissolved)
- Total phosphorus (TP), or phosphate-phosphorus as P
- Soluble reactive phosphorus (SRP), or Orthophosphate as P

Periphyton

- Periphyton 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 (˚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 (µS/cm)
- Total dissolved solids (TDS) in mg/L
- Turbidity in Nephelometric Turbidity Units (NTU)

Stream flow in CFS and river stage (feet) recorded by the USGS at established gaging stations described in **Table 3-1**, also form the water quality data used in this report.

3.3 Sampling and Analytical Methods

Specific methods of sample collection, preservation, and handling, followed by each of the monitoring program activities can be found in their respective SAPs or QAPPs (Tri-State Water Quality Council 2010) (University of Montana Watershed Health Clinic 2009). 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 regarding these methods are described in Standard Methods for the Examination of Water and Wastewater, 20th Ed (APHA/AWWA/WEF 1998) and other EPA documents. Further information regarding analytical methods may be found in the laboratories' quality assurance plans which are part of respective monitoring activity QAPPs.

Table 3-2 presents the constituents, analytical methods, and detection limits of the nutrient and chlorophyll-*a* data used in this report. Analytical methods and detection limits provided in **Table 3-2** are based on review of the dataset provided by DEQ.

Table 3-2 Summary of Analytical Constituents, Analytical Methods, and Detection Limits for the Clark Fork River Monitoring Program

Constituent	Analytical Method(s)	Range of Detection Limits
Ammonia nitrogen (NH3+NH4 as N)	350.1, 4500-NH3(H)	10 µg/L
Inorganic nitrogen (NO_2+NO_3 as N)	353.2, 353.3, 4500-NO3(I)	2, 10, 20 µg/L

Table 3-2 Summary of Analytical Constituents, Analytical Methods, and Detection Limits for the Clark Fork River Monitoring Program

Constituent	Analytical Method(s)	Range of Detection Limits
Kjeldahl nitrogen (TKN)	351.1, 351.2	100 µg/L
Nutrient-nitrogen (TPN) or Total Nitrogen (TN)	4500-N-C	10, 50, 100 µg/L
Orthophosphate (SRP)	365.1, 365.3, 4500-P-G	1, 2, 4 µg/L
Phosphate-phosphorus or Total Phosphorus (TP)	365.2, 365.3, 365.4, 4500-P-H	1, 4, 8 µg/L
Algal chlorophyll-*a* (chl-*a*)	(University of Montana Watershed Health Clinic 2009)	0.1, 1, 2, 4 mg chl-*a*/m^2
Algal ash-free dry mass (AFDM)	(University of Montana Watershed Health Clinic 2009)	0.01 g/m^2 (hoop) 0.8 g/m^2 (template)

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. *g/m^2 grams per square meter*
4. *mg/m^2 milligrams per square meter*
5. *µg/L micrograms per liter*
6. *UM-WHC University of Montana Watershed Health Clinic*

Detection limits shown in **Table 3-2** are based on the laboratory lower reporting limits. Laboratory lower reporting limits were established by the laboratories for each constituent as the lowest concentration that could be reliably achieved 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. Results detected greater than the MDL, but less than the lower reporting limit indicates the presence of the analyte, but the concentration could not be accurately quantified. Therefore, those results in the database were qualified as an estimated value. Lower reporting limits for each monitored constituent met project required quantitation limits for Clark Fork River monitoring activities established in the QAPP (Tri-State Water Quality Council 2010).

3.4 Data Quality Assurance

The QAPP established procedures for reviewing, reporting, and approving water quality data collected by the monitoring program (Tri-State Water Quality Council 2010). The quality assurance procedures include guidance provided by DEQ. Following completion of each monitoring year, the Council's monitoring committee, through their technical consultant, completed a thorough quality assurance review of monitoring data. Documentation of this review was provided in annual reports presented to the monitoring committee. The quality assurance review included review of sample handling procedures, field and analytical methodology, data quality objectives and data quality indicators prescribed in the QAPP, and other data quality checks prescribed in the QAPP. Once approved by the monitoring committee and DEQ, data were uploaded to the EPA's National STORET Warehouse, which fulfills the requirement of environmental monitoring projects funded by federal monies. This STORET data is the basis for the dataset used in this report. Data quality assurance completed in the monitoring program assures that the data used in this report were comparable and sufficiently precise and accurate for the intended purpose.

4.0 DATA ANALYSIS METHODS

This section describes the methods used to reduce the raw dataset into a format needed for analysis, and the methods used in the data analysis to evaluate for the presence of trends and 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). All methods used in data reduction and analysis were discussed with and approved by DEQ.

4.1 DATA REDUCTION

The dataset used in this report was extracted from the STORET Warehouse by DEQ. DEQ extracted all available nutrient data from the Clark Fork River monitoring program and other sources at the same monitoring station through 2012. DEQ reviewed this dataset and removed all data that did not specify a MDL or lower reporting limit. In doing this, all data prior to 1998 were removed from the dataset.

The nutrient loading analysis was completed on year-round TP and TN data collected from Station CFR-30, Clark Fork River below Cabinet Gorge Dam. Data reduction for the loading analysis also included removal of quality control samples (sample duplicates and sample blanks).

The trends analysis was completed on average monthly nutrient concentrations July through September. The following lists data reduction completed for the trends analysis dataset:

1. Duplicate and blank samples were removed
2. Extreme outliers were removed at the direction of DEQ (this applied to two values)
3. Data collected in months other than July, August, and September were removed
4. Results reported as non-detect were assigned a quantity one-half the lower reporting limit reported in the database
5. TN concentrations were calculated by summing concentrations of TKN and NO_2+NO_3 as N collected concurrently at each monitoring station for the years 1998 to 2008
6. TSIN concentrations were calculated by summing concentrations of NO_2+NO_3 as N and NH_3+NH_4 as N collected concurrently at each monitoring station for the entire dataset 1998–2012
7. Where multiple sample results at one station existed within a calendar month, the results were averaged to provide one monthly value
8. Monthly average stream flow at USGS gaging stations identified in **Table 3-1** were extracted from the USGS National Water Information System and paired to respective monitoring stations

Chlorophyll-*a* data were provided in two formats. Data from 1998 to 2009 included one average value and one maximum value for each year for each of the seven periphyton monitoring stations. Data from 2008–2012 contained all chlorophyll-*a* results of the twenty or so individual samples collected at each station, and included two sets of complete data for each station each year. Each set of individual results were averaged and then those two results were averaged to compute an overall summer average chlorophyll-*a* value at each station. The higher of the two values represents the maximum chlorophyll-*a* value at a given station. Chlorophyll-*a* values were then compiled into a single spreadsheet containing one summer average value and one maximum value for each of the seven sites, for each of the fifteen years, 1998–2012.

Following completion of data reduction activities, the dataset was quality reviewed and provided to DEQ for further quality assurance. The sample population size (N) along with the number of sample values with a result condition (RC), of the reduced dataset is provided in **Table 4-1**. The sample population shown in **Table 4-1** represents the entire number of samples collected during the monitoring period (excluding quality control samples) at each monitoring station in the reduced dataset. Monthly average concentrations were then computed, further reducing the actual N used in the trends analysis. The maximum possible N for the trends analysis is 45 (3 monthly average concentrations per year x 15 years). RC represents a reported non-detect value of the sample parameter or a non-detect value of one or more of the additive components of the parameter(s), in the case of TN and TSIN. In completing the trend analysis, direct measure of TN, which began in 2009, is assumed to be comparable to the calculated TN value described in step five above (Suplee, et al. 2012). The sample population for chlorophyll-a mean and maximum was 15 each, respectively, at each monitoring station. Reduced datasets are provided electronically in Attachment E.

Table 4-1 Sample Population Count (N) and Number of Values with Sample Result Conditions (RC) [1] of the Clark Fork River Nutrient Trends Analysis Dataset 1998–2012

Station ID	TN [2]		TPN		TKN		TSIN [3]		NO3-NO2		NH3		TP		SRP [4]	
	N	RC	N	RC	N	RC	N	RC	N	RC	N	RC	N	RC	N	RC
CFR-2.5	119	1	34	0	85	1	120	12	120	0	120	12	119	0	111	0
CFR-07	119	28	34	0	85	3	120	49	120	25	120	36	120	0	111	0
CFR-09	90	0	33	0	57	0	92	36	92	0	92	36	92	0	84	1
CFR-10	119	49	34	0	85	1	120	81	120	56	120	54	120	0	112	1
CFR-12	91	20	34	0	57	3	92	49	92	19	92	39	91	0	84	2
CFR-15.5	91	25	34	0	57	10	92	43	92	24	92	31	92	0	84	2
CFR-18	117	8	34	0	83	5	119	20	118	3	119	18	119	0	111	2
CFR-22	118	13	34	0	84	5	119	53	118	8	119	50	119	0	110	2
CFR-25	92	22	34	0	58	16	92	53	92	8	92	52	92	0	84	9
CFR-27.5	44	27	11	1	33	22	44	34	44	14	44	31	44	1	41	4
CFR-28	43	18	11	0	32	15	44	35	44	8	44	32	44	0	30	13
CFR-29	43	12	11	0	32	11	44	14	44	2	44	13	44	0	30	2
CFR-30	48	16	11	0	37	15	49	31	49	4	49	29	49	0	46	7

Notes:

1 Sample Result Condition (RC) is the number of sample results reported as a non-detect value (less than the method detection limit. For calculated constituents, TN and TSIN, RC is counted if either component was a non-detect value

2 TN sample count is the sum of measured TPN samples plus calculated TN, which is sum of paired TKN plus NO3-NO2 as N samples. TPN was analyzed beginning in 2009. TN was calculated 1998—2008.

3 TSIN sample count is the sum of paired NH3+NH4 as N and NO_2+NO_3 as N samples

4 SRP was only monitored at Stations CFR-28 and CFR-29 from 1998 to 2007

4.2 Statistical Trend Analyses

Based on review of literature (Helsel and Hirsch 2002) and previous work (Suplee, et al. 2012), and consultation with DEQ, the nonparametric Mann-Kendall trend test was selected as the appropriate method to detect trends in the available data. Two variations of the Mann-Kendall trend test were used. Selection of the method depended on the data available and previously studied relationships between the parameters and flow. Both variations of the temporal trend analyses employed two-sided tests with significance level of alpha=0.1 and a null hypothesis, H_0, that there was no trend in the series.

Previous analyses in the area concluded that discharge influenced total monthly nutrient levels at all sites (Suplee, et al. 2012). Because of this relationship, nutrient concentration data were first regressed against flow utilizing the LOWESS method. Consistent with current statistical guidance (Helsel and Hirsch 2002), and that of DEQ, this study assessed temporal nutrient trends for TN, TSIN, TP and SRP with the seasonal Mann-Kendall trend test on flow-adjusted concentrations (residuals from the LOWESS regression) against time. This method is able to distinguish temporal trends in water quality beyond that due to variation caused by temporal changes in discharge, and to correct for seasonality (Hirsch, Slack and Smith 1982) (Helsel and Hirsch 2002) (Suplee, et al. 2012). Seasonality for this study accounted for monthly trends within the dataset by utilizing the seasonal Mann-Kendall test with a period of three, for the months of July, August, and September.

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 temporal trends analysis of chlorophyll-*a*. This study assessed temporal trends of the mean and maximum annual chlorophyll-*a* values with the Mann-Kendall trend test on concentration against time.

Data evaluation, reduction, and analysis were conducted with Microsoft Excel 2010 and the add-on software XLSTAT-Pro and XLSTAT-Time series packages (Addinsoft n.d.).

4.3 Nutrient Loading Estimation Method

Clark Fork River nutrient loading (TP and TN) into Lake Pend Oreille was evaluated using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (version 3.10). 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. Method 6, *Regression Applied to Individual Flows,* has been used by the Council in previous reports (Tri-State Water Quality Council 2009) and is used in this evaluation to maintain consistency. Method 6 is generally preferred over the other regression-based methods when the discharge-nutrient concentration relationship is well defined. Method 6, *Regression Applied to Individual Flows*, is defined by Walker (1999).

For the loading analysis, nutrient concentrations were converted from µg/L to milligrams per cubic meter (mg/m^3) and discharge values were converted from CFS to cubic hectometers per year (hm^3/year).

To be consistent with previous nutrient loading analysis completed by the Council, nutrient loads were estimated using the record of mean daily discharge from USGS station 12392000, Clark Fork River at Whitehorse Rapids. This station is located downstream of Cabinet Gorge Dam and is no longer operated. Flow at this station is now calculated from the sum of measured flow at USGS station 12391950, Clark Fork River below Cabinet Gorge dam and an estimated 600 CFS groundwater inflow derived from seepage around the dam (USGS 2014).

To improve loading estimates the data were stratified by discharge. The FLUX32 model develops separate regression equations for each stratification, in this case, three separate stratum: one half the mean discharge, mean discharge, and two times the mean discharge. For each stratum, the regression equation is applied individually to each daily flow value. The sum of daily loads provides the annual estimate. Loading was estimated by annual calendar series from 1998–2012.

5.0 NUTRIENT WATER QUALITY TEMPORAL TREND RESULTS

This section presents results and findings of the temporal trends analysis of TN, TSIN, TP, SRP, mean chlorophyll-*a*, and maximum chlorophyll-*a* in the Clark Fork River 1998–2012 dataset. **Tables 5-1** to **5-6** below, tabulate the findings and interpretation of the trends tests performed for each constituent at each monitoring station.

Each table indicates the following for each station:

Numerical results

$p - value =$ The risk to reject H_0 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 study 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 Trend Not Detected

If $p < 0.1$ and If $S < 0$, then Decreasing Trend

If $p < 0.1$ and If $S > 0$, then Increasing Trend

Complete computational files from the LOWESS regression and trend test results are provided electronically in **Attachment E**. Map representations of the temporal trend test results are included in **Attachment C.** Each map symbolically represents the temporal 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) significant trend not 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 magnitude of the trend calculated.

5.1 TOTAL NITROGEN

Results of the seasonal Mann-Kendall temporal trend test for TN are presented in **Table 5-1**. Graphical presentation of the findings is provided in **Attachment C-1**. The trend analysis found one decreasing

trend in summertime TN concentrations at Station CFR-18, Clark Fork River below Missoula. One increasing trend in summertime TN concentrations was found at Station CFR-28, Clark Fork River below Thompson Falls. Trends were not detected at eleven monitoring stations.

Table 5-1 Seasonal Mann-Kendall Trend Test Results and Findings for TN at $\alpha = 0.1$ for all monitoring stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction
CFR-2.5	0.689	$p > 0.1$, Cannot reject H_0	-15	Not Detected
CFR-07	0.819	$p > 0.1$, Cannot reject H_0	9	Not Detected
CFR-09	0.909	$p > 0.1$, Cannot reject H_0	-5	Not Detected
CFR-10	0.689	$p > 0.1$, Cannot reject H_0	15	Not Detected
CFR-12	0.732	$p > 0.1$, Cannot reject H_0	-13	Not Detected
CFR-15.5	0.424	$p > 0.1$, Cannot reject H_0	-29	Not Detected
CFR-18	0.009	$p < 0.1$, Reject H_0 and Accept H_a	-93	Decreasing
CFR-22	0.648	$p > 0.1$, Cannot reject H_0	-17	Not Detected
CFR-25	0.230	$p > 0.1$, Cannot reject H_0	43	Not Detected
CFR-27.5	0.411	$p > 0.1$, Cannot reject H_0	-27	Not Detected
CFR-28	0.088	$p < 0.1$, Reject H_0 and Accept H_a	55	Increasing
CFR-29	0.752	$p > 0.1$, Cannot reject H_0	11	Not Detected
CFR-30	0.343	$p > 0.1$, Cannot reject H_0	31	Not Detected

5.2 Total Soluble Inorganic Nitrogen

Results of the seasonal Mann-Kendall temporal trend test for TSIN are presented in **Table 5-2**. Graphical presentation of the findings is provided in **Attachment C-2**. The trend analysis found two decreasing trends in summertime TSIN concentrations, at Station CFR-18, Clark Fork River below Missoula, and at Station CFR-29, Clark Fork River at Noxon Bridge. Trends were not detected at eleven monitoring stations.

Table 5-2 Seasonal Mann-Kendall Trend Test Results and Findings for TSIN at $\alpha = 0.1$ for all monitoring stations 1998–2012

Station ID	$p-value$ (two-tailed)	Interpretation H_0 There is no trend in the series H_a There is a trend in the series	S'	Trend Direction
CFR-2.5	0.123	$p > 0.1$, Cannot reject H_0	-55	Not Detected
CFR-07	0.53	$p > 0.1$, Cannot reject H_0	23	Not Detected
CFR-09	0.189	$p > 0.1$, Cannot reject H_0	47	Not Detected

Table 5-2 Seasonal Mann-Kendall Trend Test Results and Findings for TSIN at $\alpha = 0.1$ for all monitoring stations 1998–2012

Station ID	$p-value$ (two-tailed)	Interpretation H_0 There is no trend in the series H_a There is a trend in the series	S'	Trend Direction
CFR-10	0.648	$p > 0.1$, Cannot reject H_0	-17	Not Detected
CFR-12	0.458	$p > 0.1$, Cannot reject H_0	-27	Not Detected
CFR-15.5	0.137	$p > 0.1$, Cannot reject H_0	-53	Not Detected
CFR-18	0.004	$p < 0.1$, Reject H_0 and Accept H_a	-103	Decreasing
CFR-22	0.11	$p > 0.1$, Cannot reject H_0	-57	Not Detected
CFR-25	0.954	$p > 0.1$, Cannot reject H_0	-3	Not Detected
CFR-27.5	0.376	$p > 0.1$, Cannot reject H_0	-29	Not Detected
CFR-28	0.411	$p > 0.1$, Cannot reject H_0	27	Not Detected
CFR-29	0.058	$p < 0.1$, Reject H_0 and Accept H_a	-61	Decreasing
CFR-30	0.658	$p > 0.1$, Cannot reject H_0	-15	Not Detected

5.3 TOTAL PHOSPHORUS

Results of the seasonal Mann-Kendall temporal trend test for TP are presented in **Table 5-3**. Graphical presentation of the findings is provided in **Attachment C-3**. The trend analysis found decreasing trends in summertime TP concentrations at six monitoring stations including: CFR-10, CFR-12, CFR-15.5, CFR-18, CFR-22, and CFR-25. The trend analysis found one increasing trend in summertime TP concentrations at Station CFR-2.5, Silver Bow Creek at Opportunity. Trends were not detected at six monitoring stations.

Table 5-3 Seasonal Mann-Kendall Trend Test Results and Findings for TP at $\alpha = 0.1$ for all study stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction
CFR-2.5	0.012	$p < 0.1$, Reject H_0 and Accept H_a	89	Increasing
CFR-07	0.424	$p > 0.1$, Cannot reject H_0	-29	Not Detected
CFR-09	0.304	$p > 0.1$, Cannot reject H_0	-37	Not Detected
CFR-10	0.046	$p < 0.1$, Reject H_0 and Accept H_a	-71	Decreasing
CFR-12	0.016	$p < 0.1$, Reject H_0 and Accept H_a	-85	Decreasing
CFR-15.5	0.001	$p < 0.1$, Reject H_0 and Accept H_a	-113	Decreasing
CFR-18	< 0.0001	$p < 0.1$, Reject H_0 and Accept H_a	-143	Decreasing
CFR-22	< 0.0001	$p < 0.1$, Reject H_0 and Accept H_a	-143	Decreasing

Table 5-3 Seasonal Mann-Kendall Trend Test Results and Findings for TP at $\alpha = 0.1$ for all study stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction
CFR-25	0.04	$p < 0.1$, Reject H_0 and Accept H_a	-73	Decreasing
CFR-27.5	0.569	$p > 0.1$, Cannot reject H_0	-19	Not Detected
CFR-28	0.95	$p > 0.1$, Cannot reject H_0	3	Not Detected
CFR-29	0.527	$p > 0.1$, Cannot reject H_0	21	Not Detected
CFR-30	0.899	$p > 0.1$, Cannot reject H_0	-5	Not Detected

5.4 Soluble Reactive Phosphorus

Results of the seasonal Mann-Kendall temporal trend test for SRP are presented in **Table 5-4**. Graphical presentation of the findings is provided in **Attachment C-4**. The trend analysis found one decreasing trend in summertime SRP concentrations at Station CFR-18, Clark Fork River below Missoula. The trend analysis found increasing trends in summertime SRP concentrations at four monitoring stations including CFR-2.5, CFR-09, CFR-27.5, and CFR-29. Trends were not detected at eight monitoring stations.

Table 5-4 Seasonal Mann-Kendall Trend Test Results and Findings for SRP at $\alpha = 0.1$ for all study stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction
CFR-2.5	< 0.0001	$p < 0.1$, Reject H_0 and Accept H_a	129	Increasing
CFR-07	0.411	$p > 0.1$, Cannot reject H_0	27	Not Detected
CFR-09	0.007	$p < 0.1$, Reject H_0 and Accept H_a	87	Increasing
CFR-10	0.899	$p > 0.1$, Cannot reject H_0	-5	Not Detected
CFR-12	0.527	$p > 0.1$, Cannot reject H_0	-21	Not Detected
CFR-15.5	0.658	$p > 0.1$, Cannot reject H_0	-15	Not Detected
CFR-18	0.014	$p < 0.1$, Reject H_0 and Accept H_a	-79	Decreasing
CFR-22	0.23	$p > 0.1$, Cannot reject H_0	-39	Not Detected
CFR-25	0.23	$p > 0.1$, Cannot reject H_0	39	Not Detected
CFR-27.5	0.062	$p < 0.1$, Reject H_0 and Accept H_a	54	Increasing
CFR-28	1	$p > 0.1$, Cannot reject H_0	-1	Not Detected
CFR-29	0.0004	$p < 0.1$, Reject H_0 and Accept H_a	69	Increasing
CFR-30	0.245	$p > 0.1$, Cannot reject H_0	34	Not Detected

Note: SRP was only monitored at Stations CFR-28 and CFR-29 from 1998 to 2007

5.5 CHLOROPHYLL-*A*

Results of the Mann-Kendall temporal trend test for summer mean and maximum benthic chlorophyll-*a* are presented in **Tables 5-5** and **Table 5-6**, respectively. Graphical presentations of the findings are provided in **Attachments C-5 and C-6**, respectively. The trend analysis found decreasing trends in both summertime mean and maximum benthic chlorophyll-*a* at Station CFR-18, Clark Fork River below Missoula, and Station CFR-25, Clark Fork River above Flathead. Trends were not detected at five monitoring stations.

Table 5-5 Mann-Kendall Trend Test Results and Findings for Mean Benthic Chlorophyll-*a* at $\alpha = 0.1$ for all study stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S	Trend Direction
CFR-9	0.495	$p > 0.1$, Cannot reject H_0	-15	Not Detected
CFR-10	0.169	$p > 0.1$, Cannot reject H_0	-29	Not Detected
CFR-12	0.626	$p > 0.1$, Cannot reject H_0	-11	Not Detected
CFR-15.5	0.697	$p > 0.1$, Cannot reject H_0	-9	Not Detected
CFR-18	0.002	$p < 0.1$, Reject H_0 and Accept H_a	-61	Decreasing
CFR-22	0.275	$p > 0.1$, Cannot reject H_0	-23	Not Detected
CFR-25	0.074	$p < 0.1$, Reject H_0 and Accept H_a	-37	Decreasing

Table 5-6 Mann-Kendall Trend Test Results and Findings for Maximum Benthic Chlorophyll-*a* at $\alpha = 0.1$ for all study stations 1998–2012

Station ID	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S	Trend Direction
CFR-9	0.495	$p > 0.1$, Cannot reject H_0	-15	Not Detected
CFR-10	0.328	$p > 0.1$, Cannot reject H_0	-21	Not Detected
CFR-12	0.328	$p > 0.1$, Cannot reject H_0	-21	Not Detected
CFR-15.5	0.729	$p > 0.1$, Cannot reject H_0	-8	Not Detected
CFR-18	0.021	$p < 0.1$, Reject H_0 and Accept H_a	-47	Decreasing
CFR-22	0.149	$p > 0.1$, Cannot reject H_0	-30	Not Detected
CFR-25	0.020	$p < 0.1$, Reject H_0 and Accept H_a	-48	Decreasing

5.6 Summary of Trends

The results of the Clark Fork River nutrient and chlorophyll-*a* temporal trends analysis, 1998–2012, found that some discernable trends were present with varying degrees of significance and direction within the analyzed dataset. Findings of the trends analysis are provided graphically in **Attachment C** for all analyzed constituents at all monitoring stations. **Chart 5-1**, below, summarizes the trends detected in the Clark Fork River temporal nutrient trends analysis, including an indication of directionality and magnitude for detected trends.

The magnitude of trends were ranked based on guidance in the 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: $p < 0.01$

The trend analysis for summertime TN and TSIN found no trend detected at eleven of the thirteen Clark Fork River monitoring stations. Highly significant decreasing trends were found at Station CFR-18 for both TN and TSIN concentrations. There was a marginally significant increasing trend found in TN concentrations at CFR-28, and a marginally significant decreasing trend found in TSIN concentrations at CFR-29.

The trends analysis for summertime TP found the most number of trends and the most number of decreasing trends. Trends were found at seven of thirteen Clark Fork River monitoring stations, including six stations with decreasing trends and one station with an increasing trend. Of the six decreasing trends, three are considered highly significant and three significant. Significant decreasing trends for TP occurred at six consecutive monitoring stations from Station CFR-10, Clark Fork River above Little Black Foot River, downstream to Station CFR-25, Clark Fork River above Flathead River. Highly significant decreasing trends in TP concentrations were found at stations CFR-15.5, CFR-18, and CFR-22. Station CFR-2.5 was found to have a significant increasing trend in TP concentrations.

The trends analysis for summertime SRP found the most number of increasing trends. Highly significant increasing trends in SRP concentrations were found at Stations CFR-2.5, CFR-09, and CFR-29. A marginally significant increasing trend in SRP concentrations was found at Station CFR-27.5, in the Thompson River. One significant decreasing trend in SRP concentrations was found at Station CFR-18. Increasing trends in SRP concentrations were found at stations on both ends of the Clark Fork River, at the headwaters in Silver Bow Creek and also in the Clark Fork River at Noxon. The trend over the entire 1998 to 2012 time period found at Station CFR-29 is inconclusive for this trends analysis, since SRP had not been monitored at that Station, nor at Station CFR-28, since 2007.

The trend analysis for chlorophyll-*a* summertime mean and maximum found no trend detected at five of the seven monitoring stations. Decreasing trends were found at two stations. At Station CFR-18, the trend analysis found a highly significant decreasing trend in mean chlorophyll-*a* and a significant decreasing trend in maximum chlorophyll-*a*. At Station CFR-25, the trend analysis found a marginally significant trend in mean chlorophyll-*a* and a significant decreasing trend in maximum chlorophyll-*a*.

Spatially, the five monitoring stations in the upper Clark Fork River (headwaters to confluence with Blackfoot River), represented by stations CFR-2.5 to CFR-12, were found to have two decreasing temporal nutrient trends and three increasing temporal nutrient trends. The four monitoring stations in the middle Clark Fork River (confluence Blackfoot River to confluence Flathead River), represented by stations CFR-15.5 to CFR-25, were found to have eleven decreasing temporal nutrient and chlorophyll-*a* trends and no increasing tends. Six of the decreasing trends in the middle Clark Fork River are considered to be highly significant decreasing trends. Notably, Station CFR-18, Clark Fork River below Missoula, had decreasing trends for all constituents analyzed, including highly significant decreasing temporal trends for TN, TSIN, TP, and mean chlorophyll-*a*. The four monitoring stations in the lower Clark Fork River (confluence with Flathead River to below Cabinet Gorge Dam), represented by stations, CFR-27.5 to CFR-30, were found to have one decreasing temporal nutrient trend and three increasing trends.

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-27.5	●	●	●	⇧	○	○
	CFR-28	⇧	●	●	●	○	○
	CFR-29	●	⇩	●	⇧	○	○
	CFR-30	●	●	●	●	○	○

○ Not Sampled ● Trend Not Detected

Decreasing Trend			Increasing Trend
⇩	Marginally Significant:	$0.05 < p \leq 0.1$	⇧
⇩	Significant:	$0.01 < p \leq 0.05$	⇧
⇩	Highly Significant:	$p < 0.01$	⇧

Chart 5-1 Summary of Nutrient and Chlorophyll-*a* Trends for the Clark Fork River Dataset, 1998–2012, with Respective Significance Levels (Helsel and Hirsch 2002)**. Note: SRP was only monitored at Stations CFR-28 and CFR-29 from 1998 to 2007.**

5.7 Discussion

There are a number of factors that have potential to affect the results of the temporal trends analysis. These factors include sample size, number and proportion of non-detect results, methods of data reduction, analytical limits, and data outliers. To the extent possible, measures were taken throughout the monitoring period to assure a reliable dataset for the undertaking of this Nutrient Water Quality Status and Trends Report for the Clark Fork River. These measures include consistent monitoring program sampling and analysis protocols, standard analytical methods, and a thorough data quality assurance-quality control review and data validation process prior to approval and upload of data. Guidance was provided by DEQ during this trends analysis on review of sample size, how to handle non-detect results, methods of data reduction, review of analytical limits, and how to handle data outliers. Additional data quality review was provided by DEQ throughout this trends analysis on reduced data to assure a reliable dataset. Methods of data reduction and the trends analysis followed guidance provided by the DEQ project manager and other staff. Additionally, methods of data reduction and trends analysis were consistent with USGS methods (Helsel and Hirsch 2002) and with previous work (Suplee, et al. 2012).

Similar to previous work (Suplee, et al. 2012), non-detect values were assigned values at one-half the lower reporting limit. There is potential for this assumption to skew or bias results of the temporal trend analysis, particularly if there is a high proportion of non-detect values and/or a wide range of lower reporting limits for a constituent. For the dataset analyzed, the constituents that may be most affected by this type of bias are TN and TSIN, since the TP and SRP dataset contained relatively few non-detect values. TKN, NO2+NO3 as N, and NH3+NH4 as N were the three constituents with the highest proportions of non-detect values as shown **Table 4-1**. Since only four total trends were found at stations in TN and TSIN, bias from using non-detect values is not expected to be an issue. Additionally, the reporting limits for NO2+NO3 as N and NH3+NH4 as N were comparatively much lower than reported results.

Lower reporting limits for all constituents generally remained consistent throughout the monitoring period, see **Table 3-2**. The largest change in lower reporting limit came from change in TN analysis. All TN results 1998—2008 are calculated as the sum of TKN and NO2+NO3 as N. Beginning in 2009 TN was measured directly as TPN. For most samples the lower reporting limit was 100 µg/L for TKN and 50 µg/L for TPN. Since most TN results throughout the monitoring period were greater than 100 µg/L, this change in reporting limit is not thought to have skewed temporal trend findings. This is consistent with findings of previous work (Suplee, et al. 2012). There were a few results where the TSIN value was greater than the corresponding TN value, but in each of the cases the values were comparable and no correction was made to the dataset.

Since data were validated through quality assurance and quality control processes directed by the monitoring program prior to inclusion in the dataset provided by DEQ, testing for outliers was not completed as part of this trends analysis. There were two TN values from 1998 that were removed from the dataset after consultation with DEQ. These values were one to two orders of magnitude greater that the rest of the dataset. Additionally the trend analysis used average monthly values, so anomalous values would be smoothed out to reduce the potential of bias of the trend results. Only one monthly sample was collected in the lower Clark Fork River stations (CFR-27.5 to CFR-30), so the average value was represented by one grab sample. Two to three monthly samples were collected at stations in the upper and middle Clark Fork River (CFR-2.5 to CFR-25).

There is potential that outliers may have had an effect on the findings of the trends analysis, particularly that of SRP. One potential set of outliers that were analyzed in the trend analysis included SRP data from August 2005. Reported SRP results for this time period at all stations are noticeably higher than preceding and following months, up to one order of magnitude in some cases. The data were not qualified in the dataset, but the comment field for some records noted "input error." The SRP trend analysis showed increasing trends at four monitoring stations (CFR-2.5, CFR-09, CFR-27.5, and CFR-29), and a decreasing trend at one monitoring station (CFR-18). The anomalous results from August 2005 are present in the CFR-18 SRP dataset as well as the other stations where trends were found. Because the trend analysis found a decreasing trend at this CFR-18, it is likely that the anomalous results did not bias the trends results at most stations. Another note on SRP trend analysis results; no SRP data were reported in 2008, due to a problem in laboratory analyses. There is potential that this missing year of data could bias earlier data and affect the results of the trends analysis.

Bias is suspected in the SRP trend analysis finding at CFR-29. The sample population at this station was less because SRP monitoring ended here in 2007. Because of the decreased sample population and the truncated monitoring period, an outlier later in the dataset has greater potential to bias the trend result. The increasing trend in SRP found in the trend analysis at CFR-29 should be received with caution. SRP monitoring at CFR-28 also ended in 2007. No trend in SRP was found at that station. An anomalous $p-value$ result was reported in the trends analysis for SRP at CFR-28. The analysis at this station was rerun multiple times with the same results.

A note on $p-value$ computation: the software used in the trend analysis often computed approximations of the $p-value$ rather than exact values. As described by Helsel and Hirsch (2002), it is standard for software to use an approximation of the $p-values$, rather than exactly calculated values. The approximation are considered very accurate for sample sizes larger than 30 (Helsel and Hirsch 2002). For datasets with sample population larger than 30, the default approximation was used by the software. Exact $p-values$ were attempted to be calculated for smaller datasets. The Mann-Kendall trend test for mean and maximum chlorophyll-*a*, was the only test for which the dataset was smaller than 30, and in most cases an exact $p-value$ was calculated. Approximated $p-values$ are not thought to have affected the findings of the trend analysis.

6.0 NUTRIENT LOADING RESULTS

Nutrient loading estimates for TP and TN to Lake Pend Oreille from the Clark Fork River from 1998—2012 are presented below in **Table 6-1**. FLUX model flow and load summary output files for TP and TN are provided in **Appendix E**.

Also included in **Table 6-1** are the annual daily mean flow rate, percent of the average daily mean flow rate at USGS station 12392000, Clark Fork River at Whitehorse Rapids, for the published period of record (1929—2008), and annual inflow volume. Both U.S. customary units and the International System of Units (S.I.) are provided for convenience. Charts of estimated TP and TN loading from the Clark Fork River, 1998—2012, are provided in **Attachment D**. The chart of the estimated TP load also compares annual TP load from Clark Fork River and the Border Agreement TP allocated target load.

Table 6-1 Estimated Total Phosphorus and Total Nitrogen Loads to Lake Pend Oreille from the Clark Fork River 1998–2012, includes Annual Daily Mean Flow Rate, and Annual Inflow Volume

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	14,211,746	170,179	375,180	1,955,342	4,310,791
1999	22,534	103%	20,125	16,315,539	229,005	504,870	3,054,621	6,734,287
2000	18,584	85%	16,644	13,493,457	122,767	270,655	1,900,013	4,188,812
2001	11,505	52%	10,276	8,330,856	90,902	200,405	1,534,841	3,383,745
2002	23,158	106%	20,683	16,767,915	235,396	518,959	2,525,005	5,566,683
2003	17,576	80%	15,697	12,725,715	179,199	395,066	2,882,333	6,354,457
2004	17,695	81%	15,847	12,847,321	139,725	308,041	1,848,477	4,075,194
2005	17,869	81%	15,959	12,938,121	159,242	351,069	1,812,853	3,996,657
2006	22,417	102%	20,021	16,231,225	285,122	628,586	3,400,913	7,497,730
2007	18,661	85%	16,667	13,512,104	158,837	350,176	2,587,254	5,703,919
2008	23,101	105%	20,689	16,772,617	307,641	678,232	4,049,838	8,928,364
2009	19,484	89%	17,402	14,107,975	215,365	474,799	2,481,763	5,471,351
2010	17,996	82%	16,072	13,029,731	150,373	331,516	2,254,004	4,969,228
2011	32,491	148%	29,018	23,525,345	528,146	1,164,363	4,842,476	10,675,832
2012	26,219	120%	23,481	19,036,282	311,969	687,774	3,965,624	8,742,704

Notes:
CFS - cubic feet per second *lbs -- pound mass* *TP - Total Phosphorus*
ac-ft - acre feet *hm^3 - 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 1929-2008

The estimated TP load exceeded the allocated target load of 259,500 kilograms per year, four times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, and 2012. All of the exceedances have occurred in the last seven years including the last two consecutive years. The Border Agreement identifies a short term exceedance as three consecutive years greater than 110 percent of the target load. The estimated TP loads in 2011 and 2012 are greater than 110 percent of the target load. Based on this assessment, there is no short term TP load exceedance in any consecutive three year period since 1998. No targets are established for TN loading to Lake Pend Oreille.

7.0 CONCLUSIONS

This Nutrient Water Quality Status and Trends Report for the Clark Fork River completed a temporal trends analysis of summertime TN, TSIN, TP, SRP, and chlorophyll-*a* constituents, and year round nutrient loading analysis for the 1998—2012 dataset.

Based on the findings of this report we conclude that:

- Overall, TN and TSIN concentrations appear to be holding steady in the Clark Fork River. No trends were detected in summertime TN and TSIN concentrations at eleven of the thirteen monitoring stations. Highly significant decreasing trends in TN and TSIN were found at Station CFR-18, Clark Fork River below Missoula. In the lower Clark Fork River a marginally significant increasing trend in TN was found at monitoring Station CFR-28, Clark Fork River below Thompson Falls, and a marginally significant decreasing trend in TSIN was found at monitoring Station CFR-29, Clark Fork River at Noxon.
- Summertime TP concentrations have been generally declining since 1998 in the upper and middle Clark Fork River above the confluence with the Flathead River. Significant to highly significant decreasing trends in TP concentrations were found at six monitoring stations in the Clark Fork River in the approximately 160 mile reach from Garrison to Paradise, Montana, in the upper and middle reaches of the river. Summertime TP concentrations appear to be holding steading in the lower Clark Fork River. No trends in TP concentrations were found at any lower Clark Fork River monitoring station.
- Summertime SRP concentrations appear to be on the rise since 1998 in the upper and lower Clark Fork River. Increasing trends in SRP concentrations were found at four monitoring stations, including CFR-2.5, Silver Bow Creek at Opportunity, CFR-09, Clark Fork River at Deer Lodge, CFR-28, Clark Fork River below Thompson River, and CFR-29, Clark Fork River at Noxon. The only decreasing trend in SRP was found at CFR-18, Clark Fork River below Missoula.
- Summertime nutrient concentrations have been declining since 1998 in the Clark Fork River below Missoula. Highly significant decreasing trends were found for TN, TSIN, and TP; and a significant decreasing trend for SRP was found at Station CFR-18, Clark Fork River below Missoula.
- Algal trends are holding steady in the Clark Fork River upstream of Missoula. No trends were detected in summertime mean or maximum chlorophyll-*a* at four monitoring stations upstream of Missoula. Algal concentrations have been declining since 1998 in the Clark Fork River below Missoula. A highly significant decreasing trend was found in mean summertime chlorophyll-*a*, and significant decreasing trend in maximum summertime chlorophyll-*a* was found at Station CFR-18, Clark Fork River below Missoula. Algal concentrations have been declining in the Clark Fork River above the Flathead River, at Station CFR-25.
- Nutrient loading from the Clark Fork River to Lake Pend Oreille varies year to year and is proportional to the volume of inflow from the watershed. Generally in years when inflow is in excess of 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 exceeds the allocated target load four times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, and 2012. All of the exceedances have occurred in the last seven years including the last two consecutive years. TN loads were also evaluated, but no target load exists.

Much work has been done in the Clark Fork River basin to reduce and control nutrient impacts to water quality. Point source and non-point source nutrient reduction activities have occurred across the basin, and more are planned and some are already in progress. Past nutrient reduction activities in the Clark Fork River basin appear to be effective in reducing TP concentrations in the middle Clark Fork River. A basin-wide nutrient water quality monitoring program, such as the monitoring program that has been in place since 1998, is critical to evaluate effectiveness of nutrient reduction activities taken. Basin-wide nutrient water quality monitoring should continue into the futures so that cumulative, long-term impacts of nutrient reduction activities can be evaluated. The nutrient water quality monitoring program must continue to regularly assess the status and trends of water quality in the Clark Fork River basin so that planners and managers are better able to direct and focus nutrient reduction efforts in the Clark Fork River basin.

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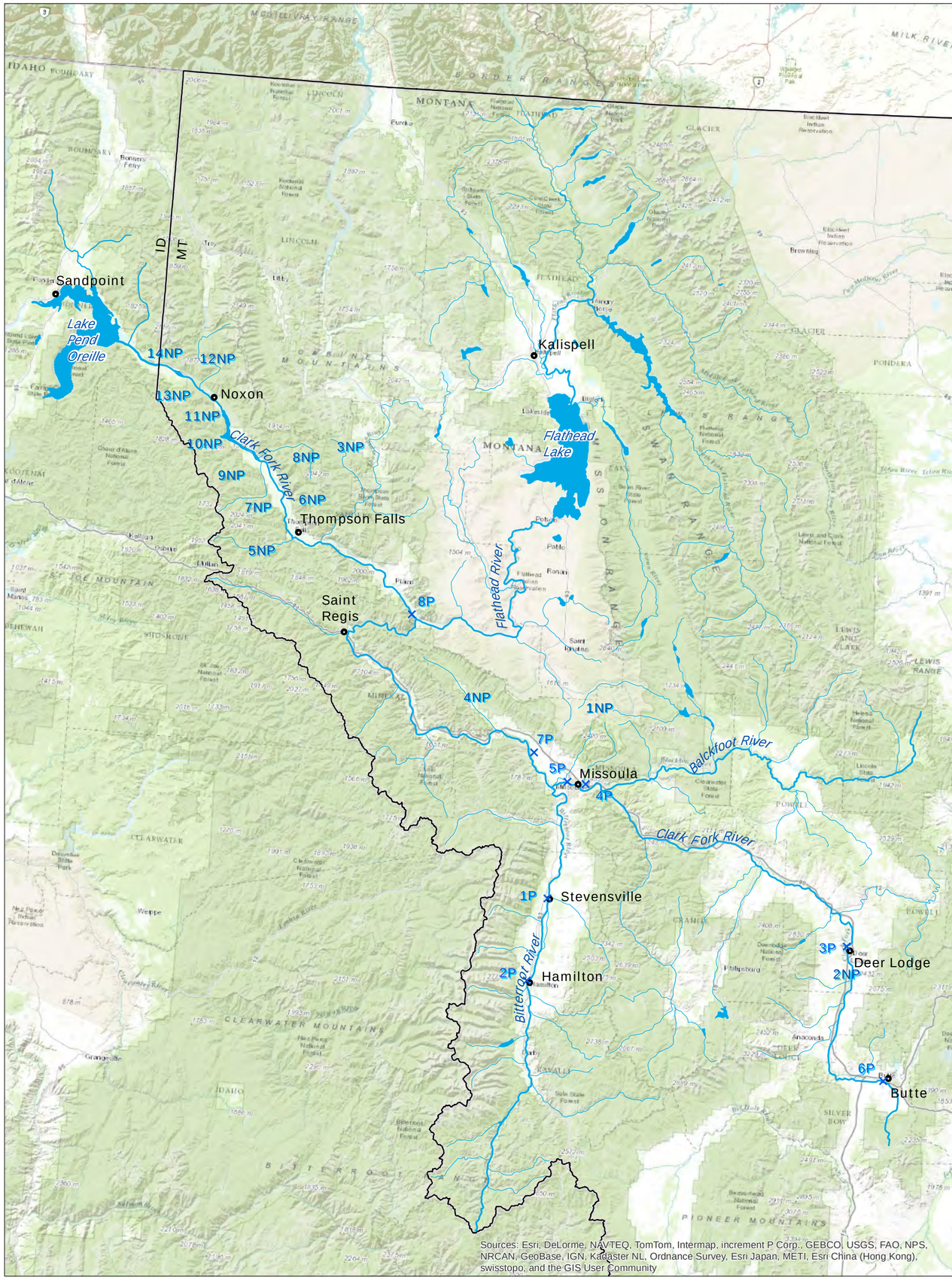
ATTACHMENT A

MAP OF NUTRIENT REDUCTION ACTIVITIES IN CLARK FORK RIVER BASIN



ATTACHMENT A

MAP OF NUTRIENT REDUCTION ACTIVITIES IN CLARK FORK RIVER BASIN

×1P Point Source Nutrient Reduction Location

6NP Watershed of Non-Point Source Nutrient Reduction Projects

N W E S

0 10 20 30 40 50

Miles

Prepared By: R. Svingem, HydroSolutions Inc Original Scale: 1:1,200,000

Point Source Nutrient Reduction Actions

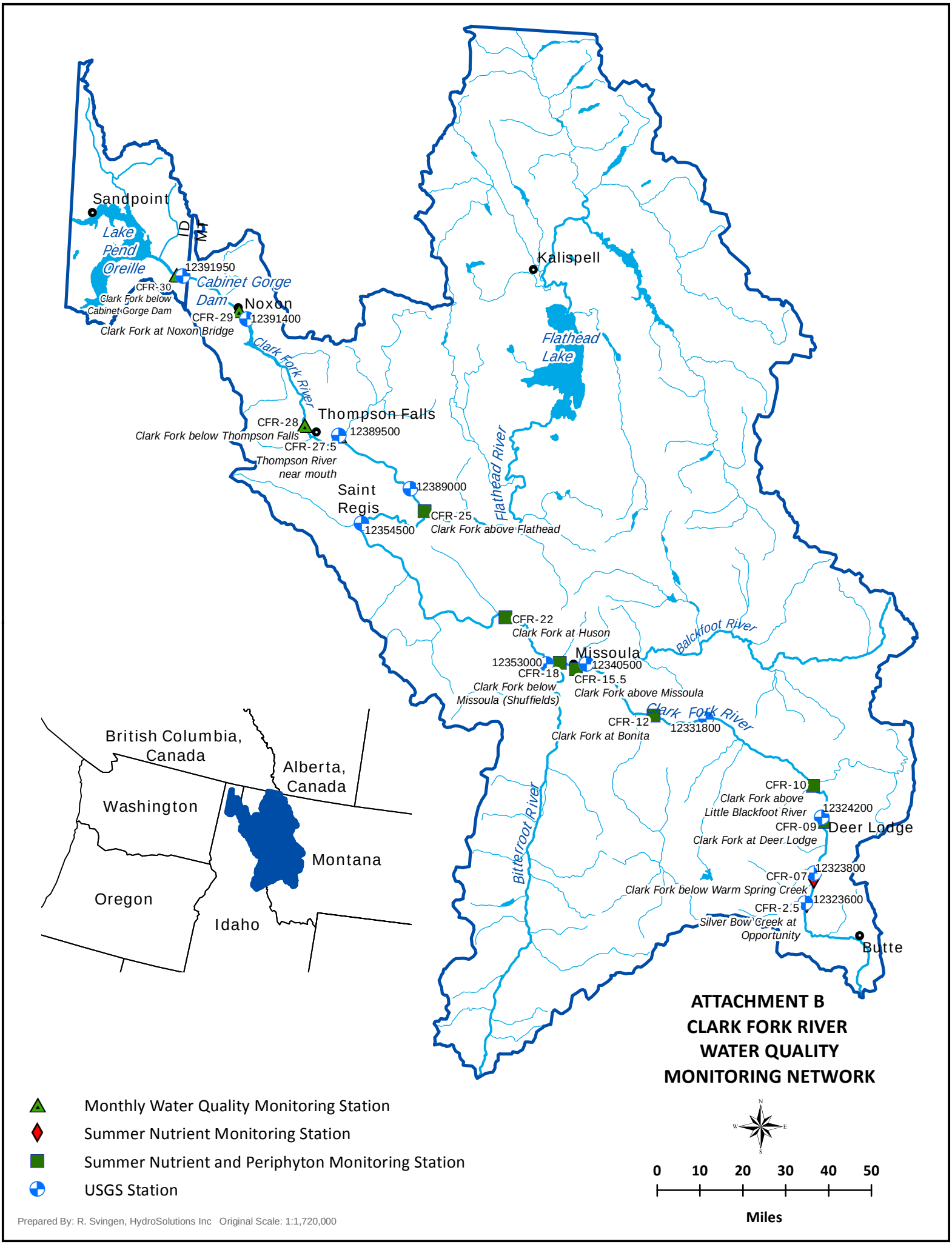
Map Key	Nutrient Source	Action Taken
1P	Stevensville	Replaced unlined polishing lagoons with a UV disinfection as a final clarifier in 2011.
2P	Hamilton wastewater treatment plant	Upgraded facility (headworks, flow meters, transfer switched for generator, computer system), added a dissolved air floatation unit, upgraded the return activated sludge pumps, and added a screw press in 2010.
3P	Deer Lodge wastewater facility	Replaced old leaking sewer lines; slipped lined sewer lines in 2009; developed a land application system for effluent to reduce direct July - September discharge to the river to zero (Note: Reductions occurred only up to 2008, as facility returned temporarily
4P	Missoula County	Connected thousands of existing home septic system to the central sewer.
5P	Missoula wastewater facility	Upgraded and expanded the facility to biological nutrient removal (BNR), and fermenter; 2004 - 2005. Launched a pilot project to irrigate 1.6 acres of poplar trees with treated effluent in 2009.
6P	Butte wastewater facility	Constructed stormwater detention basins to reduce stormwater overflow to the sanitary sewers; reduced industrial loads; grew sod with effluent in summer (Note: New membrane bioreactor facility planned to be operational by 2015); Updated facilities headworks, and installed influent and effluent Parshall flumes, and two vertical turbine effluent pumps for sod farm by 2011.
7P	Smurfit-Stone Container corporation	Reduced nutrient additions to treatment systems; no direct discharge to river July-August (used storage ponds). Closed in 2009.
8P	Basin wide	Phosphate laundry detergent ban emplaced in 1989.

Non-Point Source Nutrient Reduction Projects

Map Key	Watershed	Date	Project Name	Sponsor or Organization
1NP	Clark Fork Basin		Various Waterbodies	Plum Creek Timber Co.
2NP	Upper Clark Fork Drainage	2007 - 2012	Clark Fork River/Milltown Dam Removal	Environmental Protection Agency
		2013	Peterson Creek/Upper Clark Fork Tributary Restoration	Watershed Restoration Coalition
3NP	Thompson River Drainage, a tributary to the Lower Clark Fork	2003	Thompson River (upper)/Thompson River Riparian Restoration	Plum Creek Timber Co.
		2010	Big Rock Creek/Big Rock Creek Road Rehabilitation	Montana Fish Wildlife and Parks
4NP	Ninemile Creek Drainage, a tributary to the Lower Clark Fork	2011	Little McCormick Creek/Ninemile Watershed TMDL Implementation 2008	Trout Unlimited
		2012	St. Louis Creek/Ninemile TMDL Implementation	Trout Unlimited
5NP	Prospect Creek Drainage, a tributary to the Lower Clark Fork	2005	Daisy Creek/Daisy Creek Stream Rehabilitation	United States Forest Service
		2007	Crow Creek/Crow Creek Restoration	United States Forest Service
		2007	Cooper Gulch & Chipmunk Creek / Cooper & Chipmunk Culvert Replacement (Bridges)	United States Forest Service
		2008	Prospect Creek/Old Wilkes Creek Bridge Abutment Removal	United States Forest Service
		2008	Crow Creek/Prospect Creek/Crow Creek Restoration Project	Lower Clark For Watershed Group
		2009	Prospect Creek/Prospect Creek Riparian Re-Forestation	Lower Clark Fork Watershed Group
		2009	Prospect Creek/YPL Riparian Revegetation	Green Mountain Conservation District
6NP	Graves Creek Drainage, a tributary to the Lower Clark Fork	2007	Graves Creek/Graves Creek Restoration (Cox/Newby)	Lower Clark Fork Watershed Group
7NP	Beaver Creek Drainage, a tributary to the Lower Clark Fork	1997	Beaver Creek/Beaver 301 (ERFO)	United States Forest Service
8NP	Vermilion River Drainage, a tributary to Noxon Reservoir (the Clark Fork River)	2006	Vermilion River/Upper Vermilion Bank Stabilization	United States Forest Service
9NP	Trout Creek Drainage, a tributary to Noxon Reservoir (the Clark Fork River)	2001	Trout Creek/Trout Creek Restoration (Morkert)	Trout Creek Watershed Council
10NP	Marten Creek Drainage, a tributary to the Lower Clark Fork	2009	Marten Creek/Marten Creek -Smith	United States Forest Service
11NP	Pilgrim Creek Drainage, a tributary to the Cabinet Gorge Reservoir (the Clark Fork River)	2006	Pilgrim Creek/Pilgrim Creek Railroad Bridge	United States Forest Service and Green Mountain Conservation District
		2006	Pilgrim Creek/ Reishus/McDowell Restoration	Green Mountain Conservation District
		2007	West Fork Pilgrim Creek/West Fork Pilgrim Creek Restoration	United States Forest Service
12NP	Bull River Drainage, a tributary to the Cabinet Gorge Reservoir (the Clark Fork River)	2002 and more	East Fork Bull River/Stein - East Fork Bull River	Clark Fork – Pend Oreille Conservancy
		1999	Berray Creek/Berray Creek Restoration	United States Forest Service
		2001	Bull River/McDowell Bank Stabilization and Revegetation	Bull River Watershed Council
		2002	Snake Creek/SN-6 Snake Creek Restoration	United States Forest Service
		2003	South Fork Bull River/SFBR Slide Restoration	Bull River Watershed Council and Green Mountain Conservation District
		2006	Bull River/Dabronski Bridge Removal	United States Forest Service
		2008	East Fork Bull River/EFBR Slide Restoration	United States Forest Service
13NP	Elk River Drainage, a tributary to the Cabinet Gorge Reservoir (the Clark Fork River)	1997	Elk Creek/Elk Creek (Heron)	Elk Creek Watershed Council
		2000	West Fork Elk Creek/West Fork Elk Creek Stabilization	Elk Creek Watershed Council
		2001	Elk Creek/Hollinshead Workshop	Natrual Resource Conservation Service
		2008	Elk Creek/Elk Creek Restoration Project	Lower Clark Fork Watershed Group
		2013	East Fork Elk Creek/East Fork Elk Creek Springer Bank Stabilization	Lower Clark Fork Watershed Group
14NP	Blue Creek Drainage, a tributary to the Lower	2010	East Fork Blue Creek/Scotchman Mine Tailings Cleanup	Green Mountain Conservation District

ATTACHMENT B

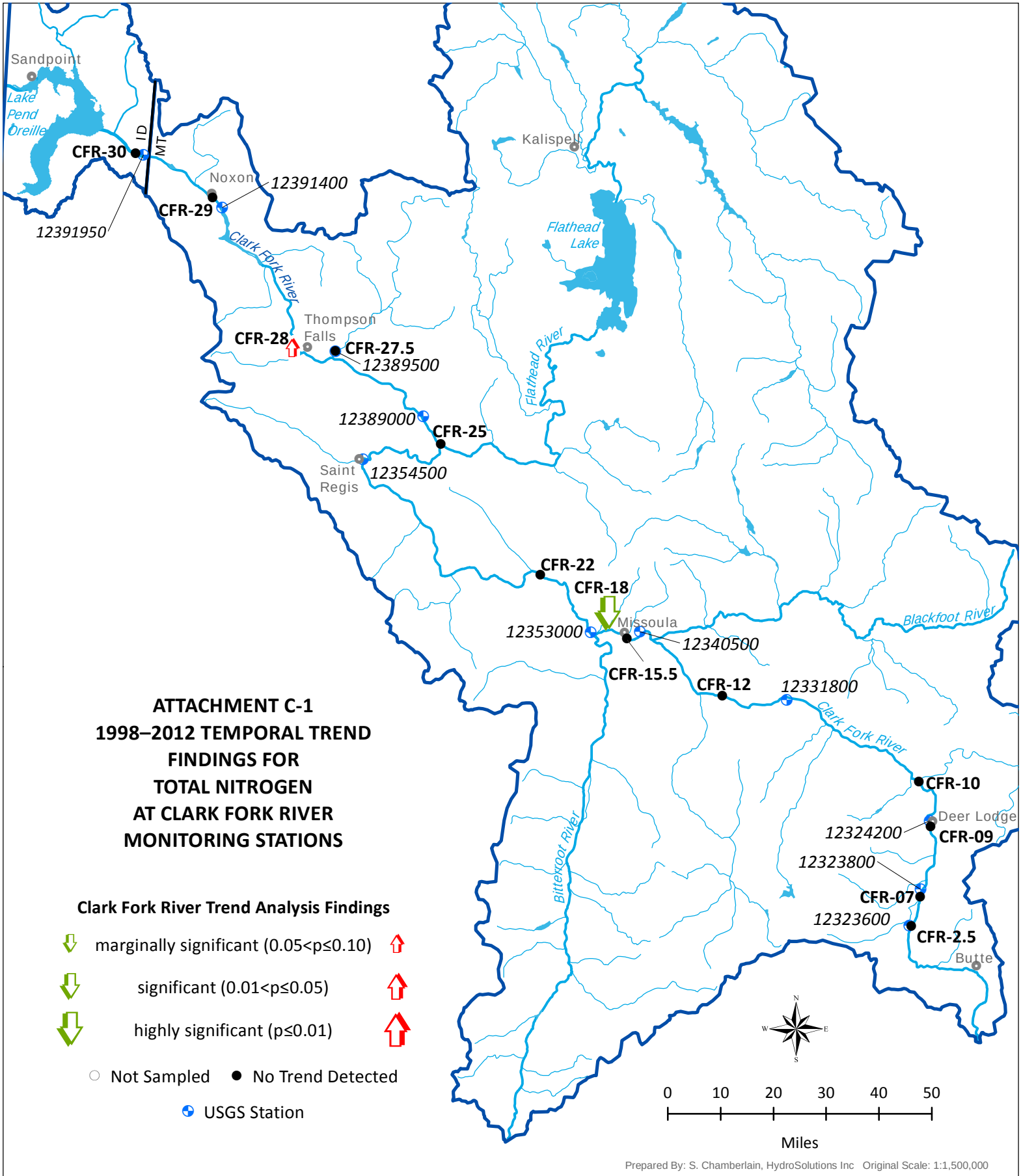
MAP OF CLARK FORK RIVER WATER QUALITY MONITORING NETWORK


Sandpoint
Lake Pend Oreille
ID
MT
12391950
CFR-30
Clark Fork below Cabinet Gorge Dam
Cabinet Gorge Dam
Noxon
CFR-29
12391400
Clark Fork at Noxon Bridge
Clark Fork River
Kalispell
Flathead Lake
Thompson Falls
CFR-28
Clark Fork below Thompson Falls
12389500
CFR-27.5
Thompson River near mouth
Flathead River
Saint Regis
12389000
CFR-25
Clark Fork above Flathead
12354500
CFR-22
Clark Fork at Huson
Blackfoot River
Missoula
12353000
CFR-18
Clark Fork below Missoula (Shuffields)
12340500
CFR-15.5
Clark Fork above Missoula
Clark Fork River
CFR-12
Clark Fork at Bonita
12331800
British Columbia, Canada
Alberta, Canada
Washington
Montana
Oregon
Idaho
Bitterroot River
CFR-10
Clark Fork above Little Blackfoot River
12324200
CFR-09
Deer Lodge
Clark Fork at Deer Lodge
12323800
CFR-07
Clark Fork below Warm Spring Creek
12323600
CFR-2.5
Silver Bow Creek at Opportunity
Butte
ATTACHMENT B
CLARK FORK RIVER
WATER QUALITY
MONITORING NETWORK
Monthly Water Quality Monitoring Station
Summer Nutrient Monitoring Station
Summer Nutrient and Periphyton Monitoring Station
USGS Station
N
W
E
S
0
10
20
30
40
50
Miles
Prepared By: R. Svingen, HydroSolutions Inc Original Scale: 1:1,720,000

ATTACHMENT C

CLARK FORK RIVER, 1998–2012, TEMPORAL TREND FINDINGS MAPS

- ATTACHMENT C-1: 1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL NITROGEN AT CLARK FORK RIVER MONITORING STATIONS
- ATTACHMENT C-2: 1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL SOLUBLE INORGANIC NITROGEN AT CLARK FORK RIVER MONITORING STATIONS
- ATTACHMENT C-3: 1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL PHOSPHORUS AT CLARK FORK RIVER MONITORING STATIONS
- ATTACHMENT C-4: 1998–2012 TEMPORAL TREND FINDINGS FOR SOLUBLE REACTIVE PHOSPHORUS AT CLARK FORK RIVER MONITORING STATIONS
- ATTACHMENT C-5: 1998–2012 TEMPORAL TREND FINDINGS FOR MEAN CHLOROPHYLL-*A* AT CLARK FORK RIVER MONITORING STATIONS
- ATTACHMENT C-6: 1998–2012 TEMPORAL TREND FINDINGS FOR MAXIMUM CHLOROPHYLL-*A* AT CLARK FORK RIVER MONITORING STATIONS



ATTACHMENT C-1
1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL NITROGEN AT CLARK FORK RIVER MONITORING STATIONS

Clark Fork River Trend Analysis Findings

marginally significant (0.05<p≤0.10)

significant (0.01<p≤0.05)

highly significant (p≤0.01)

Not Sampled

No Trend Detected

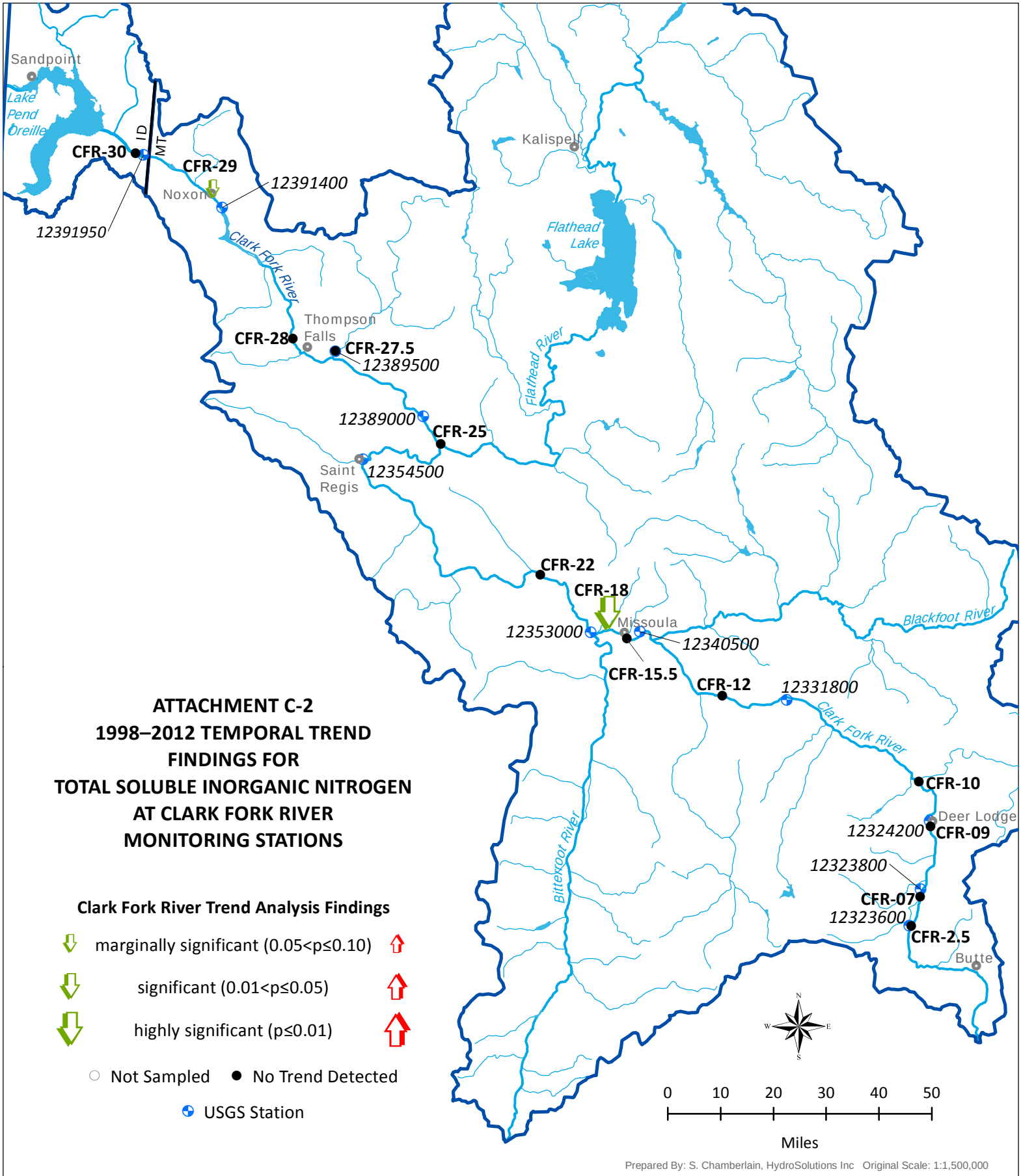
USGS Station

Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

-1998-2008 Total Nitrogen values are calculated as sum of concurrently collected Total Kjeldahl nitrogen (TKN) plus NO2+NO3 as N . Total Persulfate Nitrogen (TPN) analyzed at all stations beginning in 2009.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



ATTACHMENT C-2
1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL SOLUBLE INORGANIC NITROGEN AT CLARK FORK RIVER MONITORING STATIONS

Clark Fork River Trend Analysis Findings

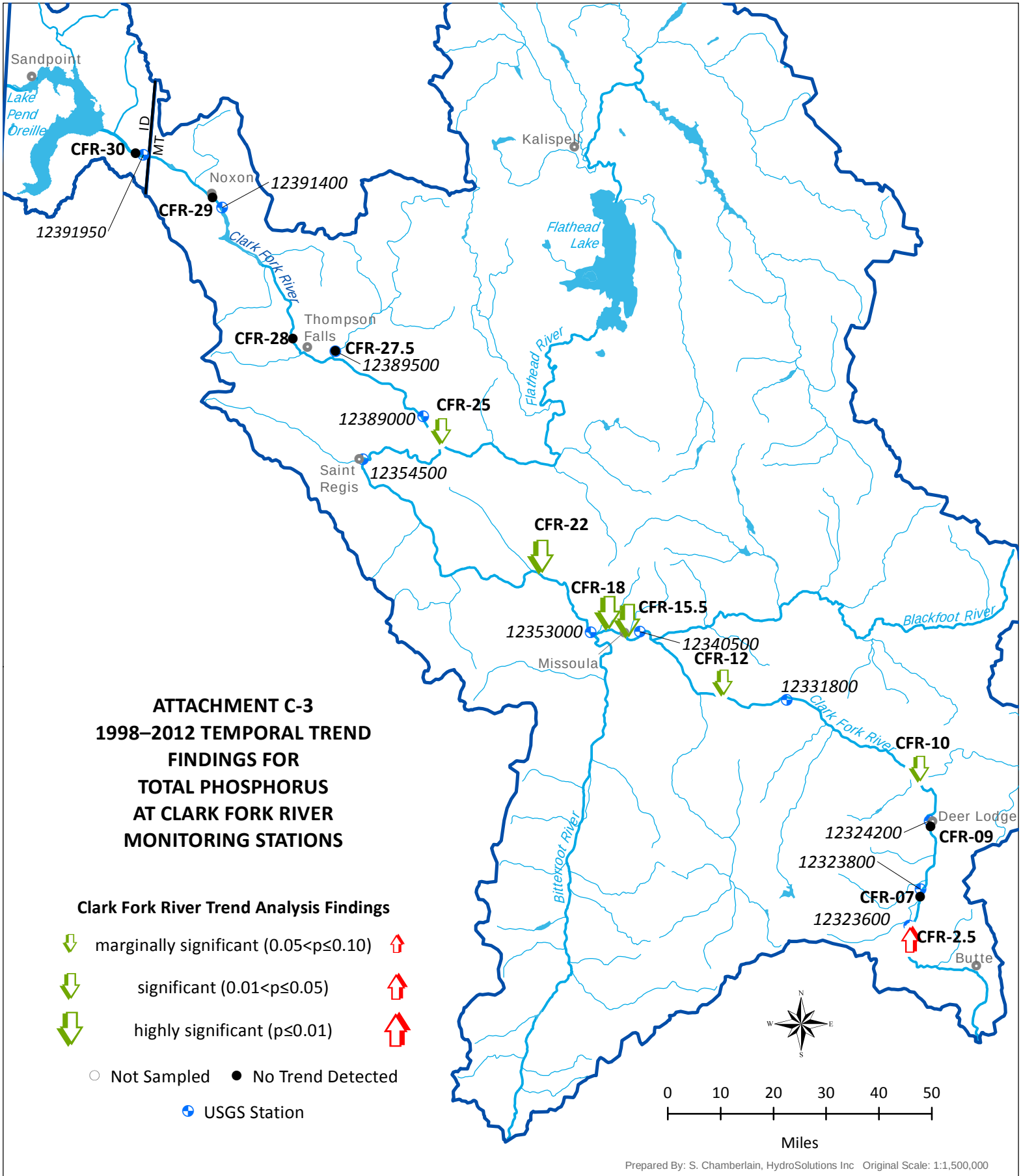
- marginally significant (0.05<p≤0.10)
- significant (0.01<p≤0.05)
- highly significant (p≤0.01)
- Not Sampled
- No Trend Detected
- USGS Station

Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

-TSIN concentrations were calculated by summing concentrations of NO2+NO3 as N and NH3+NH4 as N

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



ATTACHMENT C-3
1998–2012 TEMPORAL TREND FINDINGS FOR TOTAL PHOSPHORUS AT CLARK FORK RIVER MONITORING STATIONS

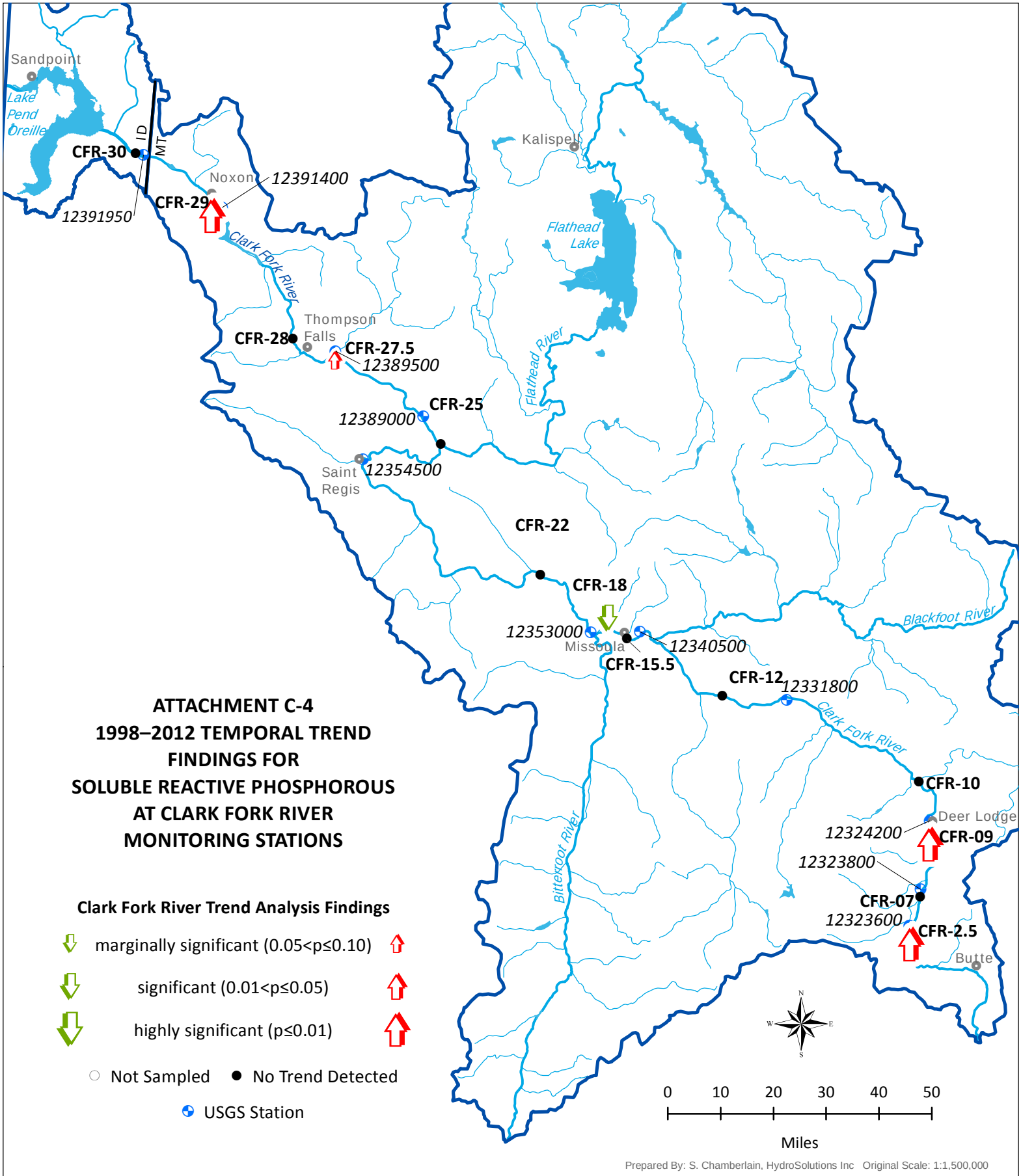
Clark Fork River Trend Analysis Findings

- marginally significant (0.05<p≤0.10)
- significant (0.01<p≤0.05)
- highly significant (p≤0.01)
- Not Sampled
- No Trend Detected
- USGS Station

Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



ATTACHMENT C-4
1998–2012 TEMPORAL TREND FINDINGS FOR SOLUBLE REACTIVE PHOSPHOROUS AT CLARK FORK RIVER MONITORING STATIONS

Clark Fork River Trend Analysis Findings

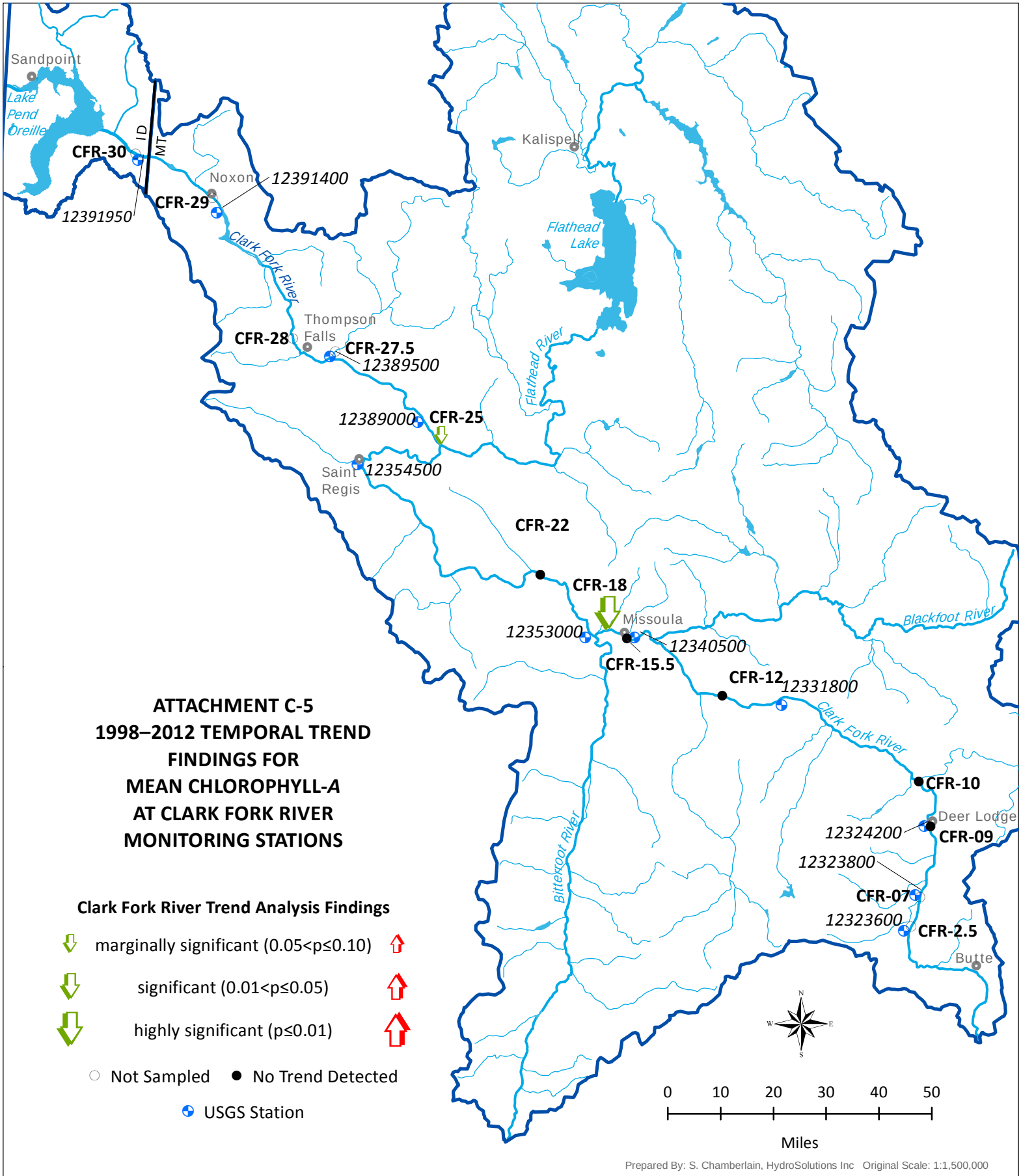
- marginally significant (0.05<p≤0.10)
- significant (0.01<p≤0.05)
- highly significant (p≤0.01)
- Not Sampled
- No Trend Detected
- USGS Station

Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

-The monitoring period for SRP at stations CFR-28 and CFR-29 was 1998-2007.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



ATTACHMENT C-5
1998–2012 TEMPORAL TREND FINDINGS FOR MEAN CHLOROPHYLL-*A* AT CLARK FORK RIVER MONITORING STATIONS

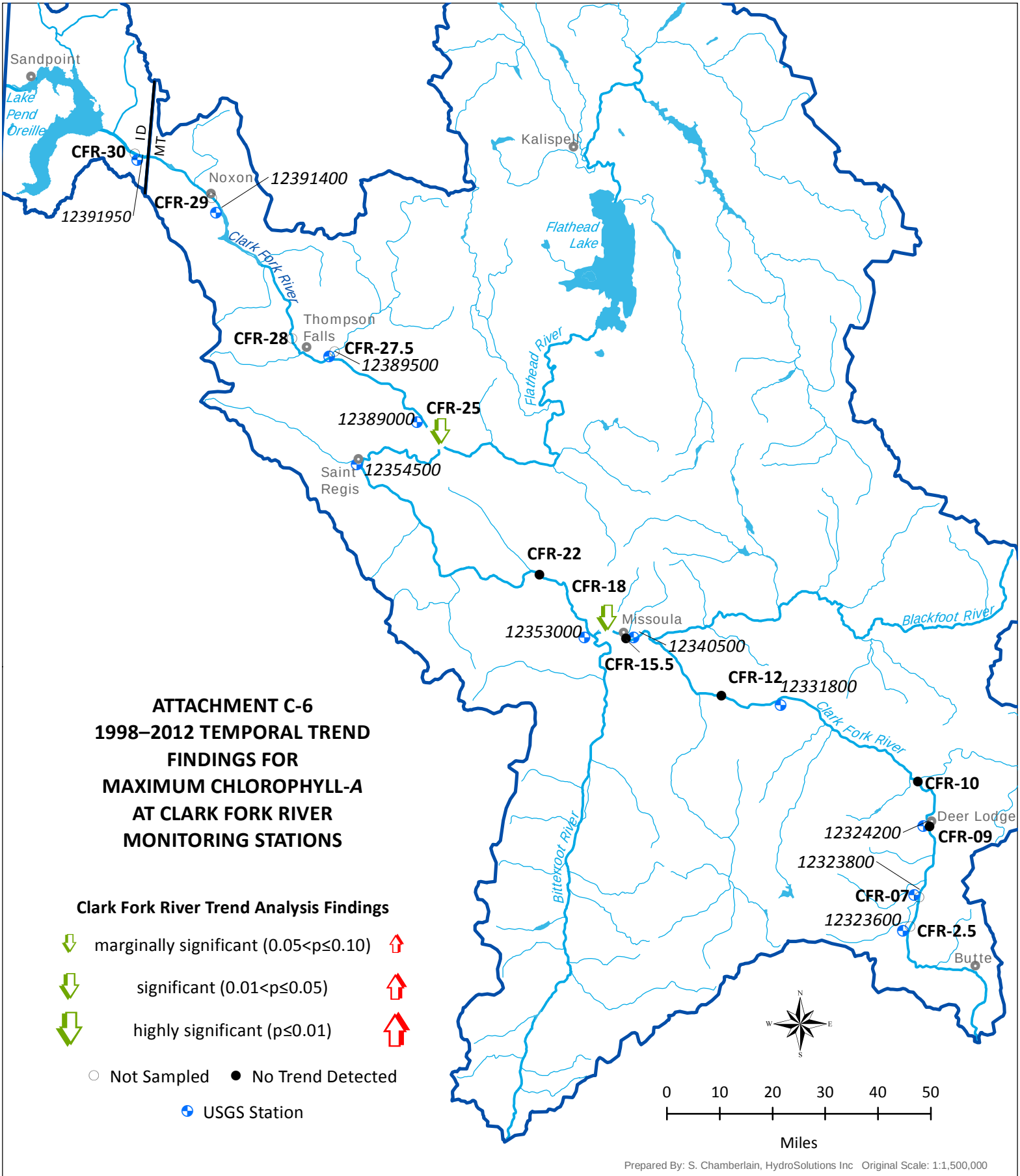
Clark Fork River Trend Analysis Findings

- marginally significant (0.05<p≤0.10)
- significant (0.01<p≤0.05)
- highly significant (p≤0.01)
- Not Sampled
- No Trend Detected
- USGS Station

Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Mann-Kendall test on mean monthly summertime (July-Sept) concentration. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



ATTACHMENT C-6
1998–2012 TEMPORAL TREND FINDINGS FOR MAXIMUM CHLOROPHYLL-*A* AT CLARK FORK RIVER MONITORING STATIONS

Clark Fork River Trend Analysis Findings

- marginally significant (0.05<p≤0.10)
- significant (0.01<p≤0.05)
- highly significant (p≤0.01)
- Not Sampled
- No Trend Detected
- USGS Station

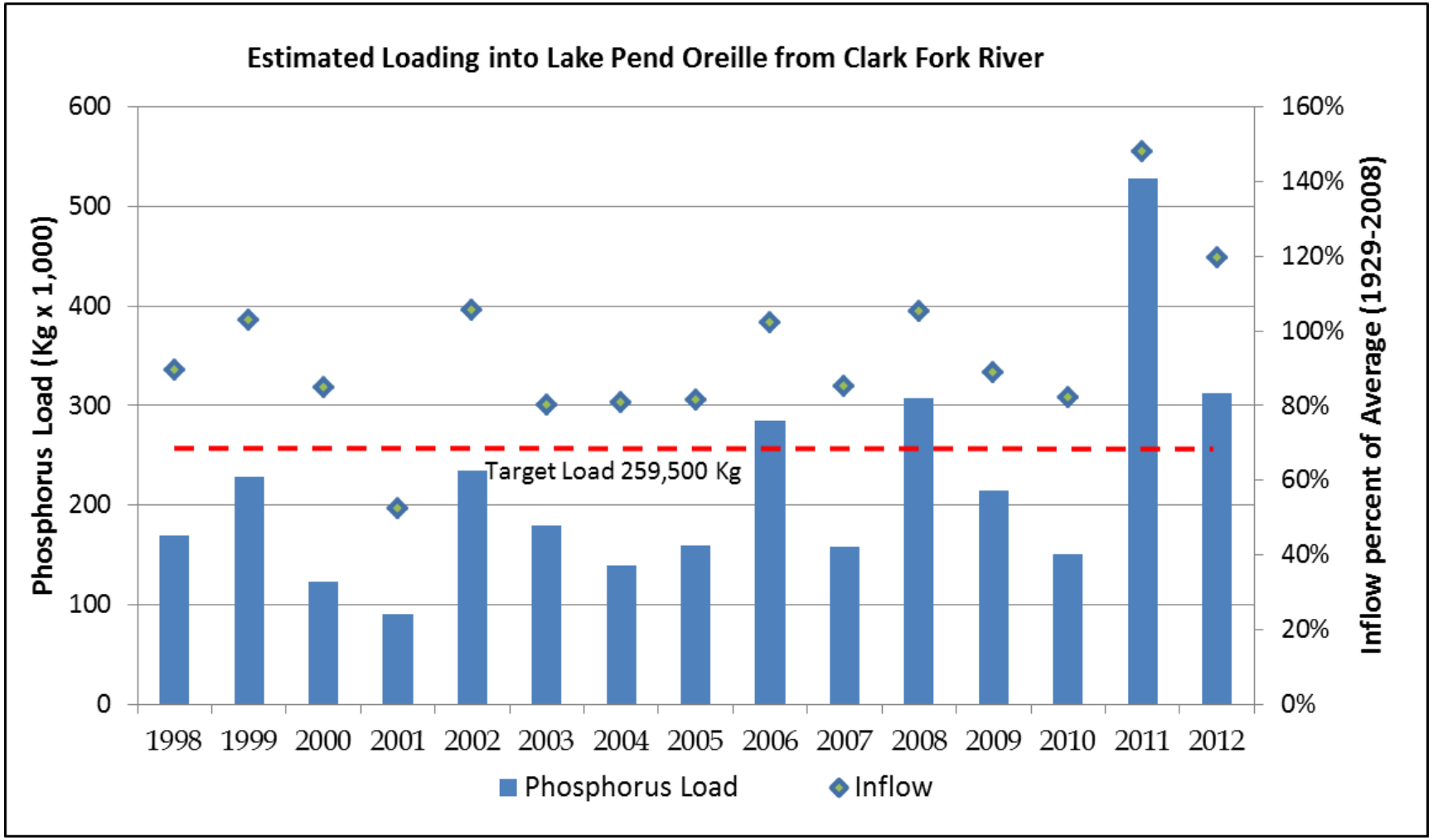
Prepared By: S. Chamberlain, HydroSolutions Inc Original Scale: 1:1,500,000

-Trend findings based on Mann-Kendall test on maximum monthly summertime (July-Sept) concentration. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2012, from Montana Department of Environmental Quality.

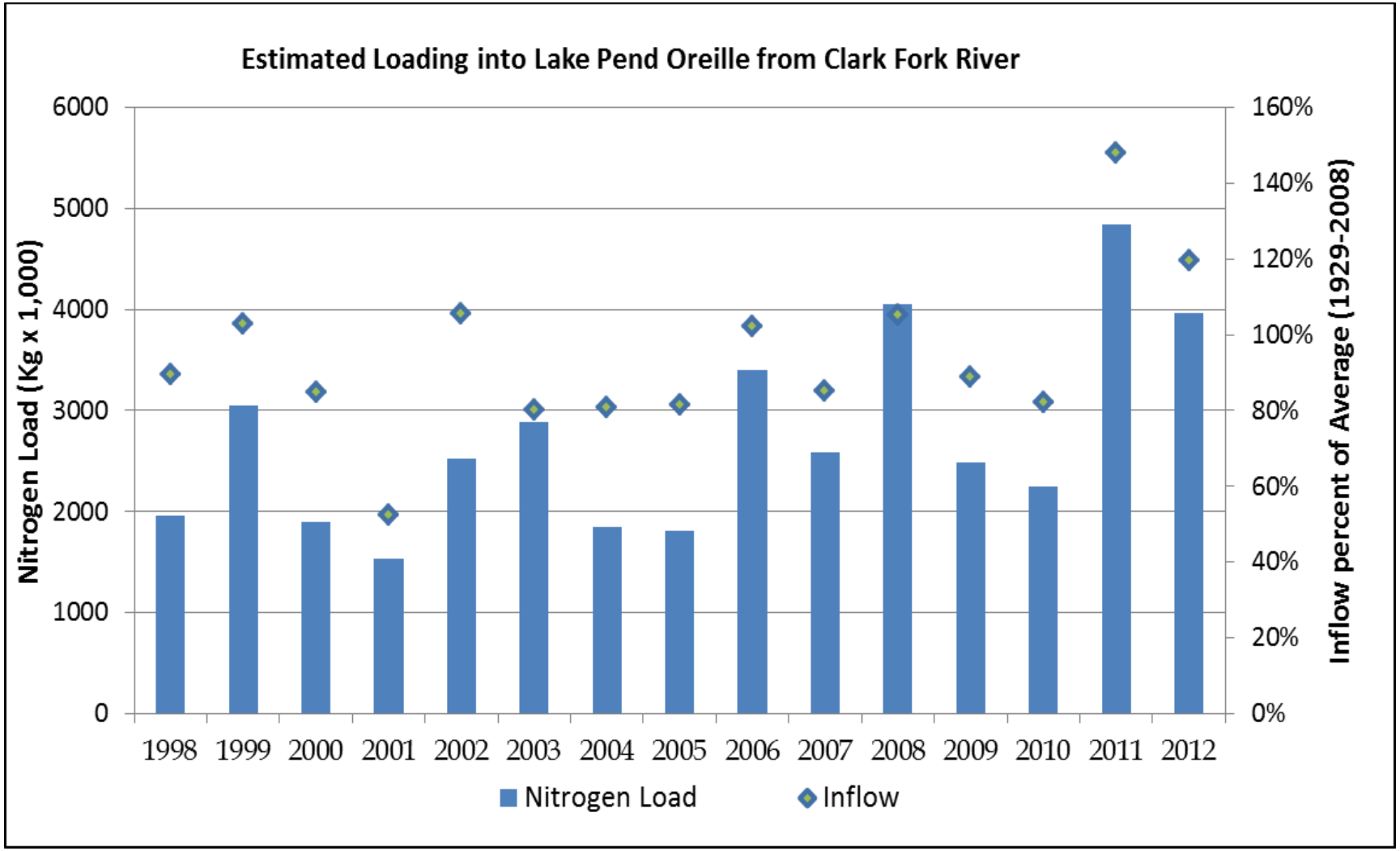
Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.

ATTACHMENT D

CHARTS OF ESTIMATED NUTRIENT LOADING FROM THE CLARK FORK RIVER 1998—2012



Attachment D-1. Estimated Total Phosphorus Loading from the Clark Fork River 1998 to 2012, based on U.S. Army Corps of Engineers FLUX model, with Method 6 regressions stratified at one half the mean discharge, mean discharge, and two times the mean discharge. Water quality sample results from monitoring station Clark Fork River below Cabinet Gorge Dam (CFR-30), inflow from USGS gaging station 12392000, Clark Fork at Whitehorse Rapids, Idaho. Target Load based on Montana-Idaho Nutrient Border Agreement, Clark Fork River annual allocation.



Attachment D-2. Estimated Total Nitrogen Loading from the Clark Fork River 1998 to 2012, based on U.S. Army Corps of Engineers FLUX model, with Method 6 regressions stratified at one half the mean discharge, mean discharge, and two times the mean discharge. Water quality sample results from monitoring station Clark Fork River below Cabinet Gorge Dam (CFR-30), inflow from USGS gaging station 12392000, Clark Fork at Whitehorse Rapids, Idaho.

ATTACHMENT E

ELECTRONIC DATA COMPILATION OF CLARK FORK RIVER NUTRIENT WATER QUALITY STATUS AND TRENDS REPORT

- ELECTRONIC FILE OF DATASET USED IN TEMPORAL TRENDS ANALYSIS
- ELECTRONIC FILE OF DATASET USED IN NUTRIENT LOADING EVALUATION AND FLUX FILES
- ELECTRONIC FILES OF KENDALL TREND TEST RESULTS
- ELECTRONIC FILES OF FLUX32 RESULTS
- ELECTRONIC REPORT FILES AND MAPS