Technical Publication SJ2025-03

UPPER ST. JOHNS RIVER BASIN PROJECT NUTRIENT LOADING AND TREATMENT ESTIMATES (2000 – 2020)

by

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Palatka, Florida

2025

The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the district conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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EXECUTIVE SUMMARY

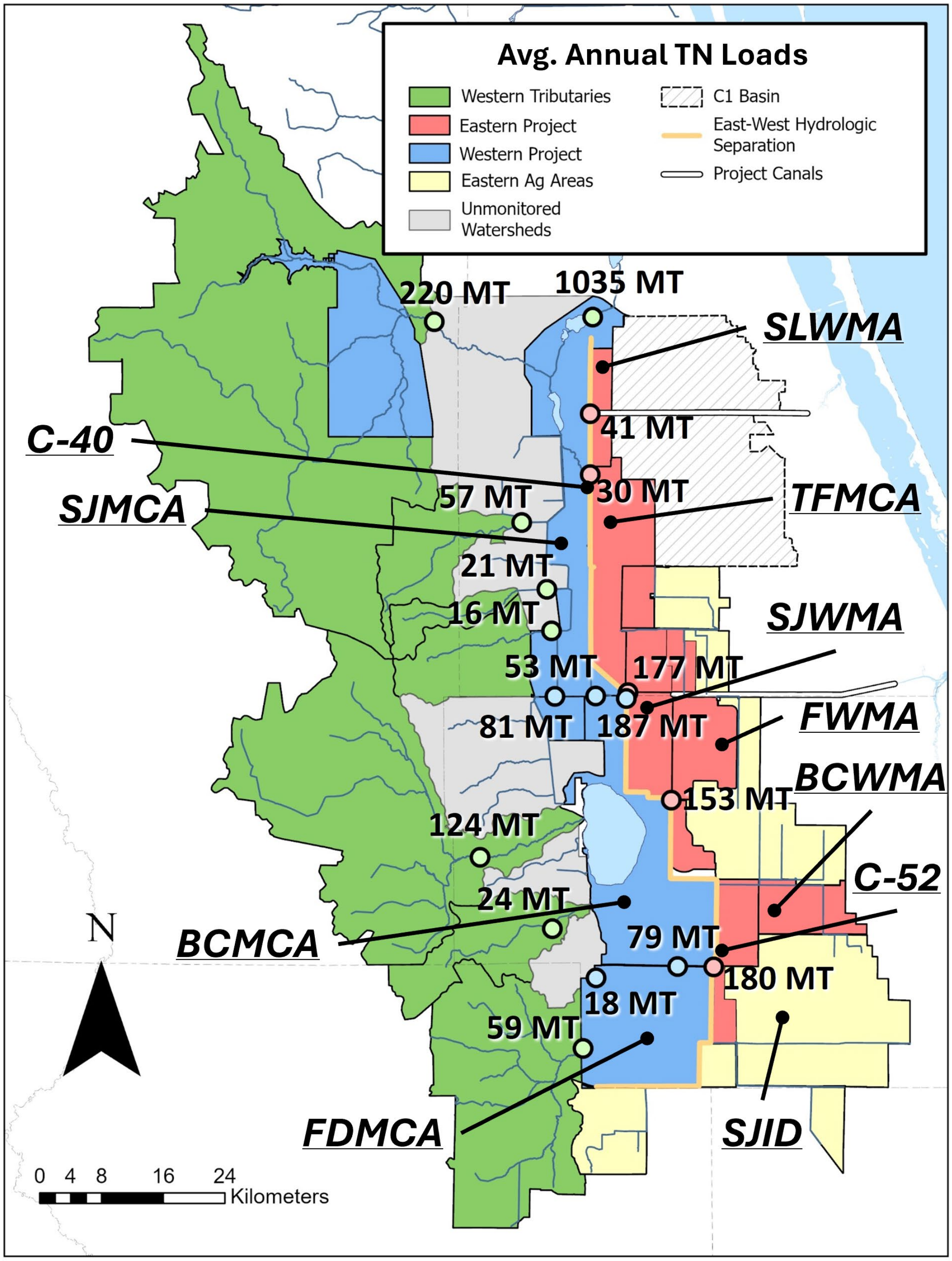
The Upper St. Johns River Basin Project (or Project) is a federal flood protection project managed by the U.S. Army Corps of Engineers (USACE) and the St. Johns River Water Management District (SJRWMD). The Project is at the headwaters of the St. Johns River and consists of several reclaimed and restored wetlands and shallow reservoirs. While flood protection was the original purpose of the Project, SJRWMD also manages the Project with the explicit goal to improve water quality and reduce nutrient loading to downstream lakes, including to three Total Maximum Daily Load (TMDL) waterbodies within the Upper Basin. For example, water management areas (WMA) in the eastern Project segregate and store agricultural discharge for treatment while marsh conservation areas (MCA) in the western Project store nutrients in their vegetation and organic soils. The east and western Project comments are hydrologically separated resulting in different inputs and sources of nutrients to their components.

The purpose of this report is to document total nitrogen (TN) and total phosphorus (TP) loads within the Project area and identify areas within this section of the Upper Basin where nutrient loading has increased. Nutrient loads were calculated by pairing the long-term water quality monitoring data collected by the SJRWMD at several sites throughout the Project as well as discharge data sets at significant water control structures and gaged tributaries within the Project watershed. We used a weighted regression on time, discharge, and season (WRTDS) method to calculate nutrient loads at tributary and river mainstem sites. For Project structures, loads were calculated monthly between 2000-2020 when both water quality and discharge data were available and aggregated to annual loads.

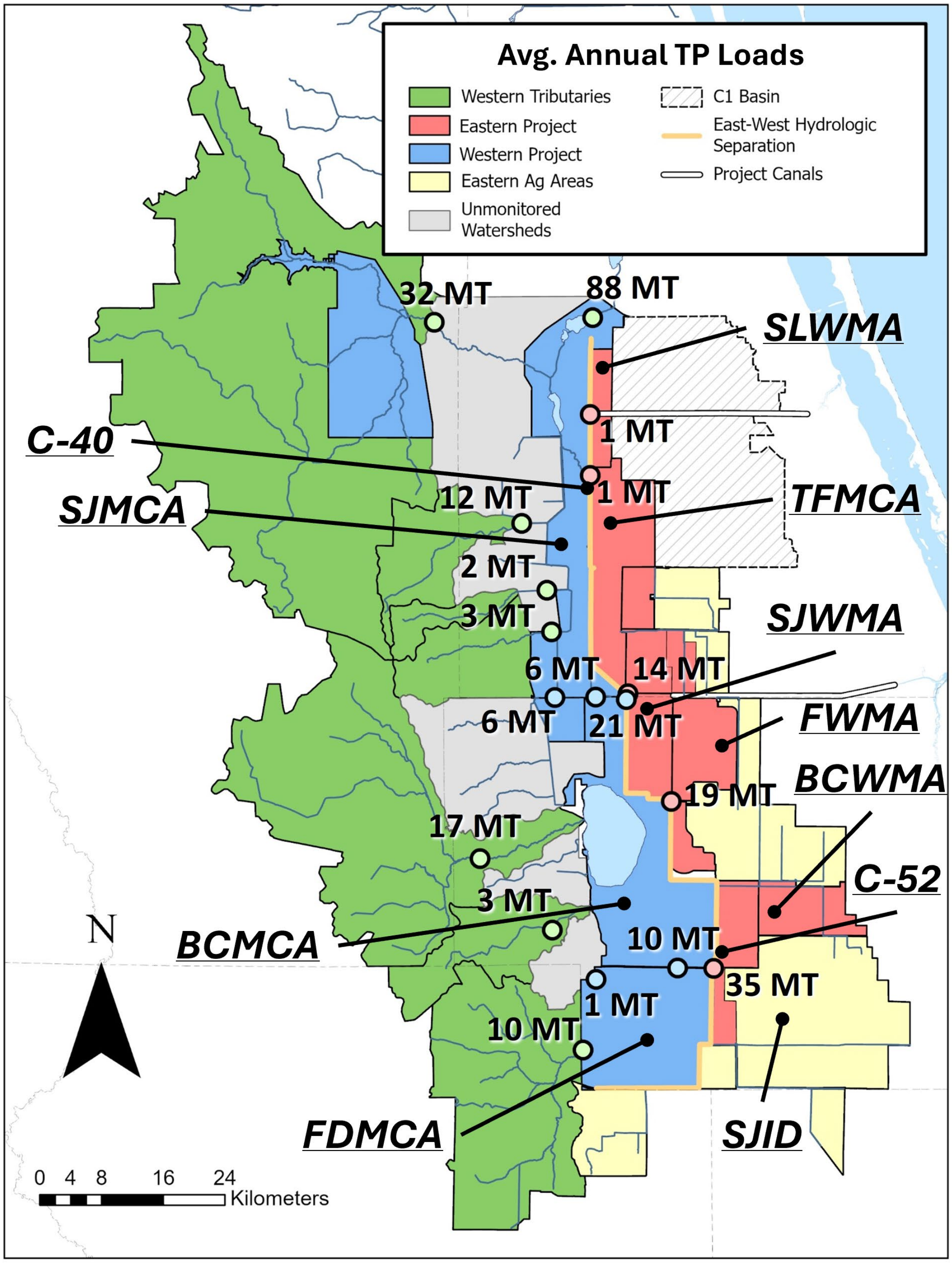
As expected, average annual loading within the Project differed geographically, with the highest TN and TP loading originating from the western tributaries (314 MT TN yr^{-1}, 49 MT TP yr^{-1}) and MCAs (244 MT TN yr^{-1}, 21 MT TP yr^{-1}) compared to the eastern WMAs (72 MT TN yr^{-1}, 2 MT TP yr^{-1}) (Figs. ES-1 & ES-2). Jane Green Creek, the largest monitored watershed within the Project area, contributed the largest individual TN and TP loads. Importantly, TP loading over the last five years of record (i.e. 2016-2020) increased at many western tributary and marsh structure sites relative to the longer-term average (Fig. ES-3). The largest relative increases in TP loading were found at Sixmile, South Wolf, Tenmile, and Jane Green Creeks. While years with significant rainfall events often drove increases in annual nutrient loading at western MCA structures, the effects of long-term water quality degradation were also evident at stations in the western Project. Previous research by SJRWMD scientists suggests increases in TP concentrations and loads in these western watersheds is likely caused by increases in the land application of P-rich Class B biosolids. Additional research is needed to determine the legacy impacts that the additional TP loading from biosolids run-off may have on the characteristics and functions of downstream wetland and lake soils.

General decreases in nutrient loads along the eastern WMA flow path suggests that these Project features are largely functioning to reduce nutrient loads from their inputs before discharging to the river channel. However, calculated removal rates were highly variable on the annual scale and differed by nutrient. Annual treatment efficiencies at Sawgrass Lakes WMA were higher for TP (51-92% removal) than TN (5-57% removal). St. Johns WMA was a net exporter of both TN (-137 to 68% removal) in 15 of 21 years and TP (-87 to 58% removal) in six of 21 years, and climate (e.g. drought, tropical rainfall events) appeared to drive some of the variability, possibly by altering hydraulic residence times within the WMA and the potential for nutrient transformation and removal. However, the influence of wetter or drier than average years on nutrient removal in the eastern WMAs was not consistent between WMA or nutrient, suggesting more complex controls on TN and TP removal. Additional studies on the drivers and important processes controlling N and P transformation within the WMAs are recommended to identify the dominant mechanisms dictating net nutrient removal versus export. Furthermore, in the case of SJWMA, TN and TP inputs were additionally incomplete due to a lack of available monitoring data before construction of Fellsmere WMA. Nutrient removal rates could also not be calculated for other WMAs within the Project due to a lack of consistent monitoring of other structures or pumps originating from the remaining agricultural inputs in the east Project watershed.

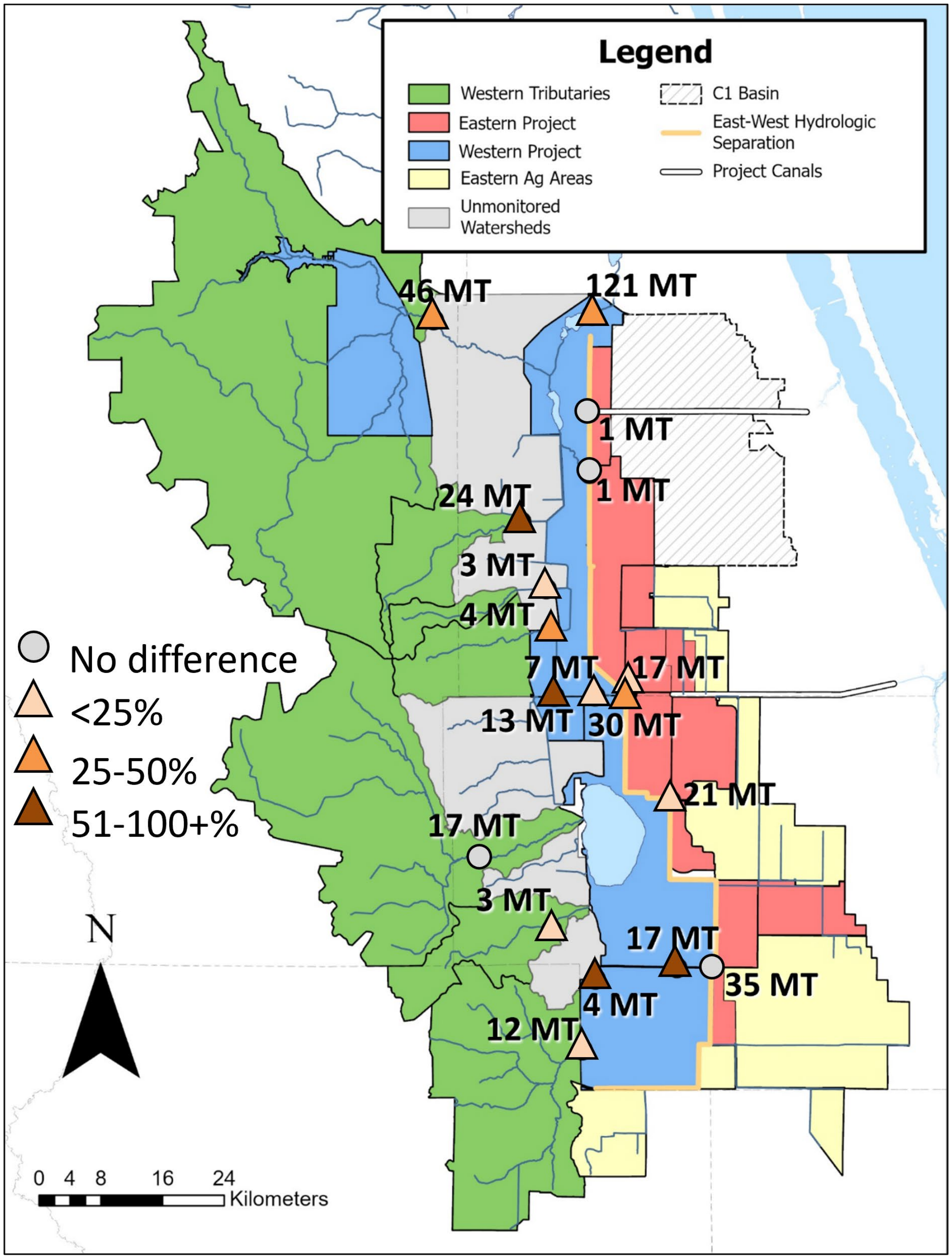
Together, these results highlight the importance of collecting long-term water quality and hydrologic monitoring data sets at structures throughout the UJSRB Project and using consistent methods for nutrient loading calculations. Regular evaluation of long-term nutrient loading trends and nutrient removal performance of USJRB Project components will assist in identifying potential improvements in water management in accordance with the adaptive management framework of the USJRB Project.



ES-1. Overview of average (avg.), annual TN loads (MT yr^{-1}) at USJRB Project structures and western tributary monitoring sites calculated from available data between 2000-2020.



ES-2. Overview of average (avg.), annual TP loads (MT yr^{-1}) at USJRB Project structures and western tributary monitoring sites calculated from available data between 2000-2020.



ES-3. Average annual TP loads (in MT yr^{-1}) at Project locations from 2016-2020. Colored triangles represent the percent difference compared to the long-term average annual TP loads at the same locations from 2000-2020 (Fig. E-2).

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LIST OF ACRONYMS

BCMCA	Blue Cypress Marsh Conservation Area
BCWMA	Blue Cypress Water Management Area
CM	Continuous monitoring
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphorus
DON	Dissolved organic nitrogen
DOP	Dissolved organic phosphorus
EAV	Emergent aquatic vegetation
EHC	Environmental hydrologic criteria
EWMP	Environmental Water Management Plan
FDEP	Florida Department of Environmental Protection
HAB	Harmful algal bloom
HSPF	Hydrologic Simulation Program - FORTRAN
IRL	Indian River Lagoon
MCA	Marsh conservation area
MCM	Millions cubic meters
MT	Metric tons
OM	Bureau of Operations and Maintenance
PLRG	Pollution Load Reduction Goals
PS	Pump station
SAV	Submerged aquatic vegetation
SLWMA	Sawgrass Lakes Water Management Area
SJID	St. Johns Improvement District
SJRWMD	St. Johns River Water Management District
SJMCA	St. Johns Marsh Conservation Area
SJWMA	St. Johns Water Management Area
STA	Stormwater treatment area
TFMCA	Threeforks Marsh Conservation Area
TMDL	Total maximum daily load
TDN	Total dissolved nitrogen
TDP	Total dissolved phosphorus
TN	Total nitrogen
TP	Total phosphorus
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USJRB	Upper St. Johns River basin
WMA	Water management area
WRTDS	Weighted regression on time, discharge, and season
WMM	Bureau of Watershed Management and Modeling
WY	Water year

ACKNOWLEDGEMENT

The authors would like to acknowledge the Bureau of Water Resources Information staff for the field collection, monitoring equipment installation, laboratory analyses, and data quality assurance of the water quality and hydrologic data used in this report. We also thank Tom Jobes and Tara Bongiovanni of the Bureau of Watershed Management and Modeling, and Matt Forhan and John Richmond of the Bureau of Operations and Maintenance, for calculating and providing structure discharge datasets to assist with loading calculations. Thank you to Jan Miller for assistance with data organization and loading calculations and to Dianne Hall, Kim Ponzio, Vickie Hoge, and Steve Miller for providing invaluable background information on the Upper Basin and history of the Project. We thank Dean Dobberfuhl and Erich Marzolf for their insightful reviews of this report.

INTRODUCTION

THE UPPER ST. JOHNS RIVER BASIN AND USJRB PROJECT

The Upper St. Johns River Basin (USJRB) encompasses the headwaters of the St. Johns River, ranging from the marshes in Okeechobee and Indian River counties to the confluence of the Econlockhatchee River in Seminole County (Fig. 1). The floodplain of the USJRB was historically more expansive than its current boundaries, totaling over 4,000 km^2 of mixed habitat dominated by herbaceous marshes and other wetlands. By the 1970s, like much of Florida, nearly 62% of the historic 100-year floodplain had been diked, drained, and converted to agriculture (Lowe 1984). This led to widespread ecological degradation of the USJRB including the loss of floodplain water storage and increased flooding, diminished water quality from nutrient enrichment, disruption of natural hydrologic and fire regimes, and nuisance species encroachment. Much of the lost water was directed eastward to the Indian River Lagoon (IRL) through newly constructed canals. This also resulted in impairment of valuable estuarine habitats due to increased nutrient and sediment transport and alterations of salinity regimes. Today, the majority land use in the USJRB is pastureland for beef cattle, natural forested areas, and remaining wetlands (Canion et al. 2022). Urban development and other forms of agriculture (e.g. citrus and row crops) are minority components of land use, primarily in the eastern basin (Fig. A-1).

In 1977, the St. Johns River Water Management District (SJRMWD or “the District”) partnered with the US Army Corp of Engineers (USACE) to revitalize the USJRB through the Upper St. Johns River Basin Project (“the Project”). The “semi-structural” approach of the Project area has expanded water storage capacity by acquiring former agricultural lands and constructing new levees, canals, and water control structures to manage water levels to meet flood protection and environmental and human water supply needs in the region. Along with state and federal partners, SJRMWD has worked to increase wetland habitat within the USJRB floodplain by over 290 km^2 through reclamation and restoration of these former agricultural lands (Zollitsch et al. 2019). Additionally, discharges to the IRL have been drastically reduced. Since its official completion in 2016, current efforts by the District focus on managing the Project features through an adaptive management approach by regularly evaluating the impact hydrologic operations and conditions have on the ecology and water quality of the system.

HYDROLOGY OF THE USJRB PROJECT

The existing levees and canals within the Project area were designed such that water is separated hydrologically between the eastern and western subbasins until discharges meet at the C-40 canal near the Three Forks region (Fig. 1). Water elevations within components of the Project areas are ultimately controlled by a series of water control structures which are operated by regulation schedules outlined in the USACE Operations Manual. Accordingly, when water elevations exceed regulation elevation (Zone A) for flood protection, downstream discharges must be initiated. However, when water elevations in an area are below its regulation schedule

(Zone B), the District is authorized to make environmental discharges to achieve various environmental goals. Zone B discharges are codified as an Environmental Water Management Plan (EWMP; Miller et al. 2022) and help to balance the distribution of water within the Project to protect its wetland habitats with its other goals of flood protection and water supply.

The Project is composed of three main features: 1) Water Management Areas (WMA), 2) Marsh Conservation Areas (MCA), and 3) Retention-Detention Areas. The WMAs are primarily found on the eastern side of the Project and largely function as shallow reservoirs for the purpose of storing water for flood protection and water supply as well as treating inputs from agricultural areas before discharge downstream. Importantly, these reservoirs were created through the re-flooding of previously cultivated lands acquired by the District but now serve as open water and marsh habitat and provide significant recreational opportunities. The project's MCAs are found largely in the western Project, with the exception of Three Forks MCA. These areas are protected wetlands that have not been altered to the extent of WMAs and provide numerous ecosystem services such as additional flood protection, carbon and nutrient storage, habitat for threatened and endangered species, and recreational opportunities for the public. Older Retention-Detention areas, such as Jane Green detention area and Taylor Creek Reservoir, are a mixture of private and public properties which store water contributed by western watersheds behind existing or decommissioned federal levees before discharge downstream through District-operated water control structures. Newer Retention-Detention areas are often managed by other state agencies for additional water storage and habitat and may operate as part of projects re-diverting flow from watersheds draining to the IRL back to the USJRB (e.g. the C-1 basin; Fig. 1).

NUTRIENTS IN THE USJRB

While the Project is now in the long-term maintenance phase, several issues of concern have emerged related to the water quality trends throughout the basin, which are central to the core mission of the District to protect and restore water quality. In 2003, Pollutant Load Reduction Goals (PLRGs) were established by the District for five USJRB lakes (Lake Hellen Blazes, Sawgrass Lake, Lake Washington, Lake Winder, and Lake Poinsett), based on a target total phosphorus (TP) concentration of 0.09 mg L^{-1}. This TP concentration was determined as the threshold that would limit the frequency of harmful algal blooms (HABs) and the dominance of the phytoplankton community by cyanobacteria with the potential to produce toxins (Keenan et al. 2003). Subsequent Total Maximum Daily Loads (TMDLs) for three USJRB waterbodies were codified by the Florida Department of Environmental Protection (FDEP) using the same TP concentration target (Gao 2006). Both the PLRGs and TMDLs required significant TP load reductions (approximately 23 – 51 MT TP) when they were established.

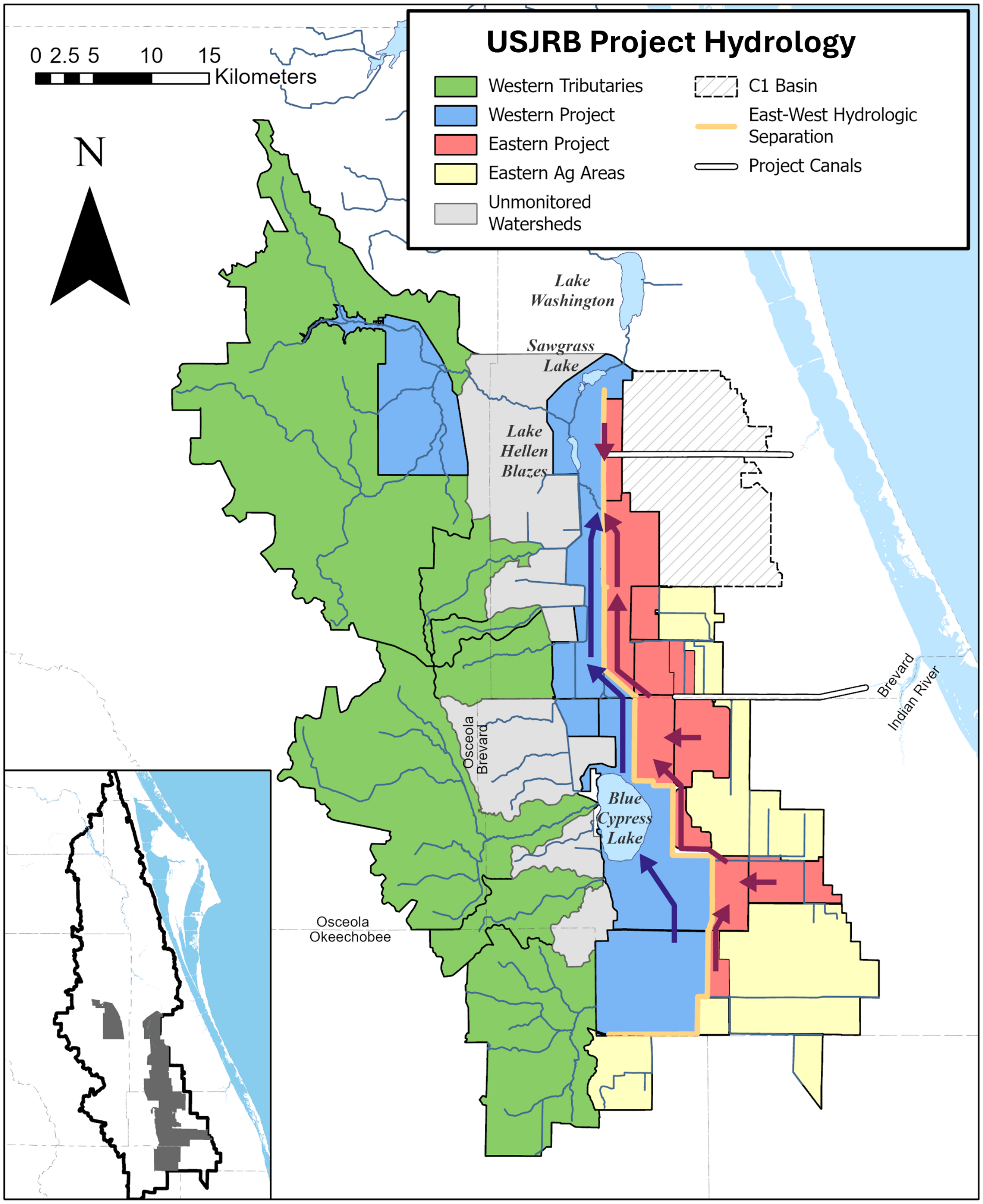

Figure 1. Map of the Upper St. Johns River Basin Project and the subbasin regions used in this report. Blue arrows show the general path of water through the western Project components while red arrows show the general path of water through the eastern Project.

Recent evaluation of water quality monitoring data against PLRG and TMDL targets suggest these goals are likely not being met for these lakes. Currently, the USJRB is widely impaired for TP, with some waterbodies additionally impaired for total nitrogen (TN), with significant impacts to the biology of waterbodies in the region (see Statewide Comprehensive Verified List of Impaired Waters, Division of Environmental Assessment and Restoration, FDEP). Recent HAB monitoring in the basin has captured intense cyanobacteria blooms in some USJRB waterbodies such as Lake Washington and Blue Cypress Lake (see Algal Bloom Dashboard, FDEP), the latter of which was not considered in the original PLRG analysis. Importantly, the majority of state waters upstream of Lake Washington, including several Project components and important tributaries in the basin, are designated as Class I waters (Chapter 62-302.400, F.A.C.) as the City of Melbourne uses Lake Washington as a potable water supply. Additionally, nutrient loads from the entire USJRB are a significant source to downstream Middle St. Johns River Basin (MSJRB) lakes which also have established nutrient TMDLs (Gao 2009). Recently, a link has been established between the land-application of Class B biosolids (i.e. minimally-treated sewage sludge) to pasture land within the USJRB and the impact of this practice to nutrient loading and water quality of watersheds in the western part of the basin (Canion et al. 2022).

Purpose of This Report

The purpose of this report is to detail nutrient (TN and TP) loading calculations within the USJRB Project. Our focus is on major Project structures and tributaries entering the Project upstream of the northern Project boundary near the river outlet at Sawgrass Lake (Fig. 1). This focal area represents approximately 2,508 km^2 of watershed. We chose to calculate nutrient loading from 2000-2020 to cover a range of recent hydrologic conditions, including drier than average (i.e. drought) and wetter than average years (Fig. A-2; Fig. A-3). Results are expected to highlight the geographic differences between eastern and western Project features, recent progress made in treating nutrient inputs to the Project, and challenges with addressing shifting sources of nutrients within the basin.

METHODS

WATER QUALITY MONITORING, DATA RETRIEVAL AND NUTRIENT CALCULATIONS

The District routinely monitors over 50 sites within the USJRB on a monthly to bimonthly basis, depending on the site, for water quality analytes including total and dissolved (i.e. filtered) N and P species. Samples were collected using FDEP standard operating procedures (FDEP 2017) and analyzed at the District laboratory or an accredited laboratory using US Environmental Protection Agency (USEPA) approved analytical methods. Stations selected for calculating nutrient loading within the Project needed to be associated with a major water control structure or tributary monitoring station where daily flow was directly monitored or could be otherwise be calculated. For some stations of interest, particularly at or within newly constructed components of the Project, water quality data were not available over the entire period of interest. In some cases, monitoring at the site nearest the structure did not fall within the period of interest (2000-2020) for this report and an appropriate, nearby station data were used instead. Sites were further grouped geographically to compare loading within the distinct regions of interest within the USJRB. These include the Eastern Project (Table 1), the Western Project (Table 2), and Western Tributaries (Table 3). Detailed maps of structure and monitoring station locations are provided in Figures 2-4. Several watershed and pump inputs on both sides of the basin are currently unmonitored for water quality and/or discharge at input locations and therefore loading could not be calculated.

Water quality data were queried from the District's Environmental Database (ED) using a custom R script, but data are publicly available at the Environmental Data online GIS tool. We selected total Kjeldahl N (TKN-T), dissolved TKN (TKN-D), nitrate-nitrite (NO_x), ammonium (NH_4), total phosphorus (TP), dissolved TP (TP-D), and Ortho-P (PO_4) from 2000 to 2020 for stations associated with Eastern or Western Project structures. Unfiltered, inorganic N (NOx-T, NH_4-T) and P (PO_4-T) concentrations were reported prior to 2005 before the District routinely filtered prior to analyses of dissolved, inorganic N (NOx-D, NH_4-D) and P (PO_4-D). All subsequent concentration data are displayed as milligrams-N or P per liter (mg L^{-1}).

For samples with reported concentrations less than the reported method detection limit (MDL), a concentration of one-half the MDL was used for completeness of available data and subsequent calculations. Concentrations of TP were averaged at sites sampled more than once per month to create a monthly time series for each site. For samples with both TKN and NOx, TN was calculated as the sum of these concentrations and then averaged for the month. For any months at a given Project structure monitoring site where calculated TN or reported TP concentrations were not available due to incomplete data, a site-specific, monthly median concentration (calculated over the 2000-2020 POR) was imputed to ensure a load could be calculated for every month in the time series. For structures of interest in which no long-term monitoring data were available, such as S-252F, a monthly median TN and TP value was used and calculated from the entire available period of record for that station.

Table 1. Information on eastern Project structures data sources used for water quality (WQ) and discharge (Q) in TN and TP loading calculations. POR = Period of Record.

Structure	Load Description	District WQ Station	Q Data Source	Load Calc POR	Notes
C-52 Flow way	Load from C-52 to BCWMA	C52FW	WMM + USGS (02231322)	2011-2020	Q is sum of S-253, SJID Weir & S-252D; S-253 Q filled with USGS data 9.20.2016 - 12.31.2020
S-96D + S-3	Load from BCWMA to SJWMA	BCWMO	WMM + OM	2000-2020	Missing WMM Q data filled with OM data
PS-4	Load from FWMA to SJWMA	FWMA1CTR	OM	2017-2020	
S-96	Load from SJWMA to IRL	STKM	WMM + OM	2000-2020	Missing WMM Q data filled with OM data
S-96B	Load from SJWMA to TFMCA	S96BO	WMM + OM	2000-2020	Missing WMM Q data filled with OM data
S-257	Load from TFMCA to Mainstem	XTRIANGLE	WMM	2012-2020	TFM257 WQ station created in 2022
SLWMA PS-1 (south)	Load to SLWMA from C-1	SLWMAPSN | SLWMAPSN HW	OM	2013-2020	District WQ station changed 8.02.2017
SLWMA PS-2 (north)	Load to SLWMA from C-1	SLWMAPSS | SLWMAPSSSTH	OM	2013-2020	District WQ station changed 8.02.2017
S-262	Load from SLWMA to Mainstem	S262S	WMM + OM	2013-2020	Missing WMM Q data filled with OM data

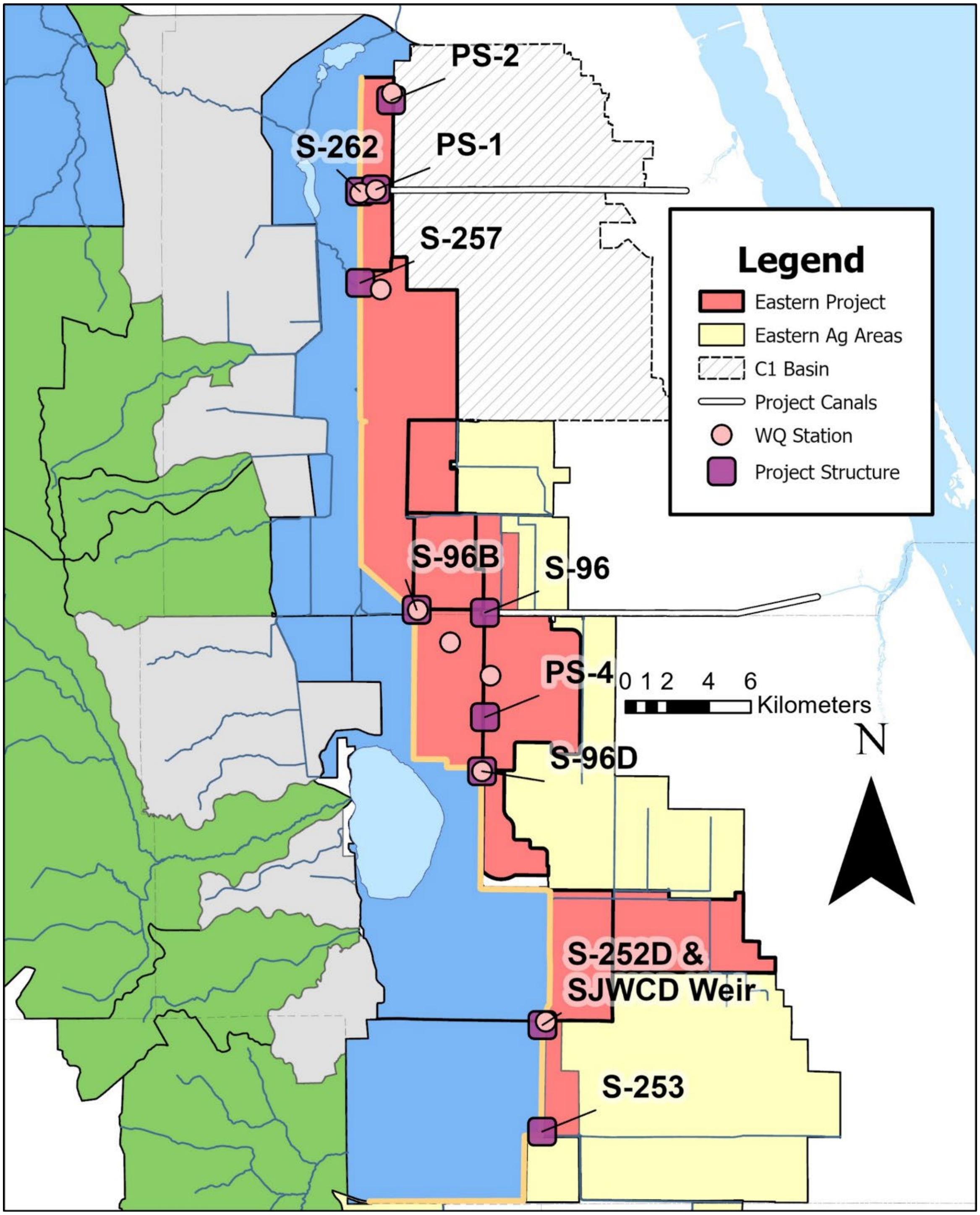

Figure 2. Locations of ambient water quality (WQ) stations associated with Project structures on the eastern side of the hydrologic boundary. Note TN and TP loading was not calculated in this report for all District structures identified due to limitations in WQ and/or discharge data availability.

For Western Tributary stations, monitoring data were acquired from 1995-2020 when available for use in longer-term load calculations and trend analysis based on previous investigations. The methodology used for tributary loading was more flexible allowing for gaps in the water quality time series, and therefore no imputation of monthly data was carried out. Since March 2018, the District has also operated a continuous monitoring (CM) station at Jane Green Creek (JGS) equipped with a Cycle-PO_4 (SeaBird Scientific, Inc.) to record Ortho-P concentrations every 15 minutes. Data from the JGS CM station was downloaded directly from the District's AQUARIUS Web portal (version 2023.3.121; Aquatic Informatics ©2025) for use in investigating the effect of capturing more frequent data on load calculation methods.

Hydrologic Monitoring, Data Retrieval, and Discharge Calculations

In addition to sites monitored for water quality, the District has several sites within the USJRB monitored for stage and water elevation (in feet, NAVD88) reported via telemetry in 15-minute increments. Hourly discharge timeseries for large water control structures (e.g. weirs, culverts, gates) within the Project were calculated by the Bureau of Watershed Management and Modeling (WMM) at locations where water elevation data from both a headwater and tailwater station were available. The upstream (or headwater) and downstream (or tailwater) hydrologic monitoring stations used for calculating discharge from each structure are listed in Table A-1. For days with missing water elevation data (e.g. due to equipment failure) or other monitoring gaps in the period of interest, daily discharge was filled using spreadsheet calculations from the Bureau of Operations and Maintenance (OM) or a nearby U.S. Geological Survey (USGS) gage when available. Discharge data sources for all Project structure loads calculated are noted in Table 1 (eastern Project) and Table 2 (western Project). All instantaneous flow rates (in cfs) at structures were averaged and converted from hourly to daily volumes (in cubic meters) and then aggregated to monthly volumes for load calculations. For ease of display, subsequent discharge data for structures is displayed in millions of cubic meters (MCM). In cases of series of structures which represented a broader nutrient load of interest (i.e. S-96D and S-3, S-252 A, B & C structures, S-250 A, B & C structures, multiple structures loading to the C-52 flow way), available discharges from multiple structures were summed to calculate one TN and TP load.

Similar to water quality stations, recently constructed structures did not have discharge data available over the entire 2000-2020 period. For some structures, discharge data were only available using calculations from OM, such as the S-250E weir. Inputs to several WMAs are also driven by pump stations (PS) operated by the District. For SLWMA south PS (i.e. PS-1) and north PS (i.e. PS-2), available pump data from OM for 2014-2020 was already reported as the water volume (in acre-feet) pumped over 15-minute increments. For FWMA PS-4, an average daily discharge (in cfs) was available from OM for September 2017-December 2020. Similar to structures, pump discharge was converted from hourly discharge to daily volumes, when necessary, before summed to monthly volumes for load calculations.

Table 2. Information on western Project structures data sources used for water quality (WQ) and discharge (Q) in TN and TP loading calculations. POR = Period of Record.

Structure	Load Description	District WQ Station	Q Data Source	Load Calc POR	Notes
S-252A+B+C	Load from FDMCA to BCMCA	FDMCAO	WMM	2010-2020	Q data missing 11.11.2003 - 1.6.2010; FDM252B station established 4.12.2022
S-252F	Load from FDMCA to BCMCA	FDM252F	WMM	2000-2020	WQ station established 4.12.2022; Loading calculation used median monthly TN/TP values for entire Q POR
S-96C	Load from BCMCA to C-40/SJMCA	BCMCU	WMM + OM	2000-2020	Missing WMM Q data filled with OM data
S-250B+C	Load from BCMCA to C-40/SJMCA	BCMCU	WMM	2000-2020	
S-250E	Load from Kenansville Lk. to SJMCA	SNKCEN	OM	2007-2020	Weir constructed in 09.2006; Q calculation does not include gated culvert that is typically closed (Miller et al. 2022)

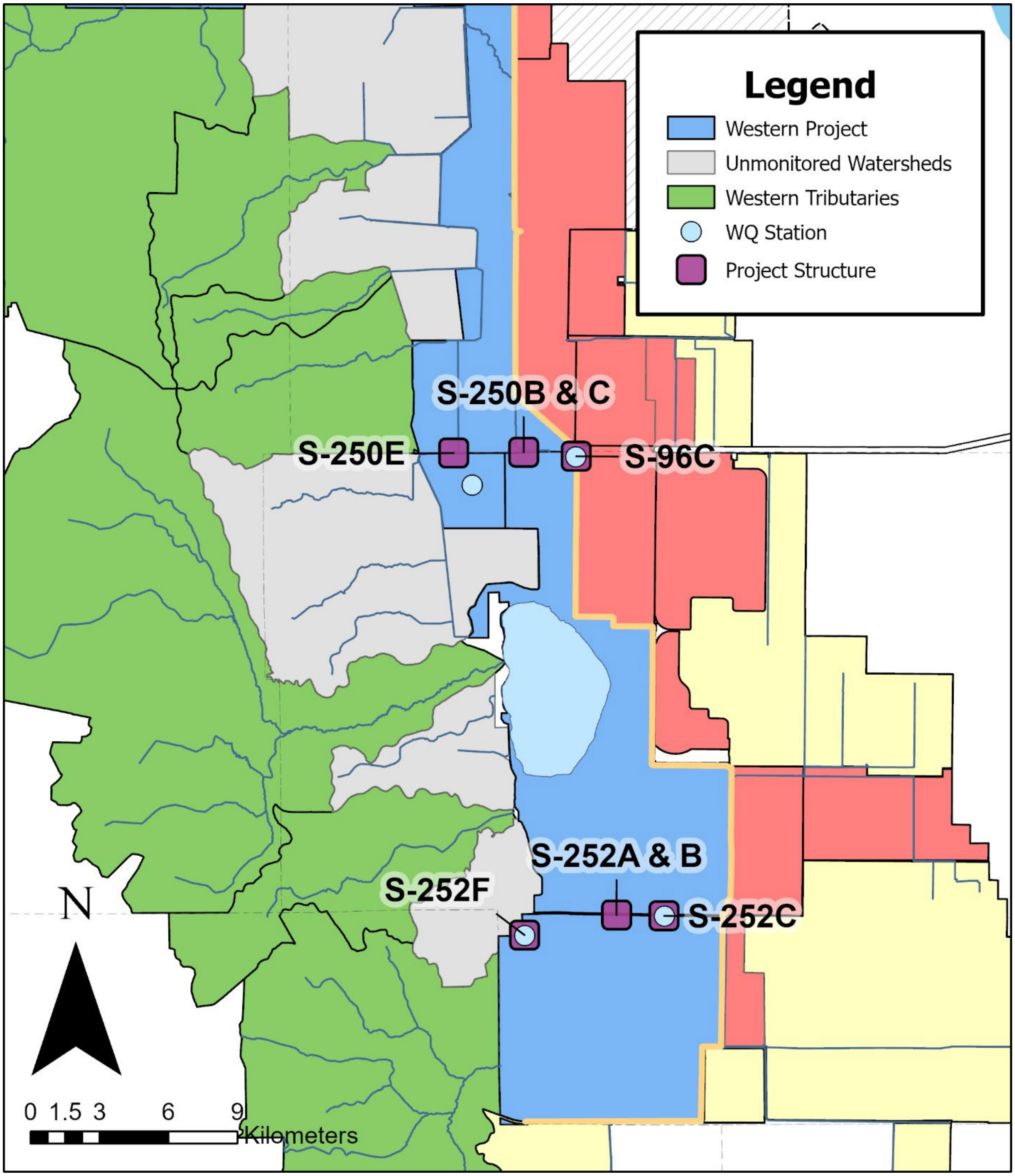

Figure 3. Locations of ambient water quality (WQ) stations associated with Project structures on the western side of the hydrologic boundary. Note TN and TP loading was not calculated in this report for all District structures due to limitations in WQ and/or discharge data availability.

Several flowing waters located in the western USJRB are gaged by USGS in cooperation with the District. Daily discharge datasets were obtained from the USGS National Water Information System database (USGS 2016) at four creeks (Ft. Drum, Blue Cypress, Jane Green, and South Wolf Creeks) and the St. Johns River mainstem gage at the outlet Sawgrass Lake. Discharges for the four ungaged sites (Sixmile, South Wolf and Tenmile Creeks and Padgett Branch) were estimated from previously calibrated Hydrologic Simulation Program-Fortran (HSPF) models (Cera et al. 2012, Jobes et al. 2021). HSPF model data were also used to fill recent discharge values at South Wolf Creek between 2009 and 2020 (Table 3).

NUTRIENT LOAD & TREATMENT EFFICIENCY CALCULATIONS

For project structures and pump inputs to Project components, monthly loads were calculated by summing the daily volume discharged for each individual month in the time series and multiplying by the corresponding monthly concentration of either TN or TP. All subsequent loads for structures are displayed in metric tons (MT) of TN or TP. Annual loading rates referenced are the 12-month calendar-year sum for each structure and nutrient. Average annual loading rates for eastern and western Project structures are displayed in Appendix B and Appendix D, respectively, with important findings highlighted in the Results section.

For SLWMA and SJWMA, TN and TP inputs were calculated on an annual basis by summing the available annual loads through inflow structures and/or pumps in addition to annual atmospheric deposition scaled to the WMA area. Annual TN and TP deposition rates of 0.71 and 0.048 g m^{-2} yr^{-1} were used, respectively, based on median annual observations from 2015-2020 at District monitoring stations at Lake Apopka (J. Di, personal comm.) which was within the range other reported deposition rates in Florida (Table 4). TN and TP outputs were calculated as the sum of available, annual loads through outflow structures. Annual WMA treatment efficiency of TN and TP was thus calculated as follows:

$$Treatment\ Efficiency\ (\%) = \frac{\sum Load\ in - \sum Load\ out}{\sum Load\ in} \times 100$$

where a positive efficiency indicates net removal of nutrients, and a negative efficiency indicates export of nutrients.

Table 3. Information on western tributaries and St. Johns River mainstem data sources used for water quality (WQ) and discharge (Q) in WRTDS model estimates of TN and TP loading. WY = Water Year, beginning May 1. POR = Period of Record.

Segment	**Watershed Area (km^2)**	**Avg. Annual Q (cfs)**	**District WQ Station**	**USGS Gage**	**Q Data Source**	**WRTDS WY POR**	**Notes**
Ft. Drum	178	43	FDCFT + FDC	02231342	USGS	1996-2022	District WQ station changed 11.01.2006
Padgett	60		PADGTT		HSPF	1996-2020	
Blue Cypress	278	106	BCC + BCCR	02231396	USGS	1997-2022	District WQ station changed 12.01.2005
Sixmile	55	13	SCR	02231454	USGS + HSPF	1996-2020	Filled with HSPF data 9.31.2018 – 12.31.2020
S. Wolf	21	13	SWOLF	02231458	USGS + HSPF	1996-2020	Filled with HSPF data 9.30.2009 – 12.31.2020
Tenmile	53	41	TMC		HSPF	1996-2020	
Jane Green	625	181	JGS	02231600	USGS	1996-2022	
River Mainstem	2508	717	SGO	02232000	USGS	1996-2022	

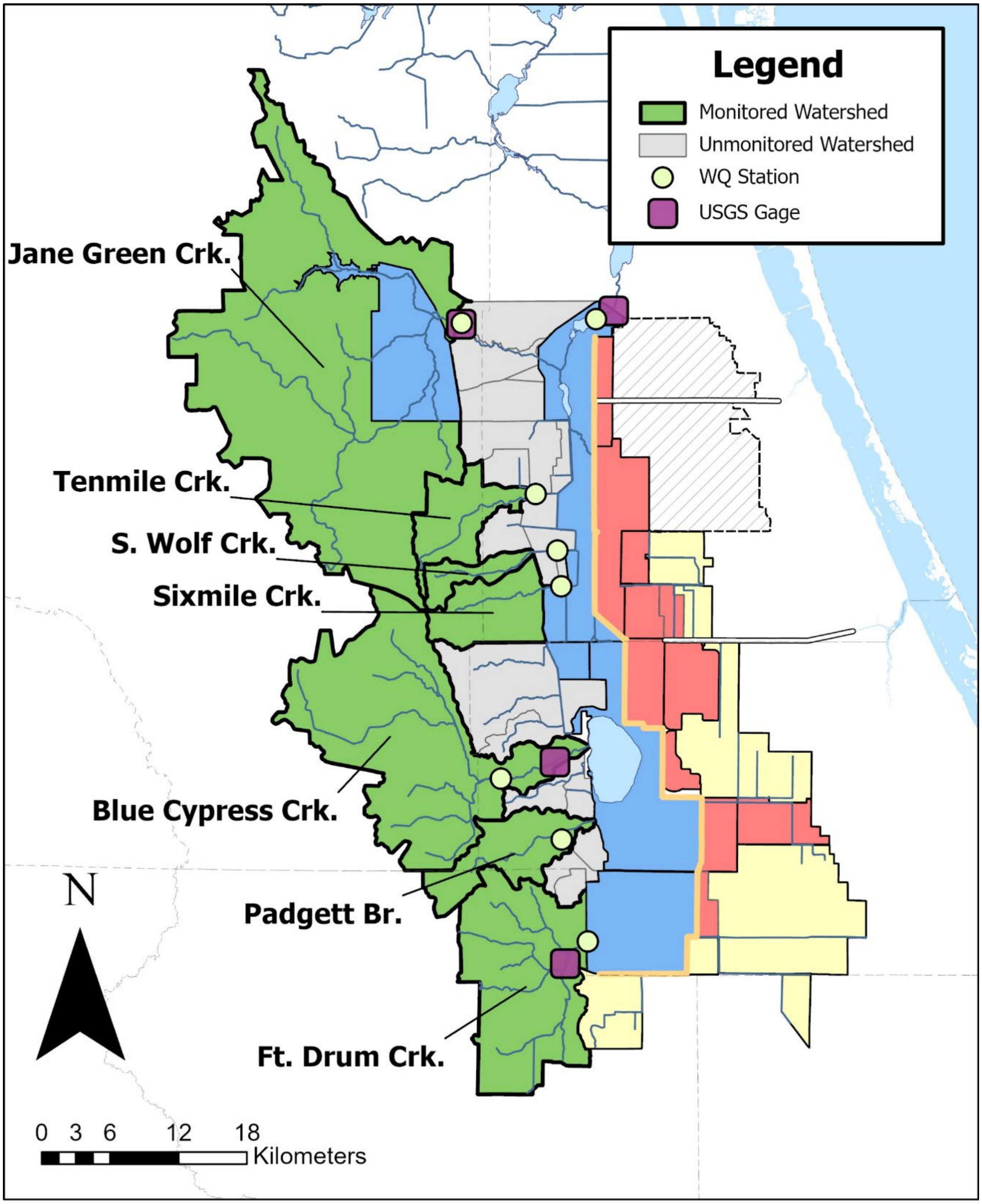

Figure 4. Locations of ambient water quality (WQ) stations and USGS gages in monitored, western tributary watersheds and on the St. Johns River mainstem near the Project outlet.

TRIBUTARY NUTRIENT LOADS & TREND CALCULATIONS

Long-term trends in TP and TN concentrations and loads for western tributaries and the St. Johns River mainstem station at the Sawgrass Lake outlet were analyzed at monitoring sites (Table 3; Fig. 4) using the WRTDS method (Hirsch et al. 2010). Briefly, the annual concentrations and fluxes for each Water Year (WY) starting May 1 were calculated using the EGRET package (v 3.0.9) in the R software environment (Hirsch and De Cicco 2015; R Core Team 2019). While WRTDS model inputs used daily discharge and monthly/bi-monthly nutrient concentration data from WY1996-2022 when available (Table 3), HSPF discharge data were only available through 2020 for certain tributaries. For the JGS CM station, a separate WRTDS model was constructed using daily discharge and daily average Ortho-P concentrations from March 2018-October 2022 to compare modeled concentrations with more frequent observations. The period of record used in this model incorporated more recent data compared to the other tributary models to ensure minimum data requirements were met for the WRTDS method.

Average loading estimates from 2000-2020 are presented for the purposes of this report for relative comparison with Project structures over the same general period of interest. Both annual flux estimates and flow-normalized estimates and trends were calculated and reported for the period of interest. Accounting for year-to-year variability in discharge, trends in flow-normalized estimates are a better indicator of long-term changes in nutrient management within the watershed, while actual annual flux estimates are more relevant to the ecology of receiving waterbodies (Hirsch et al. 2010) as well as the evaluation of meeting TMDL targets on a year-to-year basis. Further discussion on the model specifications and overall application of the WRTDS method to USJRB watersheds can be found in Canion et al. 2022.

SUPPLEMENTARY LAND COVER, VEGETATION, AND HYDROLOGIC DATA

Additional data were gathered for the purposes of interpreting spatial and temporal differences in TN and TP loading throughout the Project and are available as figures and tables in Appendix A. District Land Cover (LC) spatial layers for the USJRB were obtained for the years 1999, 2009, and 2020 to broadly compare different inputs to the Project and USJRB watersheds of interest over time (SJRWMD 1999, 2009, 2020). Detailed LC classifications were aggregated to higher levels to highlight the predominance of the different natural (e.g. wetland, upland) and anthropogenic (e.g. residential, agricultural) inputs in the region. For agricultural lands, we grouped appropriate LCs into four classifications relevant to the USJRB: 1) pasture, 2) row and field crops, 3) tree (including citrus) crops, and 4) all other agriculture.

To supplement LC maps and provide information relevant to nutrient removal within WMAs, results from plant community mapping efforts within the USJRB Project are also presented in Appendix A. While maps were originally generated for the District from aerial imagery obtained in 2001 (baseline), 2008-2010, and 2015-2017 (Sapeta et al. 2018), only the broad plant community "type" classifications for Project areas during the 2015-2017 mapping period are summarized for this report. More recent imagery of plant communities in the Project are available in the District's OpenData Portal (SJRWMD 2022, 2023) but were not within the POR for this report and used different methodology.

As hydrologic conditions greatly influence annual loading rates, monthly and annual rainfall averages are also available in Appendix A. Daily rainfall totals were acquired from the Districts historical NexRad radar database from January 1, 2000 to December 31, 2020 for all pixels included in the Project area of interest south of Sawgrass Lake. While data were accessed using a custom R script, data are also publicly available at the District's Hydrologic data search tool, which combines observed rain gage data with NexRad radar data into a mosaic for any area of interest. Daily rainfall totals for all pixels were first summed and then averaged to monthly and yearly rainfall totals. To supplement radar rainfall data, the areal extent of the nine-month Standard Precipitation Index (SPI) were obtained from the National Integrated Drought Information System (NIDIS 2025) for Brevard, Indian River, and Osceola counties from 2000-2020. This index indicates the percentage of a given area in which observed precipitation deviated from long-term averages, on a scale from exceptional drought to exceptionally wet, over the previous nine months. These data were useful for defining intra and interannual periods of considerable drought within the Project region (e.g. 2000-2001, 2006-2008, 2010-2011). Conversely, certain wetter periods aligned with significant tropical storm activity (e.g. 2004-2005, 2008, 2017); however wet conditions also spanned across calendar years with wetter than average winters (e.g. 2002-2003, 2014-2015, 2015-2016).

Lastly, daily average water elevation data (in feet NAVD88) were acquired for District HDS sites in FDMCA/S-252C (Hydron #01210437), BCMCA/Blue Cypress Lake (Hydron #00540103), and SJMCA (Six Mile—Hydron #18323731, Mulberry Mound—Hydron #00560240, and Big Bend—Hydron #00570250). Elevation data were queried using a custom Hydstra API script within R, but these data are also publicly available at the aforementioned Hydrologic data search tool. For BCMCA and FDMCA, a "Drying Event" index was calculated as the summed area of marsh exposed (in 1000s of hectare-days), using 1) the length of time (in days) when water elevation at was below the Centrical Critical Elevation (CCE) for at least seven consecutive days, and 2) the daily area of exposure using established stage-area curves of the marsh. Further information on how the CCE for each Project MCA are used as EHC to evaluate potential soil oxidation and nutrient release are available in Miller et al. 2022. Due to the significant elevation gradient in SJMCA, an established stage-area curve was not readily available (K. Ponzio, personal comm.) and therefore only the time component of drying events could be calculated.

Table 4. Annual dry and wet TP and TN atmospheric deposition rates relevant to USJRB Project loading calculations.

Location	Ann. Dry rate ($g\ m^{-2}\ yr^{-1}$)	Ann. Wet Rate ($g\ m^{-2}\ yr^{-1}$)	Total Ann. Deposition ($g\ m^{-2}\ yr^{-1}$)	Source	Notes
			TP Deposition		
Lake Apopka, FL	0.028	0.020	0.048	SJRWMD monitoring network	Median of annual values 2015 – 2020; used for this report
Tampa Bay watershed, FL			0.093	Dixon et al. 1996	Mean of 7 stations
N. Everglades Marsh, FL			0.062	Redfield 2002	Mean of 4 stations, originally from Walker 1999 in Table 2
Various sites in S. FL	0.027		0.041	Ahn & James 1999, Ahn & James 2001	Mean of 18 stations 1992 - 1996
Various sites globally			0.036	Redfield 2002	Mean of 17 values in aquatic ecosystems, from Table 3
Various sites in N. America			0.042	Tipping et al. 2014	Mean of 38 sites, from Table 1
			TN Deposition		
Lake Apopka, FL	0.15	0.56	0.71	SJRWMD monitoring network	Median of annual values 2015 – 2020; used for this report
Indian River Lagoon, FL			0.71	USEPA 2023	Mean of annual values 2000 – 2020 from Station IRL141 CASTNET monitoring network
Tampa Bay watershed, FL			0.86	Dixon et al. 1996	Mean of 7 stations
Tampa Bay, FL			0.73	Poor et al. 2001	Mean of 1 station 1996 - 1999
Everglades NP, FL			0.48	Inglett et al. 2011	Conversion of observed DIN rates to estimate bulk TN

RESULTS

EASTERN PROJECT: WATER MANAGEMENT AREAS AND THREE FORKS MARSH CONSERVATION AREA

Nutrient loads entering the eastern Project through the C-52 flow way were calculated using the sum of discharge from three main sources: the S-253 weir, the SJID weir, and S-252D which occasionally discharges from FDMCA. This site receives drainage from agricultural lands prior to any potential treatment by WMAs, and both TN and TP loads were the highest in this region of the Project at an average of 180 MT yr^{-1} and 32 MT yr^{-1}, respectively (Fig. B-1; Fig. B-2). Year-to-year variation was primarily driven by differences in flow, with the lowest loading years corresponding to drought (e.g. 2019) and the highest loading years corresponding to years with high tropical storm activity and flows (e.g. 2017). Similar storm-driven patterns in hydrology and nutrient loading were observed for most Project structures.

Loading calculated downstream at the S-96D structure found an average of 153 MT TN yr^{-1} and 19 MT TP yr^{-1} were loaded into SJWMA, suggesting some treatment occurs within BCWMA (Fig. B-3; Fig. B-4). However, the long-term annual average TN load at the S-96B outlet of SJWMA was higher at 177 MT yr^{-1} while we calculated a 5 MT yr^{-1} decrease between structures' annual average TP loads (Fig. B-7; Fig. B-8). There was again considerable year-to-year variation which also impacted the treatment efficiencies calculated for SJWMA. When accounting for loads from FWMA PS-4 and atmospheric deposition, calculated TN removal ranged from -44 to +34% TN removal and TP removal ranged from -86 to +58% removal (Fig. 5-6; Table C-1; Table C-2), suggesting SJWMA can actually be a net source of both nutrients downstream on an annual time scale. An average annual TN and TP load for S-96, which conveys water from SJWMA to the IRL, was not calculated given infrequent operations (Fig. B-5; Fig. B-6). Instead, loads were largely timed either with significant tropical rainfall events (2004—H. Charley, H. Frances, H. Jeanne; 2008—T.S. Fay; 2017—H. Irma) or releases to evaluate the structure (2014; S. Miller, personal communication).

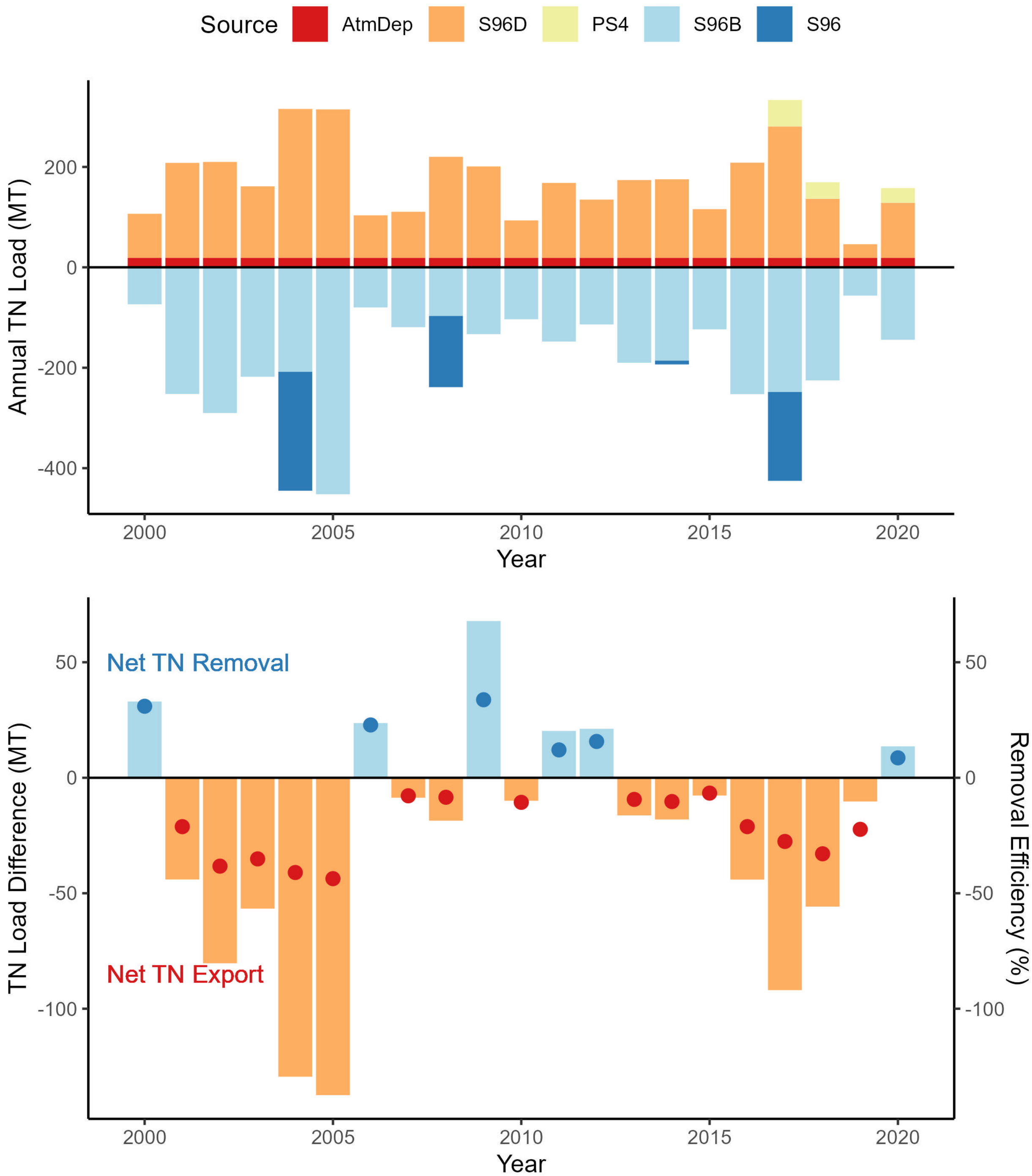

Figure 5. Top: Annual TN loading inputs and exports in SJWMA in MT. Bottom: Calculated difference in annual TN loads (bars) and annual removal efficiencies (points). A positive difference and efficiency indicate net TN removal for the year while a negative difference and efficiency indicates net TN export from SJWMA.

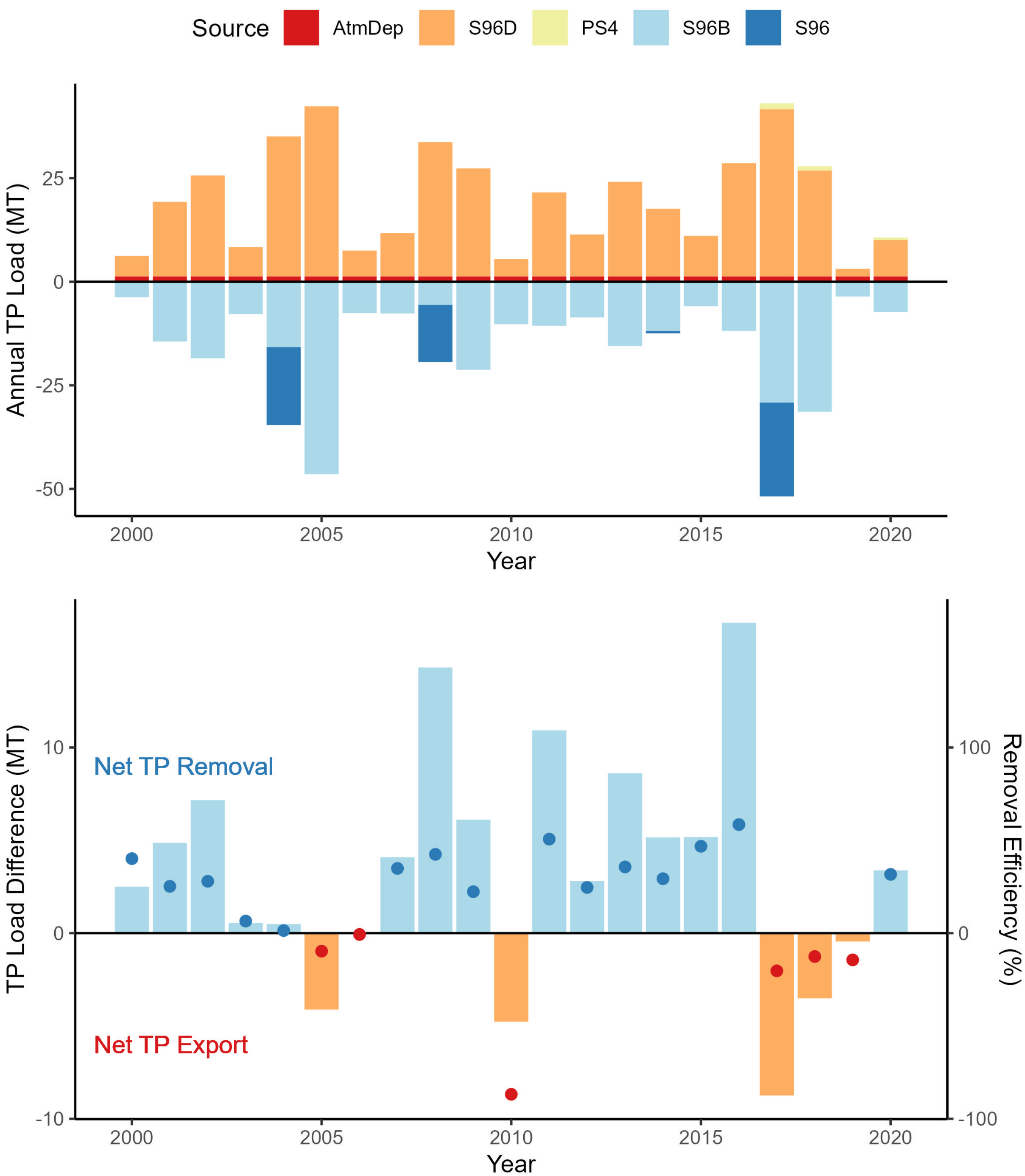

Figure 6. Top: Annual TP loading inputs and exports in SJWMA in MT. Bottom: Calculated difference in annual TP loads (bars) and annual removal efficiencies (points). A positive difference and efficiency indicate net TP removal for the year while a negative difference and efficiency indicates net TP export from SJWMA.

The most significant decreases in TN and TP loading occurred between S-96B and the S-257 weir at the outlet of TFMCA. An average of 30 MT TN yr^{-1} and 0.5 MT TP yr^{-1} were calculated for the structure (Fig. B-9; Fig. B-10), a respective 83% and 98% decrease in loads compared to calculations at the C-52 flow way despite additional external inputs throughout the flow path. Importantly, no discharge over S-257 weir was observed until 2016 after TFMCA had sufficiently filled. Similar average annual loading rates (40 MT TN yr^{-1} and 0.75 MT TP yr^{-1}) were also found at S-262 (Fig. B-11; Fig. B-12) which contributes nutrients to the St. Johns River from SLWMA treating inputs from the C-1 basin. Unlike SJWMA, annual treatment efficiencies for SLWMA were consistently positive with TP removal ranging from +51-92% and an average of 4.5 MT yr^{-1} TP removed when accounting for both surface and atmospheric inputs. TN removal efficiencies for SLWMA were lower but still positive for every year ranging from +5 to +37% (Fig. 7-8; Table C-3; Table C-4).

WESTERN PROJECT: FORT DRUM, BLUE CYPRESS, AND ST. JOHNS MARSH CONSERVATION AREAS

A combined load for S-252A, S-252B, and S-252C structures was calculated from 2010-2020 given insufficient data for the remaining period of interest. Additionally, a single water quality monitoring station at the S-252C structure was used for nutrient data that covered the entire period of interest. Comparisons to monthly water quality data recently collected at S-252B suggests some variation in TN and TP concentrations are observed at the three S-252 series structures linking FDMCA with BCMCA (unpublished data); however, monitoring at S-252B only began in 2022. While we assumed loading was largely driven by variability in structure discharge compared to the observed variability in nutrient concentrations, average TP concentrations observed at S-252C (FDMCAO) increased significantly beginning in 2017 (Fig. D-2). Under these assumptions, we calculated an annual average of 78.5 MT TN yr^{-1} and 10 MT TP yr^{-1} through the combined S-252A, B and C structures (Fig D-1; Fig. D-2).

Additional loading occurred via S-252F when culverts opened and discharges were made into the flow way that drains into BCMCA west of S-252A. No discharges were observed at this structure from 2000-2003 or in 2006. Given different source waters than the S-252A, B, and C structures, we used imputed monthly water quality over the period of interest (2000-2020) based on average monthly water quality observed since monitoring at the structure began in 2022. Under these assumptions, we calculated a modest annual TN and TP load to BCMCA from S-252F (18 MT yr^{-1} TN and 1 MT yr^{-1} TP) with higher-than-average loading years from 2017-2019 due to more frequent discharges (Fig. D-3; Fig. D-4).

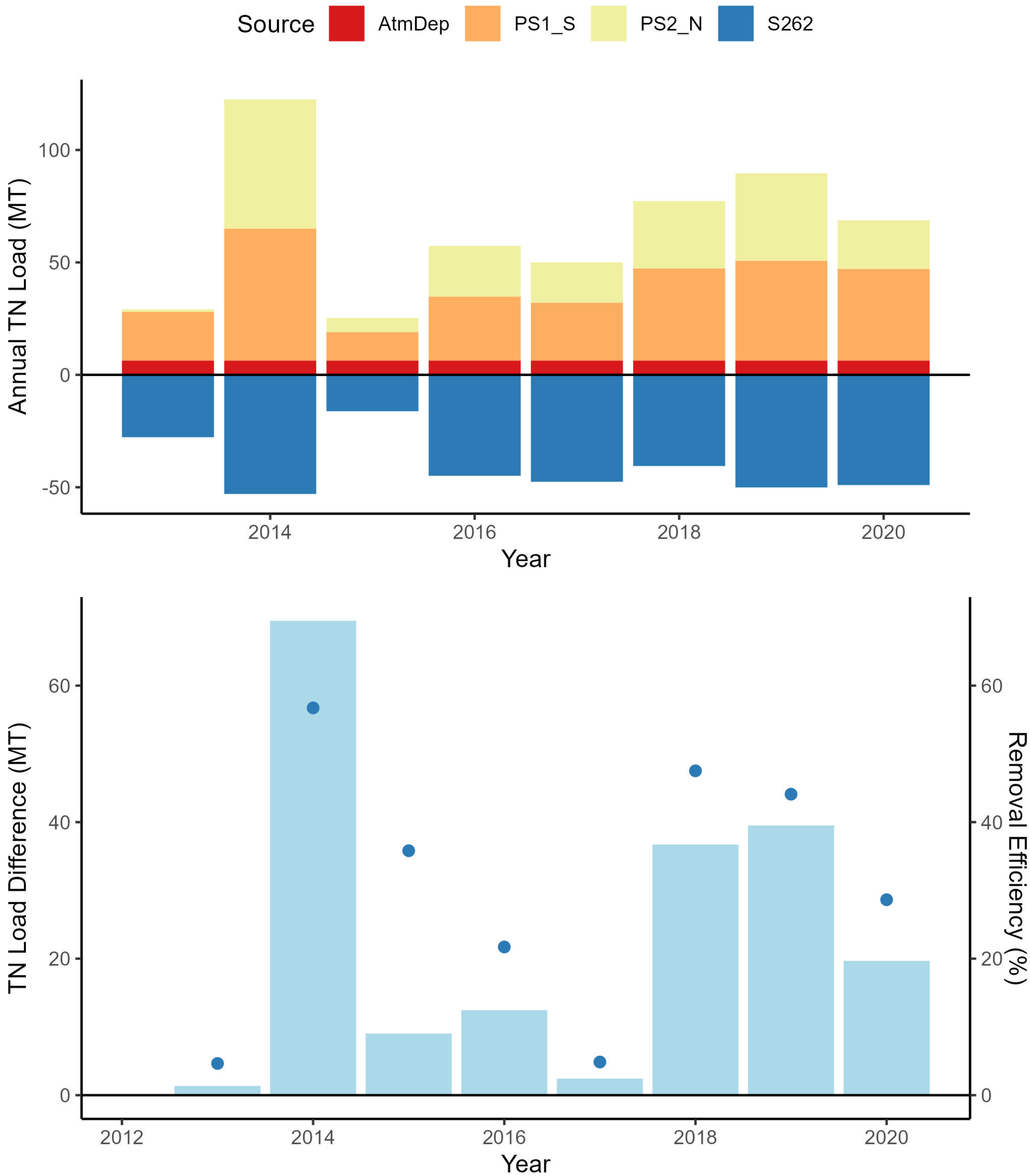

Figure 7. Top: Annual TN loading inputs and exports in SLWMA in MT. Bottom: Calculated difference in annual TN loads (bars) and annual removal efficiencies (points). A positive difference and efficiency indicate net TN removal for the year from SLWMA.

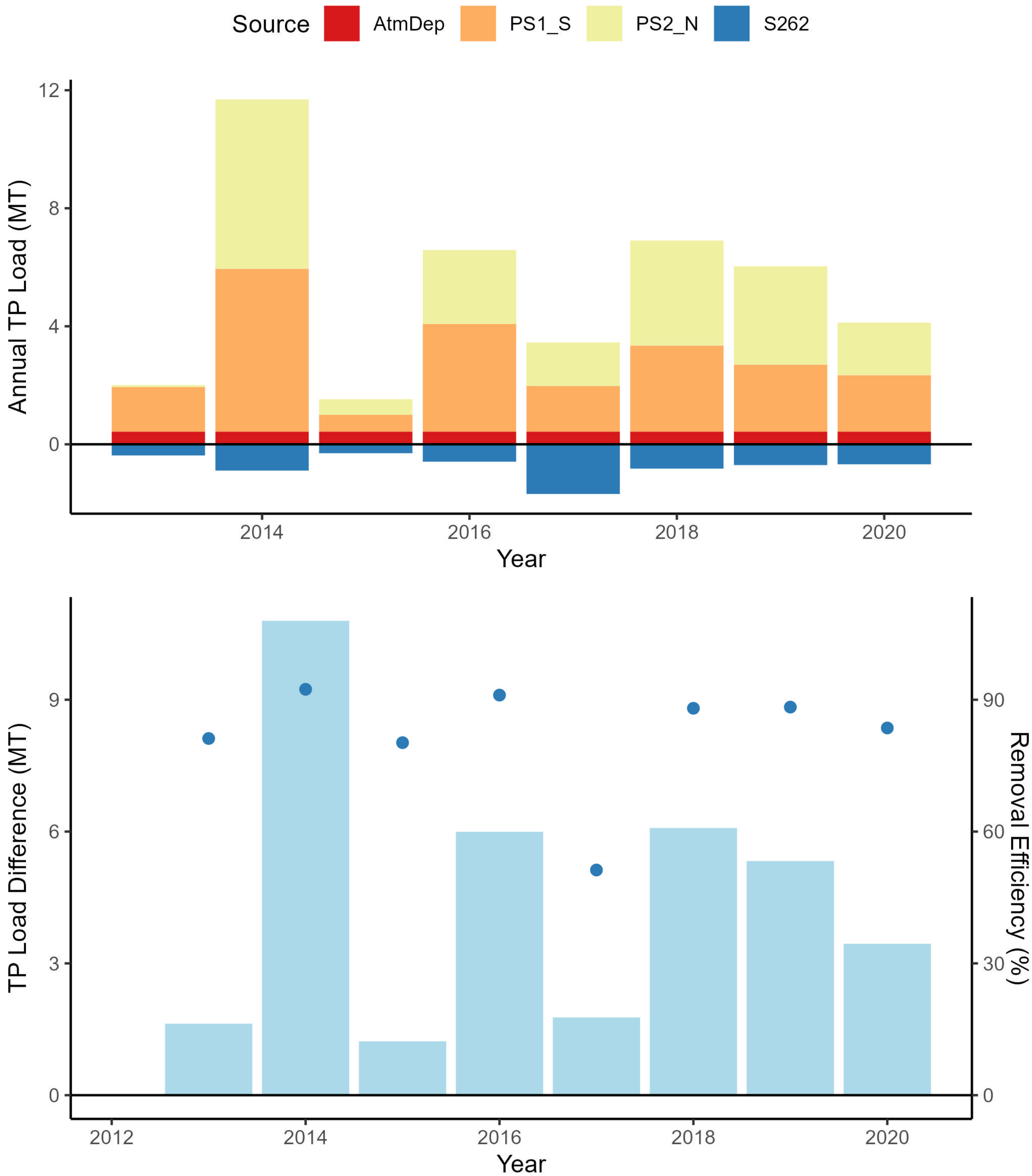

Figure 8. Top: Annual TP loading inputs and exports in SLWMA in MT. Bottom: Calculated difference in annual TP loads (bars) and annual removal efficiencies (points). A positive difference and efficiency indicate net TP removal for the year.

North of BCMCA, nutrient loading at the S-96C structure showed different patterns prior to 2012, as consistent TN and TP loads corresponded with a period of consistent environmental discharges (~30 cfs) from the structure (Fig. G-1; Fig. G-2). These discharges could help explain higher-than-average annual TN loads between 2000 and 2005, although TN loading rates otherwise appeared to closely follow year-to-year variation in regional climate similar to other structures (Fig. D-5). Since operational changes in 2012, discharge and associated nutrient loads were not observed in most dry-season months (approximately November to May). However, similar to the S-252 structures, more recent annual TP loads calculated for S-96C (Fig. D-6) appear to also be driven in part by a significant increase in TP concentrations at the nearby monitoring site (BCMCU). In particular, 2017 had a significant calculated TP load of 64 MT despite similar overall discharge volumes to 2005 (26 MT), due to a doubling in average TP concentrations (0.10 mg L^{-1} in 2005 and 0.22 mg L^{-1} in 2017). As there was no structure-specific monitoring at the S-250 structures with available discharge data, the same BCMCU water quality station was used for calculating TN and TP loads for S-250B and S-250C (Fig. D-7; Fig. D-8). Interestingly, similar trends were not found for TP loads at these structures, although average loading rates were typically an order of magnitude lower than S-96C given significant differences in flow (57 MT TN yr^{-1} and 6 MT TP yr^{-1}). For S-250E draining Kenansville Lake into SJMCA, calculated discharges over the weir were highly variable leading to highly variable TN and TP loads. No discharges were observed in 2007, immediately following construction of the weir, and calculations did not include discharges through the secondary culvert structures as they are generally closed (Miller et al. 2022). Most years had annual TN and TP loads below the average (approximately 81 MT yr^{-1} and 6 MT yr^{-1}, respectively) with the exception of 2017 and 2020 which were the only years with calculated, annual discharges >100 MCM (Fig. D-9; Fig. D-10).

WESTERN TRIBUTARIES AND PROJECT OUTLET

For all monitored western tributary calculations, annual flow-normalized loads when averaged over the WY2000-2020 period were similar to the true-condition loads when also averaged over that same period (Table 5-6). Therefore, results presented herein focus on flow-normalized estimates unless otherwise noted such as when discussing specific TMDL loading targets. Across all tributary models, the flux bias statistic (an indicator approimxating model fit) was between -0.065–0.021 for TN and -0.122–0.064 for TP (Appendix H). A flux bias statistic close to 0 indicates the model is nearly unbiased, and values between -0.1 and 0.1 indicate less than 10% bias in the long-term mean flux (Hirsch and De Cicco, 2015). Only for the Ft. Drum Creek (FDC) TP model was the flux bias statistic outside of these bounds.

Table 5. Average annual TN loads and flow-normalized (FN) loads for western tributaries over the full period of record (POR) and 2016-2020.

Tributary	**Load To**	**Actual Load; Full POR ($MT\ yr^{-1}$)**	**FN Load; Full POR ($MT\ yr^{-1}$)**	**Actual Load; 2016-2020 ($MT\ yr^{-1}$)**	**FN Load; 2016-2020 ($MT\ yr^{-1}$)**
Ft. Drum	FDMCA	58	59	66	68
Padgett	Blue Cypress Lk.	23	25	22	23
Blue Cypress	Blue Cypress Lk.	122	124	150	127
Sixmile	SJMCA	17	16	22	17
S. Wolf	SJMCA	20	21	23	22
Tenmile	SJMCA	60	57	68	60
Jane Green	River above Sawgrass Lk.	226	220	224	230

In the southwestern USJRB, three main creeks discharge into the Blue Cypress and Ft. Drum MCAs. Based on the observed USGS and modeled HSPF flows, a greater load to Blue Cypress Lake comes from Blue Cypress Creek compared to Padgett Branch due to a larger watershed area and more significant discharge from the former. Thus, despite similar average concentrations at tributary monitoring sites, the average annual TN and TP flow-normalized loads from Blue Cypress Creek was 128 MT yr^{-1} and 18 MT yr^{-1}, respectively. This is compared to the average 25 MT yr^{-1} TN and 3 MT yr^{-1} TP modeled for Padgett Branch. For Ft. Drum Creek, average annual flow-normalized loads into FDMCA were 60 MT yr^{-1} TN and 10 MT yr^{-1} TP, and again, similar averages were found for true-condition loads (Tables 5-6).

Table 6. Average annual TP loads and flow-normalized (FN) loads for western tributaries over the full period of record (POR) and 2016-2020.

Tributary	**Load To**	**Actual Load; Full POR ($MT\ yr^{-1}$)**	**FN Load; Full POR ($MT\ yr^{-1}$)**	**Actual Load; 2016-2020 ($MT\ yr^{-1}$)**	**FN Load; 2016-2020 ($MT\ yr^{-1}$)**
Ft. Drum	FDMCA	10	10	11	12
Padgett	Blue Cypress Lk.	3	3	3	3
Blue Cypress	Blue Cypress Lk.	17	17	21	17
Sixmile	SJMCA	3	3	5	4
S. Wolf	SJMCA	2	2	3	3
Tenmile	SJMCA	13	12	28	24
Jane Green	River above Sawgrass Lk.	33	32	45	46

The three monitored watersheds loading to the Project near SJMCA are Tenmile, South Wolf, and Sixmile Creeks. Collectively, a combined average of 94 MT yr^{-1} TN and 19 MT yr^{-1} TP were loaded to the Project from these tributaries, with the majority of this load coming from Tenmile Creek. The differences in load estimations are driven by an increasing trend in TP concentration, as seen in Canion et al. 2022, as well as significantly higher modeled discharge from Tenmile Creek despite similar watershed area compared to the other nearby tributaries (Table 3).

At 625 km^2 the Jane Green Creek watershed comprises the single largest catchment area within the USJRB and drains directly to the St. Johns River mainstem between Lake Hellen Blazes and Sawgrass Lake. As expected, estimated average loading over the period of interest (226 MT TN yr^{-1} and 33 MT TP yr^{-1}) was the highest of all monitored western tributaries. Results from the WRTDS model fit to the CM data at the JGS station also suggest that the approach could accurately predict observed OrthoP (PO_4) values and therefore predict loading estimates (Fig. 9). These results also highlighted that significant increases in loading were tied to storm events that drove increases in flow.

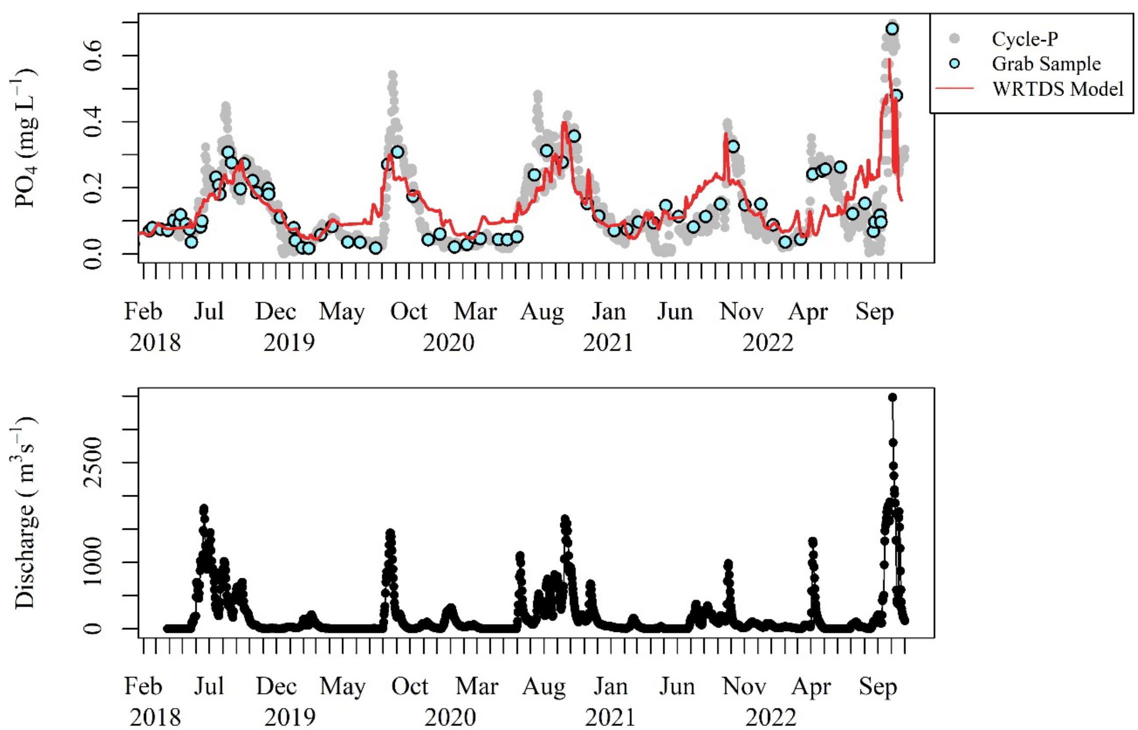

Figure 9. *Top*: Daily PO_4 concentration (mg L^{-1}) results from the JGS WRTDS model compared to grab sample and Cycle-P concentrations at the JGS monitoring station; *Bottom*: Daily average discharge (m^3 s^{-1}) at the Jane Green USGS gage.

A WRTDS model was fit for both TN and TP at the Sawgrass Lake outlet corresponding with the USGS gage at US-192, a location considered to be the integrator of the combined nutrient sources from the Project and contributing watersheds upstream. It is also near an established TMDL for the river segment above Sawgrass Lake (WBID 2893X). Results of true-estimate loading show that since the TMDL was established in 2006, TP loads did not meet the nearby target of 57 MT TP yr^{-1} in 12 of the 15 subsequent WYs (Fig. 10). Furthermore, the WRTDS modelled loads show an increasing trend in flow-normalized loads of TP suggesting a lack of progress in TP reductions watershed-wide. Flow-normalized TN loads, however, did not show a significant trend over time (Fig. H-15). Using, similar assumptions to the PLRG, we also calculated the true-condition nutrient loads to Lake Hellen Blazes, another TMDL waterbody (WBID 2893Q) by subtracting the annual loads from Jane Green Creek from the Sawgrass outlet load. Similarly, true-condition TP loads did not meet the TMDL target for the lake (44 MT yr^{-1}) in 10 of the WYs since 2006.

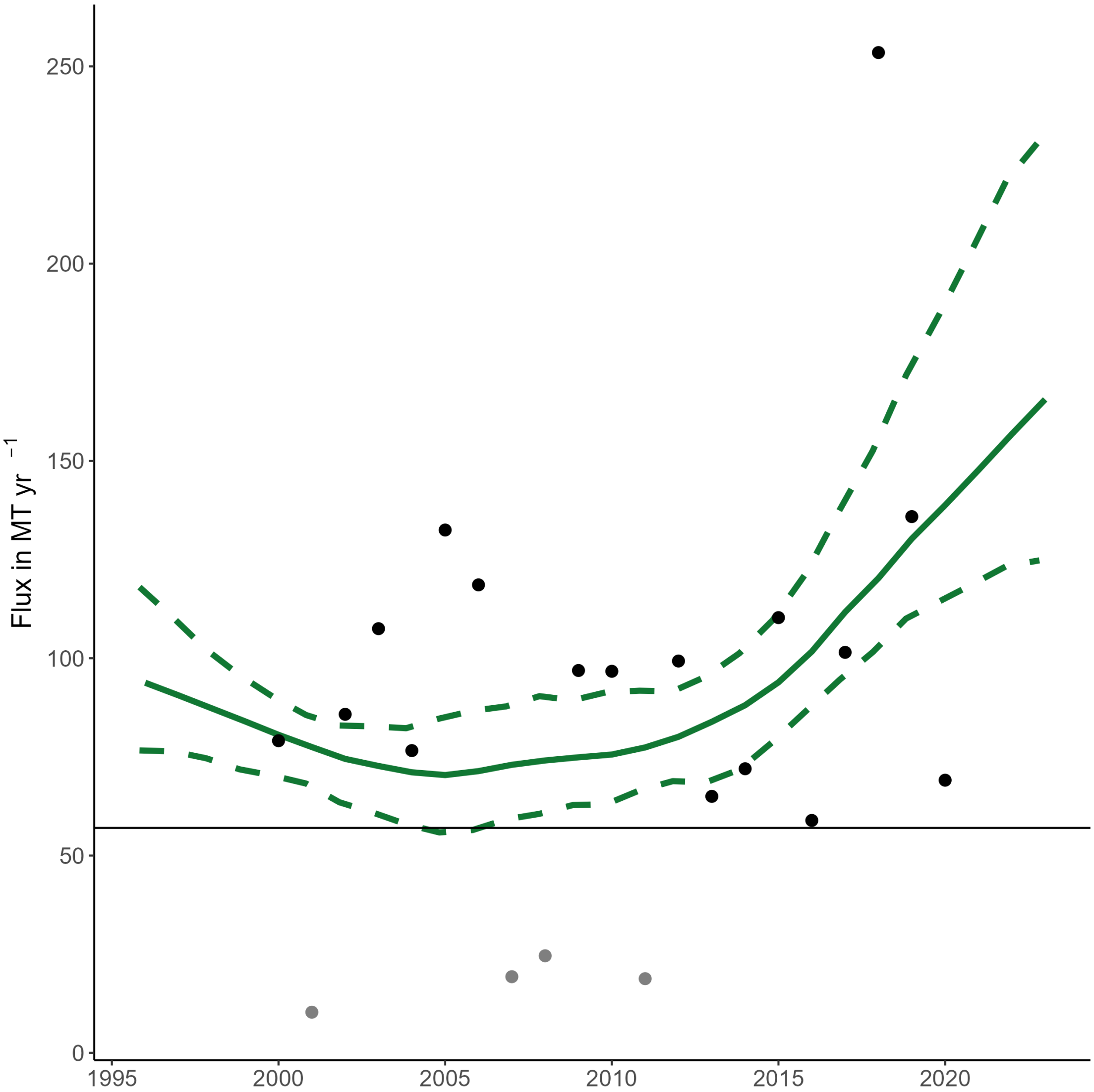

Figure 10. Results of TP WRTDS model for the St. Johns River Mainstem at Sawgrass Lake Outlet. Points represent estimated TP load for each WY between 2000-2020 with gray points meeting the 57 MT yr^{-1} TMDL and black points exceeding it. The green line is the FN TP flux from WY1996-2022 with green dashed lines representing the 95% confidence interval based on 100 bootstrap replicates.

DISCUSSION

EASTERN PROJECT TREATMENT EFFICIENCY

Improving water quality in the region is an explicit goal of the Project, with the intent to treat water contributed from surrounding agricultural lands before discharge to the St. Johns River and concurrently reduce freshwater flows and nutrient loads to the IRL. Initially, attention was on establishing and operating the WMAs on former agricultural lands to treat inputs from the remaining adjacent citrus farms. Similarly, SLWMA was specifically constructed to treat water received from the C-1 canal and its surrounding catchment and reduce any additional inputs to the IRL in anticipation of future development. On a broad spatial scale, District water quality monitoring in these eastern Project components shows a clear decrease in TP concentrations and mass loaded as water moves from BCWMA to TFMCA. This suggests the “treatment train” of water moving through these areas are largely effective at reducing P, and N to a somewhat lesser extent, before reaching the confluence with the C-40 canal near the river channel.

Between structures S96-D and S96-B, SJWMA reduced TP loads most years. The worst performing year for TP removal on a mass-basis in SJWMA was 2010, a significant drought year for the USJRB where water movement between Project components was limited. Interestingly, despite drought conditions deepening in early 2011, SJWMA we calculated net TP removal for the year. Conversely, the worst performing year on a mass load basis was a significantly wet year in 2017 when approximately 22 MT TP was diverted towards the IRL via S-96, largely in response to Hurricane Irma. TP concentrations within SJWMA remained elevated following Irma, which may have decreased removal performance in subsequent years. However, despite significant releases from S-96 in 2004 due elevated hurricane activity, we calculated net removal of TP from SJWMA although performance decreased. SJWMA was also a net exporter of TP in the following year when TP concentrations also remained elevated in 2005 during an active hurricane season without significant releases to S-96. Overall, direct releases to the IRL are rarer in recent years due to the increased water storage within the Project and recognition of the negative impact such releases have on the IRL ecosystem. These results still highlight that SJWMA generally functions to remove TP inputs except in some years with abnormal hydrologic conditions and/or elevated concentrations.

Within the Eastern Project, the largest decrease in concentrations and mass loaded for TP occurred within TFMCA, where an average of only 0.5 MT TP per year is loaded to the mainstem confluence with the C-40 canal. Furthermore, most TP leaving TFMCA does appear to be in particulate form likely due to the increased biological uptake and turnover within the 13,5000-acre, vegetated marsh (Appendix E). While WMAs generally function as shallow, open water reservoirs, mechanisms of P removal likely depend on the characteristics of the inputs and the receiving WMA. For example, less TP is likely removed through direct settling of particles in BCWMA and, by extension, SJWMA as most of the incoming load from agricultural operations via the C-52 flow way is in dissolved and/or reactive P forms. Rather, by increasing residence time, dissolved inorganic (and potentially organic) P may be removed through mechanisms such as water column uptake or sediment sorption. However, specific mechanisms of P removal have not been studied in detail within the USJRB Project WMAs. Over the years reported, removal processes help store an average 3.4 MT TP yr-1 within SJWMA when also accounting for atmospheric inputs and releases to the IRL.

Project WMAs also differ regarding the amount of vegetative coverage, which may further impact the degree of P removal. For example, SJWMA is largely open water while SLWMA, TFMCA, BCWMA, and FWMA are predominantly covered by herbaceous marsh (Table A-2). Significant submerged aquatic vegetation (SAV) loss, primarily hydrilla (*Hydrilla verticillata*), was observed in SJWMA following multiple hurricanes in 2004 (Johnson et al. 2014), and the District has assisted with recent initiatives to re-vegetate this WMA for fish habitat and water quality benefits. In addition to smaller loading rates, this may explain why the more vegetated SLWMA removed TP more efficiently compared to SJWMA. Indeed, as previously mentioned, observed increases in annual average TP concentrations at SJWMA monitoring stations tend to follow significant wet years (Fig. B-4; Fig. B-6; Fig. B-8) where inputs may exceed the storage capacity with limited biological uptake and residence times for burial. The WMAs such as SJWMA do experience occasional phytoplankton blooms, often dominated by cyanobacteria in summer months. However, phytoplankton biomass and associated nutrients are prone to recycling within the water-column and nutrients may not be sequestered long-term. Furthermore, we could not associate high loading years with subsequent bloom observations as a period of routine phytoplankton monitoring did not overlap with our loading calculations.

Similar to TP, a general decrease in TN loads was observed in TFMCA, with an average load of 30 MT TN per year at S-257. Additionally, most of the TN exported was not in the form of bioavailable DIN. Considering most TN entering WMAs is already in the particulate or dissolved, organic fractions, biological uptake and burial or permanent removal via microbial nitrification-denitrification processes may be limited by low DIN concentrations and instead rely on internal N transformations. Periods of increased water residence times may allow for organic N that is not immediately bioavailable to be re-mineralized, and the additional treatment time in TFMCA likely allows for this recycling of N to reduce TN loads more consistently compared to upstream WMAs. When accounting for all external inputs (i.e. surface inputs and atmospheric deposition) on an annual basis, SJWMA was found to often be a net exporter of TN in 15 of the years removal efficiencies were calculated. Furthermore, the direction and magnitude of TN removal or export did not appear to correlate with years of TP removal or export, suggesting different controls on both nutrients. For comparison, SLWMA had a range of TN treatment efficiencies closer to recently published data for Everglades STAs which found overall TN removal rates of 38%, although STA calculations only accounted for surface water inputs and outputs and not atmospheric deposition (Chimney 2017). Potential internal inputs from biological N_2 fixation, senescence of vegetation, or diffusive fluxes from sediment mineralization may add additional N and contribute to overall low TN removal rates for WMAs.

While most of the WMAs, as shallow reservoirs with varying coverage of marsh vegetation, are intended to sequester nutrients largely through increasing water residence time to assist both biotic and abiotic nutrient removal, it is important to continue monitoring these areas as the sources and forms of nutrients may change with changes in land use or any related changes to hydrology. Additional attention should be given to the internal nutrient dynamics of these Project components to better understand how other factors such as vegetation coverage and sediment biogeochemistry may influence nutrient removal. Changes in structure operations to increase water residence times for treatment in WMAs will be complicated by the multiple uses of WMAs for flood protection, water supply, recreation, and protected species habitat. For example, high structure loading years naturally correspond with wetter years that generally require water movement downstream in anticipation of or in response to significant tropical storm activity. But as discussed, these years are not always considered “low performance” years for TP removal. As shown by consistently positive TN and TP retention in SLWMA, and significant load reductions from TFMCA, efforts to maintain and improve coverage of emergent and submerged aquatic vegetation across the WMAs could further lower concentrations in discharges.

Future updates to nutrient loading calculations in the eastern USJRB Project will likely need to consider additional re-diversions from the IRL watershed. Our estimates in this report do include the diverted flow from the C-1 basin through SLWMA when pumps were operational. Additional projects in that basin which are expected to further reduce TN and TP loading to the IRL (e.g. C-10 WMA) could conversely add an associated load to the USJRB Project. However, we expect based on estimated flows relative to the overall flows at the Project outlet that such projects will not contribute significantly to the overall Project TN and TP loads. For example, the Crane Creek/M-1 Canal project estimates annual loadings of 24,000 lbs TN yr^{-1} (=11 MT TN yr^{-1}) and 3,100 lbs TP yr^{-1} (=1.4 MT TP yr^{-1}) will be reduced from the IRL. Even if we assume no treatment within the receiving STA before loading to the USJRB watershed, that accounts for only 1.1% and 1.7% of the average annual TN and TP loads we reported at US-192. Continued monitoring of these projects will ensure that the benefits of re-diversions do not inadvertently contribute to water quality degradation in the USJRB, particularly given continued urban development in this part of the basin. Historically, land use within the eastern Project area was dominated by tree crops but has also recently shifted towards row crops and other forms of agriculture (Fig. A-1). Citrus production in Florida has been on a long-term decline due to losses from crop damage from extreme weather events (e.g. freezes, hurricanes), diseases such as “citrus greening”, and pressure for land for residential development (Ferrarezi et al. 2020).

WESTERN MARSHES AND BLUE CYPRESS LAKE

As land use trends in the USJRB have shifted away from citrus in eastern watersheds, the relative importance of nutrient inputs to the basin has also shifted to these western watersheds. Annual TN and TP loads from western MCA structures total 77% of the total TN load and 94% of the total TP load when combined with eastern WMA structures at the C-40 confluence. While the MCAs in the Western Project area were not intended to treat external inputs, these marsh areas are assumed to store significant nutrients in their vegetation and accretion of organic soils. Given the complexity of water movement and potential nutrient sources to and within MCAs, we could not directly calculate the mass of nutrients stored in the marshes. However, by combining the loading at the two creeks loading Blue Cypress Lake with the S-252 series structures, we can estimate approximately 250 MT TN and 32 MT TP are loaded per year to BCMCA through these surface inputs. This is compared to the 244 MT TN and 27 MT TP estimated to leave via S-96C and S-250 series per year on the north end of BCMCA. Presumably, this suggests only minor treatment of external nutrient inputs in BCMCA.

Previous work in USJRB marshes suggested soils should be flooded at least 60% of the year to prevent loss from soil oxidation (Reddy et al. 2006; Miller et al. 2022) leading to recognition by District scientists that extensive drying of marsh soils during periods of drought can lead to soil oxidation and subsidence and a net export of organic matter and associated nutrients downstream when marsh soils are reflooded. Previous work on sediment flux in BCMCA has also shown that while P-enriched soils can quickly release P after simulated subsidence and subsequent reflooding (Bostic and White 2007), bulk P content alone does not explain the rate of release (Reddy et al. 2007). The most recent evaluation of environmental hydrologic criteria (EHC) to maintain no net loss of organic soils suggests that water levels in FDMCA are actually meeting the stated criteria; however, BCMCA is not meeting targets for inundation frequency or seasonal flooding (Miller et al. 2022). While alterations to S-96C releases may have reduced magnitude and duration of severe dying events in BCMCA, the marsh has still experienced extensive drying events recently and thus soil oxidation remains a concern (Fig. A-5). Indeed, increasing TP concentrations leaving Blue Cypress Lake (Fig. D-6) suggest additional internal sources (e.g. sediment flux) or perhaps unaccounted for inputs from the surrounding marsh may be contributing additional nutrients as TP concentrations in the main tributary inputs (i.e. Blue Cypress Creek and Padgett Branch) are not increasing over the same period (Fig. H-2; Fig. H-8). Earlier investigations into Blue Cypress Lake sediments found increased N and P accumulation since the 1970s, although nutrient fluxes into the water column were not measured (Brenner et al. 2001). The potential for these internal sources to contribute to eutrophication of the lake is further underscored by notable HAB-events dominated by cyanobacteria (e.g. *Microcystis* spp.) in recent years.

The increase in Blue Cypress Lake TP concentrations also appears partially responsible for a noticeable increase in TP loads at S-96C during recent wet years (e.g. >60 MT in 2017) despite similar discharge volumes in previous years (Fig. D-6). Despite less severe drying events in FDMCA (Fig. A-4), similar patterns were shown at the S-252 structures between FDMCA and BCMCA. In particular, recent increases in TP concentrations combined with significant discharges following Hurricane Irma in 2017 led to proportionally greater increases in TP loads compared to previous wetter years. Importantly, while 2017 was a wetter than average year (Fig. A-2; Fig. A-3), rainfall prior to Hurricane Irma was also at a significant deficit. Future alterations to the regulation schedule of MCAs which result in higher allowable stages during the wet season could help dampen pulses of nutrients released from the western Project in anticipation of or in response to larger storm events. Further, higher stages would theoretically reduce the areal flux of nutrients when marsh soils are reflooded if a greater extent of organic soils remains anoxic.

Extensive work on nutrient accretion in sediments in both BCMCA and SJMCA have shown trends in increased P enrichment in both marshes (Brenner et al. 2001). In the case of SJMCA, substantial differences in soil elevation moving south to north have caused the southern SJMCA to be the most severely over-drained section of the marsh. While we could not calculate the areal extent of drying events, stages throughout SJWMA have frequently dropped below the CCEs (Fig. A-6). Like BCMCA, SJMCA is broadly not meeting EHCs set to maintain its organic soils. Extensive perimeter levees and canals, some dating back to the 1940s, and regulated discharges upstream are reported to have caused an average of 1.1 feet of soil oxidation and subsidence between 2000 and 2014, a trend which has likely continued despite encroachment of woody vegetation (Miller et al. 2022). As water levels in SJWMA are not regulated by any additional structures, we could not calculate nutrient export any further north within the western Project marshes. Regardless, any nutrients exported from SJMCA are eventually loaded downstream TMDL waterbodies. Therefore, the relative roles of marsh export compared to other external sources remains an important question for USJRB nutrient budgets, in addition to legacy TP in lake sediments that is recycled internally.

THE IMPACT OF BIOSOLIDS IN THE USJRB

Accounting for nutrient loads in the Western Project is also complicated by inputs from western tributaries as the southernmost tributaries (Ft. Drum, Padgett, and Blue Cypress Creeks) flow directly into Blue Cypress Lake or surrounding MCAs while others (Sixmile, S. Wolf, and Tenmile Creeks) flow into the perimeter canals around SJMCA. These canals around SJMCA are not completely bound by levees on the SJMCA border, and where nutrients are transported to from these tributaries remains an open question. During periods of high flow and high nutrient loading, tributaries may contribute to the marsh or canal flow may bypass the marsh entirely and load to the river channel. Nutrient loads from the three tributaries of Sixmile, South Wolf, and Tenmile Creeks are also not static. Although we reported a single annual, average TN and TP flux for tributaries for the purposes of this report, previously published WRTDS models suggest a significant, recent increase in flow-normalized TP concentrations and fluxes (Canion et al. 2022).

Using similar data inputs as this report, these significant increases in TP flux from western watersheds are correlated with the recent increase in land-applications of Class B biosolids in the USJRB (Canion et al. 2022). In 2020, an estimated 78% of Class B biosolids produced in the state were transported to application sites in the District, with the majority of those applications being within the western USJRB based on available permitting data (V. Hoge, personal comm.). This concentration of land-application in the USJRB can largely be attributed to legislation that requires no net P exports at application sites in the Lake Okeechobee, St. Lucie River, and Caloosahatchee River watersheds (§373-4595, F.S.), which effectively banned Class B biosolids applications in most of south Florida. While the use of biosolids material as an N and P source may be more desirable compared to inorganic fertilizers, of particular concern is the application of P at rates beyond crop demand and potential for P mobilization and leaching. This is largely due to the low N:P ratios of Class B biosolids materials (~2.5:1) and historical application rates to meet plant N without accounting for P saturation in the soils (Torri et al. 2017; Canion et al. 2022). Such practices, in addition to the potential for denitrification to remove N to the atmosphere, help explain greater observed increases in TP loading compared to TN for western USJRB watersheds with biosolids application. Indeed, most P in focal tributaries remained in dissolved, reactive forms compared to most N found in dissolved, organic forms (Fig. E-10; Fig. E-12). High color conditions within these tributaries, a function of additional wetland and upland forest coverage in their watersheds, also likely limits within-creek primary productivity that would otherwise utilize and sequester reactive P. Previous work in other phosphorus-impacted watersheds has shown tributary streambeds are rarely at equilibrium and often act as P sinks but may counterintuitively become P sources depending on in-field conditions, streamflow, and overlying water column concentrations (Simpson et al. 2021; Kreiling et al. 2023). The net result is the delivery of highly bioavailable P to downstream waterbodies. Site-specific biogeochemical properties also dictate this balance of sediment sorption or release, and it remains unclear to what extent the system of canals and headwater streams in the western USJRB buffer nutrient delivery to waterbodies already impaired for excess nutrients.

Amendments to the rules for the land-application of Class B biosolids were legislatively ratified and became effective in 2021, including changes to the calculation of both N-based and P-based application rates for new permits, which ultimately require application based on the most restrictive nutrient (Chapter 62-640, F.A.C. 2021). Given the recency of these rule changes, lag-time in permitting and implementation, and the multiple factors that govern the mobilization of both newly applied P and legacy soil P in the landscape (Sharpley et al. 2013), it is too soon to make any conclusions regarding their impact nutrient loading in the USJRB. Continued monitoring of these impacted tributaries is therefore necessary for any future evaluation of these revised practices.

LOADING TO DOWNSTREAM RIVER-LAKES AND THE MSJRB

An important consideration for nutrient loading in the Project is ultimately the contribution of nutrients from the Project outlet to downstream TMDL waterbodies. Within the Project, Florida DEP codified significant TP reduction targets for two waterbodies, Lake Hellen Blazes and the St. Johns River above Sawgrass Lake, with 32 and 52% TP load reductions proposed, respectively (Gao 2006). Our estimates of annual loading at Sawgrass Lake and Lake Hellen Blazes suggest that since then, TMDL targets are not being met most years. Furthermore, given upwards trends in flow-normalized TP loads, any progress in nutrient reductions within the eastern Project are likely offset by increases in loading from the western watersheds.

Based on our loading calculations at the Sawgrass Lake outlet and Jane Green Creek, there is also considerable year-to-year variation in dominant upstream source of nutrients. By simply subtracting loading from Jane Green from the Sawgrass outlet load, on average, approximately 62% (28-83%) of the TP loaded from the Project originates from the St. Johns River upstream of Lake Hellen Blazes while the remaining 38% (17-62%) is from the Jane Green watershed alone (Table 8). Less variation was shown in TN with the majority of TN loading coming from upstream Lake Hellen Blazes compared to Jane Green in all years calculated (Table 7). It is important to note that these estimates are based on modeled loads with inherent limitations due to gaps in available monitoring data and other assumptions. Additionally, by using the load at the Sawgrass Lake outlet, we cannot separate potential internal loading sources within the river-lakes themselves. This is particularly the case for TN as average, annual loads from the Project structures and western tributaries do not sum to the loads calculated at the outlet of Sawgrass Lake, suggesting loading sources before the Project outlet that we did not account for. For TP, we were able to account for 90% of the average, annual loading observed (Table 9).

Immediately downstream of the northern Project boundary is Lake Washington, where recent harmful algae blooms (HABs) have impacted its use as a potable water source for the City of Melbourne and a recreational area. Although monitoring by the District, FDEP, and additional parties (e.g. Melaram and Lopez-Dueñas 2022) have not captured significant toxin production in HABs beyond recreational guidelines, observations of chlorophyll-a in recent HAB events in 2019 (120 $\mu g\ L^{-1}$), 2022 (125 $\mu g\ L^{-1}$), and 2023 (43 $\mu g\ L^{-1}$) (unpublished data) were orders of magnitude higher than those considered in the initial PLRG (Keenan et al. 2003). Annual average in-lake TP concentrations are often above the 0.09 mg L^{-1} threshold that is the basis for the PLRG and TMDLs, however the timing of HABs is not often correlated with periods of high nutrient loading. Rather, during periods of low river flow (typically <300 cfs), decreased flushing of algal biomass and decreased light limitation become favorable for growth (Fisher et al. 2009). Under these circumstances, internal nutrient recycling may favor cyanobacteria species adept at scavenging available nutrients and help drive more intense HAB events in Lake Washington. As previously mentioned, internal nutrient recycling is currently an unaccounted source in USJRB lake nutrient budgets and is a function of historical external nutrient loads.

Table 7. WRTDS estimated annual TN loads (MT yr^{-1}) for the St. Johns River at Sawgrass Lake Outlet and Jane Green stations, the calculated difference as the annual load from south of Lake Hellen Blazes (LHB), and the percentage TN load from Jane Green and LHB to SJR at SGO.

Year	SJR at SGO Load	Jane Green Load	Hellen Blazes Load (calculated)	Jane Green (%)	Hellen Blazes (%)
2000	1071	233	838	22	78
2001	175	17	158	10	90
2002	1145	200	945	17	83
2003	1478	314	1164	21	79
2004	1050	262	789	25	75
2005	1731	339	1392	20	80
2006	1730	370	1360	21	79
2007	342	73	269	21	79
2008	426	93	333	22	78
2009	1149	324	825	28	72
2010	1347	414	933	31	69
2011	299	47	252	16	84
2012	1085	348	737	32	68
2013	879	145	735	16	84
2014	903	155	748	17	83
2015	1296	291	1005	22	78
2016	761	104	658	14	86

2017	962	203	759	21	79
2018	1788	366	1422	20	80
2019	1060	321	739	30	70
2020	610	126	484	21	79

As the headwaters of the St. Johns River, the USJRB also contributes a significant load to lakes further downstream in the Middle Basin (MSJRB). Water quality models for the MSJRB TMDL at Lake Harney estimated 79% of TN loading (2,458 MT yr^{-1}) and 74.4% of TP loading (160 MT yr^{-1}) originated from upstream sources which include the USJRB and the Econlockhatchee River (Gao 2009). Given our estimates of average TN and TP loading at the Project outlet (1,008 MT yr^{-1} TN and 88 MT yr^{-1} TP), this suggests watersheds downstream of the Project additionally contribute a significant share of these nutrients. These downstream watersheds, such as those surrounding the river-lakes Washington, Winder, and Poinsett, are increasingly urbanized to the east and contribute currently unknown nutrient loads to the St. Johns River system through major drainage canals. To the west, additional biosolids-impacted watersheds of North Wolf Creek and Pennywash Creek are estimated to add a combined 70 MT TN and 9 MT TP per year (Canion et al. 2022). The watershed for Taylor Creek Reservoir, originally bounded by federal levees, also contributes nutrients downstream of Lake Poinsett. While District monitoring occurs downstream of the structure outlet, it was not included in the focal Project area for this report. Even with these additional sources, the potential for nutrient transformation and attenuation along the St. Johns River would require a more sophisticated model to allocate TN or TP entering downstream basins from specific upstream watershed sources.

Table 8. WRTDS estimated annual TP loads (MT $^{yr-1}$) for the St. Johns River at Sawgrass Lake Outlet and Jane Green stations, the calculated difference as the annual load from south of Lake Hellen Blazes (LHB), and the percentage TN load from Jane Green and LHB to SJR at SGO.

Year	SJR at SGO Load (MT yr^{-1})	Jane Green Load (MT yr^{-1})	Hellen Blazes Load (calculated, (MT yr^{-1}))	Jane Green (%)	Hellen Blazes (%)
2000	79.1	23.8	55.4	30	70
2001	10.3	1.3	9.0	13	87
2002	85.8	20.3	65.5	24	76
2003	107.5	28.0	79.5	26	74
2004	76.6	27.9	48.7	36	64
2005	132.5	41.6	90.9	31	69
2006	118.6	44.6	74.0	38	62
2007	19.3	7.3	12.0	38	62
2008	24.6	8.7	15.9	35	65
2009	96.9	49.7	47.2	51	49
2010	96.7	46.4	50.3	48	52
2011	18.8	4.5	14.3	24	76
2012	99.3	77.6	21.7	78	22

2013	65.0	18.5	46.5	28	72
2014	72.0	19.7	52.3	27	73
2015	110.3	48.6	61.7	44	56
2016	58.9	13.7	45.2	23	77
2017	101.5	41.0	60.5	40	60
2018	253.5	98.7	154.8	39	61
2019	135.9	47.5	88.4	35	65
2020	69.1	24.0	45.1	35	65

LIMITATIONS IN PROJECT LOADING CALCULATIONS AND DATA GAPS

Loading calculations required a reliable timeseries of discharge and water quality at regular intervals (i.e. daily or monthly) for accurate estimations. We prioritized using observed water quality and observed discharge estimates when available; however, some calculated or modeled discharge data were needed for major structures or watersheds of interest to provide a more complete assessment of TN and TP loading in the Project. Additionally, some imputed water quality data were used in cases of interruptions in the District monitoring network or otherwise missing data. For example, we assumed a constant annual atmospheric flux of TN and TP due to a lack of direct monitoring within the basin, and we therefore could not account for potential interannual variation in rainfall and wet deposition. Other inconsistencies in surface water quality and hydrologic monitoring, both spatially and temporally, led to gaps in understanding nutrient loading within the entire Project area and contributing watersheds. This was further complicated by changes in structure operations over time and changes in the surface water conveyance between Project areas, as new components such as FWMA were constructed within the 20-year focal period. We focused on reporting long-term average loading rates to help account for variability in rainfall or other factors that drive tributary discharges as well as operational decisions that impact structure discharges.

On the eastern side of the Project, extensive monitoring of most major structures for both water quality and flood control purposes allowed for high confidence in the data used for estimations of discharge subsequent calculations of nutrient loads. This includes loading calculations for structures at the end of the eastern "treatment train." Sporadic removal of water from the WMAs for freeze protection was assumed to be negligible, but potential data gaps still exist for considering external inputs from unmonitored sources through canals or pumps draining remaining agricultural operations in the surrounding watershed. Limited active water quality monitoring of wells within the Project meant we also did not consider groundwater inputs or outputs in our WMA treatment calculations. This lack of available data also impacts the potential for calculating nutrient removal efficiency of WMAs. For example, the historical treatment efficiency of SJWMA is likely underestimated due to the lack of a full time series for discharge and water quality of agricultural pumps prior to the District purchase and conversion of the FWMA property. Calculations for recent years (2017-2020) do account for loading from FWMA through PS-4, however high-quality data for pump loading to SJWMA were not available for earlier years. Using the average annual load from PS-4 to SJWMA (~29 MT TN; 0.7 MT TP), the WMA would shift from a negative to positive removal efficiency for TN in several years where pump loads were otherwise not monitored and able to be calculated.

Additional unmonitored agricultural pumps in the southeast Project region also send water to the S-251 structure, and these pumps have historically discharged directly into BCWMA-East during periods of breaks in canal berms (S. Miller, personal communication). Earlier studies of pump discharges in the USJRB found nutrient concentrations several times higher than the background receiving water body concentrations, particularly for dissolved, inorganic forms (Fall 1990), although changes in land use and management practices since then may have shifted water quality in recent years. And while discharge data through S-251 are available, the District halted regular water quality monitoring at the structure in 2002. TP concentrations in the interior marsh of BCWMA-East are assumed to be low (<0.05 mg L^{-1}) due to the available, historic data, although more recent observations of cattail expansion in canals may suggest nutrient enrichment and encroachment (S. Miller, personal communication). Calculating loading through S-251 is further complicated by frequent apparent reverse-flow conditions in the WMM dataset from BCWMA-West into BCWMA-East (>30% of the hourly dataset), and calculated flows sometimes changed direction on sub-daily timesteps. These calculated reverse flows are in opposition with recommendations in the EWMP for the structure to be closed when stage in BCWMA-West is higher than stage in BCWMA-East (Miller et al. 2022). Further north, there are additional unmonitored inputs to TFMCA via the S-255 and S-256 canals, suggesting nutrient removal in the marsh may be even more significant than just the load reduced if calculating the differences between S-96B and S-257 (approximately 147 MT TN and 13 MT TP per year). Since these potentially relevant inputs and outputs could not be fully accounted for, treatment efficiencies within FWMA, BCWMA, and TFMCA were not calculated.

Table 9. Annual average TN and TP loads (MT yr^{-1}) from Project outlets and western tributaries and the proportion of the WRTDS estimated loads at St. Johns River at Sawgrass Lake Outlet, with the remainder unaccounted for.

Region	Source	TN Load (MT yr^{-1})	TP Load (MT yr^{-1})	Proportion TN (%)	Proportion TP (%)
Eastern WMA	S-262	41	1	4	1
Eastern WMA	S-257	30	1	3	0
Western MCA	S-96C	187	21	18	24
Western MCA	S-250BC	57	6	6	7
Western Trib	Sixmile	16	3	2	3
Western Trib	S. Wolf	21	2	2	2
Western Trib	Tenmile	57	12	6	14
Western Trib	Jane Green	220	32	21	36
	Unaccounted	*406*	*10*	*39*	*11*

While loads were assigned to most watersheds and structures in the western Project region, there is more significant uncertainty due to 1) unmonitored watersheds near SJMCA, and 2) unmonitored structures between BCMCA and SJMCA. Regarding the former, watershed delineations used in this report correspond with those assigned to the USGS gages with the remainder assigned to monitored HSPF watersheds. While these monitored areas do collectively account for most of the overall watershed area, there are some gaps, particularly near the western Project boundary, where additional loading to these canals and SJMCA (particularly at high flow) may occur. Within the Project area, the C-40 canal is monitored for water quality further north at the E-8 plug with water elevation monitoring nearby at E-7; however, an accurate load could not be calculated near these structures due to the history of “cut-arounds” in which a significant but unaccounted for volume of water has been observed flowing around these structures (T. Jobes, personal communication). Uncertainty also exists in historic loading rates to SJMCA from BCMCA through the remaining S-250 series of structures. Currently, only loads through S-250B, C, and E could be determined due to inconsistent hydrologic monitoring at other S-250 structures. Calculations for these S-250 series structures were also done with the assumption that water quality is similar to the monitoring station at S-96C. Accurate loading calculations in this area of the Project are important due to the aforementioned concern with soil oxidation in MCAs as well tracking the impacts of loading from biosolids-impacted tributaries.

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APPENDIX A—SUPPLEMENTARY TABLES AND FIGURES OF THE LAND COVER, VEGETATION AND HYDROLOGIC CONDITIONS IN THE USJRB

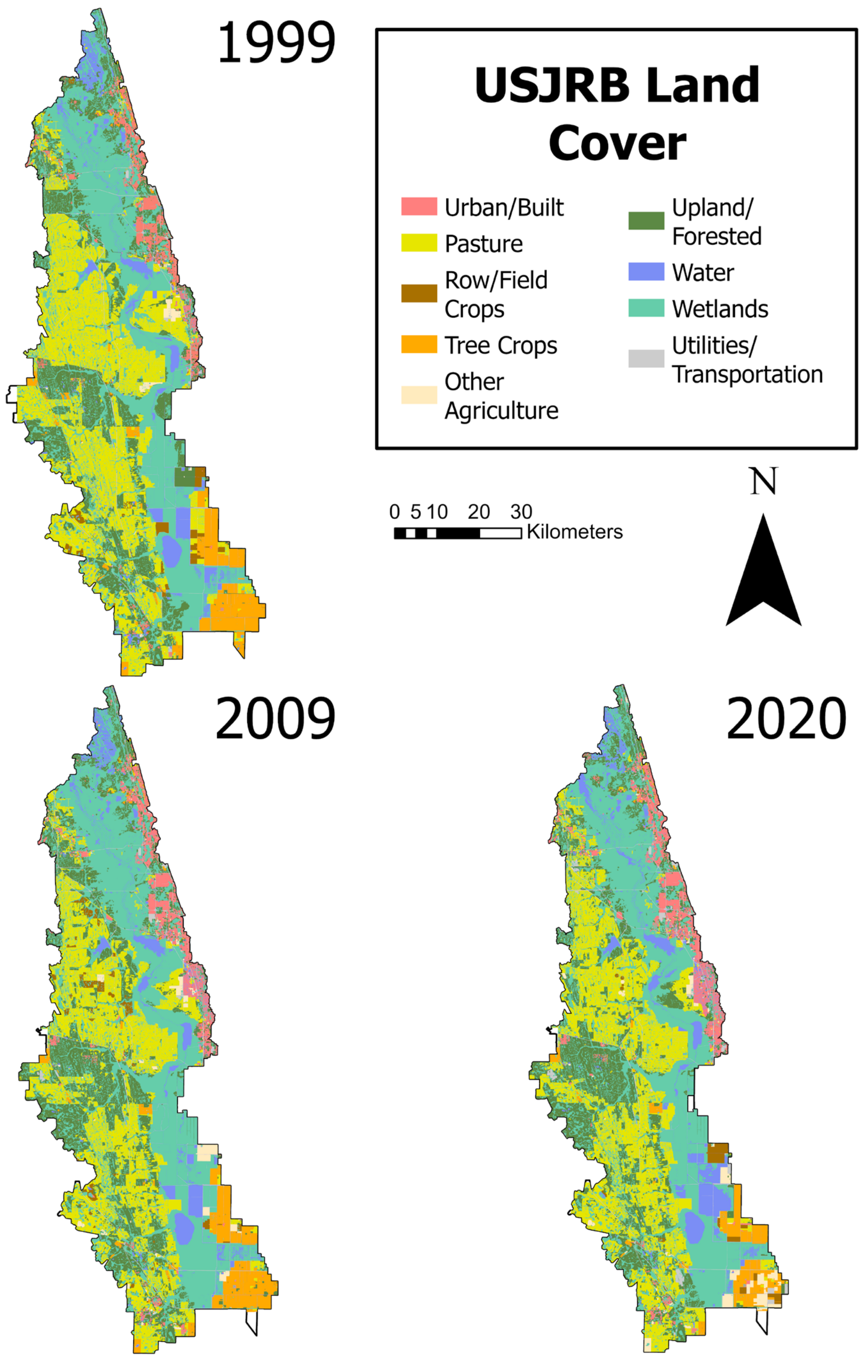

Figure A-1. Generalized Land Cover (LC) classifications in the USJRB in 1999 (upper left), 2009 (bottom left), and 2020 (bottom right). LC layers available at the SJRWMD Geospatial Open Data portal.

Table A-1. List of USJRB Project structures and the upstream (headwater) and downstream (tailwater) stations used for discharge calculations by WMM. Number in parentheses indicates number of each type of structure for those with multiple.

Structure	Upstream Hydron	Downstream Hydron	Type
S-96	00510201	00510200	Ogee-crest lift gate
S-96B	00960390	00960391	Ogee-crest lift gate
S-96C	00980400	00980401	Ogee-crest lift gate
S-96D	00990405	00990406	Ogee-crest lift gate
S-3	00990405	00990406	Gated culverts (3)
S-252A	01200447	01200448	Gated culverts (2)
S-252B	01080434	01080435	Ungated culverts (2)
S-252C	01210437	01210438	Ungated culvert
S-252D	01880119	15510806	Gated culvert
S-252F	14332574	13412575	Gated culverts (2)
S-253	01630766	01630763	Weir
S-257	32334067	32334010	Weir and Gated culverts (2)
SJID	00500100	15510806	Radial gates (5)
S-251	01100440	01100441	Gated culverts (4)
S-250B	01280545	01290546	Weir and Ungated culvert
S-250C	01290550	01300551	Weir and Ungated culvert
S-250E	01310555	0920370	Weir
S-262	32844127	32844125	Gated (1) and Ungated (3) culverts

Table A-2. Summary of acreage of each vegetation “type” by Project area within the USJRB (2015-2017) with percentage of total area in parentheses. Adapted from Table 3 of Sapeta et al. (2018).

Project Area	**Forested Upland**	**Forested Wetland**	**Herbaceous Upland**	**Herbaceous Wetland**	**Other**	**Open Water**	**Shrub Upland**	**Shrub Wetland**	**Total Area (acres)**
Bull Creek / Jane Green	3932 (14)	9308 (33)	581 (2)	2062 (7)	0 (0)	82 (<1)	10270 (37)	1652 (6)	27887
St. Johns MCA	141 (<1)	1293 (6)	191 (<1)	13456 (58)	0 (0)	1337 (6)	5 (<1)	6825 (29)	23247
C-1 RA / Sawgrass Lake WMA	43 (2)	82 (4)	105 (5)	1766 (85)	0 (0)	77 (4)	0 (0)	5 (<1)	2079
Three Forks MCA	4 (<1)	387 (<1)	227 (2)	9669 (72)	0 (0)	2301 (17)	0 (0)	850 (6)	13438
Kenansville Lake	7 (<1)	19 (3)	20 (<1)	645 (25)	0 (0)	1794 (70)	0 (0)	80 (3)	2565
St. Johns WMA	0 (0)	4 (<1)	92 (2)	56 (<1)	0 (0)	6160 (97)	0 (0)	11 (<1)	6323
Fellsmere WMA	0 (0)	198 (2)	3033 (27)	6782 (60)	14 (<1)	951 (9)	0 (0)	211 (2)	11189
Blue Cypress WMA	13 (<1)	318 (3)	169 (1)	7010 (60)	0 (0)	2889 (25)	0 (0)	1378 (12)	11776
Blue Cypress MCA	0 (0)	2721 (9)	168 (<1)	11516 (39)	0 (0)	6953 (24)	0 (0)	8028 (27)	29387
Ft. Drum MCA	863 (4.2)	3358 (16)	1810 (9)	10088 (49)	0 (0)	257 (1)	327 (2)	3952 (19)	20655

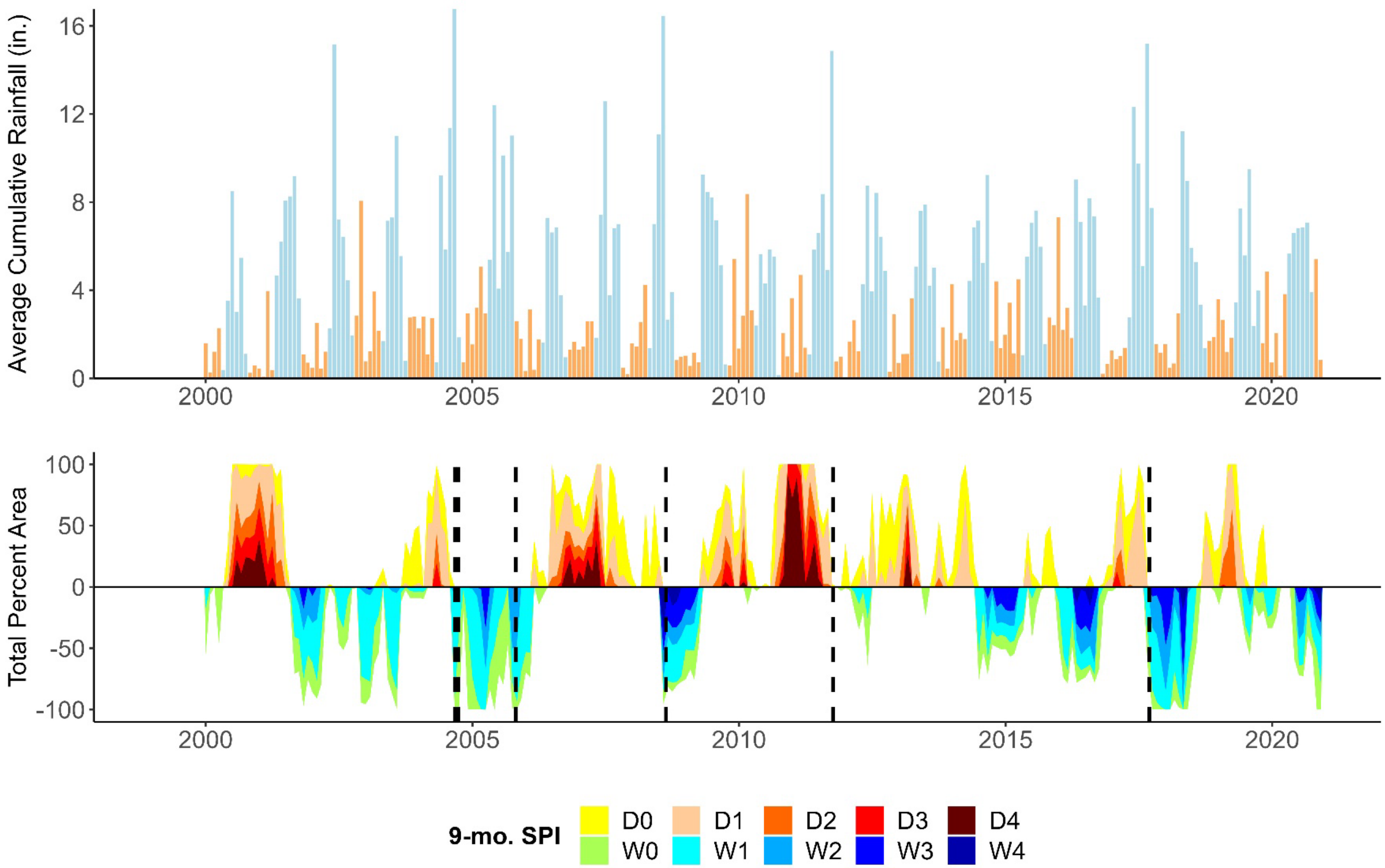

Figure A-2. *Top*: Average, monthly cumulative rainfall (in inches) from 2000-2020 for the St. Johns River watersheds south of Sawgrass Lake from SJRWMD NexRad rainfall. Wet season months are colored blue and dry season months are in orange. *Bottom*: Total percent area of Brevard, Indian River, and Oceola counties classified as each 9-month Standardized Precipitation Index category (D0 = abnormally dry, D1 = moderate drought, D2 = severe drought, D3 = extreme drought, D4 = exceptional drought, W0 = abnormally wet, W1 = moderately wet, W2 = severely wet, W3 = extremely wet, W4 = exceptionally wet) from 2000-2020. Dashed lines denote significant “named” rain events (9/5/2004—H. Frances; 9/26/2004—H. Jeanne; 10/24/2005—H. Wilma; 8/19/2008—T.S. Fay; 10/8/2011—Columbus Day storm; 9/10/2017—H. Irma).

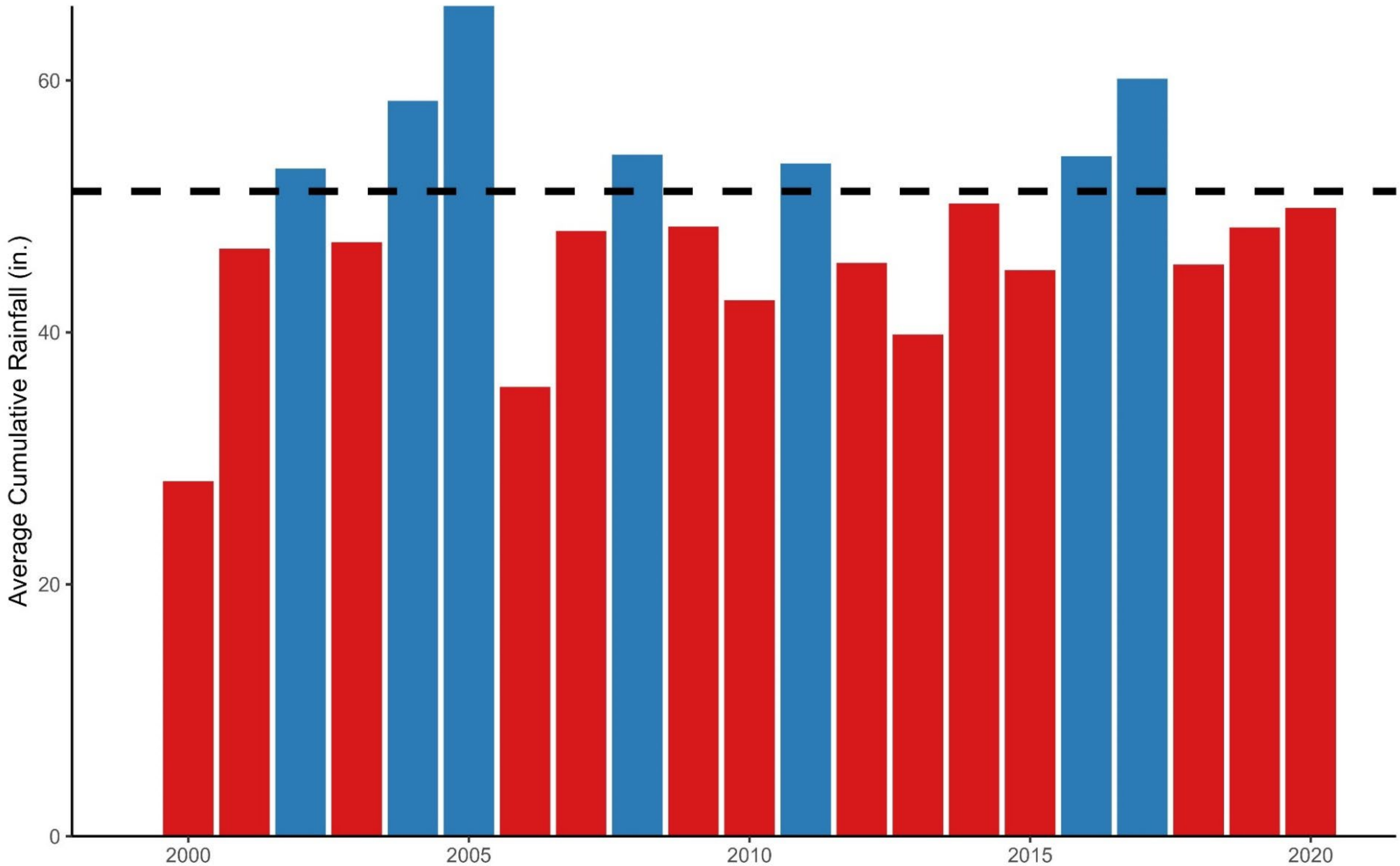

Figure A-3. Average annual cumulative rainfall (in inches) from 2000-2020 for the St. Johns River watersheds south of Sawgrass Lake from SJRWMD NexRad rainfall. The dashed line denotes the long-term average basin-wide annual rainfall (51.2”) with wetter years in blue and drier years in red.

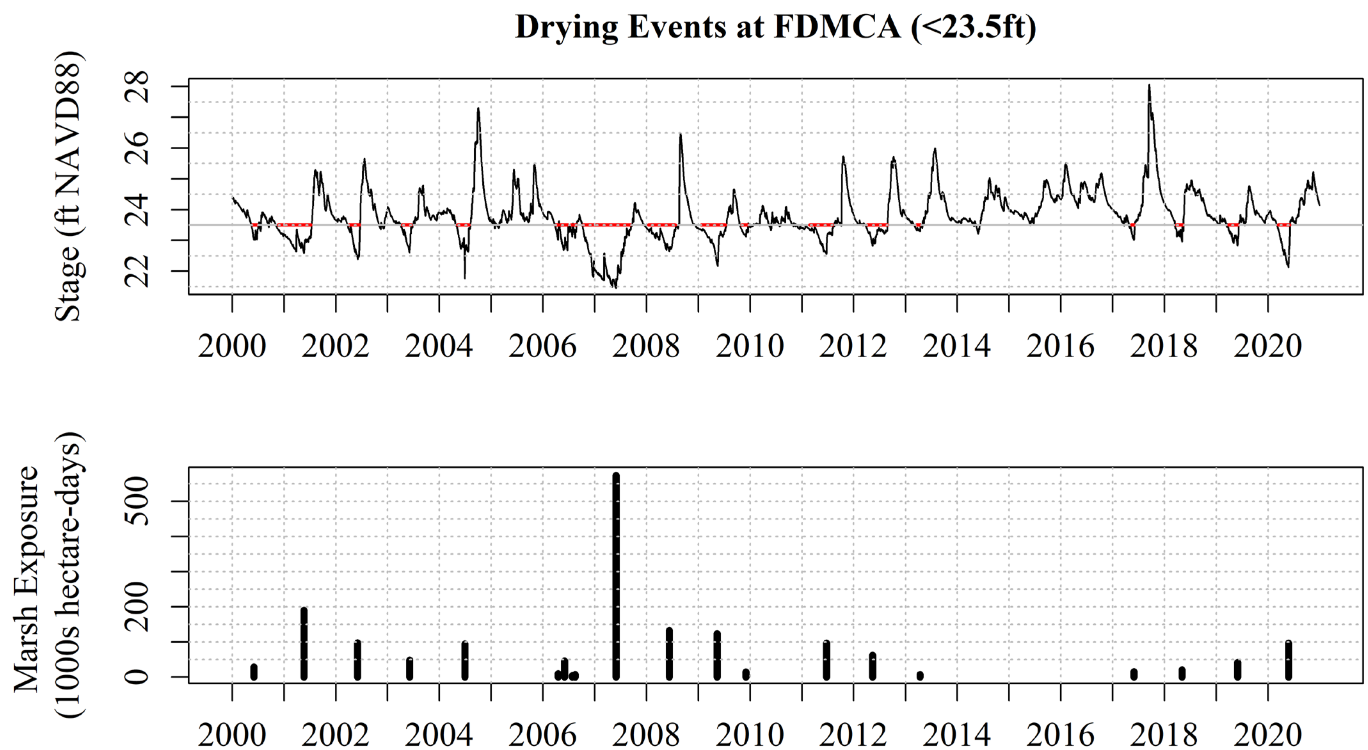

Figure A-4. *Top:* Stage (in feet NAVD88) at S-252C in FDMCA from 2000-2020 with drying events below the CCE of 23.5 ft highlighted in red. *Bottom*: Calculated marsh exposure area-days (in 1000s ha-d) from 2000-2020 for FDMCA. Bars are placed at the date of the lowest stage recorded during the event.

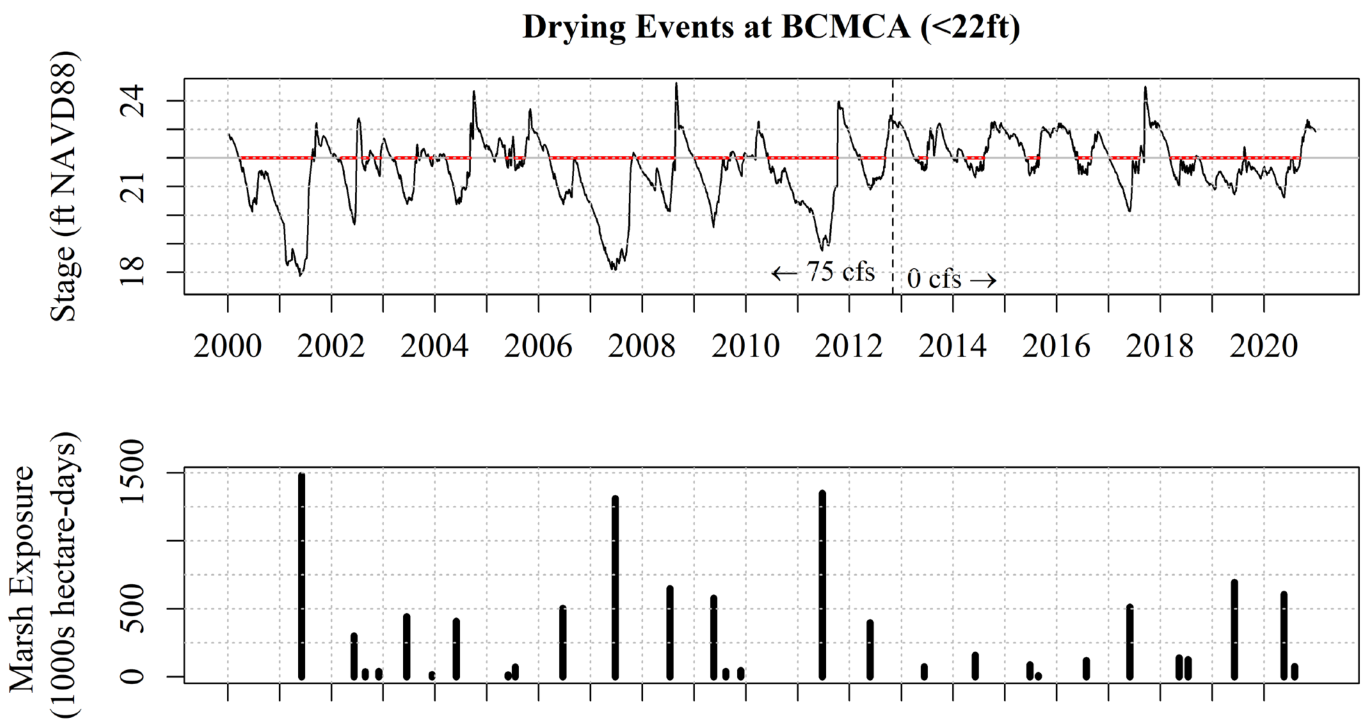

Figure A-5. *Top*: Stage (in feet NAVD88) at BCL in BCMCA from 2000-2020 with drying events below the CCE of 22 ft highlighted in red. Dashed line denotes change in S-96C environmental discharges from 75 to 0 cfs in November 2012. *Bottom*: Calculated marsh exposure area-days (in 1000s ha-d) from 2000-2020 for BCMCA. Bars are placed at the date of the lowest stage recorded during the event.

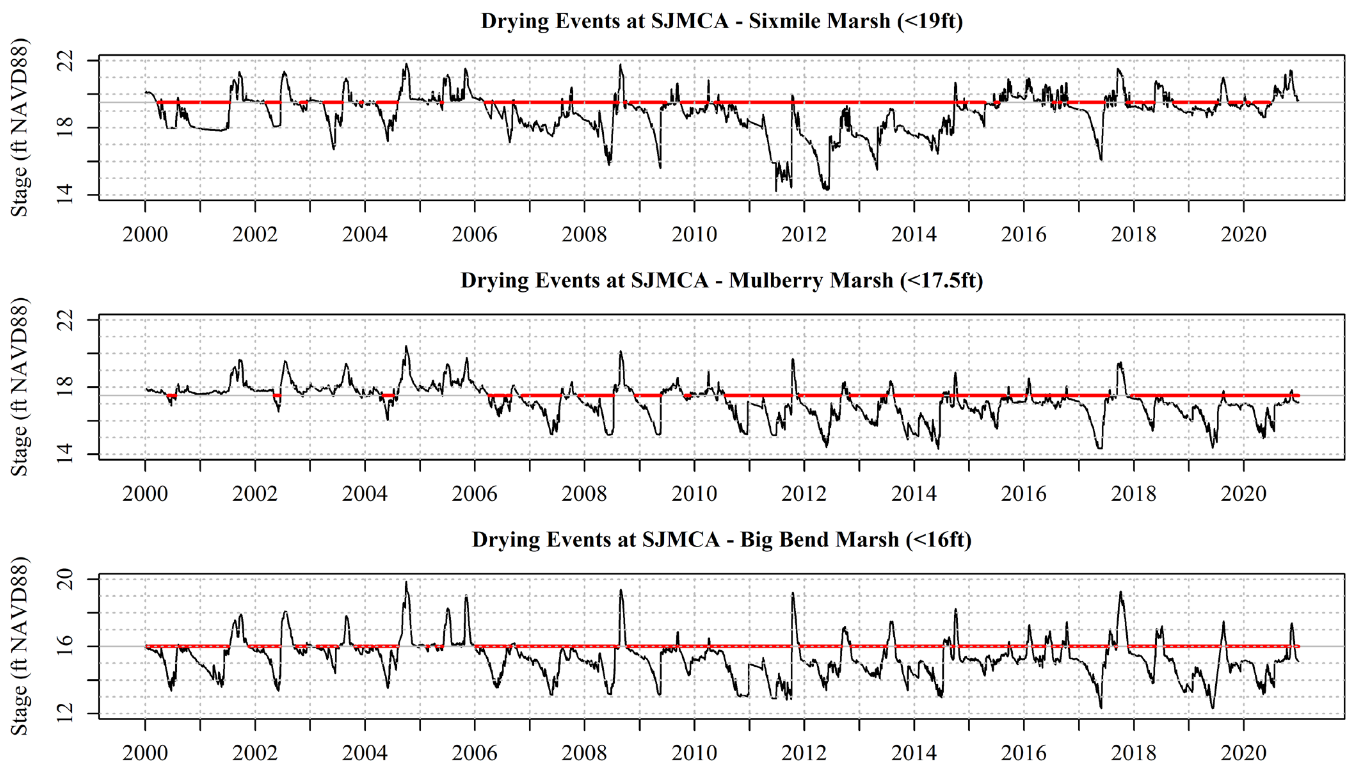

Figure A-6. Stage (in feet NAVD88) at Sixmile Marsh (top), Mulberry Marsh (middle), and Big Bend Marsh (bottom) in SJMCA from 2000-2020 with drying events below the respective CCEs of 19, 17.5, and 16 ft highlighted in red.

APPENDIX B—ANNUAL TN AND TP LOADING RESULTS FOR EASTERN PROJECT STRUCTURES

Appendix B contains annual loading plots for the eastern Project structures (see Table 1). All plots have the same results presented in each panel and vary only in the constituent (TN or TP) and structure. The panels are as follows:

A. Top: Calculated annual TN or TP load in metric tons (MT). Dashed line represents annual average load over entire POR for the structure.

B. Middle: Observed annual discharge volume at structure in millions of cubic meters (MCM).

C. Bottom: Observed average, annual TN or TP concentration (± one S.E.) in mg L^{-1} at WQ station used for loading calculation.

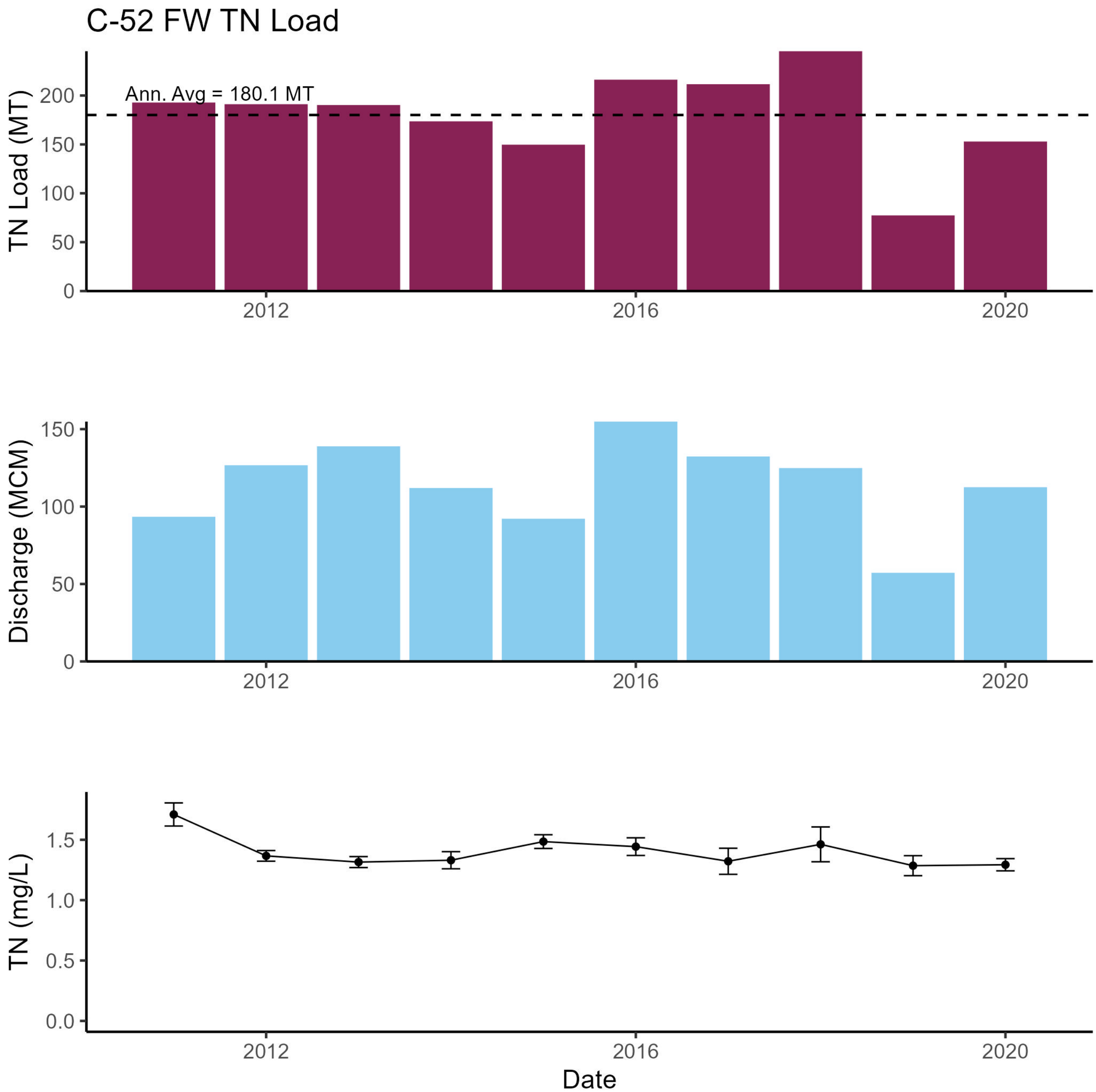

Figure B-1. C-52 flow way annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

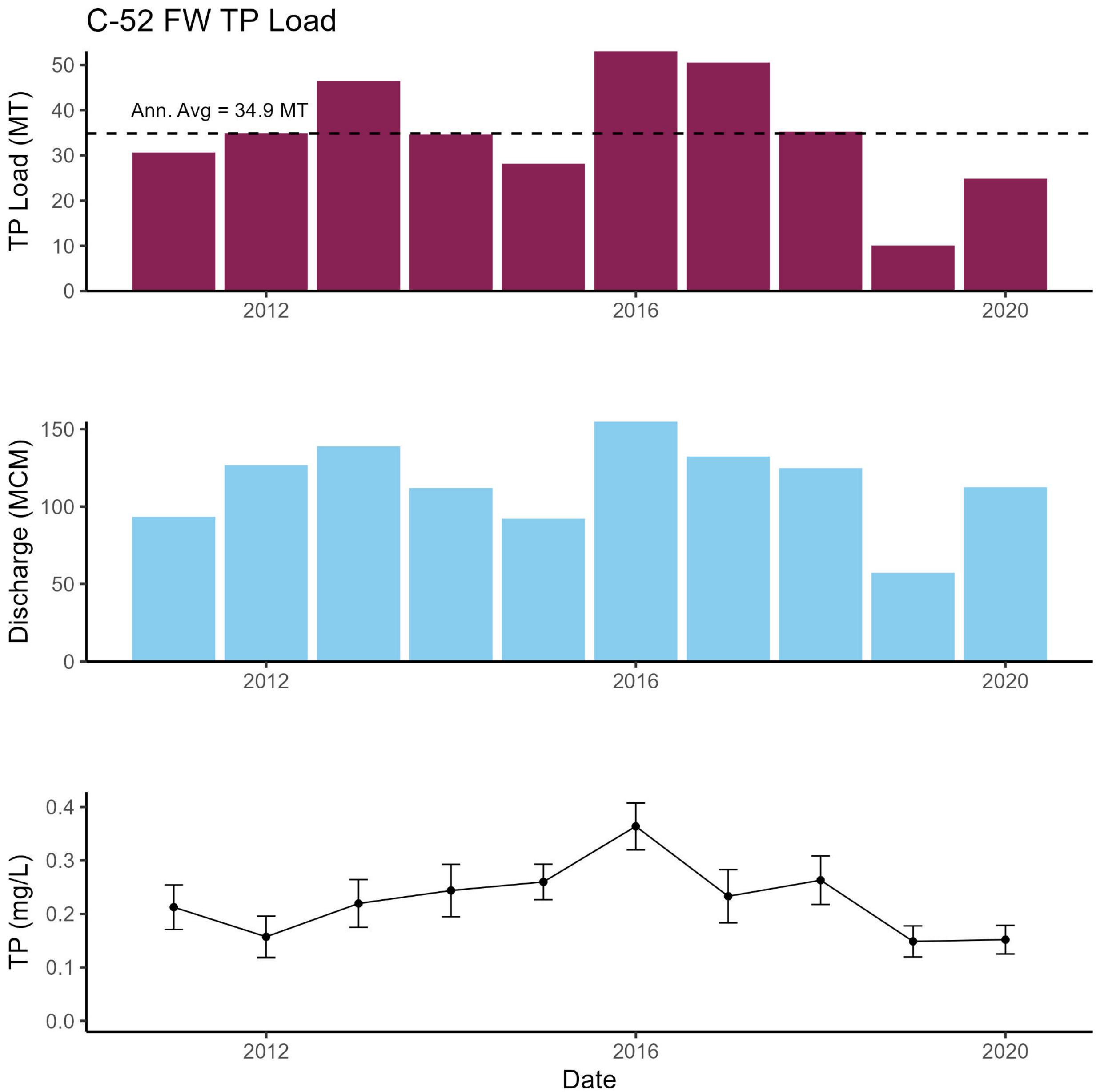

Figure B-2. C-52 flow way annual TP load, discharge, and average TP concentrations. See the beginning of Appendix B for an explanation of each panel.

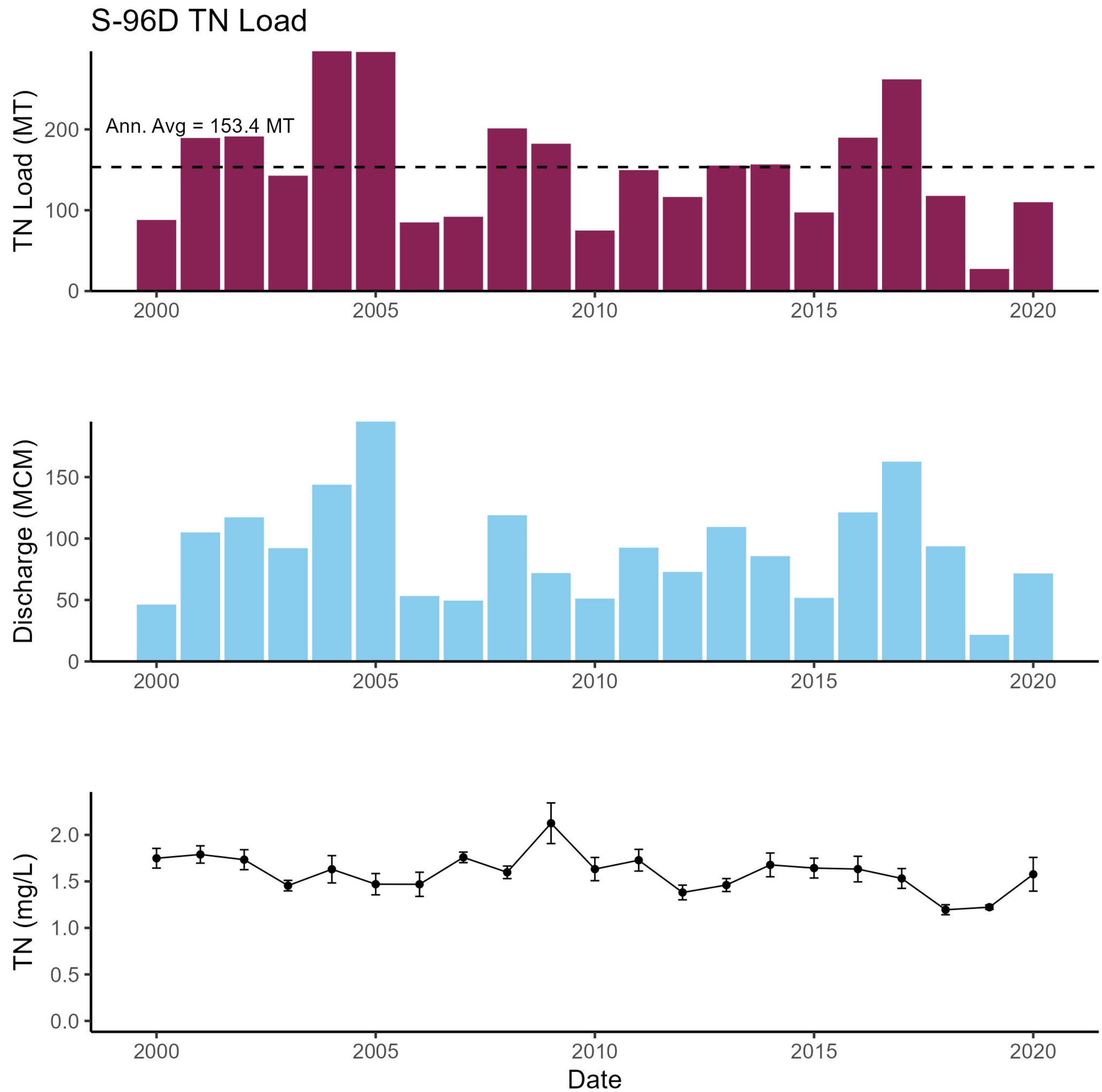

Figure B-3. S-96D annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

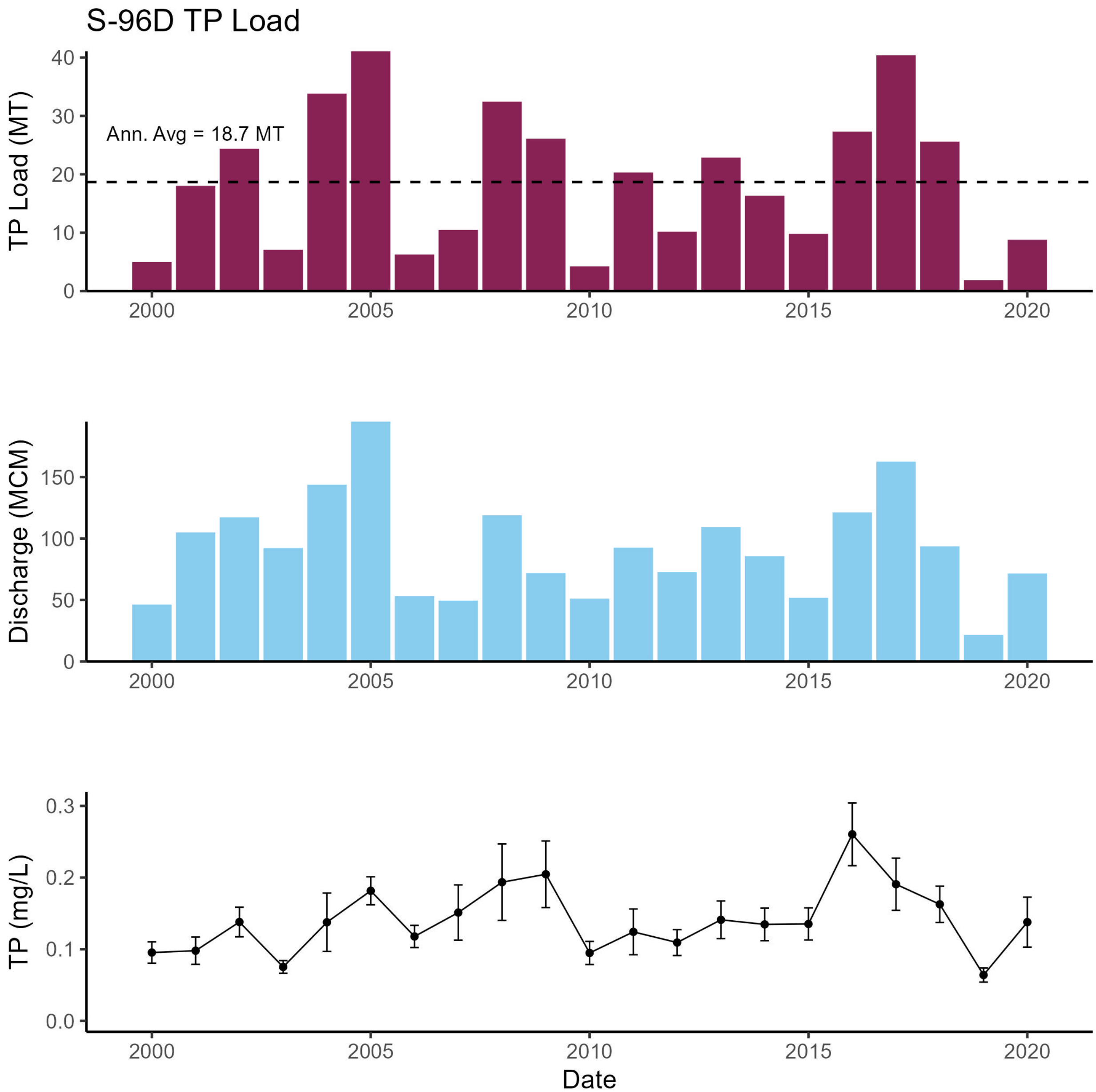

Figure B-4. S-96D annual TP load, discharge, and average TP concentrations. See the beginning of Appendix B for an explanation of each panel.

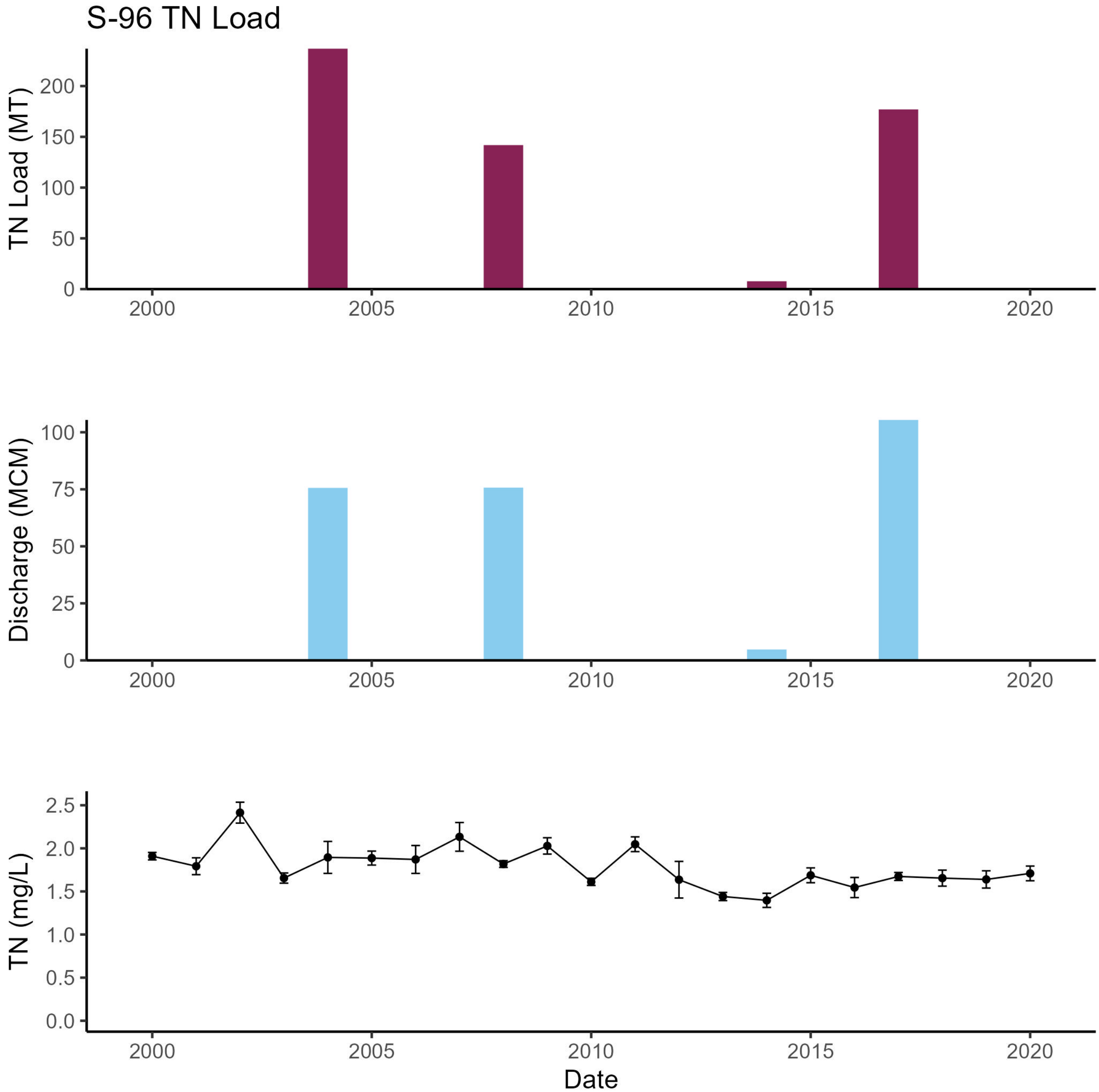

Figure B-5. S-96 annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

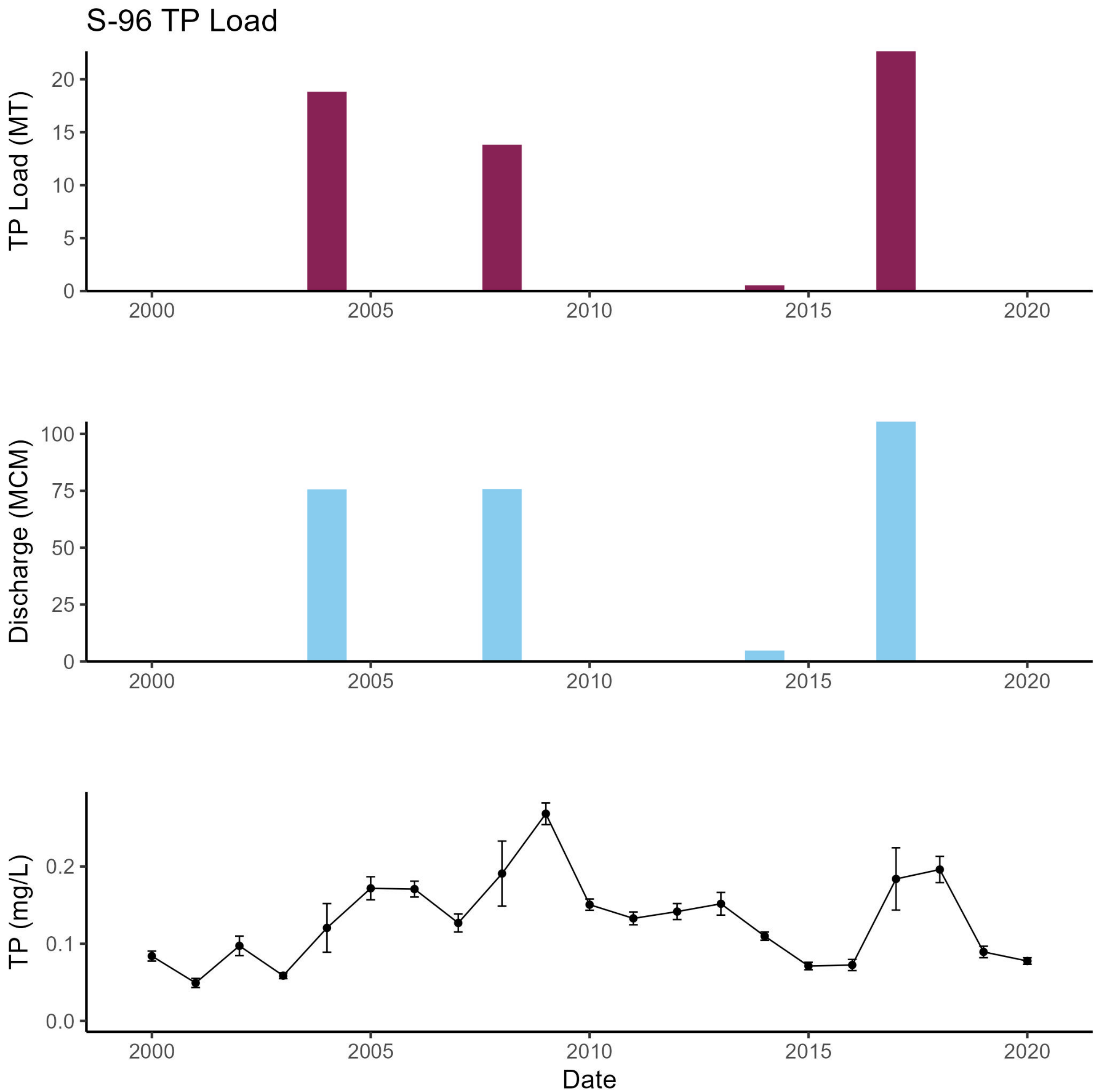

Figure B-6. S-96 annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

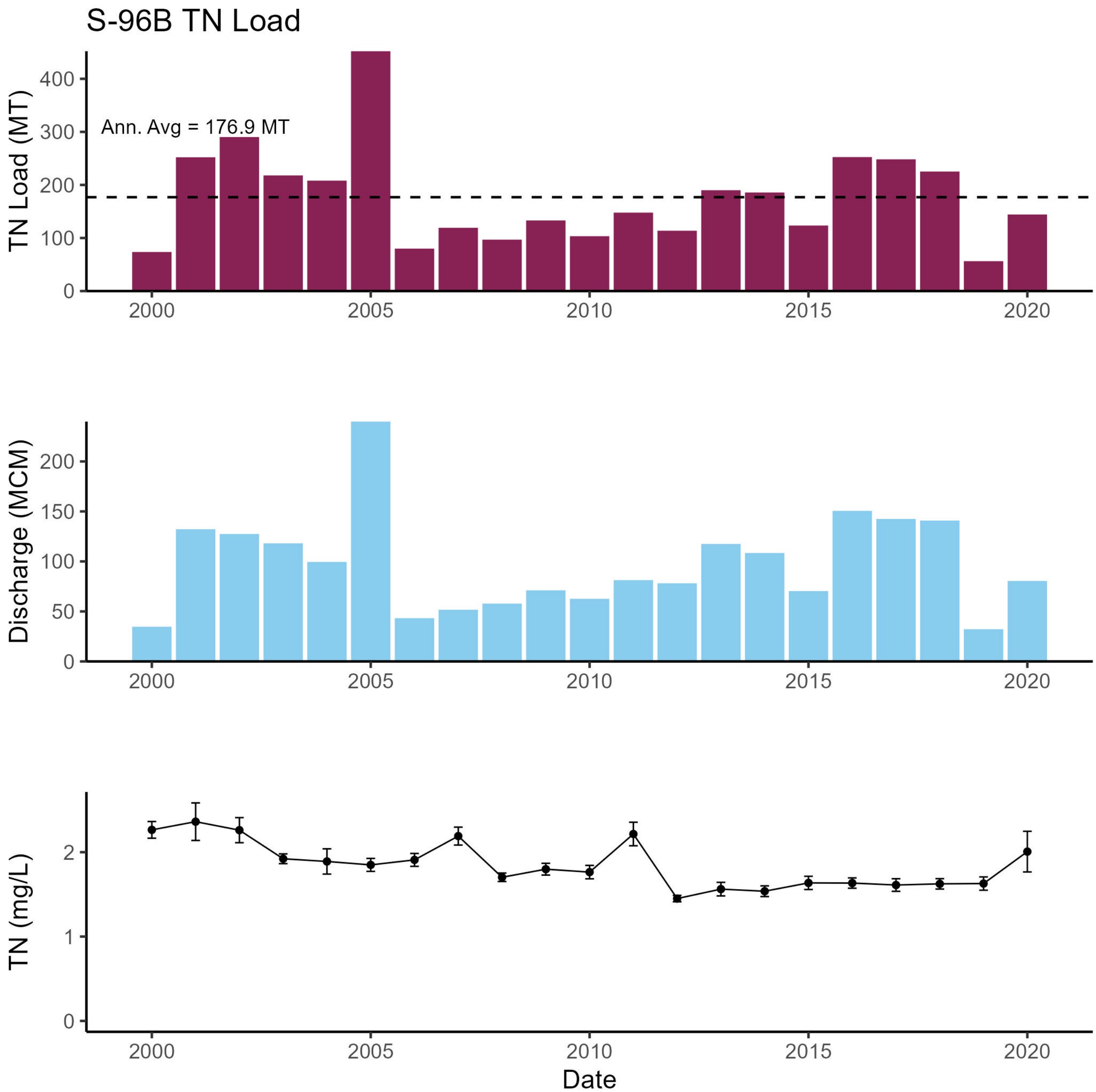

Figure B-7. S-96B annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

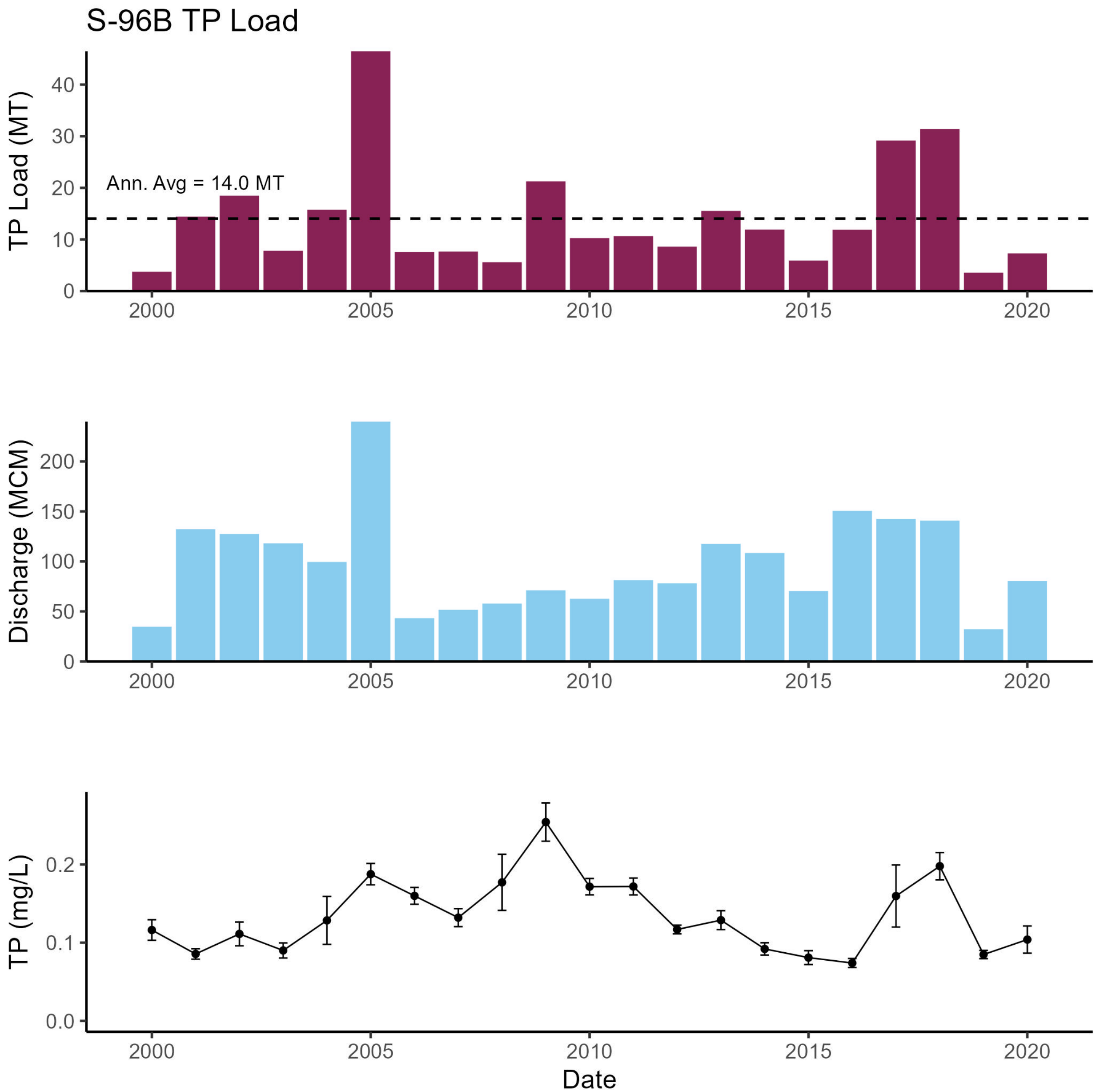

Figure B-8. S-96B annual TP load, discharge, and average TP concentrations. See the beginning of Appendix B for an explanation of each panel.

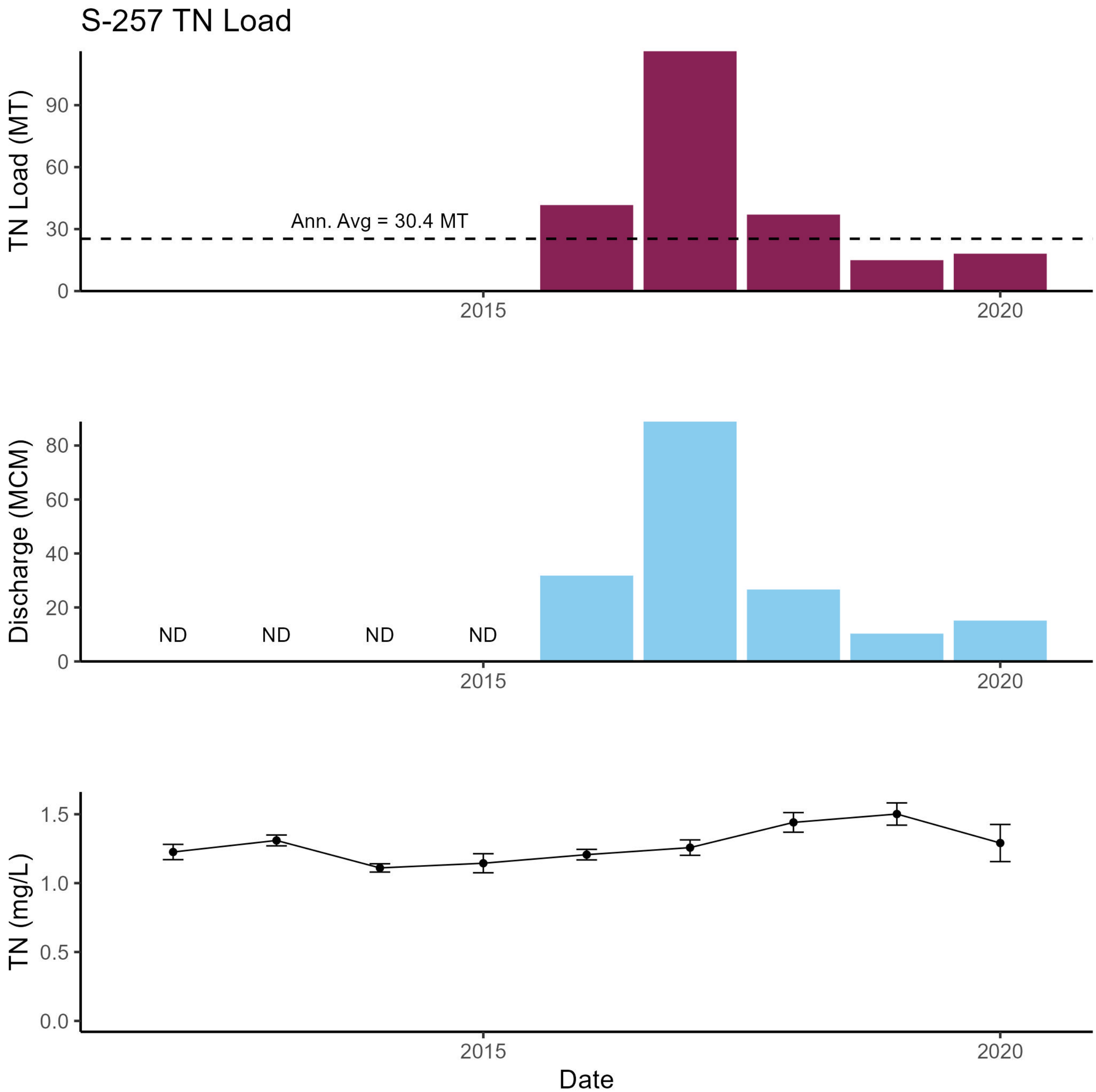

Figure B-9. S-257 annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel. ND = no discharge.

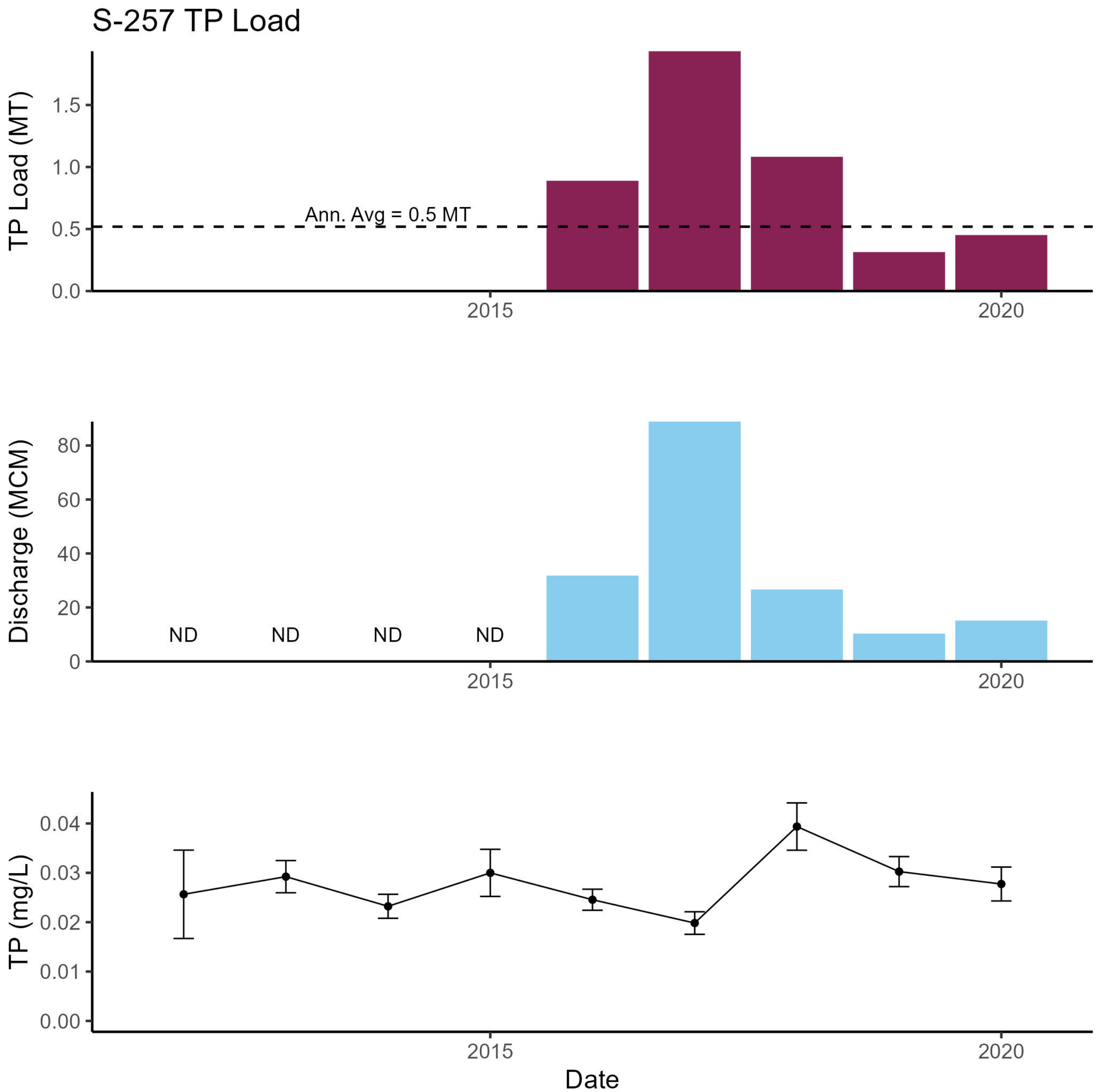

Figure B- 10. S-257 annual TP load, discharge, and average TP concentrations. See the beginning of Appendix B for an explanation of each panel. ND = no discharge.

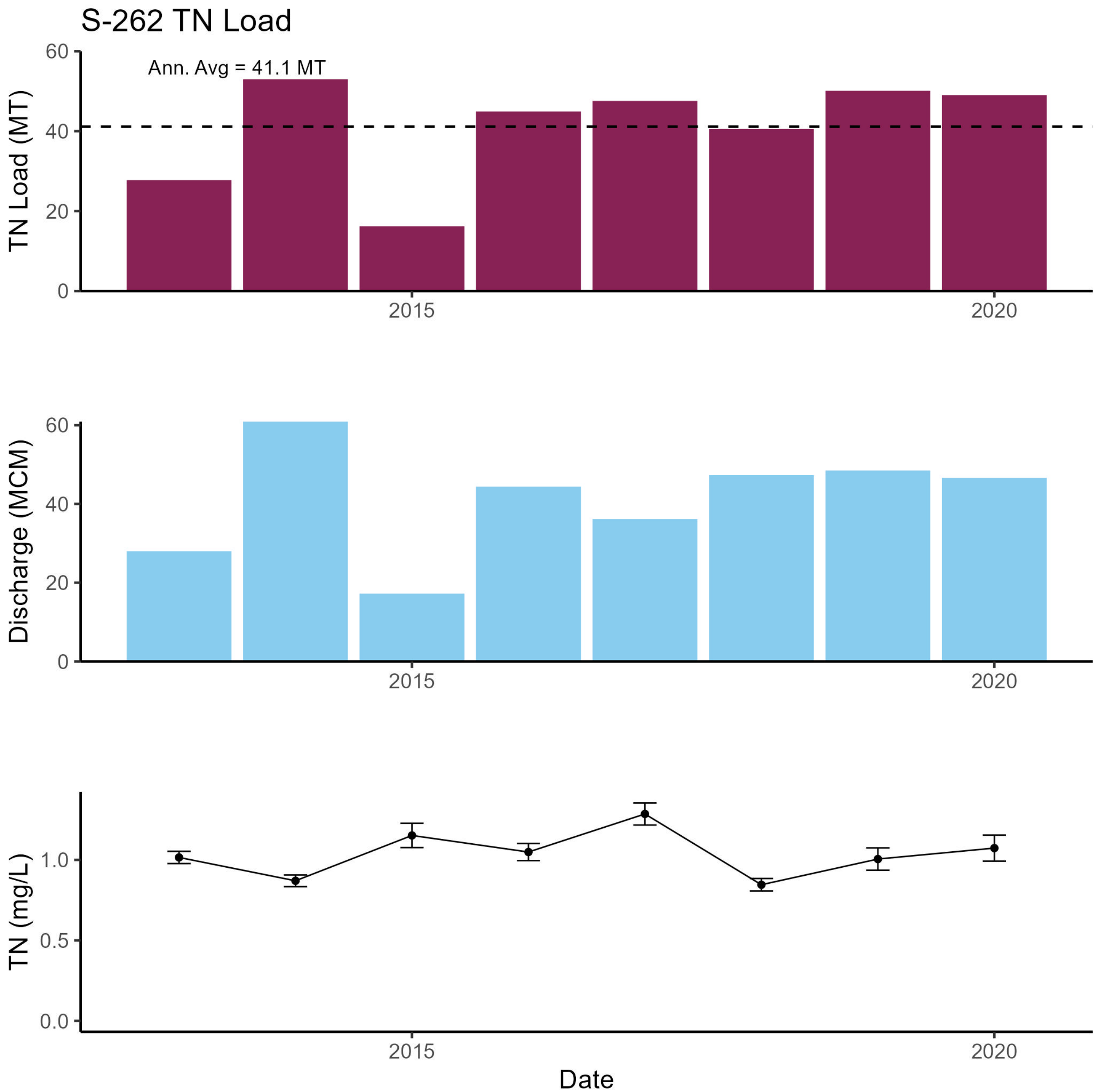

Figure B-11. S-262 annual TN load, discharge, and average TN concentrations. See the beginning of Appendix B for an explanation of each panel.

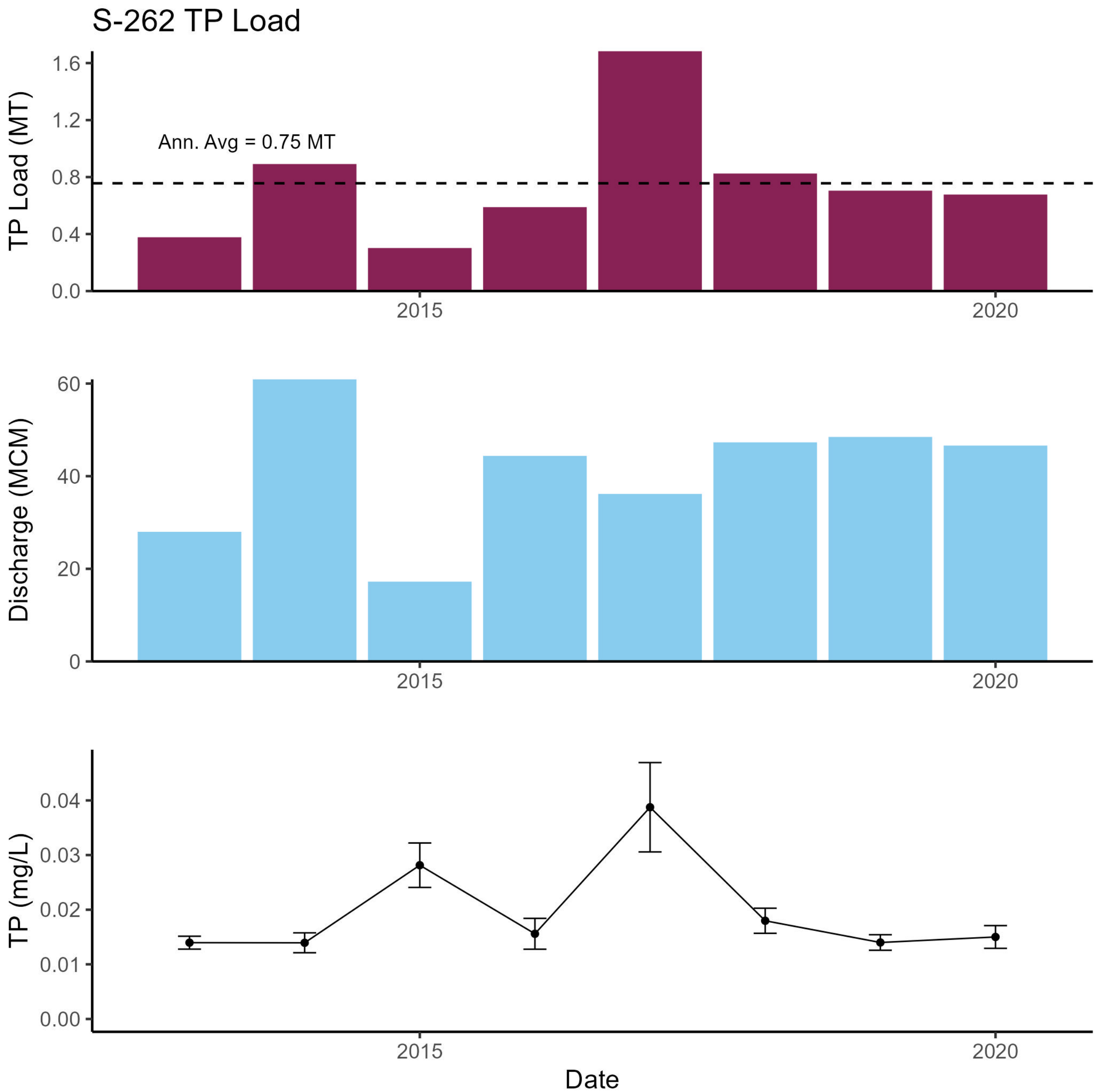

Figure B-12. S-262 annual TP load, discharge, and average TP concentrations. See the beginning of Appendix B for an explanation of each panel.

APPENDIX C—TABLES OF ANNUAL TN AND TP LOADING AND TREATMENT EFFICIENCIES IN SJWMA AND SLWMA

Table C1. Annual TN loads in and out of SJWMA and calculated treatment efficiencies from 2000-2020. NA = data not available.

Year	Inputs to SJWMA			Annual Load In	Outputs from SJWMA		Annual Load Out	Annual Load Difference	Treatment Efficiency (R%)
	S-96D	PS-4	Atm. Dep		S-96B	S-96			
2000	87.9	NA	18.7	106.6	73.6	0.0	73.6	33.0	31
2001	189.4	NA	18.7	208.1	252.1	0.0	252.1	-44.0	-21
2002	191.2	NA	18.7	209.9	290.2	0.0	290.2	-80.3	-38
2003	142.6	NA	18.7	161.3	218.0	0.0	218.0	-56.7	-35
2004	296.8	NA	18.7	315.5	208.1	236.8	444.9	-129.4	-41
2005	295.9	NA	18.7	314.6	452.0	0.0	452.0	-137.4	-44
2006	84.9	NA	18.7	103.6	79.9	0.0	79.9	23.7	23
2007	91.9	NA	18.7	110.6	119.2	0.0	119.2	-8.6	-8
2008	201.4	NA	18.7	220.1	96.9	141.8	238.7	-18.6	-8
2009	182.2	NA	18.7	200.9	133.1	0.0	133.1	67.9	34
2010	74.8	NA	18.7	93.5	103.4	0.0	103.4	-10.0	-11
2011	149.4	NA	18.7	168.1	147.8	0.0	147.8	20.3	12
2012	116.2	NA	18.7	134.9	113.7	0.0	113.7	21.2	16
2013	155.1	NA	18.7	173.8	190.0	0.0	190.0	-16.3	-9
2014	156.7	NA	18.7	175.4	185.7	7.7	193.4	-18.1	-10
2015	97.1	NA	18.7	115.8	123.5	0.0	123.5	-7.7	-7
2016	189.8	NA	18.7	208.4	252.5	0.0	252.5	-44.1	-21
2017	261.9	52.8	18.7	333.4	248.3	177.0	425.3	-91.9	-28
2018	117.8	33.0	18.7	169.5	225.2	0.0	225.2	-55.8	-33
2019	27.3	0.0	18.7	46.0	56.3	0.0	56.3	-10.3	-22
2020	109.9	29.3	18.7	157.9	144.3	0.0	144.3	13.6	9

Table C2. Annual TP loads in and out of SJWMA and calculated treatment efficiencies from 2000-2020. NA = data not available.

Year	**Inputs to SJWMA**			**Annual Load In**	**Outputs from SJWMA**		**Annual Load Out**	**Annual Load Difference**	**Treatment Efficiency (R%)**
	S-96D	PS-4	Atm. Dep.		S-96B	S-96			
2000	5.0	NA	1.3	6.2	3.7	0.0	3.7	2.5	40
2001	18.0	NA	1.3	19.3	14.4	0.0	14.4	4.9	25
2002	24.4	NA	1.3	25.6	18.5	0.0	18.5	7.2	28
2003	7.1	NA	1.3	8.3	7.8	0.0	7.8	0.5	7
2004	33.8	NA	1.3	35.1	15.8	18.8	34.6	0.5	1
2005	41.1	NA	1.3	42.3	46.5	0.0	46.5	-4.1	-10
2006	6.3	NA	1.3	7.5	7.6	0.0	7.6	-0.1	-1
2007	10.5	NA	1.3	11.7	7.6	0.0	7.6	4.1	35
2008	32.4	NA	1.3	33.7	5.6	13.8	19.4	14.3	42
2009	26.1	NA	1.3	27.4	21.2	0.0	21.2	6.1	22
2010	4.2	NA	1.3	5.5	10.3	0.0	10.3	-4.8	-87
2011	20.3	NA	1.3	21.6	10.6	0.0	10.6	10.9	51
2012	10.2	NA	1.3	11.4	8.6	0.0	8.6	2.8	25
2013	22.9	NA	1.3	24.1	15.5	0.0	15.5	8.6	36
2014	16.3	NA	1.3	17.6	11.9	0.5	12.4	5.2	29
2015	9.8	NA	1.3	11.1	5.9	0.0	5.9	5.2	47
2016	27.3	NA	1.3	28.6	11.9	0.0	11.9	16.7	58
2017	40.4	1.4	1.3	43.1	29.2	22.7	51.8	-8.7	-20
2018	25.6	1.0	1.3	27.9	31.4	0.0	31.4	-3.5	-13
2019	1.9	0.0	1.3	3.1	3.6	0.0	3.6	-0.4	-14
2020	8.8	0.6	1.3	10.7	7.3	0.0	7.3	3.4	32

Table C3. Annual TN loads in and out of SLWMA and calculated treatment efficiencies from 2013-2020. NA = data not available.

Year	**Inputs to SLWMA**			**Annual Load In**	**S-262 Load Out**	**Annual Load Difference**	**Treatment Efficiency (R%)**
	PS-1	PS-2	Atm. Dep.				
2013	21.7	1.1	6.3	29.1	27.8	1.4	5
2014	58.7	57.5	6.3	122.5	53.0	69.5	57
2015	12.7	6.3	6.3	25.2	16.2	9.0	36
2016	28.5	22.6	6.3	57.4	44.9	12.5	22
2017	25.8	17.9	6.3	50.0	47.6	2.4	5
2018	41.0	30.0	6.3	77.3	40.6	36.7	48
2019	44.4	38.9	6.3	89.6	50.1	39.5	44
2020	40.8	21.6	6.3	68.7	49.0	19.7	29

Table C4. Annual TP loads in and out of SLWMA and calculated treatment efficiencies from 2013-2020. NA = data not available.

Year	**Inputs to SLWMA**			**Annual Load In**	**S-262 Load Out**	**Annual Load Difference**	**Treatment Efficiency (R%)**
	PS-1	PS-2	Atm. Dep.				
2013	1.5	0.1	0.4	2.0	1.5	1.6	81
2014	5.5	5.7	0.4	11.7	5.5	10.8	92
2015	0.6	0.5	0.4	1.5	0.6	1.2	80
2016	3.7	2.5	0.4	6.6	3.7	6.0	91
2017	1.5	1.5	0.4	3.5	1.5	1.8	51
2018	2.9	3.6	0.4	6.9	2.9	6.1	88
2019	2.3	3.3	0.4	6.0	2.3	5.3	88
2020	1.9	1.8	0.4	4.1	1.9	3.4	84

APPENDIX D—ANNUAL TN AND TP LOADING RESULTS FOR WESTERN PROJECT STRUCTURES

Appendix D contains annual loading plots for the western Project structures (see Table 2). All plots have the same results presented in each panel and vary only in the constituent (TN or TP) and structure. The panels are as follows:

A. Top: Calculated annual TN or TP load in metric tons (MT). Dashed line represents annual average load over entire POR for the structure.

B. Middle: Observed annual discharge volume at structure in millions of cubic meters (MCM).

C. Bottom: Observed average, annual TN or TP concentration (± one S.E.) in mg L^{-1} at WQ station used for loading calculation. Note that for certain structures with no long-term monitoring, a median monthly value was used for loading calculations, and therefore an annual timeseries is not displayed.

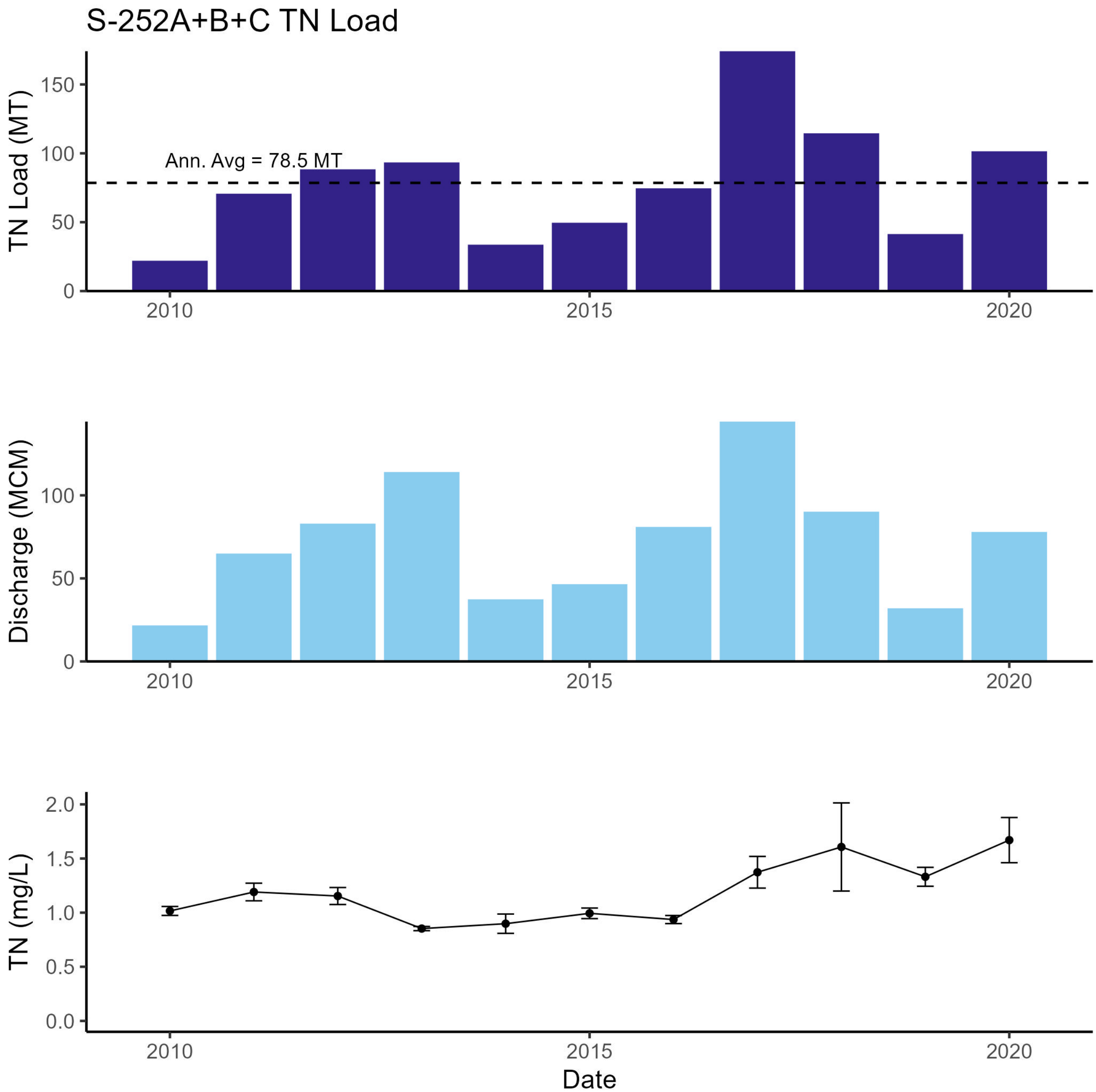

Figure D-1. S-252A, B, and C annual TN load, discharge, and average TN concentrations. See the beginning of Appendix D for an explanation of each panel.

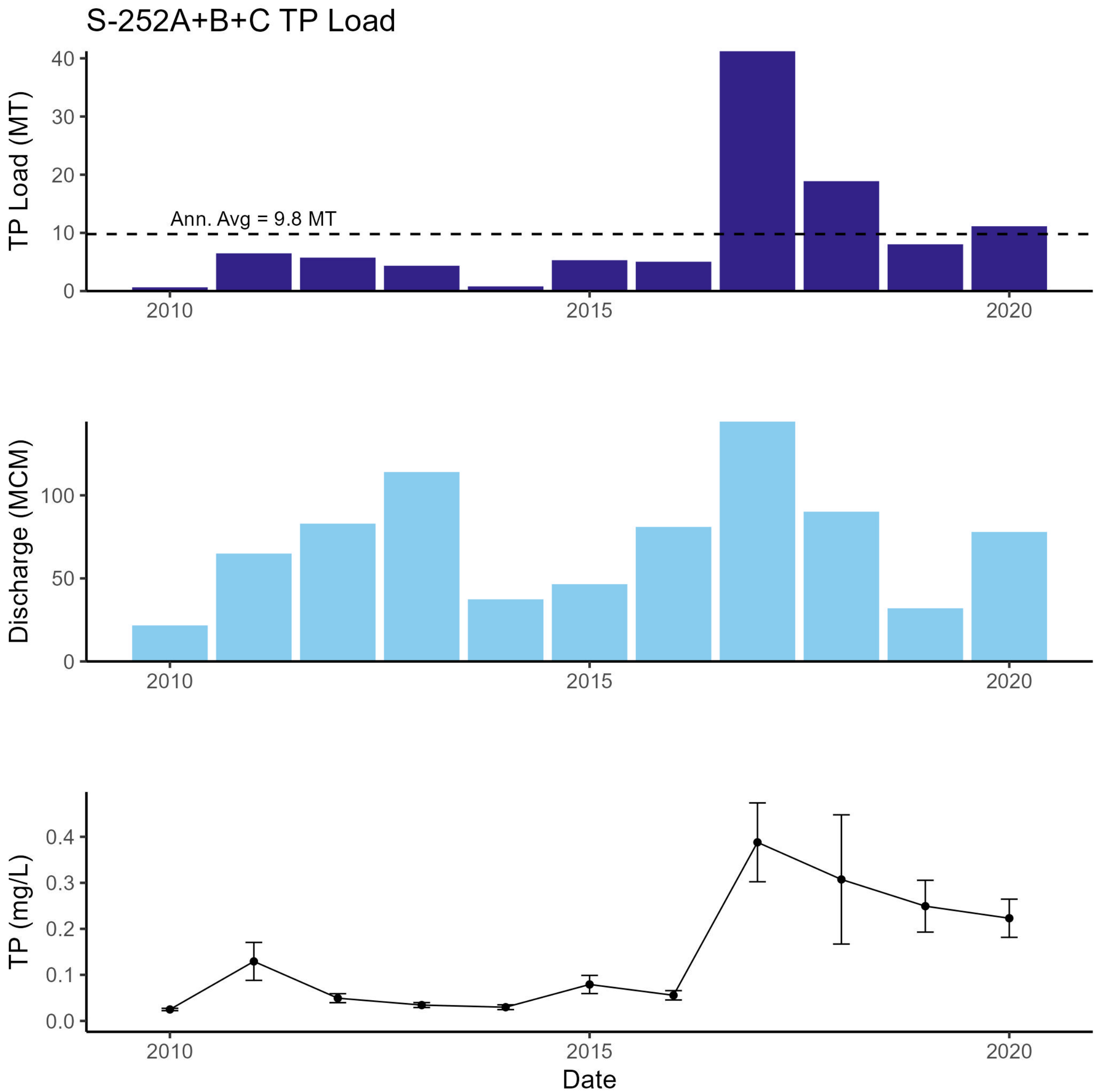

Figure D-2. S-252A, B, and C annual TP load, discharge, and average TP concentrations. See the beginning of Appendix D for an explanation of each panel.

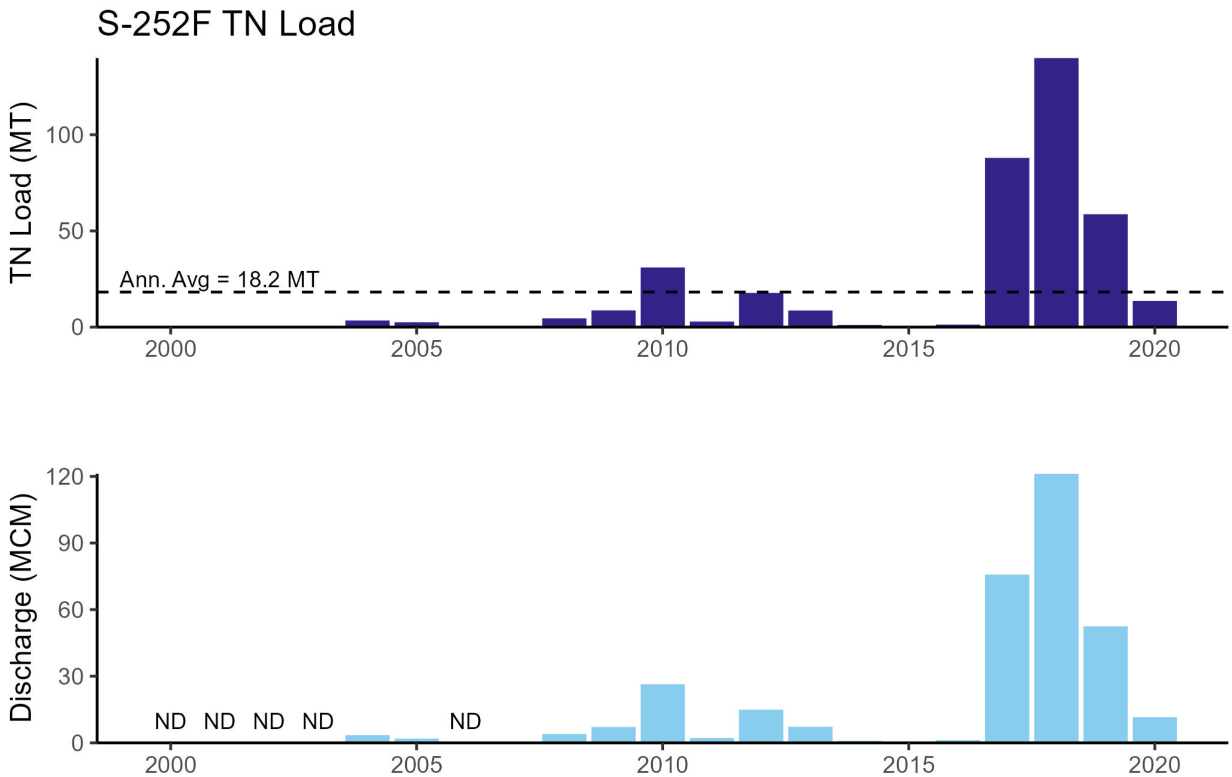

Figure D-3. S-252F annual TN load and discharge. See the beginning of Appendix D for an explanation of each panel. ND = no discharge.

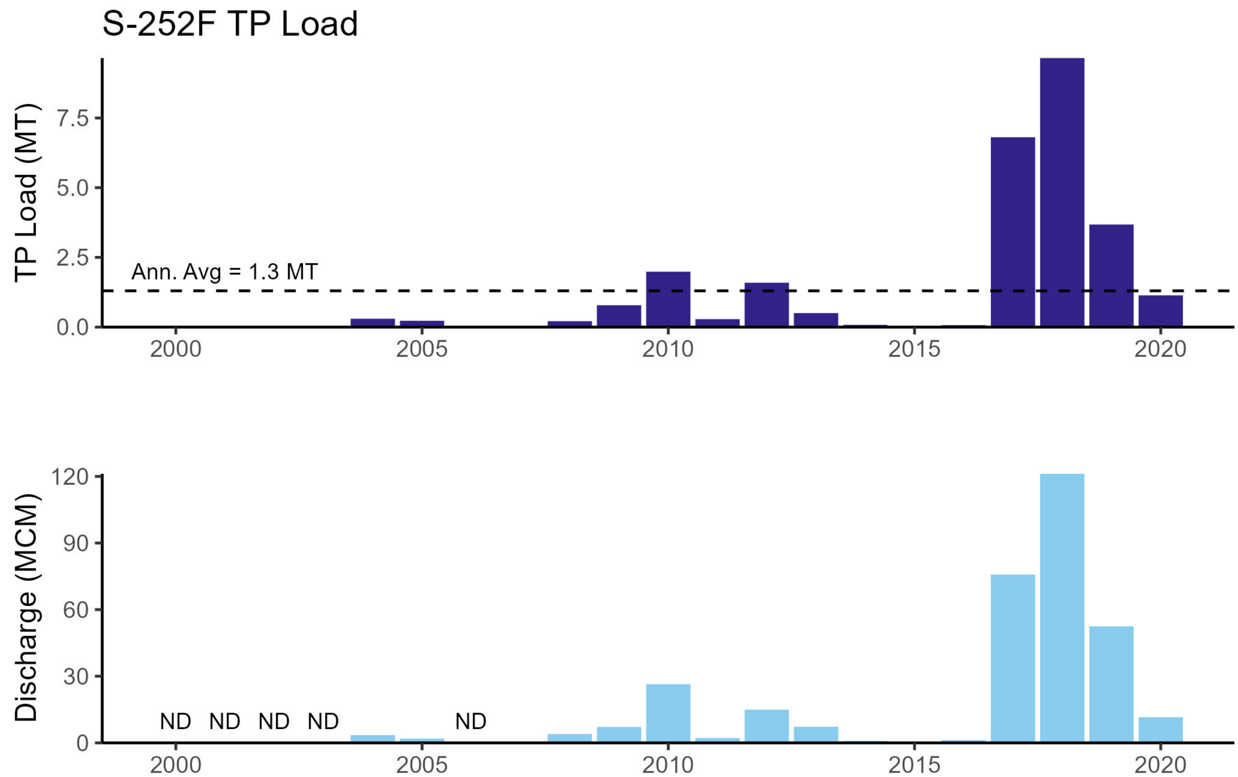

Figure D-4. S-252F annual TP load and discharge. See the beginning of Appendix D for an explanation of each panel. ND = no discharge.

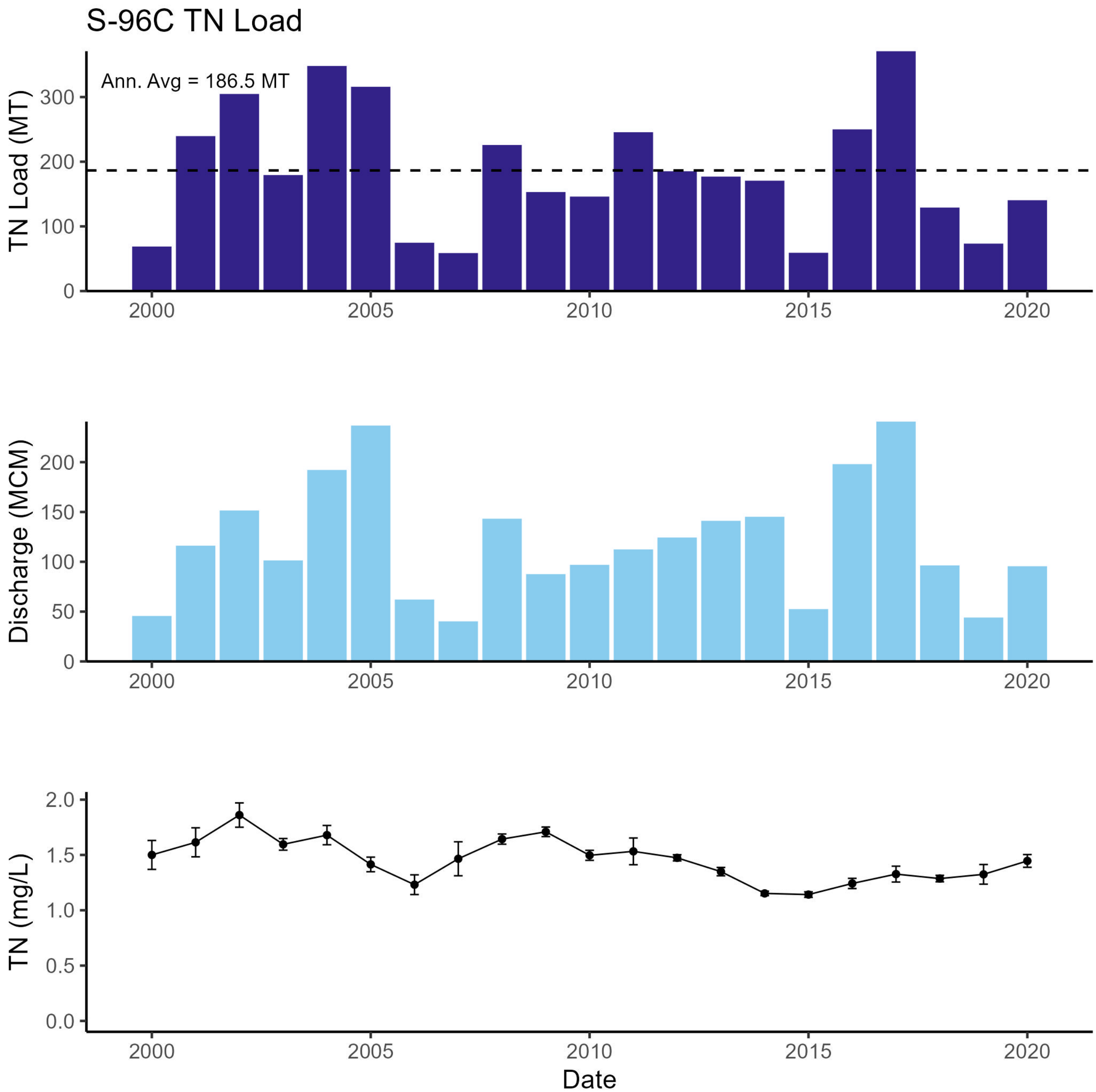

Figure D-5. S-96C annual TN load, discharge, and average TN concentrations. See the beginning of Appendix D for an explanation of each panel.

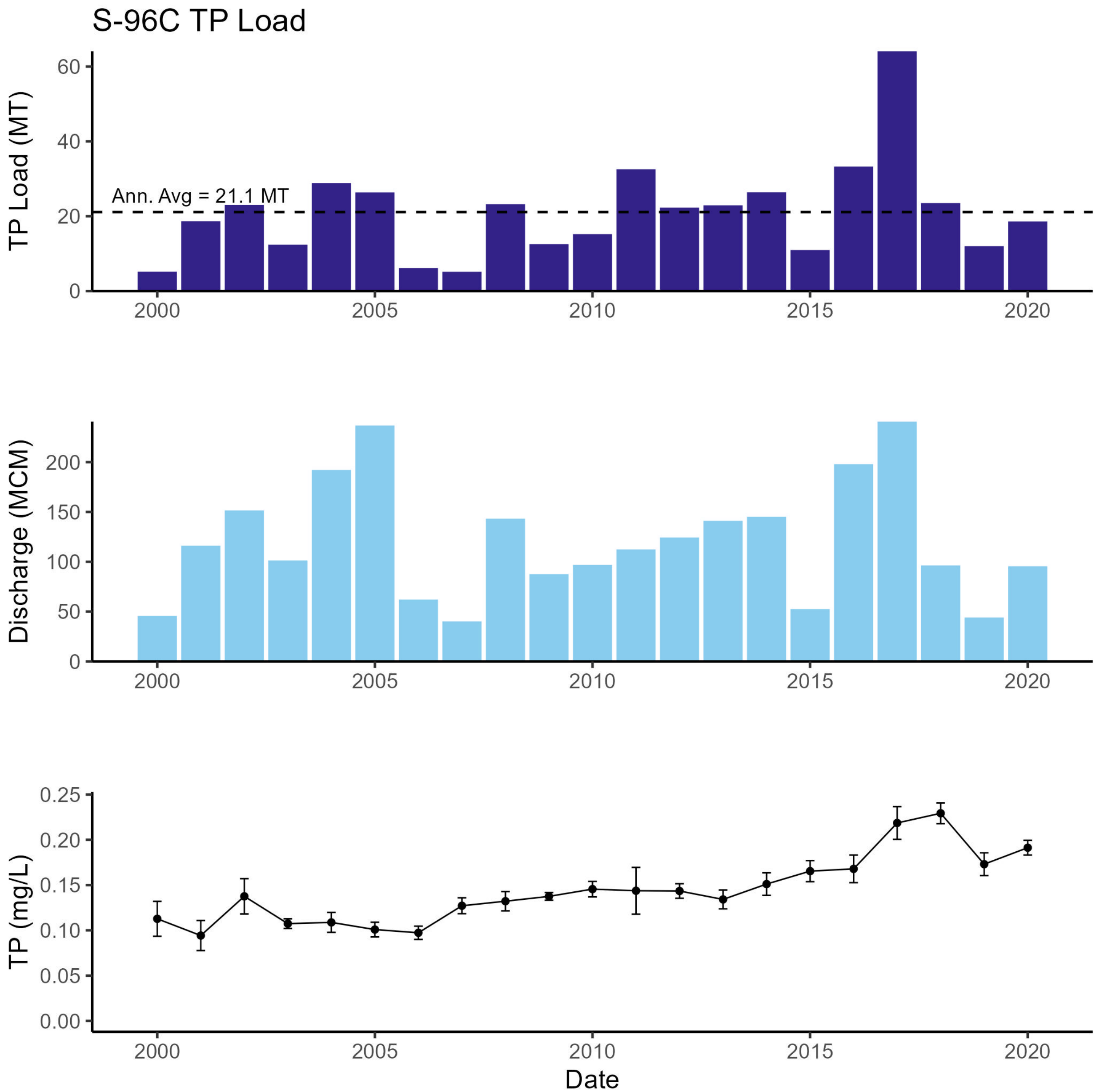

Figure D-6. S-96C annual TP load, discharge, and average TP concentrations. See the beginning of Appendix D for an explanation of each panel.

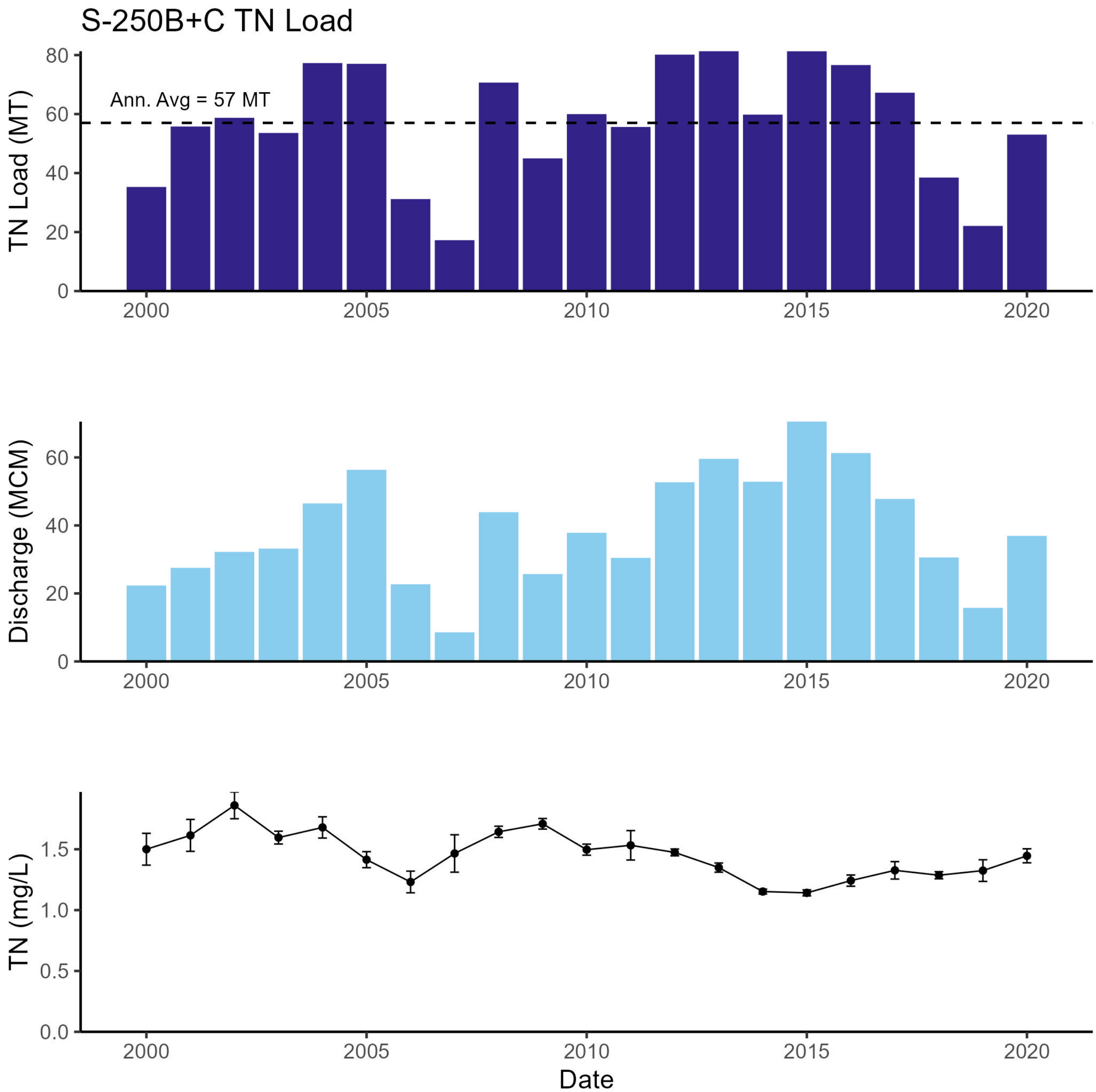

Figure D-7. S-250B and C annual TN load, discharge, and average TN concentrations. See the beginning of Appendix D for an explanation of each panel.

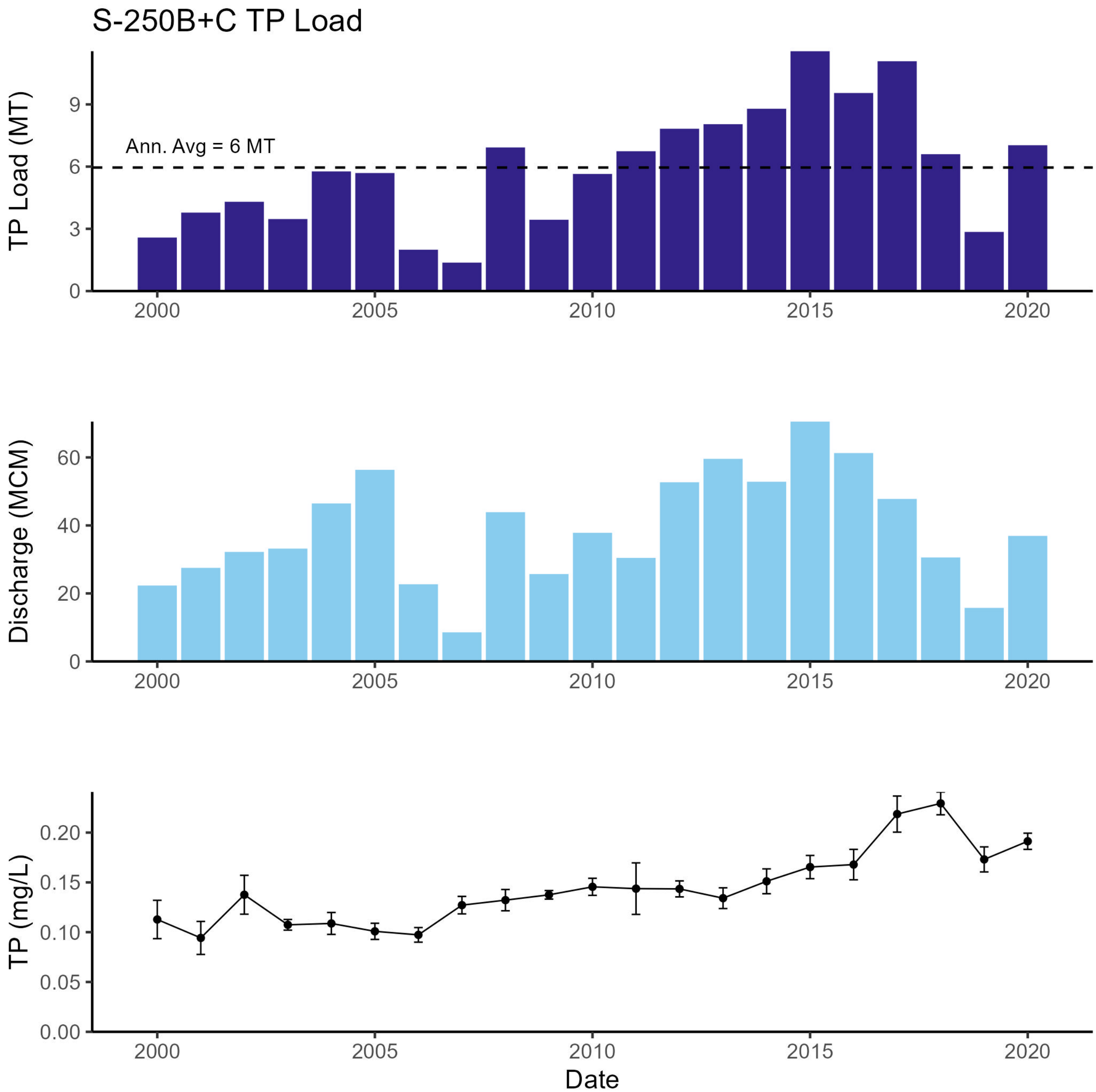

Figure D-8. S-250B and C annual TP load, discharge, and average TP concentrations. See the beginning of Appendix D for an explanation of each panel.

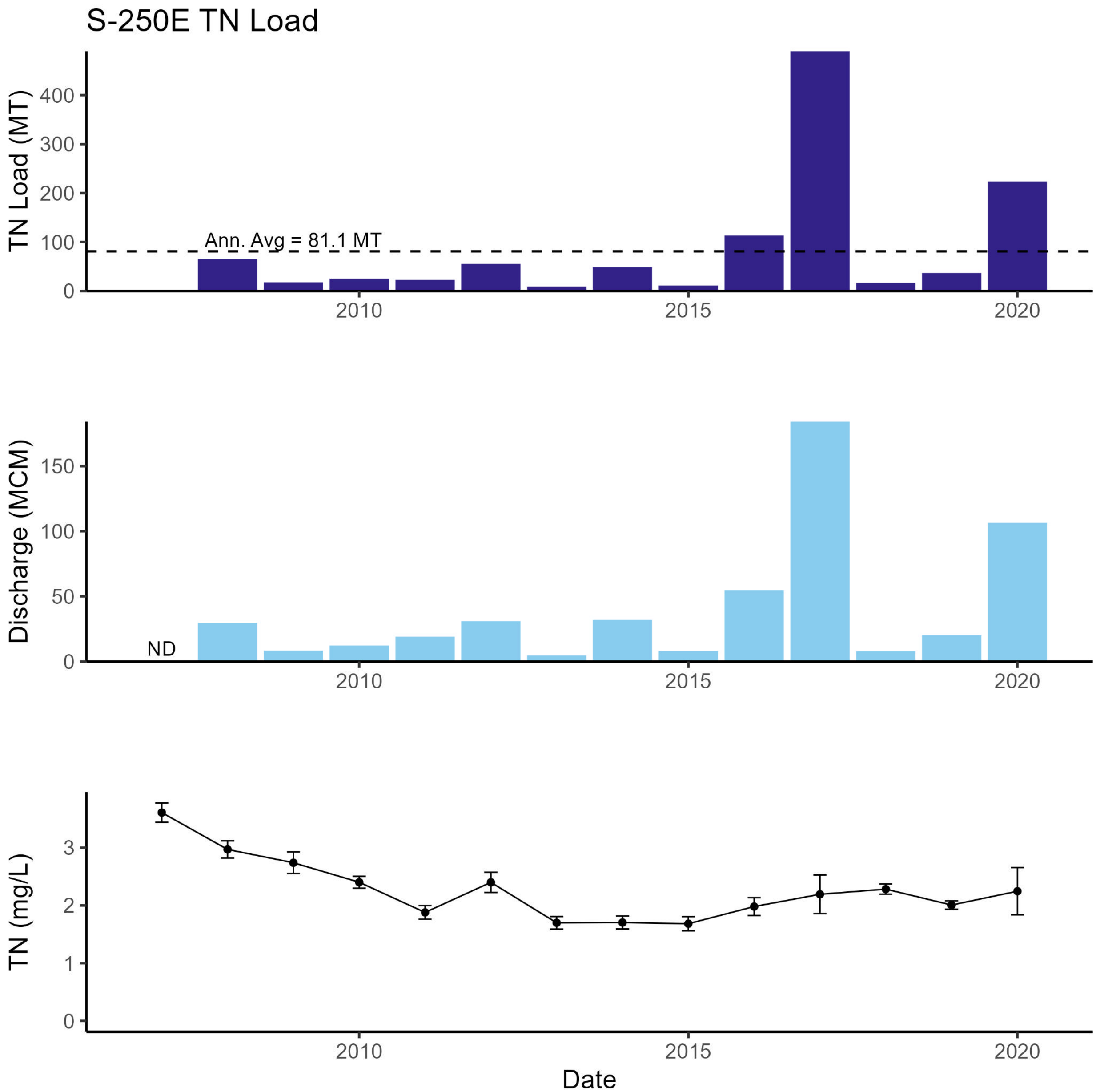

Figure D-9. S-250E annual TN load, discharge, and average TN concentrations. See the beginning of Appendix D for an explanation of each panel. ND = no discharge.

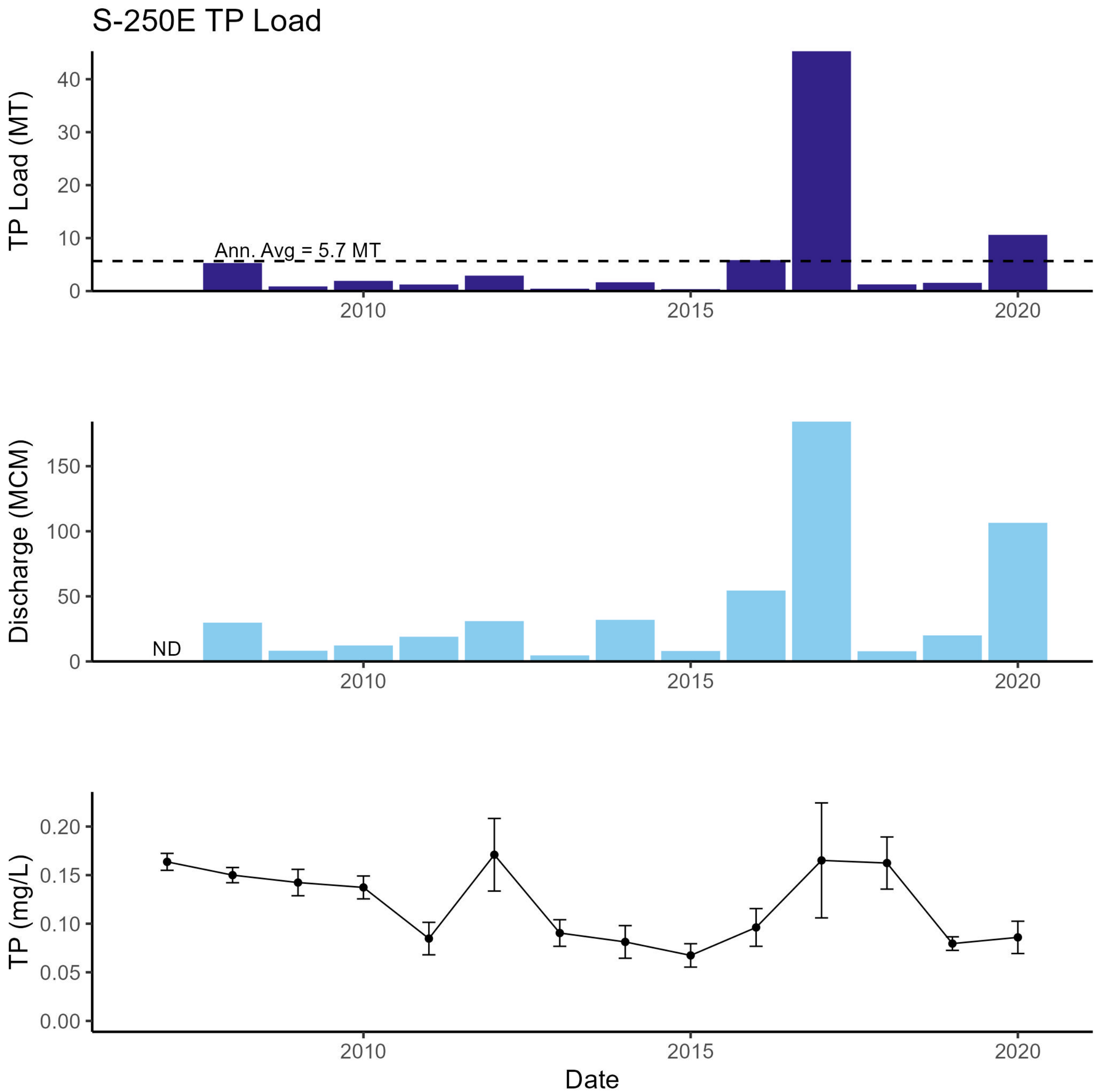

Figure D-10. S-250E annual TP load, discharge, and average TP concentrations. See the beginning of Appendix D for an explanation of each panel. ND = no discharge.

APPENDIX E—SPECIATION OF N AND P AT WATER QUALITY STATIONS OF INTEREST

Appendix E contains results from calculating additional constituent N and P species for monitoring stations used in loading calculations. Average concentrations were calculated seasonally with May through October representing the Wet season and November through April the Dry season. These average concentrations were calculated for the purposes of investigating the relative importance of dissolved versus particulate fractions and inorganic versus organic fractions within the Project. These species were calculated as follows, with analytes directly measured by the District laboratory underlined:

Total Dissolved N (TDN) = Dissolved TKN (<u>TKN-D</u>) + <u>NO_x</u>

Particulate N (PN) = (<u>TKN-T</u> + <u>NO_x</u>) – TDN

Dissolved Organic N (DON) = <u>TKN-D</u> – <u>NH_4</u>

Dissolved Inorganic N (DIN) = <u>NO_x</u> + <u>NH_4</u>

Particulate P (PP) = <u>TP</u> – Total Dissolved P (<u>TDP</u>)

Dissolved Organic P (DOP) = <u>TDP</u> – <u>PO_4</u>

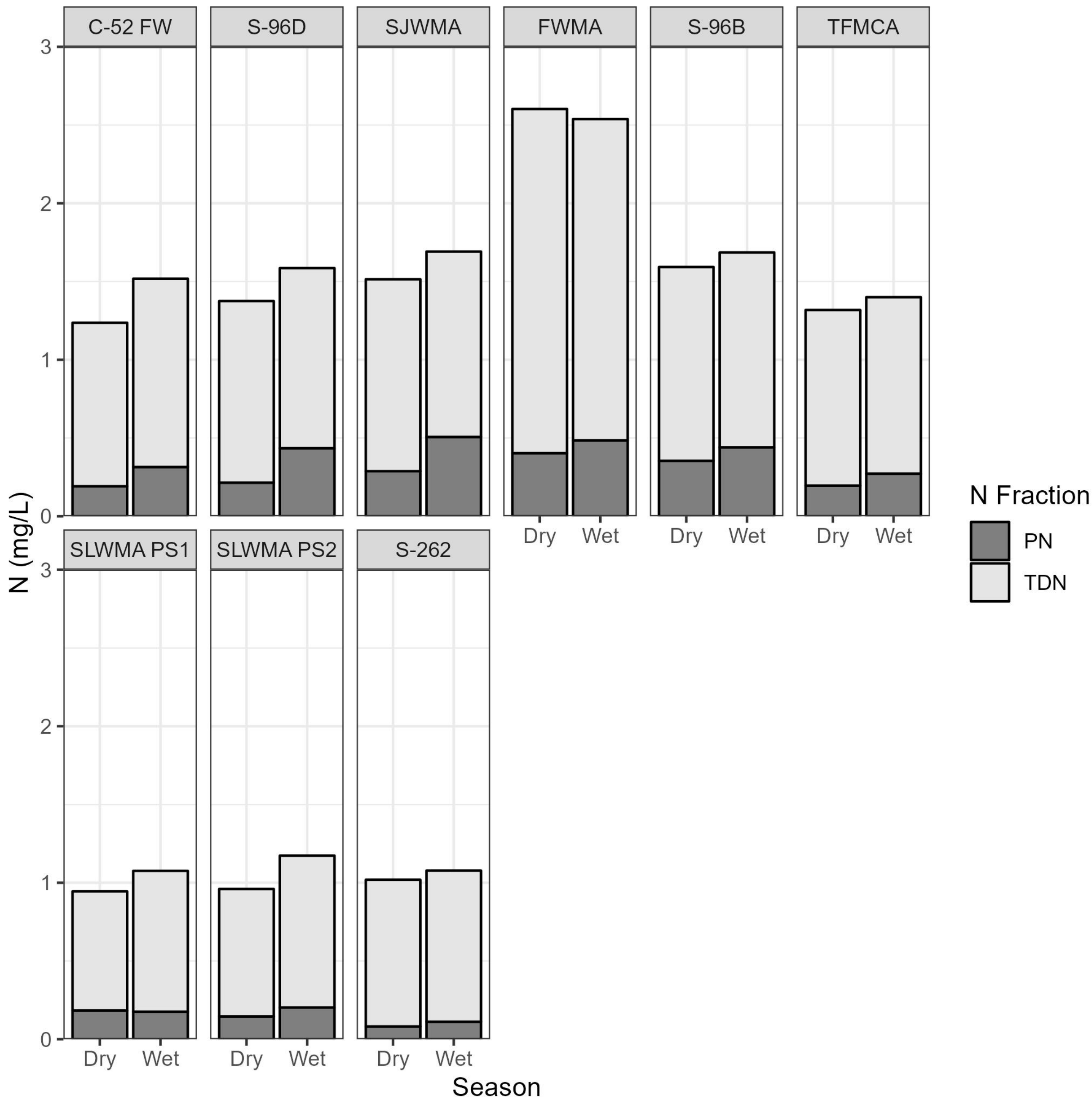

Figure E-1. Average seasonal particulate nitrogen (PN) and total dissolved nitrogen (TDN) concentrations at WQ stations in the eastern Project.

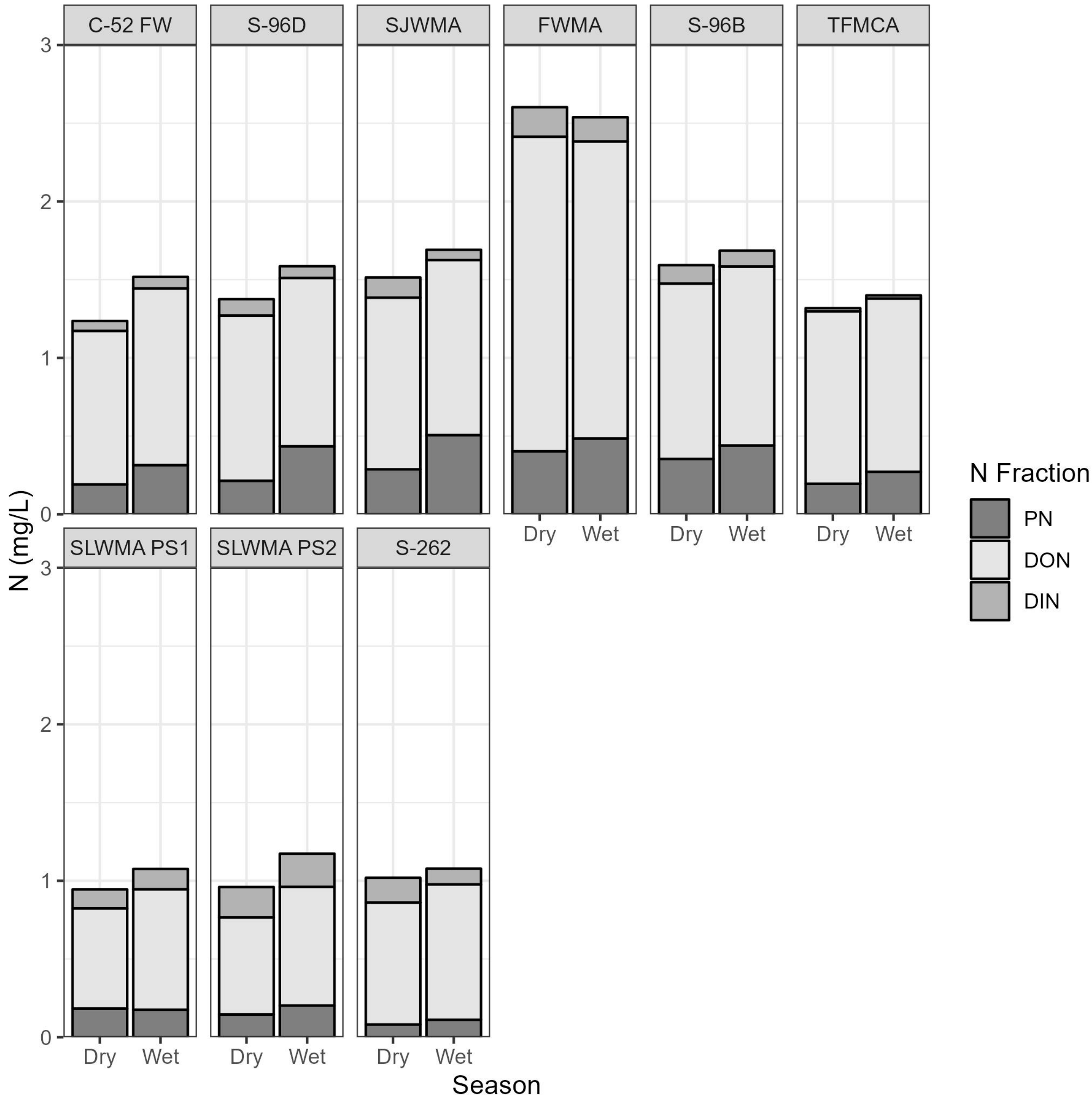

Figure E-2. Average seasonal particulate nitrogen (PN), dissolved organic nitrogen (TDN), and dissolved inorganic nitrogen (DIN) concentrations at WQ stations in the eastern Project.

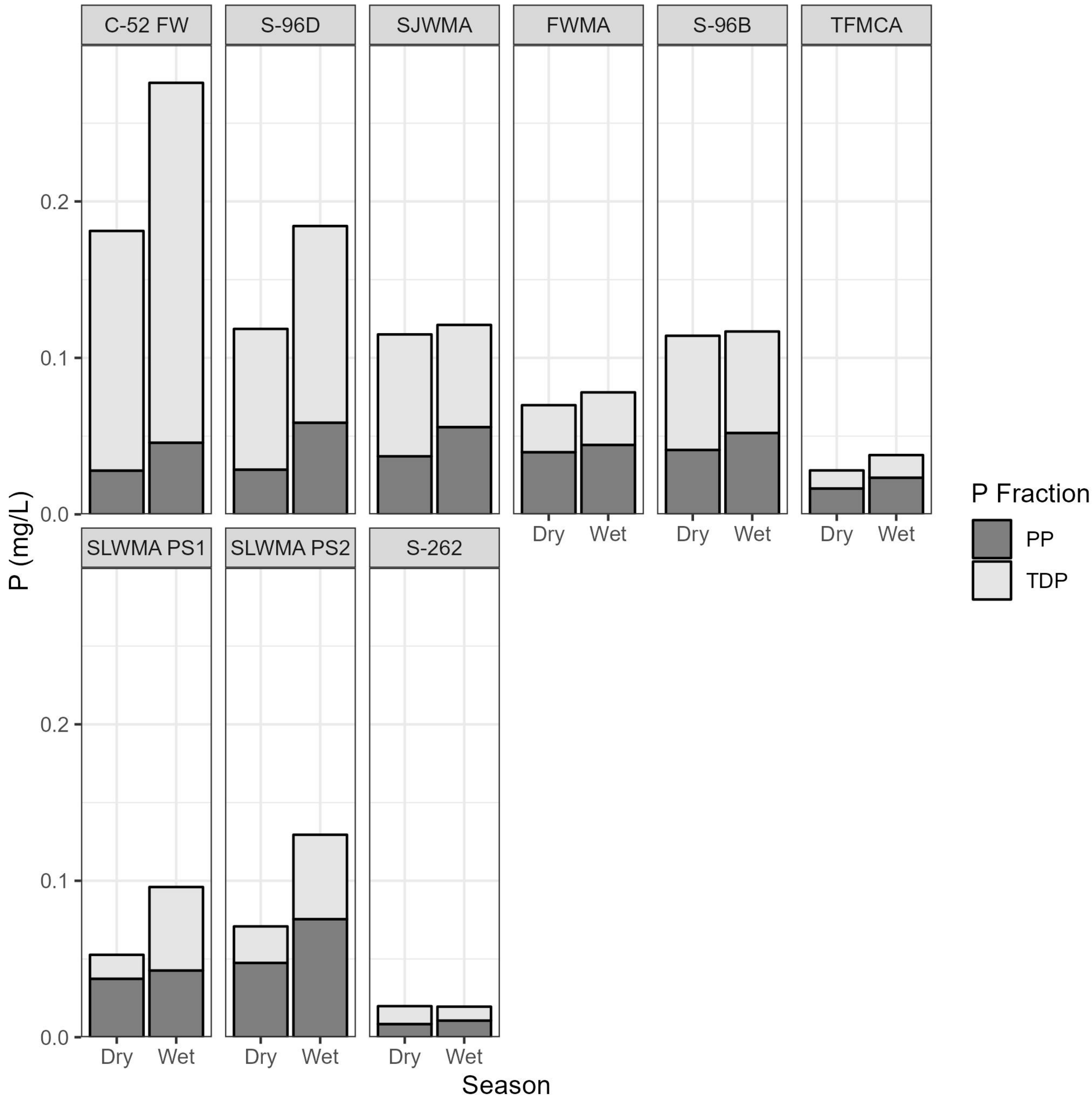

Figure E-3. Average seasonal particulate phosphorus (PP) and total dissolved phosphorus (TDP) concentrations at WQ stations in the eastern Project.

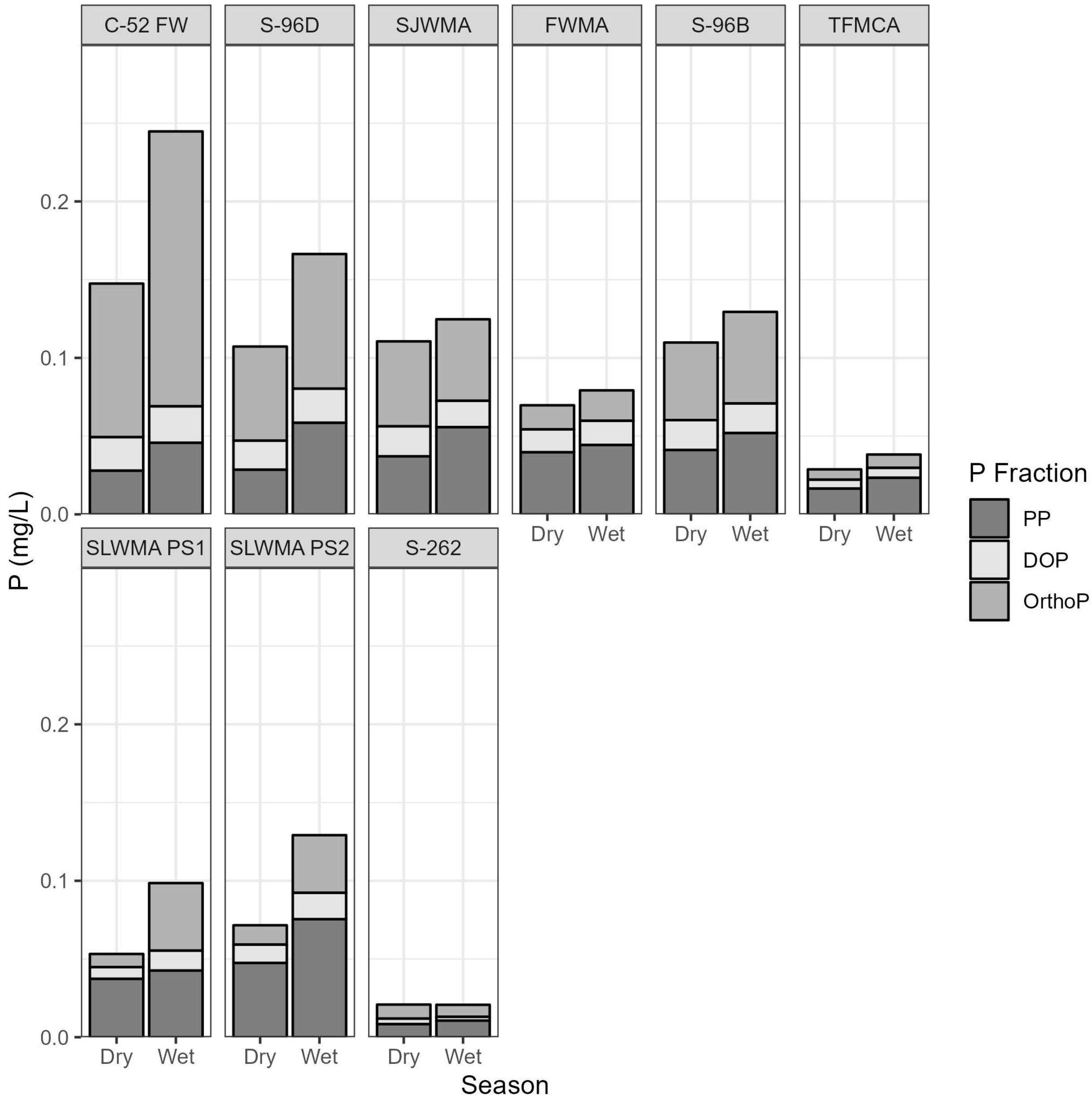

Figure E-4. Average seasonal particulate phosphorus (PP), dissolved organic phosphorus (DOP), and orthophosphate (OrthoP) concentrations at WQ stations in the eastern Project.

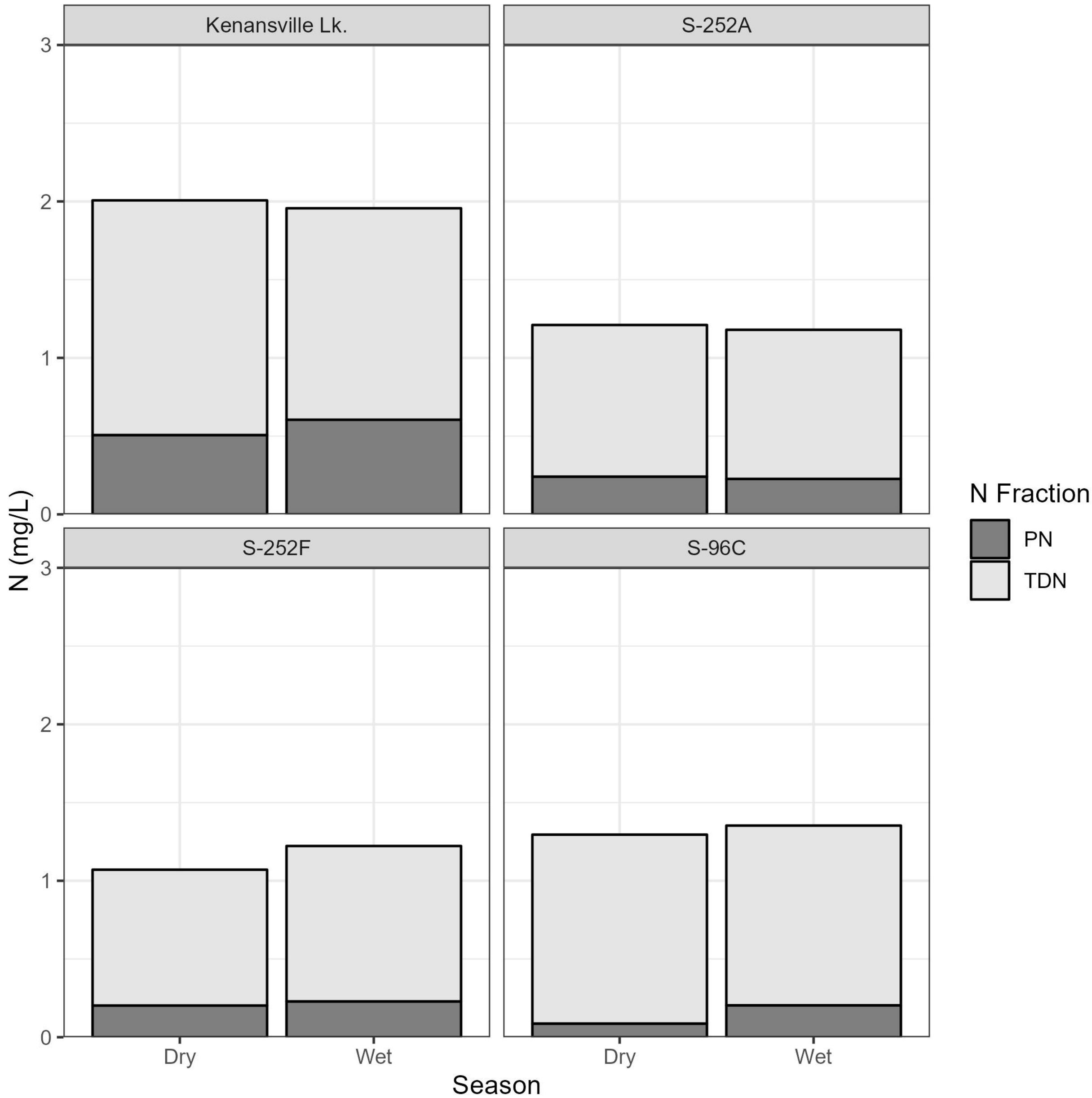

Figure E-5. Average seasonal particulate nitrogen (PN) and total dissolved nitrogen (TDN) concentrations at WQ stations in the western Project.

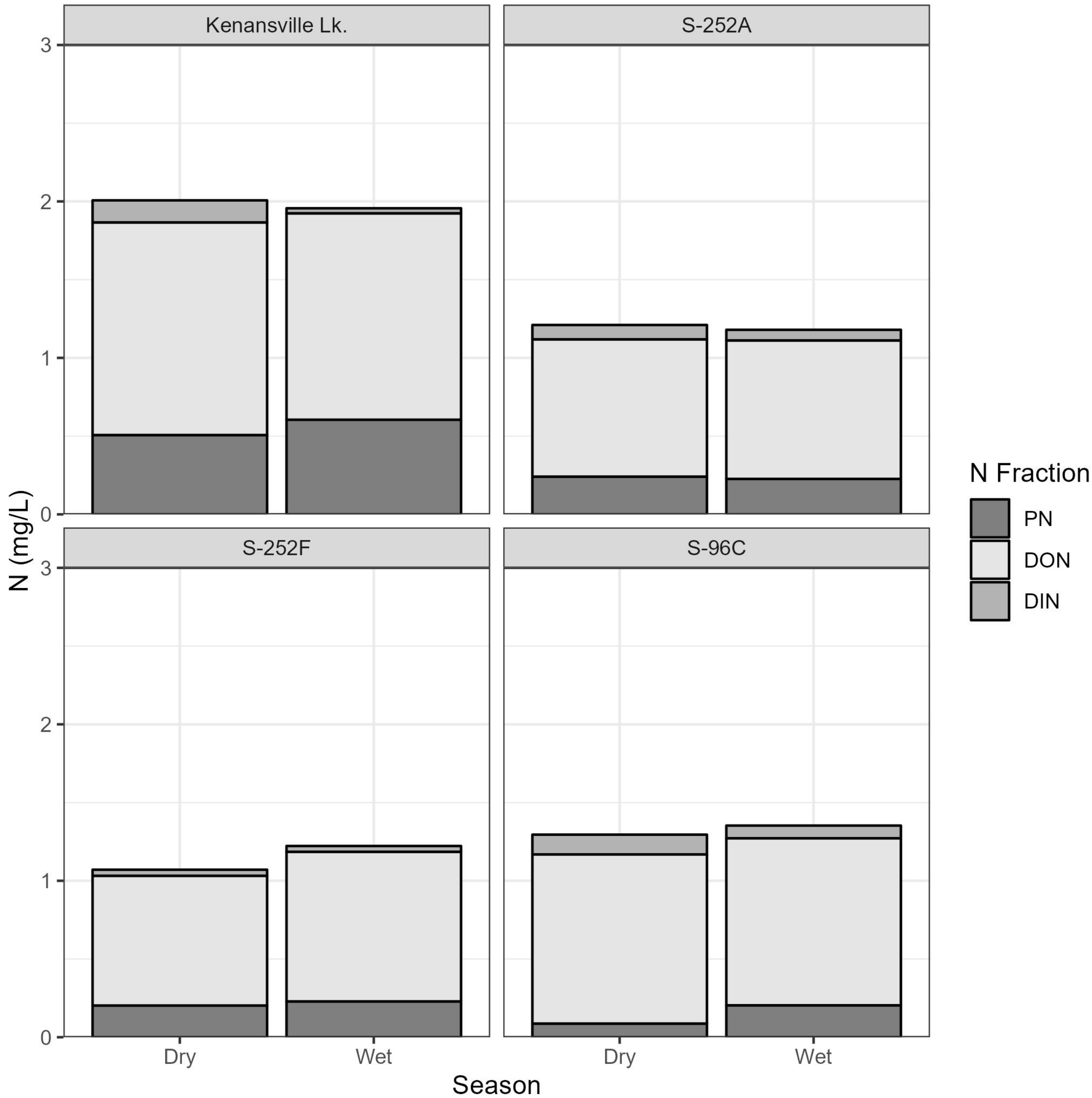

Figure E-6. Average seasonal particulate nitrogen (PN), dissolved organic nitrogen (DON), and dissolved inorganic nitrogen (DIN) concentrations at WQ stations in the western Project.

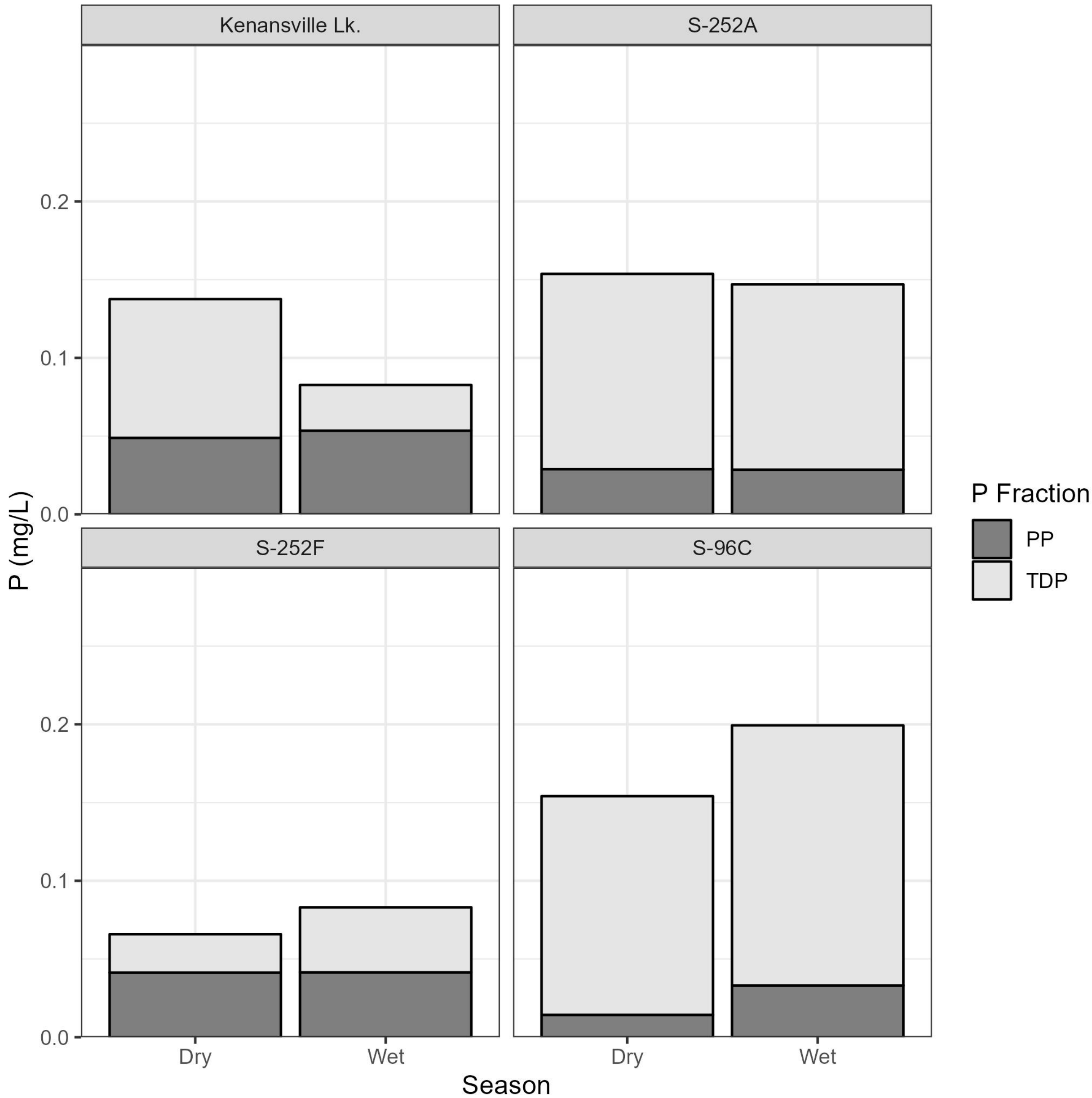

Figure E-7. Average seasonal particulate phosphorus (PP) and total dissolved phosphorus (TDP) concentrations at WQ stations in the western Project.

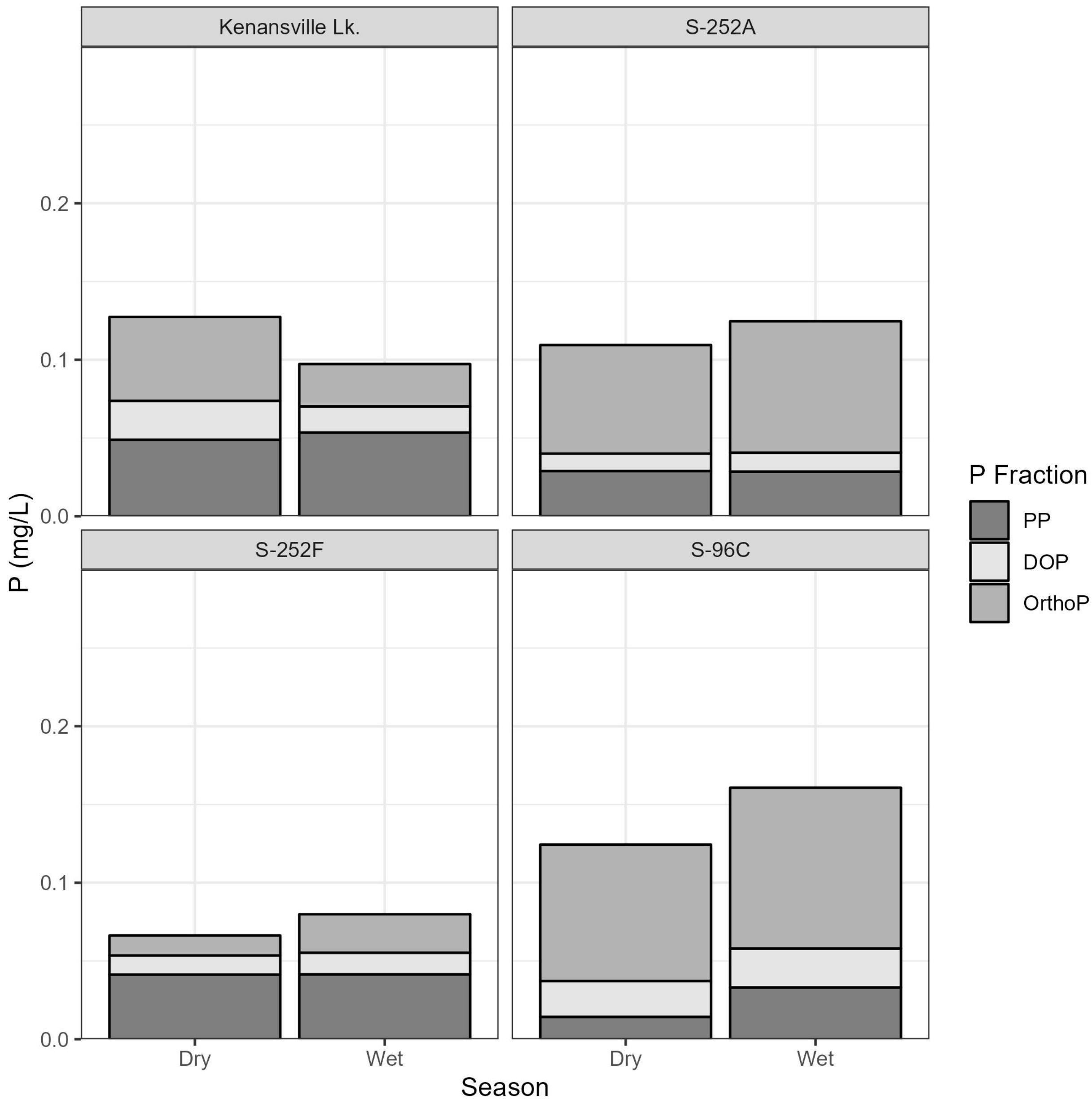

Figure E-8. Average seasonal particulate phosphorus (PP), dissolved organic phosphorus (DOP), and orthophosphate (OrthoP) concentrations at WQ stations in the western Project.

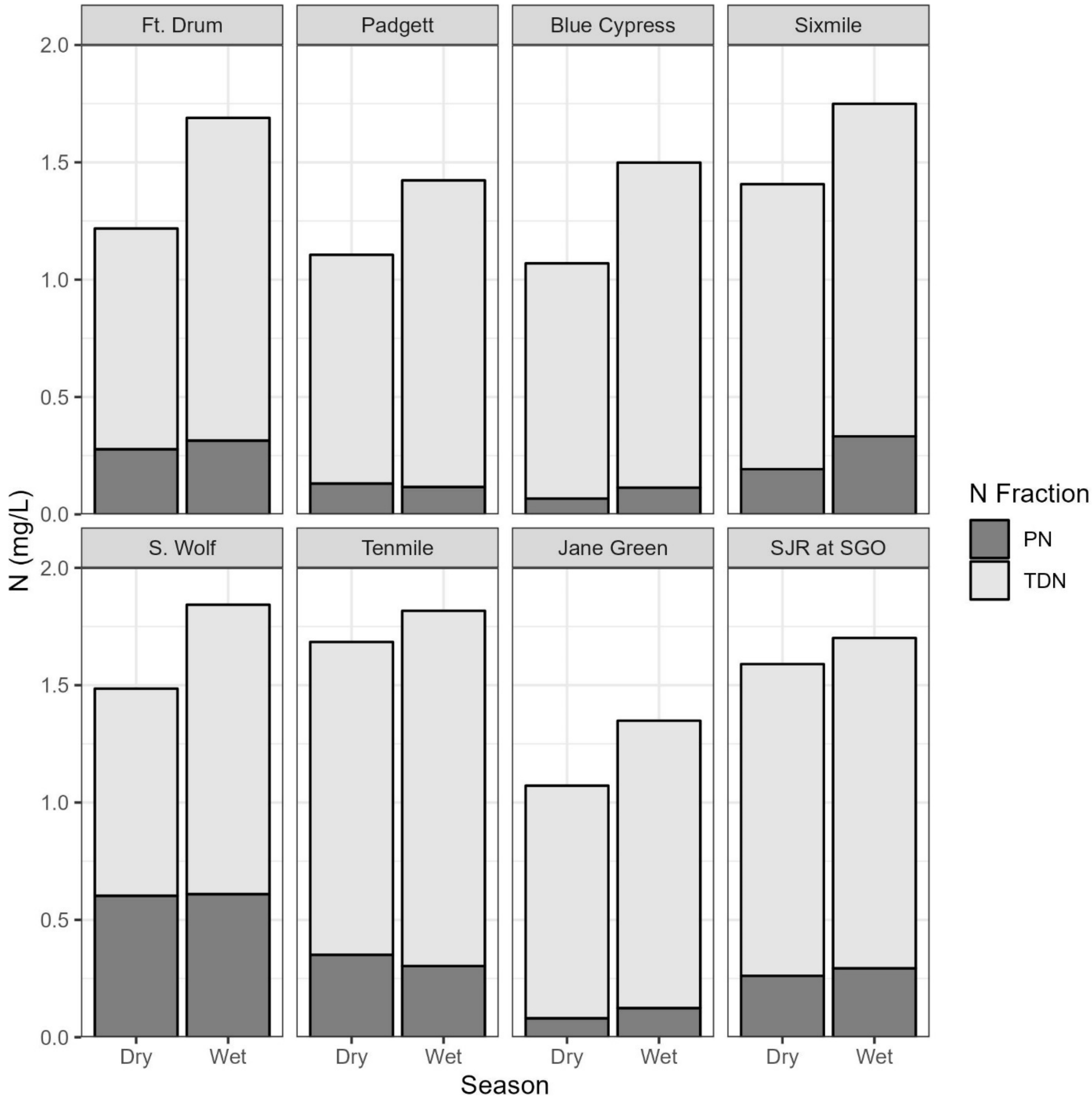

Figure E-9. Average seasonal particulate nitrogen (PN) and total dissolved nitrogen (TDN) concentrations at WQ stations in the western tributaries.

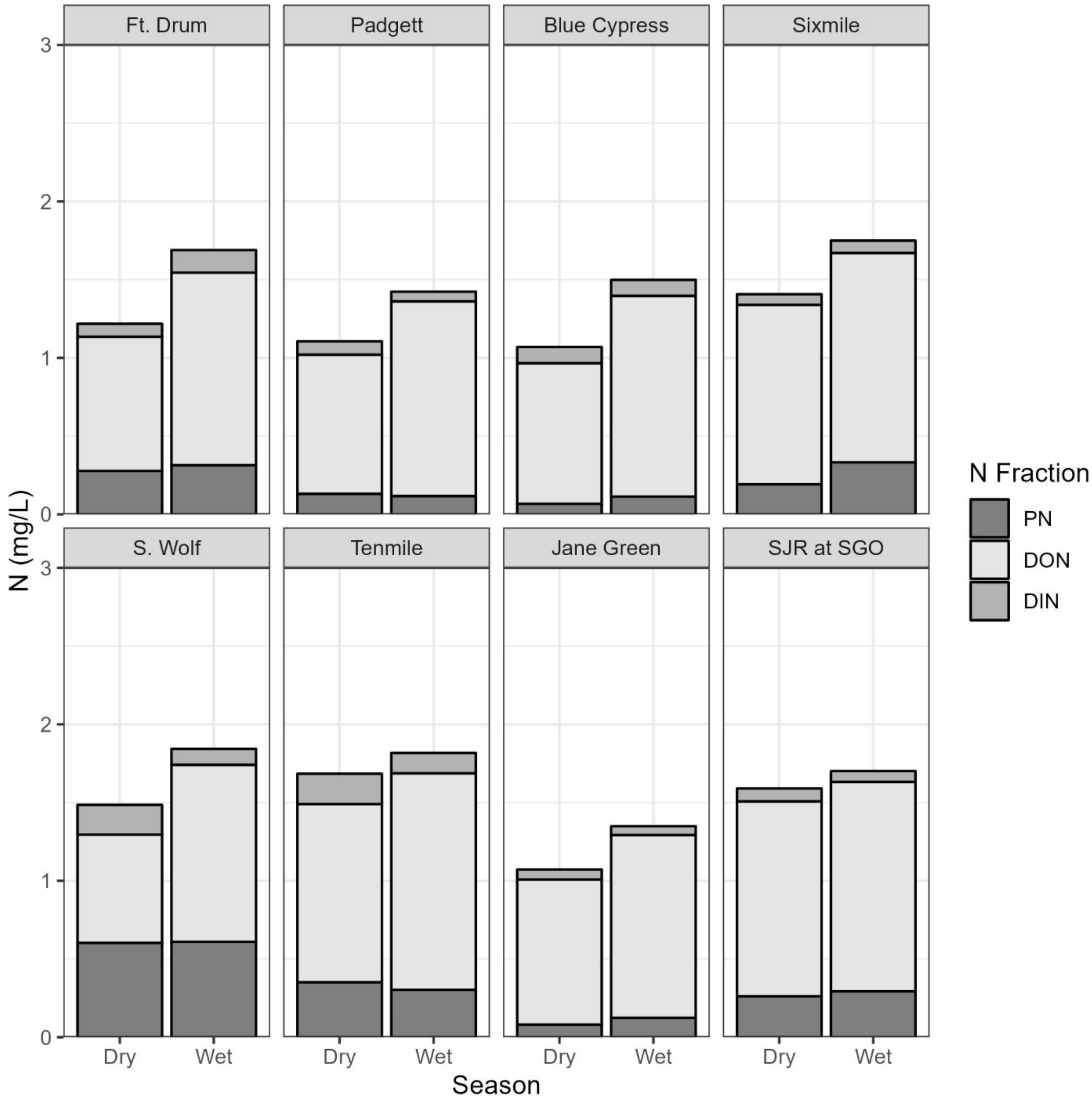

Figure E-10. Average seasonal particulate nitrogen (PN), dissolved organic nitrogen (DON), and dissolved inorganic nitrogen (DIN) concentrations at WQ stations in the western tributaries.

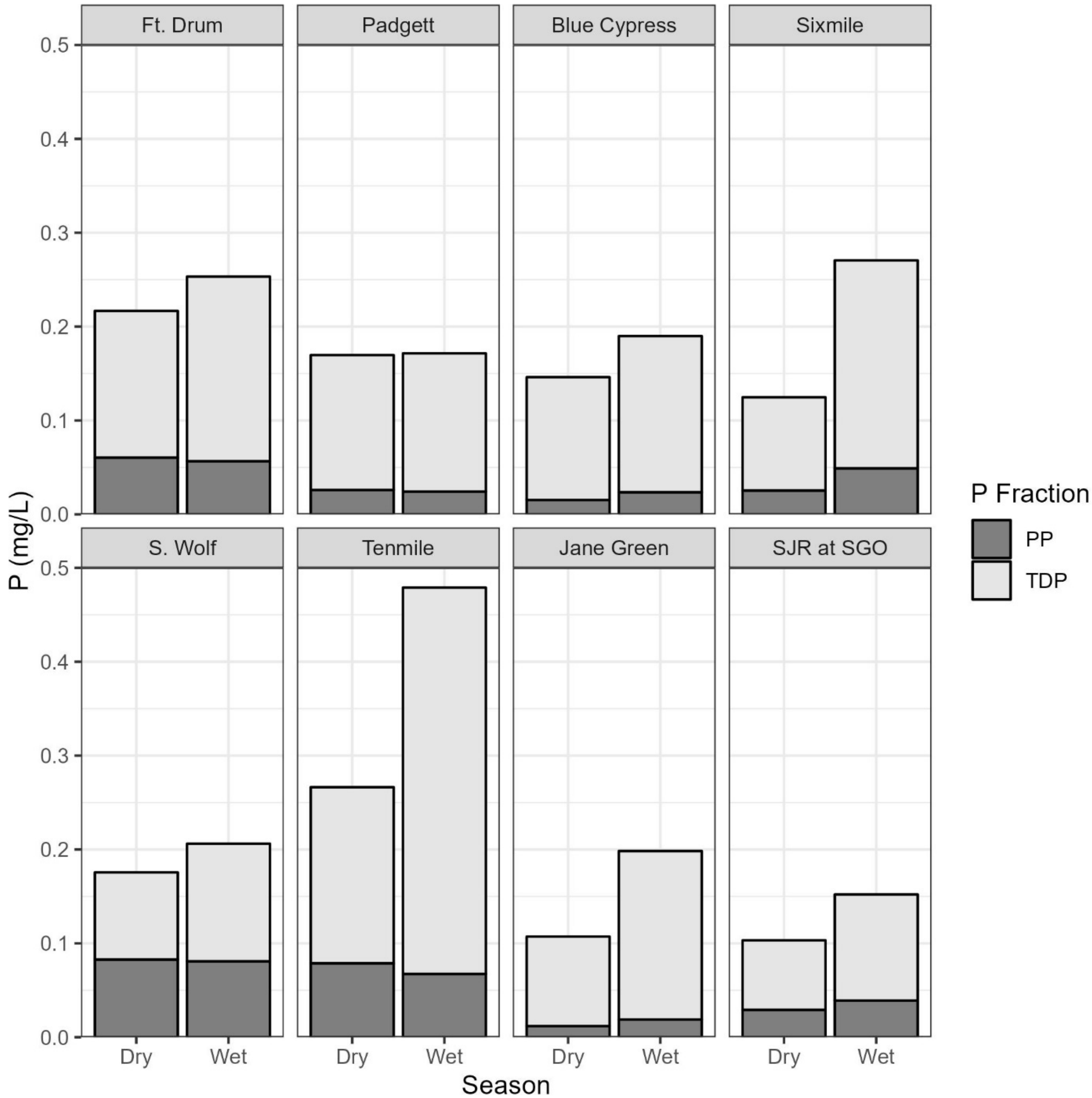

Figure E-11. Average seasonal particulate phosphorus (PP) and total dissolved phosphorus (TDP) concentrations at WQ stations in the western tributaries.

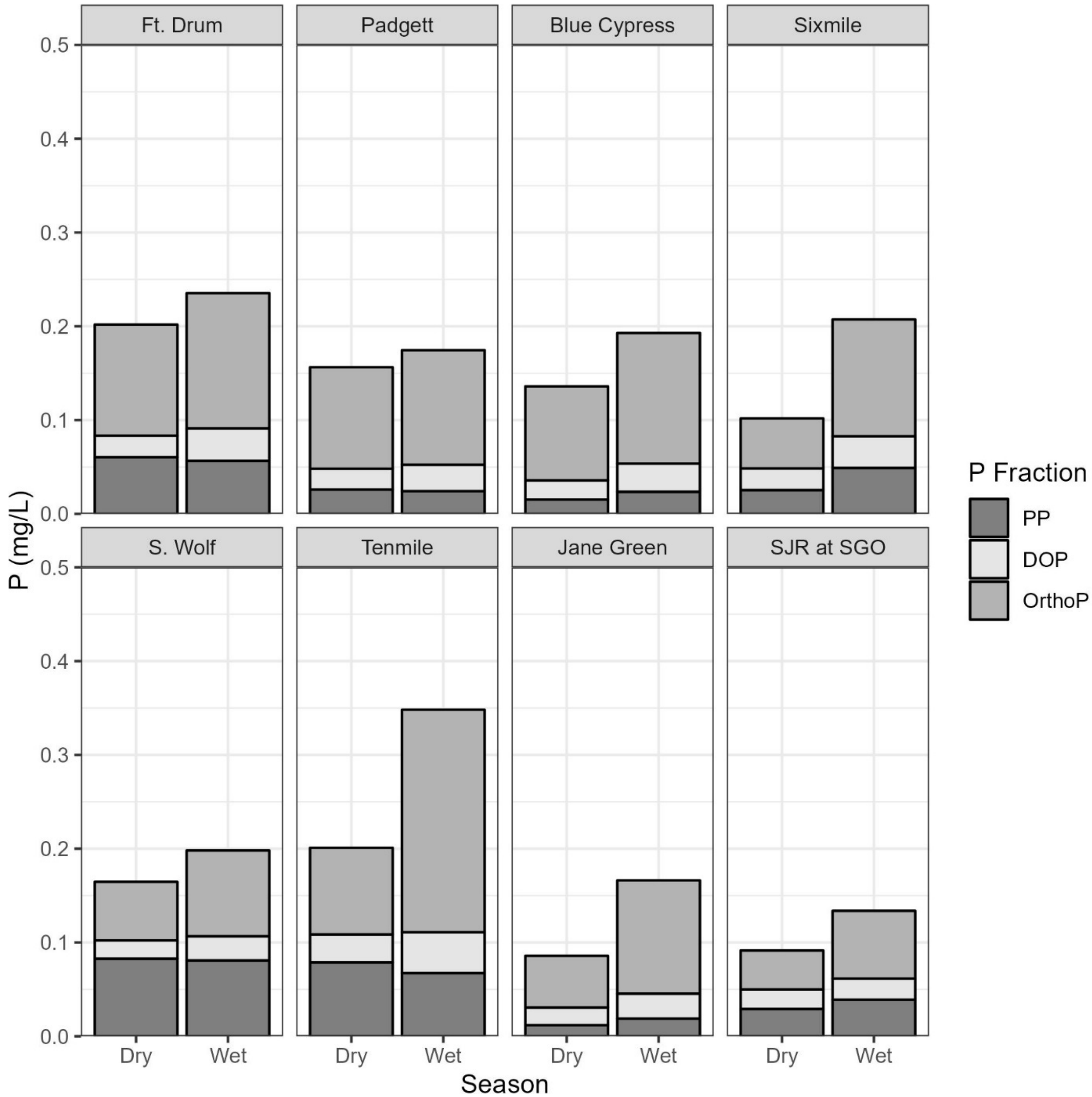

Figure E-12. Average seasonal particulate phosphorus (PP), dissolved organic phosphorus (DOP), and orthophosphate (OrthoP) concentrations at WQ stations in the western tributaries.

APPENDIX F—MONTHLY TN AND TP LOADING RESULTS FOR EASTERN PROJECT STRUCTURES

Appendix F contains monthly loading plots for the eastern Project structures (see Table 1). All plots have the same results presented in each panel and vary only in the constituent (TN or TP) and structure. The panels are as follows:

A. Top: Calculated monthly TN or TP load in metric tons (MT).

B. Middle: Observed monthly discharge volume at structure in millions of cubic meters (MCM).

C. Bottom: Observed TN or TP concentration (generally monthly) in mg L^{-1} at WQ station used for loading calculation.

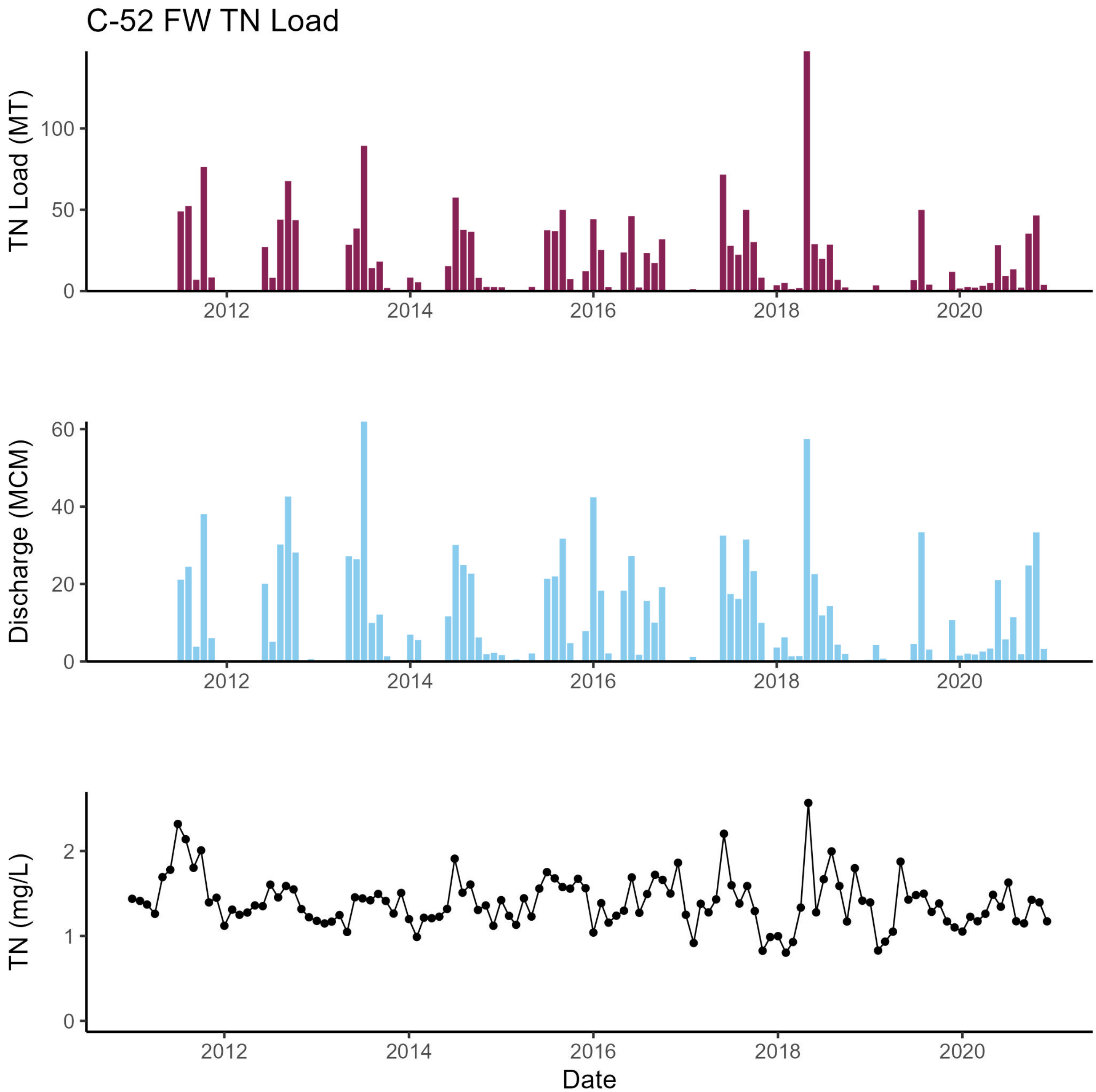

Figure F-1. C-52 flow way monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

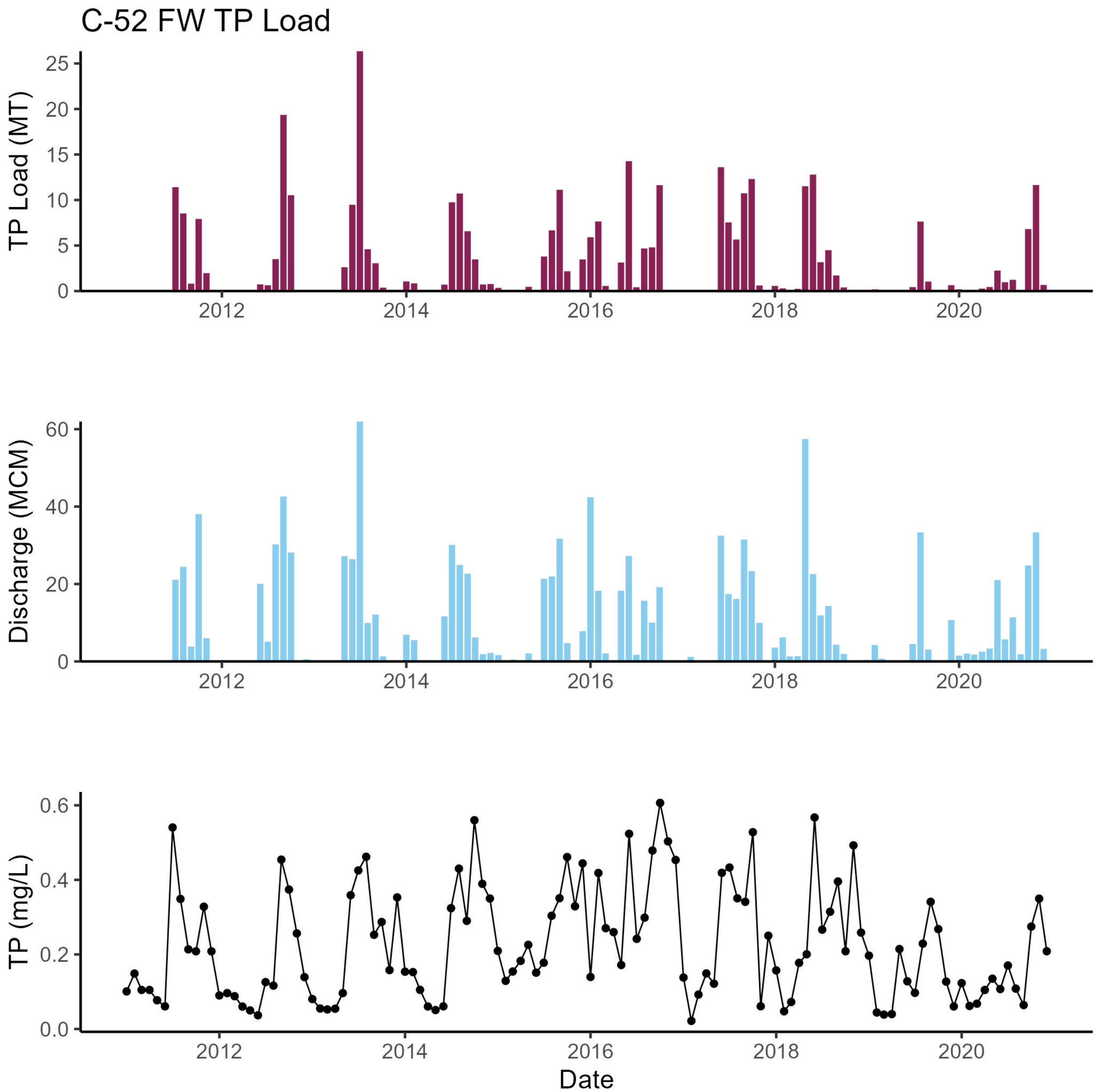

Figure F-2. C-52 flow way monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

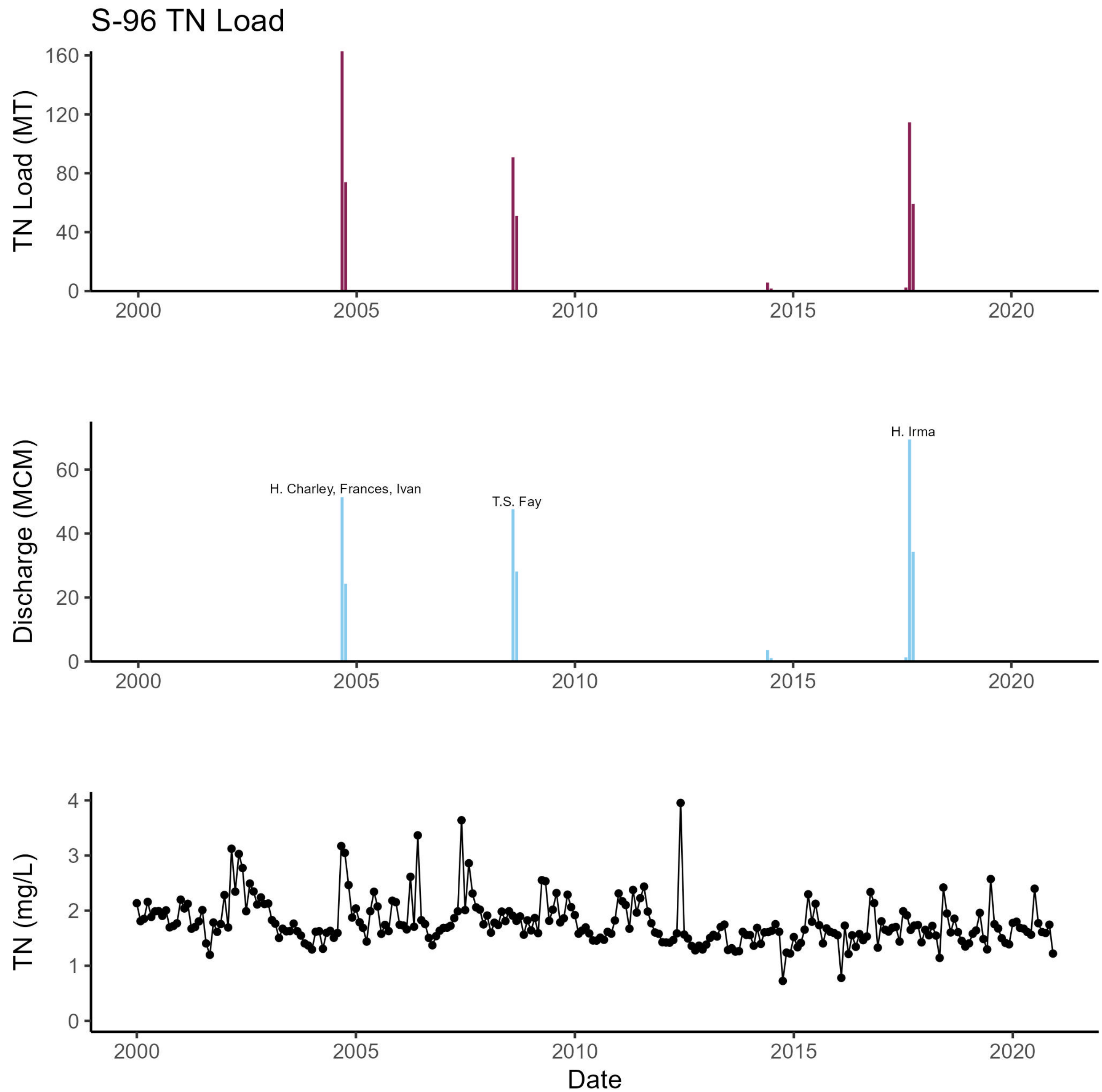

Figure F-3. S-96 monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

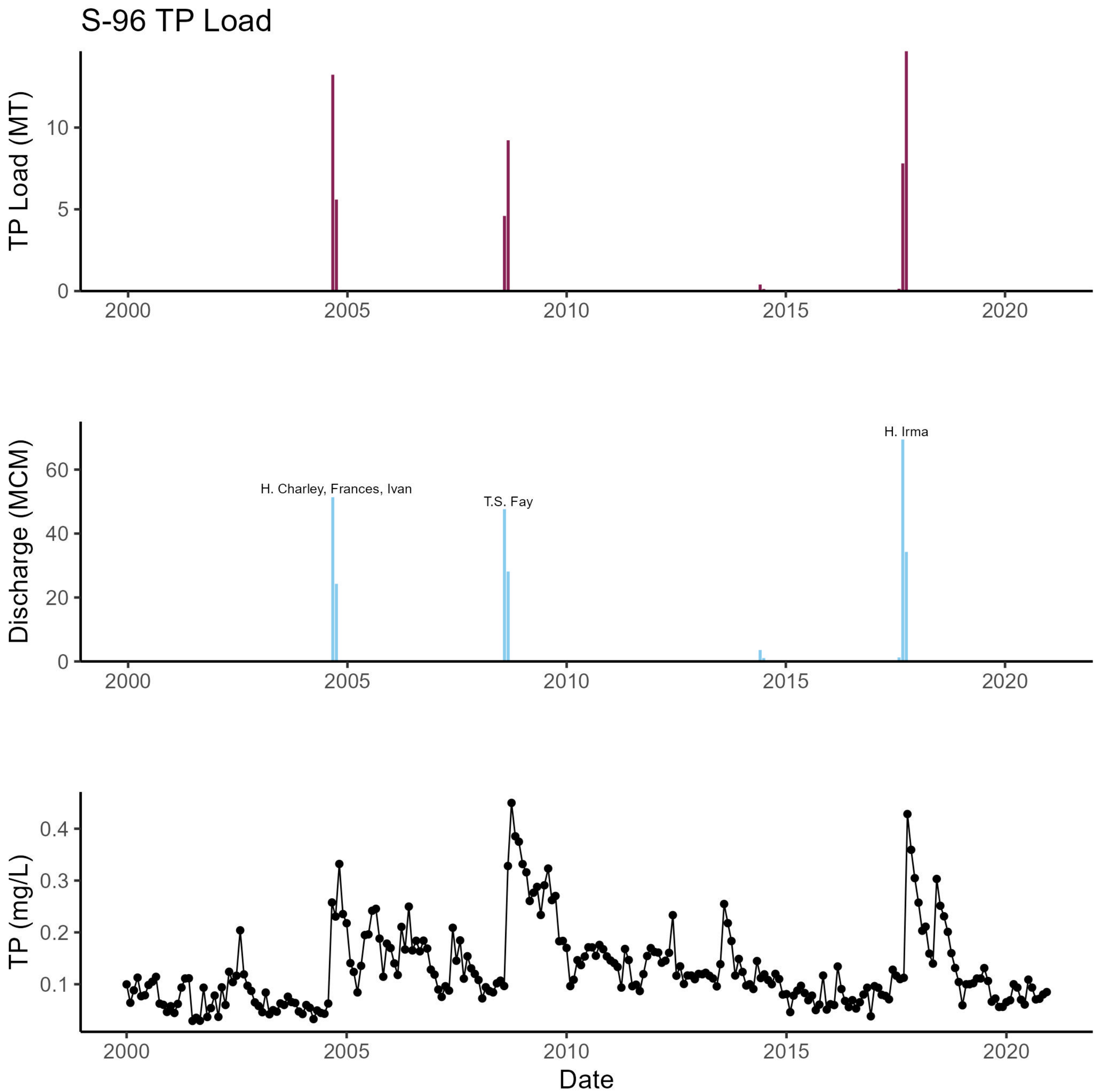

Figure F-4. S-96 monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

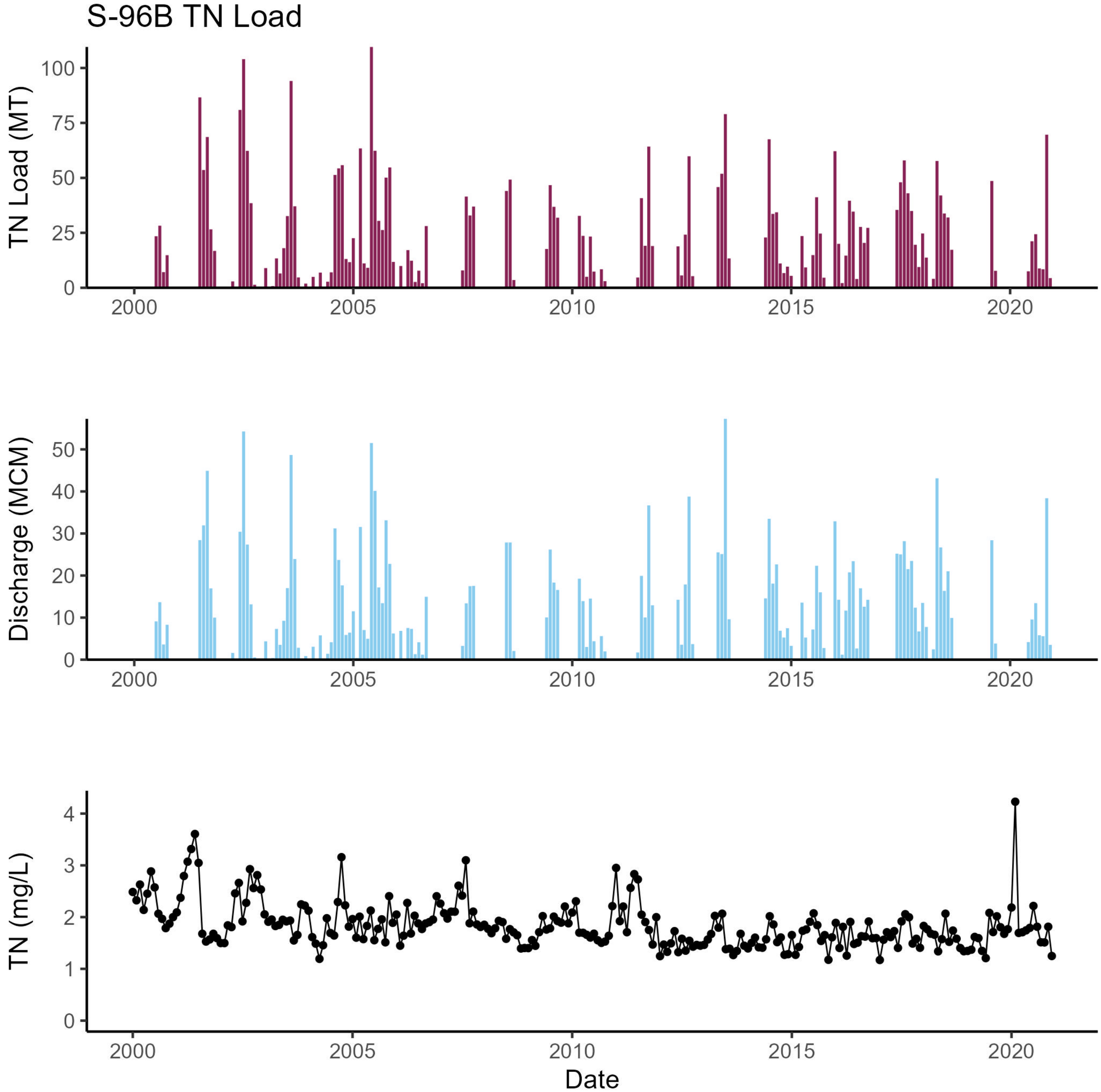

Figure F-5. S-96B monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

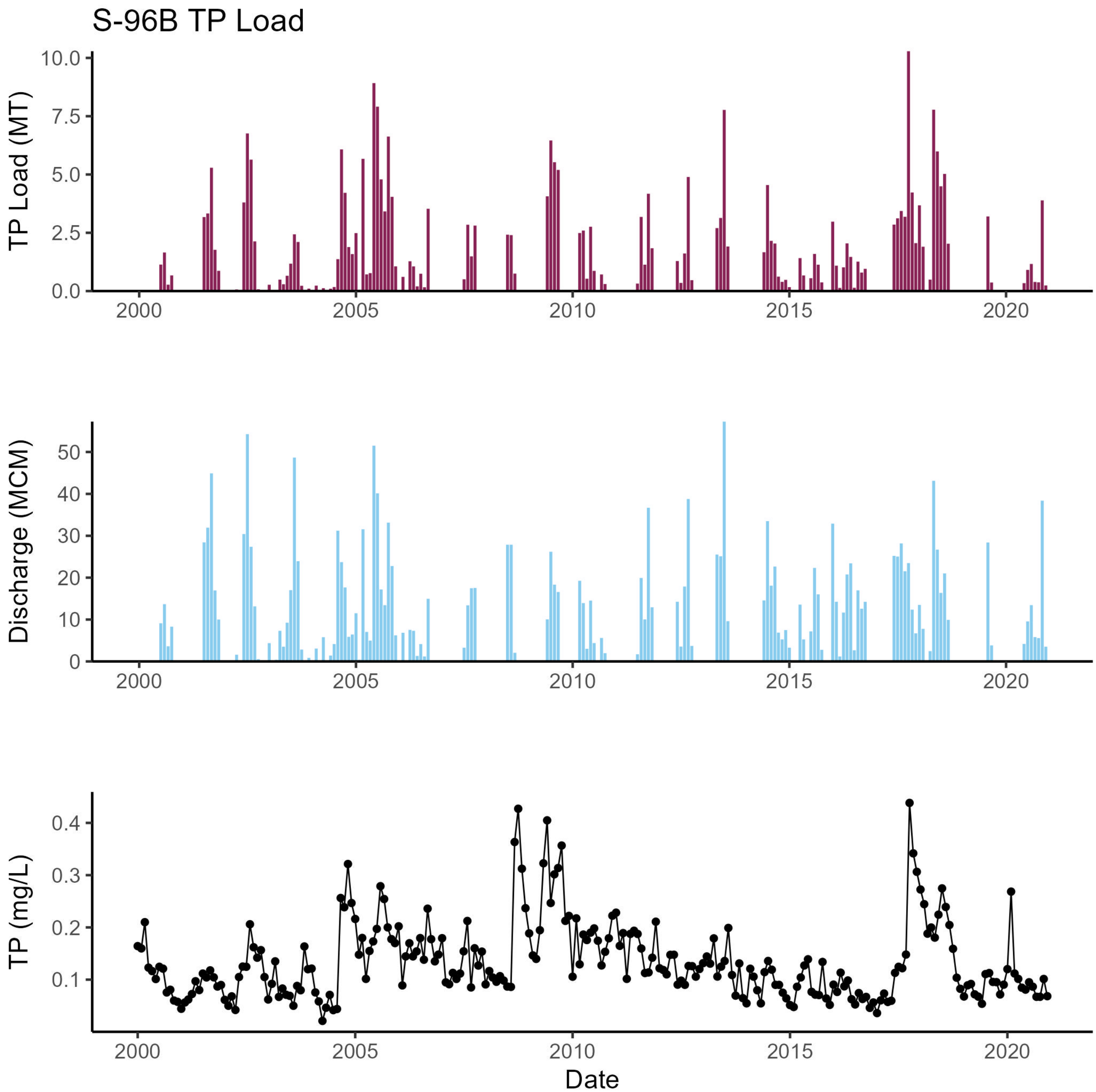

Figure F-6. S-96B monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

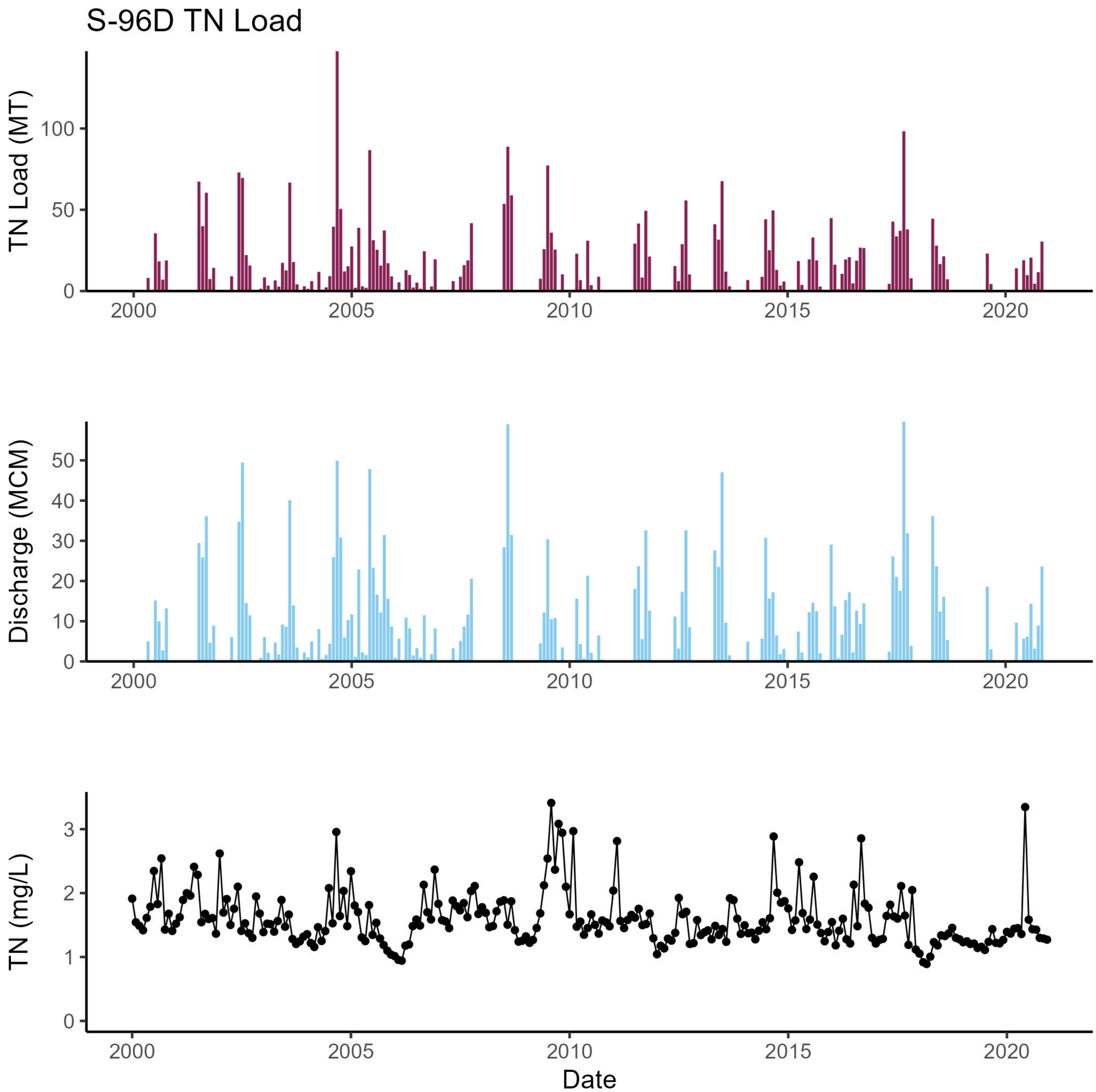

Figure F-7. S-96D monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

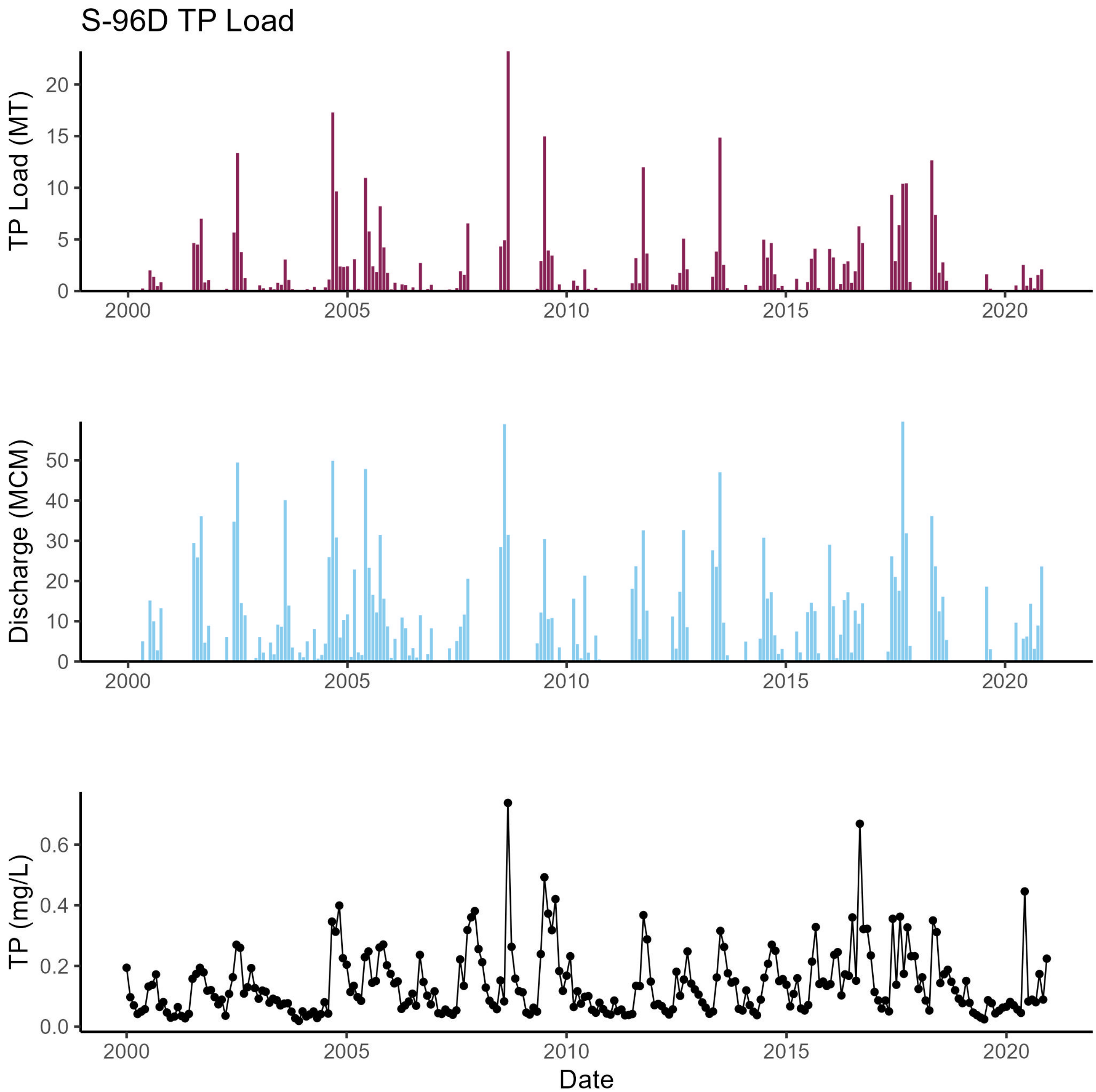

Figure F-8. S-96D monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

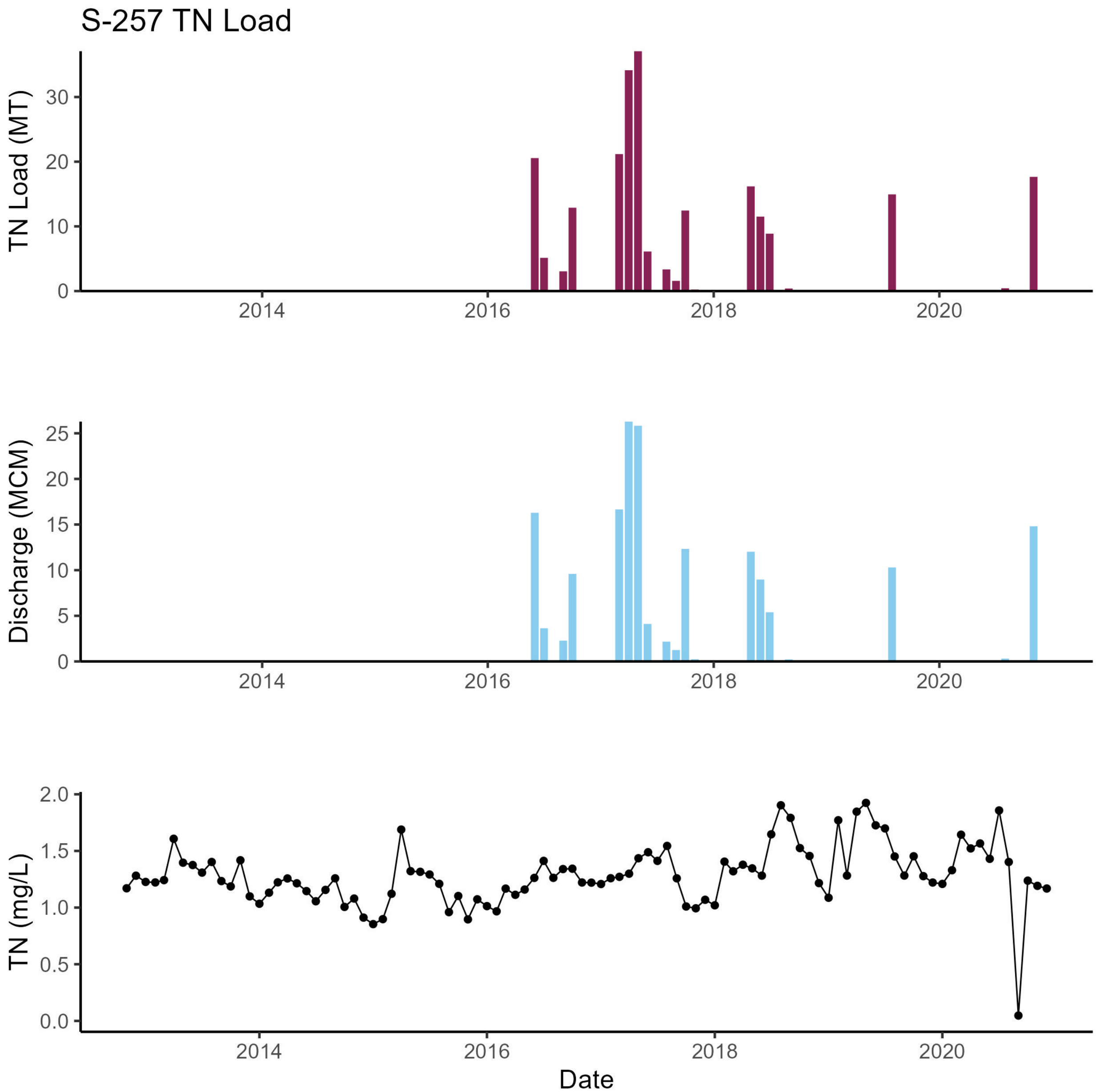

Figure F-9. S-257 monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

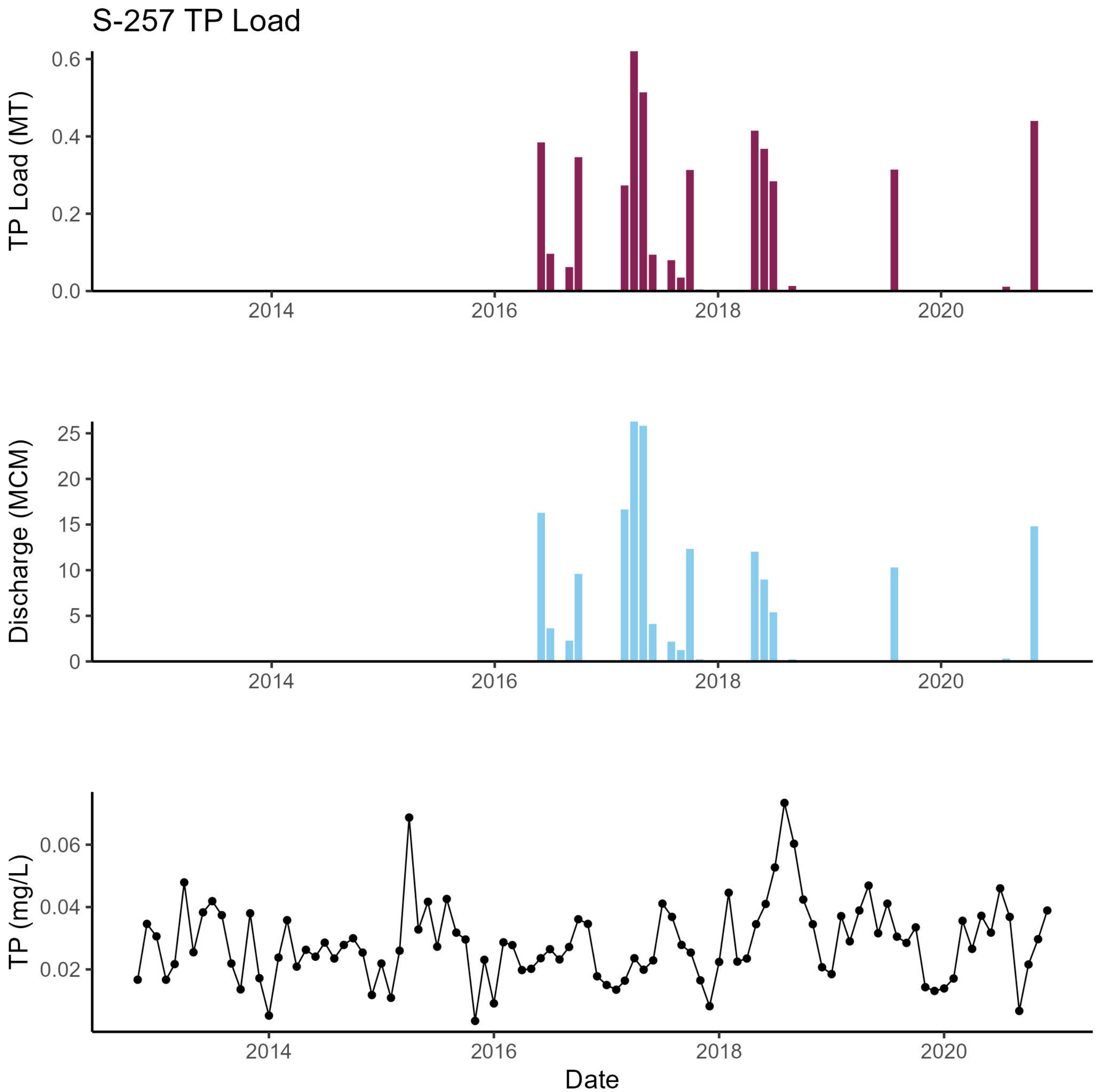

Figure F-10. S-257 monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

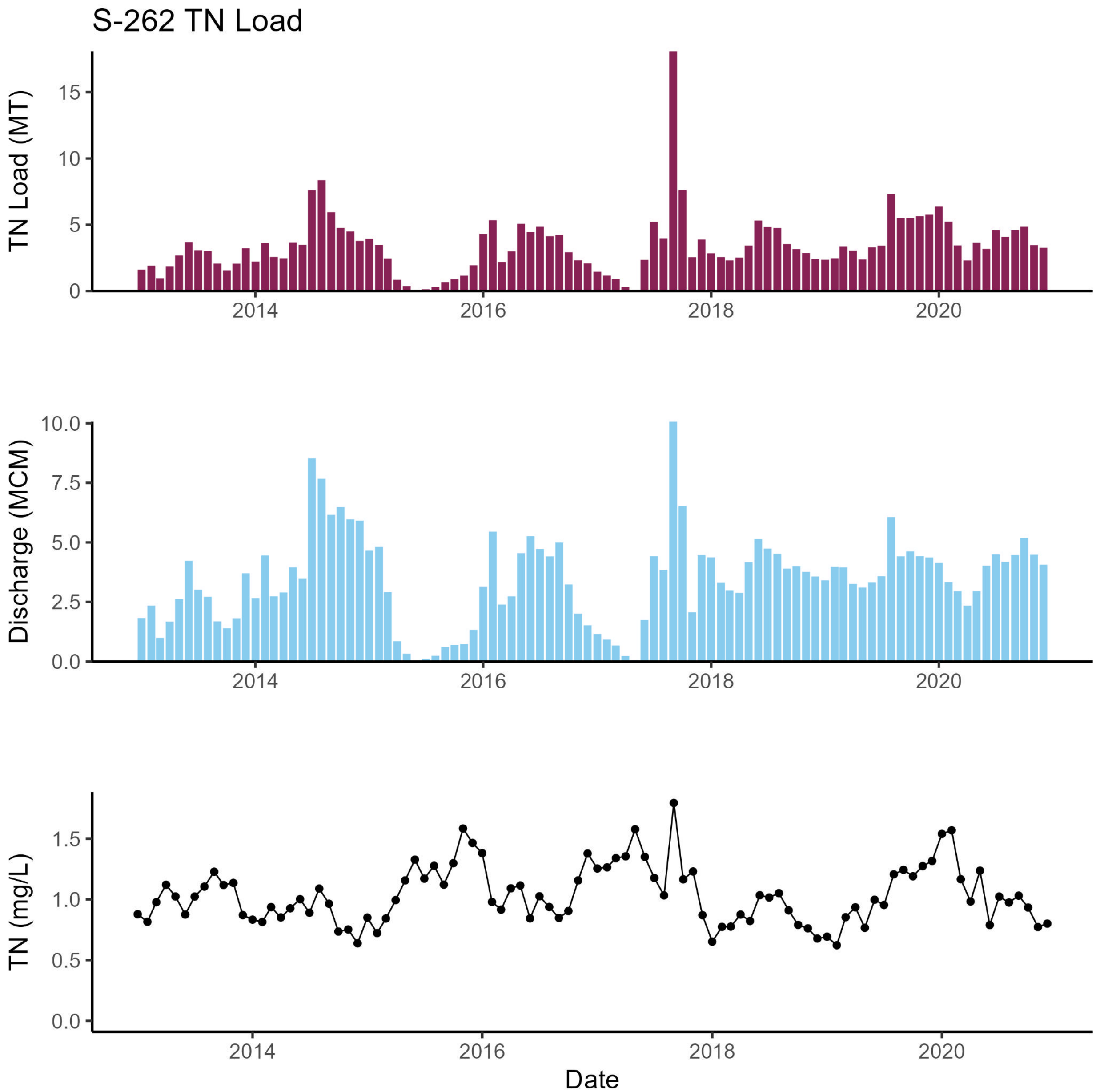

Figure F-11. S-262 monthly TN load, discharge, and TN concentrations. See the beginning of Appendix F for an explanation of each panel.

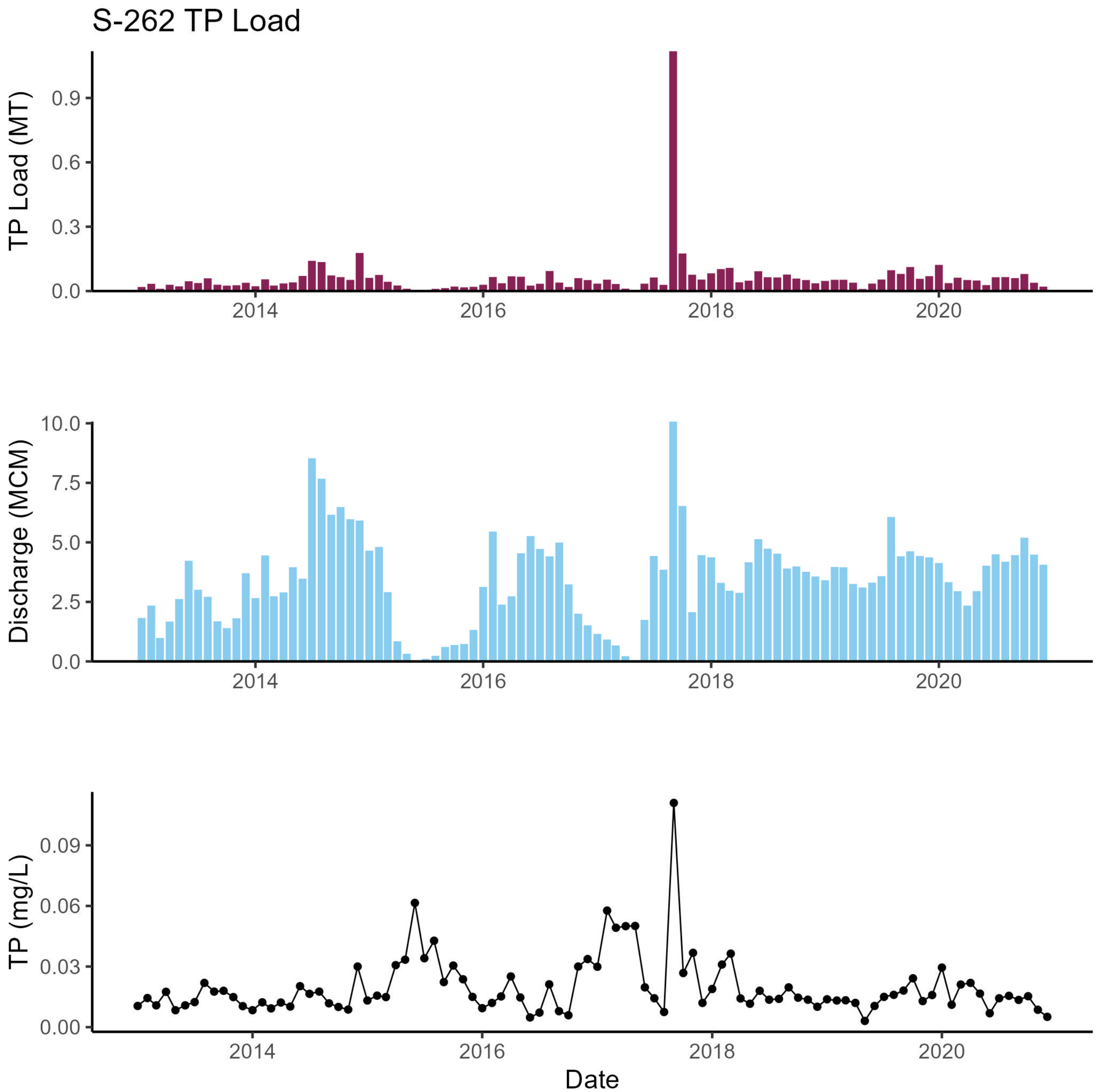

Figure F-12. S-262 monthly TP load, discharge, and TP concentrations. See the beginning of Appendix F for an explanation of each panel.

APPENDIX G—MONTHLY TN AND TP LOADING RESULTS FOR WESTERN PROJECT STRUCTURES

Appendix G contains monthly loading plots for the western Project structures (see Table 2). All plots have the same results presented in each panel and vary only in the constituent (TN or TP) and structure. The panels are as follows:

A. Top: Calculated monthly TN or TP load in metric tons (MT).

B. Middle: Observed monthly discharge volume at structure in millions of cubic meters (MCM).

C. Bottom: Observed TN or TP concentration (generally monthly) in mg L^{-1} at WQ station used for loading calculation.

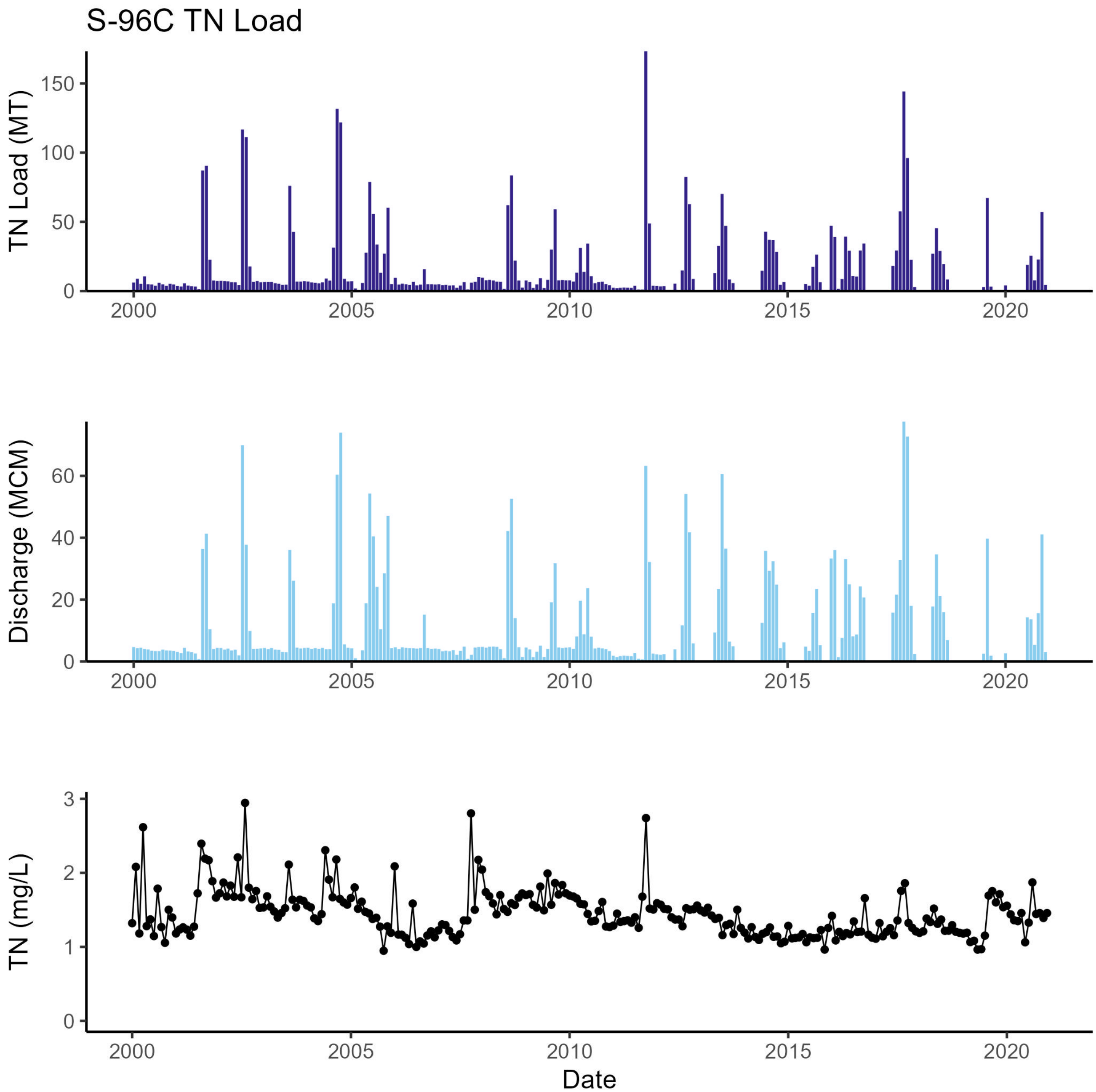

Figure G-1. S-96C monthly TN load, discharge, and TN concentrations. See the beginning of Appendix G for an explanation of each panel.

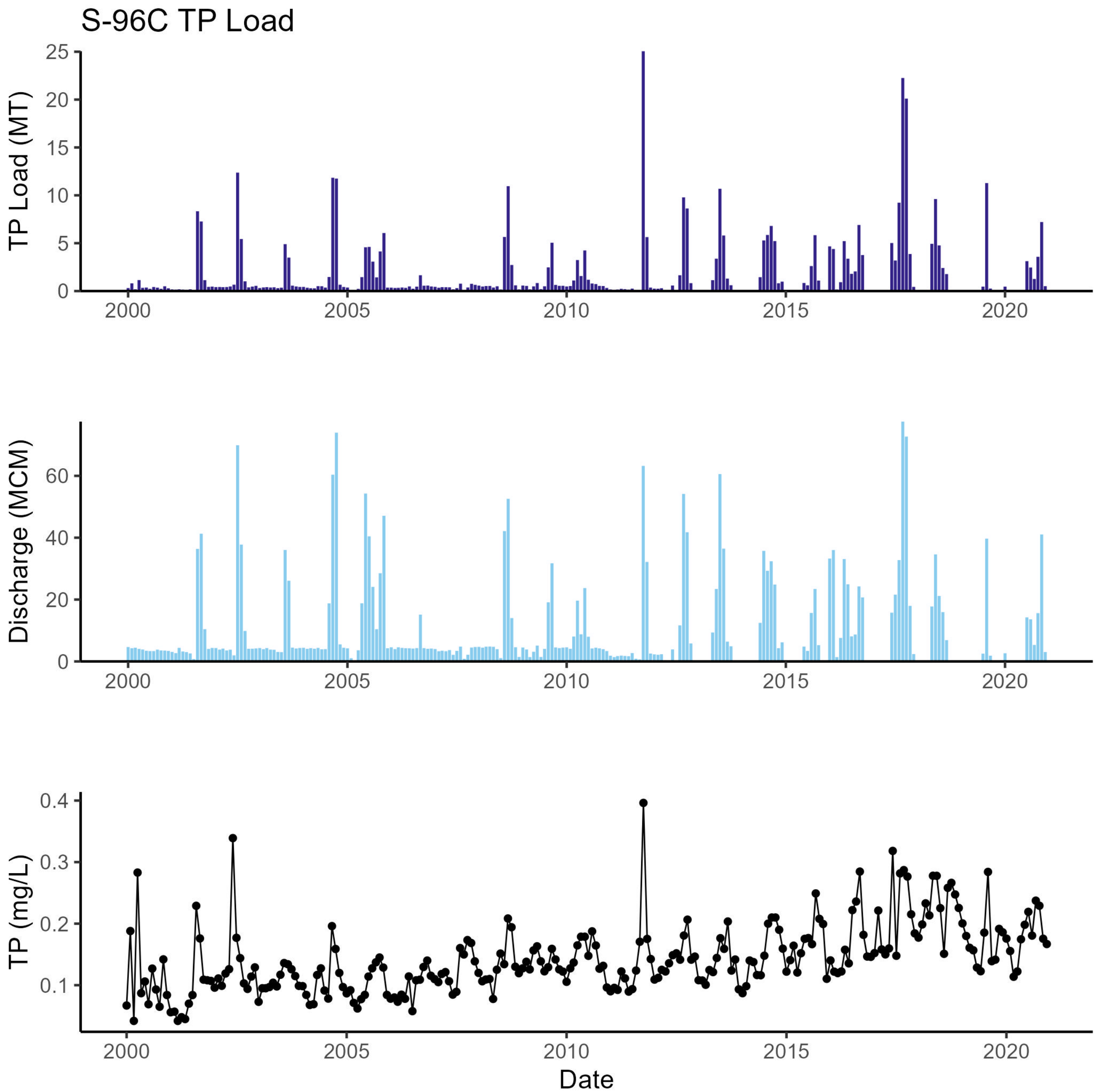

Figure G-2. S-96C monthly TP load, discharge, and TP concentrations. See the beginning of Appendix G for an explanation of each panel.

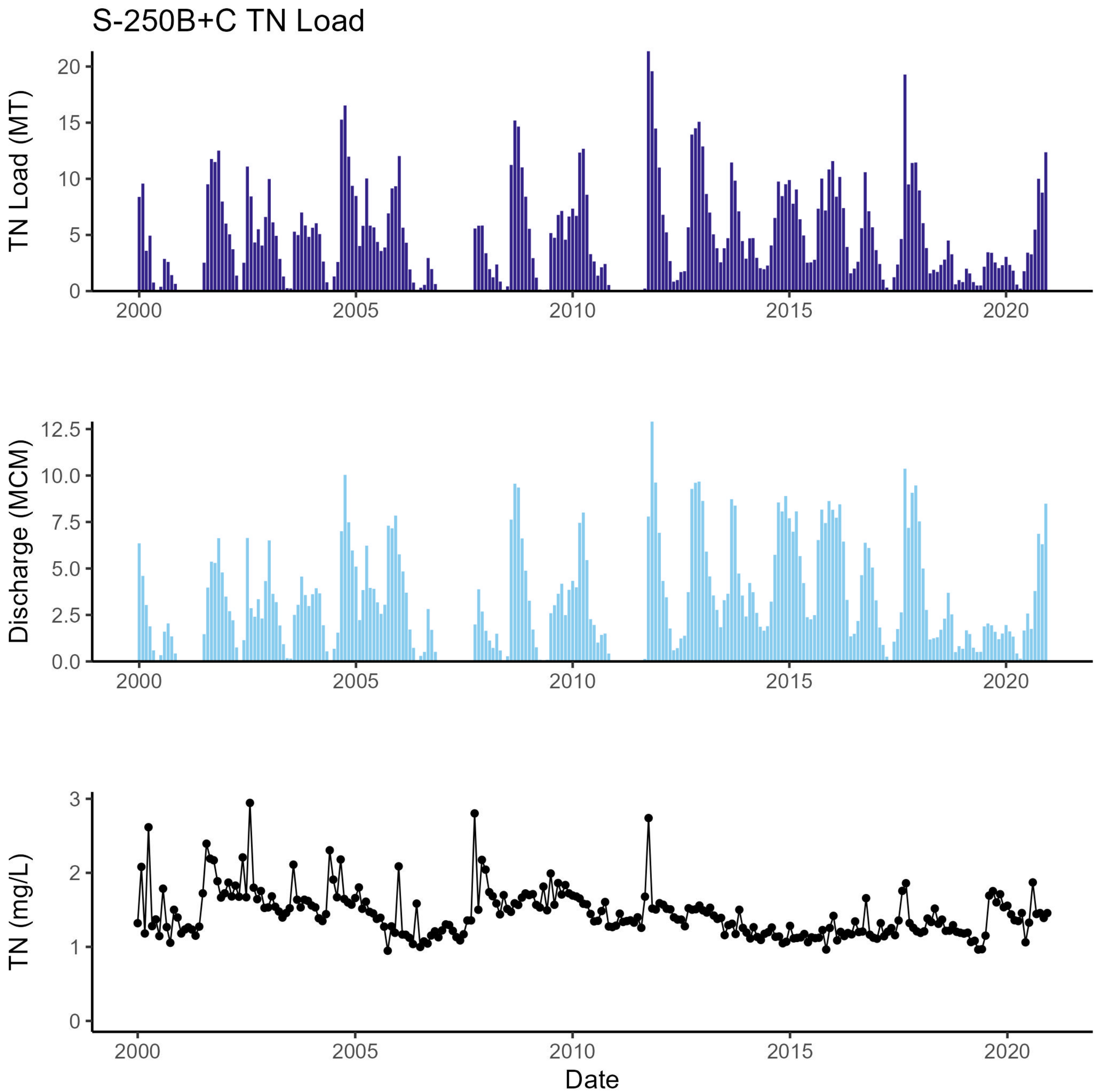

Figure G-3. S-250B and C monthly TN load, discharge, and TN concentrations. See the beginning of Appendix G for an explanation of each panel.

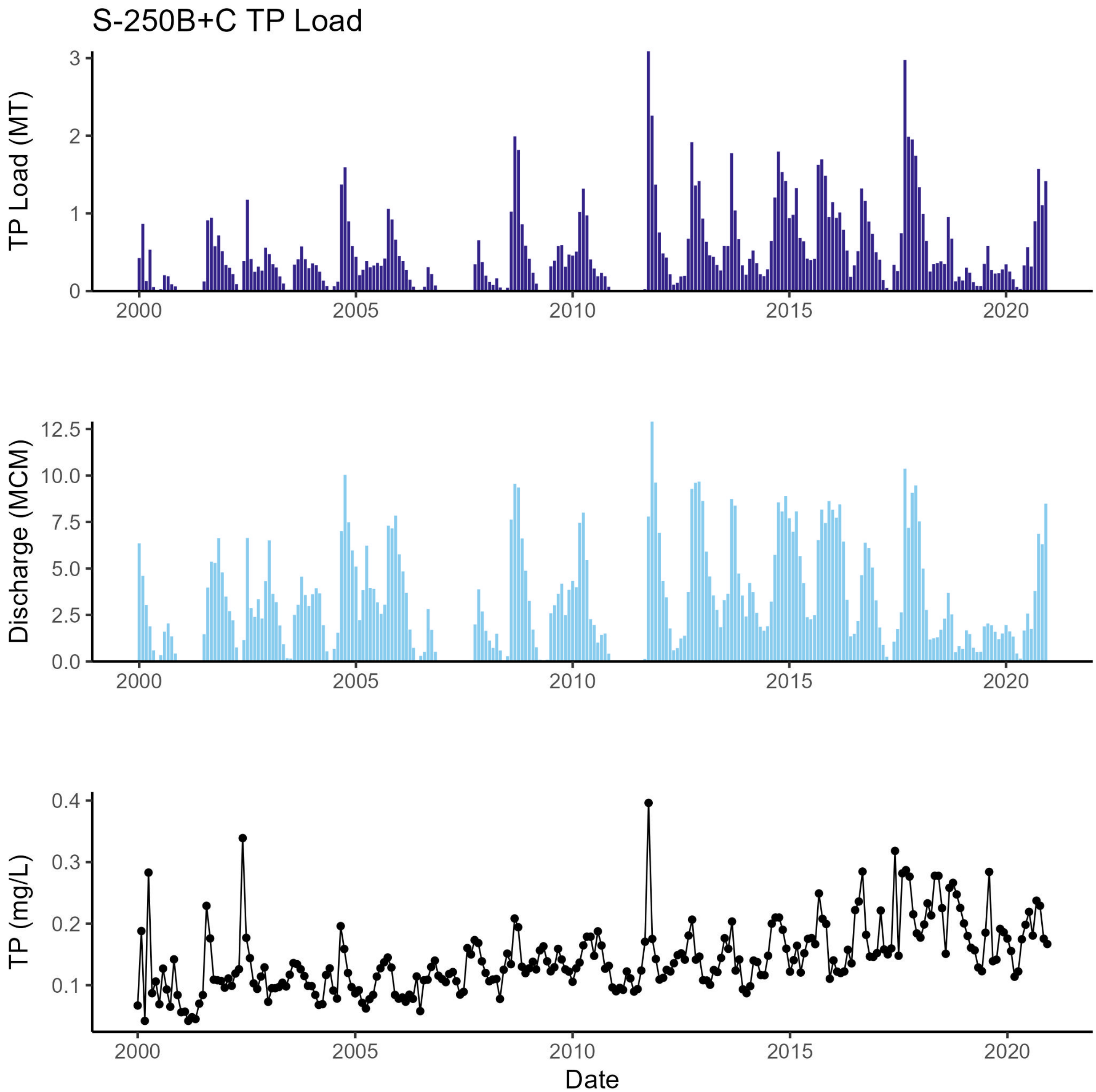

Figure G-4. S-250 B and C monthly TP load, discharge, and TP concentrations. See the beginning of Appendix G for an explanation of each panel.

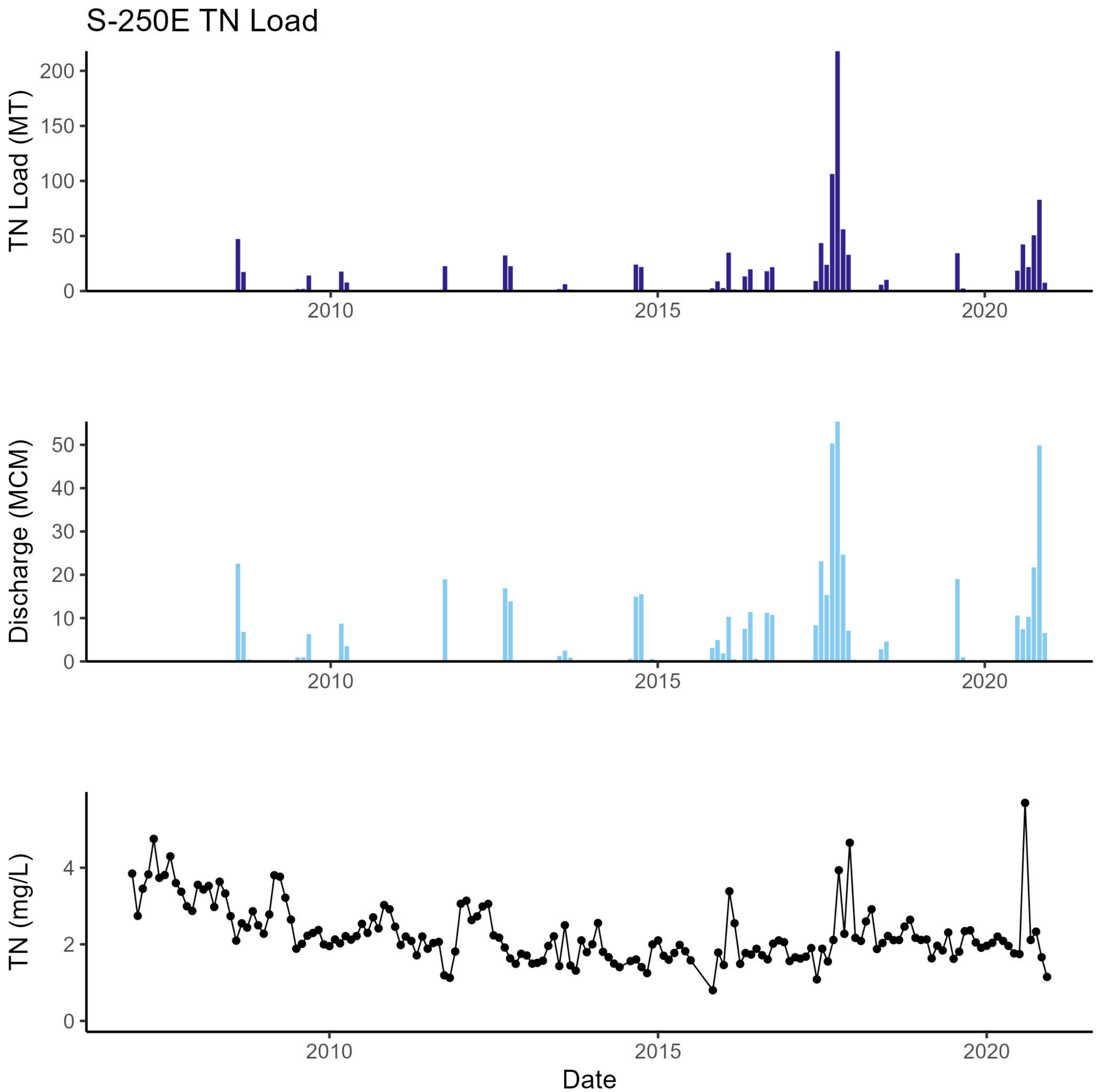

Figure G-5. S-250E monthly TN load, discharge, and TN concentrations. See the beginning of Appendix G for an explanation of each panel.

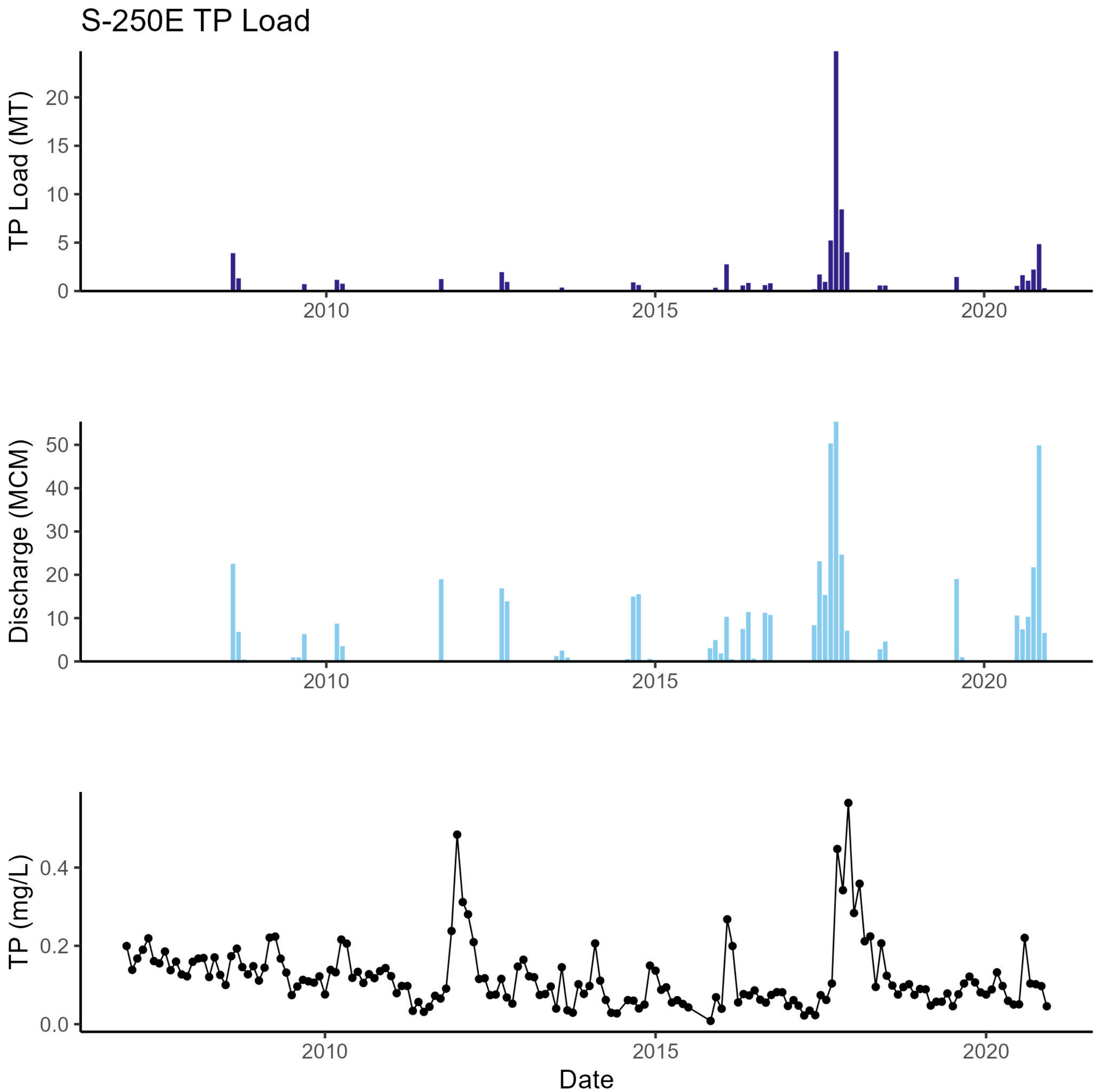

Figure G-6. S-250E monthly TP load, discharge, and TP concentrations. See the beginning of Appendix G for an explanation of each panel.

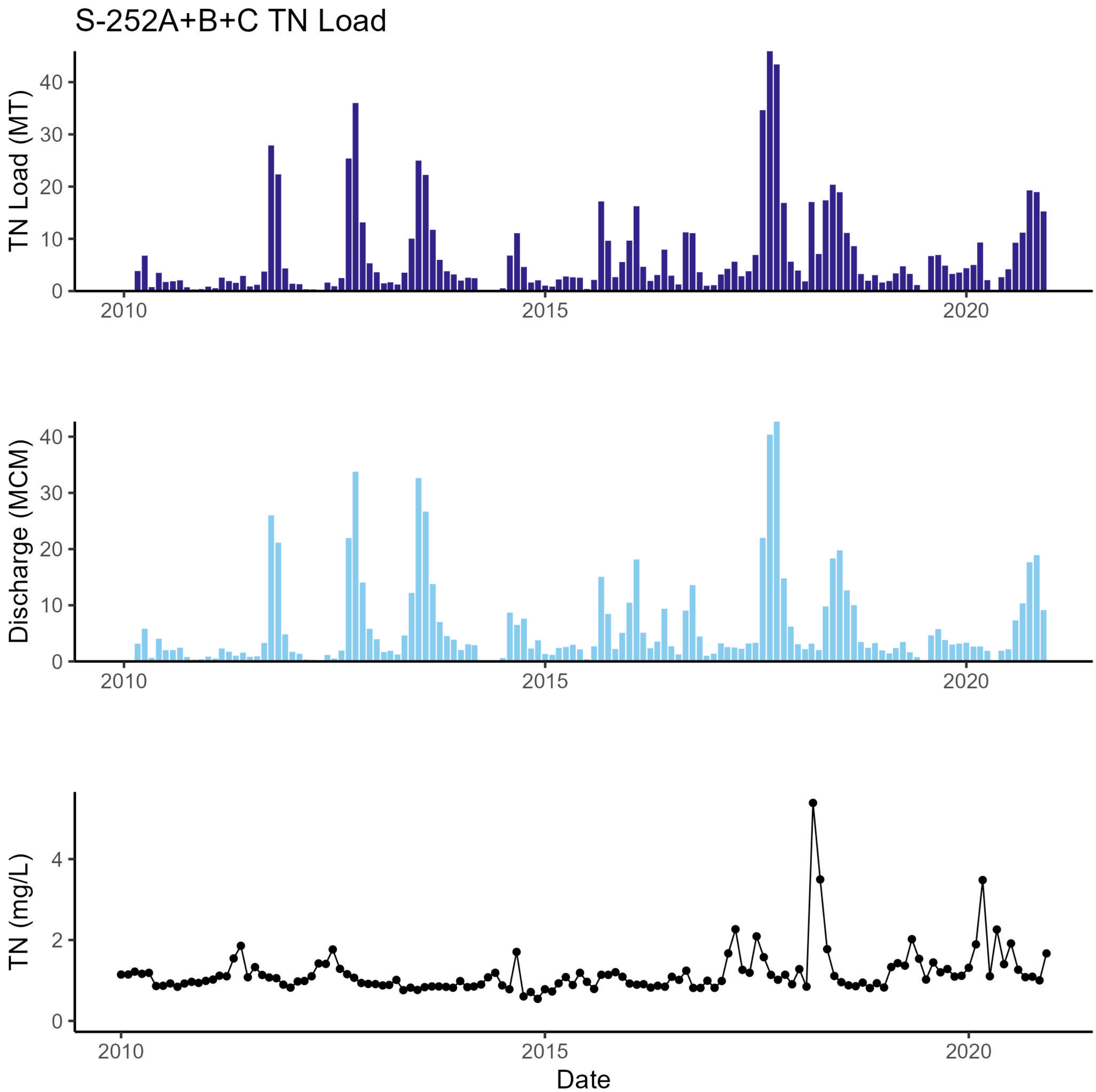

Figure G-7. S-250A, B, and C monthly TN load, discharge, and TN concentrations. See the beginning of Appendix G for an explanation of each panel.

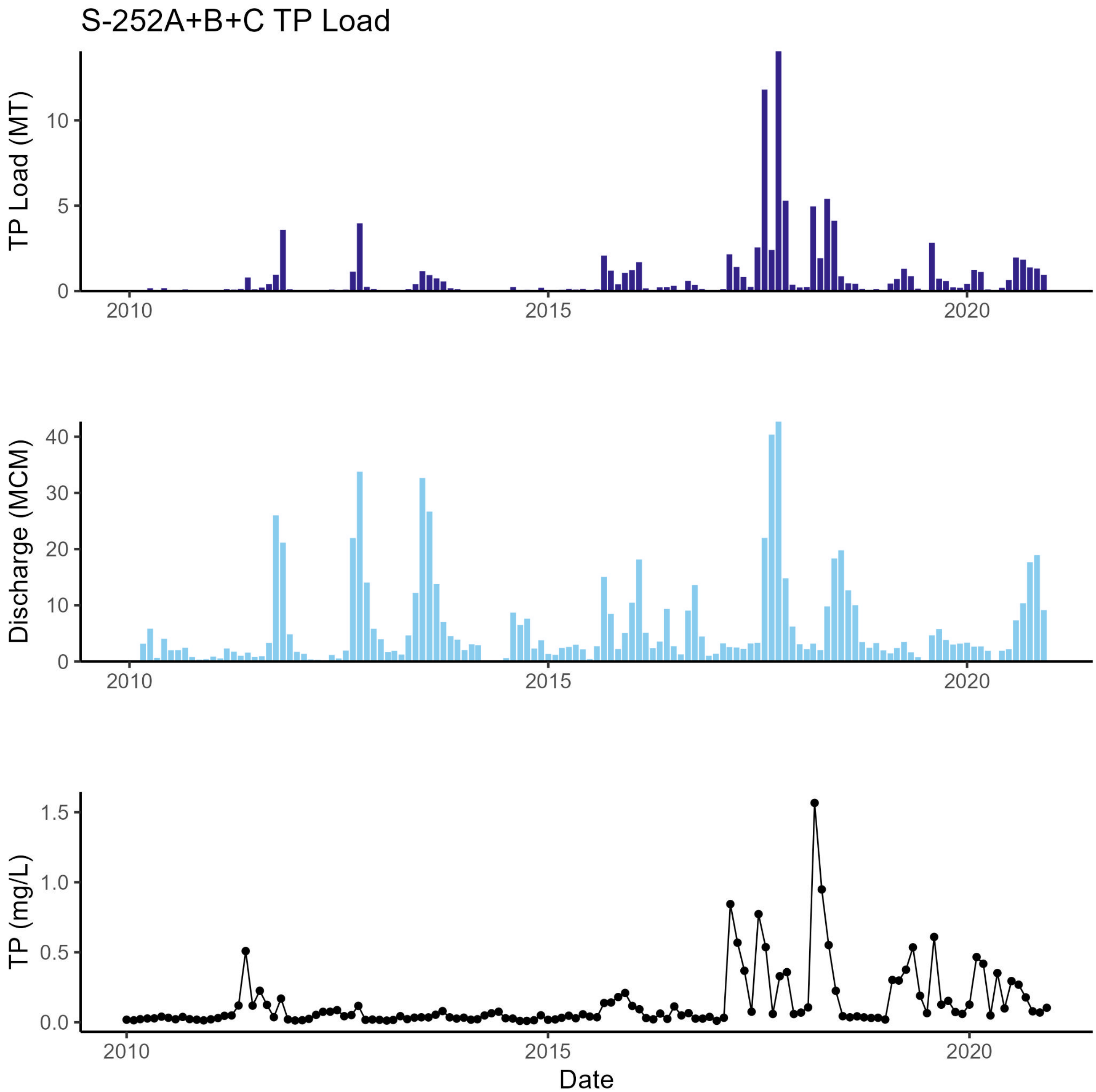

Figure G-8. S-252A, B, and C monthly TP load, discharge, and TP concentrations. See the beginning of Appendix G for an explanation of each panel.

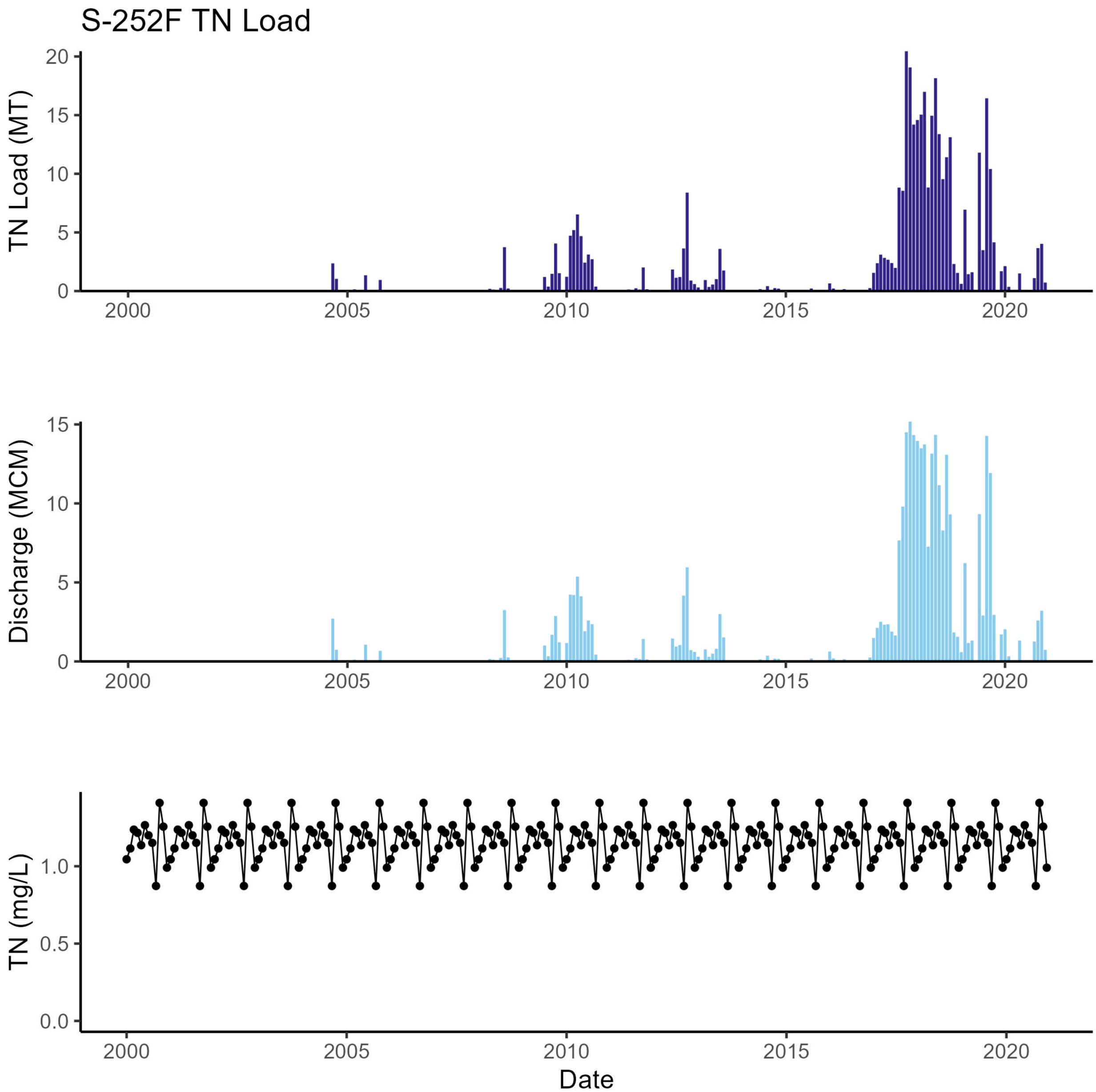

Figure G-9. S-252F monthly TN load, discharge, and TN concentrations. See the beginning of Appendix G for an explanation of each panel.

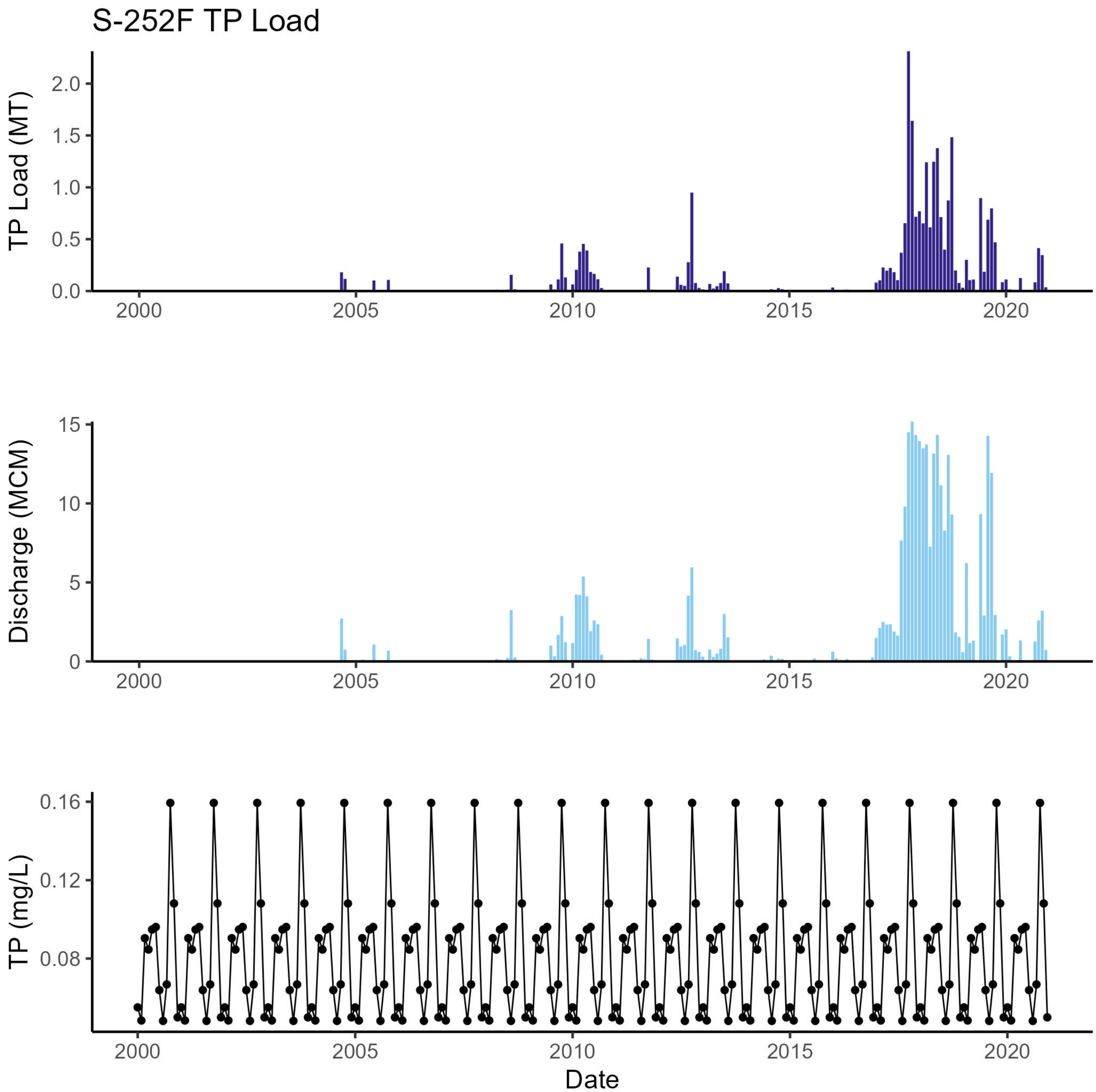

Figure G-10. S-252F monthly TP load, discharge, and TP concentrations. See the beginning of Appendix G for an explanation of each panel.

APPENDIX H—WRTDS MODEL FIT PLOTS FOR WESTERN TRIBUTARY & MAINSTEM STATIONS

Appendix H contains model fit plots for the Weighted Regressions on Time, Discharge, and Season (WRTDS) models. All plots have the same results presented in each panel and vary only in the constituent (TN or TP) and station (see Table 3). The Flux Bias Statistic is report above the plots. The panels are as follows:

A. Top Left: Predicted annual mean concentration (dots) and annual flow-normalized mean concentration (green line) with 95 % confidence intervals (dashed lines).

B. Top Right: Observed vs. predicted instantaneous concentrations.

C. Bottom Left: Predicted annual flux (dots) and annual flow-normalized flux (green line) with 95% confidence intervals (dashed lines).

D. Bottom Right: Observed vs. predicted instantaneous flux.

BCCR TN WRTDS Results

Flux Bias Statistic = -0.011

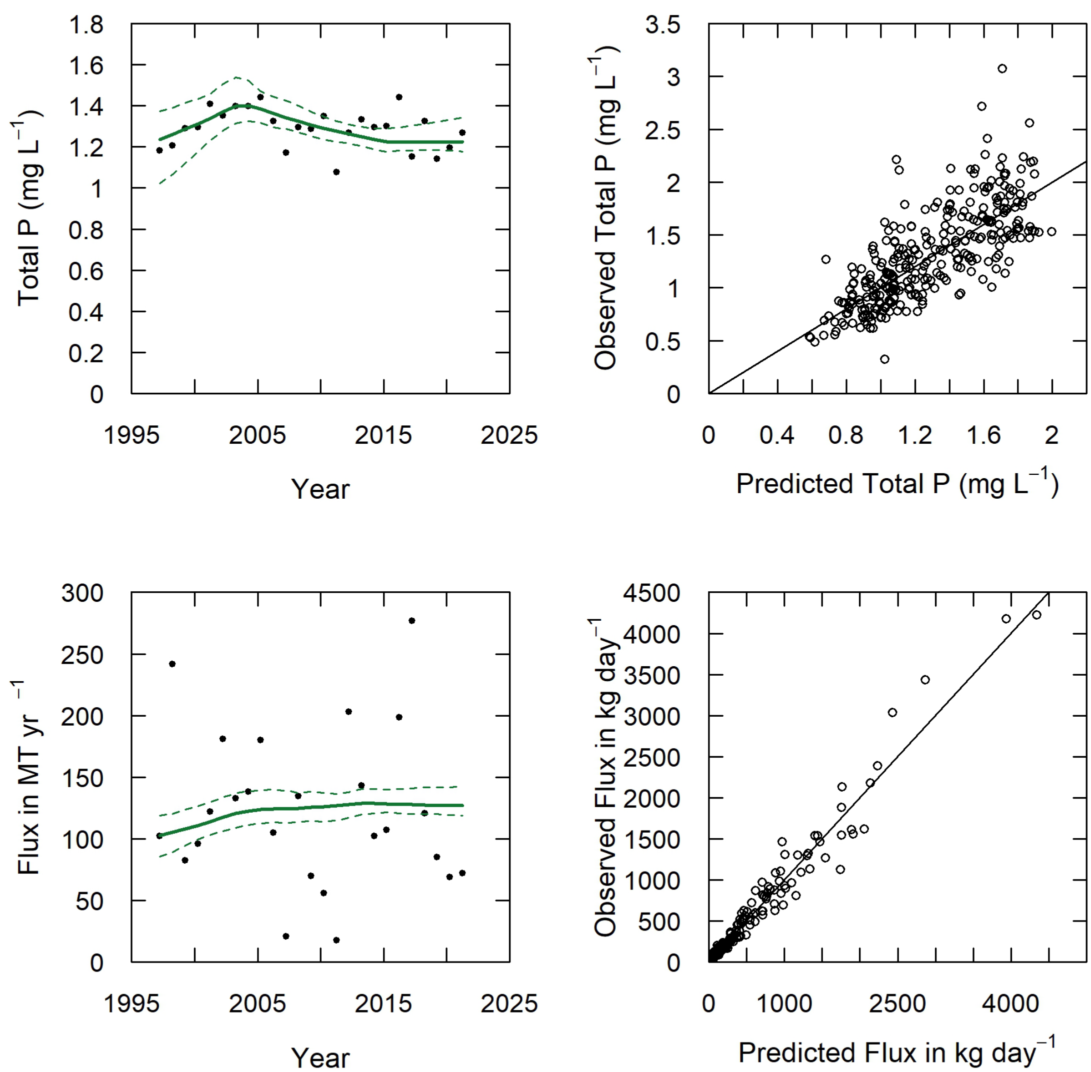

Figure H-1. Blue Cypress Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

BCCR TP WRTDS Results

Flux Bias Statistic = 0.003

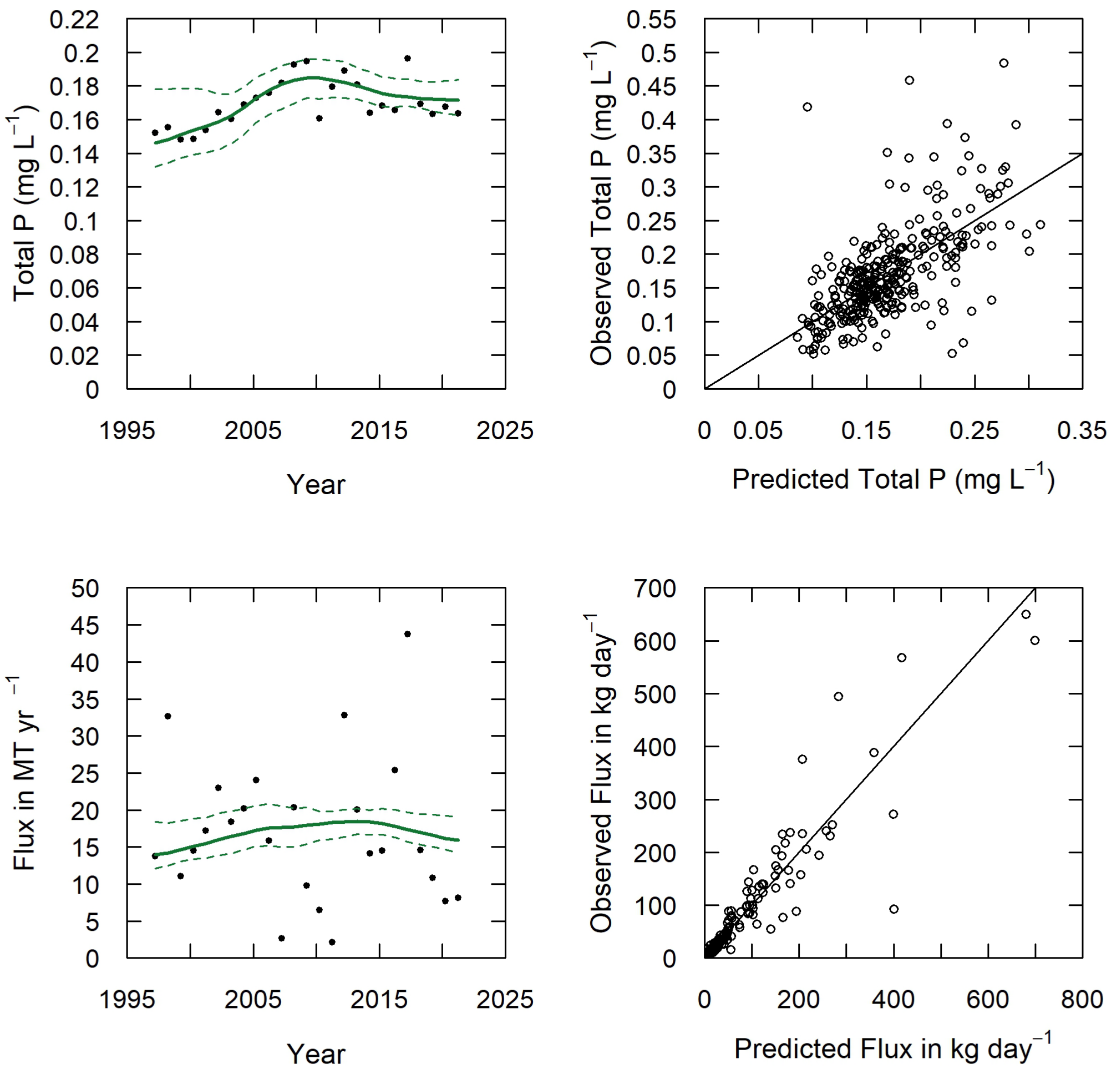

Figure H-2. Blue Cypress Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

FDC TN WRTDS Results

Flux Bias Statistic = -0.016

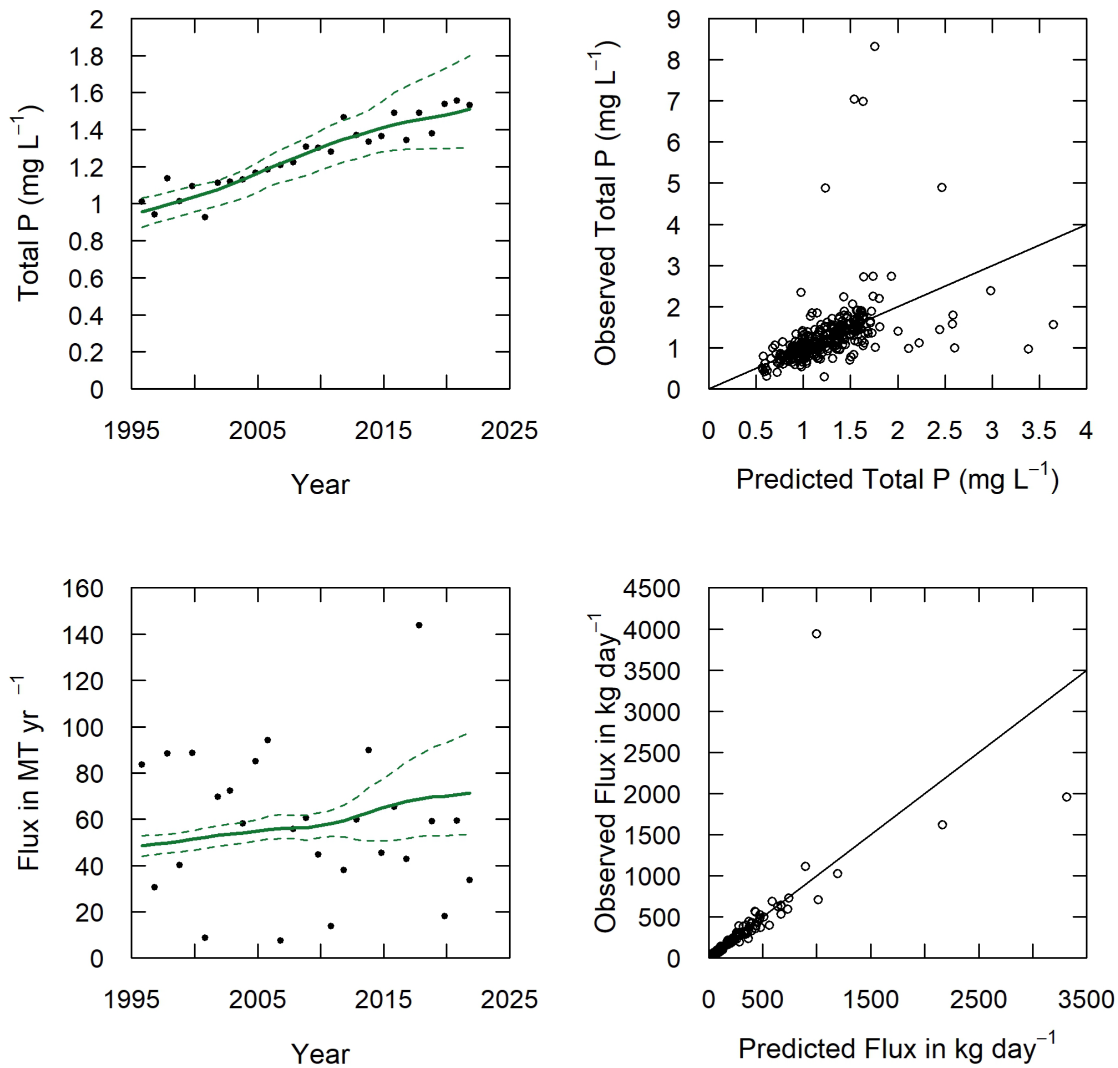

Figure H-3. Ft. Drum Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

FDC TP WRTDS Results

Flux Bias Statistic = -0.122

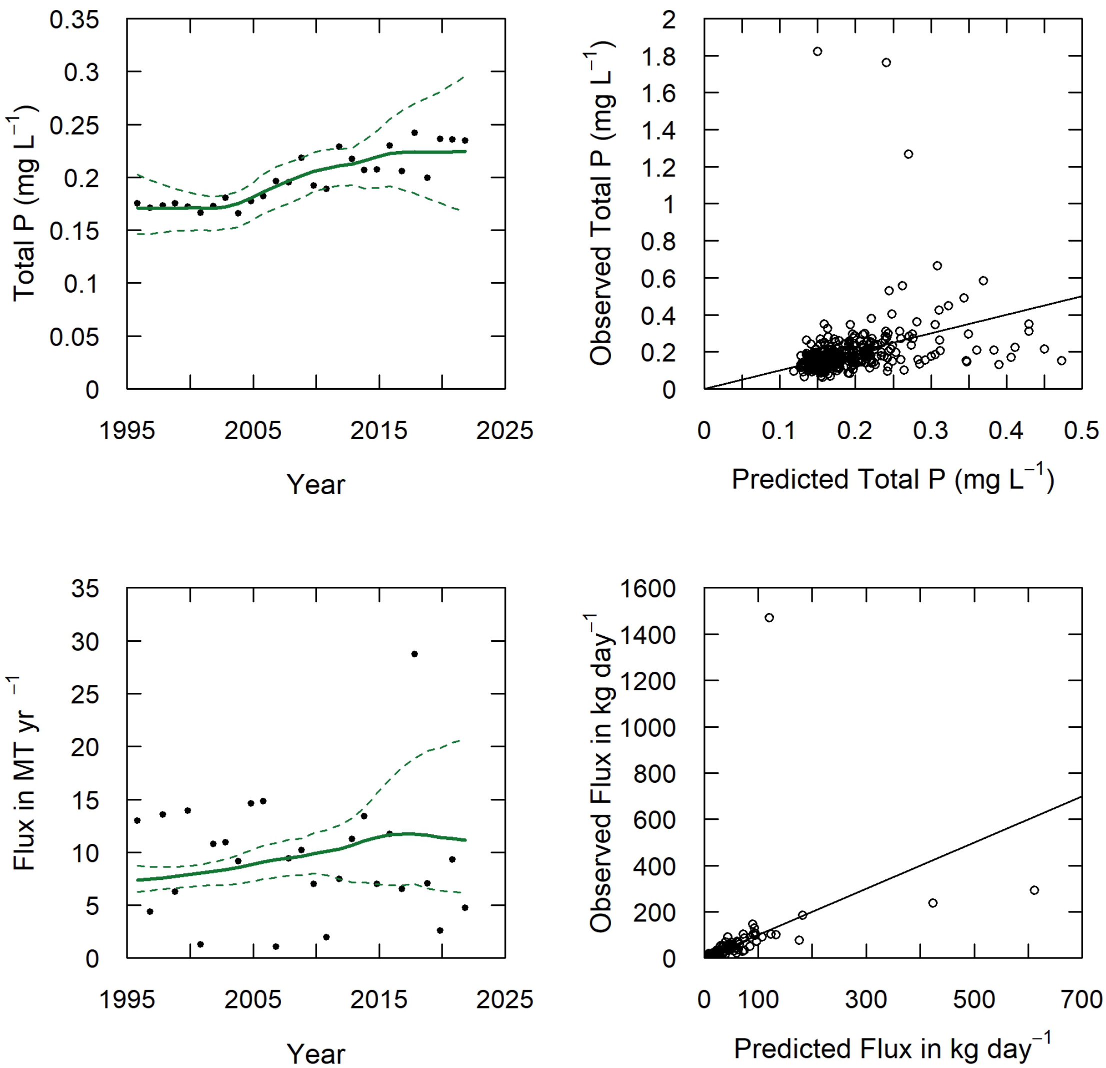

Figure H- 4. Ft. Drum Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

JGS TN WRTDS Results

Flux Bias Statistic = 0.002

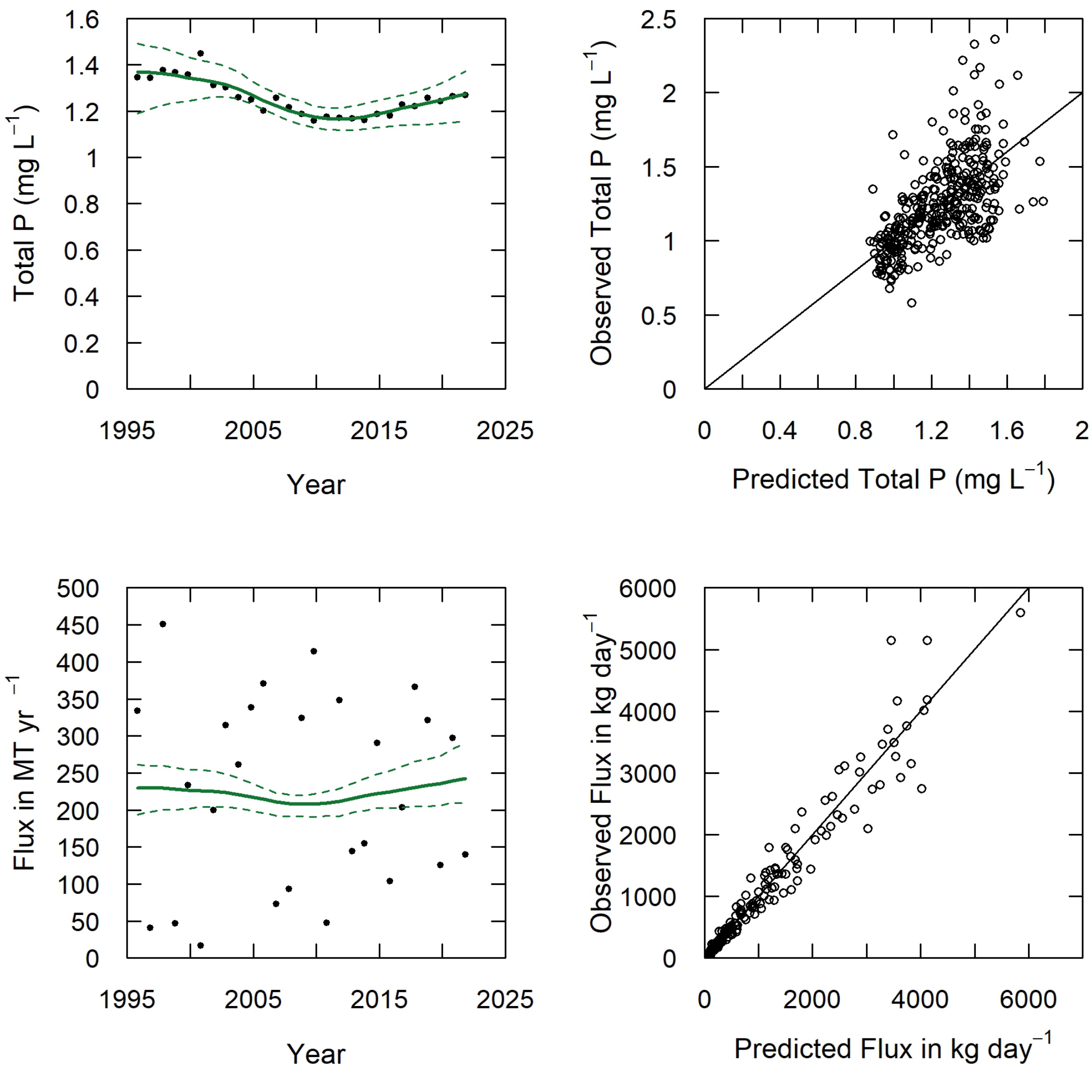

Figure H-5. Jane Green Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

JGS TP WRTDS Results

Flux Bias Statistic = 0.011

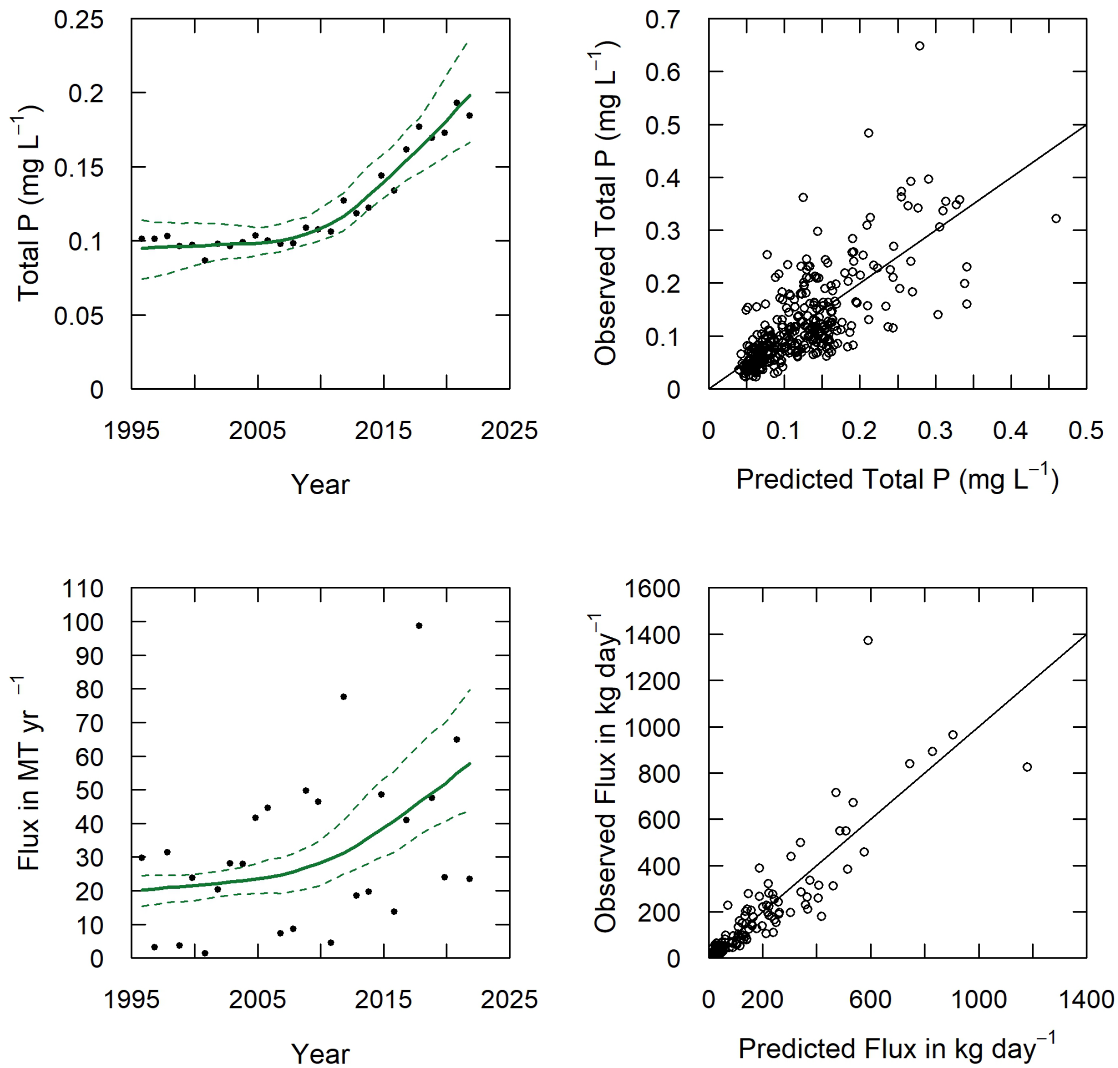

Figure H-6. Jane Green Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

PADGTT TN WRTDS Results

Flux Bias Statistic = -0.065

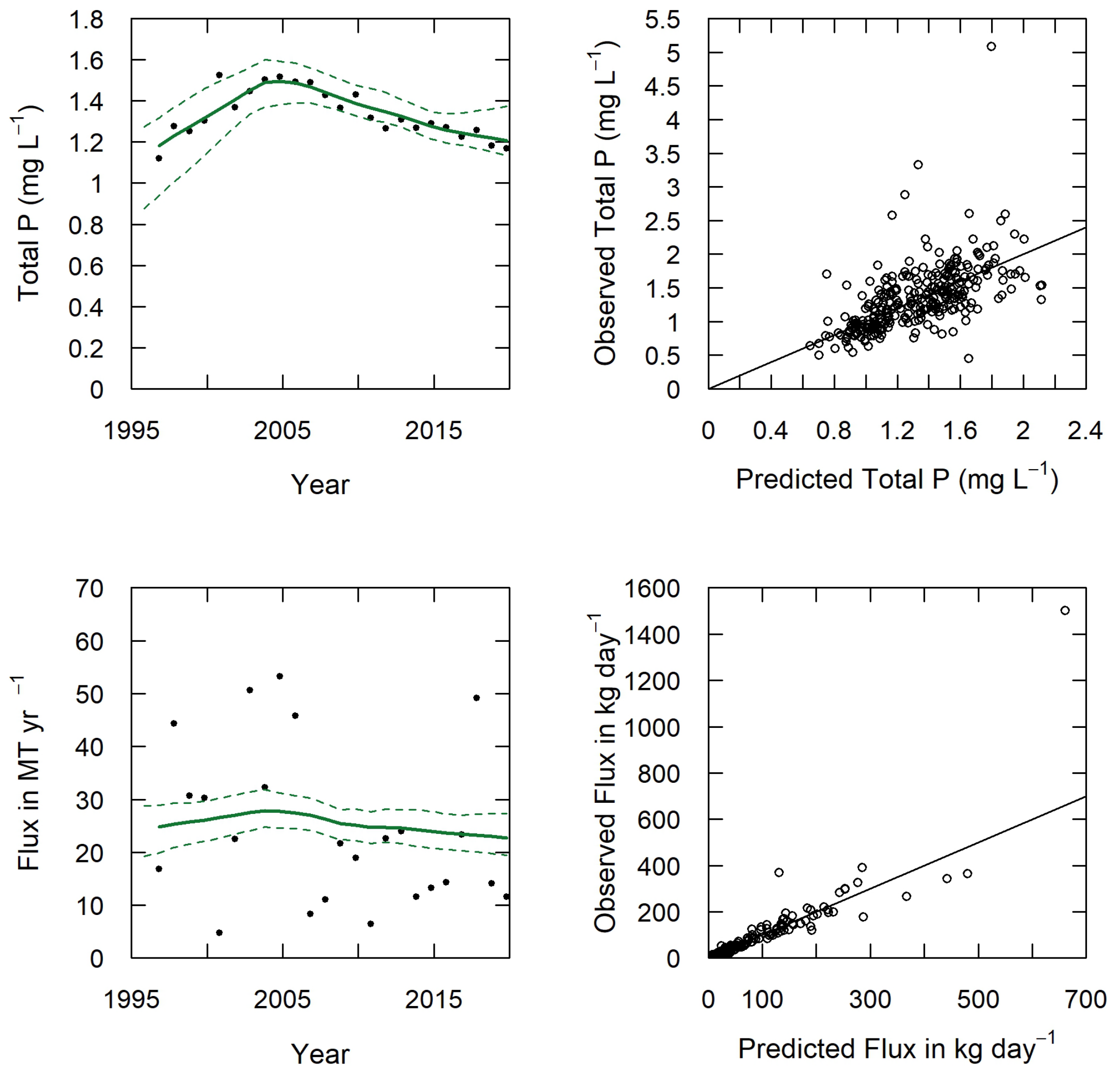

Figure H-7. Padgett Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

PADGTT TP WRTDS Results

Flux Bias Statistic = -0.061

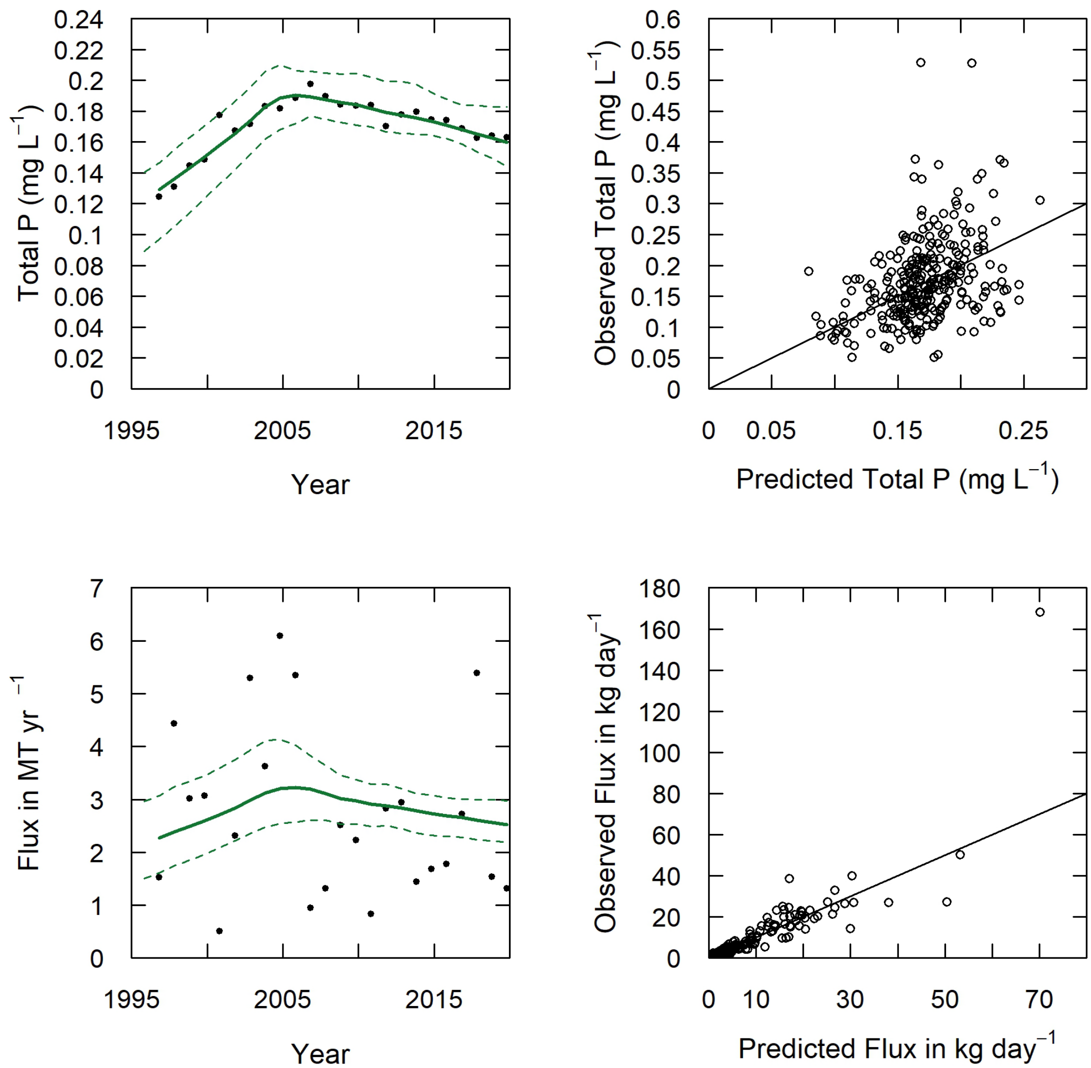

Figure H-8. Padgett Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

SCR TN WRTDS Results

Flux Bias Statistic = 0.021

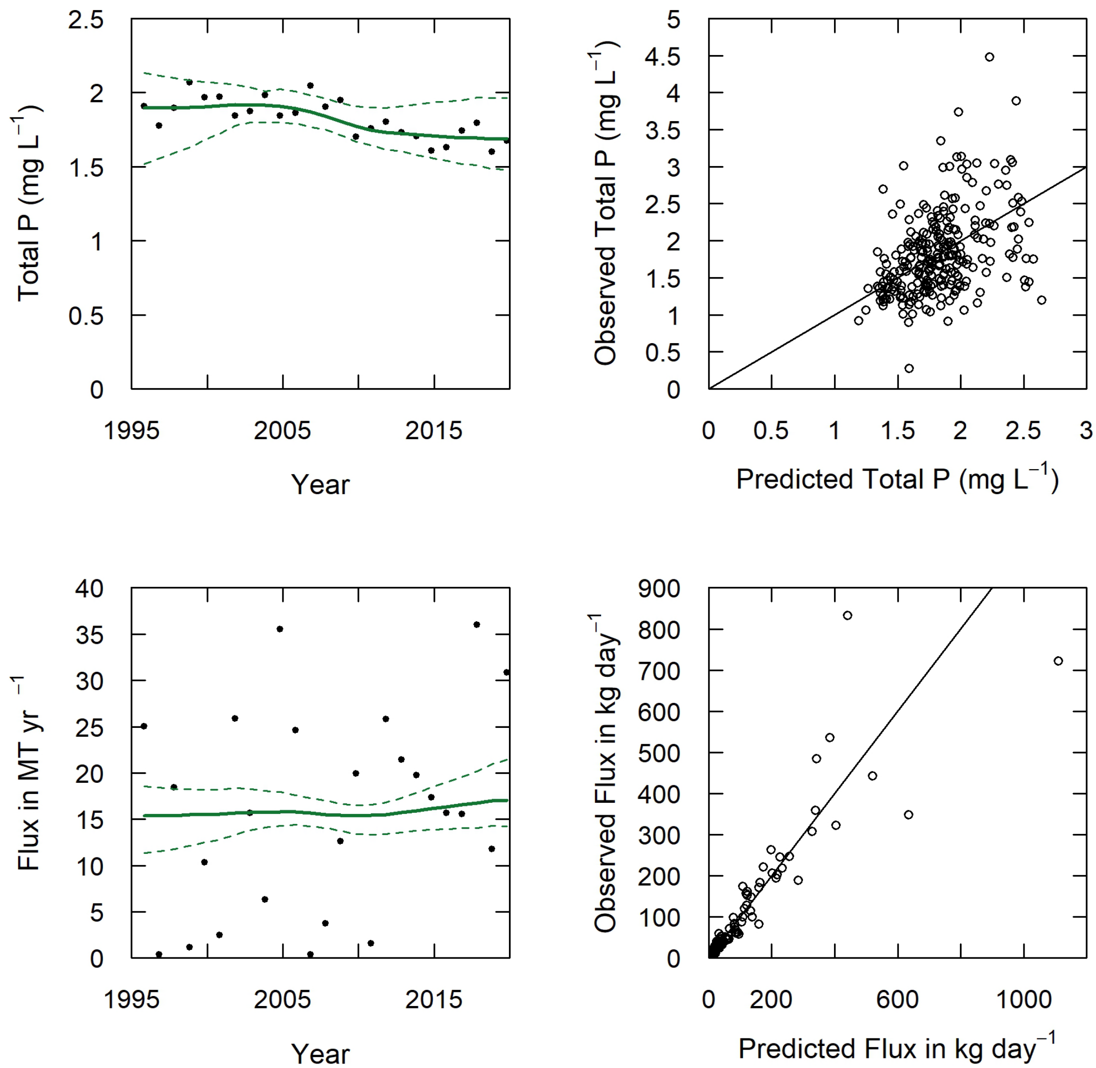

Figure H-9. Sixmile Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

SCR TP WRTDS Results

Flux Bias Statistic = 0.031

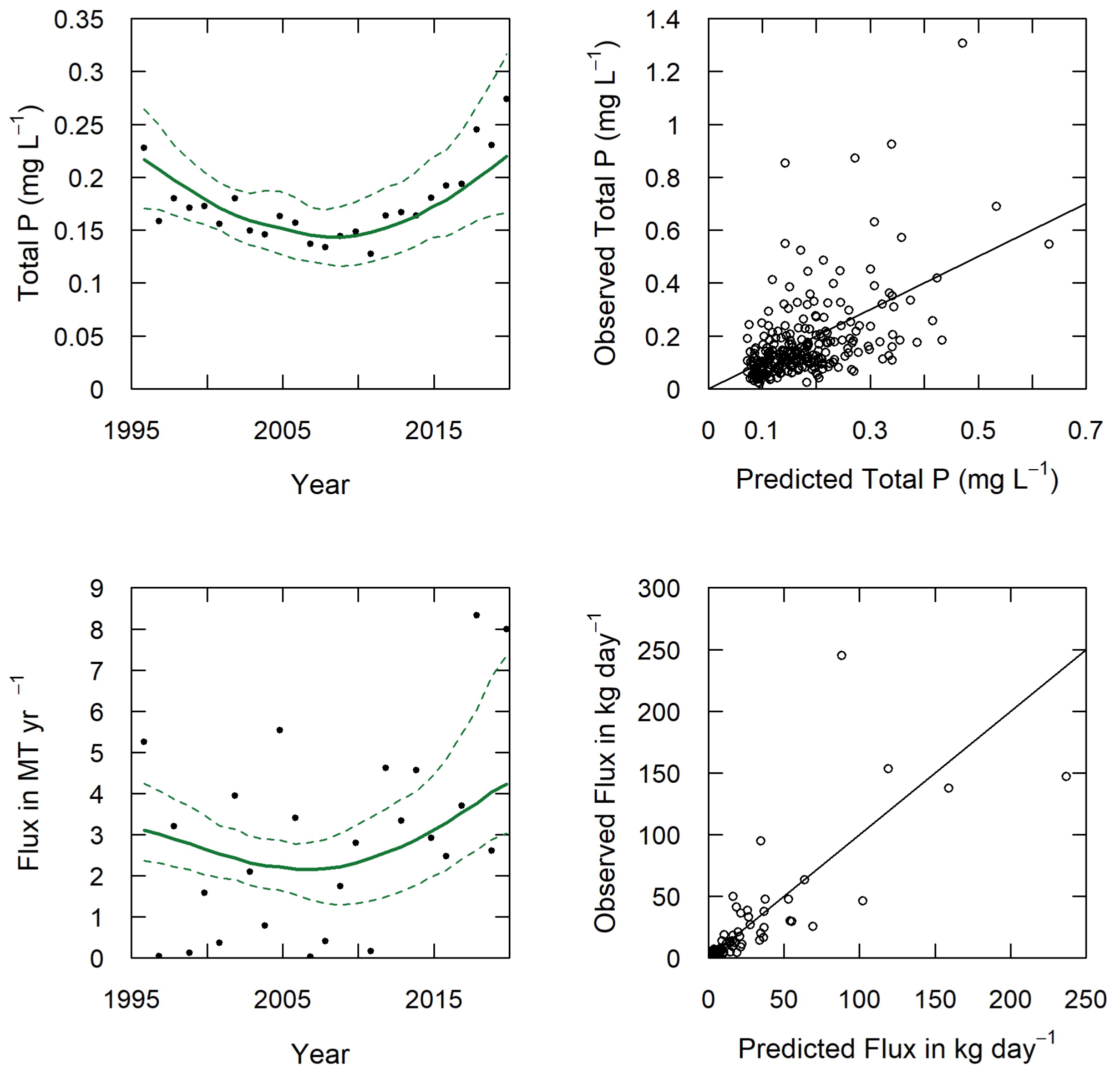

Figure H-10. Sixmile Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

SWOLFU TN WRTDS Results

Flux Bias Statistic = 0.02

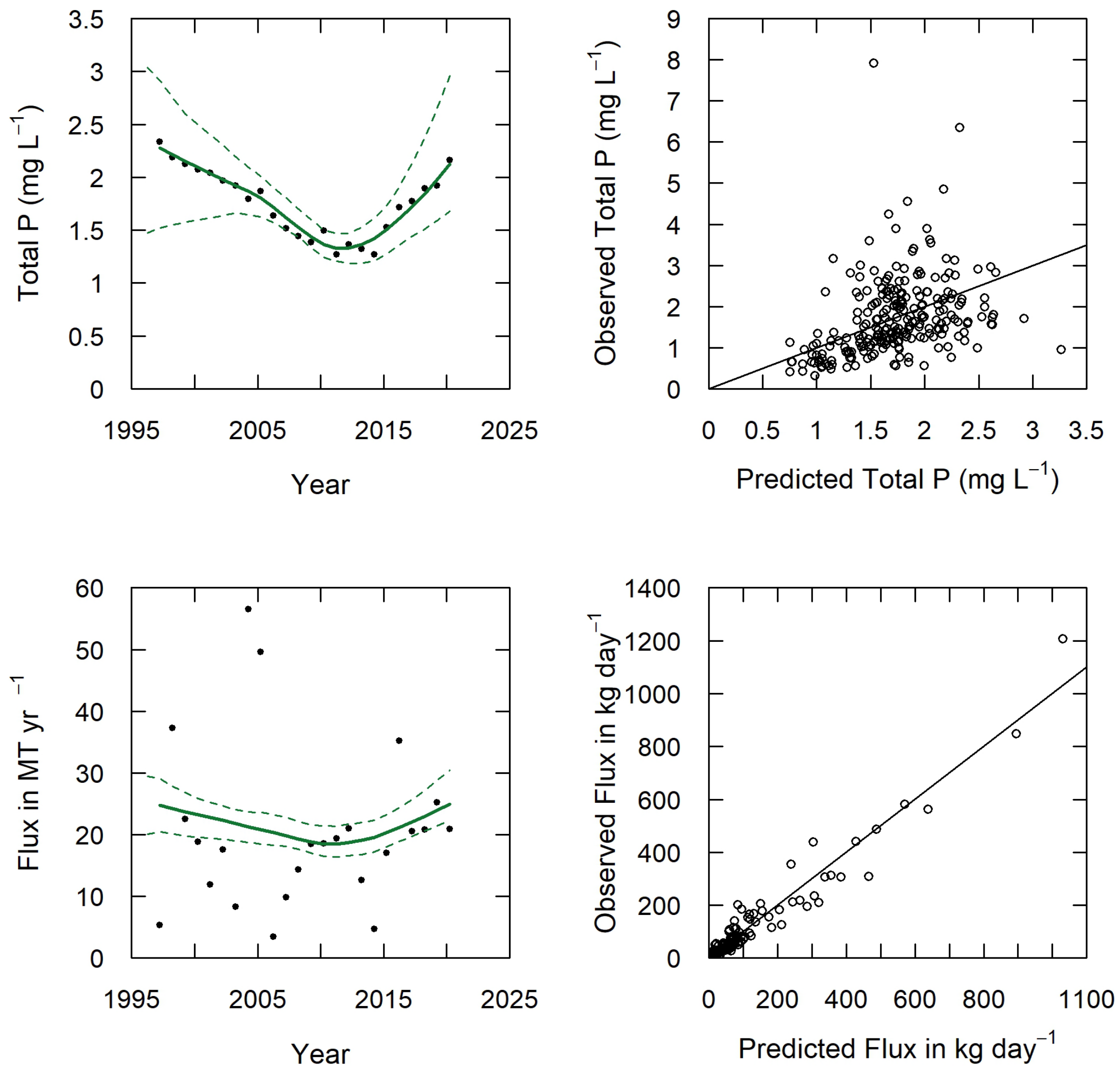

Figure H-11. South Wolf Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

SWOLFU TP WRTDS Results

Flux Bias Statistic = 0.064

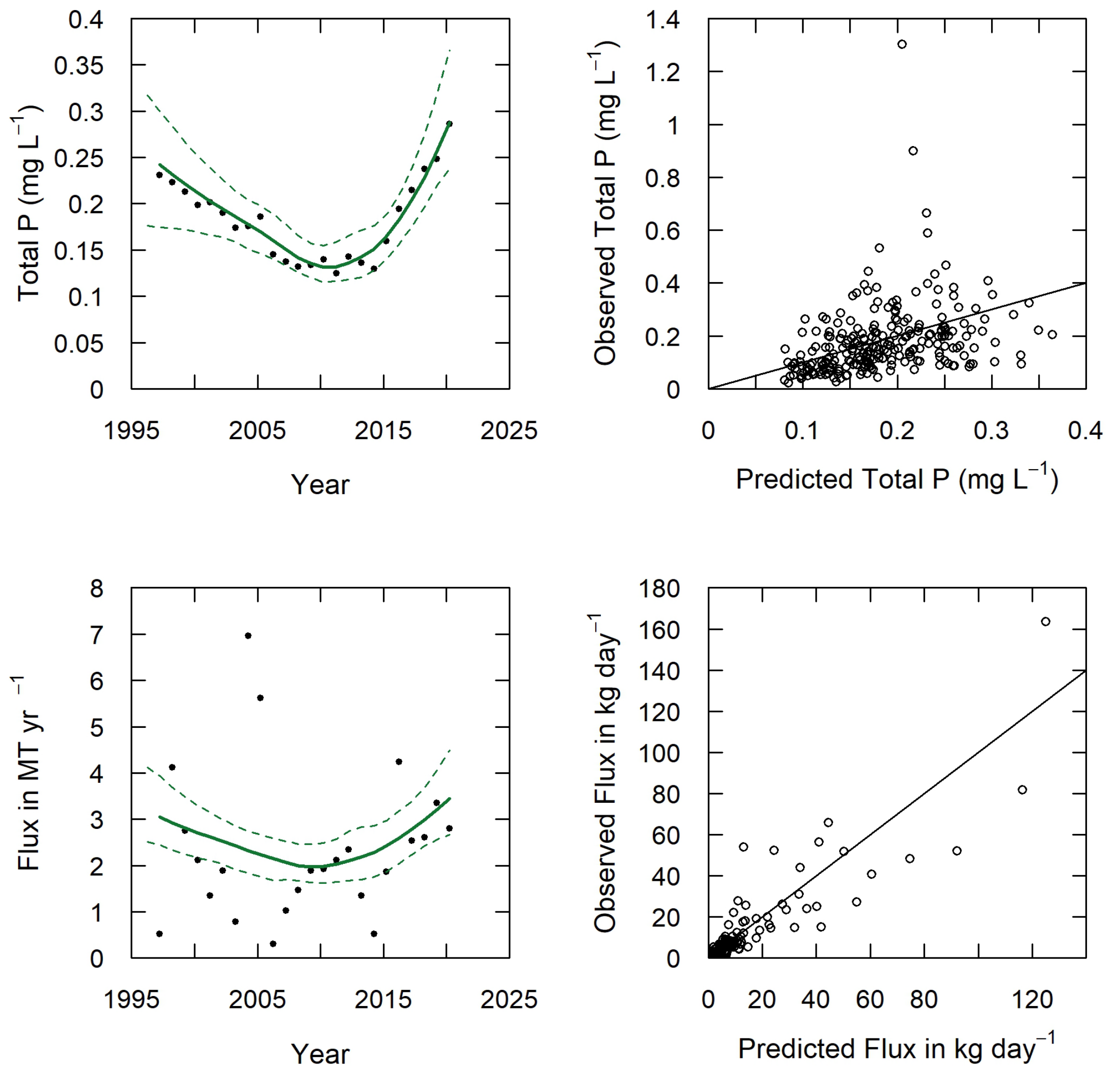

Figure H-12. South Wolf Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

TMC TN WRTDS Results

Flux Bias Statistic = -0.042

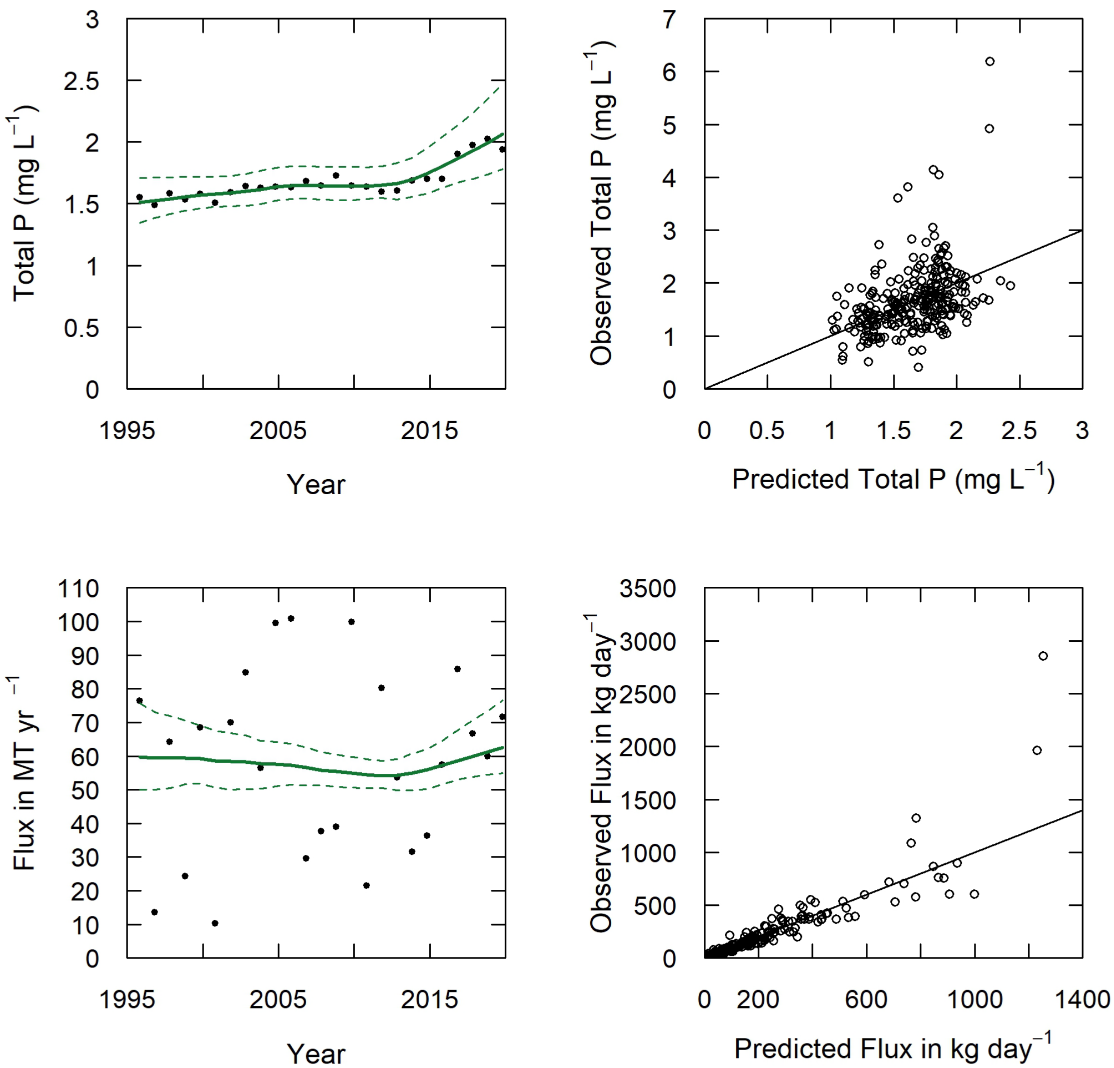

Figure H-13. Tenmile Creek WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

TMC TP WRTDS Results

Flux Bias Statistic = 0.014

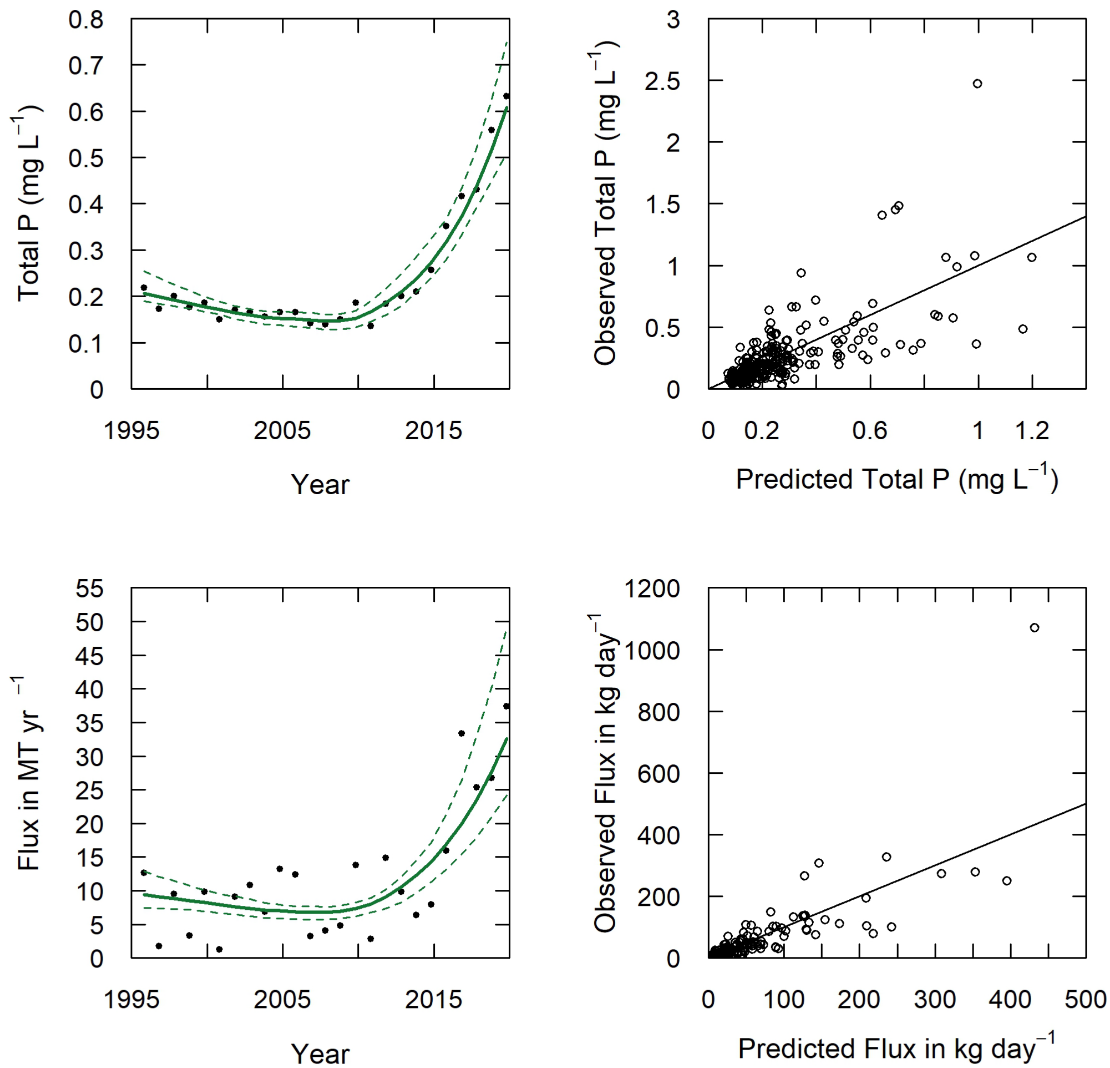

Figure H-14. Tenmile Creek WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.

SGO TN WRTDS Results

Flux Bias Statistic = 0.001

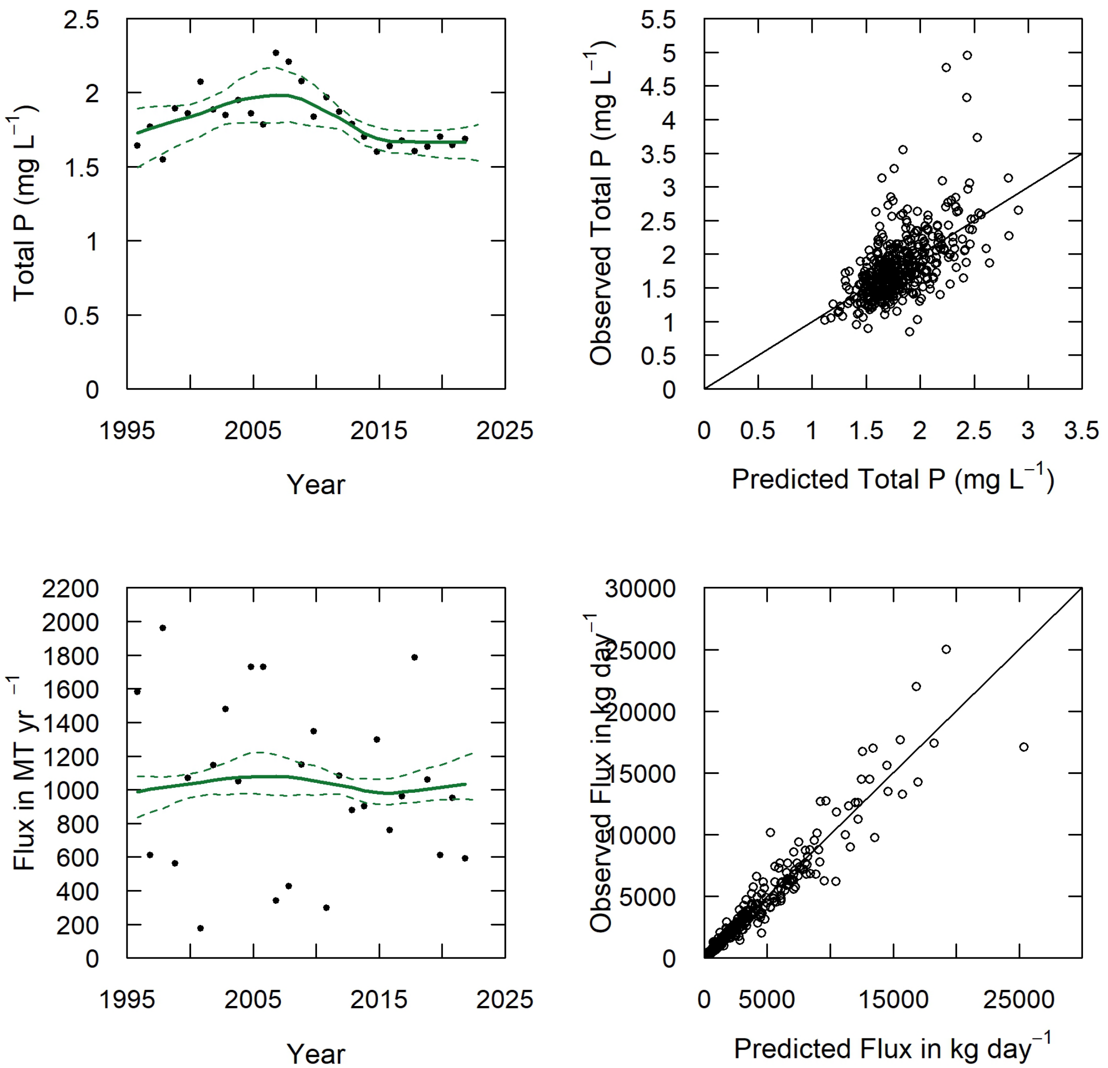

Figure H-15. St. Johns River at Sawgrass Lake Outlet WRTDS model fit for TN. See the beginning of Appendix H for an explanation of each panel.

SGO TP WRTDS Results

Flux Bias Statistic = 0.003

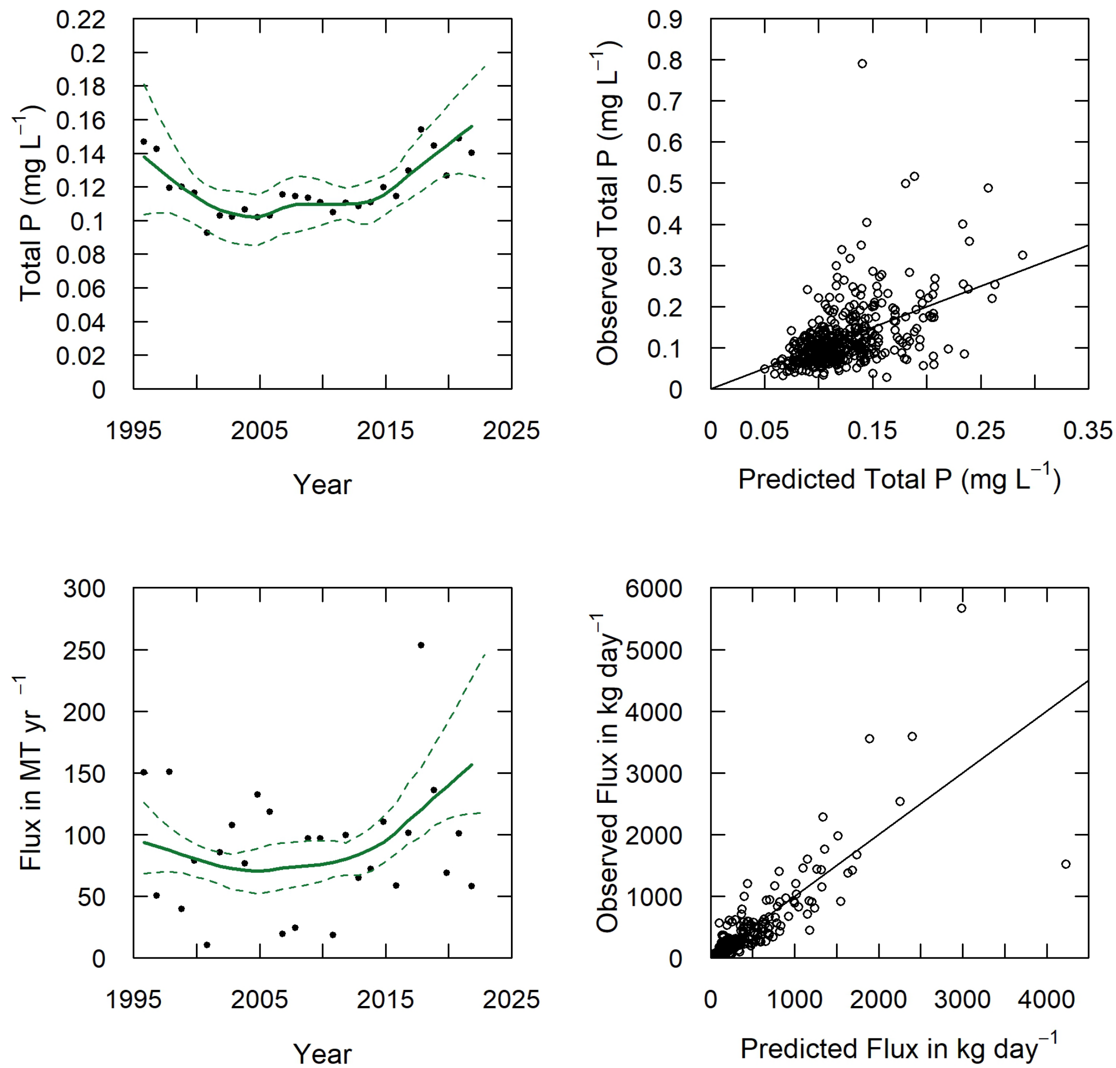

Figure H-16. St. Johns River at Sawgrass Lake Outlet WRTDS model fit for TP. See the beginning of Appendix H for an explanation of each panel.