FY2020 Water Quality Monitoring Report

Upland Stormwater Lakes and Pump Stations

September 30, 2020

Cardno®

Contact Information

Cardno
3905 Crescent Park Drive
Riverview, FL, 33578, USA
Telephone: +1.813.664.4500
www.cardno.com

Document Information

Prepared for

City of Naples-Streets and Stormwater Department Natural Resources Division
295 Riverside Circle, Naples, FL 34102
USA

Project Name	FY2020 Water Quality Monitoring Report Upland Stormwater Lakes and Pump Stations
File Reference	FY2020_NaplesWQ_Monitoring_Report_Draft_09302020.docx
Job Reference	E214055004
Date	September 2020
Version Number	3.0
Effective Date	September 24, 2020
Date Approved	September 30, 2020

Author(s)

Sheri A. Huelster
Project Scientist

Luke Westlake
Field Technician/Ecologist

Approved By

Ed Call
Senior Project Scientist

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
1.0	9/24/2020	Update Graphs/Tables	Luke Westlake	Sheri Huelster
2.0	9/28/2020	Review and update all text	Sheri Huelster	Ed Call
3.0	9/30/2020	Update text and final review	Ed Call/Sheri Huelster	City of Naples

Table of Contents

Tables

Figures

Acronyms

%Sat	Percent Saturation
Ammonia as N	Ammonia as Nitrogen
°C	Degrees Celsius
CFU/100mL	Colony forming unit per 100 milliliters
DO	Dissolved Oxygen
DO Sat	Dissolved Oxygen Saturation
FDEP	Florida Department of Environmetal Protection
FY	Fiscal Year
GeoMean	Geometric Mean
MDL	Minimum Detection Limit
Mg/L	milligrams per liter
NNC	Numeric Nutrient Criteria
NOAA	National Oceanic and Atmospheric Adminstration
NO_x	Nitrate-Nitrite Nitrogen
NTU	Nephelometric Turbidity Unit
OrthoP	Orthophosphorus
QA/QC	Quality Assurance/Quality Control
SC	Specific Conductivity
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
U	Undetected
µg/L	micrograms per liter
µmhos/cm	micro ohms per centimeter

Executive Summary

Upland Stormwater Lakes

Monitoring results from data collected at stormwater lakes were reviewed to identify any outliers that exceed Class III Surface Water Quality Standards within the data collected over the Fiscal Year (FY) 2020 sampling events amongst the various stations. Class III Surface Water Standards are used as a reference for sampling data only. Nutrient parameters (total nitrogen, total phosphorus, and chlorophyll-a) were variable by station and drainage basin during FY2020. Fecal coliform and enterococci values were variable throughout the FY2020 sampling period with isolated spikes in colony counts appearing to occur after stormwater inflows. Copper concentrations at lakes discharging to the same drainage basin appear to have a similar pattern, with 26B (draining to the Gordon River) having the highest overall concentrations.

Pump Stations

Quarterly pump station water quality monitoring was completed in November 2019, February 2020, May 2020, and August 2020 for FY2020 at pump stations 11-Pump, 14-Pump, and PW-Pump. Field measurements (temperature, dissolved oxygen, pH, specific conductivity, salinity, and turbidity) at all stations appeared to be consistent with expected temporal and seasonal variations. Nutrients remained fairly consistent during the sampling period; the exception is the elevated orthophosphate and TP concentrations in May 2020 at 14-Pump. There were also elevated copper concentrations at PW-14 and elevated TSS, mercury, and other heavy metals at PW-Pump during May 2020. Fecal coliform measurements at all pump stations exceeded the Florida Class III Surface Water Quality Standards, which are used a reference value, during this 2020 monitoring year. The data indicates that rainfall is driving fecal coliform and enterococci spikes at the pump monitoring locations.

Management Recommendations

Overall water quality parameters were variable both spatially and temporally during the FY2020 sampling period. Challenges managing stormwater and the associated nutrients are complex and often require a multifaceted approach to adequately address the many sources of nutrient loading in to lakes, ponds and stormwater systems.

Lakes that have consistently high values or trends for water quality parameters are good candidates for further studies to further evaluate the sources and type of nutrient loading occurring within these lakes. Nutrient and bacteriological sourcing studies will identify drivers within each identified lake. The results of these studies will help resource managers at the City identify the sources of nutrient and bacterial loadings and develop targeted management actions for each lake of concern. Additional management strategies for the reduction of total nitrogen (TN) and total phosphorous (TP) concentrations may include: additional littoral plantings, mechanical removal of organic muck and legacy nutrients by dredging, retrofitting stormwater conveyance systems with advanced filter treatment systems, changes in the duration and timing of street sweeping program, routine maintenance of catchment basins, and use of binding agents for inactivation of TP. Management of fecal coliform and enterococci colony counts within stormwater ponds may benefit from changes to the frequency and timing of street sweeper programs within these basins. Installing and maintaining pet waste stations coupled with targeted stormwater education/outreach may provide an effective management strategy for reducing bacterial loading from stormwater

The City of Naples should continue to monitor and collect water quality data to further identify trends in the data versus potential seasonal outliers caused by natural variability (rainfall, temperature, hurricanes, etc.). Continued data collection of marine resources (seagrass and fisheries data) is also recommended in order to compare against water quality data which will also aid in management decisions. Lastly, data from continued sampling will help to identify potential long-term trends and to update previous studies that will aide in future management decisions for each waterbody described below.

1 Introduction

This summary report provides the results of the Fiscal Year (FY) 2020 water quality monitoring of the City of Naples Streets and Stormwater Department (City) stormwater lakes and pump stations (Table 1 and Figure 1). The stations sampled and frequency of sampling during FY2020 (October 2019 to September 2020) was based on the updated survey design that began in October 2017. Monthly sampling was completed at the following ten lakes – Devils Lake (1SE-B), Swan Lake (2B), Colonnade Lake (3B), Lake Suzanne (5B), North Lake (8B), South Lake (9B), 15th Avenue North Lake-WTP Lake (19B), Forest Lake (20B), Lake Manor (22B), and NCH Lake (26B); the remaining six stormwater lakes Mandarin Lake (6B), Sun Lake Terrace (15B), Alligator Lake (10B), East Lake (11B), Lantern Lake (14B), and Half Moon Lake (24B) were sampled quarterly. Pump station monitoring was also conducted on a quarterly basis for the entirety of FY2020. None of the lakes or pump stations sampled for this report qualify as Class III waterbodies, and the Class III Surface Water Quality Standards are used as a reference value only throughout this report. This summary report provides water quality results collected by Cardno staff from October 2019 to September 2020 (laboratory data only available through August 2020).

Table 1. City of Naples stormwater lakes and pump station names, station coordinates, drainage basin, and sampling frequency.

Monitoring Location	Lake Name	Drainage Basin	Latitude	Longitude	Sampling Frequency
1SE-B	Devils Lake	Moorings Bay	26.2054	-81.8081	Monthly
2B	Swan Lake		26.1980	-81.8067	
3B	Colonnade Lake		26.1935	-81.8067	
5B	Lake Suzanne		26.1831	-81.8018	
6B	Mandarin Lake	Gordon River	26.1646	-81.7989	Quarterly
15B	Sun Lake Terrace		26.1811	-81.7924	
19B	15th Ave N Lake (WTP Lake)		26.1660	-81.7950	Monthly
20B	Forest Lake		26.1621	-81.7944	
22B	Lake Manor		26.1565	-81.7921	
26B	NCH Lake		26.1495	-81.7975	
8B	North Lake	Gulf of Mexico	26.1549	-81.8027	
9B	South Lake		26.1534	-81.8034	
10B	Alligator Lake		26.1520	-81.8072	Quarterly
11B	East Lake	Naples Bay	26.1385	-81.7990	
14B	Lantern Lake		26.1163	-81.7998	
24B	Half Moon Lake		26.1151	-81.7995	
PW-Pump	Public Works Pump	Pump Stations	26.1509	-81.7902	Quarterly
11-Pump	Cove Pump		26.1341	-81.7939	
14-Pump	Port Royal Pump		26.1155	-81.7987	

Figure 1. Stormwater lakes and pump stations.

2 Upland Stormwater Lakes

2.1 Water Quality Summaries

The following table and time series plots summarize both field and lab water quality measurements collected by Cardno staff at designated stormwater lake monitoring locations (Figure 1) from October 2019 to September 2020 (lab water quality data only available through August 2020).

Stormwater lake samples were collected at the control structures to represent water quality exiting the lake. Table 2 includes a summary of sampling days with observed flow over or into control structures, as well as minimums, maximums, and annual geometric means calculated for total nitrogen (TN), total phosphorus (TP), chlorophyll-*a*, and copper for each stormwater lake.

Results of all sampled water quality parameters are detailed in time series plots (Figures 2-19) in Sections 2.1.1 and 2.1.2. Monitoring locations are grouped on plots by the associated final drainage destinations (water bodies) and are as followed: Monitoring locations 1SE-B, 2B, 3B, and 5B correspond with lakes that discharge into Moorings Bay (represented with ■); 6B, 15B, 19B, 20B, 22B, and 26B correspond with lakes that ultimately discharge into the Gordon River (represented with a ●); 8B, 9B, 10B correspond with lakes that discharge into the Gulf of Mexico (represented with a ▲); and 11B, 14B, and 24B correspond with lakes whose final discharge destination is either Naples Bay (represented with a ♦, AMEC 2012).

Table 2. Minimums, maximums, and annual geometric means of total nitrogen, total phosphorus, chlorophyll-*a*, and copper for stormwater lakes in Naples, Florida from October 2019 to August 2020.

Lake Name	Monitoring Location	Associated Waterbody	Number of Samples	Sampling Days with Observed Flow	Total Nitrogen (mg/L)			Total Phosphorus (mg/L)			Chlorophyll-a (µg/L)			Copper (µg/L)		
					Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean*
Devils Lake	1SE-B	Moorings Bay	11	11	0.801	1.460	1.082	0.030	0.062	0.042	1.57	36.9	4.62	4.64	26.4	10.5
Swan Lake	2B		11	11	0.827	2.340	1.210	0.042	0.163	0.074	20.3	54.5	30.5	1.63	54.7	3.89
Colonnade Lake	3B		11	11	0.759	2.520	1.157	0.028	0.147	0.093	4.78	200	34.2	0.991	6.43	3.10
Lake Suzanne	5B		11	11	0.792	1.460	1.110	0.081	0.211	0.124	7.17	45.6	21.0	3.99	42.8	11.7
Mandarin Lake	6B	Gordon River	4	4	0.708	1.320	0.952	0.048	0.097	0.071	13.3	80.0	33.3	0.438	86.2	2.48
Sun Lake Terrace	15B		4	3	0.876	1.820	1.197	0.034	0.182	0.055	7.88	35.3	15.1	2.43	8.66	5.09
15th Ave N Lake (WTP Lake)	19B		11	11	1.010	1.540	1.238	0.049	0.139	0.077	7.15	71.2	21.3	U (0.346)	3.01	0.66
Forest Lake	20B		4	2	1.120	2.070	1.600	0.033	0.127	0.058	5.42	110	29.6	U (0.346)	4.59	0.75
Lake Manor	22B		11	8	0.606	1.620	0.819	0.060	0.141	0.095	4.99	54.8	11.9	U (0.272)	3.02	0.60
NCH Lake	26B		11	11	1.100	1.980	1.435	0.067	0.293	0.124	12.70	83.9	32.6	21.2	83.6	40.5
North Lake	8B	Gulf of Mexico	11	11	1.310	3.890	2.452	0.073	0.394	0.174	39.5	224	82.0	1.36	7.95	3.23
South Lake	9B		11	11	0.992	9.630	2.066	0.048	0.689	0.132	5.17	1018	46.2	1.46	10.1	3.66
Alligator Lake	10B		4	4	0.658	1.360	0.992	0.042	0.081	0.064	7.35	40.7	17.5	U (0.272)	2.63	0.65
East Lake	11B	Naples Bay	4	4	0.818	1.380	1.001	0.037	0.082	0.061	8.16	25.7	16.0	0.801	33.0	4.09
Lantern Lake	14B		4	2	1.320	1.980	1.557	0.142	0.214	0.182	50.9	81.6	65.2	U (0.272)	3.06	0.63
Half Moon Lake	24B		4	3	2.950	4.110	3.538	2.210	5.540	3.005	64.3	135	87.3	0.751	2.67	1.20

Gray shaded rows indicate monitoring locations that typically have specific conductivities of 4580 µS/cm or higher; Class III Marine Standards are provided as reference only.
*Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

2.1.1 Time Series Plots of Field Parameters

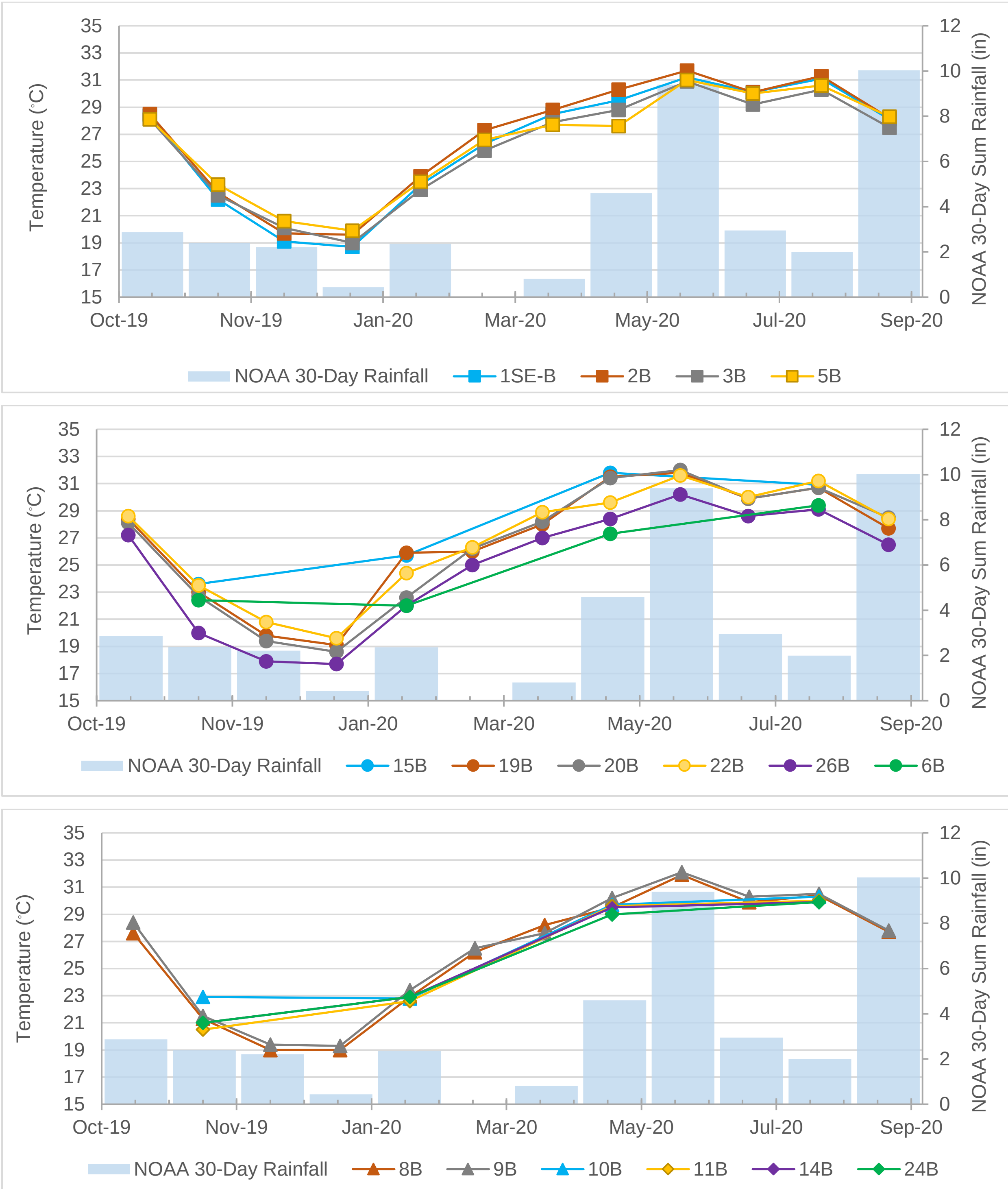


Figure 2. **Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

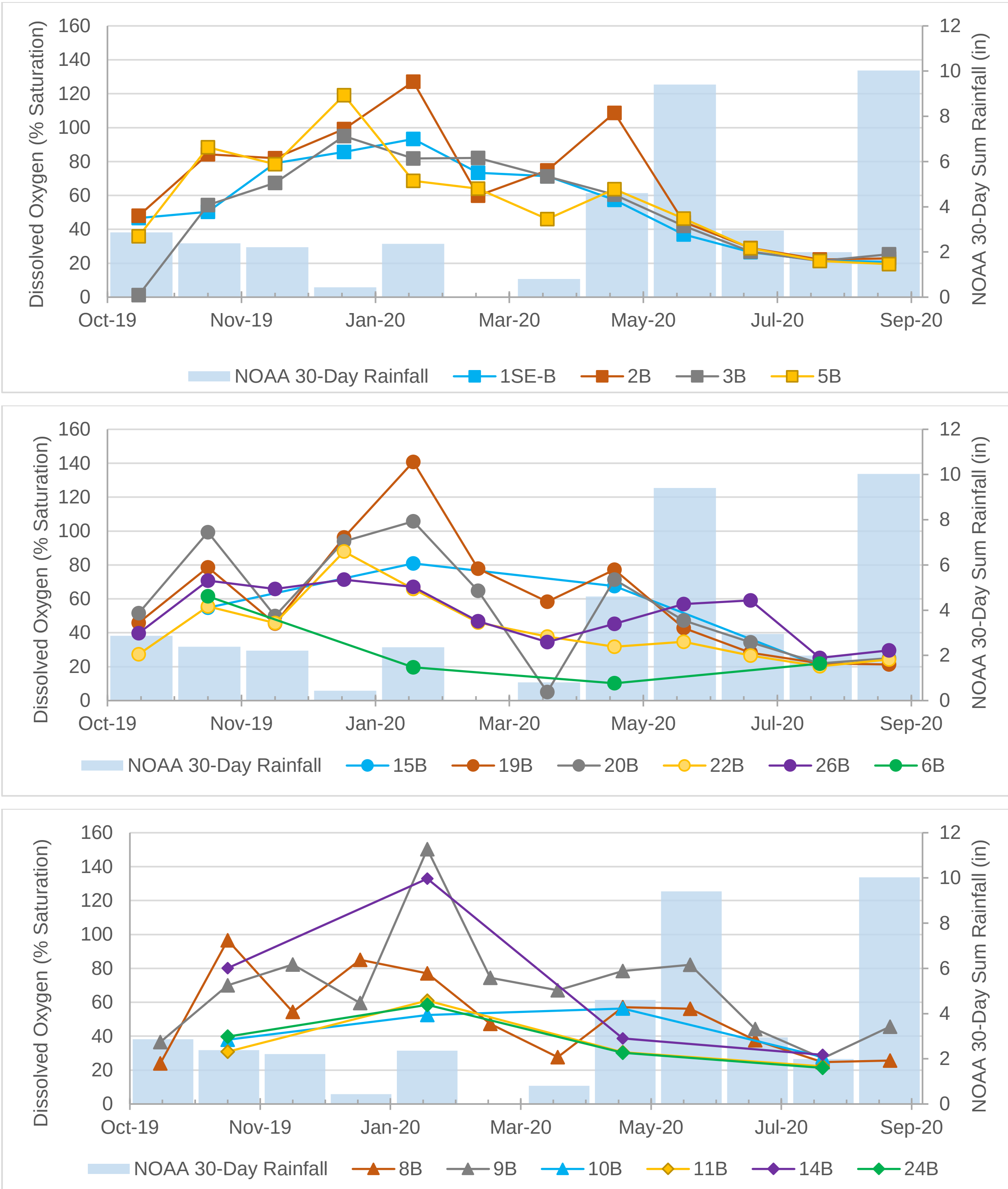


Figure 3. **Time series plots of dissolved oxygen saturation and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

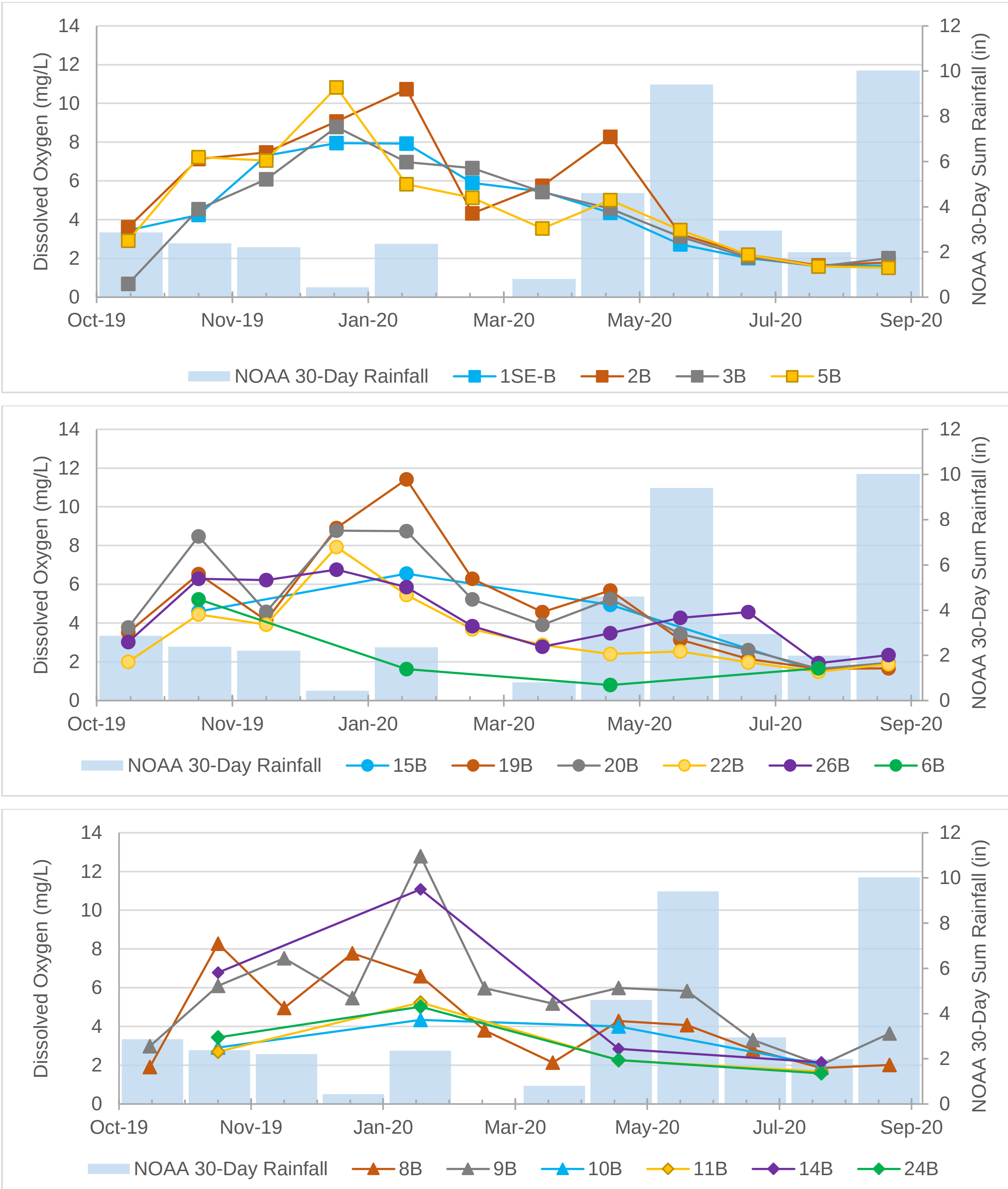


Figure 4. **Time series plots of dissolved oxygen concentration (mg/L) and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

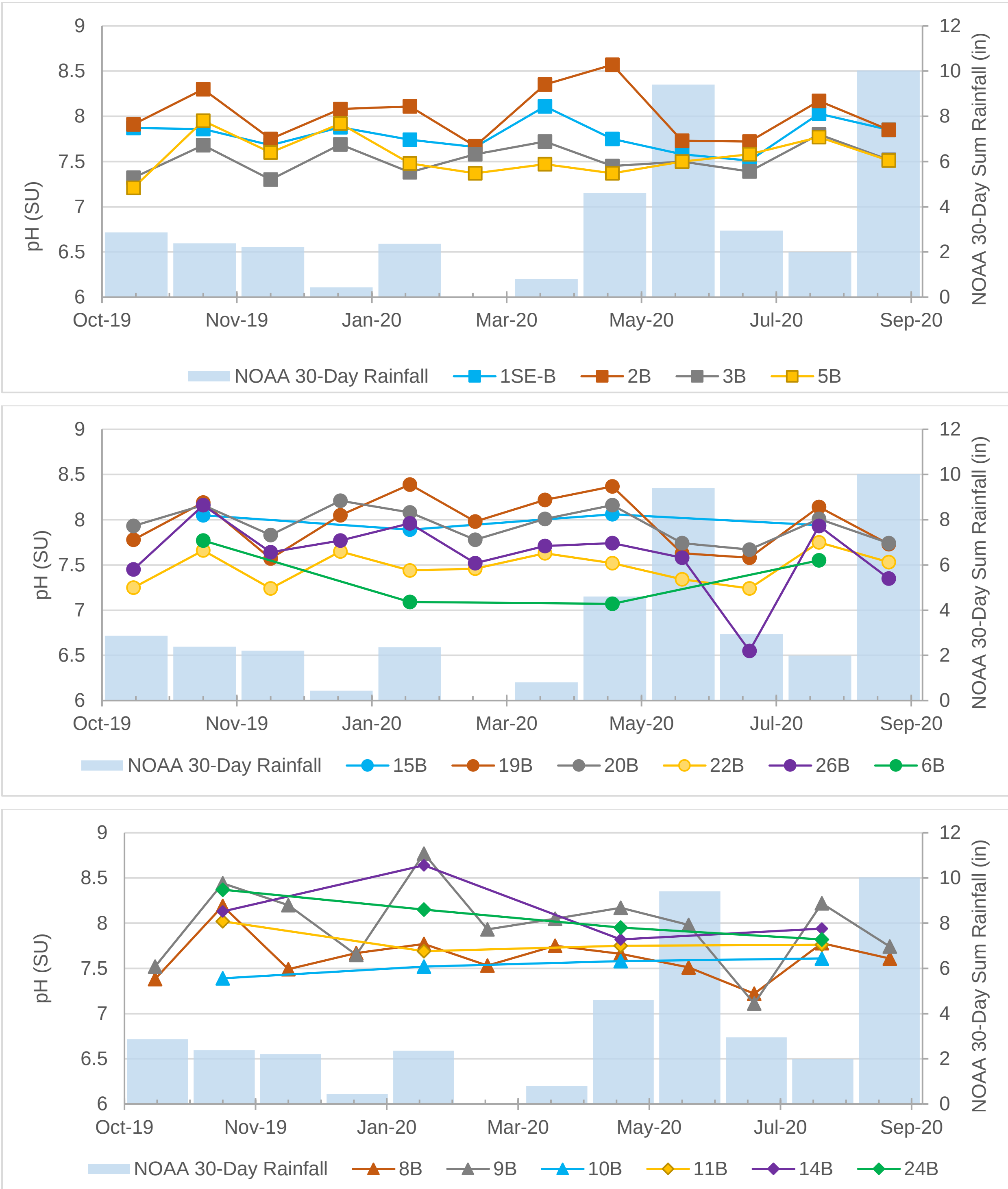


Figure 5. Time series plots of pH and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

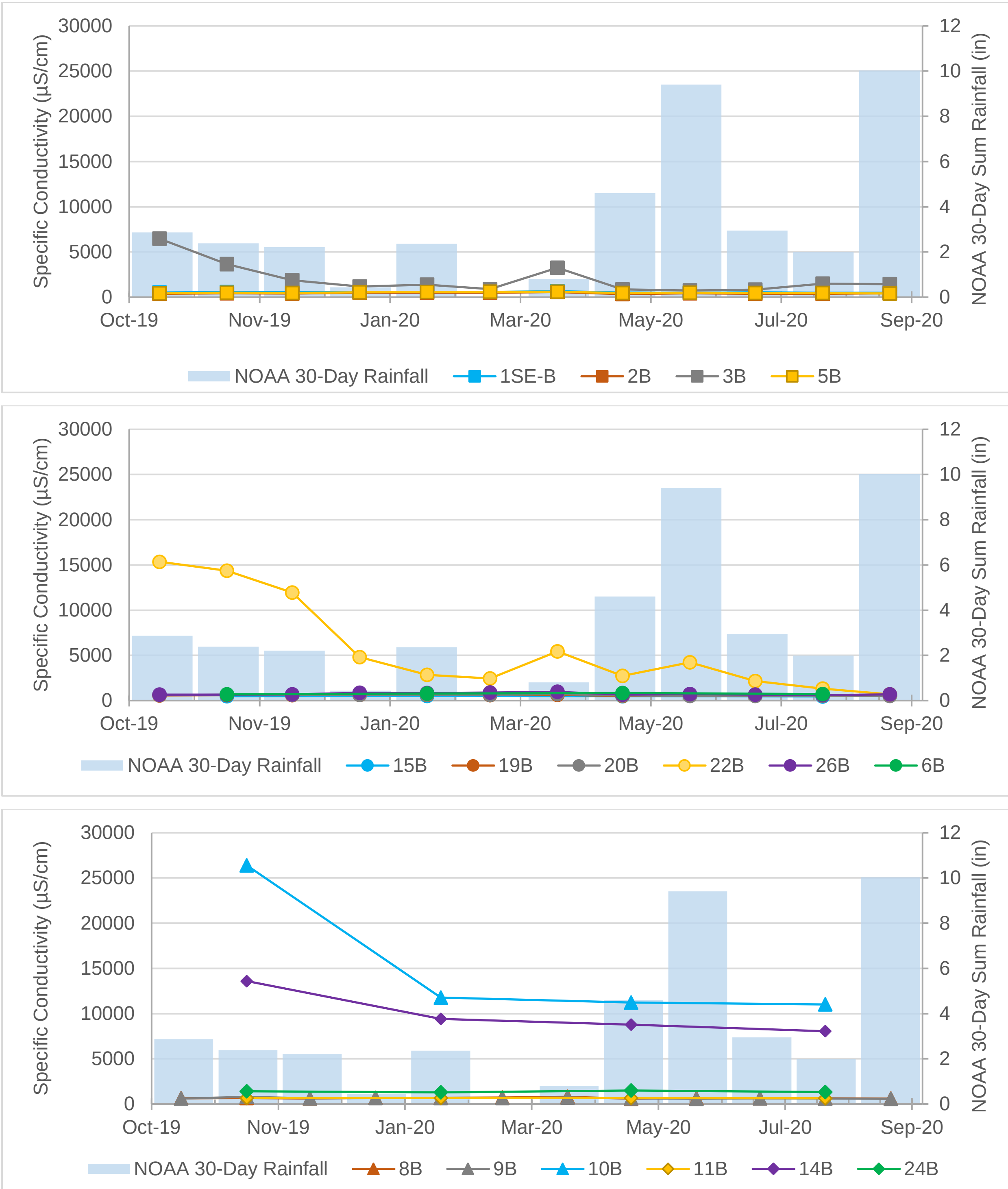
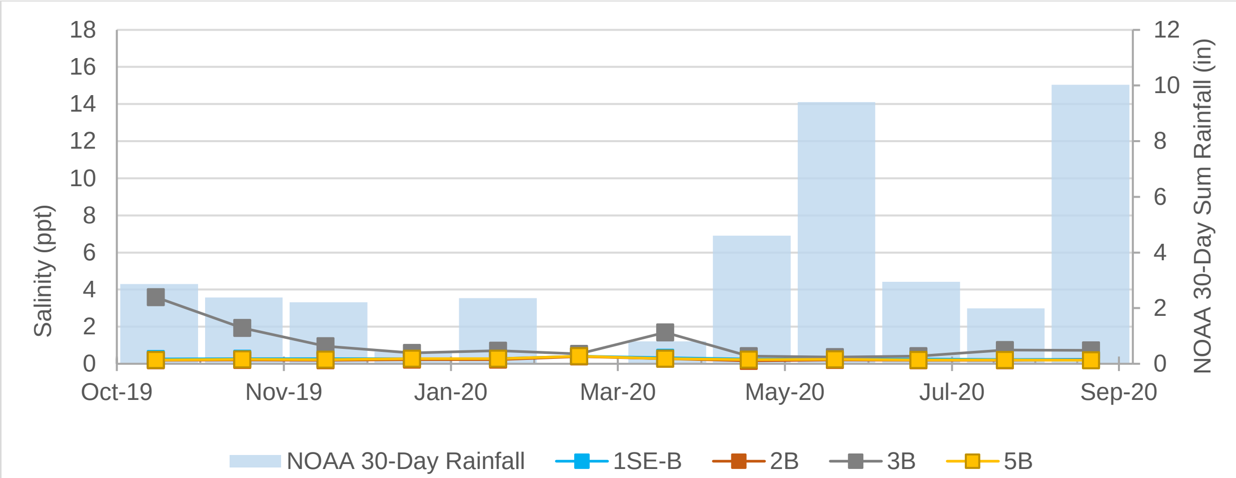
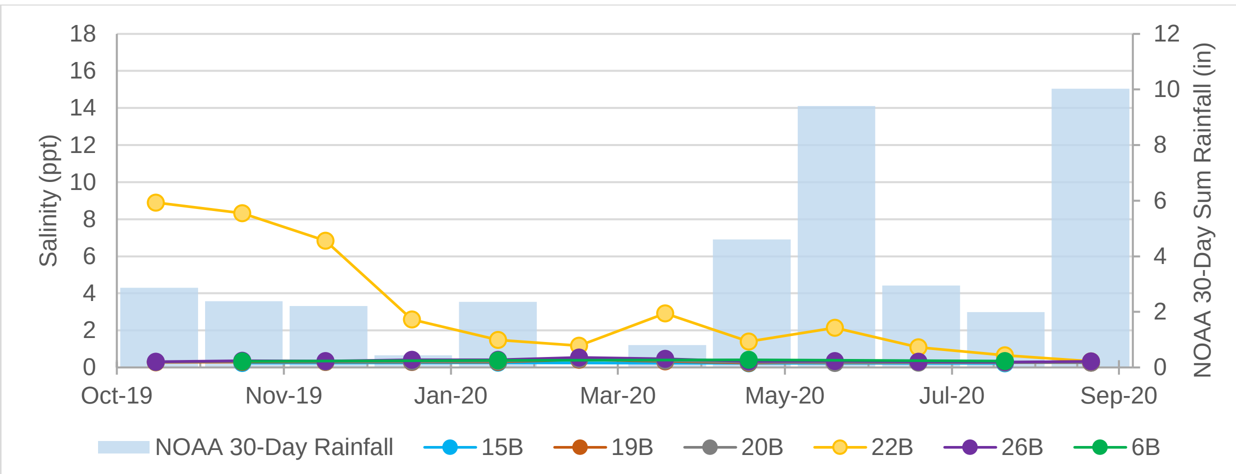


Figure 6. **Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**





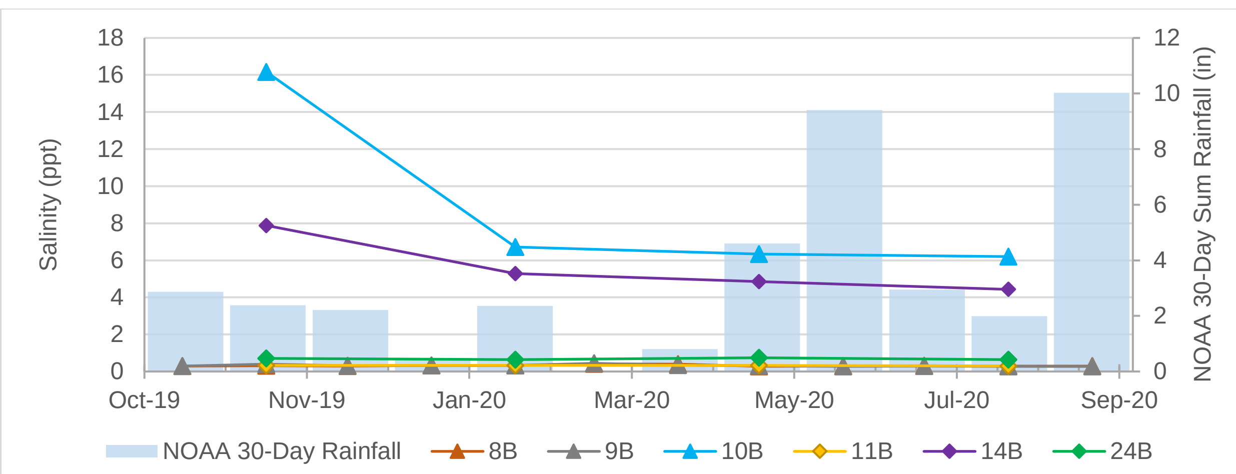


Figure 7. Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

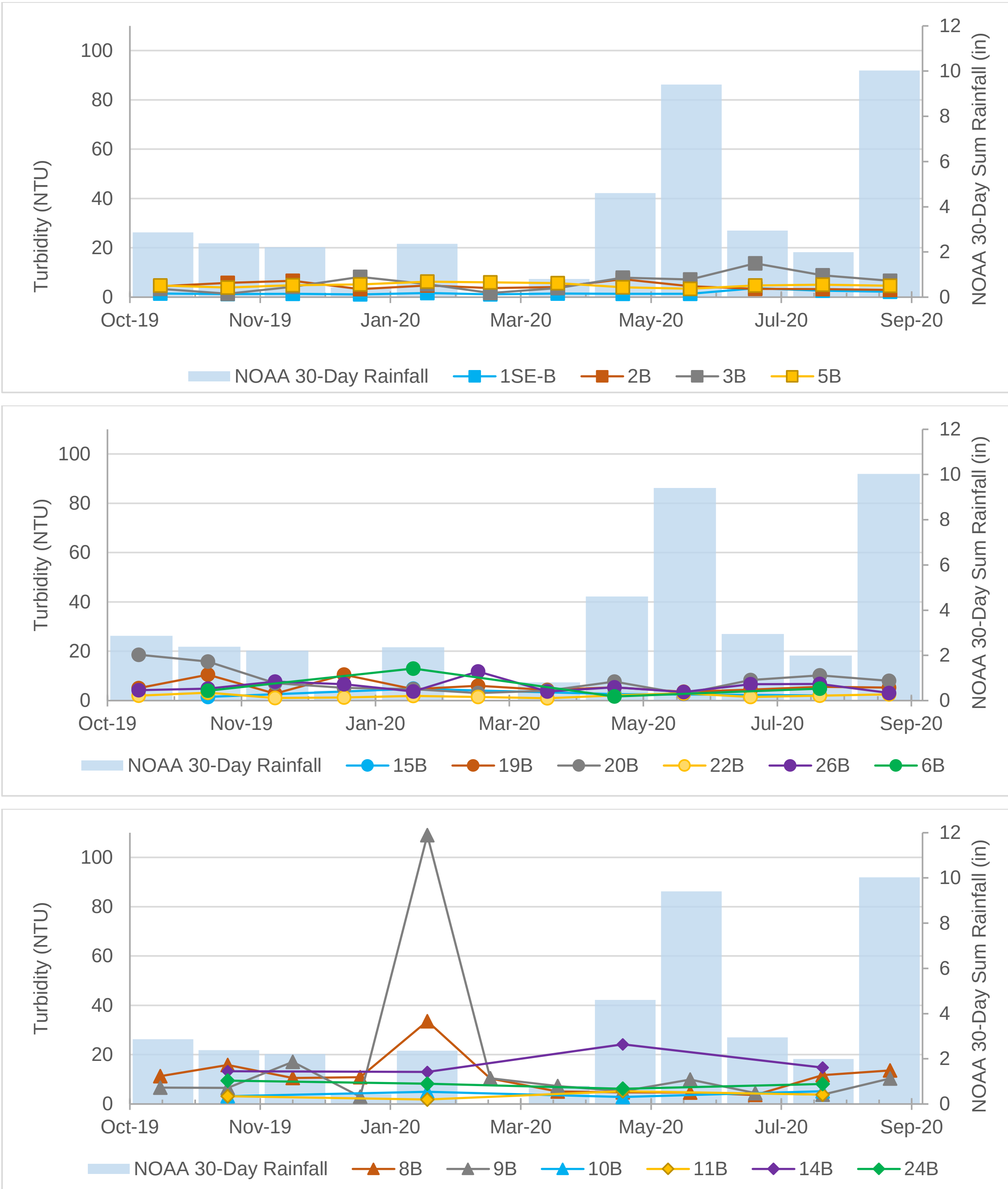
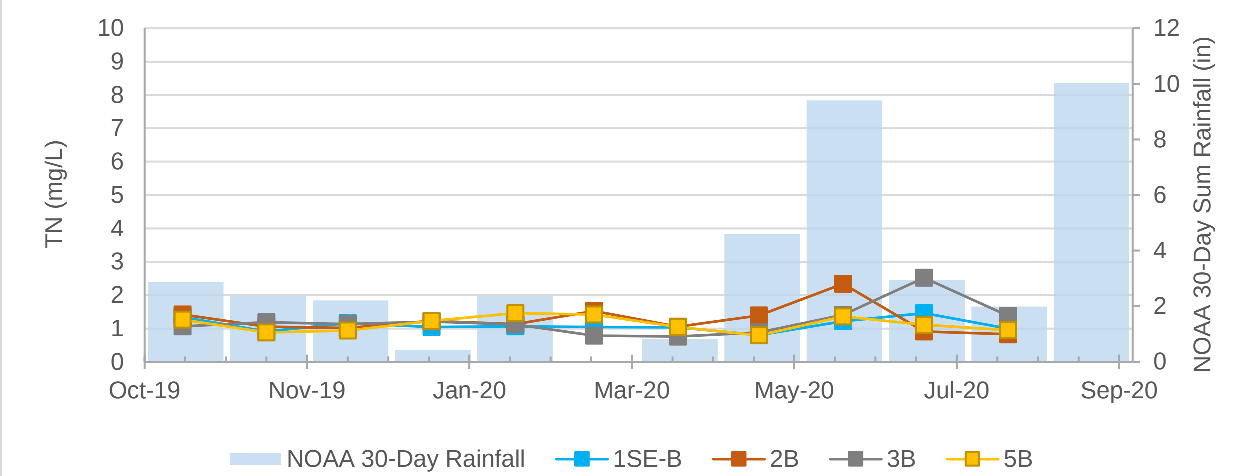
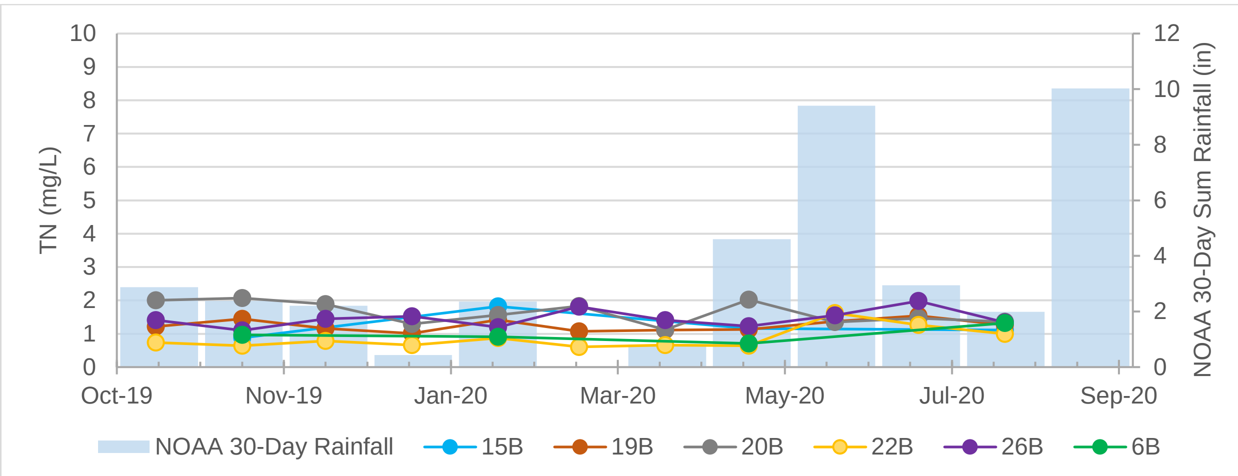


Figure 8. Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

2.1.2 Time Series Plots of Lab Parameters





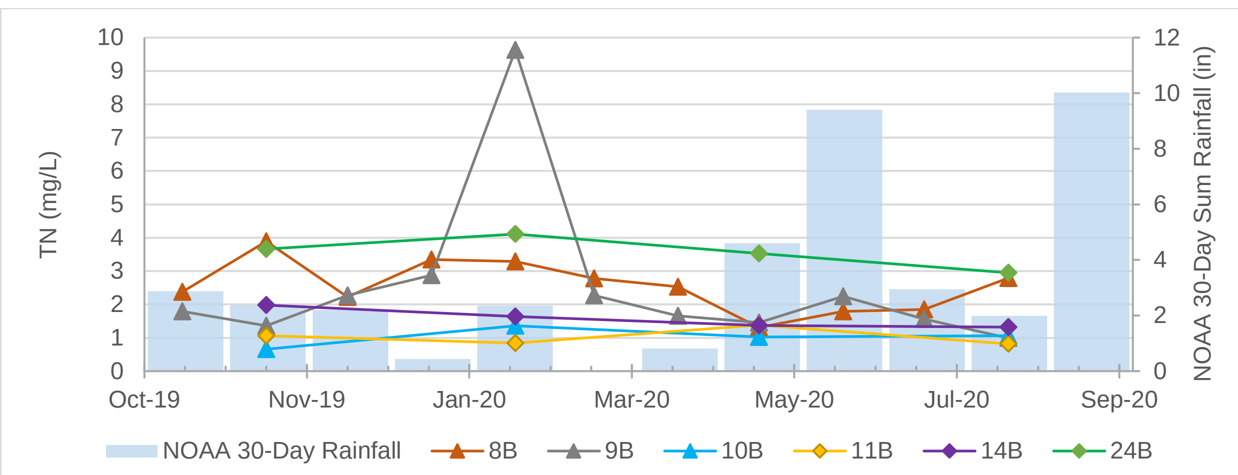


Figure 9. Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

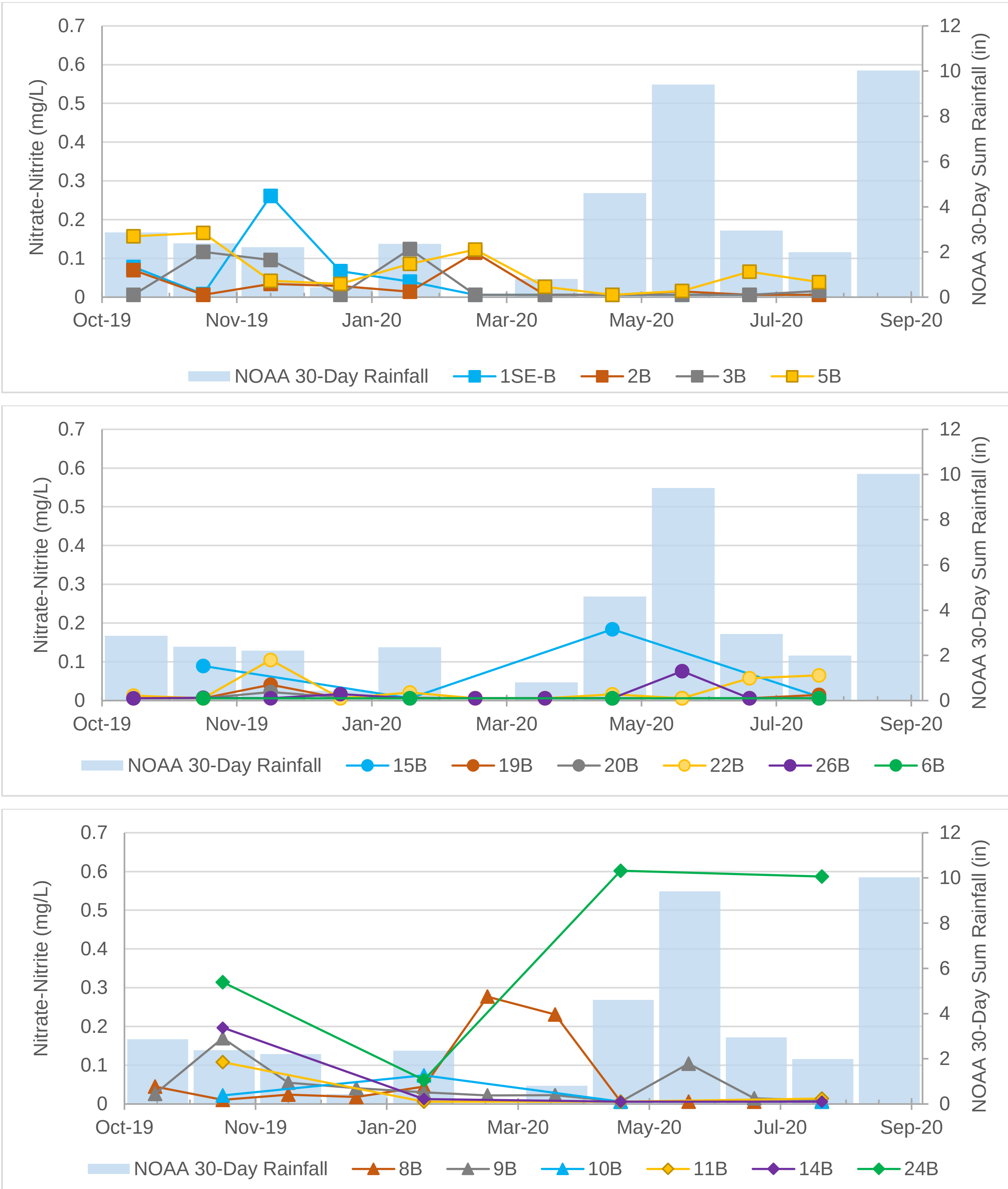


Figure 10. Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

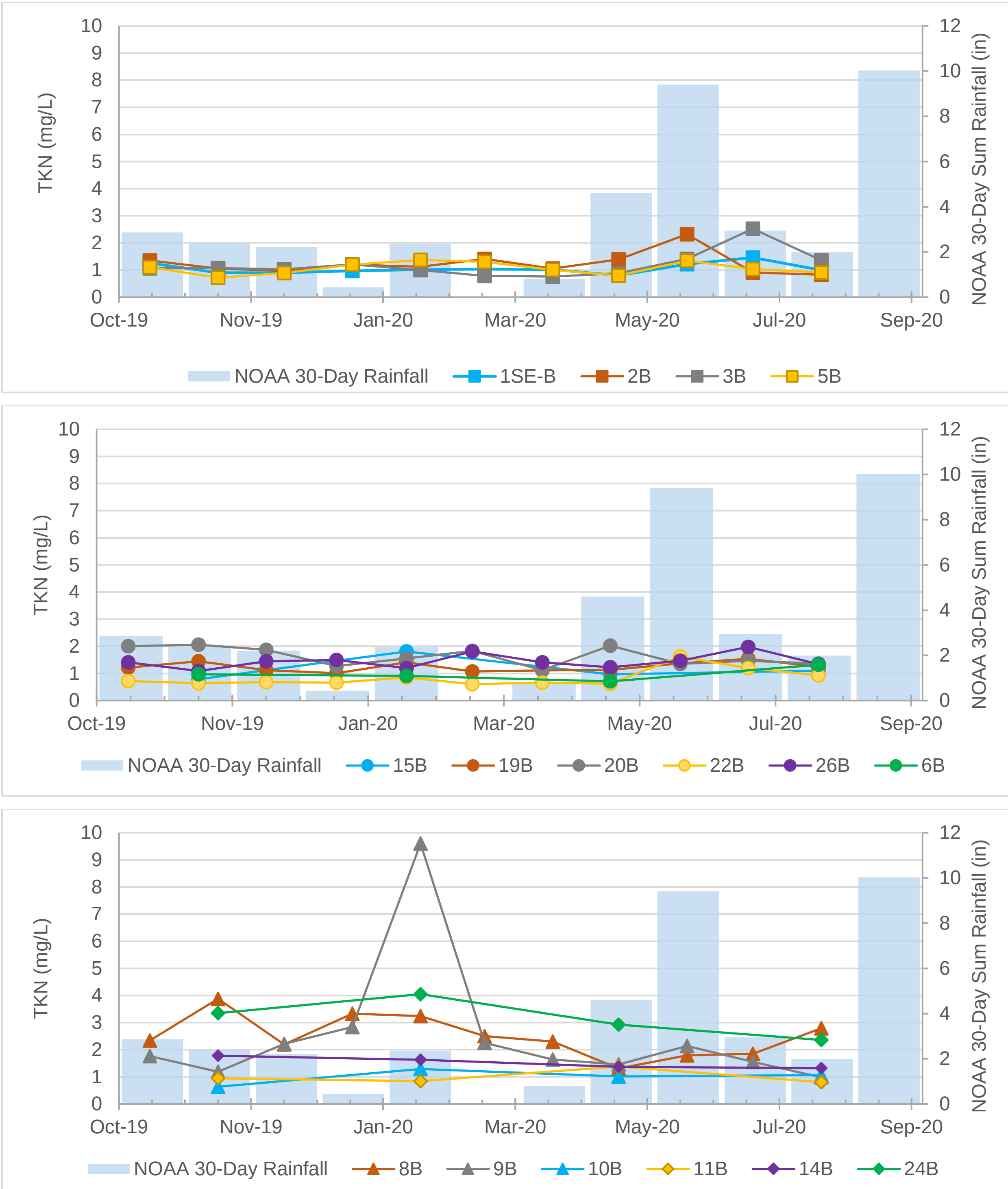


Figure 11. Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

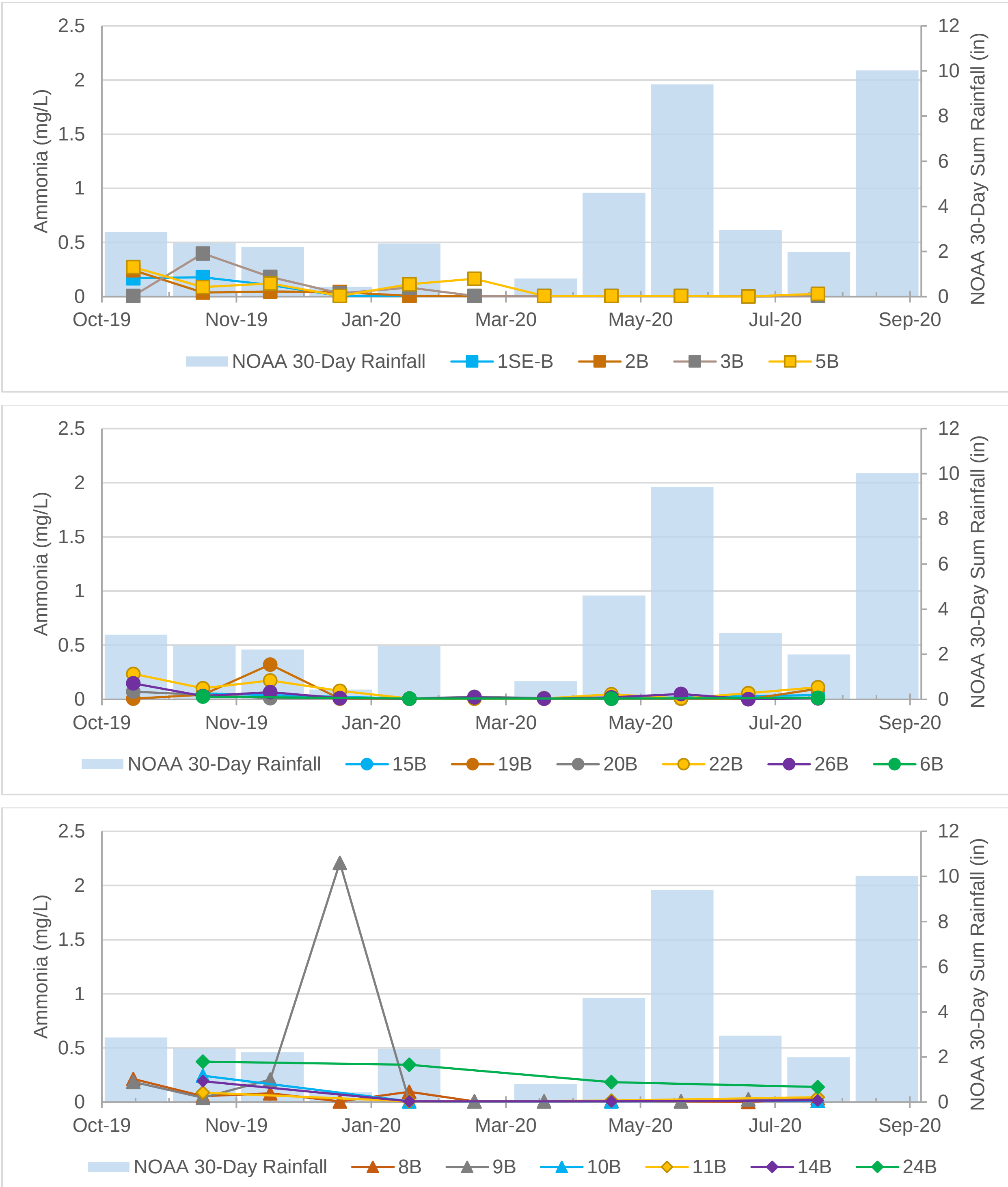


Figure 12. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

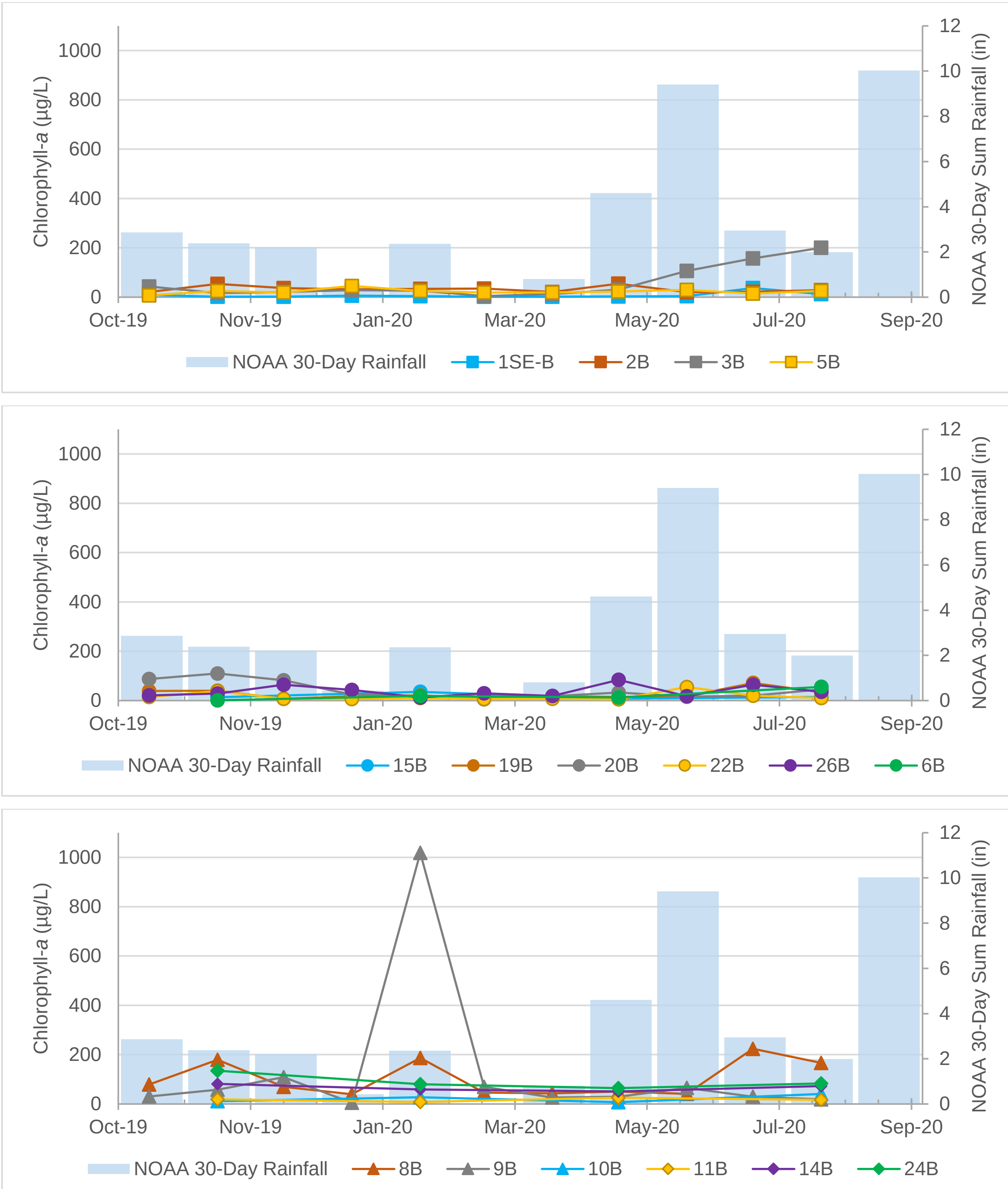


Figure 13. Time series plots of chlorophyll-*a* and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

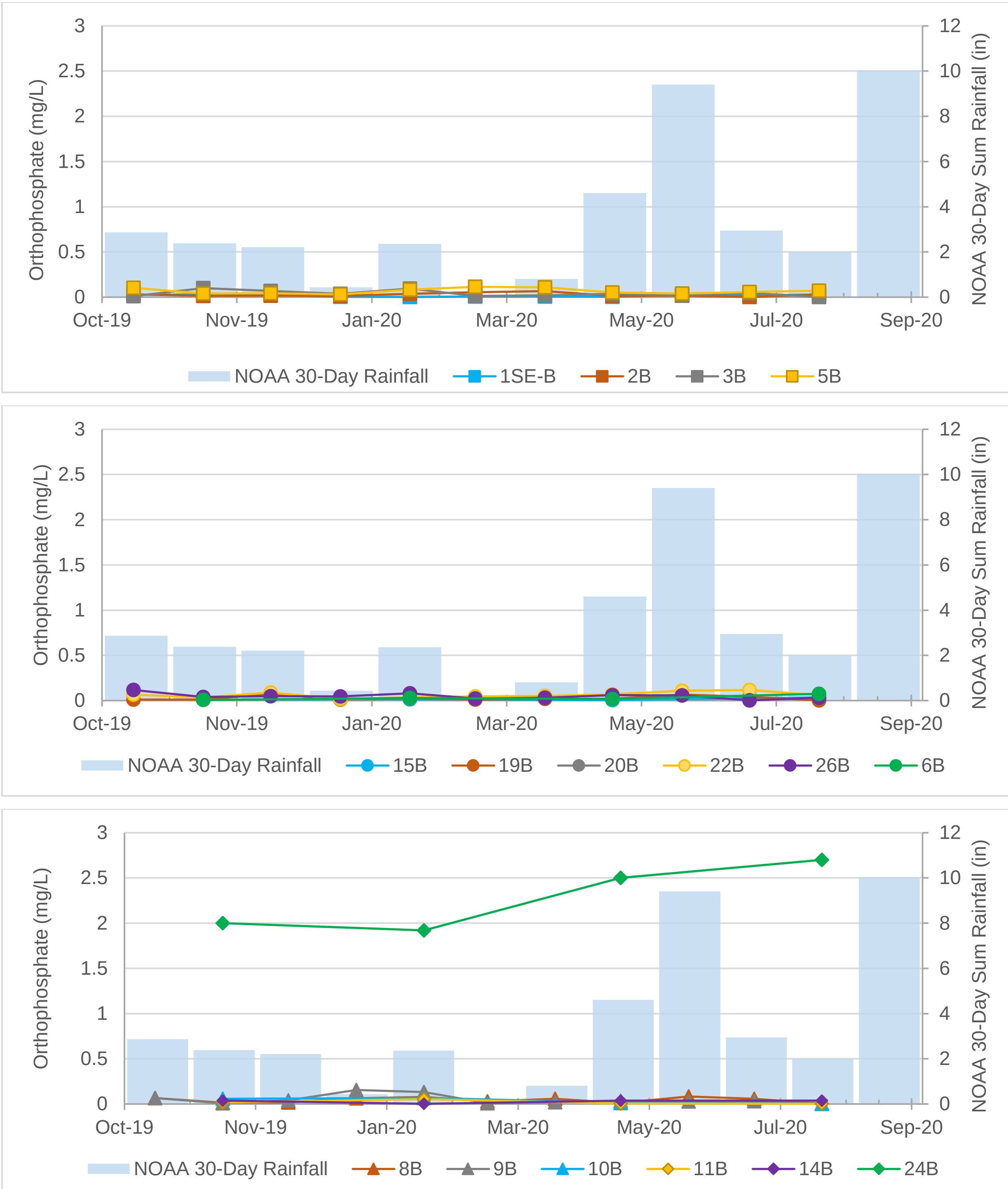


Figure 14. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

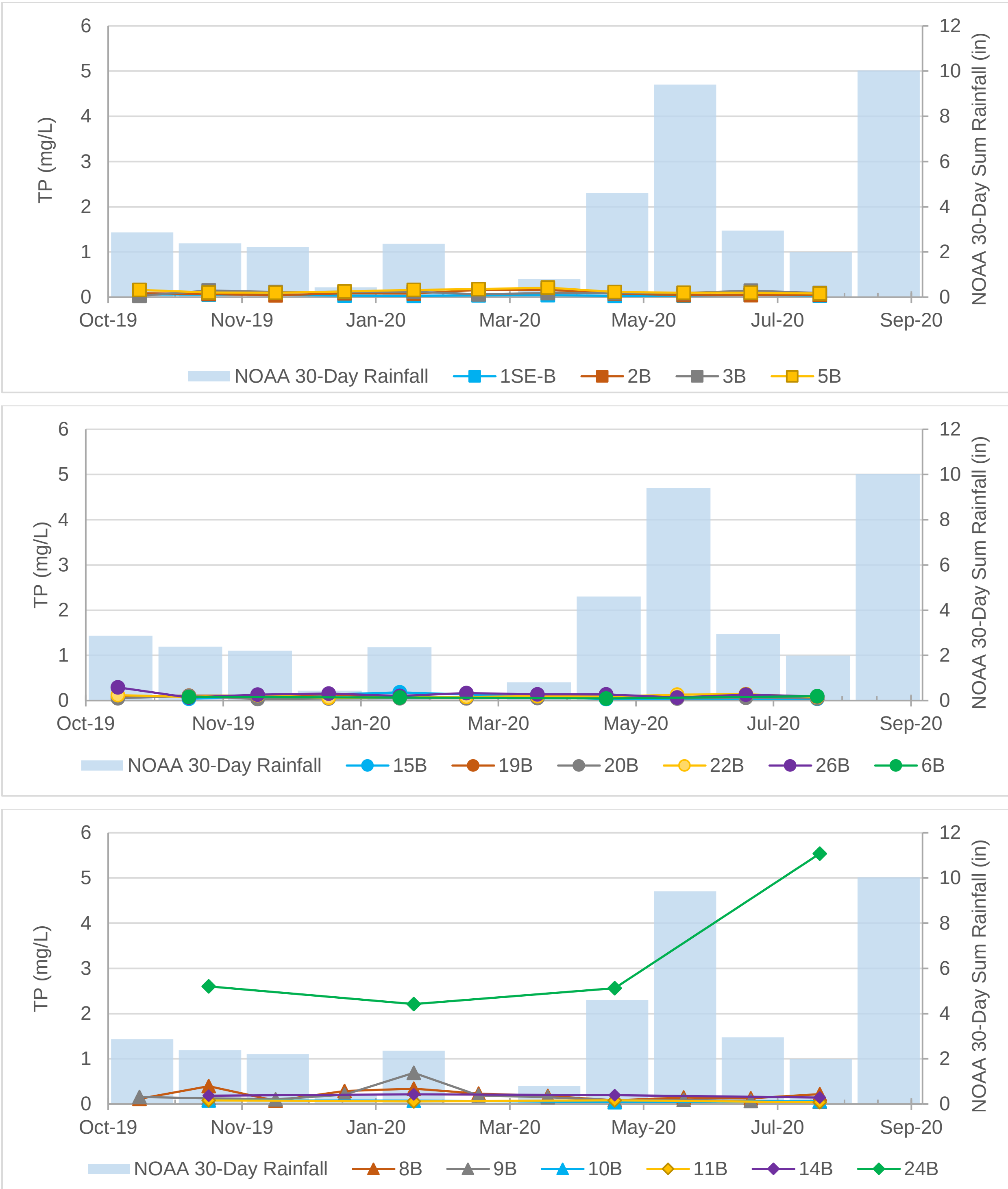


Figure 15. Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

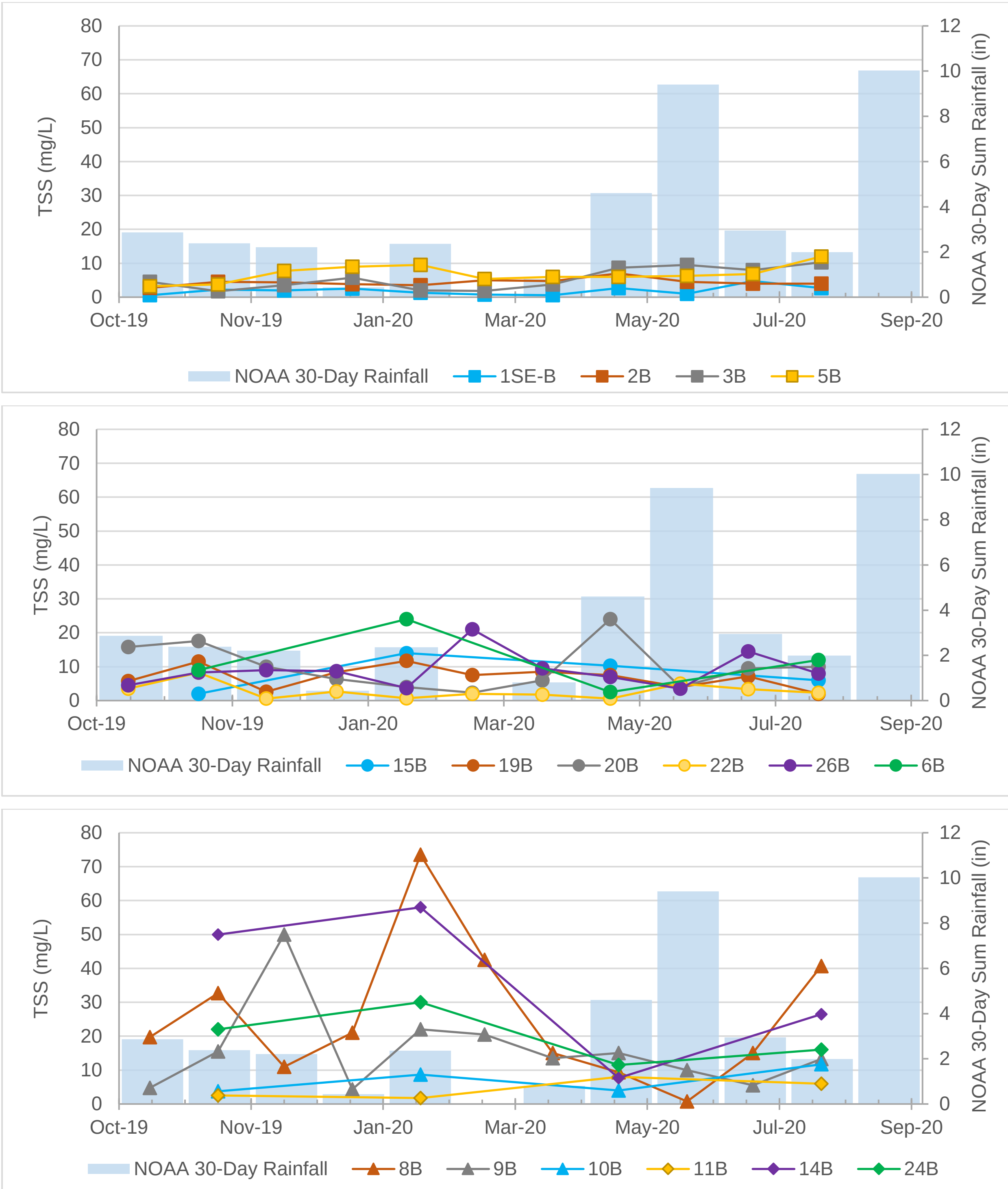


Figure 16. Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

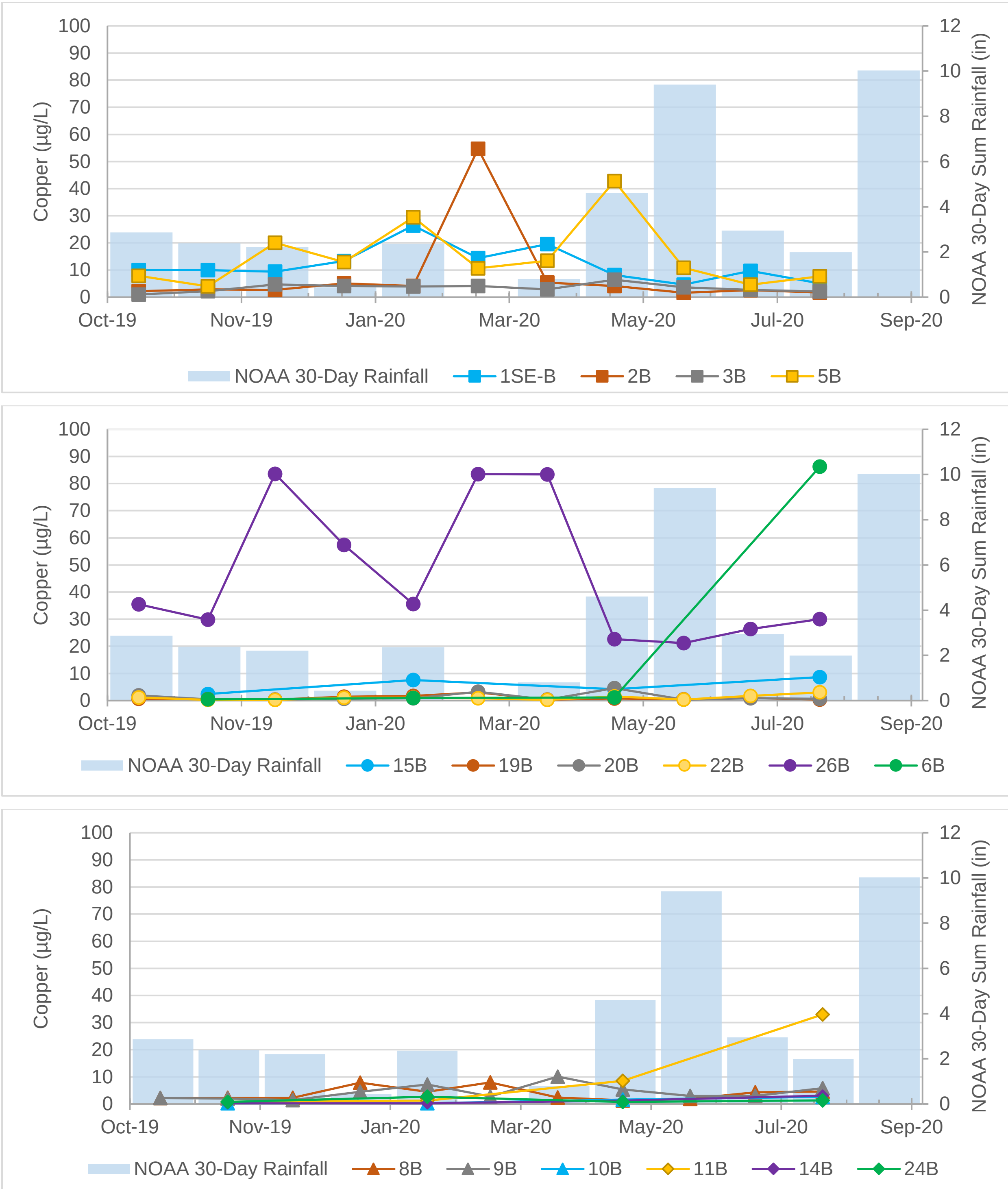
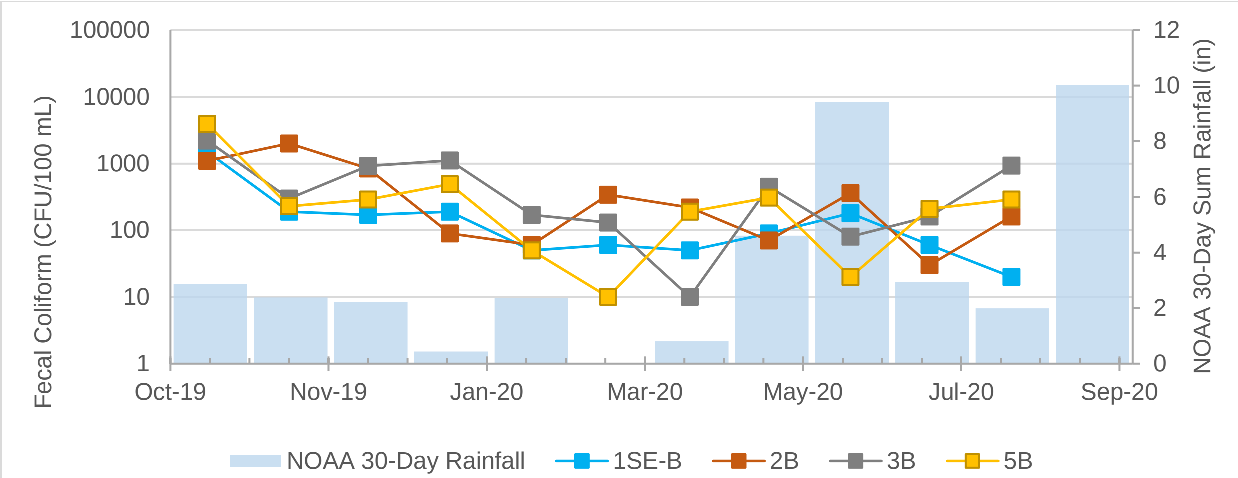
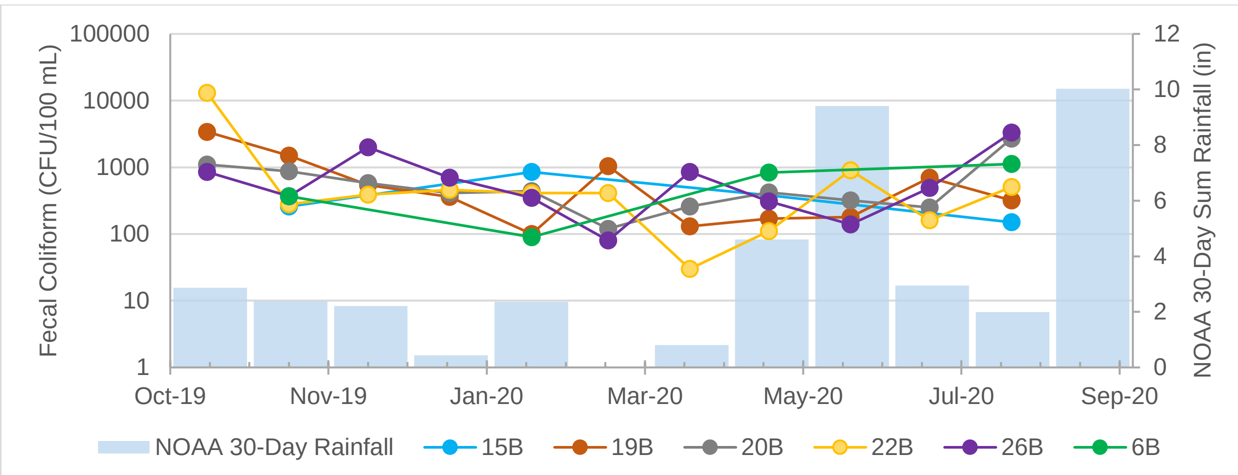


Figure 17. Time series plots of copper and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).





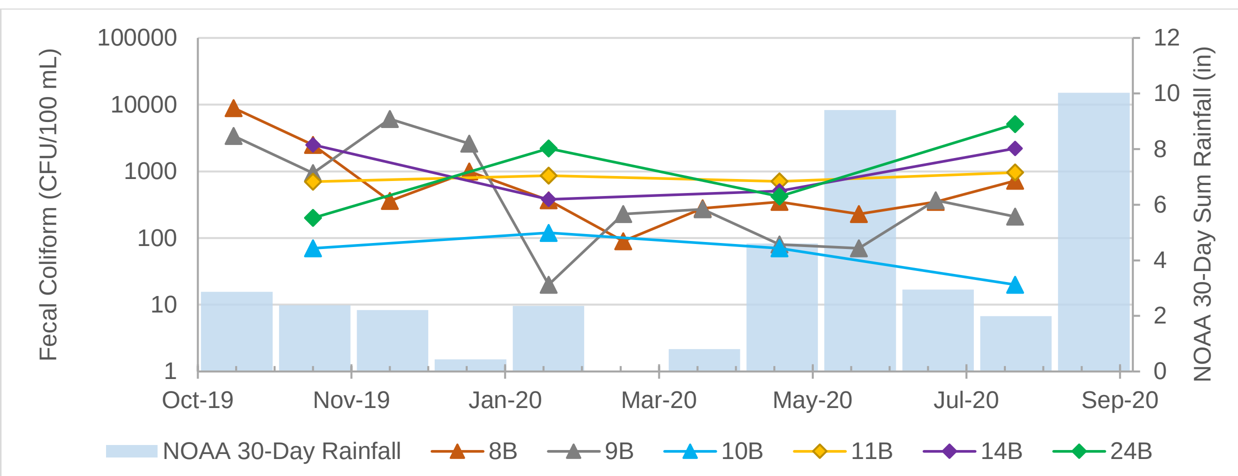


Figure 18. Time series log scale plots of fecal coliform colony forming units (CFU) per mL and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

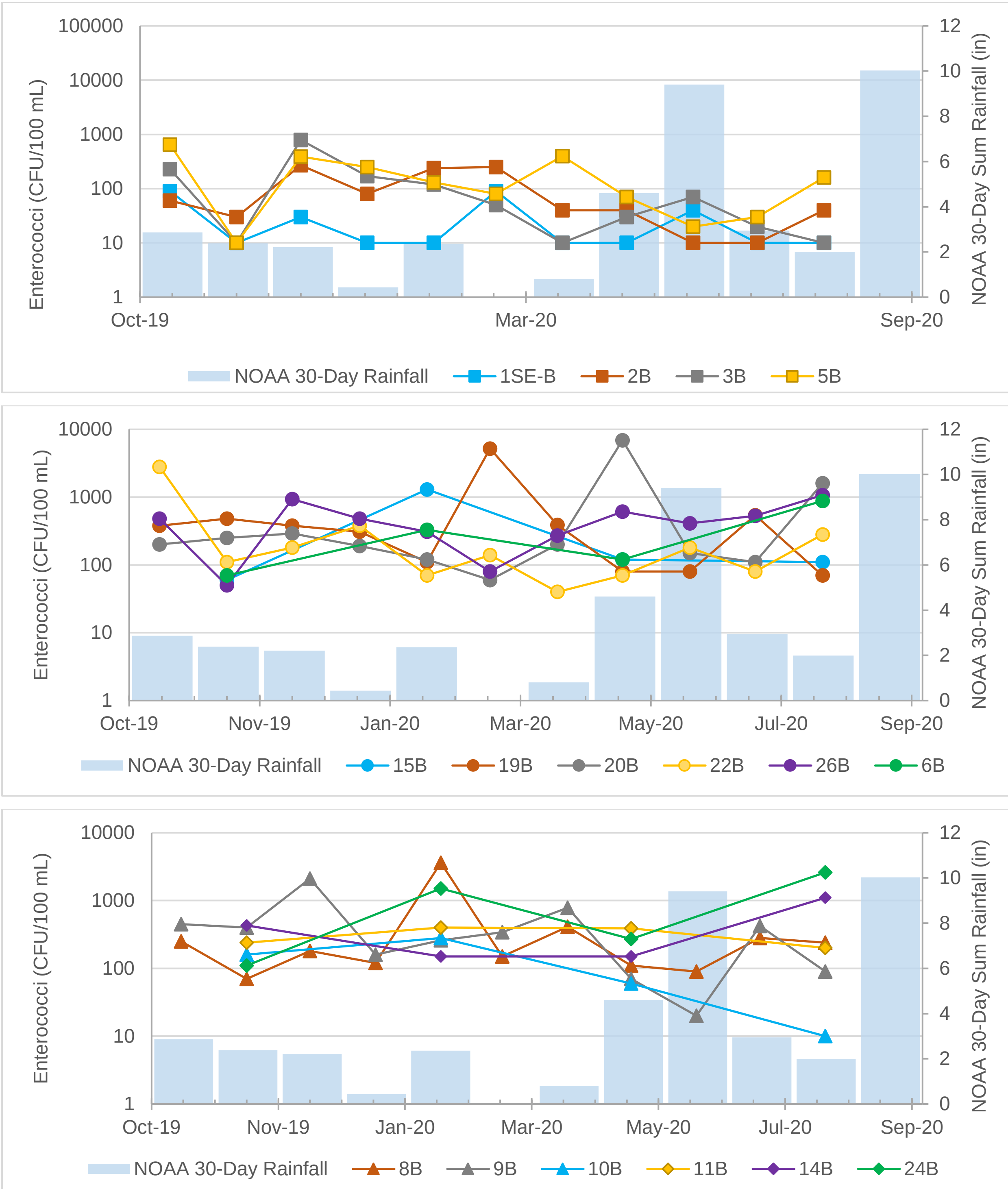


Figure 19. Time series log scale plots of enterococci CFU per mL and prior 30-day sum NOAA rainfall from October 2019 through August 2020 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

2.2 Discussion

Monitoring results from data collected at stormwater lakes were reviewed to identify any outliers or visual trends within the data collected over the FY2020 sampling events amongst the various stations. Class III Surface Water Quality Standards are used to compare collected data against as reference only and the City of Naples is not required to achieve these values during this reporting period. Field parameter measurements (temperature, dissolved oxygen, pH, specific conductivity [SC], salinity, and turbidity) recorded at lakes within the same drainage basins were variable over the sampling period (Figures 2 to 8). Temperature appears to be higher during the wet season within all drainage basins, as expected. The September 2020 temperatures at all lakes were slightly lower than other wet season months, possibly as a result of recent rains/overcast conditions days prior to the sampling event (Figure 2).

Dissolved oxygen (concentration and percent saturation) was variable among the drainage basins with periods of both super saturation (well over 100 percent saturation at the surface) and hypoxia (concentrations below 2 mg/L). The super-saturated measurements occurred in January or February 2020 while hypoxic conditions occurred during the wet season months of July through September at most lakes (Figures 3 and 4). During at least one monitoring event, lakes draining to Moorings Bay, the Gordon River, Naples Bay, and the Gulf of Mexico had dissolved oxygen saturations below the Class III time of day corrected daily average standards for fresh and marine waters (greater than 38 and 42 percent saturation, respectively). The low dissolved oxygen saturation generally occurred during warmer months (October 2019 or July to September 2020).

Levels of pH remained fairly consistent in most lakes draining to Moorings Bay, Naples Bays, and the Gulf of Mexico, while the lakes draining to the Gordon River were more variable (Figure 5). Three lakes had measurements of pH above the Class III standard maximum of 8.5 during FY2020; lake 2B was elevated in May 2020 (8.57 SU), and lakes 14B and 9B were elevated in February 2020 (8.64 and 8.77 SU, respectively).

Based on SC measurements, two of the sampling locations (10B and 14B) are typically identified as "predominately marine" (indicated by gray-shaded row headings in Table 2) according to the Florida Department of Environmental Protection (FDEP) classification of specific conductivities greater than 4,580 µS/cm (62-302.200(30), F.A.C.); the remaining fourteen stormwater lakes have exhibited freshwater SC at the time of sampling (Figure 6). Two lakes, one draining to Moorings Bay (3B) and one draining to the Gordon River (22B) had SC measurements above the Class III Freshwater Standard of 1,275 µS/cm during the various sampling events (Figure 6).

Turbidity measured at all lakes and events were within the Class III Standards for fresh and marine waters, (less than or equal to 29 NTU above background or just less than or equal to 29 NTU if no established background for both fresh and marine waters) with the exception of two lakes draining to the Gulf of Mexico (8B and 9B) during February 2020 (Figure 8). TSS was fairly stable in lakes draining to Moorings Bay and the Gordon River in FY2020, but were more variable in lakes draining to the Gulf of Mexico or Naples Bay (Figure 16).

Nutrient parameters (TN, TP, and chlorophyll-*a*) were variable by station and drainage basin during FY2020 samples. TN at locations draining to Moorings Bay remained fairly consistent from October 2019 through May 2020 but then were more variable from June to August 2020; concentrations ranged from 0.759 to 2.52 mg/L during FY2020 (Figure 9). TN concentrations at lakes draining to the Gordon River very consistent in FY2020 with measurements ranging from 0.606 to 2.07 mg/L. Lakes draining to Naples Bay had very consistent TN concentrations within each individual lake (overall range 0.818 to 4.11 mg/L), while lakes draining to the Gulf of Mexico were variable by location (measurements ranging from 0.658 to 9.63 mg/L) with higher values at 8B and lower concentrations at 10B (Figure 9). There was also a spike in TN (with TKN as the source) at 9B during February 2020.

TP concentrations for lakes draining to Moorings Bay and Gordon River were very consistent over the sampling year with no spikes in data observed (Figure 15). There were a small number of elevated concentrations in lakes draining to the Gulf of Mexico (8B during November 2019 and 9B during February 2020); while 24B draining to Naples had higher overall concentrations with an increase between May and August 2020 sampling events.

For comparison, the Naples Bay Numeric Nutrient Criteria for TN and TP are annual geometric means of 0.57 mg/L and 0.045 mg/L, respectively (Rule 62-302.532; F.A.C.). The calculated annual geometric mean TN concentration at all lakes were above the NNC criterion of 0.57 mg/L in FY2020 (Table 2). All but one lake (1SE-B draining to Moorings Bay) had TP annual geometric means above the NNC criterion of 0.045 mg/L in FY2020. While not directly subjected to that criterion, the elevated concentrations of TN and TP in lakes that ultimately drain to Naples Bay, may contribute to the impairment of that waterbody through continued inputs of higher nutrient concentrations.

Chlorophyll-*a* concentrations at stormwater lakes draining to Moorings Bay, were fairly consistent at three of the lakes, while 3B saw an increase from June through August 2020 (Figure 13). Lakes that ultimately drain to the Gordon River were fairly stable, ranging from 4.99 to 110 µg/L; higher concentrations were consistently noted at 20B from October 2019 through January 2020 (Figure 13). Stations that ultimately drain to Naples Bay and the Gulf of Mexico had variable chlorophyll-*a* concentrations ranging from around 5.17 to 224 µg/L; there was a spike in chlorophyll-*a* at 9B during February 2020 with a concentration of 1,018 µg/L (Figure 13).

Copper concentrations at lakes discharging to the same drainage basin seem to generally keep a similar pattern, one exception being Gordon River basin monitoring location 26B which had consistently higher concentrations overall (range of 21.2 to 83.6 µg/L). There was a spike in copper at 6B during August 2020, with a concentration similar to those recorded in 26B (Figure 17). Lake 11B, draining to Naples Bay had increases in copper during all four monitoring events, with the highest concentration of 33 µg/L in August 2020. Lake 1SE-B, draining to Moorings Bay generally had higher concentrations, but 5B was more variable during FY2020 with alternating monthly increases and decreases (Figure 17). Spikes of this nature may indicate recent dosing of copper sulfate.

Fecal coliform and enterococci colony counts were variable throughout the FY2020 sampling period with isolated spikes in colony counts appearing to occur after isolated stormwater inflows (Figures 18 and 19). Enterococci colony counts showed small isolated spikes throughout the sampling period as a likely response to increased rainfall.

2.2.1 Nutrient and Bacterial Management

Effective nutrient and bacterial management actions require additional sourcing studies for lakes that have either consistently high values or have statistical significant increasing trends. The information from these studies will assist the City’s resource managers in developing targeted nutrient reduction strategies.

Nutrient reduction strategies for TN and TP may include: additional littoral plantings, mechanical dredging to remove organic muck and legacy nutrients, retrofitting stormwater conveyance systems with additional treatment systems, street sweeper programs, routine weir and baffle box clean outs, public outreach and education programs, long term stormwater master planning, and evaluation of the use of binding agents (which may also effectively inactivate TP but treatments and costs vary greatly by the binding agent that is chosen).

Elevated chlorophyll-*a* concentrations often indicate water quality impairments from nutrients with stormwater runoff from urban landscapes containing readily metabolized nutrients that promote algal growth and reproduction. Management strategies that target reductions in TN and TP will also aid in reducing chlorophyll-*a* blooms within these stormwater catchments. Another area of concern is the residence time of nutrients within the lake or pond with longer periods of zero to no flow which may increase the duration and extent of a chlorophyll-*a* bloom. Algal proliferation within stormwater lakes and ponds is indicative of potential elevated nutrients. Continued monitoring and refinement of management strategies to include surface aeration or bottom diffuser, and supplemental public education on the effects of copper in Naples and Moorings Bay.

Management of fecal coliform and enterococci colonies within stormwater ponds may benefit from changes to the frequency and timing of street sweeper programs within these basins. Routine maintenance of stormwater catchment basins as well as installing and maintaining pet waste stations coupled with education and outreach activities have been shown to be effective in reducing bacterial loading from stormwater into lakes and ponds.

Overall water quality parameters were variable both spatially and temporally during the FY2020 sampling period. Challenges managing stormwater and the associated nutrients are complex and often require a multifaceted approach to adequately address the many sources of nutrient loading into lakes, ponds and stormwater systems. Continued data collection is needed to further identify trends in the data versus potential seasonal outliers caused by natural variability (rainfall, temperature, hurricanes, etc.) which will aid in future management decisions. Data from continued sampling will help to identify potential long-term trends and to update previous studies that will aide in future management decisions for each waterbody described above.

3 Pump Stations

3.1 Water Quality Summaries

The following table and time series plots summarize both field and lab water quality measurements collected quarterly by Cardno staff at the three City pump stations (Figure 1) from October 2019 to September 2020. The quarterly sampling events occurred in November 2019, February 2020, May 2020, and August 2020.

All FY2020 water quality monitoring samples were collected quarterly from the wet wells at each pump station. Table 3 includes a summary of sampling days with observed flow within wet wells, as well as minimums, maximums, and annual geometric means calculated from pump station water quality data for total nitrogen, total phosphorus and copper. Results of all sampled water quality parameters are displayed in time series plots in Sections 3.1.1 and 3.1.2 (Figures 20-45).

Table 3. Minimums, maximums, and annual geometric means of total nitrogen, total phosphorus, and copper for PW-Pump, 11-Pump, and 14-Pump in Naples, Florida measured quarterly from October 2019 to September 2020.

Lake Name	Monitoring Location	Number of Samples	Sampling Days with Observed Flow	Total Nitrogen (mg/L)			Total Phosphorus (mg/L)			Copper (µg/L)		
				Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean*
Public Works Pump	PW-Pump	4	4	1.14	1.68	1.34	0.072	0.320	0.134	U (0.272)	7.41	1.57
Cove Pump	11-Pump	4	4	1.36	1.48	1.42	0.102	0.148	0.126	U (0.346)	6.45	1.38
Port Royal Pump	14-Pump	4	4	1.02	1.97	1.41	0.123	0.684	0.282	U (0.272)	14.90	1.36

Gray shaded rows indicate monitoring locations that typically have specific conductivities of 4580 µS/cm or higher; Class III Marine Standards are used as reference values only.
*Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

3.1.1 Time Series Plots of Field Parameters

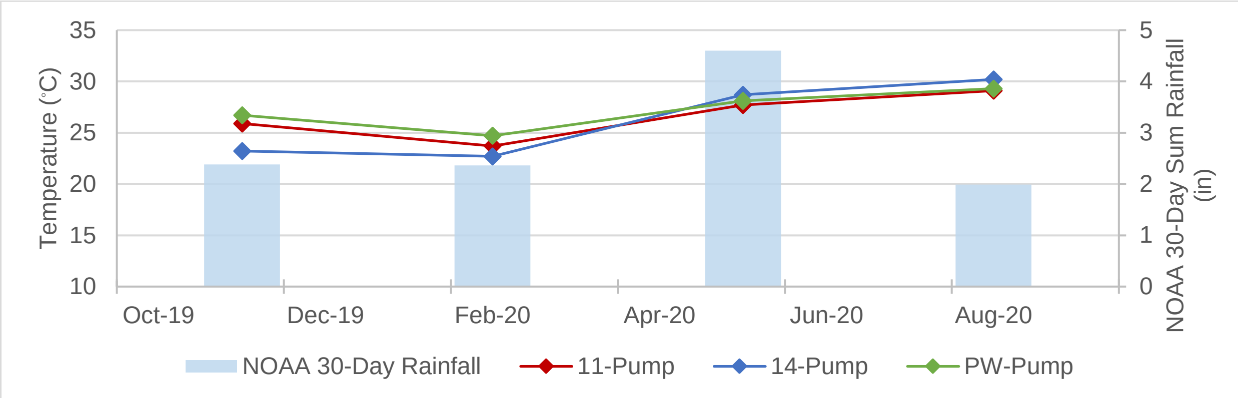


Figure 20. Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

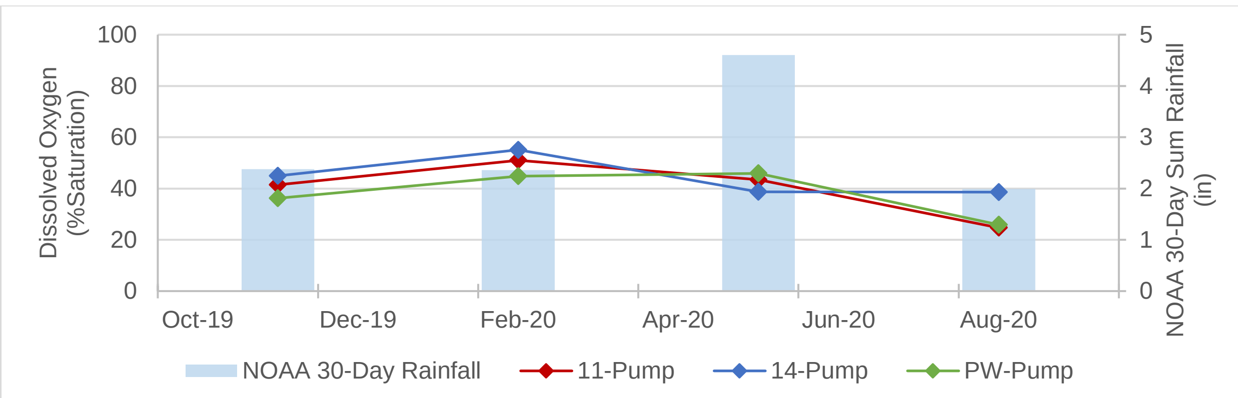


Figure 21. Time series plots of dissolved oxygen saturation and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

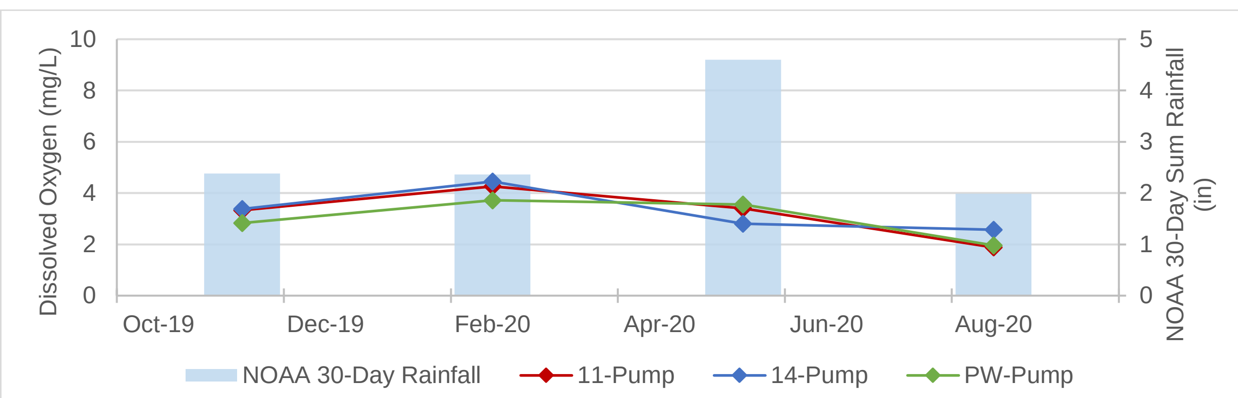


Figure 22. Time series plots of dissolved oxygen concentration (mg/L) and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

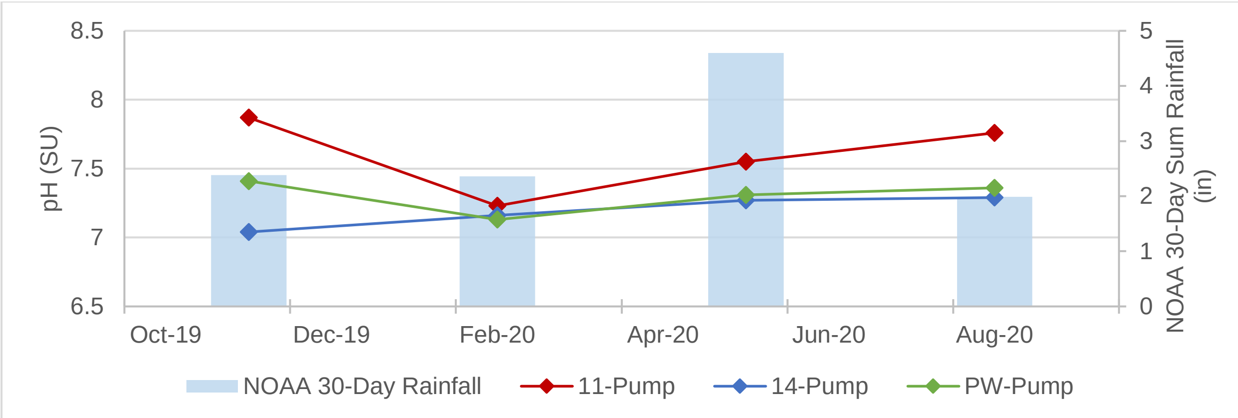


Figure 23. **Time series plots of pH and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

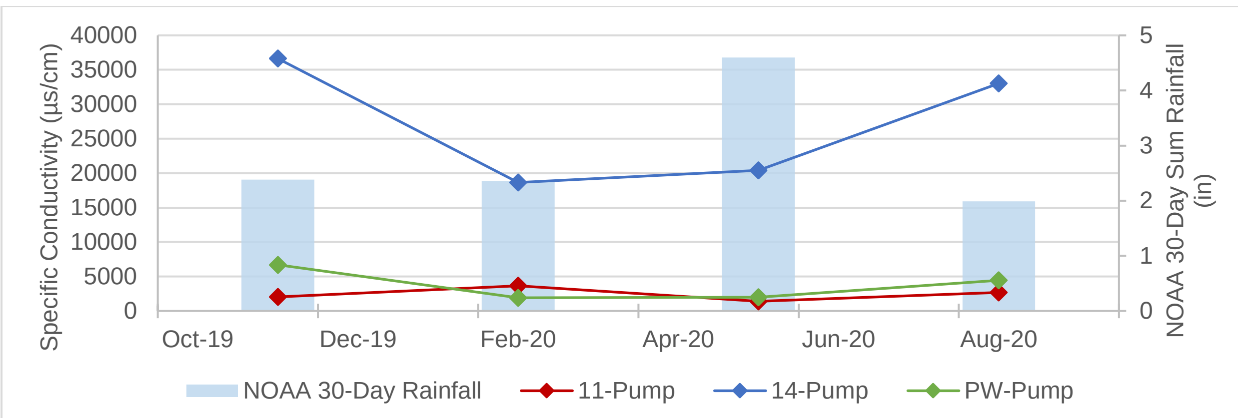


Figure 24. **Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

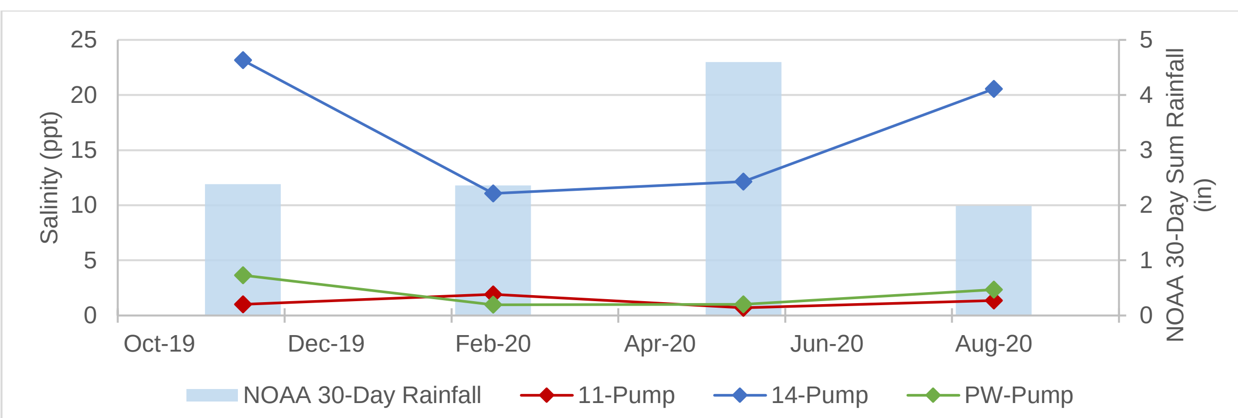


Figure 25. **Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

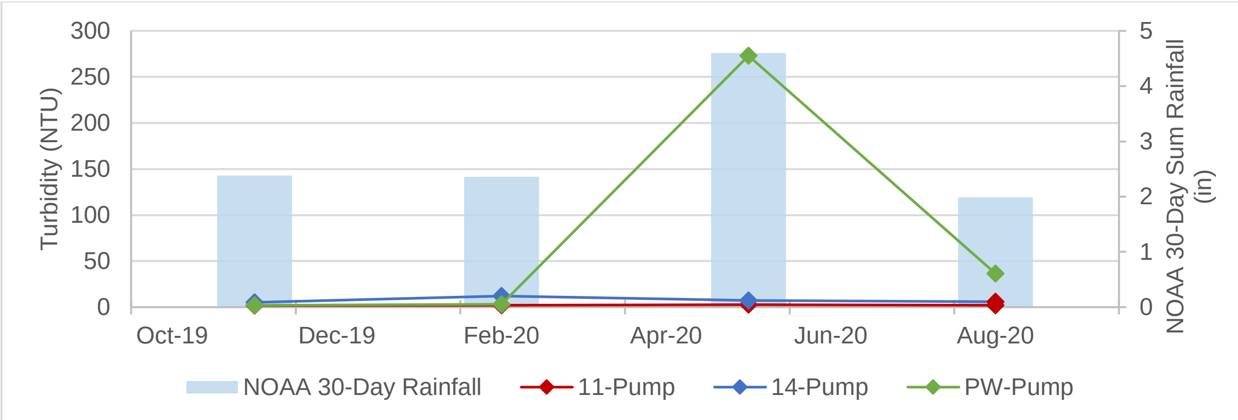


Figure 26. **Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

3.1.2 Time Series Plots of Lab Parameters

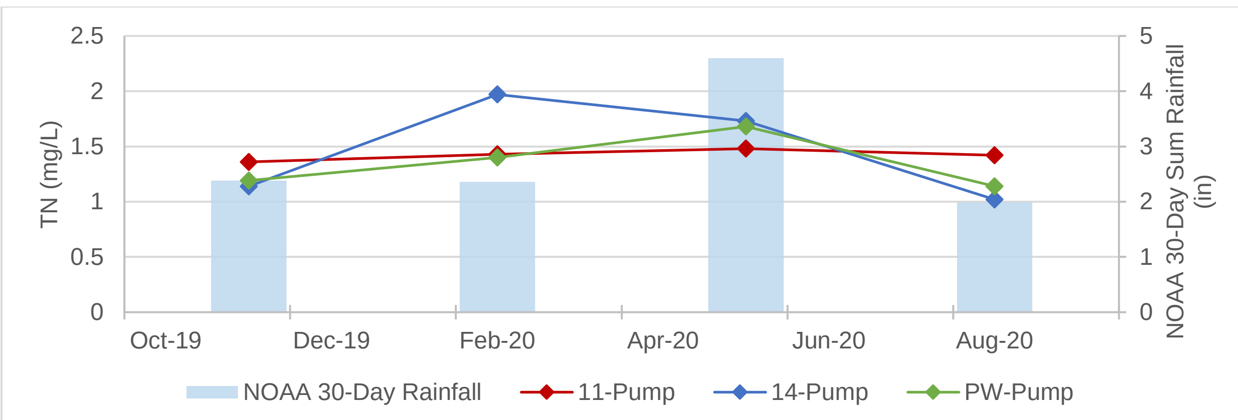


Figure 27. **Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

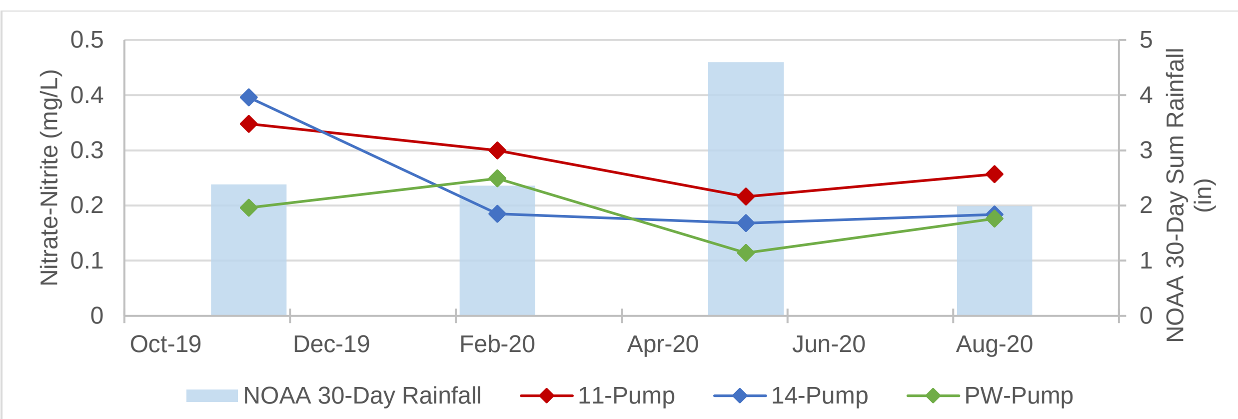


Figure 28. **Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

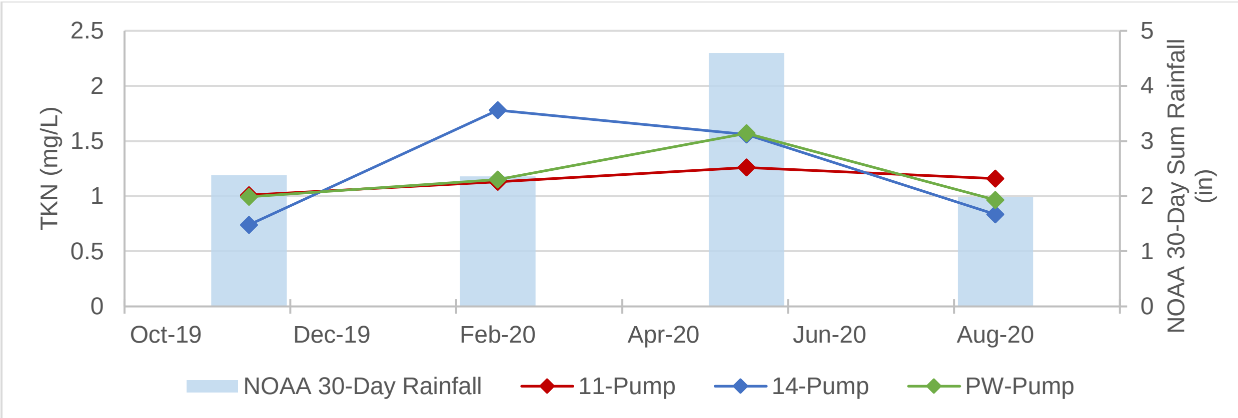


Figure 29. Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

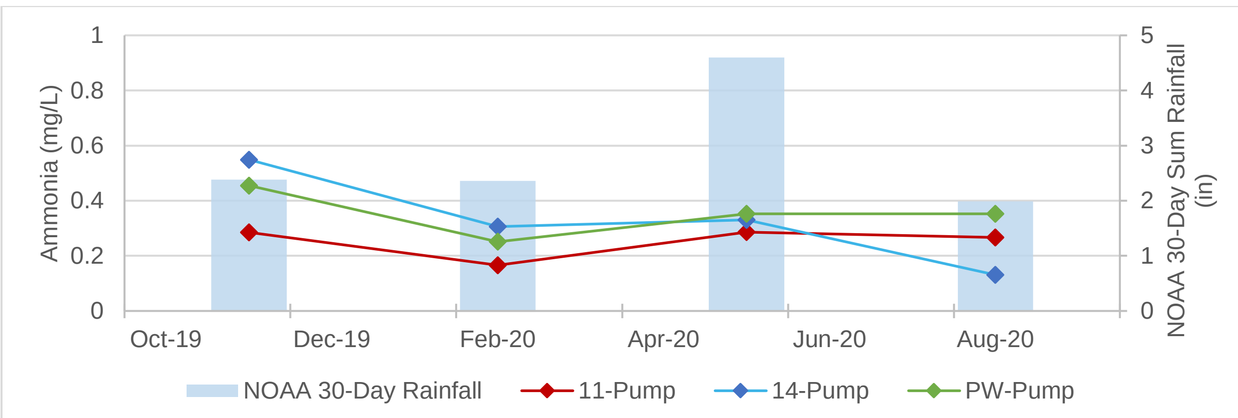


Figure 30. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

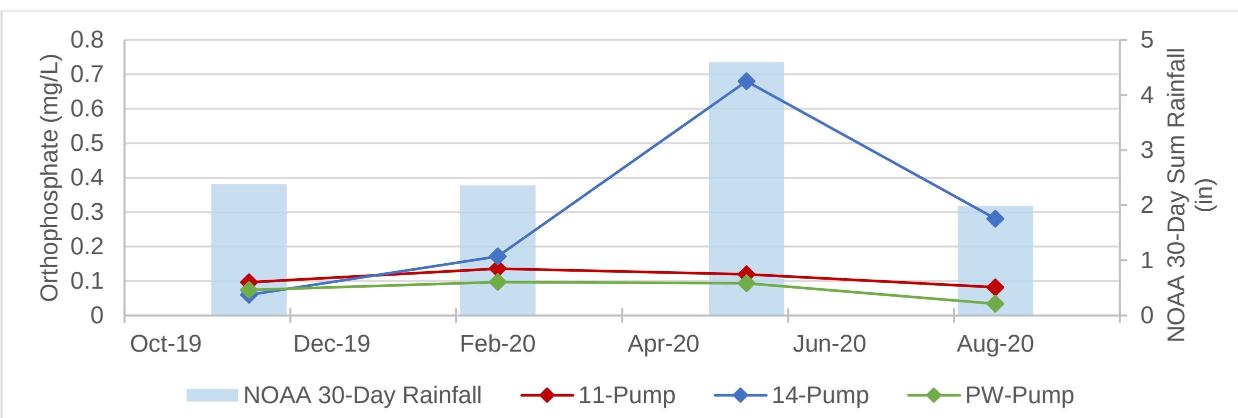


Figure 31. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.

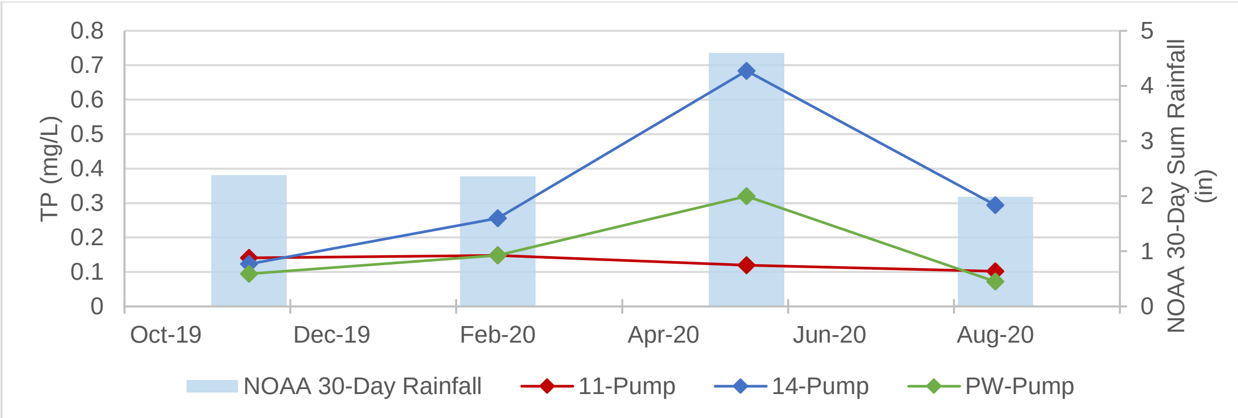


Figure 32. **Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

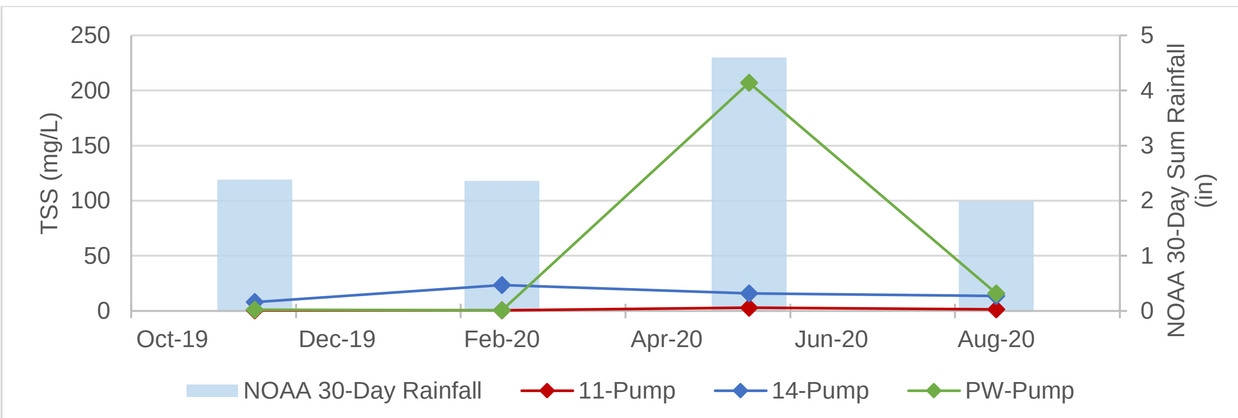


Figure 33. **Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

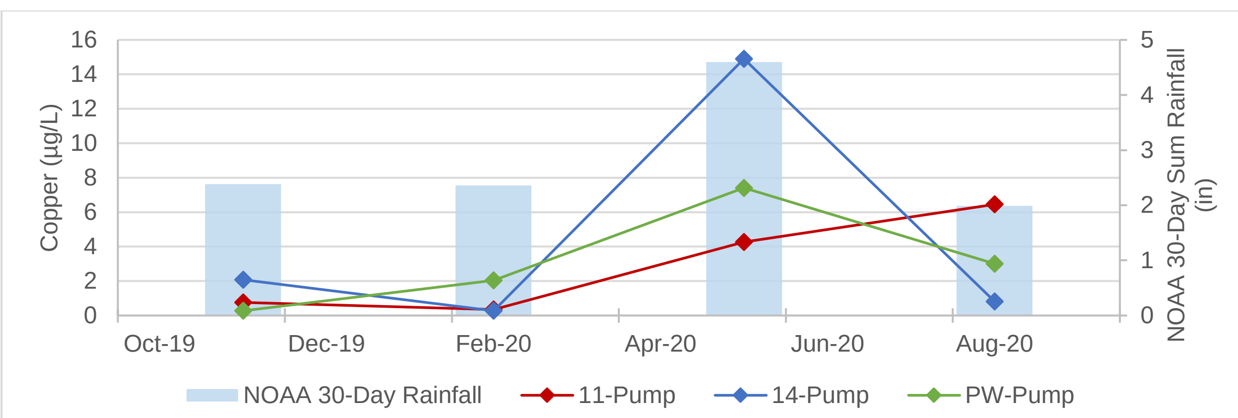


Figure 34. **Time series plots of copper and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

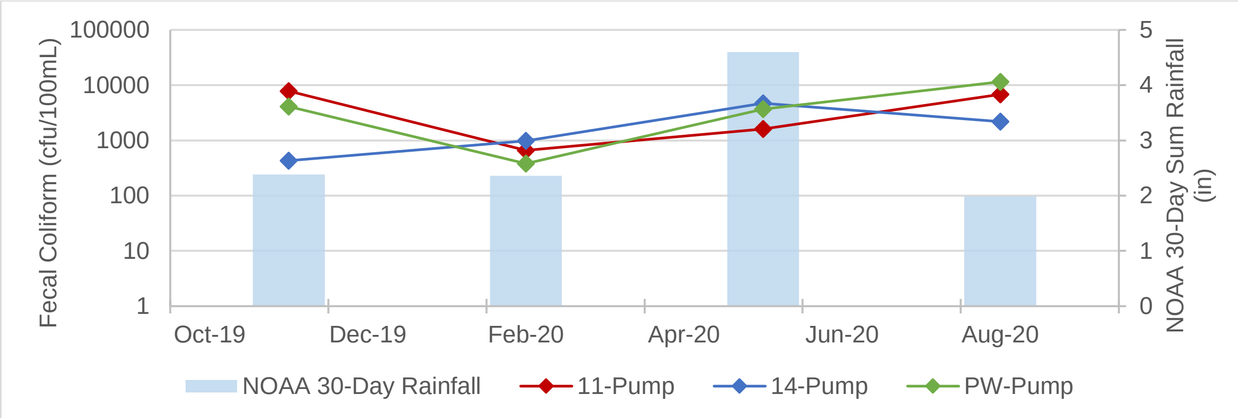


Figure 35. **Time series semi-log scale plots of fecal coliform and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

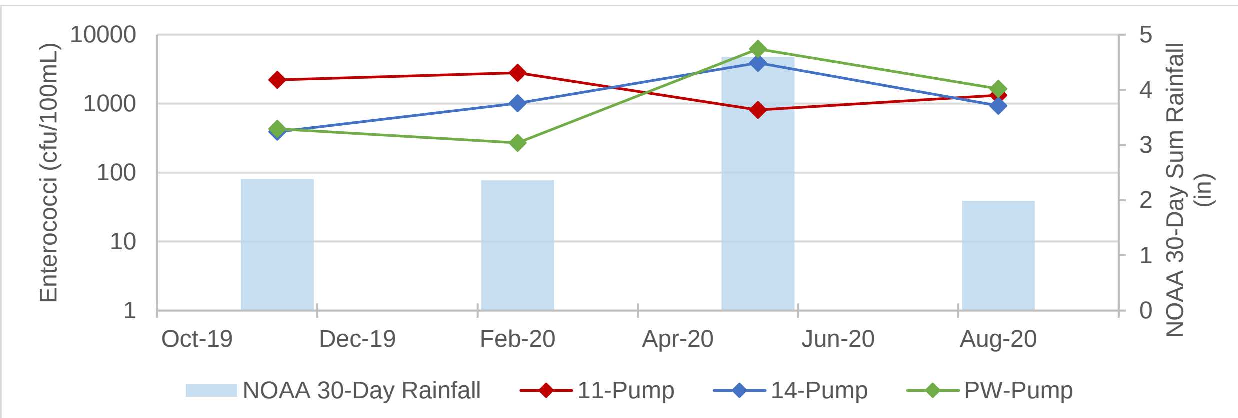


Figure 36. **Time series semi-log scale plots of enterococci and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump, 11-Pump, and 14-Pump.**

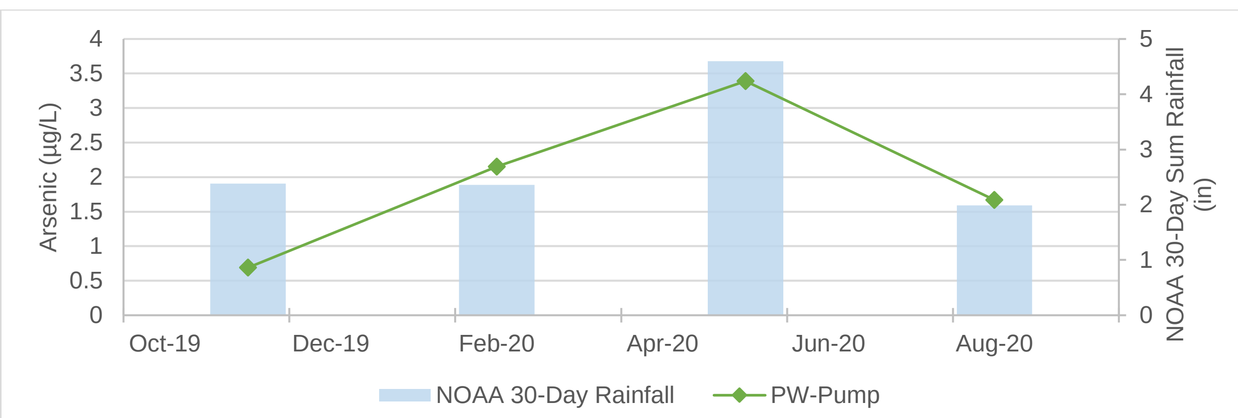


Figure 37. **Time series plots of arsenic and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.**

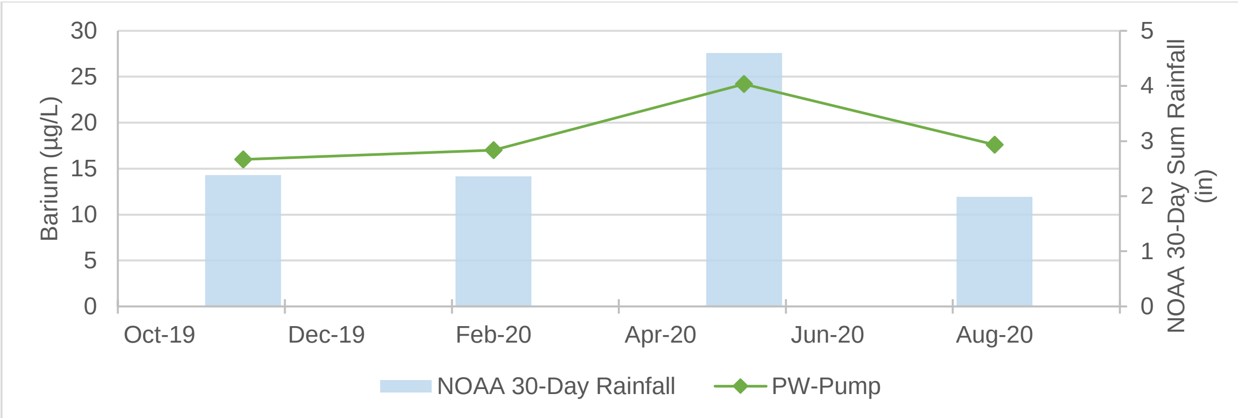


Figure 38. Time series plots of barium and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

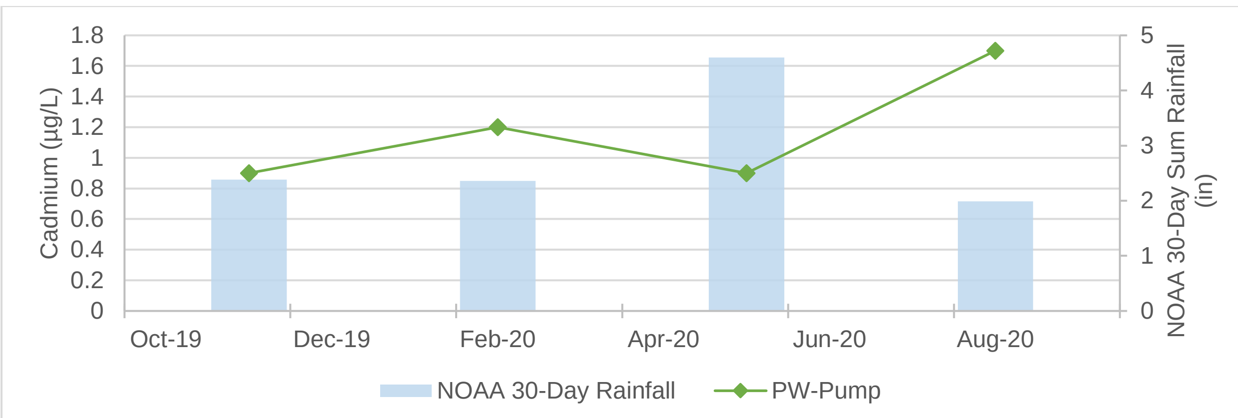


Figure 39. Time series plots of cadmium and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

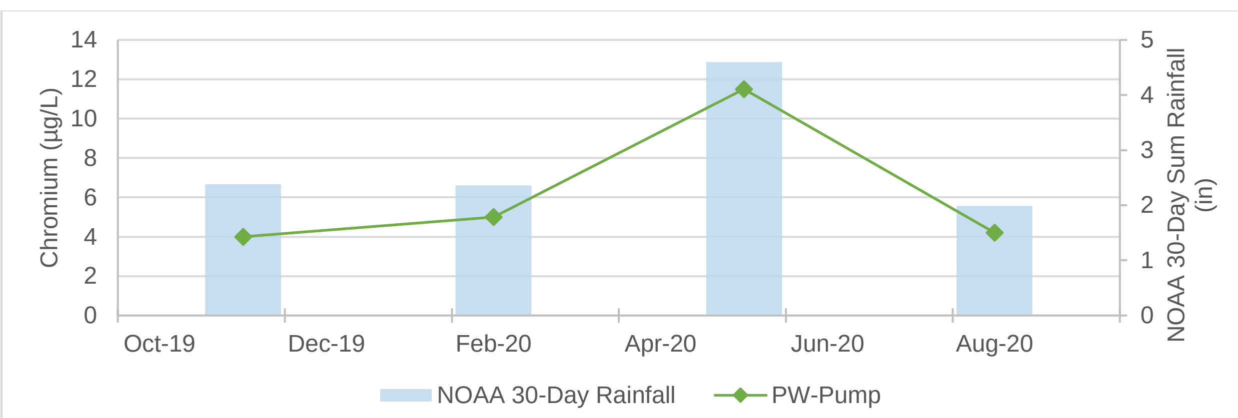


Figure 40. Time series plots of chromium and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

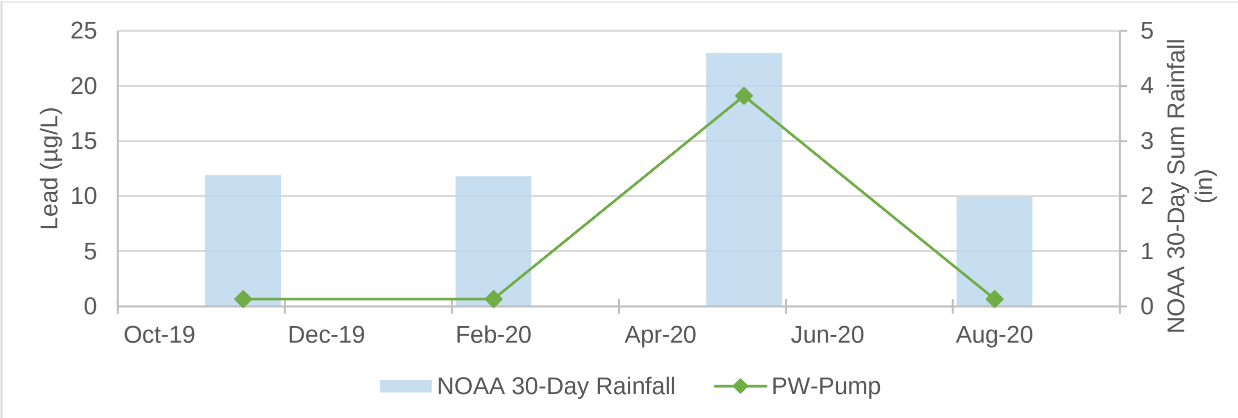


Figure 41. Time series plots of lead and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

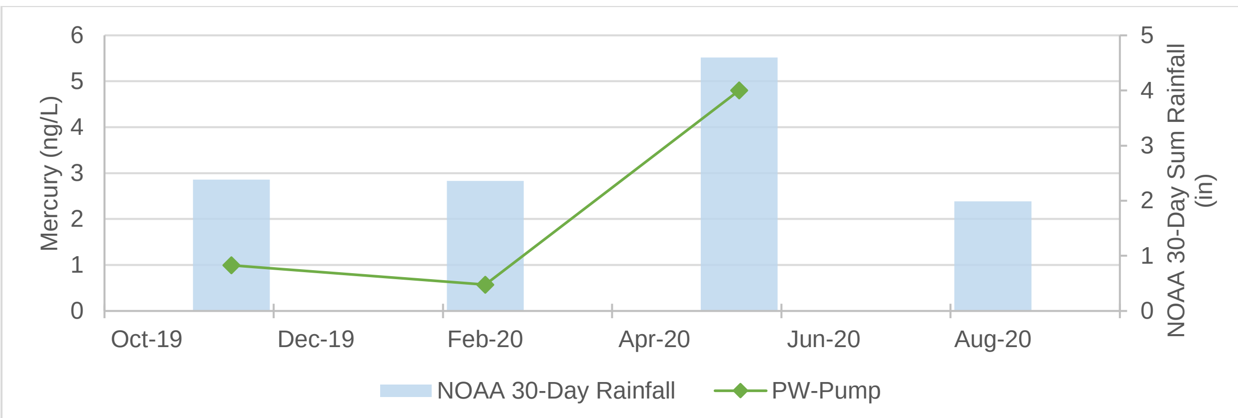


Figure 42. Time series plots of mercury and prior 30-day sum NOAA rainfall from October 2019 through September 2020[1] at PW-Pump.

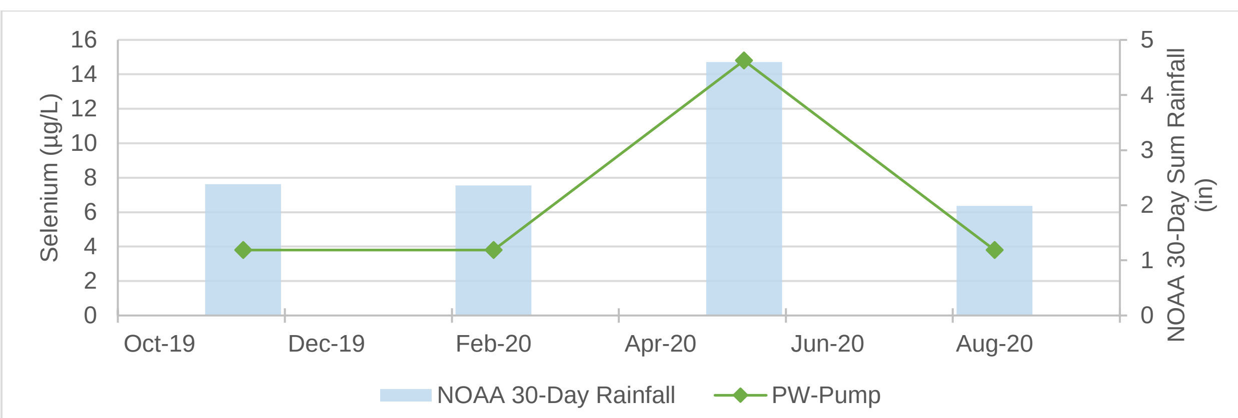


Figure 43. Time series plots of selenium and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

[1] Mercury data not available at time of reporting for August 2020.

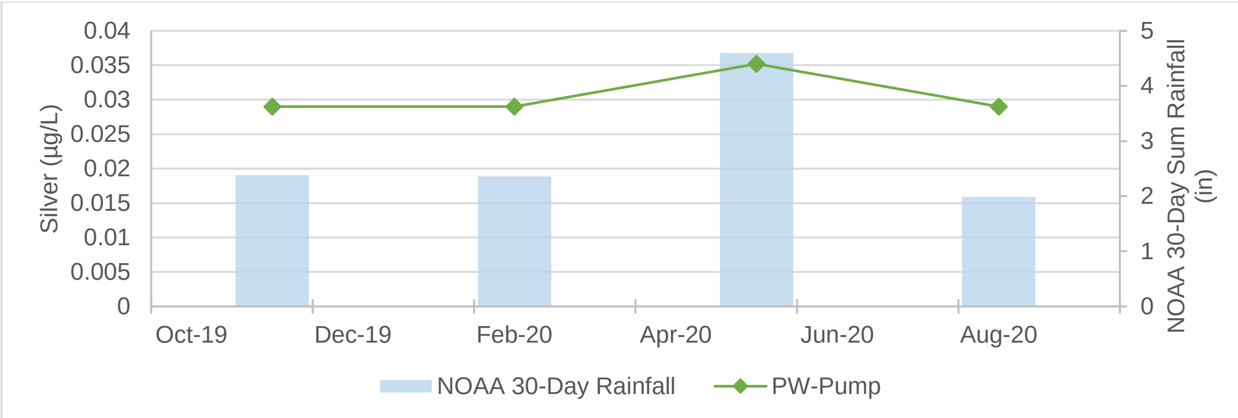


Figure 44. Time series plots of silver and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

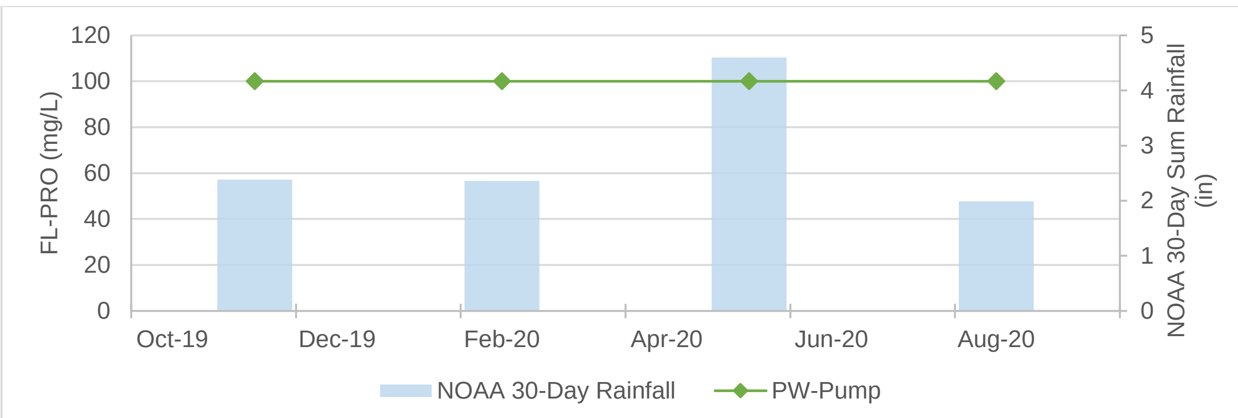


Figure 45. Time series plots of petroleum range organics (FL-PRO) and prior 30-day sum NOAA rainfall from October 2019 through September 2020 at PW-Pump.

3.2 Discussion

Monitoring data collected at pump stations were reviewed and summarized by parameter during FY2020. Pump station field measurements typically followed wet and dry seasonal trends. Temperature measurements at all pump stations increased in the wet season with the highest measurements in August 2020 (Figure 20). Dissolved oxygen had a reverse pattern, with the highest concentrations and percent saturations during February 2020 (coldest temperatures) and lowest during August 2020 (Figures 21 and 22). Levels of pH were fairly consistent during the FY2020 sampling period, with lower values recorded at 14-Pump and higher values at 11-Pump (Figure 23).

SC and salinity measurements at 14-Pump were higher than the other pump stations in FY2020 (Figures 24 and 25). The highest measurements in both SC and salinity occurred in November 2019 (36,626 µS/cm and 23.15 ppt, respectively), with lower measurements recorded during February and May 2020. Based on SC measurements, water quality measurements taken within 14-Pump were always characterized as being “predominately marine” according to the FDEP classification of specific conductivities greater than 4,580 µS/cm (62-302.200(30), F.A.C.).

All turbidity measurements were well below the Class III reference value of 29 NTU during all sampling events in FY2020 at 11-Pump and 14-Pump (Figure 26). There was a very high turbidity reading (273 NTU) at PW-Pump during the May 2020 sampling event; it was noted that the water was mucky/turbid during the sampling event as well. Turbidity was only slightly elevated (36.4 NTU) above the reference value of 29 NTU at PW-Pump during the following quarterly event in August 2020. Similarly, the TSS concentration at PW-Pump was elevated in May 2020 (207 mg/L), but returned to a lower concentration in August 2020 (Figure 33).

Nitrogen (TN, TKN, nitrate-nitrate, ammonia) and phosphorus (TP and Orthophosphate) concentrations were variable at all three pump stations in FY2020 (Figures 27 to 32). At 14-Pump, orthophosphate and TP concentrations were elevated during May 2020; TKN and TN concentrations were also elevated at 14-Pump but during February 2020 (Figures 27, 29, 31 and 32). For comparison, the Naples Bay Numeric Nutrient Criteria for TN and TP are annual geometric means of 0.57 mg/L and 0.045 mg/L, respectively (Rule 62-302.532; F.A.C.). The TN and TP annual geometric mean concentrations for all pump stations were above NNC thresholds in FY2020 with TN means ranging from 1.34 to 1.42 mg/L and TP means ranging from 0.126 to 0.282 mg/L (Table 3).

Copper concentrations typically stayed near/below 3.7 µg/L (the Class III marine standard) at all three pump stations during November 2019 and February 2020 (Figure 24). Copper concentrations were elevated at all pump stations in May 2020 (ranging from 4.26 µg/L at 11-Pump to 14.9 µg/L at 14-Pump), and there was a visual increase in concentrations at 11-Pump from February to August 2020 (Figure 34). The copper results reported were analyzed using the SM3113B method and methodology was altered depending on a monitoring location’s corresponding specific conductivity measurement.

Fecal coliform and enterococci colony counts were elevated at all three pump stations, with all but three of the twelve pump station samples collected for fecal coliform elevated above the Class III reference value of 800 cfu/100mL daily limit; 14-Pump had lower counts in November 2019 and 11-Pump and PW-Pump had lower counts in February 2020 (Figure 35). The highest fecal coliform for each station was 1,500 cfu/100mL at PW-Pump, 4,700 cfu/100mL at 14-Pump, and 7,800 cfu/100mL at 11-Pump (Figure 35). Both fecal coliform and enterococci responded to increases in rainfall with generally increased values. Maximum enterococci values were 6,200 cfu/100mL at PW-Pump and 3,900 cfu/100mL at 14-Pump in May 2020, and 2,800 cfu/100mL at 11-Pump in February 2020. The seasonal variation in the bacteria data indicates that the primary driver of the increase in fecal coliform and enterococci concentrations appears to be rainfall 30-days prior to the sampling event.

Further sampling events are recommended to assess trends and variance of fecal coliform and enterococci. In addition, implementation of regular city street sweeping clean-ups, public education on proper handling of pet waste and lawn grass clippings, and routine inspections are possible effective management strategies to consider in reducing fecal bacteria concentrations in storm water systems.

Elevated values were detected at PW-Pump locations with arsenic being above 3 µg/L in May 2020, barium above 10 µg/L during all sampling events, and mercury above 1 ng/L in May 2020 (Figures 37, 38, and 42); none of these elevated values exceeded Class I or III Surface Water Quality Reference values (Rule 62-302.530, F.A.C.). The only exception was the May 2020 selenium concentration of 14.8 µg/L which was above the Class I and III standard of 5.0 µg/L; however, this measured concentration was I-coded or between the method detection limit (MDL) and practical quantitation limit (PQL). Most of the elevated concentrations of metals during the May 2020 sampling event could have been caused by increased sediment in the sample (as previously indicated with elevated turbidity and TSS measurements). Concentrations the following sampling event returned to previous lower or undetected concentrations. All other heavy metal measurements were either non-detected or between the MDL and PQL of the methodology.

4 References

AMEC Environmental & Infrastructure, Inc. 2012. City of Naples Stormwater Quality Analysis, Pollutant Loading and Removal Efficiencies. Technical Publication Submitted to the City of Naples, Florida. 95pp.

Gordon E, Stein S. 2007. Stormwater BMPs Selection, Maintenance and Monitoring. Santa Barbara (CA): Forrester Press.

About Cardno

Cardno is an ASX-200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage, and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

Cardno Zero Harm

Cardno ZERO HARM EVERY JOB. EVERY DAY.

At Cardno, our primary concern is to develop and maintain safe and healthy conditions for anyone involved at our project worksites. We require full compliance with our Health and Safety Policy Manual and established work procedures and expect the same protocol from our subcontractors. We are committed to achieving our Zero Harm goal by continually improving our safety systems, education, and vigilance at the workplace and in the field. Safety is a Cardno core value and through strong leadership and active employee participation, we seek to implement and reinforce these leading actions on every job, every day.