ATTACHMENT A - 2018 Water Quality Report (Stormwater)

FY2018 Water Quality Monitoring Report

Upland Stormwater Lakes and Pump Stations

September 4, 2019

Cardno

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5.0	09/30/2018	Review Draft for Submission	Sheri Huelster	City of Naples
6.0	09/04/2019	Revisions of Draft	Sheri Huelster/Ed Call	

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Acronyms

TBD	To Be Determined

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) 2018 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, chlorophyll-a) were variable by station and drainage basin during FY 2018. Fecal coliform and enterococci values were variable throughout the FY2018 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, one exception being sampling location 26B in the Gordon River basin which had consistently higher values and a March measurement of 302 µg/L, while the Gulf of Mexico basin had spikes in copper in January, February and March for lakes 14B and 9B, respectively.

Pump Stations

Quarterly pump station water quality monitoring was completed in November 2017, February 2018, May 2018, and August 2018 for FY2018 at pump locations 11-Pump, 14-Pump, and PW-Pump. Field measurements (temperature, dissolved oxygen, pH, 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 rainfall-induced spikes in total nitrogen and total phosphorus during August 2018 at 14-Pump. Fecal coliform measurements at all pump stations exceeded the Florida Class III Surface Water Quality Standards during this 2018 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 FY 2018 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.

Management strategies for TN and TP concentration reduction may include: additional littoral plantings, retrofitting stormwater conveyance systems with Stormtreat and/or Aqua filter treatment systems, changes in the duration and timing of street sweeping program, routine maintenance of catchment basins and use of binding agents like Phoslock. Management of fecal coliform and Enterococci levels 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

Additional data 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 management decisions. Data from the upcoming FY 2019 sampling will help to identify potential trends that can be addressed with management decisions for each waterbody described below.

1 Introduction

This summary report provides the results of the Fiscal Year (FY) 2018 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 FY 2018 (October 2017 to September 2018) 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 FY 2018. 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 2017 to September 2018.

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	

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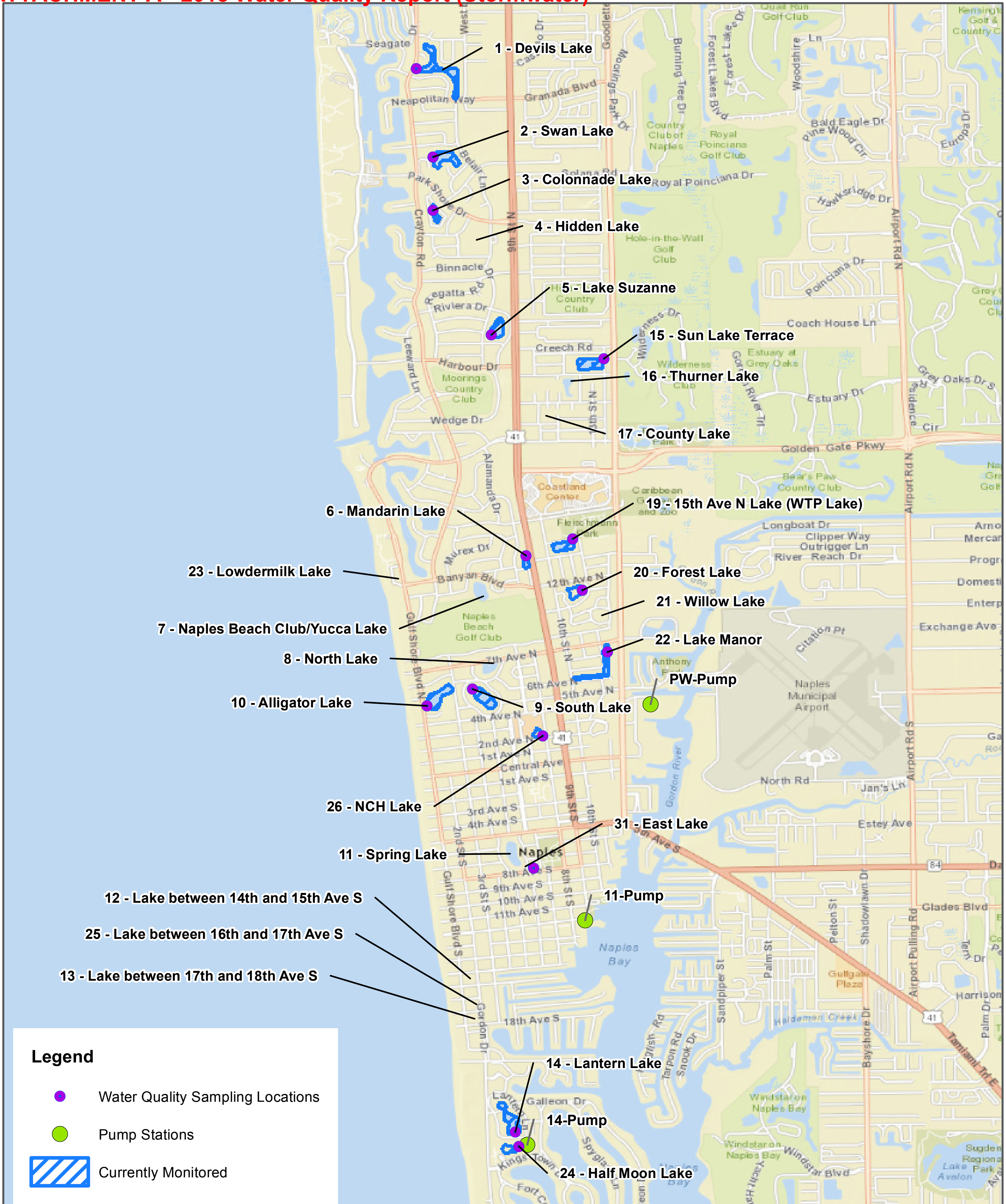

Image:ESRI

Data Source: Cardno, Inc.

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Figure 1. Stormwater Lakes and Pump Stations.

City of Naples
Collier County, Florida

0 0.75 1.5 Miles
0 1.2 2.4 Kilometers

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Date Created: 10/11/2017 Date Revised: 10/11/2017 File Path: Q:\UnitedStates\Florida\Tampa\City_Of_Naples\FY2016 Monitoring and Analysis\working\arcmap\Fig2_1City_of_Naples_Stormwater_Lakes_A_20171011.mxd
GIS Analyst: Lauren.Federsel

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 2017 to September 2018.

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, total phosphorus, chlorophyll-a, and copper for each stormwater lake.

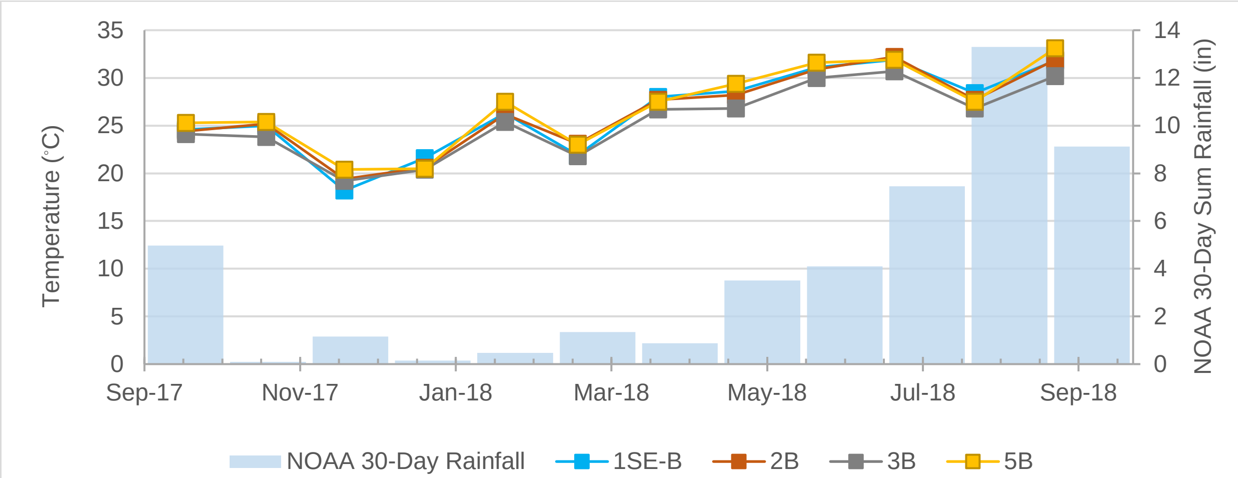
Results of all sampled water quality parameters are detailed in time series plots (Figures 2-19) in Sections 2.1.1 and 2.1.2. Monitoring locations are grouped on plots by the associated final drainage destinations (water bodies) and are as followed: Monitoring locations 1SE-B, 2B, 3B, and 5B correspond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

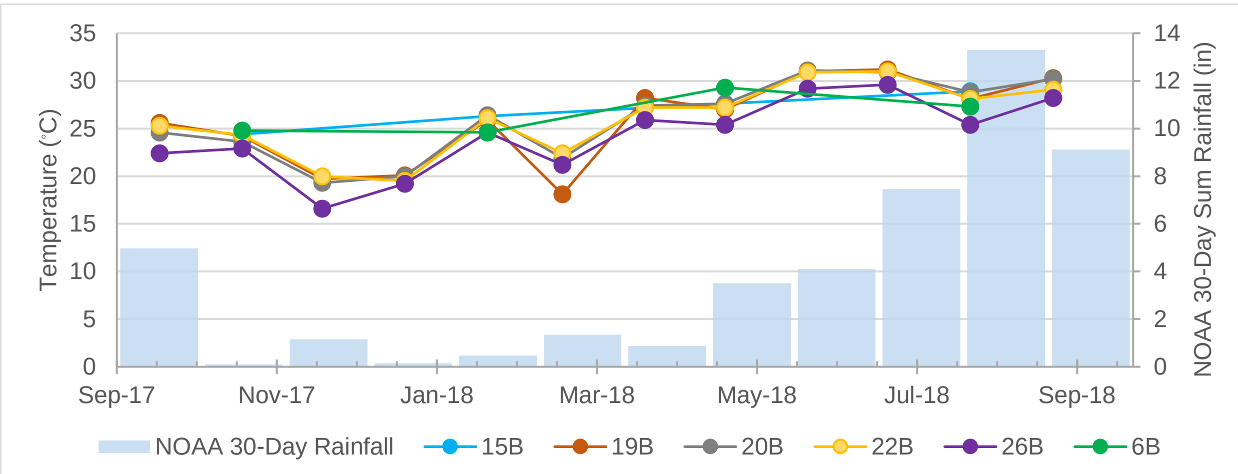
Table 2. Minimums, maximums, and annual geometric means of total nitrogen, total phosphorus, chlorophyll-a, and copper for stormwater lakes in Naples, Florida from October 2017 to September 2018.

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	12	12	0.86	1.49	1.03	U (0.008)	0.09	0.03	0.98	12.10	3.12	3.95	152	22.73
Swan Lake	2B		12	12	0.74	1.89	1.12	U (0.008)	0.22	0.08	5.34	44	19.86	2.64	59.4	7.51
Colonnade Lake	3B		12	12	0.84	1.62	1.07	0.013	0.22	0.10	4.82	187.0	19.69	2.24	13.2	4.02
Lake Suzanne	5B		12	12	0.62	1.91	1.06	0.066	0.21	0.11	9.54	57.8	22.52	2.54	5.99	4.09
Mandarin Lake	6B	Gordon River	12	3	0.92	1.55	1.10	0.016	0.12	0.05	4.82	46.3	15.40	U (0.346)	1.26	0.59
Sun Lake Terrace	15B		4	1	1.12	1.35	1.26	0.038	0.07	0.05	U (0.25)	40.6	5.39	3.34	4.69	4.10
15th Ave N Lake (WTP Lake)	19B		12	8	1.08	4.33	1.76	0.009	0.27	0.08	9.50	252.0	44.77	U (0.346)	2.83	0.66
Forest Lake	20B		12	2*	0.72	2.45	1.47	0.026	0.33	0.09	U (0.25)	71	17.87	U (0.346)	2.36	0.68
Lake Manor	22B		12	8	0.52	1.17	0.89	U (0.008)	0.27	0.04	5.00	23.1	13.99	U (0.346)	2.75	1.06
NCH Lake	26B		12	8	0.59	1.54	0.96	U (0.008)	0.10	0.03	11.0	89	28.59	30.40	302	70.31
North Lake	8B	Gulf of Mexico	12	6	1.34	2.36	1.80	0.014	0.29	0.12	25.9	147	56.25	1.40	5	2.65
South Lake	9B		12	5	1.21	2.44	1.54	0.053	0.43	0.19	25.10	236	60.24	2.39	15.2	5.76
Alligator Lake	10B		4	4	0.94	1.31	1.09	0.085	0.20	0.13	7.87	72.7	20.88	U (0.272)	3.13	1.08
East Lake	11B	Naples Bay	4	3	1.02	1.35	1.14	0.112	0.26	0.19	8.51	56.4	33.74	1.52	8.45	2.64
Lantern Lake	14B		4	4	1.85	2.75	2.25	0.311	0.88	0.54	57.5	266.0	116.84	U (0.272)	20.0	2.01
Half Moon Lake	24B		4	1	3.42	5.72	4.53	1.90	2.69	2.19	104	185	135.050	0.83	3.41	1.63

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.
*Outflow weir inaccessible; flow over weir unknown.
**Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

2.1.1 Time Series Plots of Field Parameters





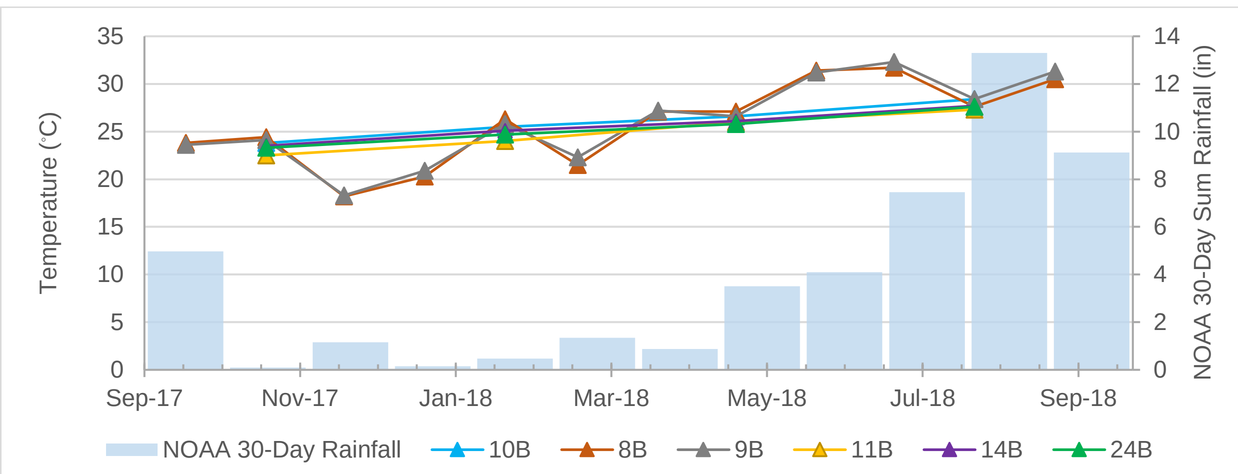


Figure 2. Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

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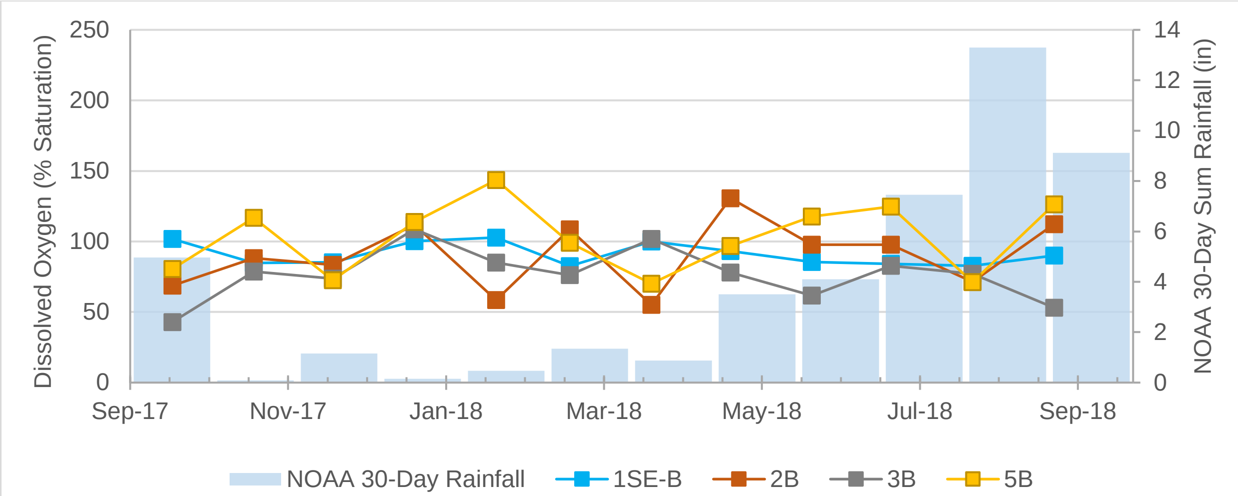

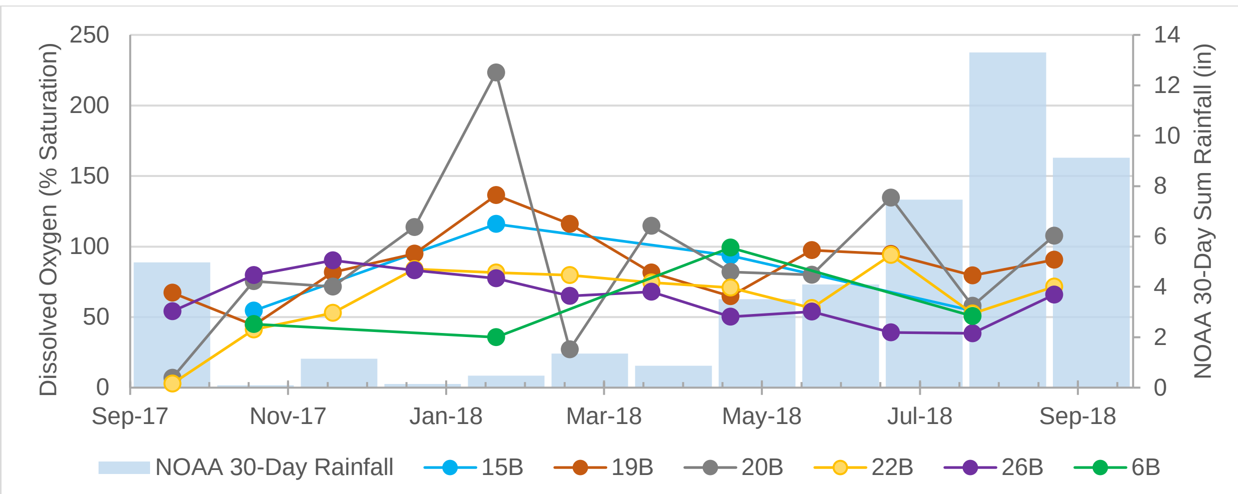

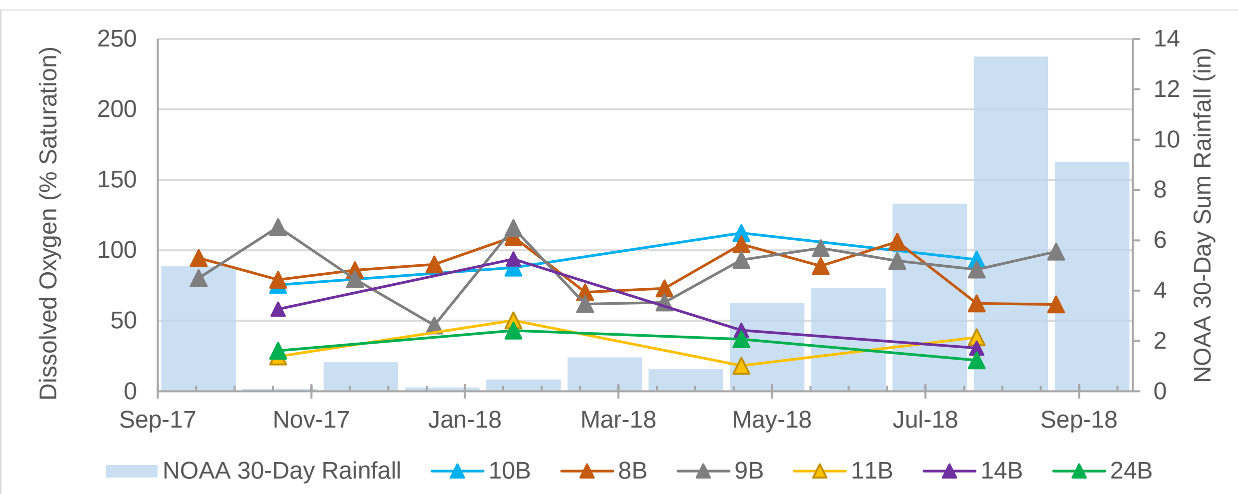

Figure 3. Time series plots of dissolved oxygen (% saturation) and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

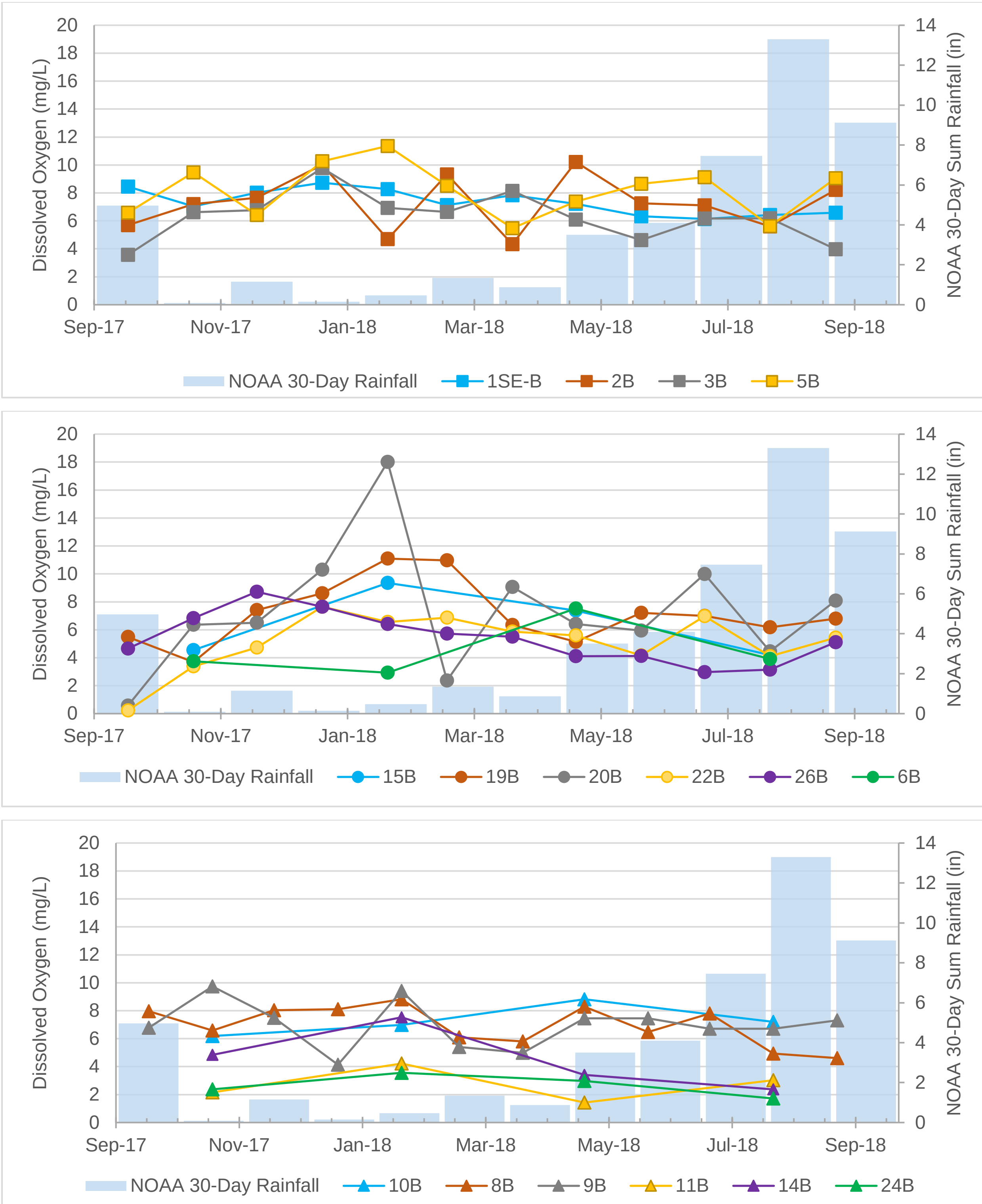

Figure 4. **Time series plots of dissolved oxygen (concentration) and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

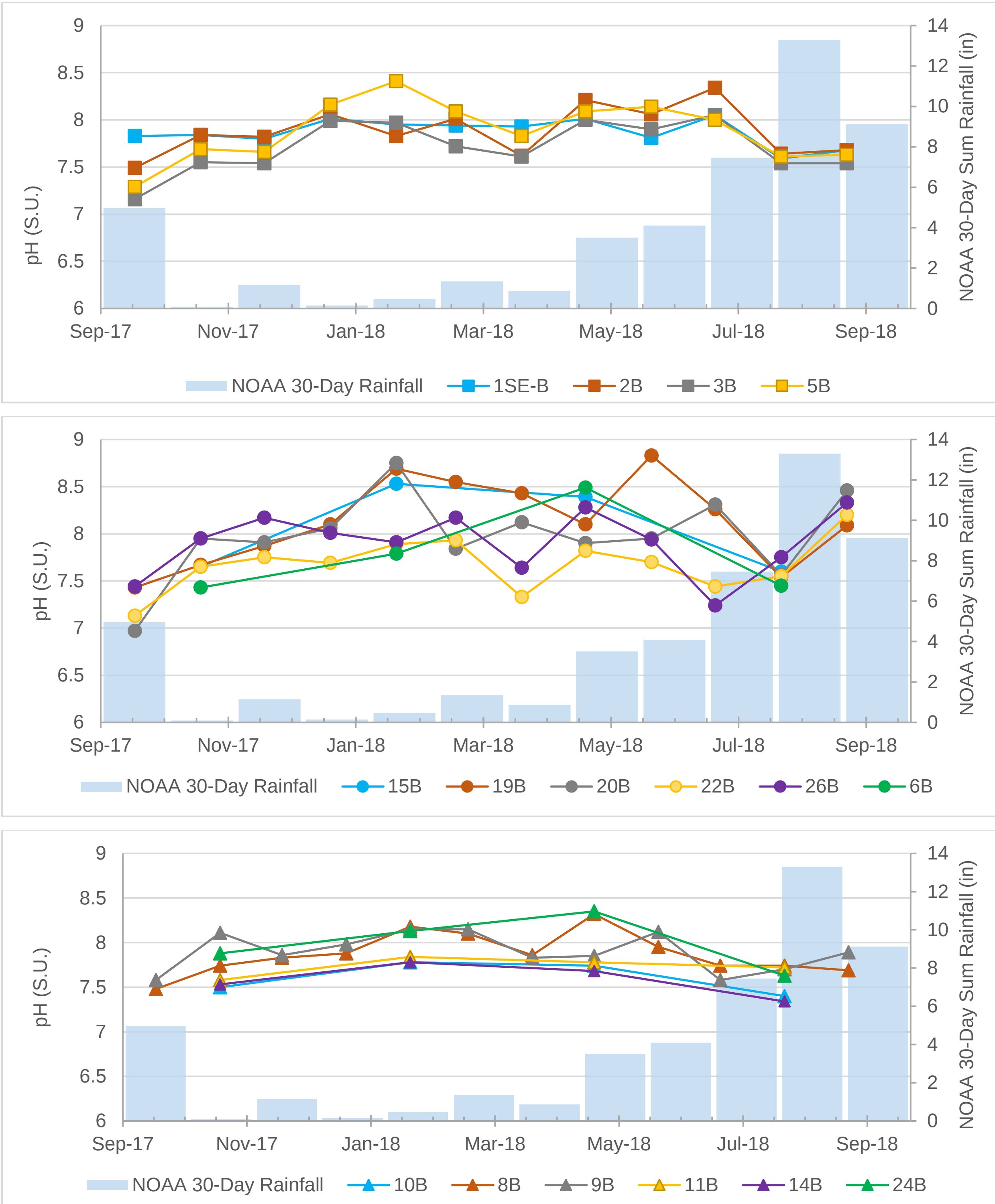

Figure 5. **Time series plots of pH and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

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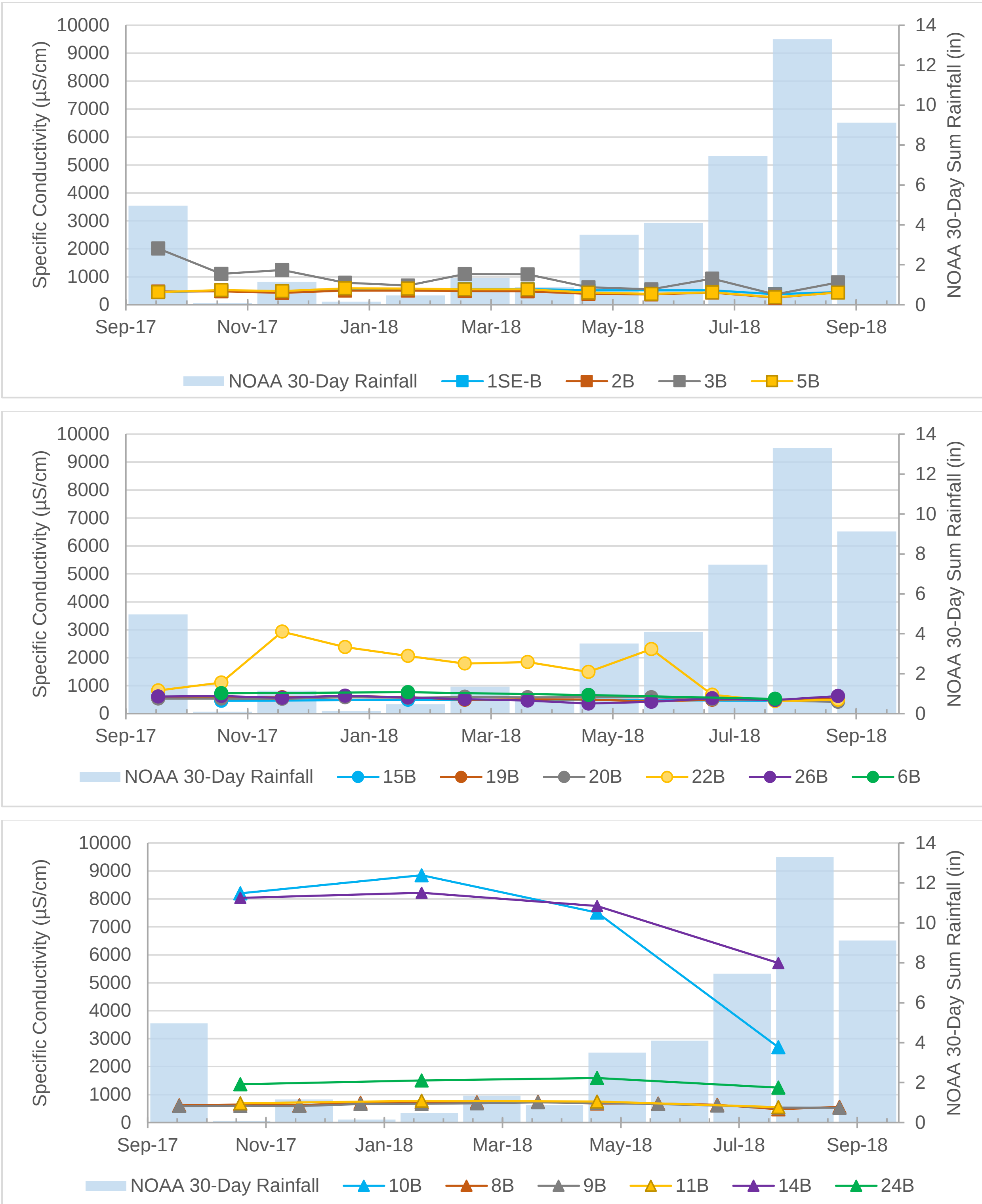

Figure 6. Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

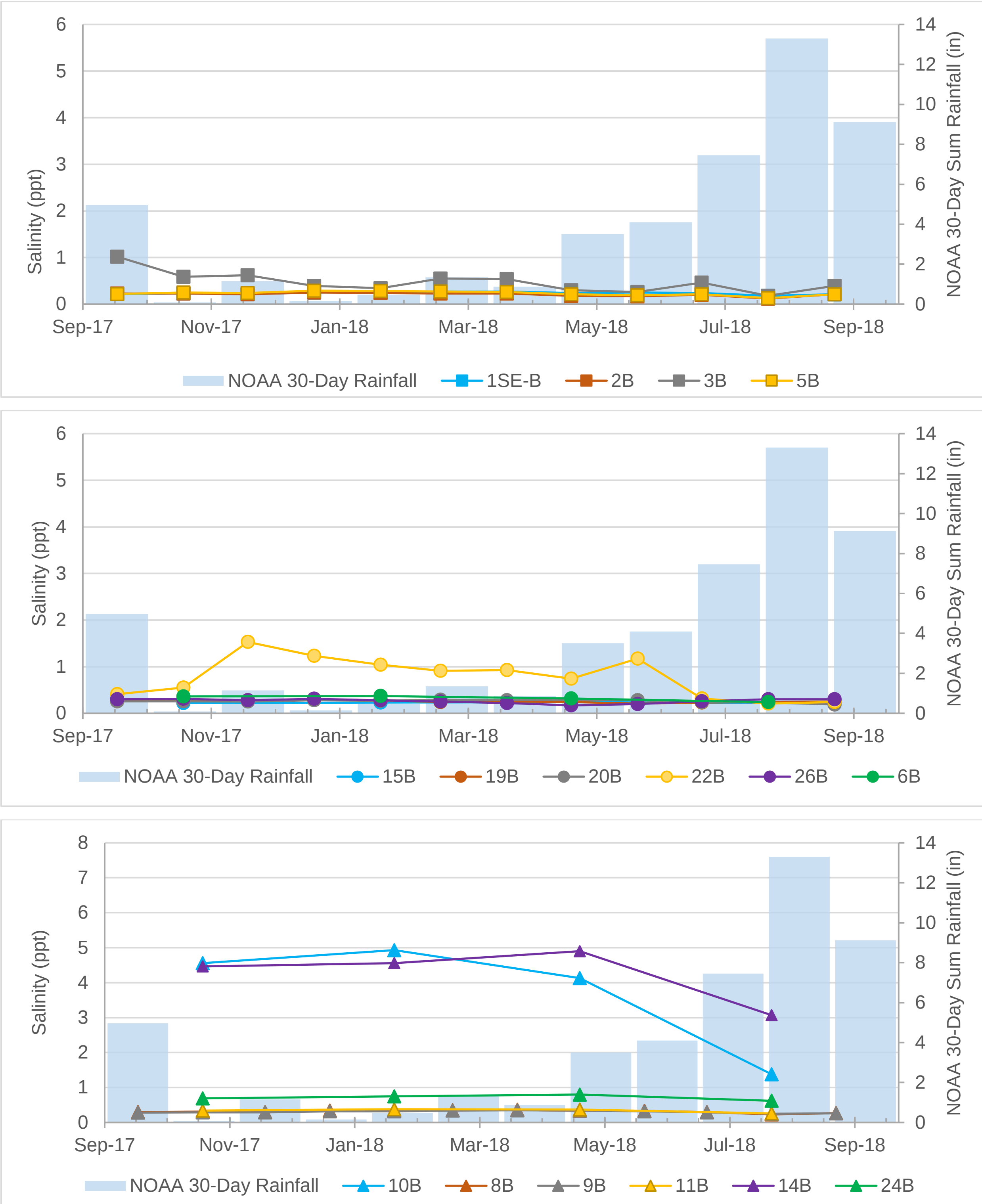

Figure 7. **Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

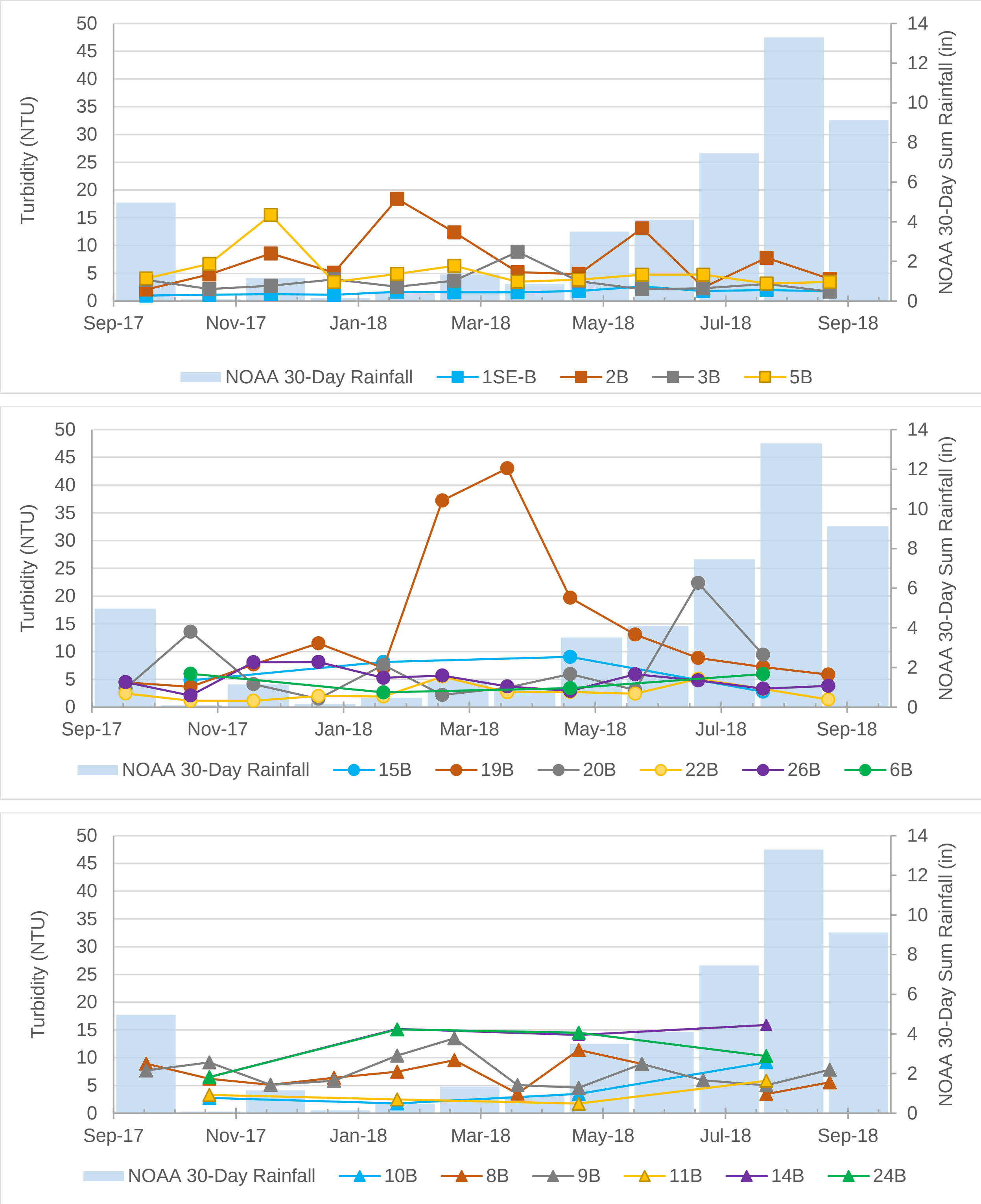

Figure 8. **Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

2.1.2 Time Series Plots of Lab Parameters

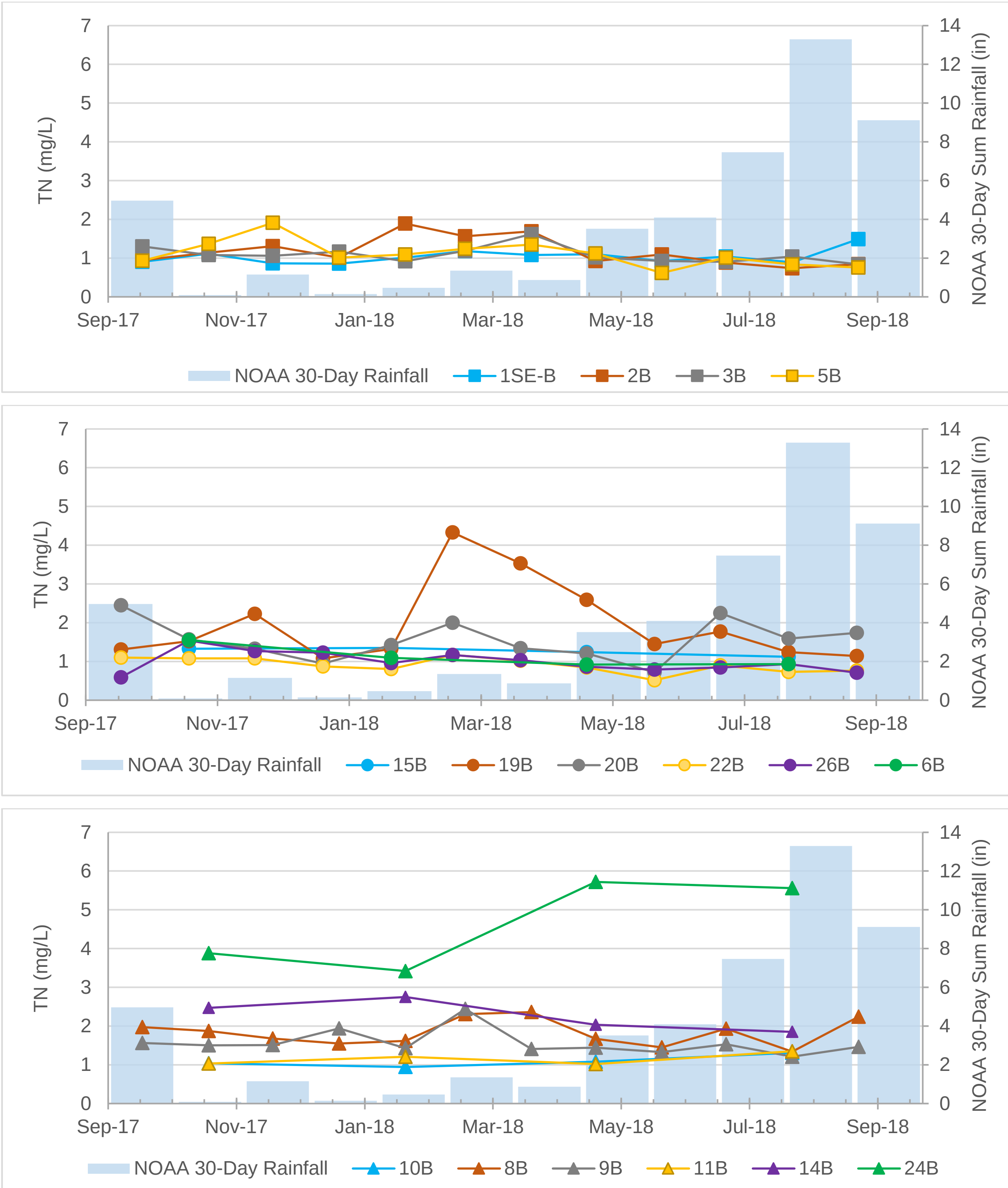

Figure 9. Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

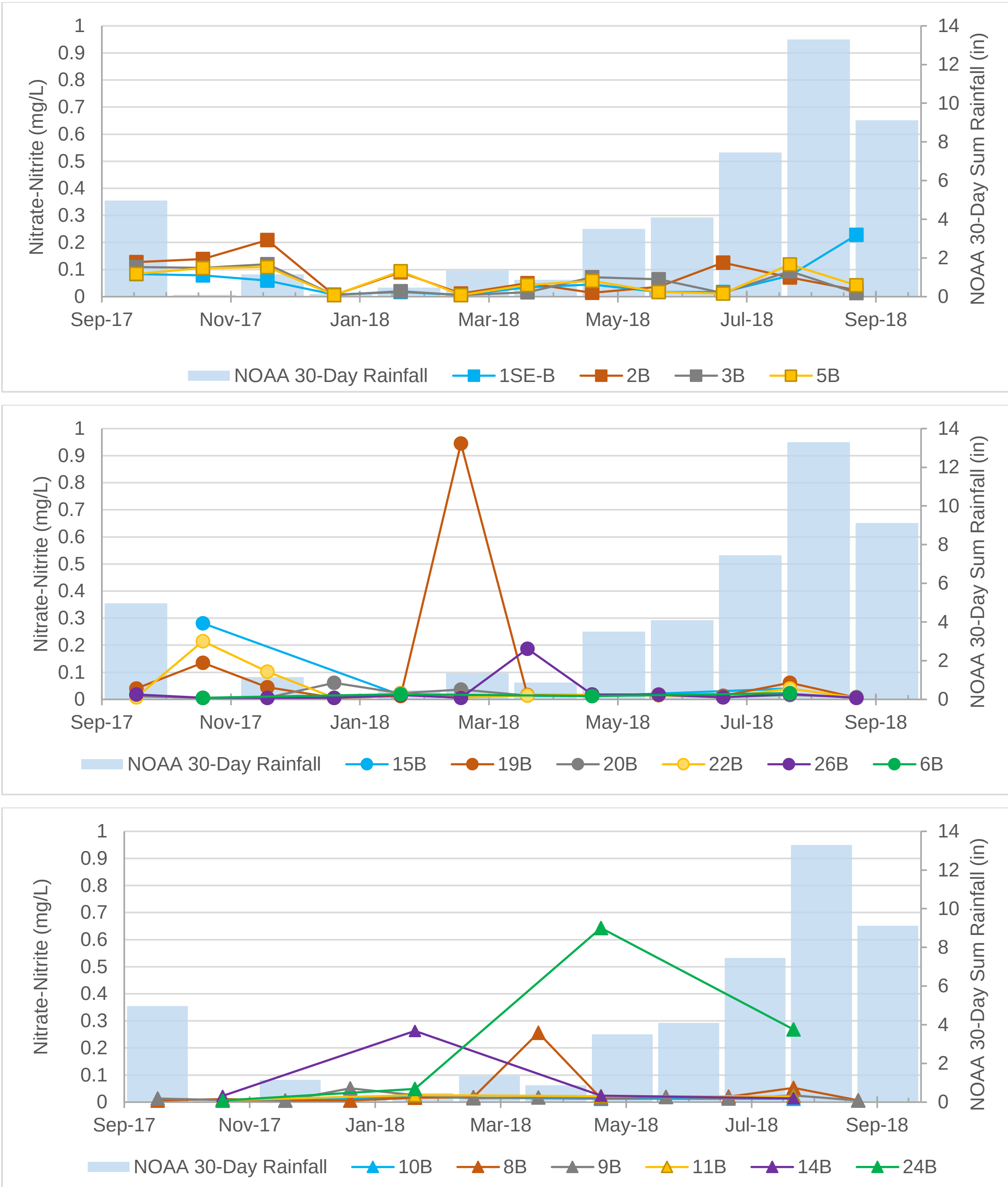

Figure 10. Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

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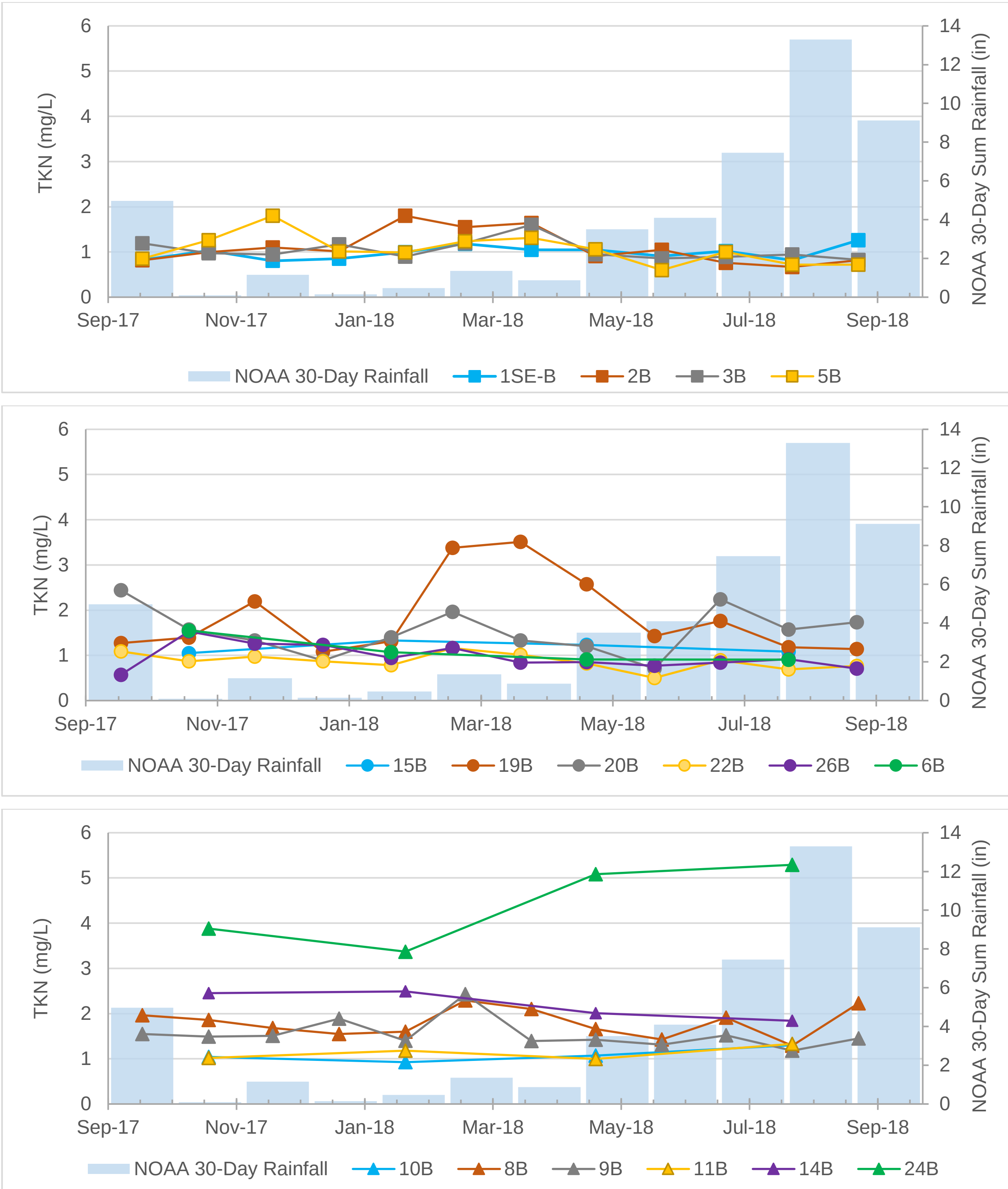

Figure 11. Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

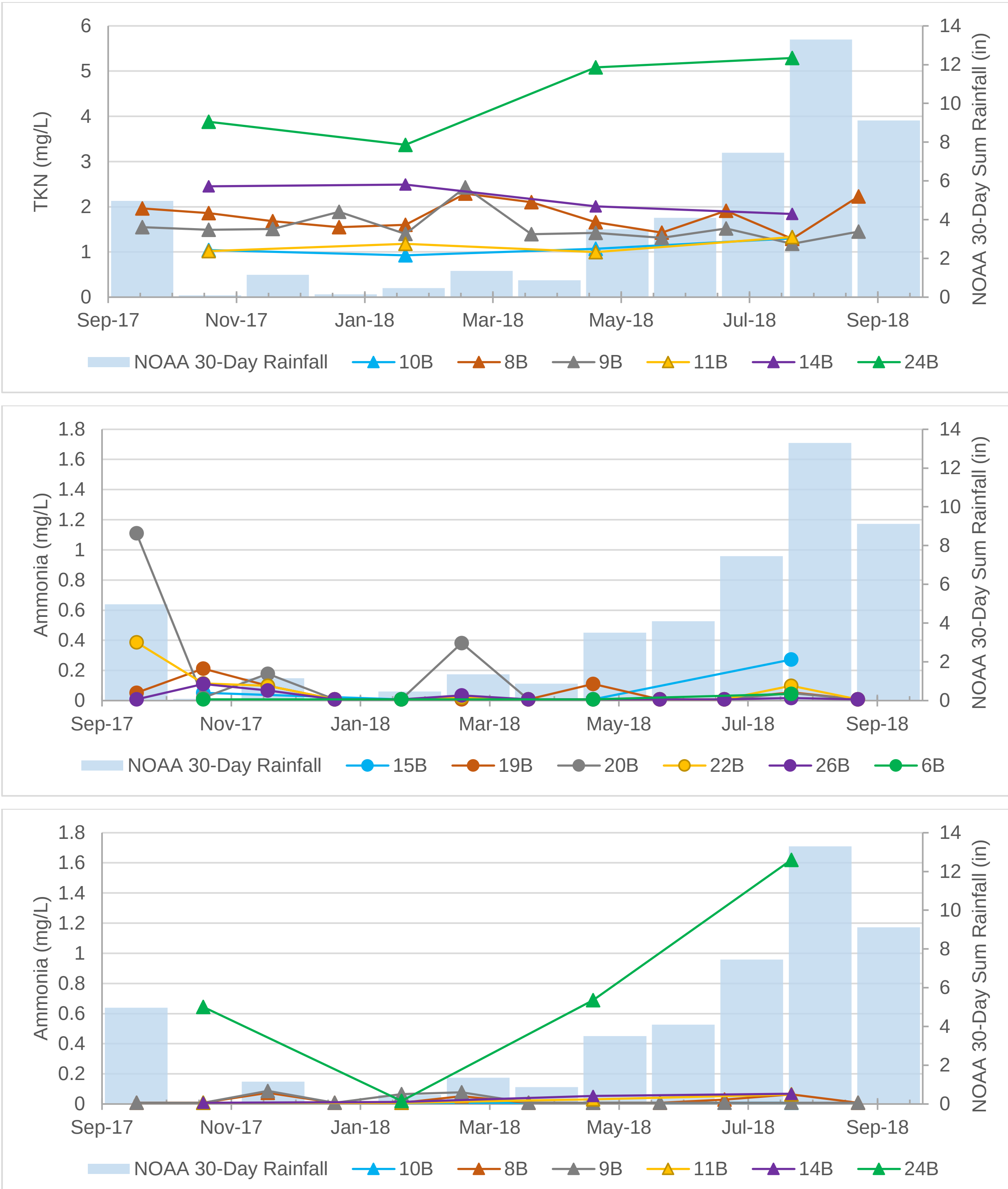

Figure 12. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

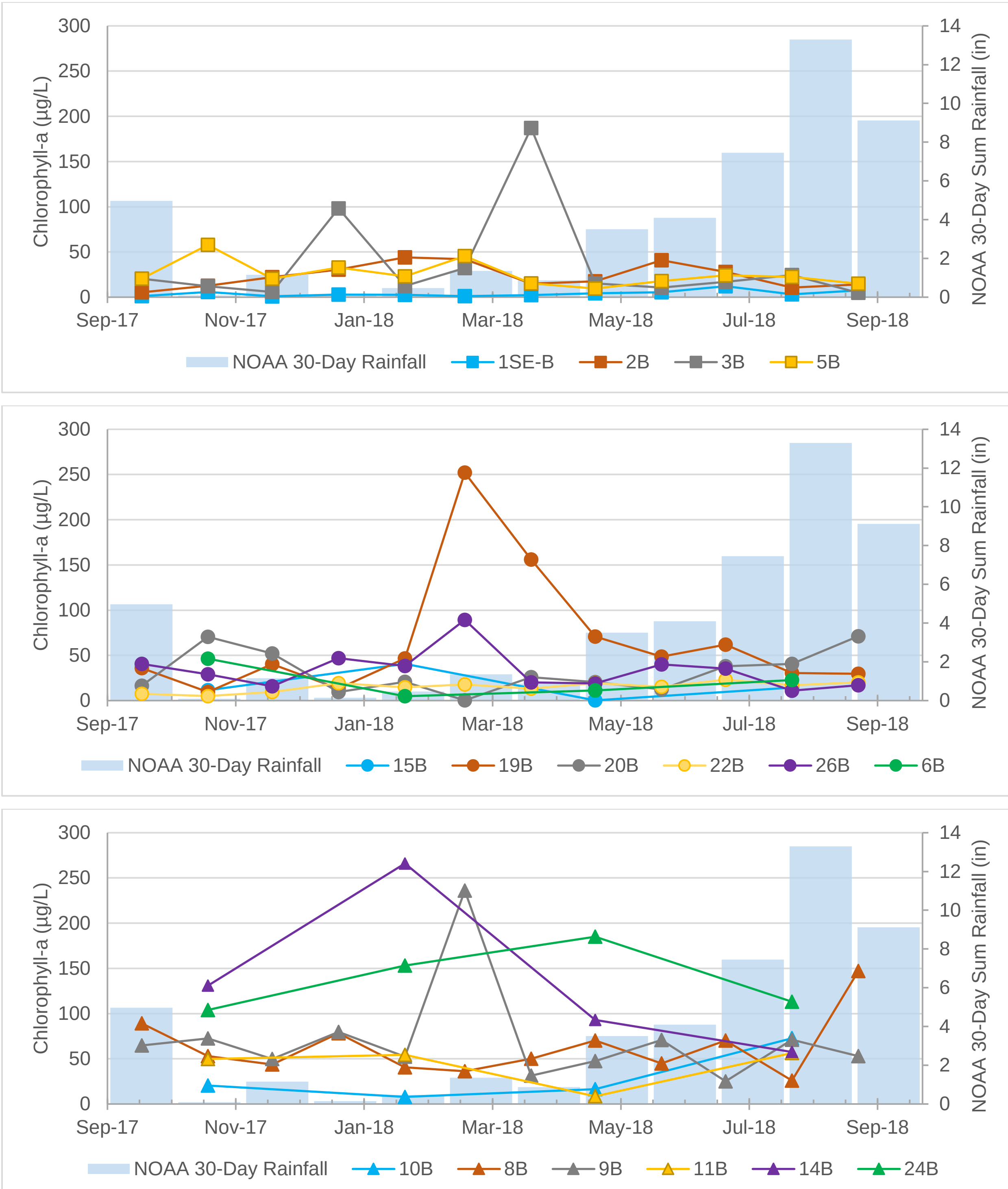

Figure 13. Time series plots of chlorophyll-a and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

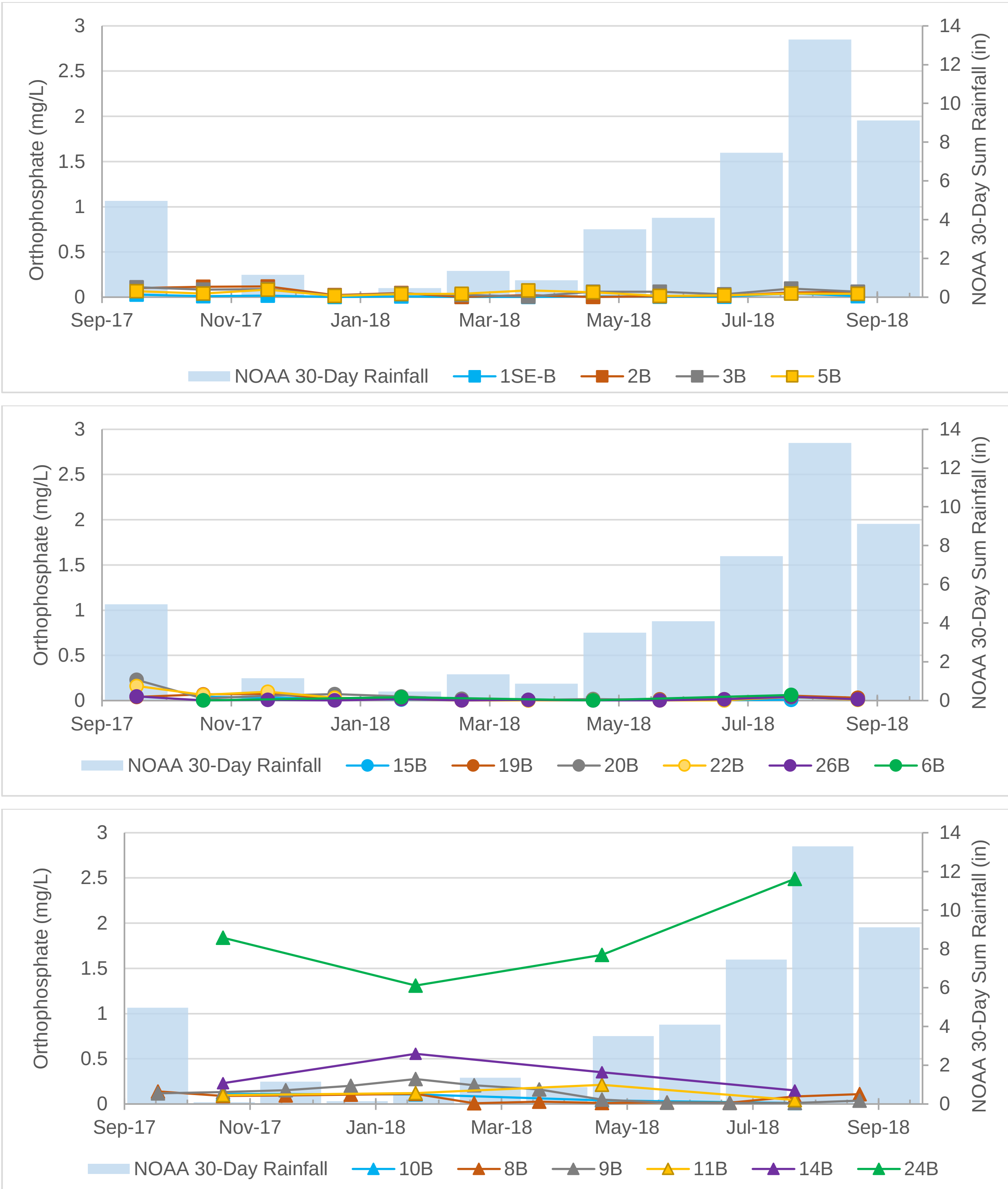

Figure 14. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

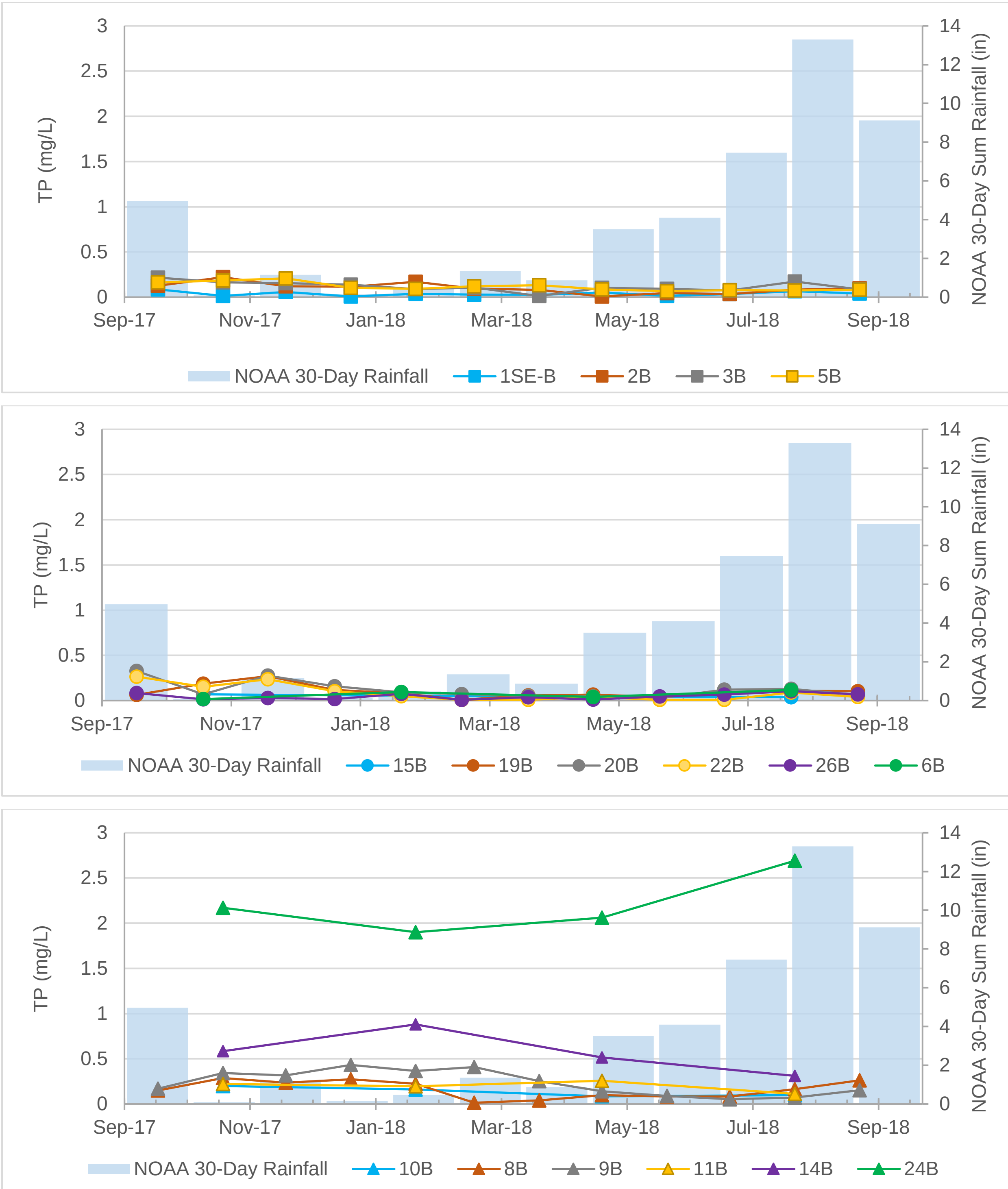

Figure 15. Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

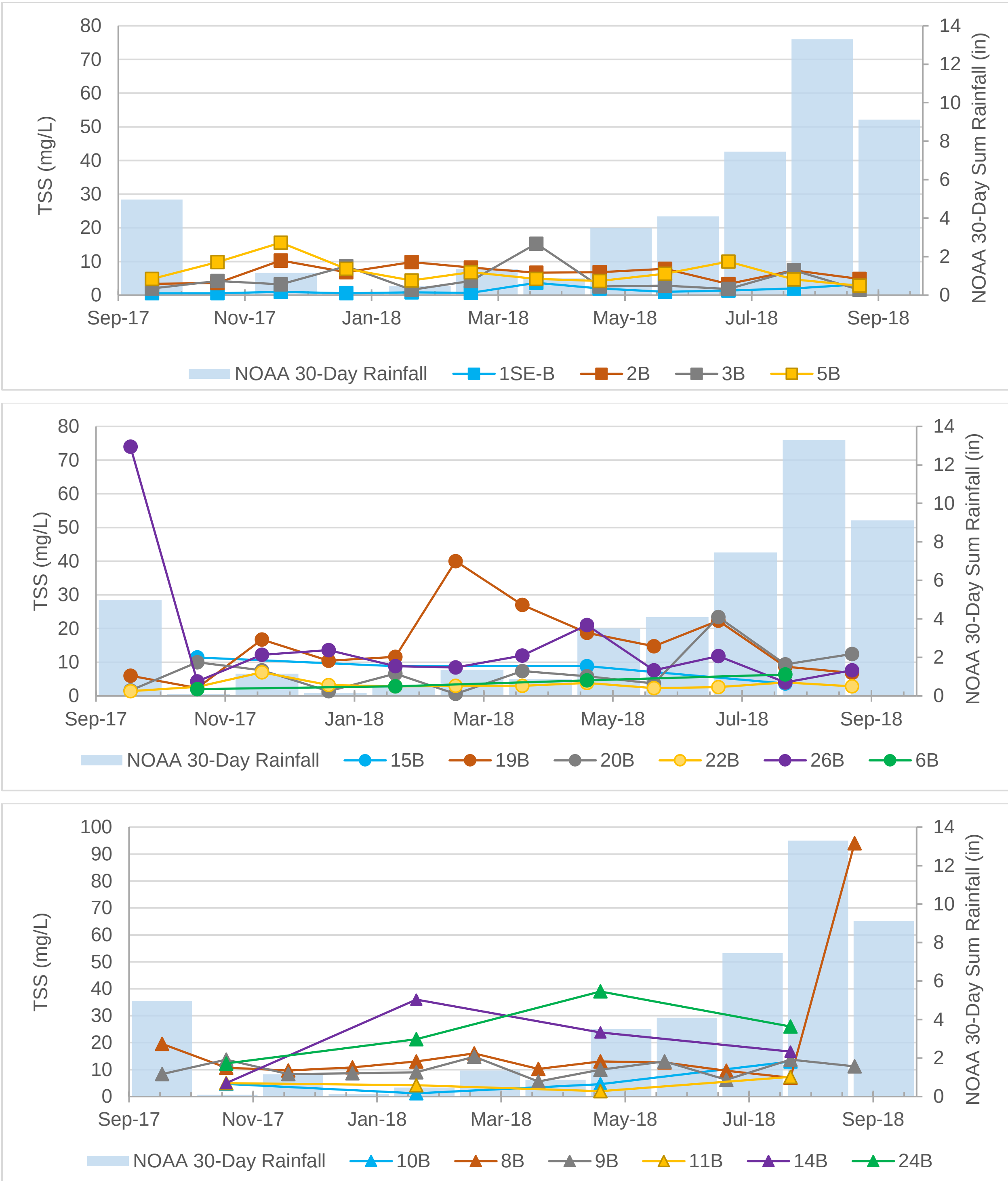

Figure 16. Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

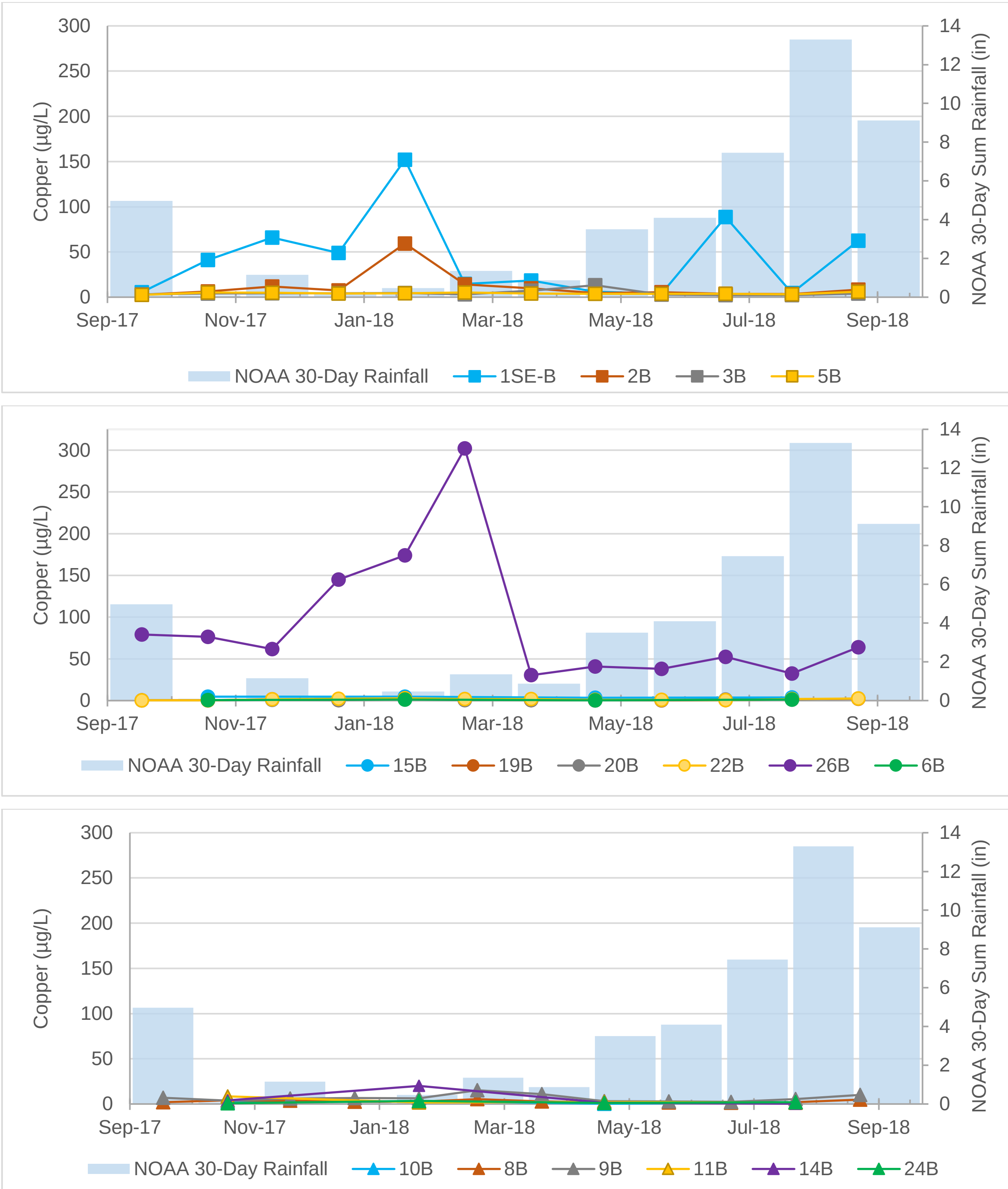

Figure 17. Time series plots of copper and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

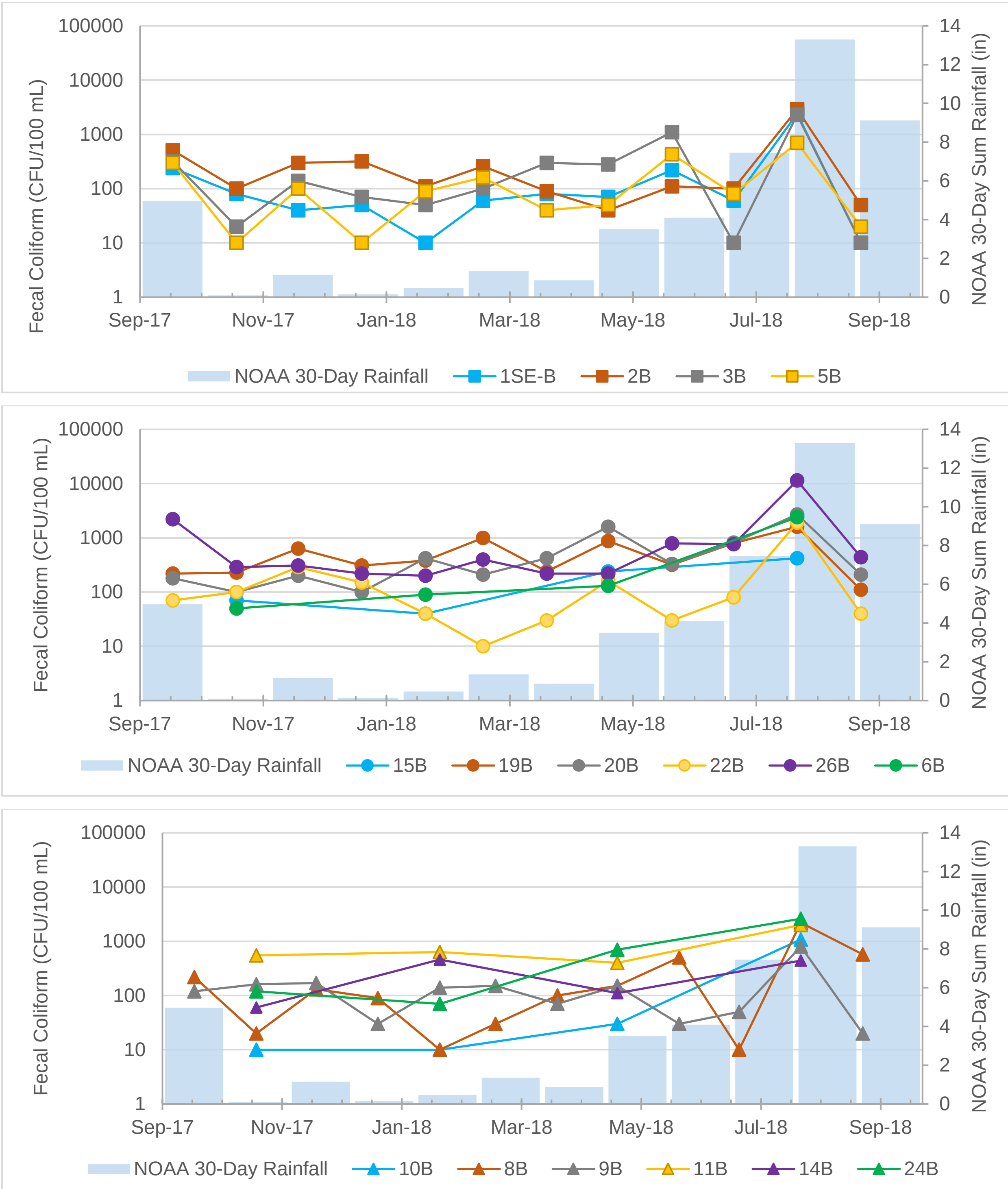

Figure 18. Time series log scale plots of fecal coliform colony forming units (CFU) per mL and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

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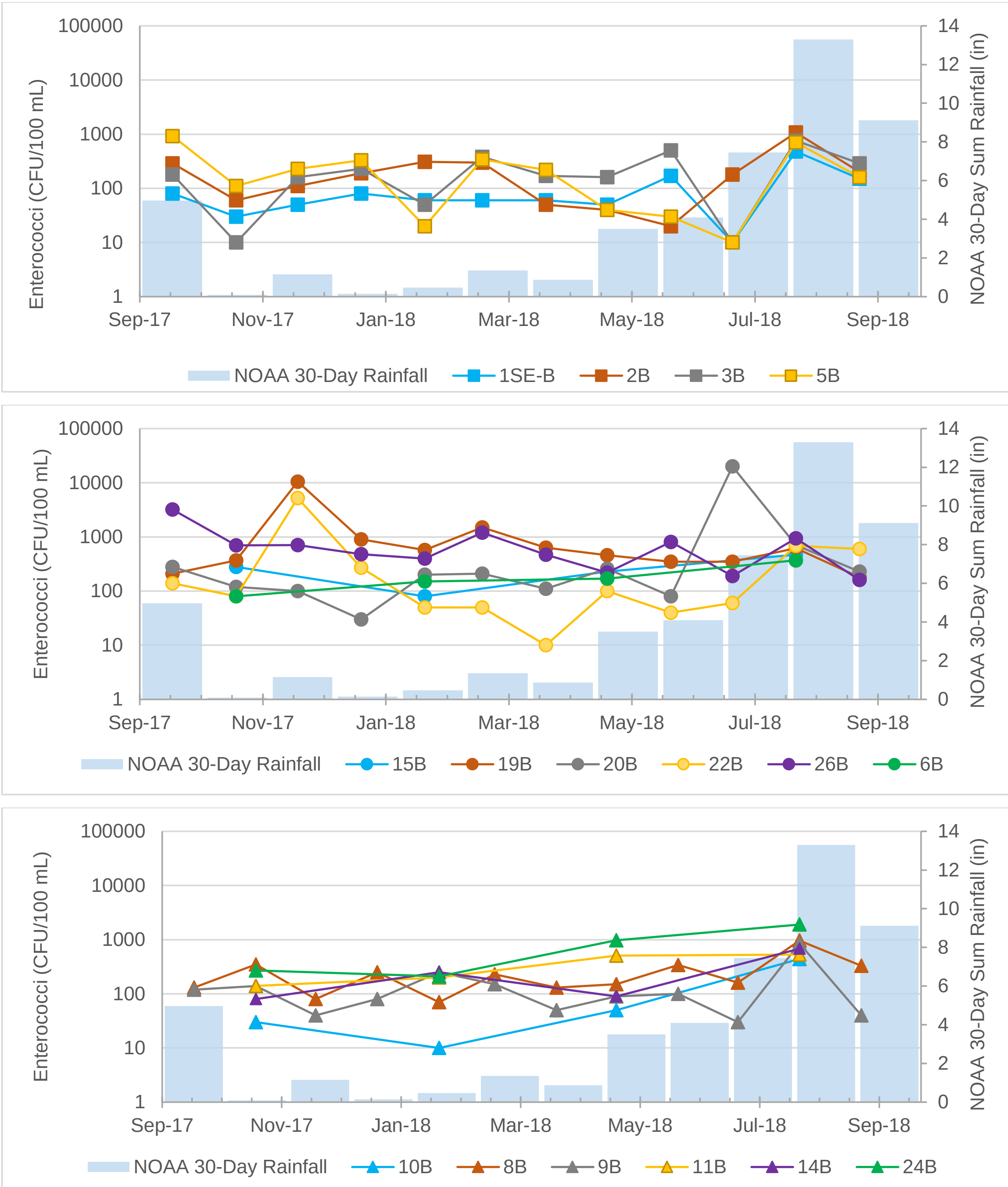

Figure 19. Time series log scale plots of enterococci CFU per mL and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

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 FY 2018 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, conductivity, 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 slightly higher during the wet season within all drainage basins, as expected (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) mainly prevalent within lakes draining either to Gordon River or Naples Bay/Gulf of Mexico (Figures 3 and 4). Three lakes each draining to the Gordon River (6B, 20B, and 22B) and Naples Bay/Gulf of Mexico (11B, 14B, 24B) 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 in 20B during March 2018 immediately followed a month with a super-saturated measurement (over 200 percent, Figure 3). Levels of pH remained consistent in stations draining to both Moorings Bay and Naples Bays/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 FY 2018; lakes 15B and 20B had measurements above 8.5 during February 2018, and lake 19B had elevated pH in February, March and June 2018 (Figure 5).

Based on conductivity 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 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 conductivities at the time of sampling (Figure 6). Two lakes, one draining to Napes Bay (24B) and one draining to the Gordon River (22B) had conductivity measures above the Class III Freshwater Standard of 1,275 µS/cm during the majority of sampling events; lake 3B draining to Moorings Bay had a single measurement above the Class III standard during October 2017 (Figure 6). Salinity followed the same patterns as conductivity at all locations (Figure 7). Turbidity measured at all lakes and events was 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 lake 19B during February and March 2018 (Figure 8).

Nutrient parameters (total nitrogen, total phosphorus, chlorophyll-a) were variable by station and drainage basin during FY 2018 samples. Total nitrogen (TN) at locations draining to Moorings Bay remained fairly consistent with isolated spikes in December 2017 and February 2018, and decreasing August 2018. TN concentrations at sites draining to the Gordon River were fairly consistent (measurements ranging from 0.59 to 2.5mg/L) with the exception of lake 19B, which had values above 2 mg/L from February to May 2018, and lake 20B during the dry season months of October 2017 and March 2018 (Figure 9). Locations draining to Naples Bay and the Gulf of Mexico were variable by location (measurements ranging from 0.56 to 5.72 mg/L) with higher values at 24B and lower concentrations at 10B (Figure 9).

Total Phosphorus (TP) concentrations for sites draining to Moorings Bay were consistently below 0.2 mg/L for the duration of FY 2018 samples collected (Figure 15). TP concentrations for the Gordon River sites were fairly consistent over the sampling year with a slight increase in both October and December 2017. Three of the stormwater lakes draining to Naples Bay and the Gulf of Mexico (10B, 11B, and 9B) were consistent during FY 2018, while 24B had higher overall values with a concentration increase between May and August 2018 sampling events. Initially, Lake 14B had higher values but decreased over the sampling period (Figure 15).

Chlorophyll-a concentrations at stormwater lakes draining to Moorings Bay, were fairly consistent among lakes 1SE-B and 2B with isolated spikes in November 2017 and January 2018 (Figure 13). Lake 3B was variable with higher values in January 2017 and March 2018 that appear independent of rainfall events. Stations that ultimately drain to the Gordon River were variable with most ranging from around 3 to 50 µg/L; higher concentrations were noted at 19B and 26B, mainly during drier months (Figure 13). Stations that ultimately drain to Naples Bay and the Gulf of Mexico had fairly stable chlorophyll-a concentrations at three locations (lakes 8B, 10B, and 11B), while lake 9B concentrations were more variable (maximum concentration of 266 µg/L recorded in February 2018). All chlorophyll-a concentrations during FY 2018 were above 100 µg/L at lake 24B, similar to concentrations observed during previous monitoring years (Figure 13).

Copper concentrations at lakes discharging to the same location seem to generally keep a similar pattern, one exception being Gordon River basin monitoring location 26B which had consistently higher concentrations overall including a March measurement of 302 µg/L. The lakes in the Gulf of Mexico basin had spikes in copper concentrations during January, February and March 2018 for lakes 14B and 9B. Lake 1SE-B, draining to Moorings Bay had higher concentrations than the other three lakes with a maximum concentration recorded at 152 µg/L during the March 2018 event (Figure 17). Spikes of this nature would indicate recent dosing of copper sulfate. During the February sampling event, Cardno staff were told of ongoing lake "management" contracted by homeowners to address algal growth in Lake 26B, within the Gordon River basin.

Fecal coliform and enterococci values were variable throughout the FY2018 sampling period with isolated spikes in colony count appearing to occur after isolated stormwater inflows (Figures 18 and 19). Fecal coliform values did have a slight upward visual trend for most of the stormwater lakes draining into the Gordon River sampling locations during the wet season (June to September). Enterococci values showed small isolated spikes throughout the sampling period as a likely response to increased rainfall. Lakes 22B, 19B and 20B had variable values and exhibited the highest enterococci values for the Gordon River Basin lakes. Fecal Coliform values were erratic having a slight overall upward visual trend within the Gulf of Mexico drainage basin associated with summer rains. Enterococci values within the Gulf of Mexico basin lakes had a similar upward visual trend associated with the summer rainy season.

2.2.1 Nutrient and Bacterial Management

Florida stormwater ponds remove on average 43 percent of TN (Table 3) with median stormwater TN concentrations of 2.636 mg/L for residential runoff, which poses potential management challenges. Management strategies for TN reduction may include additional littoral plantings, retrofitting stormwater conveyance systems with additional treatment systems such as Storm treat/ Aqua filter, street sweeper programs, routine weir and baffle box clean outs and public outreach and education programs.

Average total phosphorus treated by conventional Florida stormwater lakes is 66 percent with typical residential runoff containing a median concentration of 0.383 mg/L. Management actions may be necessary for additional TP reduction with long term stormwater master planning and associated budgets for stormwater improvement projects. Simple and cost-effective strategies may also include: supplemental littoral plantings, changes in the duration and timing of street sweeping program, routine maintenance of catchment basins, and use of binding agents like Phoslock.

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 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 supplemental shoreline plantings, stormwater upgrades, aeration, and supplemental public education.

Management of fecal coliform and Enterococci levels 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 and having an education and outreach activities have been shown as effective management strategies in reducing bacterial loading from stormwater into lakes and ponds.

Overall water quality parameters were variable both spatially and temporally during the FY 2018 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. Additional data 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 the upcoming FY 2019 sampling will help to identify potential trends that can be addressed with management decisions for each waterbody described above.

Table 3. Removal efficiency for Florida lakes[1].

Parameter	Average Removal	Lower Confidence Level	Upper Confidence Level
TSS	69%	28%	85%
TN	43%	13%	62%
Ammonia	16%	-47%	50%
TP	66%	25%	79%

[1] Data from Florida BMP Database, 2006.

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 2017 to September 2018. The quarterly sampling events occurred in November 2017, February 2018, May 2018, and August 2018.

All FY 2018 water quality monitoring samples were collected quarterly from the wet wells at each pump station. Table 4 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 4. 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 2017 to September 2018.

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	1	1.17	1.45	1.34	0.065	0.139	0.10	3.21	7.94	5.43
Cove Pump	11-Pump	4	1	1.13	1.56	1.35	0.084	0.188	0.13	1.04	3.09	1.59
Port Royal Pump	14-Pump	4	1	1.50	3.03	1.95	0.417	1.21	0.61	U (0.242)	4.38	1.10

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.
*Outflow weir inaccessible; flow over weir unknown.
**Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

3.1.1 Time Series Plots of Field Parameters

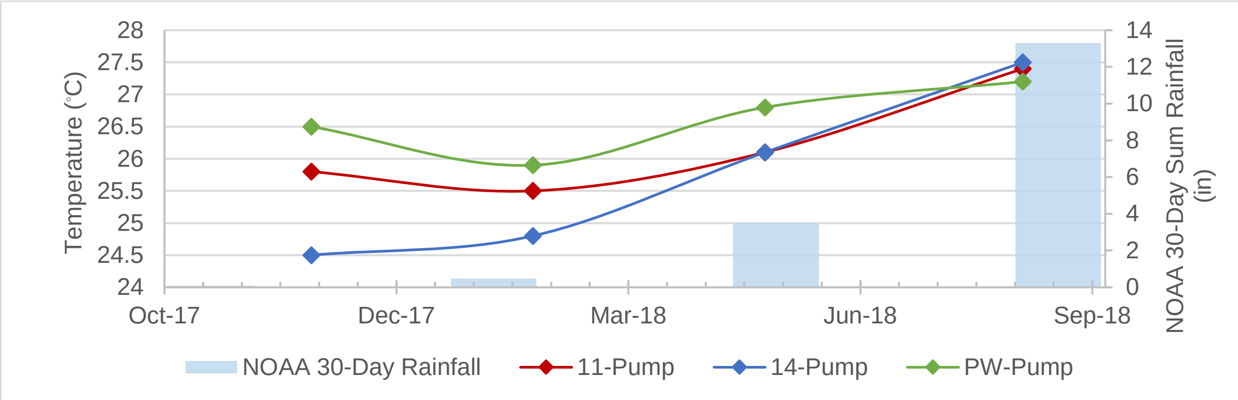

Figure 20. Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

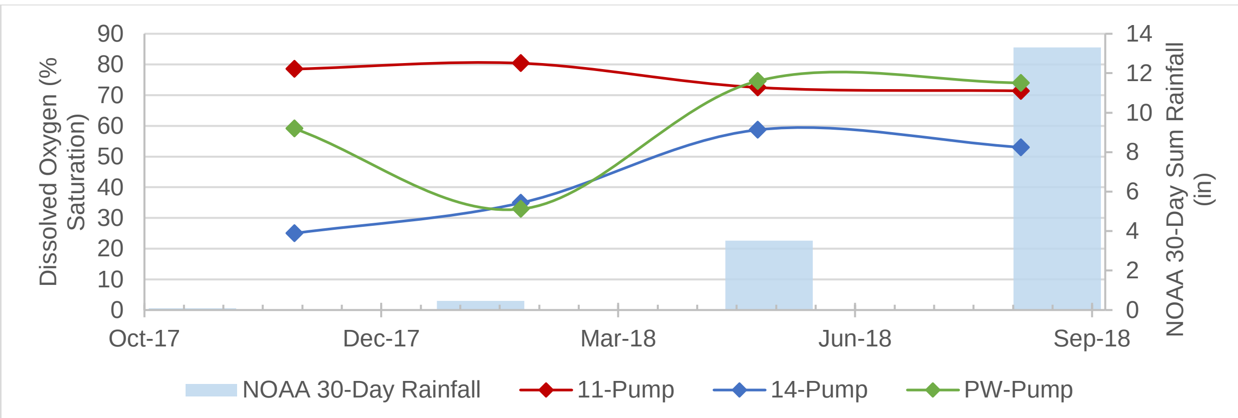

Figure 21. Time series plots of dissolved oxygen (% saturation) and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

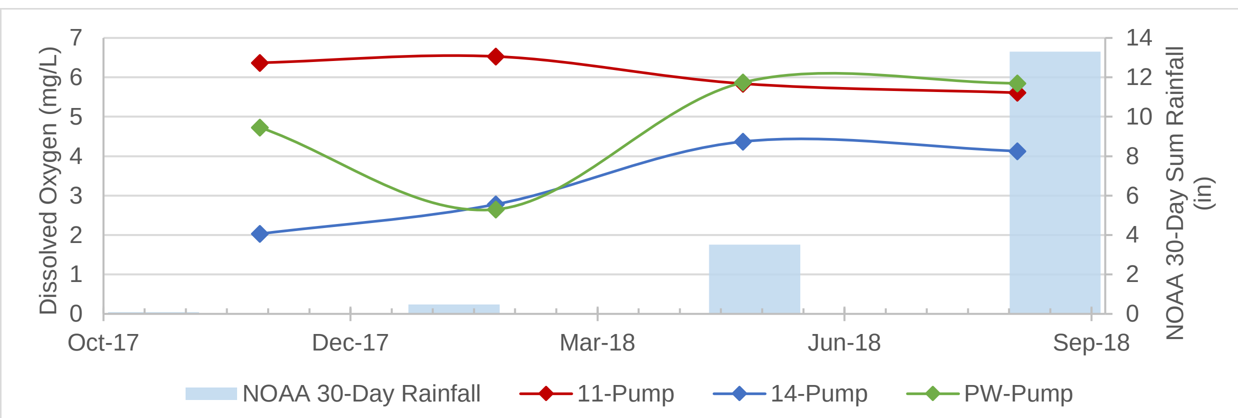

Figure 22. Time series plots of dissolved oxygen (concentration) and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

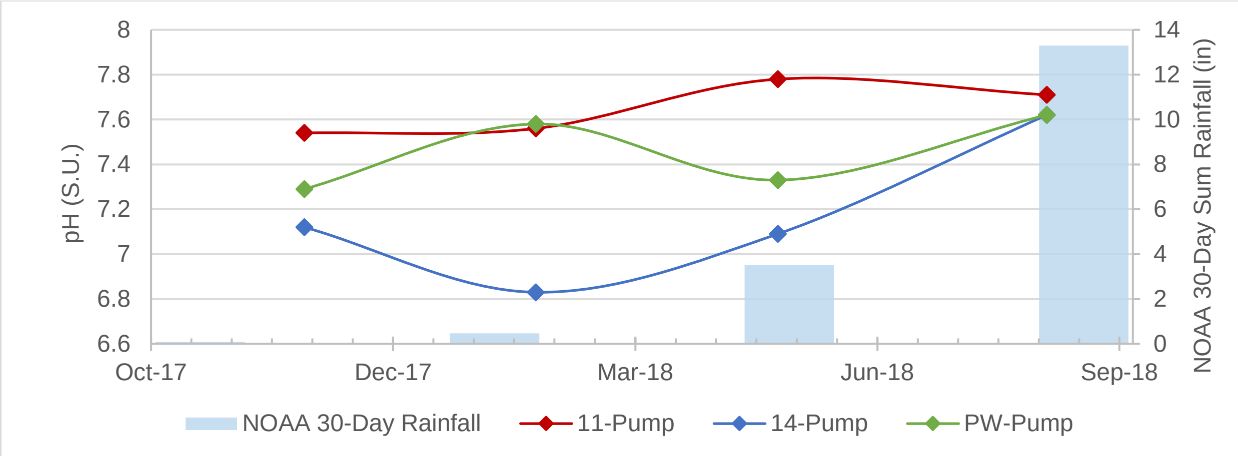

Figure 23. Time series plots of pH and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

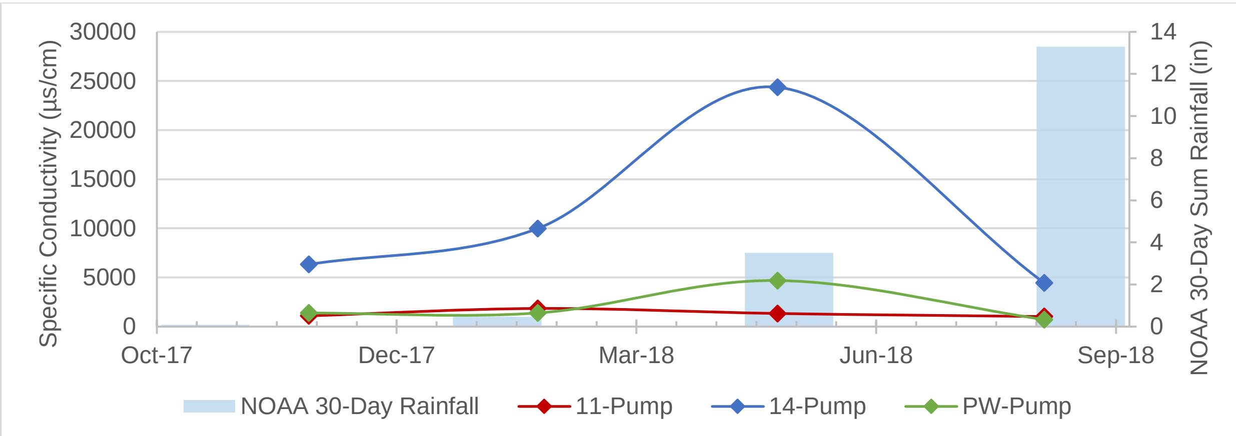

Figure 24. Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

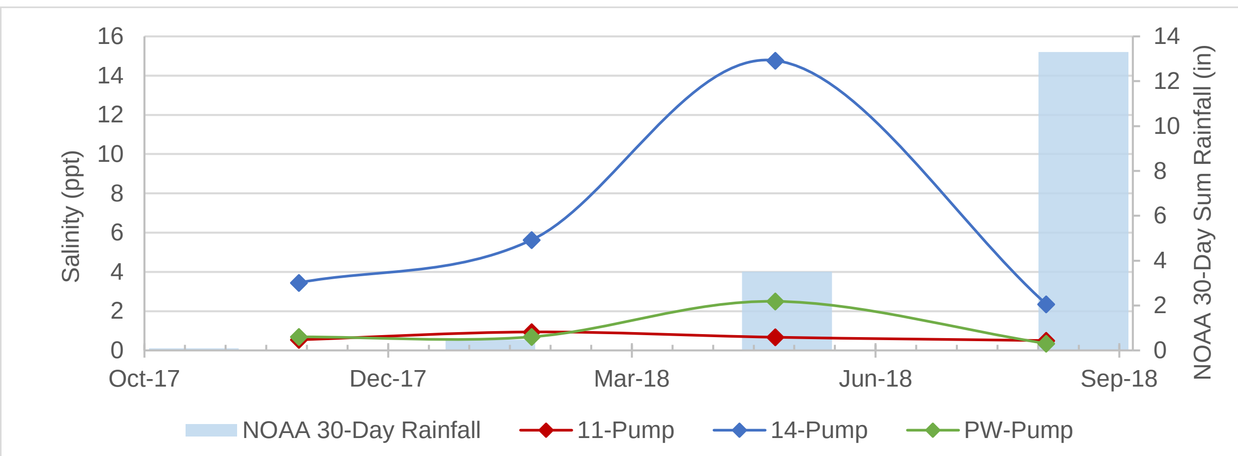

Figure 25. Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

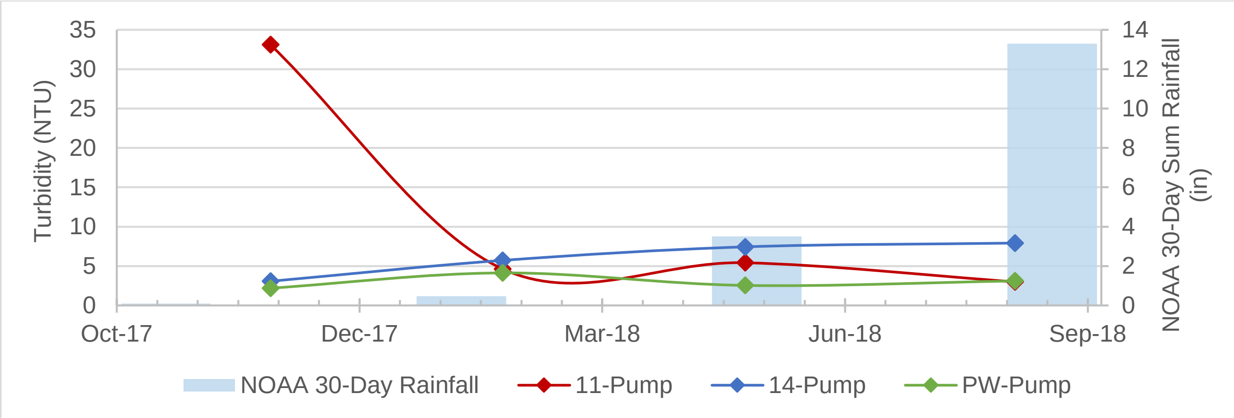

Figure 26. **Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.**

3.1.2 Time Series Plots of Lab Parameters

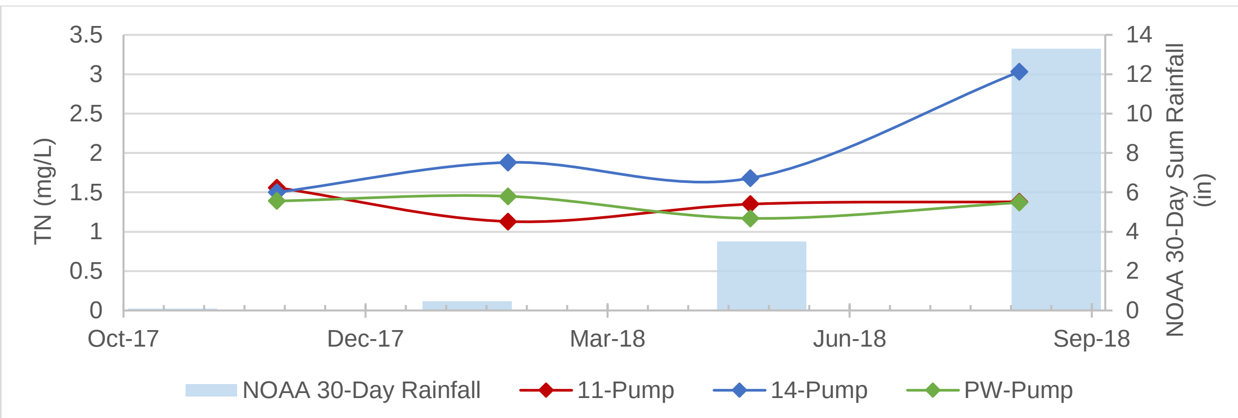

Figure 27. **Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.**

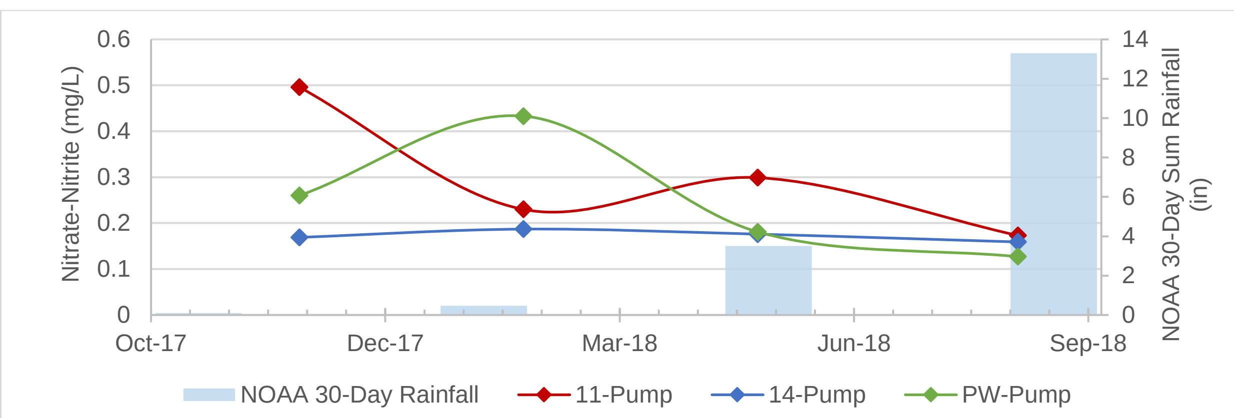

Figure 28. **Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.**

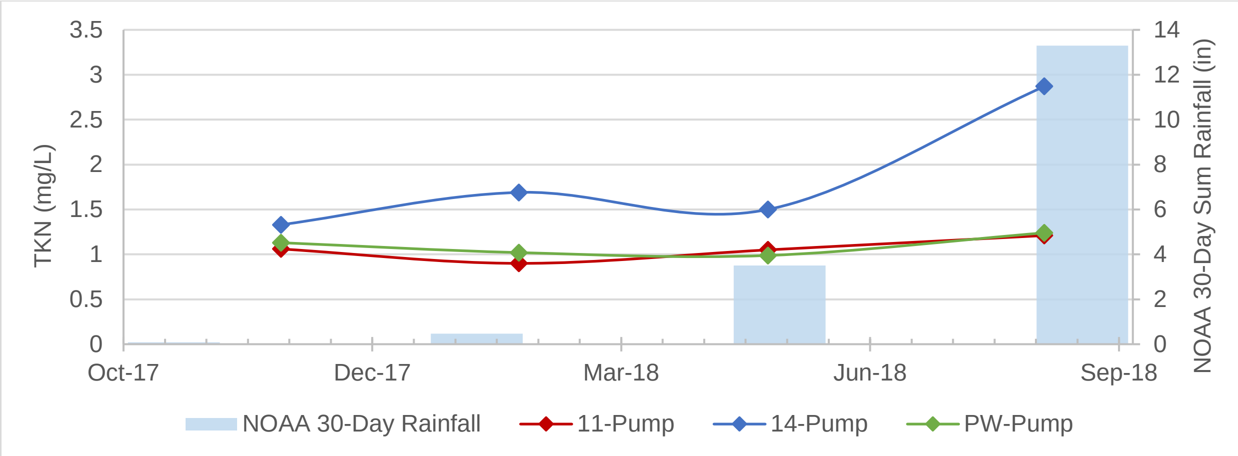

Figure 29. Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

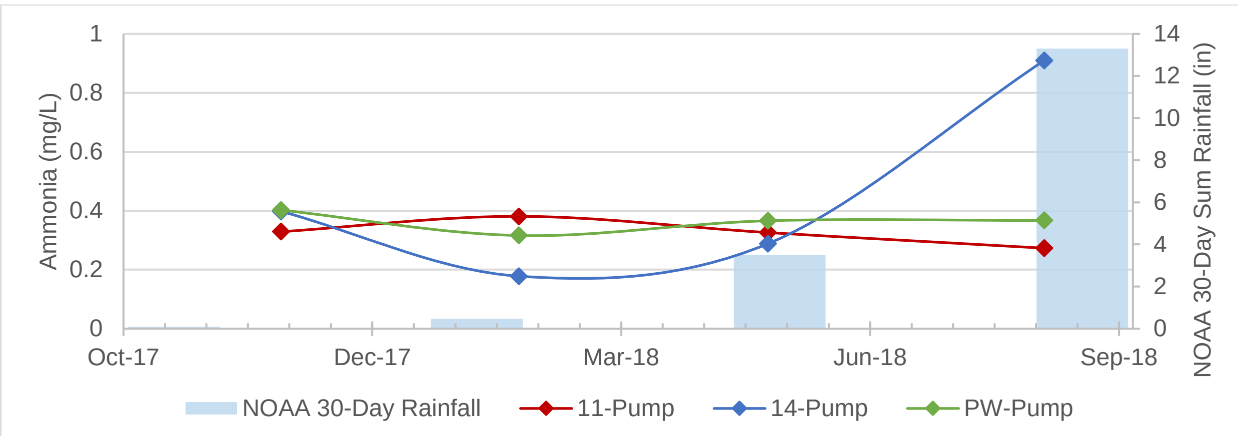

Figure 30. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

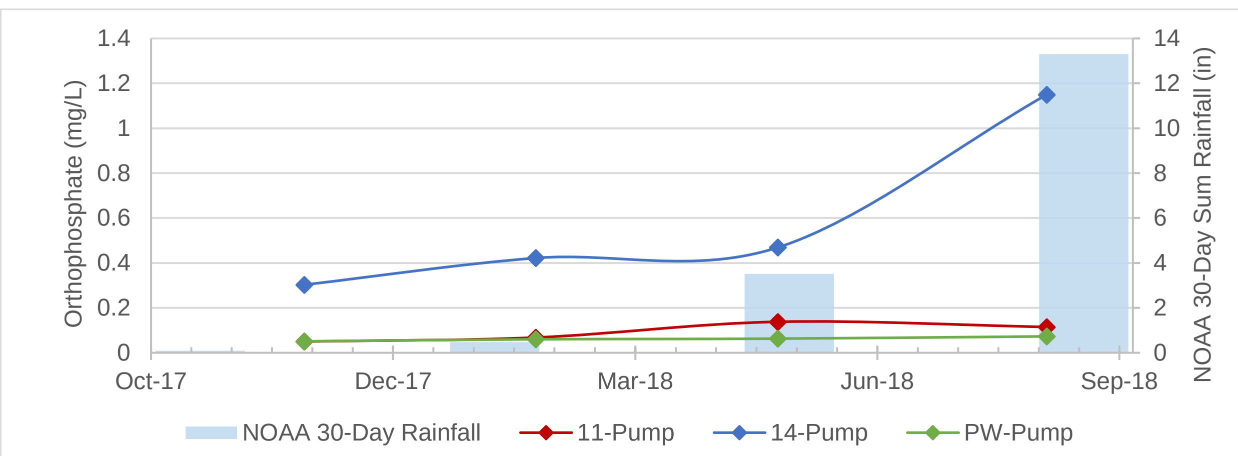

Figure 31. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

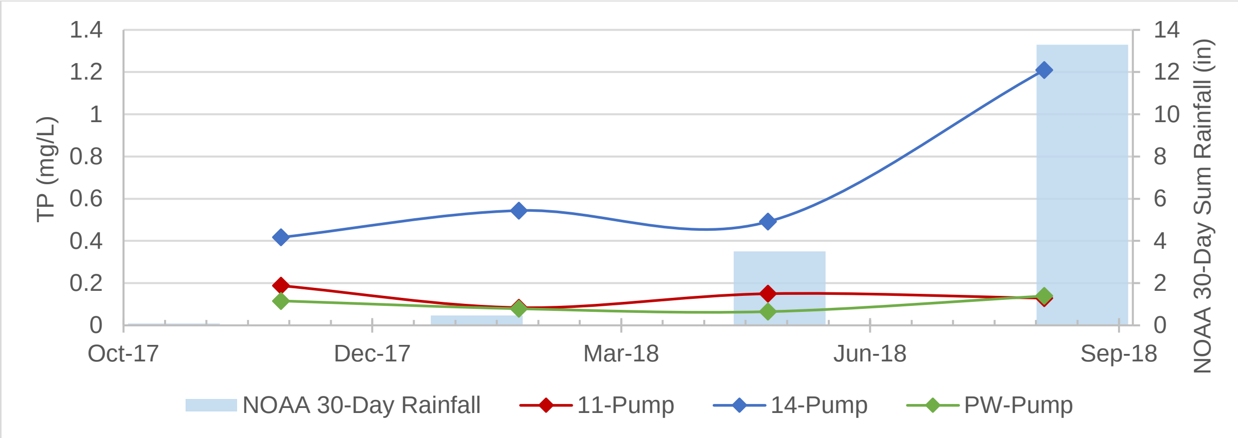

Figure 32. Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

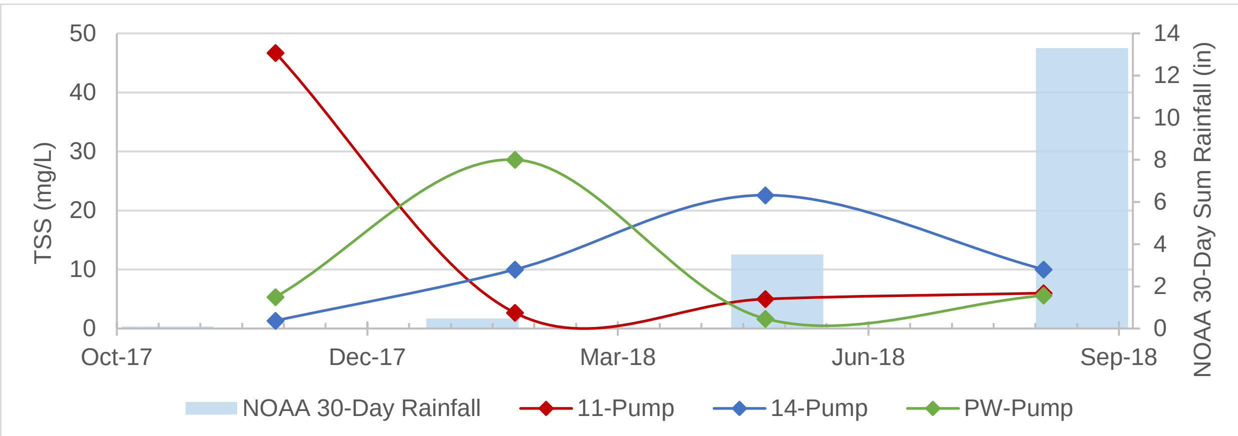

Figure 33. Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

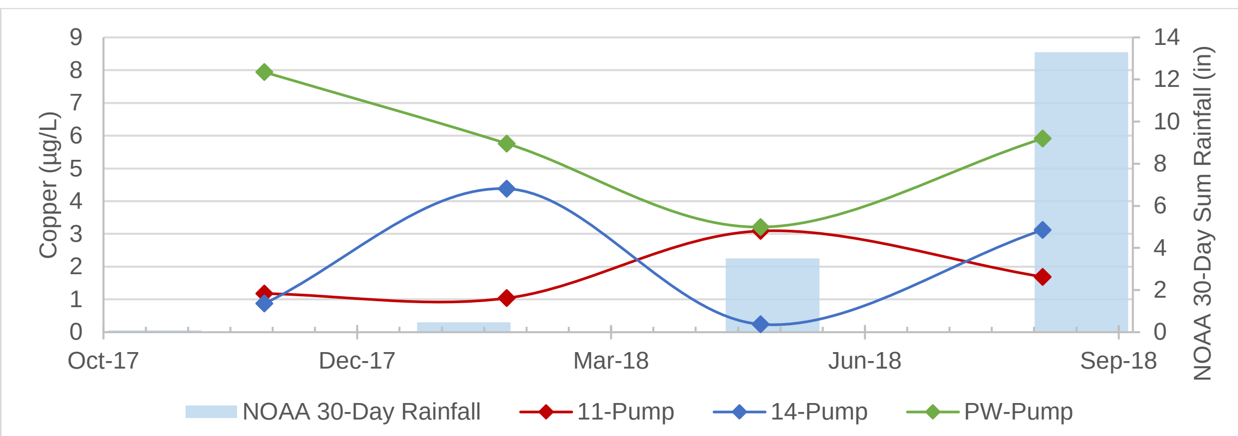

Figure 34. Time series plots of copper and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

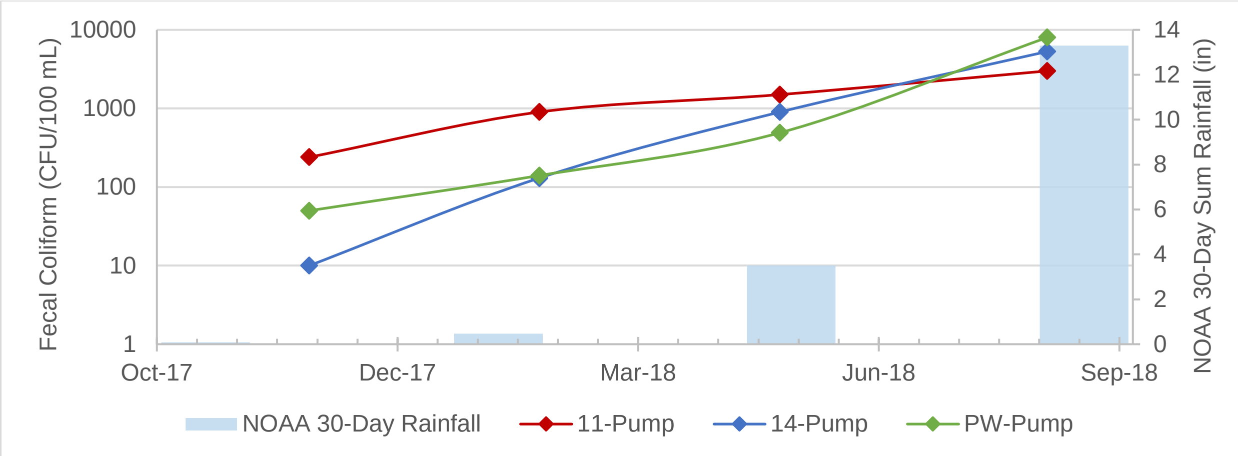

Figure 35. Time series log scale plots of fecal coliform and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

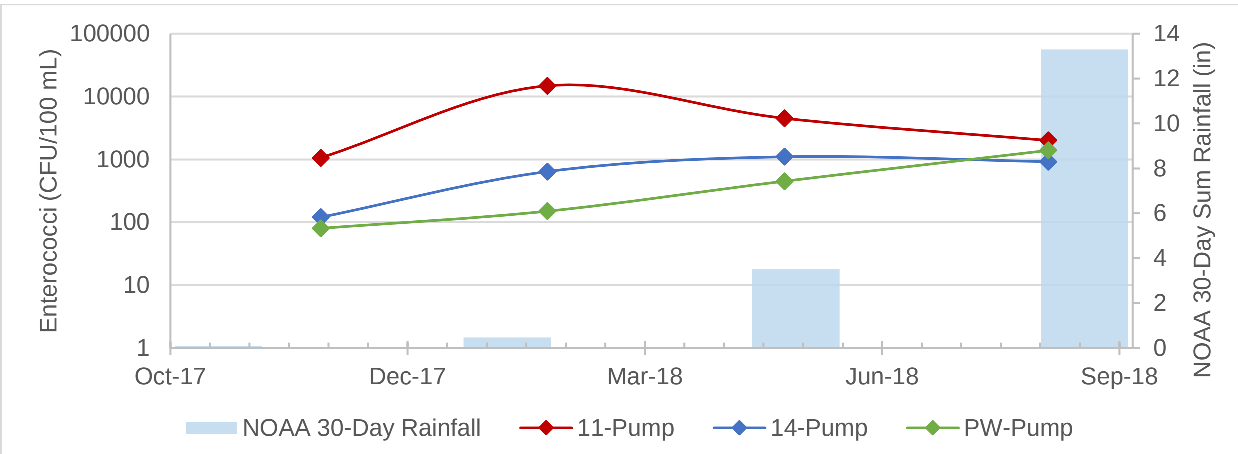

Figure 36. Time series log scale plots of enterococci and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump, 11-Pump, and 14-Pump.

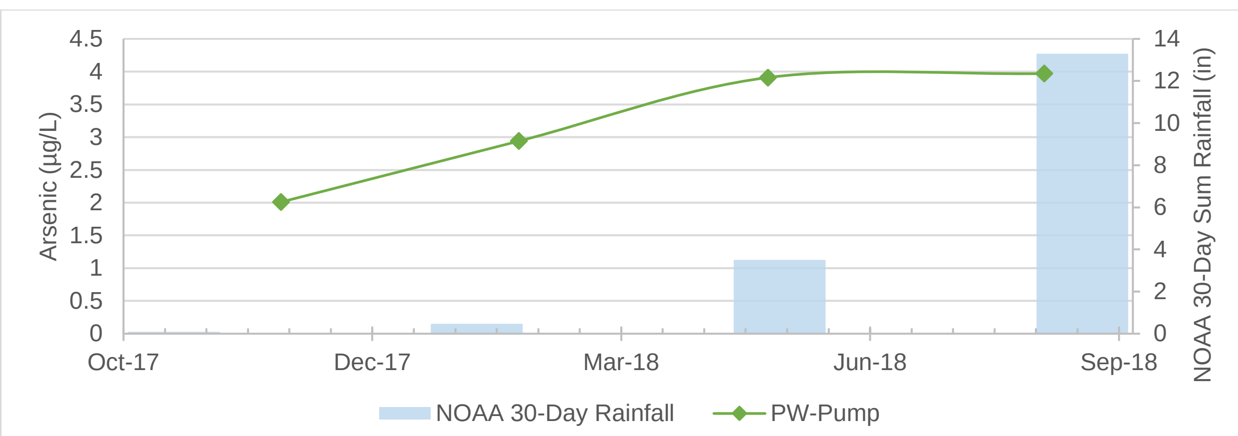

Figure 37. Time series plots of arsenic and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

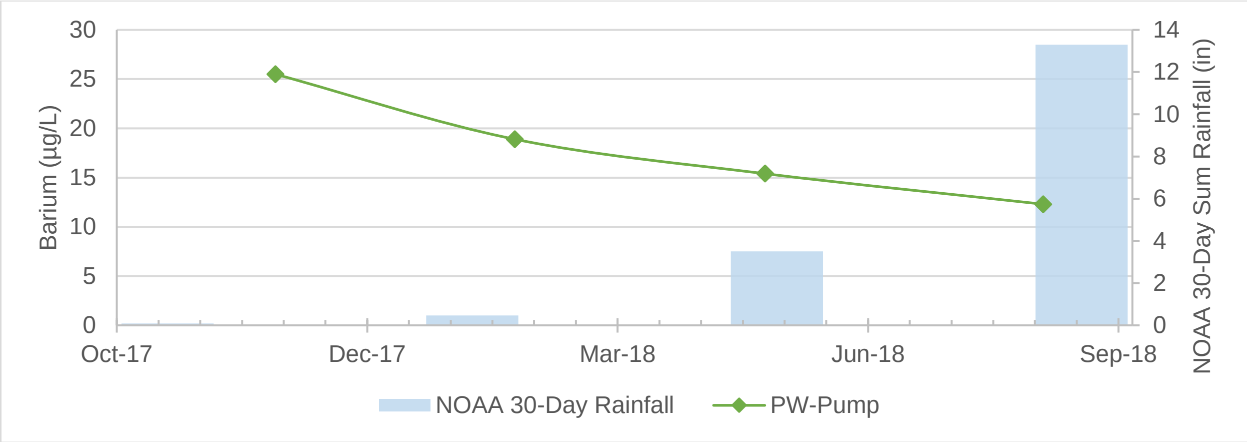

Figure 38. Time series plots of barium and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

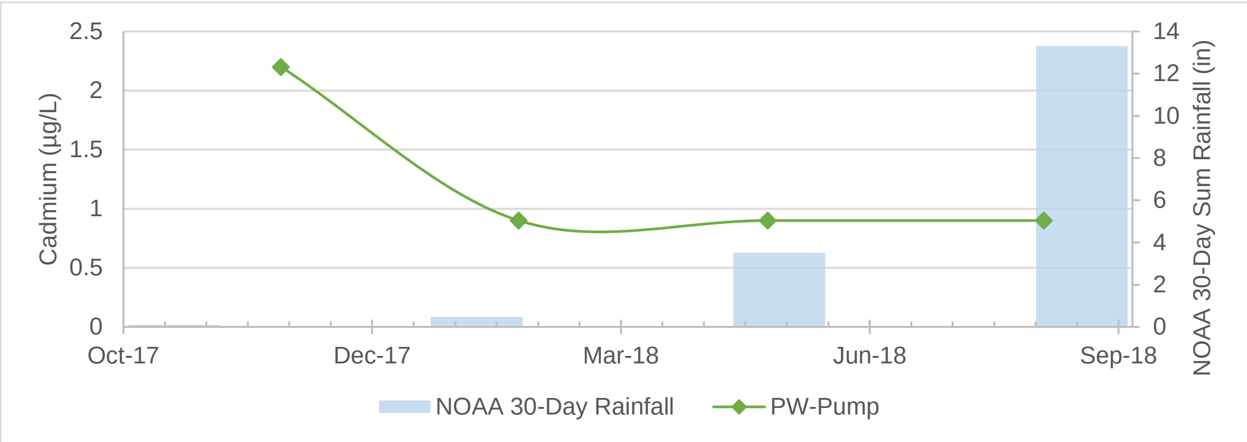

Figure 39. Time series plots of cadmium and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

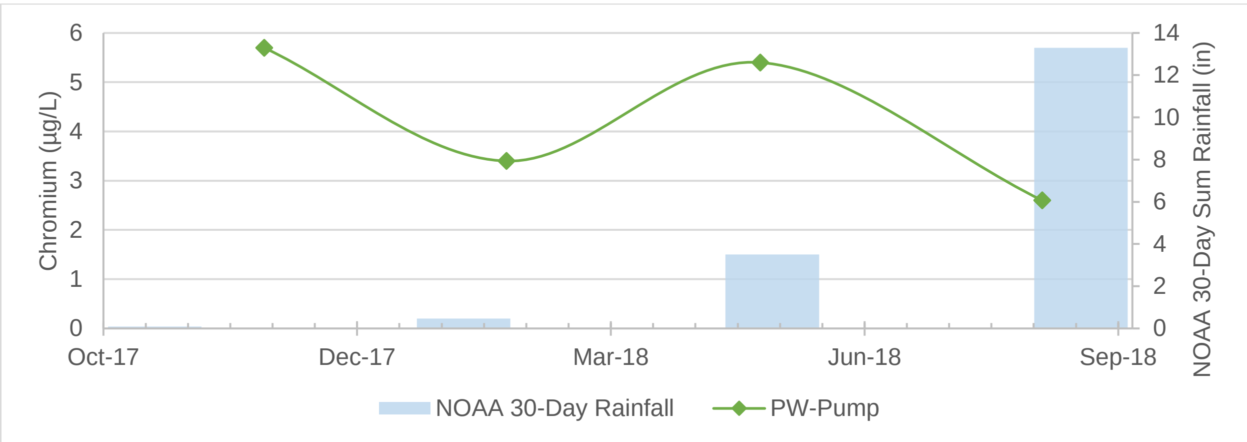

Figure 40. Time series plots of chromium and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

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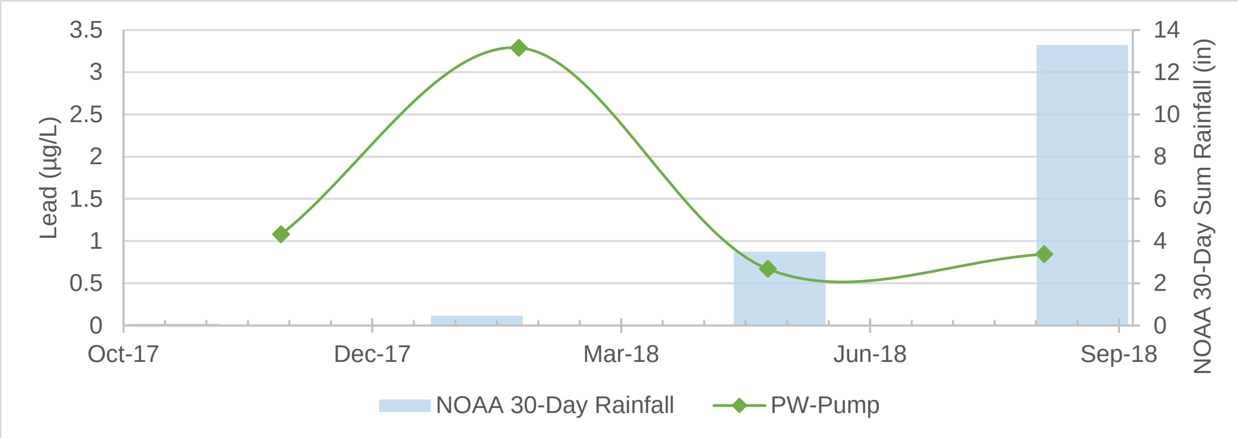

Figure 41. Time series plots of lead and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

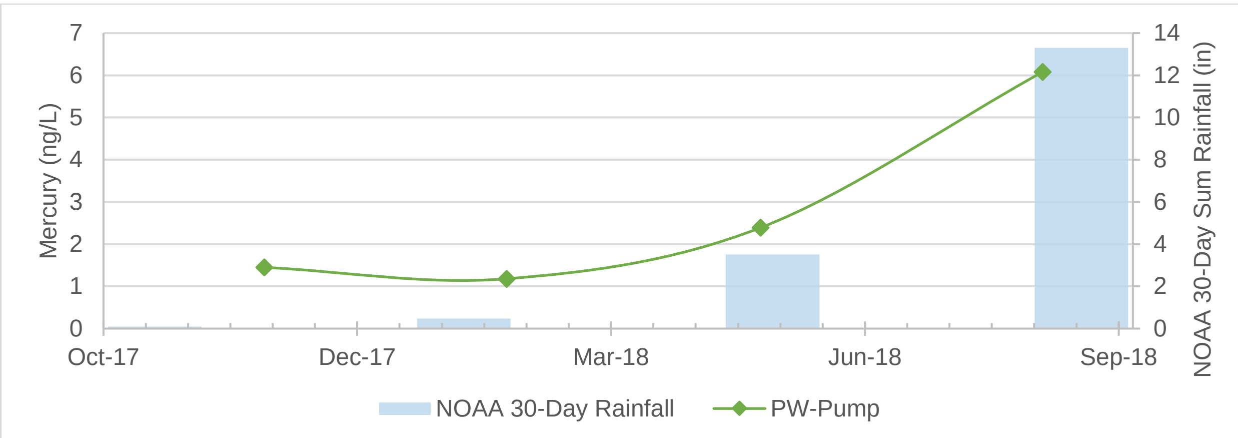

Figure 42. Time series plots of mercury and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

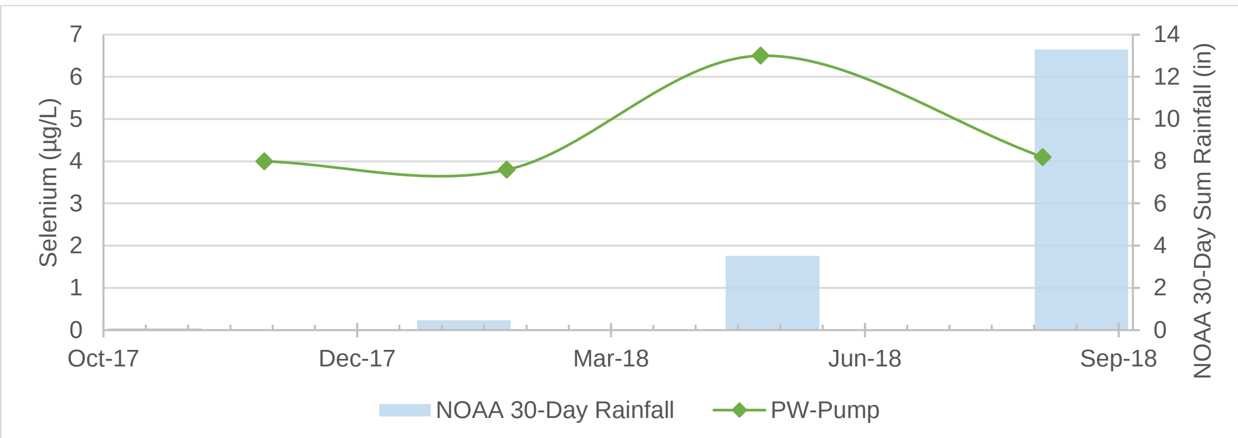

Figure 43. Time series plots of selenium and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

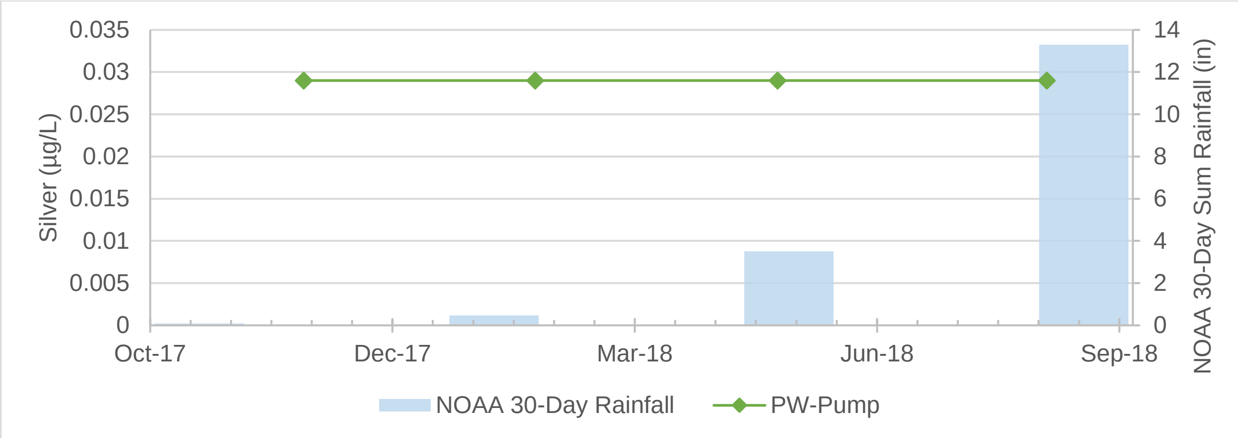

Figure 44. Time series plots of silver and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

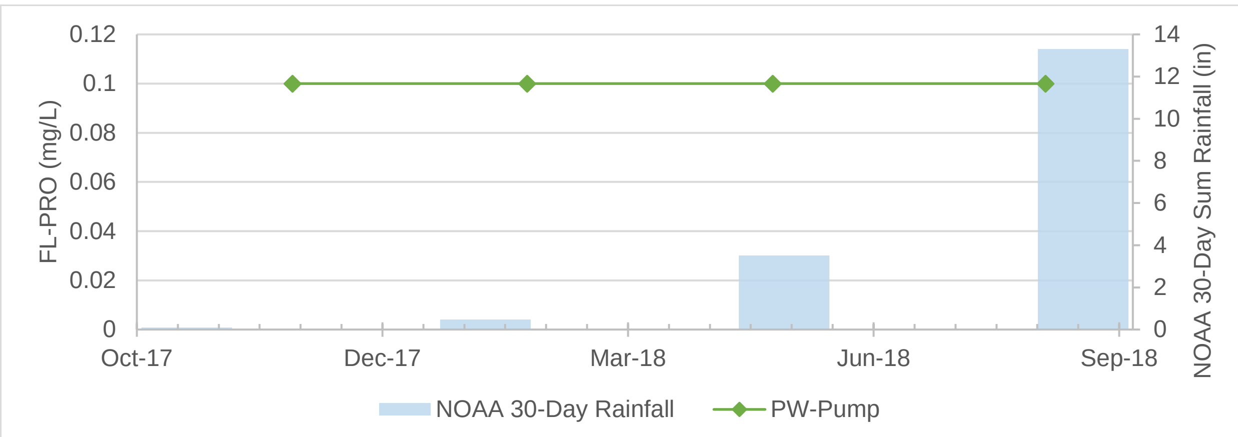

Figure 45. Time series plots of petroleum range organics and prior 30-day sum NOAA rainfall from October 2017 through September 2018 at PW-Pump.

3.2 Discussion

Monitoring data collected at pump stations were reviewed and summarized by parameter during FY2018. 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 2018. Dissolved oxygen at 14-Pump and PW-Pump were elevated during the wet season with an increased surface water flow (months where flow was recorded during sampling events, Table 4 and Figures 21 and 22). Levels of pH were variable during the FY2018 sampling period, with lower values recorded at 14-Pump and higher values at 11-Pump (Figure 23). Conductivity and salinity measurements at 14-Pump were higher than the other pump stations in FY 2018 (Figures 24 and 25). A large spike in conductivity (24,361µs/cm) was observed in May 2018 (Figures 24). Based on conductivity 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.). There was an isolated turbidity value of greater than 29 NTU at 11-Pump in November 2017 (33.1 NTU), but the Class III Surface Water Standard is only used as a reference for the pump stations.

Nitrogen (TN, TKN, nitrate-nitrate, ammonia) and phosphorus (TP and Orthophosphate) concentrations were low and showed little variability at 11-Pump and PW-Pump stations (Figures 27 to 32). At 14-Pump, the 30-day prior rainfall total of 13.3 inches during August 2018 dramatically increased TN and TP concentrations (Figures 27 and 32). For comparison, the Naples Bay Numeric Nutrient Criteria for TN and TP are 0.045 mg/L and 0.57 mg/L, respectively (Rule 62-302.532; F.A.C.). TN for 14-Pump was 3.03 mg/L and TP was 1.21 mg/L in Aug 2018.

Copper concentrations typically stayed near/below 3 µg/L at pump stations 11-Pump and 14-Pump, one exception being the February 2018 measurement of 4.38 µg/L at 14-Pump. At PW-Pump, copper concentrations were elevated and a maximum concentration of 7.94 µg/L was observed in November 2017 (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 were elevated at all 3 pump stations, with half (6/12) of the pump station samples collected for fecal coliform elevated above the Class III reference value of 800 cfu/100mL daily limit; 11-Pump had three measurements above the referenced Class III values and PW-Pump only had one measurement above (Figure 35). The highest fecal coliform for each station was 8,000 cfu/100mL at PW-Pump, 5,300 cfu/100mL at 14-Pump, and 3,000 cfu/100mL at 11-Pump (Figure 35). Both fecal coliform and enterococci responded to increases in rainfall with generally increased values. PW-Pump and 14-Pump demonstrated an upward trend with maximum values for each occurring in the wet season. Enterococci values were 1390 cfu/100mL at PW-Pump in Aug 2018 and 1100 cfu/100mL at 14-Pump in May 2018. 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.

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.

Selenium had a single elevated value in May 2018 of 6.5 µg/L at PW-Pump station (Figure 43). Elevated values were detected at PW-Pump locations with arsenic being above 3 µg/L, barium above 10 µg/L, and mercury above 1 ng/L during each monitoring event (Figures 37, 38, and 42); none of these elevated values exceeded Class I or III Surface Water Quality Standards (Rule 62-302.530, F.A.C.). All other heavy metal measurements were either non-detected or between the minimum detection limit (MDL) and practical quantitation limit (PQL) of the methodology

3.3 Pump Station Loading Summary

Estimated monthly loadings for parameters of concern to the City (nutrients, copper, and solids) were calculated for each of the three pump stations. This analysis was based on monthly discharge volume calculations from the three City pump stations, which are estimates based on the pump time and maximum pump rate for each system. Therefore, this analysis may not reflect actual volumes from each pump station, and the loadings calculated using these volume estimates should be considered estimates of the maximum loads. Because water quality monitoring is conducted quarterly for each pump station rather than monthly, we assumed the quarterly concentration to represent each month during that calendar quarter.

Table 5 shows the estimated monthly and annual total loads (in pounds) from each pump station from October 2017 through September 2018 for copper, total nitrogen, total phosphorus, and total suspended solids.

Table 5. Monthly and annual total loadings (in pounds) from City of Naples Pump Stations from October 2017 to September 2018.

Pump Station	Month	Loads (lbs)			
		Copper	Total Nitrogen	Total Phosphorus	Total Suspended Solids
PW-Pump	October-17	9.46	1656.5	138.2	6351.8
	November-17	0.88	153.8	12.8	589.7
	December-17	3.90	682.1	56.9	2615.4
	January-18	1.00	251.0	13.7	4951.5
	February-18	0.80	201.1	11.0	3966.0
	March-18	2.93	738.2	40.2	14560.3
	April-18	2.21	804.8	44.7	1148.7
	May-18	2.28	831.6	46.2	1187.0
	June-18	2.46	897.9	49.9	1281.6
	July-18	4.17	966.2	98.0	3949.4
	August-18	4.17	966.2	98.0	3949.4
	September-18	5.61	1301.1	132.0	5318.3
	Annual Total	**39.87**	**9,450**	**742**	**49,869**
11-Pump	October-17	3.14	4156.3	500.9	124422.3
	November-17	0.56	738.0	88.9	22093.0
	December-17	1.45	1918.0	231.1	57418.5
	January-18	0.47	508.6	37.8	1201.6
	February-18	0.37	400.5	29.8	946.3
	March-18	1.34	1460.1	108.5	3449.9
	April-18	4.22	1845.7	205.1	6835.9
	May-18	4.37	1907.2	211.9	7063.7
	June-18	4.58	1999.1	222.1	7404.1
	July-18	4.73	3861.2	360.9	16787.7
	August-18	4.73	3861.2	360.9	16787.7
	September-18	3.79	3090.9	288.9	13438.6
	Annual Total	**33.74**	**25,747**	**2,647**	**277,850**
14-Pump	October-17	0.24	420.5	116.9	372.9
	November-17	0.13	230.5	64.1	204.4
	December-17	0.14	236.2	65.7	209.4
	January-18	0.73	313.4	90.7	1667.1
	February-18	0.56	240.9	69.7	1281.6
	March-18	0.67	287.5	83.2	1529.4
	April-18	0.05	352.8	103.1	4746.4
	May-18	0.05	364.6	106.6	4904.6
	June-18	0.04	282.2	82.5	3795.8
	July-18	1.07	1036.8	414.0	3421.7
	August-18	1.07	1036.8	414.0	3421.7
	September-18	1.16	1123.2	448.6	3707.1
	Annual Total	**5.91**	**5,925**	**2,059**	**29,262**

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

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.