Filamentous Algae Monitoring Program: Potomac River Basin

Report to the West Virginia Department of Environmental Protection,

Division of Water and Waste Management

by

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Interstate Commission on the Potomac River Basin

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ICPRB Report

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Background

West Virginia Department of Environmental Protection (WVDEP) has been observing and evaluating the breadth and causes of filamentous green algae blooms in rivers across the state since 2007. Blooms of filamentous algae occur in rivers of the Potomac Basin and the Interstate Commission on the Potomac River Basin (ICPRB) has assisted the WVDEP in documenting algae blooms in the South Branch Potomac, Cacapon, and Shenandoah rivers since 2012.

Field methods

ICPRB biologists implemented the WVDEP Filamentous Algae Monitoring Protocol (WVDEP 2013) at 14 fixed locations over five (5) monthly rounds between June and October 2016. The 2016 effort was reduced to five (5) monthly sampling events from ten (10) bi-monthly efforts of previous years.

Table 1. Dates of 2016 sampling rounds.

Sampling Round	Sampling Dates
Round 1	Jun 20-21
Round 2	Jul 14-15
Round 3	Aug 15-16
Round 4	Sep 14-15
Round 5	Oct 12-13

Information on the WVDEP filamentous algae monitoring program, including the Standard Operating Procedures for algae observation and water chemistry sampling, and the program's field data sheet can be found on-line at:

http://www.dep.wv.gov/WWE/Programs/wqs/Pages/FilamentousAlgaeinWestVirginia.aspx

The WV filamentous algae protocols consist of routine water chemistry sampling, a rapid assessment style field form, semi-quantitative algae coverage estimates, and longitudinal surveys to document the extent of bloom events. A single ICPRB biologist (Gordon Selckmann) made the routine observations. A second biologist was present when bloom sites were extensive or required extra support. A total of three longitudinal surveys were performed in 2016. The field crews consisted of at least two biologists from ICPRB and/or WVDEP for all longitudinal surveys (ICPRB personnel: Gordon Selckmann and Zachary Smith).

Station locations

The fourteen sampling stations were targeted by the WVDEP in 2016 based upon past observations, targeted inquiries, and best professional judgment. Eight stations are located in the Cacapon basin: seven on the Cacapon River main-stem between the towns of Largent and Wardensville, and one on North River, the Cacapon's largest tributary. Six stations were located on the South Branch Potomac, three above and three below the town of Moorefield, WV (**Table 2 and**

Figure 1). Nine out of fourteen stations were located at or near bridge crossings, while the other five were accessed along nearby roadways. Seven stations had public assess put-ins, and the remainder were accessed from bridge right-aways or through private landowner permission. Stations were generally sampled one river at a time, traveling sequentially upstream.

Table 2. Sampling station names and locations.

Site Name	Site Location Description	Lat / Long Coordinates	
NO_FRKS	North River at Gaston Rd. / Forks of Cacapon	39.40194	-78.42448
CA_LRGNT	Cacapon River at Rt. 9 in the town of Largent	39.48112	-78.38448
CA_FRKS	Cacapon River at Rt. 127 / Forks of Cacapon	39.40387	-78.41842
CA_D_CPBRG	Cacapon River at farm off Cold Stream Road	39.32716	-78.42336
CA_CPBRG	Cacapon River at Rt. 50 in Capon Bridge	39.29754	-78.43517
CA_RMRCK	Cacapon River along Capon River Rd.	39.21969	-78.47605
CA_YLWSPR	Cacapon River at Rt. 259 below Wardensville	39.18281	-78.50597
CA_WRDS	Cacapon River at farm ford in Wardensville	39.07861	-78.61134
SBR_L_TRGH	South Branch at Harmison's Landing	39.22810	-78.85251
SBR_U_TRGH	South Branch at South Branch WMA	39.14630	-78.92519
SBR_L_MRFLD	South Branch at Rt. 220/28 in Moorefield	39.10424	-78.95801
SBR_U_MRFLD	South Branch at Fisher Rd above Moorefield.	39.05006	-78.99316
SB_L_PBRG	South Branch at Weldon Park	38.98815	-79.12126
SB_U_PBRG	South Branch at Rt. 200 bridge	38.99955	-79.08596

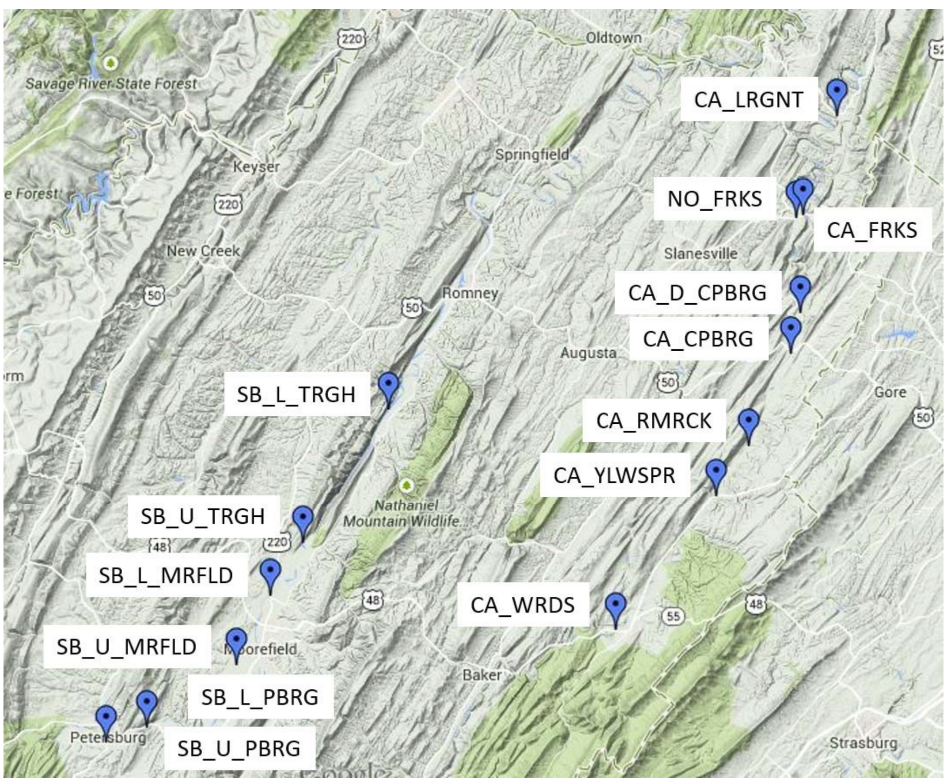


Figure 1. A map of algae monitoring stations on the Cacapon River, North River, and South Branch Potomac River.

Site characterization

The WVDEP Filamentous Algae Monitoring Form was generally completed in the field by the crew leader. As the sites are fixed positions, Global Positioning System (GPS) coordinates were taken using a Garmin Etrex20 on the first field visit to verify historical GPS recordings (2014-present). No change in GPS location were observed so locations were recorded as HIST on data sheets. If for any reason the sampling location was moved, the recorded GPS coordinates reflect that change. Relevant USGS gage hydrographs for the study period are included in **Appendix I**. Qualitative observations of periphyton, aquatic moss, aquatic vascular plants, filamentous green algae (FGA) and cyanobacteria/blue-green algae (BGA) abundance were made on each site visit.

Photo documentation

Pictures were taken on each site visit, arranged in folders according to site and sampling date, and stored on a DVD hard copy that was shared with WVDEP staff. Generally, photos were taken at the x- site, one picture each looking upstream, downstream, and across the channel. Photos were also taken of any algae observed or measured, including underwater photos, or anything else of note, including sample collection or processing, in-situ probe placement, etc. Photos were documented on page 4 of the field sheet. A Nikon AW100 and/or Iphone6 were the primary cameras used and are capable of attaching GPS coordinates of the pictures as they were taken. This information is in the details of the file properties. GPS coordinates did not always accompany pictures and are generally missing from underwater shots and videos. All pictures and videos were arranged by sample location and date and provided on a DVD hard copy to WVDEP.

Filamentous algae abundance measurements

Percent algae coverage measurements were performed according to Standard Operating Procedures (SOP) provided by WVDEP. Measurements were recorded in feet and tenths of a foot. 2014 protocols refinements included guidance on when algae measurements are measured by transect, versus a single visual estimate of the transect. Single visual estimates of the entire transect are sufficient if algae is estimated to be below 10% or above 80%. Moderate amounts of algae require transect-segment based estimate-measures. If algae is measured between 20% and 40%, three separate transect measures are required spanning a length of 3X the average channel width. Lengths and depths of the lateral transects were reported in tenths of a foot using a field tape and surveying rod. Large rivers were measured using a laser range finder. All values were entered on the field form and translated to the percent algae calculation spreadsheet file. The file was modified from that provided by WVDEP to receive the measurements as recorded, in order to calculate the percent coverage of the entire transect. The modified percent algae coverage calculation spreadsheets and associated data are provided separately as a Microsoft Excel© file with each measurement occupying one tab. Algal measurements were also performed during longitudinal surveys when filamentous algae were encountered.

In-situ water quality

In-situ water quality was collected at every site with the same YSI-556 multi-parameter sonde throughout the season. Water temperature (WTEMP), dissolved oxygen (DO), pH, specific conductance (SPCOND) and total dissolved solids (TDS) were measured in-situ and recorded on the field data sheet. The YSI-556 was calibrated at the beginning of each 2-day sampling round using concentration standards. Specific conductance was calibrated using a 447.1 µS/cm standard solution and pH was calibrated using a 2-point (7.01 and 10.00) calibration. Dissolved Oxygen was calibrated using a saturated air calibration method, according to the user manual of the YSI-556.

Water chemistry

Four sample containers were filled at each sampling location on the Cacapon River for the following parameters: Total phosphorous (TP), dissolved phosphorous (DP), total kjeldahl nitrogen (TKN), nitrate-nitrite-N (NO3-NO2-N), total alkalinity (TALK), calcium (CA), magnesium (MG), and total suspended solids (TSS). Water chemistry sample containers were provided pre-fixed with acid preservatives by the contracted analysis laboratory Bio-Chem. At each sampling location, a collection container was rinsed 3 times and samples were collected facing upstream. The sampling location within the river was indicated on the monitoring form. Filtering for the dissolved phosphorous sample was performed using a Nalgene© filter funnel cup, Nalgene© vacuum flask, 47 mm 0.45 µm cellulose-nitrate filter papers and a hand-operated vacuum pump. The vacuum flask and filter apparatus were also rinsed 3 times mid-stream prior to filtering. Samples were collected according to WVDEP Standard Operating Procedures for water chemistry sampling. Sample duplicates were collected during each round and were analyzed alongside the 8 station samples. No water chemistry samples were collected in the South Branch Potomac River in 2016.

Sample handling

Water chemistry samples were labeled with a permanent marker and immediately stored on ice. All samples were collected within a single day and delivered directly to BioChem drivers, typically in Wardensville at the end of the Cacapon River sampling round.

Completeness

All 14 stations identified by WVDEP personnel were observed throughout the study period. Five (5) monthly observation rounds were completed during the study period. All sites were monitored within a consecutive 2-day period. Complete sets of Cacapon River water chemistry samples were collected on each of the 5 rounds. WVDEP requested that ICPRB not sample the South Branch River for the 2016 season. Algae transects were performed whenever algae were observed and estimated to be above 10% coverage.

Longitudinal surveys

Longitudinal surveys were employed to document the magnitude and extent of filamentous algae blooms in a sequence of targeted areas over the last three years. In order to survey suspected bloom areas that are not visible from roadways, biologists used canoes/kayaks to travel along a river reach and record observations and measurements in suspected algae occurrence areas. The longitudinal surveys are an informal assessment method, but consist primarily of documenting observations with written accounts, photographs and videos, and associated GPS coordinates at observation points.

ICPRB conducted three longitudinal surveys within the Cacapon River in 2016. WVDEP biologist, James Summers, and ICPRB biologist, Gordon Selckmann, surveyed a 16 km section between the town of Cacapon Bridge and Cacapon Forks on July 19th, 2016. Due to dense SAV mats and early filamentous green algae/blue green algae growth, WVDEP requested a follow up survey be conducted. A second follow-up survey of this stretch was conducted on September 1st, 2016. Survey of the upper Cacapon River from Wardensville to below Camp Rim Rock was conducted on July 20th 2016 by two separate crews. Completion of this reach was accomplished by dividing the efforts of James Summers and Gordon Selckmann into two adjoining sections totaling 27 km. James Summers surveyed the reach from the waste water plant in Wardensville to the Old Iron Bridge (14 km). Gordon Selckmann surveyed from the Old Iron Bridge to the public canoe take out between Camp Rim Rock and the Town of Capon Bridge.

Data Processing and Laboratory Methods

Data processing

Digital scans and hard-copy datasheets were sent to WVDEP c/o James Peterson. Data were entered into MS Excel for exploratory analyses. A copy of this electronic dataset is included in the MS Excel spreadsheet appendix accompanying this report. All analyses were performed using R and analysis scripts are provided, preceding the associated analysis or chart in the data file. Four parameters were calculated from the water chemistry data for analysis purposes. Total nitrogen (TN) was calculated by summing the NO3-NO2-N and TKN values for each independent sample. Total hardness (HARDNESS) is represented as molar equivalents of CaCO3 in mg/L, calculated using the equation:

$$[CaCO_3] = 2.5[Ca^{+}] + 4.1[Mg^{2+}]$$

Two Calcium-Magnesium ratio indices were calculated, following the analysis performed in the 2008 WVDEP Report on filamentous algae assessment report (Summers 2008). A traditional Ca:Mg ratio index with both ratio and additive terms of Ca^{2+} and Mg^{2+} (CA_MG_INDEX):

$$\log[Ca^{2+}/Mg^{2+}] - 0.5 \log[Ca^{2+} + Mg^{2+}],$$

A modified index considering only an additive variable (MOD_CA_MG):

$$-\log[Ca^{2+} + Mg^{2+}].$$

Algal identification

Algae samples were collected during rounds 1, 3, and 4 from the Cacapon River and South Branch Potomac opportunistically and preserved on ice. The samples were transported back to the ICPRB lab where identifications were made. Samples from the Cacapon and South Branch Rivers were used in the EPA Region 3 Filamentous ID workshop at ICPRB offices on August 10, 2016.

Results from the 2016 season

Summary of algal observations and measurements by station

Summary algae measurements are included in **Table 3** below. This table includes actual measurements, and qualitative visual estimates of low abundance algae occurrences. The below subsections are brief narratives that describe general trends in algal abundance.

Cacapon River at Rt. 9 in the town of Largent (CA_LRGNT)

Small amounts of FGA were observed persisting on the downstream submerged portion of a descending left bank gravel bar, just downstream of the Rt. 9 bridge. Cool water was observed in June flowing in from a small creek on descending right bank with light algae. Creek was dried up by August. Low algal density was observed for the duration of the five sampling events.

North River at Gaston Rd. / Forks of Cacapon (NO_FRKS)

The site at the North River continues to be dominated by a type of benthic riverweed (*Podostemum* sp.). No algae was observed in June, July, or October 2016. Trace amounts of filamentous green algae were observed in near the bridge in August and September.

Cacapon River at Rt. 127 / Forks of Cacapon (CA_FRKS)

River access was changed from downstream (through field) access to below the bridge boat ramp. Biologists were forced to enter the river via boat ramp and wade down to make observations. The land owner fenced off and posted historic access. Very little filamentous green algae was observed at this site throughout 2016. Small isolated tufts of SAV were common but not overly abundant. Typical small isolated tufts of filamentous green algae were observed stuck to SAV.

Cacapon River at farm off Cold Stream Road (CA_D_CPBRG)

Filamentous green algae was not present at densities greater than 10% coverage throughout 2016. In August, filamentous green algae was observed at its highest density when an assemblage of unattached FGA collected on a fallen tree on the right bank. Also observed during Round 3, detached blue green algae (cyanobacteria) tufts continuously floated past in the water column, but were not observed attached to the substrate. Higher densities of filamentous green algae and cyanobacteria were found intermixed with extremely dense SAV growth roughly 1 km upstream of this site (see Longitudinal Results). Higher densities of FGA and *Podostemum* sp. were observed 750 m downstream from this site. The abundance of primary production, both above and below the CA_D_CPRBRG site, raises questions of whether this site is an appropriate location to make regular observations.

Cacapon River at Rt. 50 in Capon Bridge (CA_CPBRG)

Primary production at this site was limited to mostly short, periphytic growth on the cobble/boulder substrate upstream of the bridge. Isolated tufts of *Potomogeton* sp. were common. This site has an unusually high density of gastropods throughout the year, potentially explaining the low amounts of algae production.

Cacapon River along Capon River Rd. and downstream of Camp Rim Rock (CA_RMRCK)

This site continues to manifest the highest density of filamentous green algae blooms and dense SAV beds in the Cacapon River, repeating a pattern observed since before 2012. In the 2015 West Virginia filamentous algae report, ICPRB suggested flows greater than 1,000 cfs inhibit algal establishment at the CA_RMRCk site. This hypothesis was supported in 2016 where June and July (Rounds 1 and 2 respectively) manifested very little algae due to the majority of the time prior to sampling experiencing flows greater than 1000 cfs. Additionally, the round 5 October time point was preempted by a single flow spike of greater than 3000 cfs from a stable September flow of 60-70 cfs. Rounds 1, 2, and 5 all experienced scour inducing flow regimes that led to very low (<5% cover, <5% cover, <10% cover, respectively) algal abundance. August and September (Rounds 3 and 4) experienced flows with peaks that never exceeded 800 cfs which coincided with the highest algal densities of the year, at 53.12% cover and 58.43% cover respectively. Submerged aquatic vegetation (SAV) in the form of *Hydrilla* and several pondweed species (*Potomogeton* sp.) dominated greater than 65% benthic coverage during the entire 2016 observation season. Reduced column fill was observed in the Spring when compared to August and September.

Cacapon River at Rt. 259 below Wardensville (CA_YLWSPR)

Filamentous green algae and blue-green algae were not observed in 2016. This site is comprised of primarily bedrock and is moderately channelized, making it not ideal for algal establishment and longevity. Cool water springs were found upon investigation of this site which suggest this region and proximally further downstream could be effected by ground water chemistry and nutrient transport.

Cacapon River at farm ford in Wardensville (CA_WRDS)

Filamentous green algae and blue-green algae were not observed in 2016. The most upstream site on the Cacapon has consistently been the location where the least amount of algae is observed. This site, as has been reported in earlier years, is able to produce dense periphyton communities.

South Branch at Harmison's Landing (SB_L_TRGH)

The lower trough site is best described in two parts; a bed rock channel (thalweg) 1/3 the width of the river on the descending left bank and a shallow cobble and bedrock bar that makes up the remaining 2/3 of the river. As long as ICPRB has made observations of this site, biologist have never seen algae in the thalweg. The shallow cobble bar holds isolated SAV tufts for much of the year. A large J-shaped assemblage of *Spirogyra* (16.23% benthic algal coverage at its widest, September) was observed running roughly 100 m longitudinally through the site. Spirogyra cover similar to what was observed at the lower trough site was found downstream at the Romney Bridge and at Indian Rocks boat launch.

South Branch at South Branch WMA (SB_U_TRGH)

There were no significant algae blooms observed at this site in 2016. The shallow and fast flow of this site do not appear beneficial to algal establishment. Periphyton was observed on cobble bar in spring and fall, however, cobble bar is dewatered during summer flows.

South Branch at Rt. 220/28 in Moorefield (SB_L_MRFLD)

There were no significant algae blooms observed at this site in 2016. Submerged aquatic vegetation beds continue to dominate more of the site than what has been observed in the past two years.

South Branch at Fisher Rd above Moorefield (SB_U_MRFLD)

There were no significant algae observed at this site in 2016. This site was observed at the boat ramp and above the Fisher Road bridge. The river above the bridge is shallow, fast-moving and composed of cobble substrate. The boat ramp is a deeper pool with a cobble bar midstream. At no point in 2016 did either of these two different algal habitats produce any more than trace amounts of filamentous green algae.

South Branch at Weldon Park off Rt.220/55 (SB_L_PBRG)

The SB_L_PTBRG site, specifically at the boat ramp, did not produce algae in 2016. Periphyton and sediment can be found on the descending left bank (DLB) year round. The site drops off to several feet deep away from the DLB bank at which point periphyton and sediment is also reduced due to water depth and velocity. Isolated tufts of SAV can be found along the shallow portions of this site. Upstream roughly 0.5 km *Spyrogyra* FGA was observed just below a shallow riffle. The bloom was predictably there year round but only covered less than 5% of the river.

South Branch at Rt.220 in Petersburg (SB_U_PBRG)

FGA was often present at this location in low densities (<5% coverage). The filamentous green algae (*Spirogyra*) at this location did not manifest in the thalweg of the channel but was often present in extensive shallow flats where the river was only a few inches in depth. Many Petersburg locals that frequent the park report dense algae growth at this site, despite no significant blooms observed during ICPRB's 5 sampling rounds.

Table 3. Summary of percent filamentous algae cover measurements made during the 2016 season. Null values indicate when judgment was impaired by poor visibility, "ND" values indicate non-detects, values up to 10% were visually estimated and recorded as "<5" or "<10", all other values are actual algae measurements using the wadeable transect method.

SITE_NAME	WATERBODY	Rd 1	Rd 2	Rd 3	Rd 4	Rd 5
CA_LRGNT	CACAPON	<5	<5	<5	<5	<5
CA_FRKS	CACAPON	ND	<5	<5	<5	<5
NO_FRKS	NORTH RIVER	ND	ND	<5	<5	ND
CA_D_CPBRG	CACAPON	ND	<5	<10	<5	<5
CA_CPBRG	CACAPON	ND	<5	<5	<5	ND
CA_RMRCK	CACAPON	<5	<5	**53.12**	**58.43**	<10
CA_YLWSPR	CACAPON	ND	ND	ND	ND	ND
CA_WRDS	CACAPON	ND	ND	ND	ND	ND
SB_L_TRGH	SOUTH BRANCH	<5	<5	<5	**16.23**	<5
SB_U_TRGH	SOUTH BRANCH	ND	<5	ND	ND	ND
SB_L_MRFLD	SOUTH BRANCH	<5	<5	<5	<5	<5
SB_U_MRFLD	SOUTH BRANCH	ND	<5	<5	<5	<5
SB_L_PBRG	SOUTH BRANCH	<5	<5	<10	<10	<5
SB_U_PBRG	SOUTH BRANCH	<5	<5	<10	<5	<5

Water Chemistry Trends 2016

Median and mean values of the measured water quality parameters for each site are provided in Table 4 and Table 5, respectively. Temporal trends can be observed graphically in Appendix III. ICPRB did not collect water chemistry for the South branch in 2016 and so, reporting will be left blank or referred to previous trends.

Calcium, Magnesium, Total Alkalinity and Hardness

The highest alkalinity and hardness concentrations in the Cacapon were observed at the most upstream sites. The highest alkalinity and hardness measurements were observed in summer (July, August and September) when primary production was at its highest and flows were at their lowest. Downstream from CA_WRDS ionic water chemistry stabilized and did not change significantly between sites. The Cacapon alkalinity levels were observed above the minimal threshold for algae production. Interestingly, the North River for a large part of the season had the lowest alkalinity and did not produce filamentous green algae.

Nitrogen and Phosphorous

Phosphorous was highest in the Cacapon River, below the city of Capon Bridge (CA_D_CPBRG), which appeared to have grey water discharging into the river, possibly due to the input of the Capon Bridge WWTP, a small treatment facility serving less than 250 residents. In general, all sites had a decreasing trend in phosphorus as the season progressed. Anomalies in phosphorus low points can be attributed to rain events that occurred on round 2. Interestingly, the round 2 dip in phosphorus concentrations did not appear as significant at the Rim Rock site.

Nitrogen displayed a pattern that was consistent with previous years (2013, 2014, 2015); the highest nitrogen levels observed were at the upstream site, CA_WRDS, where the Cacapon rises from the ground. Nitrogen concentrations decreased abruptly in July and remained low until the fall turnover in October. Abrupt drops in nitrogen concentration coincides with the increased primary production within the Cacapon river.

Dissolved Oxygen, pH, Specific Conductance, Water Temperature, and Total Suspended Solids

Water temperature did not vary greatly between waterbodies, though the sites proximal to large SAV beds saw elevated temperatures and wider pH ranges. On the Cacapon, both DO and pH displayed strong swings and increases likely associated with excessive primary production. Similarly, pH at the CA_RMRCK station was increased overall and had a higher variance than nearby stations, as the SAV and algae took up or released CO2.

Table 4. Median values of the collected water chemistry variables across sample sites.

Parameter	CA_LRGNT	CA_FRKS	NO_FRKS	CA_D_CPBRG	CA_CPBRG	CA_RMRCK	CA_YLWSPR	CA_WRDS	SB_L_TRGH	SB_U_TRGH	SB_L_MRFLD	SB_U_MRFLD	SB_L_PTBRG	SB_U_PTBRG
WTEMP	23.6	22.3	20.9	23.0	23.7	25.0	25.3	22.4	24.7	24.6	24.3	24.5	23.1	23.6
PH	7.86	7.87	7.6	7.71	7.82	8.83	8.43	8.46	8.12	8.14	8.02	8.28	8.23	8.42
DO	6.37	6.5	7.54	7.06	8.08	11.29	8.64	9.06	6.09	8.22	7.41	8.42	8.99	8.8
SPCOND	168	192	153	166	160	157	164	186	226	224	217	224	219	211
TSS	7	9	7.5	3.5	5.5	9	4	6						
DP	0.012	0.018	0.017	0.024	0.019	0.017	0.019	0.021						
TP	0.029	0.030	0.026	0.033	0.026	0.020	0.027	0.028						
NO3_NO2	0.037	0.102	0.072	0.085	0.046	0.123	0.226	0.555						
TKN	0.320	0.270	0.310	0.300	0.310	0.270	0.310	0.210						
TN	0.367	0.360	0.392	0.486	0.366	0.363	0.536	0.851						
CA	24.900	27.800	18.600	27.000	24.900	25.300	28.300	29.200						
MG	4.700	5.100	4.800	5.000	4.700	4.800	4.700	5.300						
ALK	72.400	88.800	61.600	77.900	71.700	75.400	81.900	84.200						
HARDNESS	82.020	96.410	66.180	88.000	81.520	82.930	90.020	94.730						
CA_MG_RAT	0.124	0.113	0.156	0.115	0.118	0.115	0.103	0.110						
MOD_CA_MG	2.939	2.881	3.053	2.908	2.942	2.935	2.892	2.875						

Table 5. Mean values of the collected water chemistry variables across sample sites.

Parameters	CA_LRGNT	CA_FRKS	NO_FRKS	CA_D_CPBRG	CA_CPBRG	CA_RMRCK	CA_YLWSPR	CA_WRDS	SB_L_TRGH	SB_U_TRGH	SB_L_MRFLD	SB_U_MRFLD	SB_L_PTBRG	SB_U_PTBRG
WTEMP	23.25	21.77	21.51	22.21	23.85	24.00	24.12	22.47	23.61	23.53	23.39	23.43	22.44	23.04
PH	7.69	7.75	7.54	7.55	7.89	8.63	8.35	8.50	7.92	8.20	8.10	8.27	8.32	8.45
DO	7.15	6.64	8.08	7.32	8.13	10.99	8.63	8.82	7.02	8.09	7.54	7.86	8.48	8.82
SPCOND	143.8	161.8	126.4	145.4	139.6	135.4	148.2	159.6	232.8	230.4	202.2	200.0	203.8	191.2
TSS	7.600	9.000	7.500	3.500	5.500	9.000	4.000	6.000						
DP	0.014	0.019	0.018	0.022	0.018	0.017	0.019	0.021						
TP	0.029	0.029	0.027	0.033	0.026	0.025	0.030	0.029						
NO3_NO2	0.138	0.250	0.173	0.228	0.233	0.218	0.260	0.422						
TKN	0.338	0.292	0.296	0.263	0.310	0.262	0.314	0.196						
TN	0.476	0.542	0.469	0.578	0.543	0.480	0.574	0.772						
CA	23.82	27.78	19.82	24.70	23.90	23.98	26.02	27.88						
MG	4.840	5.380	4.700	4.660	4.600	4.520	4.520	5.080						
ALK	70.42	81.28	60.44	71.58	67.00	69.08	74.18	79.70						
HARDNESS	79.39	91.50	68.82	80.85	78.61	78.48	83.58	90.52						
CA_MG_RAT	0.123	0.117	0.149	0.115	0.117	0.115	0.106	0.111						
MOD_CA_MG	2.962	2.896	3.048	2.951	2.965	2.963	2.933	2.900						

Longitudinal Surveys

Longitudinal #1: July 19, 2016 *Capon Bridge to Cacapon at Forks*

The decision to repeat the 2015 longitudinal between Capon Bridge and Cacapon at Forks was due to WVDEP's request to observe the 14 km stretch of river that otherwise has no direct access. This inaccessible area in previous year's longitudinals produced large amounts of filamentous green algae as well as large tracts of dense SAV beds.

At the beginning of the longitudinal at Capon Bridge there was a heavy amount of periphyton and gastropods but no filamentous green algae or cyanobacteria. Roughly 0.75 km downstream from the put-in we observed a small discharge of grey water from the WWTP outfall (Appendix II, Event # 2). The discharge came from a metal pipe (marked with permit # WV0103730), unlike in 2014 when it was observed to be flowing directly from of the adjacent field. At this time there was little detectable odor. Roughly 2 km below the discharge we observed the beginning of a dense *Hydrilla* and pondweed bed. This bed spans nearly 1.5 km and was so dense it was capable of stalling a canoe's momentum. Due to the potential for this site to produce algae later in the year, this site was flagged as a site of interest for a return visit. The large SAV bed terminates at a deep pool devoid of any vegetation. In previous years this pool has held blue green algae blooms at greater depths however, during this transect the site was devoid of FGA and BGA. No significant vegetation was observed until the riffle that parallels Cold Stream Rd (Appendix II, Event 8). At this point, a riffle and shallow cobble bar roughly 0.5 km long holds dense *Potostemum* growth. In summer 2015 this site held dense FGA as well as *Potostemum*, however none was observed. At the beginning of the inaccessible area (Appendix II, Event 9), *Rhizoclonium* (FGA) beds were witnessed growing atop dense SAV. Floating transects estimated roughly 30% algal coverage for 500 m downstream. For the next 7 km of longitudinal the river held dense SAV beds with light *Rhizoclonium* growing amongst them. Filamentous green algae were frequent during this length of river but never occupied more than 20% coverage. The dense SAV beds terminated at Weeping Rocks (Appendix II, Event 13). Blue green algae were observed growing within the water flowing from the rock face. The remainder of the longitudinal was comprised of slow, deep water where no significant FGA or SAV was observed.

Longitudinal #2: July 20, 2016 *Old Iron Bridge to Below Camp Rim Rock*

Note: Reporting of observations from longitudinal #2 are only observations made by Gordon Selckmann et al. on the lower segment of the split longitudinal.

The beginning of this longitudinal started at the Old Iron Bridge above CA_YLWSPR. For roughly 8.5 km there was no significant filamentous green algae or SAV present other than a few isolated observations of *Chara* (Appendix 2, Event 2), a plant we have not observed anywhere else on the Cacapon River. Primary production markedly increases near Camp Rim Rock (Appendix 2, Event 6). Abruptly, algae cover goes from <10% coverage in isolated eddies and strainers to dense SAV and >50% FGA around the islands. The bloom that begins at Camp Rim Rock runs for over 3.5 km. A floatable transect was conducted with VADEQ (Appendix 2, Event 8) where SAV was observed at 80% coverage and FGA 65% coverage. The 65% FGA coverage continued for nearly the entire 3.5 km with the only exception a riffle below CA_RMRCK entry point. Although the 3.5 km reach was not as dense with algae as previous years, it remains the most predictably plant dense region surveyed in the Cacapon River.

Longitudinal #3: September 1, 2016 *Cacapon Bridge to Cacapon at Forks*

Longitudinal #3 was a reiteration of Longitudinal #1 held on July 19, 2016. This longitudinal was conducted by Gordon Selckmann (ICPRB), Zachary Smith (ICPRB) and a recreational boater (Jon Dawes, Water Reporter APP). Heavy periphyton and high densities of snails were still observed at the put-in point. Shortly after starting the longitudinal we again arrived at the WWTP outfall (permit # WV0103730). The condition of the river below outflow had significantly worsened. Most markedly, the smell of the river for nearly .25Km below the outfall was strong with sewage. Additionally, dense submerged aquatic vegetation beds grew right up to the out flow. A revisit of this site strongly suggests that the waste outflow below the CA_CPBRG site is providing the necessary nutrients to cause dense SAV and algal blooms. The dense SAV beds observed in July are now 90% covered with Cladophora giving the appearence of nearly total coverage of FGA. Closer investigation revealed that the FGA was only 15cm- 30cm thick and had established ontop of dense Hydrilla and Potomogeton blooms. SAV coverage approached 100% with nearly 90% column fill. Production in this area made paddling a boat nearly impossible as we were forced to push through the SAV/FGA beds for nearly 2Km. Once below the deep pool at the bend above the CA_D_CPBRG (Event 6), there was little FGA or BGA was observed until the riffle with Potostemum (Event 7). A floating transect through this section revealed around 40% FGA (Cladophora) coverage intermixed with SAV. At the beginning of the inaccessible area (Appendix II, Event 8) *Rhizoclonium* beds were witnessed growing atop dense SAV on the descending left bank. Floating transects estimated roughly 50% algal coverage for 500m downstream. For the next 7Km of longitudinal the river held dense SAV beds with light *Rhizoclonium* growing amongst them. The remainder of the longitudinal did not bear any significant SAV, FGA, or BGA. As expected, the points of interest defined by Longitudinal #1 in July worsened as the low flows of summer progressed into September. It is relatively easy to pinpoint the waste water outflow as a nutrient point source below the town of Capon Bridge. It is more difficult, however, to identify why there is such significant primary production in a forested low population area.

Conclusions and Suggestions for the Future

Algae observed in the Cacpon and South Branch Rivers during 2016 survey were very similar to observations made in 2015. For the second year, early season elevated flows (Appendix I) appear to delay algal growth until later in the summer. The delay in spring algal blooms may potentially give slower growing rooted vegetation such as *Potostemum sp*. and *Potomogeton sp*. a competitive advantage which result in dense SAV beds where filamentous green algal beds would otherwise have grown.

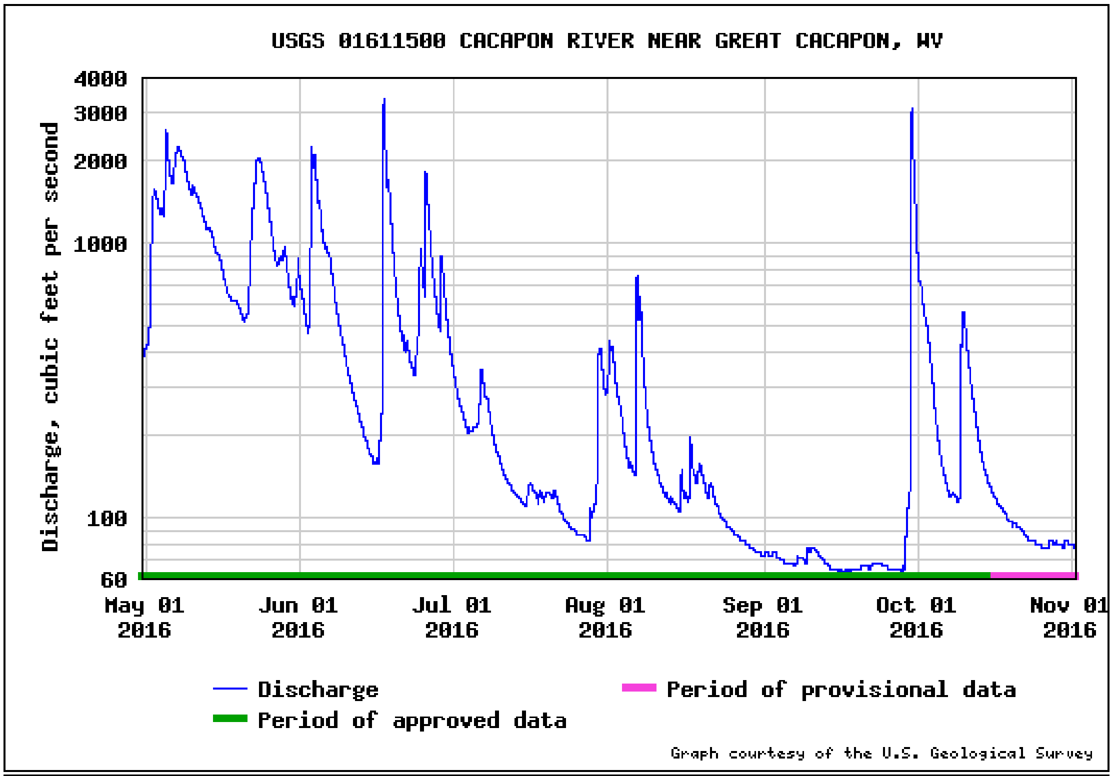
Considerations for the Cacapon River

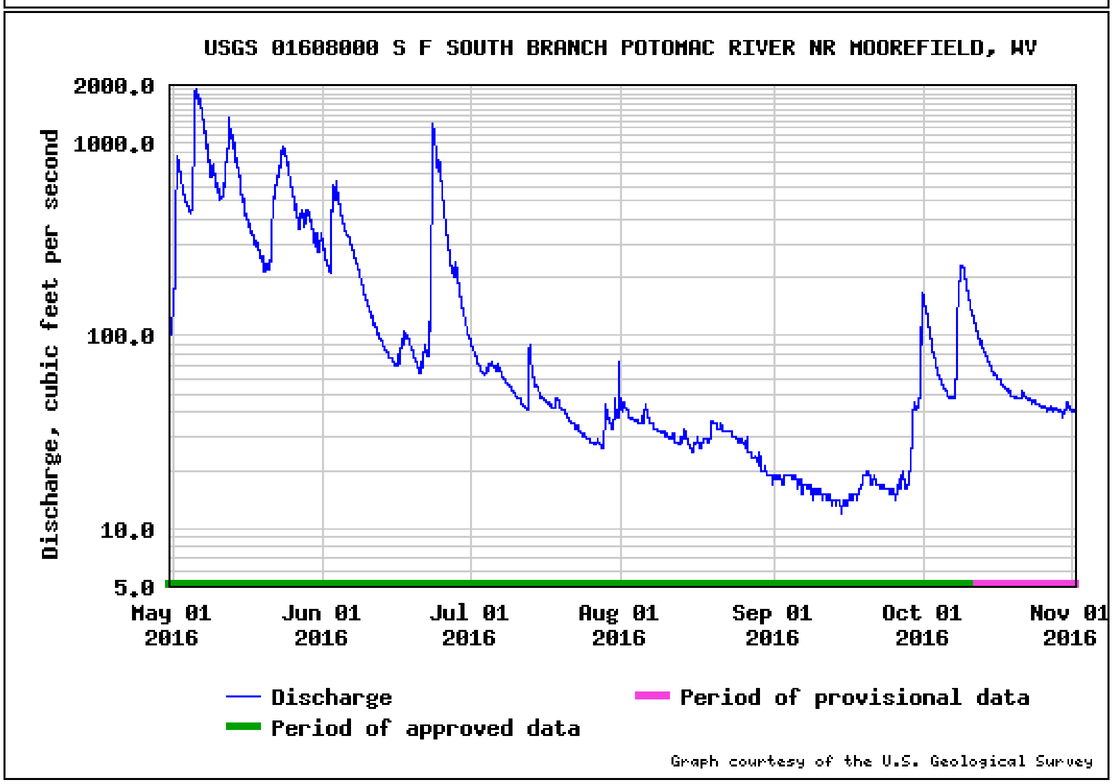
Considerations for future work on the Cacapon river should include more focused nutrient source tracking in the upper Cacapon. Regardless of spring time flows, the Camp Rim Rock site predictably produces the highest density of filamentous green algae year after year suggesting there is an abundance of nutrients impacting this region. Increased effort in both temporal and spatial sampling of the upper Cacapon may elucidate an influx of nutrients and further explain why this reach is so much more productive than the rest of the lower Cacapon River. If nutrient source tracking were to take place, additional focus on groundwater connectivity and nutrient transport should be considered as well. The upper Cacapon has several spring inputs that effect the chemistry profile of this region and will likely complicate nutrient sourcing efforts.

Considerations for the South Branch River

Considerations for future work on the South Branch Potomac River should include observation of the river below the town of Romney. ICPRB biologist in 2016 often had to observe the lower South Branch Potomac below the town of Romney, WV while conducting their large river survey. During this time dense algal mats were observed just below the scope of this study at the Rt 9 Romney Bridge, the Indian Rocks Boating Access, and at Little Orleans off of High Germany Rd. Interestingly, the algae observed at these sites colonized very similarly, where *Spirogyra* established in the summer in lower velocities followed by dense *Cladophora* (short branched morphology). Additionally, there was a concentrated blue-green algae bloom below the Romney bridge, a common recreational swimming location for the town of Romney, in August. Although no significant algae blooms have been reported on the South Branch between Petersburg and Romney since 2013, the river is still capable of producing algal blooms, only they may not be detected within the confines of the current study.

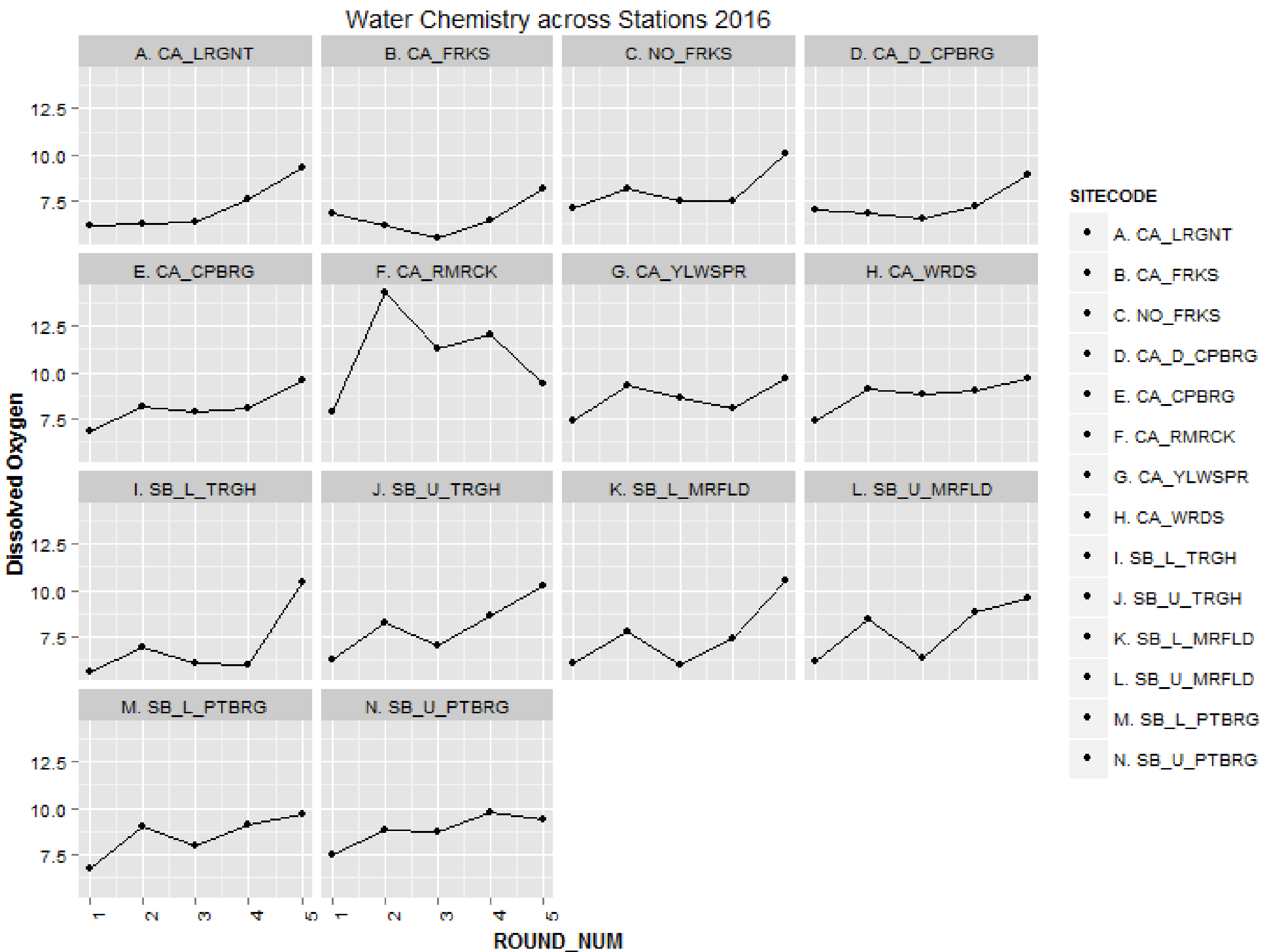
Appendix I. USGS Hydrographs; May 1, 2016 – November 1, 2016.

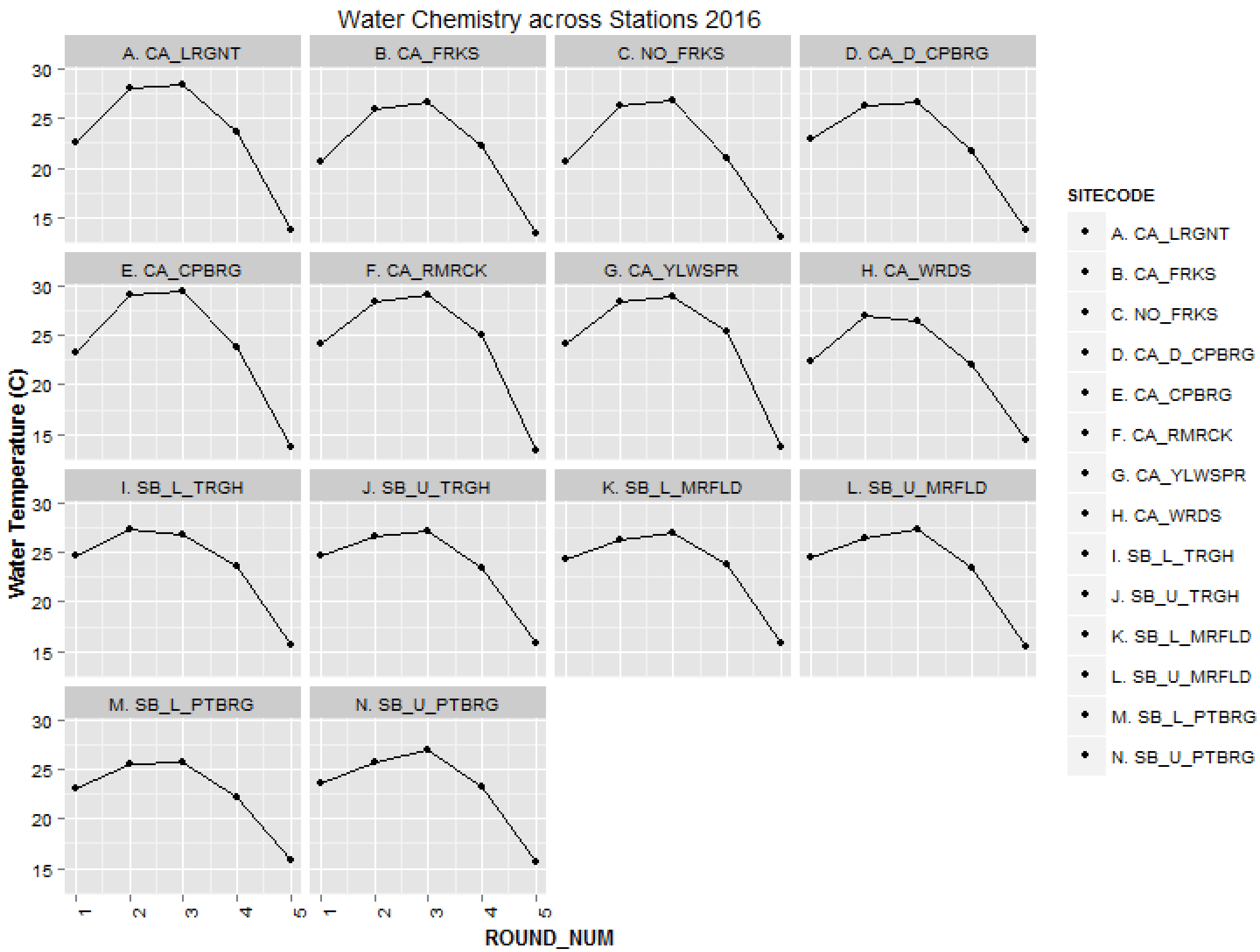


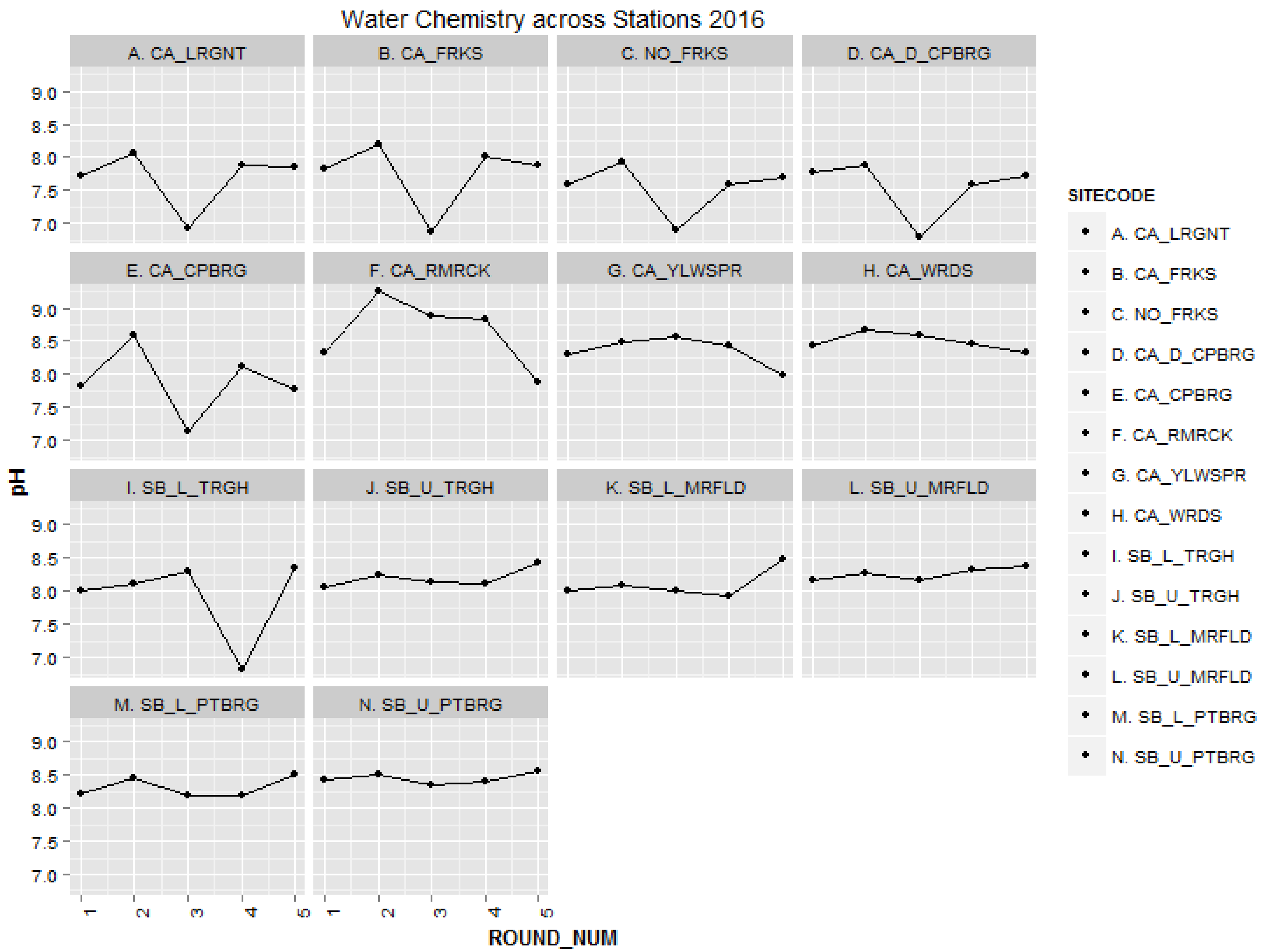


Appendix II: Water Chemistry Analysis

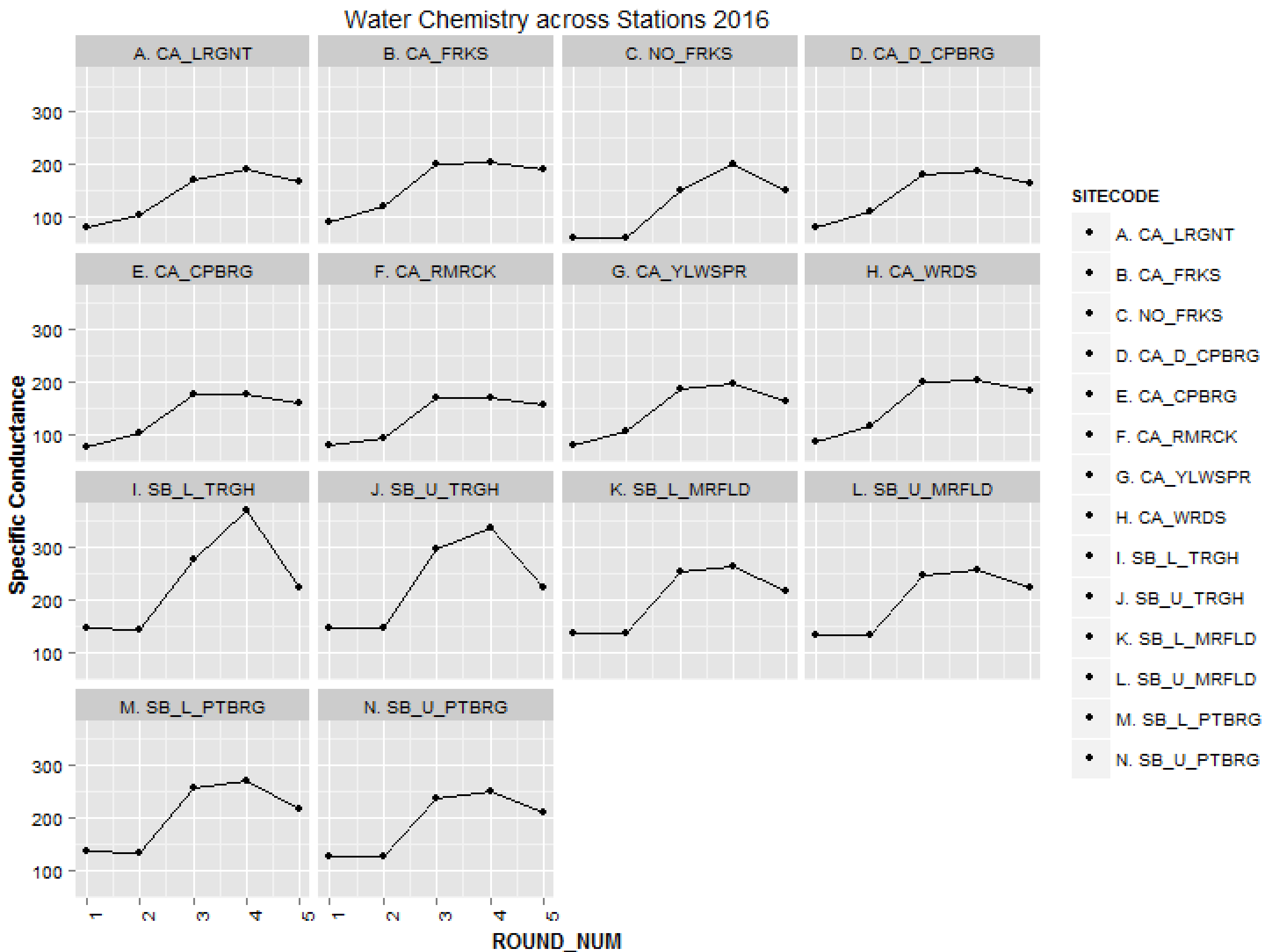
Water Chemistry: YSI measurements



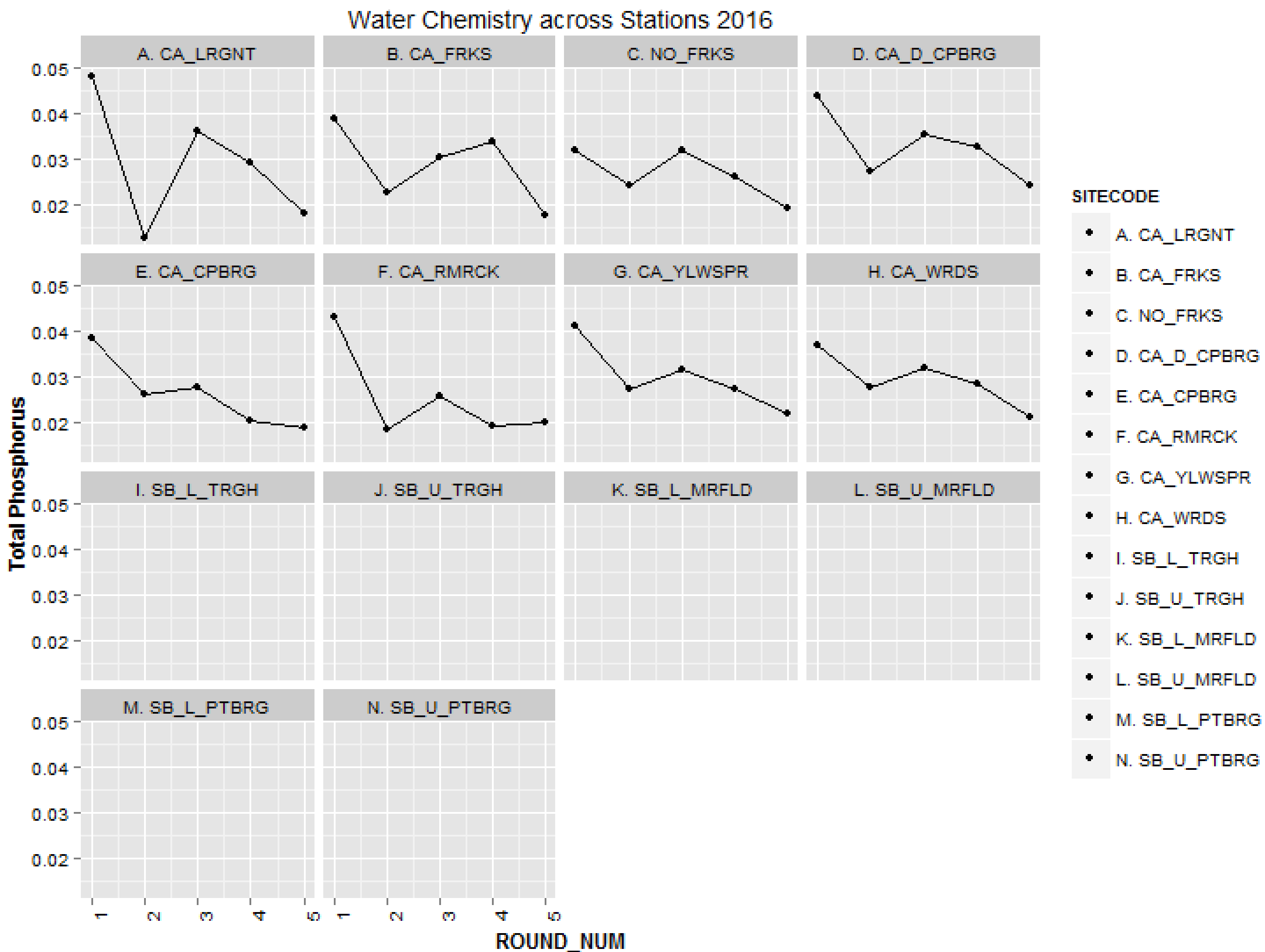

Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Water Temperature (C)
ROUND_NUM
SITECODE
30
25
20
15
1
2
3
4
5

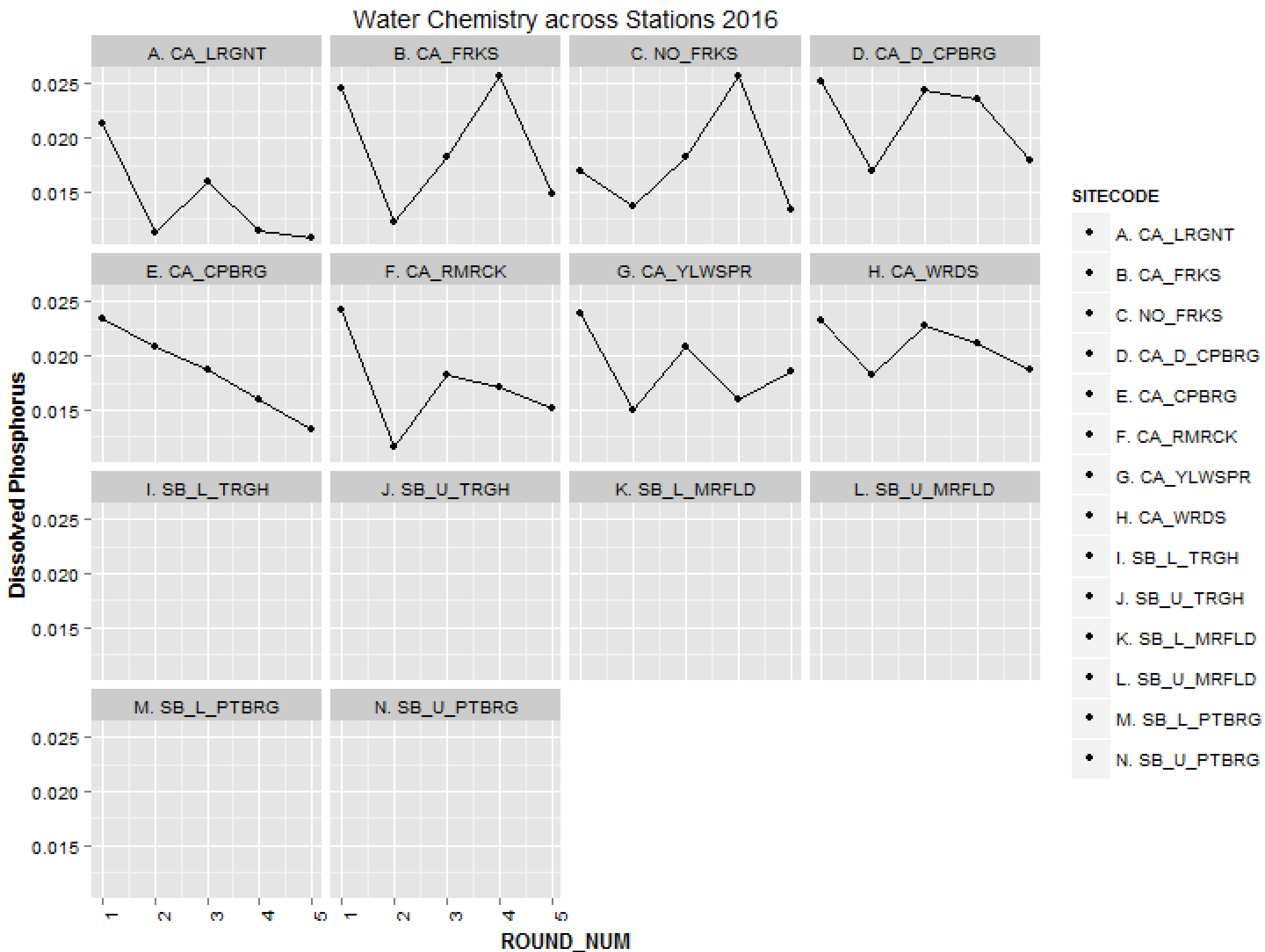


Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
9.0
8.5
8.0
7.5
7.0
pH
1
2
3
4
5
ROUND_NUM
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG

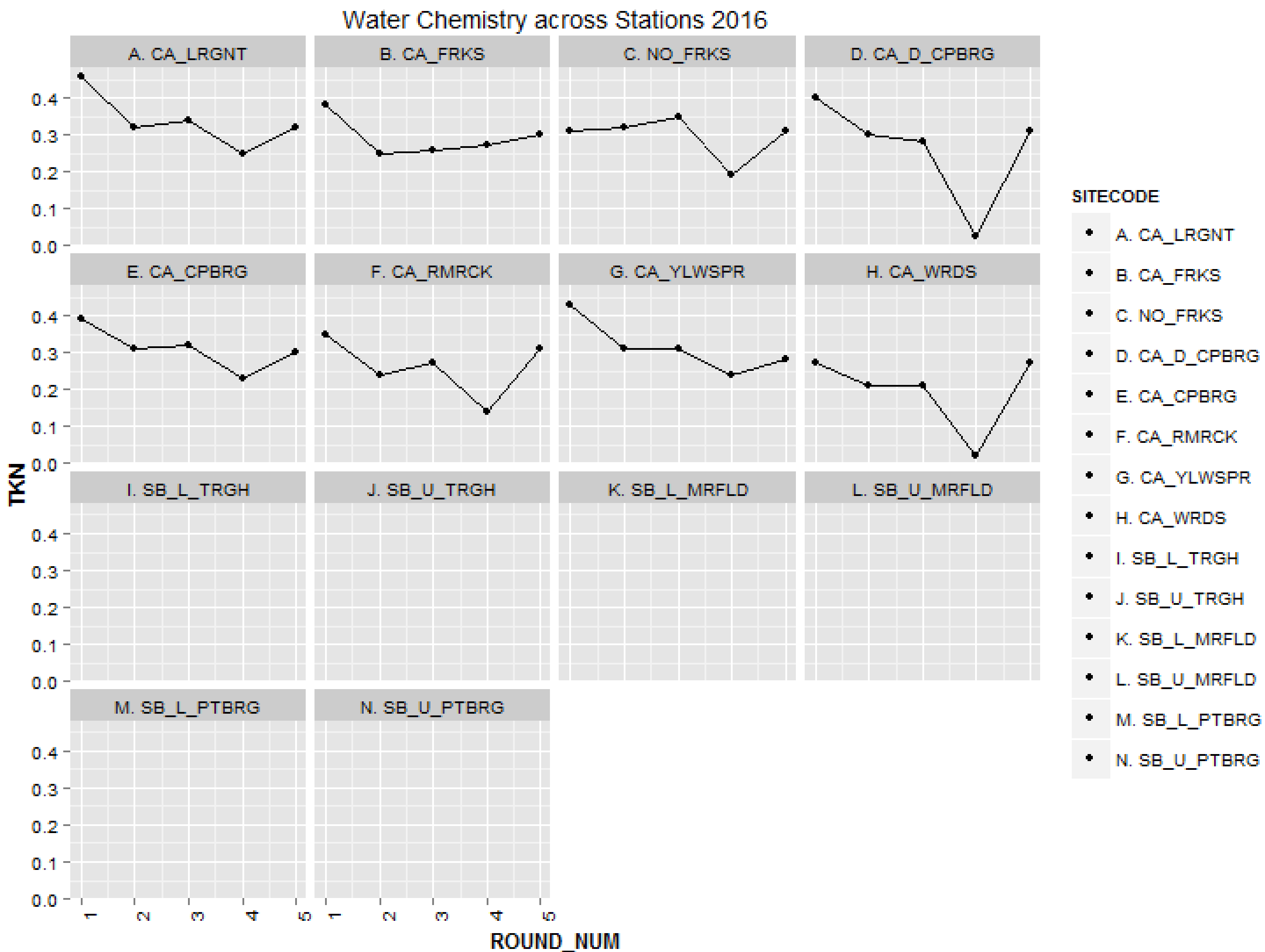

Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Specific Conductance
100
200
300
ROUND_NUM
1
2
3
4
5
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG

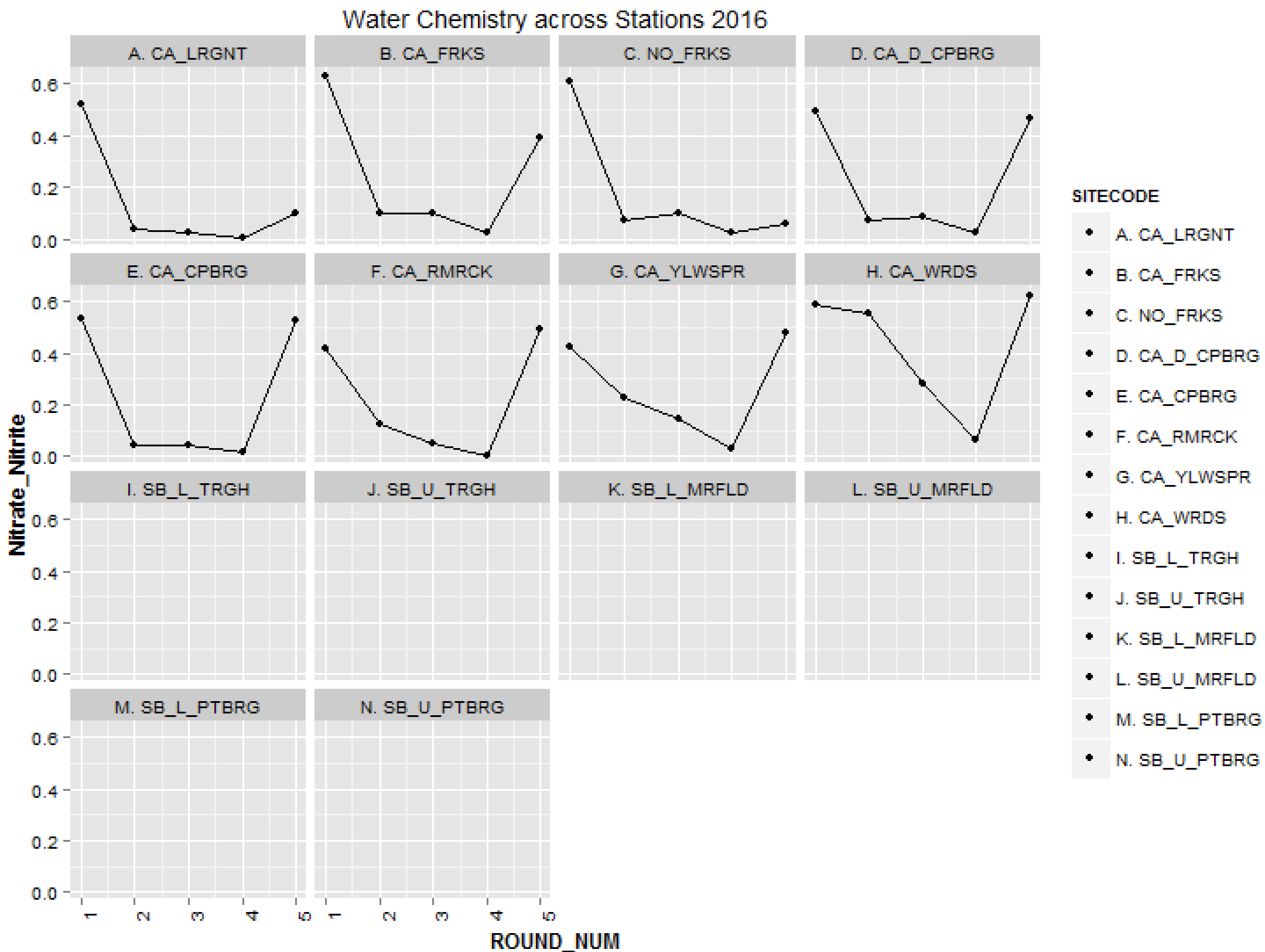
Water Chemistry: Nutrients (*Phosphorus*)



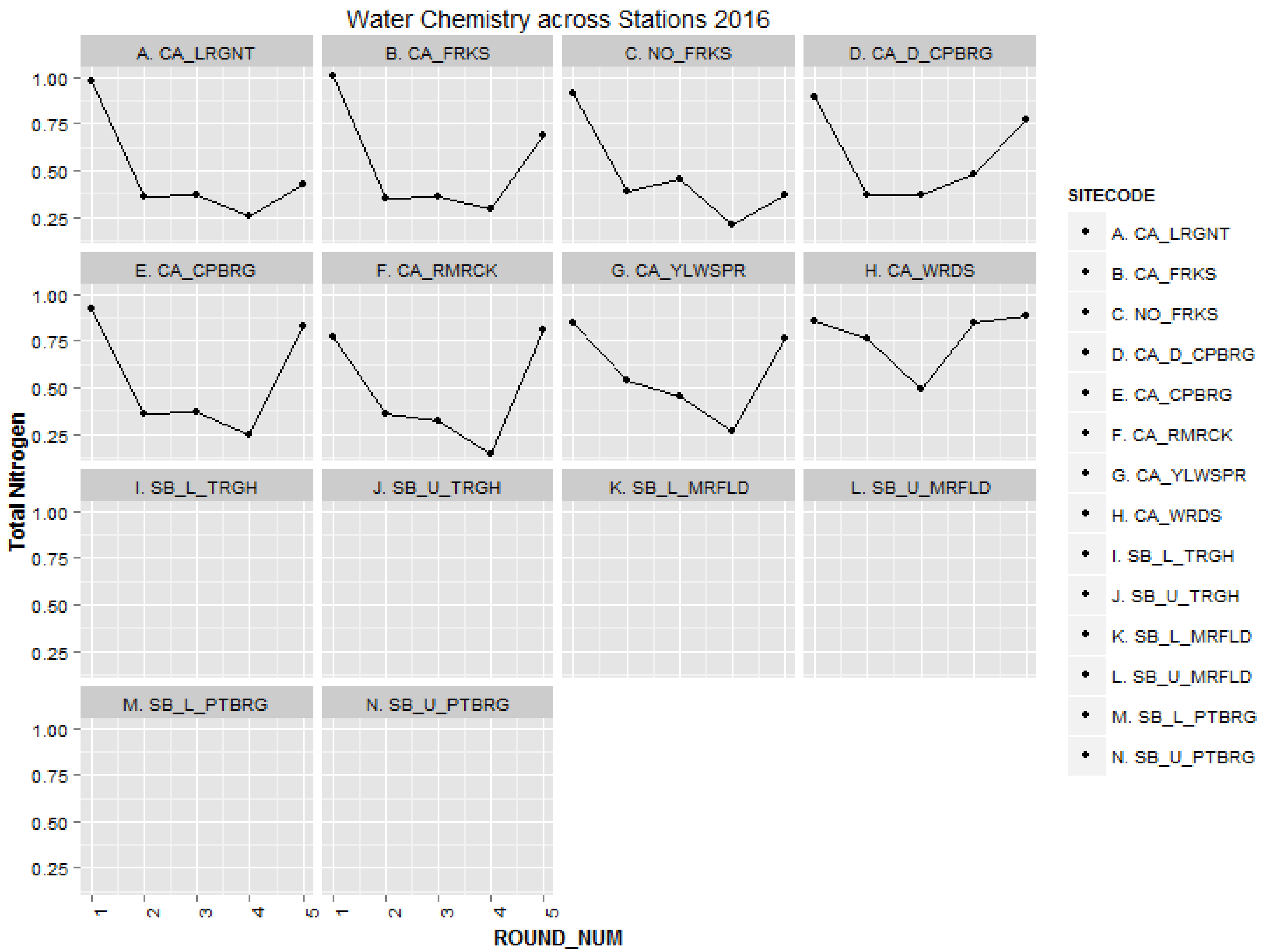

Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Dissolved Phosphorus
0.025
0.020
0.015
ROUND_NUM
1
2
3
4
5
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG

Water Chemistry: Nutrients (Nitrogen)

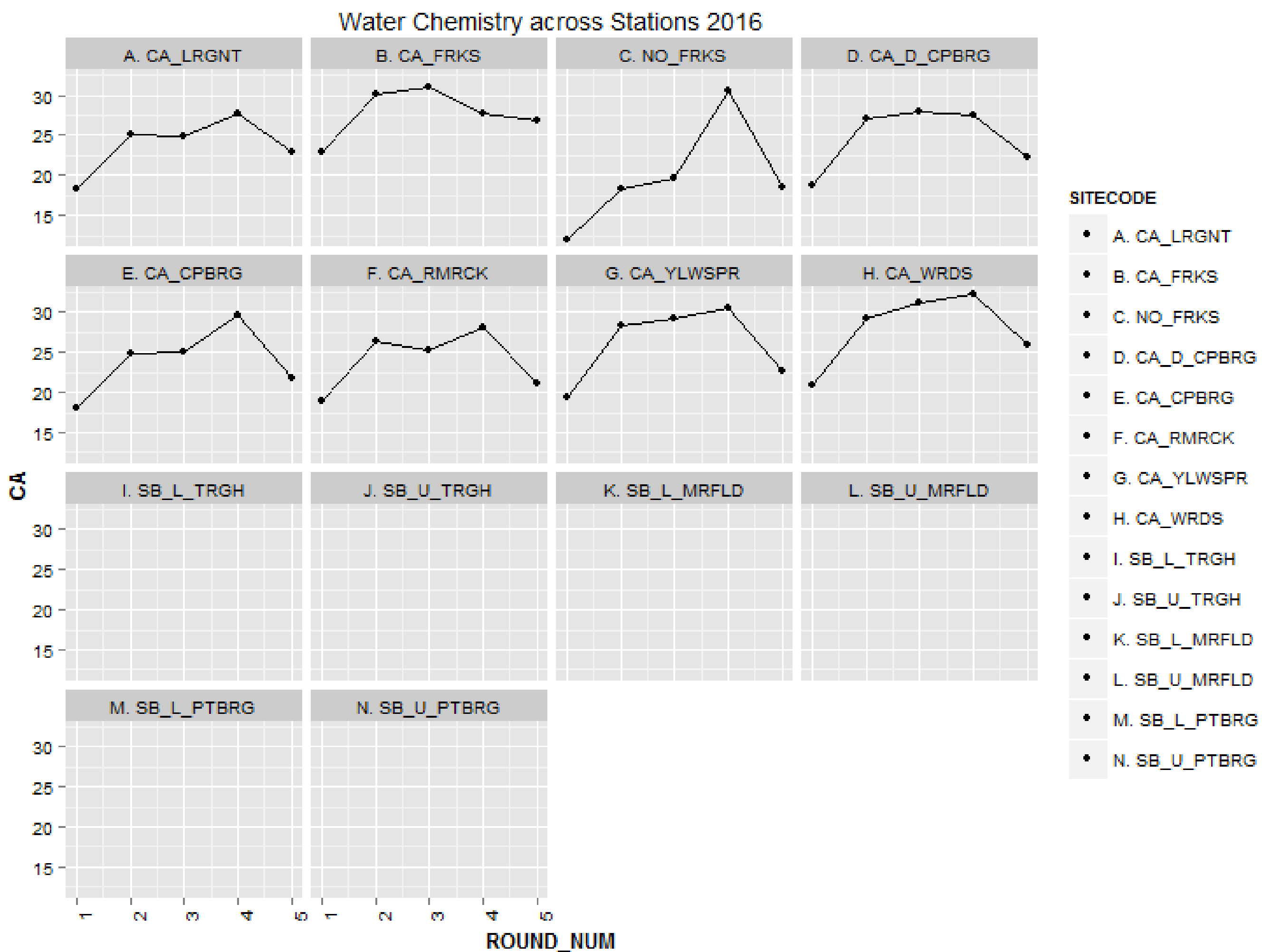


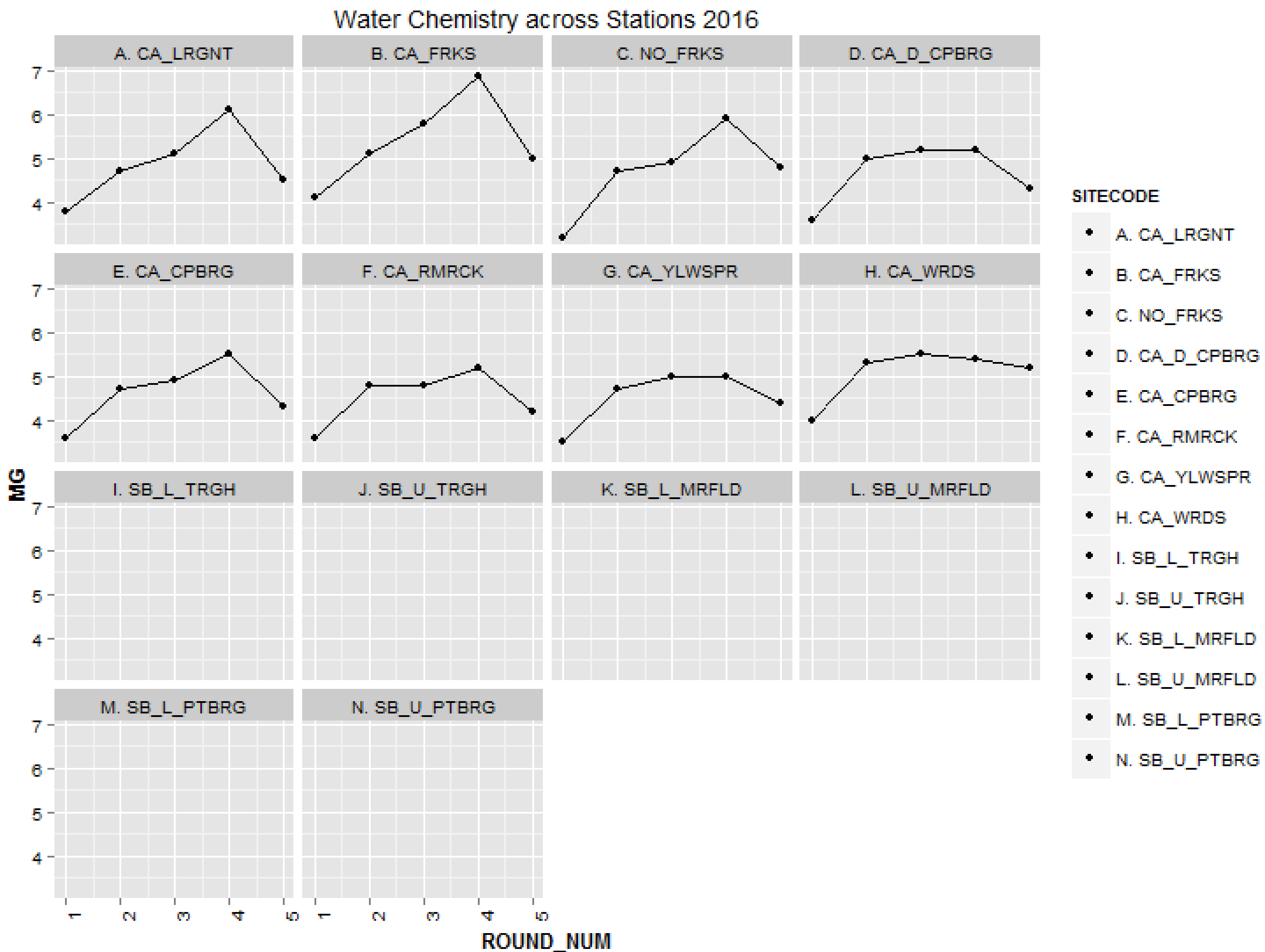


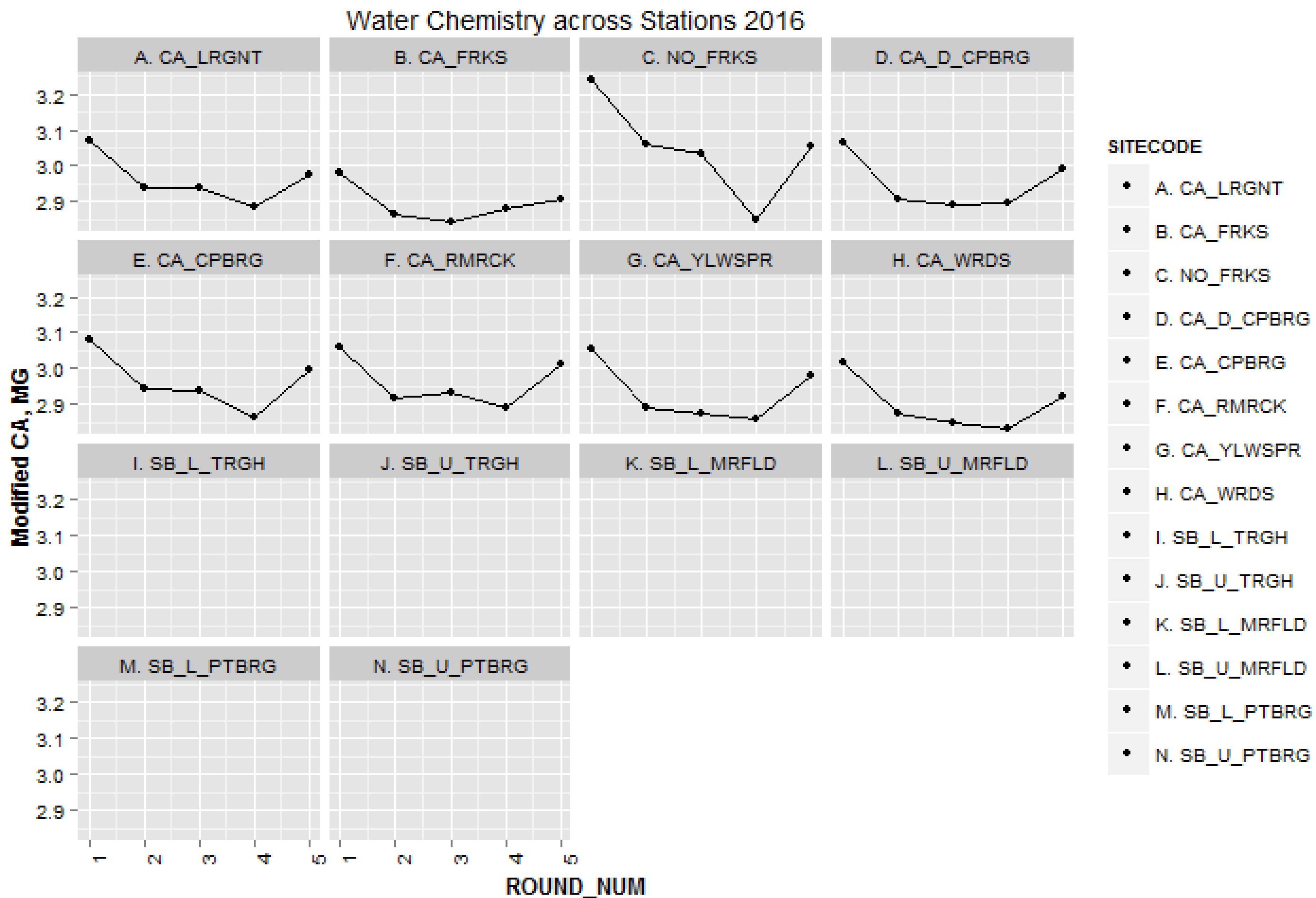
Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Nitrate_Nitrite
ROUND_NUM
SITECODE

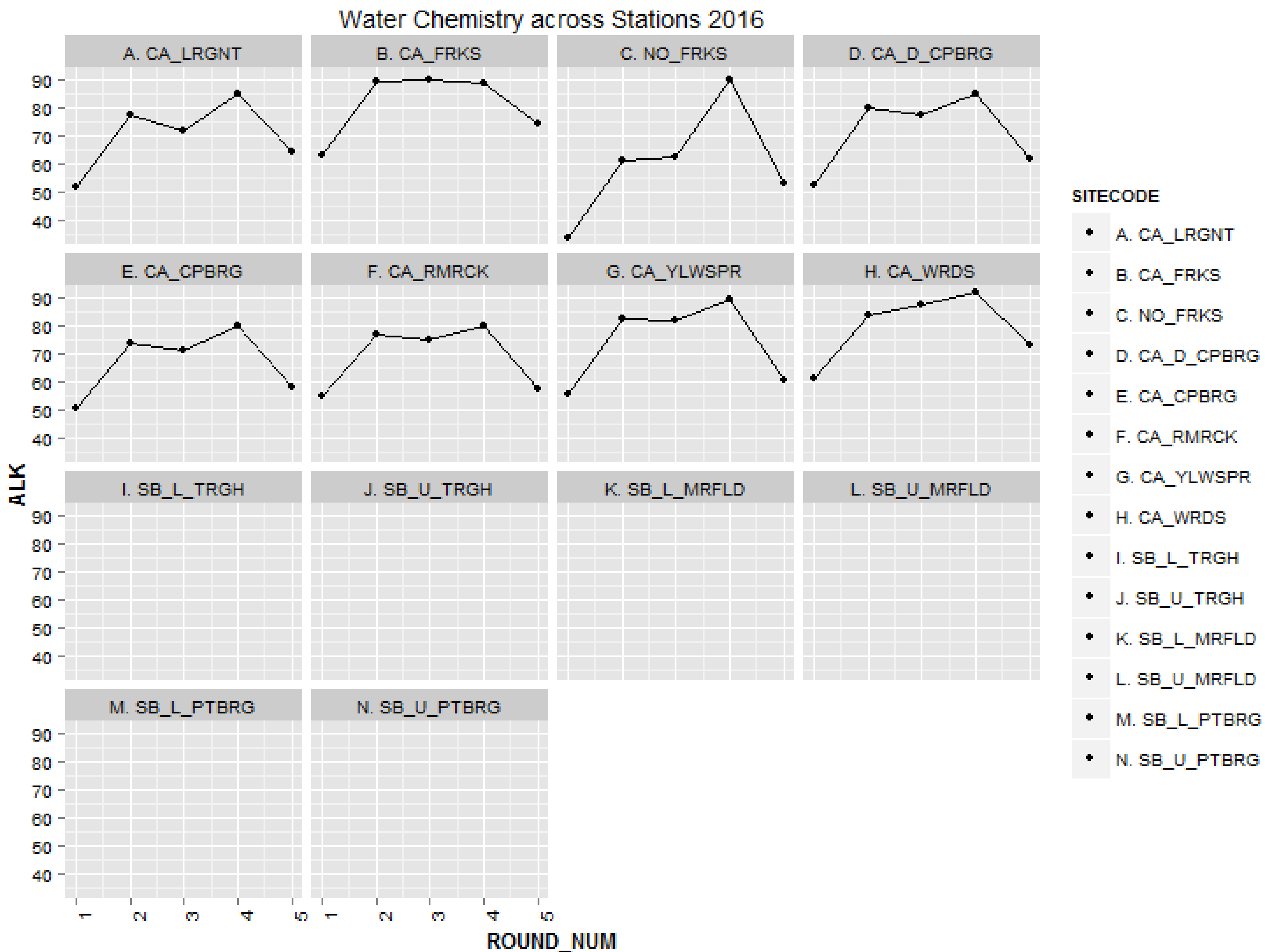

Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Total Nitrogen
1.00
0.75
0.50
0.25
ROUND_NUM
1
2
3
4
5
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG

Water Chemistry: Ions

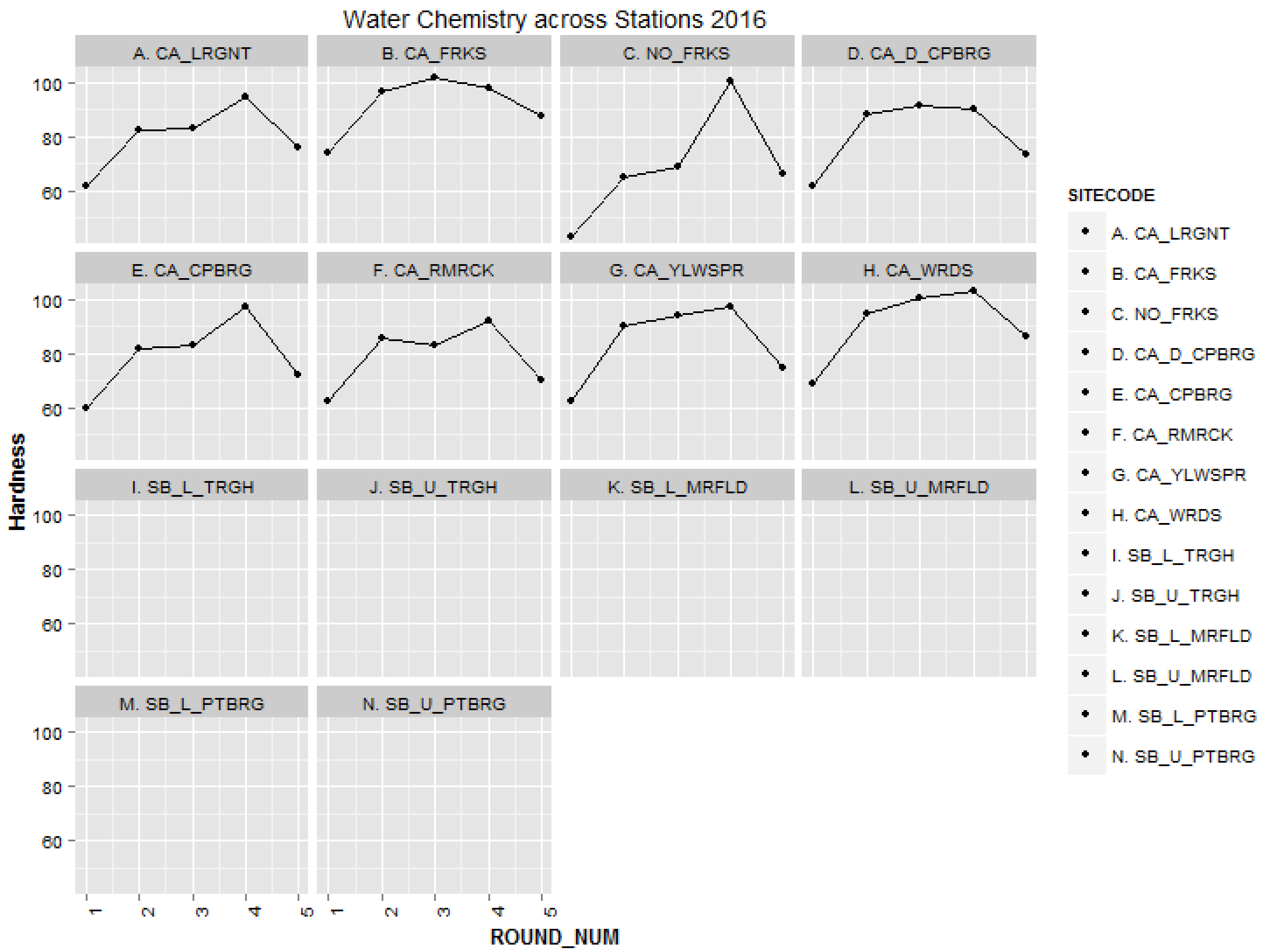



Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
MG
ROUND_NUM
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG


Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Modified CA, MG
3.2
3.1
3.0
2.9
1
2
3
4
5
ROUND_NUM
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG



Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
ALK
90
80
70
60
50
40
ROUND_NUM
1
2
3
4
5
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG



Water Chemistry across Stations 2016
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG
Hardness
100
80
60
1
2
3
4
5
ROUND_NUM
SITECODE
A. CA_LRGNT
B. CA_FRKS
C. NO_FRKS
D. CA_D_CPBRG
E. CA_CPBRG
F. CA_RMRCK
G. CA_YLWSPR
H. CA_WRDS
I. SB_L_TRGH
J. SB_U_TRGH
K. SB_L_MRFLD
L. SB_U_MRFLD
M. SB_L_PTBRG
N. SB_U_PTBRG

Appendix III. Longitudinal Event Logs and Map

Longitudinal #1

Date: July 19, 2016

Crew: Gordon Selckmann (ICPRB), James Summers (WVDEP)
Start Point Town of Capon Bridge
End Point Cacapon at Forks

Event:	Latitude	Longitude	Event Description
1	39.29759 N	78.43522 W	Start point
2	39.29980 N	78.43221 W	Formerly grey water discharge. Not observed to extent of previous years but still mildly present.
3	39.30011 N	78.43176 W	Formerly end of grey water. Observe this reach for rest of the year.
4	39.304374°	-78.429808°	SAV Patch: Predominantly curly and slender pond weed.
5	39.308811°	-78.419033°	*Hydrilla* becomes more prominent
6	39.322229°	-78.410076°	Deep pool with some blue green algae present
7	39.325498°	-78.417030°	Vegetation between riffles
8	39.334088°	-78.424193°	Mixed vegetation (*Potostemum* dense on rocks)
9	39.344483°	-78.429337°	Start of *Rhizoclonium* type algae growing on top of *Hydrilla* (DLB) - 30% for 500 m
10	39.344802°	-78.424972°	End of *Rhizoclonium* algae covering SAV
11	39.352425°	-78.426070°	SAV and FGA beds patchy. Frequent but nothing over 20% until event 12.
12	39.364558°	-78.429815°	End of sparse FGA/SAV patchiness. Begin dense SAV growth
13	39.376656°	-78.423685°	End of dense SAV growth. Dense SAV ends at Weeping Rocks. Note: BGA was witnessed growing from water discharge from rock face.
14	39.402757°	-78.417532°	End of Longitudinal

*Red test represents regions with significant filamentous green algae growth.

Longitudinal #2

Date: July 20, 2016

Crew: Gordon Selckmann (ICPRB), Ted Turner (VADEQ), and Don Kain (VaDEQ).
James Summers paddled Wardensville waste water plant to Old Iron Bridge.

Start Point Historic Iron Bridge above Yellow Springs

End Point Public Access below Camp Rim Rock

Event:	Latitude	Longitude	Event Description
1	39.157911°	-78.535092°	Start point
2	39.171324°	-78.519729°	*Chara* observed (have not observed elsewhere on Cacapon)
3	39.179837°	-78.509100°	FGA (<10%) observed in slack water. Substrate appears to be more stony.
4	39.182581°	-78.505979°	No growth observed at CA_YLWSPR
5	39.199863°	-78.501046°	Deep channelized section.
6	39.204991°	-78.489699°	Roughly where the Cacapon turns high production
7	39.213227°	-78.483730°	FGA becomes dense (>50% cover) around islands. SAV becomes abundant as well
8	39.214653°	-78.482504°	Floatable transect conducted with VADEQ. Calculated 65% FGA cover.
9	39.219542°	-78.476129°	CA_RMRCK. SAV 80%+ from event 8 to event 9. FGA 65%+ from event 8 to 9.
10	39.220427°	-78.474885°	Riffle. No FGA.
11	39.221420°	-78.474118°	FGA growing on top SAV >60%.
12	39.231582°	-78.467640°	END of FGA dense reach
13	39.233195°	-78.464587°	End of longitudinal

*Red test represents regions with significant filamentous green algae growth.

Longitudinal #3

Date: September 1, 2016

Crew: Gordon Selckmann (ICPRB), Zachary Smith (ICPRB), John Dawes (Water Reporter App)
Start Point Capon Bridge, WV
End Point Cacapon at Forks

Event	Latitude	Longitude	Event Description
1	39.29759 °	78.43522 °	Start point
2	39.29980 °	78.43221 °	Grey water discharge. Strong smell. Recreational boater present on paddle reported it was too strong to bear.
3	39.307590°	-78.429325°	End of grey water. Smell has dropped off. No color difference observed below this point.
4	39.304374°	-78.429808°	Dense SAV patch observed here in early summer is now topped with 90%+ FGA
5	39.308811°	-78.419033°	*Hydrilla* patch holding 90% FGA
6	39.322229°	-78.410076°	End of increased primary production. Deep pool with little BGA or other FGA
7	39.334088°	-78.424193°	Mixed vegetation (*Potostemum* dense on rocks). FGA (*Cladophora*) intermixed with SAV. 40% of roughly 75 m.
8	39.344483°	-78.429337°	*Rhizoclonium* algae growing on top of *Hydrilla* (DLB) - 50% for 500 m
9	39.344802°	-78.424972°	End of *Rhizoclonium* algae covering SAV
10	39.352425°	-78.426070°	SAV and FGA beds patchiness continues. Frequent FGA but nothing over 20% coverage.
11	39.364558°	-78.429815°	End of sparse FGA/SAV patchiness. Dense SAV with some pockets of FGA observed in eddies.
12	39.376656°	-78.423685°	Primary production ends at Weeping Rocks. Note: BGA was witnessed growing from water discharge from rock face. Sonde data collected. No significant change in chemistry (ex. water temp). Would be worth water chem?
13	39.402757°	-78.417532°	End of Longitudinal

*Red test represents regions with significant filamentous green algae growth.

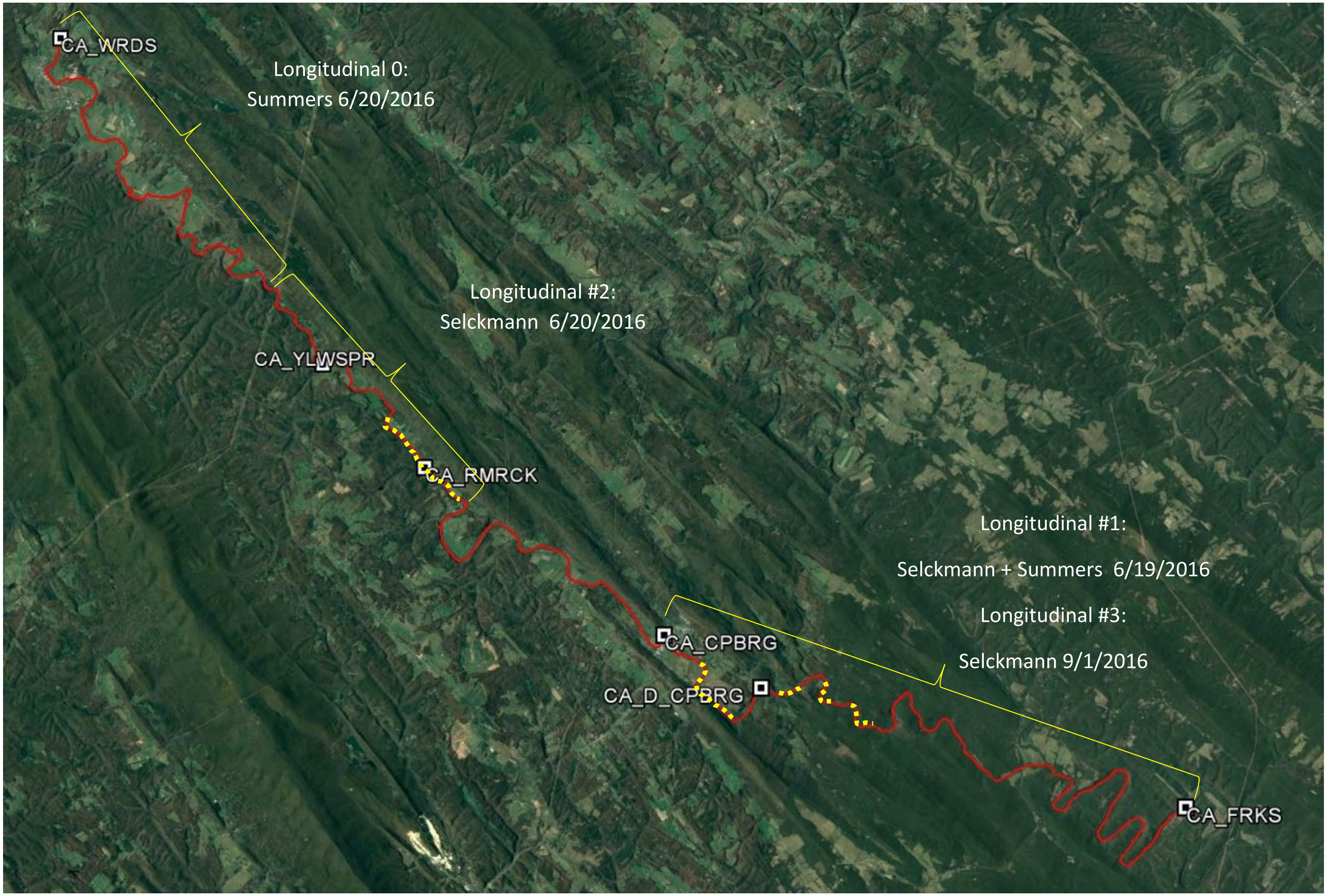


Figure 2. Bloom distribution map with significant algae blooms highlighted in yellow (dotted lines). Brackets represent the respective ranges of each longitudinal that was conducted on the Cacapon River in 2016.