21 Month Assessment of In-Lake Mechanical Circulation and Effects Related to Water Quality Standards in the Morgan Creek and Haw River Arms of Jordan Lake

May 3, 2016

Executive Summary

This assessment of water quality data from the Jordan Lake nutrient mitigation demonstration project is the second evaluation of in lake conditions as they pertain to impairments of water quality standards. The initial preliminary assessment released in October 2016 was conducted using data from the first 13 months of the demonstration project, in addition to historical data. This assessment includes an additional eight months of recent water quality information to further evaluate conditions on Jordan Lake. This report is generated pursuant to SL 2013-360 Sec. 14.3A(b).

Water quality monitoring data were used to evaluate conditions in Jordan Lake through two questions:

1. Did water quality improve in areas of the lake where SolarBees were deployed?
2. Were there shifts in phytoplankton community composition at sites where SolarBees were deployed?

Water quality was evaluated by comparing data from three indicators:

pH level	A measure of acid to base balance of a solution.
Chlorophyll *a* concentration	A level of pigment found in algae (phytoplankton) that can be used as an indicator of biological growth.
Phytoplankton community structure	A representation of algal groups found living in a waterbody.

1. Did Water Quality Improve?

Comparison to historical data indicates that project term conditions in Morgan Creek and Haw River arms of Jordan Lake for pH and chlorophyll *a* (Chl *a*) are similar to, and well within normal annual variability. Statistical comparison of these values indicate a percent change of less than 2.5% from historical data to SolarBee project period data. Comparisons of values at all SolarBee treatment areas versus control sites during SolarBee deployment indicate no statistically significant differences in pH and Chl *a*, with the exception of higher Chl *a* concentrations at the Haw River project site compared to its control site. These preliminary results indicate that nutrient related water quality conditions did not significantly improve in areas of the lake where SolarBees were deployed.

2. Have there been shifts in phytoplankton composition?

Phytoplankton community composition was similar at all pairs of treatment versus control sites during the study period, averaging from 69% to 86% similar. Furthermore, there were no statistical differences in relative abundances of blue-green algae and green algae at the three project treatment versus control site comparisons. These preliminary results indicate that a shift in phytoplankton community composition did not occur exclusively at sites where SolarBees were deployed.

This study is ongoing and data collected after April 2016 will be included in future assessments of the demonstration project. Results for the study are still considered to be preliminary estimates due to the limited project period, inherent environmental variability, and the extension of the project through 2018.

Purpose
The purpose of this preliminary assessment is to investigate efficacy of the Jordan Lake Nutrient Mitigation Demonstration Project and ultimately, to evaluate the potential of solar powered mechanical circulation (SolarBee) to reduce nutrient related impairments for this water supply reservoir. Project information and study plan can be found at: Jordan Circulator Demo. Overall success of the demonstration project will be measured by comparing concentrations of surface pH and photic zone chlorophyll *a* (herein referred to as Chl *a*) to water quality standards using the current assessment methodology for impairment (less than 10 % exceedance with at least 90% confidence) approved by the Environmental Management Commission in 2013.

Assessment
Water quality monitoring data were used to answer two questions in this report:

1. Did water quality improve in areas of the lake where SolarBees were deployed?
This question was addressed by analyzing pH and Chl *a* values and percent exceedances during the SolarBee project against historical trends, in addition to statistically comparing results for pH and Chl *a* among sites spatially in the immediate vicinity of SolarBees (project treatment) versus outside of the project area in Jordan Lake (control).

2. Were there shifts in phytoplankton community composition at sites where SolarBees were deployed?
This question was addressed by constructing algal similarity indices based on group densities among treatment and control sites, as well as statistically comparing relative abundances of Cyanobacteria (a group of blue-green algae that can potentially produce toxin) to Chlorophyta (green algae) among treatment and control sites.

Specifically, data used in analysis represent conditions spanning from January 2006 through April 2016 for historical trends (pH and Chl *a*) and during the SolarBee project time frame of August 2014 through April 2016 for spatial treatment / control comparisons (pH, Chl *a,* and phytoplankton).

Figure 1. Jordan Lake Monitoring Locations and Site Comparison Pairs
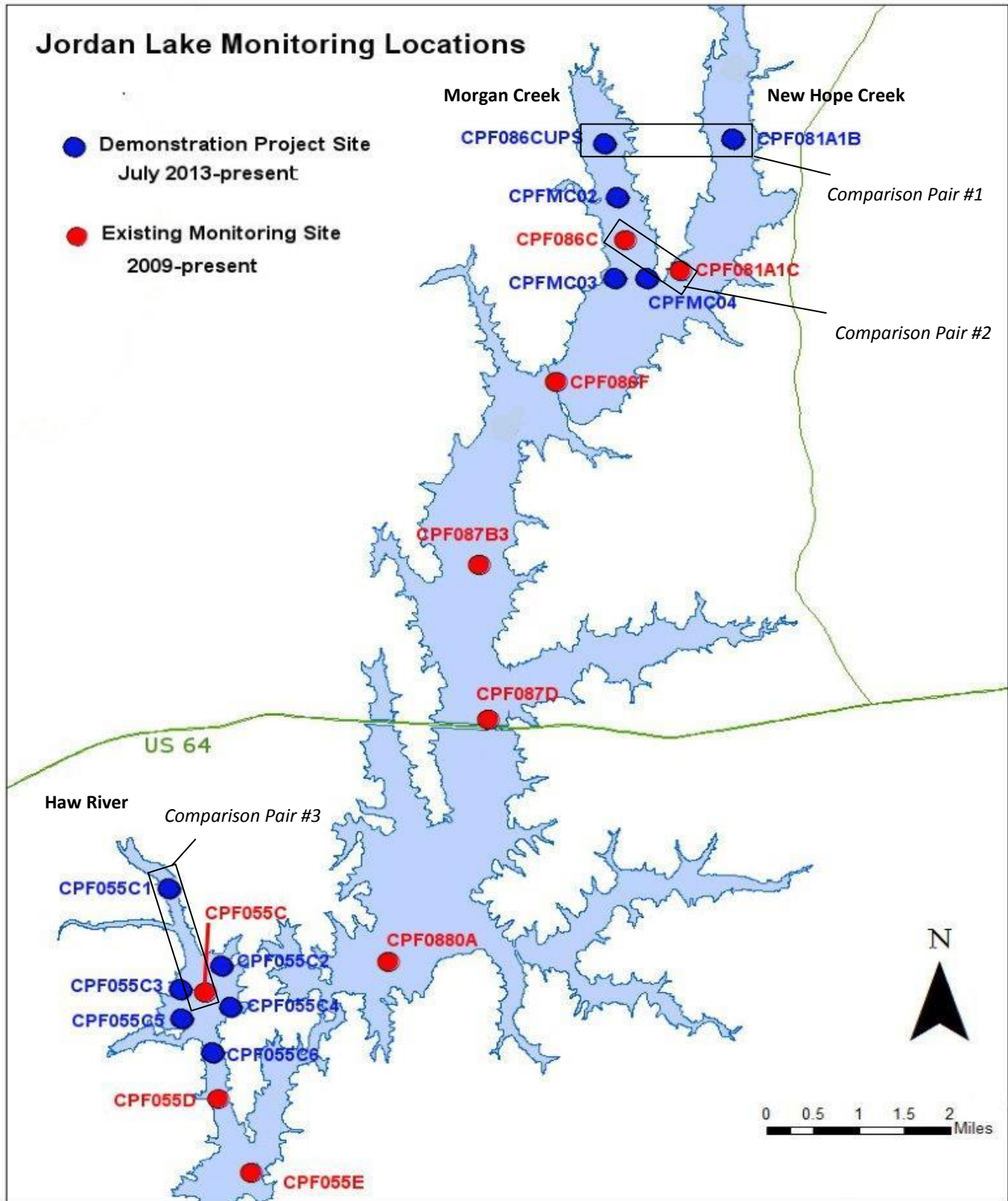
Analysis and Results

pH temporal trends

Results indicate pH conditions in Morgan Creek and Haw River arms of Jordan Lake are similar to historical conditions, but percent exceedances are above average. During the SolarBee study period, Morgan Creek long term site CPF086C exceeded the pH standard 19% of the time. Haw River long term sites CPF055C exceeded the pH standard 29% of the study period sampling events.

Three sampling sites, CPF081A1C in New Hope Creek; CPF086C in Morgan Creek; and CPF055C in Haw River arm, have been monitored on a monthly basis since 2006, and twice a month basis May through September since 2010, as required by section 3.(c) of S.L. 2009-216 (Figure 1). The Morgan Creek and Haw River sites are the SolarBee study areas, whereas the New Hope Creek site is not. Each of the three long term sites serves as a proxy for other sites in its immediate vicinity for pH as no statistical difference was determined by t-tests from each long term site compared to averaged pooled values from proximal sites (Appendix 1). The objective of this analysis is to gather an understanding of surface pH behavior and subsequent percent exceedances of class C water quality standards for pH (greater than 9.0 s.u. or less than 6.0 s.u.) in Jordan Lake as far back as 2006, in addition to time during the SolarBee project.

Box plots of pH values were constructed for individual years from 2006 to 2014 and during the SolarBee study period, August 2014 through April 2016 (Figure 2). Yearly variation in pH is apparent at each of the locations over the historical data period. From 2006 to 2015, the New Hope Creek and Morgan Creek sites appear to behave similarly, including outlier pH minimum values of 5.2 s.u. and 5.3 s.u. in April 2015. Substantial rainfall on the Lake a few weeks prior to the April sampling event led to a large inflow and outflow increases (data from the USACE Wilmington District and USGS Water Science Center, Appendix 2). Higher rates of discharge may contribute to the lower pH values, through flushing of naturally acidic headwater areas. The SolarBee project box plots for the Morgan Creek and Haw River sites show pH median and maximum values in line with yearly variation.

Median pH values and percent exceedances were compiled for individual years from 2006 to 2015 and during the SolarBee study period (Table 1). During the majority of considered time frames, each of the three sites was above criteria for exceedance of the pH standard (10%). The project period data show percent exceedances for pH that are above average in both the Morgan Creek (17% change) and Haw River (61% change) project areas. Percent change was calculated by determining the difference between the '06- '15 average and SolarBee percent exceedances, then divided by the '06-'15 average percent exceedance. Median pH values during the project period are within the standard deviation for data observed during the 2006 through 2015 period and are considered not significantly different from historical conditions.

Figure 2. Box plots of pH values for three long term Jordan Lake sampling sites annually from 2006 to 2014 and by SolarBee project time frame.
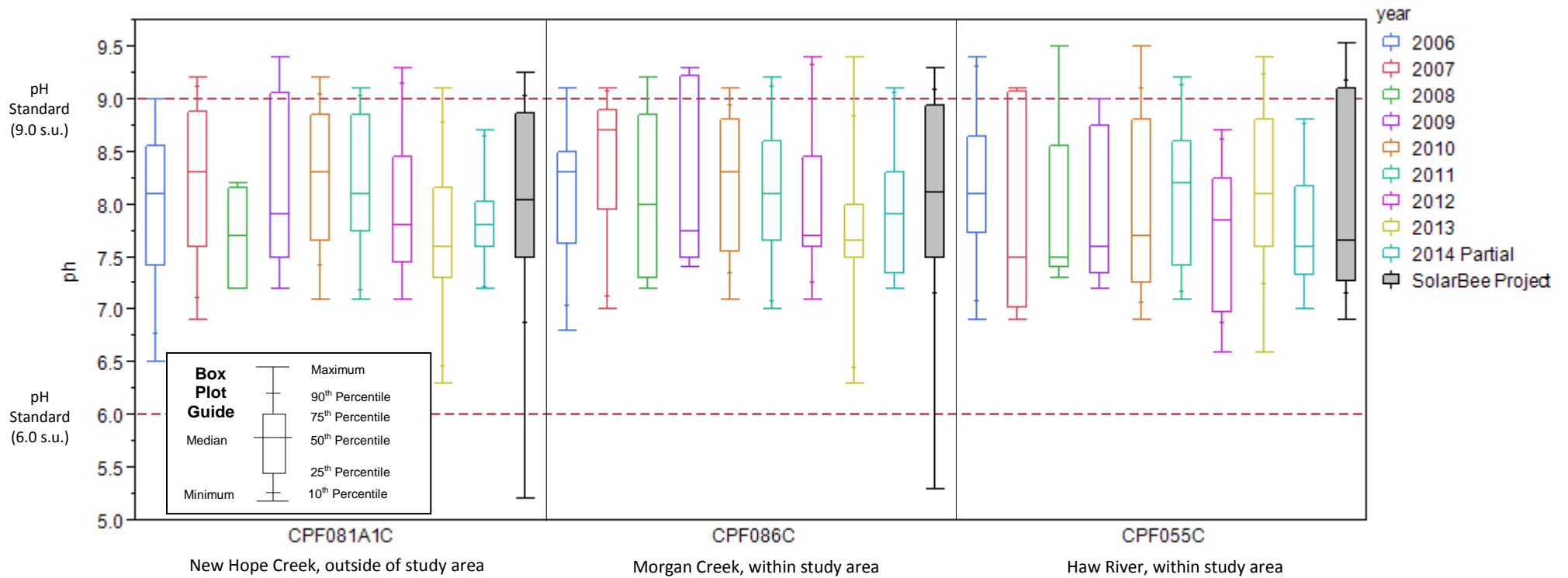

Table 1. Median pH and % exceedances annually from 2006 to 2015 and during SolarBee project for three long term Jordan Lake sampling sites.

Time frame	CPF081A1C			CPF086C			CPF055C		
	Total number of samples	%exceedance	pH median	Total number of samples	%exceedance	pH median	Total number of samples	%exceedance	pH median
2006	12	17	8.1	12	17	8.3	12	17	8.1
2007	12	8	8.3	12	17	8.7	12	33	7.5
2008	9	0	7.7	9	22	8	9	22	7.5
2009	9	22	7.9	10	30	7.8	9	11	7.6
2010	17	18	8.3	17	6	8.3	17	18	7.7
2011	17	12	8.1	17	18	8.1	16	13	8.2
2012	17	12	7.8	17	12	7.7	18	0	7.9
2013	17	6	7.6	16	6	7.7	17	18	8.1
2014	17	6	7.8	17	18	7.9	17	0	7.6
2015	16	25	8.5	16	19	8.5	17	47	8.8
SolarBee (Aug'14 – Apr'16)	*27*	*19*	*8.0*	*26*	*19*	*8.1*	*28*	*29*	*7.7*
'06-'15 average		**13**	**8.0**		**16**	**8.1**		**18**	**7.9**
'06-'15 standard deviation		**7.9**	**0.3**		**7.2**	**0.3**		**14**	**0.4**

pH comparisons pre and post SolarBee installation at two long term project sites

The project period data have pH values that are similar to the 8.5 years of pre SolarBee installation values, which are from January 2006 through July 2014 (Figure 3 and Table 2). There was a 0.5% change between the time frame averages at the Morgan Creek site CPF086C and 0.8% change at the Haw River site CPF055C. Percent change was calculated by determining the difference between the pre SolarBee and SolarBee pH averages, then divided by the pre SolarBee pH average. Comparison of historical and project term data from these two sites indicate no significant difference (p value <0.05= significant) in pH conditions.

Figure 3. pH values and means during pre-SolarBee and post SolarBee installation time frames at project sites in Morgan Creek (CPF086C) and Haw River (CPF055C) within Jordan Lake
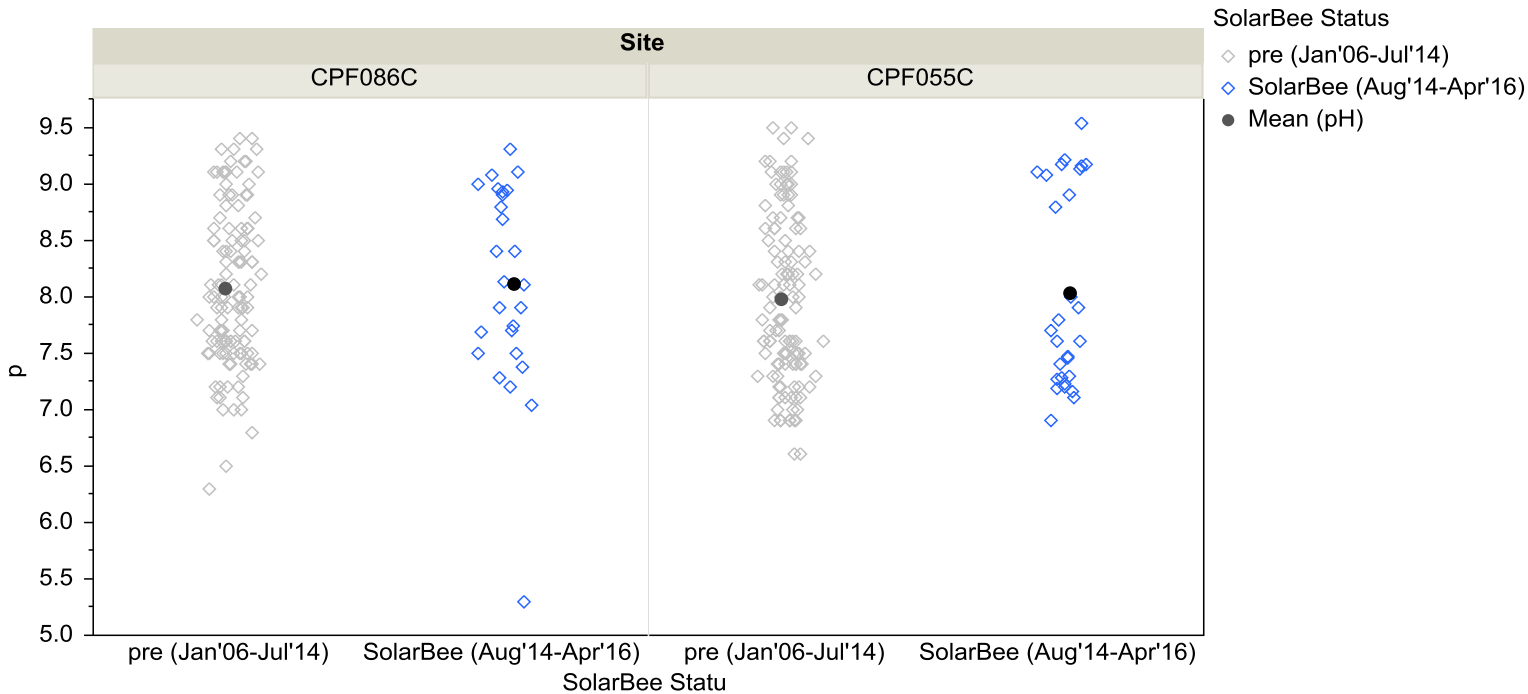
Table 2. pH pre & post SolarBee time frame t-test details including sites within each group, data time frame, test result, and result interpretation (p <0.05= significant difference)

Site	Time frame	Total number of samples	Average pH	p-value test result	Interpretation	Percent Change
CPF086C (Morgan Creek)	Pre (Jan'06 – Jul'14)	120	8.07	0.81	no difference	0.5%
	SolarBee (Aug'14-Apr'16)	26	8.11			
CPF055C (Haw River)	Pre (Jan'06 – Jul'14)	120	7.98	0.71	no difference	0.8%
	SolarBee (Aug'14-Apr'16)	28	8.03			

pH comparisons between project treatment and control sites

There were no statistically significant differences (p value <0.05= significant) in pH at all three project treatment versus control site comparisons during SolarBee deployment. Morgan Creek project area sites had the same or lower percent exceedances than their control sites in New Hope Creek. The Haw River area site had a higher percent exceedance than its control site.

Three pairs of sites, each consisting of a site within the SolarBee project treatment area and one outside of the project area as a control, were analyzed to determine differences in surface pH values during the project study period, August 2014 through April 2016 (Figure 1. for site locations). Additionally, pH values from one year prior to SolarBee deployment, July 2013 to July 2014, were also tested for significant differences. These sites have been monitored on a twice a month basis May through September and monthly basis the remainder of the year. The objective of this analysis is to determine if SolarBees have reduced impairment values in the treatment area by way of statistically significant lower surface pH means when compared to the control sites. A p-value of less than 0.05 indicates a statistically significant difference between sites, with 95% confidence.

All three treatment versus control site comparisons prior to or during SolarBee deployment were not significant (6 tests total), indicating pH values among sites were not significantly different (Table 3). The mean pH ranged from 7.8 s.u. to 8.3 s.u. over the six sites (Figures 4-6). When comparing pH percent exceedances between project area and control area sites, the Haw River area was higher than its control site during the project period (Figure 6). In the Morgan Creek area, the percent exceedance was higher than control sites in New Hope Creek prior to SolarBee deployment, and the same or lower than control sites during the project period (Figures 4 and 5).

Table 3. pH t-test details including sites within each group, data time frame, test result, and result interpretation
(p <0.05= significant difference)

| Comparison pair #	Group 1: treatment site	Group 2: control site	Time frame	Total number of samples	p-value test result	Interpretation
1	CPF086CUPS (Morgan Creek)	CPF081A1B (New Hope Creek)	SolarBee (Aug'14-Apr'16)	50	0.81	no difference
			Pre (July'13 – Jul'14)	26	0.27	no difference
2	CPF086C (Morgan Creek)	CPF081A1C (New Hope Creek)	SolarBee (Aug'14-Apr'16)	53	0.65	no difference
			Pre (July'13 – Jul'14)	38	0.75	no difference
3	CPF055C (Haw River)	CPF055C1 (Haw River)	SolarBee (Aug'14-Apr'16)	54	0.61	no difference
			Pre (July'13 – Jul'14)	33	0.74	no difference

Figure 4. Comparison pair #1 pH values and means of a treatment site in Morgan Creek (CPF086CUPS) and a control site in New Hope Creek (CPF081A1B) within Jordan Lake, used in t-tests for pre-SolarBee and SolarBee time frames
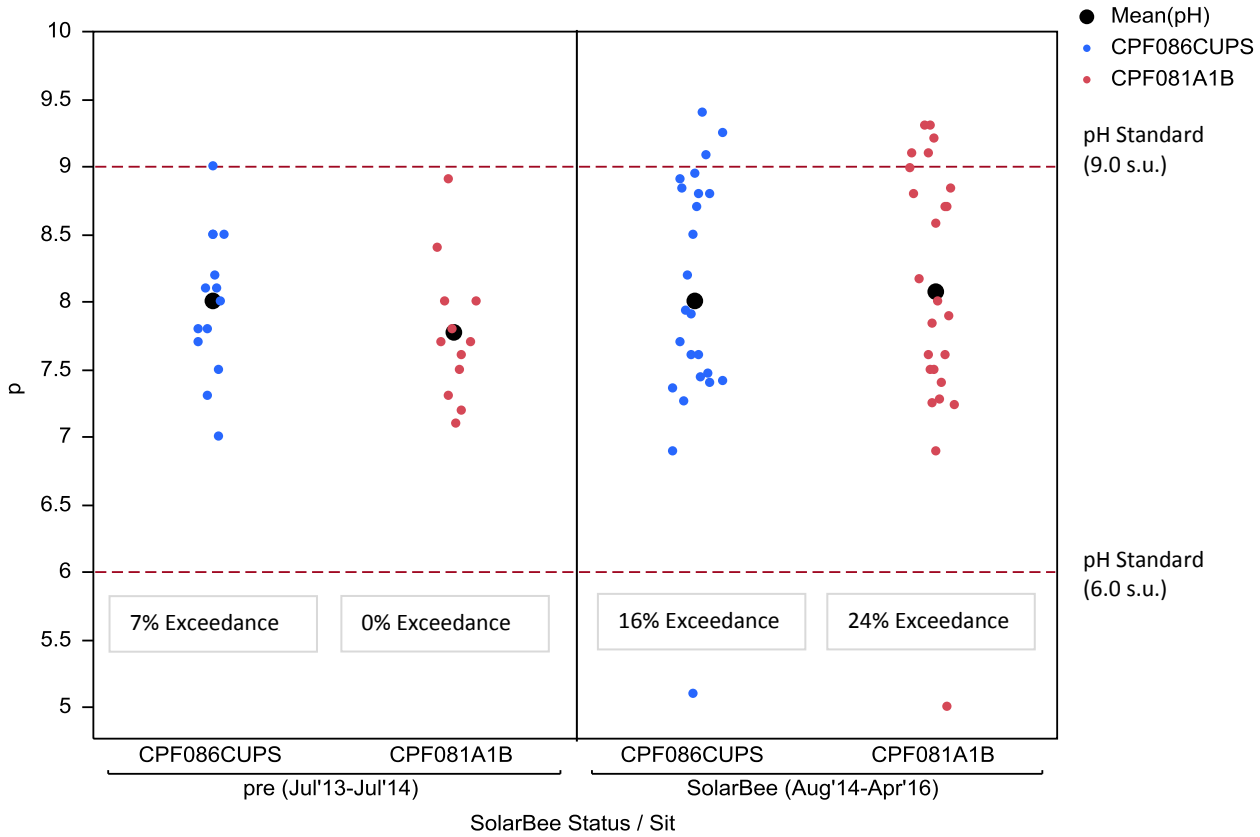
Figure 5. Comparison pair #2 pH values and means of a treatment site in Morgan Creek (CPF086C) and a control site in New Hope Creek (CPF081A1C) within Jordan Lake, used in t-tests for pre-SolarBee and SolarBee time frames
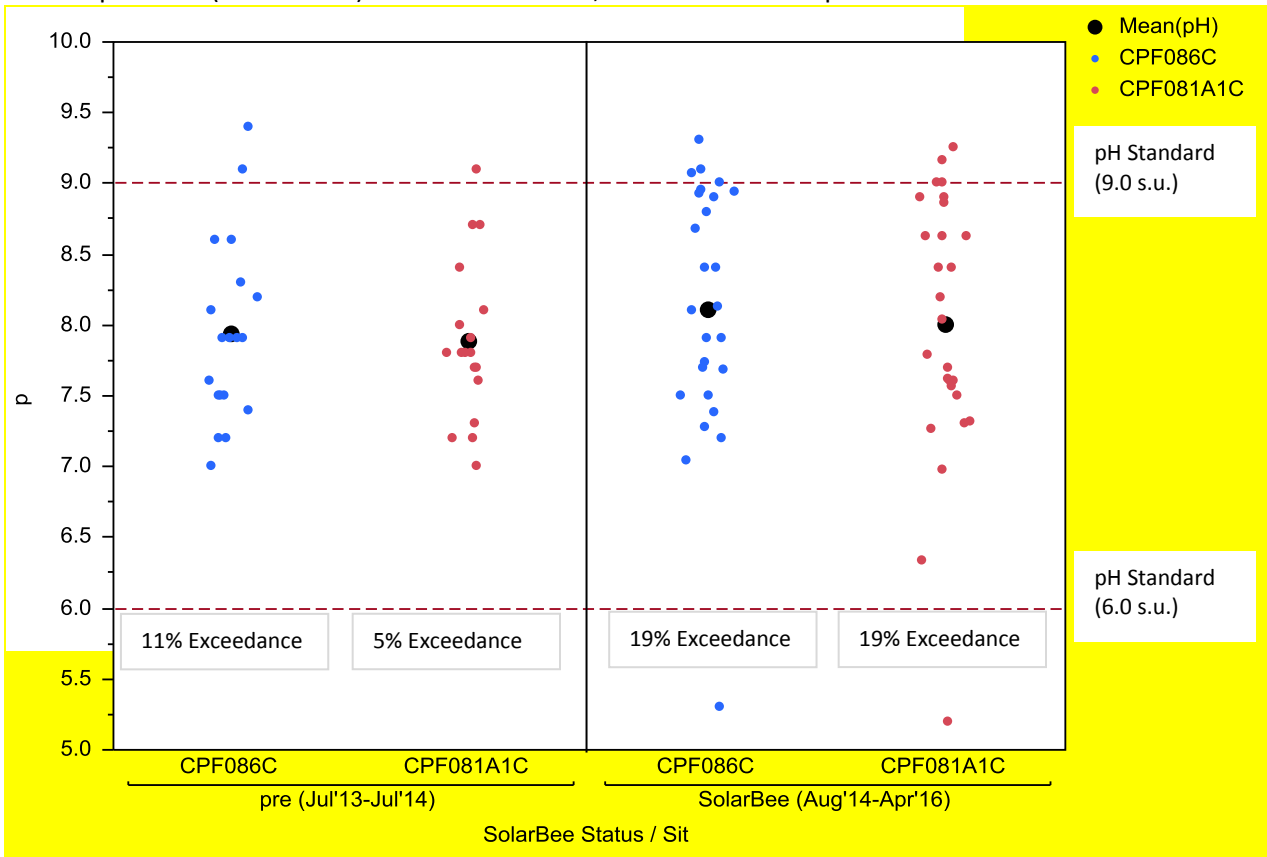
Figure 6. Comparison pair #3 pH values and means of a project treatment (CPF055C) and a control site (CPF055C1) in Jordan Lake Haw River Arm, used in t-tests for pre SolarBee and SolarBee time frames
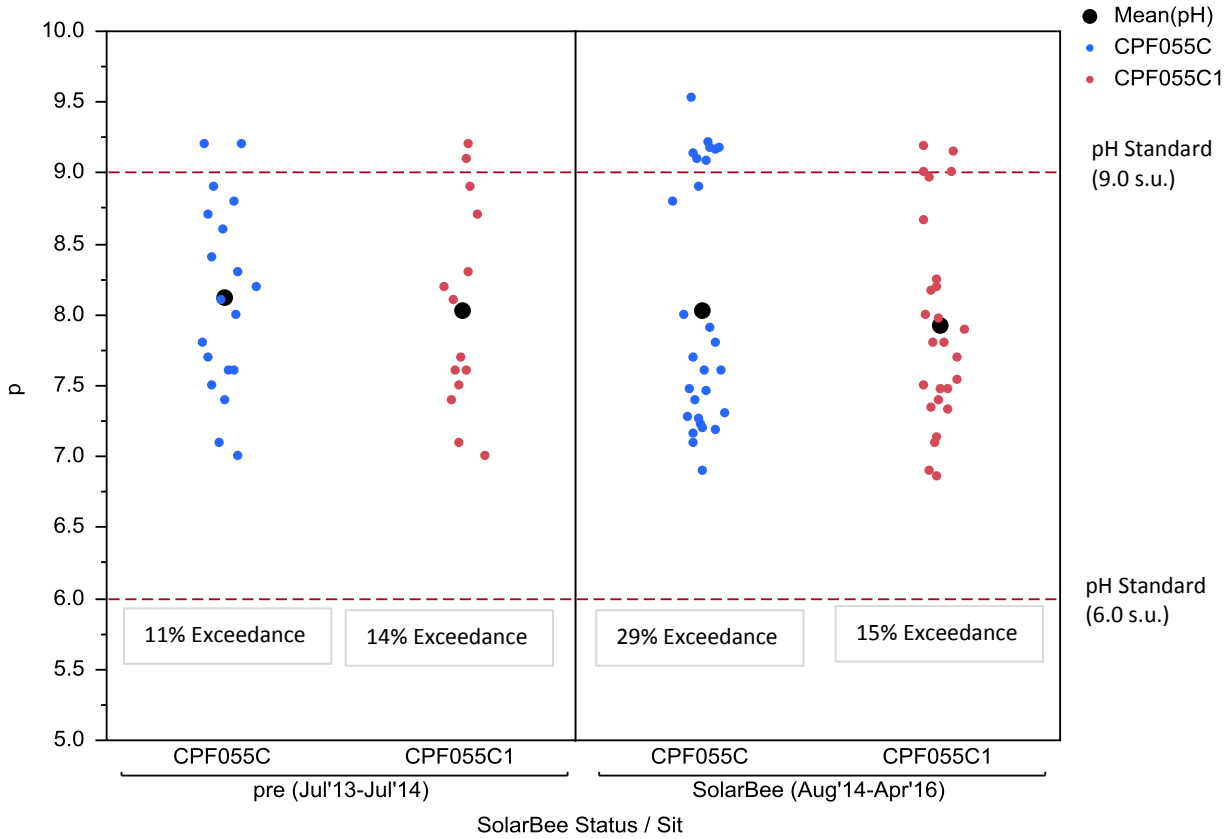
Chlorophyll a temporal trends

Results indicate the concentrations of Chl *a* in Morgan Creek and Haw River arms of Jordan Lake are similar to historical conditions. During the SolarBee study period, Morgan Creek long term site CPF086C exceeded the Chl *a* standard 79% of the time. Haw River long term site CPF055C exceeded the standard 32% of the study period sampling events.

Each of the three long term sites, CPF081A1C in New Hope Creek; CPF086C in Morgan Creek; and CPF055C in Haw River arm, serves as a proxy for other sites in its immediate vicinity for Chl *a* as no statistical difference was determined by t-tests from each long term site compared to averaged pooled values from proximal sites (Appendix 1). The objective of this analysis is to gather an understanding of Chl *a* fluctuations and subsequent percent exceedances of class C water quality standards (40 µg/L) for Jordan Lake as far back as 2006, in addition to during the SolarBee project.

Box plots of Chl *a* values were constructed to compare individual years from 2006 to 2014 and during the SolarBee study period (Figure 7). Yearly variation in Chl *a* is apparent at each of the locations over the historical data period. Values in 2009 are inflated in relation to adjacent years. A region-wide drought in 2007-2008 and state-wide higher than average rainfall in May and June of 2009 (2 inches more than previous year) may have created a nutrient input influx (data from the Southeast Regional Climate Center http://www.sercc.com/). From 2006 to 2015, the New Hope Creek and Morgan Creek sites appear to behave similarly, whereas the Haw River site (CPF055C) had noticeably lower Chl *a* medians. These differences can be observed in long term percent exceedance and median Chl *a* values described in Figure 7 and Table 4. This difference is due in part to different hydrologic and morphologic conditions in Morgan and New Hope Creeks. The SolarBee project box plots for the Morgan Creek and Haw River sites show Chl *a* minimum, median, and maximum values in line with yearly variation.

Median Chl *a* values and percent exceedances were compiled for individual years from 2006 to 2015 and during the SolarBee study period (Table 4). Criteria for impairment is greater than 10% of data exceeding standard with greater than or equal to 90% confidence. The project period data show percent exceedance values for chlorophyll *a* that are close to average in both the Morgan Creek (1% change) and Haw River (8% change) project areas. Percent change was calculated by determining the difference between the '06- '15 average and SolarBee percent exceedances, then divided by the '06-'15 average percent exceedance. Median Chl *a* values during the project period are within the standard deviation for data observed during the 2006 through 2015 data period and are considered not significantly different from historical conditions.

Figure 7. Box plots of Chl *a* values for three long term Jordan Lake sampling sites annually from 2006 to 2014 and by SolarBee project time frame
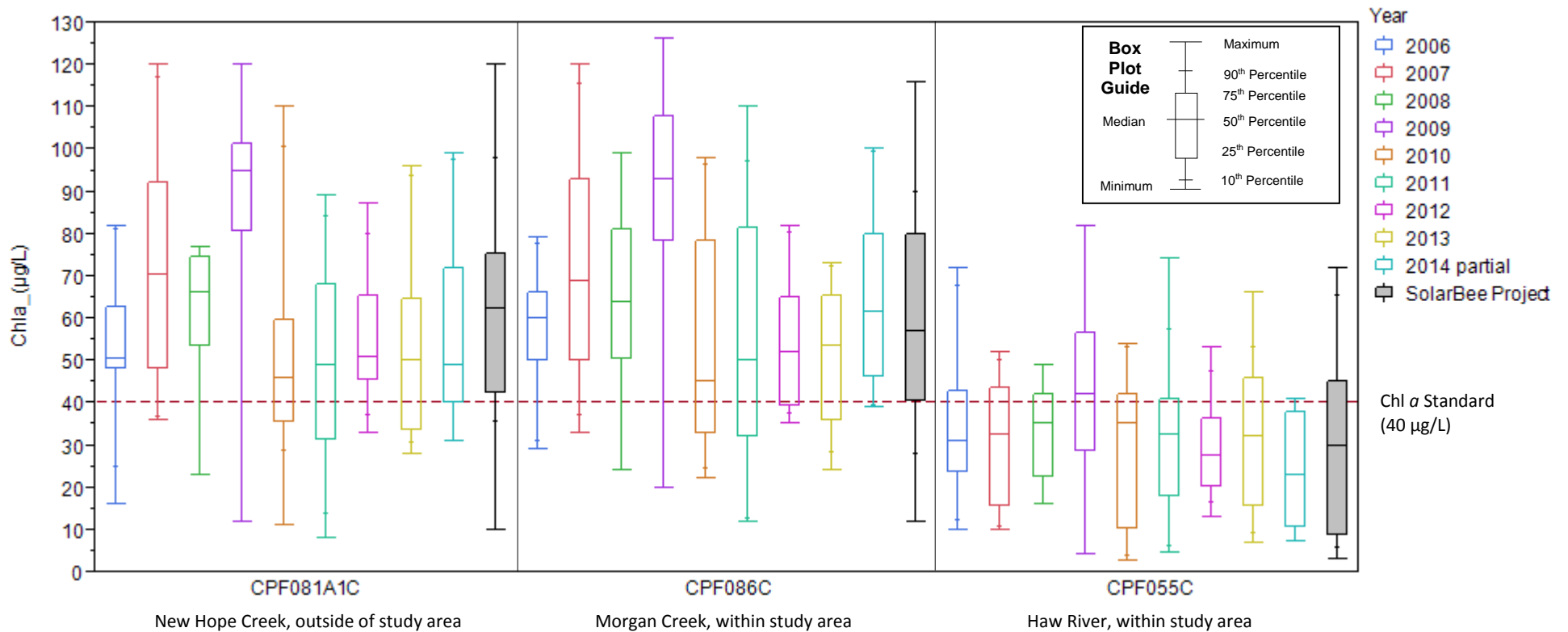

Table 4. Median Chl *a* and % exceedances annually from 2006 to 2015 and during SolarBee project for three long term Jordan Lake sampling sites.

Time frame	CPF081A1C			CPF086C			CPF055C		
	Total number of samples	%exceedance	Chl a median (µg/L)	Total number of samples	%exceedance	Chl a median (µg/L)	Total number of samples	%exceedance	Chl a median (µg/L)
2006	12	92	51	12	83	60	12	42	31
2007	12	83	71	12	92	69	12	42	33
2008	9	89	66	9	89	64	9	22	35
2009	9	90	95	9	89	93	9	56	42
2010	17	65	46	17	65	45	17	35	35
2011	17	65	49	17	65	50	16	31	33
2012	17	88	51	17	77	52	18	22	28
2013	17	65	50	16	69	54	17	35	32
2014	17	83	57	17	88	61	17	35	29
2015	17	94	67	17	81	58	17	29	33
SolarBee (Aug'14-Apr'16)	*28*	*86*	*63*	*28*	*79*	*57*	*28*	*32*	*30*
'06-'15 average		**81**	**60**		**80**	**61**		**35**	**33**
'06-'15 standard deviation		**11.7**	**15.0**		**10.4**	**13.4**		**9.9**	**4.0**

Chlorophyll a comparisons pre and post SolarBee installation at two long term project sites

The project period data have Chl *a* values that are similar to the 8.5 years of pre SolarBee installation values, which are from January 2006 through July 2014 (Figure 8 and Table 5). There was a 2% change between the time frame averages at the Morgan Creek site CPF086C and 1% change at the Haw River site CPF055C. Percent change was calculated by determining the difference between the pre SolarBee and SolarBee Chl *a* averages, then divided by the pre SolarBee Chl *a* average. Comparison of historical and project term data from these two sites indicate no significant difference (p value <0.05= significant) in Chl *a* conditions.

Figure 8. Chl *a* values and means during pre-SolarBee and post SolarBee installation time frames at project sites in Morgan Creek (CPF086C) and Haw River (CPF055C) within Jordan Lake
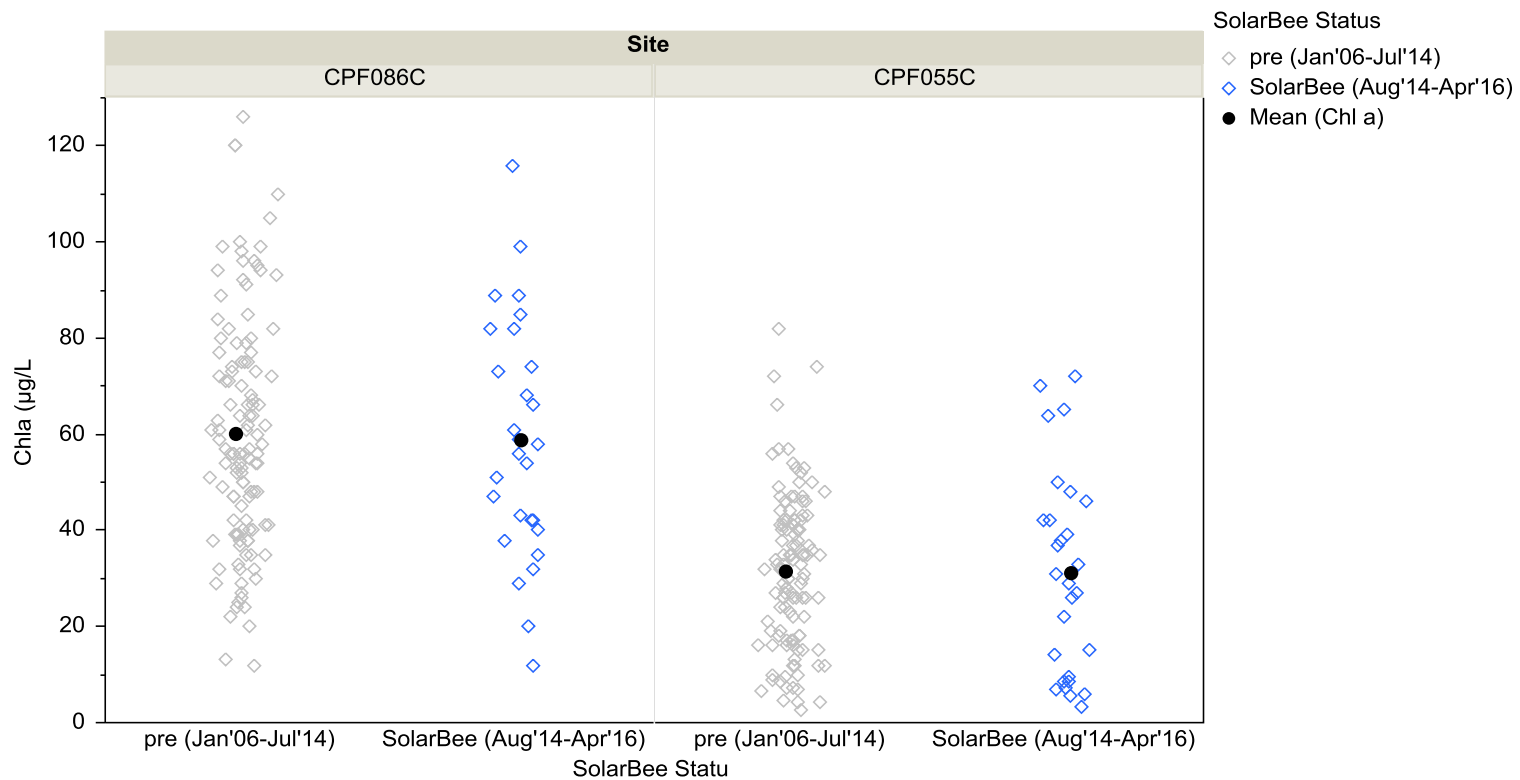
Table 5. Chl *a* pre & post SolarBee time frame t-test details including sites within each group, data time frame, test result, and result interpretation (p <0.05= significant difference)

Site	Time frame	Total number of samples	Average Chl a (µg/L)	p-value test result	Interpretation	Percent Change
CPF086C (Morgan Creek)	Pre (Jan'06 – Jul'14)	119	59.9	0.80	no difference	2.1%
	SolarBee (Aug'14-Apr'16)	28	58.6			
CPF055C (Haw River)	Pre (Jan'06 – Jul'14)	120	31.4	0.88	no difference	1.7%
	SolarBee (Aug'14-Apr'16)	28	30.9			

Chlorophyll a comparisons between project treatment and control sites

There were no statistically significant differences in Chl *a* concentrations (p value <0.05= significant) at the two project treatment versus control site comparisons in Morgan Creek versus New Hope Creek during SolarBee deployment. Morgan Creek project area sites had lower percent exceedances than its control sites. The Haw River project area site had significantly higher Chl *a* concentrations than its control site and subsequently also had a higher percent exceedance than its control site.

The same three pairs of sites analyzed for pH, each consisting of a site within the SolarBee project treatment area and one outside of the project area as a control, were analyzed to determine differences in Chl *a* concentrations during the project study period, August 2014 through April 2016. Chl *a* concentrations from one year prior to SolarBee deployment, July 2013 to July 2014, were also tested for significant differences, as pH was. The objective of this analysis is to determine if SolarBees have reduced impairment values in the treatment area by way of statistically significant lower Chl *a* means when compared to the control sites. A p-value of less than 0.05 indicates a statistically significant difference among sites, with 95% confidence.

In Morgan Creek versus New Hope Creek, there were no significant differences in Chl *a* concentrations between treatment and control sites (comparison pairs # 1 and 2) prior to or during SolarBee deployment (Table 6). In the Haw River arm, project site CPF055C had a significantly higher Chl *a* mean of 31 compared to 18 µg/L at the control site CPF055C1 during the SolarBee project (Figure 11). The Chl *a* values at these locations were not statistically different for the one year prior to deployment, but the treatment site mean was also slightly larger than at the control site. Morphometric differences between the Haw River treatment and control sites, namely an increase in river width and slower flow conditions present at most times in the treatment area, coupled with yearly weather and hydrologic variation, likely contribute to this discrepancy.

When comparing Chl *a* percent exceedances between project area and control area sites, the Morgan Creek area was lower than its control site during the project period, and the Haw River area was higher than its control site (Figures 9-11).

Table 6. Chl *a* t-test details including sites within each group, data time frame, test result, and result interpretation (p <0.05= significant difference)

| Comparison pair #	Group 1: treatment site	Group 2: control site	Time frame	Total number of samples	p-value test result	Interpretation
1	CPF086CUPS (Morgan Creek)	CPF081A1B (New Hope Creek)	SolarBee (Aug'14-Apr'16)	52	0.27	no difference
			Pre (July'13 – Jul'14)	26	0.39	no difference
2	CPF086C (Morgan Creek)	CPF081A1C (New Hope Creek)	SolarBee (Aug'14-Apr'16)	58	0.48	no difference
			Pre (July'13 – Jul'14)	38	0.99	no difference
3	CPF055C (Haw River)	CPF055C1 (Haw River)	SolarBee (Aug'14-Apr'16)	53	**0.03**	significant difference
			Pre (July'13 – Jul'14)	33	0.60	no difference

Figure 9. Comparison pair #1 chlorophyll *a* values and means of a treatment site in Morgan Creek (CPF086CUPS) and a control site in New Hope Creek (CPF081A1B) within Jordan Lake, used in t-tests for pre-SolarBee and SolarBee time frames
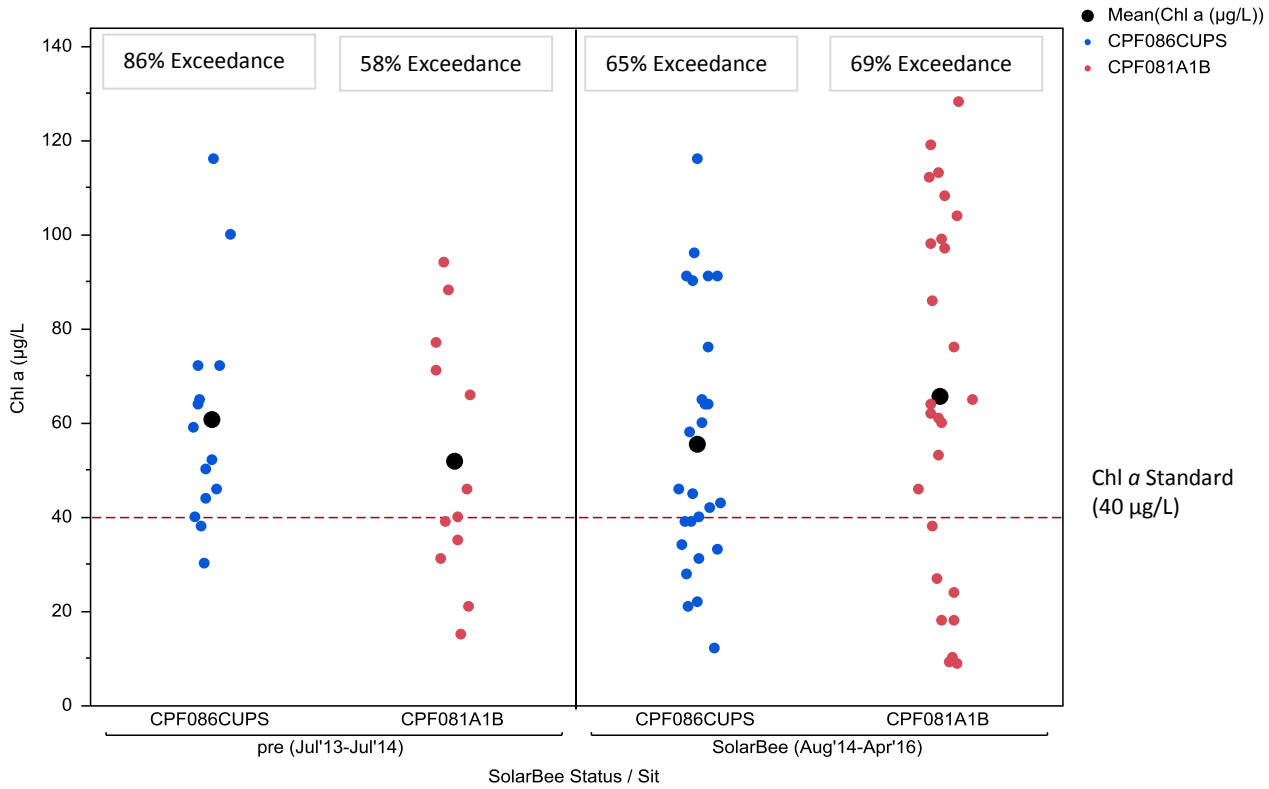
Figure 10. Comparison pair #2 chlorophyll *a* values and means of a treatment site in Morgan Creek (CPF086C) and a control site in New Hope Creek (CPF081A1C) within Jordan Lake, used in t-tests for pre-SolarBee and SolarBee time frames
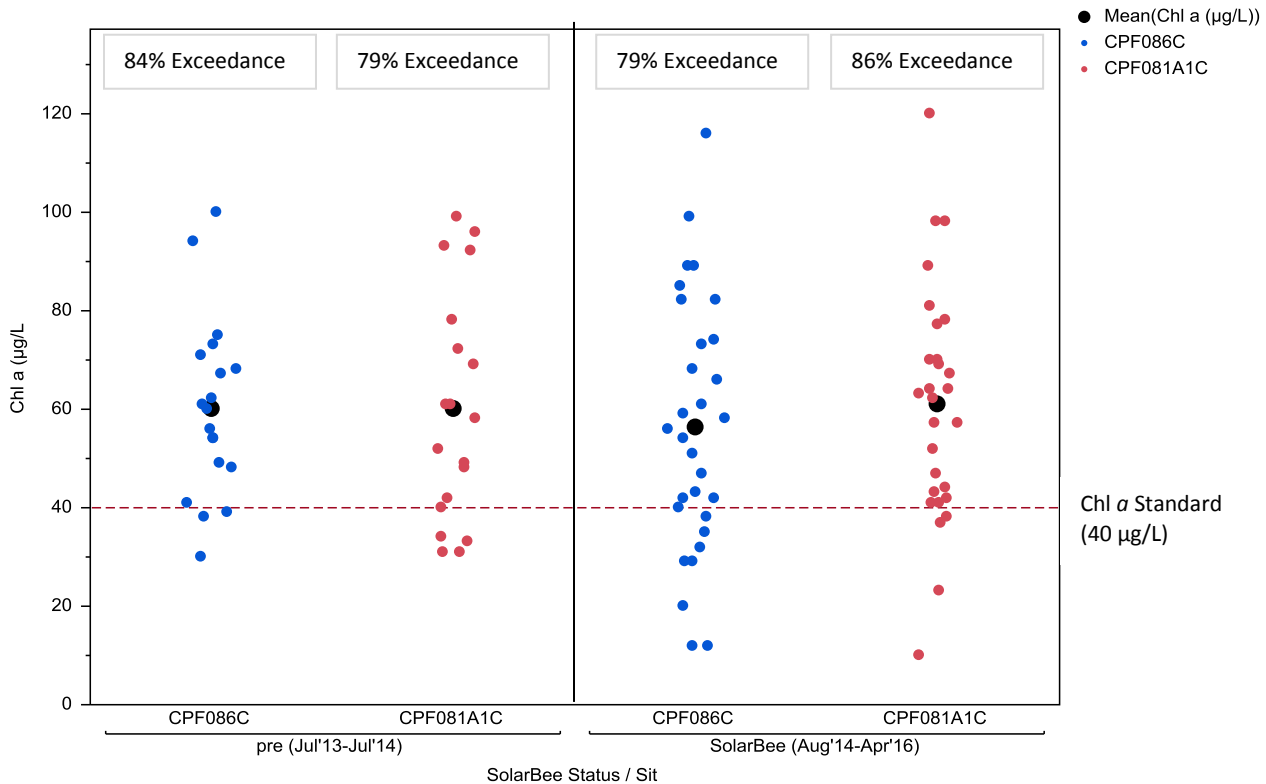
Figure 11. Comparison pair #3 chlorophyll *a* values and means of a project treatment (CPF055C) and a control site (CPF055C1) in Jordan Lake Haw River Arm, used in t-tests for pre SolarBee and SolarBee time frames
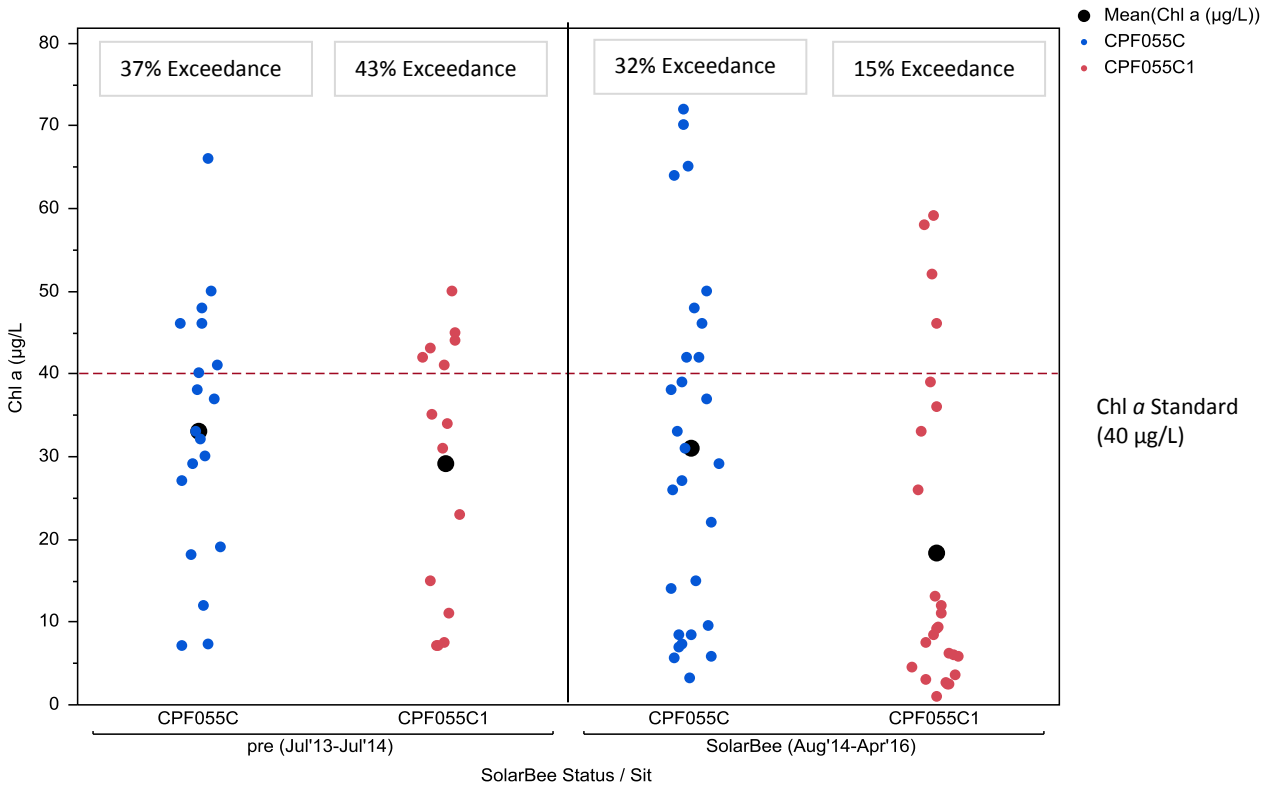
Phytoplankton Community Composition: Bray-Curtis Similarity Index on pairs of project treatment / control sites

Results indicate phytoplankton community composition was similar at all pairs of treatment versus control sites during the study period, averaging from 69% to 86% similarity.

A Bray-Curtis Similarity Index, a statistic used to quantify the compositional similarity between two different sites, was constructed using phytoplankton community compositions at each of the three pairs of project treatment versus control sites from October 2014 to April 2016, which was within the SolarBee study period. The phytoplankton compositions consisted of density counts of all present algal groups (ex. blue-greens, greens, diatoms). The objective of this analysis is to determine if SolarBees have had an effect on phytoplankton in project areas by way of shifting densities among algal groups, resulting in dissimilar algal community compositions at control sites.

Bray-Curtis similarities suggest that algal groups found within each pair of treatment versus control sites are similar. Over the 23 month sample period, the average phytoplankton composition similarity was near or above 70% for all three paired site comparisons, with treatment site CPF086C and control CPF081A1C having the most similar algal communities averaging at 86%. The lowest similarity was in the Haw River between treatment sites CPF055C and CPF055C1 on September 25 2015, with 15%. As mentioned, lake morphometric differences between the two sites likely contribute to this dissimilarity.

Table 7. Bray- Curtis Similarity Indices of phytoplankton community composition (unit density) for treatment / control sites from October 2014 through April 2016.

Date	Treatment / Control Sites		
	Morgan Creek / New Hope Creek Arms		Haw River Arm
	CPF086CUPS / CPF081A1B	**CPF086C / CPF081A1C**	**CPF055C / CPF055C1**
10/8/14	84%	92%	94%
11/25/14	75%	93%	51%
12/30/14	56%	89%	85%
1/27/15	57%	83%	71%
2/11/15	-	92%	79%
3/24/15	74%	72%	69%
4/22/15	87%	76%	81%
5/6/15	65%	66%	58%
5/20/15	85%	84%	69%
6/10/15	78%	91%	44%
6/22/15	88%	73%	80%
7/7/15	95%	94%	93%
7/23/15	95%	93%	94%
8/6/15	62%	97%	93%
8/24/15	97%	94%	79%
9/9/15	93%	92%	27%
9/24/15	-	89%	15%
10/12/15	94%	86%	45%
11/12/15	89%	96%	83%
12/7/15	76%	82%	76%
1/27/16	65%	84%	65%
2/17/16	86%	82%	82%
3/3/16	73%	86%	67%
4/6/16	78%	83%	61%
Average Similarity	**80%**	**86%**	**69%**

Cyanobacteria and Chlorophyta comparisons between project treatment and control sites

Results indicate no statistical differences in relative abundances of blue-green algae and green algae at the three project treatment vs control site comparisons.

The relative abundances, a proportion of the total algal density that is made up by one group, of algal groups Cyanobacteria (blue-green algae) and Chlorophyta (green algae) were separately analyzed for the three pairs of treatment versus control sites from October 2014 through April 2016, which was within the SolarBee study period. The objective of this analysis is to determine if SolarBees have shifted the proportional make-up of the algal community by way of statistically significant lower blue-green algae relative abundances (a group of algae in which some species can produce toxins) and subsequently higher green algae relative abundances compared to control sites. A p-value of less than 0.05 indicates a statistically significant difference among sites, with 95% confidence.

Blue-green algae and green algae relative abundances were not significantly different at any of the three project treatment versus control site comparisons (Table 8). Blue-green algae mean relative abundances at all SolarBee treatment sites were close to or slightly higher than at control sites. Additionally, this algal group dominated community composition at all Morgan Creek and New Hope Creek sites the majority of the 18 month time period, representing more than 50% of the algal community and as much as 97% (Figures 12 and 13). Blue-green algae did not dominate community composition as often in the Haw River sites (Figure 14). Green algae mean relative abundances ranged from 15% to 26% for the six sites with no consistent treatment versus control pattern.

Table 8. Cyanobacteria and Chlorophyta t-test details including sites within each group, algal group tested, test result, and result interpretation
(p <0.05= significant difference)

| Comparison pair #	Group 1: treatment site	Group 2: control site	Algal group	Total number of samples	p-value test result	Interpretation
1	CPF086CUPS (Morgan Creek)	CPF081A1B (New Hope Creek)	Cyanobacteria (blue-green algae)	44	0.42	no difference
			Chlorophyta (green algae)	44	0.77	no difference
2	CPF086C (Morgan Creek)	CPF081A1C (New Hope Creek)	Cyanobacteria (blue-green algae)	48	0.88	no difference
			Chlorophyta (green algae)	48	0.60	no difference
3	CPF055C (Haw River)	CPF055C1 (Haw River)	Cyanobacteria (blue-green algae)	48	0.42	no difference
			Chlorophyta (green algae)	48	0.14	no difference

Figure 12. Comparison pair #1 of **A)** Cyanobacteria (blue-green algae) and **B)** Chlorophyta (green algae) relative abundances of a treatment site in Morgan Creek (CPF086CUPS) and a control site in New Hope Creek (CPF081A1B) with Jordan Lake, used in t-tests.

A)

B)
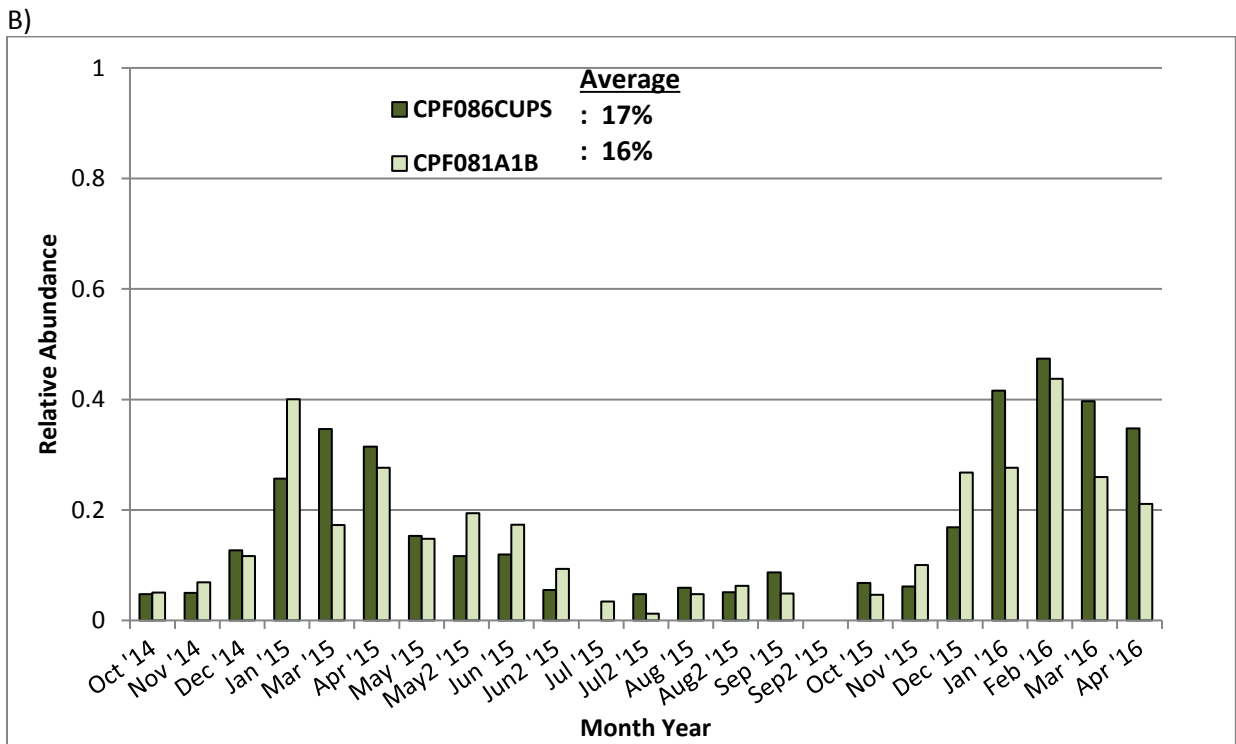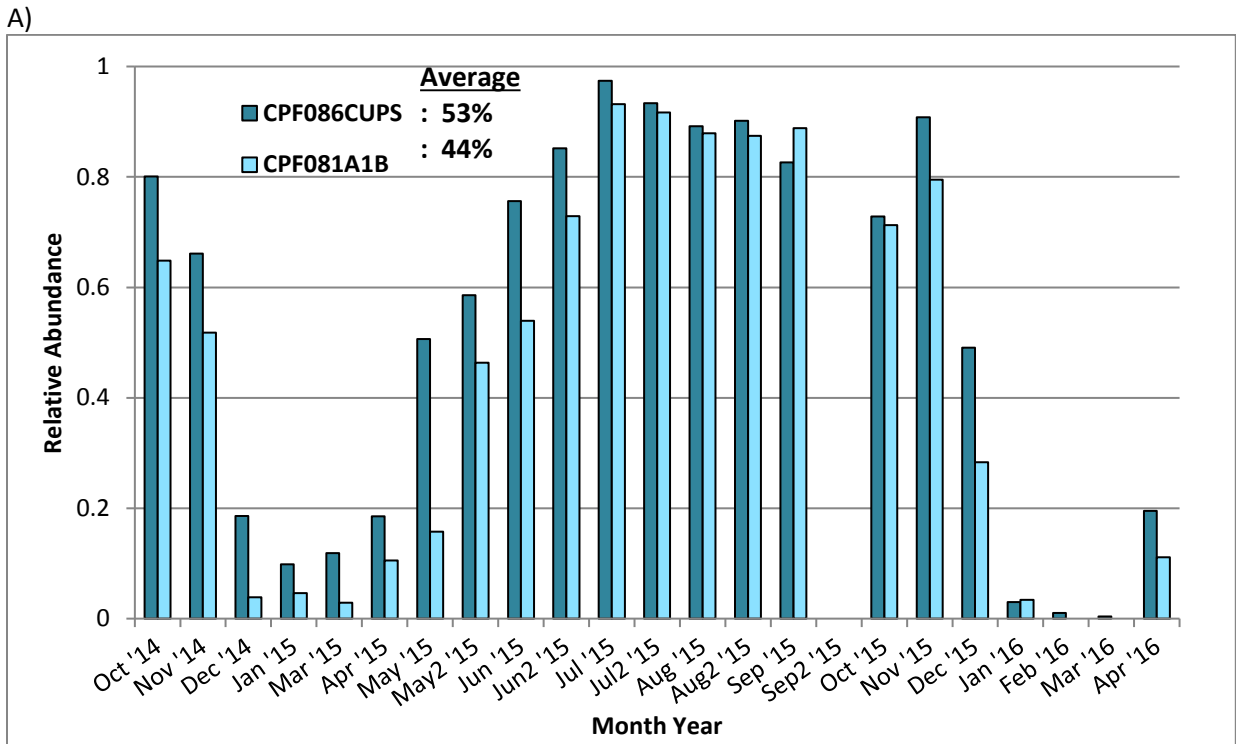
Figure 13. Comparison Pair #2 of **A)** Cyanobacteria (blue-green algae) and **B)** Chlorophyta (green algae) relative abundances of a treatment site in Morgan Creek (CPF086C) and a control site in New Hope Creek (CPF081A1C) within Jordan Lake, used in t-tests.

A)

B)
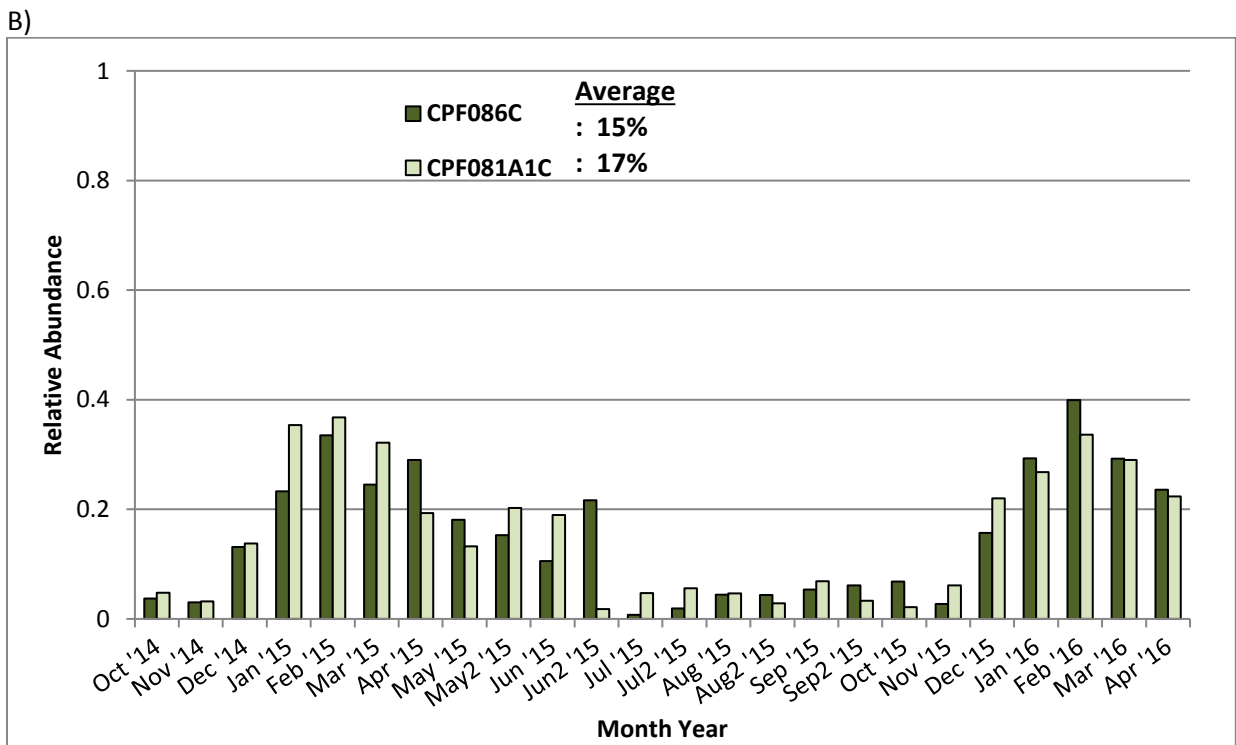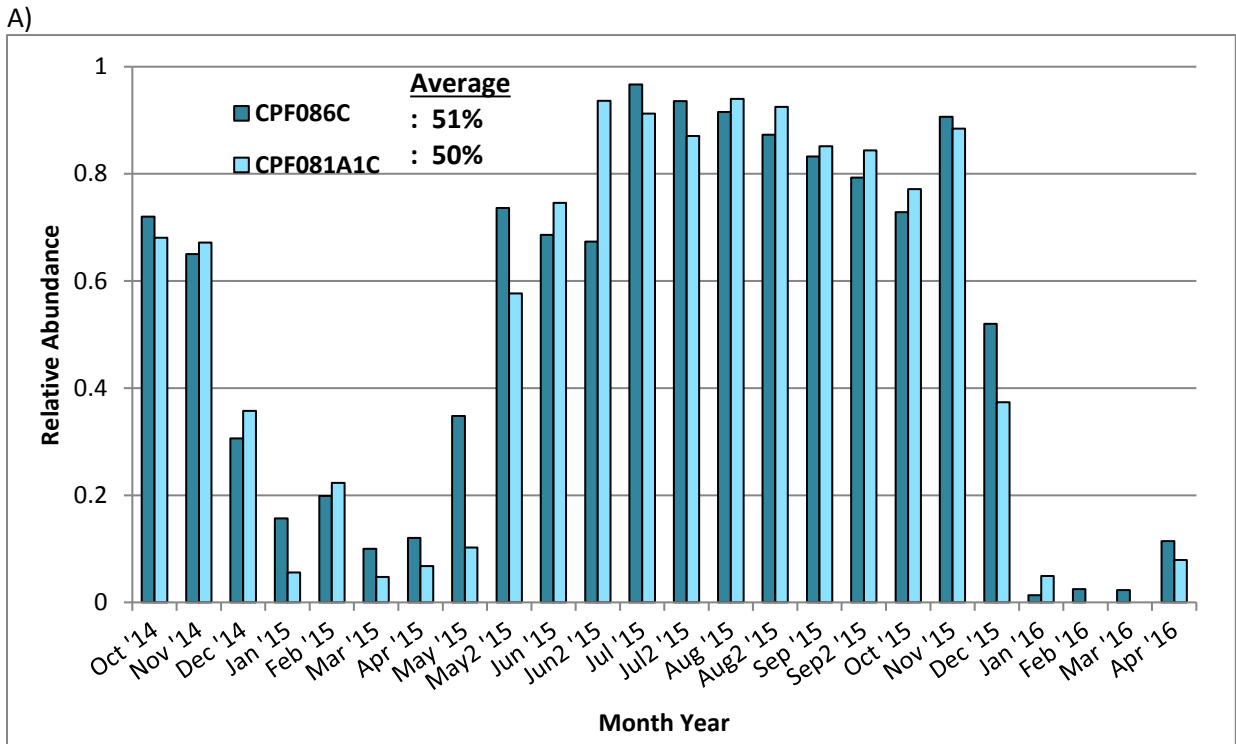
Figure 14. Comparison Pair #3 of **A)** Cyanobacteria (blue-green algae) and **B)** Chlorophyta (green algae) relative abundances of a treatment (CPF055C) and a control (CPF055C1) site in Jordan Lake Haw River Arm, used in t-tests.

A)

B)
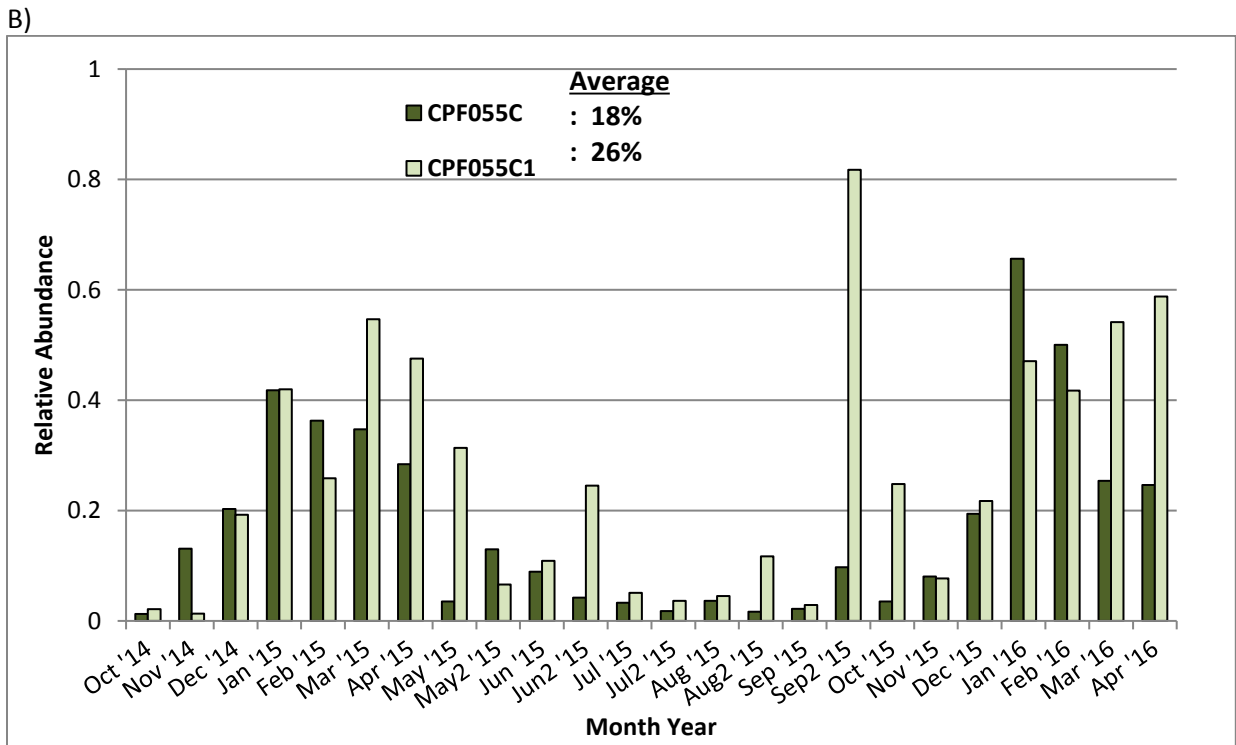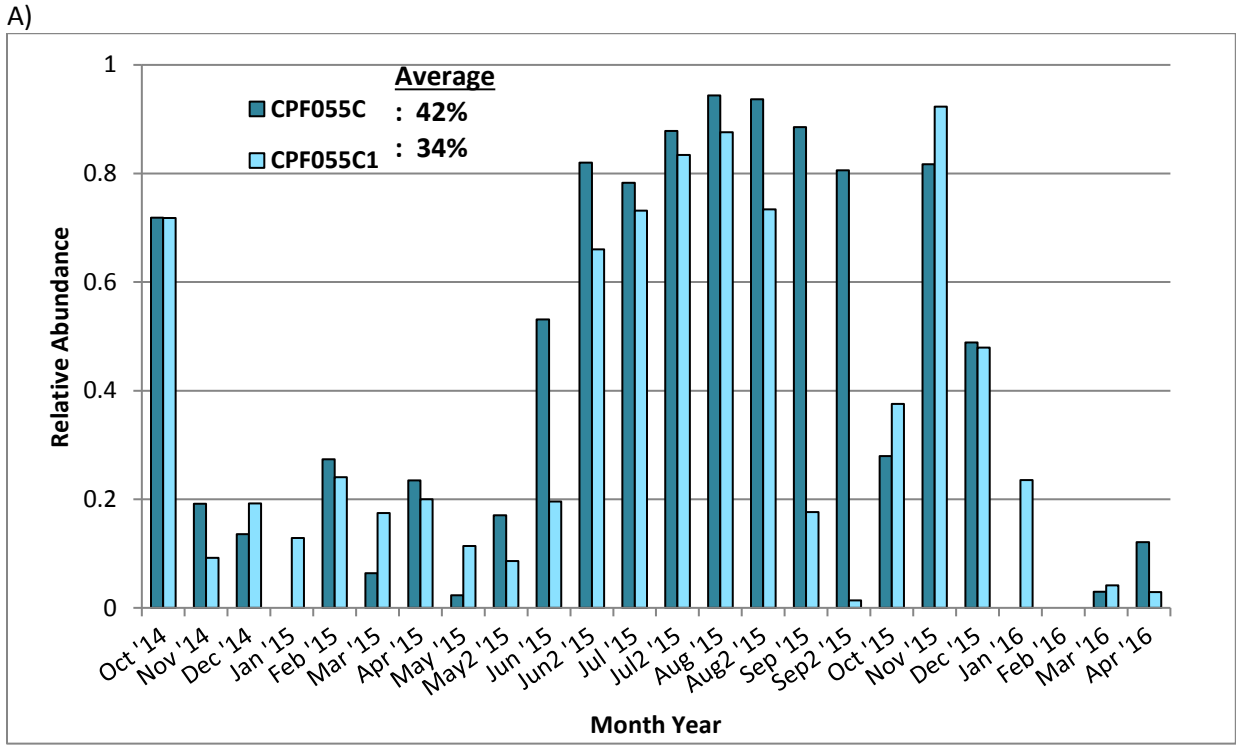
Summary

Comparisons to historical data indicates that project term conditions in Morgan Creek and Haw River arms of Jordan Lake for pH and chlorophyll *a* (Chl *a*) are similar to, and well within normal annual variability. Statistical comparison of these values indicate a percent change of 2.1% or less from historical data to SolarBee project period data. Comparisons of values at all SolarBee treatment areas versus control sites during SolarBee deployment indicate no statistically significant differences in pH and Chl *a*, with the exception of higher Chl *a* concentrations at the Haw River project site compared to its control site. These preliminary results indicate that nutrient related water quality conditions did not significantly improve in areas of the lake where SolarBees were deployed.

Phytoplankton community composition was similar at all pairs of treatment versus control sites during the study period, averaging from 69% to 86% similar. Furthermore, there were no statistical differences in relative abundances of blue-green algae and green algae at the three project treatment versus control site comparisons. These preliminary results indicate that a shift in phytoplankton community composition did not occur exclusively at sites where SolarBees were deployed.

This study is ongoing and data collected after April 2016 will be included in future assessments of the demonstration project. Results for the study are still considered to be preliminary estimates due to the limited project period, inherent environmental variability, and the extension of the project through 2018.

Appendix 1. *Comparison of long-term Jordan Lake sampling sites to proximal sites in New Hope Creek, Morgan Creek, and Haw River arms for pH and Chl a*

Statistical t-tests were performed to analyze differences in mean pH and chlorophyll *a* separately between two groups, in this case a long term site compared to a group of proximal sites (Table 1). Each test consisted of average monthly data from one long term site and average monthly data pooled from corresponding proximal sites from July 2013 through April 2016. A p-value test result of < 0.05 indicates significant differences among groups. Mean pH and Chl *a* at the long term site was not significantly different than the collective proximal site mean at New Hope Creek, Morgan Creek, as well as Haw River arms of Jordan Lake.

Table 1. T-test details including sites within each group, parameter tested, test result, and result interpretation (p <0.05= significant difference)

Jordan Lake arm	Group 1: long term site	Group 2: proximal site(s)	Parameter	Total number of samples	p-value test result	Interpretation
New Hope Creek	CPF081A1C	CPF081A1B	pH	67	0.93	no difference
			Chl *a*	67	0.94	no difference
Morgan Creek	CPF086C	CPF086CUPS, CPFMC02, CPFMC03, CPFMC04	pH	67	0.63	no difference
			Chl *a*	68	0.64	no difference
Haw River	CPF055C	CPF055C2, CPF055C3, CPF055C4, CPF055C5, CPF055C6	pH	68	0.82	no difference
			Chl *a*	68	0.77	no difference

Figure 1. A) pH and B) Chl *a* values and group means between a long term site and grouped proximal sites in each of the three Jordan Lake arms, used in t-tests
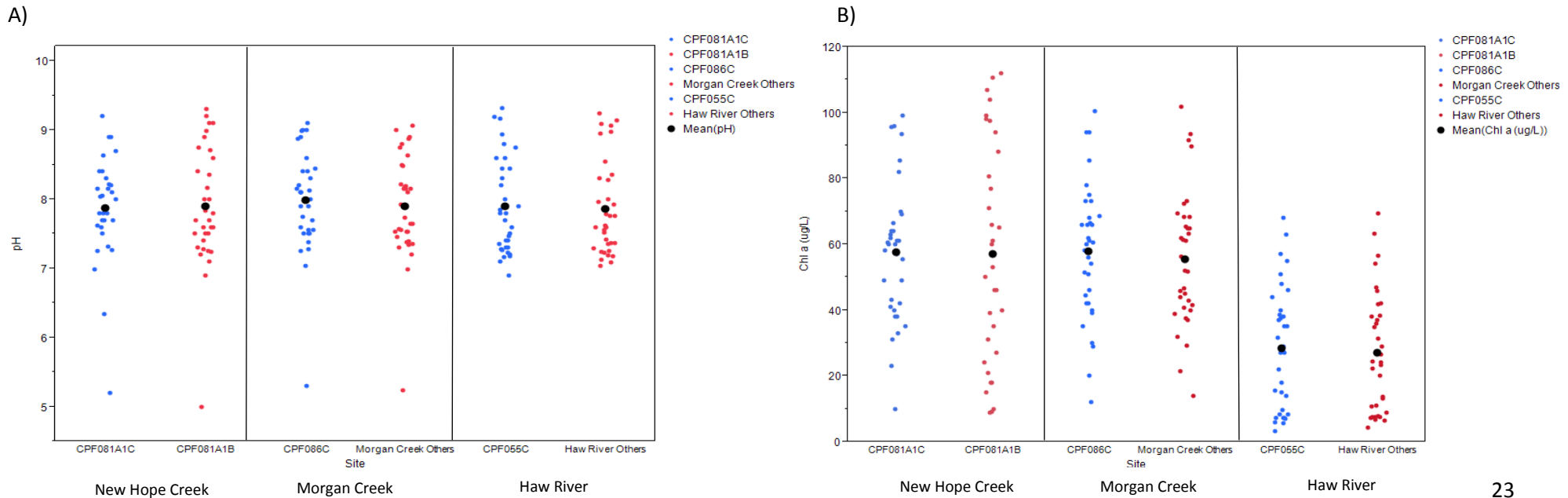
Appendix 2. *Jordan Lake rainfall and discharge data from USACE and USGS stream gages*

Rainfall events in middle to late April 2015 for the entirety of Jordan Lake are listed in Figure 1 with corresponding water in-flow and out-flow rates. The NC Division of Water Resources sampled the lake on 4-22-2015 when the outflow was recorded at 4613 cubic feet per second. Discharges in the Haw River arm of Jordan Lake are substantially higher than those of Morgan Creek and New Hope Creek arms (Figure 2) due to having a larger catchment basin. However, stark increases in discharge are evident in all three Lake arms despite scale, which may contribute to changes in physical lake parameters such as pH.

Figure 1. U.S. Army Corps of Engineers Wilmington District Rainfall totals and average inflows and outflows from the B. Everett Jordan Project.

Date	Rainfall (inches)	In-flow (cfs)	Outflow (cfs)
4-10-2015	**2.20**	**4950**	1348
4-11-2015	0.00	1934	2720
4-12-2015	0.00	1068	2747
4-13-2015	0.00	736	2611
4-14-2015	0.00	1162	2514
4-15-2015	**0.93**	1579	1988
4-16-2015	**0.55**	2353	2614
4-17-2015	**0.31**	2651	2986
4-18-2015	0.01	1887	2505
4-19-2015	**0.41**	2897	1487
4-20-2015	**0.73**	**11837**	496
4-21-2015	0.00	**9104**	2165
4-22-2015 (NCDWR sampling event)	0.00	3770	**4613**

Figure 2. USGS discharge gage data at New Hope Creek, Morgan Creek, and Haw River during the SolarBee project period, August 2014 to August 2015