2016

CARLYLE LAKE

WATER QUALITY

REPORT

U.S. ARMY CORPS OF ENGINEERS, ST. LOUIS DISTRICT
ENVIRONMENTAL QUALITY SECTION – WATER QUALITY

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Executive Summary

The purpose of this report is to provide an annual analysis of the water quality in the lake for the past year. Carlyle Lake is located in south central Illinois, approximately 50 miles east of St. Louis, Missouri. The lake is 12 miles long and is 1 to 3 miles wide and has approximately 26,000 acres of water surface at summer pool. The lake shoreline is 83 miles and there are approximately 11,000 acres of public land managed primarily by the Corps of Engineers. The lake is located on the Kaskaskia River at river mile 94.2 upstream from its confluence with the Mississippi River and approximately ½ mile upstream of the town of Carlyle.

With the exception of high phosphate and total suspended solids levels, the water of Carlyle Lake and the downstream river channel is generally good or within acceptable limits as recommended by the State of Illinois. The lake is a shallow reservoir susceptible to high winds. These conditions prevent the lake from stratifying permanently during the summer months. During low discharge in the heat of the summer fish kills have occurred in the old river channel below the dam due to low dissolved oxygen levels. Several years ago a remote sensor was installed on the spillway wall to allow project and water quality personnel to remotely monitor temperature and oxygen readings to avoid such fish kills by changing the release rate. No fish kills were observed during this past year.

All sampling sites met the appropriate state standards during 2016 except lake phosphorous levels and total suspended solids levels. No beach bacteria samples exceeded the state standard. Phosphorous levels have exceeded the state standard on a routine basis. The project area has several pollution potentials, with agriculture being the major contributor, but at present time, no major form of degradation to the lake or streams is apparent. Constant water quality monitoring will continue to check future degradation of the watershed.

WATER QUALITY MONITORING PROGRAM

1.0 GENERAL OVERVIEW

This report summarizes water quality activities of the St. Louis District for Fiscal Year 2016 in accordance with ER 1110-2-8154 Water Quality & Environmental management for Corps Civil Works Projects and ETL 1110-2-362 Environmental Engineering Initiatives for Water Management. According to the U.S. Environmental Protection Agency (USEPA) high levels of nutrients and poor lakeshore habitat are some of the most significant problems in our nation's lakes. Shoreline vegetation provides shelter for aquatic wildlife and reduces sediment and nutrient movement. The biology of a lake is characterized by the diversity of its organisms. The number and kinds of plant and animal species present is a direct measure of a lake's well-being. Water quality at Carlyle Lake is directly assessed using stream and lake data from 5 site locations (see figure 1).

Water quality monitoring remains one of the Section's major responsibilities in the area of environmental stewardship. The objective is to maintain a reasonable environmental monitoring program for the Mississippi River and the 5 lakes under the St. Louis District's control. The District's reservoirs consist of Mark Twain and Wappapello Lakes in Missouri, and Shelbyville, Carlyle and Rend Lakes in Illinois. Water quality sampling is conducted within the lakes and their tributaries to establish trend analysis and to maintain water quality at or above state and federal regulations.

The main objective is to provide technical expertise of an environmental nature to all Corps elements requesting assistance in accordance with ER 1110-2-8154. This would include updating the water quality management priorities for the district's projects to ensure water quality meets the state and federal regulations for protection of human health and the environment and for the safety and economic welfare of those at Corps projects. Ongoing goals include ensuring that downstream water quality meets all state and federal regulations, is suitable for aquatic and human life, and to continue to evaluate trend analysis in relation to baseline conditions at all projects.

Water quality data is provided to the Illinois Environmental Protection Agency (IEPA) to be used in the Illinois Integrated Water Quality Report which is required every two years by the Clean Water Act Sections 303(d) and 305(b). IEPA does not typically monitor the three Corps lakes in Illinois. However, IEPA has stated that since the Corps lakes are the 3 largest lakes in the state, it is critical that their quality be routinely assessed. The state indicated that having the federally collected water quality data available now and in the future is critical to the state of Illinois meeting their mission in complying with the Clean Water Act Sections 305(b) and 303(d).

The National Water Quality Inventory Report to Congress 305(b) report is the primary vehicle for informing Congress and the public about general water quality conditions in the United States. This document characterizes our water quality, identifies widespread water quality problems of national significance, and describes various programs implemented to restore and protect our waters.

Under Section 303(d) of the 1972 Clean Water Act, states, territories and authorized tribes are required to develop a list of water quality limited segments. These waters on the list do not meet water quality standards, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for water on the lists and develop action plans, called Total Maximum Daily Loads (TMDL), to improve water quality.

Currently the IEPA has listed Carlyle Lake as impaired for Total Suspended Solids (TSS), Total Phosphorous, and mercury. The lists of sources for these impairments are contaminated sediments, crop production, and unknown sources. The Kaskaskia River is impaired by the above parameters as well as many others. Continued monitoring of the lake and its tributaries is vital in assisting the future assessment of the lake for these and other possible impairments. The water quality monitoring program represents the single metric that encompasses the overall health of the watershed as it is a direct measure of how well the environmental stewardship programs are working.

1.1 INTRODUCTION

Carlyle Lake is within the Kaskaskia River Basin in central Illinois. The lake serves as a heavy recreational usage lake and supplies water to numerous communities. The land surrounding the lake is used predominately for agriculture. Surrounding communities have existing industrial/commercial operations as well as residential communities which discharge wastewater into municipal wastewater treatment plants that ultimately discharge treated water into the Kaskaskia River Basin. Agricultural runoff and municipal wastewater treatment facilities are the primary potential source of pollution into the Carlyle Lake watershed. Additional sources are marinas, recreational watercraft discharges and effluent from nearby subdivisions and a golf course.

Water quality monitoring was conducted during 2016 to assure safe conditions for human recreation, wildlife and aquatic life as maintained and managed within the lake system. Previous to 2009 five sampling events were conducted during the recreational season. In the initial phase of the sampling program during the 1970s and 80s six or seven sampling events were conducted. A restored number of sampling events would provide the ability to better evaluate water quality trends, to better defend project operations (lake levels, releases, maintenance projects, construction projects, etc.), to better confirm that we meet state water quality standards, and to better confirm that human health and safety are adequately protected. Three sampling events were conducted at five sites. The sampling sites include the following: Site 1 (Car-1) Spillway, Site 2 (Car-02) Lake side in front of Dam, Site 4 (Car-04) Keyesport, Site 13 (Car-13) Kaskaskia River at bridge on route 900, and Site 12 (Car-12) Cox Bridge. During the sampling period one site was selected for quality control duplication and denoted as CAR-15. The locations of the five sampling sites are depicted on the lake map in Figure 1. In 2014, it was decided to replace Car-9 at Vandalia with another site closer to the lake. Car-13 (Route 900N bridge over Kaskaskia River) was substituted for Car-9 at Vandalia. This tributary site was chosen to provide a site closer to the lake which included additional tributaries. This site provides a better opportunity to monitor water quality coming directly into Carlyle Lake from the Kaskaskia River and its tributaries.

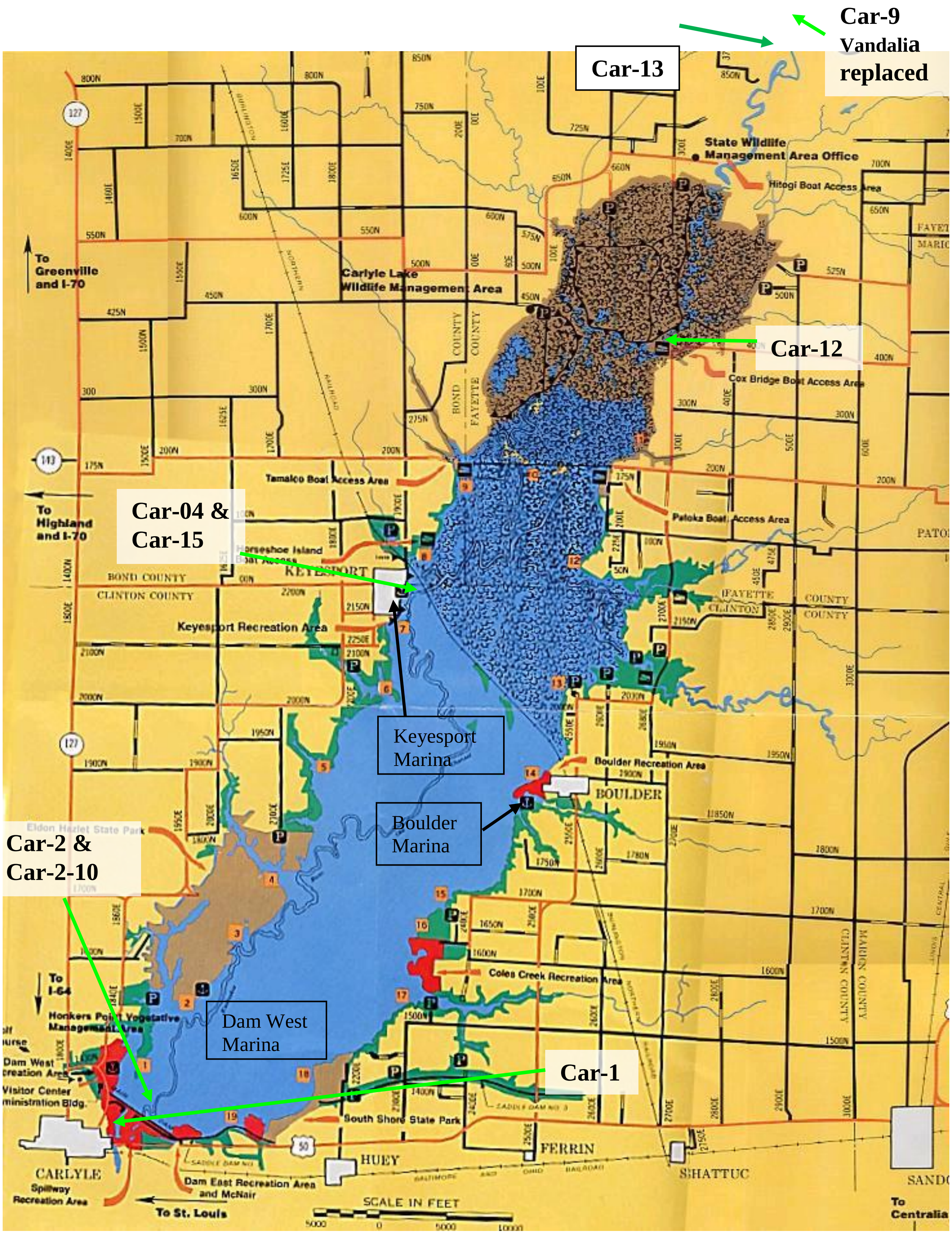


Figure 1. Location of sample sites.
In 2014 Car 13 replaced Car 9

2.0 WATER QUALITY ASSESSMENT CRITERIA

The water quality assessment criteria, which have been generally accepted criteria for sustaining adequate aquatic plant and animal growth, were based upon the State of Illinois regulatory limits for certain contaminants. The sampling and analysis which were conducted at the Carlyle Lake sites reflect the minimal set of parameters needed to analyze the current status of water quality for the Carlyle Lake system.

The following parameters were analyzed in the Fiscal Year 2016 sampling at Carlyle Lake: Total Organic Carbon (TOC), iron, manganese, ammonia-nitrogen, nitrate-nitrogen, orthophosphate, total phosphate, Total Suspended Solids (TSS), Total Volatile Suspended Solids (TVSS), Escherichia . coli (E. coli), pH, temperature, dissolved oxygen, specific conductance, oxidation-reduction potential (ORP), chlorophyll, pheophytin-a, atrazine, alachlor, chlorpyrifos, cyanazine, metolachlor, metribuzin, trifluralin, and pendmathalin.

2.1 WATER

The Illinois Environmental Protection Agency in Title 35, Subtitle, C, classifies water quality criteria based on end usage. Subpart B contains regulations for general use water, while subparts C and D delineate those for public and food processing water and secondary contact and indigenous aquatic life standards, respectively. These standards are used to determine the aquatic water quality of the lake. Table 2.1 provides a listing of the regulatory limits where a limit has been established for the parameters analyzed.

TABLE 2.1

State of Illinois
Water Quality Standards

PARAMETER	LIMIT
Temperature	Rise of 2.8°C above normal seasonal temp
Ammonia Nitrogen	15 mg/L
Nitrate Nitrogen	10 mg/L
Total Iron	2.0 mg/L (2nd Contact & Aquatic Life)
Manganese	1.0 mg/L
Total Phosphate	0.05 mg/L Lakes; 0.61 mg/L Streams
E. Coli	Illinois standard is 235 E. coli per 100ml for single sample or 126 for geometric mean.
pH	Range: 6.5 to 9.0
DO	> 5.0 mg/L
Conductivity	1,667 *u*S/cm≈TDS of 1,000 mg/L
Total Suspended Solids (TSS)	116mg/L (Streams); >=12mg/L (Lakes)
Atrazine	0.003 mg/L[1]; 82ug/L[2]; 9ug/L[3]
Alachlor	0.002 mg/L (Drinking Water Standard)
Chlorpyrifos	10ug/L[1]
Cyanazine	370ug/L Acute; 30ug/L[3]
Metolachlor	1.7mg/L[2]

Metribuzin	200ug/L[1] 91ug/L HRL
Simazine	4.0ug/L [1]
Trifluralin	26ug/L Acute; 1.1ug/L[3]
Pendmethalin (PROWL)	70ug/L HBSL, 20ug/L[1]

[1] Drinking Water Standard
[2] Acute
[3] Chronic
Health Based Screening Level (HBSL)
Health Reference Level (HRL)

Nitrogen is an essential component of proteins, genetic material, chlorophyll, and other key organic molecules. All organisms require nitrogen in order to survive. Nitrogen exists in several forms. These forms include gaseous nitrogen (N_2), nitrites (NO_2), nitrate (NO_3), ammonia nitrogen (NH_3-N), and ammonium (NH_4). Ammonia can be toxic to fish and other aquatic organisms at certain levels. Unlike ammonia, ammonium (NH4) is not toxic to aquatic organisms and is readily available for uptake by plankton and macrophytes. Nitrogen levels have increased as human activities have accelerated the rate of fixed nitrogen being put into circulation. High nitrogen levels can cause eutrophication. Eutrophication increases biomass of phytoplankton, decreases water transparency, and causes oxygen depletion. Ammonia nitrogen is monitored so that the effects on fish spawning, hatching, growth rate and pathologic changes in gills, liver and kidney tissue can be related to the detected levels of ammonia nitrogen. Nitrate-nitrogen degrades to nitrite or produces ammonia which has a detrimental effect on aquatic life and, therefore, has been monitored to assure levels are below the regulatory "safe" limit.

Phosphate has been analyzed as phosphorus and has been monitored due to the potential for uptake by nuisance algae. Levels of phosphate can indicate the potential for rapid growth of algae (algae bloom) which can cause serious oxygen depletion during the algae decay process. Phosphorous is typically the limiting nutrient in a water body. Therefore, addition of phosphorous to the ecosystem stimulates the growth of plants and algae. Phosphorous is delivered to lakes and streams by way of storm water runoff from agricultural fields, residential property, and construction sites. Other sources of phosphorous are anaerobic (absent of oxygen) decomposition of organic matter, leaking sewer systems, waterfowl, and point source pollution. The general standard for phosphorous in lake water is 0.05mg/L. Dissolved phosphorous, also called ortho-phosphorous, is generally found in much smaller concentrations than total phosphorous and is readily available for uptake. For this reason dissolved phosphorous concentrations are variable and difficult to use as an indicator of nutrient availability.

The metals manganese and iron are nutrients for both plants and animals. Living organisms require trace amounts of metals. However, excessive amounts can be harmful to the organism. Heavy metals exist in surface waters in three forms: colloidal, particulate, and dissolved. Water chemistry determines the rate of adsorption and desorption of metals to and from sediment. Metals are desorbed from the sediment if the water experiences increases in salinity, decreases in redox potential, or decreases in pH. Metals in surface waters can be from natural or human sources. Currently human sources contribute more metals than natural sources. Metal levels in surface water may pose a health risk to humans and the environment.

Photosynthetic activity can be hindered by the levels of total suspended solids. Total suspended solids concentrations, which cause the photosynthetic activity to be reduced by more than 10% from the seasonably established norm, can have a detrimental effect on aquatic life. Soil particles, organic material, and other debris comprise suspended solids in the water column. Secchi disk measurements are inverse to suspended solid measurements. As total suspended solids (TSS) increase, the secchi disk depth or water transparency decreases. Total suspended solids can be an important indicator of the type and degree of turbidity. TSS measurements represent a combination volatile suspended solids (VSS), that consist of organic material, and nonvolatile suspended solids (NVSS), which are comprised of inorganic mineral particles in the water. In order to more accurately determine the types and amounts of suspended solids, VSS are analyzed. VSS concentration represents the organic portion of the total suspended solids. Organic material often includes plankton and additional plant and animal debris that is present in water. Total VSS indicates the presence of organics in suspension and, therefore, show additional demand levels of oxygen. Illinois does not currently have a standard for TSS or TVSS. However, IEPA literature suggests that NVSS above 15mg/L could highly impair recreational lake use. A NVSS of 3 to 7mg/L might cause slight impairment.

Chlorophyll and pheophytin-a are monitored to provide indicators of algae growth and, therefore, potential oxygen depletion activity. Chlorophyll is measured in lakes to estimate the type and amount of algal productivity in the water column. Chlorophyll *a* is present in green algae, blue-green algae, and in diatoms. Chlorophyll *a* is often used to indicate the degree of eutrophication. Chlorophyll *b* and *c* are used to estimate the extent of algal diversity and productivity. Chlorophyll *b* is common in green algae and is used as an auxiliary pigment for photosynthesis. Chlorophyll *c* is most common in diatom species and serves as an auxiliary pigment. Algal productivity and diversity can be determined by the concentrations of the individual pigments. For example high concentrations of chlorophyll *a* and *b* would indicate that green algae is abundant. High concentrations of chlorophyll *a* would indicate abundance of blue-green algae and high concentrations of chlorophyll *a* and *c* would indicate diatoms are the dominant species. Chlorophyll production is currently being connected with hypoxia. EPA's current guidance as of December 2016 for recreational Ambient Water Quality Criteria (AWQC) for Cyanotoxins is 4ug/L for microcystins and 8ug/L for Cylindrospermopsin.

Fecal coliform bacteria is monitored for the protection of human health as it relates to full body contact of recreational waters. People can be exposed to disease-causing organisms, such as bacteria, viruses and protozoa in beach and recreational waters mainly through accidental ingestion of contaminated water or through skin contact. These organisms, called pathogens, usually come from the feces of humans and other warm-blooded animals. If taken into the body, pathogens can cause various illnesses and on rare occasions, even death. Waterborne illnesses include diseases resulting from bacterial infections such as cholera, salmonellosis, and gastroenteritis; viral infections such as hepatitis, gastroenteritis, and intestinal diseases; and protozoan infections such as ameobic dysentery and giardiasis. The most commonly monitored recreational water indicator organisms are fecal coliform, Escherichia coli (E. coli) and enterococci. Fecal coliform are bacteria that live in the intestinal tracts of warm-blooded animals. The standard for fecal coliform is less than 235 colonies per 100ml per single sample water or geometric mean of 126 colonies per 100ml. Fecal coliform was originally recommended in 1968 by the Federal Water Pollution Control Administration (predecessor to the EPA) as an effective water quality indicator organism for recreational waters. Recent studies indicate that fecal coliform show less correlation to illness than other indicator organisms such as E.

coli and enterococci. The EPA currently recommends E. coli or enterococci as an indicator organism for fresh waters. Since 2009 the St. Louis District has been using E. coli as the standard indicator.

Atrazine and Alachlor herbicides are commonly used agricultural chemicals which can be readily transported by rainfall runoff. Both compounds are suspected of causing cancer and therefore were monitored for the protection of human and aquatic health. Organic compounds include many pesticides. A pesticide can be any substance that is intended to prevent, destroy, repel, or mitigate any pest. This includes insecticides, herbicides, fungicides, fumigants, algaecides and other substances. Herbicides which are pesticides used to kill vegetation are the most widely used and sampled. Ten of the most frequently used herbicides detected in water are Atrazine, Metolachlor, Alachlor, 2,4-D, Trifluralin, Glyphosate, Dicamba, Cyanazine, Simazine, and 2,4,5-T. Two of the most widely used pesticides are Atrazine and Alachlor. Atrazine is a preemergence or postemergence herbicide use to control broadleaf weeds and annual grasses. Atrazine is most commonly detected in ground and surface water due to its wide use and its ability to persist in soil and move in water. Alachlor is a Restricted Use Pesticide (RUP) due to the potential to contaminate groundwater. The drinking water standard for Atrazine is 0.003mg/L and 0.002 mg/L for Alachlor.

Temperature, dissolved oxygen and pH are monitored for the protection of aquatic life. Temperature is important because it controls several aspects of water quality. Colder water holds more dissolved oxygen which is required by aquatic organisms. Plants grow more rapidly and use more oxygen in warmer water. Decomposition of organic matter which uses oxygen is accelerated in warmer water. Temperature can also determine the availability of toxic compounds such as ammonia. Since aquatic organisms are cold blooded, water temperature regulates their metabolism and ability to survive. The number and kinds of organisms that are found in streams or lakes is directly related to temperature. Certain organisms require a specific temperature range, such as trout, which require water temperatures below 20^oC. Most aquatic organisms require a minimum concentration of dissolved oxygen to survive (5 mg/l or above). In spring, surface waters of the lake mix with the water below by wind and thermal action. This mixing diminishes as the upper layer of water becomes warmer and less dense. Solar insulation during the summer months stratifies the lake into three zones. The upper warmer water zone is called the epilimnion and the lower cooler water zone is called the hypolimnion. The epilimnion and the hypolimnion zones are divided by a transition zone known as the metalimnion. A rapid change in temperature within the metalimnion occurs and is referred to as a thermocline. During the summer months the hypolimnion may become anaerobic. In this anaerobic zone, chemical reduction of iron and manganese or the production of methane and sulfides can occur. Iron rapidly oxidizes in aerobic environments, but manganese oxidizes slowly and can remain in the reduced state for long distances downstream even in aerobic environments. The degree of acidity of water is measured by a logarithmic scale ranging from 0 to 14 and is known as the pH scale. A reading of 7 indicates a neutral pH while readings below seven are acidic and above are alkaline. Most Illinois lakes range from 6 to 9 on the pH scale. If a body of water is alkaline, then it has the ability to act as a buffer which can neutralize incoming acidic conditions. A high alkalinity concentration indicates an increased ability to neutralize pH and resist changes, whereas a low alkalinity concentration indicates that a water body is vulnerable to changes in pH.

Conductivity is a measure of water’s ability to conduct an electrical current. The ability to carry a current is often driven by the dissolved materials present in a water column. These materials can include dissolved ions and other materials in the water and thus are directly proportional to the concentration of total dissolved solids (TDS) present in the water column. Typically TDS concentrations represent 50-60% of the conductivity measurements. Conductivity is also affected by water temperature. The warmer the water, the higher the conductivity. Conductivity in streams and rivers is affected by the geology of the area. Streams running through granite areas tend to have lower conductivity due to granite being composed of inert material, materials that do not ionize or dissolve into ionic compounds in water. Conversely, streams that run through areas of limestone or clay soils tend to have higher conductivity readings because of the presence of materials that ionize. Conductivity is useful as a general measure of water quality. A stream tends to have a relatively constant range of conductivity that once established can be used as a baseline. Significant changes, either high or low, might indicate that a source of pollution has been introduced into the water. The pollution source could be a treatment plant, which raises the conductivity, or an oil spill, which would lower the conductivity.

Redox or Oxidation-Reduction Potential (ORP) is a measurement of oxygen reduction activity. Oxidation involves an exchange of electrons between 2 atoms. The atom that loses an electron is oxidized and the one that gains an electron is reduced. ORP sensors measure the electrochemical potential between the solution and a reference electrode. Readings are expressed in millivolts. Positive readings indicate increased oxidizing potential while negative readings indicate increased reduction. The ORP probe is essentially a millivolt meter, measuring the voltage across 2 electrodes with the water in between. ORP values are used much like pH values to determine water quality. While pH readings characterize the state of a system relative to the receiving or donating hydrogen ions (base or acid), ORP readings characterize the relative state of losing or gaining electrons. The conversion of ammonia (NH_3) requires an oxidating environment to convert it into nitrites (NO_2) and nitrates (NO_3). Ammonia levels as low as 0.002mg/L can be harmful to fish. Generally ORP readings above 400mV are harmful to aquatic life. However, ORP is a non-specific measurement which is a reflection of a combination of effects of all the dissolved materials in the water. Therefore, the measurement of ORP in relatively clean water has only limited utility unless a predominant redox-active material is known to be present.

Water clarity is intuitively used by the public to judge water quality. Secchi depth has been used for many years as a limnological characterization tool for characterizing water clarity. Secchi depth is a measure of light penetration into a waterbody and is a function of the absorption and scattering of light in the water. There are three characteristics of water which affect the penetration of light: (1) color of water, (2) amount of phytoplankton in the water column, and (3) amount of inorganic material in the water column. Secchi depth integrates the combined impacts of all three of these factors. Water transparency was measured using a Secchi disk. Secchi disk readings were taken at all lake sites.

2.2 Sediment

In accordance with EM-1110-2-1201, sediment samples should be taken to monitor and assess potential impacts to aquatic and human health. To assess ecological risk, sample values are compared against toxicity information published in the National Oceanic Atmospheric Administrations (NOAA) Screening Quick Reference Tables (SQRT) or similar references for ecological receptors in freshwater sediment. Without standards or other widely applicable numerical tools, NOAA scientists found it difficult to estimate the possible toxicological significance of chemical concentrations in sediment. Therefore, numerical sediment quality guidelines (SQG's) were developed as informal, interpretive tools. The SQGs were not promulgated as regulatory standards, but rather as informal, non-regulatory guidelines for interpreting chemical data from analyses of sediments. For potential ecological risk from inorganic contaminants, seven metals are typically of "most concern" with regards to fish and wildlife: Arsenic, Copper, Cadmium, Selenium, Mercury, Lead, and Zinc. Avian species are thought to be particularly sensitive to arsenic, which is considered a carcinogenic, mutagenic, and teratogenic contaminant in a variety of species in elevated doses over time. Avian species are also known to be particularly sensitive to lead in the environment with effects ranging from mortality, reduced growth and reproductive output, behavior changes, blood chemistry alterations, and lesions of major organs. Finally, the embryo stages in fish and avian species are known to be the most sensitive to selenium affecting reproductive success.

For potential human health risk, there are no known values in Illinois for sediments. While not a direct correlation, sample results are compared against Illinois Tiered Approach to Corrective Action Objectives (TACO) and Non-TACO lowest default target levels for all soil types and exposure pathways for soils.

3.0 SUMMARY OF MONITORING RESULTS

3.1 Water Quality Summary

The monitoring program for Carlyle Lake during Fiscal Year 2016 revealed overall good water quality when compared to limits established by the IEPA for general use, secondary contact, and indigenous aquatic life. Water quality trends on a yearly basis are hard to determine when only conducting 3-4 sampling events. However, over the course of a 5 year period these 3-4 sampling events per year are adequate to determine trends in water quality. Agricultural nutrient runoffs were primary concerns for the lake's water quality. Better land management practices, erosion control and buffering zones are methods used to reduce such contaminants from entering the lake.

E. coli are sampled at the marinas to ensure that the marina areas are not being contaminated by boats with restroom facilities. E. coli levels at the marinas did not exceeded the Illinois standard of 235 mpn/100ml for a single sample. The project office is notified as soon as any readings not meeting standards are received. E. coli beach data was received from the project office. No beach samples were above the Illinois standard.

Total iron and total manganese are sampled above the dam near the bottom of the channel (Car-2-10) and in the spillway area (Car-1). As previously stated living organisms require trace amounts of metals; however, excessive amounts can be harmful to the organism. Iron and Manganese were found to be below the Illinois contact and aquatic life Water Quality Standard at sites Car-1 and Car-2-10.

Nitrogen and phosphates are sampled at all sites. In 2016 nitrogen levels recorded were well within the state water quality standards (ammonia nitrogen = 15mg/l, nitrate nitrogen = 10mg/l). As in the past several years, the 2016 phosphate results at all lake sites are above the 0.05 mg/L standard. Because phosphorus in water is not considered directly toxic to humans and animals, no drinking water standards have been established for phosphorus. However, phosphorus can cause health threats through the stimulation of toxic algal blooms and the resulting oxygen depletion. Nitrates can pose a threat to human and animal health. Nitrate in water is toxic at high levels and has been linked to toxic effects of livestock and to blue baby disease (methemoglobinemia) in infants. The Maximum Contaminant Level (MCL) for nitrate-N in drinking water is 10mg/L to protect babies 3 to 6 months of age. The Illinois Water Quality Standard for ammonia nitrogen (NH_3-N) is 15mg/L. The increased levels of phosphate in combination with nitrogen and other lake conditions, such as temperature, pH and stagnant lake conditions, can lead to increased algae growth. Eutrophication is currently the most widespread water quality problem in the U.S. and many other countries. Restoration of eutrophic waters requires the reduction of nonpoint inputs of phosphorous and nitrogen. The resulting detrimental effects of algae toxins and oxygen depletion could result in health problems for fish and other aquatic species as well as land animals utilizing the water supply. There was an algal bloom reported near Boulder Marina on June 12, 2015 and cyanobacteria wsa confirmed. However, in 2016 no algal blooms were reported.

Chlorophyll *a* was sampled at 3 sites, Car-2, Car-4, (Car-15 is a duplicate sample at site Car-4) and Car-12. Illinois does not currently have a standard for chlorophyll. The data indicates a normal increase in chlorophyll levels during the warmer summer months, which is not a concern. Chlorophyll *a* is a green pigment found in plants. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass. They can be an effective measure of trophic status and used as a measure of water quality. High levels often indicate poor water quality and low levels suggest good conditions. However, elevated levels are not necessarily bad. It is the long term persistence of elevated levels that can lead to problems. It is natural for chlorophyll *a* levels to fluctuate over time. Chlorophyll *a* tends to be higher after storm events and during the summer months when water temperatures and light levels are elevated. Chlorophyll can reduce the clarity of the water and the amount of oxygen available to other organisms. Chlorophyll is monitored to provide indicators of algae growth and, therefore, potential oxygen depletion activity. Chlorophyll concentrations and cyanobacteria cell counts serve as proxies for the actual presence of algal toxins. Exposure to cyanobacteria or their toxins may produce allergic reactions such as skin rashes, eye irritations, respiratory symptoms, and in some cases more severe health effects. Microcystin is currently believed to be the most common cyanotoxin in lakes. EPA's current guidance as of December 2016 for recreational Ambient Water Quality Criteria (AWQC) for Cyanotoxins is 4ug/L for microcystins and 8ug/L for Cylindrospermopsin. Carlyle Lake was in the moderate risk of exposure category for chlorophyll.

Atrazine and Alachlor are pesticides that were sampled at all sites. These chemicals are herbicides used to control weed growth. Sampling did not indicate any elevated pesticide levels. Cyanizine, Metolachlor, Trifluralin and Simazine were also analyzed as part of the pesticide screening. The Carlyle Lake watershed consists of approximately 75% cropland. These substances can enter water bodies as a result of drift during spraying, surface runoff, and leaching through soil. In order to eliminate pesticide contamination of waters it is important for the public to be educated and institute best management practices when using these chemicals.

Total Suspended Solids (TSS) and Total Volatile Suspended Solids (TVSS) samples are collected at all sites. CAR-13 exceeded the TSS Illinois standard for streams on 4 August 2015. All lake sites except site 2 exceeded the Illinois standard for TSS in lakes at least once during the recreation season. Solids can affect water quality by increasing temperature through the absorption of sunlight by the particles in the water, which also effects the clarity of the water. This can then effect the amount of oxygen in the water. Illinois guidelines for identifying potential causes of impairment of aquatic life in lakes list a TSS above 12mg/L could impair recreational lake use and a TSS of 116mg/L may cause impairment of streams. Data indicates that sediment settles out as it travels down the lake.

Total Organic Carbon (TOC) is collected at all sites. Data indicates that early in the year TOC is higher in the upper portions of the lake. TOC is an indicator of the organic character of water. The larger the carbon or organic content, the more oxygen is consumed. This may be a result of plant material, which had grown all summer and begins to decay. Illinois does not currently have a standard for TOC. Since Illinois does not have a standard for this parameter, observations of high or low are relative to the current sampling period.

Temperature and dissolved oxygen levels were taken at all sites. See Appendix C graphs C1-C3. Measurements were taken at 1 meter intervals at the lake sites. During the summer months the lake stratifies and a boundary is formed between the upper warmer water and the lower cooler water. This transition area is known as the thermocline, the area where the temperature drops significantly. Oxygen levels can also change drastically as a function of depth. This area where the oxygen level significantly drops is called the oxycline. The depth of the thermocline and oxycline can have an effect on the aquatic organisms. Occasionally the thermocline and oxycline are at or near the same depth.

pH is taken at all sites and at 1 meter intervals at lake sites. All sites were within the Illinois standard of 6 to 9 pH range. Variances in pH can be caused by increase runoff due to a rainfall event, unusual temperature extremes, or erosion from land disturbances. Another cause may be that photosynthesis uses up dissolved carbon dioxide, which acts like carbonic acid (H_2CO_3) in water. CO_2 removal in effect reduces the acidity of the water thus the pH increases.

Conductivity and redox are taken at all sites and at 1 meter intervals at lake sites. Illinois does not currently have a standard for redox, but does have a standard of less than 1,667 uS/cm for conductivity. No samples exceeded this standard.

Secchi disk readings indicate that as the water travels down the lake it becomes clearer. This is most likely the result of sediments dropping out of the water column as the water moves down stream toward the dam.

The remote sensor in the spillway was monitored and maintained throughout the year to allow the project as well as water quality personnel to remotely monitor temperature and oxygen readings to acquire data to inform operational actions in order to avoid fish kills. During low flow, water is discharged through the sluice gates from the bottom of the lake. This water is low in oxygen and can create a low oxygen area below the dam. The sensor allows the project to track oxygen levels below the dam and make appropriate adjustments to avoid a possible fish kill. Normally allowing water to spill through the tainter gates will alleviate low oxygen levels below the dam. No fish kills were observed this year. The sonde was serviced approximately once each month from May through September. Dissolved oxygen did drop below the 5mg/l standard in June, August, and September due to the algae build up on the probe.

3.2 Sediment Summary

Sediment sampling was not conducted in 2016. Sediment sampling is normally conducted every 5 years if funding is available. Sediment sampling was last conducted in 2007.

It is recommended that the next round of sediment samples focus on organochlorines in freshwater sediment to assess potential chronic aquatic impacts (e.g. aldrin, chlordane, endrin, endosulfan, DDT, methoxychlor) as well as metals, nitrates, and phosphates.

4.0 PLANNED 2017 STUDIES

The Carlyle Lake water quality monitoring will continue in Fiscal Year 2017 in much the same way as 2016. The 2017 monitoring schedule will include one additional sampling event compared to 2016 for a total of four. Carlyle Lake provides water supplies to many communities and is a high usage recreational lake. The monitoring of water quality is imperative to assure the water quality is within acceptable limits for the designated usage.

The sampling sites include the following: Site 1 (Car-1) Spillway, Site 2 (Car-02) Lake side in front of Dam, Site 4 (Car-04) Keyesport, Site 13 (Car-13) Kaskaskia River at bridge on route 900, and Site 12 (Car-12) Cox Bridge. This combination of sites effectively represents the incoming contaminants and their effects on the lake.

Sediment sampling may be conducted if the schedule allows and funding is available. If sediment sampling does not occur, it is recommended for 2018.

In addition, water quality personnel will continue to maintain and remotely monitor the DO & temperature probe in the spillway.

5.0 OTHER STUDIES

In 2015 a study was conducted (Pearce et al) at Carlyle Lake to investigate the internal nutrient dynamics to ascertain the potential for sedimentary nutrients to stimulate harmful algal blooms. This thesis has been published in the journal of Science of the Total Environment in 2017, '*Characterizing nutrient distributions and fluxes in a eutrophic reservoir, Midwestern United States'*. The abstract is quoted below.

Abstract

"Harmful algal blooms are increasingly common in aquatic ecosystems and have been linked to runoff from agricultural land. This study investigated the internal nutrient (i.e., phosphorus (P) and nitrogen (N)) dynamics of a eutrophic reservoir in the Midwestern United States to constrain the potential for sedimentary nutrients to stimulate harmful algal blooms. The spatial distribution of nutrients in the water column (soluble reactive P (SRP), nitrate/nitrite-N (NOx-N), and ammonium-N (NH4 +-N)) and sediments (total P, total carbon (C), total N, and organic matter (OM)) were quantified and mapped. Water column nutrients varied spatially and temporally, with generally higher concentrations near the dam wall during normal lake levels. The upper portion of the lake, near the inlet, was sampled during a flood event and had overall higher nutrient concentrations and lower chlorophyll levels compared to normal lake level samples. Mean sedimentary total P (936mg/kg) was ~30% higher in the reservoir than the surrounding upland soils, with the highest concentrations near the dam wall (1661mg/kg) and a significant positive correlation found between sedimentary total P, total C, and OM. Additionally, 15 intact sediment cores were manipulated ex situ to examine mechanisms of nutrient flux across the sediment-water interface (SWI) that may trigger algal blooms. Core treatment conditions included advection (i.e., simulating potential nutrient fluxes during wind events through sediment resuspension) and diffusion. Core experiments indicated both advective and diffusive conditions at the SWI may trigger the flux of nutrients important for algal growth from lake sediments, with diffusion contributing both N and P to the water column, while intense advection increased water column N, but decreased P. Release of P to the water column may be more diffusion-driven than advection-driven, whereas N release to the water column appears to be both diffusion- and advection-driven."

Pearce concludes that 'algal activity could be favored under most conditions in the lake'. "Large inputs of N to the water column during advection due to a wind storm could stimulate algae, which would then assimilate the nutrients until the water column is relatively depleted. This depletion would then stimulate a diffusion gradient, where stored N and P could be drawn up and continue to feed algal blooms. Our characterization of the behavior of nutrients under diffusive and advective conditions could allow reservoir managers to forecast the extent of nutrient release and the possible impacts on water quality and chemistry." EC-EQ recognizes that, due to the physical characteristics and agricultural inputs, Carlyle Lake is eutrophic and therefore prone to algal blooms. Given the findings of this study we now have evidence that suggests that most conditions at Carlyle favor algal blooms and that there is a good possibility bloom events will be perpetuated for extended periods due to the positive feedback loop scenario described above These findings allow us to better understand the potential causes and extent of future algal blooms at Carlyle Lake.

APPENDIX A

DATA
LAB DATA

LAB DATA

Site #	Collection Date	Parameter	Flag	Reported Result	MDL	PQL	Units
CAR-1	4/14/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Alachlor	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Alachlor	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Alachlor	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Alachlor	<	0.22	0.22	0.22	UG/L
CAR-4	4/14/2016	Alachlor	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Alachlor	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Alachlor	<	0.20	0.20	0.20	UG/L
CAR-1	4/14/2016	Ammonia Nitrogen		0.14	0.030	0.030	MG/L
CAR-1	6/21/2016	Ammonia Nitrogen		0.19	0.030	0.030	MG/L
CAR-1	9/13/2016	Ammonia Nitrogen		0.12	0.030	0.030	MG/L
CAR-12	4/14/2016	Ammonia Nitrogen		0.18	0.030	0.030	MG/L
CAR-12	6/21/2016	Ammonia Nitrogen		0.065	0.030	0.030	MG/L
CAR-12	9/13/2016	Ammonia Nitrogen		0.18	0.030	0.030	MG/L
CAR-13	6/21/2016	Ammonia Nitrogen		0.071	0.030	0.030	MG/L
CAR-13	9/13/2016	Ammonia Nitrogen		0.25	0.030	0.030	MG/L
CAR-15	4/14/2016	Ammonia Nitrogen		0.18	0.030	0.030	MG/L
CAR-15	6/21/2016	Ammonia Nitrogen		0.062	0.030	0.030	MG/L
CAR-15	9/13/2016	Ammonia Nitrogen		0.12	0.030	0.030	MG/L
CAR-2-0	4/14/2016	Ammonia Nitrogen		0.088	0.030	0.030	MG/L
CAR-2-0	6/21/2016	Ammonia Nitrogen		0.042	0.030	0.030	MG/L
CAR-2-0	9/13/2016	Ammonia Nitrogen		0.13	0.030	0.030	MG/L
CAR-2-10	4/14/2016	Ammonia Nitrogen		0.080	0.030	0.030	MG/L
CAR-2-10	6/21/2016	Ammonia Nitrogen		0.38	0.030	0.030	MG/L
CAR-2-10	9/13/2016	Ammonia Nitrogen		0.13	0.030	0.030	MG/L
CAR-4	4/14/2016	Ammonia Nitrogen		0.16	0.030	0.030	MG/L
CAR-4	6/21/2016	Ammonia Nitrogen		0.12	0.030	0.030	MG/L
CAR-4	9/13/2016	Ammonia Nitrogen		0.056	0.030	0.030	MG/L
CAR-1	4/14/2016	Atrazine	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Atrazine		0.70	0.21	0.21	UG/L
CAR-1	9/13/2016	Atrazine		0.42	0.22	0.22	UG/L
CAR-12	4/14/2016	Atrazine		1.3	0.21	0.21	UG/L
CAR-12	6/21/2016	Atrazine		0.90	0.22	0.22	UG/L
CAR-12	9/13/2016	Atrazine	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Atrazine		0.81	0.21	0.21	UG/L
CAR-13	9/13/2016	Atrazine		0.49	0.22	0.22	UG/L
CAR-15	4/14/2016	Atrazine		1.3	0.20	0.20	UG/L
CAR-15	6/21/2016	Atrazine		1.6	0.21	0.21	UG/L

CAR-15	9/13/2016	Atrazine	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Atrazine	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Atrazine		0.73	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Atrazine		0.39	0.22	0.22	UG/L
CAR-4	4/14/2016	Atrazine		1.3	0.20	0.20	UG/L
CAR-4	6/21/2016	Atrazine		1.6	0.21	0.21	UG/L
CAR-4	9/13/2016	Atrazine	<	0.20	0.20	0.20	UG/L
CAR-12	4/14/2016	Chlorophyll a		12.8	2.0	2.0	MG/CU.M.
CAR-12	6/21/2016	Chlorophyll a		18.2	2.0	2.0	MG/CU.M.
CAR-12	9/13/2016	Chlorophyll a		64.1	2.0	2.0	MG/CU.M.
CAR-15	4/14/2016	Chlorophyll a		17.1	2.0	2.0	MG/CU.M.
CAR-15	6/21/2016	Chlorophyll a		98.3	2.0	2.0	MG/CU.M.
CAR-15	9/13/2016	Chlorophyll a		74.8	2.0	2.0	MG/CU.M.
CAR-2-0	4/14/2016	Chlorophyll a		78.3	2.0	2.0	MG/CU.M.
CAR-2-0	6/21/2016	Chlorophyll a		79.0	2.0	2.0	MG/CU.M.
CAR-2-0	9/13/2016	Chlorophyll a		37.6	2.0	2.0	MG/CU.M.
CAR-4	4/14/2016	Chlorophyll a		17.1	2.0	2.0	MG/CU.M.
CAR-4	6/21/2016	Chlorophyll a		105	2.0	2.0	MG/CU.M.
CAR-4	9/13/2016	Chlorophyll a		69.9	2.0	2.0	MG/CU.M.
CAR-1	4/14/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Chlorpyrifos	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Chlorpyrifos	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Chlorpyrifos	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Chlorpyrifos	<	0.22	0.22	0.22	UG/L
CAR-4	4/14/2016	Chlorpyrifos	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Chlorpyrifos	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Chlorpyrifos	<	0.20	0.20	0.20	UG/L
CAR-1	4/14/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Cyanazine	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Cyanazine	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Cyanazine	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Cyanazine	<	0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Cyanazine	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Cyanazine	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Cyanazine	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Cyanazine	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Cyanazine	<	0.22	0.22	0.22	UG/L

CAR-4	4/14/2016	Cyanazine	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Cyanazine	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Cyanazine	<	0.20	0.20	0.20	UG/L
CAR-BL-MARINA	6/21/2016	E. Coliform		71.0	1.0	1.0	COL/100 ML
CAR-BL-MARINA	9/13/2016	E. Coliform		25.0	1.0	1.0	COL/100 ML
CAR-DW-MARINA	6/21/2016	E. Coliform		19.0	1.0	1.0	COL/100 ML
CAR-DW-MARINA	9/13/2016	E. Coliform		175	1.0	1.0	COL/100 ML
CAR-KP-MARINA	6/21/2016	E. Coliform		71.0	1.0	1.0	COL/100 ML
CAR-KP-MARINA	9/13/2016	E. Coliform		75.0	1.0	1.0	COL/100 ML
CAR-1	4/14/2016	Iron		1.3	0.050	0.10	MG/L
CAR-1	6/21/2016	Iron		0.48	0.050	0.10	MG/L
CAR-1	9/13/2016	Iron		0.72	0.050	0.10	MG/L
CAR-2-10	4/14/2016	Iron		1.2	0.050	0.10	MG/L
CAR-2-10	6/21/2016	Iron		0.38	0.050	0.10	MG/L
CAR-2-10	9/13/2016	Iron		0.90	0.050	0.10	MG/L
CAR-1	4/14/2016	Manganese		0.12	0.0050	0.010	MG/L
CAR-1	6/21/2016	Manganese		0.26	0.0050	0.010	MG/L
CAR-1	9/13/2016	Manganese		0.16	0.0050	0.010	MG/L
CAR-2-10	4/14/2016	Manganese		0.11	0.0050	0.010	MG/L
CAR-2-10	6/21/2016	Manganese		0.22	0.0050	0.010	MG/L
CAR-2-10	9/13/2016	Manganese		0.19	0.0050	0.010	MG/L
CAR-1	4/14/2016	Metolachlor	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Metolachlor		1.8	0.21	0.21	UG/L
CAR-1	9/13/2016	Metolachlor		0.39	0.22	0.22	UG/L
CAR-12	4/14/2016	Metolachlor		0.36	0.21	0.21	UG/L
CAR-12	6/21/2016	Metolachlor		1.0	0.22	0.22	UG/L
CAR-12	9/13/2016	Metolachlor	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Metolachlor		0.87	0.21	0.21	UG/L
CAR-13	9/13/2016	Metolachlor		0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Metolachlor		0.33	0.20	0.20	UG/L
CAR-15	6/21/2016	Metolachlor		2.9	0.21	0.21	UG/L
CAR-15	9/13/2016	Metolachlor	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Metolachlor	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Metolachlor		1.9	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Metolachlor		0.38	0.22	0.22	UG/L
CAR-4	4/14/2016	Metolachlor		0.38	0.20	0.20	UG/L
CAR-4	6/21/2016	Metolachlor		2.8	0.21	0.21	UG/L
CAR-4	9/13/2016	Metolachlor	<	0.20	0.20	0.20	UG/L
CAR-1	4/14/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Metribuzin	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Metribuzin	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Metribuzin	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Metribuzin	<	0.22	0.22	0.22	UG/L

CAR-15	4/14/2016	Metribuzin	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Metribuzin	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Metribuzin	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Metribuzin	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Metribuzin	<	0.22	0.22	0.22	UG/L
CAR-4	4/14/2016	Metribuzin	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Metribuzin	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Metribuzin	<	0.20	0.20	0.20	UG/L
CAR-1	4/14/2016	Nitrate as Nitrogen		1.7	0.040	0.040	MG/L
CAR-1	6/21/2016	Nitrate as Nitrogen		0.15	0.040	0.040	MG/L
CAR-1	9/13/2016	Nitrate as Nitrogen		0.22	0.040	0.040	MG/L
CAR-12	4/14/2016	Nitrate as Nitrogen		2.1	0.040	0.040	MG/L
CAR-12	6/21/2016	Nitrate as Nitrogen		6.6	0.10	0.10	MG/L
CAR-12	9/13/2016	Nitrate as Nitrogen		1.1	0.040	0.040	MG/L
CAR-13	6/21/2016	Nitrate as Nitrogen		6.6	0.10	0.10	MG/L
CAR-13	9/13/2016	Nitrate as Nitrogen		0.97	0.040	0.040	MG/L
CAR-15	4/14/2016	Nitrate as Nitrogen		1.2	0.040	0.040	MG/L
CAR-15	6/21/2016	Nitrate as Nitrogen		1.3	0.040	0.040	MG/L
CAR-15	9/13/2016	Nitrate as Nitrogen		0.12	0.040	0.040	MG/L
CAR-2-0	4/14/2016	Nitrate as Nitrogen		1.8	0.040	0.040	MG/L
CAR-2-0	6/21/2016	Nitrate as Nitrogen		0.070	0.040	0.040	MG/L
CAR-2-0	9/13/2016	Nitrate as Nitrogen		0.21	0.040	0.040	MG/L
CAR-2-10	4/14/2016	Nitrate as Nitrogen		1.8	0.040	0.040	MG/L
CAR-2-10	6/21/2016	Nitrate as Nitrogen		0.069	0.040	0.040	MG/L
CAR-2-10	9/13/2016	Nitrate as Nitrogen		0.20	0.040	0.040	MG/L
CAR-4	4/14/2016	Nitrate as Nitrogen		1.3	0.040	0.040	MG/L
CAR-4	6/21/2016	Nitrate as Nitrogen		1.3	0.040	0.040	MG/L
CAR-4	9/13/2016	Nitrate as Nitrogen		0.10	0.040	0.040	MG/L
CAR-1	4/14/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Pendimethalin	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Pendimethalin	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Pendimethalin	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Pendimethalin	<	0.22	0.22	0.22	UG/L
CAR-4	4/14/2016	Pendimethalin	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Pendimethalin	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Pendimethalin	<	0.20	0.20	0.20	UG/L
CAR-12	4/14/2016	Pheophytin a		2.1	2.0	2.0	MG/CU.M.
CAR-12	6/21/2016	Pheophytin a		3.5	2.0	2.0	MG/CU.M.
CAR-12	9/13/2016	Pheophytin a		10.7	2.0	2.0	MG/CU.M.
CAR-15	4/14/2016	Pheophytin a	<	2.0	2.0	2.0	MG/CU.M.

CAR-15	6/21/2016	Pheophytin a		25.8	2.0	2.0	MG/CU.M.
CAR-15	9/13/2016	Pheophytin a		12.0	2.0	2.0	MG/CU.M.
CAR-2-0	4/14/2016	Pheophytin a		11.4	2.0	2.0	MG/CU.M.
CAR-2-0	6/21/2016	Pheophytin a		19.7	2.0	2.0	MG/CU.M.
CAR-2-0	9/13/2016	Pheophytin a		12.6	2.0	2.0	MG/CU.M.
CAR-4	4/14/2016	Pheophytin a		5.3	2.0	2.0	MG/CU.M.
CAR-4	6/21/2016	Pheophytin a		7.5	2.0	2.0	MG/CU.M.
CAR-4	9/13/2016	Pheophytin a		13.0	2.0	2.0	MG/CU.M.
CAR-1	4/14/2016	Phosphorus		0.25	0.010	0.010	MG/L
CAR-1	6/21/2016	Phosphorus		0.25	0.010	0.010	MG/L
CAR-1	9/13/2016	Phosphorus		0.48	0.010	0.010	MG/L
CAR-12	4/14/2016	Phosphorus		0.61	0.010	0.010	MG/L
CAR-12	6/21/2016	Phosphorus		0.16	0.010	0.010	MG/L
CAR-12	9/13/2016	Phosphorus		0.38	0.010	0.010	MG/L
CAR-13	6/21/2016	Phosphorus		0.16	0.010	0.010	MG/L
CAR-13	9/13/2016	Phosphorus		0.32	0.010	0.010	MG/L
CAR-15	4/14/2016	Phosphorus		0.79	0.010	0.010	MG/L
CAR-15	6/21/2016	Phosphorus		0.29	0.010	0.010	MG/L
CAR-15	9/13/2016	Phosphorus		0.48	0.010	0.010	MG/L
CAR-2-0	4/14/2016	Phosphorus		0.25	0.010	0.010	MG/L
CAR-2-0	6/21/2016	Phosphorus		0.21	0.010	0.010	MG/L
CAR-2-0	9/13/2016	Phosphorus		0.47	0.010	0.010	MG/L
CAR-2-10	4/14/2016	Phosphorus		0.27	0.010	0.010	MG/L
CAR-2-10	6/21/2016	Phosphorus		0.23	0.010	0.010	MG/L
CAR-2-10	9/13/2016	Phosphorus		0.49	0.010	0.010	MG/L
CAR-4	4/14/2016	Phosphorus		0.75	0.010	0.010	MG/L
CAR-4	6/21/2016	Phosphorus		0.30	0.010	0.010	MG/L
CAR-4	9/13/2016	Phosphorus		0.54	0.010	0.010	MG/L
CAR-1	4/14/2016	Phosphorus, -ortho		0.051	0.010	0.010	MG/L
CAR-1	6/21/2016	Phosphorus, -ortho		0.13	0.010	0.010	MG/L
CAR-1	9/13/2016	Phosphorus, -ortho		0.37	0.010	0.010	MG/L
CAR-12	4/14/2016	Phosphorus, -ortho		0.11	0.010	0.010	MG/L
CAR-12	6/21/2016	Phosphorus, -ortho		0.045	0.010	0.010	MG/L
CAR-12	9/13/2016	Phosphorus, -ortho		0.088	0.010	0.010	MG/L
CAR-13	6/21/2016	Phosphorus, -ortho		0.036	0.010	0.010	MG/L
CAR-13	9/13/2016	Phosphorus, -ortho		0.096	0.010	0.010	MG/L
CAR-15	4/14/2016	Phosphorus, -ortho		0.089	0.010	0.010	MG/L
CAR-15	6/21/2016	Phosphorus, -ortho		0.098	0.010	0.010	MG/L
CAR-15	9/13/2016	Phosphorus, -ortho		0.17	0.010	0.010	MG/L
CAR-2-0	4/14/2016	Phosphorus, -ortho		0.051	0.010	0.010	MG/L
CAR-2-0	6/21/2016	Phosphorus, -ortho		0.067	0.010	0.010	MG/L
CAR-2-0	9/13/2016	Phosphorus, -ortho		0.36	0.010	0.010	MG/L
CAR-2-10	4/14/2016	Phosphorus, -ortho		0.056	0.010	0.010	MG/L
CAR-2-10	6/21/2016	Phosphorus, -ortho		0.11	0.010	0.010	MG/L
CAR-2-10	9/13/2016	Phosphorus, -ortho		0.36	0.010	0.010	MG/L
CAR-4	4/14/2016	Phosphorus, -ortho		0.092	0.010	0.010	MG/L
CAR-4	6/21/2016	Phosphorus, -ortho		0.10	0.010	0.010	MG/L
CAR-4	9/13/2016	Phosphorus, -ortho		0.18	0.010	0.010	MG/L
CAR-1	4/14/2016	Solids, Total Suspended		33.5	5.0	5.0	MG/L
CAR-1	6/21/2016	Solids, Total Suspended		21.5	5.0	5.0	MG/L

CAR-1	9/13/2016	Solids, Total Suspended		22.0	3.3	3.3	MG/L
CAR-12	4/14/2016	Solids, Total Suspended		128	10.0	10.0	MG/L
CAR-12	6/21/2016	Solids, Total Suspended		54.0	6.7	6.7	MG/L
CAR-12	9/13/2016	Solids, Total Suspended		62.5	5.0	5.0	MG/L
CAR-13	6/21/2016	Solids, Total Suspended		65.5	5.0	5.0	MG/L
CAR-13	9/13/2016	Solids, Total Suspended		75.5	5.0	5.0	MG/L
CAR-15	4/14/2016	Solids, Total Suspended		139	10.0	10.0	MG/L
CAR-15	6/21/2016	Solids, Total Suspended		59.3	6.7	6.7	MG/L
CAR-15	9/13/2016	Solids, Total Suspended		62.0	5.0	5.0	MG/L
CAR-2-0	4/14/2016	Solids, Total Suspended		34.3	3.3	3.3	MG/L
CAR-2-0	6/21/2016	Solids, Total Suspended		14.5	5.0	5.0	MG/L
CAR-2-0	9/13/2016	Solids, Total Suspended		20.7	3.3	3.3	MG/L
CAR-2-10	4/14/2016	Solids, Total Suspended		32.5	5.0	5.0	MG/L
CAR-2-10	6/21/2016	Solids, Total Suspended		15.0	5.0	5.0	MG/L
CAR-2-10	9/13/2016	Solids, Total Suspended		26.2	3.8	3.8	MG/L
CAR-4	4/14/2016	Solids, Total Suspended		117	6.7	6.7	MG/L
CAR-4	6/21/2016	Solids, Total Suspended		60.7	6.7	6.7	MG/L
CAR-4	9/13/2016	Solids, Total Suspended		72.0	10.0	10.0	MG/L
CAR-1	4/14/2016	Solids, Volatile Suspended		6.0	5.0	5.0	MG/L
CAR-1	6/21/2016	Solids, Volatile Suspended		8.5	5.0	5.0	MG/L
CAR-1	9/13/2016	Solids, Volatile Suspended		5.0	3.3	3.3	MG/L
CAR-12	4/14/2016	Solids, Volatile Suspended		11.0	10.0	10.0	MG/L
CAR-12	6/21/2016	Solids, Volatile Suspended		8.7	6.7	6.7	MG/L
CAR-12	9/13/2016	Solids, Volatile Suspended		6.0	5.0	5.0	MG/L
CAR-13	6/21/2016	Solids, Volatile Suspended		10.0	5.0	5.0	MG/L
CAR-13	9/13/2016	Solids, Volatile Suspended		6.0	5.0	5.0	MG/L
CAR-15	4/14/2016	Solids, Volatile Suspended		14.0	10.0	10.0	MG/L
CAR-15	6/21/2016	Solids, Volatile Suspended		14.7	6.7	6.7	MG/L
CAR-15	9/13/2016	Solids, Volatile Suspended		8.5	5.0	5.0	MG/L
CAR-2-0	4/14/2016	Solids, Volatile Suspended		6.3	3.3	3.3	MG/L
CAR-2-0	6/21/2016	Solids, Volatile Suspended		9.5	5.0	5.0	MG/L
CAR-2-0	9/13/2016	Solids, Volatile Suspended		4.0	3.3	3.3	MG/L
CAR-2-10	4/14/2016	Solids, Volatile Suspended		6.0	5.0	5.0	MG/L
CAR-2-10	6/21/2016	Solids, Volatile Suspended		8.5	5.0	5.0	MG/L
CAR-2-10	9/13/2016	Solids, Volatile Suspended		4.6	3.8	3.8	MG/L
CAR-4	4/14/2016	Solids, Volatile Suspended		13.3	6.7	6.7	MG/L
CAR-4	6/21/2016	Solids, Volatile Suspended		14.7	6.7	6.7	MG/L
CAR-4	9/13/2016	Solids, Volatile Suspended	<	10.0	10.0	10.0	MG/L
CAR-1	4/14/2016	Total Organic Carbon		3.4	1.0	1.0	MG/L
CAR-1	6/21/2016	Total Organic Carbon		4.2	1.0	1.0	MG/L
CAR-1	9/13/2016	Total Organic Carbon		4.4	2.0	2.0	MG/L
CAR-12	4/14/2016	Total Organic Carbon		4.8	1.0	1.0	MG/L
CAR-12	6/21/2016	Total Organic Carbon		2.0	1.0	1.0	MG/L
CAR-12	9/13/2016	Total Organic Carbon		4.3	2.0	2.0	MG/L
CAR-13	6/21/2016	Total Organic Carbon		2.0	1.0	1.0	MG/L
CAR-13	9/13/2016	Total Organic Carbon		5.0	2.0	2.0	MG/L
CAR-15	4/14/2016	Total Organic Carbon		5.4	1.0	1.0	MG/L
CAR-15	6/21/2016	Total Organic Carbon		3.8	1.0	1.0	MG/L
CAR-15	9/13/2016	Total Organic Carbon		4.4	2.0	2.0	MG/L
CAR-2-0	4/14/2016	Total Organic Carbon		3.4	1.0	1.0	MG/L

CAR-2-0	6/21/2016	Total Organic Carbon		4.4	1.0	1.0	MG/L
CAR-2-0	9/13/2016	Total Organic Carbon		4.4	2.0	2.0	MG/L
CAR-2-10	4/14/2016	Total Organic Carbon		3.4	1.0	1.0	MG/L
CAR-2-10	6/21/2016	Total Organic Carbon		4.5	1.0	1.0	MG/L
CAR-2-10	9/13/2016	Total Organic Carbon		4.3	2.0	2.0	MG/L
CAR-4	4/14/2016	Total Organic Carbon		5.3	1.0	1.0	MG/L
CAR-4	6/21/2016	Total Organic Carbon		3.8	1.0	1.0	MG/L
CAR-4	9/13/2016	Total Organic Carbon		4.5	2.0	2.0	MG/L
CAR-1	4/14/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-1	6/21/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-1	9/13/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-12	4/14/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-12	6/21/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-12	9/13/2016	Trifluralin	<	0.20	0.20	0.20	UG/L
CAR-13	6/21/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-13	9/13/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-15	4/14/2016	Trifluralin	<	0.20	0.20	0.20	UG/L
CAR-15	6/21/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-15	9/13/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-2-0	4/14/2016	Trifluralin	<	0.25	0.25	0.25	UG/L
CAR-2-0	6/21/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-2-0	9/13/2016	Trifluralin	<	0.22	0.22	0.22	UG/L
CAR-4	4/14/2016	Trifluralin	<	0.20	0.20	0.20	UG/L
CAR-4	6/21/2016	Trifluralin	<	0.21	0.21	0.21	UG/L
CAR-4	9/13/2016	Trifluralin	<	0.20	0.20	0.20	UG/L

U Analyte was not detected
J Estimated value between Method Detection Limit (MDL) and Practical Quantitation Limit (PQL)

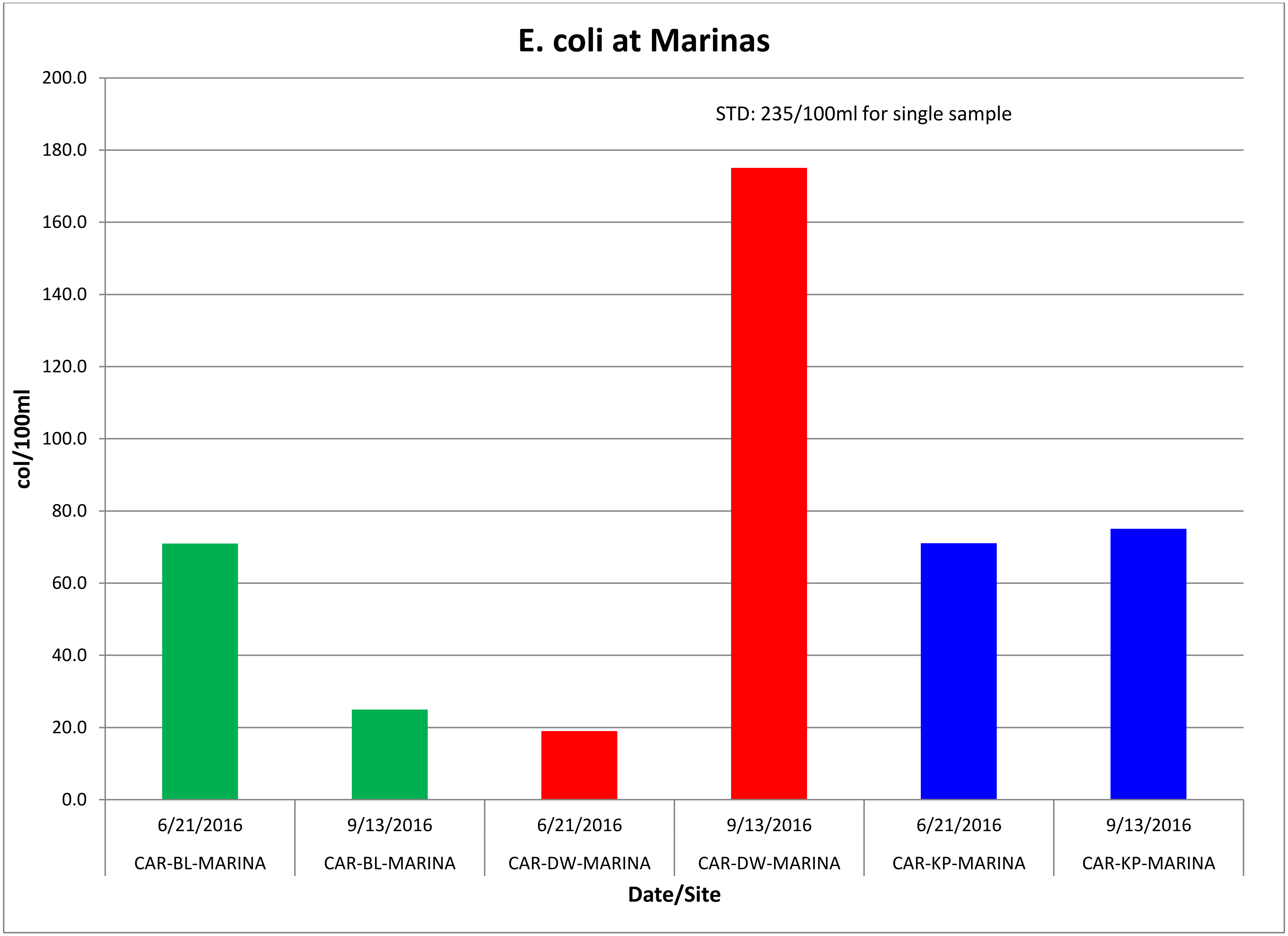
FIELD DATA

Site	Date	Depth (m)	Water Temp (^0C)	Redox (mv)	Cond (uS)	DO %	DO mg/l	pH	Time	Seechi (in)
CAR-1	4/14/2016	0.49	12.32	262	377	122	12.9	8.53	845	
CAR-1	6/21/2016	0.3	27.6	292	203	86.2	6.65	8.18	850	
CAR-1	9/13/2016	0.2	24.72	254	304	102	8.39	8.04	843	
CAR-13	6/21/2016	0.2	28.02	297	503	89.2	6.86	8.14	1145	
CAR-13	9/16/2016	0.4	22.29	193	377	73.7	6.32	7.72	1141	
CAR-12	4/14/2016	0.2	12.95	241	311	85.6	8.91	7.53	1230	
CAR-12	6/21/2016	0.1	28.19	296	502	88.1	6.77	8.1	1220	
CAR-12	9/13/2016	0.1	22.88	201	461	66.7	5.65	7.71	1221	
CAR-2	4/14/2016	0.3	12.26	227	383	124	13.15	8.55	920	10
CAR-2	4/14/2016	1	11.92	234	381	120	12.96	8.54		
CAR-2	4/14/2016	2	11.92	234	381	121	12.92	8.54		
CAR-2	4/14/2016	3	11.9	235	381	120	12.89	8.55		
CAR-2	4/14/2016	4	11.92	236	381	121	12.93	8.55		
CAR-2	4/14/2016	5	11.87	238	381	119	12.72	8.54		
CAR-2	4/14/2016	6	11.83	239	381	119.7	12.81	8.55		
CAR-2	6/21/2016	0.3	28.27	307	361	107.9	8.16	8.8	920	14.5
CAR-2	6/21/2016	1	28.28	302	362	106	8	8.8		
CAR-2	6/21/2016	2	28	301	363	94	7.25	8.73		
CAR-2	6/21/2016	3	28	300	364	89	6.8	8.7		
CAR-2	6/21/2016	4	27.6	303	371	52	3.7	8.3		
CAR-2	6/21/2016	5	27	306	379	12	0.9	7.9		
CAR-2	6/21/2016	6	26.9	306	379	1.3	0.1	7.8		
CAR-2	9/13/2016	0.4	24.7	237	305	56.3	4.61	7.97	927	12
CAR-2	9/13/2016	1	24.67	242	305	57.5	4.71	7.98		
CAR-2	9/13/2016	2	24.68	244	305	58.8	4.86	8		
CAR-2	9/13/2016	3	24.68	245	305	58.1	4.77	8.01		
CAR-2	9/13/2016	4	24.65	246	305	55.7	4.57	7.99		
CAR-2	9/13/2016	5	24.63	251	305	49	4.02	7.94		
CAR-2	9/13/2016	6	24.62	251	305	48.6	3.99	7.94		
CAR-4	4/14/2016	0.3	11.73	252	261	86	9.23	7.72	1029	3
CAR-4	4/14/2016	1	11.73	255	260	85	9.17	7.66		
CAR-4	4/14/2016	2	11.7	257	261	85.5	9.16	7.63		
CAR-4	4/14/2016	3	12.61	258	260	83.9	8.97	7.61		
CAR-4	4/14/2016	4	11.81	260	262	85.5	9.14	7.6		

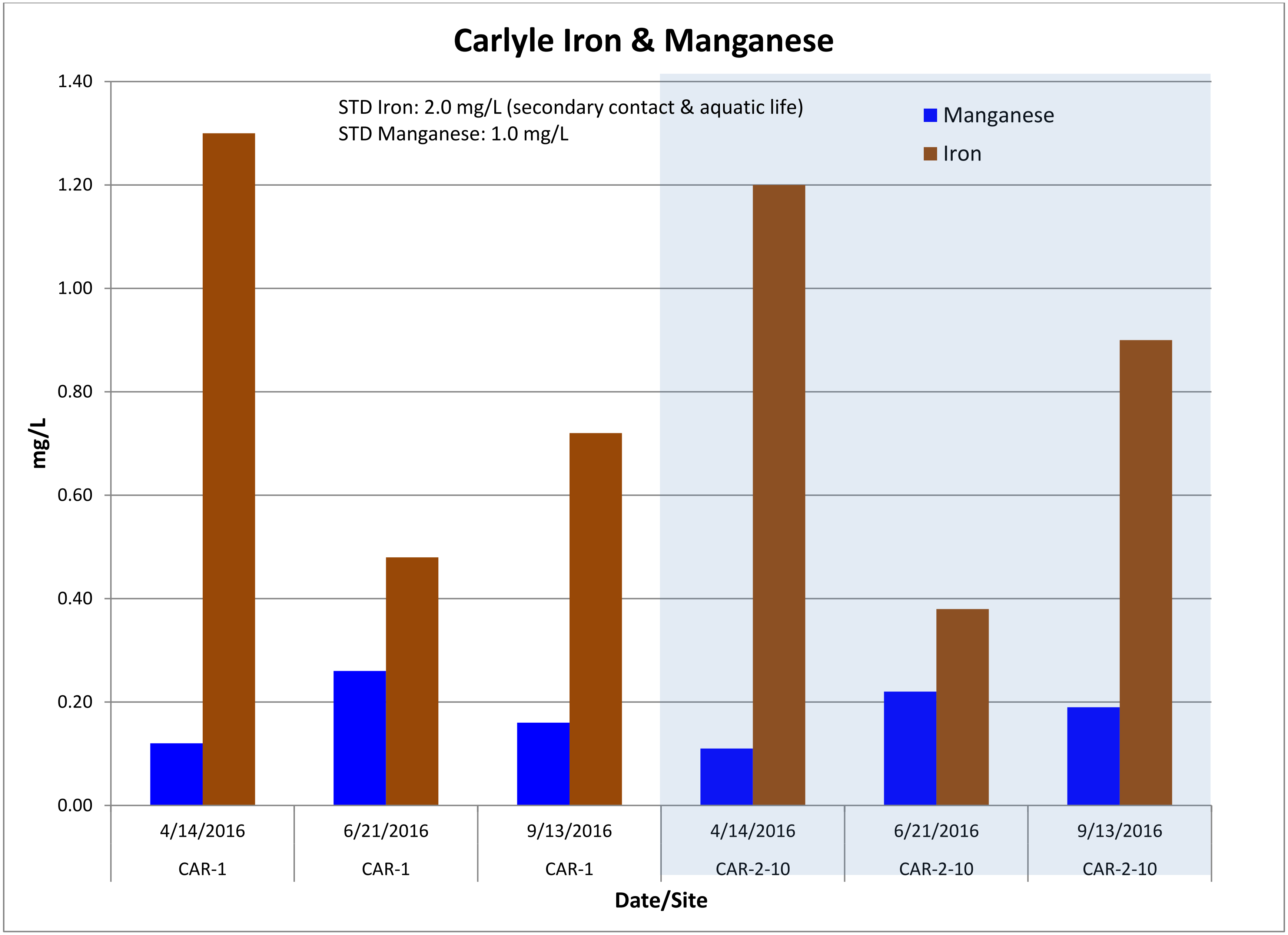
CAR-4	6/21/2016	0.3	28.7	296	439	90	6.8	8.6	1045	7
CAR-4	6/21/2016	1	28.6	295	435	87	6.6	8.6		
CAR-4	6/21/2016	2	28.4	293	433	95	7.2	8.6		
CAR-4	6/21/2016	3	28.2	294	438	84	6.4	8.5		
CAR-4	6/21/2016	4	28.2	303	442	76	5.8	8.5		
CAR-4	6/21/2016	5	28.1	301	441	78	6	8.5		
CAR-4	9/13/2016	0.4	23.99	210	309	87.2	7.24	8.26	1045	4
CAR-4	9/13/2016	1	24.06	212	319	85.1	7.07	8.27		
CAR-4	9/13/2016	2	23.81	217	309	82.1	6.86	8.26		
CAR-4	9/13/2016	3	23.73	217	315	83.3	6.99	8.3		
CAR-4	9/13/2016	4	23.76	224	311	82	6.86	8.29		
CAR-4	9/13/2016	5	23.7	225	326	84.8	7.09	8.33		
CAR-4	9/13/2016	6	23.62	225	338	87.9	7.37	8.41		

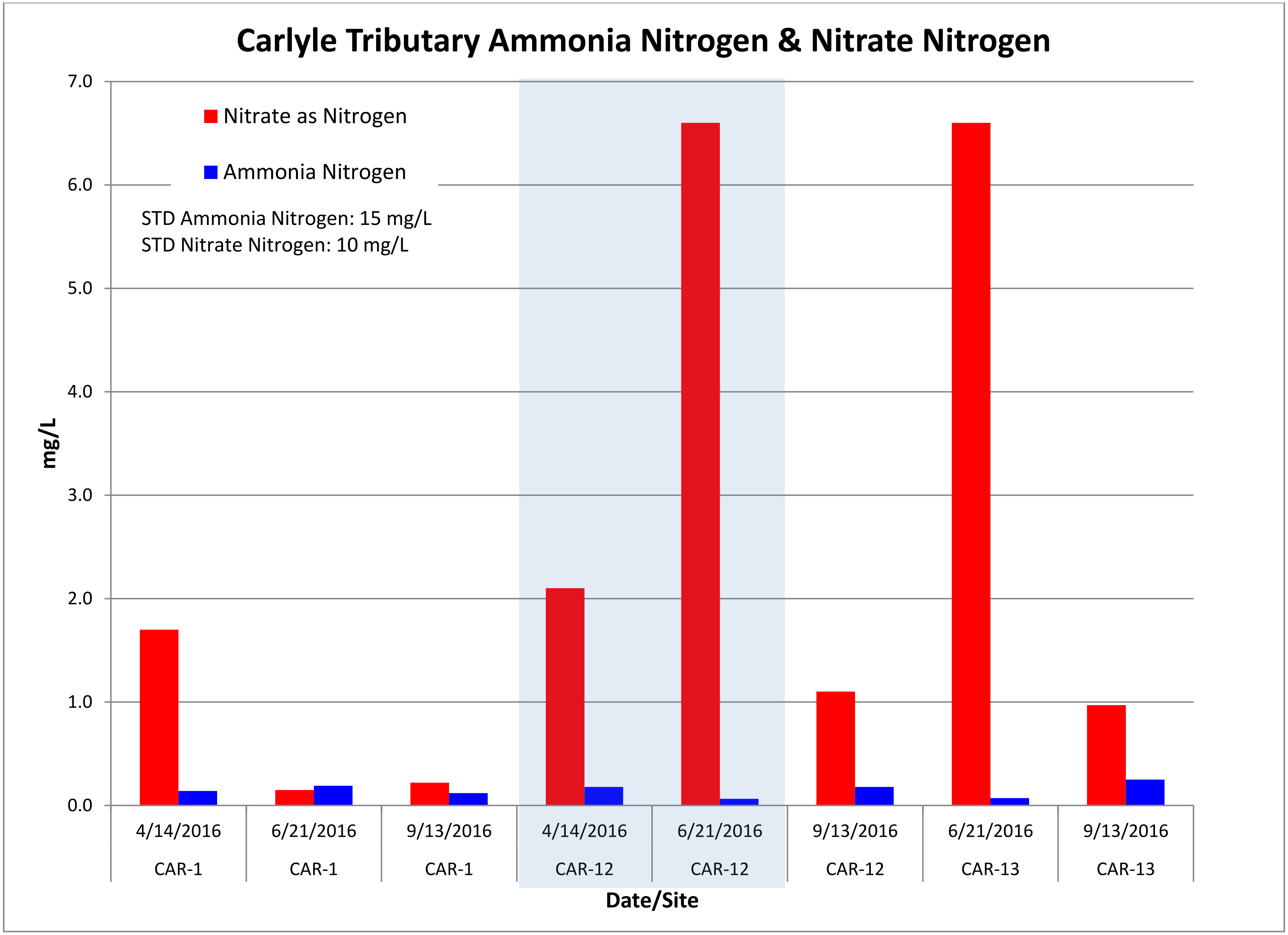
APPENDIX B

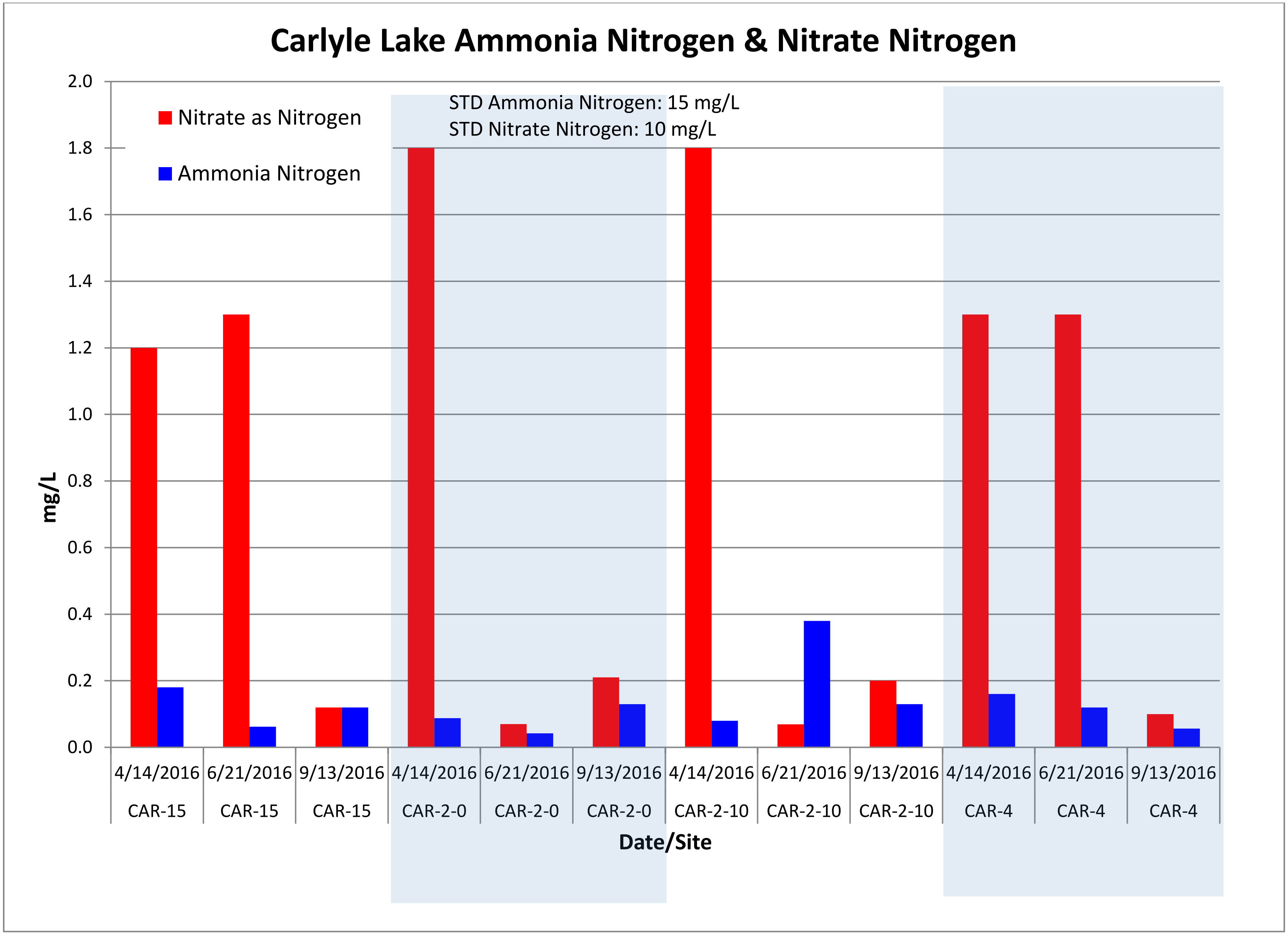
LAB DATA
GRAPHS

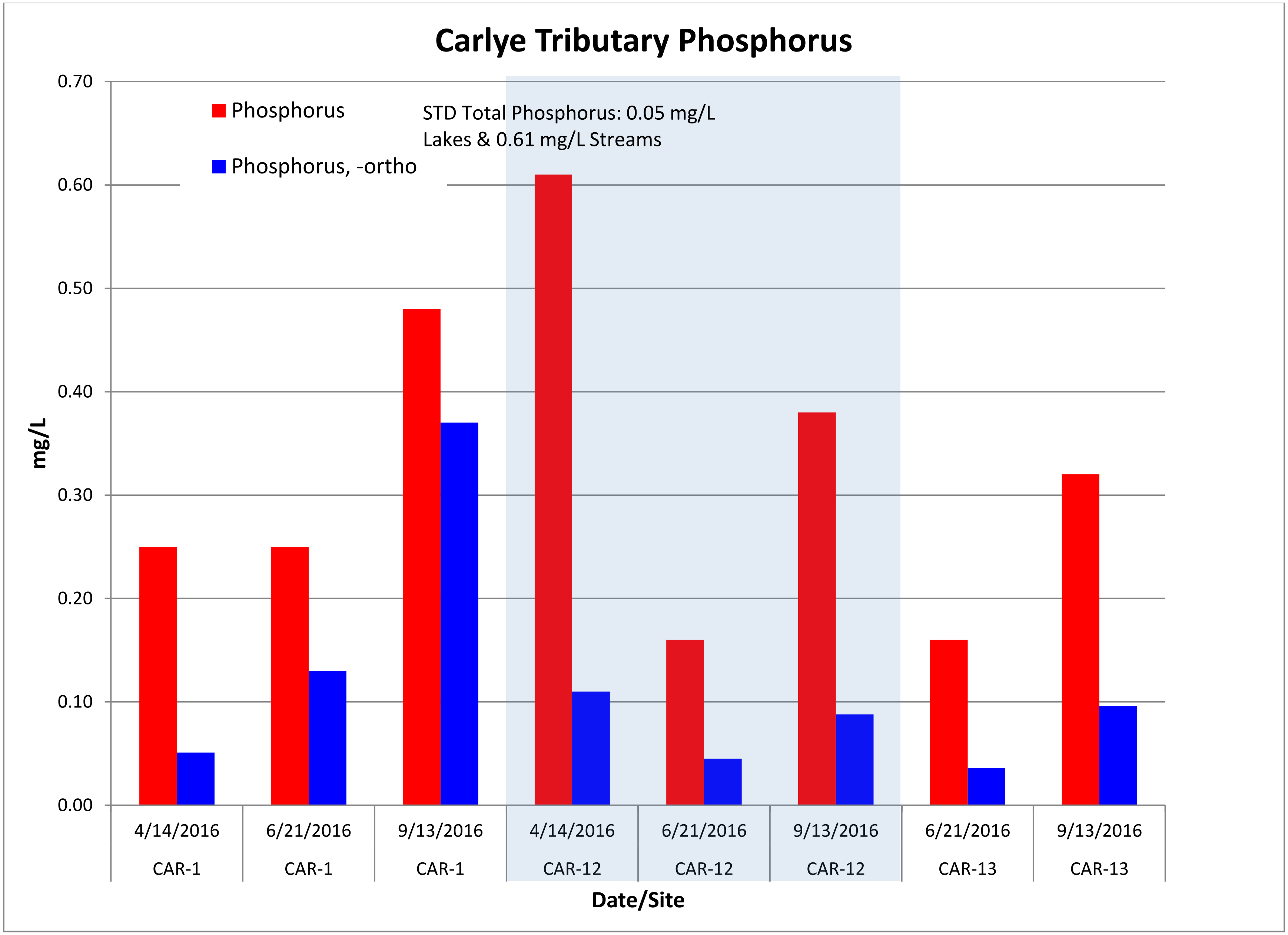


E. coli at Marinas
STD: 235/100ml for single sample
col/100ml
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
6/21/2016
CAR-BL-MARINA
9/13/2016
CAR-BL-MARINA
6/21/2016
CAR-DW-MARINA
9/13/2016
CAR-DW-MARINA
6/21/2016
CAR-KP-MARINA
9/13/2016
CAR-KP-MARINA
Date/Site

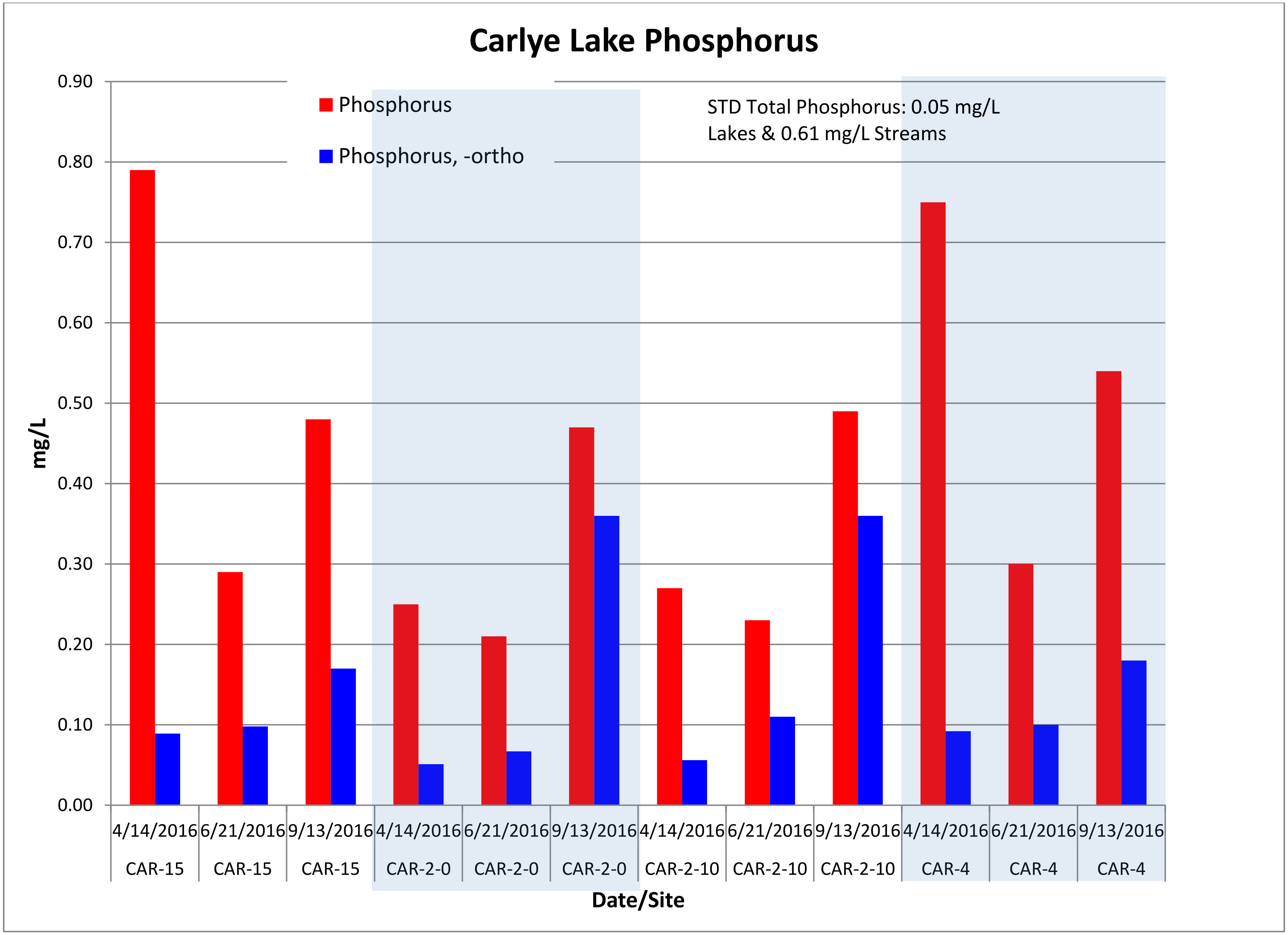

Carlyle Iron & Manganese
STD Iron: 2.0 mg/L (secondary contact & aquatic life)
STD Manganese: 1.0 mg/L
Manganese
Iron
mg/L
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
4/14/2016
CAR-1
6/21/2016
CAR-1
9/13/2016
CAR-1
4/14/2016
CAR-2-10
6/21/2016
CAR-2-10
9/13/2016
CAR-2-10
Date/Site

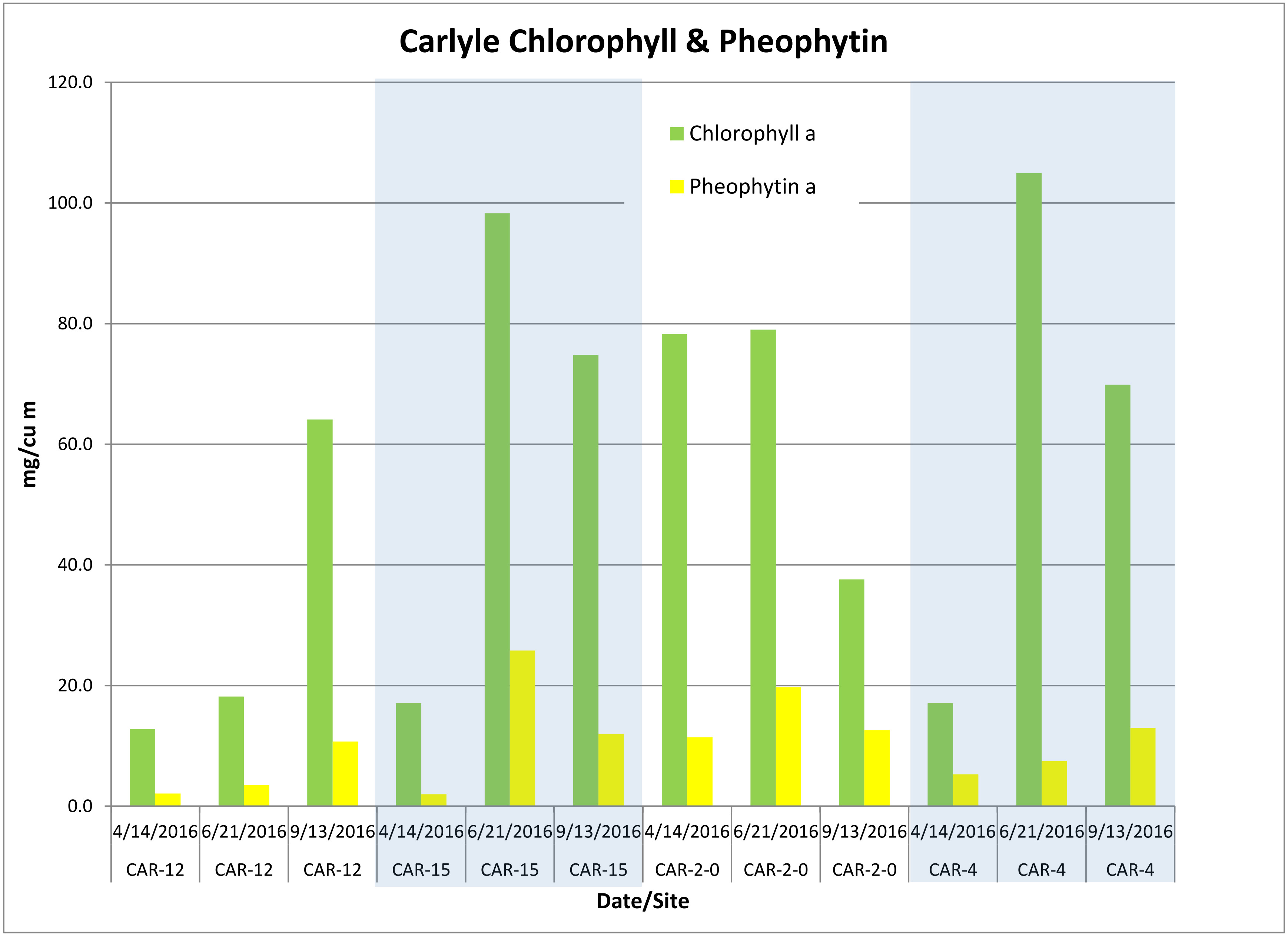

Carlyle Tributary Ammonia Nitrogen & Nitrate Nitrogen
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
mg/L
Nitrate as Nitrogen
Ammonia Nitrogen
STD Ammonia Nitrogen: 15 mg/L
STD Nitrate Nitrogen: 10 mg/L
4/14/2016 CAR-1
6/21/2016 CAR-1
9/13/2016 CAR-1
4/14/2016 CAR-12
6/21/2016 CAR-12
9/13/2016 CAR-12
6/21/2016 CAR-13
9/13/2016 CAR-13
Date/Site


Carlyle Lake Ammonia Nitrogen & Nitrate Nitrogen
STD Ammonia Nitrogen: 15 mg/L
STD Nitrate Nitrogen: 10 mg/L
Nitrate as Nitrogen
Ammonia Nitrogen
mg/L
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/14/2016
6/21/2016
9/13/2016
CAR-15
CAR-2-0
CAR-2-10
CAR-4
Date/Site

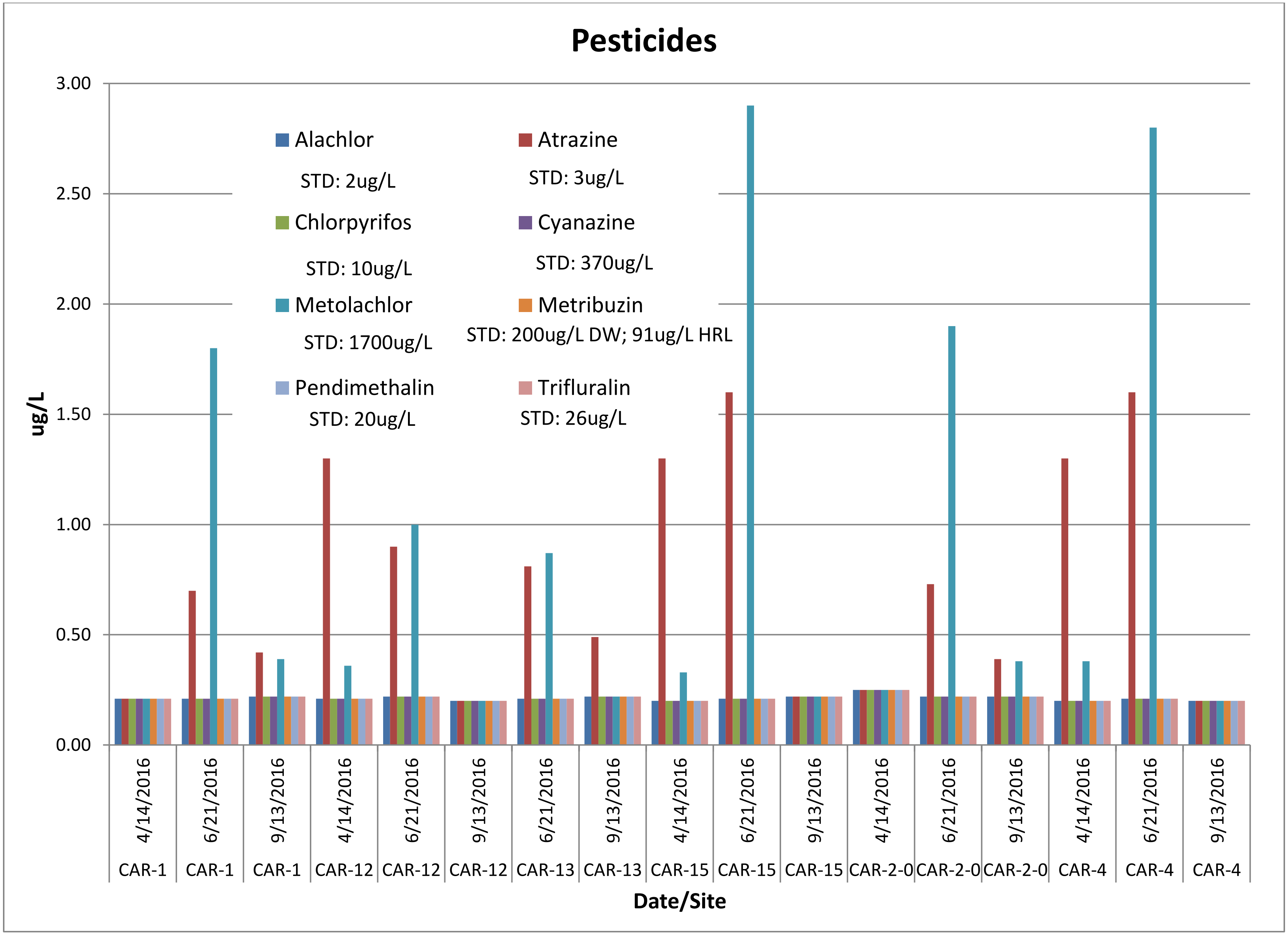


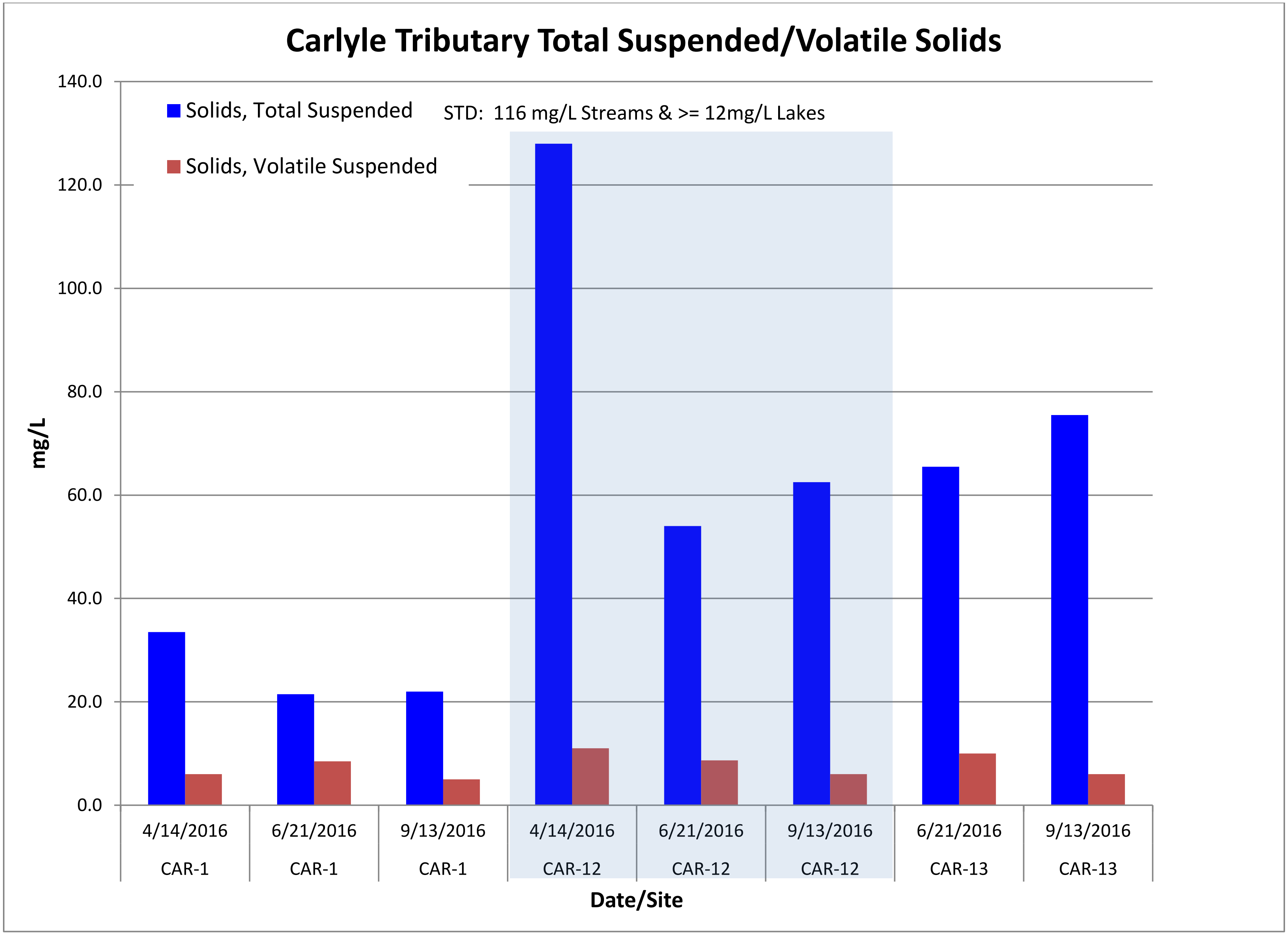
Carlye Tributary Phosphorus
Phosphorus
Phosphorus, -ortho
STD Total Phosphorus: 0.05 mg/L
Lakes & 0.61 mg/L Streams
mg/L
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
4/14/2016 CAR-1
6/21/2016 CAR-1
9/13/2016 CAR-1
4/14/2016 CAR-12
6/21/2016 CAR-12
9/13/2016 CAR-12
6/21/2016 CAR-13
9/13/2016 CAR-13
Date/Site

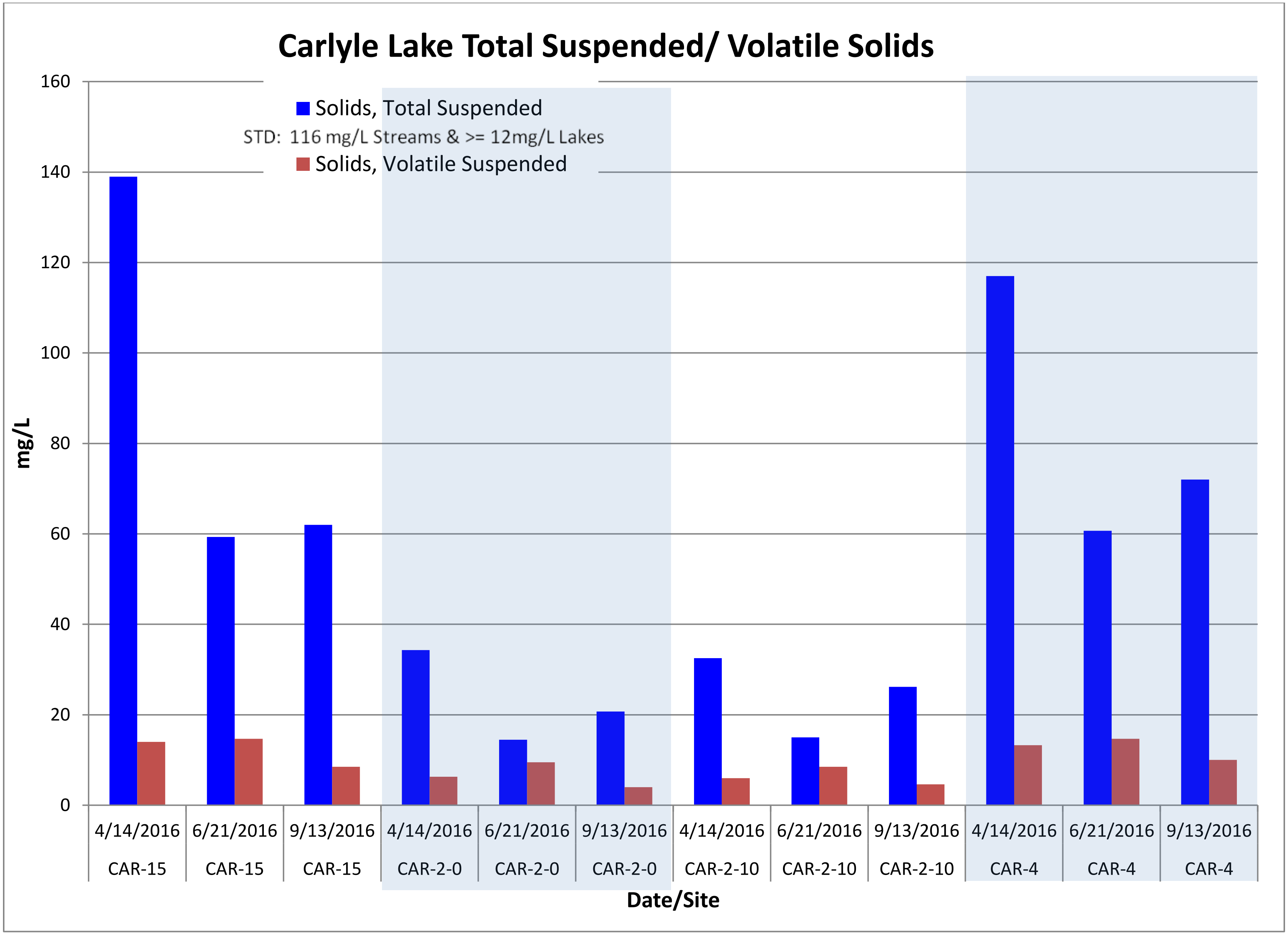

Carlye Lake Phosphorus
Phosphorus
Phosphorus, -ortho
STD Total Phosphorus: 0.05 mg/L
Lakes & 0.61 mg/L Streams
mg/L
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
4/14/2016
6/21/2016
9/13/2016
CAR-15
CAR-2-0
CAR-2-10
CAR-4
Date/Site

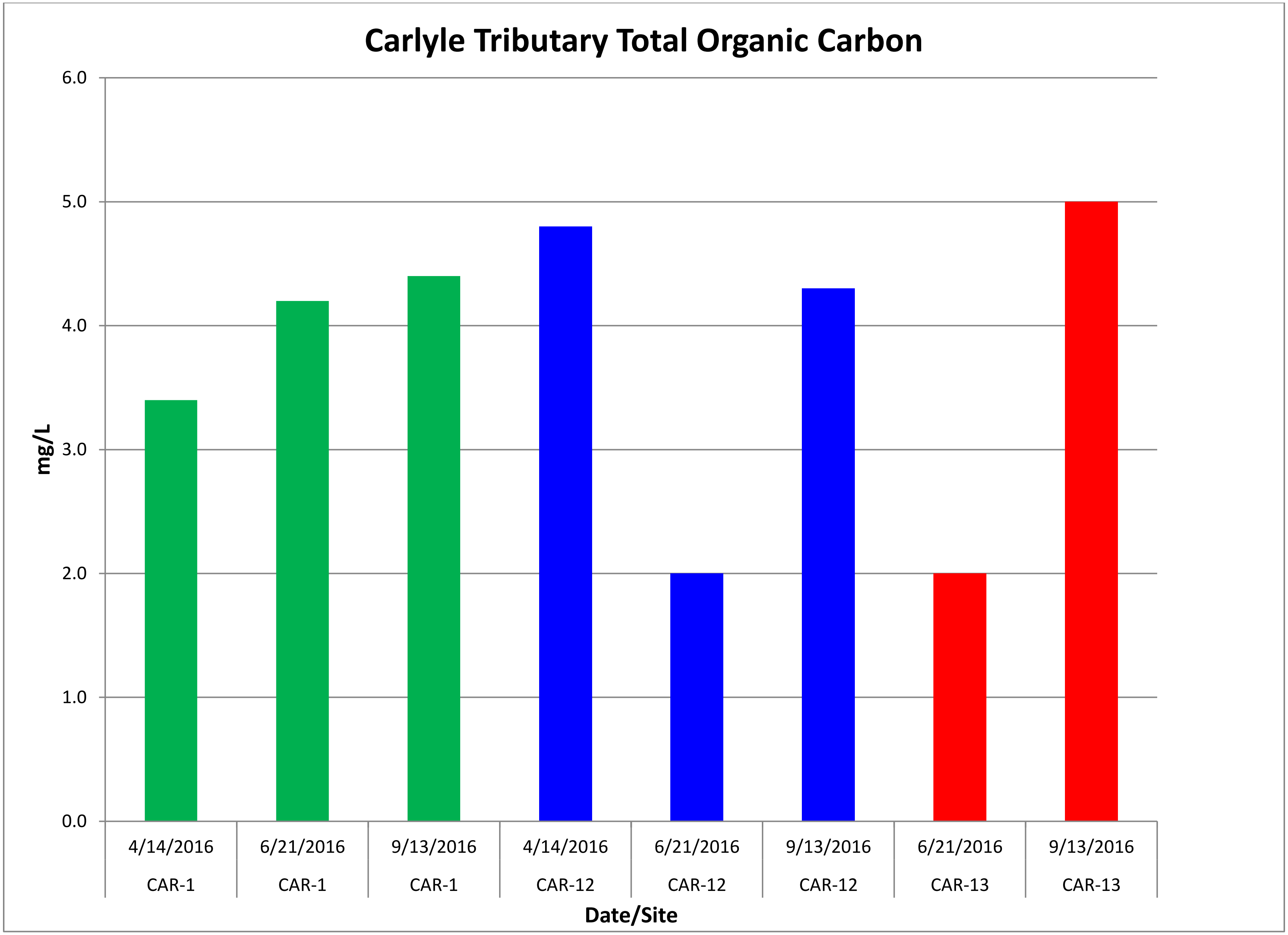


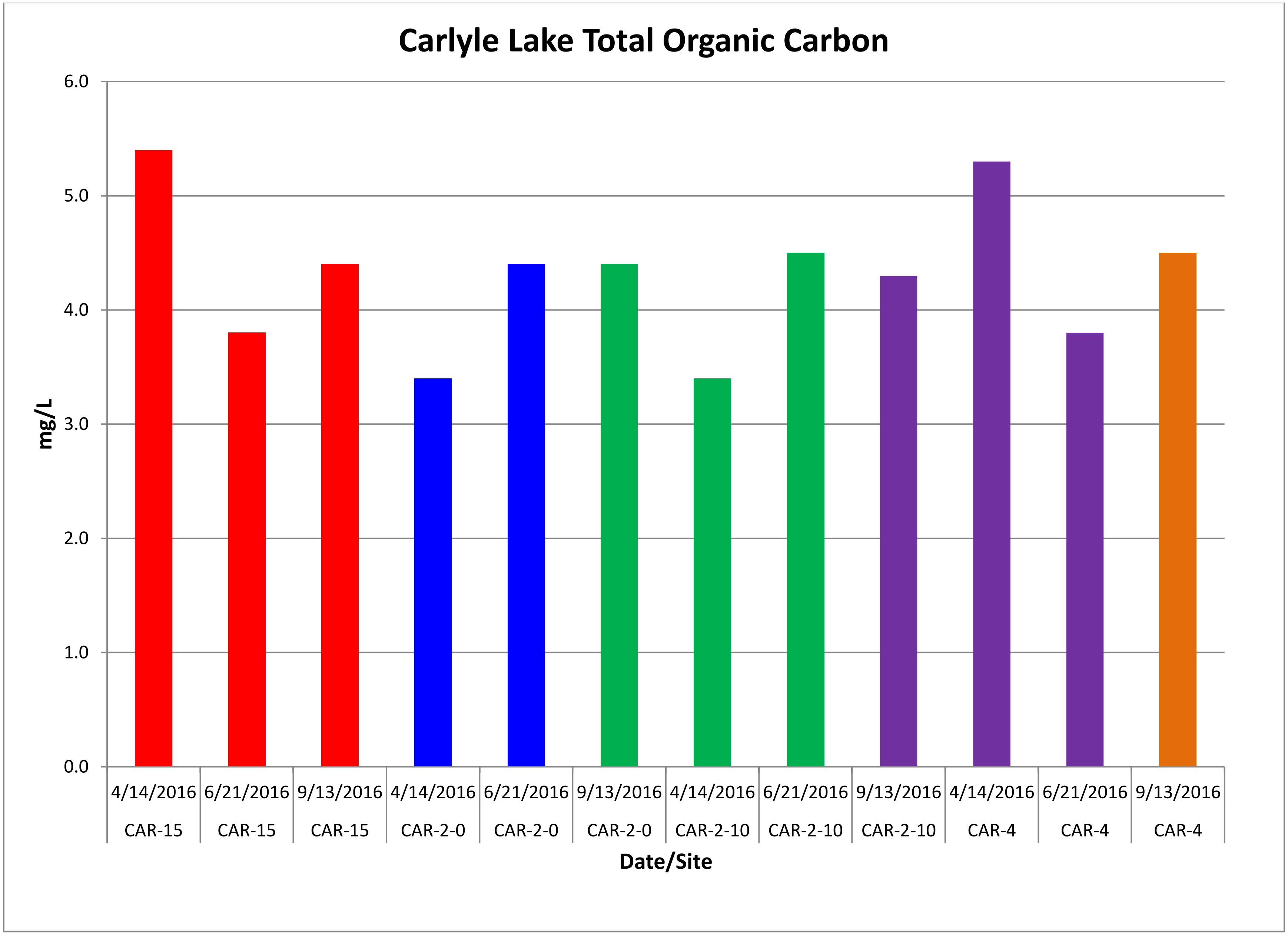
Carlyle Chlorophyll & Pheophytin
Chlorophyll a
Pheophytin a
mg/cu m
120.0
100.0
80.0
60.0
40.0
20.0
0.0
4/14/2016
6/21/2016
9/13/2016
4/14/2016
6/21/2016
9/13/2016
4/14/2016
6/21/2016
9/13/2016
4/14/2016
6/21/2016
9/13/2016
CAR-12
CAR-12
CAR-12
CAR-15
CAR-15
CAR-15
CAR-2-0
CAR-2-0
CAR-2-0
CAR-4
CAR-4
CAR-4
Date/Site


Pesticides
Alachlor
STD: 2ug/L
Atrazine
STD: 3ug/L
Chlorpyrifos
STD: 10ug/L
Cyanazine
STD: 370ug/L
Metolachlor
STD: 1700ug/L
Metribuzin
STD: 200ug/L DW; 91ug/L HRL
Pendimethalin
STD: 20ug/L
Trifluralin
STD: 26ug/L
ug/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00
4/14/2016 CAR-1
6/21/2016 CAR-1
9/13/2016 CAR-1
4/14/2016 CAR-12
6/21/2016 CAR-12
9/13/2016 CAR-12
6/21/2016 CAR-13
9/13/2016 CAR-13
4/14/2016 CAR-15
6/21/2016 CAR-15
9/13/2016 CAR-15
4/14/2016 CAR-2-0
6/21/2016 CAR-2-0
9/13/2016 CAR-2-0
4/14/2016 CAR-4
6/21/2016 CAR-4
9/13/2016 CAR-4
Date/Site


Carlyle Tributary Total Suspended/Volatile Solids
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/L
Solids, Total Suspended
Solids, Volatile Suspended
STD: 116 mg/L Streams & >= 12mg/L Lakes
4/14/2016
CAR-1
6/21/2016
CAR-1
9/13/2016
CAR-1
4/14/2016
CAR-12
6/21/2016
CAR-12
9/13/2016
CAR-12
6/21/2016
CAR-13
9/13/2016
CAR-13
Date/Site

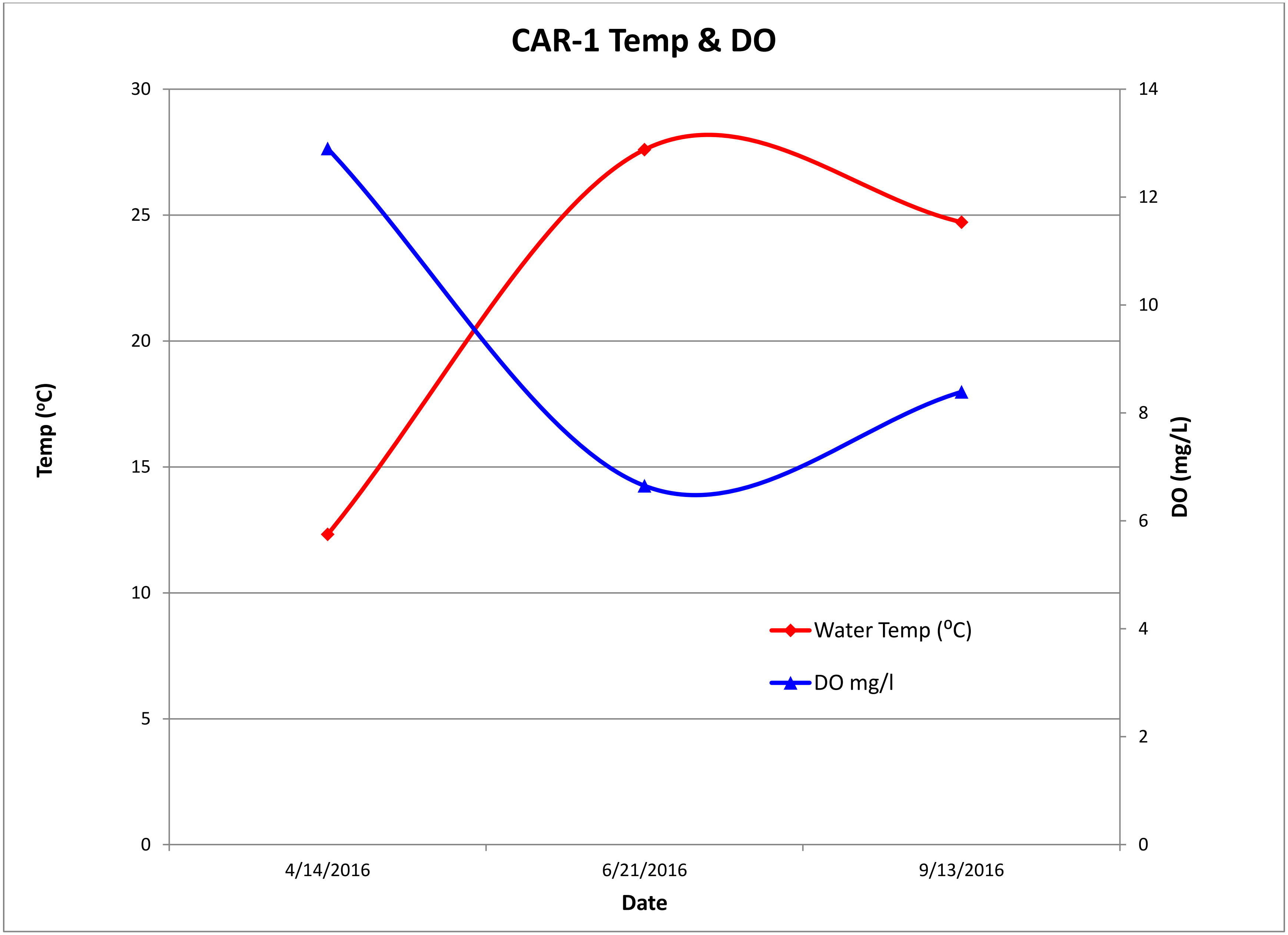

Carlyle Lake Total Suspended/ Volatile Solids
Solids, Total Suspended
STD: 116 mg/L Streams & >= 12mg/L Lakes
Solids, Volatile Suspended
mg/L
160
140
120
100
80
60
40
20
0
4/14/2016
6/21/2016
9/13/2016
CAR-15
CAR-2-0
CAR-2-10
CAR-4
Date/Site

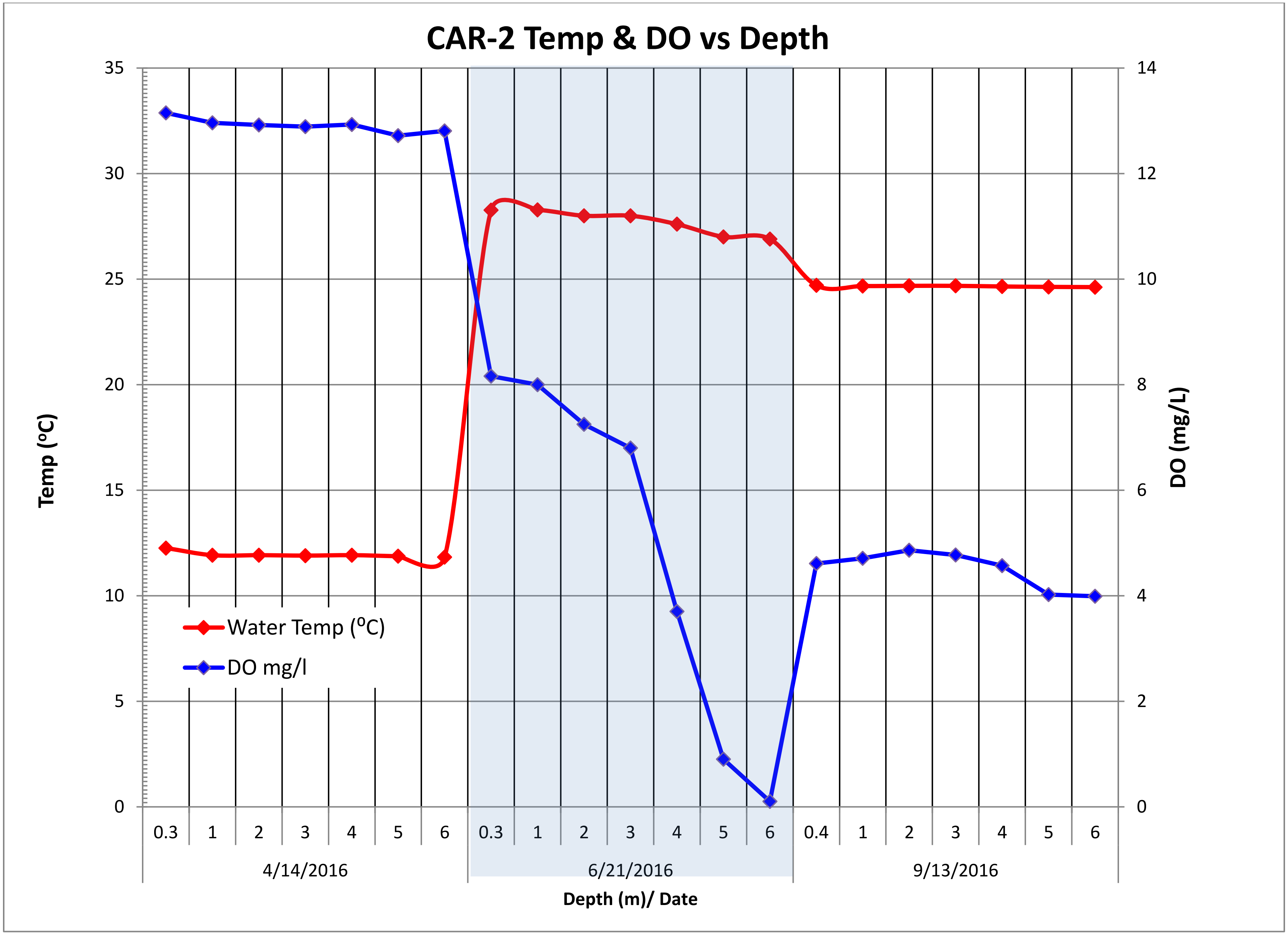

Carlyle Tributary Total Organic Carbon
6.0
5.0
4.0
3.0
2.0
1.0
0.0
mg/L
4/14/2016
CAR-1
6/21/2016
CAR-1
9/13/2016
CAR-1
4/14/2016
CAR-12
6/21/2016
CAR-12
9/13/2016
CAR-12
6/21/2016
CAR-13
9/13/2016
CAR-13
Date/Site


Carlyle Lake Total Organic Carbon
6.0
5.0
4.0
3.0
2.0
1.0
0.0
mg/L
4/14/2016
CAR-15
6/21/2016
CAR-15
9/13/2016
CAR-15
4/14/2016
CAR-2-0
6/21/2016
CAR-2-0
9/13/2016
CAR-2-0
4/14/2016
CAR-2-10
6/21/2016
CAR-2-10
9/13/2016
CAR-2-10
4/14/2016
CAR-4
6/21/2016
CAR-4
9/13/2016
CAR-4
Date/Site

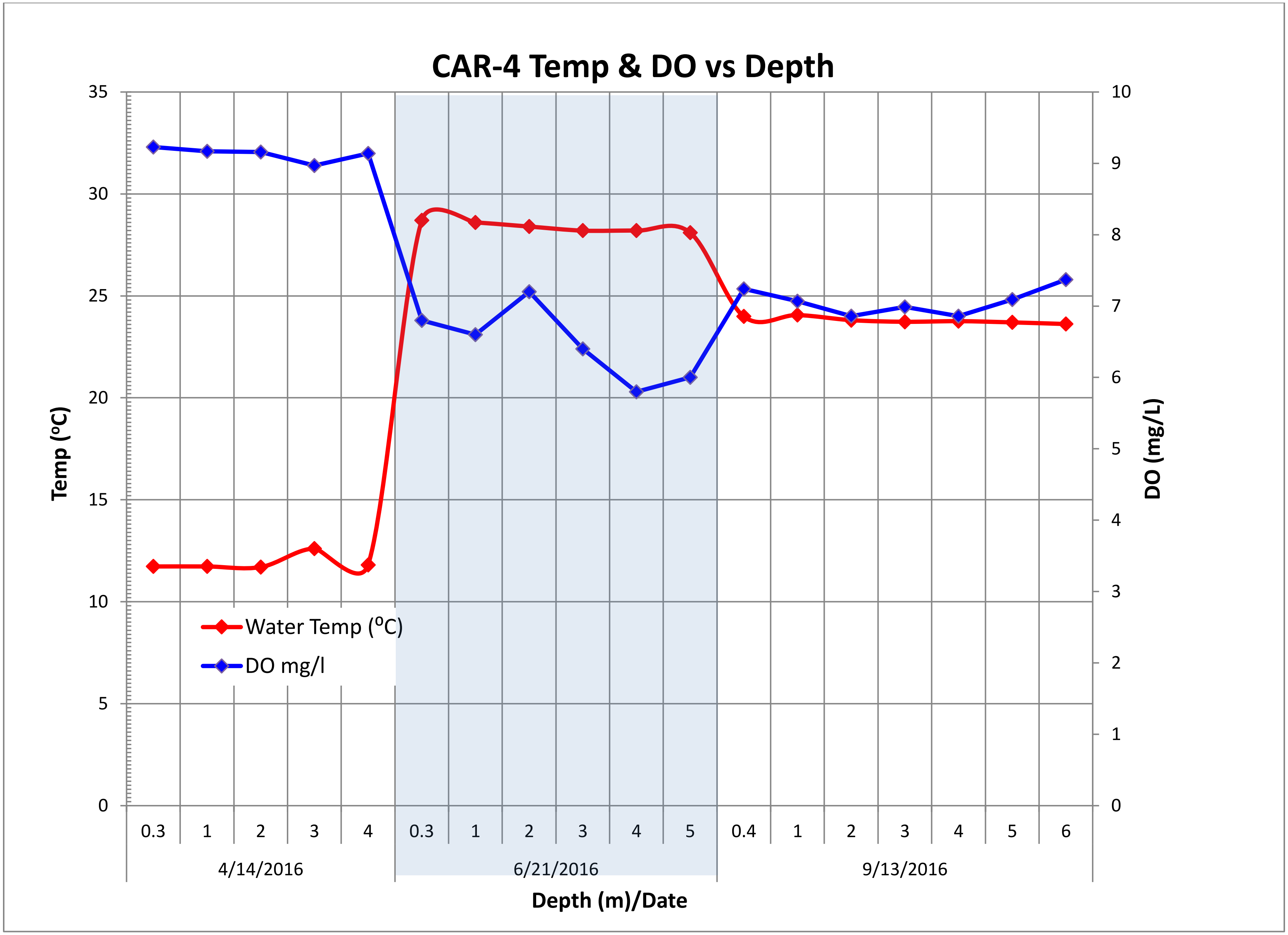
APPENDIX C

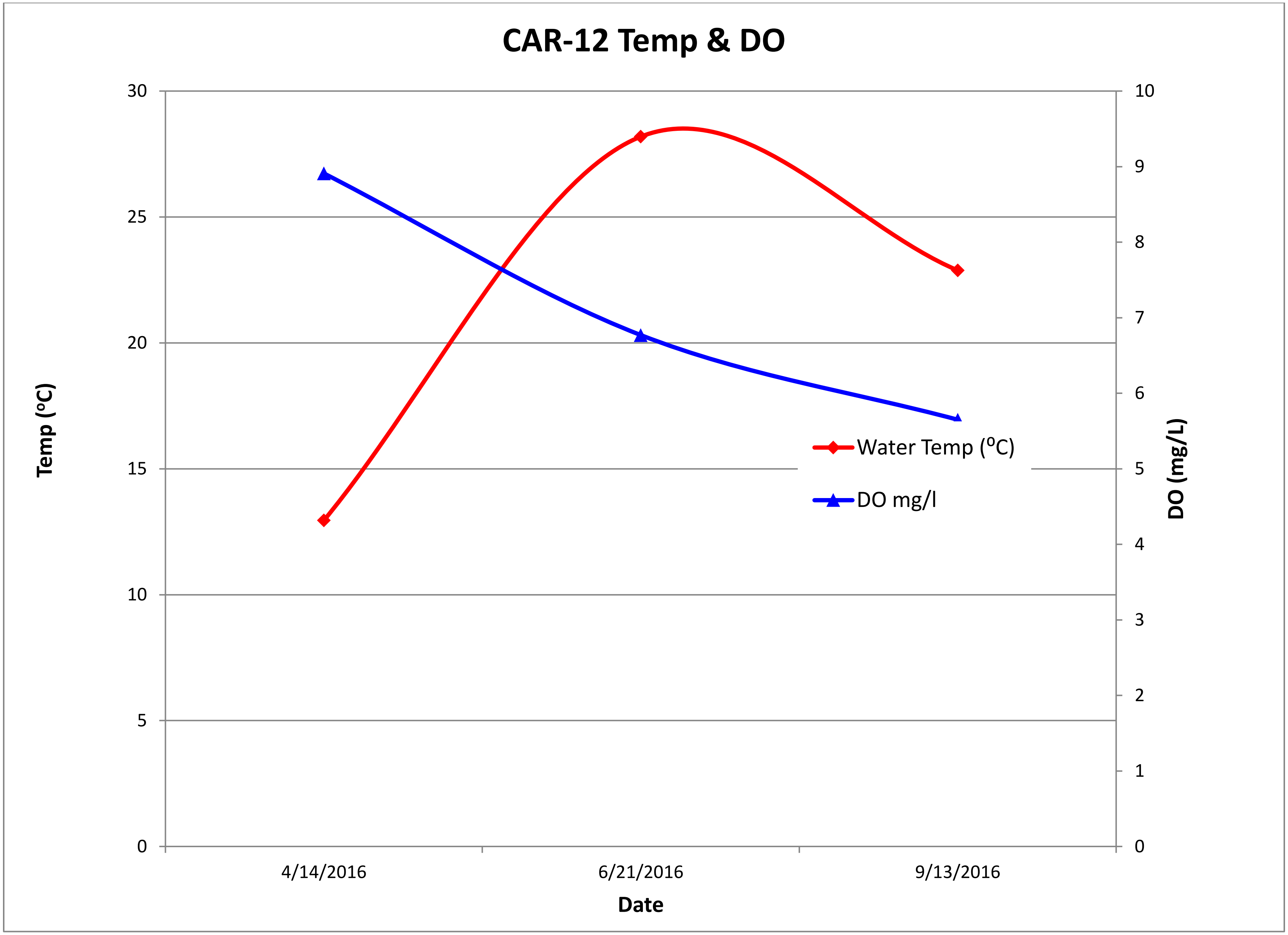
FIELD DATA
GRAPHS


CAR-1 Temp & DO
30
25
20
15
10
5
0
Temp (ºC)
14
12
10
8
6
4
2
0
DO (mg/L)
4/14/2016
6/21/2016
9/13/2016
Date
Water Temp (ºC)
DO mg/l

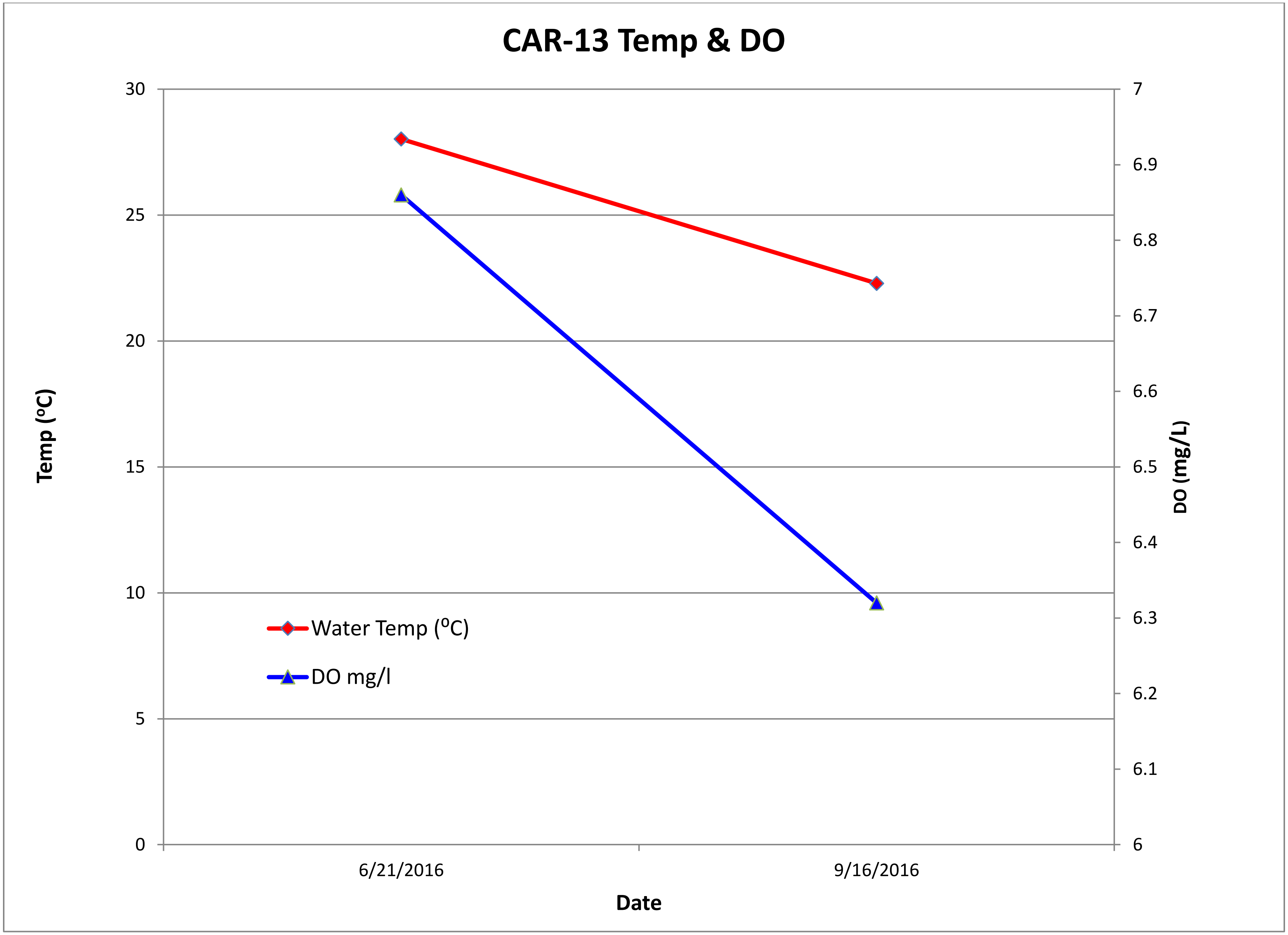


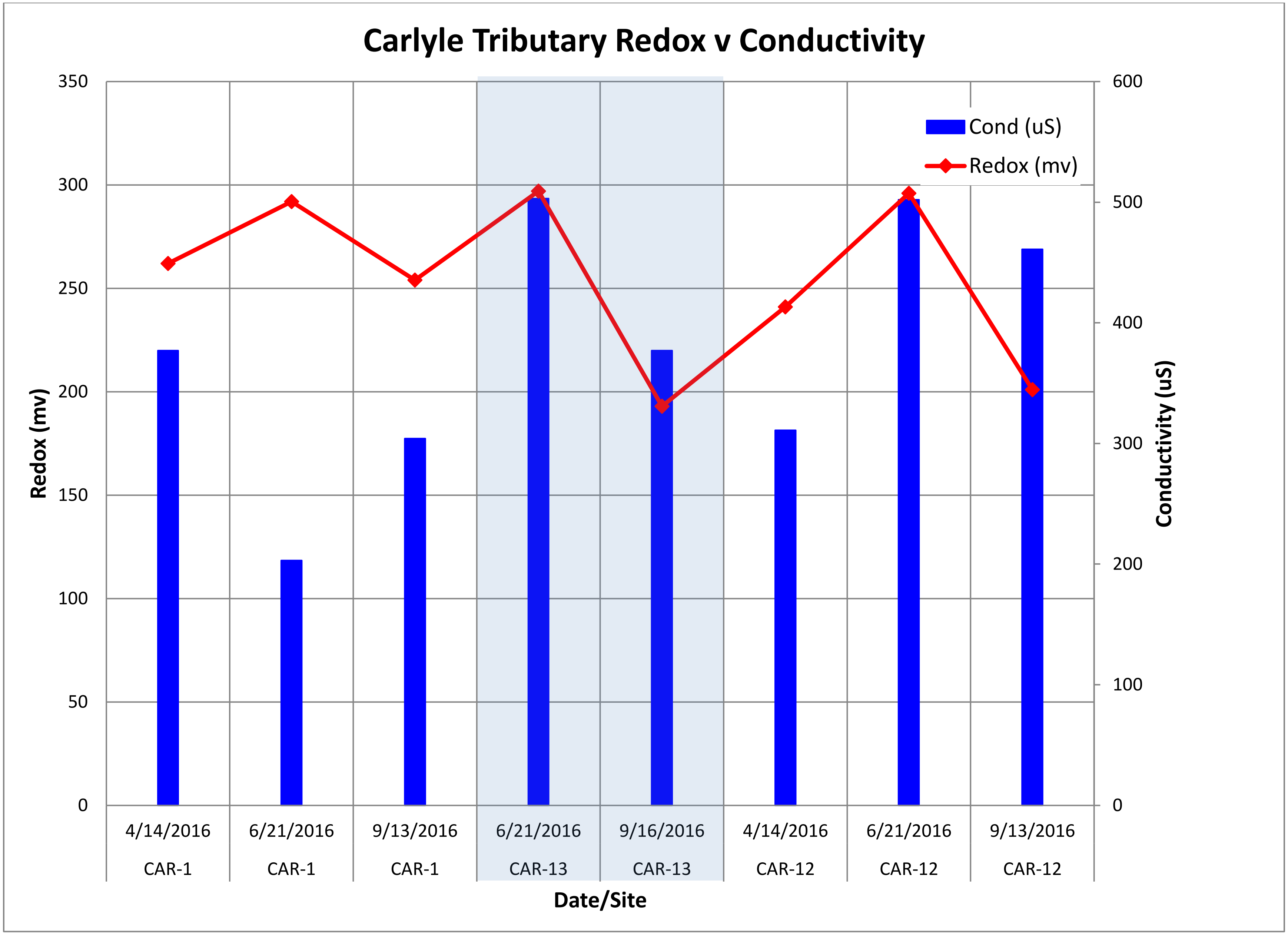
CAR-2 Temp & DO vs Depth
35
30
25
20
15
10
5
0
14
12
10
8
6
4
2
0
Temp (°C)
DO (mg/L)
Water Temp (°C)
DO mg/l
0.3
1
2
3
4
5
6
0.3
1
2
3
4
5
6
0.4
1
2
3
4
5
6
4/14/2016
6/21/2016
9/13/2016
Depth (m)/ Date


CAR-4 Temp & DO vs Depth
Temp (oC)
DO (mg/L)
35
30
25
20
15
10
5
0
10
9
8
7
6
5
4
3
2
1
0
Water Temp (oC)
DO mg/l
0.3
1
2
3
4
0.3
1
2
3
4
5
0.4
1
2
3
4
5
6
4/14/2016
6/21/2016
9/13/2016
Depth (m)/Date

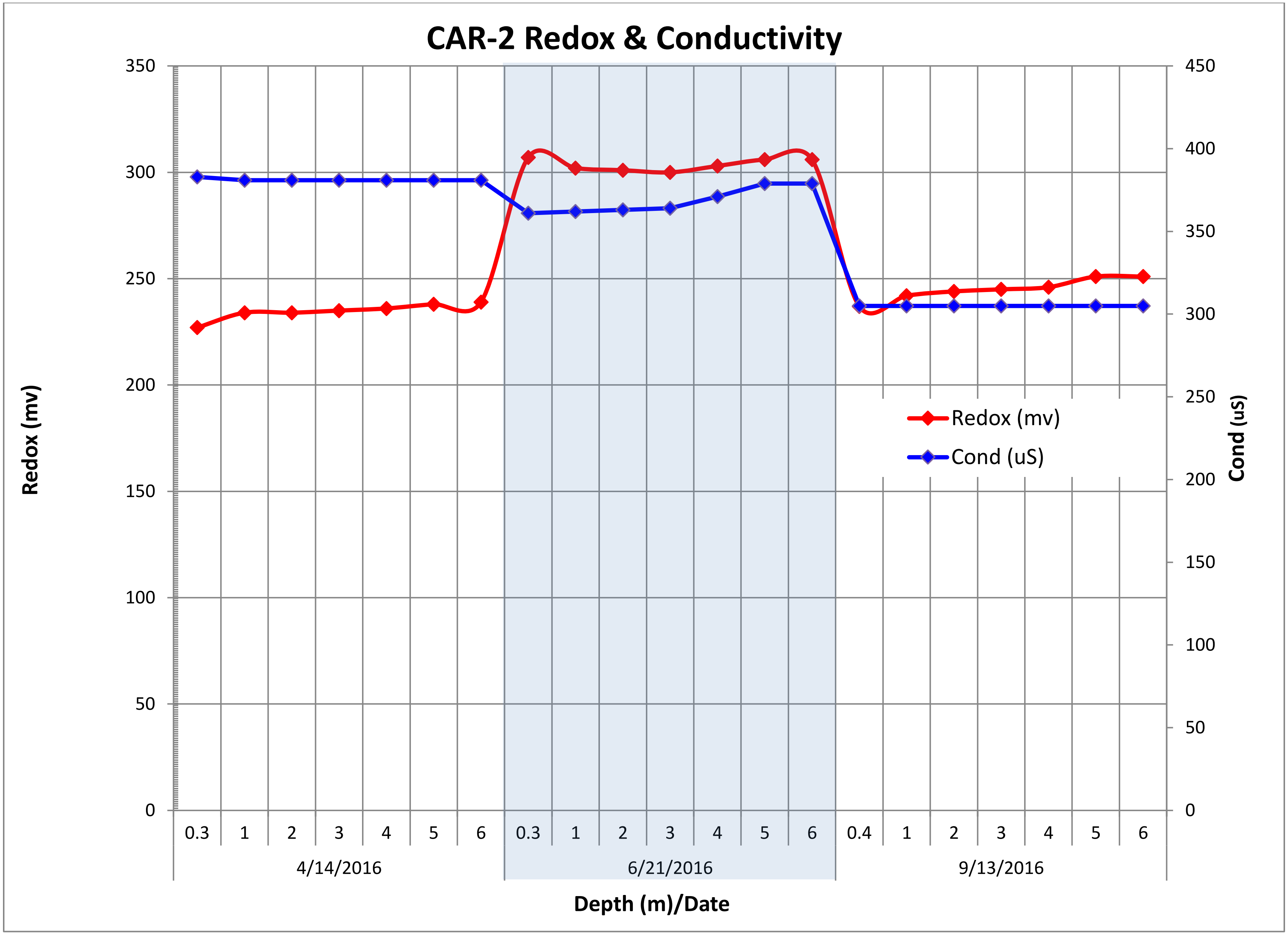


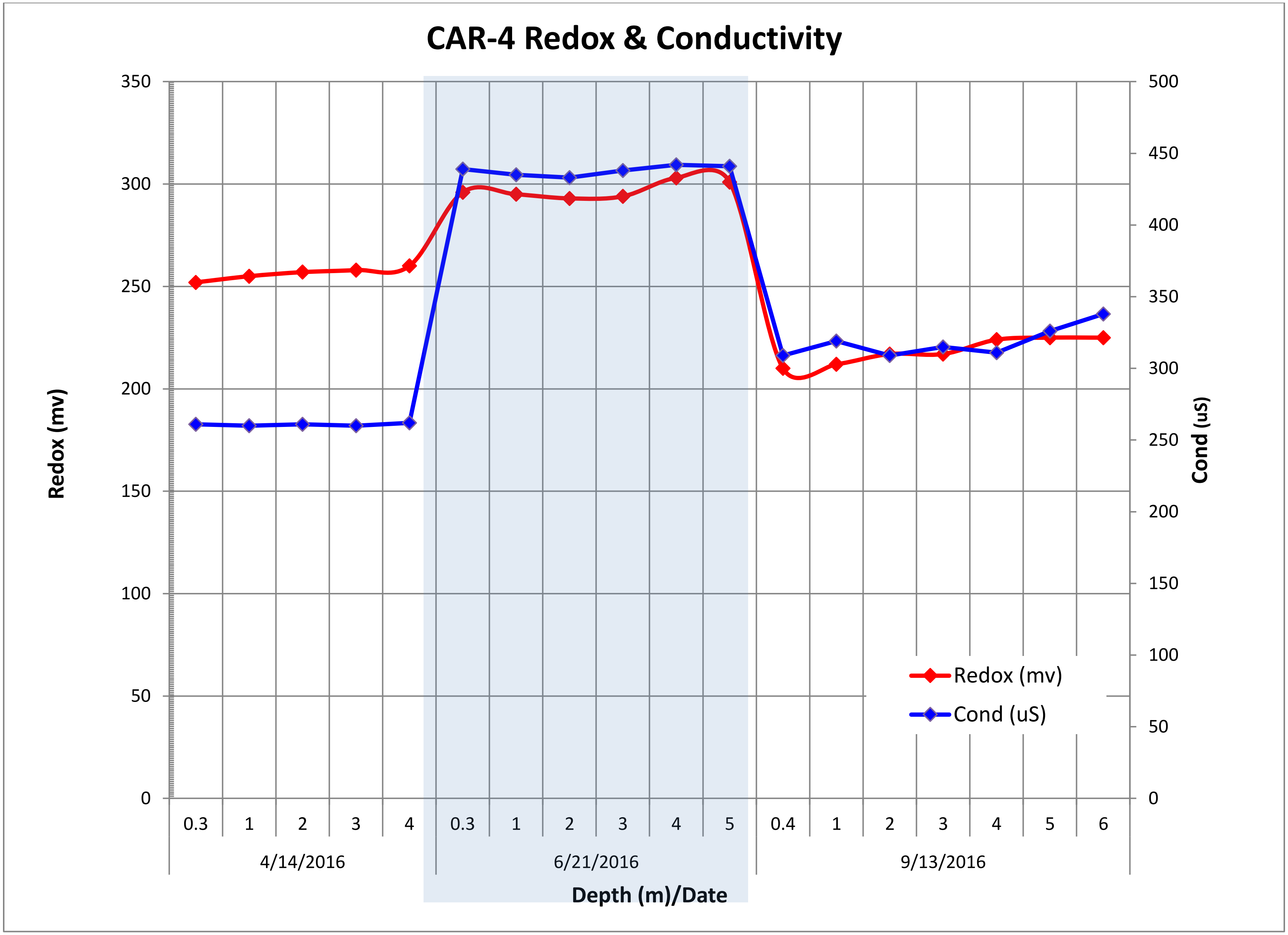
CAR-12 Temp & DO
30
25
20
15
10
5
0
10
9
8
7
6
5
4
3
2
1
0
Temp (oC)
DO (mg/L)
Water Temp (oC)
DO mg/l
4/14/2016
6/21/2016
9/13/2016
Date

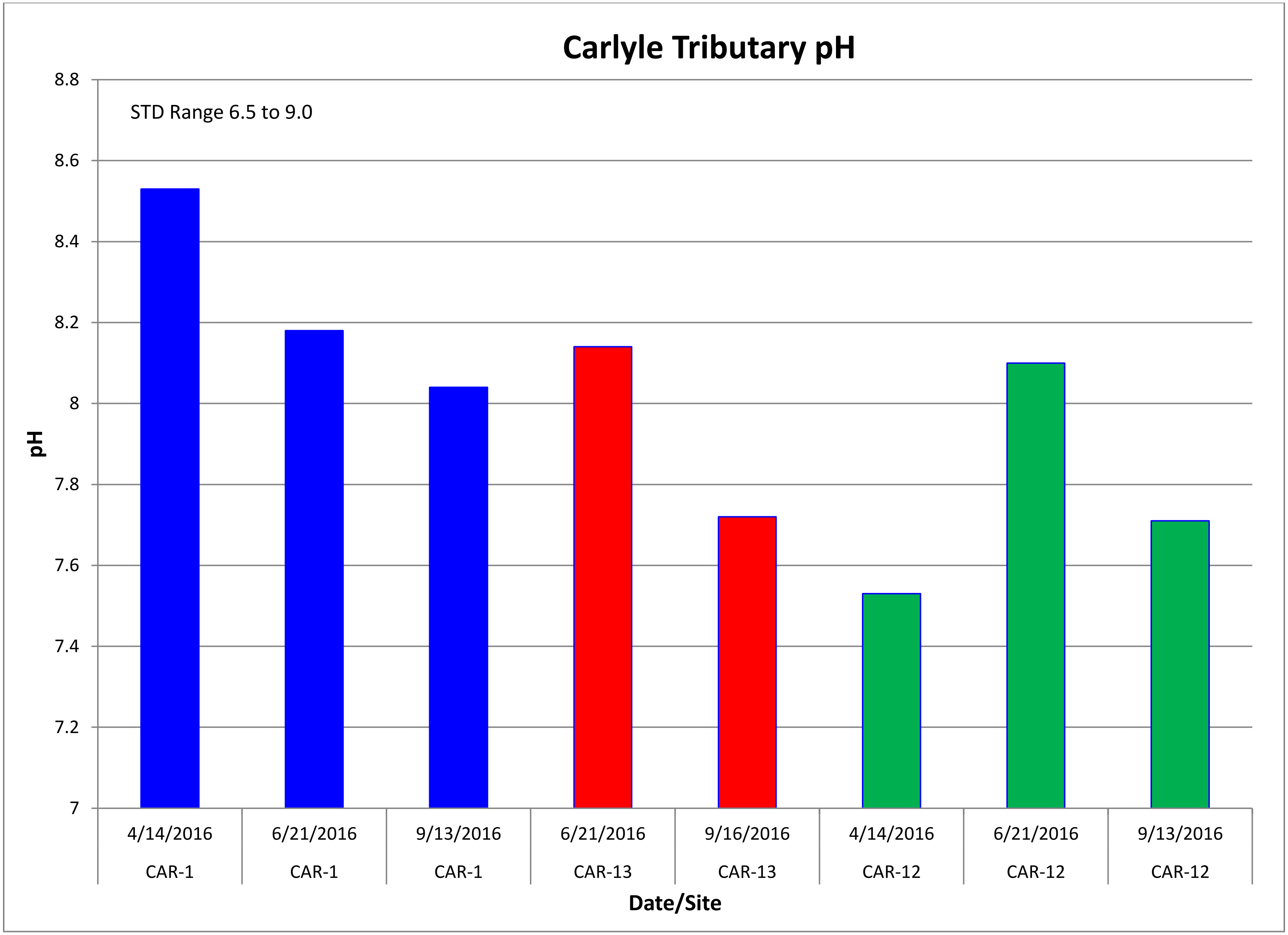

CAR-13 Temp & DO
30
25
20
15
10
5
0
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
Temp (ºC)
DO (mg/L)
Water Temp (ºC)
DO mg/l
6/21/2016
9/16/2016
Date

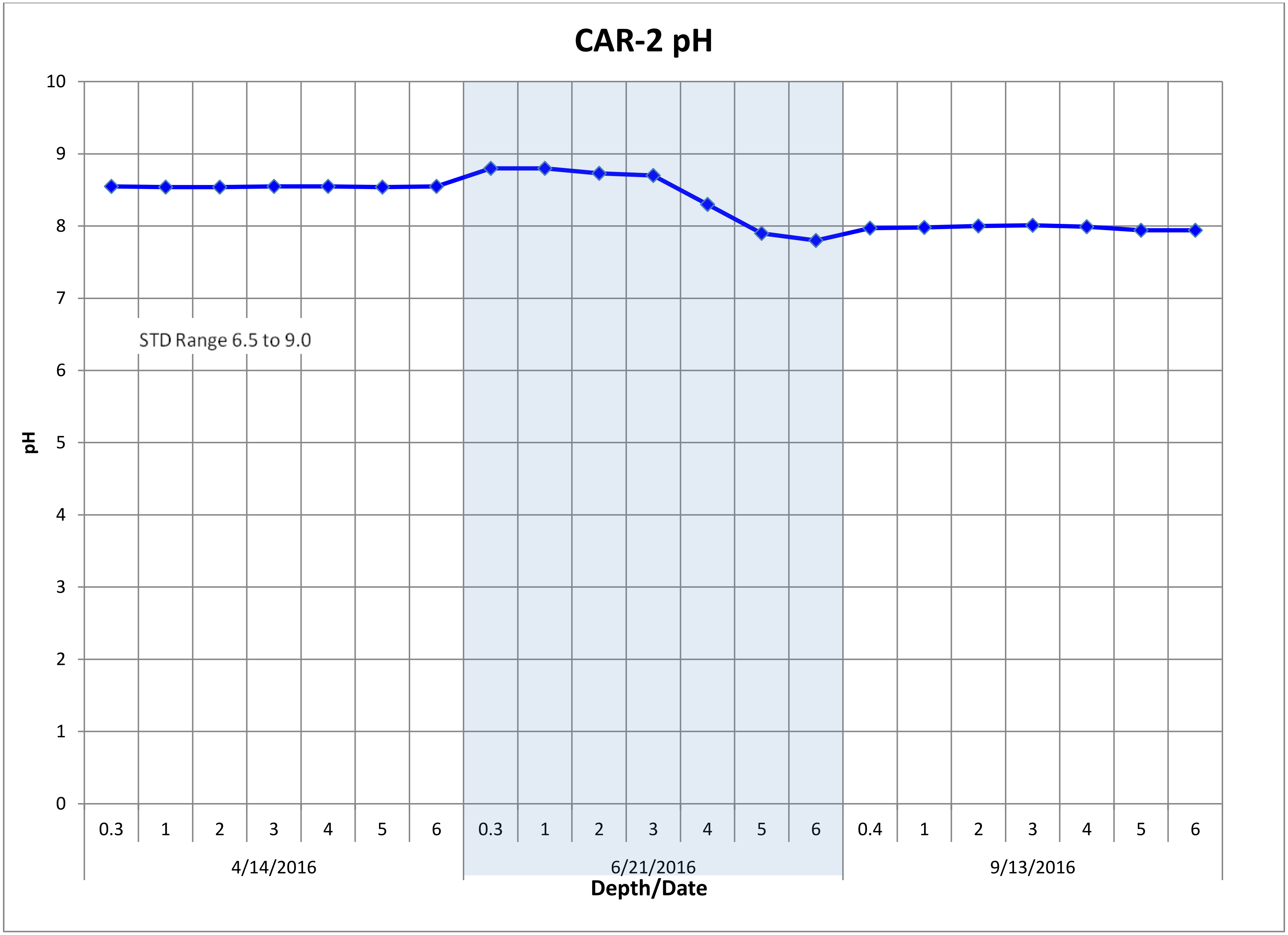


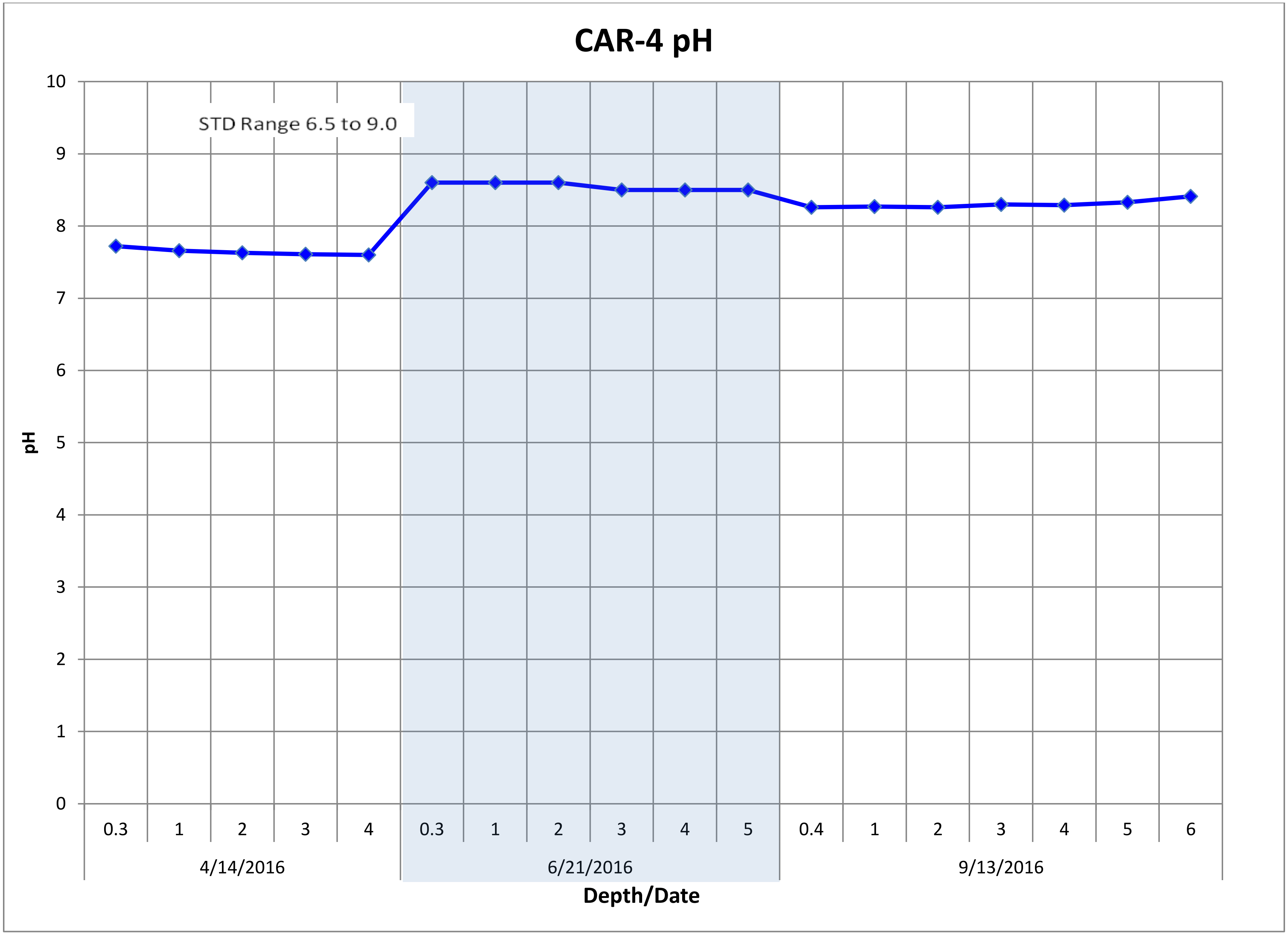
Carlyle Tributary Redox v Conductivity
Redox (mv)
Conductivity (uS)
350
300
250
200
150
100
50
0
600
500
400
300
200
100
0
Cond (uS)
Redox (mv)
4/14/2016
CAR-1
6/21/2016
CAR-1
9/13/2016
CAR-1
6/21/2016
CAR-13
9/16/2016
CAR-13
4/14/2016
CAR-12
6/21/2016
CAR-12
9/13/2016
CAR-12
Date/Site

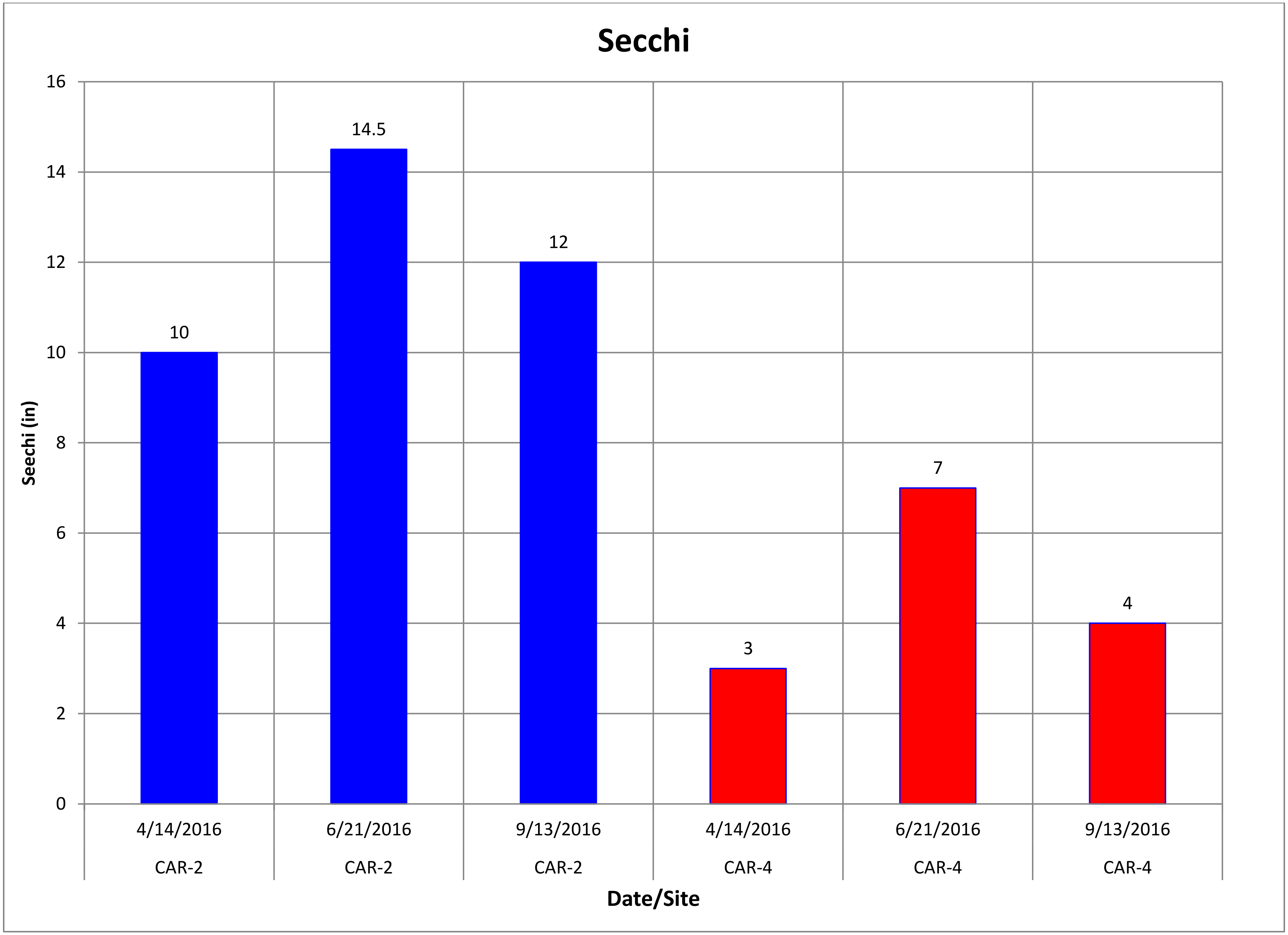

CAR-2 Redox & Conductivity
Redox (mv)
Cond (uS)
Depth (m)/Date
4/14/2016
6/21/2016
9/13/2016
0.3
1
2
3
4
5
6
0.4
350
300
250
200
150
100
50
0
450
400
Redox (mv)
Cond (uS)

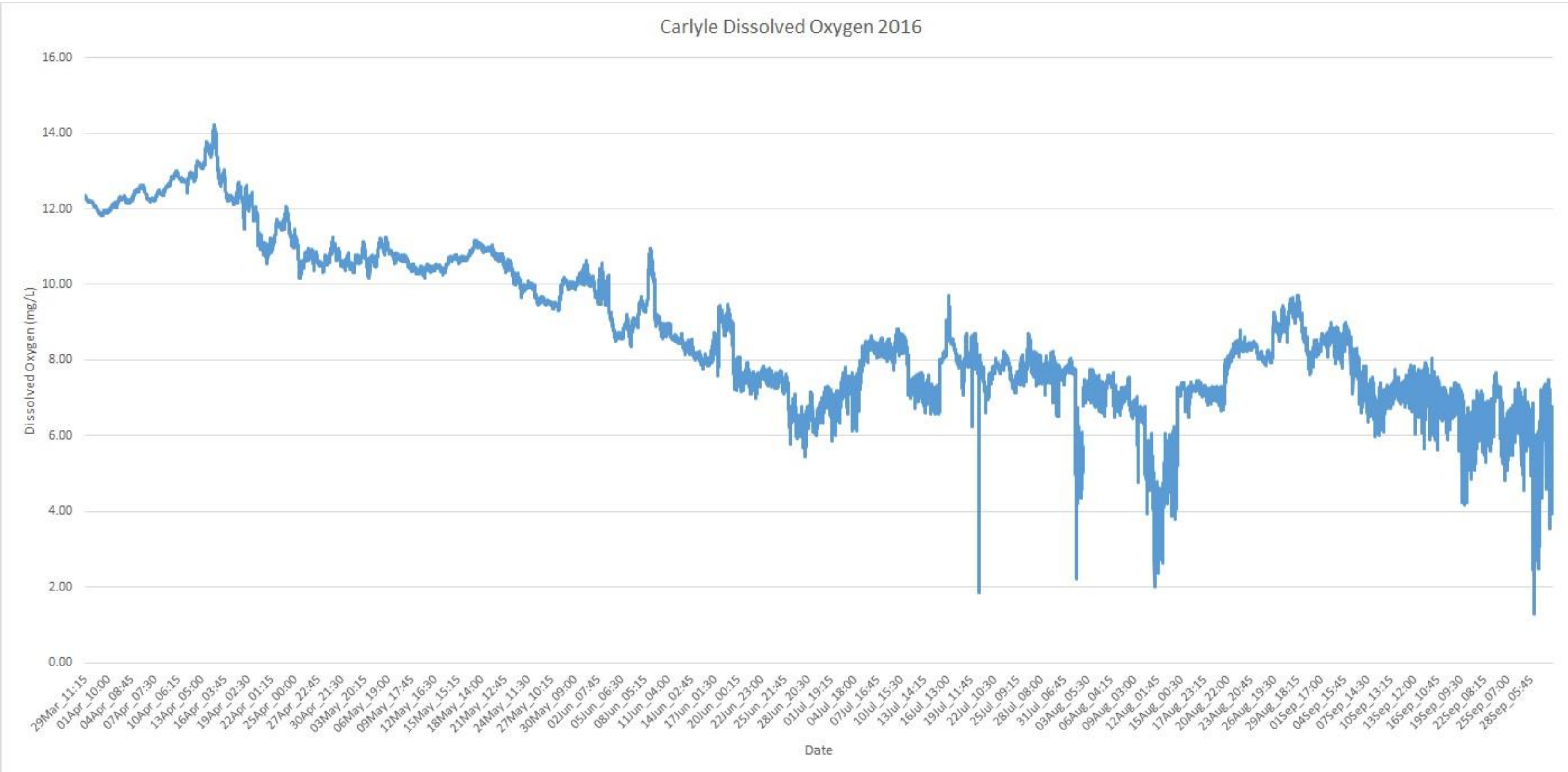

CAR-4 Redox & Conductivity
Redox (mv)
Cond (uS)
350
300
250
200
150
100
50
0
500
450
400
350
300
250
200
150
100
50
0
0.3
1
2
3
4
0.3
1
2
3
4
5
0.4
1
2
3
4
5
6
4/14/2016
6/21/2016
9/13/2016
Depth (m)/Date
Redox (mv)
Cond (uS)


Carlyle Tributary pH
STD Range 6.5 to 9.0
pH
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
4/14/2016 CAR-1
6/21/2016 CAR-1
9/13/2016 CAR-1
6/21/2016 CAR-13
9/16/2016 CAR-13
4/14/2016 CAR-12
6/21/2016 CAR-12
9/13/2016 CAR-12
Date/Site


CAR-2 pH
10
9
8
7
6
5
4
3
2
1
0
pH
STD Range 6.5 to 9.0
0.3
1
2
3
4
5
6
0.3
1
2
3
4
5
6
0.4
1
2
3
4
5
6
4/14/2016
6/21/2016
9/13/2016
Depth/Date


CAR-4 pH
STD Range 6.5 to 9.0
pH
10
9
8
7
6
5
4
3
2
1
0
0.3
1
2
3
4
0.3
1
2
3
4
5
0.4
1
2
3
4
5
6
4/14/2016
6/21/2016
9/13/2016
Depth/Date

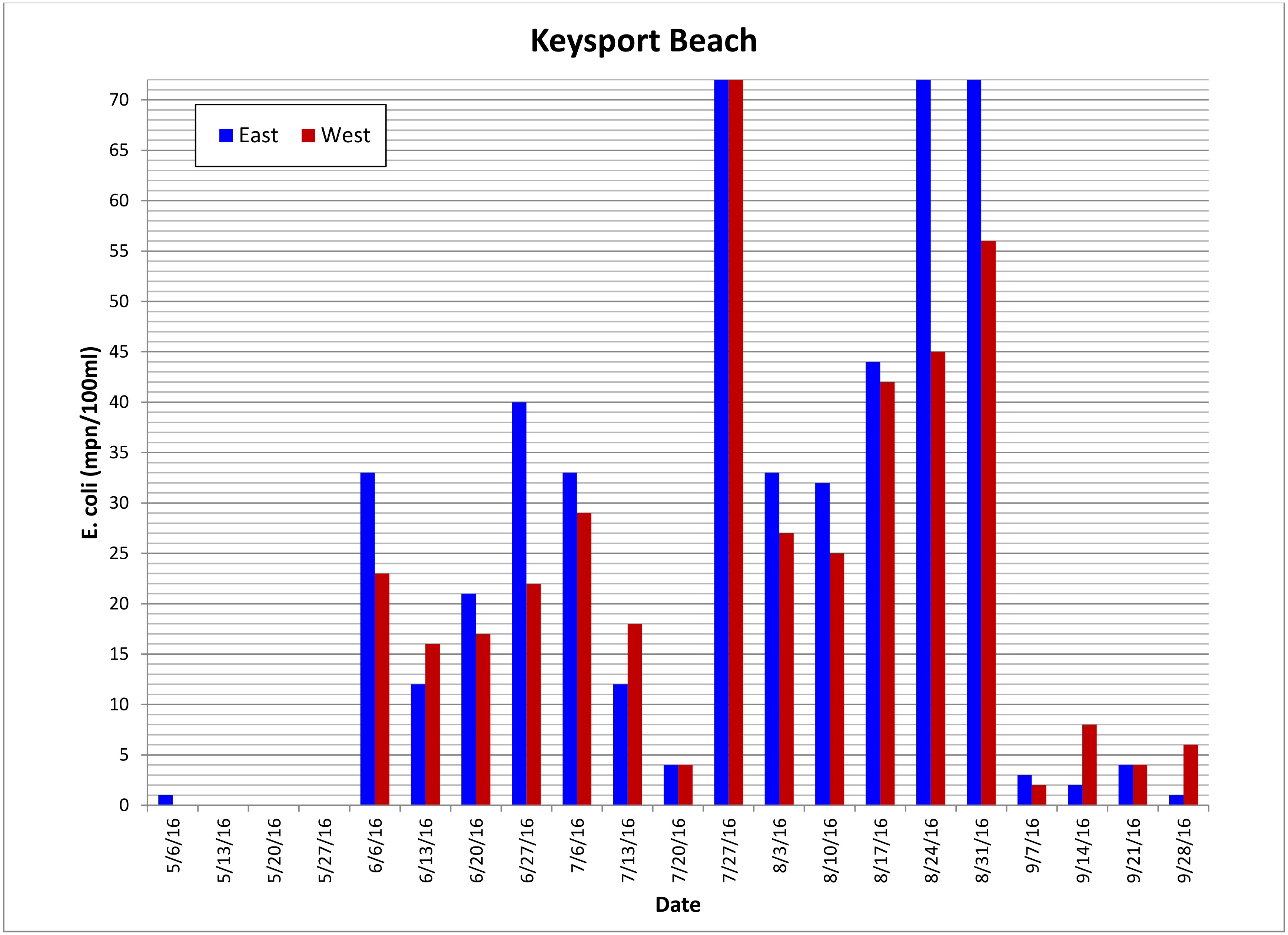

Secchi
16
14
12
10
8
6
4
2
0
Seechi (in)
14.5
12
10
7
4
3
4/14/2016
CAR-2
6/21/2016
CAR-2
9/13/2016
CAR-2
4/14/2016
CAR-4
6/21/2016
CAR-4
9/13/2016
CAR-4
Date/Site

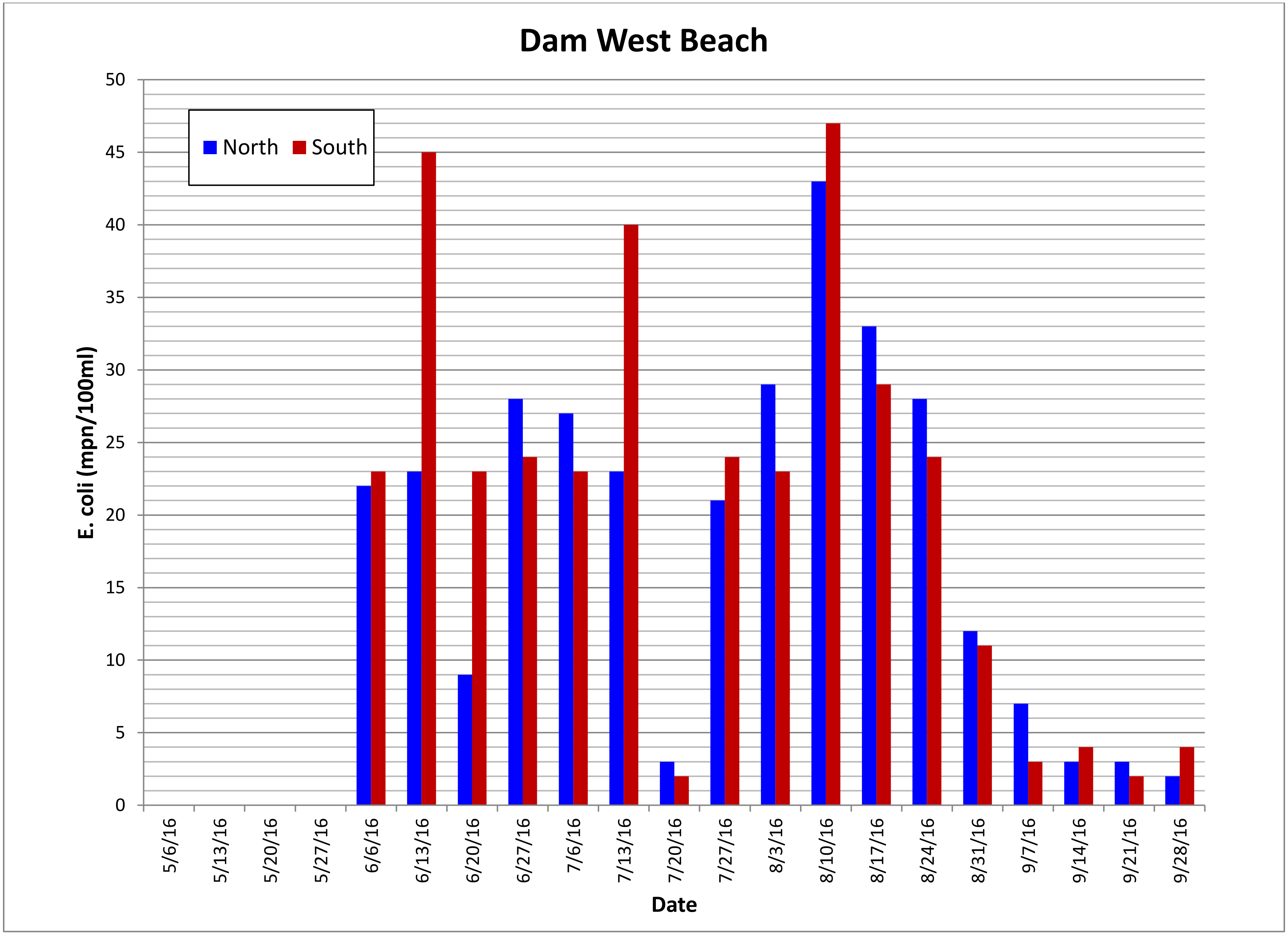


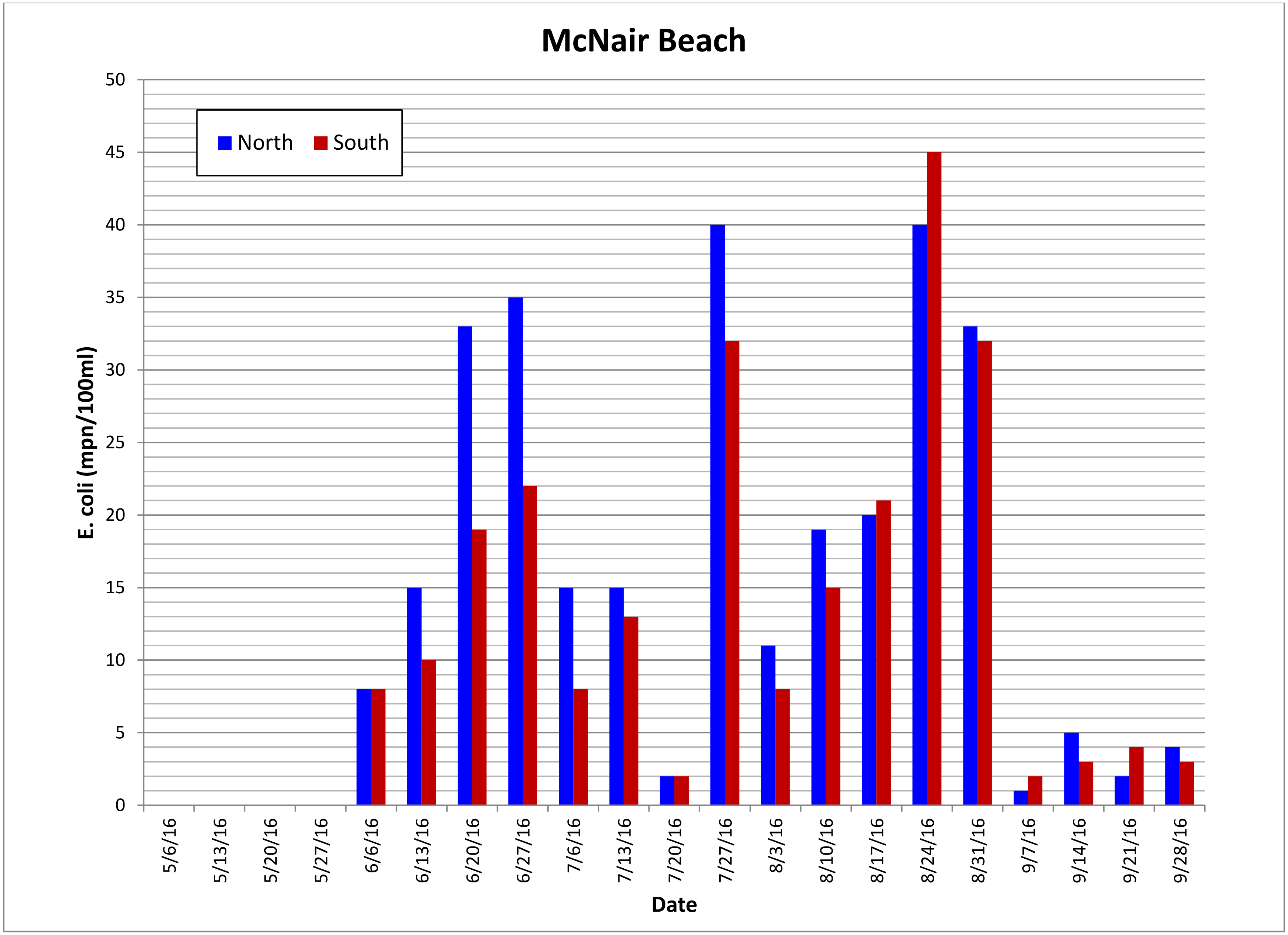
DO for Sonde in spillway

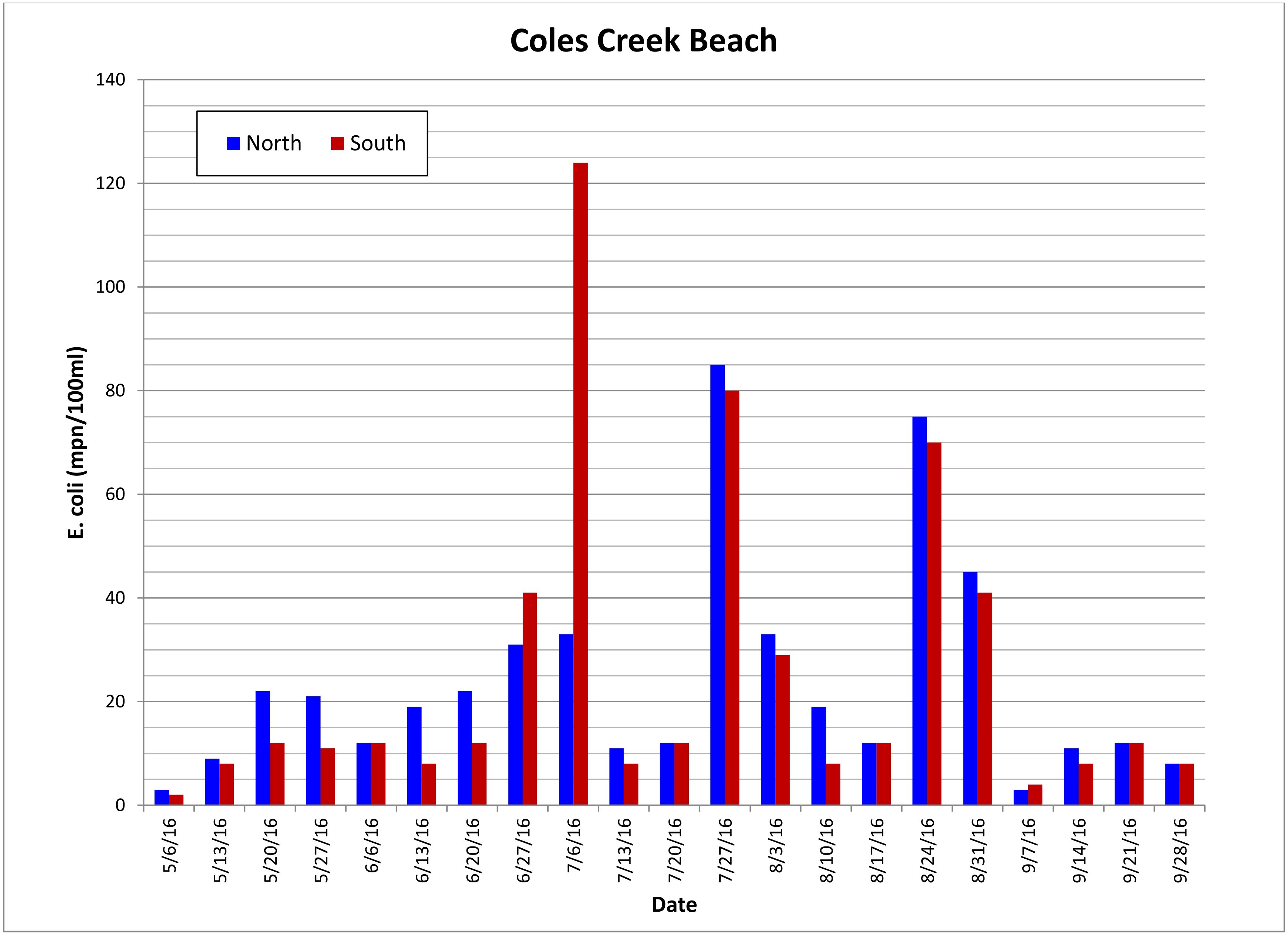
APPENDIX D

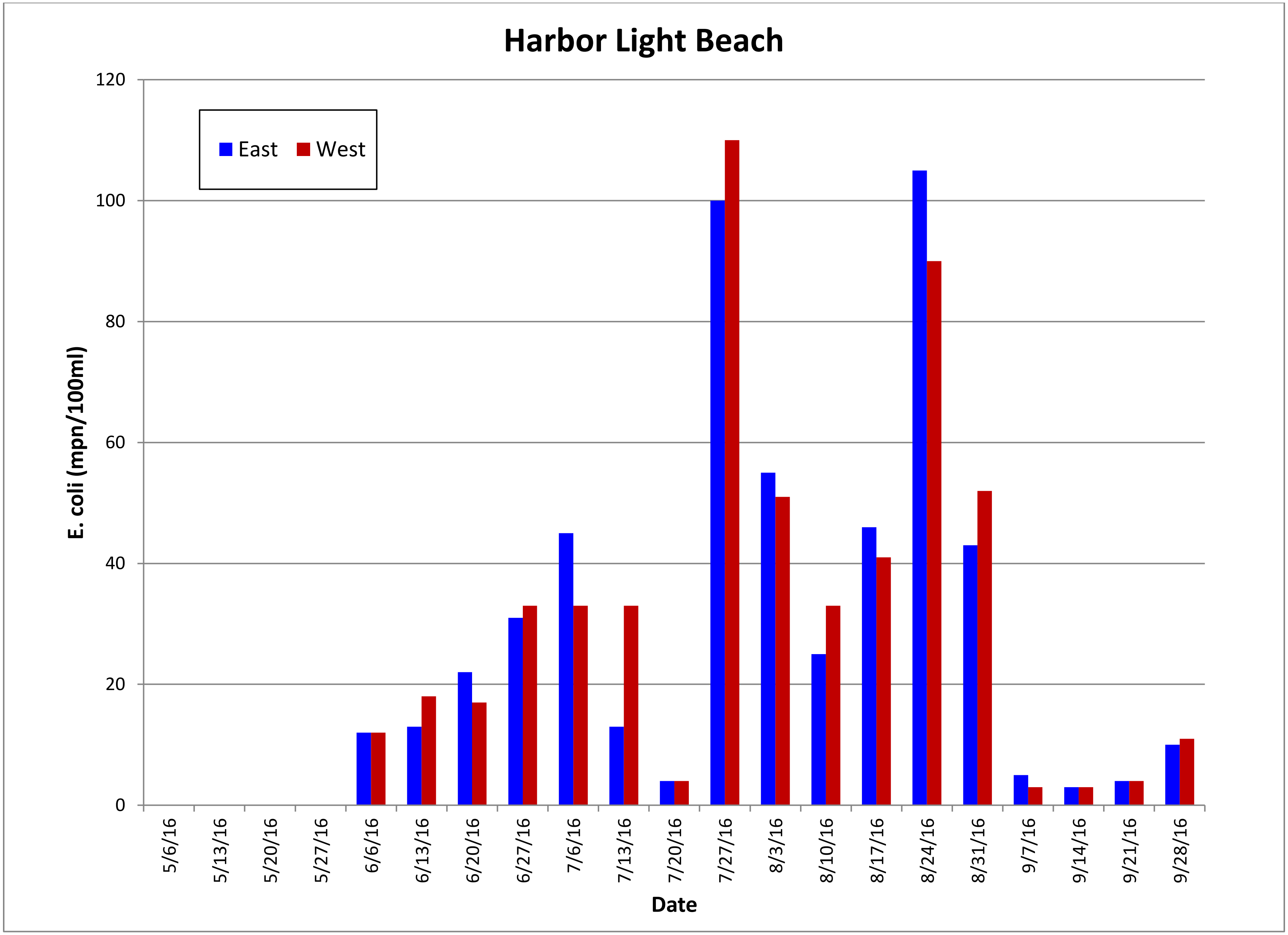
BEACH GRAPHS


Keysport Beach
East
West
E. coli (mpn/100ml)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
5/6/16
5/13/16
5/20/16
5/27/16
6/6/16
6/13/16
6/20/16
6/27/16
7/6/16
7/13/16
7/20/16
7/27/16
8/3/16
8/10/16
8/17/16
8/24/16
8/31/16
9/7/16
9/14/16
9/21/16
9/28/16
Date


Dam West Beach
North
South
E. coli (mpn/100ml)
0
5
10
15
20
25
30
35
40
45
50
5/6/16
5/13/16
5/20/16
5/27/16
6/6/16
6/13/16
6/20/16
6/27/16
7/6/16
7/13/16
7/20/16
7/27/16
8/3/16
8/10/16
8/17/16
8/24/16
8/31/16
9/7/16
9/14/16
9/21/16
9/28/16
Date


McNair Beach
North
South
E. coli (mpn/100ml)
Date
0
5
10
15
20
25
30
35
40
45
50
5/6/16
5/13/16
5/20/16
5/27/16
6/6/16
6/13/16
6/20/16
6/27/16
7/6/16
7/13/16
7/20/16
7/27/16
8/3/16
8/10/16
8/17/16
8/24/16
8/31/16
9/7/16
9/14/16
9/21/16
9/28/16


Coles Creek Beach
North
South
E. coli (mpn/100ml)
0
20
40
60
80
100
120
140
5/6/16
5/13/16
5/20/16
5/27/16
6/6/16
6/13/16
6/20/16
6/27/16
7/6/16
7/13/16
7/20/16
7/27/16
8/3/16
8/10/16
8/17/16
8/24/16
8/31/16
9/7/16
9/14/16
9/21/16
9/28/16
Date



Carlyle Beach Data

Date	Keysport		Harbor Light		Dam West		McNair		Coles Creek	
	East	West	East	West	North	South	North	South	North	South
5/6/16	1	0	0	0	0	0	0	0	3	2
5/13/16	0	0	0	0	0	0	0	0	9	8
5/20/16	0	0	0	0	0	0	0	0	22	12
5/27/16	0	0	0	0	0	0	0	0	21	11
6/6/16	33	23	12	12	22	23	8	8	12	12
6/13/16	12	16	13	18	23	45	15	10	19	8
6/20/16	21	17	22	17	9	23	33	19	22	12
6/27/16	40	22	31	33	28	24	35	22	31	41
7/6/16	33	29	45	33	27	23	15	8	33	124
7/13/16	12	18	13	33	23	40	15	13	11	8
7/20/16	4	4	4	4	3	2	2	2	12	12
7/27/16	180	165	100	110	21	24	40	32	85	80
8/3/16	33	27	55	51	29	23	11	8	33	29
8/10/16	32	25	25	33	43	47	19	15	19	8
8/17/16	44	42	46	41	33	29	20	21	12	12
8/24/16	80	45	105	90	28	24	40	45	75	70
8/31/16	76	56	43	52	12	11	33	32	45	41
9/7/16	3	2	5	3	7	3	1	2	3	4
9/14/16	2	8	3	3	3	4	5	3	11	8
9/21/16	4	4	4	4	3	2	2	4	12	12
9/28/16	1	6	10	11	2	4	4	3	8	8

Beach Water
250 mpn - Max (Shut down)
<100 mpn - Good
<10 mpn - Excellent

Potable Water
Any E.-coli would require the water lines to be burned with chlorine