

SYNOPTIC STUDY OF PHOSPHORUS CONCENTRATIONS IN
FARMINGTON BAY

by

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ABSTRACT

Farmington Bay, in the Southeast corner of the Great Salt Lake is hypereutrophic. There is increasing concern that phosphorus concentrations in Farmington Bay due to loading from wastewater treatment plants and urban and agricultural runoff may harm the beneficial uses of the Bay. Although a number of studies on Farmington Bay and the surrounding wetlands have been undertaken, there has been no systematic sampling of the entire Bay to determine phosphorus concentrations in the water column.

Water samples were collected from 11 locations for 3 to 6 months representing three different sections of Farmington Bay; these location can be divided into the following categories: Near Shore, Shallow Channel, and Channel sites. Samples were tested for total and ortho-phosphorus, salinity, pH, dissolved oxygen and water temperature, as well as dissolved oxygen of the underlying sediment.

Phosphorus varied significantly in both concentration and type between Near Shore, Shallow Channel, and Channel sites. Channel sites were typified as having no ortho-phosphorus, and a constant total phosphorus concentration of about 0.5 mg/L P. Near Shore sites had the highest phosphorus concentrations and were mostly comprised of ortho-phosphorus (0.9 mg/L P). Shallow Channel sites closely resembled Channel sites in having nearly no ortho-phosphorus. Total concentrations were higher at about 0.8 mg/L P and were more variable. Phosphorus concentrations did not appear to

be directly influenced by sediment dissolved oxygen or any of the water column parameters recorded.

To my husband, Clint, for moving to Utah and for his love and support

To my mom, my extremely dedicated editor-in-chief, for her time, effort, and enormous
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INTRODUCTION

Problem Statement

There is growing concern by the scientific community and citizens that the ecological and beneficial uses of Farmington Bay will not be sustained due to high levels of phosphorus loading. The eutrophication of Farmington Bay in response to high nutrient loading from natural and anthropogenic sources has not been fully investigated, and the effects of eutrophication on the waterbird community and other beneficial uses are poorly understood. Concern over the eutrophic state of the Bay has prompted a number of investigations of nutrient loading and cycling in the Bay.

Farmington Bay is located on the southeast corner of the Great Salt Lake. It covers approximately 100 mi² (260 km²) and is shallow (Wurtsbaugh and Marcarelli 2006), having an average water depth of 1 m in the main channel, and 6 inches or less on the wide margins surrounding the channel. The Bay is separated from the rest of the Great Salt Lake by a causeway, built in 1964 to connect Antelope Island to the mainland, and a second causeway to the south built for construction of I-80 in 1959. These physical barriers reduce mixing between the Bay and the main portion of the lake. In addition to reduced mixing, there are several fresh water sources that empty into the Bay and, as a result, Farmington Bay is significantly less saline than the rest of the lake.

Seven wastewater treatment plants (WWTP) discharge either directly or indirectly into Farmington Bay. The seven plants (South Valley, Central Valley, Salt Lake City, South Davis South, South Davis North, Central Davis, and North Davis) contribute roughly 45% of the total phosphorus reaching Farmington Bay (Myers et al. 2006a). Phosphorus also enters the Bay through other nonpoint sources such as urban and agricultural runoff. The combination of lower salinity and high phosphorus concentrations contributes to the large quantities of cyanobacteria in Farmington Bay that are not as prevalent in other parts of the Great Salt Lake. Due to its status as hypereutrophic (Wurtsbaugh and Marcarelli 2006), it is important to investigate phosphorus concentrations in Farmington Bay. Further studies of Farmington Bay are needed to gain a fuller understanding of the Bay and the impacts of high phosphorus loading.

One of the challenges of understanding Farmington Bay is its variability from year to year. The size and depth of the Bay can change dramatically. Variations in inflows can cause considerable changes in size, depth, and water quality of the Bay. For example, during higher flow years, the salinity of Farmington Bay is lower than in low flow years, and an increase in cyanobacteria is often seen. It may be necessary to conduct research during multiple years to gain a thorough understanding of the Bay during high, low, and average flow years.

Literature Review

Phosphorus in surface waters is typically found as phosphate, and can be divided into three groups: ortho-phosphorus, organically bound phosphorus, and poly-phosphates.

Ortho-phosphorus refers to inorganic forms of phosphorus (H_2PO_4^- , HPO_4^{2-} , and PO_4^-). It is often referred to as reactive or bioavailable, meaning it is available for immediate use. In the pH range of Farmington Bay the dominant forms are H_2PO_4^- , and HPO_4^{2-} . Organically bound phosphorus is the phosphorus tied up in plant or animal tissue. Polyphosphates are strings of phosphate polymers such as tripolyphosphate ($\text{P}_3\text{O}_{10}^{5-}$) or hexametaphosphate ($(\text{PO}_3)_6^{3-}$). Total phosphorus is the sum of these three categories. It includes both dissolved and particulate forms (Sawyer and McCarty 1978; Smith 1993). Phosphorus concentrations in the water of Farmington Bay can potentially be influenced by a number of factors, including phosphorus loading into the Bay, conditions in the sediment, water column characteristics, and mixing between the sediment and the water column.

Phosphorous concentrations within Farmington Bay are impacted by the amount of phosphorous introduced by incoming water sources, and these may be expected to vary seasonally at some sites. Phosphorous concentrations in WWTP effluents range from 2 to 3.2 mg/L (Myers et al. 2006a) and, depending on interactions with the sediment during conveyance, phosphorus concentrations reaching Farmington Bay will vary. Runoff is episodic and, therefore, will affect the phosphorus concentrations in the Bay sporadically.

There are several water sources entering Farmington Bay. At the south end, water enters via the Jordan River, the Sewer Canal, the Surplus Canal, and duck clubs. Farther north, Kays Creek empties into Farmington Bay most of the year. Two WWTPs discharge directly into Farmington Bay. Additionally, some mixing between Farmington Bay and the main body of the Lake occurs at the causeway.

Phosphorus concentrations in the water column are also influenced by a variety of conditions in Bay sediments. The literature describes two different systems for phosphorus cycling within a water body. The first is an iron dependent system which is governed by the redox conditions in the sediment. Ferric iron (Fe(III)) exists as insoluble oxyhydroxides in sediment which can adsorb phosphate to form solid FeOOH-PO_4 complexes, creating a sink in the sediment under oxic conditions. In contrast, under anoxic conditions, dissolved ferrous iron (Fe(II)) dominates such that, during transition from oxic to anoxic conditions, phosphate associated with dissolving iron oxyhydroxides is released into the water column (Kelton et al. 2004; Sondergaard et al. 2003; Lee et al. 1977). The second system is a concentration-dependent system, where elevated concentrations of phosphate in the aqueous phase drive transfer to sediment, with depletion in the aqueous phase driving release from sediment. Several, or all, of these factors could influence phosphorus concentrations in the water column of Farmington Bay. In a study that examined the absorption and release of ortho-phosphorus in Farmington Bay, Myers et al. (2006b) found that mixing events influenced phosphorus concentrations. Their study showed that aerobic sediments released phosphorus when mixed with water containing a low concentration of phosphorus. The sediments also removed (adsorbed) phosphorus from the water column when mixed with water containing a high concentration of phosphorus. However, sediments that appeared to be anaerobic released phosphorus regardless of the initial concentration of phosphorus in the water column. In contrast, Patrick and Khalid (1974) demonstrated that anaerobic sediments act as a sink when the overlying water has high phosphorus concentrations but can release phosphorus when the overlying water has low initial phosphorus

concentrations. This research showed that sediment-water interactions can be complex, either adding or removing phosphorus from the water column.

Physical factors such as wind or bioturbation can cause mixing between sediment and the water column resuspending particulate phosphorus, which can then be released to the water column. Because Farmington Bay is so shallow (maximum depth of about 1 m), it is likely that wind plays a role in stirring up sediments and releasing phosphorus into the water column (Myers et al. 2006b; Sondergaard et al. 2003).

Conditions in the water column also vary across the bay and may be influenced by a variety of parameters such as water temperature, pH, salinity, and dissolved oxygen (DO). Water temperature varies seasonally, as well as with time of day. Temperature has been shown to have an effect on biologically mediated processes and, thus, may influence the release rate of phosphorus from sediment to water column (Sondergaard et al. 2003). Elevated temperatures can increase mineralization and release organic phosphorus bound in sediment (Jensen and Anderson 1992). Research has also shown that the effects of temperature on phosphorus are more pronounced when there is a significant amount of iron bound phosphorus (Jensen and Anderson 1992).

Daily changes in redox condition (e.g., DO) are also expected. During nighttime hours, plants consume oxygen and then release it during the day through photosynthesis. It is also known that the salinity in Farmington Bay varies from about 0.5 to 10‰ (Wurtsbaugh and Marcarelli 2006). Salinity typically increases throughout the summer as the water level of the bay decreases. In addition, lower salinities are recorded at the south end of Farmington Bay where the majority of the fresh water sources enter.

The pH can also effect phosphorus concentrations in the water column, especially in lakes where phosphorus release from sediment is dependent on iron. As pH increases, hydroxyl ions compete with phosphorus ions for binding sites in the sediment, causing an increase in water column phosphorus concentrations (Sondergaard et al. 2003). A study by Seitzinger showed that under aerobic conditions, phosphorus release increased as the pH of the overlying water increased. At a pH of around 7 to 8, minimal phosphate release occurred from the sediment to the water column. However, at a pH above 9.5, significant release was observed, likely due to the release of phosphate from iron complexes (Seitzinger 1991).

Research Objectives

The concentration and cycling of phosphorus in Farmington Bay is a complex problem. Previous research on Farmington Bay found average phosphorus concentrations of approximately 0.5 mg/L in the water column (Wurtsbaugh and Marcarelli 2006). However, the samples in this study were taken only from the channel where water depths are about 1 m and it is believed that the same phosphorus concentrations would not be found in other, more shallow, parts of the Bay. Due to the differing water sources entering the bay, variations in the water column, and variations in the dissolved oxygen of the sediment, it is believed that the levels of phosphorus would vary from the main channel to the shore.

The purpose of this research is to provide a synoptic study of the water column phosphorus throughout Farmington Bay for Central Davis Sewer District, to measure field parameters such as salinity, water temperature, pH and dissolved oxygen, and to

correlate the expected variations in phosphorus concentrations with varying water sources, water column characteristics, and sediment characteristics. The hypothesis on which this research is based is that phosphorus concentration will vary across the Bay and that this may be attributable to the differing water sources, water column and sediment characteristics, and physical mixing of sediment and water column in this shallow bay.

METHODS

Sampling Sites

Eleven sites in Farmington Bay were sampled approximately weekly from May through July (Table 1, Fig. 1). Four sampling sites were within the channel with an average depth of about 1 m. The remaining seven sites were Shallow Channel or Near Shore sites with an average depth of 6 inches or less. 2007 was a year of drought and the shoreline receded during the study period. As a consequence, sampling Sites 2, 5, and 6 had to be moved during the study period. The revised sampling locations are denoted as 2a, 5a, 5b, 6a, and 6b. New sampling locations were chosen based on proximity to the previous sampling location. Each new site was about 0.5 miles from the previous site. It is important to note that when Site 6 was moved, Sites 6a and 6b represented the Shallow Channel and not the Near Shore.

Table 1: Classification of Sites

Near shore sites	Channel Sites	Shallow Channel Sites
Site 1	Site 8	Site 5
Site 2	Site 9	Site 5a
Site 3	Site 10	Site 5b
Site 4	Site 11	Site 6a
Site 6		Site 6b
Site 7		



Fig. 1: Map of Sampling Sites in Farmington Bay

From August through October, only Sites 1 - 3 were sampled. Because phosphorus data from the four Channel sites (8-11) were stable from May through July and were consistent with prior studies, it was determined that no further sampling at these locations would be necessary (Wurtsbaugh and Marcarelli 2006; Myers et al. 2006a). Additionally, due to the receding shoreline during summer 2007, Sites 4, 6, and 7 were eliminated from the sampling set at the end of July. Finally, because phosphorous concentrations from Sites 1-3 varied significantly throughout the summer, these three sites were sampled bimonthly during August and September and once during October.

Sample Collection

Samples were collected in plastic bottles by hand. Samples were stored at 4 °C until tested. Water column parameters were obtained using a YSI 556 MPS at the time of sampling (starting on May 31, 2007). Salinity, pH, DO, total dissolved solids, and temperature were recorded using the YSI meter at a depth equal to that of the sample. The YSI meter calculated the TDS from the conductivity ($0.65 \times \text{conductivity}$). The YSI meter also calculated the salinity from the temperature and the total dissolved solids using a complex algorithm (Appendix A). Starting in July, the DO of the sediment was recorded using a Hach Luminescent Dissolved Oxygen probe. The validity of luminescent DO probe's application in the sediment was previously determined by the staff at Central Davis Sewer District (Appendix B). The DO probe was attached to a long PVC pipe, and the probe was inserted a few inches into the sediment.

Sample Testing

Samples were equilibrated to room temperature and tested for ortho-phosphorus and total phosphorus using a Hach DR/4000U spectrophotometer and standard methods outlined by Hach. All samples were prepared and tested in duplicate according to method 8048 for ortho-phosphorus and method 8190 followed by 8048 for total phosphorus. All reagents were ordered from Hach and used within the accepted shelf life for the reagent.

Method 8190

A Potassium Persulfate Powder Pillow (25 mL) was added to 25 mL of sample and mixed. 2 mL of 5.25 N sulfuric acid was added and the solution was gently boiled for 30 minutes. The purpose of these steps was to convert organic and inorganic forms of phosphorus to ortho-phosphorus. The sample was then cooled to room temperature and 2 mL of 5.0 N sodium hydroxide was added. The volume of the sample was then adjusted to 25 mL followed by method 8048.

Method 8048

A 25 mL sample cell was filled with sample and used as a blank. A second 25 mL sample cell was filled with sample and a PhosVer 3 phosphate Powder Pillow (25 mL) was added. The solution was mixed and allowed to react for 2 minutes for the ortho-phosphorus test and 10 minutes for the total phosphorus test. The blank was used to zero and the sample was read.

Notes

Reporting. All phosphorus results are reported as mg P/L.

Dilution. Some samples required dilution prior to testing with method 8048 to ensure the phosphorus concentrations were within the range of the method. The Hach reading was then multiplied by the dilution factor to obtain the actual phosphorus concentration in the sample.

Filtering. In accordance with the above methods, samples were not filtered and samples were allowed to settle prior to being tested. Two equal aliquots of each sample

collected were used to fill the sample cells; one was used as the blank (no addition of the PhosVer3 reagent) and the other was analyzed for phosphorus as described in methods 8091 and 8048. Because the sample was also used as the blank, the presumption was that turbidity should not be an influencing factor in the results.

Spiking. A spiking study was carried out to determine percent recovery for the ortho-phosphorus method. Sample from Site 10 was spiked with varying amounts of 25 mg/L phosphorus standard to create a 0.25, 0.5, and 0.75 mg/L spike. Results are in Appendix C.

PHREEQC and Geochemist Workbench Modeling

Water chemistry data (Table 2) from within the main channel were obtained from Dave Naftz of the USGS (Dave Naftz, personal communication, January 15, 2008). The water sample provided was collected on December 3, 2002 at the north end of Farmington Bay at the Causeway where the channel of the Bay enters the Great Salt Lake. Phosphorus and iron were not included in the water chemistry data and concentrations were assumed to be 0.5 mg/L for each. PHREEQC, a USGS program, was used to determine the activity coefficients for each ion. These activity coefficients were then used in Geochemist Workbench to create an Eh-pH diagram.

Table 2: Water Chemistry Data at Farmington Bay Causeway

Density	Alkalinity	Cl	SO4	Na	Mg	K	Br	Ca	Si	B	Sr	Li	P	Fe
g/cm ³	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1.0448	499	33900	4770	20900	2000	1070	12	140	3	8	1.7	10	0.5	0.5

RESULTS

Salinity

The salinity of Channel sites varied slightly throughout the study period of May through July, and showed a generally increasing trend over time. Fig. 2a is a plot of salinity vs. time for Channel Site 8 (as representative of Channel sites) and reveals an increase in salinity from about 40 parts per thousand (ppt) to 65 ppt (4 - 6.5 %). This trend held true for all channel sites with an average range of about 40 ppt (4%) to 70 ppt (7%). Salinity in Shallow Channel sites (Fig. 2b) showed a higher degree of variability than the Channel sites. Additionally, the Shallow Channel sites showed the highest salinity in the Bay, ranging from approximately 30 ppt (3%) to 80 ppt (8%). Near shore sites were the least saline with values less than 2 ppt; see Fig. 2c. There were two exceptions to this general trend: Site 2 showed a spike to about 7 ppt on June 8th and Site 4 showed a significant spike on June 29th and July 3rd (Appendix E).

pH

The pH in Farmington Bay varied from about 7 to 10 and fluctuated from sample date to sample date, as well as from site to site (Fig. 3). However, the seasonal average for each group of sites revealed that Channel sites had the highest pH at 9.5. Shallow Channel sites had a pH of 9.1, followed by Near Shore sites with a pH of 8.5.

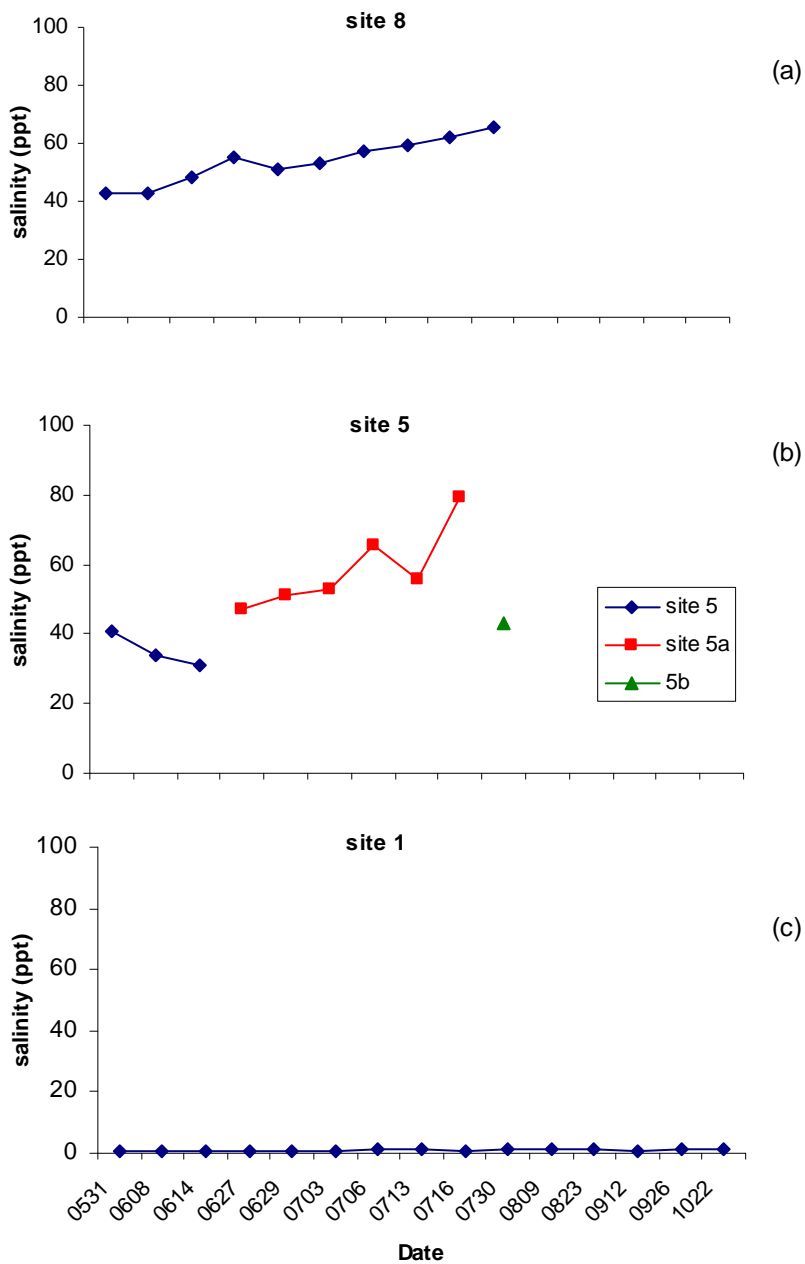


Fig. 2 Representative Plots of Changes in Salinity at (a) Channel, (b) Shallow Channel, and (c) Near Shore Sites

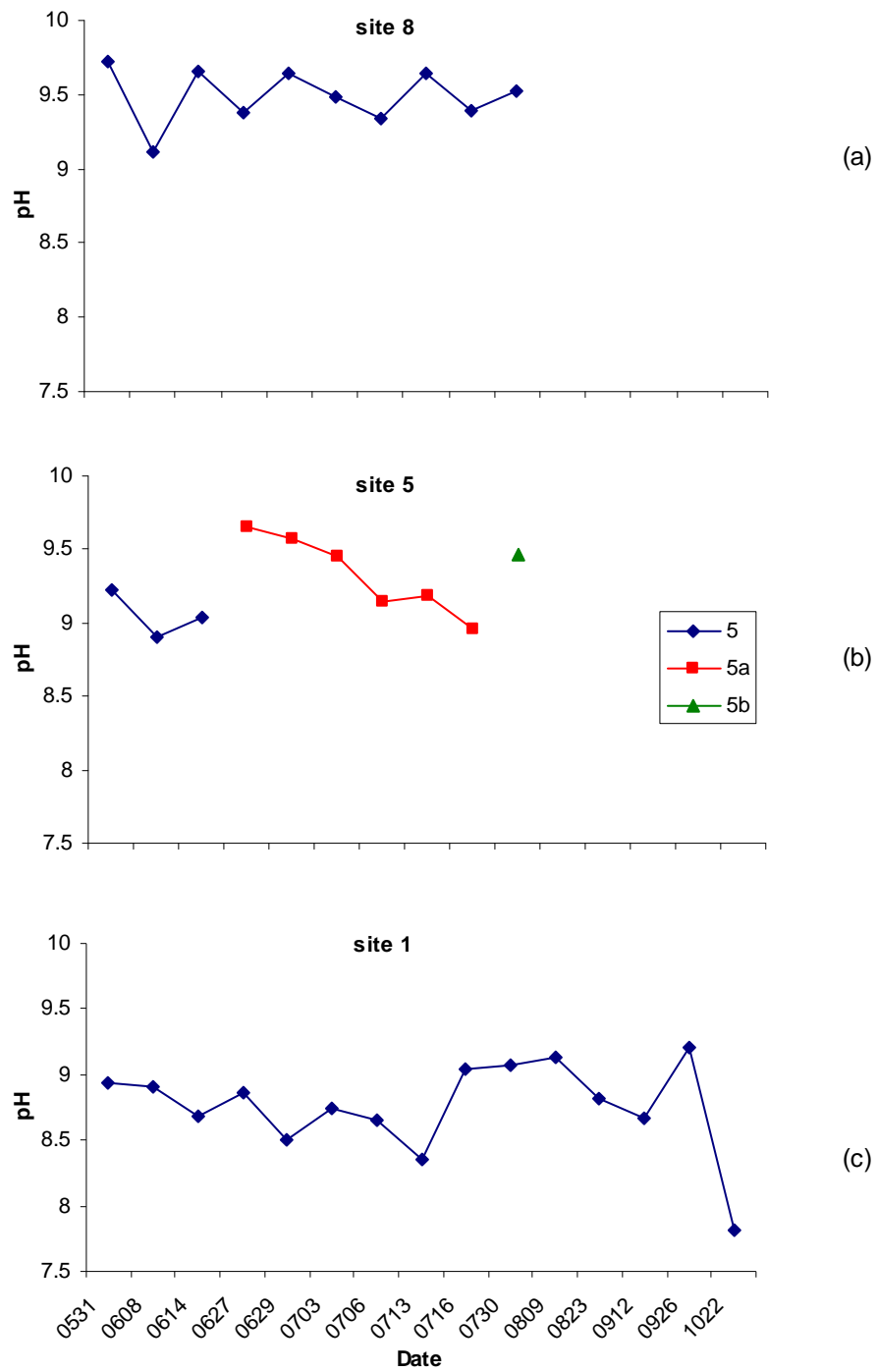


Fig. 3: Representative Plots of Changes in pH at (a) Channel, (b) Shallow Channel, and (c) Near Shore Sites

Dissolved Oxygen in Water Column

DO varied significantly throughout the study and showed variations from site to site (Fig. 4). No clear trend distinguishing the DO in the sample groups could be ascertained. This is likely due in large part to the fact that samples were not pulled at the same time of day. DO is known to vary significantly throughout the day, reaching a minimum at night when plants consume DO.

Water Temperature

Water temperature is known to be effected by time of day, water depth, and air temperature. Due to the multiple influences on water temperature, no clear trend between Channel, Shallow Channel, and Near Shore sites was found (Fig. 5).

Sediment Dissolved Oxygen

Sediment DO values (Table 3) for all sites were less than 0.35 mg/L throughout the study period after removing one outlier on July 6th at Site 5a; the detection limit of the probe is 0.1mg/L. The average DO concentration was 0.17 mg/L. There was little variation in sediment DO concentrations and the values indicate that there is continuously little to no dissolved oxygen in the sediment; i.e., that sediment conditions were suboxic to anoxic.

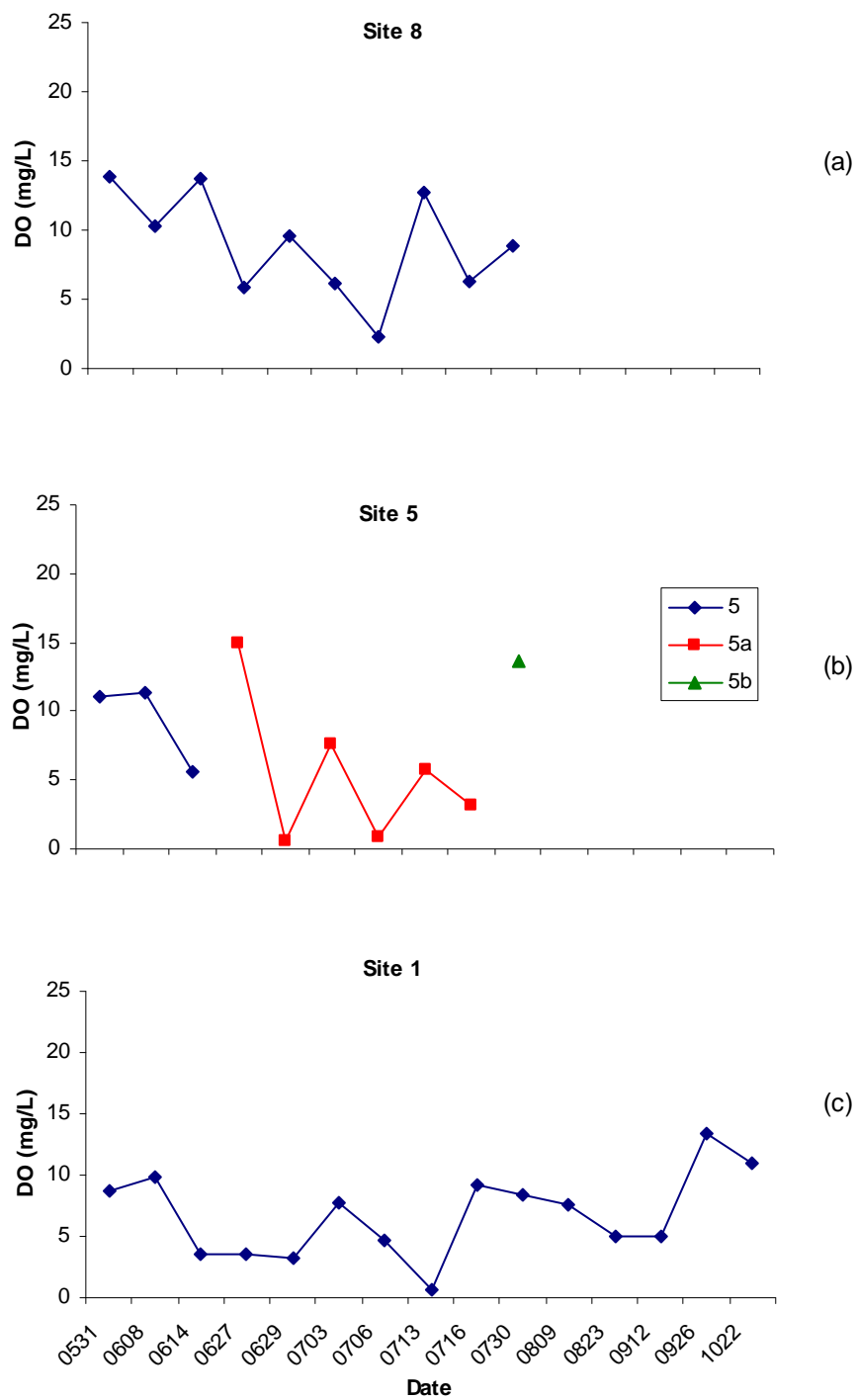


Fig. 4: Representative Plots of Changes in Dissolved Oxygen at (a) Channel, (b) Shallow Channel, and (c) Near Shore Sites

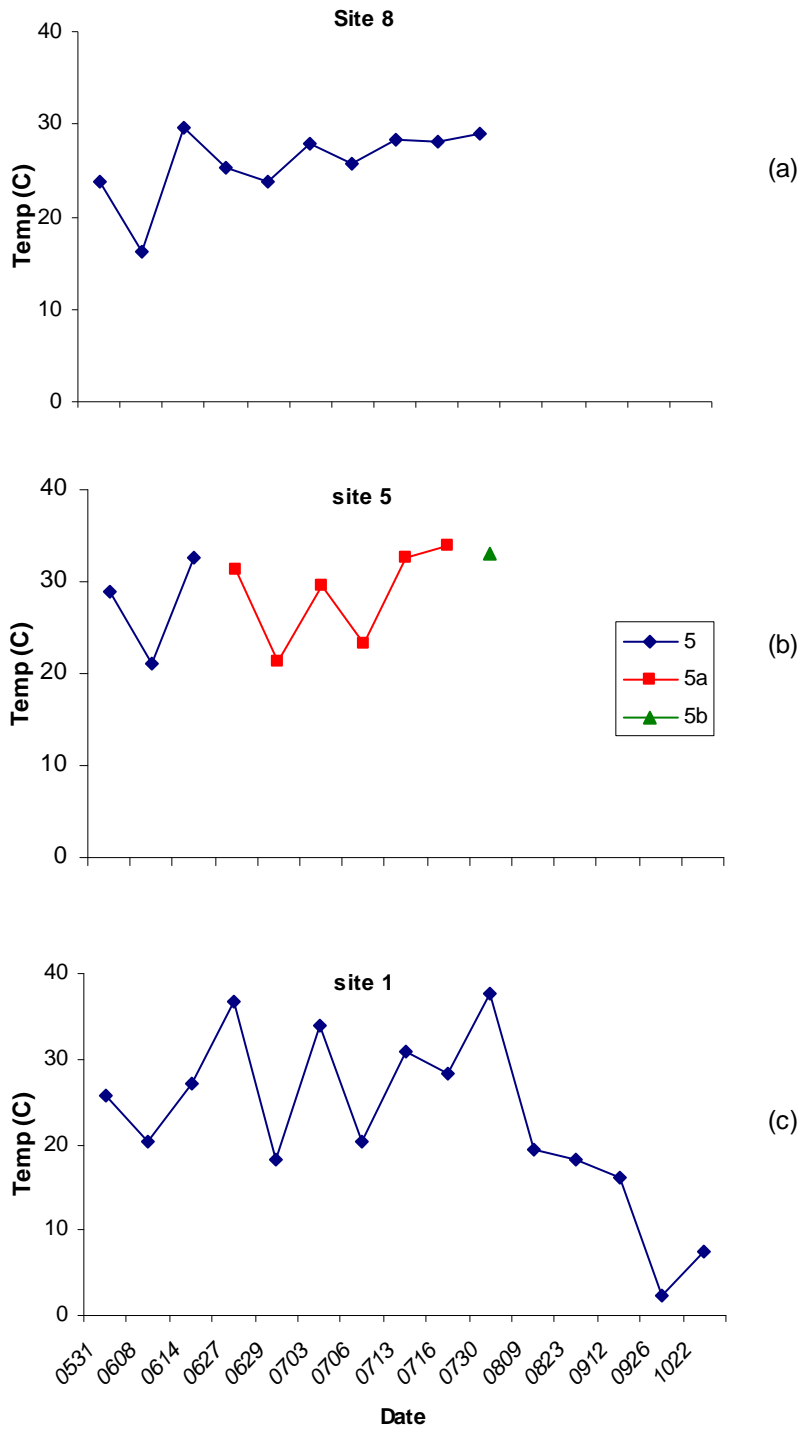


Fig. 5: Representative Plots of Changes in Temperature at (a) Channel, (b) Shallow Channel and (c) Near Shore Sites

Table 3: Sediment Dissolved Oxygen at Each Sampling Site

Site	070607	071307	071697	073007	080907	082307	091207	0926
	sediment DO (mg/L)							
1	0.14	0.09	0.11	0.14	0.15	0.21	0.22	0.31
2	0.16	0.11	0.16					
2a				0.14	0.18	0.23	0.26	0.34
3	0.12	0.11	0.12	0.03	0.17	0.21	0.22	0.3
4	0.18	0.11	0.24	0.13	0.28			
7		0.22	0.22	0.29				
5a	0.66	0.12	0.12					
5b				0.15				
6a	0.13	0.11	0.17					
6b				0.22				
8		0.11	0.12	0.16				
9		0.09	0.13	0.17				
10		0.12	0.14	0.18				
11		0.17		0.18				

Phosphorus

There were significant differences in phosphorus concentrations of the Channel, Shallow Channel, and Near Shore sites (Fig. 6). Channel sites showed total phosphorus concentrations between 0.2 and 0.55 mg/L with an average concentration of 0.36mg/L P. Ortho-phosphorus was consistently less than 0.1 mg/L and, in many instances, concentrations were below the level of detection. There was very little variation in Channel phosphorus concentration throughout the study period.

Shallow Channel sites likewise also had essentially no ortho-phosphorus. Total phosphorus fluctuated significantly throughout the sampling period with concentrations ranging from 0.4 to 2.5 mg/L.

Near Shore sites were unique in being comprised of mostly ortho-phosphorus and showed three somewhat different trends (Fig. 7). Sites 1, 4, and 6 showed phosphorus

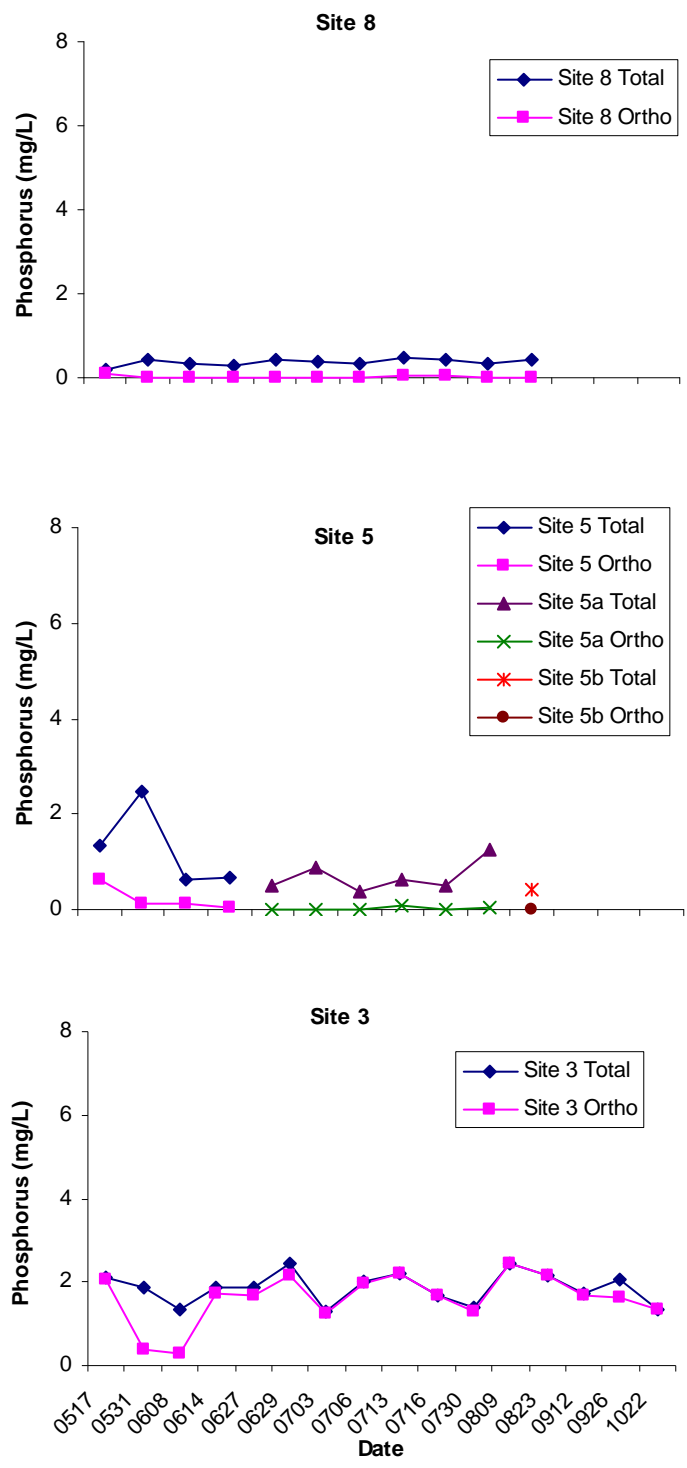


Fig. 6: Representative Plots of Changes in Phosphorus at (a) Channel, (b) Shallow Channel and (c) Near Shore Sites

concentrations with minimal fluctuations from sampling date to sampling date. However, Sites 3 and 7 showed considerable variation throughout the sampling season, and both showed a characteristic difference between ortho-phosphorus and total phosphorus concentrations at the beginning of the study period. Site 2 had mostly ortho-phosphorus except at the end of May, the beginning of June, and the end of July. In the intervening time, there were large swings in the phosphorus concentrations, ranging from 0.34 to 7 mg/L total phosphorus (Fig. 7b) and, for this reason, Site 2 was excluded from averages for Near Shore sites. See the Appendix G for plots of these sites. Although the three sites in Fig. 7 appear to have different trends, Site 1 does trend similarly to Site 2, albeit at much lower concentrations. To better demonstrate this relationship, the phosphorus data was plotted on a log scale (Fig. 8). As can be seen in the figure, Sites 1 and 2 do trend together throughout most of the study. At times, Site 3 also trends with Sites 1 and 2. Site 4 trends similarly to Site 1 and Site 7 trends similarly to Site 3 (Appendix G).

Because the Near Shore sites were closest to incoming water sources, a more detailed examination of each of these sites was conducted and compared to the incoming water. Site 1 is fed by the Farmington Bay Waterfowl Management Area (FBWMA). Sites 2 and 4 are fed by water from various duck clubs. Site 6 was in Kays Creek, which is mostly freshwater with agricultural runoff. Site 3 was in the outfall of the Sewer Canal, and Site 7 was in the North Davis Sewer District outfall, both of which carry treated effluent from WWTPs.

Site 1 was chosen for additional analysis because there was only one incoming water source (FBWMA) and it was easily accessible for sampling. Samples were

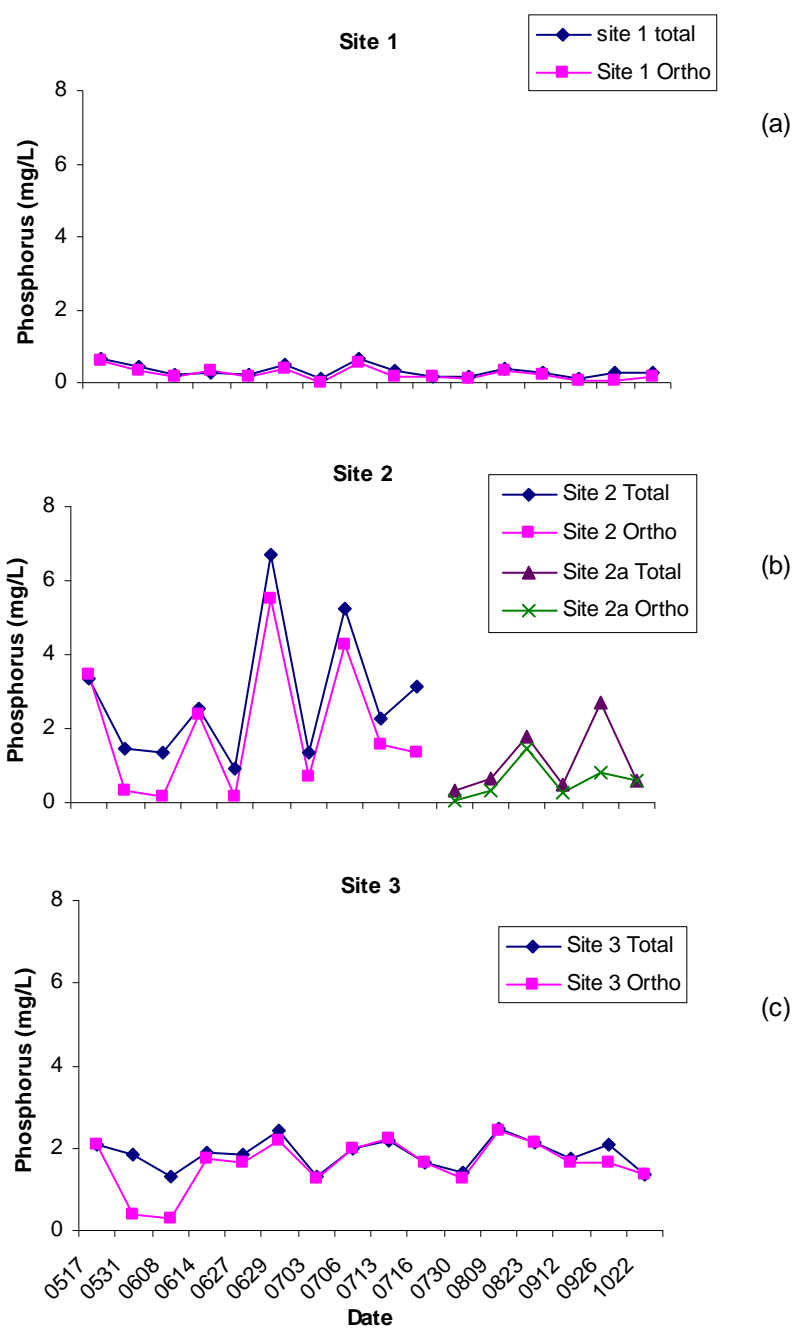


Fig. 7: Changes in Phosphorus at Three Near Shore Sites
(a) Site 1, (b) Site 2, (c) Site 3

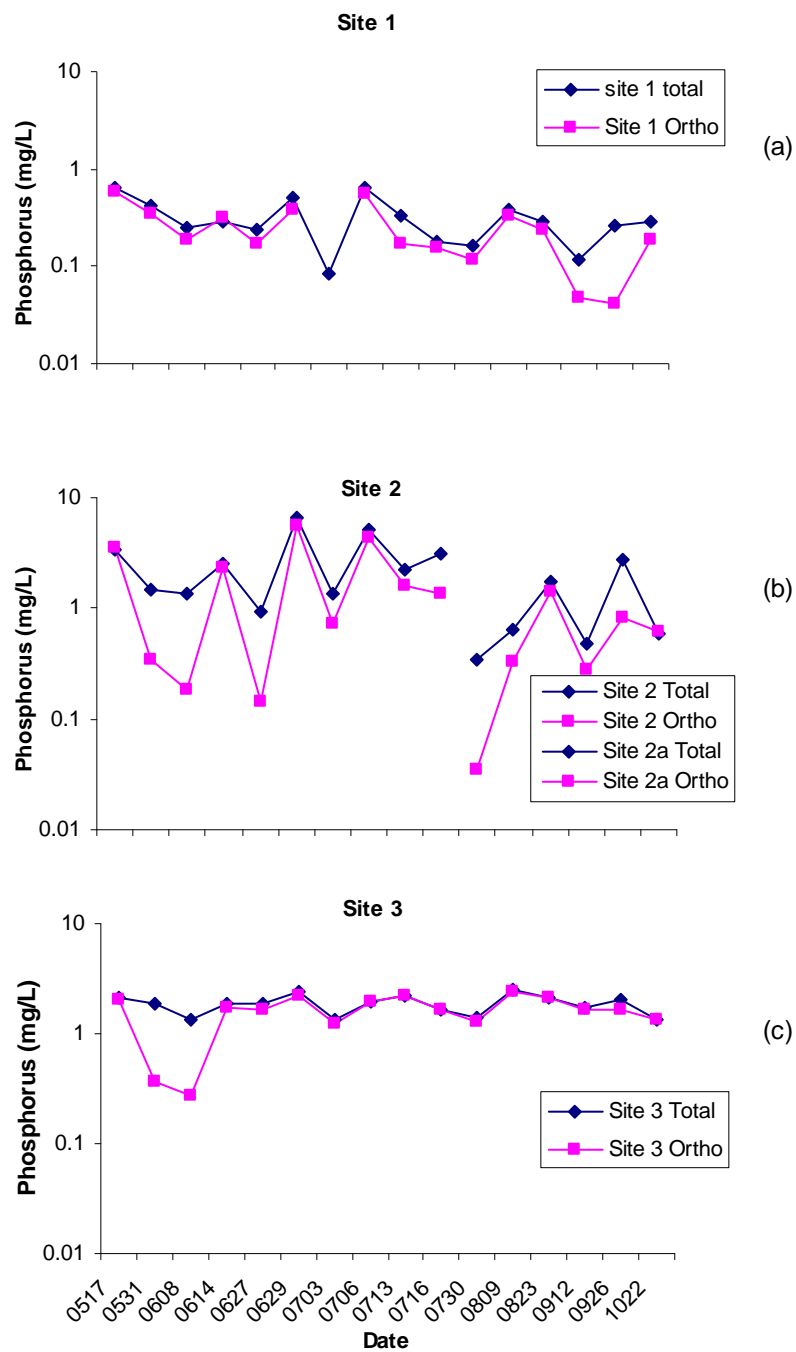


Fig. 8: Phosphorus Concentrations at Three Near Shore Sites on Log Scale

(a) Site 1, (b) Site 2, (c) Site 3

collected and tested for total and ortho-phosphorus five times at the entrance of FBWMA water into Farmington Bay. Comparison to the phosphorus concentrations at Site 1 are presented in Table 4. These two sampling locations were approximately 1 mile apart. The average ortho-phosphorus concentrations at Site 1 and FBWMA were 0.168 mg/L and 0.170 mg/L, respectively. Total phosphorus at Site 1 was 0.259 mg/L and was 0.269 mg/L at FBWMA. The concentration of phosphorus at FBWMA and Site 1 are similar and trend together.

Total Dissolved Solids

Concern was raised regarding the effect that TDS may have on the phosphorus test. This was investigated by plotting TDS vs. phosphorus concentration. If there is a significant difference in ortho-phosphorus and total phosphorus concentrations, and the TDS spikes up on this same date, then TDS may be interfering in the test (Ramesh Goel, personal communication, January 29, 2008). Fig. 9 is a plot of TDS and phosphorus concentrations at Site 3. Site 3 was chosen because it has the separation between total and ortho-phosphorus that may indicate an interference.

Table 4: Phosphorus Concentrations at FBWMA and Site 1

Date	FBWMA		Site 1	
	TOTAL	ORTHO	TOTAL	ORTHO
0809	0.236	0.1575	0.385	0.3385
0823	0.385	0.3255	0.292	0.237
0912	0.141	0.102	0.1155	0.0485
0926	0.208	0.056	0.267	0.0405
1022	0.327	0.199	0.283	0.185

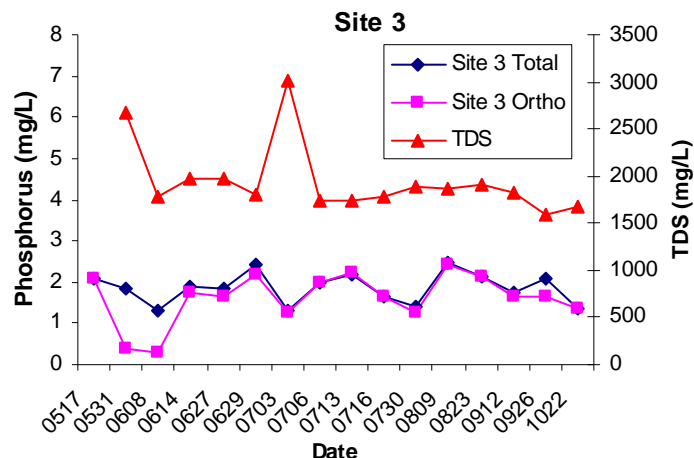


Fig. 9: Changes in TDS and Phosphorus Concentrations at Site 3

As can be seen, there were large deviations between ortho-phosphorus and total phosphorus on May 31st and June 8th. On May 31st, TDS was 2676 mg/L. However, on June 8th, the TDS was significantly lower (1789 mg/L), and equal to almost every other sampling date. On days with similar TDS values, there was no significant deviation between the two forms of phosphorus. Additionally, TDS spiked to 3020 mg/L on July 3rd; however, the ortho-phosphorus concentration was essentially the same as the total phosphorus concentration. Similar findings were seen at the other sites (Appendix H) and, therefore, it is believed that TDS was not an interference in the phosphorus test.

Phosphorus Speciation Modeling

One of the interesting results discussed above was that Near Shore sites were comprised mostly of ortho-phosphorus, whereas Channel and Shallow Channel sites were mostly total phosphorus. Because one possible explanation for the decrease in phosphorus concentrations in the water column is a loss to the sediment, an investigation

into possible phosphorus species present in the sediment was undertaken using Geochemist Workbench. The Eh-pH diagram shown in Fig. 10 was created using Geochemist Workbench.

According to the diagram, at the pH values found in this part of Farmington Bay, the dominant form of phosphate should be hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_3\text{OH}$), regardless of redox conditions. Under reducing conditions, a small amount of strengite ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$) may also form (Fig. 10). Together, these predictions indicate that phosphorus can be stored in the sediment.

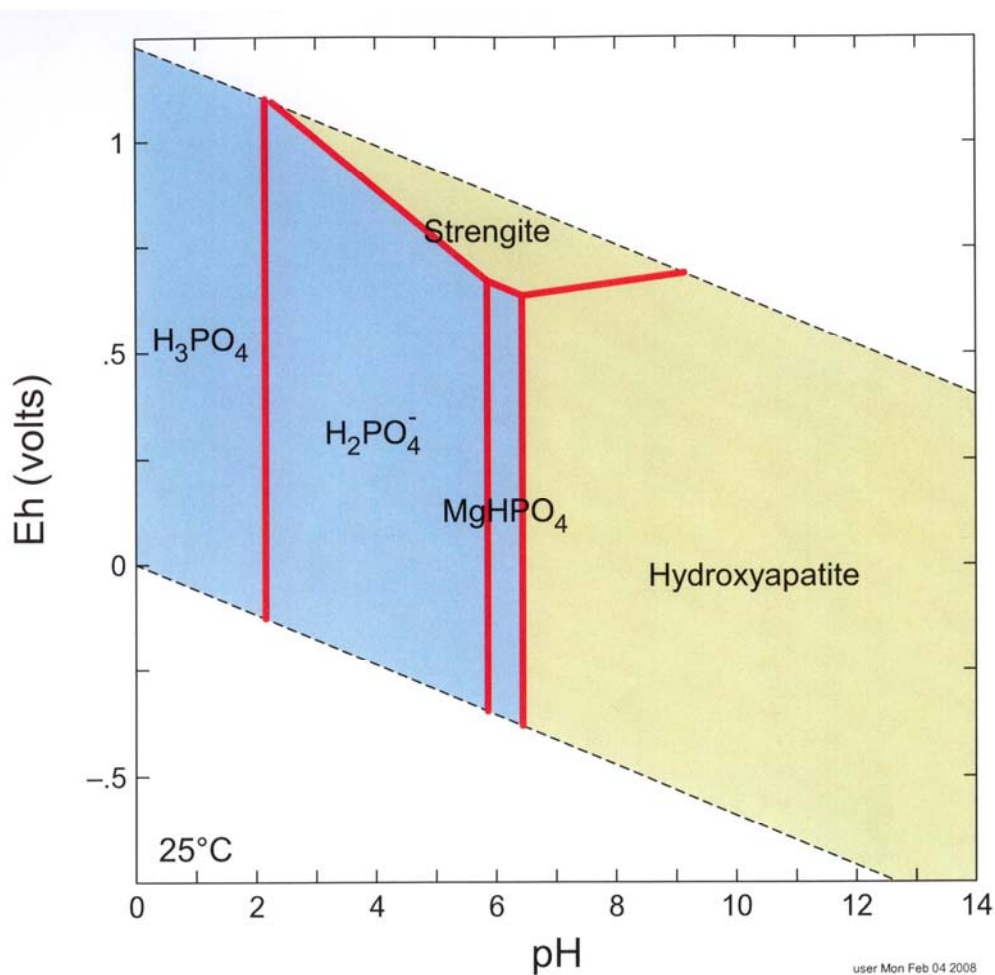


Fig. 10: Eh-pH Diagram

DISCUSSION

The most important finding of this investigation is that there are significant differences in phosphorus concentration and composition across Farmington Bay. Most notably, the highest phosphorus concentrations are in the Near Shore sites where total phosphorus averages 1.17mg/L and is composed of mostly ortho-phosphorus, which averages 0.93 mg/L (excluding the outlier Site 2 data). Channel sites have significantly lower total phosphorus, with an average 0.36 mg/L, confirming channel data previously reported (Wurtsbaugh and Marcarelli 2006; Myers et al. 2006a). In contrast to Near Shore sites, there is little or no ortho-phosphorus at Channel sites. Shallow Channel sites mirror the Channel sites, with low total phosphorus and essentially no ortho-phosphorus, but there is much more temporal variability in total phosphorus. This variability of Shallow Channel sites may be due to the fact that these sites represent a transition zone between Channel and Near Shore sites, and the variability is due to mixing between the sites. It should be noted that the Shallow Channel Sites represent the weakest data because the sites had to be moved so often due to a rapidly receding shoreline in the drought of 2007. The variability of the data could be a function of the new sampling location.

Phosphorus concentrations may be influenced by a variety of factors in the underlying sediments. The dissolved oxygen of sediment throughout Farmington Bay is

extremely low, yielding an essentially anaerobic environment. This condition can cause the sediment to release phosphorus (via reduction of iron) to the overlying water column. When the phosphorus concentrations are high in the water column, phosphorus will be deposited in the sediment regardless of the oxic condition (Myers et al. 2006b; Kelton et al. 2004; Sondergaard et al. 2003; Lee et al. 1977; Patrick and Khalid 1974).

Research has demonstrated that increased temperature will mobilize phosphorus from sediment to overlying water by affecting mineralization rates or biologically mediated processes (Jensen and Anderson 1992; Sondergaard et al. 2003). Unfortunately, this expectation was not observed in Farmington Bay. This is likely attributable to pulling samples at different times of day throughout the study. Additionally, sampling order in the Bay usually involved taking the Near Shore site samples earlier in the day when the water temperatures were cooler. Therefore, it was not possible to correlate water temperature to water column phosphorus concentrations.

Research presented in the literature review demonstrates that increasing pH can cause a release of phosphorus from sediments, especially in cases where release and uptake are controlled by iron oxides, as hydroxyl ions compete with phosphorus for binding sites (Sondergaard et al. 2003; Seitzinger 1991). However, this trend was not observed in this study.

No references regarding the effects of salinity or water column dissolved oxygen on phosphorus concentrations or phosphorus flux from the sediment to the water column was found. These parameters were measured to document as much data about the sample sites as possible. As expected, no correlation of these parameters to water column phosphorus concentrations could be made. Site to site trends in salinity were found

between Shallow Channel, Channel, and Near Shore sites, with the Shallow Channel sites reaching the highest salinity (Fig. 2). Conversely, no temporal trends were found with respect to water column DO. Because the sites were not tested at the same time every day, and dissolved oxygen concentrations fluctuate over a 24-hour period, no site-to-site trends were discernable (Fig. 4).

As previously mentioned, Near Shore sites had the highest phosphorus concentrations. Although the water column parameters do not appear to have an influence on phosphorus concentrations, it is possible that the higher phosphorus concentrations in the Near Shore sites may be a result of incoming water sources (WWTPs, FBWMA, etc.) As the results for Site 1 demonstrate, there is good correlation between FBWMA water entering the Bay and Site 1 (Table 4). Relatively high phosphorous concentrations at FBWMA are coincident with relatively high phosphorous concentrations at Site 1, and the same is true for relatively low phosphorous concentrations. However, results show that neither water is always higher in phosphorus than the other. Where phosphorus concentrations at Site 1 were lower than FBWMA, the difference could have been due to losses during conveyance. When Site 1 is higher than FBWMA, inputs from the sediment to the water column could have occurred.

As discussed above, Site 3 is in the Sewer Canal and Site 7 is in the outfall of North Davis Sewer District. The phosphorus concentrations at these sites were largely influenced by the concentration of phosphorus in wastewater treatment effluent. At these two sites, phosphorus concentrations were within the range of phosphorus expected in WWTP effluent (approximately 2 – 3.2 mg/L) (Myers et al. 2006a). Lower values may

represent a loss during conveyance in the channel or as the flow spreads out in the wetlands and the lake.

The results from Site 2 represent a special case among the Near Shore sites. Although the other Near Shore sites fluctuated similarly (Fig. 8), the concentrations were much lower and the see-saw pattern was much less obvious. The phosphorus concentrations at Site 2 were highly variable (Fig. 6), especially from mid-June through mid-July. The phosphorus fluctuations were suggestive of a diurnal pattern and, to better investigate this possibility, sampling times were plotted against phosphorus concentration and the results are presented in Fig. 11. Samples pulled prior to 9 am had the highest phosphorus whereas samples pulled later in the day had significantly lower phosphorus concentrations. The only observed difference between Site 2 and other Near Shore sites during this June-July time period was the presence of algae in the sample water. It is possible that the perceived influence of time of day was actually a product of algal

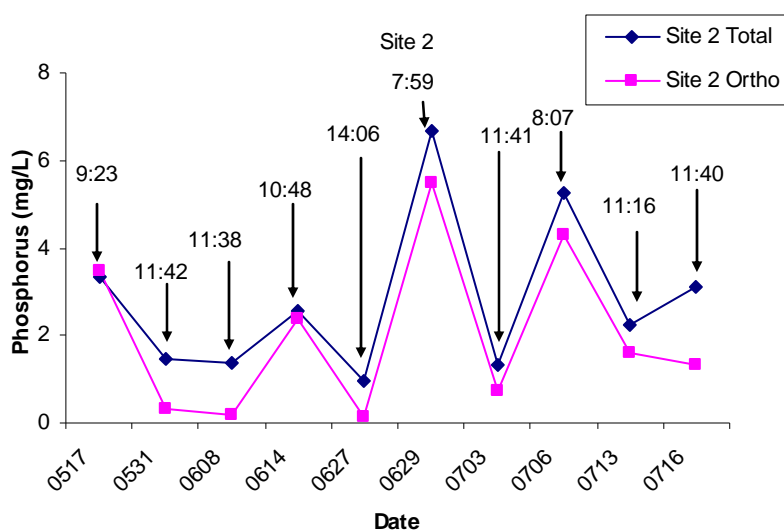


Figure 11: Sampling Times at Site 2.

photosynthesis. Algae may have taken up phosphorus during the day, and then released it at night, leading to the high phosphorus concentrations seen in the early morning samples. Although no identification of the algae was performed, it may have been *chlorella* or *dunaliella*, depending on the salinity. *Chlorella* is more often found in fresh water whereas *dunaliella* is often found in waters higher in salinity (Paul Krauth, personal communication December 11, 2007; Theron Miller, personal communication December 20, 2007). Because the other Near Shore sites demonstrate a trend similar to Site 2 (at much lower concentrations), algae or other vegetation may be a factor at these sites as well.

This study documented significant variations in phosphorus composition across Farmington Bay. Ortho-Phosphorus was predominant in the Near Shore sites, and ortho-phosphorus concentrations decreased as sample sites moved outward from Near Shore to Channel sites. A possible explanation for this observation is that ortho-phosphorus was being deposited in sediment closer to the shore, and was therefore not present in the water column of Channel sites. Research has shown that phosphorus can be deposited and stored in the sediment regardless of the oxic condition of the sediment, and that it is occurring in Farmington Bay (Myers et al. 2006b; Kelton et al. 2004; Sondergaard et al. 2003; Lee et al. 1977; Patrick and Khalid 1974). Myers also demonstrated that phosphorus content in the top two inches of sediment decreased as distance from shore increased (Myers et al. 2006b), which is consistent with the trend seen in water column concentrations. Therefore, it is possible that phosphorus is being retained in Farmington Bay sediments, leading to a decrease in water column phosphorus as flow moves through the Bay.

Because water column phosphorus may be retained in the sediments as flow moves from Near Shore to Channel Sites, it is important to understand how it is being stored in the sediment. Geochemist Workbench was used to investigate how phosphorus is being stored in the sediment. As discussed above, the Geochemist Workbench modeling study suggests that the dominant species should be hydroxyapatite, regardless of redox conditions and, under reducing conditions, a small amount of strengite (Fig. 9) may form. However, Geochemist Workbench only predicts possible species and does not account for adsorption, which may be a major mechanism for phosphorus removal from the water column. Research on the Great Salt Lake (Diaz et al., unpublished manuscript, 2008) demonstrated that there are multiple iron and aluminum species in sediments, both of which are excellent at adsorbing phosphates (Kelton et al. 2004; Sondergaard et al. 2003; Lee et al. 1977). Although this research was done on the main body of the Great Salt Lake, it is likely that many of these same species would be found in Farmington Bay.

CONCLUSIONS

Both phosphorus concentration and composition clearly vary across Farmington Bay. Ortho-phosphorus concentrations are at a maximum in the shallow Near Shore sites and decrease as sample sites move outwards towards the deeper center of Farmington Bay. Channel sites consistently demonstrate no ortho-phosphorus and average about 0.5 mg/L total phosphorus. Shallow Channel sites are also characterized by no ortho-phosphorus; however, total phosphorus concentrations are more variable than at Channel sites. In contrast, Near Shore sites contain mostly ortho-phosphorus and are more variable than Channel and Shallow Channel sites. Phosphorus concentrations do not correlate with other field parameters. Neither salinity, pH, dissolved oxygen, nor water temperature have a discernible effect on phosphorus in the water column.

Channel sites appear to have few influences, as demonstrated by their constant phosphorus concentrations throughout the study period. Shallow Channel sites may be influenced by mixing of Channel and Near Shore sites. Near Shore sites appear to be greatly influenced by incoming water sources. Ortho-Phosphorus may decrease from Near Shore to Channel sites because sediments take up water column phosphorus as water flows through the Bay.

There are a number of areas for future research. Because Farmington Bay is so shallow, wind events and other mixing mechanisms may have a significant effect on re-

suspension of phosphorus from Bay sediments, and this factor should be a consideration in future studies. Additionally, because the sediment in much of Farmington Bay is anaerobic, redox and equilibrium conditions may also play a major role in controlling phosphorus concentration in the water column. If phosphorus loading to the Bay is reduced, internal loading may have a greater influence in water column phosphorus concentrations and it will be important to investigate this interaction. Future research should focus on phosphorus speciation in the sediment to determine how mobile sediment phosphorus is.

The ultimate goal is to understand the impact of high phosphorus loading into Farmington Bay and to determine if the beneficial uses of the bay are being adversely affected. This will require a thorough understanding of phosphorus speciation and cycling in Farmington Bay. Furthermore, because Farmington Bay can change dramatically from year to year depending on weather conditions and in-flows, it will be important to investigate the Bay during high flow, low flow, and average years. This synoptic survey of phosphorus concentrations during a drought year is just a first scientific step to understanding the dynamics of phosphorus loading in Farmington Bay.

APPENDIX A

YSI MPS 556 PRACTICAL SALINITY SCALE

Practical Salinity Scale (PSS 78)

Salinity in the range of 2 to 42

Constants from the 19th Edition of Standard Methods

R cond.ratio	0.0329	$R = \frac{C}{42.914 \text{ mS/cm}}$							
C Cond at t	1.412	Input conductivity in mS/cm of sample							
t deg. C	25.00	Input temperature of sample solution							
P dBar	0	Input pressure at which sample is measured in decibars							
R _p	1.0000	$R_p = 1 + \frac{p(e_1 + e_2 p + e_3 p^2)}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t)R}$							
r _t	1.2365	$r_t = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4$							
R _t	0.0266	$R_t = \frac{R}{R_p \times r_t}$							
Delta S	-0.0061	$\text{Delta S} = \frac{(t-15)}{1+k(t-15)} (b_0 + b_1 R_t^{1/2} + b_2 R_t + b_3 R_t^{3/2} + b_4 R_t^2 + b_5 R_t^{5/2})$							
S = Salinity	0.706	$S = a_0 + a_1 R_t^{1/2} + a_2 R_t + a_3 R_t^{3/2} + a_4 R_t^2 + a_5 R_t^{5/2} + \text{delta S}$							
a0	0.0080	b0	0.0005	c0	0.6766	d1	3.426E-02	e1	2.070E-04
a1	-0.1692	b1	-0.0056	c1	0.0201	d2	4.464E-04	e2	-6.370E-08
a2	25.3851	b2	-0.0066	c2	0.0001	d3	4.215E-01	e3	3.989E-12
a3	14.0941	b3	-0.0375	c3	-6.9698E-07	d4	-3.107E-03		
a4	-7.0261	b4	0.0636	c4	1.0031E-09				
a5	2.7081	b5	-0.0144						
		k	0.0162						

R = ratio of measured conductivity to the conductivity of the Standard Seawater Solution

Conductivity Ratio R is a function of salinity, temperature, and hydraulic pressure.

So that we can factor R into three parts i.e.

$$R = R_t \times R_p \times r_t$$

$$R = C(S,t,p)/C(35,15,0)$$

C = 42.914 mS/cm at 15 deg C and 0 dbar pressure ie C(35,15,0) where 35 is the salinity

APPENDIX B

LUMINESCENT DO PROBE

Evaluation of Hach Optical DO Sensor for Analysis
of Sediment Oxygen

A literature search of luminescence dissolved oxygen (LDO) sensors was conducted to determine if this type of sensor could be used in the analysis of oxygen in sediments. Several articles referencing its uses in bioanalytics seemed to suggest that it would also be able to read dissolved oxygen in sediments. Hach Technologies manufactures an LDO sensor and meter which differs from the ones in literature but may still work effectively. Contact with Hach technical staff confirmed their belief that said sensor would work in sediments if care is taken not to damage the sensor's surface.

In order to test the ability of the sensor in sediments, several tests were conducted in the Great Salt Lake. Three tests were conducted on the wetted edge of the lake where recent surface drying had occurred. Test pits were dug in the sediment and allowed to fill with surface/ground water. The surface/ground water in the pit was then tested for DO. The sediment at the bottom of the test pit was also tested for DO. Table 5 shows the results of the tests. As can be seen, DO was registered in both water and sediment. At the last location, the sediment was more organic in nature (as indicated by sediment odor) and significantly lower DOs were observed.

Table 5: Pit Test

Latitude	Longitude	DO in Water	DO in Sediment	Water Temperature
40°57'33" N	111°58'00" W	4.82 mg/L	4.65 mg/L	25.5°C
40°57'29" N	111°58'34" W	5.59 mg/L	5.58 mg/L	26.3°C
40°57'11" N	111°59'30" W	0.67 mg/L	0.07 mg/L	23.4°C

Two springs in the lake bed were also tested. Each spring had bubbling water in weep holes about one foot ground surface. Water and sediment DO were tested in each spring. Table 6 gives the results of these tests. As can be seen, in each case the DO in water was suppressed in both water and sediment. At both springs, the sediment appeared to be higher in organic matter as exhibited by hydrogen sulfide and other decay odors. The results above seem to indicate that oxygen deficit may be present when the sediment is higher in organic matter. Since most of the sampling points in the phosphorus study tend to have organic odors, sediments may be depressing the sediment dissolved oxygen.

In order to further validate the LDO sensors ability to detect DO in sediments, two samples were taken back to the laboratory for additional testing. The two samples were taken at different locations; one sample was a gray silty clay with no odor or visible organic material, whereas the second sample was a black silty clay, was highly odorous, and included some visible organic material. Total volatile solids (VS) concentration was measured for each sample. The no-odor sample had a VS of 9.1% while the high-odor sample has a VS of 16.9%. About 350 ml of sediment was added to a 2-L beaker. Sediment samples were blended and tap water was added to the beaker. The tap water had a DO of 7.8 mg/L. The water temperature was not measured. After about five

Table 6: Spring Test

Latitude	Longitude	DO in Water	DO in Sediment	Water Temperature
40°58'21" N	111°58'07" W	0.14 mg/L	0.08 mg/L	22.9°C
40°57'30" N	111°59'15" W	0.17 mg/L	0.05 mg/L	17.1°C

minutes of stabilization time, DO readings were taken in the water and then the probe was submerged in the sediment and a second reading taken. Table 7 shows the results of the tests.

The results of the laboratory test seem to confirm two conclusions. The first conclusion is that an LDO sensor submerged in saturated sediment will measure dissolved oxygen. From the five tests conducted in the field and the two laboratory analyses, the varying measurements demonstrate the ability to differentiate DO in sediment. The second conclusion that may be reached is that higher organic sediment could have significant oxygen deficit. Without significant transfer of oxygen to the sediment, this low/no DO condition may continue indefinitely.

Based on the results of this study, the decision has been made to continue measurement of sediment DO at the phosphorus sampling locations.

Table 7: Laboratory Tests

Sediment Identification	Water DO	Sediment DO
No-Odor Lower Organic Sediment	7.44 mg/L	7.42 mg/L
High-Odor Higher Organic Sediment	4.66 mg/L	0.17 mg/L

APPENDIX C

SPIKING STUDY

A spiking study was carried out to determine percent recovery for the ortho-phosphorus method, as shown in Table 8. Sample from Site 10 was spiked with varying amounts of 25 mg/L phosphorus, from 0 to 0.75 mg/L. Samples were spiked with 0, 0.25, 0.5, and 0.75 mg/L phosphorus.

Table 8: Spiking Study Results

Sample	Actual (mg/L)	Theoretical (mg/L)	% recovery
sample + 0 mg/L	0.079		
sample + 0.25 mg/L	0.27	0.191	76.4
sample + 0.5 mg/L	0.54	0.461	92.2
sample + 0.75 mg/L	0.791	0.712	94.9

Theoretical = Actual – non-spiked ample

% recovery = 100* (Theoretical/amount spiked)

APPENDIX D

WATER CHEMISTRY DATA

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 20	111 57 39	5/31/2007 11:32	25.76	1.339	1.358	0.87	0.67	8.72	8.94
2	40 56 33	110 59 29	5/31/2007 11:42	24.18	2.209	2.174	1.436	1.13	14.29	9.09
3	41 54 37	112 02 24	5/31/2007 12:02	23.65	4.118	4.012	2.676	2.18	11.94	8.35
4	40 54 05	112 04 01	5/31/2007 12:15	22.96	3.733	3.587	2.426	1.97	10.66	8.79
5	40 57 24	112 03 56	5/31/2007 12:31	28.85	60.889	65.37	39.58	40.77	11.02	9.22
6	41 00 36	11204 56	5/31/2007 12:47	30.21	5.764	6.337	3.746	3.1	8.52	9.29
7	41 04 37	112 07 56	5/31/2007 13:12	29.36	1.299	1.408	0.844	0.64	19.41	8.93
8	41 03 28	1112 08 42	5/31/2007 13:24	23.71	63.396	61.83	41.21	42.83	13.79	9.72
9	41 02 25	112 08 42	5/31/2007 13:31	22.82	63.205	60.57	41.08	42.7	12.29	9.61
10	41 01 40	112 08 35	5/31/2007 13:37	22.62	62.493	59.65	40.62	42.15	14.67	9.71

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 20 N	111 57 38	6/8/2007 11:23	20.41	1.41	1.286	0.917	0.71	9.76	8.91
2	40 56 31	110 59 31	6/8/2007 11:38	17.64	12.365	10.63	8.037	7.12	15.2	8.89
3	41 54 36	112 02 26	6/8/2007 11:58	18.15	2.753	2.393	1.789	1.43	9.02	8.03
4	40 54 04	112 04 02	6/8/2007 12:09	17.61	5.531	4.751	3.595	3.01	13.31	8.92
5	40 57 25	112 03 57	6/8/2007 12:31	21.15	51.367	47.59	33.39	33.81	11.4	8.9
6	41 00 35	112 04 57	6/8/2007 12:52	25.22	3.332	3.346	2.166	1.74	19.62	9.17
7	41 04 40	112 07 53	6/8/2007 13:25	19.41	1.052	0.939	0.684	0.52	6.71	7.73
8	41 03 29	112 08 41	6/8/2007 13:37	16.2	63.08	52.48	41	42.57	10.31	9.11
9	41 02 37	112 08 42	6/8/2007 13:47	13.65	66.01	51.69	42.9	44.7	12.03	9.19
10	41 01 42	112 08 35	6/8/2007 13:57	16.86	63.24	53.4	41.11	42.71	12.8	9.21
11	40 59 35	112 08 36	6/8/2007 14:14	16.08	62.15	51.55	40.4	41.85	14.24	9.23

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 20	111 57 41	6/14/2007 10:38	27.2	1.142	1.19	0.742	0.56	3.62	8.68
2	40 56 31	111 59 32	6/14/2007 10:48	25.94	4.659	4.743	3.028	2.48	5.33	8.73
3	41 54 36	112 02 26	6/14/2007 11:10	24.53	3.043	3.016	1.978	1.58	11.13	8.21
4	40 54 04	112 04 02	6/14/2007 11:21	25.13	4.169	4.18	2.71	2.21	10.46	8.87
5	40 57 23	112 03 56	6/14/2007 11:48	32.6	48.32	55.33	31.41	31.28	5.65	9.04
6	41 00 35	112 04 57	6/14/2007 12:05	34	0.114	0.134	0.074	0.05	10.79	9.02
7	41 04 40	112 07 55	6/15/2007 18:15	22.75	1.322	1.265	0.859	0.66	7.47	8.33
8	41 03 30	112 08 42	6/15/2007 18:01	29.65	70.96	77.27	46.13	48.53	13.66	9.66
9	41 02 37	112 08 42	6/15/2007 17:48	23.54	72.07	70.06	46.85	49.59	21.68	9.74
10	41 01 43	112 08 34	6/14/2007 12:43	25.63	62.83	63.59	40.84	42.35	20.13	9.82
11	40 59 36	112 08 39	6/14/2007 12:23	24.73	61.78	61.46	40.16	41.57	22.26	9.89

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 19	111 57 39	6/27/2007 14:16	36.73	1.569	1.92	1.02	0.77	3.54	8.86
2	40 56 32	111 59 31	6/27/2007 14:06	38.13	4.206	5.26	2.734	2.18	8.98	8.75
3	40 54 37	112 02 26	6/27/2007 13:52	29.29	3.025	3.273	1.967	1.56	13.09	8.38
4	40 54 06	112 04 02	6/27/2007 13:38	32.46	5.111	5.839	3.322	2.71	10.39	9
5a	40 57 24	112 04 24	6/27/2007 13:22	31.35	69.29	77.7	45.04	47.15	14.95	9.65
6a	41 00 24	112 05 44	6/27/2007 12:08	30.59	69.42	76.84	45.12	47.28	12.77	9.67
7	41 04 42	112 07 55	6/27/2007 11:54	23.96	1.222	1.198	0.794	0.61	7.76	7.67
8	41 03 28	112 08 43	6/27/2007 12:02	25.22	79.48	79.82	51.66	55.48	5.89	9.38
9	41 02 36	112 08 43	6/27/2007 12:12	24.86	69.07	68.89	44.9	47.21	11.81	9.49
10	41 01 41	112 08 35	6/27/2007 12:22	27.37	66.35	69.36	43.13	45.01	10.75	9.56
11	40 59 35	112 08 36	6/27/2007 12:32	26.78	62.28	64.4	40.48	41.9	17.39	9.84

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 20	111 57 41	6/29/2007 7:45	18.15	1.677	1.457	1.09	0.85	3.17	8.51
2	40 56 32	111 59 34	6/29/2007 7:59	17.25	5.301	4.516	3.446	2.87	4.04	8.5
3	40 54 37	112 02 27	6/29/2007 8:13	19.8	2.776	2.5	1.804	1.44	4.04	7.83
4	40 54 05	112 04 03	6/29/2007 8:24	19.73	37.11	33.38	24.12	23.56	0.53	8.9
5a	40 57 23	112 04 24	6/29/2007 8:52	21.21	73.87	68.52	48.02	51.04	0.61	9.57
6a	41 00 25	112 05 45	6/29/2007 9:12	22.12	1.397	1.32	0.908	0.7	9.49	8.47
7	41 04 39	112 07 55	6/29/2007 9:12	22.12	1.397	1.32	0.908	0.7	9.49	8.47
8	41 03 29	112 08 41	6/29/2007 9:29	23.83	73.63	71.98	47.86	50.82	9.57	9.64
9	41 02 37	112 08 42	6/29/2007 9:39	24.36	74.62	73.71	48.51	51.6	12.6	9.67
10	41 01 42	112 08 35	6/29/2007 9:49	24.87	74.69	74.5	48.55	51.64	13.68	9.67
11	40 59 36	112 08 35	6/29/07 10:04	23.83	70.46	68.88	45.8	48.31	15.18	9.78

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 19	111 57 39	7/3/2007 11:28	33.83	1.92	2.244	1.248	0.96	7.69	8.74
2	40 56 33	111 59 32	7/3/2007 11:41	32.9	3.798	4.371	2.469	1.98	4.19	8.54
3	40 54 36	112 02 26	7/3/2007 12:02	27.24	3.108	3.241	3.02	1.61	10.75	8.28
4	40 54 05	112 04 03	7/3/2007 12:15	29.03	27.31	29.41	17.75	16.68	14.76	9.25
5a	40 57 23	112 04 23	7/3/2007 12:28	29.48	76.34	82.87	49.62	52.81	7.55	9.45
6a	40 00 25	112 05 43	7/3/2007 12:52	31.24	78.72	88.11	51.17	54.64	8.12	9.45
7	41 04 40	112 07 54	7/3/2007 13:16	27.93	1.31	1.384	0.852	0.65	12.95	8.17
8	41 03 26	11208 40	7/3/2007 13:34	27.97	76.79	81.14	49.91	53.23	6.21	9.48
9	41 02 37	112 08 37	7/3/2007 13:46	28.7	79	84.59	51.35	54.98	4.34	9.43
10	41 01 43	112 08 36	7/3/2007 13:57	28.3	78	82.92	50.7	54.19	4.14	9.45
11	40 59 36	112 08 36	7/3/2007 14:10	28.42	73.58	78.38	47.82	50.65	6.89	9.59

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 19	111 57 39	07/06/077:49	20.32	2.172	1.978	1.412	1.11	4.72	8.65
2	40 56 38	11159 36	7/6/2007 8:07	21.25	2.869	2.663	1.865	1.49	0.52	7.53
3	40 54 36	112 02 25	7/6/2007 8:27	22.39	2.687	2.553	1.747	1.39	3.25	7.77
4	40 54 05	11204 00	7/6/2007 8:38	20.6	4.045	3.705	2.629	2.15	5.51	8.13
5a	40 57 23	112 04 24	7/6/2007 9:00	23.34	91.28	88.39	59.33	65.25	0.81	9.14
6a	41 00 25	112 05 44	7/6/2007 9:17	23.14	79.35	76.54	51.58	55.42	0.97	9.4
7	41 04 42	112 07 53	7/8/2007 9:24	22.38	1.377	1.308	0.895	0.69	6.49	8.4
8	41 03 29	112 08 44	7/8/2007 9:12	25.64	81.59	82.59	53.03	57.18	2.33	9.34
9	41 02 37	112 08 43	7/8/2007 8:56	26.24	82.45	84.4	53.59	57.87	0.26	9.27
10	41 03 52	112 13 43	7/8/2007 8:42	25.75	82.11	83.28	53.37	57.61	0.31	9.24
11	40 59 35	112 08 35	7/6/2007 9:31	26.46	73.52	75.58	47.79	50.67	0.76	9.42

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 20	111 57 40	7/13/2007 10:57	30.92	1.963	2.185	1.276	0.99	0.63	8.35
2	40 56 34	111 59 36	7/13/2007 11:16	33.25	3.195	3.699	2.077	1.65	0.74	8.23
3	40 54 38	112 02 27	7/13/2007 11:29	25.92	2.68	2.727	1.742	1.38	10.41	8.23
4	40 54 03	112 04 01	7/13/2007 11:42	28.3	4.871	5.177	3.166	2.59	12.61	8.92
5a	4057 23	112 04 25	7/13/2007 12:00	32.6	80.09	91.71	52.06	55.68	5.72	9.19
6a	41 00 26	112 05 43	7/13/2007 12:20	35.41	90.71	108.7	58.96	64.24	0.65	8.7
7	41 04 40	112 07 54	7/13/2007 12:37	25.84	1.662	1.688	1.08	0.84	6.25	8.22
8	41 03 27	112 08 42	7/13/2007 12:47	28.28	83.93	89.18	54.55	59.01	12.67	9.64
9	41 02 36	112 08 43	7/13/2007 12:58	29.66	84.76	92.3	55.09	59.63	9.47	9.57
10	41 01 40	112 08 35	7/13/2007 13:08	29.95	86.22	93.22	56.04	60.86	5.98	9.43
11	40 59 35	112 08 38	7/13/2007 13:19	29.49	82.44	89.5	53.58	57.74	6.66	9.49

Site	location		DateTime M/D/Y	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms) N	Lon(dms) W								
1	40 57 19	111 57 39	7/16/2007 11:29	28.21	1.131	1.2	0.735	0.56	9.14	9.04
2	40 56 35	111 59 33	7/16/2007 11:40	28.25	6.565	6.972	4.267	3.57	3.62	8.84
3	40 54 36	112 02 25	7/16/2007 11:51	26.51	2.749	2.828	1.787	1.42	10.31	8.23
4	4054 03	112 04 01	7/16/2007 12:02	26.02	4.875	4.97	3.168	2.6	10.51	8.81
5a	40 57 26	112 04 29	7/18/2007 12:46	33.87	108.1	126.4	70.24	79.3	3.14	8.96
6a	41 00 24	112 05 44	7/18/2007 12:26	33.1	108.4	125.2	70.49	79.69	0.53	8.77
7	41 04 42	112 07 54	7/18/2007 12:02	24.96	1.345	1.344	0.874	0.67	6.26	7.69
8	44 03 29	112 08 43	7/18/2007 13:36	28.17	87.77	93.09	57.05	62.19	6.33	9.39
9	4102 37	112 08 43	7/18/2007 13:29	27.03	88.93	92.38	57.8	63.19	1.92	9.15
10	41 01 41	112 08 34	7/18/2007 13:19	26.69	88.7	91.57	57.66	63.02	0.16	9.02
11	40 59 39	11208 36	7/18/2007 13:05	27.12	85.38	88.83	55.49	60.24	0.82	9.1

Site	location		Date Time	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms)	N Lon(dms) W								
1	40 57 22	111 57 35	7/30/2007 14:02	37.65	2.459	3.053	1.598	1.24	8.35	9.07
2a	40 56 36	111 59 36	7/30/2007 13:50	38.85	2.157	2.728	1.402	1.08	6.56	8.69
3	40 54 35	112 02 24	7/30/2007 13:29	29.55	2.892	3.144	1.88	1.49	13.03	8.37
4	40 54 04	112 04 00	7/30/2007 13:18	31.35	3.527	3.954	2.292	1.83	11.09	8.95
5b	40 57 17	112 04 44	7/30/2007 12:58	33.06	64.31	74.21	41.8	43.21	13.61	9.46
6b	41 00 10	11205 55	7/30/2007 12:40	33.81	96.42	112.6	62.67	69.17	7.01	8.82
7	41 04 42	112 07 53	7/30/2007 11:45	25.24	1.202	1.207	0.781	0.6	5.84	7.57
8	41 03 28	112 08 42	7/30/2007 11:57	29.03	91.76	98.82	59.64	65.49	8.87	9.52
9	41 02 37	112 08 42	7/30/2007 12:05	29.36	96.86	104.9	62.96	69.8	9.2	9.36
10	41 01 42	112 0835	7/30/2007 12:13	29.5	93.73	101.8	60.93	67.13	13.58	9.52
11	40 59 35	112 08 36	7/30/2007 12:26	29.85	90.93	99.35	59.11	64.76	11.86	9.53

Site	location		Date Time	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms)	N Lon(dms) W								
1	40 57 23	111 57 34	8/9/2007 9:13	19.46	2.347	2.099	1.525	1.21	7.6	9.13
2a	40 56 35	111 59 37	8/9/2007 9:29	21.63	3.678	3.441	2.391	1.94	5.68	8.59
3	40 54 37	112 02 26	8/9/2007 9:43	21.5	2.878	2.685	1.871	1.5	7.97	7.91
4	40 54 07	112 03 59	8/9/2007 9:55	20.39	3.381	3.083	2.197	1.78	7.85	8.25

Site	location		Date Time	Temp C	SpCond mS/cm	Cond ms/cm	TDS g/L	Salinity ppt	Do mg/L	pH
	Lat(dms)	N Lon(dms) W								
1	40 57 22	111 57 34	8/23/2007 8:50	18.25	2.685	2.339	1.745	1.4	4.95	8.81
2	40 56 35	111 59 37	8/23/2007 9:05	18.56	4.21	3.693	2.737	2.25	3.88	8.6
3	40 54 38	112 02 27	8/23/2007 9:18	20.23	2.938	2.67	1.91	1.53	5.29	7.79
FBWMA			8/23/2007 9:42	22.16	2.422	2.291	1.574	1.25	4.05	9.07

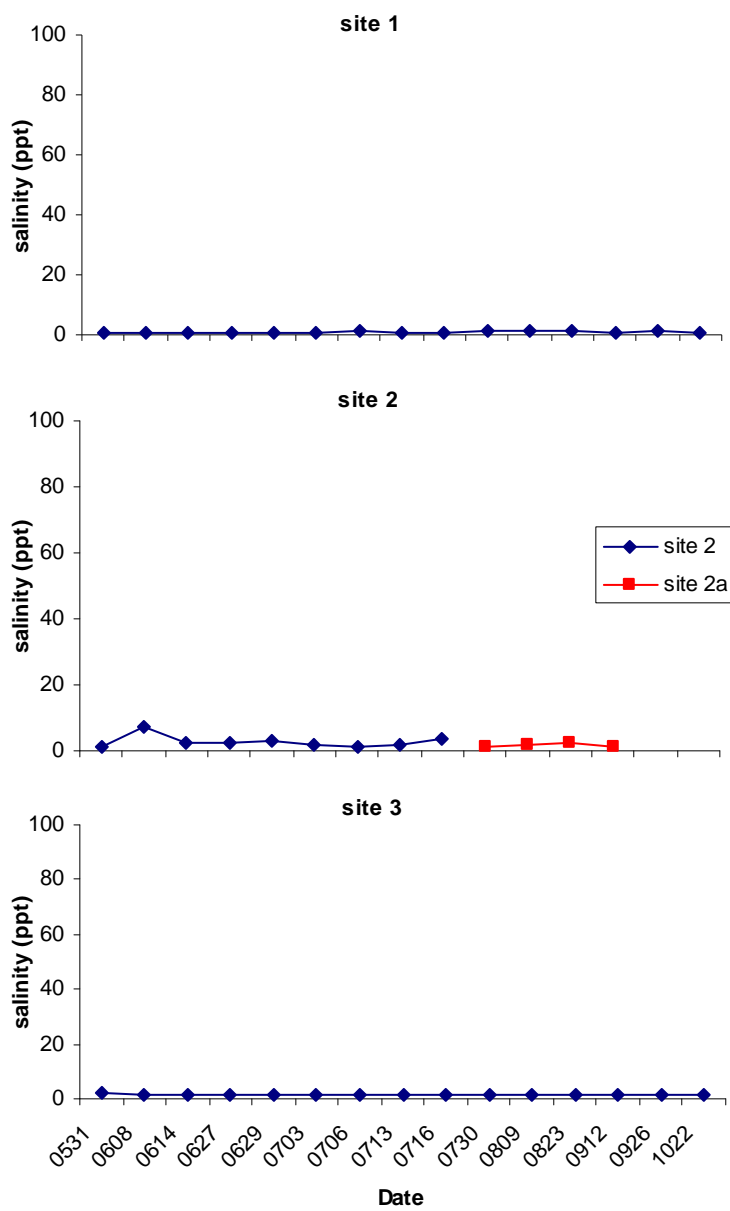
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	Lat(dms)	N Lon(dms) W								
1	40 57 21	111 57 34	9/12/2007 8:56	16.09	1.663	1.38	1.081	0.85	5.04	8.67
2	40 56 35	111 59 36	9/12/2007 9:10	14.86	2.785	2.246	1.811	1.45	7.62	8.25
3	40 54 38	112 02 27	9/12/2007 9:27	14:24	2.794	2.399	1.816	1.46	5	7.63
FBWMA			9/12/2007 10:56	20.48	2.247	2.053	1.461	1.16	7.63	9.83

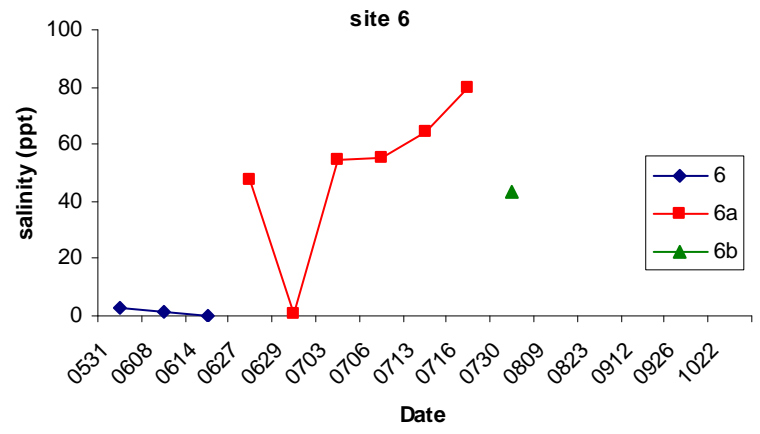
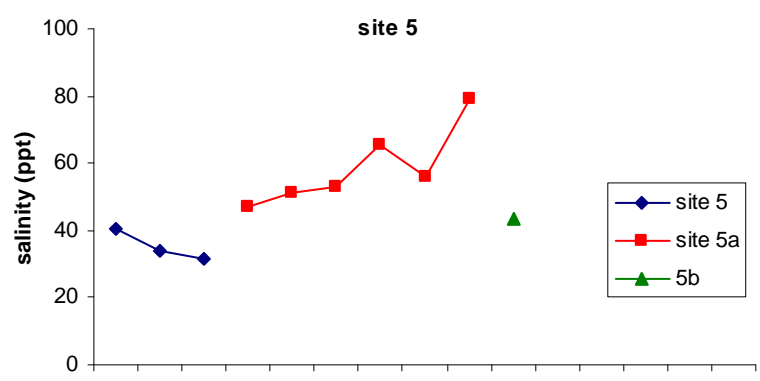
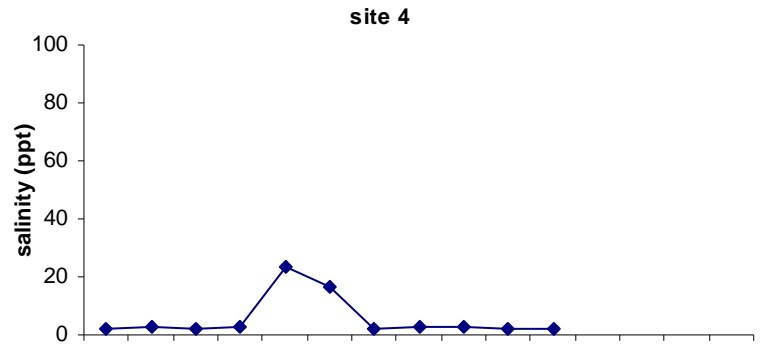
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	Lat(dms)	N Lon(dms) W								
1	40 57 23	111 57 35	9/26/2007 8:29	12.34	2.318	1.757	1.506	1.2	13.42	9.2
2	40 56 35	111 59 36	9/26/2007 8:43	8.51	2.383	1.633	1.549	1.23	6.54	8.55
3	40 54 37	112 02 27	9/26/2007 8:57	1:26	2.451	1.892	1.593	1.27	5.44	7.98
FBWMA			9/26/2007 9:25	13.25	2.286	1.773	1.486	1.18	14.46	9.54

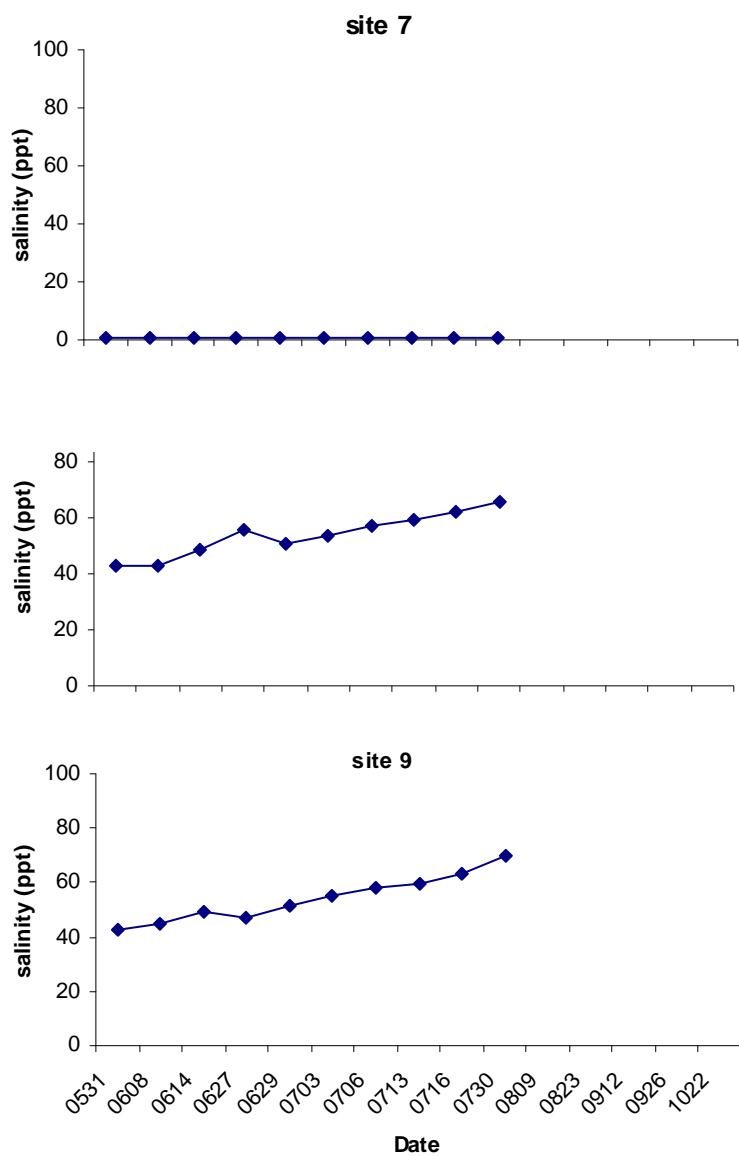
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	Lat(dms) N	Lon(dms) W								
1	40 57 22	111 57 34	10/22/2007 9:08	7.38	1.955	1.297	1.271	1	10.97	7.82
2	40 56 34	111 59 36	10/22/2007 9:17	2.44	4.384	2.495	2.85	2.3	11.83	8.48
3	40 54 37	112 02 26	10/22/2007 9:31	9.23	2.591	1.811	1.684	1.34	4.95	7.69
FBWMA			10/22/2007 9:56	7.87	2.05	1.379	1.332	1.05	16.69	8.97

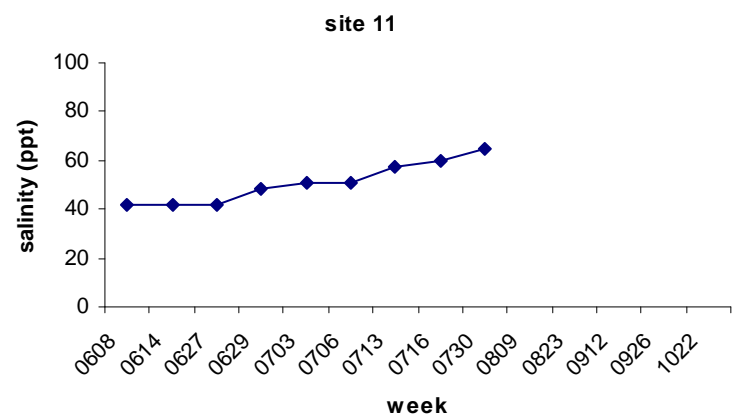
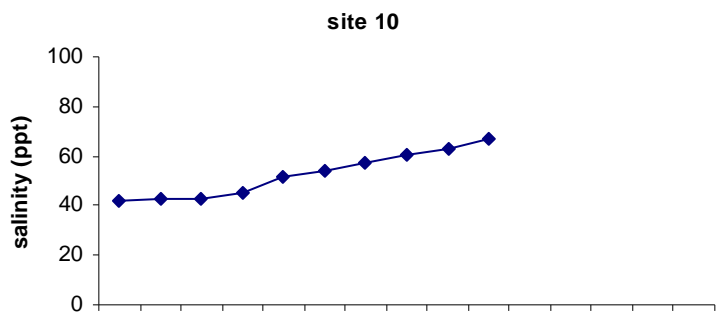
APPENDIX E

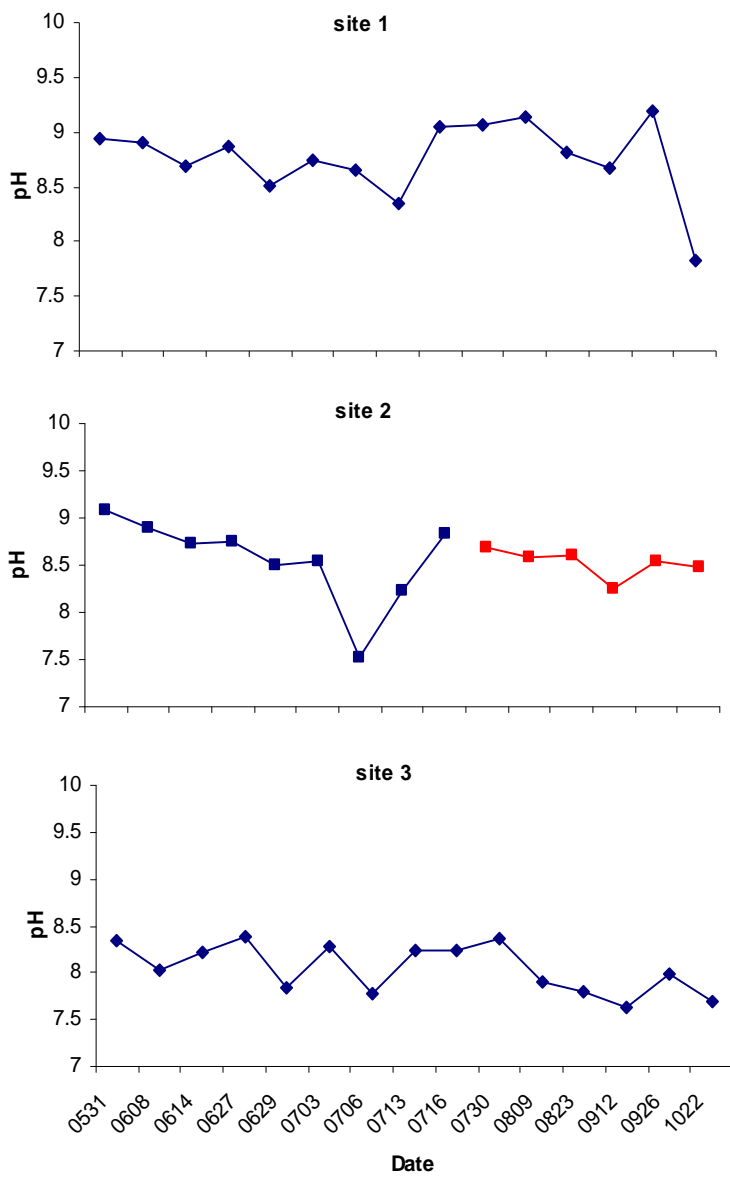
WATER CHEMISTRY PLOTS

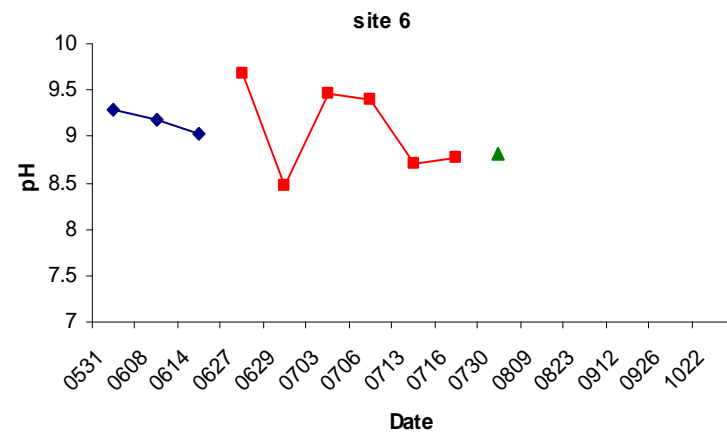
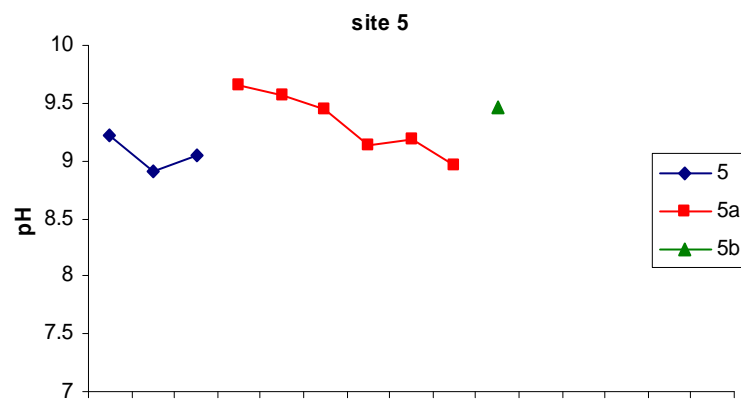
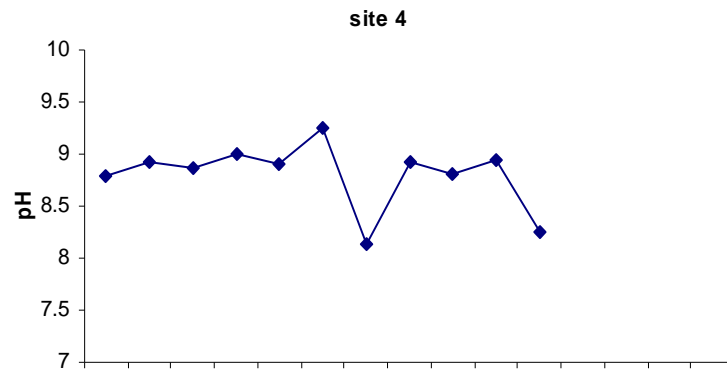


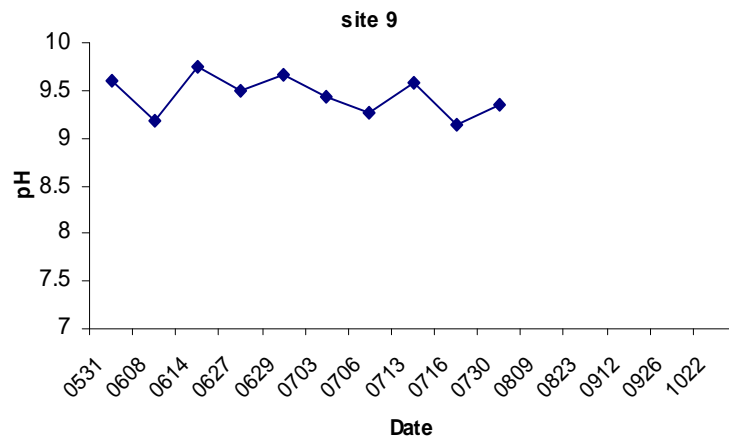
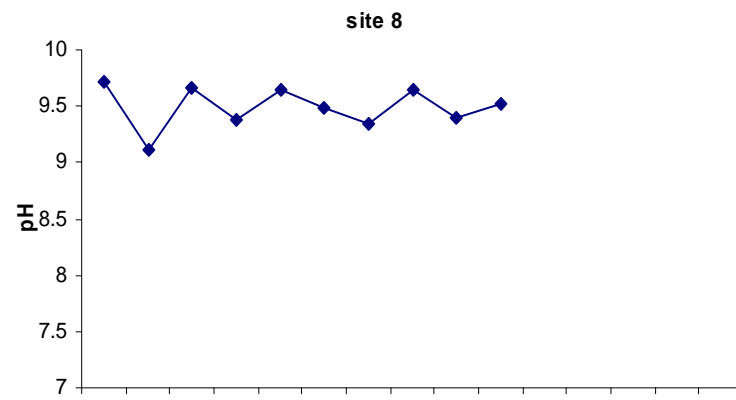
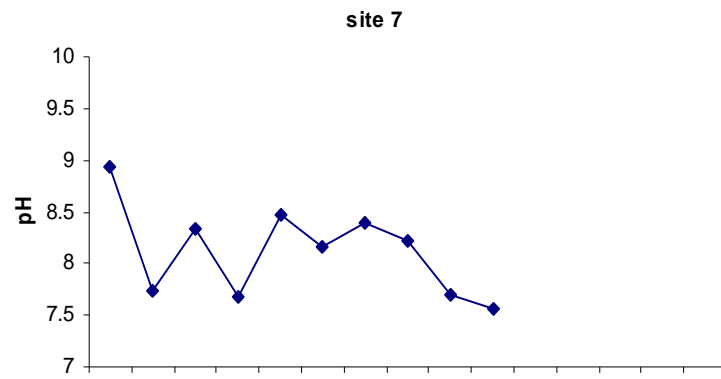


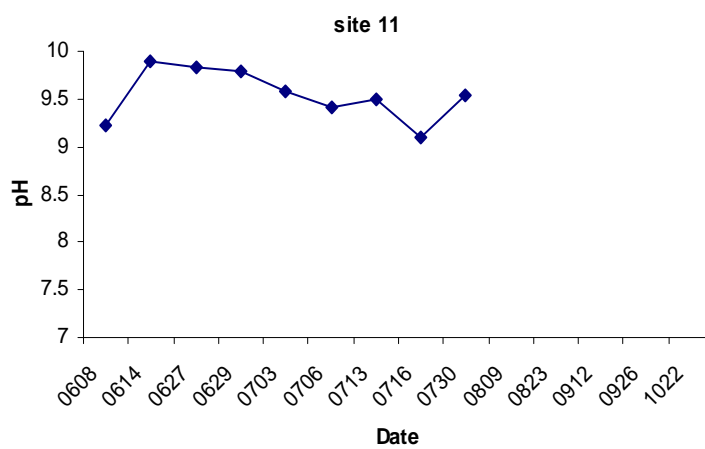
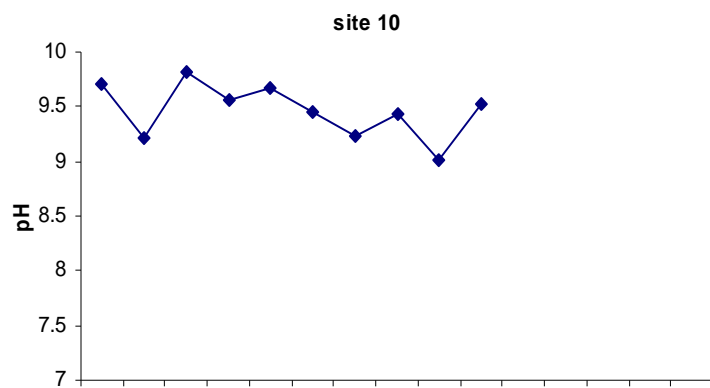


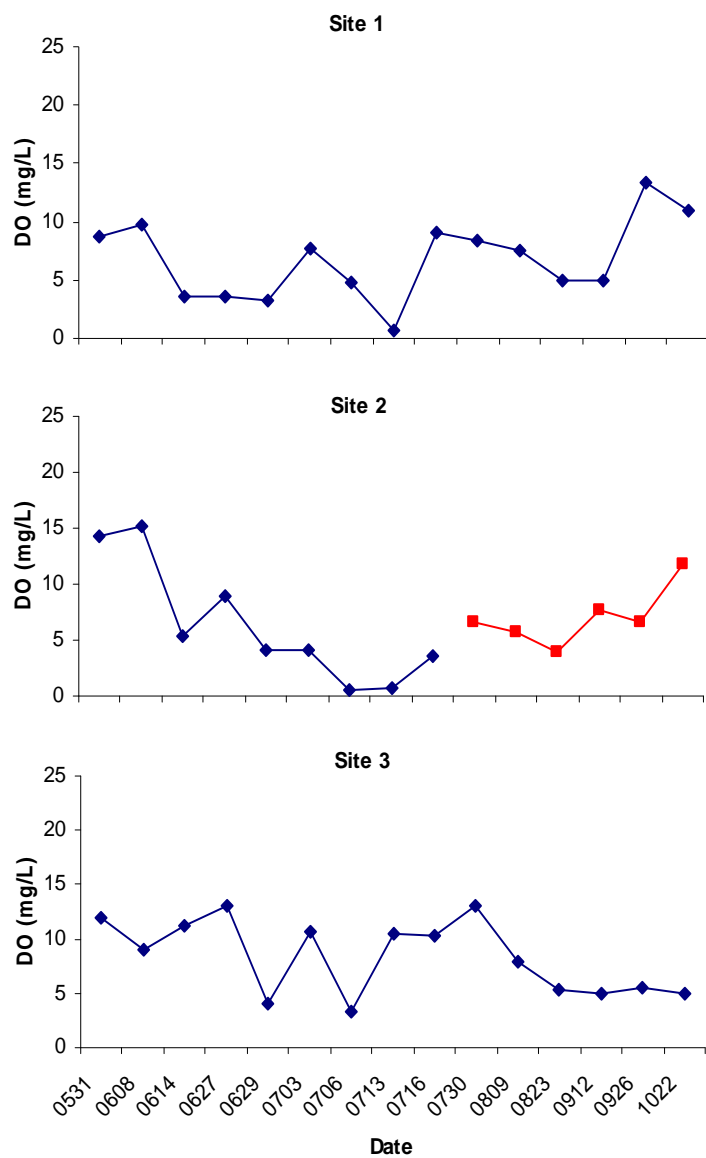


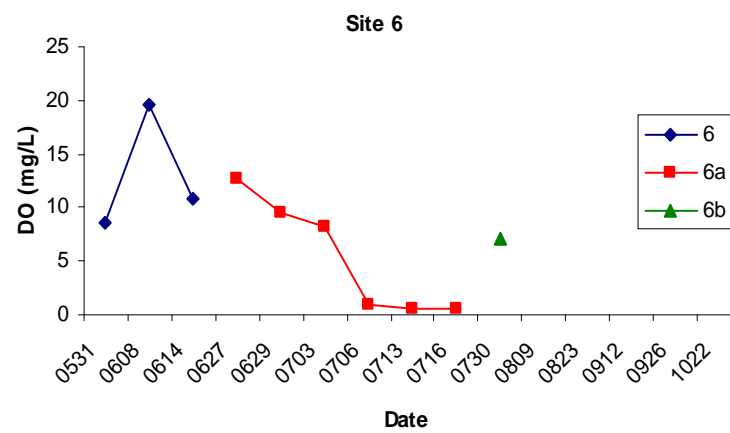
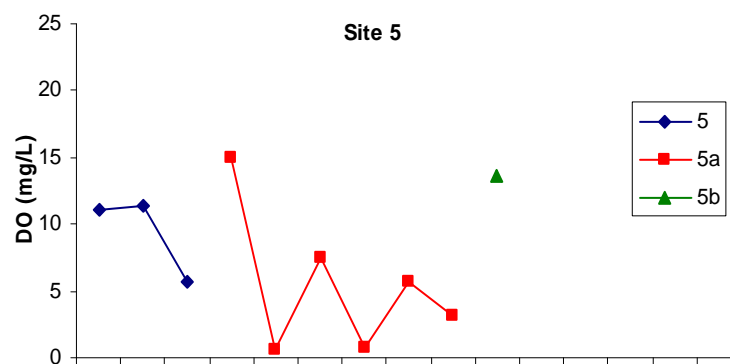
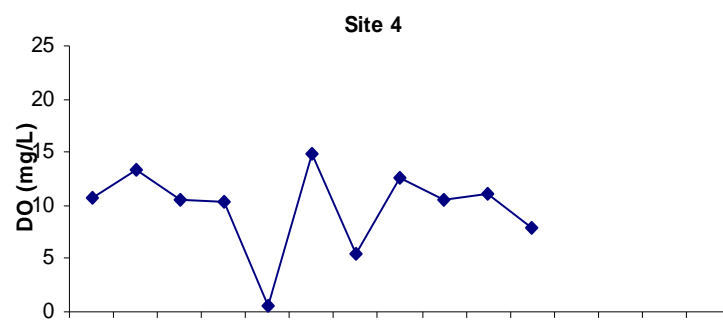


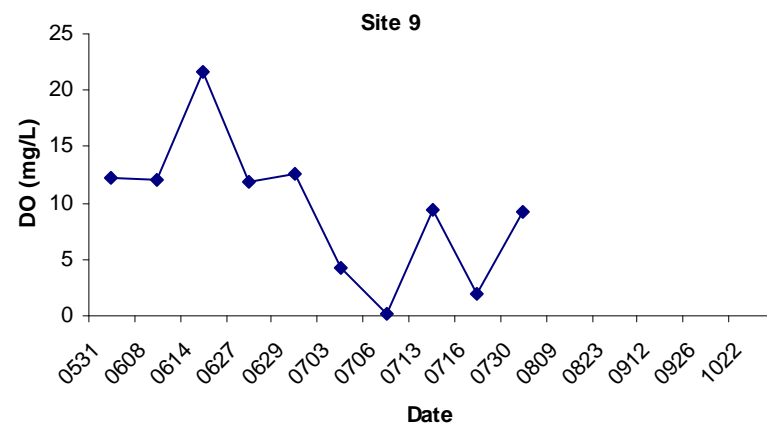
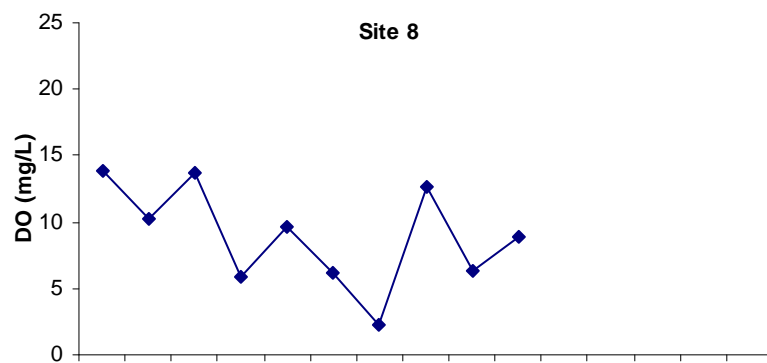
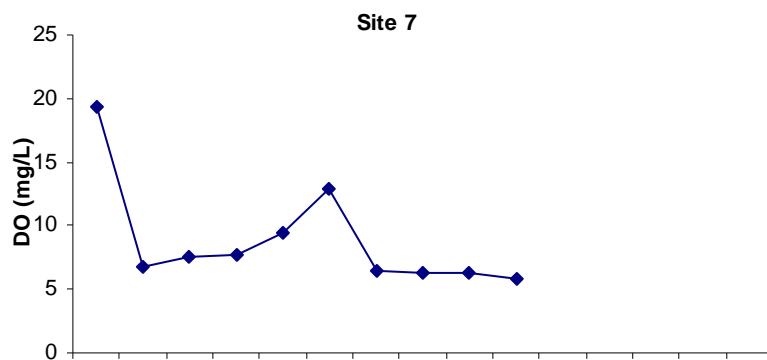


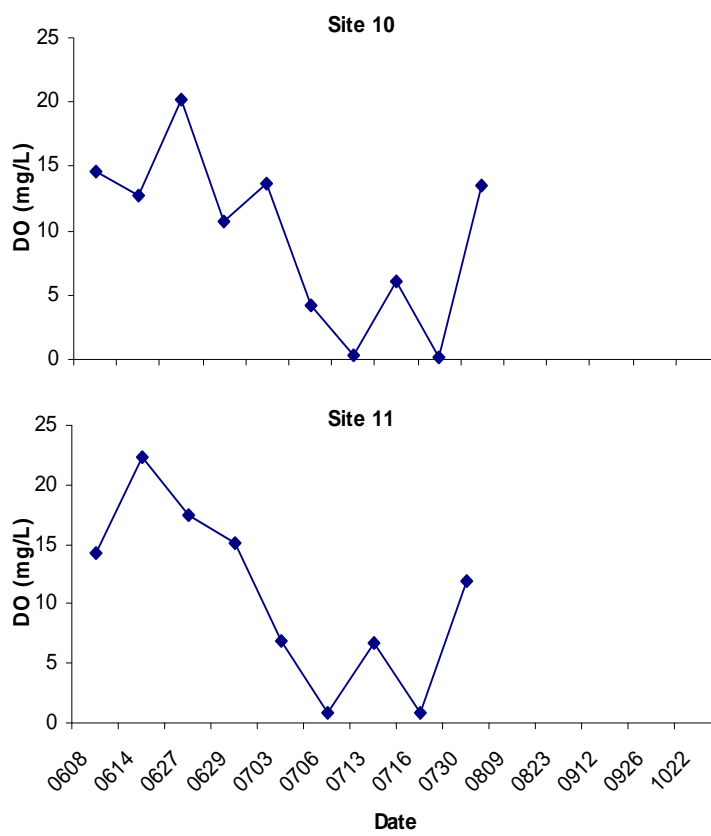


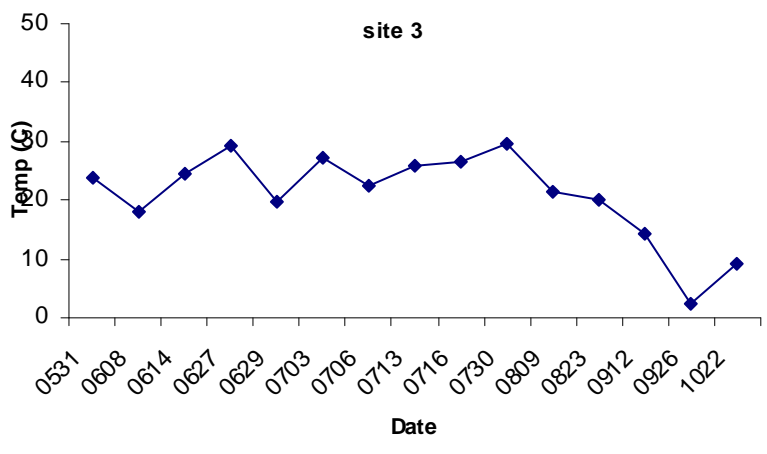
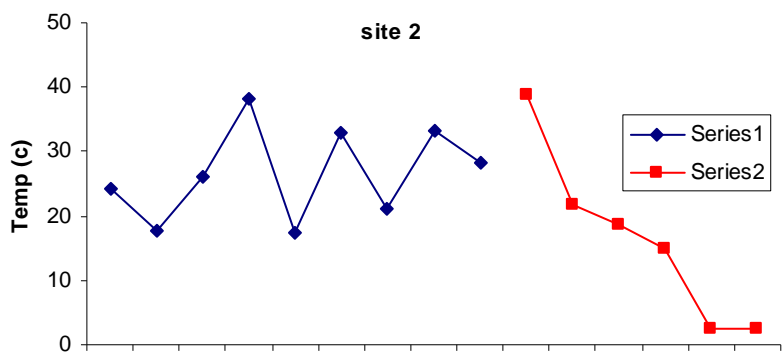
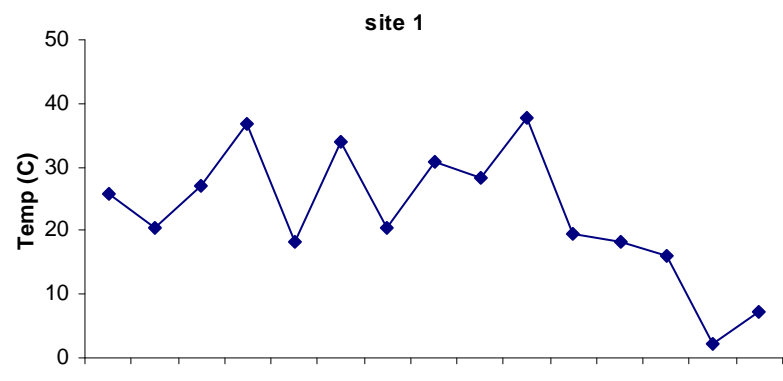


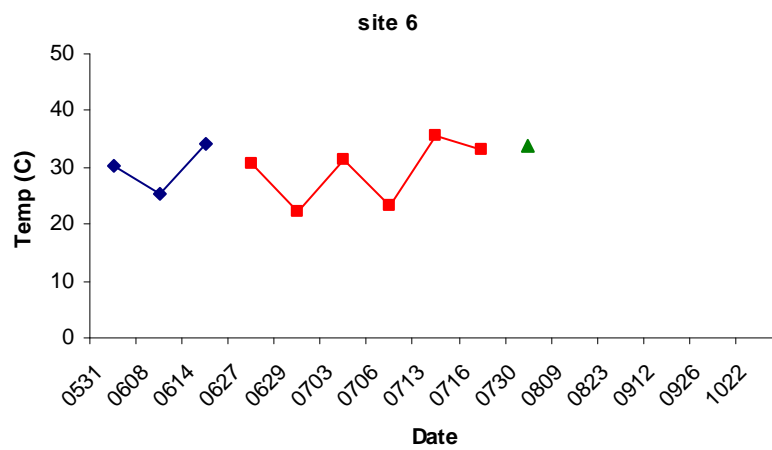
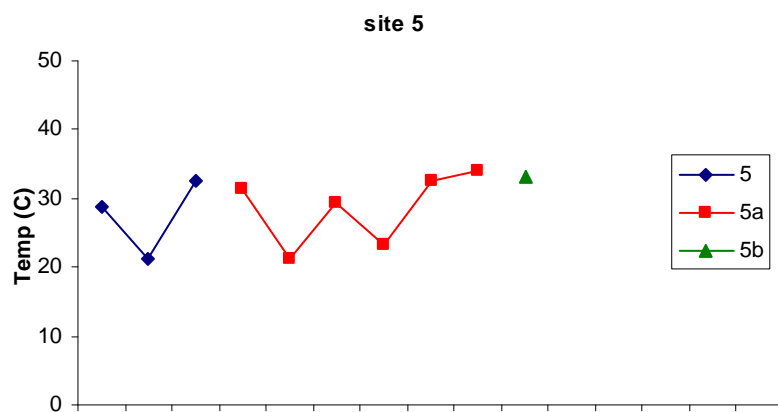
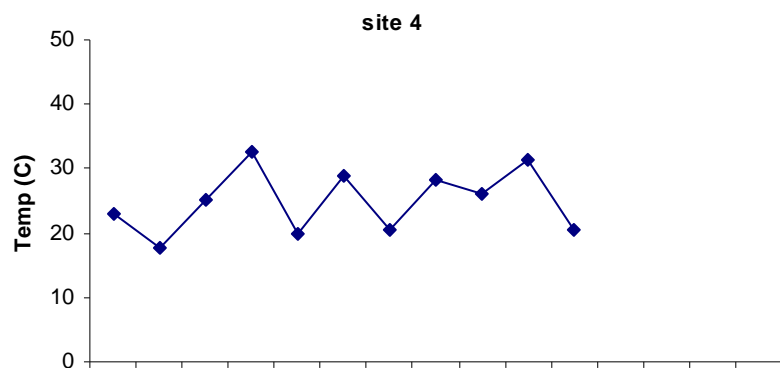


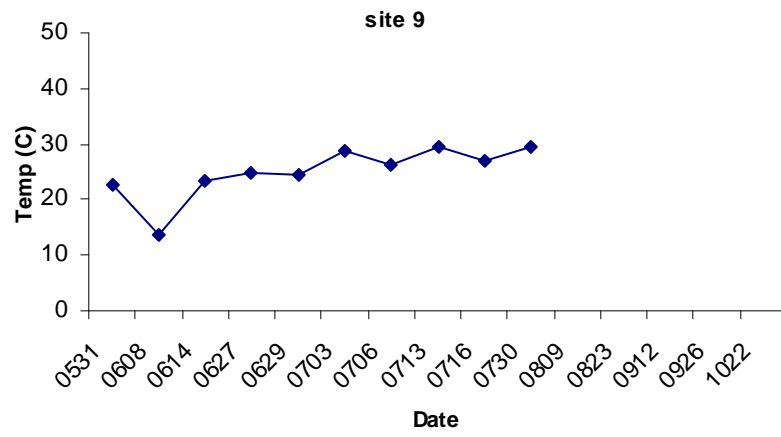
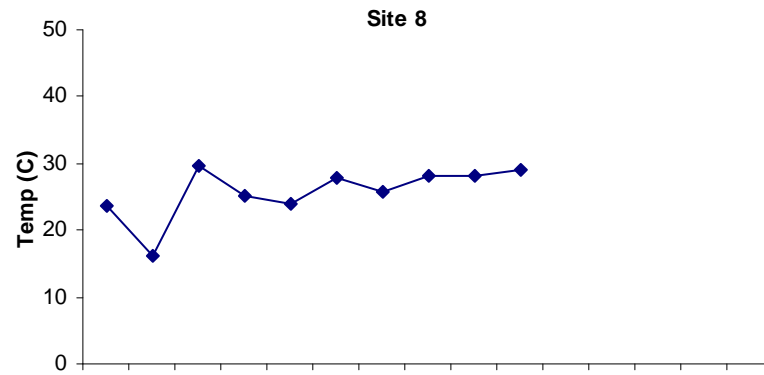
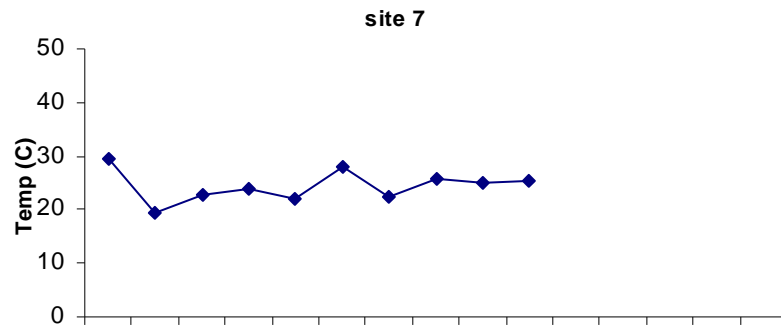


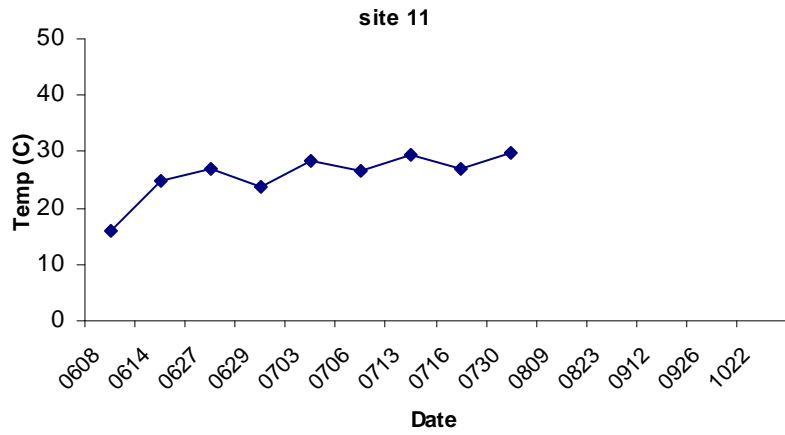
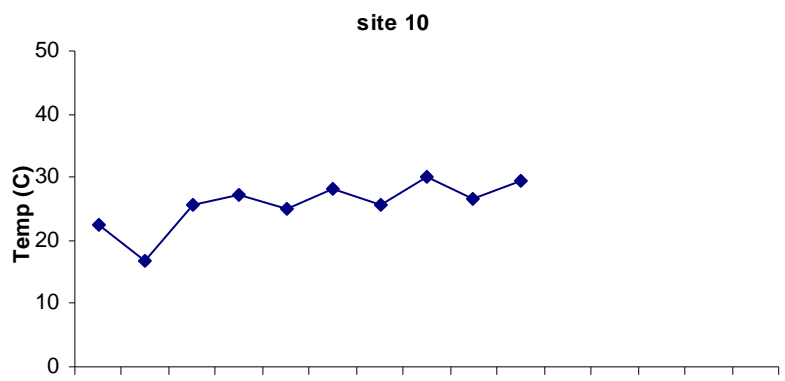












APPENDIX F

PHOSPHORUS RESULTS

Date Tested: 051707

Sample	Total	Ortho
1-1	0.625	0.575
1-2	0.66	0.585
average	0.6425	0.58

Sample	Total	Ortho
6-1	0.45	0.043
6-2	0.465	0.049
average	0.4575	0.046

Sample	Total	Ortho
2-1	3.3	3.25
2-2	3.415	3.69
average	3.3575	3.47

Sample	Total	Ortho
4-1	0.46	0.325
4-2	0.405	0.345
average	0.4325	0.335

Sample	Total	Ortho
3-1	2.065	2.07
3-2	2.12	2.055
average	2.0925	2.0625

Sample	Total	Ortho
5-1	1.47	0.61
5-2	1.205	0.607
average	1.3375	0.6085

Date Tested 052407

Sample	Total	Ortho
7-1	-	1.795
7-2	2.108	2.095
average	-	1.945

Sample	Total	Ortho
9-1	0.354	0
9-2	0.73	0
average	0.542	-

Sample	Total	Ortho
8-1	0.064	0.17
8-2	0.358	0.011
average	0.211	0.0905

Sample	Total	Ortho
10-1	0.328	0.009
10-2	0.5	0
average	0.414	0.0045

Date Tested: 053107

Sample	Total	Ortho
1-1	0.425	0.361
1-2	0.405	0.323
average	0.415	0.342

Sample	Total	Ortho
6-1	0.725	0.103
6-2	0.71	0.109
average	0.7175	0.106

Sample	Total	Ortho
2-1	-	0.332
2-2	1.455	0.348
average	-	0.34

Sample	Total	Ortho
7-1	1.642	0.278
7-2	1.592	0.252
average	1.617	0.265

Sample	Total	Ortho
3-1	1.805	0.353
3-2	1.9	0.378
average	1.8525	0.3655

Sample	Total	Ortho
8-1	0.37	0
8-2	0.474	0
average	0.422	-

Sample	Total	Ortho
4-1	0.415	0.32
4-2	0.41	0.334
average	0.4125	0.327

Sample	Total	Ortho
9-1	0.248	0
9-2	0.298	0
average	0.273	-

Sample	Total	Ortho
5-1	2.42	0.13
5-2	2.495	0.13
average	2.4575	0.13

Sample	Total	Ortho
10-1	0.346	0
10-2	0.374	0
average	0.36	-

Date Tested: 060807

Sample	Total	Ortho
1-1	0.25	0.197
1-2	0.242	0.186
average	0.246	0.1915

Sample	Total	Ortho
6-1	0.202	0.036
6-2	0.178	0.043
average	0.19	0.0395

Sample	Total	Ortho
2-1	1.33	0.197
2-2	1.416	0.176
average	1.373	0.1865

Sample	Total	Ortho
7-1	1.74	0.354
7-2	1.512	0.41
average	1.626	0.382

Sample	Total	Ortho
3-1	1.385	0.275
3-2	1.26	0.265
average	1.3225	0.27

Sample	Total	Ortho
8-1	0.334	0.011
8-2	0.348	0.01
average	0.341	0.0105

Sample	Total	Ortho
4-1	0.232	0.207
4-2	0.234	0.187
average	0.233	0.197

Sample	Total	Ortho
9-1	0.33	0
9-2	0.322	0.001
average	0.326	0.0005

Sample	Total	Ortho
5-1	0.592	0.111
5-2	0.628	0.117
average	0.61	0.114

Sample	Total	Ortho
10-1	0.32	0
10-2	0.326	0.002
average	0.323	0.001

Sample	Total	Ortho
11-1	0.39	0.001
11-2	0.406	0
average	0.398	0.0005

Date Tested: 061407

Sample	Total	Ortho
1-1	0.27	0.316
1-2	0.295	0.317
average	0.2825	0.3165

Sample	Total	Ortho
6-1	0.294	0.11
6-2	0.356	0.107
average	0.294	0.1085

Sample	Total	Ortho
2-1	2.39	2.365
2-2	2.73	2.385
average	2.56	2.375

Sample	Total	Ortho
7-1	2.29	2.205
7-2	2.34	2.205
average	2.315	2.205

Sample	Total	Ortho
3-1	1.88	1.735
3-2	1.875	1.725
average	1.8775	1.73

Sample	Total	Ortho
8-1	0.304	0.003
8-2	0.306	0
average	0.305	0.0015

Sample	Total	Ortho
4-1	0.575	0.458
4-2	0.54	0.453
average	0.5575	0.4555

Sample	Total	Ortho
9-1	0.282	0
9-2	0.3	0.018
average	0.291	0.009

Sample	Total	Ortho
5-1	0.714	0.032
5-2	0.656	0.037
average	0.685	0.0345

Sample	Total	Ortho
10-1	0.418	0
10-2	0.354	0.006
average	0.386	0.003

Sample	Total	Ortho
11-1	0.394	0.012
11-2	0.39	0.011
average	0.392	0.0115

Date Tested: 062707

Sample	Total	Ortho
1-1	0.245	0.194
1-2	0.225	0.149
average	0.235	0.1715

Sample	Total	Ortho
6-1a	0.57	0.024
6-2a	0.572	0.018
average	0.57	0.021

Sample	Total	Ortho
2-1	0.93	0.16
2-2	0.96	0.125
average	0.945	0.1425

Sample	Total	Ortho
7-1	1.58	1.455
7-2	1.495	1.525
average	1.5375	1.49

Sample	Total	Ortho
3-1	1.855	1.655
3-2	1.875	1.68
average	1.865	1.6675

Sample	Total	Ortho
8-1	0.514	0.024
8-2	0.372	0.021
average	0.443	0.0225

Sample	Total	Ortho
4-1	0.555	0.375
4-2	0.51	0.341
average	0.5325	0.358

Sample	Total	Ortho
9-1	0.358	0.011
9-2	0.412	0.006
average	0.385	0.0085

Sample	Total	Ortho
5-1a	0.486	0
5-2a	0.48	0
average	0.483	-

Sample	Total	Ortho
10-1	0.352	0.007
10-2	0.368	0.008
average	0.36	0.0075

Sample	Total	Ortho
11-1	0.374	0
11-2	0.398	0
average	0.386	-

Date Tested: 062907

Sample	Total	Ortho
1-1	0.515	0.365
1-2	0.51	0.391
average	0.5125	0.378

Sample	Total	Ortho
6-1a	0.448	0.015
6-2a	0.48	0.014
average	0.464	0.0145

Sample	Total	Ortho
2-1	6.54	5.38
2-2	6.83	5.62
average	6.685	5.5

Sample	Total	Ortho
7-1	1.535	1.52
7-2	1.49	1.595
average	1.5125	1.5575

Sample	Total	Ortho
3-1	2.52	2.18
3-2	2.32	2.175
average	2.42	2.1775

Sample	Total	Ortho
8-1	0.326	0
8-2	0.448	0
average	0.387	0

Sample	Total	Ortho
4-1	3.08	2.71
4-2	3.01	2.735
average	3.045	2.7225

Sample	Total	Ortho
9-1	0.196	0.01
9-2	0.218	0.007
average	0.207	0.0085

Sample	Total	Ortho
5-1a	0.63	0.013
5-2a	1.115	0.003
average	0.8725	0.008

Sample	Total	Ortho
10-1	0.3	0.025
10-2	0.298	0.018
average	0.299	0.0215

Sample	Total	Ortho
11-1	0.37	0
11-2	0.204	0
average	0.287	-

Date Tested: 070307

Sample	Total	Ortho
1-1	0.065	0
1-2	0.105	0
average	0.085	-

Sample	Total	Ortho
6-1a	0.344	0.002
6-2a	0.544	0.005
average	0.444	0.0035

Sample	Total	Ortho
2-1	1.38	0.695
2-2	1.315	0.735
average	1.3475	0.715

Sample	Total	Ortho
7-1	4.74	4.44
7-2	4.4	3.99
average	4.57	4.215

Sample	Total	Ortho
3-1	1.145	1.235
3-2	1.485	1.265
average	1.315	1.25

Sample	Total	Ortho
8-1	0.302	0.014
8-2	0.384	0.019
average	0.343	0.0165

Sample	Total	Ortho
4-1	0.495	0.525
4-2	0.62	0.605
average	0.5575	0.565

Sample	Total	Ortho
9-1	0.304	0.003
9-2	0.278	0.002
average	0.291	0.0025

Sample	Total	Ortho
5-1a	0.35	0.019
5-2a	0.415	0.018
average	0.3825	0.0185

Sample	Total	Ortho
10-1	0.322	0.013
10-2	0.292	0.009
average	0.307	0.011

Sample	Total	Ortho
11-1	0.21	0.005
11-2	0.314	0.025
average	0.262	0.015

Date Tested: 070607

Sample	Total	Ortho
1-1	0.67	0.543
1-2	0.6	0.553
average	0.635	0.548

Sample	Total	Ortho
6-1a	0.646	0.05
6-2a	0.642	0.058
average	0.644	0.054

Sample	Total	Ortho
2-1	5.22	4.52
2-2	5.26	4.06
average	5.24	4.29

Sample	Total	Ortho
7-1	2.375	2.435
7-2	2.485	2.445
average	2.43	2.44

Sample	Total	Ortho
3-1	2.005	2.01
3-2	1.985	1.96
average	1.995	1.985

Sample	Total	Ortho
8-1	0.44	0.062
8-2	0.468	0.058
average	0.454	0.06

Sample	Total	Ortho
4-1	0.552	0.501
4-2	0.53	0.507
average	0.541	0.504

Sample	Total	Ortho
9-1	0.324	0.013
9-2	0.396	0.019
average	0.36	0.016

Sample	Total	Ortho
5-1a	0.626	0.068
5-2a	0.594	0.07
average	0.61	0.069

Sample	Total	Ortho
10-1	0.318	0.009
10-2	0.364	0.006
average	0.341	0.0075

Sample	Total	Ortho
11-1	0.482	0
11-2	0.414	0.002
average	0.448	0.001

Date Tested: 071307

Sample	Total	Ortho
1-1	0.328	0.168
1-2	0.334	0.17
average	0.331	0.169

Sample	Total	Ortho
6-1a	0.642	0.014
6-2a	0.618	0.011
average	0.63	0.0125

Sample	Total	Ortho
2-1	2.345	1.615
2-2	2.175	1.55
average	2.26	1.5825

Sample	Total	Ortho
7-1	2.08	1.915
7-2	2.125	2.055
average	2.1025	1.985

Sample	Total	Ortho
3-1	2.255	2.145
3-2	2.125	2.28
average	2.19	2.2125

Sample	Total	Ortho
8-1	0.44	0.034
8-2	0.422	0.026
average	0.431	0.03

Sample	Total	Ortho
4-1	0.32	0.258
4-2	0.314	0.26
average	0.317	0.259

Sample	Total	Ortho
9-1	0.386	0.004
9-2	0.386	0.005
average	0.386	0.0045

Sample	Total	Ortho
5-1a	0.494	0
5-2a	0.482	0.005
average	0.488	0.0025

Sample	Total	Ortho
10-1	0.342	0.003
10-2	0.324	0
average	0.333	0.0015

Sample	Total	Ortho
11-1	0.482	0
11-2	0.414	0
average	0.448	-

Date Tested:071607

Sample	Total	Ortho
1-1	0.184	0.149
1-2	0.172	0.167
average	0.178	0.158

Sample	Total	Ortho
6-1a	2.356	0.405
6-2a	2.292	0.487
average	2.324	0.446

Sample	Total	Ortho
2-1	3.315	1.275
2-2	2.925	1.395
average	3.12	1.335

Sample	Total	Ortho
7-1	2.485	2.55
7-2	2.705	2.605
average	2.595	2.5775

Sample	Total	Ortho
3-1	1.605	1.62
3-2	1.71	1.705
average	1.6575	1.6625

Sample	Total	Ortho
8-1	0.338	0.022
8-2	0.336	0.024
average	0.337	0.023

Sample	Total	Ortho
4-1	0.292	0.262
4-2	0.302	0.262
average	0.297	0.262

Sample	Total	Ortho
9-1	0.326	0.018
9-2	0.334	0.016
average	0.33	0.017

Sample	Total	Ortho
5-1a	1.228	0.057
5-2a	1.292	0.04
average	1.26	0.0485

Sample	Total	Ortho
10-1	0.46	0.016
10-2	0.516	0.018
average	0.488	0.017

Sample	Total	Ortho
11-1	0.408	0.018
11-2	0.346	0.025
average	0.377	0.0215

Date Tested: 073007

Sample	Total	Ortho
1-1	0.17	0.111
1-2	0.162	0.12
average	0.166	0.1155

Sample	Total	Ortho
6-1a	0.542	0.004
6-2a	0.602	0.006
average	0.572	0.005

Sample	Total	Ortho
2-1	0.328	0.047
2-2	0.35	0.024
average	0.339	0.0355

Sample	Total	Ortho
7-1	1.7	1.64
7-2	1.7	1.615
average	1.7	1.6275

Sample	Total	Ortho
3-1	1.37	1.295
3-2	1.425	1.26
average	1.3975	1.2775

Sample	Total	Ortho
8-1	0.398	0.002
8-2	0.436	0.004
average	0.417	0.003

Sample	Total	Ortho
4-1	0.18	0.125
4-2	0.168	0.123
average	0.174	0.124

Sample	Total	Ortho
9-1	0.374	0.004
9-2	0.404	0
average	0.389	0.002

Sample	Total	Ortho
5-1a	0.404	0.008
5-2a	0.41	0.009
average	0.407	0.0085

Sample	Total	Ortho
10-1	0.41	0.007
10-2	0.416	0.005
average	0.413	0.006

Sample	Total	Ortho
11-1	0.41	0.009
11-2	0.378	0
average	0.394	0.0045

Date Tested: 080907

Sample	Total	Ortho
1-1	0.394	0.339
1-2	0.376	0.338
average	0.385	0.3385

Sample	Total	Ortho
2-1	0.648	0.342
2-2	0.642	0.326
average	0.645	0.334

Sample	Total	Ortho
3-1	2.47	2.42
3-2	2.46	2.435
average	2.465	2.4275

Sample	Total	Ortho
4-1	0.224	0.158
4-2	0.244	0.138
average	0.234	0.148

Sample	Total	Ortho
FBWMA-1	0.212	0.162
FBWMA-2	0.26	0.153
average	0.236	0.1575

Date Tested: 082307

Sample	Total	Ortho
1-1	0.286	0.244
1-2	0.298	0.23
average	0.292	0.237

Sample	Total	Ortho
2-1	1.785	1.45
2-2	1.755	1.43
average	1.77	1.44

Sample	Total	Ortho
3-1	2.13	2.13
3-2	2.145	2.15
average	2.1375	2.14

Sample	Total	Ortho
FBWMA-1	0.39	0.324
FBWMA-2	0.38	0.327
average	0.385	0.3255

Test Date: 091207

Sample	Total	Ortho
1-1	0.156	0.051
1-2	0.075	0.046
average	0.1155	0.0485

Sample	Total	Ortho
2-1	0.47	0.276
2-2	0.472	0.278
average	0.471	0.277

Sample	Total	Ortho
3-1	1.75	1.655
3-2	1.7	1.68
average	1.725	1.655

Sample	Total	Ortho
FBWMA-1	0.142	0.1
FBWMA-2	0.14	0.104
average	0.142	0.102

Test Date: 092607

Sample	Total	Ortho
1-1	0.276	0.039
1-2	0.258	0.042
average	0.267	0.0405

Sample	Total	Ortho
2-1	2.565	0.755
2-2	2.86	0.885
average	2.7125	0.82

Sample	Total	Ortho
3-1	2.09	1.655
3-2	2.04	1.6
average	2.065	1.6275

Sample	Total	Ortho
ch-1	0.213	0.057
ch-2	0.203	0.055
average	0.208	0.056

Test Date: 102207

Sample	Total	Ortho
1-1	0.288	0.186
1-2	0.278	0.184
average	0.283	0.185

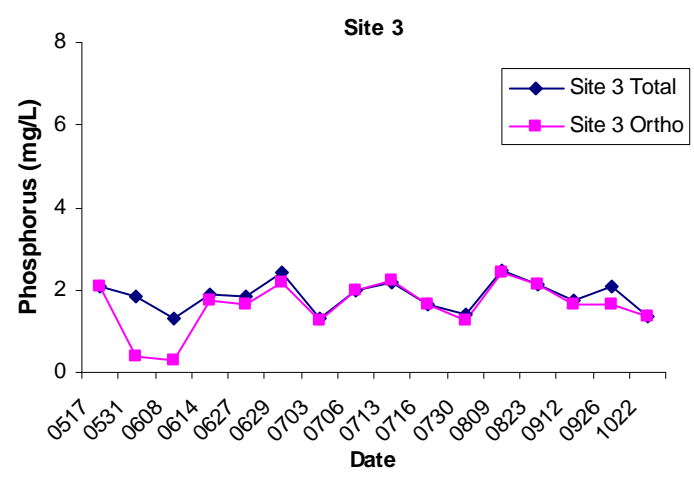
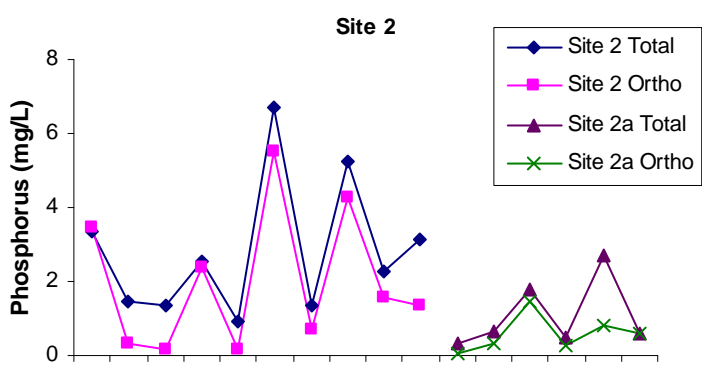
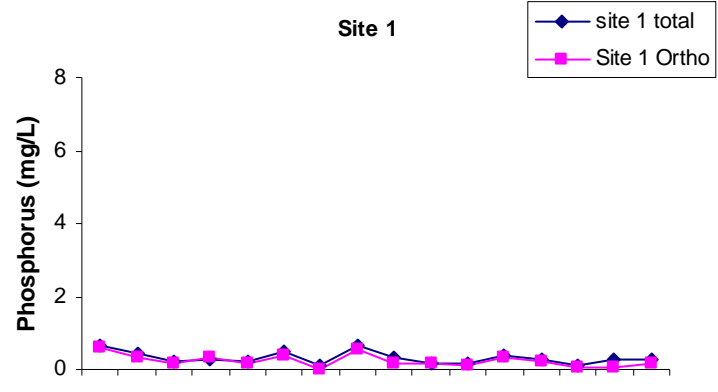
Sample	Total	Ortho
2-1	0.675	0.61
2-2	0.52	0.555
average	0.5975	0.5825

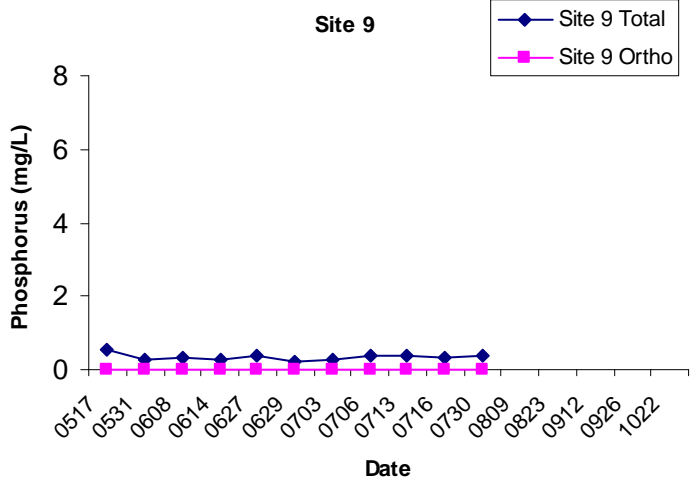
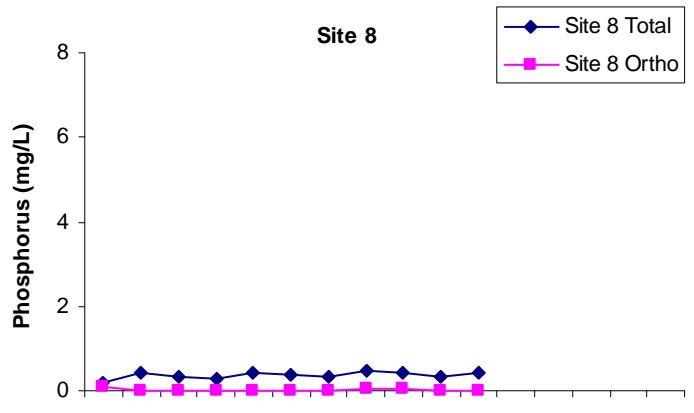
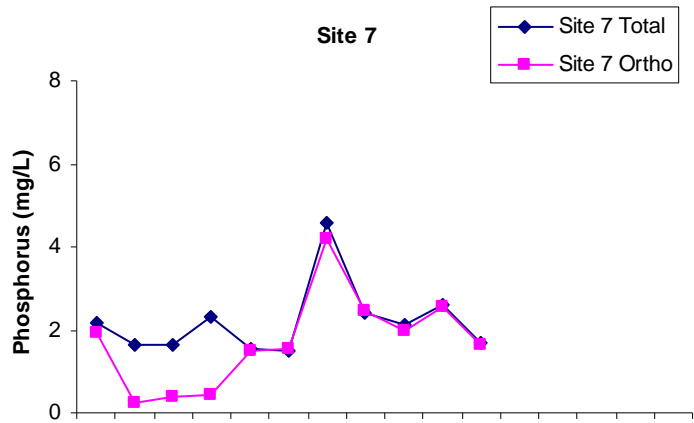
Sample	Total	Ortho
3-1	1.405	1.385
3-2	1.275	1.285
average	1.34	1.335

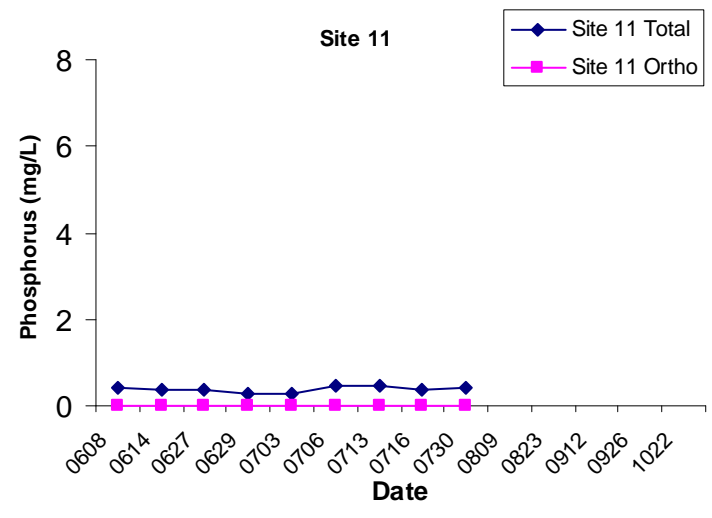
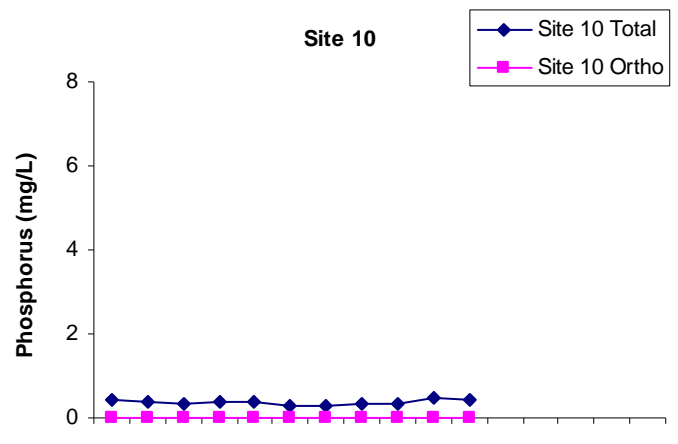
Sample	Total	Ortho
FBWMA-1	0.33	0.2
FBWMA-2	0.324	0.198
average	0.327	0.199

APPENDIX G

PHOSPHORUS PLOTS

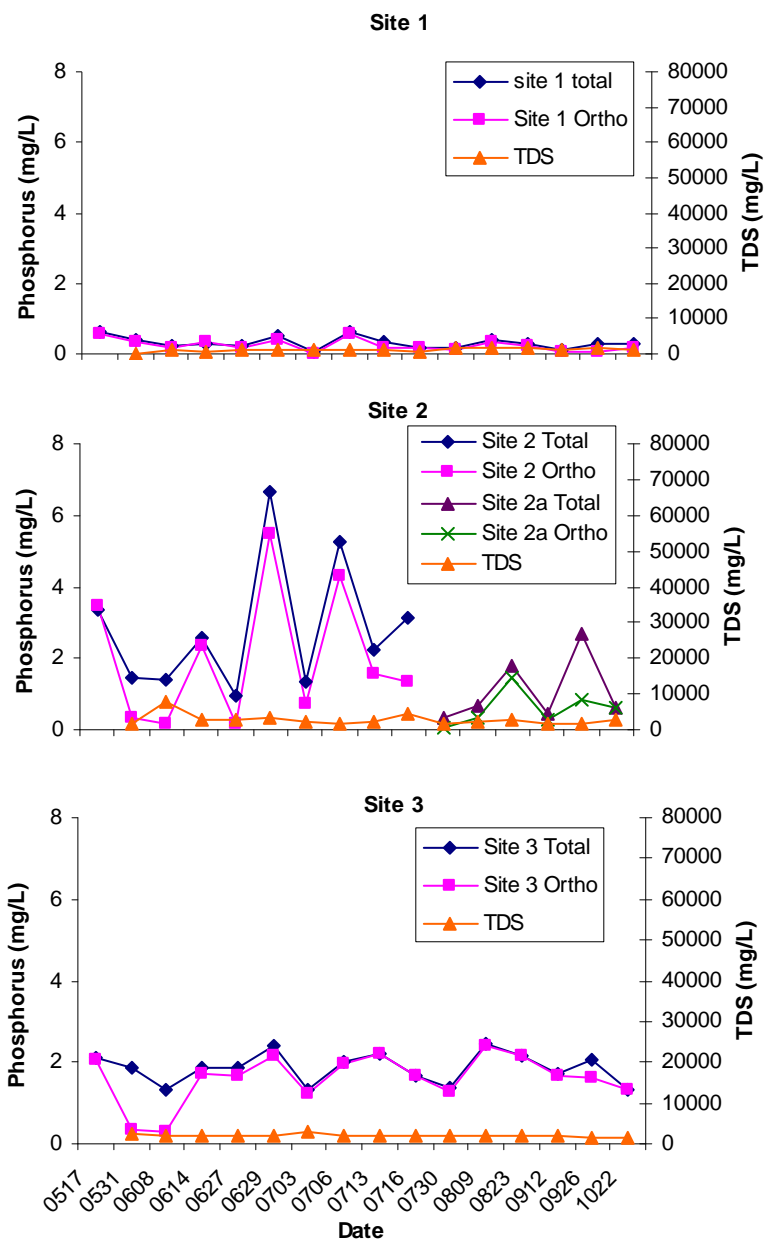


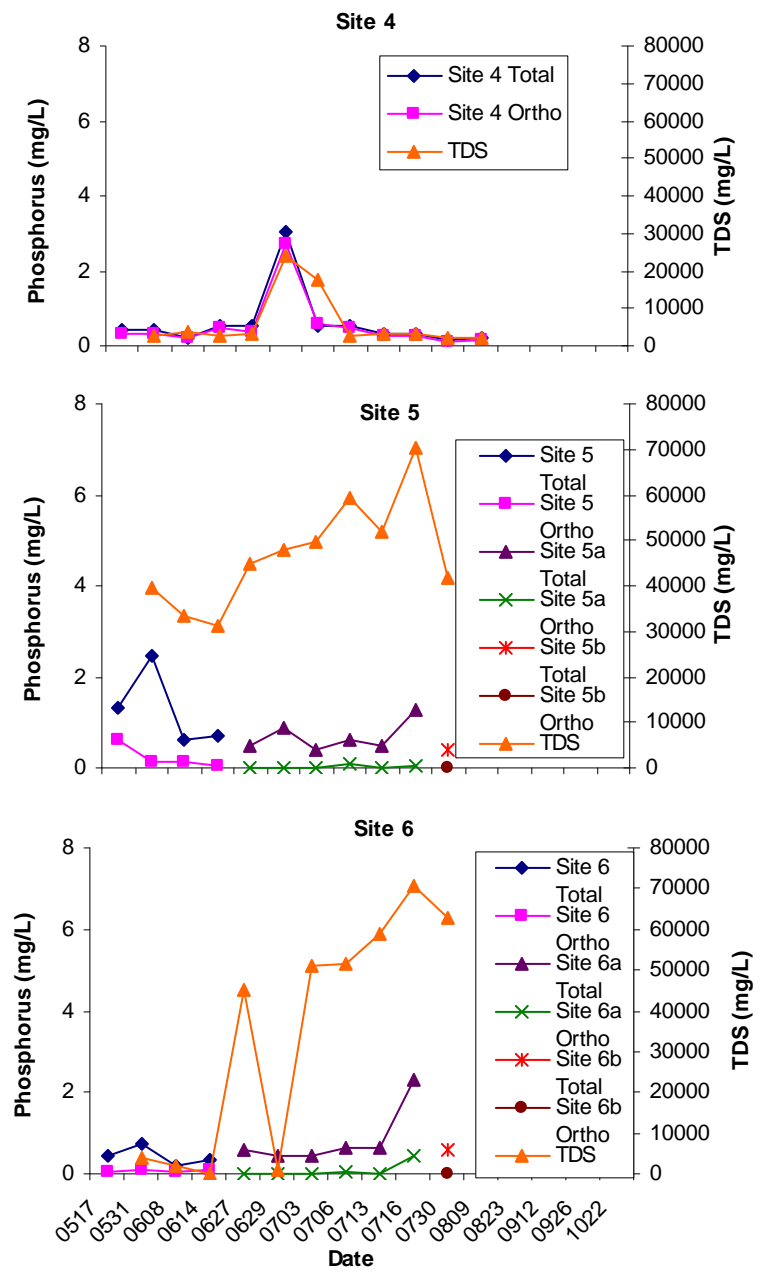


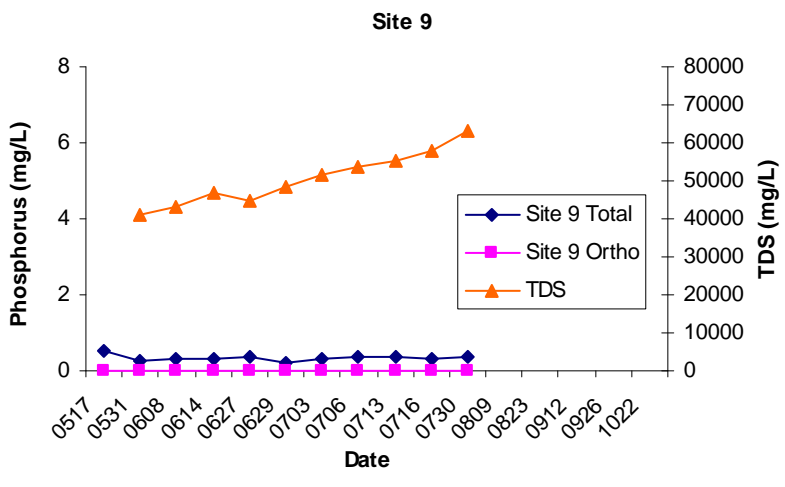
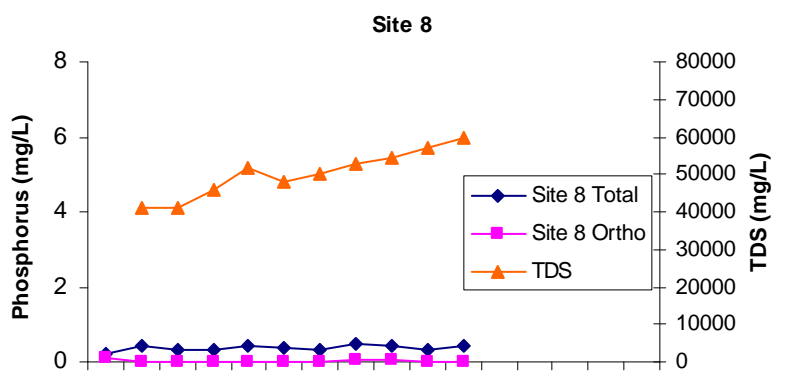
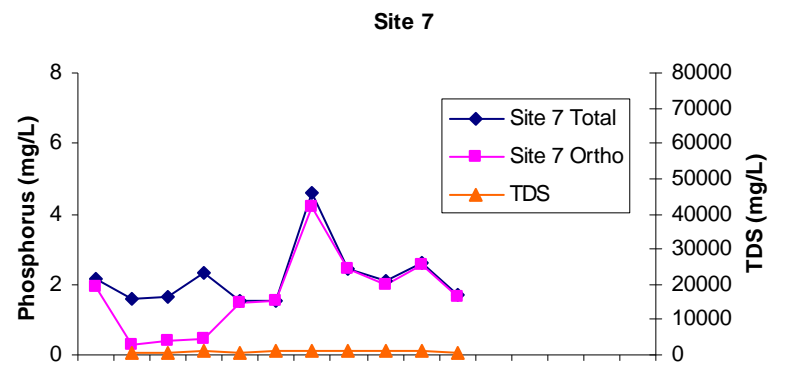


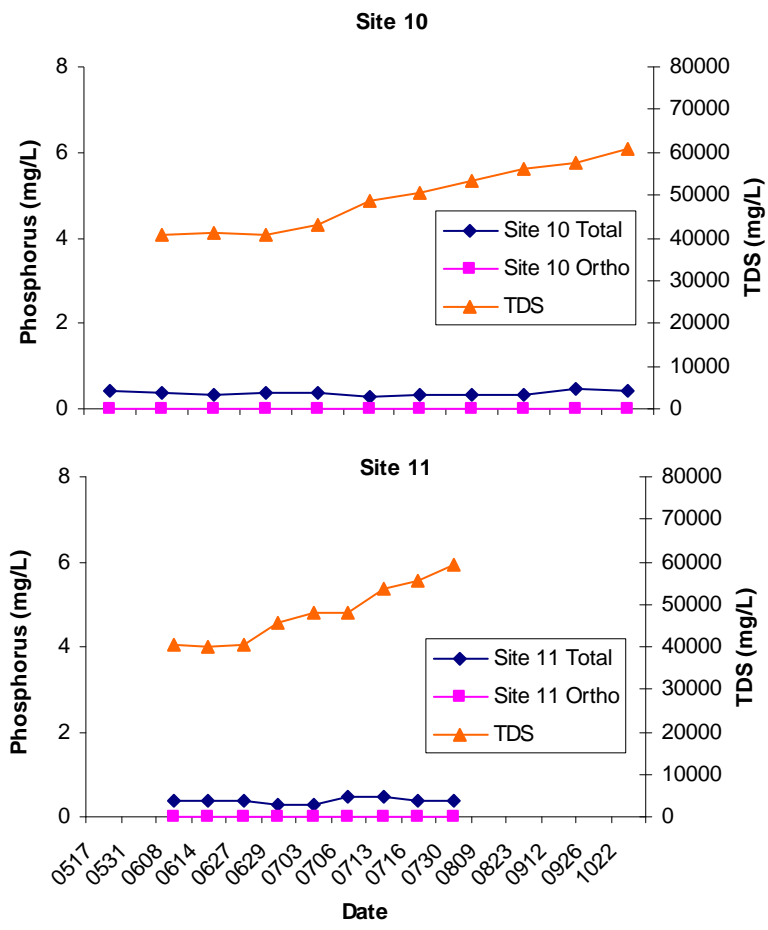
APPENDIX H

TDS VS. PHOSPHORUS PLOTS









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