INTERACTIONS OF WATER AND SEDIMENT PHOSPHORUS IN LAKE EYMIR

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ABSTRACT

INTERACTIONS OF WATER AND SEDIMENT PHOSPHORUS IN LAKE EYMIR

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A detailed study is held in Lake Eymir, a shallow eutrophic lake, investigating the phosphorus concentrations in water and the bottom sediment. Water depth, secchi depth, TSS, sediment soluble total phosphorus, sediment soluble PO_4-P, Chl-a , TKN, NH_4-N, NO_2-N, NO_3-N, alkalinity, temperature, pH, conductivity, dissolved oxygen, turbidity and PAR parameters are monitored for 21 months and Principal Component Analysis (PCA) is applied to identify trend of phosphorus concentration in water column. Results indicated that total phosphorus concentrations in water column and sediment at lake bottom are susceptible to changes caused by the variations in other water quality parameters compared to average, surface and mid-depth values. Correlations observed between P and other parameters were the highest in Bottom – 3 data set. In order to model sediment soluble total phosphorus in Lake Eymir, chlorophyll-a, NH_3, total phosphorus, PO_4-P, temperature, conductivity, pH, turbidity, ΔT and dissolved oxygen are defined as effective parameters. Linear regression models were more successful in predicting sediment soluble phosphorus concentrations compared to non-linear ones. Turbidity is a good tracer for total phosphorus concentrations in Lake Eymir. Temperature is seasonally effective on phosphorus concentrations, and may create stratified water in summer. Stratification causes phosphorus to build up in bottom water layer. Particle size distribution results show that area of sampling point 1 has different characteristics compared to other sampling locations since it is located at the inlet. The exchange of phosphorus from water to sediment is mostly completed within the first 7-8 hours. On average, 30% of the exchange is completed in an hour. It is clearly seen that although sediment layer in the lake is a phosphorus source, it has not reached its phosphorus binding capacity yet. Adsorption isotherm is found to be pseudo-second-order with a coefficient of determination greater than 0.9909 at all sampling points. Sediment phosphorus content has been fractioned into NH_4Cl-P, BD-P, NaOH-P and HCl-P in order to identify permanent and bioavailable parts. Fractionation results show that even if the soluble concentrations are low, they are high enough to cause eutrophication problems.

Keywords: Phosphorus, sediment, fractionation, adsorption, Principal Component Analysis

ÖZ

EYMİR GÖLÜNDEKİ SU VE SEDİMAN FOSFORUNUN ETKİLEŞİMLERİ

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Sığ ve ötröfik durumdaki Eymir Gölünde, su ve dip çamuru fosfor konsantrasyonlarını incelemek amacıyla kapsamlı bir çalışma yürütülmüştür. Su derinliği, secchi derinliği, AKM, sediman çözünür toplam fosfor, sediman çözünür PO_4-P, klorofil-a, TKN, amonyak-N, NO_2-N, NO_3-N, alkalinite, sıcaklık, pH, iletkenlik, çözünmüş oksijen, bulanıklık ve FAR parametreleri 21 ay boyunca izlenmiş, Temel Bileşen Analizi (TBA) kullanılarak su kolonundaki fosfor konsantrasyonunun değişimi izlenmiştir. Sonuçlara göre, dip seviyede su ve sedimandaki toplam fosforun, ortalama değerler ile, yüzey ve orta seviyedeki değerlere oranla diğer su kalitesi parametrelerindeki değişimlerden daha fazla etkilendiği görülmüştür. Toplam fosfor ile diğer parametreler arasındaki etkileşimin Dip – 3 veri setinde en yüksek olduğu görülmüştür. Doğrusal regresyon modelinin sediman toplam fosforunu tahmin etmede lineer olmayan modele göre daha başarılı olduğu görülmüştür. Bulanıklık değeri Eymir Gölü fosfor konsantrasyonu için iyi bir izleyicidir. Sıcaklık fosfor konsantrasyonlarını mevsimsel olarak etkilemekle birlikte, yaz aylarında tabakalaşmaya neden olabilmektedir. Tabakalaşma su kolonunun dibinde fosfor birikmesine neden olmaktadır. Tane büyüklüğü dağılımından çıkan sonuca göre 1 numaralı örnekleme noktası gölün girişinde bulunduğundan, tane karakteristiği diğer örnekleme noktalarından farklıdır. Sudan sedimana fosfor geçişi 7-8 saat gibi bir sürede tamamlanmaktadır. Genellikle ilk 1 saat içinde toplam geçişin %30'u bitmektedir. Sediman tabakası göl için bir fosfor kaynağı olmakla birlikte, fosfor bağlama kapasitesine ulaşamamıştır. Adsorpsiyon izotermi pseudo-ikinci-derece denklem olarak bulunmuş olup, kararlılık derecesi tüm örnekleme noktalarında minimum 0,9909'dur. Kalıcı ve biyolojik olarak kullanıma hazır fosfor konsantrasyonlarını belirlemek amacıyla dip çamurundaki fosfor bileşenleri NH_4Cl-P, BD-P, NaOH-P ve HCl-P olarak parçalanmıştır. Ayrıştırma sonucunda HCl ve NaOH'e bağlı fosfor miktarının BD bağlı fosfordan fazla olduğu belirlenmiştir. Ayrıştırma deneylerinden çıkan sonuçlara göre hazır kullanılabilir fosfor miktarı düşük gibi görünse de, gölde ötröfikasyon yaratmak için yeterli miktardadır.

Anahtarsözcük: Fosfor, sediman, kısımlara ayırma, absorpsiyon, Temel Bileşen Analizi

To my family

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CHAPTER 1

INTRODUCTION

Eutrophication leads to high phytoplankton growth, turbid water and some biological changes. These unwanted changes may be loss of biological diversity, disappearance of submerged macrophytes, changes in fish stock and decreasing top-down (Sondergaard et al., 2003). Eutrophication in shallow lakes is coupled with critical changes such as shifting from a clear macrophyte dominant state to a turbid phytoplankton dominant state with sediment re-suspension (Gervais et al., 1999).

Eutrophication has increased drastically in last years due to human activity oriented external nutrient inputs, especially phosphorus inputs, to lake and marine ecosystems (Azzoni et al., 2005; Nixon, 1995; Cloern, 2001). Rate of production in ecological systems is controlled by phosphorus limitations since it is the least available nutrient in a living environment. What makes phosphorus an essential nutrient for living organisms is taking place in chemical formation of ATP and calcium phosphate. ATP is a universal source of chemical energy in all living cells (Zhang et al. 2010) and PO_4-P is a common acid anion essential as a plant nutrient (Navratil et al. 2009). High phosphorus content can lead to excess growth of phytoplankton, turbidity, and some biological changes in surface water in lake environment. These problems show that phosphorus availability in a lake is the most important factor for water quality (Dong and Yang, 2010; Sondergaard et al., 2003; Zhu et al., 2008).

There is a great number of studies on the role of phosphorus in an ecosystem and its cycle (Ahmet and Abdallah, 2010; Golterman, 2004). Phosphorus pollution is accepted to be the main problem for eutrophication since phosphorus input to the system continues even after decreasing the external inputs (Song et al., 2006; Sondergaard et al., 2003). Even if the external inputs of phosphorus are reduced, internal loading from the sediment may prevent or delay lake recovery for several years (Gao et al., 2005). Fish, plankton and macrophyte are natural sources of large amounts of phosphorus found in a lake ecosystem (Graneli, 1999; Andersson et al., 1988). Retention of phosphorus in lake and reservoir ecosystems are mostly formed of sedimentation processes (Brzáková, 2003). Under anaerobic conditions, phosphorus is released from the sediment while H_2S and NH_4 are produced and NO_3 is denitrified. Since nitrogen uptake can be achieved by nitrogen fixing bacteria from the atmosphere, in most cases phosphorus is the main reason for eutrophication (Scarlatos, 1997). Nitrogen to phosphorus ratio of greater than 14:1 is considered as phosphorus limiting condition (Perrone et al., 2008). For controlling the eutrophication in lakes, extent of sediment phosphorus recycle is critical (Mayer et al. 2006).

In shallow lakes, high ratio of sediment surface to water depth gains an importance for sediment layer being a source of phosphorus (Dong and Yang, 2010). In lotic ecosystems, a significant fraction of nutrients required for primary biological activities can be provided by nutrients releasing from sediment layer (Burger, 2007; Sondergaard et al. 1999). If sediment layer is disturbed, mixing of anoxic pore water with bottom layer bulk water may deplete oxygen and cause other adverse effects (House, 2003). In shallow ecosystems, most of these biogeochemical processes take place at water-sediment interface due to high sediment-water ratio (Azzoni et al., 2005; Caumette et al. 1996). Trophic state of the lake, sediment composition, rate of sedimentation, physicochemical conditions and the extent of diagenetic processes are the parameters modifying the concentration of phosphorus in the sediment (Gao et al., 2005). The history of lakes may be interpreted by analyzing the sediment layer although it is hard to know the difference between sources of phosphorus. Phosphorus concentration in surface sediment layer may be due to phosphorus sedimentation, release of phosphorus from sediment or loss of phosphorus by mineralization and dissolution processes (Hupfer et al., 1995).

Due to phosphorus release at sediment water interface under anoxic conditions, the seasonally accumulated phosphorus could be greater than annual load from the watershed (Caraco et al., 1993; Nurnberg, 1987). Therefore, the trophic state of a water body is highly dependent on the availability of phytoplankton to use the phosphorus released from anoxic bottom waters. In order to achieve this, phosphorus released from the bottom sediment should reach trophogenic waters by mixing upwards. The vertical distribution of soluble reactive phosphorus in pore water may be influenced by decomposition of organics, reduction of iron oxides and microbiological activity in sediment (Gao et al., 2005; Sundby et al., 1992).

Lake Eymir is a shallow eutrophic lake located at 20 km south of Ankara. Although shifts have been observed in the limited nutrient in the lake, phosphorus has been reported as a major limiting nutrient (Elahdab, 2006; Beklioglu et al., 2003; Karul et al., 2000; Karakoç et al., 2003; Yenilmez et al., 2010; Yüzügüllü, 2011; Atiker, 2011; Beklioglu et al., 2010). Yet, studies so far focused on phosphorus concentrations and its impact on algal growth in the water column. No study has been done to investigate the relationships between sediment and water concentrations. The aim of this study is to monitor and evaluate the concentration of phosphorus in water column and sediment in Lake Eymir with respect to parameters that impact its concentration. Moreover, the sediment in Lake Eymir is studied in order to identify its properties, and phosphorus fractions.

CHAPTER 2

STUDY SITE AND BACKGROUND

2.1. Study Site

Lake Eymir is located at 20 km south of Ankara and it is located at 39.28 north latitudes 32.30 east longitudes, at an altitude of 969 m (Yüzügüllü, 2011). The basin is protected by the "Specially Protected Area by Law" within the basin which has been accepted by the Council of Minister in 1990. It covers both Lake Eymir and Lake Mogan and their surroundings within an area of 245 km^2 (Yağbasan, 2007). Location of Lake Eymir is given in Figure 2.1.

Formation of the lake is predicted to be as a result of tectonic activities that took place in 4th geological age (Diker, 1992) and alluvium build up (Çamur et al., 1997). With an average depth of about 3 m, Lake Eymir is classified as a shallow lake. The lake area changes between 100-125 ha depending on the depth of water. The catchment area is 971 km^2 with 13 km of shoreline (Tan and Beklioglu, 2005). The average volume of the water in the lake is 3,88x106 m^3. Changing volume provides a detention time of 3.4 to 35.4 years as reported by Tan (2002).

The main inflow to Lake Eymir is the outflow of Lake Mogan, which was halted for a certain amount of time in the past few years. The natural channel connecting these two lakes was modified by a concrete gate channel to sustain the water level in Lake Mogan. However, on April 2010, the water depth in Lake Eymir increased suddenly due to flood from Lake Mogan. The gate which controls the inflow from Lake Mogan has broken due to the pressure resulting from large volume of water in Lake Mogan. As a result of this event, the depth of water in Lake Eymir increased by approximately 1 m within a few days. Further with heavy precipitation, the increase in the water depth of Lake Eymir reached to 1.5 – 1.7 m. In April 2010, the channel was rehabilitated and the gate was reinstalled by the Gölbaşı Municipality (Yüzügüllü, 2011). Meteorological data showing rainfall intensity is given in Appendix F.

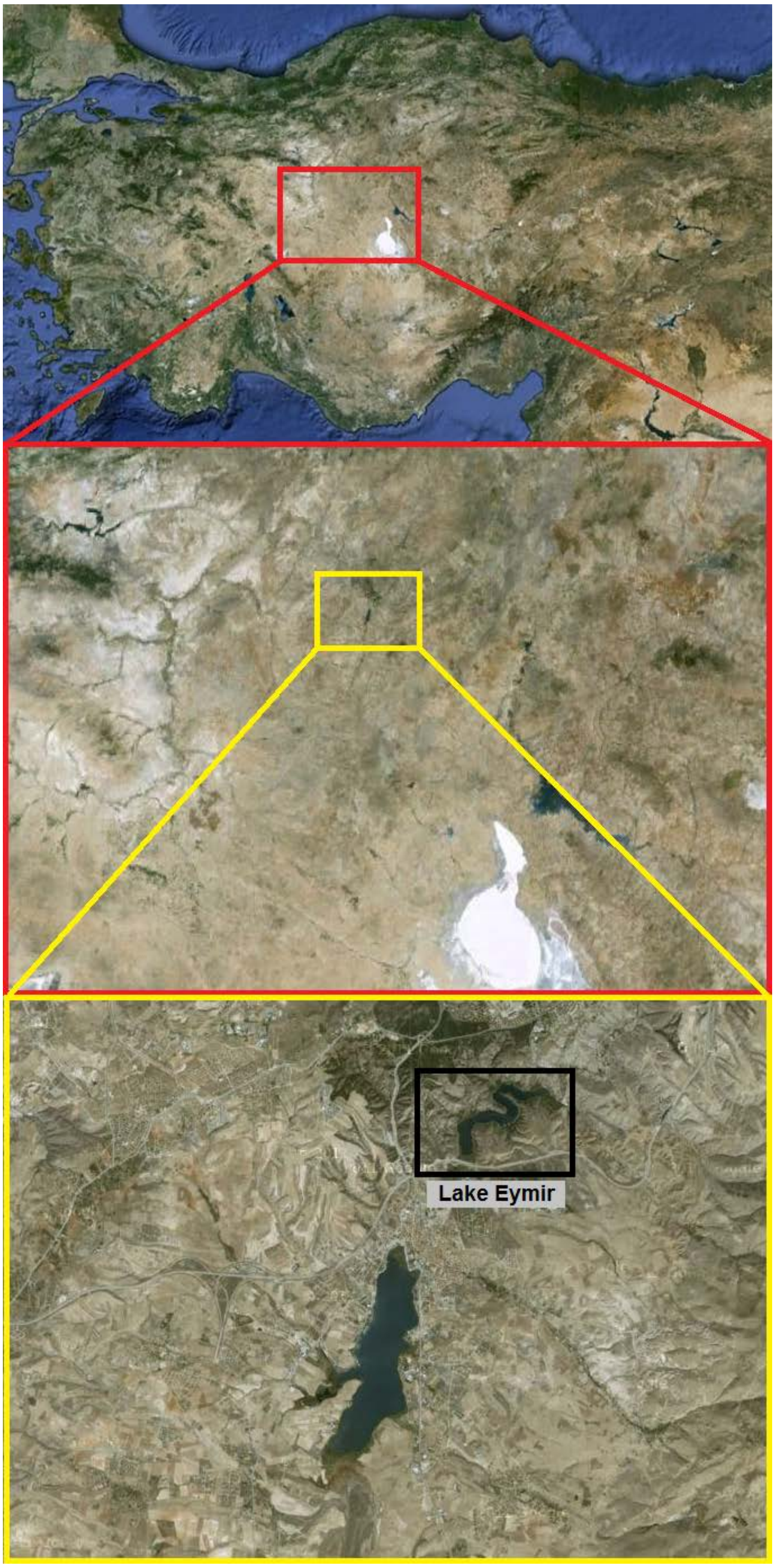


Figure 2.1: Location of Lake Eymir

Naturally, the water level in Lake Mogan is 3 m higher than for Lake Eymir. Yet, there are fluctuations in water levels of both lakes that vary seasonally. The result of this level difference causes the flow from Lake Mogan to Lake Eymir. Figure 2.2 shows hydraulic heads in different wells in the vicinity of the lakes. The hydraulic head in the shallow well numbered as 4 in the upstream of Lake Eymir is greater than that of the deep well numbered as 5 in the downstream of Lake Mogan, and both are greater than Lake Eymir's water level. As a result, Lake Eymir is fed by the groundwater system from Lake Mogan (Yağbasan, 2007).

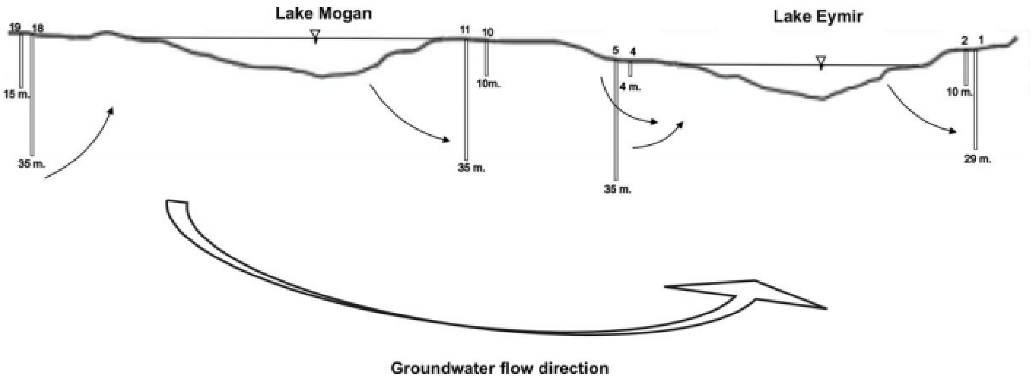


Figure 2.2: Groundwater Flow from Lake Mogan to Lake Eymir (Yağbasan, 2007)

According to Canpolat et al. (1997), the inorganic parameters of this groundwater flow are affected by Gölbaşı Municipality Solid Waste Disposal Site between Lake Eymir and Lake Mogan. Table 2.1 shows the rate of inorganic parameter concentrations in contaminated wells 4 and 6 at Lake Eymir upstream with respect to uncontaminated well 9 in Lake Mogan.

Table 2.1: Rate of Inorganic Parameter Concentrations in Contaminated Wells 4 and 6 with Respect to Uncontaminated Well 9 Concentrations (Canpolat et al. 1997)

	Well #4	Well #6	Well #9
T (°C)	0.98	1.04	14.0
pH	0.94	0.98	7.73
Alkalinity (mg/L)	0.64	0.48	732
Hardness (mg/L, $CaCO_3$)	0.96	1.58	480
TDS (mg/L)	0.91	1.27	661
Conductivity (mS/cm)	0.93	1.29	1.30
Mg (mg/L)	0.27	0.72	80.92
Ca (mg/L)	2.5	3.54	58.8
Na (mg/L)	0.694	0.586	232.43
K (mg/L)	1	2	1.6
HCO_3 (mg/L)	0.64	0.48	732
Cl (mg/L)	1.38	2.34	52
SO_4 (mg/L)	45	170	2
SiO_2 (mg/L)	0.95	0.54	28.20
Cu (mg/L)	150	259	0.01
F (mg/L)	0.39	0.96	0.74
Fe (mg/L)	135	12	0.01
Mn (mg/L)	1.97	0	0.41
NO_3 (mg/L)	1	15.99	0.442
NO_2 (mg/L)	0.05	0.11	0.086
NH_3 (mg/L)	2.20	0.09	0.244

The second inflow to Lake Eymir is the Kışlakçı Creek which enters the lake from the northern part. Flow is mostly observed in late winter and spring. In addition, an underground water inflow at northern part feeds the lake at an approximate flowrate of 17 L/hr (Altınbilek et al., 1995). Besides these inflows, Diker (1992) reports that the drainage area of Lake Eymir contains some of the regions in the Elmadağ and this provides additional water inflow originating from the mountain to the lake. The average precipitation in the area is approximately 390 ± 76 mm/year. As depicted in Figure 2.3, the lake drains into İmrahor Creek at north. Evaporation and groundwater discharge can be counted as the other outflows. In a yearly basis, the average evaporation amount is 1092,2 mm. According to Altınbilek et al (1995), there is a discharge to underground layer in an average amount of 2 L/hr.

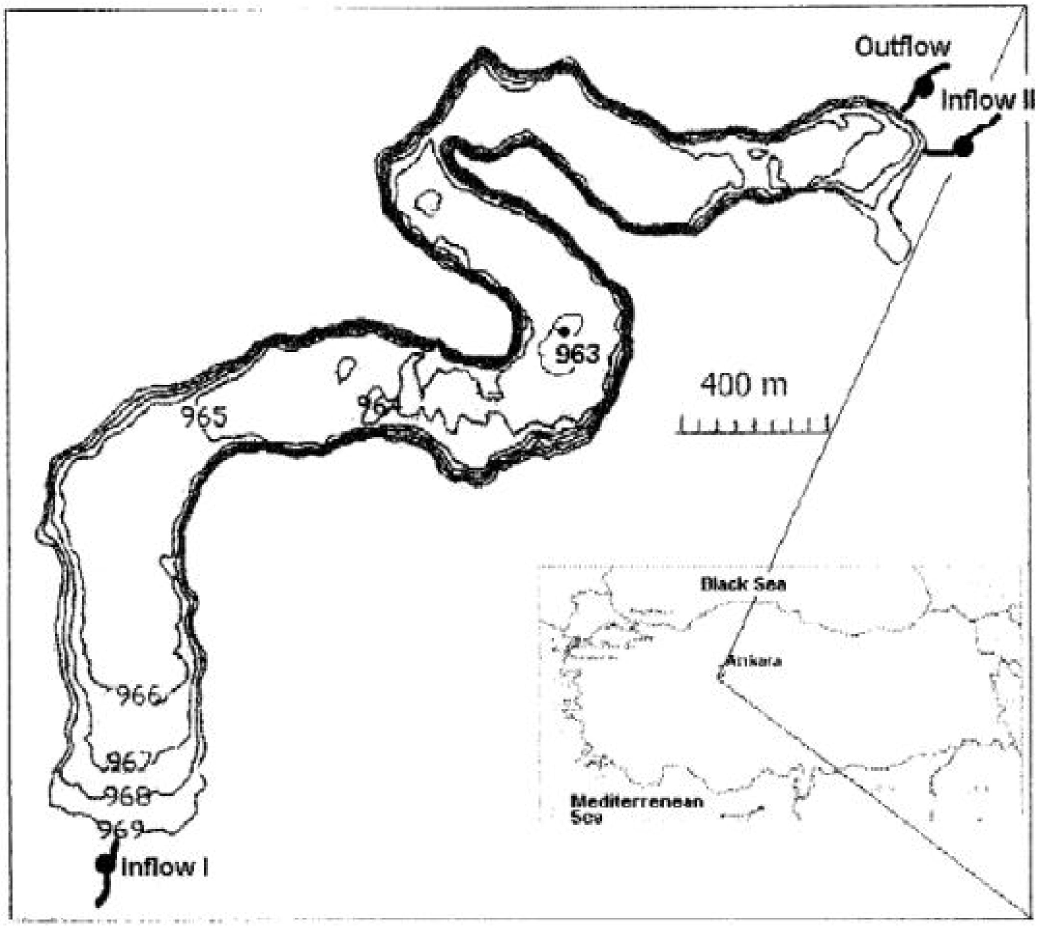


Figure 2.3: Surface Water Inputs and Outputs to Lake Eymir (Altınbilek et al., 1995)

The largest residential area that is located in the vicinity of the lake is Gölbaşı District with a population of 103,627 people in 2011 (TÜİK, 2011). TEAŞ (Turkish Electricity Transmission Corporation) settlement with an approximate population of 5000 capita and the Police Academy is in close vicinity of Lake Eymir. In addition to these settlements, there are also some small scaled industries around the lake, and a municipal solid waste disposal site is present in the area, which is currently not used (Yüzügüllü, 2011).

Geldiay (1949) characterized Lake Eymir as having clear water and with dense macrophyte beds. Secchi disc depth was greater than 4 meter at deepest point (Geldiay, 1949). However, after 1970s, the lake received raw sewage effluents that resulted in deterioration of water quality, increased total phosphorus (Total-P) concentrations and observation of low Secchi disc depth. In year 1995, a by-pass line was constructed to divert the input from the Gölbaşı Municipality sewage system to the outflow of Lake Eymir for the purpose of reducing the pollution load to the lake (Altınbilek et al., 1995; Beklioglu et al., 2003). However, since the by-pass line had not been operated continuously, the lake continued to be a receiving body until 2001. Lake Eymir has been declared as highly eutrophic by many researchers (Diker, 1992; Altınbilek, 1995; Elahdab, 2006; Beklioglu et al., 2003; Karul et al., 2000; Karakoç et al., 2003; Yenilmez et al., 2010; Yüzügüllü, 2011; Atiker, 2011; Beklioglu et al., 2010).

2.2. Sources and Sinks of Phosphorus

Oberdorfer et al. (1990) and many other researchers (Lee, 1977; Johannes, 1980; Capone and Bautista, 1985) have indicated the importance of external inputs to a lake ecosystem through groundwater. While differing from surface inputs by flow velocity and length of shoreline, groundwater sources also carry human and animal wastes, fertilizers, reactive from geologic materials and leachate containing nutrients. Point and non-point sources of precipitation, surface water runoff, soil leaching and anthropological pollutants are the main external inputs of phosphorus in lakes (Ahmet and Abdallah, 2010; Kaiserli et al., 2002). According to Douglas et al. (2006), transfer of pollutants depends on the catchment hydrological flow paths. In rural areas, agricultural diffuse sources are main problem for external phosphorus loading.

Phosphorus enters an aquatic system in its particulate or dissolved form, however mostly it is in particulate form. The dissolved part can be absorbed on particles and settle out of the water phase (Shilla et al., 2009). According to Eckert et al. (2003), settling particles in lakes are formed from allochthonous, autochthonous and re-suspended materials. Drought in the region of a lake reservoir may cause less allochthonous materials to reach the lake and as a result decrease in Ca-bound phosphorus is observed in the sediment surface. Inorganic-P is found in its soluble form as a part of a mineral or in the form of $CaO(PO_4)_3(OH)$, $FePO_4$, $AlPO_4$ and $Ca_3(PO_4)_2$ (Dong et al., 2010; Reynolds and Davies, 2001). Inorganic polyphosphates are energy rich phosphoanhydride bounds such as ATP and can be found in many living cells including one celled organisms, plants and animals. These polymers are source of energy and phosphorus (Eixler et al. 2005). Phosphorus can be stored by microorganisms when growth is limited by other elements. (Montigny and Prairie, 1993).

According to Bostrom et al. (1988), the deposition of phosphorus to sediment layer in lake ecosystems can be described by six major mechanisms.

1. Sedimentation of mineral rocks
2. Adsorption or precipitation with inorganic compounds including:
    a. Iron and Manganese
    b. Clays, amorphous oxyhydroxides
    c. Carbonates
3. Sedimentation of allochthonous organic matter
4. Sedimentation of autochthonous organic matter
5. Direct uptake from water
6. Adsorption onto particles in sediments

Phosphorus release from sediments occurs under certain chemical, physical or biological reactions. The release of phosphorus from sediment can be in following ways according to Bostrom et al. (1988):

1. Desorption
2. Dissolution of phosphorus bound precipitates
3. Exchange mechanisms (ion exchange)
4. Hydrolysis of phosphate-ester bounds
5. Release from living cells
6. Cell autolysis

It is hard to establish relationships between sediment and lake water characteristics after reducing the external load of phosphorus since there is little known about the mechanisms of internal loading in lakes. Monitoring of lake water and sediment phosphorus concentrations together with laboratory scale experiments have been used to describe the mechanism of internal release. In order to gather accurate data, a costly and precise approach of mass balance can be used (Sondergaard et al. 1999).

Sediment layer may increase the phosphorus concentrations in water column while acting like a source and this is called internal phosphorus loading. Internal loading is more important if external sources are not present (Dong and Yang, 2010; Kaiserli et al. 2002). Since the concentration of nutrients in sedimentary pore water is greatly higher than the average concentrations in water, re-suspension has a direct effect on internal loading of phosphorus (Qin et al., 2004). Although it is not easy to figure out whether if the sediment is acting as a sink or a source for phosphorus, Brzáková (2003) mentioned that the indirect indicator is in the form of a decrease in phosphorus concentrations in hypolimnion (Omlin et al. 2001) or a decrease in sestonic C:P ratio with depth (Gachter, Mares, 1985). The first assumption suggests that phosphorus decrease in hypolimnion is caused by adsorption of phosphorus on iron(III) released from sediments and the second assumption suggests that phosphorus reduction occurs by consumption of mineralized phosphorus-poor organic particles. Sediment layer acts as a sink for phosphorus when allogenic apatite minerals, organic and inorganic phosphorus complexes are accumulated and acts as a source when concentration difference between sediment phosphorus concentration and bottom water layer phosphorus concentration occur (Eckert et al., 1997). Capacity of phosphorus release or uptake is highly dependent on sediment composition as well as the oxidation/reduction potential, temperature and bioturbation (Devesa-Ray, 2009; Holdren and Armstrong, 1980). Amount of Total-P in deeper sites are found to be greater than shallow sites (Shilla et al., 2009).

The seasonal cycle of phosphorus (Figure 2.4) occurs by interaction with iron hydroxides. The high amount of phosphorus concentrations observed in the sediment could be a sign of authigenic Ca-P fraction. Authigenic minerals or in other terms the sedimentary rocks are formed during sedimentation or by precipitation but they are not transported by water currents or winds. Once these minerals are formed, they are very stable and can be classified as long term phosphorus sinks (Beusekom et al., 1999; Ruttenberg and Berner, 1993).

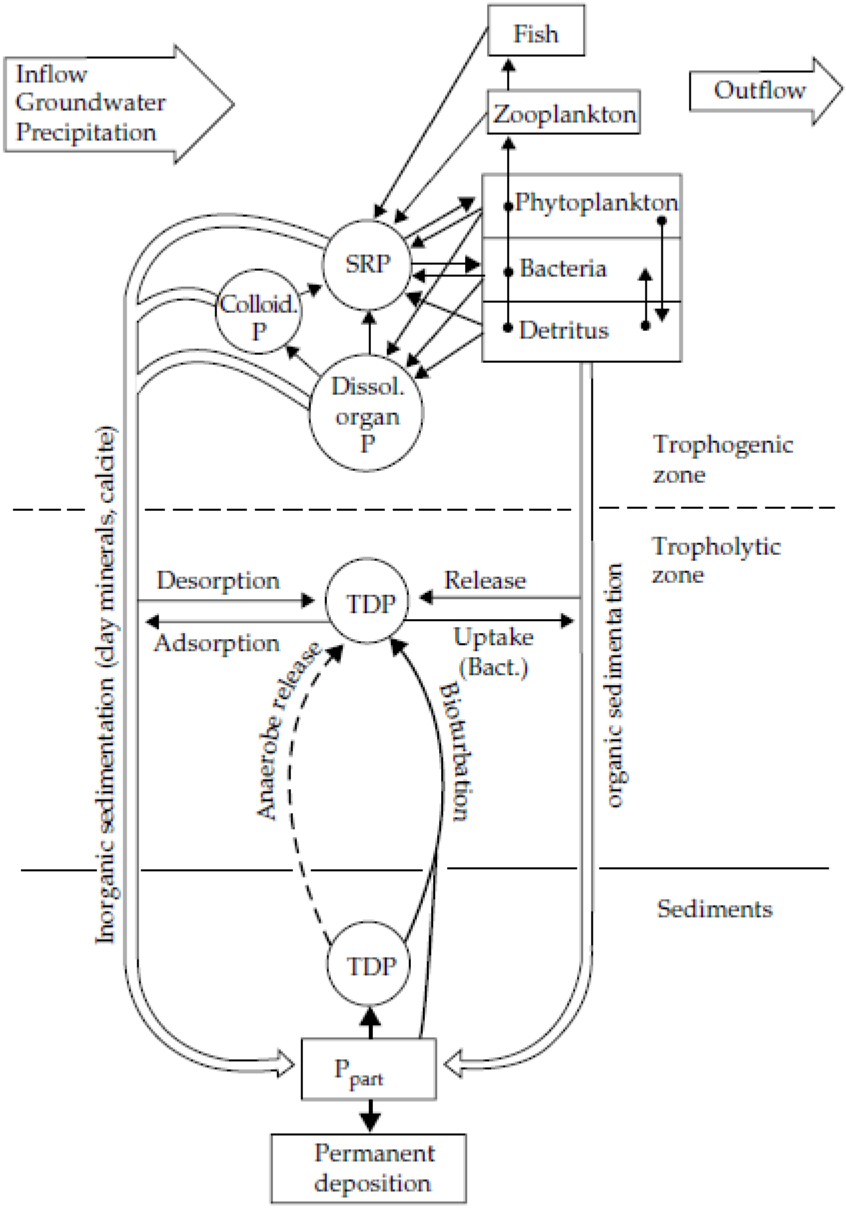


Figure 2.4: The Phosphorus Cycle in Lakes (Lampert and Sommer, 2007)

*SRP: Soluble Reactive Phosphorus
**TDP: Total Dissolved Phosphorus

2.3. Phosphorus Release Mechanisms from Sediment

The exchange of phosphorus in sediment-water interface can be explained by equilibrium phosphorus concentration. If concentration of phosphorus is greater than this equilibrium, adsorption to the sediment takes place. If phosphorus concentration is below the limit, release from sediment takes place. This means that even in a system with low phosphorus concentration, release from sediment could be observed and in a system with high phosphorus concentration, adsorption to sediment could occur (Kerr et al., 2011).

Phosphorus is known to be reacting with a wide range of surfaces and being adsorbed and released from both living (biogenic) and non-living (abiogenic) environments. The shift of release and adsorption is controlled by a mechanism mainly involving temperature and dissolved oxygen. Under reducing conditions at sediment-water interface, P- bounds are broken and phosphorus is released to pore water and then to the water overlying the sediment layer. This release is mostly observed in spring and summer with the help of increased temperature triggering the reducing environment (Serpa et al., 2007). The fraction of phosphorus which is not bioavailable but is a source for bioavailable phosphorus is released under certain conditions of temperature, pH and oxidation/reduction conditions. (Shilla et al., 2009; Fytianos and Kotzakioti, 2005). The highest rate is observed in the hottest three months in summer and reduces in fall when temperature falls down (Gomez et al., 1998). According to Jensen et al. (1992), 70% of the seasonal cycle in sediment phosphorus can be explained by temperature change.

Both physical and chemical properties of sediment are important for explaining the exchange of phosphorus at the sediment water interface (Gonsiorczyk et al., 1978). The availability and mobility of sediment phosphorus is also affected by processes involving iron and sulphide (Azzoni et al., 2005; Hejis et al., 2000). Interactions of phosphate with iron, aluminum and calcium, and the adsorptive properties of carbonates and clays are of special interest (Fytianos and Kotzakioti, 2005; Jensen et al., 1992). Einsele (1936, 1938) and Mortimer (1941, 1942) found that phosphorus is kept adsorbed to sediments by fixation to Iron(III) under oxic conditions and reduced sediments have a tendency to release phosphorus by reduction of iron complexes. The studies of Einsele (1936) and Mortimer (1941) demonstrated that phosphorus release from sediment occurs under anoxic conditions by reduction of Fe(III) while redox potential is below 200 mV and this has been used for over forty years as the only behavior of phosphorus release from sediment (Montigny and Prairie, 1993; Bostrom et al. 1988).

According to Song et al. (2006), abiotic exchange of phosphorus at the sediment water interface due to changing redox conditions are regulated by microorganism at bottom water layer (Davelaar, 1993). Microorganisms lower the redox potential by consuming oxygen and consume organic phosphorus for polyphosphates (Kelton et al., 2004; Mitchell et al., 1998). As a result, release of phosphorus from sediment Fe(III) complexes become easier. When Fe(III) is reduced to Fe(II), both Fe(II) and adsorbed phosphorus release to the water column and Fe(III) reducing bacteria catalyzes this process (Dong et al., 2010; Hupfer and Lewandowski, 2008). If sediment surface layers are oxidized, Fe^{+2} is re-oxidized to form a micro layer with a high sorption capacity for phosphorus in the sediment water interface (Eckert et al. 1997). Reduced Fe^{+2} can precipitate back as FeOOH under aerobic conditions (Özkan and Kocataş, 2008). Phosphorus release from sediments can also take place under oxic conditions. Phosphorus that is not bound to Fe and Al, or incorporated to living organisms, may be diffused to bottom water through mineralization or reduction (Lukkari et al., 2009; Boström et al. 1982).

The mechanism proposed by Mortimer (1941) and Einsele (1936) on internal phosphorus recycling mechanism of lakes in which phosphorus is released from Fe(III) under reducing conditions in hypolimnion is found to be inadequate to explain phosphorus release since several studies showed that presence of anoxic conditions in hypolimnion does not favor phosphorus release from sediment. Montigny and Praire (1993) proposed that due to changing redox environment, content of dead bacteria releasing to water can be the source of phosphorus in hypolimnion (Amirbahman et al., 2003). According to Golterman (2001), the proposal of Mortimer (1941, 1942) cannot be used as a general mechanism. The ratio of Fe/P does not have any effect on the amount of phosphorus released from sediment and a constant relationship between Fe and P could not be found.

Until 1980's, abiotic processes held responsible from the cycle of phosphorus at the sediment water interface. After the discovery of microorganisms that can participate in release or uptake of phosphorus, this view has changed (Eckert et al., 1997). The bioavailability of phosphorus depends on phosphorus speciation. Geochemical reactions with calcium, carbonates, iron, aluminum and humic compounds determine the phosphorus speciation (Azzoni et al., 2005; Golterman, 1995; Jensen et al. 1998). Among soluble phosphorus fractions, only orthophosphate (PO_4^{-3}) is the bioavailable form and orthophosphate forms insoluble compounds with Fe^{+3} and Ca^{+3} under aerobic conditions (Gikuma-Njuru et al., 2010).

The role of microorganisms in phosphorus cycle is they can release or take up phosphorus in aerobic or anoxic conditions (Clavero et al., 1999; Fleischer, 1983) and store phosphorus when excess is available (Clavero et al. 1999). If sufficient light is available to micro-algae, they can grow with ease and store the internal phosphorus released due to anoxic conditions in their cells, while inhibiting the re-suspension of sediment. If light is not available, heterotrophs start to dominate biofilms and increase the rate at which phosphorus is released from sediment under redox sensitive conditions and absorb pore water phosphorus (Spears et al., 2007). Dissolved phosphate (PO_4-P) is consumed in aquatic systems while phytoplanktons are growing and regenerated back into the system with bacterial decomposition (Sundby et al., 1992). Clavero et al. (1999) found that flux of theoretical and measured phosphates were higher in the absence of microbiological activity. Their mass balance showed that while bacterial activity is present, phosphorus is accumulated in the sediment layer and without bacterial activity, phosphorus concentrations in sediment layer decreased.

Stratification in summer limits the availability of phosphorus to surface microorganisms. Many lake waters mix in fall with turnovers and phosphorus accumulated in summer becomes available to microorganisms (Caraco et al., 1993; Schindler et al., 1980). After the turnover, phosphorus in oxygen rich waters precipitates by bonding to iron oxides (Caraco et al., 1993; Lean et al., 1986). Supply of Fe determines the mobility of phosphorus in water since sorption capacity is related to Fe (Heidenreich and Kleeberg, 2003). Profundal sediment water interfaces of stratified lakes show high concentration gradients for dissolved components (Gonsiorczyk et al., 1997). According to Golosov and Ignatieva (1999), the sharp increase in nutrient concentrations after summer stagnation cannot be explained by molecular diffusion since it is a very slow process. In shallow lakes with an upper limit of 10-15 m depth, during autumn cooling, upper sediment layer is warmer than the bottom water layer. This temperature difference creates viscous density convection in which nutrients release to water by thermal macro volumes with positive buoyancy and the effectiveness of the transfer is several orders higher than the molecular diffusion. In general, the internal phosphorus release can occur in two different mechanisms in shallow ecosystems. The first one is the release of phosphorus from sediment-water interface under anoxic conditions or diffusion. The second one is the advection as a result of fluctuating water table, sediment re-suspension or bioturbation (Bhadha et al., 2010).

Following summer stagnation, high correlations between soluble reactive phosphorus and NH_4 in hypolimnion are signs of phosphorus release through mineralization of organic matter (Gonsiorczyk et al., 1997). To oxidize surface sediments, both O_2 and NO_3^- can be used by microorganisms, since both substances can be used as electron acceptors. NO_3^- is a better oxidizer since it can penetrate deeper into the sediment layer. However, NO_3^- also stimulates mineralization in the absence of nitrogen and may increase phosphorus release from sediment (Hansen et al. 2003). Since in anaerobic mineralization of organics by bacteria, a larger part of the organic must be fermented in order to acquire the same amount of energy of aerobic mineralization, anaerobic mineralization may enhance release of phosphorus from sediment layer

(Lehtoranta and Heiskanen, 2003; Golterman, 2001). Also, nitrate concentrations could reduce phosphorus release in winter and early summer while, it increases it in late summer (Dong et al., 2010). Oxygen and nitrogen are thermodynamically the most favorable electron acceptors in organic matter decomposition (Hensen et al., 2006).

High concentrations of SO_4 might produce high amounts of S(-II) in summer under anoxic conditions and reduce Fe(III) hydroxide. This reduction releases phosphorus bound to iron molecules and also precipitates Fe(II) as FeS (Amirbahman et al., 2003; Cook 1984). Caraco et al. (1993) showed that Fe:P ratios in bottom waters of lakes are greatly related to sulfate concentration in surface. Sulfate is precipitated as FeS by bonding to Fe(II). Lack of Fe(II) prevents the reduction of Fe to Fe(III) and indirectly prevents phosphorus from precipitation in aerobic conditions. The second effect of sulfate presence is sulfate reduction can interact with particles of Fe(III) and increases Fe(II). As a result, high sulfate concentrations have double effect on phosphorus release by increasing the phosphorus release from sediments and by preventing the precipitation of phosphorus in surface waters.

Particle size is an important factor affecting phosphorus exchange on the sediment water interface. Rate of phosphorus adsorption correlates positively with the percentage of fine particles less than 63 µm diameter in sediment (An and Li, 2009; Wang et al., 2005). Less than 2 mm diameter particle size fraction of sediment layer can have importance in phosphorus retention formed by Fe and Mn oxides as well as organic matter. The concentration of phosphorus in <63 µm diameter is much more than the concentration in <2 mm diameter particles (Devesa-Ray, 2009).

Phosphorus cycle in calcareous lakes is different than non-calcareous lakes and iron plays a less important role in exchange reactions. $CaCO_3$ precipitation is favored by high temperature and high pH. Otsuki and Wetzel (1972) discovered that precipitation of phosphorus with carbonate is enhanced by increasing the temperature and increasing pH (within the interval of 8-10). In shallow calcareous lakes, if pH is high, phosphorus is released from Fe(OOH)-P by ion exchange and precipitates with Ca^{+2} in water. If the pH decreases, released phosphorus precipitates back as Fe(OOH)-P (Dong et al., 2010; Golterman, 2004). Increasing pH shifts the equilibrium for phosphorus desorption by substituting phosphorus for OH^-. In calcareous waters, releasing phosphorus can precipitate back as hydroxyl appetite or $CaCO_3$. Differing from non-calcareous lakes, phosphorus precipitation may be observed at higher pH levels. The only possible way of releasing carbonate bound phosphorus is to lower the pH (Eckert et al., 1997). Moreover, Navratil et al. (2009) found that phosphorus is strongly adsorbed to $Al(OH)_3$ and could only be released after substantial dissolution of sediment below pH 3.67 (Navratil et al., 2009).

Sediment water interactions are greater in shallow lakes than deeper lakes and can be easily disturbed by winds (Zhu et al. 2006). Sun et al. (2006) studied the effect of wind induced sediment re-suspension on phosphorus release. They found that Total-P concentrations in Lake Taihu and Lake Chaohu increased by 6 and 3 times, respectively, while dissolved Total-P was increased by 100% and 70%, respectively. Fan et al. (2004) found that soluble reactive phosphorus in surface sediments is 2 to 30 times greater after disturbance by waves in different lakes in China. Under low and moderate wind speed, re-suspension of sediment was low to lead to a significant increase in phosphorus release. However under high wind speed, silt and fine sands and even coarse sands were disturbed and contributed to re-suspension. As a result phosphorus exchange between suspended particles and water increased significantly.

2.4. Phosphorus Fractionation

Not all phosphorus fractions are released under certain conditions (An and Li, 2009; Wang et al., 2005). Therefore, Total-P concentration in sediments cannot be used to evaluate the amount of phosphorus as a pollutant since not all of phosphorus content is bioavailable or requires specific conditions for release as a phosphorus source (Ahmet and Abdallah, 2010; Knapp et al., 2002). Fraction of the phosphorus that can be considered as a source of pollutant can be evaluated by fractionation of phosphorus into different forms (Shilla et al., 2009). The cycle of phosphorus and practical control of eutrophication in lakes can only be understandable if composition and distribution of phosphorus forms are known (Jun et al., 2006). The top 10 cm of the sediment layer is enough to represent the phosphorus load of many years of external loading (Gran, 1999).

Sequential extraction of phosphorus is a very useful tool for characterizing various phosphorus forms (Shilla et al., 2009; Psenner et al., 1984; Zhou et al. 2001). Phosphorus reserves in sediment layers can be divided into different forms according to their solubility and reactivity (Lukkari et al., 2008). Study of phosphorus fractions in sediment layer is a tool for identifying the potential release since Fe bound phosphorus is usually bioavailable while calcium bound phosphorus is not (Dong et al., 2010)

Determining each phosphorus bound fraction of a sediment layer can be helpful for determining which fraction is involved in an exchange process (Garcia and Iorio, 2003; Psenner et al., 1984). Currently there is not any accepted standard method for sediment phosphorus analysis and some common techniques based on sequential extraction with some critical steps are being used (Azzoni et al., 2005; De Groot and Golterman, 1990). Sequential extractions of phosphorus schemes suggested by many researchers (Williams et al, 1971; Hieltjes and Lijklema, 1980; Golterman 1982; Psenner et al. 1984; Ruttenberg, 1992) are useful tools for phosphorus characterization. An example extraction scheme conducted by Hupfer et al. (1995) is given below in Table 2.2.

Table 2.2: Sequential Extraction Scheme by Hupfer et al. (1995)

Extractant	Time		Expected P-forms
1. NH_4Cl (1M)	0.5 h	SRP / NRP	P in the interstitial water loosely adsorbed to surface (e.g. surfaces of Fe and CaCO3), immediately available P
2. BD (0.11 M bicarbonate/dithionite	1 h	SRP	Redox-sensitive P mainly bound to Fe-hydroxides and Mn-compounds
		NRP	Organic-C
3. NaOH (1 M)	16 h	SRP	P bound to metal oxides mainly of Al and Fe, which is exchangeable against OH- ions; inorganic P compounds soluble in bases
		NRP	P in microorganisms including poly-P, organic P in detritus, P bound in humic compounds
4. HCl (0.5 M)	16 h	SRP	P bound to carbonates and apatite-P, traces of hydrolyzed organic P
		NRP	Organic P
5. Residual-P		Total-P	Organic and other refractory P

The immediately available portion NH_4Cl-P is the loosely bound phosphorus to the surface of Fe and $CaCO_3$ and soluble reactive phosphorus in interstitial water and phosphorus from decaying cells of microorganisms (Jun et al., 2008). The determination of mobile phosphorus in surface sediments is important for predicting the future internal loading and transport of phosphorus downstream (Rydin, 1999). Hieltjes et al. (1980) investigated different extraction procedures and found out that NH_4Cl extraction is a necessary step for a successful discrimination between Fe-P, Al-P and Ca-P. According to Dorich et al. (1985) and Zhou et al. (2001), NaOH fraction of the sediment phosphorus can be used for estimation of both short and long term available phosphorus and is a measure of available phosphorus to algae. NaOH-P is bound to metal oxides and exchangeable against OH^- ion and inorganic phosphorus compounds soluble in bases. This kind of phosphorus is only released in high pH due to OH^- substitution. HCl-P is the portion bound to carbonates, apatite phosphorus and hydrolyzed organic phosphorus. This portion is known as the permanent burial of phosphorus in sediments (Jun et al. 2008). Since organic phosphorus is a complex fraction, the nature of it is not precisely known (Perrone et al., 2008).

Pettersson (1986) investigated the sedimentary phosphorus in fractional components. The results of these experiments are given below in Table 2.3 and characteristics of the lakes in which the samples were taken are as follows. Lake Vallentunasjön is a lake loaded with sewage and has a low phosphorus retention capacity. Lake Bergundasjön is rich in iron and humic materials and has a high phosphorus retention capacity. Lake Erken is an unpolluted meso-trophic lake and Lae Hastevatten is an acidified oligotrophic lake. It is clear that if lake environment is not polluted, residual phosphorus percentage in sediment increases. In iron rich lake, amount of NaOH-P bound is much greater than other lakes and this is a sign of precipitation of phosphorus with iron. Unpolluted meso-trophic Lake Erken is dominated by calcium bound phosphorus precipitates.

Table 2.3: Phosphorus Fractions Reported for Different Lakes (Pettersson, 1986)

Lake	NH_4Cl-P	NaOH-P	HCl-P	Res.-P	Tot-P
	(---------------------------	% of total P	---------------------------	)	(mg g^{-1} dw)
L. Vallentunasjön	7.6	14.2	17.4	60.8	1.81
L. S. Bergundasjön	3.9	61.9	10.9	23.4	6.49
L. Erken	1.2	11.1	37.5	50.2	1.23
L. St. Hastevatten	1.1	6.3	2.0	90.6	0.95

CHAPTER 3

METHODOLOGY

The aim of this study is to determine the relations between phosphorus concentrations of water with respect to other water quality parameters in Lake Eymir. The state of the lake and progress through a 21 months interval has been observed in order to study the key factors effecting the phosphorus concentrations. The studies began in June 2009, and ended in March 2011 which included both the field measurements and the laboratory experiments. The field study aimed to monitor the phosphorus concentrations throughout the years and the sediment experiments aimed further investigation of the phosphorus sources and equilibrium constants for phosphorus release. Although sediment experiments are conducted once, water quality analysis and readily available phosphate determination in sediment are conducted on a routine explained in Section 3.1. The field study is funded by TUBİTAK project 108Y116, "Determination of nitrogen compounds in different phases produced by microbiological activity, their fluxes among reservoirs in an eutrophied lake." Field works were employed by the help of co-workers Onur YÜZÜGÜLLÜ, Selen ATİKER and Ezgi ÖĞÜN. The procedure followed through the study is summarized below in Figure 3.1 and details are given in the flowing sub sections.

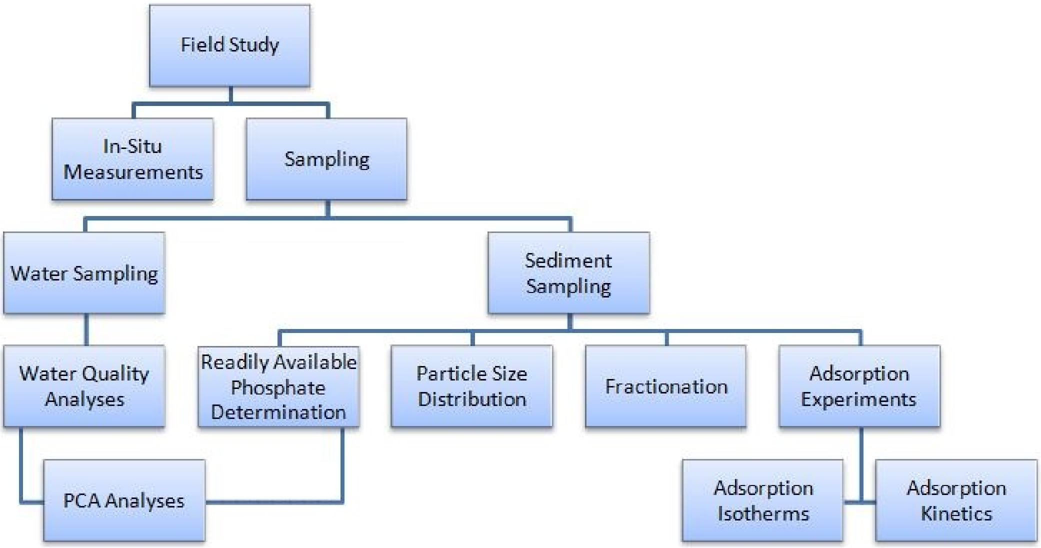


Figure 3.1: Summary of the Methodology

3.1. Field Study

The time interval for sampling collection was two weeks. On some very rare occasions, the interval was increased to a month due to freezing of water or malfunctions in field equipment. The initial scope of the field study was to collect samples from four different sampling locations. Following November-2009, the number of sampling locations was increased to five (Sampling point 4 is the additional location) to have a better and even distribution and to better analyze the change in water quality parameter concentrations with respect to water depth. The sampling locations were determined in order to match the previous studies (i.e. Elahdab, 1996). These are shown in Figure 3.2 and the coordinates of the sampling points are given in Table 3.1. The first sampling location is close to the inlet. There is a groundwater flow from Lake Mogan to Lake Eymir in the vicinity of this location. Sampling location 5 is close to the outlet.

Figure 3.2: Sampling Locations in Lake Eymir

Table 3.1: Coordinates of the Sampling Points

Sampling Location	North	East
1	32°49’12”	32°49’10”
2	39°49’30”	32°49’33”
3	39°49’46”	32°49’47”
4	39°49’53”	32°50’00”
5	39°49’51”	32°50’25”

The field work is consisted of collection of samples for laboratory analysis and in-situ measurements. Following sampling, samples were brought to the laboratory for analysis.

3.1.1. In-Situ Measurements

The following parameters were monitored in situ using relevant method and equipment:

- Temperature
- pH
- Conductivity
- Dissolved oxygen (DO)
- Turbidity
- Photosynthetically active radiation (PAR)
- Secchi disk depth
- Water depth

The temperature (°C), pH, conductivity (μs/cm), DO (mg/L) and turbidity (NTU) were measured using a YSI 6600 EDS multi-parameter sonde (Figure 3.3). The sonde consists of two parts called the probe and the keypad. Sonde is the part doing reading and keypad is used to display instantaneous data. The sonde can collect data with respect to depth so as to plot parameters versus depth graphics.

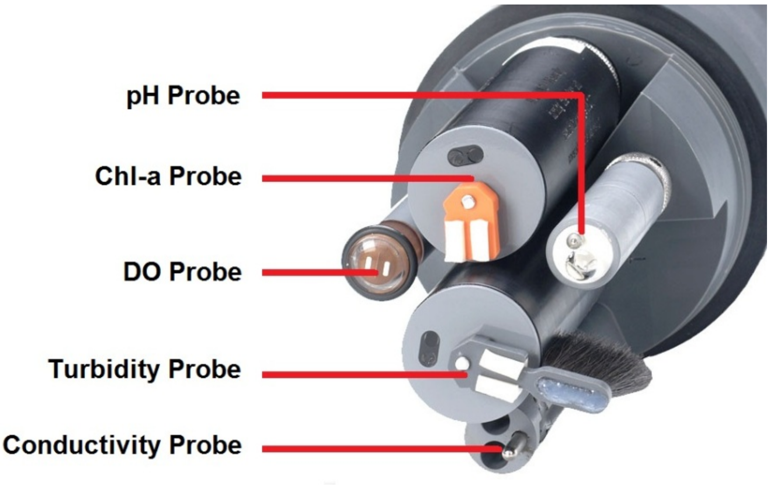


Figure 3.3: YSI 6600 EDS Probe

For each parameter, the sonde probe is calibrated by calibration standards before usage. Usually three point calibration curve is applied. Temperature is calibrated using a water bath and a thermometer at three different temperatures. pH is calibrated using pH 4-7-10 Hach Lange calibration standards. For turbidity calibration, hydrazine sulfate and hexamethylenetetramine solution at 100 and 250 NTU and a blank (pure water) is used. DO probe is calibrated with saturated water pressure at a known height (from sea level) right before using. Conductivity is calibrated using a calibration solution at 25 °C. The depth is perceived by the water pressure so calibration of the depth sensor is done in air before submerging into water.

PAR is measured using a LI-COR LI-193SA underwater PAR sensor (Figure 3.4). A special bulb measures photon flux from all directions which is referred as photosynthetic photon flux fluence rate or quantum scalar irradiance. Data is collected at every 25 cm of water depth and normalized with respect to pre-submerged PAR data since PAR data is heavily dependent on weather conditions. The Lambert-Beer law is used to determine the light effect (Atiker, 2011).

Figure 3.4: PAR Sensor Equipment (Atiker, 2011)

Secchi depth is measured using a Wildco Limnological Secchi Disk of 20 cm diameter (Figure 3.5). Black and white disc is submerged into water until the color differences between black and white parts are not distinguishable. Secchi depth is usually a reference for turbidity in water bodies and measures the length of light particles in water. Secchi disk is also used for measuring water depth. The principle of determining the Secchi disk depth is illustrated in Figure 3.6.

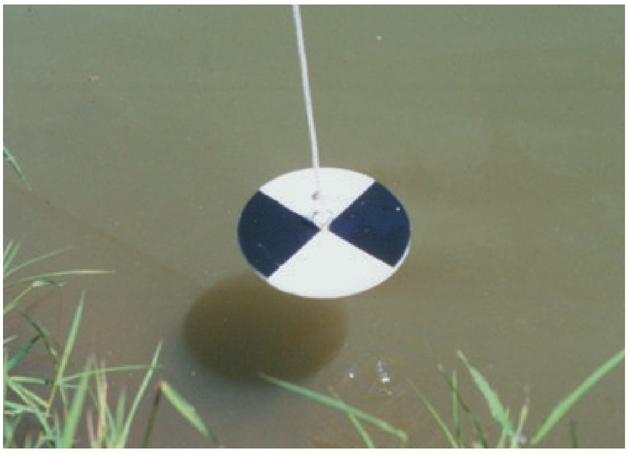


Figure 3.5: Secchi Disk

Figure 3.6: Secchi Depth Reading

3.1.2. Sampling

3.1.2.1. Water Sampling

From each sampling location, three samples from various depths were collected. First sample was taken at a depth of 25 cm below the water surface, the second was from 25 cm above the lake bottom and third one was at the mid-depth. From now on, these samples will be referred as “surface sample”, “bottom sample” and “mid-depth sample”, respectively. The bottom samples were collected with case so as not to interfere with the sediment layer.

The importance of collecting samples from at least three different depths is to observe the changes in water quality parameters in case of stratification (MacIntyre and Cullen 1995). Opaque sampling bottles were used to transport the samples without exposure to sun beams. Also bottles were carried in a cooler to prevent heating from various sources and to have additional light protection. Samples were collected using a Van-Dorn sampler. The model used for sampling is a Wildco Alpha Horizontal Acrylic 2,2 L Water Sampler (Figure 3.7). Sampler descends in water to the bottom while the seals on each end are attached to a trigger on the sampler. A heavy object called the “messenger” is released after the target depth is reached and triggers the mechanism which traps the water inside.

Figure 3.7: Horizontal Van-Dorn Sampler

3.1.2.2. Sediment Sampling

Sediment samples were also collected for analysis. A standard Wildco Ekman Grab (Figure 3.8) was used for collecting samples. The working principle of the grab sampler is same as the water sampler. The only difference is the grab sampler has a jaw closure system. After the sampler submerges into sediment layer, a messenger is sent to trap sediment inside.

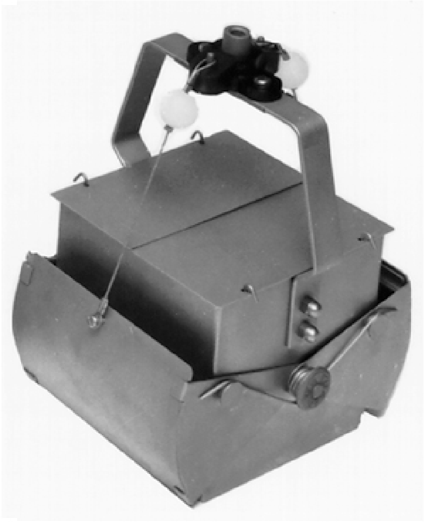


Figure 3.8: Ekman Grab Sampler

3.2. Laboratory Analysis of Samples

Collected samples were analyzed in laboratory for various parameters. These were:

- Total-P
- PO_4-P
- Sediment Soluble Total-P (S-STP)
- Sediment Soluble PO_4-P (S-SP)
- Chlorophyll-a (Chl-a)
- Total Suspended Solids (TSS)
- Total Kjeldahl Nitrogen (TKN)
- Ammonia (NH_4-N)
- Nitrite (NO_2-N)
- Nitrate (NO_3-N)
- Alkalinity

All water sample analysis were carried out using Standard Methods, unless otherwise specified. Sartorius Basic (BA210S) was used for weighing of samples and Hach Lange DR2400 spectrophotometer was used for spectrophotometric readings.

3.2.1. Water Quality Analysis

Total-P analysis was made by using Standard Methods 4500-P. Persulfate Digestion Method 4500-P.B.5 was used for digestion and Ascorbic Acid Method 4500-P.E was used for colorimetric reading. PO_4-P (phosphate) analysis is made by using Standard Methods 4500-P. Ascorbic Acid Method 4500-P.E was used for colorimetric reading. ISO 10260, Standard Ethanol Extraction Method was used for determination of Chl-a concentrations in sample waters (Yüzügüllü, 2011). TSS were determined by the Standard Methods 2540-D. Standard Methods 4500-N_{org}-B Macro-Kjeldahl Method was used for the determination of TKN. NH_3-N was measured by using Hach Lange DR/2400 Nessler Method (Method 8038), which was adopted from Standard Methods 4500- NH_3 B&C.

NO_3-N and NO_2-N were measured by using Hach Lange DR/2400 Cadmium Reduction Method (Method 8171) and Hach Lange DR/2400 Diazotization Method (Method 8507), respectively. Standard Method 2320-B Titration was used for the determination of alkalinity.

3.2.2. Sediment Analysis

3.2.2.1. Sediment Soluble Total Phosphorus and PO_4-P Determination

Water soluble Total-P and PO_4-P were measured in lake sediments. Measurements of Total-P and PO_4-P follow similar procedures as for analysis in water samples, once Total-P and PO_4-P are released into water. TS-EN Determination of Phosphorus in Soil Samples (TS 8340, 1990) method was used to extract phosphorus into water. Steps of extraction method are as follows:

- Sediment is dried at 105°C
- After cooling, dried sample is milled
- 10 gr dry sample is poured into 100 ml beaker
- Samples are mixed for 16 hours by using an orbital shaker
- Samples are centrifuged at 3500 RPM for 10 minutes
- Clear part is filtered at 0.45 µm-pore-diameter membrane filter
- Phosphorus in filtered samples is measured using Standard Methods for Total-P and PO_4-P determination.

3.2.2.2. Particle Size Distribution Analysis

Since fractionation of phosphorus concentrations is studied at a certain particle size, size distribution of the particles forming the sediment layer has been investigated by Sieve Analysis. Steps of measurement are as follows:

- Sediment samples are freeze-thawed
- Dewatered samples are milled gently without disturbing the particle properties (size)
- Samples are sieved through different pore size sieves
- Particles are classified according to ISO 14688-1:2002
- Distribution graphs are plotted

Table 3.2 shows the particle diameter ranges for classification of sediment particles. It is known that highest concentrations of pollutants are contained at silt and clay particles. (Fytianos, Kotzakioti, 2005). Pore diameters of the sieves were selected in order to collect particles less than 63 µm diameter. Table 3.3 summarizes the sieve range used in the experiment.

Table 3.2: Soil Classification

Classification			Size Range
Very Coarse Soil		Large Boulder (LBo)	> 630 mm
		Boulder (Bo)	> 200 – 630 mm
		Cobble (Co)	> 63 – 200 mm
Coarse Soil	Gravel	Coarse Gravel (CMr)	> 20 – 63 mm
		Medium Gravel (MGr)	> 6,3 – 20 mm
		Fine Gravel (FGr)	> 2 – 6,3 mm
	Sand	Coarse Sand (CSa)	> 0,63 – 2 mm
		Medium Sand (MSa)	> 0,2 – 0,63 mm
		Fine Sand (FSa)	> 0,063 – 0,2 mm
Fine Soil	Silt	Coarse Silt (CSi)	> 0,02 – 0,063 mm
		Medium Silt (MSi)	> 0,0063 – 0,02 mm
		Fine Silt (FSi)	> 0,002 – 0,0063
	Clay (Cl)		≤ 0,002 mm

Table 3.3: Sieve Pore Sizes Used in the Experiment and Corresponding Particle Classifications

Sieve Size (µm)	Classification
>1180	Coarse Sand
850 – 1180	Coarse Sand
710 – 850	Coarse Sand
500 – 710	Medium Sand + Coarse Sand
425 – 500	Medium Sand
355 – 425	Medium Sand
300 – 355	Medium Sand
175 – 300	Fine Sand + Medium Sand
150 – 175	Fine Sand
100 – 150	Fine Sand
75 – 100	Fine Sand
63 – 75	Fine Sand
38 – 63	Coarse Silt
<38	Clay + Fine Silt + Medium Silt

3.3. Fractionation of Sediment Phosphorus

Fractionation experiments were carried out using a modified extraction procedure proposed by Psenner et. al. (1984) with some modifications (Hupfer et al., 1995). Freeze-thaw is used to de-water the sediment samples. The advantage of freeze-thawing over heat drying is soil particles do not stick to each other, so those particles do not disintegrate. Sieving was applied after drying in order to collect particles with less than 63 µm diameter. Fractionation procedure was applied to particles with less than 63 µm diameter at room temperature. 1 gr sample was used for each sampling location. A brief explanation of the five stage sequential-extraction procedure is shown in Figure 3.9. Phosphorus determination was done using Standard Methods for Total-P and PO_4-P as mentioned in the previous part.

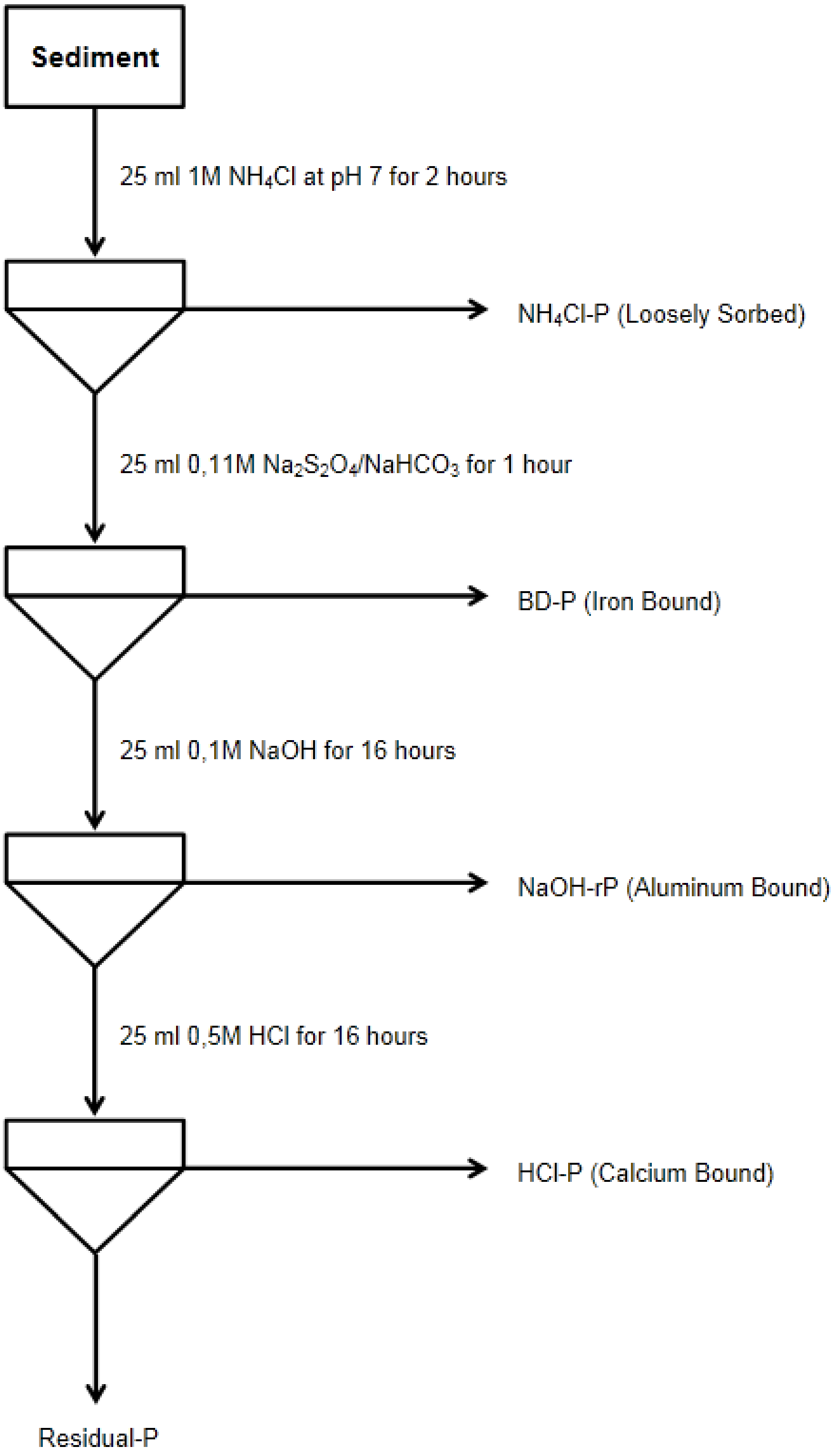


Figure 3.9: Sequential Extraction of Phosphorus

3.3.1. NH_4Cl Extraction

The first fraction is the hydrolyzed form of phosphorus which can be assumed as readily available phosphorus. The extraction and measurement procedure is as follows:

- 25 ml 1M NH_4Cl is added to 1 gr sample and mixed thoroughly for 2 hours at pH 7.
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is separated
- Residue is washed with 25 ml 1M NH_4Cl
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is added to the previous sample
- Residue (sediment) is taken for BD-Extraction
- The aliquot is filtered through 0,45 µm-pore-diameter membrane filter

For Total-P determination

- 20 ml of the filtered aliquot is taken
- Standard Method is applied for Total-P measurement

For PO_4-P determination

- 20 ml of the filtered aliquot is taken
- Standard Method is applied for PO_4-P measurement

3.3.2. Buffered Dithionite (BD) Extraction

After measuring the readily available phosphorus, iron bound phosphorus is measured. The main form of phosphorus bound is assumed to be iron hydroxide surfaces. The extraction and measurement procedure is as follows:

- 25 ml 0,11M $Na_2S_2O_4/NaHCO_3$ mixed reagent is added to the residual sediment and mixed thoroughly for 1 hour
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is separated
- Residue is washed with 25 ml 0,11M $Na_2S_2O_4/NaHCO_3$
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is added to the previous sample
- Residue (sediment) is taken for NaOH-Extraction
- The aliquot is filtered through 0,45 µm-pore-diameter membrane filter

For Total-P determination

- 5 ml of the filtered aliquot is taken
- Standard Method is applied for Total-P measurement

For PO_4-P determination

- 10 ml of the filtered aliquot is taken
- 2ml 0,025M EDTA is added
- Air is passed through the sample for 1 hour by using a pump
- Standard Method is applied for PO_4-P measurement

3.3.3. NaOH Extraction

The third part of the sequential extraction is for measuring phosphate adsorbed to metal oxides (mainly Al_2O_3) and any other exchangeable with OH ion. The extraction and measurement procedure is as follows:

- 25 ml 0,1M NaOH mixed reagent is added to the residual sediment and mixed thoroughly for 16 hours
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is separated
- Residue is washed with 25 ml 0,1M NaOH
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is added to the previous sample
- Residue (sediment) is taken for HCl-Extraction
- The aliquot is filtered through 0,45 µm-pore-diameter membrane filter

For Total-P determination

- 5 ml of the filtered aliquot is taken
- Standard Method is applied for Total-P measurement

For PO_4-P determination

- 5 ml of the filtered aliquot is taken
- 2ml 0,025M EDTA is added
- Standard Method is applied for PO_4-P measurement

3.3.4. HCl Extraction

For determining phosphorus particles bound to carbonates, HCl extraction is applied. The extraction and measurement procedure is as follows:

- 25 ml 0,5M HCl mixed reagent is added to the residual sediment and mixed thoroughly for 16 hours
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is separated
- Residue is washed with 25 ml
- Sample is centrifuged at 3000 RPM for 10 minutes
- Clear part is added to the previous sample
- Residue (sediment) is taken for Residual-P determination
- The aliquot is filtered through 0,45 µm-pore-diameter membrane filter

For Total-P determination

- 10 ml of the filtered aliquot is taken
- Standard Method is applied for Total-P measurement

For PO_4-P determination

- 10 ml of the filtered aliquot is taken
- Standard Method is applied for PO_4-P measurement

3.3.5. Residual-P Determination

The remaining phosphorus concentration is determined by using Walkley-Black Method. Remaining concentration was calculated by taking the difference of measured concentrations in previous extraction steps from the Total-P concentration of 1 gr dry sediment sample. The extraction and measurement procedure is as follows:

- 1 gr dry sample is taken
- 10 ml 1N $K_2Cr_2O_7$ is added
- 20 ml H_2SO_4 is added
- The solution is let stand for 30 minutes
- Solution is diluted to 200 ml with a graduated flask

For Total-P determination

- 10 ml of the solution is taken
- 1 ml 11N H_2SO_4 solution is added
- 0,4 gr Ammonium Persulfate $(NH_4)_2S_2O_8$ is added
- Samples are digested at 98 to 137 kPa for 30 min in an autoclave
- Aliquot is diluted to 100 ml using a volumetric flask
- 8 ml mixed reagent is added to 50 ml sample
- Absorbance is measured at 880 nm in 10 to 30 minutes

For PO_4-P determination

- Not applicable due to digestion with $K_2Cr_2O_7$ and H_2SO_4

3.3.6. Calibration for Fractionation Experiments

For calibration and control sample (blank) preparation, following procedure was used. All calibration standards were exposed to the same conditions as the extraction and measurement method. First, stock solutions of 1 mg/L, 0.8 mg/L, 0.6 mg/L, 0.5 mg/L, 0.4 mg/L, 0.2 mg/L, 0.1 mg/L, 0.05 mg/L and 0.0025 mg/L are prepared. If 10 ml of sample is used in fractionation experiment for phosphorus determination, 10 ml from each of these stock solutions are taken and same amount of chemicals used in fractionation step is added to these solutions. Since final volume is 100 ml for samples used in fractionation, stock solutions are also diluted to 100 ml before measuring.

For example, while preparing the calibration curve for “Part 2: Buffered Dithionite (BD) Extraction”, following steps were applied:

- Calibration standards at 1 mg/L, 0.8 mg/L, 0.6 mg/L, 0.5 mg/L, 0.4 mg/L, 0.2 mg/L, 0.1 mg/L, 0.05 mg/L are prepared
- Since 5 ml and 10 ml sample is used for measuring in the extraction method, 5 and 10 ml calibration standards of each concentration is taken into a conical flask (2 duplicates of each one)
- Blanks with 5 and 10 ml ultra-pure water are prepared
- 5 ml 0,11M $Na_2S_2O_4/NaHCO_3$ mixed reagent is added to solutions and blanks

For Total-P determination calibration curve

- Samples containing 5 ml calibration standard are taken
- Standard Method is applied for Total-P measurement

For PO_4-P determination calibration curve

- Samples containing 10 ml calibration standard are taken
- 2ml 0,025M EDTA is added
- Standard Method is applied for PO_4-P measurement

The theory behind following the exact extraction procedure steps for blank and calibration preparation is to expose calibration curve to all errors that may come from the solutions used in the experiment. Also by applying this procedure, further dilution of the calibration standards is avoided since it is applied in this step.

Preparation of calibration curves are summarized in Table 3.4. All experiments are carried out with at least 2 duplicates. Values shown in calibration results are average for the related part. Experimental results for calibration data are given in Appendix A while calibration curves are given in Figure 3.10 and Figure 3.11. Since the amount of stock solution used is different for each step, 5 ml and 10 ml sample results are multiplied by 4 and 2 before drawing the curves in order to overcome the dilution effect. Multiplication factor is added in order to see how the data prepared for different steps match each other and to see if adding chemicals in samples cause any interference. Non-multiplied fitting equations of the calibration data is given in Appendix A.

Table 3.4: Additions to Calibration Standards

Extraction Step	**Experiment**	**Sample Amount Used in the Experiment**	**Stock Solution Used in Calibration**	**1M NH_4Cl**	**0,11M $Na_2S_2O_4/NaHCO_3$**	**0,025M EDTA**	**0,1M NaOH**	**0,5M HCl**
Part 1	Total-P	20 ml	20 ml	5 ml	-	-	-	-
	PO_4-P	20 ml	20 ml	5 ml	-	-	-	-
Part 2	Total-P	5 ml	5 ml	-	5 ml	-	-	-
	PO_4-P	10 ml	10 ml	-	5 ml	2 ml	-	-
Part 3	Total-P	5 ml	5 ml	-	-	-	5 ml	-
	PO_4-P	5 ml	5 ml	-	-	2 ml	5 ml	-
Part 4	Total-P	10 ml	10 ml	-	-	-	-	5 ml
	PO_4-P	10 ml	10 ml	-	-	-	-	5 ml

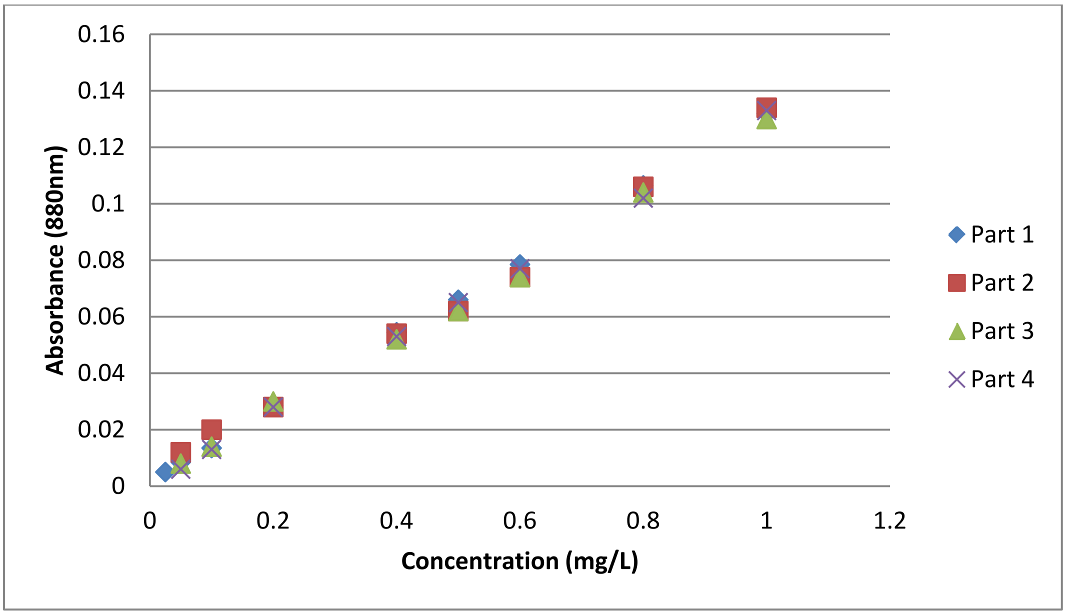


Figure 3.10: Calibration Curves for Total-P Extraction

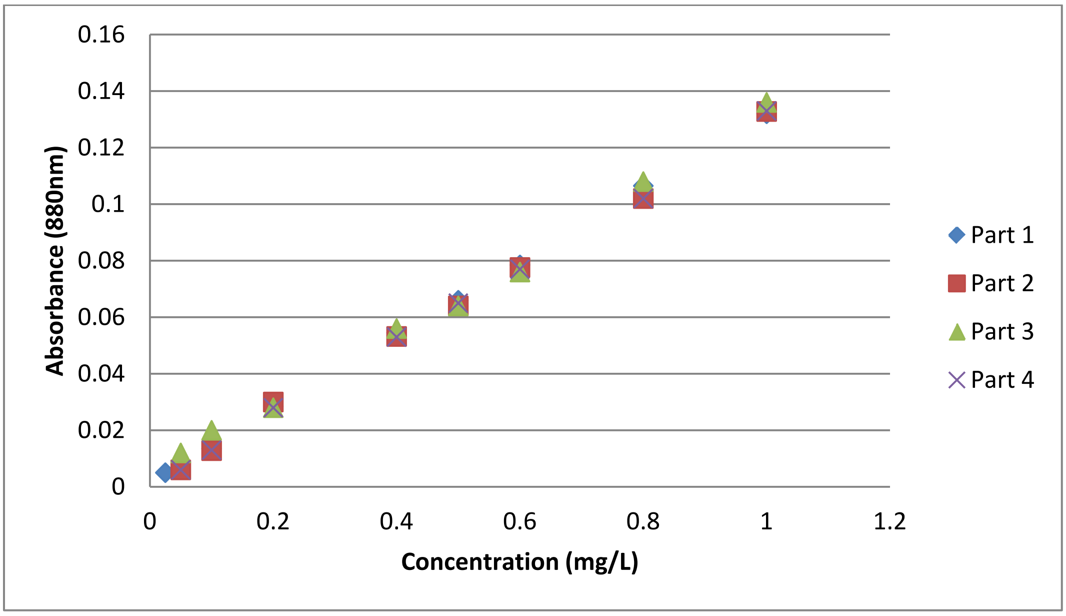


Figure 3.11: Calibration Curves for PO_4-P Extraction

3.4. Phosphate Adsorption Kinetics and Isotherm Experiments

To find out the phosphate adsorption characteristics, adsorption kinetics experiment and adsorption isotherm experiment are conducted. From these experiments, time required for complete adsorption is measured and tendency of sediment whether to release or adsorb phosphate has been investigated. Methods used for experiments are as follows:

Phosphate Adsorption Kinetics

- 200 ml phosphate solutions containing 1 mg/L phosphate are prepared
- 2 gr dry sediment sample is added
- pH is set to Lake Eymir's natural pH value
- Samples are placed in an orbital shaker at 200 RPM
- 5 ml sample is collected at 0 – 0,25 – 0,5 – 1 – 2 – 5 – 10 – 24 – 32 – 48 and 54 hours
- Collected samples are centrifuged at 3500 RPM for 10 minutes
- Clear part is filtered at 0,45 µm-pore-diameter membrane filter
- Phosphate in filtered samples are measured using Standard Methods for Total-P determination

Phosphate Adsorption Isotherm

- 30 ml phosphate solutions at 0 – 0,05 – 0,1 – 0,2 – 0,3 – 0,5 – 0,8 and 1 mg/L concentration are prepared
- 0,3 gr dry sediment is added
- pH is set to Lake Eymir's natural pH value
- Samples are placed in an orbital shaker at 200 RPM
- 10 ml sample is collected after 48 hours
- Collected samples are centrifuged at 3500 RPM for 10 minutes
- Clear part is filtered at 0,45 µm-pore-diameter membrane filter
- Phosphate in filtered samples are measured using Standard Methods for Total-P determination

Calibration

Similar to the fractionation experiment, calibration curves are formed for the kinetics and isotherm experiments and given in Appendix A, Figure 3.12 and Figure 3.13.

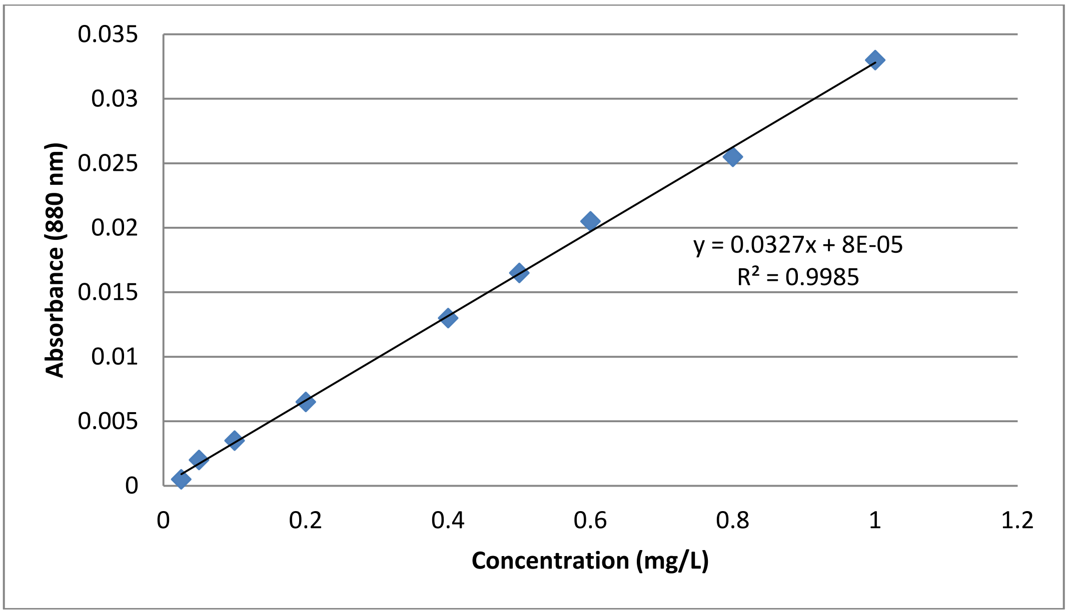


Figure 3.12: Calibration Graph for Adsorption Kinetics Experiment

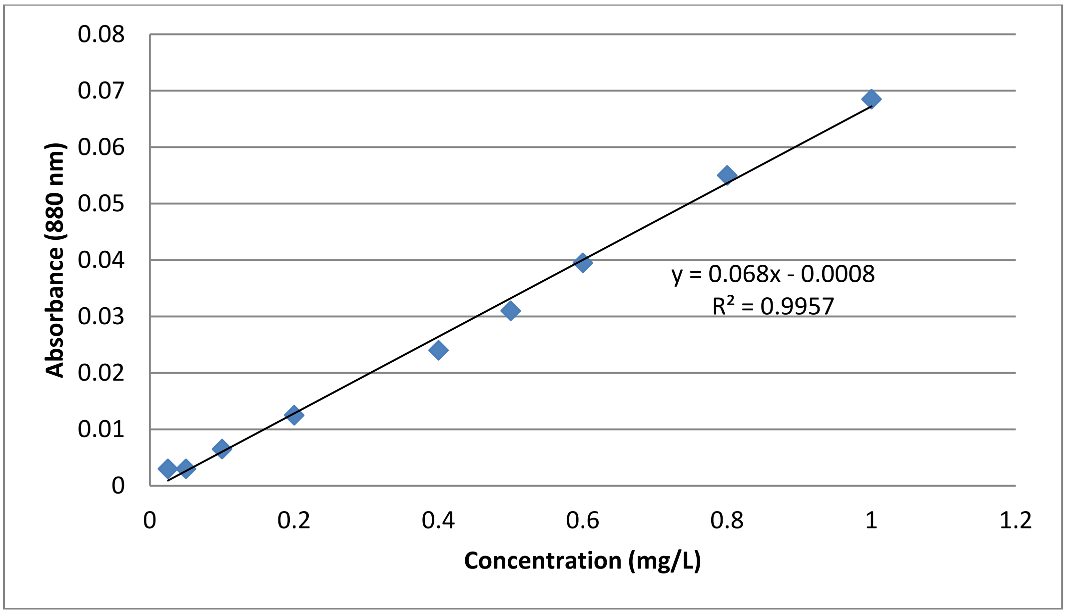


Figure 3.13: Calibration Graph for Adsorption Isotherm Experiment

Data acquired from experiments is fitted into different adsorption isotherms in order to identify phosphate adsorption processes. Isotherm models tested are listed below in Table 3.5.

Table 3.5: Isotherm Models Used

Model	Equation Number	Equation	Plot
Pseudo-first-order*	1	$\ln\left[\frac{Q_e - Q_t}{Q_e}\right] = -k * t$	$\ln\left[\frac{Q_e - Q_t}{Q_e}\right]$ vs t
Pseudo-second-order**	2	$\frac{t}{Q_t} = \frac{1}{k * Q_e^2} + \frac{1}{Q_e} * t$	$\frac{t}{Q_t}$ vs t
	3	$\frac{1}{Q_t} = \frac{1}{k * Q_e^2} * \frac{1}{t} + \frac{1}{Q_e}$	$\frac{1}{Q_t}$ vs $\frac{1}{t}$
	4	$Q_t = Q_e - \frac{1}{k * Q_e^2} * \frac{Q_t}{t}$	Q_t vs $\frac{Q_t}{t}$
	5	$\frac{Q_t}{t} = k * Q_e^2 - k * Q_e * Q_t$	$\frac{Q_t}{t}$ vs Q_t
Langmuir	6	$\frac{C_e}{C_A} = \frac{1}{B} * C_e + \frac{1}{A * B}$	$\frac{C_e}{C_A}$ vs C_e

* Vrtoch and Augustin, 2009
** Khambhaty et. al., 2008

Q_t is the amount of phosphorus adsorbed at time t and Q_e is the adsorbed amount of phosphorus at equilibrium. C_A is the concentration adsorbed to adsorbent, which is phosphorus binding on sediment in our case and C_e is the equilibrium phosphorus concentration at time t in solution. A, B and k values are constants.

3.5. Data and Principal Component Analysis

3.5.1. PCA

Principal Component Analysis (PCA) has been used to find out the parameters effecting the change of phosphorus in lake and some basic statistical analysis. PCA is an add-in for Microsoft Excel which can be used to identify which parameters have less defining changes in a system in order to eliminate them (Yüzügüllü, 2011). For PCA, three different data set each having three different sub-sets has been used. First sub set is for results obtained before 18.03.2010 which is the date of flooding from Lake Mogan to Lake Eymir. Second one is from the time of flooding to the end of field study and third one is for all time data set. Summary of the data sets used are given in Table 3.6 below.

Table 3.6: Data Sets Used for PCA

Data Set	Time Interval
Surface – 1	Analysis of surface water sample results before 18.03.2010
Surface – 2	Analysis of surface water sample results after 30.03.2010
Surface – 3	Analysis of surface water sample results of all time
Mid – 1	Analysis of mid-water sample results before 18.03.2010
Mid – 2	Analysis of mid-water sample results after 30.03.2010
Mid – 3	Analysis of mid-water sample results of all time
Bottom – 1	Analysis of bottom water sample results before 18.03.2010
Bottom – 2	Analysis of bottom water sample results after 30.03.2010
Bottom – 3	Analysis of bottom water sample results of all time
Average – 1	Analysis of lake average results before 18.03.2010
Average – 2	Analysis of lake average results after 30.03.2010
Average – 3	Analysis of lake average results of all time

PCA gives a correlation matrix (Pearson (n)) which shows the relations between parameters. Numbers in bold show that there is a relationship between two parameters and magnitude of this relation is given on a scale from -1 to 1. Values greater than 0,6 or less than -0,6 are strongly related to each other while other values are weakly related.

PCA results show how many principal components (Factors) define what percentage of a system. Since we determined the cumulative variability in a system to be larger than 80%, corresponding number of principal components will be used to define our system. Each parameter used in PCA has a factor loading between -1 and 1. Negative values are for negative correlations while positive values are used to show positive correlations. Values greater than 0,6 or lesser than -0,6 are efficient parameters in the system and can be used for modeling analysis.

Also, in order to investigate change of phosphorus concentrations with respect to other parameters, results of measurements are normalized by dividing with their average. Average values are used for parameters which cannot be measured at three different depths, such as water depth and PAR parameters.

The relevance between phosphorus values and other parameter values are either positive or negative. Positive means both are increasing and decreasing at the same time and negative means increase or decrease are in opposite ways.

Water depth, secchi depth, TSS, Total-P, PO_4-P, S-STP, S-SP, Chl-a, TKN, NH_4-N, NO_2-N, NO_3-N, alkalinity, temperature, pH, conductivity, DO, turbidity and PAR had been measured for the monitoring study for 21 months.

3.5.2. Linear and Non-Linear Regression Models

Linear and non-linear regressions are applied to create a model for S-STP. Data acquired from PCA is used to eliminate parameters which are not effective enough to represent changes in the model. Linear and non-linear models used for S-STP are respectively, provided below.

$$Sediment\ Soluble\ Total\ Phosphorus\ \left(\frac{mg}{gr}\right) = C + \sum_{i=1}^{n} (P_i * X_i) \tag{Eq-1}$$

$$Sediment\ Soluble\ Total\ Phosphorus\ \left(\frac{mg}{gr}\right) = \sum_{i=1}^{n} (P_i * X_i^{K_i}) \tag{Eq-2}$$

XLStat software is used to determine the constants C, P_i, and K_i in Equation 1 and 2, while maximizing coefficient of determination (R^2) and minimizing root mean square error (RMSE). X_i values are representing the independent parameters provided from PCA and their number is represented by n.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Relationship of Phosphorus with Other Parameters

The results of the monitoring study in Lake Eymir will be given as a relationship with phosphate concentrations in water. Calibration and sample preparation methods are given in Chapter 3. Results are plotted with respect to time in order to investigate changes with time and seasonal changes. However the data set has been disturbed two times by external factors. First, in March 2010, the gate preventing water flow from Lake Mogan to Lake Eymir has broken (Hürriyet Ankara, 12.08.2010). Also after repairing the gate, water from Lake Mogan has been discharged into Lake Eymir as a precaution of further flooding. The second factor affecting the water quality in Lake Eymir is excessive precipitation in winter and spring 2010. As a result, more water than readily available has discharged into Lake Eymir. This flow has changed both the concentration of pollutants and physical properties of lake water. The effect of this interference can be seen easily in graphs.

Although average concentrations give a clue about change of parameters over the study time, they are not specific enough for change of phosphorus concentration in Lake Eymir. Graphs given below in Figure 4.1 and Figure 4.2 shows that change of phosphorus concentration at various depths are quite different from each other. Increase of bottom layer phosphorus concentrations after 24.03.2010 is a sign of stratification and causes of this change is discussed in following sections.

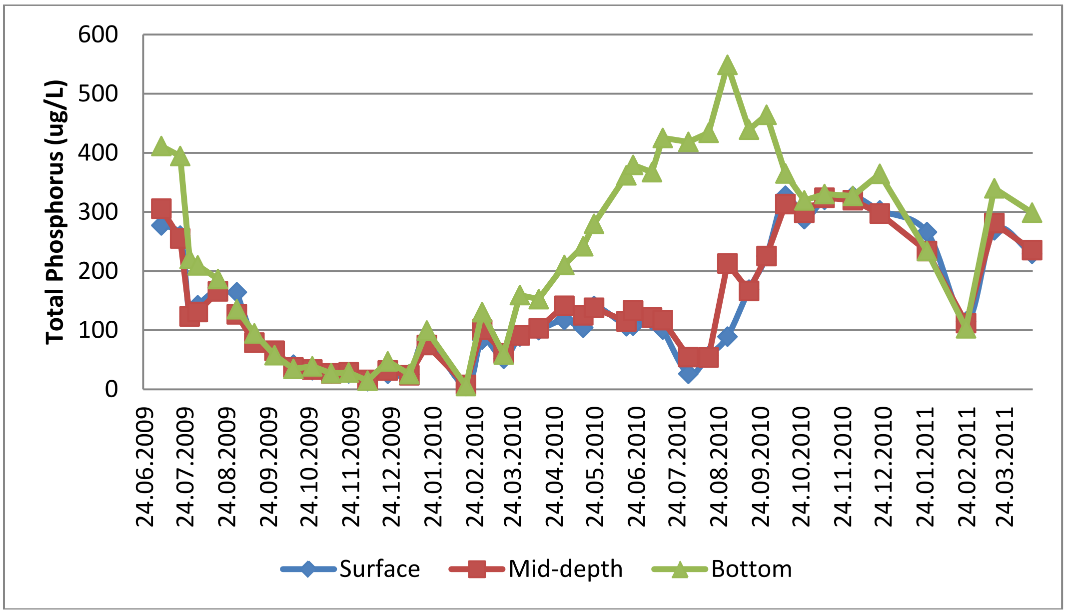


Figure 4.1: Average Total-P Concentrations of Surface, Mid and Bottom Sampling Points vs. Time Graph

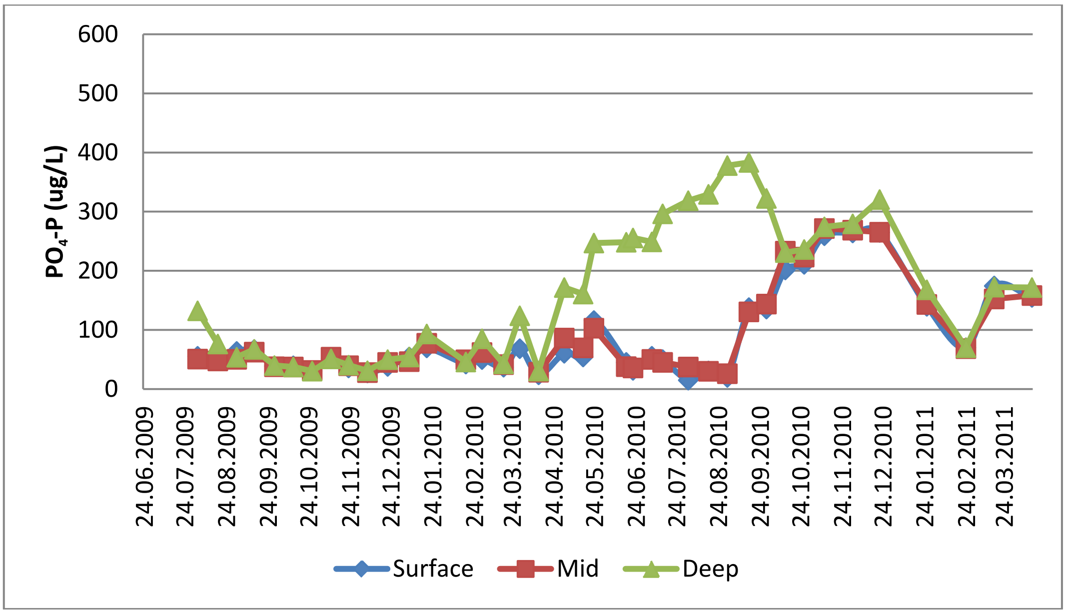


Figure 4.2: Average PO_4-P Concentrations of Surface, Mid and Bottom Sampling Points vs. Time Graph

4.1.1. PCA Results

4.1.1.1. PCA Results for Average Data

Results for phosphorus parameters from average data sets are summarized below in Table 4.1, Table 4.2 and Table 4.3 for the Average – 1, Average – 2, Average – 3, respectively. Numbers in bold show that there is a relationship between two parameters and magnitude of this relation is given on a scale from -1 to 1. From results given below, we can conclude that Total-P concentration is represented best by the data set for all time (Average – 3). On the other hand, S-STP is represented best by the data set after flooding (Average – 2).

Table 4.1 : Pearson Correlation Matrix for Average - 1 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	-0.241	-0.094	**0.426**	-0.007
TSS	-0.154	-0.079	-0.110	0.000
TKN	0.023	-0.029	-0.174	0.073
NH_3	0.119	-0.132	0.157	-0.001
NO_2	-0.205	-0.029	**-0.282**	0.026
NO_3	0.034	-0.103	-0.039	**0.359**
Total-P	**1**	**0.774**	-0.035	-0.018
PO_4-P	**0.774**	**1**	0.063	0.022
Alkalinity	-0.170	0.069	-0.155	-0.050
Secchi Depth	-0.248	-0.050	**-0.308**	**0.324**
Water Depth	0.232	0.115	**0.595**	**0.315**
PAR	0.139	0.253	0.159	0.172
S-STP	-0.035	0.063	**1**	0.160
S-SP	-0.018	0.022	0.160	**1**
Temperature	-0.053	-0.208	0.002	**0.412**
Conductivity	**-0.325**	-0.023	-0.251	0.239
pH	**-0.262**	-0.033	**-0.502**	0.250
DO	0.199	0.145	**0.274**	**-0.419**
Turbidity	0.224	-0.054	0.014	**-0.280**
ΔT	**0.445**	0.203	0.208	-0.151

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.2: Pearson Correlation Matrix for Average - 2 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	-0.031	-0.067	0.032	0.110
TSS	0.091	0.073	**0.272**	**0.249**
TKN	-0.010	0.014	0.127	0.166
NH_3	**0.625**	**0.732**	**0.376**	**0.223**
NO_2	**0.430**	**0.532**	**0.211**	0.131
NO_3	**0.311**	**0.335**	0.090	0.140
Total-P	**1**	**0.912**	**0.431**	**0.233**
PO_4-P	**0.912**	**1**	**0.437**	**0.301**
Alkalinity	**0.551**	**0.524**	**0.189**	0.019
Secchi Depth	-0.061	-0.100	-0.182	**-0.260**
Water Depth	**0.197**	**0.202**	**0.585**	**0.561**
PAR	**0.253**	**0.194**	0.051	0.024
S-STP	**0.431**	**0.437**	**1**	**0.721**
S-SP	**0.233**	**0.301**	**0.721**	**1**
Temperature	-0.011	-0.089	0.083	0.120
Conductivity	0.110	0.081	0.144	0.148
pH	-0.187	**-0.268**	-0.185	-0.109
DO	**-0.432**	**-0.390**	**-0.301**	-0.089

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.3: Pearson Correlation Matrix for Average - 3 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	0.016	-0.020	0.141	0.083
TSS	**-0.162**	-0.112	0.060	0.117
TKN	0.057	0.052	0.082	0.144
NH_3	**0.719**	**0.743**	**0.391**	**0.204**
NO_2	**0.235**	**0.367**	0.090	0.100
NO_3	**0.373**	**0.358**	0.122	**0.208**
Total-P	**1**	**0.904**	**0.397**	**0.195**
PO_4-P	**0.904**	**1**	**0.409**	**0.242**
Alkalinity	**0.424**	**0.457**	0.132	0.021
Secchi Depth	**0.321**	**0.202**	-0.032	-0.076
Water Depth	**0.596**	**0.479**	**0.598**	**0.421**
PAR	**0.207**	**0.194**	0.072	0.046
S-STP	**0.397**	**0.409**	**1**	**0.514**
S-SP	**0.195**	**0.242**	**0.514**	**1**
Temperature	**0.380**	**0.210**	**0.182**	**0.227**
Conductivity	**-0.216**	-0.139	-0.028	0.105
pH	**-0.671**	**-0.551**	**-0.368**	-0.088
DO	**-0.368**	**-0.331**	-0.145	**-0.241**

Values in bold are different from 0 with a significance level alpha=0.05

Factors representing more than 80% of the variation in the data set and, therefore, the effective parameters in each factor are given in Table 4.4, Table 4.5 and Table 4.6 for the Average – 1, Average – 2, Average – 3, respectively. Variability values in the tables explain what percentage of the changes in the system is caused by a given factor.

Table 4.4: Factors Representing More Than 80% in System and Effective Parameters for Average - 1 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	5,206	2,999	2,180	1,885	1,720	1,496	0,905
Variability	26,030	14,994	10,900	9,423	8,602	7,480	4,524
Cumulative (%)	26,030	41,025	51,925	61,348	69,950	77,430	81,954
Parameters	NH_3	Chl-a	S-SP	Total-P	S-STP	TKN	pH
	Alkalinity	TSS		PO_4-P		ΔT	Turbidity
	Secchi Depth	NO_3					
	Conduct.						
	DO						

Table 4.5: Factors Representing More Than 80% in System and Effective Parameters for Average - 2 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	4.419	3.393	2.262	1.469	1.191	1.056	0.871
Variability	24.548	18.852	12.565	8.161	6.618	5.866	4.837
Cumulative (%)	24.548	43.400	55.965	64.126	70.744	76.609	81.447
Parameters	NH_3	Chl-a	S-SP				TKN
	Total-P	NO_2					
	PO_4-P	Temp.					
	Alkalinity	Conduct.					
	S-STP						
	DO						

Table 4.6: Factors Representing More Than 80% in System and Effective Parameters for Average - 3 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	4.987	2.900	1.760	1.554	1.176	0.971	0.936
Variability	27.704	16.112	9.776	8.633	6.536	5.392	5.202
Cumulative (%)	27.704	43.816	53.593	62.225	68.761	74.154	79.356
Parameters	Water Depth	Conduct.		NO_2	PAR	PAR	TSS
	NH_3	Chl-a					Alkalinity
	pH	Temp.					
	PO_4-P						
	Total-P						

4.1.1.2. PCA Results for Surface Data

Results for phosphorus parameters from surface data sets are summarized below in Table 4.7, Table 4.8 and Table 4.9 for the Surface – 1, Surface – 2, Surface – 3, respectively. Numbers in bold show that there is a relationship between two parameters and magnitude of this relation is given on a scale from -1 to 1. From results given above, we can conclude that both Total-P concentration and S-STP concentration are represented best by using PCA data set for all time (Surface – 3).

Table 4.7: Pearson Correlation Matrix for Surface - 1 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	-0.056	-0.043	**0.278**	0.117
TSS	-0.070	-0.018	-0.024	0.147
TKN	-0.233	0.006	-0.254	0.171
NH_3	0.029	-0.095	0.102	0.028
NO_2	-0.234	0.029	-0.187	0.018
NO_3	0.077	-0.129	-0.014	**0.291**
Total-P	**1**	**0.422**	-0.164	-0.145
PO_4-P	**0.422**	**1**	0.050	0.032
Alkalinity	**-0.315**	0.114	-0.095	-0.057
Secchi Depth	**-0.359**	-0.056	**-0.308**	**0.324**
Water Depth	0.180	0.111	**0.595**	**0.315**
PAR	-0.024	**0.321**	0.159	0.172
S-STP	-0.164	0.050	**1**	0.160
S-SP	-0.145	0.032	0.160	**1**
Temperature	0.081	-0.200	0.025	**0.391**
Conductivity	**-0.408**	0.034	-0.246	0.235
pH	-0.154	0.046	**-0.564**	0.251
DO	0.215	0.113	0.230	**-0.401**
Turbidity	**0.383**	-0.071	0.014	**-0.280**
ΔT	**0.350**	0.126	0.208	-0.151

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.8: Pearson Correlation Matrix for Surface - 2 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	0.140	0.053	0.123	0.182
TSS	-0.054	-0.109	0.137	0.170
TKN	-0.003	0.000	-0.008	0.048
NH_3	**0.751**	**0.795**	**0.335**	0.143
NO_2	**0.597**	**0.659**	0.185	0.088
NO_3	-0.149	-0.061	0.015	0.073
Total-P	**1**	**0.937**	0.183	-0.024
PO_4-P	**0.937**	**1**	**0.205**	0.069
Alkalinity	**0.255**	**0.255**	0.146	0.013
Secchi Depth	0.074	0.052	-0.182	**-0.260**
Water Depth	-0.071	-0.053	**0.585**	**0.561**
PAR	**0.295**	**0.235**	0.051	0.024
S-STP	0.183	**0.205**	**1**	**0.721**
S-SP	-0.024	0.069	**0.721**	**1**
Temperature	**-0.580**	**-0.555**	0.100	0.135
Conductivity	**-0.198**	-0.144	0.140	0.127
pH	**-0.556**	**-0.555**	-0.119	0.009
DO	**-0.410**	**-0.376**	-0.169	0.045

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.9: Pearson Correlation Matrix for Surface - 3 Data Set for Phosphorus Parameters

	Total-P	**PO$_4$-P**	**S-STP**	**S-SP**
Chl-a	-0.028	-0.038	0.126	0.133
TSS	**-0.178**	**-0.163**	0.016	0.129
TKN	-0.051	-0.024	-0.061	0.056
NH$_3$	**0.779**	**0.777**	**0.350**	0.150
NO$_2$	**0.401**	**0.536**	0.090	0.062
NO$_3$	0.042	0.025	0.067	0.146
Total-P	**1**	**0.888**	**0.252**	0.042
PO$_4$-P	**0.888**	**1**	**0.244**	0.096
Alkalinity	**0.245**	**0.270**	0.111	0.010
Secchi Depth	**0.329**	**0.215**	-0.032	-0.076
Water Depth	**0.383**	**0.236**	**0.598**	**0.421**
PAR	**0.264**	**0.244**	0.072	0.046
S-STP	**0.252**	**0.244**	**1**	**0.514**
S-SP	0.042	0.096	**0.514**	**1**
Temperature	-0.030	**-0.205**	**0.200**	**0.225**
Conductivity	**-0.345**	**-0.220**	-0.039	0.106
pH	**-0.715**	**-0.564**	**-0.349**	-0.032
DO	**-0.321**	**-0.293**	-0.058	-0.152

Values in bold are different from 0 with a significance level alpha=0.05

Factors representing more than 80% of the variation in the data set and, therefore, the effective parameters in each factor are given in Table 4.10, Table 4.11 and Table 4.12 for the Surface – 1, Surface – 2, Surface – 3, respectively. Variability values in the tables explain what percentage of the changes in the system is caused by a given factor.

Table 4.10: Factors Representing More Than 80% in System and Effective Parameters for Surface - 1 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	4.978	3.101	2.210	1.870	1.529	1.424	0.877
Variability	24.891	15.507	11.051	9.350	7.646	7.119	4.383
Cumulative (%)	24.891	40.398	51.449	60.799	68.445	75.564	79.946
Parameters	Alkalinity	TSS	S-SP		PO$_4$-P	NH$_3$	
	Conduct.	Chl-a			Total-P		
	pH	NO$_3$					
	TKN	Secchi Depth					
	ΔT	Temp.					

Table 4.11: Factors Representing More Than 80% in System and Effective Parameters for Surface - 2 Data Set

Factor	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	4.595	3.013	2.390	1.949	1.119	0.966	0.771
Variability	25.529	16.736	13.276	10.825	6.218	5.366	4.285
Cumulative (%)	25.529	42.265	55.542	66.367	72.585	77.951	82.236
Parameters	NH_3	Conduct.	Alkalinity	Water Depth			Conduct.
	NO_2	S-STP	DO				
	pH						
	PO_4-P						
	Temp.						
	Total-P						

Table 4.12: Factors Representing More Than 80% in System and Effective Parameters for Surface - 3 Data Set

Factor	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	4.563	2.713	2.062	1.816	1.146	0.978	0.843
Variability	25.351	15.074	11.458	10.090	6.368	5.433	4.684
Cumulative (%)	25.351	40.426	51.883	61.973	68.341	73.774	78.458
Parameters	NH_3	Conduct.		Water Depth			
	pH	Temp.					
	PO_4-P						
	Total-P						

4.1.1.3. PCA Results for Mid-Depth Data

Results for phosphorus parameters from mid-depth data sets are summarized below in Table 4.13, Table 4.14 and Table 4.15 for the Mid – 1, Mid – 2, Mid – 3, respectively. Numbers in bold show that there is a relationship between two parameters and magnitude of this relation is given on a scale from -1 to 1. From results given above, we can conclude that both Total-P concentration and S-STP concentration are represented best by using PCA data set for all time (Mid – 3).

Table 4.13: Pearson Correlation Matrix for Mid - 1 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	-0.167	-0.083	**0.418**	-0.095
TSS	-0.089	-0.083	-0.080	0.051
TKN	-0.052	0.033	**-0.298**	0.178
NH_3	0.022	-0.103	0.135	0.000
NO_2	-0.071	0.017	-0.243	0.106
NO_3	0.064	-0.036	-0.096	**0.343**
Total-P	**1**	**0.943**	0.043	0.103
PO_4-P	**0.943**	**1**	0.070	0.088
Alkalinity	-0.036	0.012	-0.204	0.044
Secchi Depth	-0.091	-0.003	**-0.308**	**0.324**
Water Depth	0.166	0.074	**0.595**	**0.315**
PAR	0.192	0.241	0.159	0.172
S-STP	0.043	0.070	**1**	0.160
S-SP	0.103	0.088	0.160	**1**
Temperature	-0.074	-0.148	0.003	**0.406**
Conductivity	-0.136	0.001	-0.239	0.235
pH	-0.140	-0.035	**-0.455**	0.217
DO	0.135	0.091	**0.351**	**-0.420**
Turbidity	0.045	-0.079	0.014	**-0.280**
ΔT	**0.330**	0.171	0.208	-0.151

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.14: Pearson Correlation Matrix for Mid - 2 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	**-0.273**	**-0.254**	0.186	**0.210**
TSS	-0.035	-0.041	**0.270**	0.181
TKN	0.003	0.062	0.089	0.121
NH_3	**0.677**	**0.777**	**0.298**	0.127
NO_2	**0.537**	**0.619**	0.117	0.004
NO_3	0.008	0.045	0.076	0.096
Total-P	**1**	**0.882**	**0.198**	0.003
PO_4-P	**0.882**	**1**	0.174	0.040
Alkalinity	**0.385**	**0.328**	0.176	-0.008
Secchi Depth	0.051	0.028	-0.182	**-0.260**
Water Depth	-0.039	-0.054	**0.585**	**0.561**
PAR	**0.286**	**0.266**	0.051	0.024
S-STP	**0.198**	0.174	**1**	**0.721**
S-SP	0.003	0.040	**0.721**	**1**
Temperature	**-0.391**	**-0.473**	0.085	0.124
Conductivity	-0.098	-0.118	0.145	0.146
pH	**-0.314**	**-0.400**	-0.179	-0.075
DO	**-0.214**	**-0.193**	**-0.270**	-0.037

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.15: Pearson Correlation Matrix for Mid - 3 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	**-0.308**	**-0.220**	**0.207**	0.052
TSS	**-0.203**	-0.127	0.041	0.085
TKN	-0.004	0.046	0.031	0.113
NH_3	**0.669**	**0.589**	**0.326**	0.136
NO_2	**0.281**	**0.382**	0.004	0.019
NO_3	0.140	0.072	0.084	**0.182**
Total-P	**1**	**0.848**	**0.265**	0.096
PO_4-P	**0.848**	**1**	**0.187**	0.088
Alkalinity	**0.295**	**0.218**	0.067	0.039
Secchi Depth	**0.295**	0.136	-0.032	-0.076
Water Depth	**0.394**	**0.167**	**0.598**	**0.421**
PAR	**0.248**	**0.229**	0.072	0.046
S-STP	**0.265**	**0.187**	**1**	**0.514**
S-SP	0.096	0.088	**0.514**	**1**
Temperature	0.072	**-0.164**	**0.185**	**0.227**
Conductivity	**-0.283**	**-0.165**	-0.030	0.097
pH	**-0.580**	**-0.359**	**-0.356**	-0.081
DO	**-0.199**	-0.121	-0.094	**-0.204**

Values in bold are different from 0 with a significance level alpha=0.05

Factors representing more than 80% of the variation in the data set and, therefore, the effective parameters in each factor are given in Table 4.16, Table 4.17 and Table 4.18 for the Mid – 1, Mid – 2, Mid – 3, respectively. Variability values in the tables explain what percentage of the changes in the system is caused by a given factor.

Table 4.16: Factors Representing More Than 80% in System and Effective Parameters for Mid - 1 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	5.073	2.953	2.224	1.923	1.582	1.529	0.940
Variability	25.364	14.764	11.122	9.613	7.908	7.645	4.698
Cumulative (%)	25.364	40.128	51.249	60.862	68.770	76.414	81.112
Parameters	DO	NO_3	PO_4-P				
	Conduct.		S-SP				
	pH		Total-P				
	Secchi Depth						

Table 4.17: Factors Representing More Than 80% in System and Effective Parameters for Mid - 2 Data Set

Factor	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	4.121	3.354	2.340	1.797	1.063	1.045	0.937
Variability	22.894	18.633	13.000	9.985	5.906	5.807	5.208
Cumulative (%)	22.894	41.527	54.527	64.512	70.418	76.225	81.433
Parameters	NH_3	Alkalinity		Water Depth	Chl-a	PO_4-P	DO
	NO_2	Conduct.					
	PO_4-P	S-STP					
	Temp.						
	Total-P						

Table 4.18: Factors Representing More Than 80% in System and Effective Parameters for Mid - 3 Data Set

Factor	F1	F2	F3	F4	F5	F6	F7	F8
Eigenvalue	4.258	2.742	1.930	1.766	1.136	0.969	0.926	0.870
Variability	23.656	15.233	10.725	9.813	6.310	5.383	5.143	4.831
Cumulative (%)	23.656	38.889	49.614	59.427	65.737	71.120	76.263	81.094
Parameters	Water Depth	Cond.		Water Depth		Chl-a		DO
	NH_3	NO_3						
	PO_4-P	Temp.						
	pH							
	Total-P							

4.1.1.4. PCA Results for Bottom Data

Results for phosphorus parameters from bottom data sets are summarized below in Table 4.19, Table 4.20 and Table 4.21 for the Bottom – 1, Bottom – 2, Bottom – 3, respectively. Numbers in bold show that there is a relationship between two parameters and magnitude of this relation is given on a scale from -1 to 1. From results given above, we can conclude that Total-P concentration is represented best by using PCA data set for all time (Bottom – 3), and S-STP concentration are represented best by using PCA data set after flood (Bottom – 2).

Table 4.19: Pearson Correlation Matrix for Bottom - 1 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	**-0.313**	-0.129	**0.348**	-0.025
TSS	-0.110	0.044	-0.148	-0.134
TKN	0.090	-0.058	-0.065	-0.001
NH_3	**0.382**	-0.011	0.186	-0.026
NO_2	**-0.263**	-0.154	**-0.332**	-0.044
NO_3	-0.083	-0.248	0.000	**0.383**
Total-P	**1**	**0.613**	-0.080	-0.162
PO_4-P	**0.613**	**1**	-0.005	**-0.333**
Alkalinity	-0.103	**0.299**	-0.008	-0.193
Secchi Depth	**-0.332**	-0.225	**-0.308**	**0.324**
Water Depth	0.256	0.217	**0.595**	**0.315**
PAR	0.058	-0.026	0.159	0.172
S-STP	-0.080	-0.005	**1**	0.160
S-SP	-0.162	**-0.333**	0.160	**1**
Temperature	-0.098	**-0.366**	-0.023	**0.437**
Conductivity	**-0.276**	-0.109	-0.232	0.210
pH	**-0.460**	-0.216	**-0.460**	**0.265**
DO	0.110	0.231	0.154	**-0.351**
Turbidity	**0.331**	0.139	0.014	**-0.280**
ΔT	**0.466**	**0.306**	0.208	-0.151

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.20: Pearson Correlation Matrix for Bottom - 2 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	**0.394**	**0.342**	-0.054	0.020
TSS	0.126	0.124	**0.244**	**0.195**
TKN	**0.267**	**0.264**	0.151	0.171
NH_3	**0.466**	**0.535**	**0.371**	**0.309**
NO_2	**0.270**	**0.329**	**0.253**	**0.240**
NO_3	**0.663**	**0.654**	0.124	0.176
Total-P	**1**	**0.946**	**0.458**	**0.382**
PO_4-P	**0.946**	**1**	**0.498**	**0.438**
Alkalinity	**0.485**	**0.513**	**0.223**	0.049
Secchi Depth	-0.172	**-0.217**	-0.182	**-0.260**
Water Depth	**0.379**	**0.404**	**0.585**	**0.561**
PAR	0.057	0.015	0.051	0.024
S-STP	**0.458**	**0.498**	**1**	**0.721**
S-SP	**0.382**	**0.438**	**0.721**	**1**
Temperature	**0.487**	**0.416**	0.053	0.086
Conductivity	**0.318**	**0.263**	0.145	0.169
pH	-0.025	-0.074	**-0.200**	**-0.204**
DO	**-0.424**	**-0.403**	**-0.414**	**-0.280**

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.21: Pearson Correlation Matrix for Bottom - 3 Data Set for Phosphorus Parameters

	Total-P	**PO_4-P**	**S-STP**	**S-SP**
Chl-a	**0.429**	**0.404**	0.056	0.040
TSS	-0.015	0.013	0.086	0.069
TKN	**0.274**	**0.273**	0.128	0.135
NH_3	**0.659**	**0.680**	**0.393**	**0.257**
NO_2	**0.264**	**0.320**	0.138	**0.172**
NO_3	**0.608**	**0.627**	**0.156**	**0.221**
Total-P	**1**	**0.958**	**0.423**	**0.273**
PO_4-P	**0.958**	**1**	**0.460**	**0.313**
Alkalinity	**0.419**	**0.477**	**0.197**	0.004
Secchi Depth	**0.229**	0.145	-0.032	-0.076
Water Depth	**0.636**	**0.600**	**0.598**	**0.421**
PAR	0.086	0.051	0.072	0.046
S-STP	**0.423**	**0.460**	**1**	**0.514**
S-SP	**0.273**	**0.313**	**0.514**	**1**
Temperature	**0.588**	**0.525**	0.145	**0.217**
Conductivity	-0.045	-0.022	-0.013	0.107
pH	**-0.558**	**-0.501**	**-0.362**	-0.133
DO	**-0.463**	**-0.443**	**-0.292**	**-0.323**

Values in bold are different from 0 with a significance level alpha=0.05

Factors representing more than 80% of the variation in the data set and, therefore, the effective parameters in each factor are given in Table 4.22, Table 4.23 and Table 4.24 for the Bottom – 1, Bottom – 2, Bottom – 3, respectively. Variability values in the tables explain what percentage of the changes in the system is caused by a given factor.

Table 4.22: Factors Representing More Than 80% in System and Effective Parameters for Bottom - 1 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalue	5.084	2.652	2.549	1.811	1.717	1.144	1.009
Variability	25.418	13.260	12.744	9.057	8.585	5.721	5.046
Cumulative (%)	25.418	38.678	51.421	60.478	69.063	74.784	79.831
Parameters	Conduct.	Chl-a	S-SP	S-STP			Turbidity
	NH_3		Temp.				pH
	pH						
	Secchi Depth						

Table 4.23: Factors Representing More Than 80% in System and Effective Parameters for Bottom - 2 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Eigenvalue	5.113	2.579	1.726	1.349	1.222	1.120	0.891	0.852
Variability	28.407	14.327	9.591	7.492	6.791	6.224	4.949	4.734
Cumulative (%)	28.407	42.734	52.325	59.818	66.609	72.833	77.781	82.515
Parameters	DO	Temp.		pH		PAR		DO
	NO_3							
	PO_4-P							
	S-STP							
	Total-P							

Table 4.24: Factors Representing More Than 80% in System and Effective Parameters for Bottom - 3 Data Set

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Eigenvalue	5.544	2.234	1.591	1.326	1.135	0.987	0.940	0.772
Variability	30.801	12.410	8.840	7.366	6.307	5.482	5.222	4.291
Cumulative (%)	30.801	43.212	52.052	59.418	65.724	71.206	76.428	80.719
Parameters	DO	Cond.	S-SP	TSS	PAR	TKN		
	Water Depth			NO_2				
	NH_3							
	NO_3							
	pH							
	PO_4-P							
	Temp.							
	Total-P							

4.1.1.5. Summary of PCA Runs

In Table 4.25 and Table 4.26, the best results of the PCA runs presented before are tabulated for Total-P and PO_4-P, respectively, for comparison. These comparison tables show that changes in Total-P and PO_4-P concentrations can be evaluated using the Bottom – 3 data set. Concentration change of Total-P with respect to other parameters is given in Chapter 4, subsection 4.1.2 and bottom layer phosphorus concentrations are evaluated according to results given in Table 4.25 and Table 4.26.

Table 4.25: Comparison of Pearson Total-P Correlation Matrices

	Average - 3	**Surface - 3**	**Mid - 3**	**Bottom - 3**
Chl-a	0.016	-0.028	**-0.308**	**0.429**
TSS	**-0.162**	**-0.178**	**-0.203**	-0.015
TKN	0.057	-0.051	-0.004	**0.274**
NH_3	**0.719**	**0.779**	**0.669**	**0.659**
NO_2	**0.235**	**0.401**	**0.281**	**0.264**
NO_3	**0.373**	0.042	0.140	**0.608**
PO_4-P	**0.904**	**0.888**	**0.848**	**0.958**
Alkalinity	**0.424**	**0.245**	**0.295**	**0.419**
Secchi Depth	**0.321**	**0.329**	**0.295**	**0.229**
Water Depth	**0.596**	**0.383**	**0.394**	**0.636**
PAR	**0.207**	**0.264**	**0.248**	0.086
S-STP	**0.397**	**0.252**	**0.265**	**0.423**
S-SP	**0.195**	0.042	0.096	**0.273**
Temperature	**0.380**	-0.030	0.072	**0.588**
Conductivity	**-0.216**	**-0.345**	**-0.283**	-0.045
pH	**-0.671**	**-0.715**	**-0.580**	**-0.558**
DO	**-0.368**	**-0.321**	**-0.199**	**-0.463**

Values in bold are different from 0 with a significance level alpha=0.05

Table 4.26: Comparison of Pearson PO_4-P Correlation Matrices

	Average - 3	**Surface - 3**	**Mid - 3**	**Bottom - 3**
Chl-a	-0.020	-0.038	**-0.220**	**0.404**
TSS	-0.112	**-0.163**	-0.127	0.013
TKN	0.052	-0.024	0.046	**0.273**
NH_3	**0.743**	**0.777**	**0.589**	**0.680**
NO_2	**0.367**	**0.536**	**0.382**	**0.320**
NO_3	**0.358**	0.025	0.072	**0.627**
Total-P	**0.904**	**0.888**	**0.848**	**0.958**
Alkalinity	**0.457**	**0.270**	**0.218**	**0.477**
Secchi Depth	**0.202**	**0.215**	0.136	0.145
Water Depth	**0.479**	**0.236**	**0.167**	**0.600**
PAR	**0.194**	**0.244**	**0.229**	0.051
S-STP	**0.409**	**0.244**	**0.187**	**0.460**
S-SP	**0.242**	0.096	0.088	**0.313**
Temperature	**0.210**	**-0.205**	**-0.164**	**0.525**
Conductivity	-0.139	**-0.220**	**-0.165**	-0.022
pH	**-0.551**	**-0.564**	**-0.359**	**-0.501**
DO	**-0.331**	**-0.293**	-0.121	**-0.443**

Values in bold are different from 0 with a significance level alpha=0.05

From 12 different PCA runs that employed different data sets, effective parameters in the system are determined by observing their number of occurrences in 12 different factor analysis. Effective parameters for modeling of phosphorus concentrations in sediment layer are summarized below in Table 4.27. It is seen that Total-P, PO_4-P, conductivity, NH_3, and temperature can define the system at a higher frequency. pH, DO, Chl-a and S-STP are other important parameters which take a partial role in the system.

Average and bottom water quality data are used for linear and non-linear modeling. Parameters that appear more frequently (≥7), listed above, are selected for further elimination. S-STP is the dependent variable. Total-P, PO_4-P, conductivity, NH_3, temperature, pH, DO, and Chl-a are explanatory variables. If strong correlation is found between two or more parameters in a data set, one of them is selected as the independent variable and others are eliminated in order to prevent multicollinearity. Therefore, a second elimination is applied based on multicollinearity information. Following this two-stage elimination the parameters that will constitute the independent variables of the regression models are determined (Table 4.28). Models are developed using 6 different data sets (Table 4.28). In case the number of data is insufficient for modeling other parameters were considered as well in modeling as will be discussed where applicable. These parameters exhibited no multicollinearity as well.

Table 4.27: Factor Analysis Comparison

	Average - 1	**Surface - 1**	**Mid - 1**	**Bottom - 1**	**Average - 2**	**Surface - 2**	**Mid - 2**	**Bottom - 2**	**Average - 3**	**Surface - 3**	**Mid - 3**	**Bottom - 3**	**# of Occurrence**
Chl-a	F2	F2		F2	F2		F5		F2		F6		7
TSS	F2	F2							F7			F4	4
TKN	F6	F1			F7							F6	4
NH_3	F1	F6		F1	F1	F1	F1		F1	F1	F1	F1	10
NO_2					F2	F1	F1		F4			F4	5
NO_3	F2	F2	F2					F1			F2	F1	6
Total-P	F4	F5	F3		F1	F1	F1	F1	F1	F1	F1	F1	11
PO_4-P	F4	F5	F3		F1	F1	F1	F1	F1	F1	F1	F1	11
Alkalinity	F1	F1			F1	F3	F2		F7				6
Secchi Depth	F1	F2	F1	F1									4
Water Depth						F4	F4		F1	F4	F1	F1	6
PAR								F6	F5			F5	3
S-STP	F5			F4	F1	F2	F2	F1				F3	7
S-SP	F3	F3	F3	F3	F3								5
Temperature		F2		F3	F2	F1	F1	F2	F2	F2	F2	F1	10
Conductivity	F1	F1	F1	F1	F2	F2	F2		F2	F2	F2	F2	11
pH	F7	F1	F1	F1		F1			F1	F1	F1	F1	9
DO	F1		F1		F1	F3	F7	F1			F8	F1	8
Turbidity	F7			F7									2
ΔT	F6	F1											2

Table 4.28: Parameters Used as the Independent Variables in Regression Models

	Symbol Used in Models	Average-1	Bottom-1	Average-2	Bottom-2	Average-3	Bottom-3
Chl-a	**Chl-a**	**X**	**X**			**X**	
NH_3	**N**			**X**			
Total-P	**W-TP**	**X**		**X**	**X**	**X**	**X**
PO_4-P	**W-OP**						
S-STP	**S-STP**	**X**	**X**	**X**	**X**		**X**
Temperature	**T**		**X**		**X**	**X**	**X**
Conductivity	**E**			**X**		**X**	**X**
pH	**pH**	**X**	**X**				**X**
DO	**DO**	**X**		**X**	**X**		**X**
Turbidity*	**B**	**X**	**X**				
ΔT*	**ΔT**	**X**	**X**				

* Additional parameters used in regression models

4.1.2. Modeling of Sediment Soluble Total Phosphorus

Independent variables acquired from the PCA (Table 4.28) have been used to run linear and non-linear regression models and results are given below. For Bottom – 1 and Average – 1 data sets, turbidity and ΔT are also added into modeling since they are not evaluated well due to lack of data in sets 2 and 3.

The following equations are obtained from linear regression modeling of S-STP. Water quality data used to obtain these equations are given in Table 4.29.

Table 4.29: Water Quality Data Used to Obtain Equations

Water Quality Analysis Result	Equation
Bottom – 1	3
Bottom – 2	4
Bottom – 3	5
Average – 1	6
Average – 2	7
Average – 3	8

$$\textit{S-STP (mg/gr)} = 34{,}9723 + (0{,}02159 * \textit{Chl-a}) + (0{,}02290 * T) - (3{,}7976 * pH) - (0{,}07779 * B) - (0{,}02011 * \Delta T) \qquad \text{(Eq-3)}$$

$$\text{S-STP (mg/gr)} = 2{,}3049 + (0{,}002590 * \text{W-TP}) - (0{,}04527 * \text{T}) - (0{,}09006 * \text{DO}) \qquad \text{(Eq-4)}$$

$$\textit{S-STP (mg/gr)} = 4{,}7497 - (0{,}02830 * T) + (0{,}08419 * E) - (0{,}3539 * pH) - (0{,}03490 * DO) + (0{,}002022 * \textit{W-TP}) \qquad \text{(Eq-5)}$$

$$\textit{S-STP (mg/gr)} = 31{,}9280 + (0{,}0199 * \textit{Chl-a}) - (0{,}001616 * \textit{W-TP}) - (3{,}4484 * pH) + (0{,}02086 * DO) - (0{,}07533 * B) + (0{,}1104 * \Delta T) \qquad \text{(Eq-6)}$$

$$\textit{S-STP (mg/gr)} = 0{,}8934 + (0{,}2441 * NH_3\textit{-N}) + (0{,}002822 * \textit{W-TP}) + (0{,}1624 * E) - (0{,}02840 * DO) \qquad \text{(Eq-7)}$$

$$\textit{S-STP (mg/gr)} = 1{,}0475 + (0{,}004869 * \textit{Chl-a}) + (0{,}003649 * \textit{W-TP}) - (0{,}01194 * T) + (0{,}09335 * E) \qquad \text{(Eq-8)}$$

The statistical data pertaining to fits obtained by models are presented in Table 4.30. As it is seen from the table, modeling with the first data set (the set before the gate between Lake Eymir and Lake Mogan is broken) fits better than others. This might be due more stable conditions compared to disturbed conditions caused by floods from Lake Mogan and heavy precipitation in 2010. Even though R^2 values are not very high at 95% confidence level, there is still correlation between measured and predicted values. Figure 4.3 shows the distribution of predicted S-STP concentrations versus measured concentrations. For Bottom – 2 model, 4 samples out of 109; for Bottom – 3, 7 out of 166; for Average – 2, 4 samples out of 109 and for Average – 3, 7 samples out of 166 are outside of the confidence range

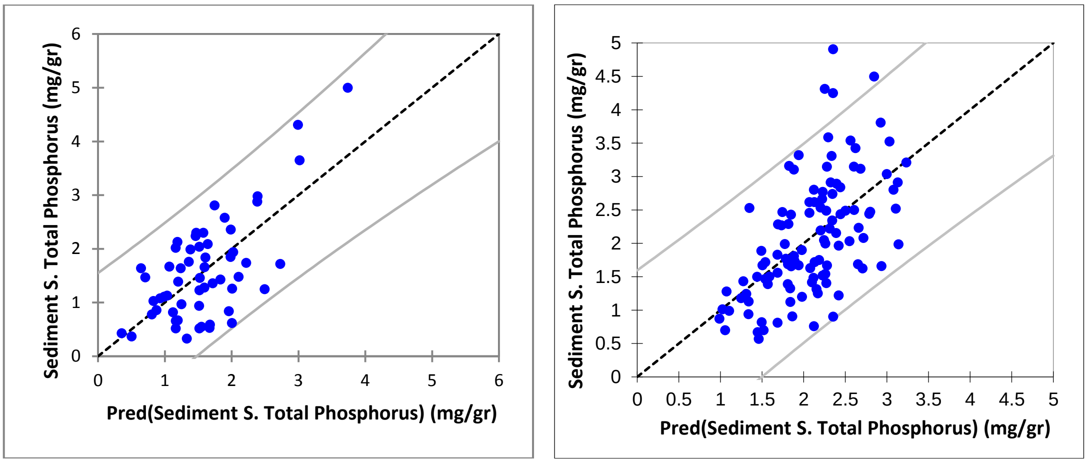
Standardized coefficients showing weigh of parameters on S-STP concentrations change is given in Appendix G. Correlations obtained through standardized coefficients are given in Table 4.31. As seen from the table, Chl-a, Total-P, DO and pH are more effective in creating a change in the dependent variable, the S-STP concentration. The effect of Chl-a and Total-P on S-STP is positive while DO and pH is negative. This is expected since the concentration of phosphorus in water column is directly effective on S-STP concentrations. It is also known that phosphorus releases from sediment layer under anoxic conditions and at low pH values.

Table 4.30: Comparison of Linear Regression Models

	Bottom - 1	**Bottom - 2**	**Bottom - 3**	**Average - 1**	**Average - 2**	**Average - 3**
# of Independent Parameters	5	3	4	6	4	4
# of Samples	57	109	166	57	109	166
Coefficient of Determination	0.459	0.335	0.227	0.520	0.224	0.180
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Root Mean Square Error	0.729	0.748	0.876	0.693	0.812	0.870

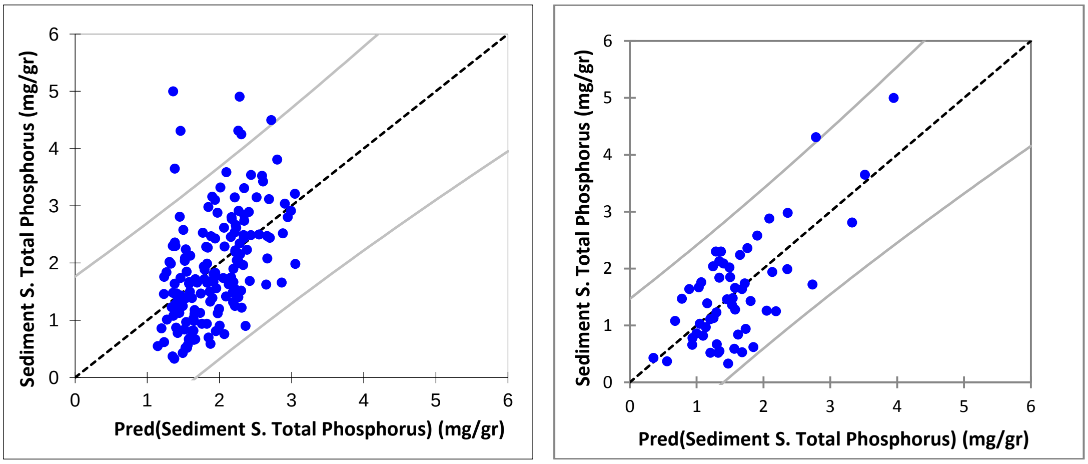
Table 4.31: Standardized Coefficients for Modeling Results

	Bottom - 1	**Bottom - 2**	**Bottom - 3**	**Average - 1**	**Average - 2**	**Average - 3**
Chl-a	0.461			0.480		0.167
NH_3					0.175	
Total-P		0.463	0.403	-0.069	0.267	0.435
Conductivity			0.037		0.083	0.041
pH	-0.669		-0.128	-0.548		
DO		-0.335	-0.128	0.080	-0.103	
Turbidity	-0.235			-0.228		
Temperature	0.104	-0.303	-0.184			-0.085
ΔT	-0.017			0.093		



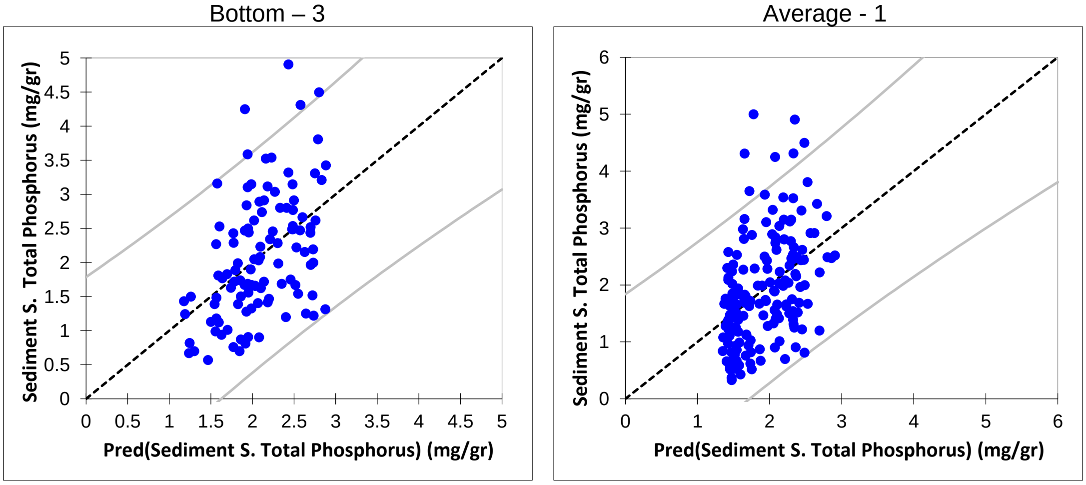
Bottom - 1

Bottom - 2



Bottom – 3

Average - 1



Average – 2

Average - 3

Figure 4.3: Predicted S-STP Concentrations vs. S-STP Concentrations for Linear Regression

Modeling using non-linear regression resulted in poor fits compared to linear ones. Only results from non-linear regression with Bottom – 1 data set which has an R^2 of 0.510 and RMSE of 0.724. For others, the maximum R^2 was 0.212. The results of the statistical analysis are given in Table 4.32.

Table 4.32: Comparison of Non-Linear Regression Models

	Bottom - 1	**Bottom - 2**	**Bottom - 3**	**Average - 1**	**Average - 2**	**Average - 3**
# of Independent Parameters	5	3	5	6	4	4
# of Samples	57	109	166	57	109	166
Coefficient of Determination	0.510	0.212	0.169	0.167	0.208	0.015
Root Mean Square Error	0.724	225	38684	0.964	0.833	$6*10^9$

4.1.3. Comparison of Normalized Field Monitoring Data

4.1.3.1. Water Depth

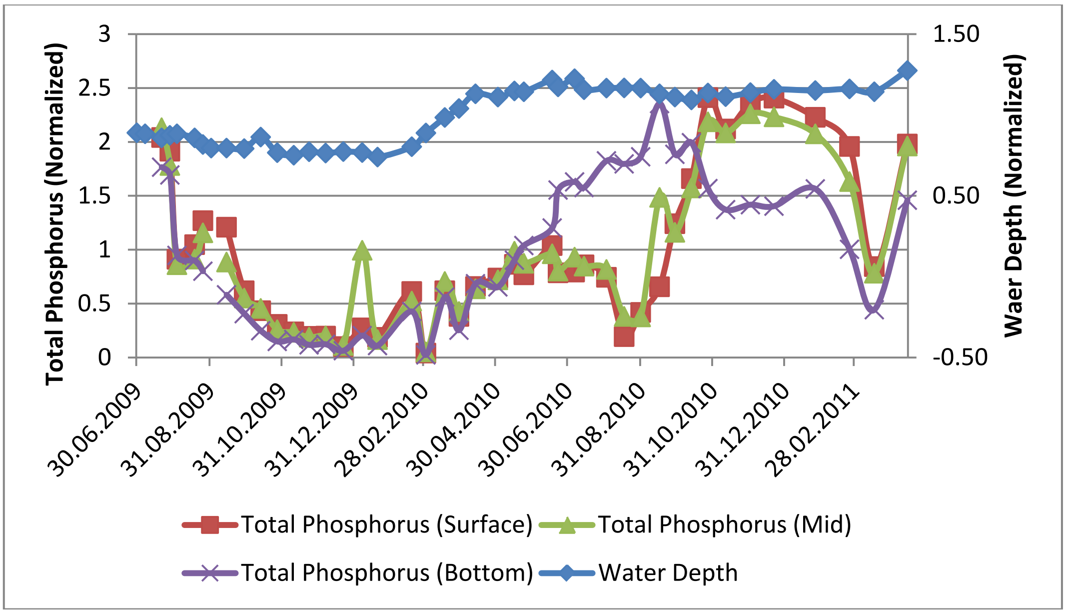


Figure 4.4: Total-P vs. Water Depth (Normalized) for Lake Average

Surface, mid-depth and bottom measurements for water depth are not applicable. Change of water depth with respect to time in Lake Eymir is given in Appendix E. Figure 4.4 shows graph of normalized Total-P values at different depths and normalized average water depth with respect to time. Results from Surface – 3 PCA and Mid – 3 PCA also do not show any correlation for theses parameters.

Results from Bottom – 3 PCA show 0,397 positive correlation for these parameters. Since we know that as ratio of sediment surface/water depth decreases, phosphorus release is expected to increase. It is seen from Figure 4.4 that bottom layer phosphorus concentrations increase after the lake is flooded by Lake Mogan in March 2010. This could be due to settling of a water layer by density difference.

4.1.3.2. Secchi Depth

Change of secchi depth with respect to time in Lake Eymir is given in Appendix E. The reason behind this increase in Secchi depth is similar to reasons increasing water depth. In March 2010 and 2011, Secchi depth has increased drastically as a result of flooding from Lake Mogan and clear water entrance to the lake through precipitation and melting of snow. Since Secchi depth is a sign of water clarity, it was affected from clear water entrance.

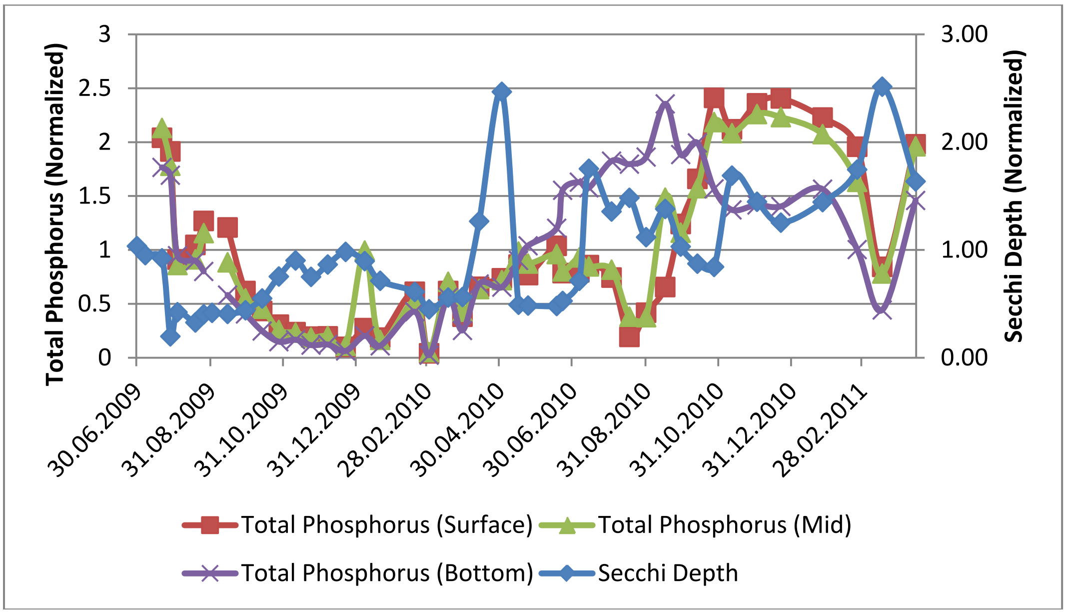


Figure 4.5: Total-P vs. Secchi Depth (Normalized) for Lake Average

Surface, mid-depth and bottom measurements for Secchi depth are not applicable. Figure 4.5 shows graph of normalized Total-P values at different depths and normalized average Secchi Depth with respect to time. Results from PCA do not show any correlation between two parameters. However, there is a negative relationship between Total-P and Secchi Depth. The increase in Secchi depth can affect light penetration.

4.1.3.3. Total Suspended Solids

TSS concentration is a sign of algal activity as well as particles in water. Similar to water depth and Secchi depth, TSS concentration has been affected by floods and heavy precipitation in March 2010 and 2011.

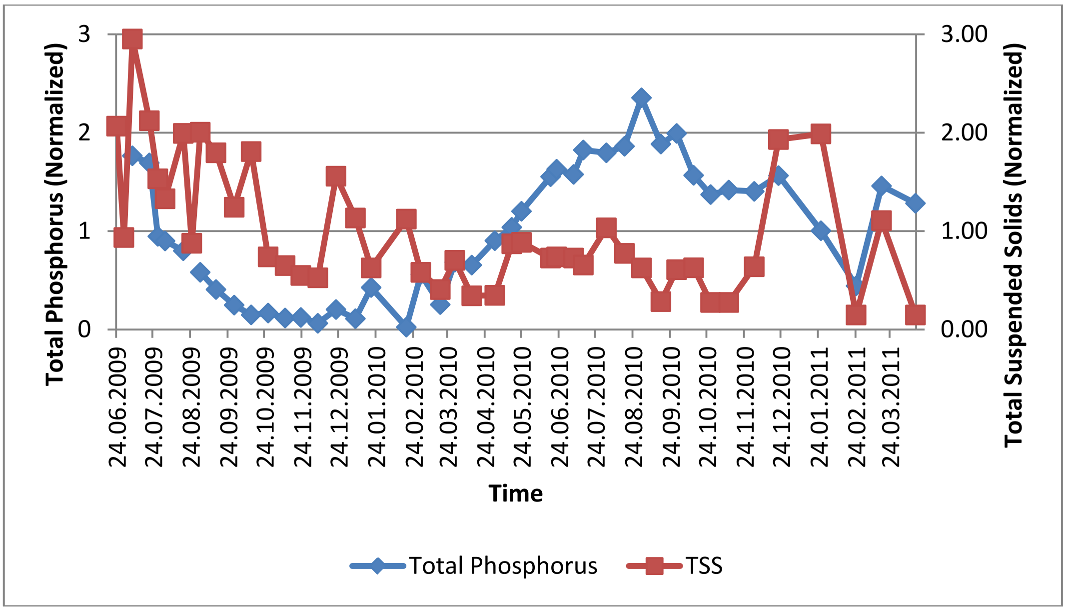


Figure 4.6: Total-P vs. TSS (Normalized) For Bottom Samples

Change of TSS with respect to time in Lake Eymir is given in Appendix E. It is seen that TSS concentrations decrease in time and cannot reach previous years value. Figure 4.6 shows graph of normalized Total-P and TSS with respect to time for average data set. By looking at normalized graph, there is a positive relationship until October 2010 between Total-P and TSS. Results from PCA do not show any correlation between two parameters.

October 2010 is a critical date for the relationship of TSS data with Total-P data. We know that stratified conditions started In March 2010 and were present until the end of summer in 2010. Correlation between Total-P and TSS concentrations might be disturbed after summer 2010 due to mixing. Increasing phosphorus concentration in bottom layer despite of the fact that TSS concentrations decreasing shows that phosphorus concentration increase in bottom layer may not be related to suspended particles.

4.1.3.4. Turbidity

Change of turbidity with respect to time in Lake Eymir is given in Appendix E. If we compare the pattern followed by turbidity, turbidity change is similar to TSS concentration. Both the turbidity and TSS concentration are signs of microbiological activity. It is clearly seen that turbidity increases with microbiological activity in summer and decreases in autumn. Differing from TSS concentration, turbidity is slightly affected by floods and heavy precipitation in March 2010 and 2011.

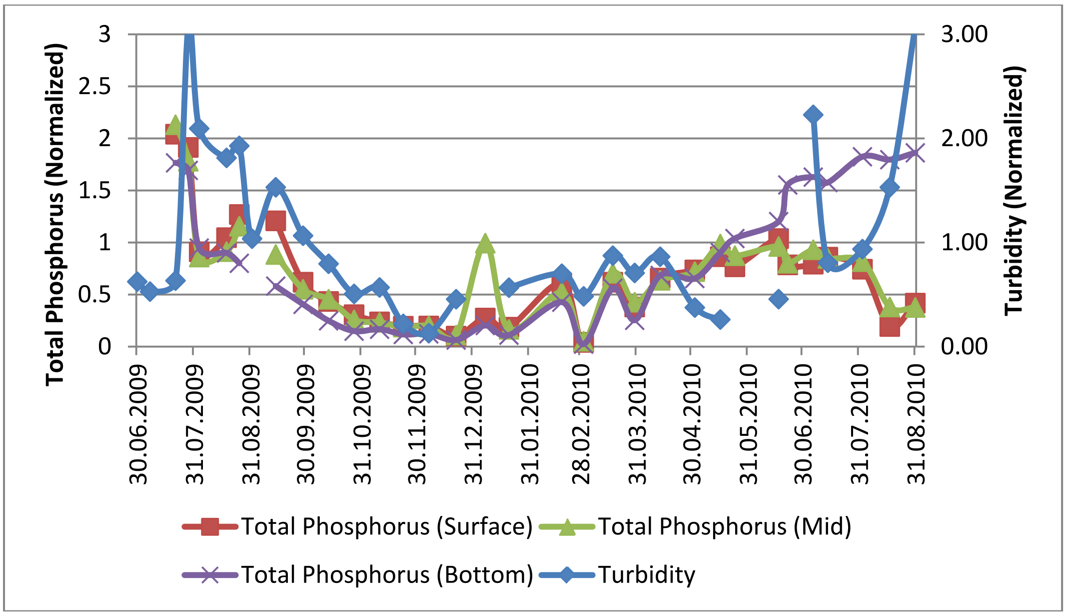


Figure 4.7: Total-P vs. Turbidity (Normalized)

Surface, mid-depth and bottom measurements for turbidity are not applicable. Figure 4.7 shows graph of normalized Total-P for various depths and average normalized turbidity with respect to time. By looking at normalized graph, positive relationship between Total-P and Turbidity can be observed. PCA could not be applied between these two parameters since data after August 2010 is missing. Increase of Total-P with increasing turbidity can be due to particles carrying phosphorus source releasing from sediment layer. Turbid water may be a sign of mixing at the bottom of the lake. If particles from sediment layer are released into water, they will surely increase Total-P concentration. Increasing turbidity in summer 2010 could be a sign of stratification. Turbidity is the best tracer for Total-P changes in Lake Eymir.

4.1.3.5. Temperature

It is clearly seen from Figure 4.8 that only seasonal changes affect the temperature change in Lake Eymir. Since temperature difference in shallow lakes is important for turn-over mechanism, we should have a look at surface and bottom water temperatures difference. When the temperature difference is greater than a few centigrade degrees, there is an increase probability of turn-over by mixing of heated surface layer and colder bottom layer. By looking at Figure 4.8, we can conclude that there has been a turnover after summer 2010 since difference between bottom and surface phosphorus concentrations disappeared.

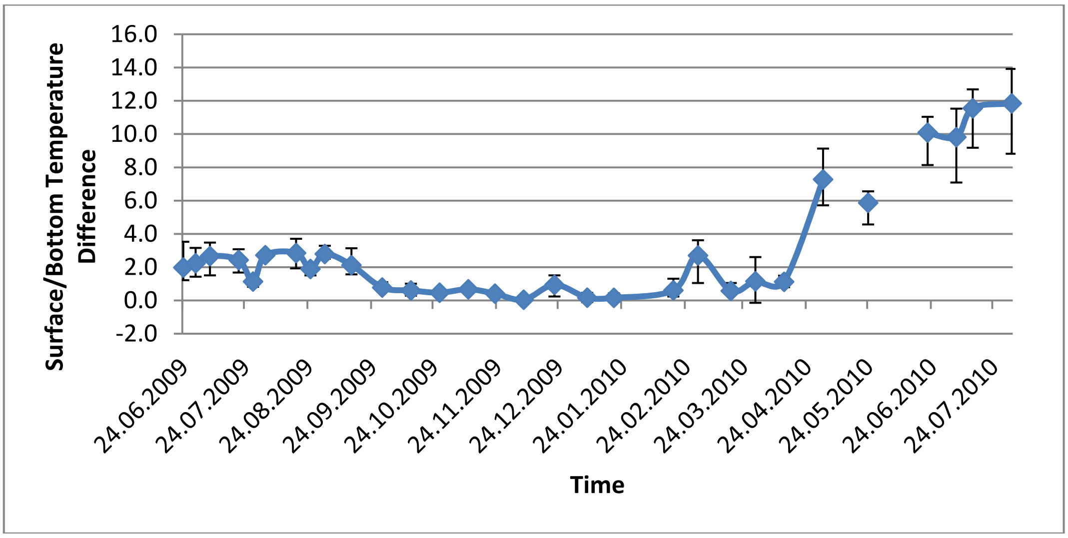


Figure 4.8: Surface-Bottom Temperature Difference Graph for Lake Average

Change of temperature with respect to time in Lake Eymir is given in Appendix E. Figure 4.9 shows graph of normalized Total-P and Temperature with respect to time for bottom data set. By looking at normalized graph, positive relationship between Total-P and Temperature can be observed. Also PCA results for temperature show 0,487 positive correlance for Bottom – 3 data set. Water is trapped at the bottom of the lake so that there is limited mixing between water layers. This causes an increase in bottom Total-P concentration. Also high temperature provides necessary conditions for microorganism growth. Under excess growth, microorganisms can uptake phosphorus from sediment layer and cause an increase in Total-P concentration. However, PCA results for temperature do not show any correlance for Surface – 3, Mid – 3, or Average – 3 data set. This can be due to lack of data after August 2010.

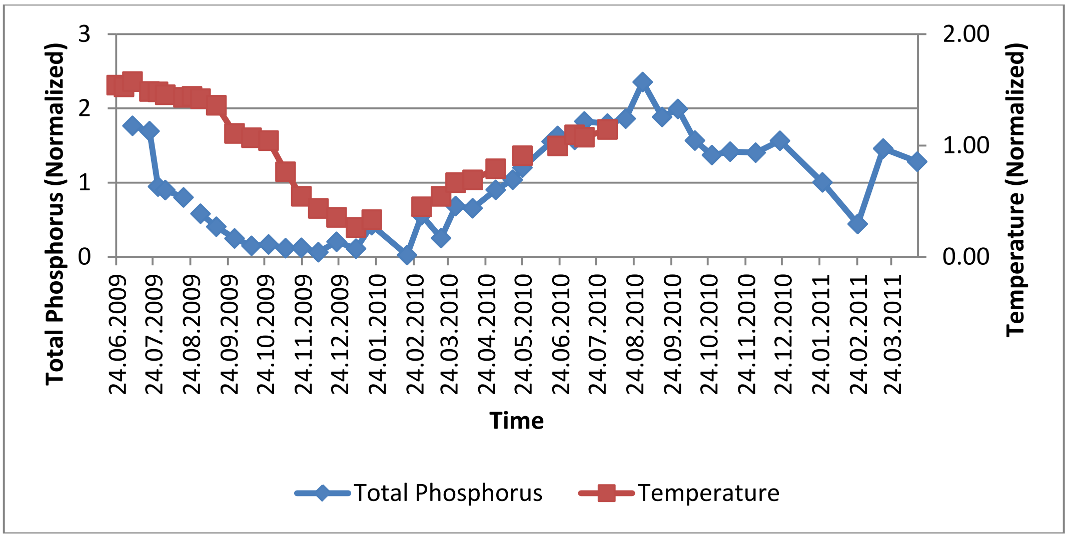


Figure 4.9: Total-P vs. Temperature (Normalized) for Bottom Samples

4.1.3.6. Conductivity

Change of conductivity with respect to time in Lake Eymir is given in Appendix E. Figure 4.10 shows graph of normalized Total-P and Conductivity with respect to time for bottom data. Results from PCA do not show any correlation for these parameters. It is seen from the graph that conductivity was negatively related to phosphorus concentrations before floods in 2010. After this point a sharp decrease takes place and this might be due to characteristics of water in Lake Mogan.

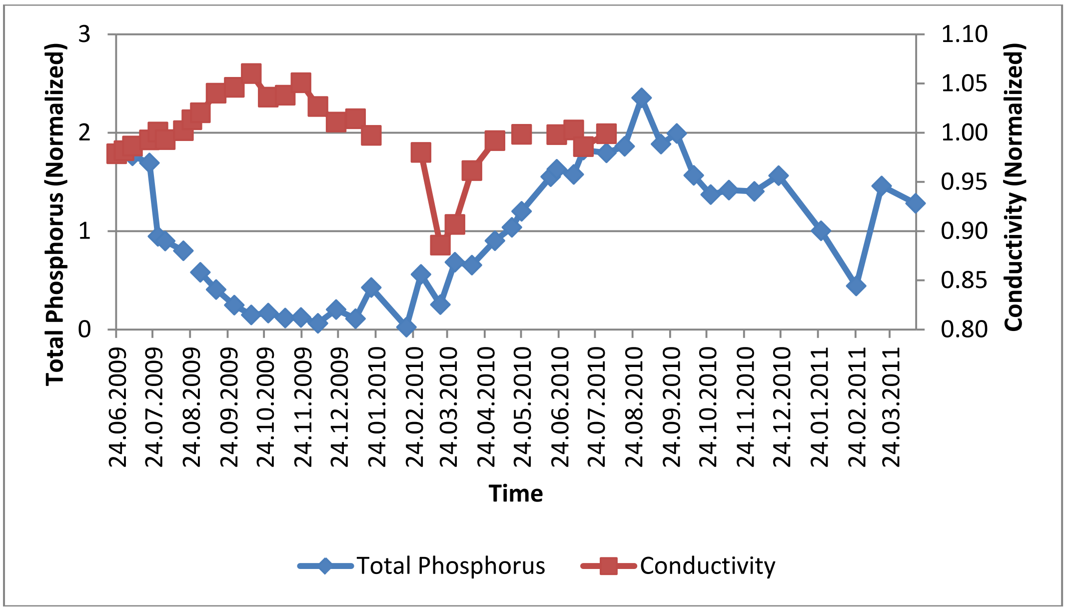


Figure 4.10: Total-P vs. Conductivity (Normalized) for Bottom Samples

4.1.3.7. pH

Change of pH with respect to time in Lake Eymir is given in Appendix E. pH can be easily affected by CO_2 changes due to photosynthesis and respiration. In order to understand how pH values fluctuate at a certain value, alkalinity of Lake Eymir must be investigated since it acts as a buffer solution in lake. Alkalinity is evaluated in Section 4.1.2.8.

Figure 4.11 shows graph of normalized Total-P and pH with respect to time for bottom data. A negative relationship between ph and phosphorus concentrations is observed. Results from Bottom – 3 PCA show -0,558 correlation for these parameters. High pH values keep the sediment phosphorus from releasing to bottom water layer.

Results from average, surface and mid-depth PCA also show negative correlation for these parameters. High pH values in Lake Eymir favors precipitation of phosphorus by Ca. Calcium precipitates are known as permanent bounds and acidic conditions are required to break phosphorus bonds with Ca. Correlation of mid-depth is not as strong as surface correlation. This might be due to higher amount of phosphorus availability at the bottom layer with respect to surface.

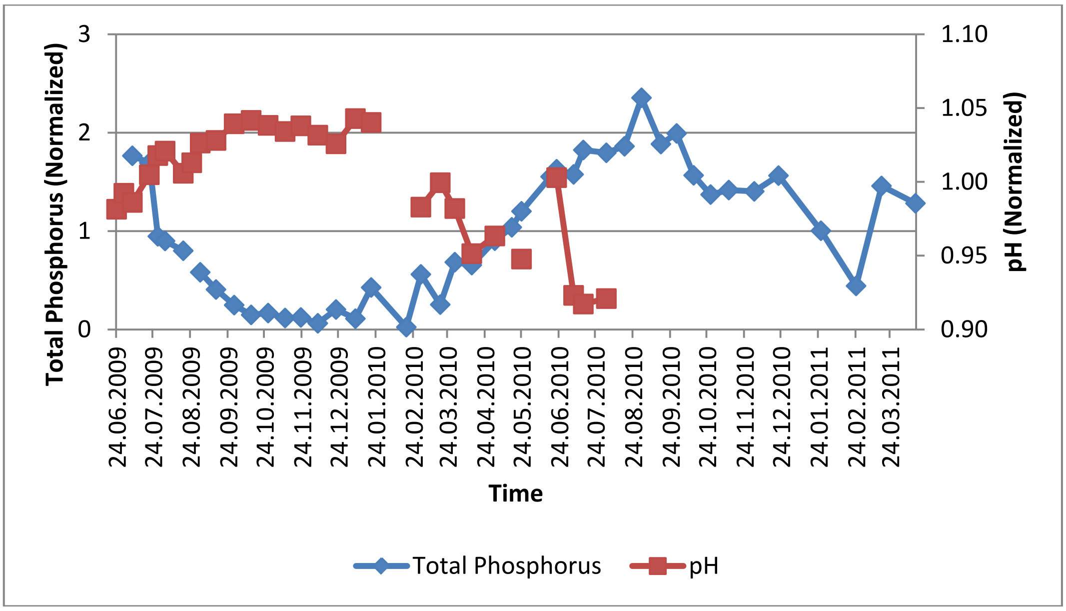


Figure 4.11: Total-P vs. pH (Normalized) for Bottom Samples

4.1.3.8. Alkalinity

The average alkalinity value has a seasonal pattern which decreases in winter and increases slowly through spring and summer. Change of alkalinity with respect to time in Lake Eymir is given in Appendix E. A high value of alkalinity is usually seen at water bodies with high nutritions. High alkalinity can be a sign of calcareous soil as well.

Figure 4.12 shows graph of normalized Total-P and alkalinity with respect to time for bottom data. Since normalization for alkalinity does not create any distinguishable pattern, it is hard to comment on relationship between Total-P and Alkalinity by looking at normalized graph. Result from Bottom – 3 PCA show 0,419 positive correlation for these parameters. Alkalinity is important for keeping lake water pH at a certain value. High alkalinity provides high pH values and prevents phosphorus releasing from sediment layer. Results from average, surface and mid-depth PCA also shows positive correlation for these parameters.

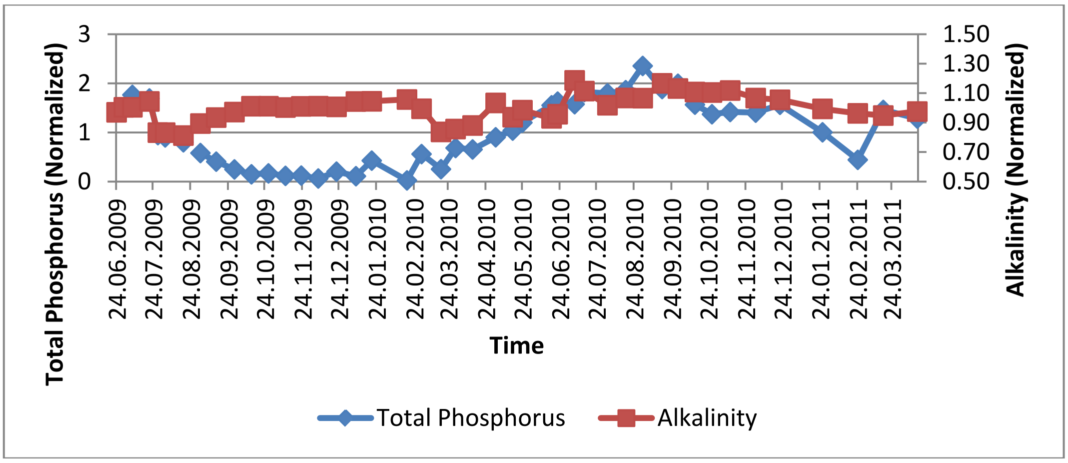


Figure 4.12: Total-P vs. Alkalinity (Normalized) for Bottom Samples

4.1.3.9. Dissolved Oxygen

Figure 4.13 shows graph of normalized Total-P and DO with respect to time for lake bottom. Negative pattern between these two parameters is observed from this graph. Results from Bottom – 3 PCA show 0,463 negative correlation for these two parameters. Negative correlation between these two parameters shows that in the absence of oxygen, phosphorus is released from sediment layer. Fe(III) may be reduced to Fe(II) and Fe(II) cannot bind to phosphorus. Also phosphorus-iron bonds are broken by heterotrophs under anaerobic conditions to supply phosphorus.

Change of DO with respect to time in Lake Eymir is given in Appendix E. It is seen in Figure 4.13 that phosphorus is released in summer 2010. At that time frame, oxygen is limited and uptake of DO can be observed in Figure 4.14. Figure 4.14 shows the change in DO/DO_S with respect to time. When DO/DO_S is below 1, Do level is below saturation and DO becomes limited. When it is above 1, super saturation is observed, which can be as a result of turbulence but mainly algal activity.

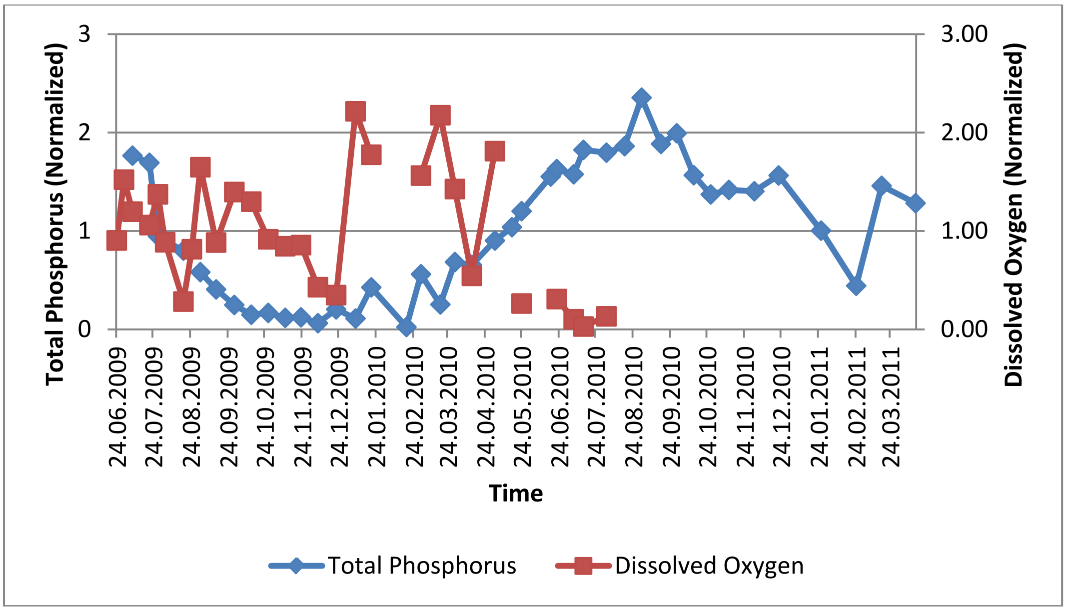


Figure 4.13: Total-P vs. DO (Normalized) for Bottom Samples

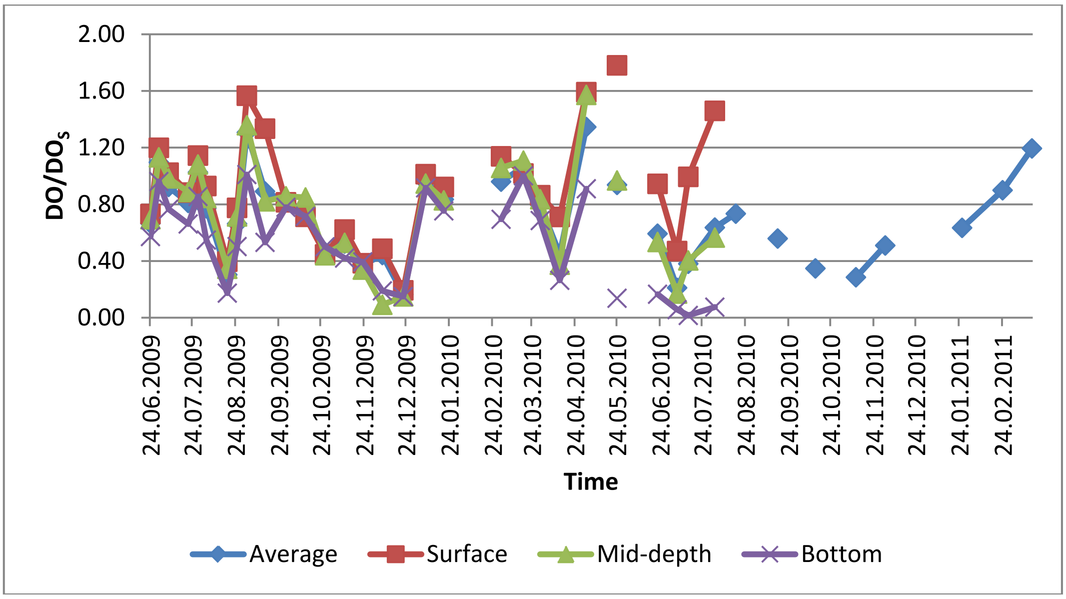


Figure 4.14 : DO/DO$_S$ Graph for Lake Average

4.1.3.10. Chlorophyll-a

If we compare the distribution of Chl-a and DO over time, similarities in profiles can be easily observed. However, concentration of Chl-a is not only dependant on DO but photosynthetically active radiation (PAR) is also important for biomass growth. Change of Chl-a with respect to time in Lake Eymir is given in Appendix E. PAR data is given in Section 4.1.2.11.

Figure 4.15 shows graph of normalized Total-P and Chl-a with respect to time for bottom data. By looking at normalized graph, we can conclude that they have a positive relationship throughout the sampling process. Results from Bottom – 3 PCA show 0,429 positive correlation for these two parameters.

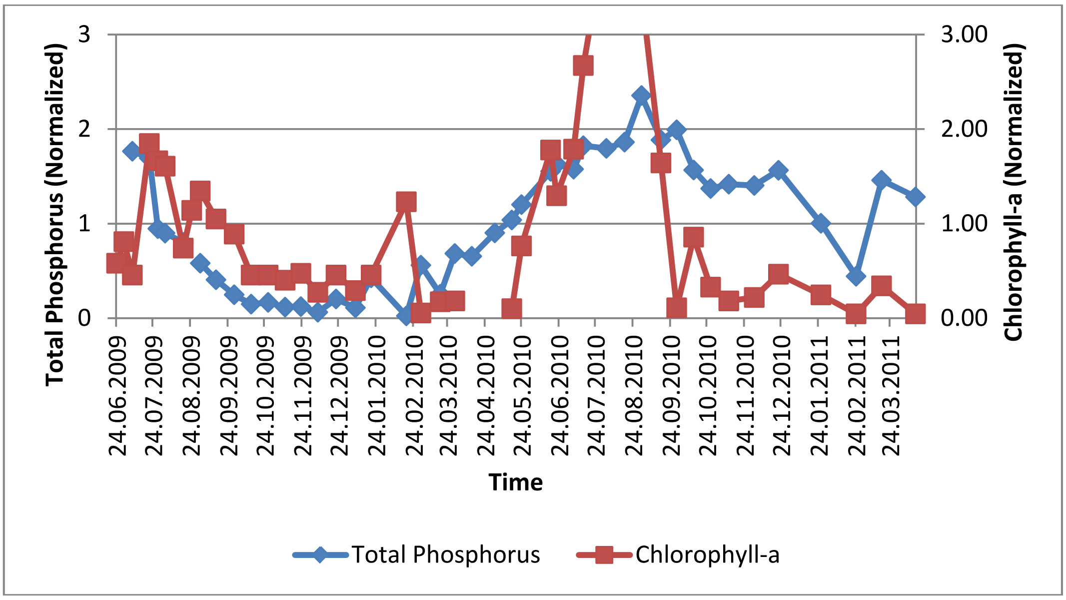


Figure 4.15: Total-P vs. Chl-a (Normalized) for Bottom Samples

4.1.3.11. PAR

Even cloudy weathers can affect PAR values, PAR ratio gives an idea about light permeability in Lake Eymir. Light permeability and secchi disk depth decreases with increasing turbidity. The increase in PAR values in summer 2009 could not be observed in 2010, and this is thought to be a result of mixing in lake. Change of PAR with respect to time in Lake Eymir is given in Appendix E.

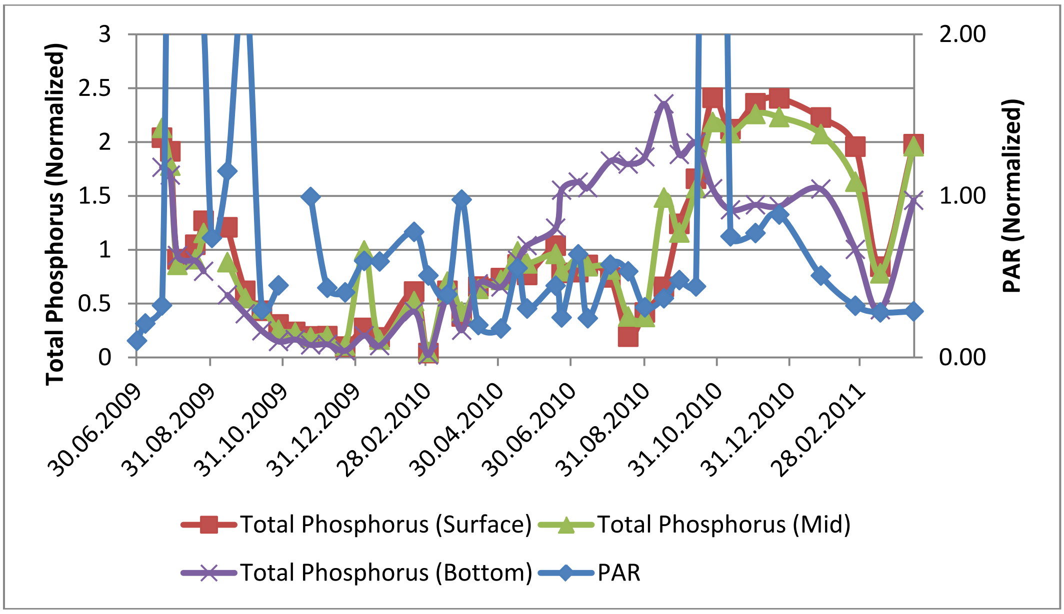


Figure 4.16: Total-P vs. PAR (Normalized)

Surface, mid-depth and bottom measurements are not applicable for PAR data. Figure 4.16 shows graph of normalized Total-P at various depths and normalized average PAR with respect to time. By looking at normalized graph, we can predict that they have a positive relationship throughout the sampling process. Results from PCA also show positive weak correlation for these two parameters.

We can relate change of Chl-a concentrations at water samples to phosphorus concentrations directly. When light is available, growth takes place in lake and available phosphorus is used in the process. The rate of growth is limited with the available phosphorus concentrations since there is not any other source.

Low light permeability is always a problem at bottom water layer. Since we cannot compare any changes between light presence and absence, having no correlation between them is not surprising.

4.1.3.12. TKN

Change of TKN with respect to time in Lake Eymir is given in Appendix E. Accumulation of nitrogen could be observed from this graph. Figure 4.17 shows graph of normalized Total-P and TKN with respect to time for bottom data set. Due to fluctuating pattern between these two parameters, it is hard to comment on their relationship by looking at normalized graph. Results from Bottom – 3 PCA show 0,429 positive correlation for these two parameters. In order to evaluate relationship of phosphorus with nitrogen, NH_4-N, NO_2-N and NO_3-N is evaluated.

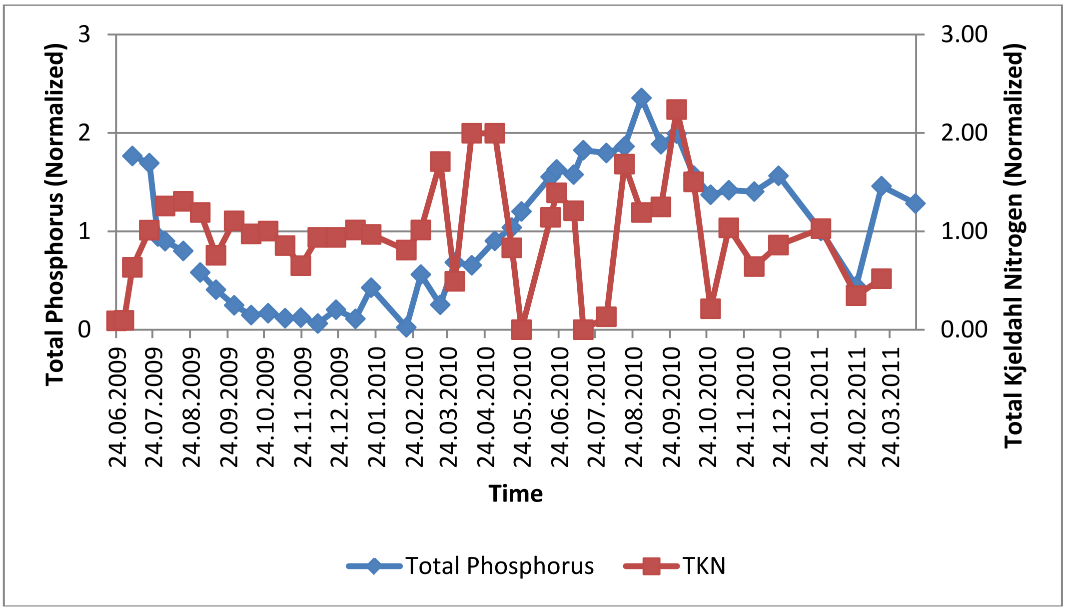


Figure 4.17: Total-P vs. TKN (Normalized) for Bottom Samples

4.1.3.13. NH_4-N

Change of NH_4-N with respect to time in Lake Eymir is given in Appendix E. Figure 4.18 shows graph of normalized Total-P and NH_4-N with respect to time for lake bottom. By looking at normalized graph, we can say that they have a positive relationship throughout the sampling process. Results from Bottom – 3 PCA also show 0,659 positive correlation for these two parameters. Also PCA results from other depths are also showing positive relationship.

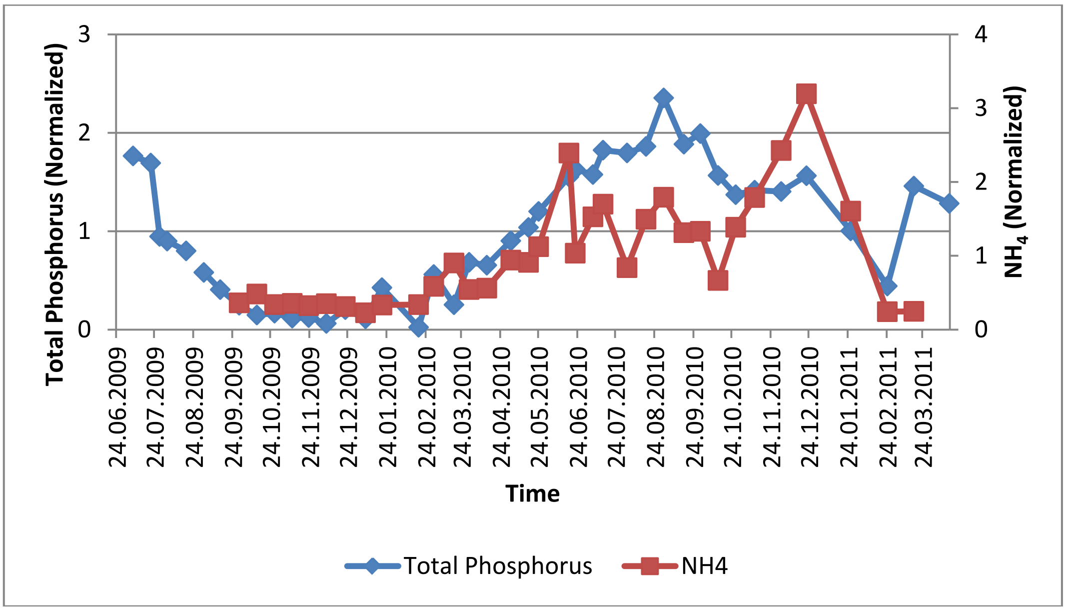


Figure 4.18: Total-P vs. NH_4-N (Normalized) for Bottom Samples

4.1.3.14. NO_2-N

Change of NO_2-N with respect to time in Lake Eymir is given in Appendix E. Figure 4.19 shows graph of normalized Total-P and NO_2-N with respect to time for bottom data. A correlation between these two parameters could not be observed both from normalization pr PCA.

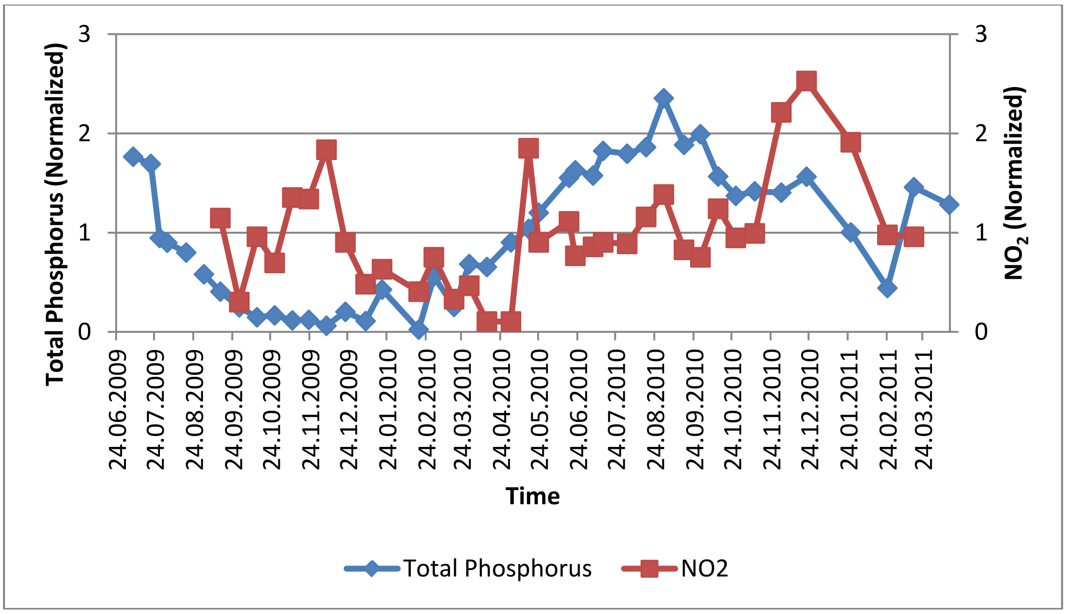


Figure 4.19: Total-P vs. NO_2-N (Normalized) for Bottom Samples

4.1.3.15. NO_3-N

Change of NO_3-N with respect to time in Lake Eymir is given in Appendix E. Figure 4.20 shows graph of normalized Total-P and NO_3-N with respect to time for bottom data. By looking at normalized graph, we can predict that they have a positive relationship throughout the sampling process. Results from Bottom – 3 PCA show 0,608 positive correlation for these two parameters while no correlation is observed at other depths.

NO_3-N is a stronger oxidizer than oxygen. When DO is low NO_3-N is used in place of oxygen and can penetrate deeper into sediment layer. This reaction will release more phosphorus than aerobic conditions. Since more organic matter is required to be fermented in anaerobic conditions in order to acquire same energy with respect to aerobic conditions, greater portion of phosphorus releases from sediment. High concentrations of NO_3-N, NH_4-N and TKN can be due to increased biological activity and increased nutrient inputs to lake.

By evaluation of TKN, NH_4-N, NO_2-N and NO_3-N concentration graphs, we can say that nutrition balance has been greatly disturbed by floods from Lake Mogan and heavy precipitation in springs. Excess NH_4-N and NO_3-N concentrations are signs of nutrient inputs and high biological activity in lake. High activity in summer 2010 and DO/DO_S ratio is also a sign of this input.

A seasonal pattern can be observed in NO_3-N concentration. Average NO_3-N concentrations decrease gradually during summer and increase sharply at the beginning of summer due to biological activity in lake.

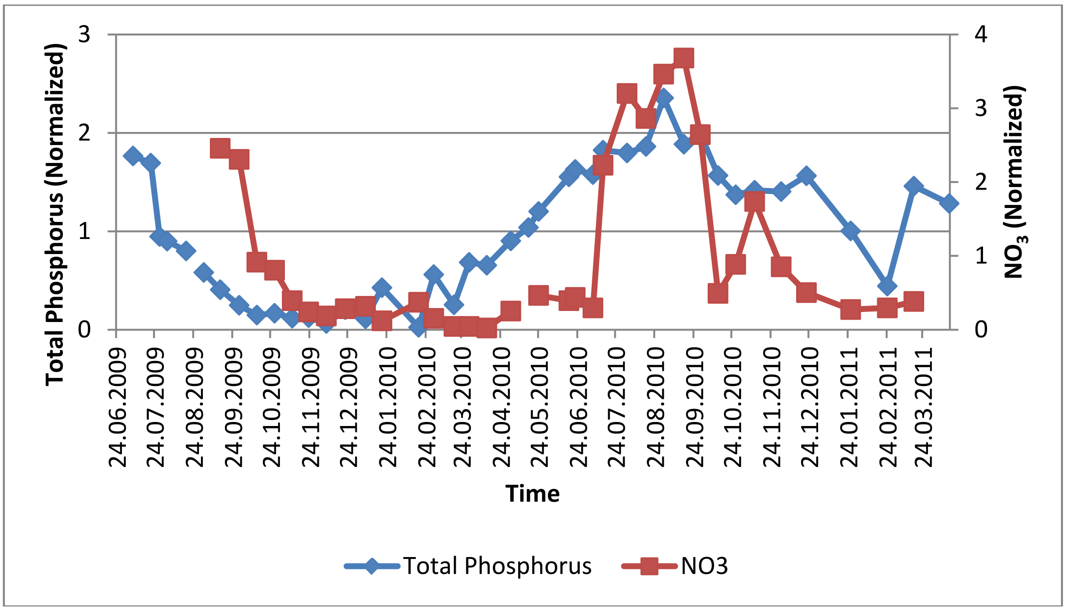


Figure 4.20: Total-P vs. NO_3-N (Normalized) for Bottom Samples

4.1.3.16. Total Phosphorus

Figure 4.21 shows the change of surface Total-P concentration in Lake Eymir for surface samples. Error bars are showing maximum and minimum surface Total-P concentrations for five different sampling locations. Maximum surface Total-P concentration difference between sampling locations is 182,12 µg/L and observed in July 2009. Minimum surface Total-P concentration recorded in Lake Eymir is 4 µg/L at sampling locations two and four in February 2010 while the maximum is 346,26 µg/L at sampling location two in October 2010.

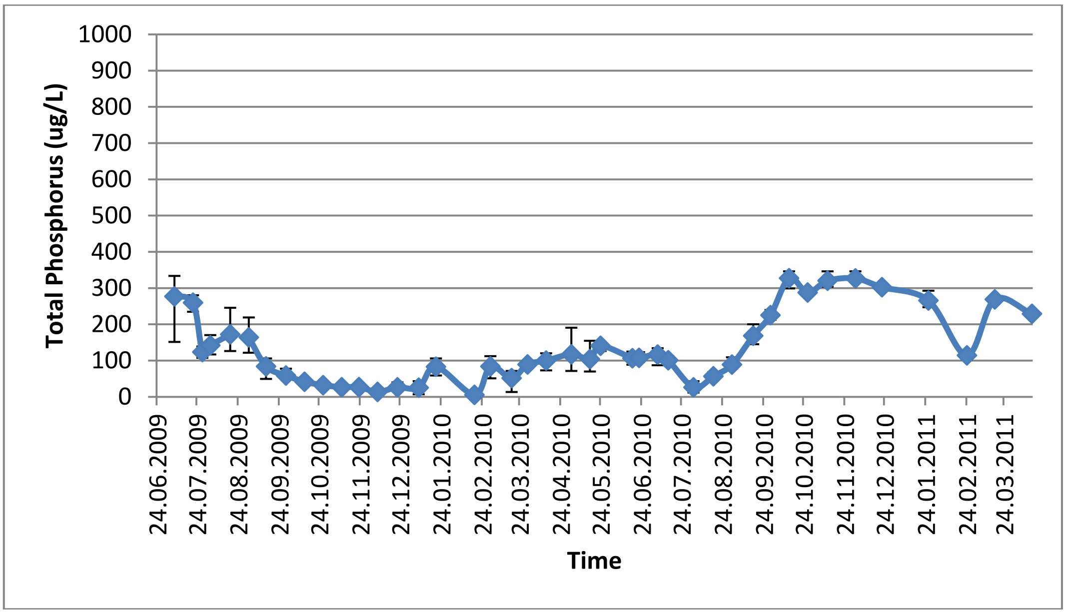


Figure 4.21: Total-P Concentration vs. Time Graph for Surface Samples

Figure 4.22 shows the change of mid-depth Total-P concentration in Lake Eymir for mid-depth data. Error bars are showing maximum and minimum mid-depth Total-P concentrations for five different sampling locations. Maximum mid-depth Total-P concentration difference between sampling locations is 580,9 µg/L and observed in December 2009. Minimum mid-depth Total-P concentration recorded in Lake Eymir is 5,57 µg/L at sampling locations one, two, three and four in February 2010 while the maximum is 600,6 µg/L at sampling location three in December 2010.

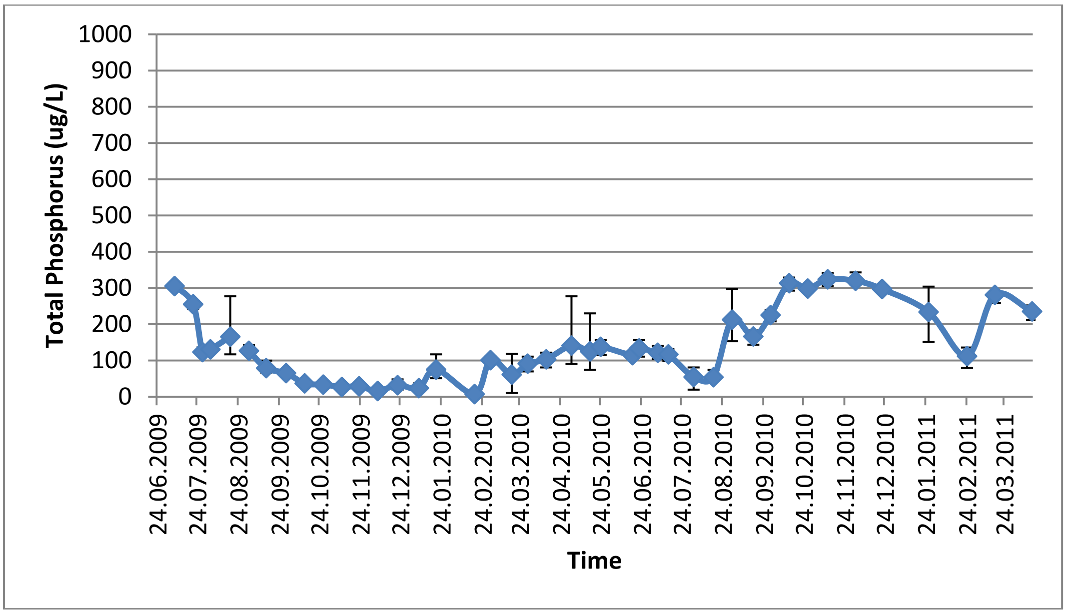


Figure 4.22: Total-P Concentration vs. Time Graph for Mid-Depth Samples

Figure 4.23 shows the change of bottom Total-P concentration in Lake Eymir for bottom data. Error bars are showing maximum and minimum bottom Total-P concentrations for five different sampling locations. Maximum bottom Total-P concentration difference between sampling locations is 723,77 µg/L and observed in September 2010. Minimum bottom Total-P concentration recorded in Lake Eymir is 4 µg/L at sampling locations three and five in February 2010 while the maximum is 895,76 µg/L at sampling location three in September 2010.

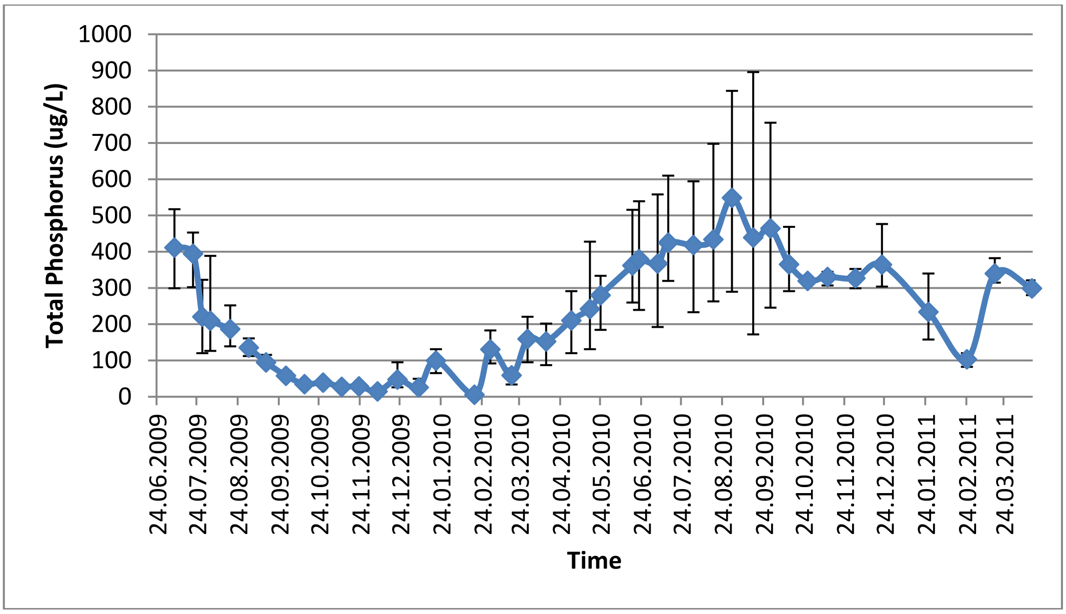


Figure 4.23: Total-P Concentration vs. Time Graph for Bottom Samples

4.1.3.17. PO_4-P

Figure 4.24 shows the change of average PO_4-P concentration in Lake Eymir for lake average. Error bars are showing maximum and minimum PO_4-P concentrations for five different sampling locations. Maximum PO_4-P concentration difference between sampling locations is 887,05 µg/L and observed in December 2009. Minimum PO_4-P concentration recorded in Lake Eymir is 7,14 µg/L at sampling location one in August 2010 while the maximum is 914,6 µg/L at sampling location three in September 2010.

By further investigation, sampling locations one, two and five have lower average PO_4-P concentrations throughout the field study by 91,90 µg/L, 115,53 µg/L and 88,70 µg/L respectively. Sampling locations two and three have an average concentration of 137,16 µg/L and 141,27 µg/L respectively.

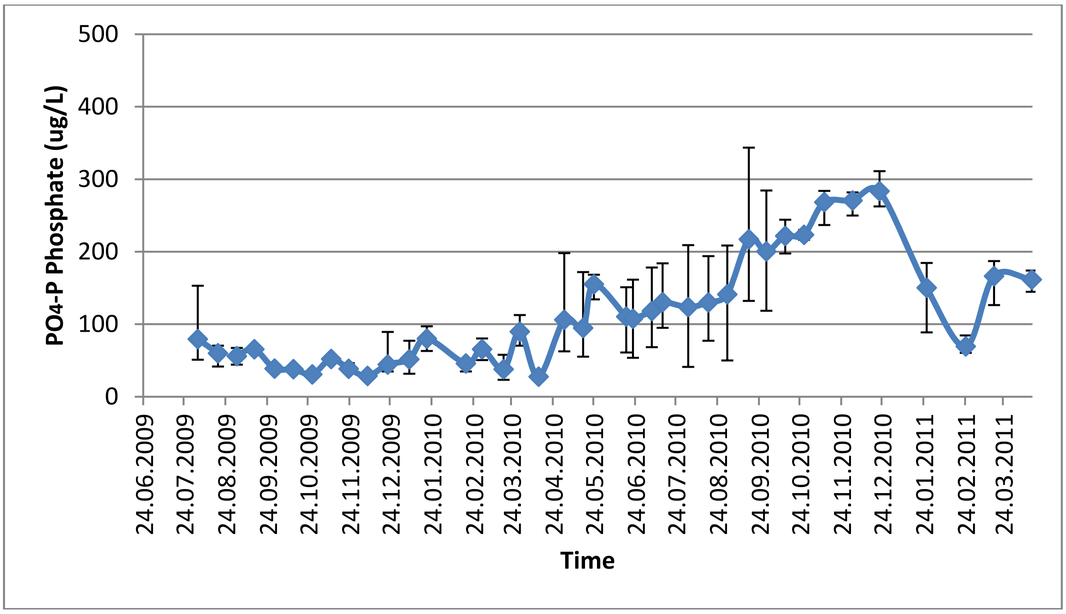


Figure 4.24: PO_4-P Concentration vs. Time Graph for Lake Average

Figure 4.25 shows the change of surface PO_4-P concentration in Lake Eymir for surface data. Error bars are showing maximum and minimum surface PO_4-P concentrations for five different sampling locations. Maximum surface PO_4-P concentration difference between sampling locations is 292,02 µg/L and observed in December 2009. Minimum surface PO_4-P concentration recorded in Lake Eymir is 7,14 µg/L at sampling location one in August 2010 while the maximum is 324,28 µg/L at sampling location three in December 2009.

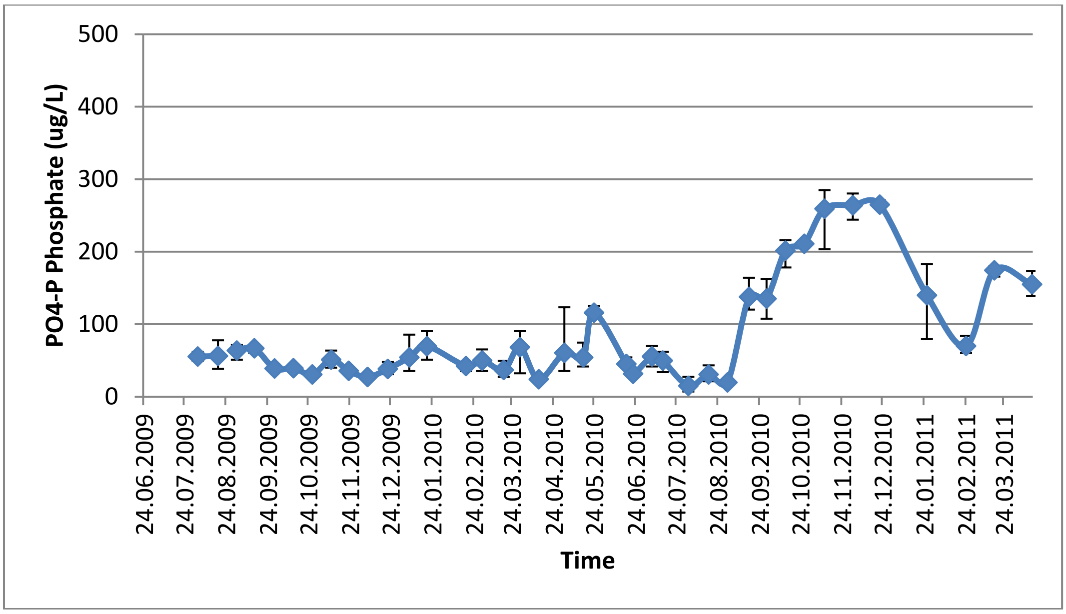


Figure 4.25: PO_4-P Concentration vs. Time Graph for Surface Samples

Figure 4.26 shows the change of mid-depth PO_4-P concentration in Lake Eymir for mid-depth data. Error bars are showing maximum and minimum mid-depth PO_4-P concentrations for five different sampling locations. Maximum mid-depth PO_4-P concentration difference between sampling locations is 887,05 µg/L and observed in December 2009. Minimum mid-depth PO_4-P concentration recorded in Lake Eymir is 10,28 µg/L at sampling location one in August 2010 while the maximum is 914,6 µg/L at sampling location three in December 2009.

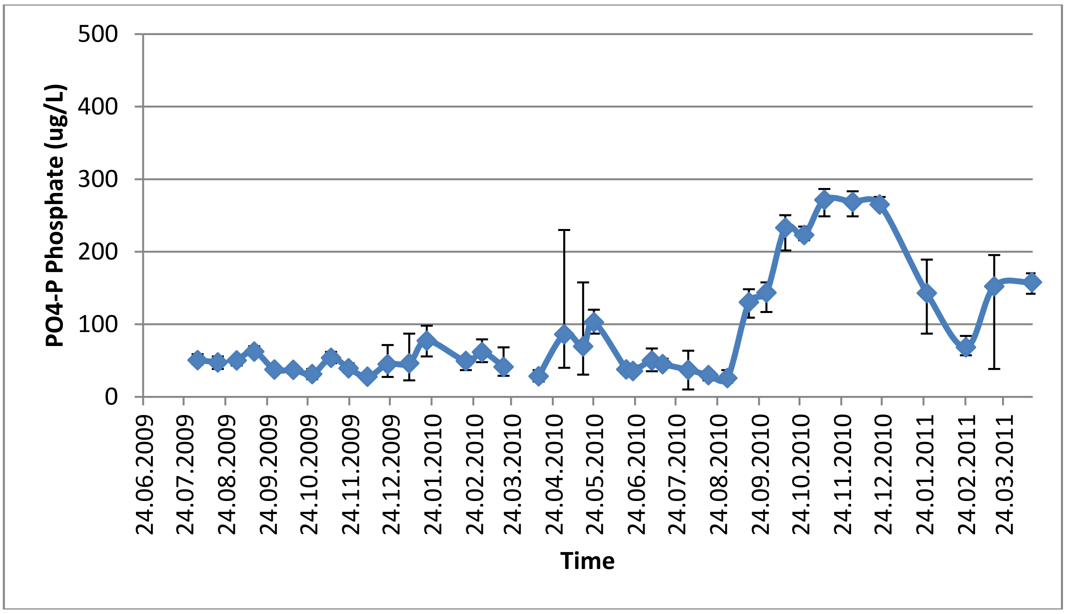


Figure 4.26: PO_4-P Concentration vs. Time Graph for Mid-Depth Samples

Figure 4.27 shows the change of bottom PO_4-P concentration in Lake Eymir for bottom data. Error bars are showing maximum and minimum bottom PO_4-P concentrations for five different sampling locations. Maximum bottom PO_4-P concentration difference between sampling locations is 640,56 µg/L and observed in September 2010. Minimum bottom PO_4-P concentration recorded in Lake Eymir is 22,84 µg/L at sampling location three in March 2010 while the maximum is 782.72 µg/L at sampling location three in September 2010.

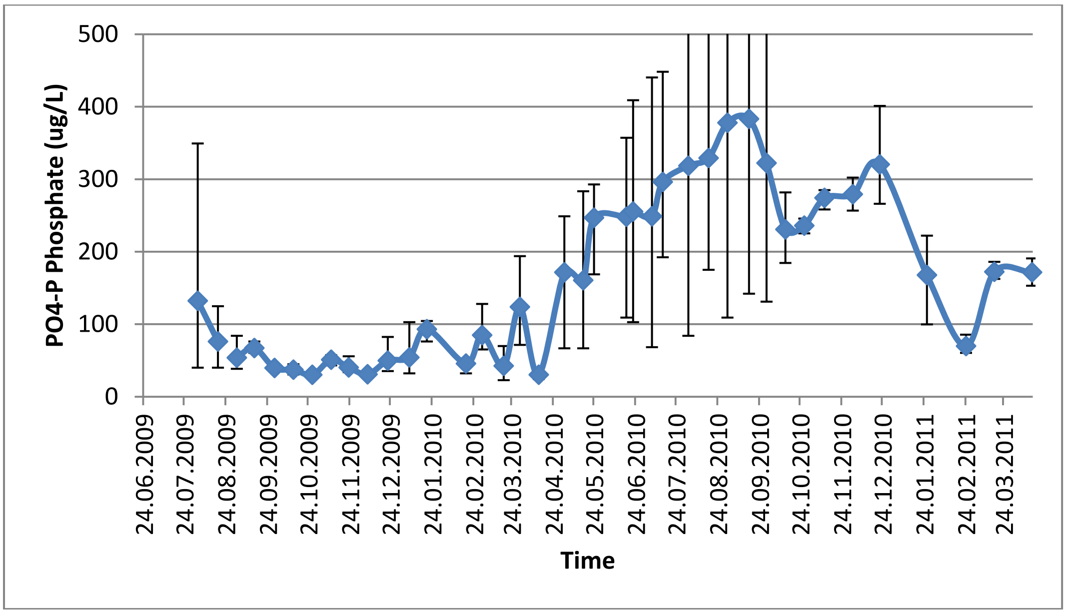


Figure 4.27: PO_4-P Concentration vs. Time Graph for Bottom Samples

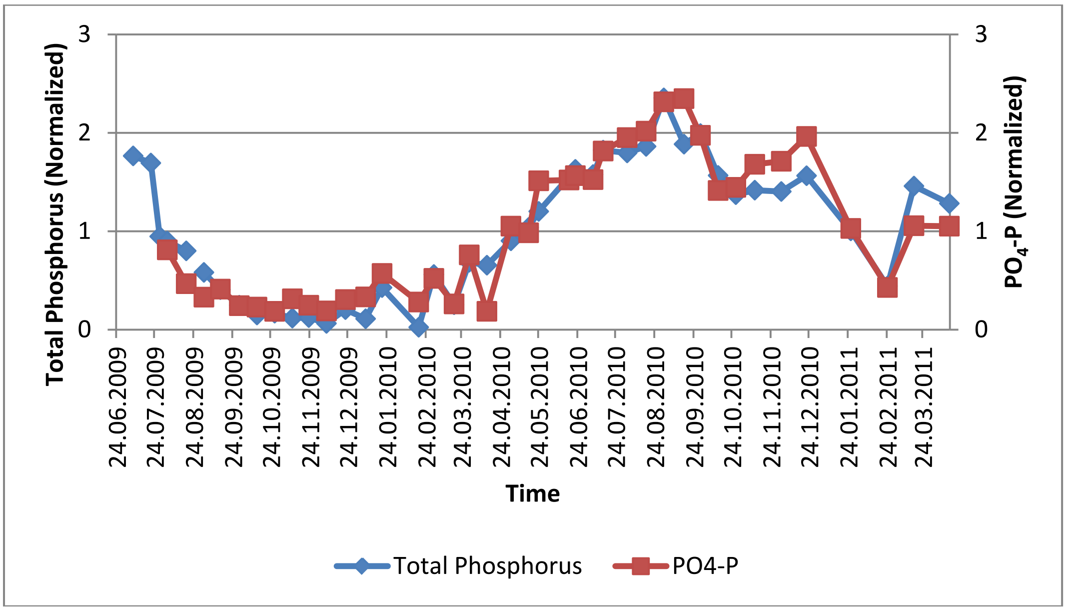


Figure 4.28: Total-P vs. PO_4-P (Normalized) for Bottom Samples

Figure 4.28 shows graph of normalized Total-P and PO_4-P with respect to time for bottom samples. PO_4-P shows near 100% fit with Total-P data as expected. Since PO_4-P is the readily available form of phosphorus in lakes, we may conclude that phosphorus released from sediment is used rapidly. Results from Bottom – 2 PCA also show 0,946 positive correlation for these two parameters.

4.1.3.18. Sediment Soluble Total Phosphorus

Figure 4.29 shows the change of average S-STP concentration in Lake Eymir. Error bars are showing maximum and minimum S-STP concentrations for five different sampling locations. Maximum S-STP concentration difference between sampling locations is 0,18 mg/gr-Dry Sediment and observed in February 2010. Minimum S-STP concentration recorded in Lake Eymir is 0,009 mg/gr-Dry Sediment at sampling location five in July and September 2010 while the maximum is 0,25 mg/gr-Dry Sediment at sampling location one in February 2010.

By further investigation, sampling locations one and five have lower average S-STP concentrations throughout the field study by 0,076 mg/gr-Dry Sediment and 0,049 mg/gr-Dry Sediment respectively. Sampling locations two, three and four have an average concentration of 0,109 mg/gr-Dry Sediment, 0,119 mg/gr-Dry Sediment and 0,099 mg/gr-Dry Sediment respectively.

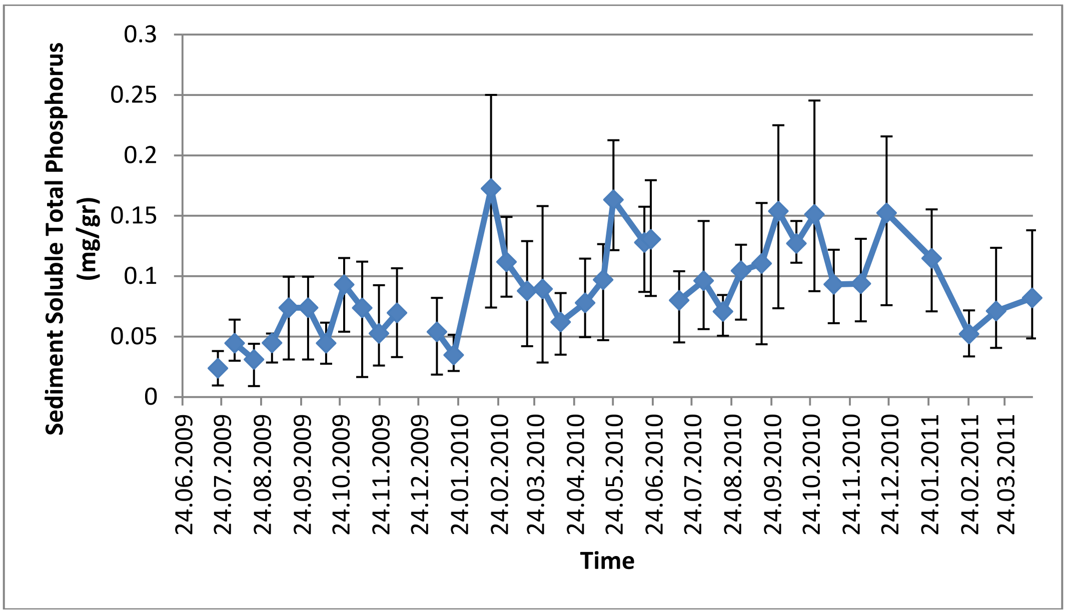


Figure 4.29: S-STP Concentration vs. Time Graph for Lake Average

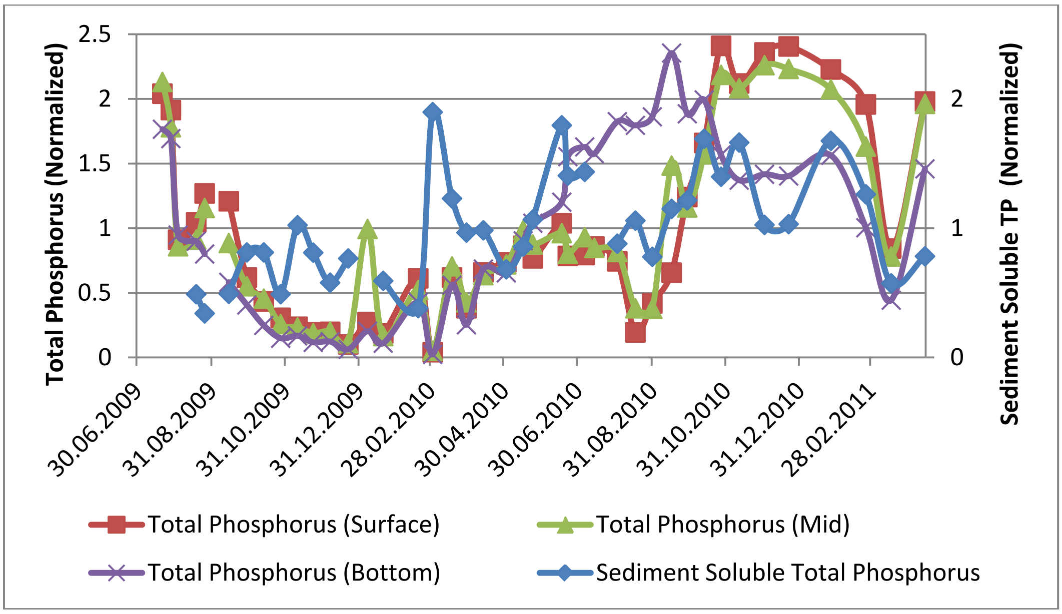


Figure 4.30: Total-P vs. S-STP (Normalized)

Bottom, mid-depth and surface measurements for S-STP are not applicable. Figure 4.30 shows graph of normalized Total-P at various depths and normalized average S-STP with respect to time. By looking at normalized graph, we can say that they have an alternating both positive and negative relationship which is not expected. Results from Bottom – 3 PCA also show 0,423 positive correlation for these two parameters. Results from Surface – 2 and Mid – 2 PCA do not show any correlation for these two parameters. Since we are looking for S-STP concentrations, an increase was expected. While adsorbed phosphate releases from sediment, it changes its form to soluble phosphorus.

4.1.3.19. Sediment Soluble PO_4-P

Figure 4.31 shows the change of average S-SP concentration in Lake Eymir. Error bars are showing maximum and minimum S-SP concentrations for five different sampling locations. Maximum S-SP concentration difference between sampling locations is 0,083 mg/gr-Dry Sediment and observed in September 2009. Minimum S-SP concentration recorded in Lake Eymir is 0,0006 mg/gr-Dry Sediment at sampling location five in March 2010 while the maximum is 0,092 mg/gr-Dry Sediment at sampling location one in September 2009.

By further investigation, sampling locations one and five have lower average S-SP concentrations throughout the field study by 0,022 mg/gr-Dry Sediment and 0,009 mg/gr-Dry Sediment respectively. Sampling locations two, three and four have an average concentration of 0,034 mg/gr-Dry Sediment, 0,039 mg/gr-Dry Sediment and 0,026 mg/gr-Dry Sediment respectively.

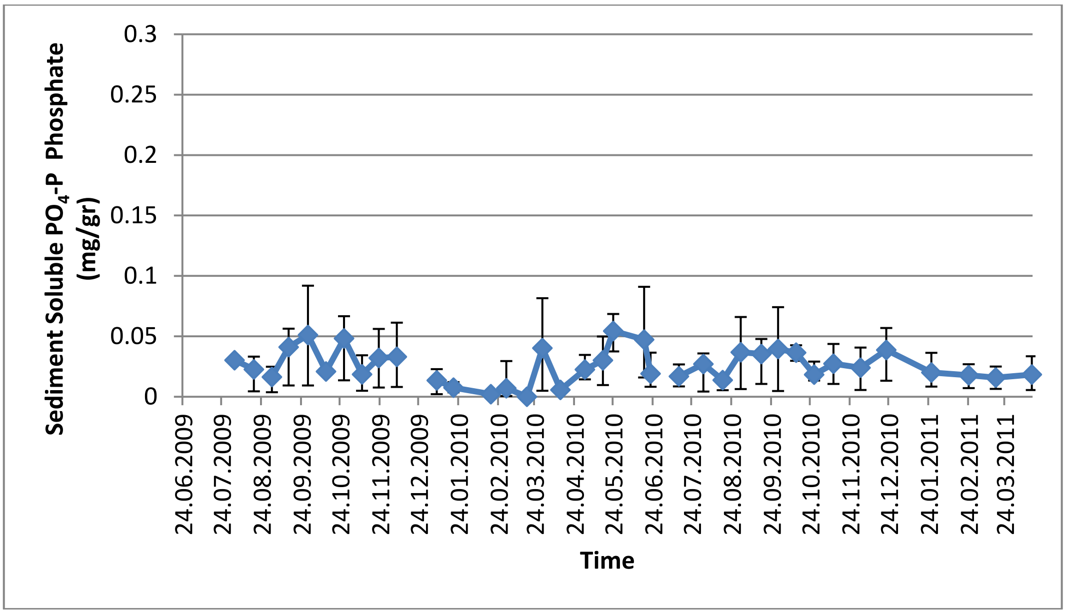


Figure 4.31: S-SP Concentration vs. Time Graph for Lake Average

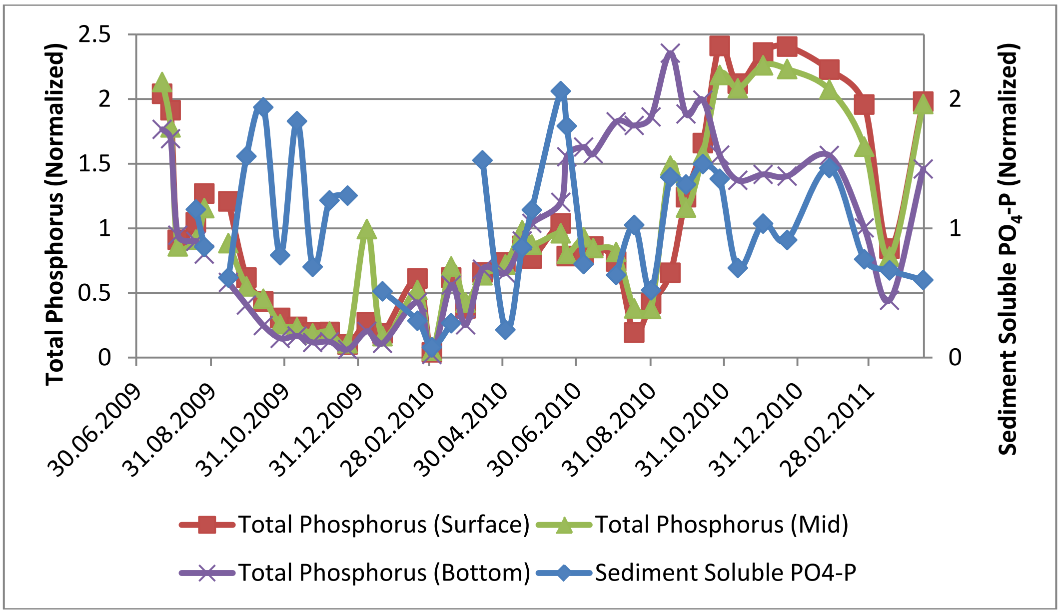


Figure 4.32: Total-P vs. S-SP (Normalized)

Bottom, mid-depth and surface measurements for S-SP are not applicable. Figure 4.32 shows graph of normalized Total-P at various depths and normalized average S-SP with respect to time. Correlations are similar to S-STP patterns with weaker correlations. These are the results of readily useable phosphorus concentrations in sediment and can change in very short amount of time due to biological activity and absorption.

4.2. Results of the Sediment Study

4.2.1. Particle Size Distribution

Freeze dried sediment samples are subjected to a sieving analysis. The first objective of the particle size distribution is to collect particles less than 63 µm for fractionation of sediment phosphorus. The second objective is to determine the distribution of particle sizes in a sample. Sample size is kept large enough to be representative (>60 gr).

Sieve analysis is a simple and cheap method for grain size distribution. Simple shaking is used for particles to pass from different sized sieves. Sieves with greater pore size are placed at the top and smallest pore sized sieve takes place at the bottom. Results of the sieve analysis are given in Appendix B.

From sieve analysis data, we can conclude that particles with less than 63 µm grain size represent samples by following weight percentages in Table 4.33.

Table 4.33: Weight Percentages of the Particles Passing Through 63µm

Sampling Point	Cumulative Weight (%)
1	: 33,09
2	: 11,04
3	: 11,03
4	: 6,26
5	: 10,18

Histogram of particle weight percentage retained on sieves is given in Figure 4.33. Figure 4.34 shows the percentage of particles passing through each sieve size. In Table 4.34, uniformity and curvature coefficients of sampling points are given. When coefficient of uniformity (C_c) is between 1 and 3, and when coefficient of curvature (C_u) is less than 6, sample is classified as poorly-graded (uniform) and if C_c is less than 1, it is classified as gap-graded. Gap graded soils could be either uniform or non-uniform. According to C_u and C_c values given in Table 4.34, sediment soil is uniform at sampling points 2, 3, 4, and 5. Point 1 deviates from this result. Figure 4.34 shows that Lake Eymir water flow acts as a plug flow with an equalization basin right before sampling point 1. Small particles settle before reaching sampling point 2 and uniformity is provided. These results support the idea of using particles less than 63 µm for phosphorus determination since it is seen from the graph that once particles settle out, they remain in their place. However, particles smaller than 63 µm can be easily mobilized.

Table 4.34: Coefficient of Uniformity and Curvature Values for Sampling Points

Sampling Location	**Coefficient of Uniformity (C_u)**	**Coefficient of Curvature (C_c)**
1	5,26	0,44
2	5,93	1,57
3	4,59	1,28
4	4,84	1,06
5	5,39	1,19

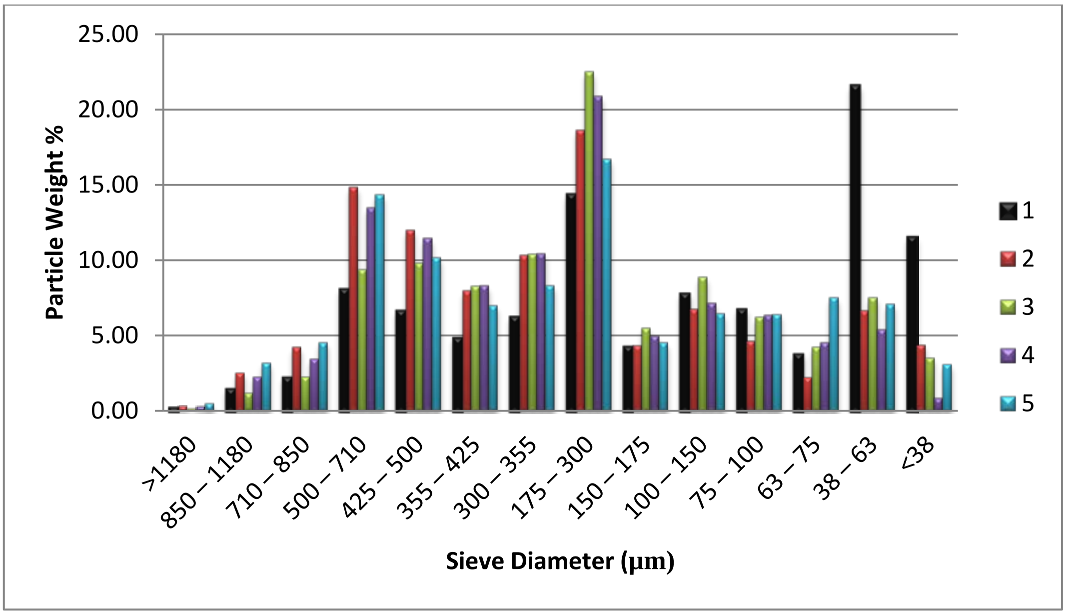


Figure 4.33: Weight Percentage of Particles Retained on Sieves

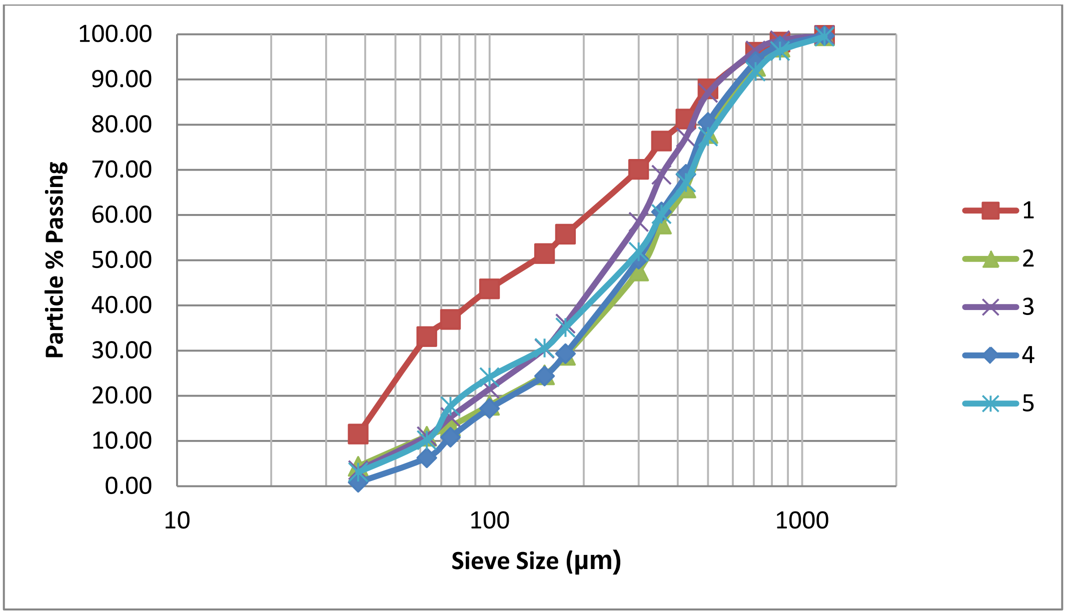


Figure 4.34: Graph of Particle Percentage Passing Through (All Sampling Points)

4.2.2. Adsorption Experiments

4.2.2.1. Phosphate Adsorption Kinetics Experiments

Freeze-dried samples are subjected to adsorption kinetics experiment and allowed to reach saturation by using solutions with high concentrations of phosphorus (1 mg/L). The purpose of this experiment is to see the saturation concentration and rate of adsorption to the sediment layer. Concentrations in water after the experiment is given in

Appendix C. Concentrations are converted to milligram phosphorus adsorption per kilogram sediment and results are shown in Figure 4.35.

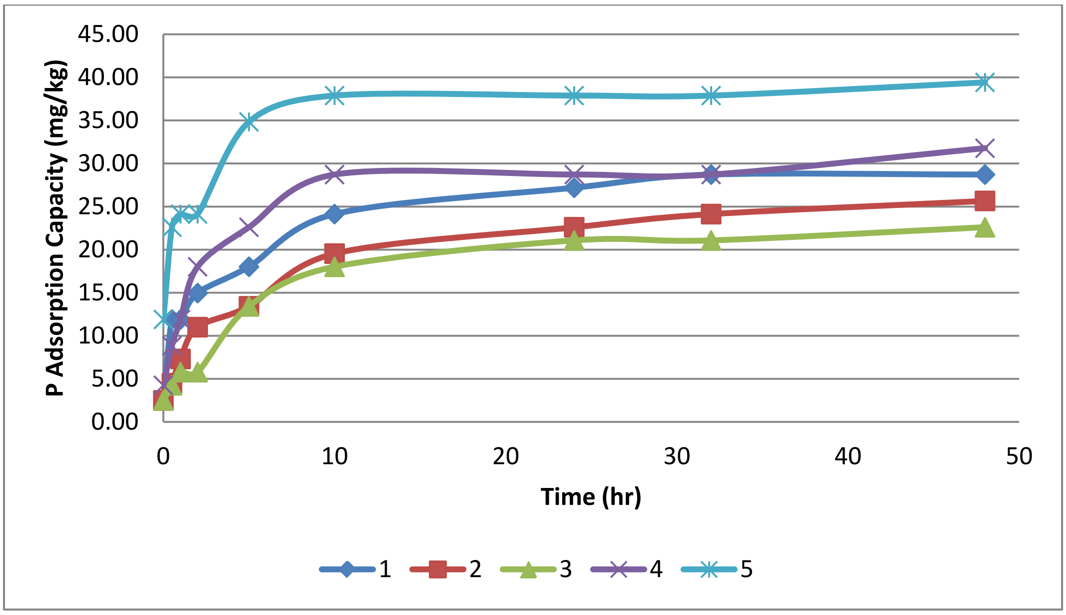


Figure 4.35: Phosphorus Adsorption Capacity of Sampling Points

From Figure 4.35, it is clearly seen that the exchange of phosphorus is mostly completed within the first 7-8 hours. On average, 30% of the exchange is completed in a 1 hour interval.

It is important to note that sediment samples used in this experiment are raw lake samples and their phosphorus content is different than each other. It is clearly seen that although sediment layer in lake is a threat for being a phosphorus source, it has not reached its phosphorus binding capacity yet.

4.2.2.2. Phosphate Adsorption Isotherm Experiments

In order to investigate in which conditions phosphorus is going to be released from or sorbed to sediment layer, adsorption isotherm experiment has been conducted. Initial and final concentration of solutions are recorded and given in Appendix C.

In order to determine equilibrium phosphorus concentrations, linearly fit graphs of Mass Adsorbed vs Initial Concentration is drawn and equilibrium concentration of each sampling point is determined from fitting equations. Then to confirm uniformity, each concentration is uniformed by using Total-P concentration at each sampling point provided from fractionation experiment. Related graphs are given in Figure 4.36 to Figure 4.40 and equilibrium concentrations are given in Table 4.35.

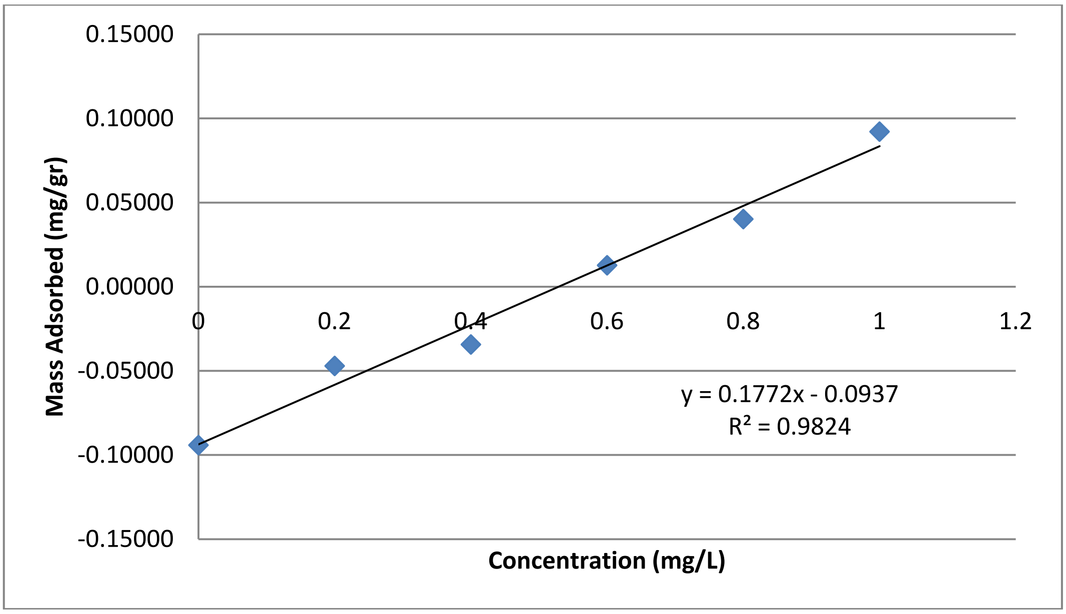


Figure 4.36: Equilibrium Graph for Sampling Point 1

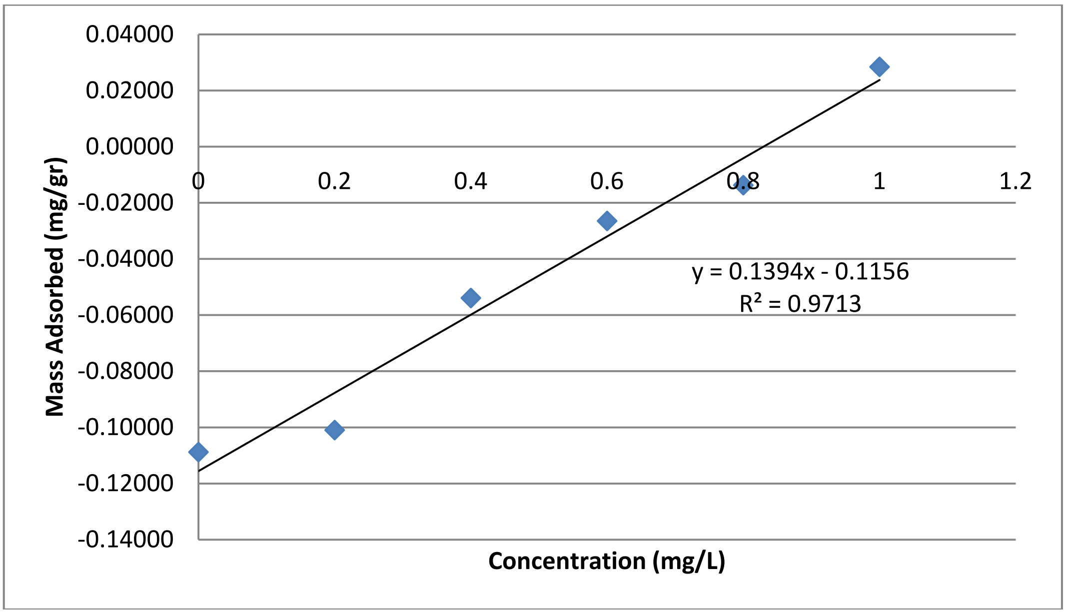


Figure 4.37: Equilibrium Graph for Sampling Point 2

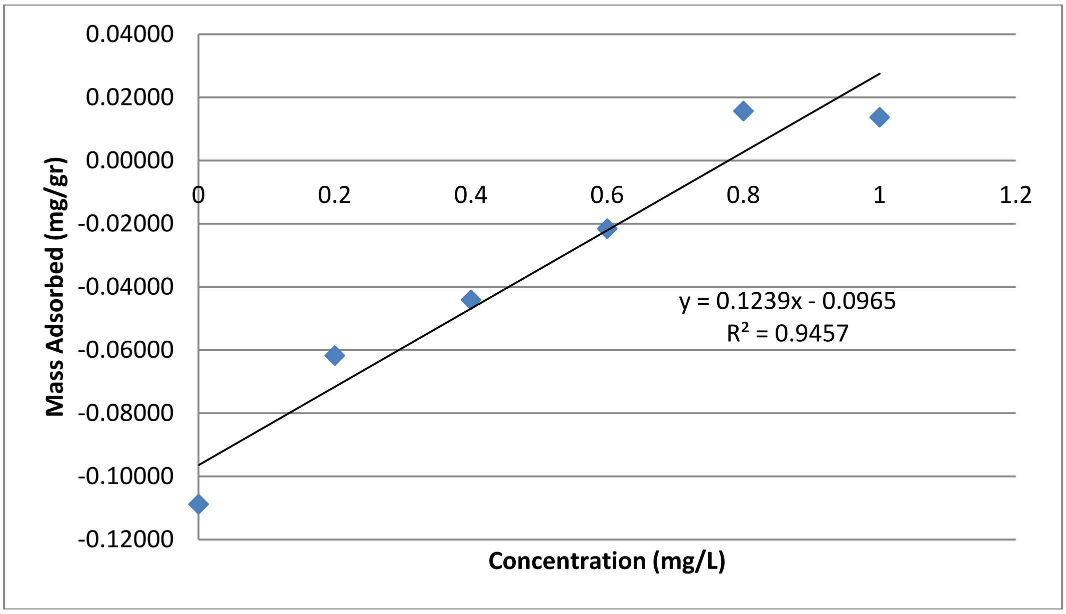


Figure 4.38: Equilibrium Graph for Sampling Point 3

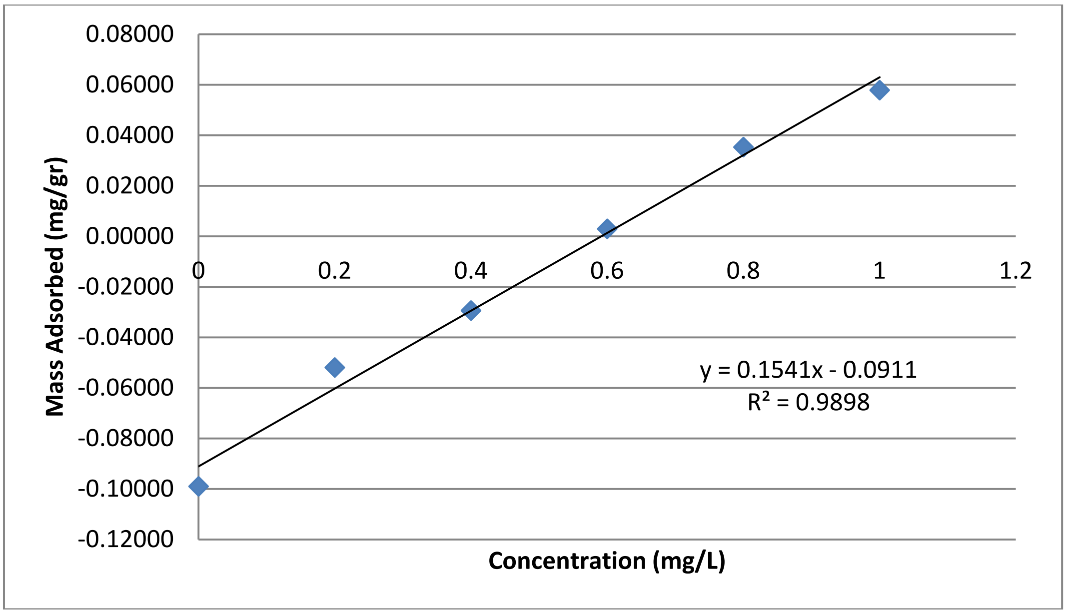


Figure 4.39: Equilibrium Graph for Sampling Point 4

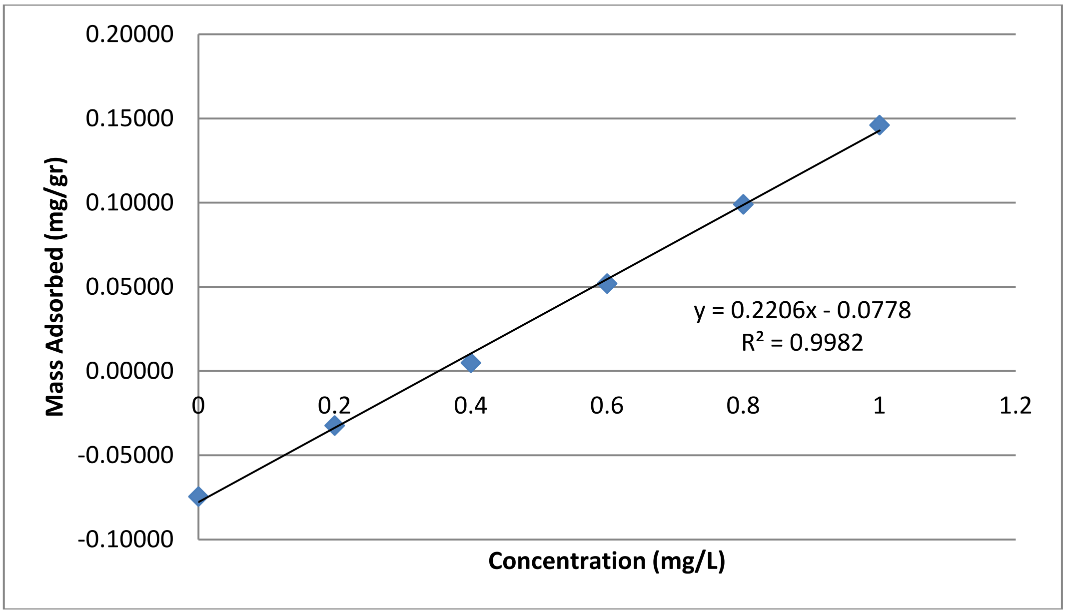


Figure 4.40: Equilibrium Graph for Sampling Point 5

Table 4.35: Equilibrium Concentrations for Sampling Points

	Point 1	Point 2	Point 3	Point 4	Point 5
C_{eq} (mg/L)	0.528	0.829	0.778	0.591	0.352
Total P (mg/kg)	1.979	2.767	2.896	2.579	1.661
C_{eq} (Uniformed)	0.267	0.300	0.269	0.229	0.212

From Table 4.35, C_{eq} values show at which concentration phosphorus will start to release from sediment or adsorbed to sediment surface at current situation. If concentration in water is below C_{eq} concentrations, phosphorus is released and if above, phosphorus is adsorbed. Equilibrium concentrations are different at each sampling point since their initial phosphorus concentration is different. In order to remove this non-uniform situation, C_{eq} concentrations are uniformed by dividing with Total-P concentrations and given in order to compare differences between sampling points. What we see from uniformed results is, there is very little difference between sampling points and phosphorus adsorption/desorption potential of each sampling point is slightly different from each other.

Graphical representations of the adsorption isotherm models are given in Appendix C. Langmuir and Pseudo-First-Order equations do not fit well enough to experimental data. Pseudo-Second-Order adsorption isotherms are suitable to use for adsorption kinetics and experimental results are given below in Table 4.36. It is seen from the results that third equation in Table 3.5 results in a high R^2 (Table 4.36) at all sampling points and equilibrium phosphorus concentrations are closer to measured data than any other equation.

Table 4.36: Pseudo-Second-Order Kinetic Parameters

Sampling Point	Equation Number	k (kg/(gr-hr)	Q_e (gr/kg)	R^2
1	2	0.110300	14.20	0.9595
	3	0.021637	29.59	0.9970
	4	0.074682	36.23	0.7462
	5	0.051882	25.57	0.6760
2	2	0.080500	23.07	0.9718
	3	0.013595	26.46	0.9932
	4	0.020626	23.09	0.9909
	5	0.017119	24.55	0.9290
3	2	0.087100	21.47	0.9352
	3	0.013605	23.69	0.9909
	4	0.033178	17.36	0.8549
	5	0.019881	21.06	0.7582
4	2	0.067100	24.95	0.7253
	3	0.022092	31.65	0.9959
	4	0.027105	29.67	0.9811
	5	0.024006	30.68	0.9541
5	2	0.085600	13.08	0.7031
	3	0.040576	39.37	0.9992
	4	0.074682	36.23	0.7462
	5	0.067153	37.15	0.7189

4.2.3. Fractionation of Phosphorus in Sediment

Phosphorus in sediment has been fractionated using a modified extraction method proposed by Psenner et. al. (1984) with some modifications (Hupfer et al., 1995). Readily available phosphorus, iron bound phosphorus, phosphate adsorbed to metal oxides, phosphorus particles bound to carbonates and residual phosphorus is aimed to be measured in a 1 gr sediment sample. Residual phosphorus concentration is found by subtracting the calculated phosphorus concentrations from Total-P concentration. Since calculation of PO_4-P is not applicable with Total-P method, total PO_4-P is assumed to be same as Total-P. The results for phosphorus fractionation for sediment samples and numerical representation of the study are given in Appendix D. Graphical representation of fractionation results are given in Figure 4.41 to Figure 4.44.

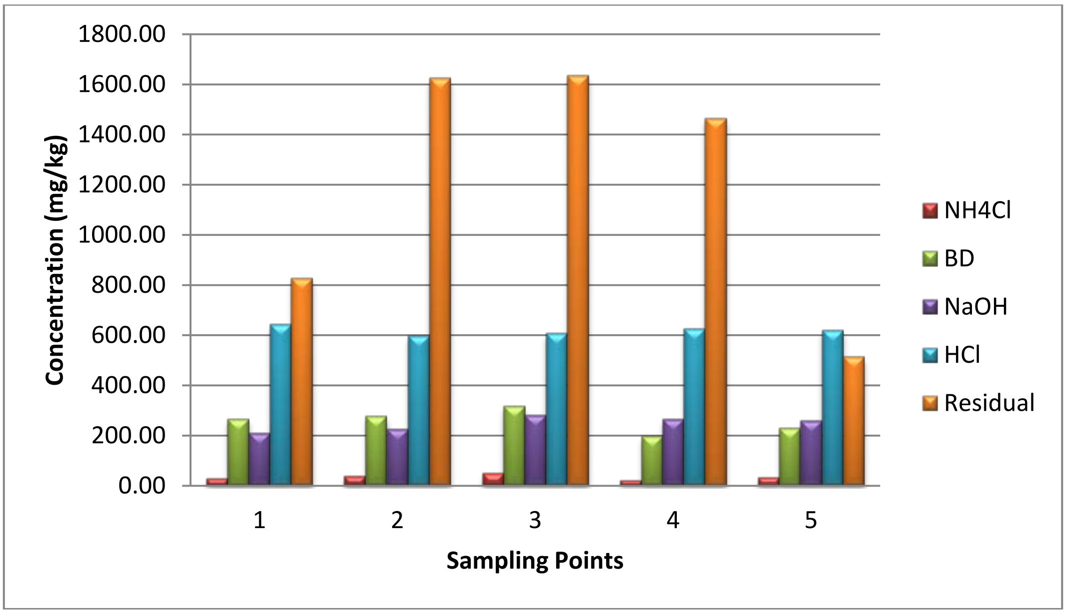


Figure 4.41: Graphical Representation of Total-P Fractionation

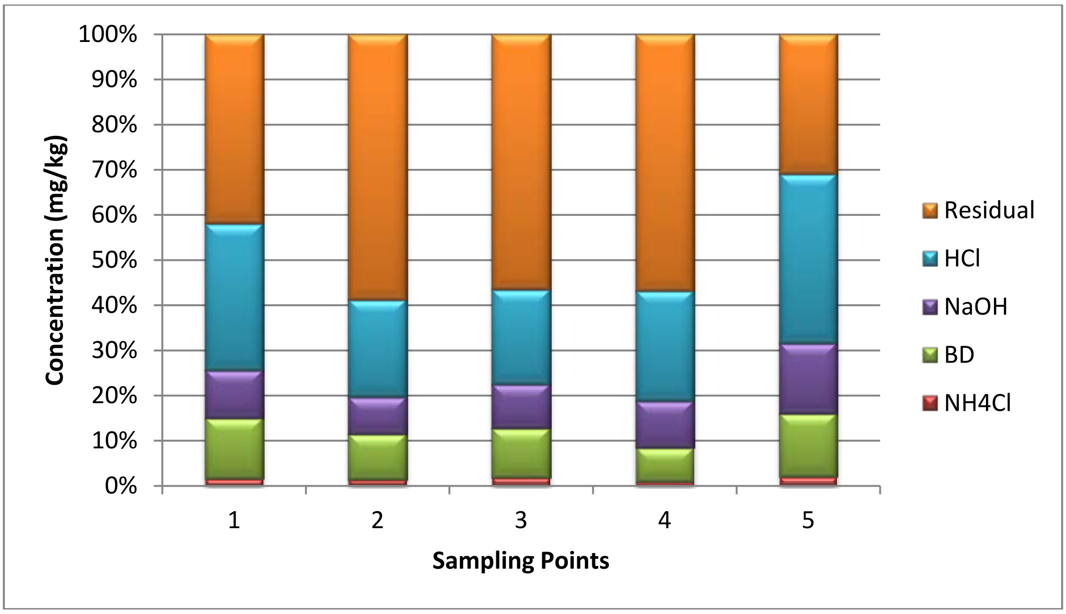


Figure 4.42: Percent Based Representation of Total-P Fractionation

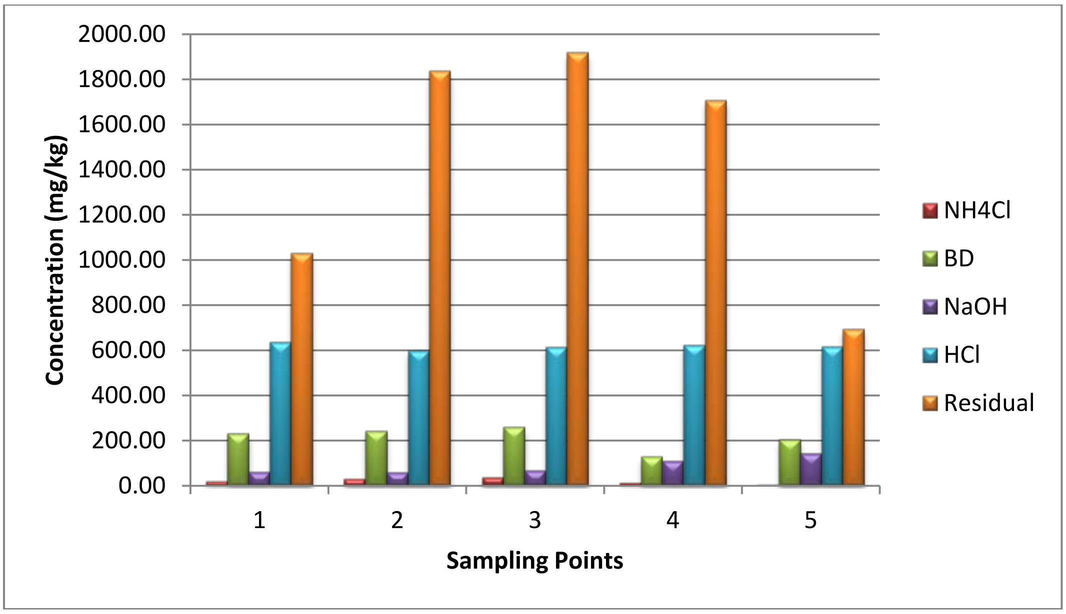


Figure 4.43: Graphical Representation of PO_4-P Fractionation

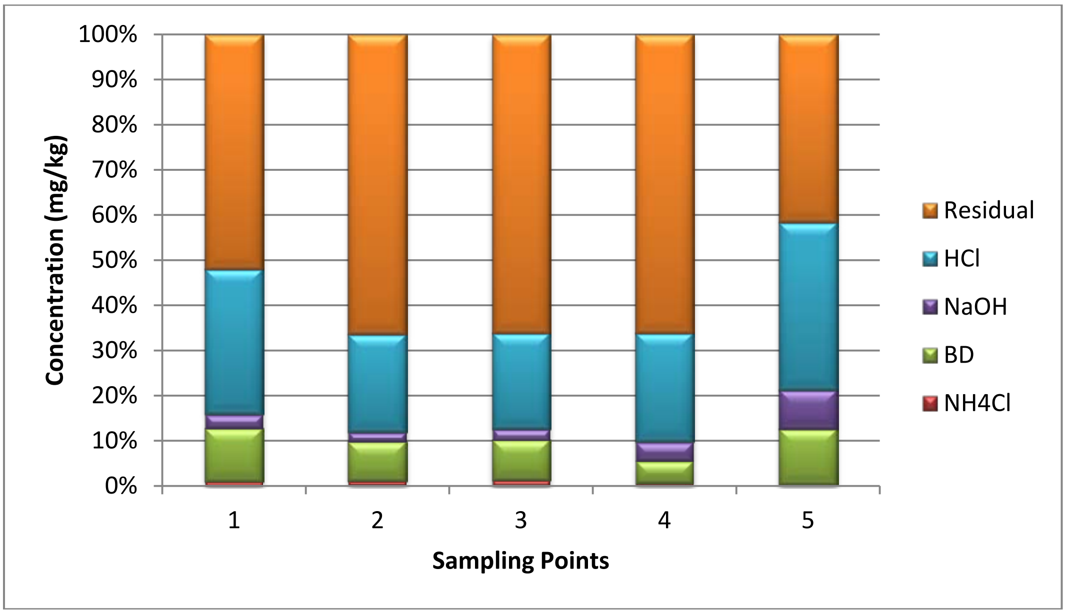


Figure 4.44: Percent Based Representation of PO_4-P Fractionation

Results obtained through fractionation experiments show that more than at least 30% of Total-P in sediment samples are bound to inert particles and can only be released through strong acid digestion. For PO_4-P, more than at least 40% of phosphorus in samples is bound to inert particles. Amount of HCl-bound phosphorus in both total and PO_4-P changes between 20% and 37%, which is known to be assumed as permanent bound and can only be released under low pH conditions in nature. NaOH-bound phosphorus changes between 2% and 16%, and NaOH-P is an especially important parameter since it is used for estimation of short and long term available phosphorus. Experimental results show that BD bound Total-P changes between 8% and 14% while PO_4-P is less than half with between 2% and 8%. A similar difference is observed at

NH_4Cl phosphorus and these results show that readily available phosphorus is used continuously which is a sign of phosphorus limitation in Lake Eymir.

Another important result is readily available PO_4-P can also be found in sediment samples with particles diameter of less than 63 µm. Difference of Total-P and PO_4-P at different fractionation steps is due to phosphorus remaining bound to other particles. This shows that even if we dissolve phosphate in extraction solutions, some amount of the available phosphorus does not dissolve completely.

Amount of soluble phosphorus fraction found is relatively low if we compare it with other bindings. However if we take a look at its concentration, total soluble phosphorus concentration changes between 21,80 mg/kg and 50,96 mg/kg which is enough to cause eutrophication in lake.

To investigate if particles less than 63 µm diameter can represent the whole sample, a simple mass balance is applied. From particle size distribution graphs, we know that more than 30% of particles pass through 150 µm pore size. A mass balance has been applied between following samples for NH_4C – P and BD Bound – P steps of the fractionation. Samples used in mass balance are given in Table 4.37.

Table 4.37: Samples Used for Mass Balance

	Sample Number			
	1	**2**	**3**	**4**
Particle Diameter (µm)	0-63	63-100	100-150	0-150
Sample Weight (kg)	0.9	0.9	0.9	0.9

The objective of the experiment is to add the calculated phosphorus fractions in first three samples and get the same result from fourth sample. Experiment is repeated twice and results are tabulated in Appendix G.

Errors are calculated by using average of the sum of total concentrations of first three samples. Difference between this average and concentration of fourth sample is the error from non-uniform sampling or experimental interferences. For Total-P measurements, error is 9.44 % and for PO_4-P measurements, error is 6.59 %. These numbers show how much error is expected from fractionation experiment results to represent the whole sample.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Results of the PCA showed that Total-P concentrations in water column and sediment at lake bottom are susceptible to changes caused by the variations in other water quality parameters compared to average, surface and mid-depth values. While average P data set is the next sensitive data set to interactions with other parameters, impact in terms of magnitude is less compared to bottom concentrations. Correlations observed between P and other parameters were the highest in Bottom – 3 data set. While Pearson correlation matrix is an effective way of identifying key parameters for changes in a system, it is not enough on its own. Factor analysis of the same data sets shows that release of phosphorus from sediment layer (S-STP Concentration) in Lake Eymir is best represented by the average values of water quality parameters and the values obtained in bottom samples. As a result, in monitoring studies care should be given to obtain bottom samples as well. Using just surface samples will not be representative. It is known that in monitoring of the lake by the Turkish Ministry of Environment and Urbanization, only surface samples are used.

In order to model S-STP in Lake Eymir, Chl-a, NH_3, Total-P, PO_4-P, temperature, conductivity, pH, turbidity, ΔT and DO are defined as effective parameters. Linear and non-linear regression models are created by using these parameters. Linear regression models were more successful in predicting S-STP concentrations compared to non-linear ones. Models created with the data set obtained before flooding of Lake Mogan are definitely better than others. Continuous disturbance after that incident might be responsible from poor results. The release of phosphorus from sediment is positively related with Chl-a, Total-P and temperature. Increase in these parameters enhances phosphorus concentrations. DO and pH are found to be negatively related to phosphorus release.

Water depth is found to be significantly effective on Total-P concentrations as well as on other parameters. Total-P concentrations change with sediment surface area/water depth ratio. Also increased water depth decreases light penetration and DO concentrations at bottom. As a result, the gate that controls the flow from lake Mogan to Lake Eymir has an important role for the water quality and phosphorus concentrations in Lake Eymir.

Turbidity is a good tracer for Total-P concentrations in Lake Eymir. Normalized graphical representations of turbidity versus Total-P indicate almost perfect relationship. Temperature is seasonally effective on phosphorus concentrations, and may create stratified water in summer. Stratification causes phosphorus to build up in bottom water layer. Algae are important sources of oxygen in Lake Eymir. In summer 2010, high Chl-a and biological activity (nitrification) is observed while DO concentrations were low. However algal bloom created supersaturation condition in the lake.

Particle size distribution results show that area of sampling point 1 has different characteristics compared to other sampling locations since it is located at the inlet. Most particles settle out before reaching sampling point 2. Sediment particles are generally uniformly distributed. However, at the inlet, they are gap-graded, which could be either uniform or non-uniform. As a result in sampling programs, the inlet should always be sampled because of different characteristics compared to other locations.

The exchange of phosphorus from water to sediment is mostly completed within the first 7-8 hours. On average, 30% of the exchange is completed in an hour. It is clearly seen that although sediment layer in the lake is a phosphorus source, it has not reached its phosphorus binding capacity yet. Adsorption kinetics and isotherm experiments show that even if sediment layer is high in phosphorus content, there is still more space for sorption of phosphorus. The phosphorus adsorption/desorption potential of each sampling point is slightly different from each other. Adsorption isotherm is found to be pseudo-second-order with a coefficient of determination greater than 0.9909 at all sampling points.

Fractionation results show that even if the soluble concentrations are low, they are high enough to cause eutrophication problems. Permanent bounds are highly observed in Lake Eymir sediments. Fractionation results showed that HCl and NaOH bound phosphates are greater than BD bound phosphorus. High alkalinity and pH may cause this outcome. Precipitation of calcium and aluminum bound phosphates are important sources of permanent bound phosphorus. Since, pH is always high in Lake Eymir, NH_4Cl and BD bound phosphates are primary threat for the lake.

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APPENDIX A

CALIBRATION DATA

Table A. 1: Fractionation Calibration Results for Total-P Experiments

Concentration	**Part 1**	**Part 2**	**Part 3**	**Part 4**
0,025	0,005			
0,05	0,0085	0,003	0,002	0,003
0,1	0,0135	0,005	0,0035	0,0065
0,2	0,0285	0,007	0,0075	0,014
0,4	0,0545	0,0135	0,013	0,0265
0,5	0,066	0,0155	0,0155	0,0325
0,6	0,0785	0,0185	0,0185	0,0385
0,8	0,1065	0,0265	0,026	0,051
1	0,132	0,0335	0,0325	0,0665

Table A. 2: Fractionation Calibration Results for PO_4-P Results

Concentration	**Part 1**	**Part 2**	**Part 3**	**Part 4**
0,025	0,005			
0,05	0,0085	0,003	0,003	0,003
0,1	0,0135	0,0064	0,005	0,0065
0,2	0,0285	0,015	0,007	0,014
0,4	0,0545	0,0266	0,014	0,0265
0,5	0,066	0,032	0,016	0,0325
0,6	0,0785	0,0388	0,019	0,0385
0,8	0,1065	0,051	0,027	0,051
1	0,132	0,0664	0,034	0,0665

Table A. 3: Fitting Equations for Fractionation Calibration Solutions

	Total-P	**PO_4-P**
Part 1	$y = 0,1303*x + 0,0016$	$y = 0,1303*x + 0,0016$
Part 2	$y = 0,0315*x + 0,0009$	$y = 0,0649*x + 0,0003$
Part 3	$y = 0,0317*x + 0,0004$	$y = 0,0317*x + 0,0004$
Part 4	$y = 0,0653*x + 0,00003$	$y = 0,0653*x + 0,00003$

Table A. 4: Calibration Results for Adsorption Kinetics and Isotherm Experiments

Concentration	Kinetics	Isotherm
0,025	0,0005	0,003
0,05	0,002	0,003
0,1	0,0035	0,0065
0,2	0,0065	0,0125
0,4	0,013	0,024
0,5	0,0165	0,031
0,6	0,0205	0,0395
0,8	0,0255	0,055
1	0,033	0,0685

APPENDIX B

PARTICLE SIZE DISTRIBUTION DATA

Table B. 1: Particle Size Distribution for Sampling Point 1

Sieve Size (µm)	**Weight (gr)**	**% Retained**	**% Passing**
>1180	0.1934	0.24	99.76
850 – 1180	1.1924	1.49	98.27
710 – 850	1.8012	2.25	96.02
500 – 710	6.4914	8.11	87.91
425 – 500	5.3445	6.67	81.24
355 – 425	3.8991	4.87	76.37
300 – 355	5.0161	6.26	70.10
175 – 300	11.4913	14.35	55.75
150 – 175	3.4371	4.29	51.46
100 – 150	6.2526	7.81	43.65
75 – 100	5.4231	6.77	36.88
63 – 75	3.0383	3.79	33.09
38 – 63	17.2681	21.57	11.52
<38	9.2246	11.52	0.00
Total Sample Weight	80.0732	**Initial Sample Weight**	81.5192
Sample Lost During Sieve Analysis		1.45 gr (1.77 %)	

Table B. 2: Particle Size Distribution for Sampling Point 2

Sieve Size (µm)	**Weight (gr)**	**% Retained**	**% Passing**
>1180	0.2604	0.34	99.66
850 – 1180	1.9328	2.52	97.14
710 – 850	3.259	4.25	92.89
500 – 710	11.4104	14.87	78.03
425 – 500	9.2438	12.05	65.98
355 – 425	6.129	7.99	57.99
300 – 355	7.9694	10.39	47.61
175 – 300	14.3214	18.66	28.94
150 – 175	3.3147	4.32	24.62
100 – 150	5.1764	6.75	17.88
75 – 100	3.5612	4.64	13.24
63 – 75	1.6873	2.20	11.04
38 – 63	5.1108	6.66	4.38
<38	3.3598	4.38	0
Total Sample Weight	76.7364	**Initial Sample Weight**	77.8387
Sample Lost During Sieve Analysis		1.10 gr (1.41 %)	

Table B. 3: Particle Size Distribution for Sampling Point 3

Sieve Size (µm)	**Weight (gr)**	**% Retained**	**% Passing**
>1180	0.0981	0.15	99.85
850 – 1180	0.7433	1.17	98.67
710 – 850	1.4393	2.27	96.41
500 – 710	5.9545	9.38	87.02
425 – 500	6.2356	9.83	77.19
355 – 425	5.2636	8.30	68.90
300 – 355	6.6161	10.43	58.47
175 – 300	14.2827	22.51	35.96
150 – 175	3.5137	5.54	30.42
100 – 150	5.6325	8.88	21.54
75 – 100	3.9741	6.26	15.28
63 – 75	2.698	4.25	11.03
38 – 63	4.764	7.51	3.52
<38	2.2325	3.52	0
Total Sample Weight	63.448	**Initial Sample Weight**	64.1631
Sample Lost During Sieve Analysis		0.72 gr (1.11 %)	

Table B. 4: Particle Size Distribution for Sampling Point 4

Sieve Size (µm)	**Weight (gr)**	**% Retained**	**% Passing**
>1180	0.2052	0.31	99.69
850 – 1180	1.5068	2.26	97.43
710 – 850	2.2931	3.44	93.99
500 – 710	9.0125	13.52	80.48
425 – 500	7.6465	11.47	69.01
355 – 425	5.5468	8.32	60.69
300 – 355	6.9814	10.47	50.22
175 – 300	13.9428	20.91	29.31
150 – 175	3.3047	4.96	24.36
100 – 150	4.7815	7.17	17.18
75 – 100	4.246	6.37	10.82
63 – 75	3.0387	4.56	6.26
38 – 63	3.6129	5.42	0.84
<38	0.5613	0.84	0
Total Sample Weight	66.6802	**Initial Sample Weight**	67.5298
Sample Lost During Sieve Analysis		0.85 gr (1.25 %)	

Table B. 5: Particle Size Distribution for Sampling Point 5

Sieve Size (µm)	**Weight (gr)**	**% Retained**	**% Passing**
>1180	0.4052	0.51	99.49
850 – 1180	2.5227	3.18	96.30
710 – 850	3.5984	4.54	91.76
500 – 710	11.3873	14.38	77.38
425 – 500	8.0693	10.19	67.20
355 – 425	5.5404	6.99	60.20
300 – 355	6.6112	8.35	51.85
175 – 300	13.2752	16.76	35.09
150 – 175	3.5868	4.53	30.57
100 – 150	5.1215	6.47	24.10
75 – 100	5.0846	6.42	17.68
63 – 75	5.9445	7.50	10.18
38 – 63	5.6159	7.09	3.09
<38	2.4445	3.09	0
Total Sample Weight	79.2075	**Initial Sample Weight**	80.7443
Sample Lost During Sieve Analysis		1.54 gr (1.90 %)	

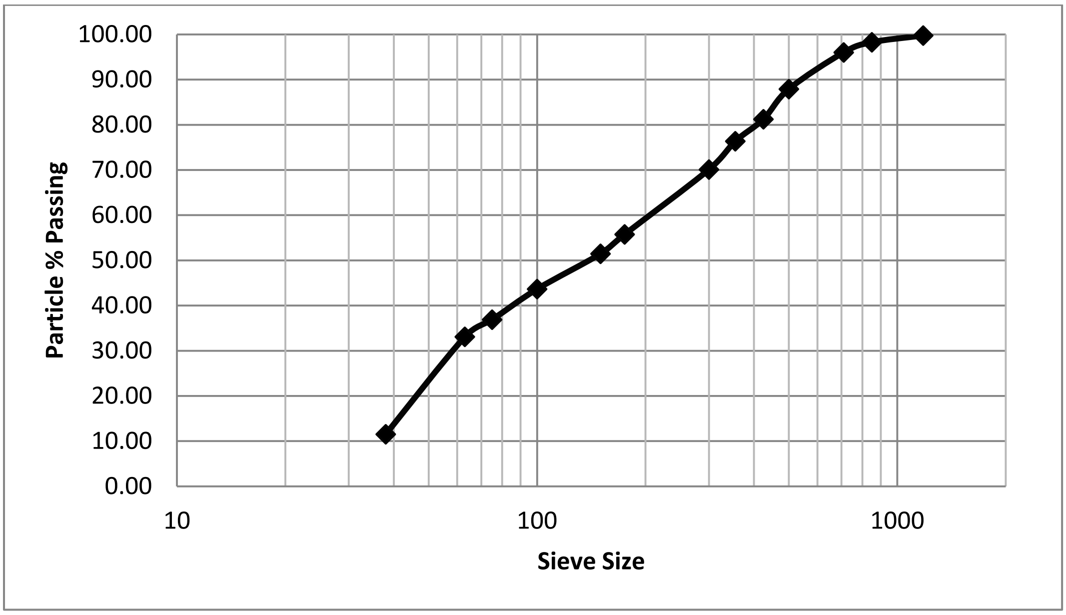

Figure B. 1: Graph of Particle Percentage Passing Through for Sampling Point 1

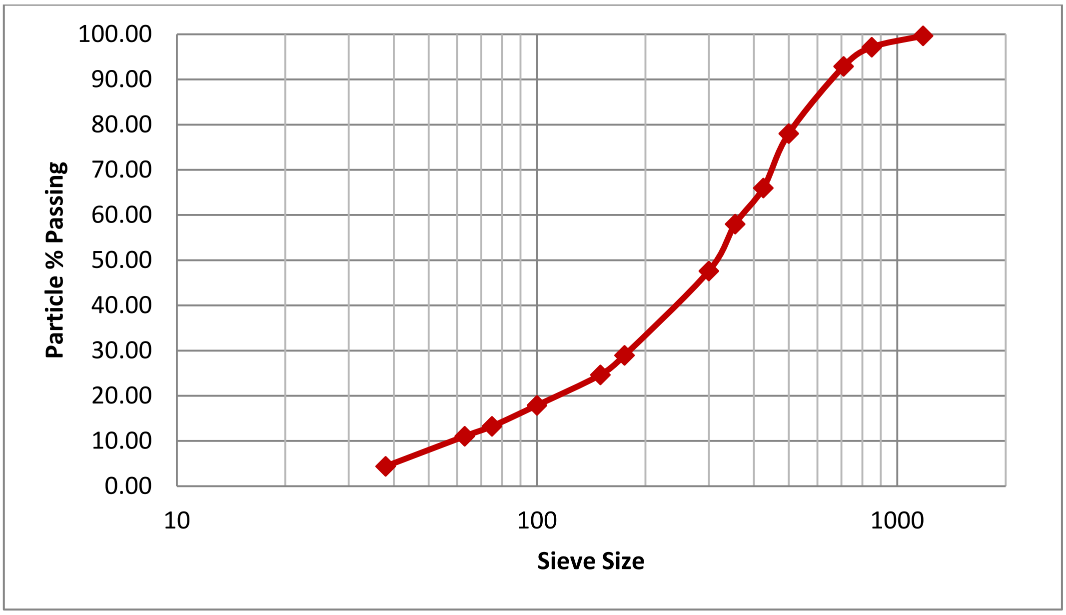

Figure B. 2: Graph of Particle Percentage Passing Through for Sampling Point 2

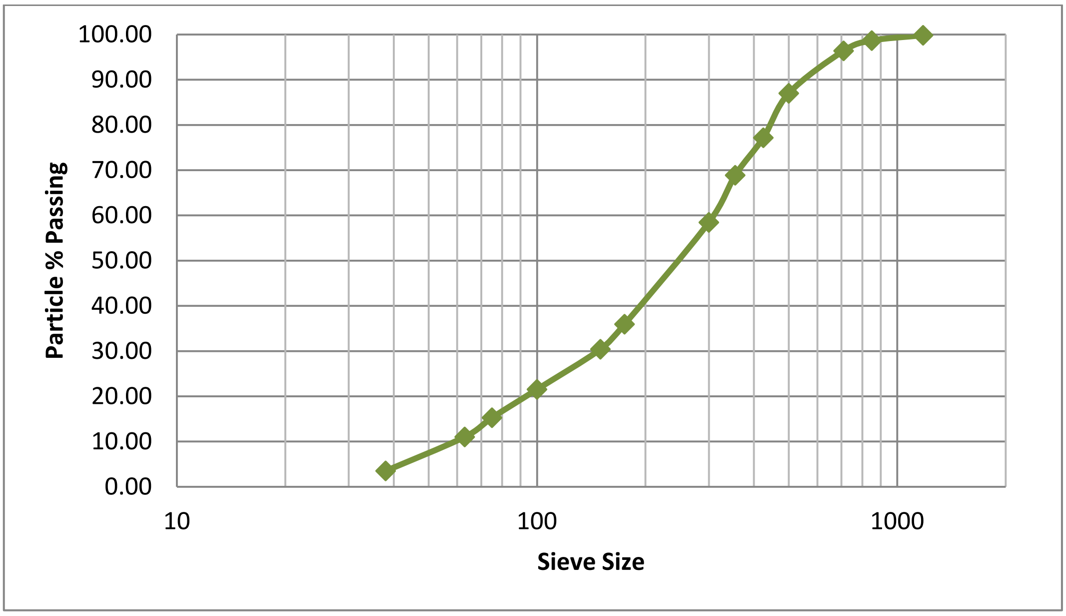

Figure B. 3: Graph of Particle Percentage Passing Through for Sampling Point 3

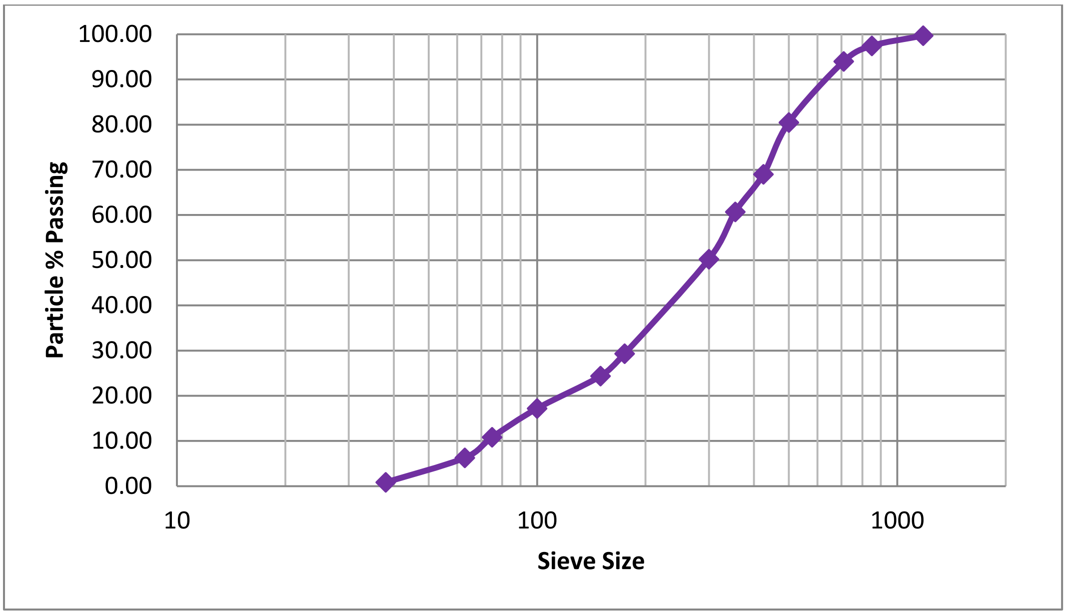

Figure B. 4: Graph of Particle Percentage Passing Through for Sampling Point 4

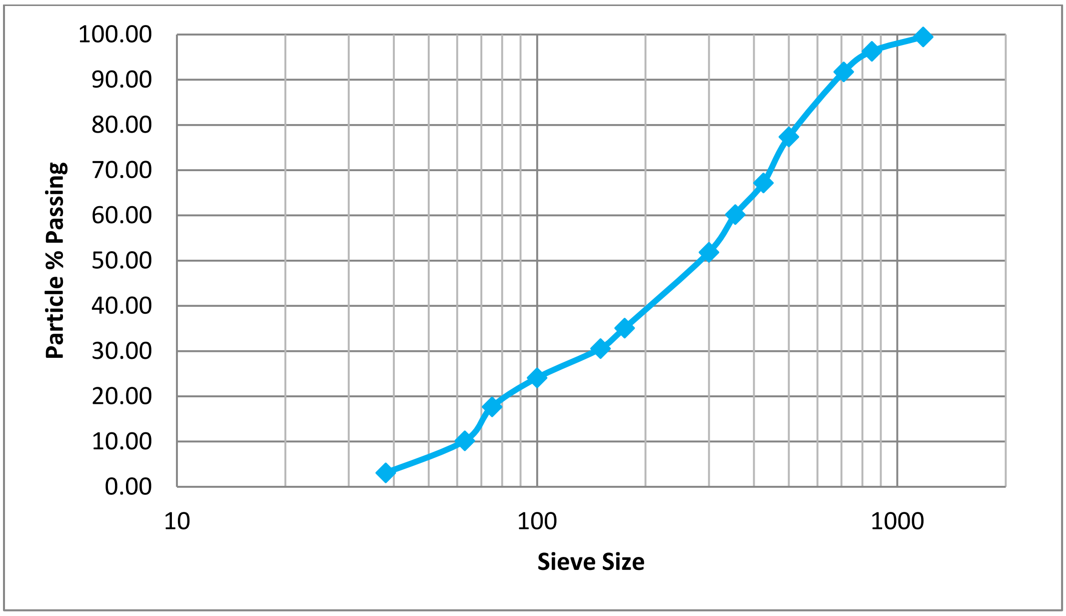

Figure B. 5: Graph of Particle Percentage Passing Through for Sampling Point 5

APPENDIX C

ADSORPTION DATA

Table C. 1: Phosphorus Concentrations in Solution after Kinetics Experiment

Time (hr)	**Sampling Point**				
	1 (mg/L)	**2 (mg/L)**	**3 (mg/L)**	**4 (mg/L)**	**5 (mg/L)**
0	0.95	0.95	0.95	0.91	0.76
0.5	0.76	0.91	0.91	0.82	0.55
1	0.76	0.85	0.88	0.76	0.52
2	0.70	0.78	0.88	0.64	0.52
5	0.64	0.73	0.73	0.55	0.30
10	0.52	0.61	0.64	0.43	0.24
24	0.46	0.55	0.58	0.43	0.24
32	0.43	0.52	0.58	0.43	0.24
48	0.43	0.49	0.55	0.36	0.21

Table C. 2: Initial and Final Concentrations of Phosphorus in Solution

Initial Concentration (C1) (mg/L)	**Final Concentration (C2) (mg/L)**				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
0	0.28	0.33	0.33	0.30	0.22
0.2	0.34	0.50	0.39	0.36	0.30
0.4	0.50	0.56	0.53	0.49	0.39
0.6	0.56	0.68	0.66	0.59	0.44
0.8	0.68	0.84	0.75	0.69	0.50
1	0.72	0.91	0.96	0.83	0.56
1.2	0.89	1.11	1.02	0.97	0.69
1.5	1.02	1.25	1.19	1.14	0.83
2	1.56	1.69	1.66	1.58	1.19
2.5	1.87	2.12	2.00	1.94	1.44
3	2.33	2.46	2.37	2.27	2.02
3.5	2.56	2.89	2.81	2.69	2.06
4	3.09	3.25	3.21	3.11	2.41

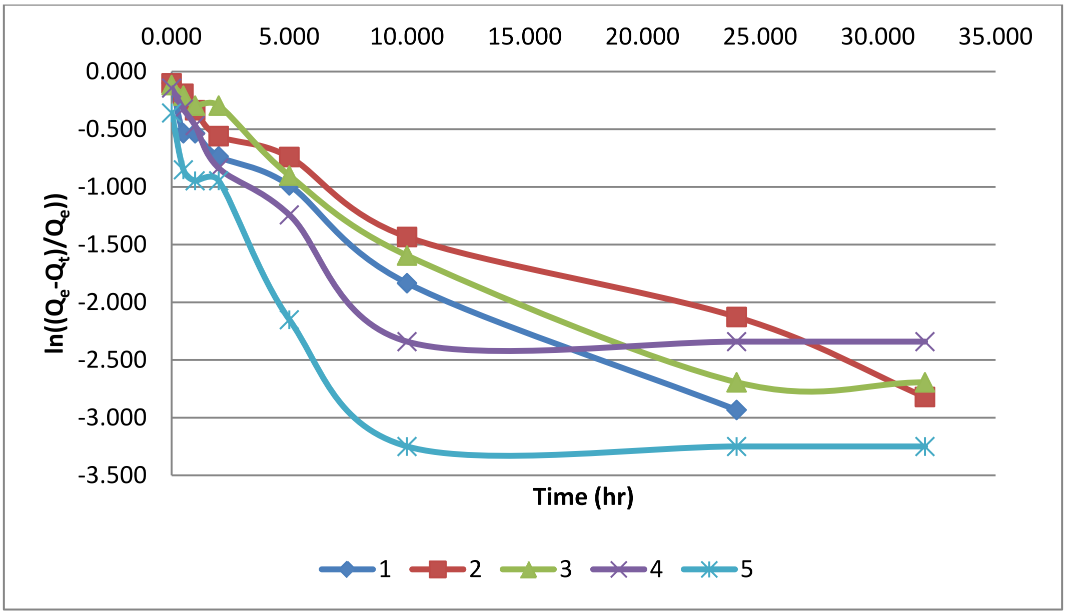

Figure C. 1: Equation 1 Adsorption Isotherm Model Plot

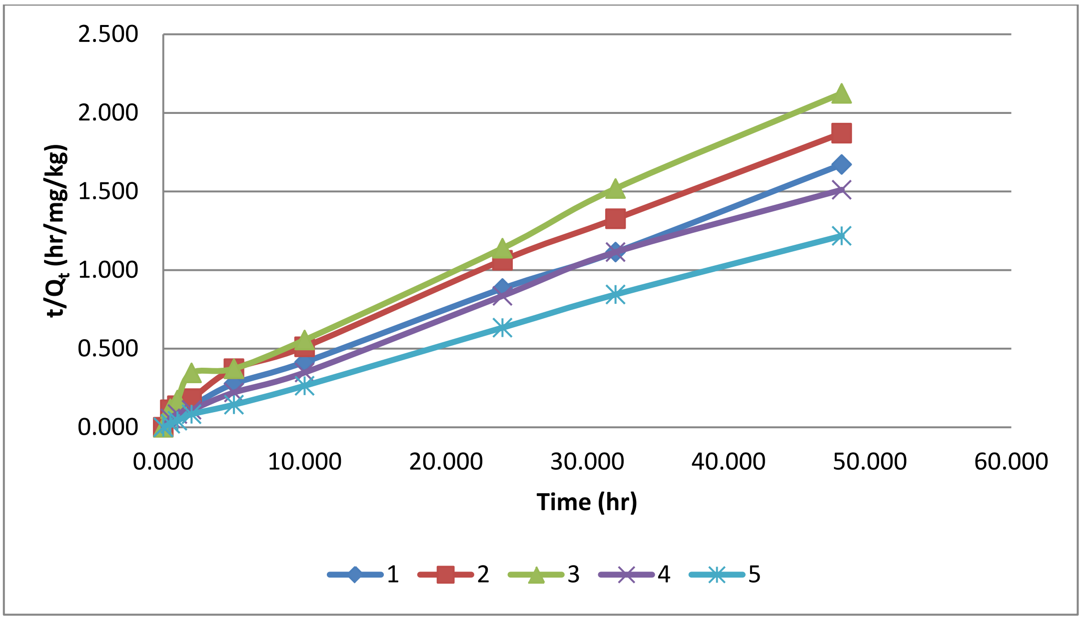

Figure C. 2: Equation 2 Adsorption Isotherm Model Plot

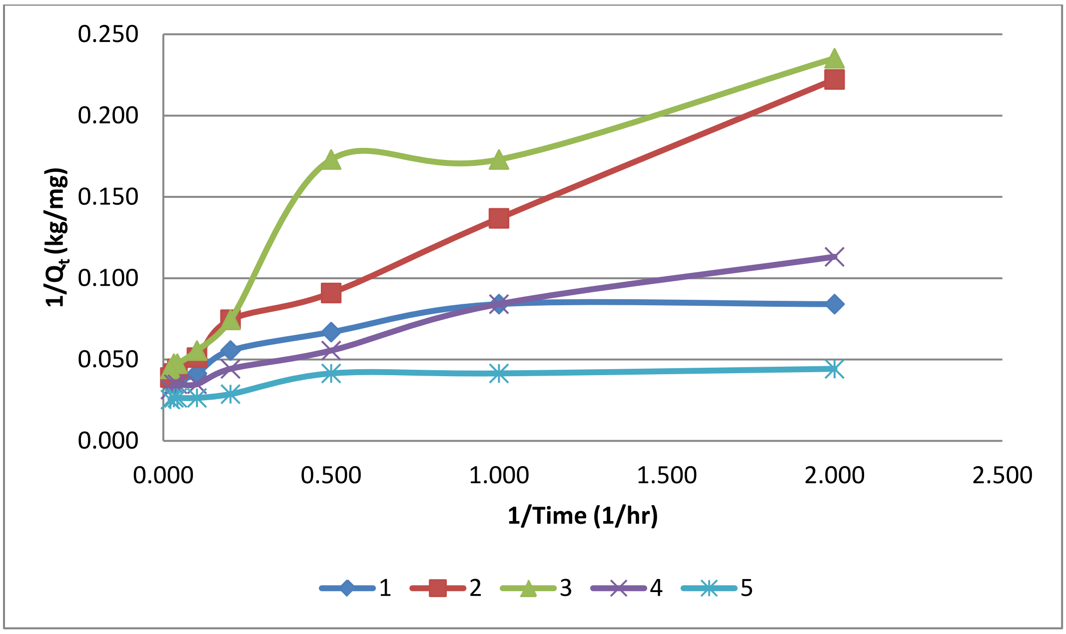

Figure C. 3: Equation 3 Adsorption Isotherm Model Plot

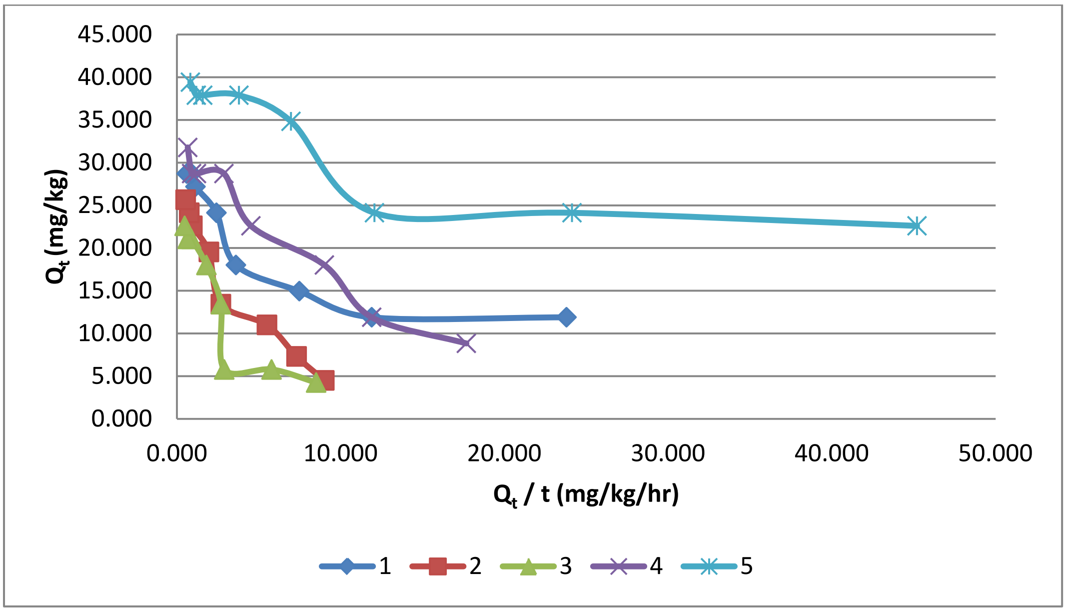

Figure C. 4: Equation 4 Adsorption Isotherm Model Plot

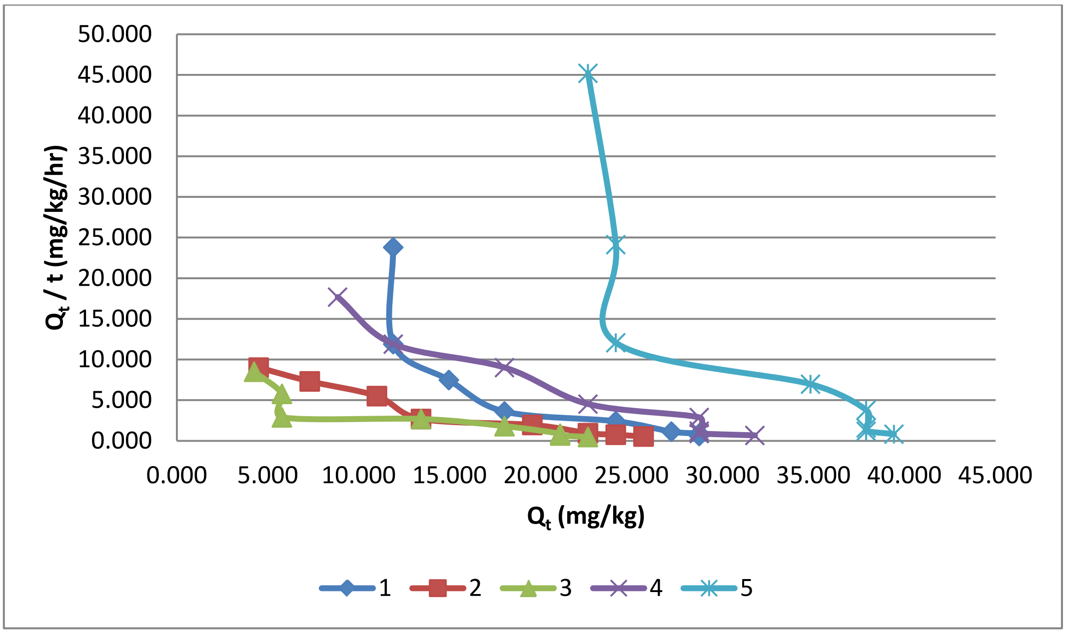

Figure C. 5: Equation 5 Adsorption Isotherm Model Plot

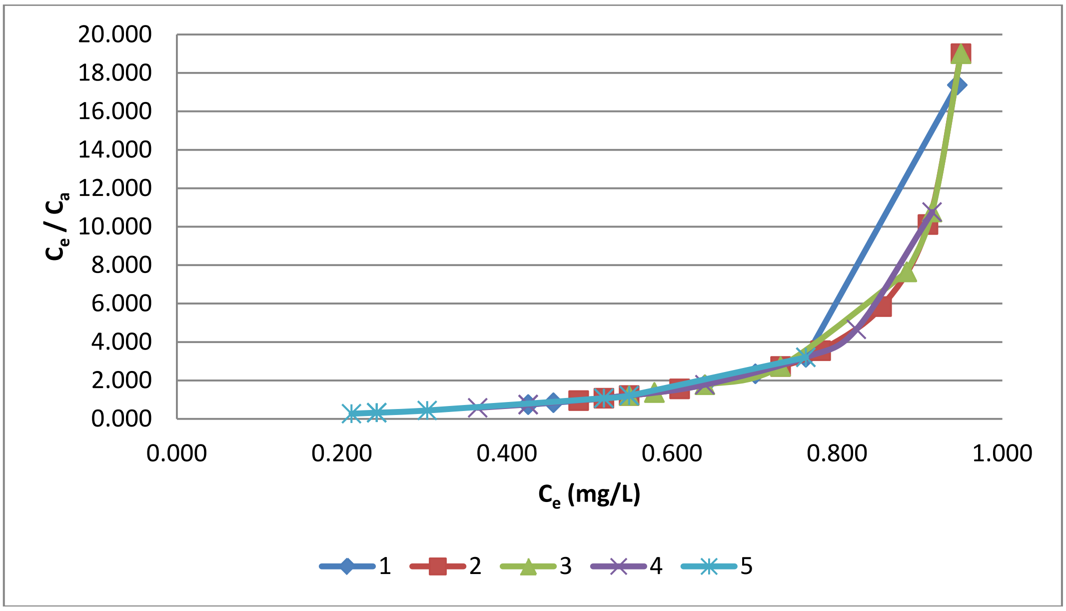

Figure C. 6: Equation 6 Adsorption Isotherm Model Plot

APPENDIX D

FRACTIONATION DATA

Table D. 1: Fractionation Results for Total-P Measurements

Fractionation Step	**Sampling Point**				
	1	**2**	**3**	**4**	**5**
Total – P (mg/kg)	1978,82	2767,06	2896,47	2578,82	1661,18
NH_4Cl – P (mg/kg)	29,47	40,21	50,96	21,80	32,54
BD – P (mg/kg)	266,98	276,51	317,78	197,14	232,06
NaOH – P (mg/kg)	210,09	225,87	282,65	266,88	260,57
HCl – P (mg/kg)	643,14	598,73	607,92	626,29	621,70
Residual – P (mg/kg)	829,13	1625,74	1637,17	1466,71	514,31

Table D. 2: Fractionation Results for PO_4-P Measurements

Fractionation Step	**Sampling Point**				
	1	**2**	**3**	**4**	**5**
Total – P (mg/kg)	1978,82	2767,06	2896,47	2578,82	1661,18
NH_4Cl – P (mg/kg)	18,96	28,93	36,61	12,05	3,61
BD – P (mg/kg)	231,90	241,43	258,89	128,73	204,92
NaOH – P (mg/kg)	61,83	58,68	68,14	109,15	143,85
HCl – P (mg/kg)	635,48	598,73	614,04	621,70	615,57
Residual – P (mg/kg)	1030,65	1839,29	1918,79	1707,20	693,23

Table D. 3: Fractionation Results for Total-P Measurements as Percentage

Fractionation Step	**Sampling Point**				
	1	**2**	**3**	**4**	**5**
NH_4Cl – P (%)	1,49	1,45	1,76	0,85	1,96
BD – P (%)	13,49	9,99	10,97	7,64	13,97
NaOH – P (%)	10,62	8,16	9,76	10,35	15,69
HCl – P (%)	32,50	21,64	20,99	24,29	37,43
Residual – P (%)	41,90	58,75	56,52	56,88	30,96

Table D. 4: Fractionation Results for PO_4-P Measurements as Percentage

Fractionation Step	**Sampling Point**				
	1	**2**	**3**	**4**	**5**
NH_4Cl – P (%)	0,96	1,05	1,26	0,47	0,22
BD – P (%)	11,72	8,73	8,94	4,99	12,34
NaOH – P (%)	3,12	2,12	2,35	4,23	8,66
HCl – P (%)	32,11	21,64	21,20	24,11	37,06
Residual – P (%)	52,08	66,47	66,25	66,20	41,73

Table D. 5: Samples Used for Mass Balance (Total-P Results)

	Sample Number				Error
	1	**2**	**3**	**4**	**%**
Soluble – P (mg/kg)	0.60	0.72	0.79	0.75	4.33
	0.64	0.72	0.79	0.80	9.44
Fe – P (mg/kg)	2.83	3.18	3.08	2.96	7.23
	2.99	3.18	3.24	3.18	4.29

Table D. 6: Samples Used for Mass Balance (PO_4-P Results)

	Sample Number				Error
	1	**2**	**3**	**4**	**%**
Soluble – P (mg/kg)	0.33	0.33	0.33	0.39	6.59
	0.35	0.33	0.36	0.39	5.54
Fe – P (mg/kg)	1.70	1.67	1.76	1.67	4.13
	1.73	1.65	1.91	1.73	3.12

APPENDIX E

MONITORING DATA

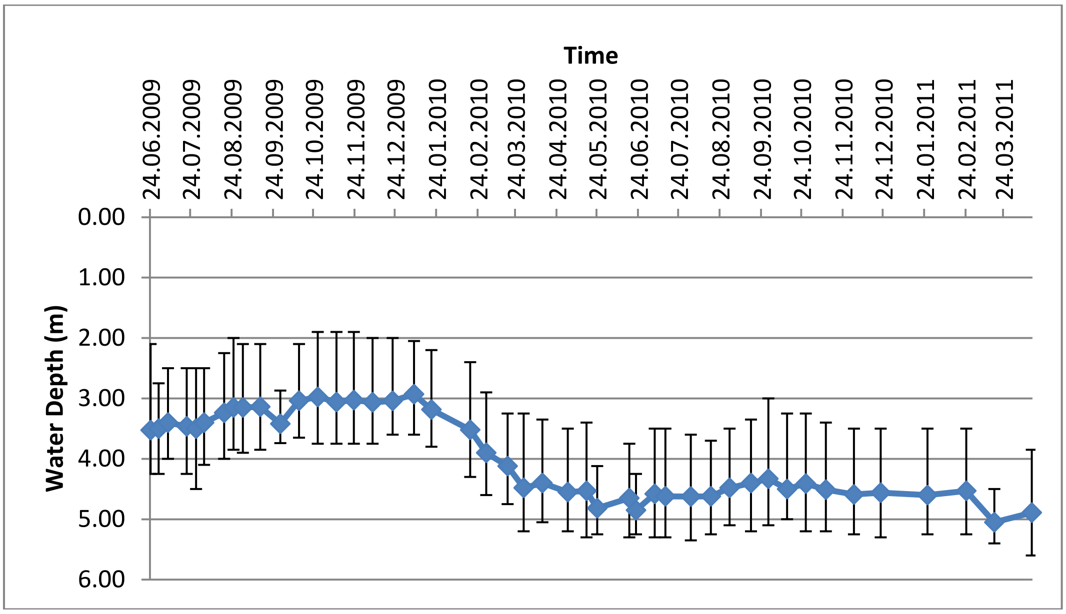

Figure E. 1: Water Depth vs. Time Graph

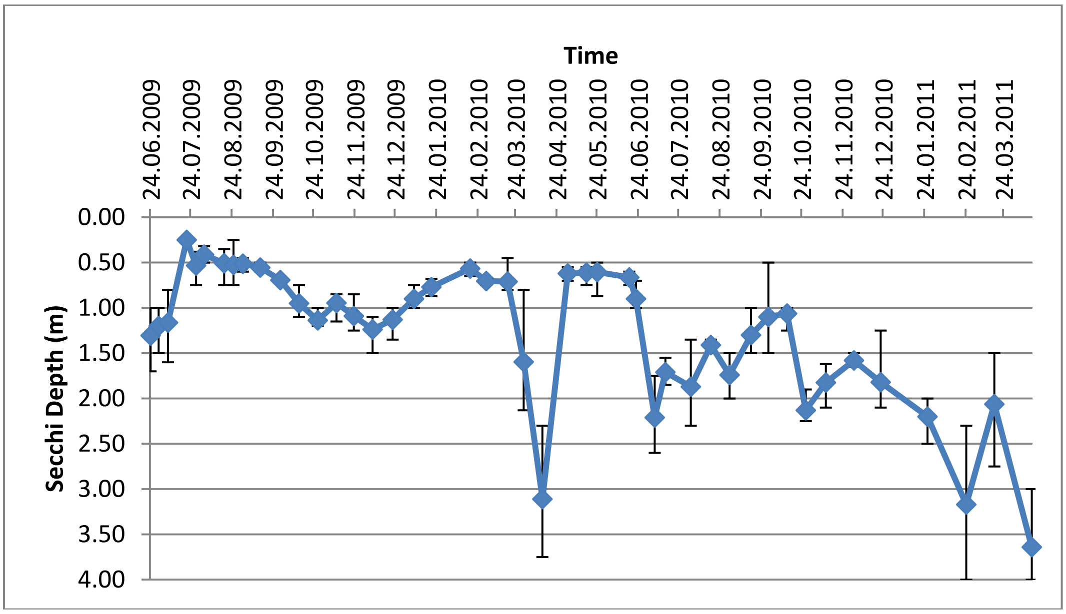

Figure E. 2: Secchi Depth vs. Time Graph

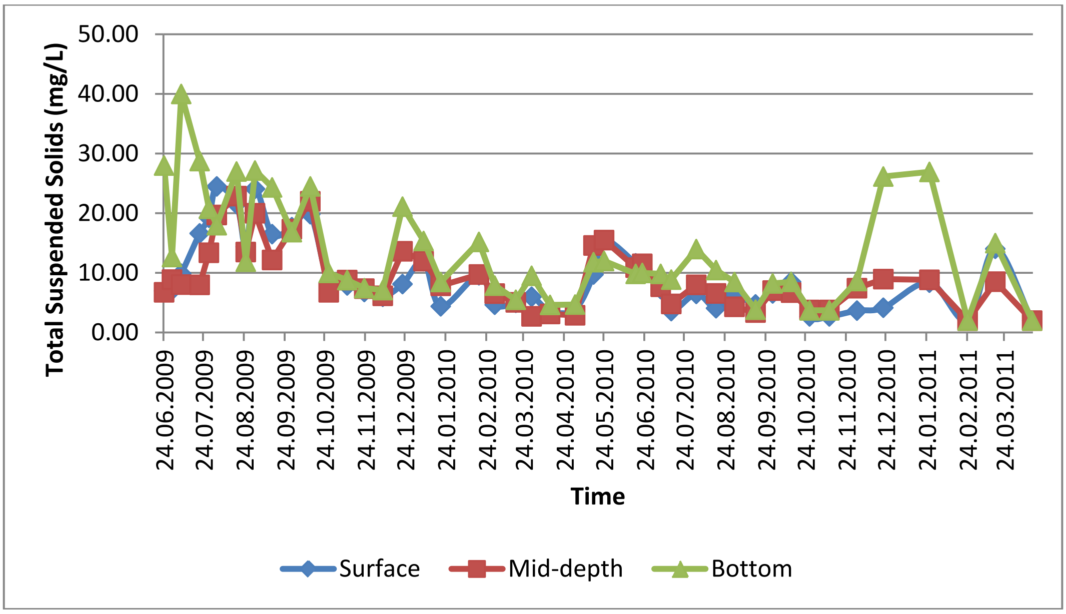

Figure E. 3: TSS vs. Time Graph

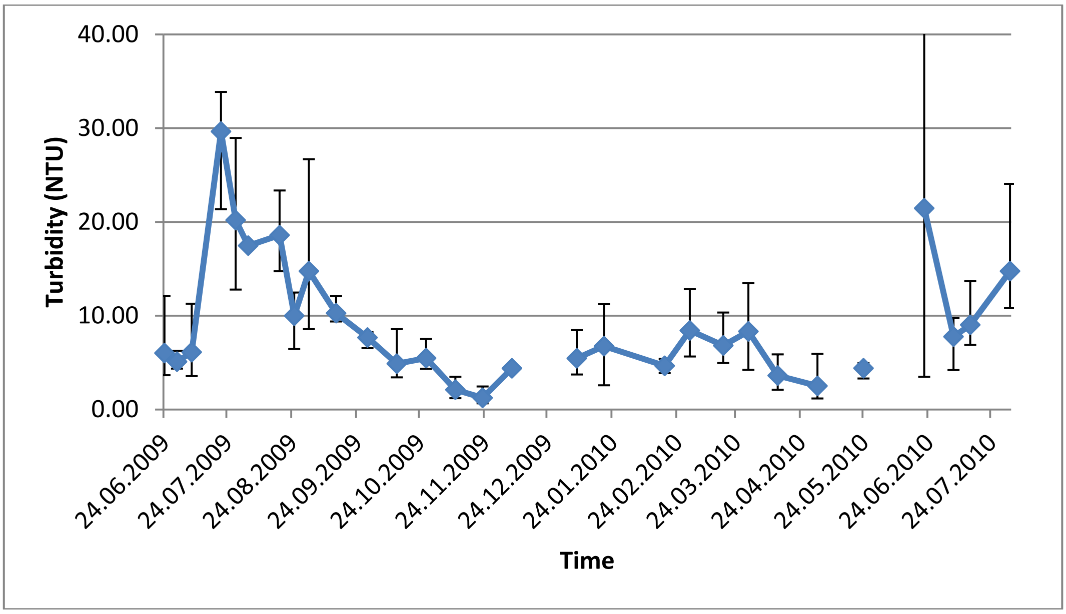

Figure E. 4: Turbidity vs. Time Graph

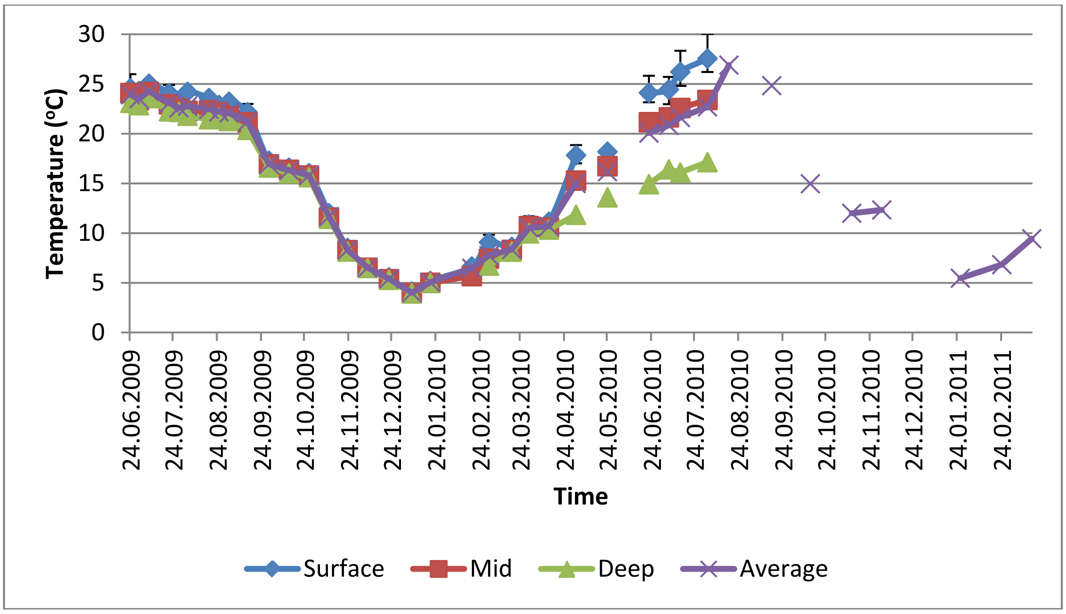

Figure E. 5: Temperature vs. Time Graph

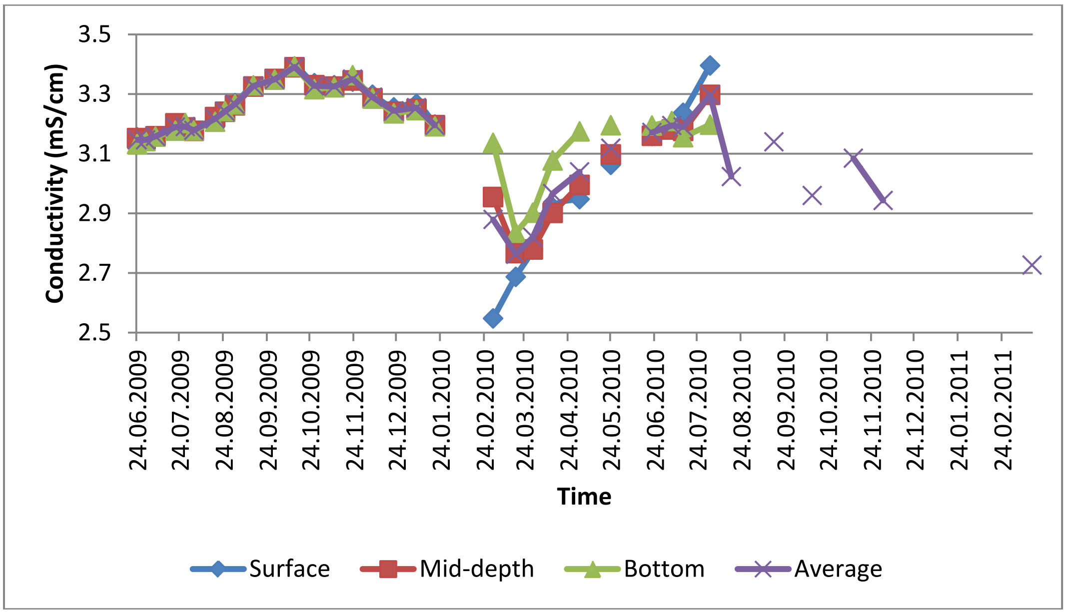

Figure E. 6: Conductivity vs. Time Graph

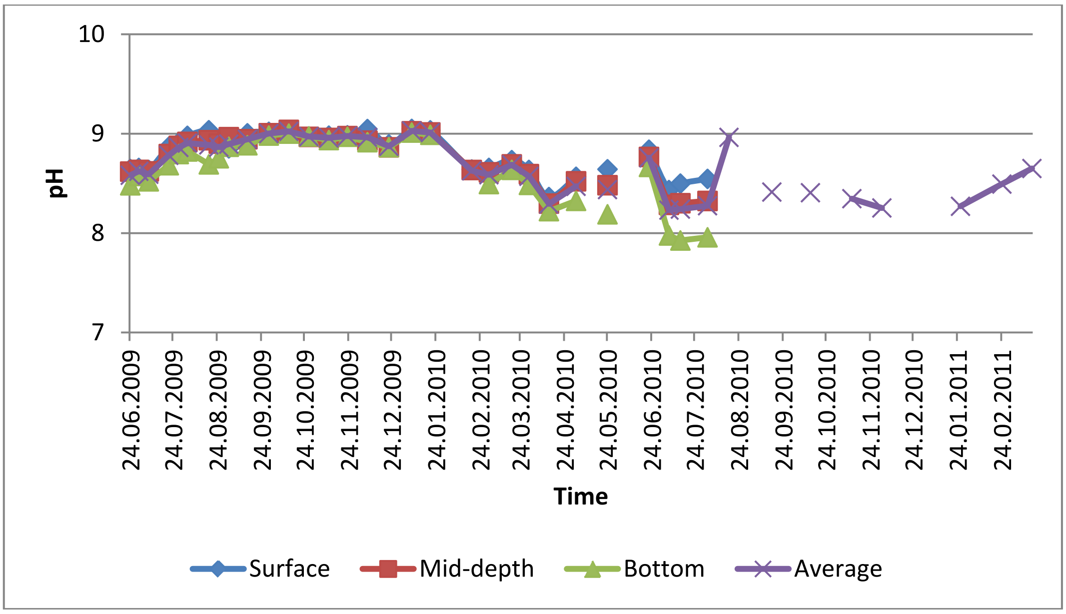

Figure E. 7: pH vs. Time Graph

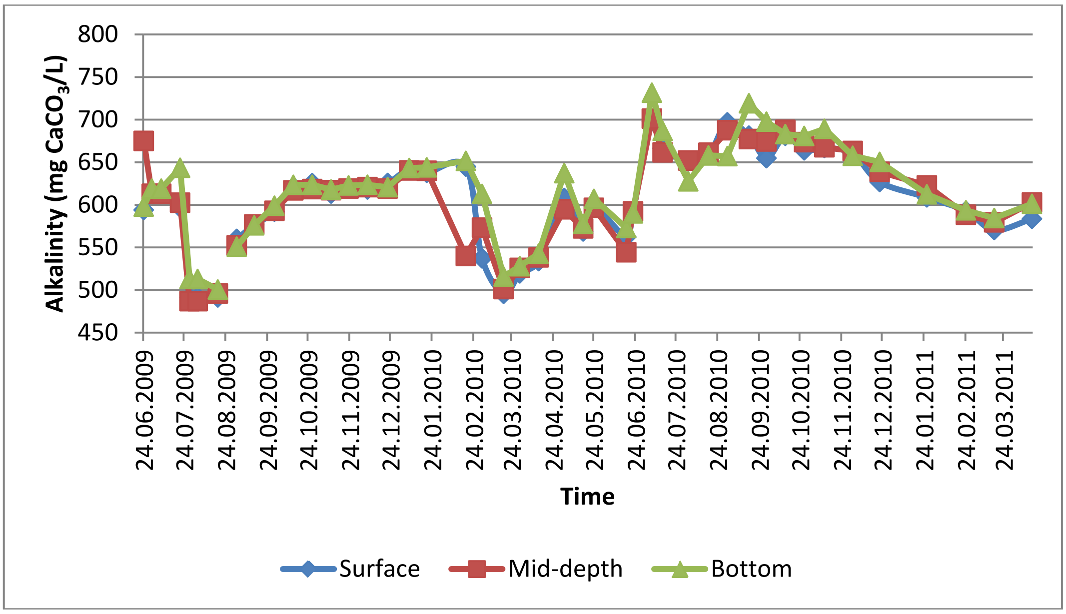

Figure E. 8: Alkalinity vs. Time Graph

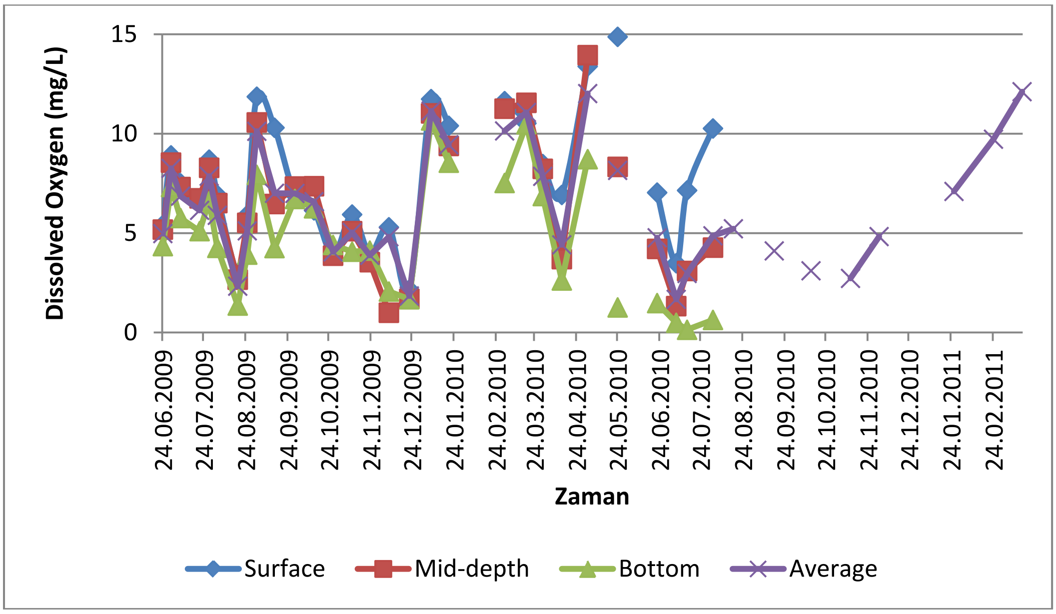

Figure E. 9: DO vs. Time Graph

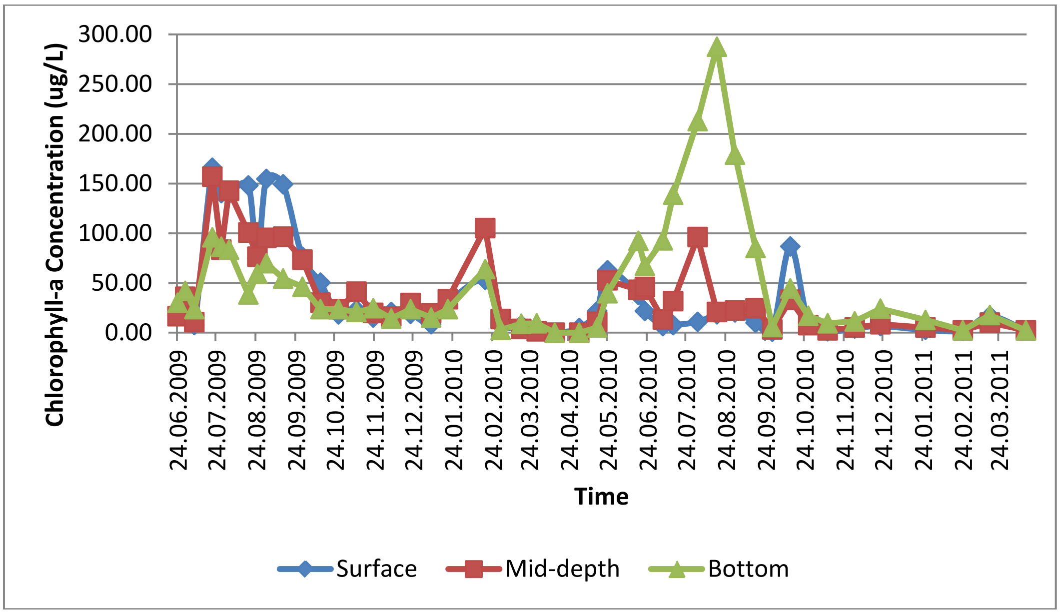

Figure E. 10: Chl-a vs. Time Graph

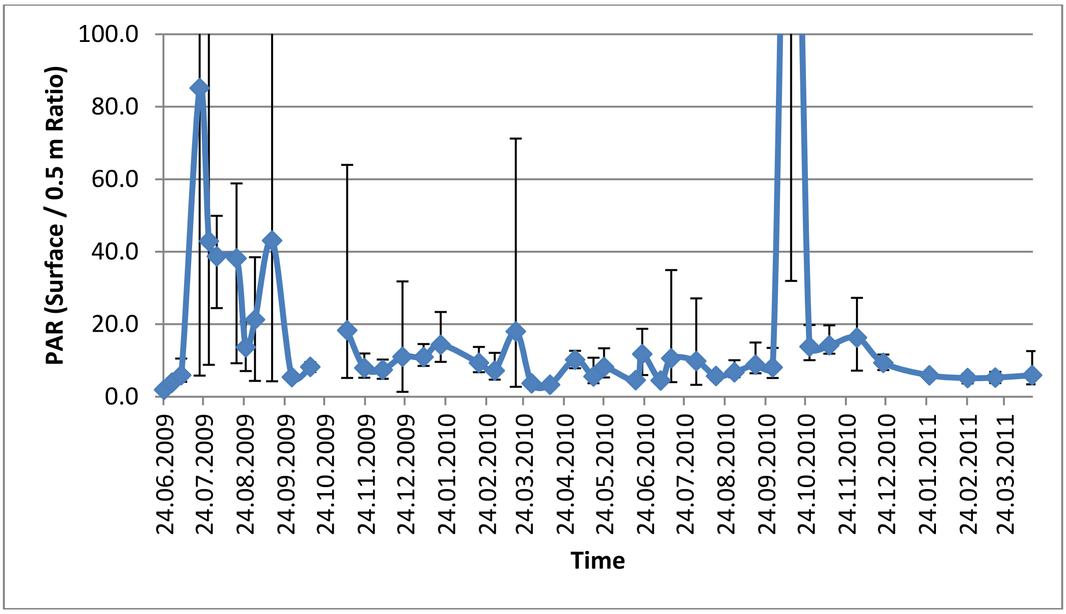

Figure E. 11: PAR vs. Time Graph

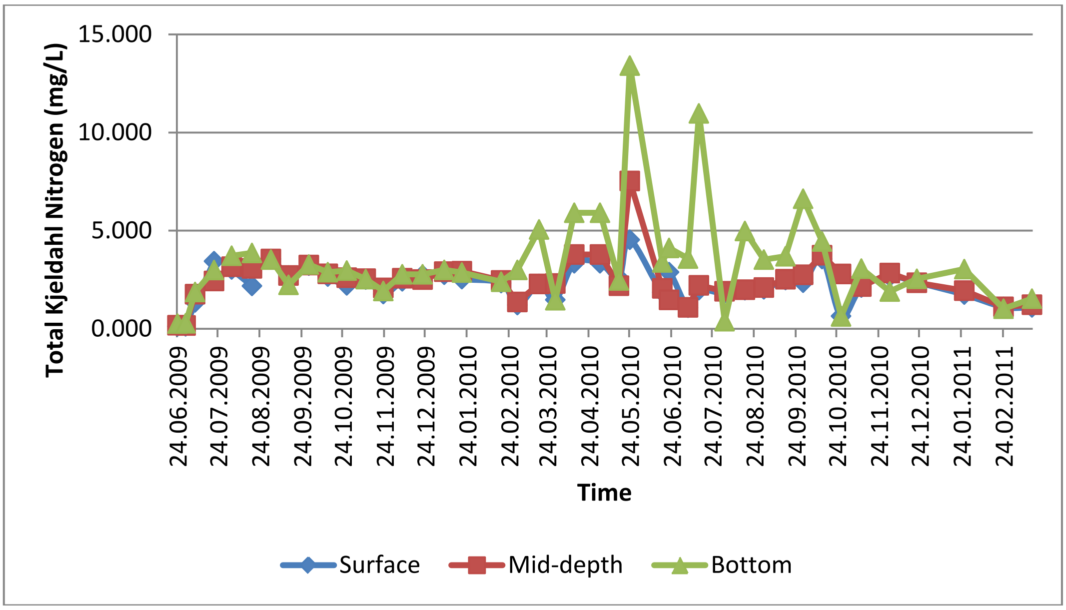

Figure E. 12: TKN vs. Time Graph

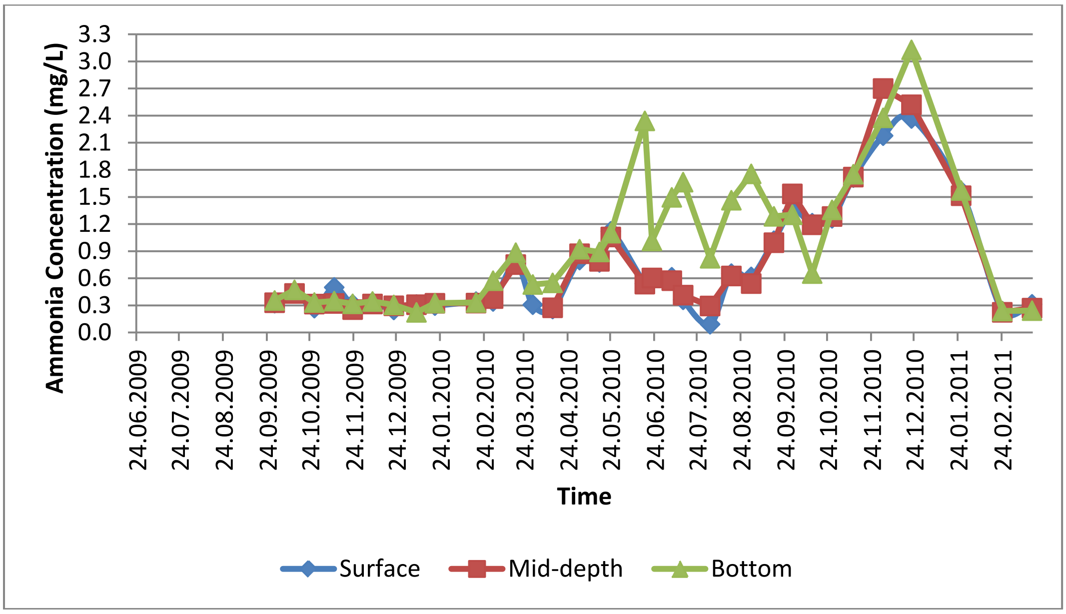

Figure E. 13: NH_4-N vs. Time Graph

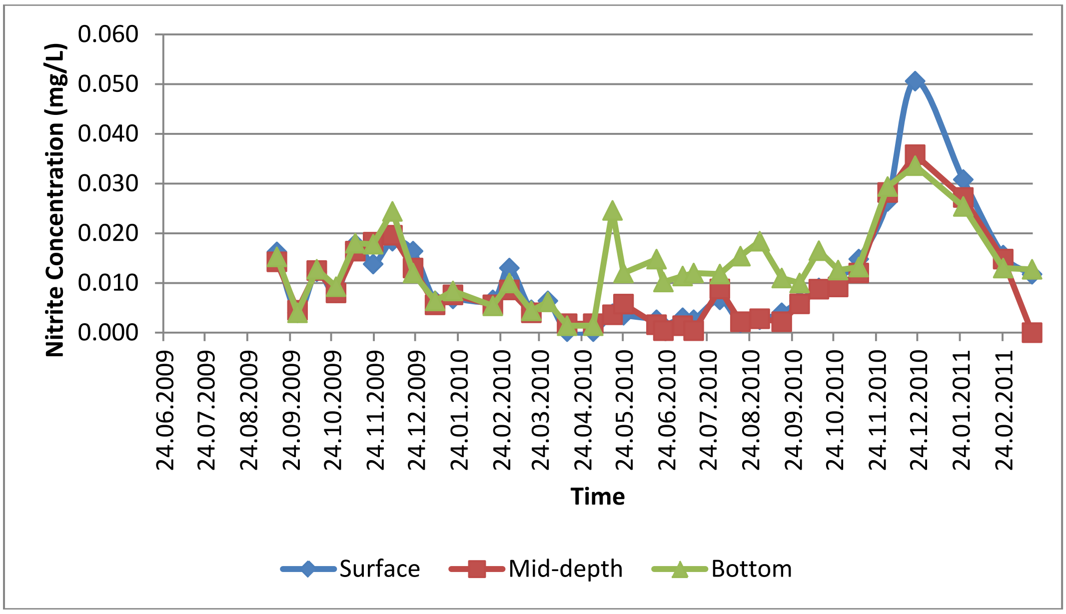

Figure E. 14: NO_2-N vs. Time Graph

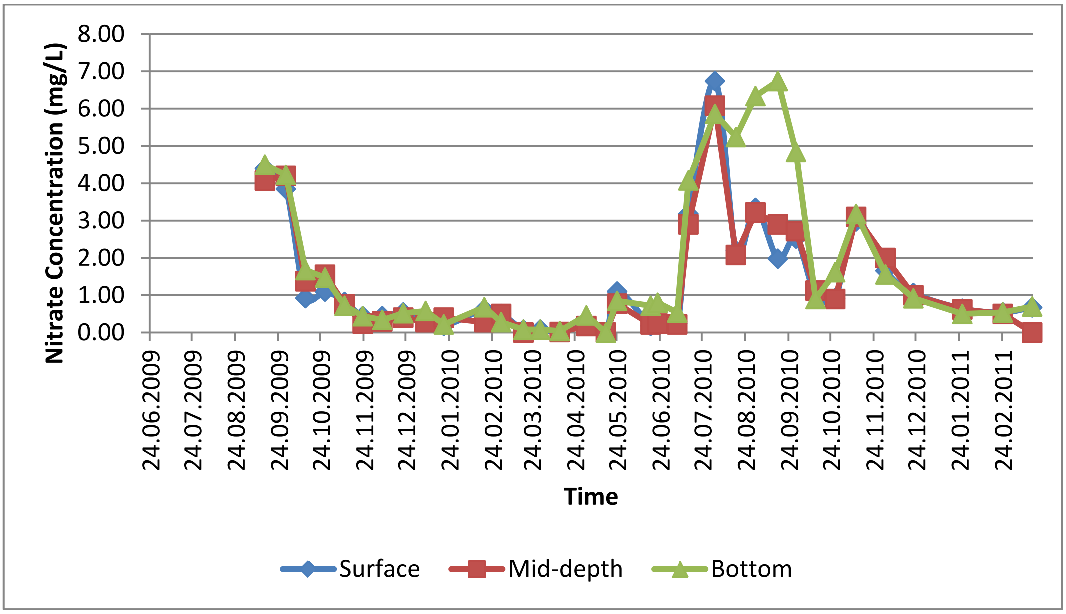

Figure E. 15: NO_3-N vs. Time Graph

APPENDIX F

METEOROLOGICAL DATA

Table F. 1: Highest Precipitation Values Observed at Standard Times in Ankara

YEAR	**MINUTES**				**HOUR**									
	5	**10**	**15**	**30**	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**12**	**18**	**24**
2010	3.1	4.8	6.3	10.9	16.0	20.4	22.0	24.0	26.1	28.5	31.8	37.3	44.6	47.8
2009	2.1	4.1	4.4	5.2	7.1	8.8	9.1	9.4	9.4	9.5	9.5	16.1	18.4	18.6
2008	4.5	7.0	7.9	9.2	9.4	9.4	16.9	17.3	17.4	17.4	17.7	26.8	28.7	28.8
2007	3.8	6.1	7.1	7.1	7.2	10.6	11.9	12.0	12.4	12.7	12.9	13.8	20.0	20.0
2006	3.7	6.2	8.9	10.3	11.3	13.7	16.0	20.0	20.9	20.9	21.0	21.1	21.5	24.2
2005	5.8	9.6	14.3	22.8	25.3	37.6	39.7	40.3	40.3	40.4	40.4	40.4	41.2	41.6
2004	2.6	4.8	5.2	5.8	6.7	8.0	10.0	10.9	11.3	11.8	12.5	12.6	12.7	22.4
2003	2.0	2.8	3.6	4.7	6.1	10.3	11.9	13.5	14.7	16.0	17.5	19.5	25.3	25.8
2002	4.5	5.6	7.4	10.8	13.9	16.4	22.7	22.9	23.3	27.7	28.2	29.3	29.4	29.8
2001	5.2	6.0	6.7	9.4	11.1	14.4	16.2	16.2	16.2	16.2	16.2	18.6	24.1	36.7
2000	7.3	8.6	9.0	9.4	9.8	9.8	9.8	10.3	12.2	12.3	12.3	12.3	12.4	12.4
1999	4.6	6.0	6.2	7.6	9.4	10.4	10.7	11.1	11.1	11.1	11.1	11.2	11.2	11.2
1998	4.1	6.7	7.5	8.9	9.4	14.0	14.0	17.1	20.7	21.9	21.9	22.0	22.4	22.4
1997	11.4	20.6	26.3	43.9	65.5	69.3	70.7	72.1	74.7	77.8	83.5	88.0	88.8	88.8
1996	2.3	3.9	5.8	9.2	9.2	13.8	18.7	20.9	21.0	21.1	21.1	21.1	21.1	21.1
1995	11.7	22.0	27.7	47.4	60.9	61.8	62.0	62.0	62.5	62.6	62.6	62.6	62.6	62.6
1994	2.6	3.2	3.3	5.1	7.1	7.7	10.4	10.5	10.5	10.5	11.0	12.8	15.8	20.0
1993	3.0	4.6	5.4	8.0	11.7	15.7	21.2	22.0	22.3	22.4	22.4	22.4	22.7	22.7
1992	5.8	7.9	9.5	12.6	13.6	13.8	13.8	13.8	13.8	17.2	17.2	17.2	17.2	17.2
1991	10.0	15.3	16.1	16.8	16.9	21.7	22.1	22.1	22.1	22.1	22.1	22.1	22.6	25.2
1990	4.5	5.1	5.7	6.7	9.9	17.2	20.3	23.8	25.8	26.7	31.2	32.2	32.2	42.6
1989	7.1	13.1	14.1	17.4	17.4	17.4	20.7	22.4	24.0	24.3	25.0	25.5	25.5	33.0
1988	6.7	10.9	12.2	12.2	12.2	13.5	16.9	19.4	20.0	20.3	20.3	20.3	21.6	24.1
1987	6.0	6.5	6.5	7.1	7.6	7.6	7.7	8.4	9.0	13.8	13.8	14.8	15.2	27.9
1986	9.5	16.7	19.4	20.6	22.0	24.9	25.6	26.0	26.2	26.2	26.2	26.2	26.2	26.2
1985	5.7	7.0	7.2	7.2	7.8	9.6	11.3	12.8	13.0	13.8	15.2	15.7	17.0	26.9
1984	6.5	8.6	11.1	13.5	14.8	16.1	18.6	23.4	23.7	23.7	23.7	23.7	23.7	23.7
1983	5.7	8.2	10.5	10.5	11.1	15.9	18.4	20.0	22.4	23.3	24.6	24.9	26.4	27.5
1982	9.2	11.1	14.0	19.5	23.0	32.0	35.9	36.2	36.3	36.3	36.8	51.3	68.1	72.1
1981	3.0	5.3	5.5	5.5	10.9	15.7	18.6	24.6	26.1	27.8	29.7	32.4	32.4	36.0
1980	3.6	4.2	4.4	6.0	7.5	8.5	10.9	12.5	13.6	14.4	16.2	23.7	33.2	40.5
1979	3.5	6.5	7.0	8.0	8.7	10.6	11.1	12.0	13.2	13.4	16.8	20.3	20.3	22.1
1978	7.1	9.3	12.3	14.3	17.1	17.6	21.4	25.4	28.2	28.2	28.2	28.7	28.8	30.0
1977	2.2	2.8	3.1	4.5	4.7	7.7	10.9	11.5	11.8	11.8	16.8	19.4	19.5	19.5
1976	3.2	5.0	6.2	7.6	10.2	16.8	21.9	27.6	29.0	30.5	34.9	36.1	36.2	36.2
1975	8.5	12.0	16.6	24.5	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	47.7
1974	9.3	14.5	18.7	21.8	21.8	21.8	21.8	21.8	21.8	21.8	23.7	32.0	43.6	46.6

Table F. 1: Highest Precipitation Values Observed at Standard Times in Ankara (Cont'd)

1973	8.3	14.9	18.2	24.6	30.6	36.4	40.1	41.2	41.2	41.2	41.2	41.2	47.9	47.9
1972	6.9	10.6	12.9	13.4	13.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	22.3
1971	11.0	12.5	12.5	12.5	12.5	12.7	14.0	14.0	14.0	14.0	15.4	20.5	23.3	23.3
1970	5.4	8.2	8.7	9.0	13.3	14.9	16.0	16.0	17.5	18.4	20.9	24.1	24.5	24.5
1969	4.1	6.6	6.8	8.9	11.3	11.4	15.5	15.6	17.0	17.0	19.5	28.1	36.6	47.2
1968	5.7	8.2	8.7	11.8	11.8	15.4	16.6	19.4	21.6	21.8	22.0	25.5	26.4	28.1
1967	3.9	7.6	8.6	12.9	15.9	18.2	18.2	18.2	18.3	18.5	18.5	18.6	18.6	18.6
1966	6.7	7.1	9.1	11.0	15.0	15.1	16.8	16.8	16.9	19.7	21.1	25.8	32.5	32.6
1965	6.5	6.8	7.9	9.9	10.1	11.3	11.3	11.3	11.3	12.2	15.1	22.2	28.5	30.2
1964	7.0	10.8	10.8	11.8	11.8	12.0	12.3	12.4	13.6	14.5	14.5	19.2	22.2	29.1
1963	9.1	11.2	12.0	13.5	26.4	27.7	29.7	30.0	30.2	32.8	33.2	33.4	34.7	44.3
1962	11.0	12.5	14.7	16.3	16.5	16.5	16.5	16.5	16.5	21.5	26.1	26.1	27.1	28.2
1961	12.0	16.0	18.0	24.5	32.5	44.5	47.5	50.5	51.5	54.0	54.0	54.0	57.5	63.3
1960	8.0	12.0	15.5	15.5	16.8	20.5	20.5	20.5	20.5	20.5	20.5	20.5	24.8	24.8
1959	5.0	9.0	13.5	16.2	17.5	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9	34.1
1958	11.5	11.5	11.5	14.5	18.8	20.2	20.2	20.2	20.2	20.2	20.2	20.2	31.2	32.3
1957	11.5	12.0	15.0	17.5	22.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	32.9
1956	5.5	6.5	7.2	14.3	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
1955	10.0	12.0	12.5	15.2	15.2	15.2	15.3	19.2	22.8	22.8	24.6	28.7	30.9	30.9
1954	8.2	10.5	12.5	15.5	22.5	24.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	28.5
1953	7.0	8.5	9.5	14.2	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	26.1
1952	2.3	3.0	4.3	7.5	7.5	14.1	15.1	15.8	16.8	17.3	17.3	17.5	19.1	19.1
1951	4.8	6.8	7.5	8.6	12.5	15.0	15.7	15.7	16.2	16.9	16.9	16.9	16.9	31.6
1950	2.5	2.8	3.5	4.0	4.5	5.8	6.4	6.6	6.7	6.8	6.8	6.8	6.8	19.6
1949	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1948	3.2	3.8	4.4	7.6	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	41.1
1947	7.6	8.0	13.6	18.5	21.2	21.6	22.0	22.0	22.3	22.3	22.3	22.3	22.3	69.8
1946	8.4	13.4	13.4	18.2	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	21.9
1945	4.1	6.2	7.2	9.8	11.9	16.9	19.0	19.4	19.4	19.4	21.2	26.1	26.1	26.1
1944	2.6	3.1	4.2	4.2	5.2	5.2	5.2	5.7	5.8	5.8	5.8	5.8	7.0	28.2
1943	6.0	8.2	8.2	15.0	16.8	17.1	17.2	17.2	18.6	19.8	20.0	20.0	21.7	24.8
1942	4.2	5.0	5.6	10.6	12.2	14.1	15.1	15.2	15.3	15.3	15.3	17.0	17.0	17.7
1941	6.2	6.4	7.7	8.5	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	19.7
1940	5.2	7.9	8.2	15.0	19.8	21.2	21.3	21.4	21.4	21.4	21.5	21.5	21.5	22.2

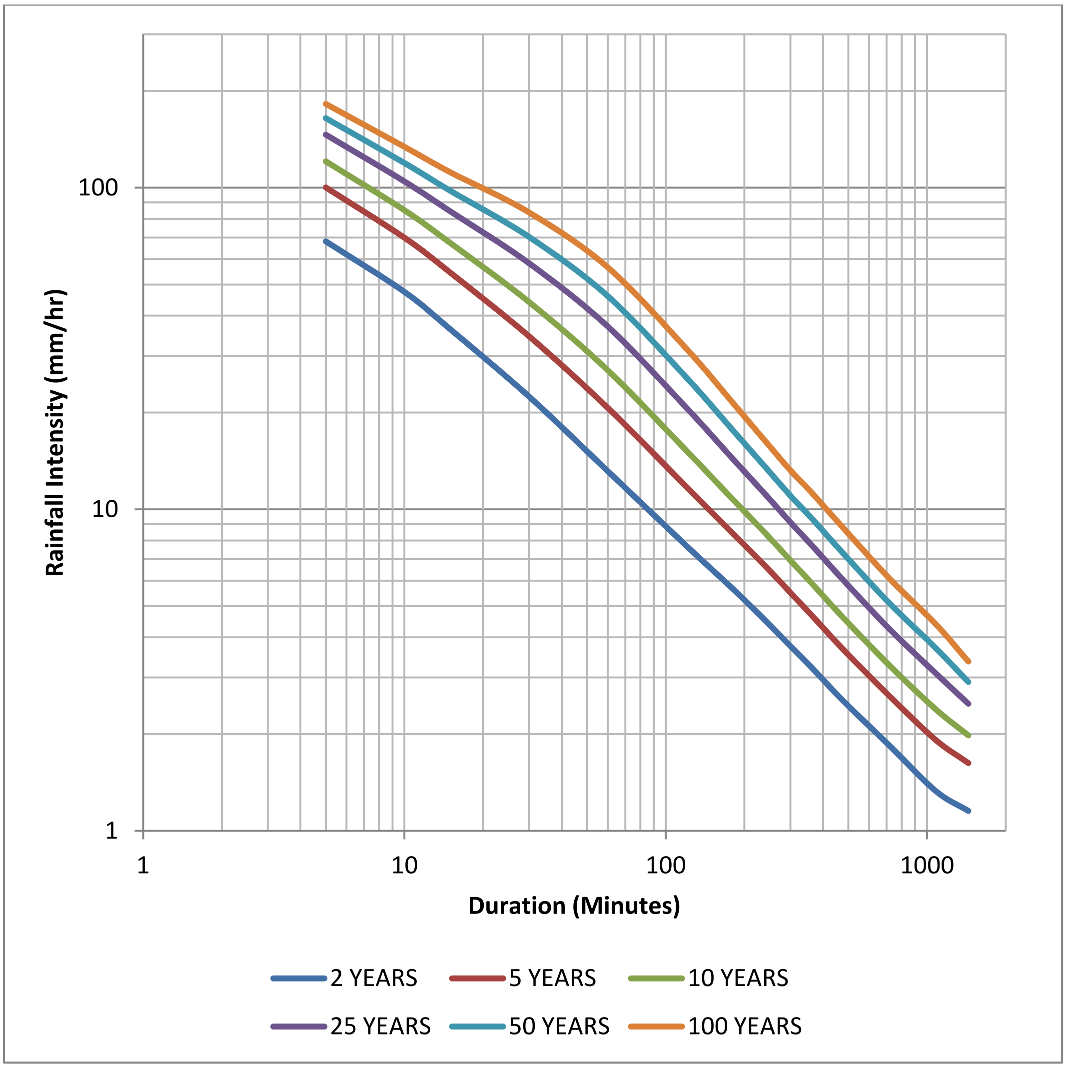

Figure F. 1: Ankara Meteorological Station Rainfall Intensity-Duration-Frequency Curve

APPENDIX G

PCA DATA

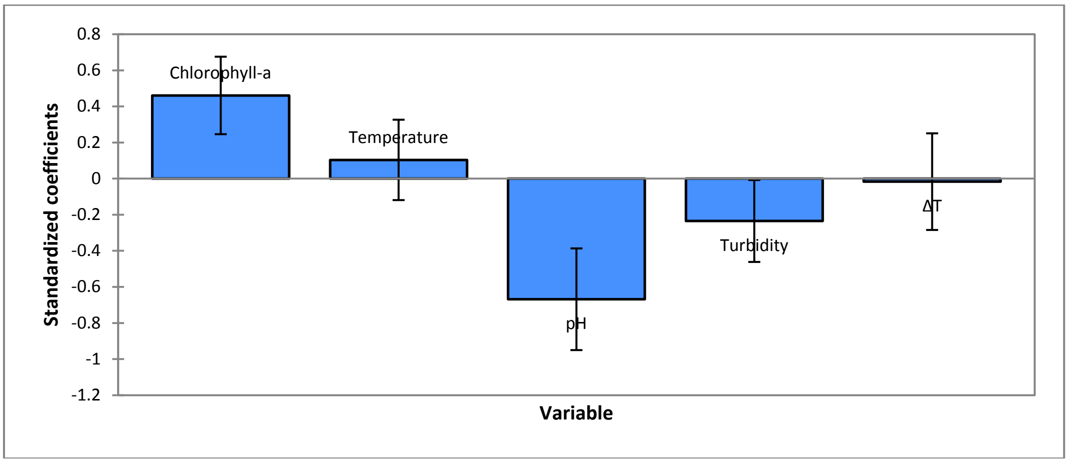

Figure G. 1: Standardized Coefficients for S-STP at 95% Confidence Interval for Bottom – 1 Model

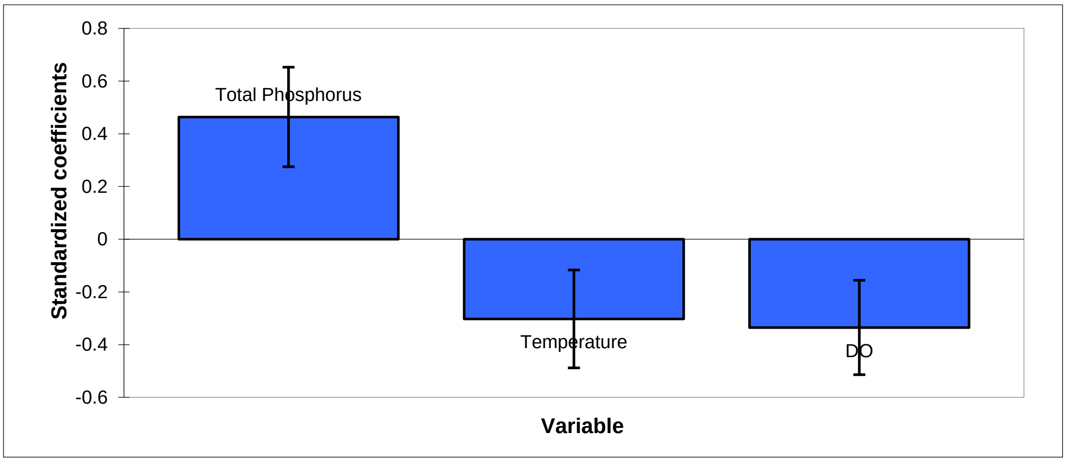

Figure G. 2: Standardized Coefficients for S-STP at 95% Confidence Interval for Bottom – 2 Model

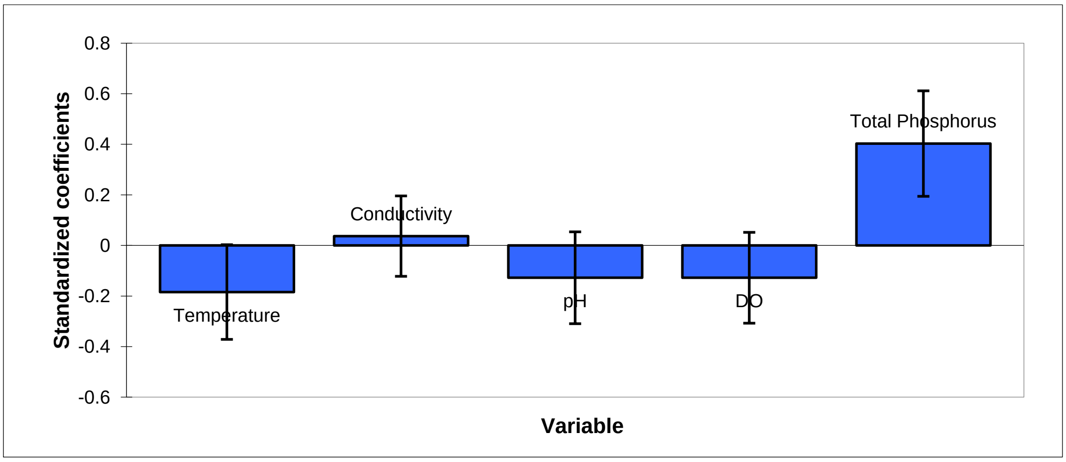

Figure G. 3: Standardized Coefficients for S-STP at 95% Confidence Interval for Bottom – 3 Model

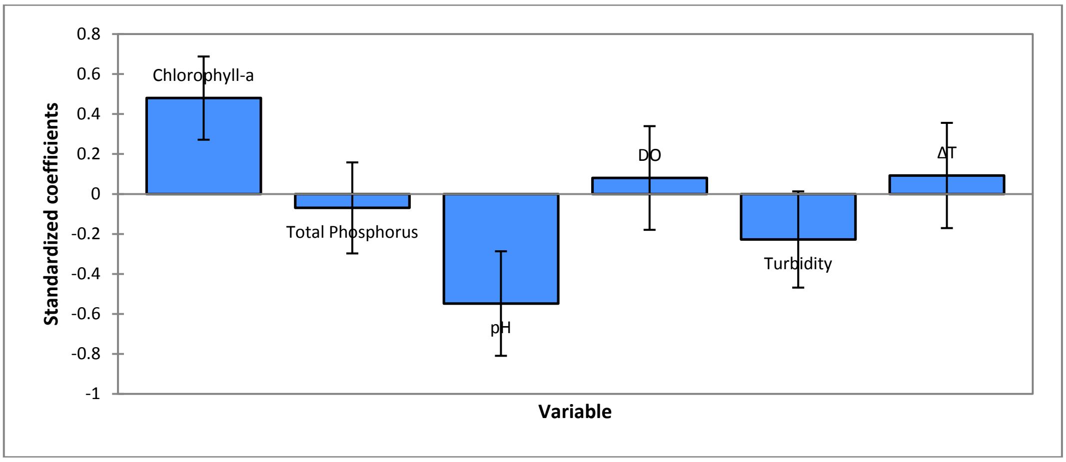

Figure G. 4: Standardized Coefficients for S-STP at 95% Confidence Interval for Average – 1 Model

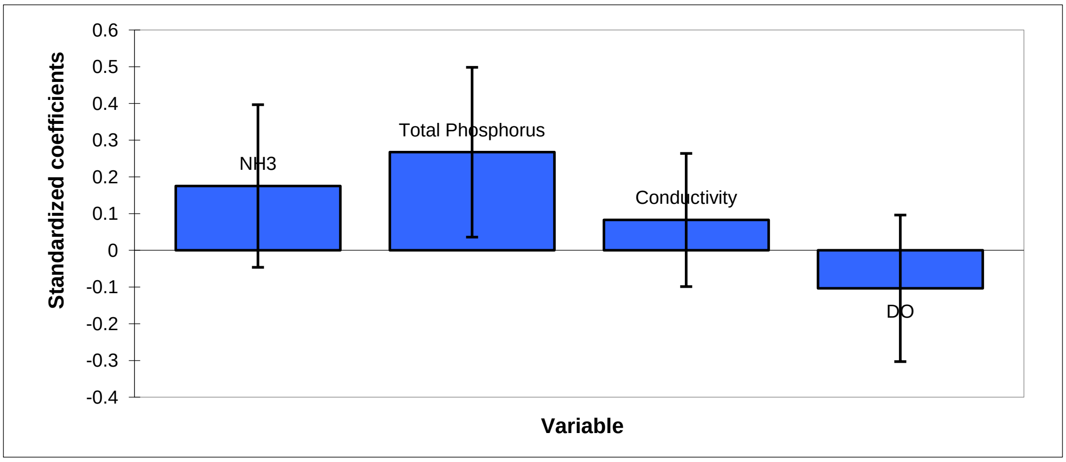

Figure G. 5: Standardized Coefficients for S-STP at 95% Confidence Interval for Average – 2 Model

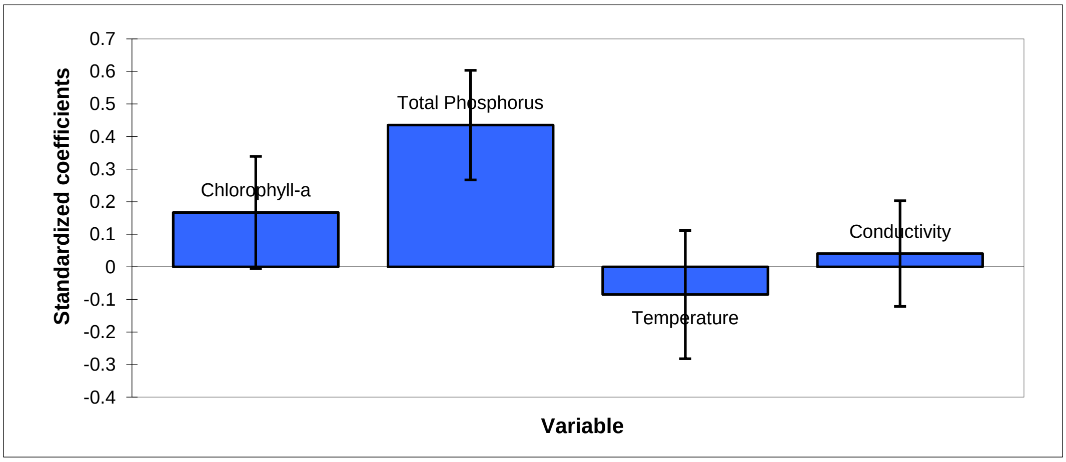

Figure G. 6: Standardized Coefficients for S-STP at 95% Confidence Interval for Average – 3 Model

Table G. 1: Pearson Correlation Matrix for Average – 1 Data Set

Variables	ΔT	Turbidity	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.17	0.05	0.13	0.10	**0.32**	0.25	-0.01	**0.43**	-0.10	0.00	**-0.34**	0.17	-0.09	-0.24	**0.50**	-0.24	-0.24	0.11	**0.34**	**1.00**
TSS	-0.06	0.10	-0.04	**0.38**	**0.44**	**0.42**	0.00	-0.11	-0.18	**-0.28**	-0.07	**0.32**	-0.08	-0.15	**0.49**	-0.12	-0.16	0.20	**1.00**	**0.34**
TKN	**-0.37**	0.05	0.09	0.11	-0.04	0.09	0.07	-0.17	-0.03	-0.07	-0.03	-0.08	-0.03	0.02	0.20	-0.16	0.15	**1.00**	0.20	0.11
NH_3	0.11	0.20	0.26	**-0.50**	**-0.68**	0.12	0.00	0.16	0.25	**0.42**	**-0.35**	**-0.70**	-0.13	0.12	-0.17	-0.26	**1.00**	0.15	-0.16	-0.24
NO_2	-0.02	**-0.53**	**-0.56**	0.22	**0.34**	-0.04	0.03	**-0.28**	-0.06	**-0.27**	**0.68**	0.23	-0.03	-0.21	-0.25	**1.00**	-0.26	-0.16	-0.12	-0.24
NO_3	0.01	0.19	-0.17	**0.29**	**0.38**	**0.73**	**0.36**	-0.04	-0.15	-0.17	-0.16	0.04	-0.10	0.03	**1.00**	-0.25	-0.17	0.20	**0.49**	**0.50**
Total-P	**0.45**	0.22	0.20	**-0.26**	**-0.33**	-0.05	-0.02	-0.04	0.14	0.23	-0.25	-0.17	**0.77**	**1.00**	0.03	-0.21	0.12	0.02	-0.15	-0.24
PO_4-P	0.20	-0.05	0.14	-0.03	-0.02	-0.21	0.02	0.06	0.25	0.12	-0.05	0.07	**1.00**	**0.77**	-0.10	-0.03	-0.13	-0.03	-0.08	-0.09
Alkalinity	**-0.39**	-0.25	-0.25	**0.60**	**0.71**	-0.09	-0.05	-0.16	-0.10	**-0.36**	**0.33**	**1.00**	0.07	-0.17	0.04	0.23	**-0.70**	-0.08	**0.32**	0.17
Secchi	**-0.28**	**-0.62**	**-0.62**	**0.41**	**0.46**	0.02	**0.32**	**-0.31**	-0.06	-0.23	**1.00**	**0.33**	-0.05	-0.25	-0.16	**0.68**	**-0.35**	-0.03	-0.07	**-0.34**
Water Depth	0.21	-0.10	0.23	**-0.45**	**-0.43**	-0.09	**0.32**	**0.60**	0.23	**1.00**	-0.23	**-0.36**	0.12	0.23	-0.17	**-0.27**	**0.42**	-0.07	**-0.28**	0.00
PAR	-0.04	-0.06	0.05	0.00	-0.09	-0.07	0.17	0.16	**1.00**	0.23	-0.06	-0.10	0.25	0.14	-0.15	-0.06	0.25	-0.03	-0.18	-0.10
S-STP	0.21	0.01	**0.27**	**-0.50**	-0.25	0.00	0.16	**1.00**	0.16	**0.60**	**-0.31**	-0.16	0.06	-0.04	-0.04	**-0.28**	0.16	-0.17	-0.11	**0.43**
S-SP	-0.15	**-0.28**	**-0.42**	0.25	0.24	**0.41**	**1.00**	0.16	0.17	**0.32**	**0.32**	-0.05	0.02	-0.02	**0.36**	0.03	0.00	0.07	0.00	-0.01
Temperature	0.07	0.05	**-0.37**	0.24	**0.33**	**1.00**	**0.41**	0.00	-0.07	-0.09	0.02	-0.09	-0.21	-0.05	**0.73**	-0.04	0.12	0.09	**0.42**	0.25
Conductivity	**-0.46**	**-0.44**	**-0.53**	**0.77**	**1.00**	**0.33**	0.24	-0.25	-0.09	**-0.43**	**0.46**	**0.71**	-0.02	**-0.33**	**0.38**	**0.34**	**-0.68**	-0.04	**0.44**	**0.32**
pH	**-0.53**	**-0.29**	**-0.46**	**1.00**	**0.77**	0.24	0.25	**-0.50**	0.00	**-0.45**	**0.41**	**0.60**	-0.03	**-0.26**	**0.29**	0.22	**-0.50**	0.11	**0.38**	0.10
DO	0.16	**0.51**	**1.00**	**-0.46**	**-0.53**	**-0.37**	**-0.42**	**0.27**	0.05	0.23	**-0.62**	-0.25	0.14	0.20	-0.17	**-0.56**	0.26	0.09	-0.04	0.13
Turbidity	**0.33**	**1.00**	**0.51**	**-0.29**	**-0.44**	0.05	**-0.28**	0.01	-0.06	-0.10	**-0.62**	-0.25	-0.05	0.22	0.19	**-0.53**	0.20	0.05	0.10	0.05
ΔT	**1.00**	**0.33**	0.16	**-0.53**	**-0.46**	0.07	-0.15	0.21	-0.04	0.21	**-0.28**	**-0.39**	0.20	**0.45**	0.01	-0.02	0.11	**-0.37**	-0.06	-0.17

Table G. 2: Pearson Correlation Matrix for Average – 2 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	**-0.23**	**0.29**	**0.37**	**0.65**	0.11	0.03	0.15	0.08	**-0.23**	**0.28**	-0.07	-0.03	**0.49**	**-0.25**	-0.17	0.11	0.18	**1.00**
TSS	0.17	-0.02	0.05	-0.03	**0.25**	**0.27**	0.01	0.17	**-0.30**	-0.15	0.07	0.09	-0.10	**0.23**	0.16	0.08	**1.00**	0.18
TKN	0.01	-0.09	**0.25**	0.17	0.17	0.13	0.11	0.06	**-0.33**	0.01	0.01	-0.01	0.01	**-0.21**	0.09	**1.00**	0.08	0.11
NH_3	**-0.32**	**-0.36**	0.00	-0.15	**0.22**	**0.38**	0.02	0.04	-0.15	**0.38**	**0.73**	**0.62**	0.08	**0.67**	**1.00**	0.09	0.16	-0.17
NO_2	0.00	**-0.29**	**-0.47**	**-0.51**	0.13	**0.21**	0.03	0.05	**0.19**	0.09	**0.53**	**0.43**	-0.05	**1.00**	**0.67**	**-0.21**	**0.23**	**-0.25**
NO_3	**-0.45**	-0.08	**0.31**	**0.58**	0.14	0.09	-0.05	0.11	-0.02	**0.50**	**0.34**	**0.31**	**1.00**	-0.05	0.08	0.01	-0.10	**0.49**
Total-P	**-0.43**	-0.19	0.11	-0.01	**0.23**	**0.43**	**0.25**	**0.20**	-0.06	**0.55**	**0.91**	**1.00**	**0.31**	**0.43**	**0.62**	-0.01	0.09	-0.03
PO_4-P	**-0.39**	**-0.27**	0.08	-0.09	**0.30**	**0.44**	**0.19**	**0.20**	-0.10	**0.52**	**1.00**	**0.91**	**0.34**	**0.53**	**0.73**	0.01	0.07	-0.07
Alkalinity	**-0.67**	**-0.23**	**0.22**	**0.45**	0.02	**0.19**	**0.20**	0.00	-0.02	**1.00**	**0.52**	**0.55**	**0.50**	0.09	**0.38**	0.01	-0.15	**0.28**
Secchi	-0.17	**-0.21**	**-0.51**	**-0.39**	**-0.26**	-0.18	-0.14	0.02	**1.00**	-0.02	-0.10	-0.06	-0.02	**0.19**	-0.15	**-0.33**	**-0.30**	**-0.23**
Water Depth	-0.06	0.00	0.02	-0.04	**0.56**	**0.58**	-0.02	**1.00**	0.02	0.00	**0.20**	**0.20**	0.11	0.05	0.04	0.06	0.17	0.08
PAR	-0.15	-0.04	0.04	-0.03	0.02	0.05	**1.00**	-0.02	-0.14	**0.20**	**0.19**	**0.25**	-0.05	0.03	0.02	0.11	0.01	0.15
S-STP	**-0.30**	-0.18	0.14	0.08	**0.72**	**1.00**	0.05	**0.58**	-0.18	**0.19**	**0.44**	**0.43**	0.09	**0.21**	**0.38**	0.13	**0.27**	0.03
S-SP	-0.09	-0.11	0.15	0.12	**1.00**	**0.72**	0.02	**0.56**	**-0.26**	0.02	**0.30**	**0.23**	0.14	0.13	**0.22**	0.17	**0.25**	0.11
Temperature	**-0.40**	**0.26**	**0.66**	**1.00**	0.12	0.08	-0.03	-0.04	**-0.39**	**0.45**	-0.09	-0.01	**0.58**	**-0.51**	-0.15	0.17	-0.03	**0.65**
Conductivity	**-0.31**	0.03	**1.00**	**0.66**	0.15	0.14	0.04	0.02	**-0.51**	**0.22**	0.08	0.11	**0.31**	**-0.47**	0.00	**0.25**	0.05	**0.37**
pH	**0.28**	**1.00**	0.03	**0.26**	-0.11	-0.18	-0.04	0.00	**-0.21**	**-0.23**	**-0.27**	-0.19	-0.08	**-0.29**	**-0.36**	-0.09	-0.02	**0.29**
DO	**1.00**	**0.28**	**-0.31**	**-0.40**	-0.09	**-0.30**	-0.15	-0.06	-0.17	**-0.67**	**-0.39**	**-0.43**	**-0.45**	0.00	**-0.32**	0.01	0.17	**-0.23**

Table G. 3: Pearson Correlation Matrix for Average – 3 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.15	0.11	**0.31**	**0.53**	0.08	0.14	0.13	0.09	**-0.17**	**0.27**	-0.02	0.02	**0.49**	**-0.24**	-0.11	0.11	**0.19**	**1.00**
TSS	0.15	**0.25**	**0.19**	-0.05	0.12	0.06	-0.03	**-0.17**	**-0.32**	-0.06	-0.11	**-0.16**	-0.02	0.13	-0.04	0.07	**1.00**	**0.19**
TKN	0.00	-0.10	**0.18**	**0.18**	0.14	0.08	0.10	0.08	**-0.23**	0.01	0.05	0.06	0.05	**-0.20**	0.12	**1.00**	0.07	0.11
NH_3	**-0.31**	**-0.59**	**-0.20**	**0.17**	**0.20**	**0.39**	0.06	**0.39**	0.13	**0.33**	**0.74**	**0.72**	**0.19**	**0.51**	**1.00**	0.12	-0.04	-0.11
NO_2	-0.13	-0.13	**-0.36**	**-0.36**	0.10	0.09	0.02	-0.01	**0.20**	0.12	**0.37**	**0.24**	-0.07	**1.00**	**0.51**	**-0.20**	0.13	**-0.24**
NO_3	**-0.41**	**-0.21**	**0.20**	**0.64**	**0.21**	0.12	-0.03	**0.20**	0.10	**0.44**	**0.36**	**0.37**	**1.00**	-0.07	**0.19**	0.05	-0.02	**0.49**
Total-P	**-0.37**	**-0.67**	**-0.22**	**0.38**	**0.20**	**0.40**	**0.21**	**0.60**	**0.32**	**0.42**	**0.90**	**1.00**	**0.37**	**0.24**	**0.72**	0.06	**-0.16**	0.02
PO_4-P	**-0.33**	**-0.55**	-0.14	**0.21**	**0.24**	**0.41**	**0.19**	**0.48**	**0.20**	**0.46**	**1.00**	**0.90**	**0.36**	**0.37**	**0.74**	0.05	-0.11	-0.02
Alkalinity	**-0.56**	**-0.18**	**0.20**	**0.38**	0.02	0.13	**0.17**	0.05	0.11	**1.00**	**0.46**	**0.42**	**0.44**	0.12	**0.33**	0.01	-0.06	**0.27**
Secchi	**-0.31**	**-0.45**	**-0.53**	-0.02	-0.08	-0.03	-0.09	**0.31**	**1.00**	0.11	**0.20**	**0.32**	0.10	**0.20**	0.13	**-0.23**	**-0.32**	**-0.17**
Water Depth	-0.13	**-0.58**	**-0.27**	**0.31**	**0.42**	**0.60**	0.05	**1.00**	**0.31**	0.05	**0.48**	**0.60**	**0.20**	-0.01	**0.39**	0.08	**-0.17**	0.09
PAR	-0.12	-0.07	0.01	0.01	0.05	0.07	**1.00**	0.05	-0.09	**0.17**	**0.19**	**0.21**	-0.03	0.02	0.06	0.10	-0.03	0.13
S-STP	-0.14	**-0.37**	-0.03	**0.18**	**0.51**	**1.00**	0.07	**0.60**	-0.03	0.13	**0.41**	**0.40**	0.12	0.09	**0.39**	0.08	0.06	0.14
S-SP	**-0.24**	-0.09	0.10	**0.23**	**1.00**	**0.51**	0.05	**0.42**	-0.08	0.02	**0.24**	**0.20**	**0.21**	0.10	**0.20**	0.14	0.12	0.08
Temperature	**-0.44**	**-0.26**	**0.32**	**1.00**	**0.23**	**0.18**	0.01	**0.31**	-0.02	**0.38**	**0.21**	**0.38**	**0.64**	**-0.36**	**0.17**	**0.18**	-0.05	**0.53**
Conductivity	**-0.21**	**0.34**	**1.00**	**0.32**	0.10	-0.03	0.01	**-0.27**	**-0.53**	**0.20**	-0.14	**-0.22**	**0.20**	**-0.36**	**-0.20**	**0.18**	**0.19**	**0.31**
pH	**0.23**	**1.00**	**0.34**	**-0.26**	-0.09	**-0.37**	-0.07	**-0.58**	**-0.45**	**-0.18**	**-0.55**	**-0.67**	**-0.21**	-0.13	**-0.59**	-0.10	**0.25**	0.11
DO	**1.00**	**0.23**	**-0.21**	**-0.44**	**-0.24**	-0.14	-0.12	-0.13	**-0.31**	**-0.56**	**-0.33**	**-0.37**	**-0.41**	-0.13	**-0.31**	0.00	0.15	-0.15

Table G. 4: Pearson Correlation Matrix for Surface – 1 Data Set

Variables	ΔT	Turbidity	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.18	0.09	-0.07	0.08	**0.31**	**0.36**	0.12	**0.28**	0.00	0.03	-0.20	0.17	-0.04	-0.06	**0.53**	-0.17	-0.07	**0.34**	**0.48**	**1.00**
TSS	-0.19	0.07	-0.17	**0.31**	**0.46**	**0.54**	0.15	-0.02	-0.19	-0.18	-0.12	**0.28**	-0.02	-0.07	**0.57**	-0.21	-0.03	**0.49**	**1.00**	**0.48**
TKN	**-0.51**	-0.04	-0.13	**0.51**	**0.55**	0.12	0.17	-0.25	0.03	**-0.27**	0.04	**0.33**	0.01	-0.23	**0.38**	-0.14	-0.02	**1.00**	**0.49**	**0.34**
NH_3	-0.02	0.07	0.13	-0.25	**-0.39**	0.13	0.03	0.10	**0.32**	**0.32**	**-0.31**	**-0.58**	-0.10	0.03	-0.14	-0.09	**1.00**	-0.02	-0.03	-0.07
NO_2	0.13	**-0.45**	**-0.35**	0.07	0.11	-0.06	0.02	-0.19	-0.04	-0.16	**0.56**	0.05	0.03	-0.23	-0.22	**1.00**	-0.09	-0.14	-0.21	-0.17
NO_3	0.02	0.17	-0.21	0.20	**0.28**	**0.64**	**0.29**	-0.01	-0.17	-0.18	-0.18	0.03	-0.13	0.08	**1.00**	-0.22	-0.14	**0.38**	**0.57**	**0.53**
Total-P	**0.35**	**0.38**	0.22	-0.15	**-0.41**	0.08	-0.14	-0.16	-0.02	0.18	**-0.36**	**-0.32**	**0.42**	**1.00**	0.08	-0.23	0.03	-0.23	-0.07	-0.06
PO_4-P	0.13	-0.07	0.11	0.05	0.03	-0.20	0.03	0.05	**0.32**	0.11	-0.06	0.11	**1.00**	**0.42**	-0.13	0.03	-0.10	0.01	-0.02	-0.04
Alkalinity	**-0.48**	**-0.29**	-0.23	**0.52**	**0.80**	-0.15	-0.06	-0.09	-0.07	**-0.35**	**0.28**	**1.00**	0.11	**-0.32**	0.03	0.05	**-0.58**	**0.33**	**0.28**	0.17
Secchi	**-0.28**	**-0.62**	**-0.51**	**0.41**	**0.42**	-0.01	**0.32**	**-0.31**	-0.06	-0.23	**1.00**	**0.28**	-0.06	**-0.36**	-0.18	**0.56**	**-0.31**	0.04	-0.12	-0.20
Water Depth	0.21	-0.10	0.23	**-0.40**	**-0.42**	-0.06	**0.32**	**0.60**	0.23	**1.00**	-0.23	**-0.35**	0.11	0.18	-0.18	-0.16	**0.32**	**-0.27**	-0.18	0.03
PAR	-0.04	-0.06	0.01	0.04	-0.04	-0.07	0.17	0.16	**1.00**	0.23	-0.06	-0.07	**0.32**	-0.02	-0.17	-0.04	**0.32**	0.03	-0.19	0.00
S-STP	0.21	0.01	0.23	**-0.56**	-0.25	0.02	0.16	**1.00**	0.16	**0.60**	**-0.31**	-0.09	0.05	-0.16	-0.01	-0.19	0.10	-0.25	-0.02	**0.28**
S-SP	-0.15	**-0.28**	**-0.40**	0.25	0.23	**0.39**	**1.00**	0.16	0.17	**0.32**	**0.32**	-0.06	0.03	-0.14	**0.29**	0.02	0.03	0.17	0.15	0.12
Temperature	0.14	0.08	**-0.40**	0.17	0.19	**1.00**	**0.39**	0.02	-0.07	-0.06	-0.01	-0.15	-0.20	0.08	**0.64**	-0.06	0.13	0.12	**0.54**	**0.36**
Conductivity	**-0.64**	**-0.43**	**-0.38**	**0.67**	**1.00**	0.19	0.23	-0.25	-0.04	**-0.42**	**0.42**	**0.80**	0.03	**-0.41**	**0.28**	0.11	**-0.39**	**0.55**	**0.46**	**0.31**
pH	**-0.44**	-0.24	**-0.45**	**1.00**	**0.67**	0.17	0.25	**-0.56**	0.04	**-0.40**	**0.41**	**0.52**	0.05	-0.15	0.20	0.07	-0.25	**0.51**	**0.31**	0.08
DO	0.10	**0.45**	**1.00**	**-0.45**	**-0.38**	**-0.40**	**-0.40**	0.23	0.01	0.23	**-0.51**	-0.23	0.11	0.22	-0.21	**-0.35**	0.13	-0.13	-0.17	-0.07
Turbidity	**0.33**	**1.00**	**0.45**	-0.24	**-0.43**	0.08	**-0.28**	0.01	-0.06	-0.10	**-0.62**	**-0.29**	-0.07	**0.38**	0.17	**-0.45**	0.07	-0.04	0.07	0.09
ΔT	**1.00**	**0.33**	0.10	**-0.44**	**-0.64**	0.14	-0.15	0.21	-0.04	0.21	**-0.28**	**-0.48**	0.13	**0.35**	0.02	0.13	-0.02	**-0.51**	-0.19	-0.18

Table G. 5: Pearson Correlation Matrix for Surface – 2 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	0.07	0.15	0.17	0.12	0.18	0.12	**0.52**	0.04	**-0.39**	0.08	0.05	0.14	-0.06	-0.17	0.03	**0.25**	**0.42**	**1.00**
TSS	**0.35**	**0.24**	0.12	0.11	0.17	0.14	0.05	0.10	**-0.37**	**-0.20**	-0.11	-0.05	-0.14	-0.13	-0.09	0.08	**1.00**	**0.42**
TKN	0.15	-0.03	0.17	0.06	0.05	-0.01	0.17	0.05	**-0.27**	-0.05	0.00	0.00	-0.03	-0.10	0.17	**1.00**	0.08	**0.25**
NH_3	**-0.39**	**-0.54**	-0.10	**-0.35**	0.14	**0.34**	0.12	-0.02	-0.14	**0.30**	**0.80**	**0.75**	-0.05	**0.64**	**1.00**	0.17	-0.09	0.03
NO_2	-0.16	**-0.48**	**-0.49**	**-0.60**	0.09	0.18	0.01	0.04	**0.26**	0.05	**0.66**	**0.60**	-0.05	**1.00**	**0.64**	-0.10	-0.13	-0.17
NO_3	**-0.20**	-0.03	**0.35**	**0.45**	0.07	0.02	-0.03	0.07	0.01	**0.46**	-0.06	-0.15	**1.00**	-0.05	-0.05	-0.03	-0.14	-0.06
Total-P	**-0.41**	**-0.56**	**-0.20**	**-0.58**	-0.02	0.18	**0.30**	-0.07	0.07	**0.26**	**0.94**	**1.00**	-0.15	**0.60**	**0.75**	0.00	-0.05	0.14
PO_4-P	**-0.38**	**-0.56**	-0.14	**-0.55**	0.07	**0.20**	**0.24**	-0.05	0.05	**0.25**	**1.00**	**0.94**	-0.06	**0.66**	**0.80**	0.00	-0.11	0.05
Alkalinity	**-0.61**	**-0.21**	**0.27**	**0.40**	0.01	0.15	**0.22**	-0.01	-0.02	**1.00**	**0.25**	**0.26**	**0.46**	0.05	**0.30**	-0.05	**-0.20**	0.08
Secchi	**-0.24**	**-0.29**	**-0.47**	**-0.43**	**-0.26**	-0.18	-0.14	0.02	**1.00**	-0.02	0.05	0.07	0.01	**0.26**	-0.14	**-0.27**	**-0.37**	**-0.39**
Water Depth	0.08	0.12	0.02	0.02	**0.56**	**0.58**	-0.02	**1.00**	0.02	-0.01	-0.05	-0.07	0.07	0.04	-0.02	0.05	0.10	0.04
PAR	-0.17	-0.10	0.04	-0.06	0.02	0.05	**1.00**	-0.02	-0.14	**0.22**	**0.24**	**0.30**	-0.03	0.01	0.12	0.17	0.05	**0.52**
S-STP	-0.17	-0.12	0.14	0.10	**0.72**	**1.00**	0.05	**0.58**	-0.18	0.15	**0.20**	0.18	0.02	0.18	**0.34**	-0.01	0.14	0.12
S-SP	0.05	0.01	0.13	0.13	**1.00**	**0.72**	0.02	**0.56**	**-0.26**	0.01	0.07	-0.02	0.07	0.09	0.14	0.05	0.17	0.18
Temperature	-0.09	**0.42**	**0.71**	**1.00**	0.13	0.10	-0.06	0.02	**-0.43**	**0.40**	**-0.55**	**-0.58**	**0.45**	**-0.60**	**-0.35**	0.06	0.11	0.12
Conductivity	-0.10	**0.21**	**1.00**	**0.71**	0.13	0.14	0.04	0.02	**-0.47**	**0.27**	-0.14	**-0.20**	**0.35**	**-0.49**	-0.10	0.17	0.12	0.17
pH	**0.37**	**1.00**	**0.21**	**0.42**	0.01	-0.12	-0.10	0.12	**-0.29**	**-0.21**	**-0.56**	**-0.56**	-0.03	**-0.48**	**-0.54**	-0.03	**0.24**	0.15
DO	**1.00**	**0.37**	-0.10	-0.09	0.05	-0.17	-0.17	0.08	**-0.24**	**-0.61**	**-0.38**	**-0.41**	**-0.20**	-0.16	**-0.39**	0.15	**0.35**	0.07

Table G. 6: Pearson Correlation Matrix for Surface – 3 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	0.04	**0.21**	**0.24**	0.05	0.13	0.13	**0.38**	-0.09	**-0.36**	0.07	-0.04	-0.03	0.04	-0.15	-0.06	**0.25**	**0.46**	**1.00**
TSS	**0.18**	**0.34**	**0.25**	0.05	0.13	0.02	0.00	-0.15	**-0.37**	-0.09	**-0.16**	**-0.18**	-0.03	-0.12	**-0.17**	0.14	**1.00**	**0.46**
TKN	0.10	0.07	**0.22**	0.02	0.06	-0.06	**0.15**	-0.05	**-0.25**	-0.01	-0.02	-0.05	0.00	-0.10	0.12	**1.00**	0.14	**0.25**
NH_3	**-0.32**	**-0.61**	**-0.23**	-0.01	0.15	**0.35**	0.14	**0.29**	0.09	**0.25**	**0.78**	**0.78**	0.05	**0.52**	**1.00**	0.12	**-0.17**	-0.06
NO_2	**-0.18**	**-0.23**	**-0.38**	**-0.48**	0.06	0.09	0.00	-0.03	**0.23**	0.04	**0.54**	**0.40**	-0.08	**1.00**	**0.52**	-0.10	-0.12	-0.15
NO_3	**-0.22**	**-0.16**	**0.24**	**0.52**	0.15	0.07	-0.02	**0.16**	0.10	**0.39**	0.02	0.04	**1.00**	-0.08	0.05	0.00	-0.03	0.04
Total-P	**-0.32**	**-0.71**	**-0.34**	-0.03	0.04	**0.25**	**0.26**	**0.38**	**0.33**	**0.25**	**0.89**	**1.00**	0.04	**0.40**	**0.78**	-0.05	**-0.18**	-0.03
PO_4-P	**-0.29**	**-0.56**	**-0.22**	**-0.21**	0.10	**0.24**	**0.24**	**0.24**	**0.22**	**0.27**	**1.00**	**0.89**	0.02	**0.54**	**0.78**	-0.02	**-0.16**	-0.04
Alkalinity	**-0.50**	-0.15	**0.31**	**0.33**	0.01	0.11	**0.18**	0.02	0.10	**1.00**	**0.27**	**0.25**	**0.39**	0.04	**0.25**	-0.01	-0.09	0.07
Secchi	**-0.30**	**-0.48**	**-0.47**	-0.04	-0.08	-0.03	-0.09	**0.31**	**1.00**	0.10	**0.22**	**0.33**	0.10	**0.23**	0.09	**-0.25**	**-0.37**	**-0.36**
Water Depth	0.00	**-0.51**	**-0.27**	**0.34**	**0.42**	**0.60**	0.05	**1.00**	**0.31**	0.02	**0.24**	**0.38**	**0.16**	-0.03	**0.29**	-0.05	-0.15	-0.09
PAR	-0.14	-0.10	0.02	-0.01	0.05	0.07	**1.00**	0.05	-0.09	**0.18**	**0.24**	**0.26**	-0.02	0.00	0.14	**0.15**	0.00	**0.38**
S-STP	-0.06	**-0.35**	-0.04	**0.20**	**0.51**	**1.00**	0.07	**0.60**	-0.03	0.11	**0.24**	**0.25**	0.07	0.09	**0.35**	-0.06	0.02	0.13
S-SP	-0.15	-0.03	0.11	**0.22**	**1.00**	**0.51**	0.05	**0.42**	-0.08	0.01	0.10	0.04	0.15	0.06	0.15	0.06	0.13	0.13
Temperature	**-0.22**	**-0.17**	**0.35**	**1.00**	**0.22**	**0.20**	-0.01	**0.34**	-0.04	**0.33**	**-0.21**	-0.03	**0.52**	**-0.48**	-0.01	0.02	0.05	0.05
Conductivity	-0.11	**0.42**	**1.00**	**0.35**	0.11	-0.04	0.02	**-0.27**	**-0.47**	**0.31**	**-0.22**	**-0.34**	**0.24**	**-0.38**	**-0.23**	**0.22**	**0.25**	**0.24**
pH	**0.20**	**1.00**	**0.42**	**-0.17**	-0.03	**-0.35**	-0.10	**-0.51**	**-0.48**	-0.15	**-0.56**	**-0.71**	**-0.16**	**-0.23**	**-0.61**	0.07	**0.34**	**0.21**
DO	**1.00**	**0.20**	-0.11	**-0.22**	-0.15	-0.06	-0.14	0.00	**-0.30**	**-0.50**	**-0.29**	**-0.32**	**-0.22**	**-0.18**	**-0.32**	0.10	**0.18**	0.04

Table G. 7: Pearson Correlation Matrix for Mid – 1 Data Set

Variables	ΔT	Turbidity	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.07	0.01	0.21	-0.01	0.22	0.11	-0.10	**0.42**	-0.13	0.06	**-0.37**	**-0.36**	-0.08	-0.17	0.24	-0.22	-0.24	0.25	0.22	**1.00**
TSS	-0.05	0.02	0.01	**0.35**	**0.39**	**0.39**	0.05	-0.08	-0.09	-0.14	-0.10	0.12	-0.08	-0.09	**0.43**	-0.15	-0.07	**0.35**	**1.00**	0.22
TKN	**-0.61**	-0.05	-0.03	**0.65**	**0.45**	0.22	0.18	**-0.30**	0.06	**-0.29**	0.04	0.16	0.03	-0.05	**0.44**	-0.11	-0.15	**1.00**	**0.35**	0.25
NH_3	0.05	0.24	**0.30**	**-0.45**	**-0.73**	0.08	0.00	0.13	0.14	**0.39**	**-0.34**	**-0.34**	-0.10	0.02	-0.14	**-0.36**	**1.00**	-0.15	-0.07	-0.24
NO_2	-0.05	**-0.56**	**-0.50**	0.26	**0.39**	-0.01	0.11	-0.24	-0.04	-0.22	**0.68**	0.21	0.02	-0.07	-0.18	**1.00**	**-0.36**	-0.11	-0.15	-0.22
NO_3	0.05	0.21	-0.11	**0.32**	**0.38**	**0.73**	**0.34**	-0.10	-0.13	-0.19	-0.15	0.05	-0.04	0.06	**1.00**	-0.18	-0.14	**0.44**	**0.43**	0.24
Total-P	**0.33**	0.05	0.13	-0.14	-0.14	-0.07	0.10	0.04	0.19	0.17	-0.09	-0.04	**0.94**	**1.00**	0.06	-0.07	0.02	-0.05	-0.09	-0.17
PO_4-P	0.17	-0.08	0.09	-0.04	0.00	-0.15	0.09	0.07	0.24	0.07	0.00	0.01	**1.00**	**0.94**	-0.04	0.02	-0.10	0.03	-0.08	-0.08
Alkalinity	**-0.28**	-0.15	-0.22	**0.52**	**0.42**	0.01	0.04	-0.20	-0.07	**-0.27**	**0.32**	**1.00**	0.01	-0.04	0.05	0.21	**-0.34**	0.16	0.12	**-0.36**
Secchi	**-0.28**	**-0.62**	**-0.67**	**0.35**	**0.46**	0.01	**0.32**	**-0.31**	-0.06	-0.23	**1.00**	**0.32**	0.00	-0.09	-0.15	**0.68**	**-0.34**	0.04	-0.10	**-0.37**
Water Depth	0.21	-0.10	0.22	**-0.47**	**-0.42**	-0.10	**0.32**	**0.60**	0.23	**1.00**	-0.23	**-0.27**	0.07	0.17	-0.19	-0.22	**0.39**	**-0.29**	-0.14	0.06
PAR	-0.04	-0.06	0.08	-0.01	-0.11	-0.07	0.17	0.16	**1.00**	0.23	-0.06	-0.07	0.24	0.19	-0.13	-0.04	0.14	0.06	-0.09	-0.13
S-STP	0.21	0.01	**0.35**	**-0.45**	-0.24	0.00	0.16	**1.00**	0.16	**0.60**	**-0.31**	-0.20	0.07	0.04	-0.10	-0.24	0.13	**-0.30**	-0.08	**0.42**
S-SP	-0.15	**-0.28**	**-0.42**	0.22	0.23	**0.41**	**1.00**	0.16	0.17	**0.32**	**0.32**	0.04	0.09	0.10	**0.34**	0.11	0.00	0.18	0.05	-0.10
Temperature	0.05	0.06	**-0.28**	**0.27**	**0.35**	**1.00**	**0.41**	0.00	-0.07	-0.10	0.01	0.01	-0.15	-0.07	**0.73**	-0.01	0.08	0.22	**0.39**	0.11
Conductivity	**-0.37**	**-0.43**	**-0.53**	**0.75**	**1.00**	**0.35**	0.23	-0.24	-0.11	**-0.42**	**0.46**	**0.42**	0.00	-0.14	**0.38**	**0.39**	**-0.73**	**0.45**	**0.39**	0.22
pH	**-0.52**	-0.25	**-0.39**	**1.00**	**0.75**	**0.27**	0.22	**-0.45**	-0.01	**-0.47**	**0.35**	**0.52**	-0.04	-0.14	**0.32**	0.26	**-0.45**	**0.65**	**0.35**	-0.01
DO	0.25	**0.53**	**1.00**	**-0.39**	**-0.53**	**-0.28**	**-0.42**	**0.35**	0.08	0.22	**-0.67**	-0.22	0.09	0.13	-0.11	**-0.50**	**0.30**	-0.03	0.01	0.21
Turbidity	**0.33**	**1.00**	**0.53**	-0.25	**-0.43**	0.06	**-0.28**	0.01	-0.06	-0.10	**-0.62**	-0.15	-0.08	0.05	0.21	**-0.56**	0.24	-0.05	0.02	0.01
ΔT	**1.00**	**0.33**	0.25	**-0.52**	**-0.37**	0.05	-0.15	0.21	-0.04	0.21	**-0.28**	**-0.28**	0.17	**0.33**	0.05	-0.05	0.05	**-0.61**	-0.05	-0.07

Table G. 8: Pearson Correlation Matrix for Mid – 2 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.15	0.08	**0.34**	**0.40**	**0.21**	0.19	**0.20**	0.16	**-0.26**	0.12	**-0.25**	**-0.27**	**0.44**	-0.18	**-0.20**	0.11	**0.34**	**1.00**
TSS	0.17	0.03	0.18	0.07	0.18	**0.27**	0.01	0.10	**-0.47**	-0.13	-0.04	-0.03	-0.12	0.01	0.13	0.16	**1.00**	**0.34**
TKN	0.09	-0.07	0.15	-0.01	0.12	0.09	0.14	-0.03	**-0.25**	-0.06	0.06	0.00	-0.09	-0.03	0.15	**1.00**	0.16	0.11
NH_3	**-0.23**	**-0.42**	-0.05	**-0.28**	0.13	**0.30**	0.09	-0.03	-0.13	**0.36**	**0.78**	**0.68**	0.06	**0.65**	**1.00**	0.15	0.13	**-0.20**
NO_2	0.01	**-0.36**	**-0.52**	**-0.60**	0.00	0.12	0.02	-0.01	**0.26**	0.10	**0.62**	**0.54**	0.02	**1.00**	**0.65**	-0.03	0.01	-0.18
NO_3	**-0.43**	-0.16	**0.29**	**0.45**	0.10	0.08	-0.01	0.07	0.01	**0.47**	0.05	0.01	**1.00**	0.02	0.06	-0.09	-0.12	**0.44**
Total-P	**-0.21**	**-0.31**	-0.10	**-0.39**	0.00	**0.20**	**0.29**	-0.04	0.05	**0.38**	**0.88**	**1.00**	0.01	**0.54**	**0.68**	0.00	-0.03	**-0.27**
PO_4-P	**-0.19**	**-0.40**	-0.12	**-0.47**	0.04	0.17	**0.27**	-0.05	0.03	**0.33**	**1.00**	**0.88**	0.05	**0.62**	**0.78**	0.06	-0.04	**-0.25**
Alkalinity	**-0.66**	**-0.26**	**0.22**	**0.40**	-0.01	0.18	**0.20**	-0.01	0.02	**1.00**	**0.33**	**0.38**	**0.47**	0.10	**0.36**	-0.06	-0.13	0.12
Secchi	**-0.27**	**-0.26**	**-0.51**	**-0.40**	**-0.26**	-0.18	-0.14	0.02	**1.00**	0.02	0.03	0.05	0.01	**0.26**	-0.13	**-0.25**	**-0.47**	**-0.26**
Water Depth	-0.07	0.01	0.00	-0.04	**0.56**	**0.58**	-0.02	**1.00**	0.02	-0.01	-0.05	-0.04	0.07	-0.01	-0.03	-0.03	0.10	0.16
PAR	-0.14	-0.06	0.05	-0.04	0.02	0.05	**1.00**	-0.02	-0.14	**0.20**	**0.27**	**0.29**	-0.01	0.02	0.09	0.14	0.01	**0.20**
S-STP	**-0.27**	-0.18	0.14	0.08	**0.72**	**1.00**	0.05	**0.58**	-0.18	0.18	0.17	**0.20**	0.08	0.12	**0.30**	0.09	**0.27**	0.19
S-SP	-0.04	-0.07	0.15	0.12	**1.00**	**0.72**	0.02	**0.56**	**-0.26**	-0.01	0.04	0.00	0.10	0.00	0.13	0.12	0.18	**0.21**
Temperature	**-0.32**	**0.30**	**0.68**	**1.00**	0.12	0.08	-0.04	-0.04	**-0.40**	**0.40**	**-0.47**	**-0.39**	**0.45**	**-0.60**	**-0.28**	-0.01	0.07	**0.40**
Conductivity	**-0.26**	0.08	**1.00**	**0.68**	0.15	0.14	0.05	0.00	**-0.51**	**0.22**	-0.12	-0.10	**0.29**	**-0.52**	-0.05	0.15	0.18	**0.34**
pH	**0.32**	**1.00**	0.08	**0.30**	-0.07	-0.18	-0.06	0.01	**-0.26**	**-0.26**	**-0.40**	**-0.31**	-0.16	**-0.36**	**-0.42**	-0.07	0.03	0.08
DO	**1.00**	**0.32**	**-0.26**	**-0.32**	-0.04	**-0.27**	-0.14	-0.07	**-0.27**	**-0.66**	**-0.19**	**-0.21**	**-0.43**	0.01	**-0.23**	0.09	0.17	-0.15

Table G. 9: Pearson Correlation Matrix for Mid – 3 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	0.04	**0.20**	**0.33**	0.14	0.05	**0.21**	0.11	-0.05	**-0.31**	-0.15	**-0.22**	**-0.31**	**0.30**	**-0.16**	**-0.24**	0.11	**0.33**	**1.00**
TSS	**0.16**	**0.29**	**0.28**	-0.01	0.08	0.04	-0.02	**-0.19**	**-0.43**	-0.07	-0.13	**-0.20**	-0.02	-0.01	-0.04	**0.16**	**1.00**	**0.33**
TKN	0.07	0.00	**0.16**	0.01	0.11	0.03	0.13	-0.05	**-0.21**	-0.02	0.05	0.00	-0.04	-0.04	0.13	**1.00**	**0.16**	0.11
NH_3	**-0.23**	**-0.56**	**-0.22**	0.03	0.14	**0.33**	0.11	**0.29**	0.10	**0.28**	**0.59**	**0.67**	0.13	**0.48**	**1.00**	0.13	-0.04	**-0.24**
NO_2	-0.09	-0.09	**-0.36**	**-0.47**	0.02	0.00	0.00	-0.10	**0.21**	0.11	**0.38**	**0.28**	-0.04	**1.00**	**0.48**	-0.04	-0.01	**-0.16**
NO_3	**-0.37**	**-0.21**	**0.19**	**0.53**	**0.18**	0.08	0.00	0.14	0.10	**0.35**	0.07	0.14	**1.00**	-0.04	0.13	-0.04	-0.02	**0.30**
Total-P	**-0.20**	**-0.58**	**-0.28**	0.07	0.10	**0.27**	**0.25**	**0.39**	**0.29**	**0.29**	**0.85**	**1.00**	0.14	**0.28**	**0.67**	0.00	**-0.20**	**-0.31**
PO_4-P	-0.12	**-0.36**	**-0.17**	**-0.16**	0.09	**0.19**	**0.23**	**0.17**	0.14	**0.22**	**1.00**	**0.85**	0.07	**0.38**	**0.59**	0.05	-0.13	**-0.22**
Alkalinity	**-0.49**	**-0.15**	0.14	**0.33**	0.04	0.07	0.14	0.04	**0.15**	**1.00**	**0.22**	**0.29**	**0.35**	0.11	**0.28**	-0.02	-0.07	-0.15
Secchi	**-0.35**	**-0.47**	**-0.54**	-0.02	-0.08	-0.03	-0.09	**0.31**	**1.00**	**0.15**	0.14	**0.29**	0.10	**0.21**	0.10	**-0.21**	**-0.43**	**-0.31**
Water Depth	-0.10	**-0.57**	**-0.29**	**0.31**	**0.42**	**0.60**	0.05	**1.00**	**0.31**	0.04	**0.17**	**0.39**	0.14	-0.10	**0.29**	-0.05	**-0.19**	-0.05
PAR	-0.11	-0.08	0.01	0.00	0.05	0.07	**1.00**	0.05	-0.09	0.14	**0.23**	**0.25**	0.00	0.00	0.11	0.13	-0.02	0.11
S-STP	-0.09	**-0.36**	-0.03	**0.19**	**0.51**	**1.00**	0.07	**0.60**	-0.03	0.07	**0.19**	**0.27**	0.08	0.00	**0.33**	0.03	0.04	**0.21**
S-SP	**-0.20**	-0.08	0.10	**0.23**	**1.00**	**0.51**	0.05	**0.42**	-0.08	0.04	0.09	0.10	**0.18**	0.02	0.14	0.11	0.08	0.05
Temperature	**-0.36**	**-0.24**	**0.32**	**1.00**	**0.23**	**0.19**	0.00	**0.31**	-0.02	**0.33**	**-0.16**	0.07	**0.53**	**-0.47**	0.03	0.01	-0.01	0.14
Conductivity	**-0.19**	**0.38**	**1.00**	**0.32**	0.10	-0.03	0.01	**-0.29**	**-0.54**	0.14	**-0.17**	**-0.28**	**0.19**	**-0.36**	**-0.22**	**0.16**	**0.28**	**0.33**
pH	**0.23**	**1.00**	**0.38**	**-0.24**	-0.08	**-0.36**	-0.08	**-0.57**	**-0.47**	**-0.15**	**-0.36**	**-0.58**	**-0.21**	-0.09	**-0.56**	0.00	**0.29**	**0.20**
DO	**1.00**	**0.23**	**-0.19**	**-0.36**	**-0.20**	-0.09	-0.11	-0.10	**-0.35**	**-0.49**	-0.12	**-0.20**	**-0.37**	-0.09	**-0.23**	0.07	**0.16**	0.04

Table G. 10: Pearson Correlation Matrix for Bottom – 1 Data Set

Variables	ΔT	Turbidity	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	-0.20	0.02	0.23	0.19	0.16	0.13	-0.03	**0.35**	-0.11	-0.13	-0.24	**0.28**	-0.13	**-0.31**	**0.36**	-0.23	**-0.30**	-0.03	**0.36**	**1.00**
TSS	0.03	0.13	0.10	0.24	**0.28**	0.21	-0.13	-0.15	-0.18	**-0.36**	0.00	0.24	0.04	-0.11	**0.26**	-0.09	-0.17	0.01	**1.00**	**0.36**
TKN	-0.16	0.08	0.17	-0.17	**-0.28**	0.03	0.00	-0.07	-0.06	0.06	-0.06	-0.23	-0.06	0.09	0.01	-0.10	0.13	**1.00**	0.01	-0.03
NH_3	0.25	0.24	0.17	**-0.64**	**-0.67**	0.09	-0.03	0.19	0.21	**0.45**	**-0.32**	**-0.73**	-0.01	**0.38**	-0.18	-0.23	**1.00**	0.13	-0.17	**-0.30**
NO_2	-0.10	**-0.46**	**-0.62**	0.24	**0.42**	-0.02	-0.04	**-0.33**	-0.07	**-0.35**	**0.62**	0.18	-0.15	**-0.26**	-0.22	**1.00**	-0.23	-0.10	-0.09	-0.23
NO_3	-0.03	0.15	-0.09	**0.31**	**0.41**	**0.70**	**0.38**	0.00	-0.12	-0.12	-0.12	0.01	-0.25	-0.08	**1.00**	-0.22	-0.18	0.01	**0.26**	**0.36**
Total-P	**0.47**	**0.33**	0.11	**-0.46**	**-0.28**	-0.10	-0.16	-0.08	0.06	0.26	**-0.33**	-0.10	**0.61**	**1.00**	-0.08	**-0.26**	**0.38**	0.09	-0.11	**-0.31**
PO_4-P	**0.31**	0.14	0.23	-0.22	-0.11	**-0.37**	**-0.33**	0.00	-0.03	0.22	-0.23	**0.30**	**1.00**	**0.61**	-0.25	-0.15	-0.01	-0.06	0.04	-0.13
Alkalinity	-0.18	-0.18	-0.14	**0.41**	**0.63**	-0.18	-0.19	-0.01	-0.13	-0.25	0.14	**1.00**	**0.30**	-0.10	0.01	0.18	**-0.73**	-0.23	0.24	**0.28**
Secchi	**-0.28**	**-0.62**	**-0.55**	**0.42**	**0.46**	0.05	**0.32**	**-0.31**	-0.06	-0.23	**1.00**	0.14	-0.23	**-0.33**	-0.12	**0.62**	**-0.32**	-0.06	0.00	-0.24
Water Depth	0.21	-0.10	0.14	**-0.45**	**-0.40**	-0.10	**0.32**	**0.60**	0.23	**1.00**	-0.23	-0.25	0.22	0.26	-0.12	**-0.35**	**0.45**	0.06	**-0.36**	-0.13
PAR	-0.04	-0.06	0.06	-0.02	-0.16	-0.05	0.17	0.16	**1.00**	0.23	-0.06	-0.13	-0.03	0.06	-0.12	-0.07	0.21	-0.06	-0.18	-0.11
S-STP	0.21	0.01	0.15	**-0.46**	-0.23	-0.02	0.16	**1.00**	0.16	**0.60**	**-0.31**	-0.01	0.00	-0.08	0.00	**-0.33**	0.19	-0.07	-0.15	**0.35**
S-SP	-0.15	**-0.28**	**-0.35**	**0.27**	0.21	**0.44**	**1.00**	0.16	0.17	**0.32**	**0.32**	-0.19	**-0.33**	-0.16	**0.38**	-0.04	-0.03	0.00	-0.13	-0.03
Temperature	0.01	0.03	**-0.33**	**0.27**	**0.40**	**1.00**	**0.44**	-0.02	-0.05	-0.10	0.05	-0.18	**-0.37**	-0.10	**0.70**	-0.02	0.09	0.03	0.21	0.13
Conductivity	-0.16	**-0.39**	**-0.56**	**0.68**	**1.00**	**0.40**	0.21	-0.23	-0.16	**-0.40**	**0.46**	**0.63**	-0.11	**-0.28**	**0.41**	**0.42**	**-0.67**	**-0.28**	**0.28**	0.16
pH	**-0.59**	**-0.36**	**-0.30**	**1.00**	**0.68**	**0.27**	**0.27**	**-0.46**	-0.02	**-0.45**	**0.42**	**0.41**	-0.22	**-0.46**	**0.31**	0.24	**-0.64**	-0.17	0.24	0.19
DO	0.07	**0.45**	**1.00**	**-0.30**	**-0.56**	**-0.33**	**-0.35**	0.15	0.06	0.14	**-0.55**	-0.14	0.23	0.11	-0.09	**-0.62**	0.17	0.17	0.10	0.23
Turbidity	**0.33**	**1.00**	**0.45**	**-0.36**	**-0.39**	0.03	**-0.28**	0.01	-0.06	-0.10	**-0.62**	-0.18	0.14	**0.33**	0.15	**-0.46**	0.24	0.08	0.13	0.02
ΔT	**1.00**	**0.33**	0.07	**-0.59**	-0.16	0.01	-0.15	0.21	-0.04	0.21	**-0.28**	-0.18	**0.31**	**0.47**	-0.03	-0.10	0.25	-0.16	0.03	-0.20

Table G. 11: Pearson Correlation Matrix for Bottom – 2 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	**-0.30**	0.15	**0.25**	**0.62**	0.02	-0.05	-0.02	0.03	-0.09	0.18	**0.34**	**0.39**	**0.44**	-0.03	0.11	0.07	0.08	**1.00**
TSS	0.08	-0.10	-0.18	-0.18	**0.19**	**0.24**	-0.03	0.18	-0.04	-0.09	0.12	0.13	-0.07	**0.25**	**0.31**	-0.02	**1.00**	0.08
TKN	**-0.25**	-0.19	**0.23**	0.17	0.17	0.15	0.03	0.09	**-0.26**	0.15	**0.26**	**0.27**	0.17	-0.07	0.12	**1.00**	-0.02	0.07
NH_3	**-0.29**	**-0.22**	0.12	0.10	**0.31**	**0.37**	-0.12	0.14	-0.13	**0.36**	**0.54**	**0.47**	**0.22**	**0.45**	**1.00**	0.12	**0.31**	0.11
NO_2	0.05	-0.05	-0.19	-0.11	**0.24**	**0.25**	0.06	0.11	-0.04	0.12	**0.33**	**0.27**	0.09	**1.00**	**0.45**	-0.07	**0.25**	-0.03
NO_3	**-0.32**	0.04	**0.22**	**0.66**	0.18	0.12	-0.07	0.13	-0.05	**0.44**	**0.65**	**0.66**	**1.00**	0.09	**0.22**	0.17	-0.07	**0.44**
Total-P	**-0.42**	-0.02	**0.32**	**0.49**	**0.38**	**0.46**	0.06	**0.38**	-0.17	**0.48**	**0.95**	**1.00**	**0.66**	**0.27**	**0.47**	**0.27**	0.13	**0.39**
PO_4-P	**-0.40**	-0.07	**0.26**	**0.42**	**0.44**	**0.50**	0.01	**0.40**	**-0.22**	**0.51**	**1.00**	**0.95**	**0.65**	**0.33**	**0.54**	**0.26**	0.12	**0.34**
Alkalinity	**-0.40**	-0.17	0.17	**0.46**	0.05	**0.22**	0.17	0.01	-0.05	**1.00**	**0.51**	**0.48**	**0.44**	0.12	**0.36**	0.15	-0.09	0.18
Secchi	0.11	-0.06	**-0.54**	**-0.30**	**-0.26**	-0.18	-0.14	0.02	**1.00**	-0.05	**-0.22**	-0.17	-0.05	-0.04	-0.13	**-0.26**	-0.04	-0.09
Water Depth	**-0.21**	-0.11	0.04	-0.10	**0.56**	**0.58**	-0.02	**1.00**	0.02	0.01	**0.40**	**0.38**	0.13	0.11	0.14	0.09	0.18	0.03
PAR	-0.07	0.03	0.03	0.01	0.02	0.05	**1.00**	-0.02	-0.14	0.17	0.01	0.06	-0.07	0.06	-0.12	0.03	-0.03	-0.02
S-STP	**-0.41**	**-0.20**	0.14	0.05	**0.72**	**1.00**	0.05	**0.58**	-0.18	**0.22**	**0.50**	**0.46**	0.12	**0.25**	**0.37**	0.15	**0.24**	-0.05
S-SP	**-0.28**	**-0.20**	0.17	0.09	**1.00**	**0.72**	0.02	**0.56**	**-0.26**	0.05	**0.44**	**0.38**	0.18	**0.24**	**0.31**	0.17	**0.19**	0.02
Temperature	**-0.39**	**0.26**	**0.51**	**1.00**	0.09	0.05	0.01	-0.10	**-0.30**	**0.46**	**0.42**	**0.49**	**0.66**	-0.11	0.10	0.17	-0.18	**0.62**
Conductivity	**-0.50**	-0.17	**1.00**	**0.51**	0.17	0.14	0.03	0.04	**-0.54**	0.17	**0.26**	**0.32**	**0.22**	-0.19	0.12	**0.23**	-0.18	**0.25**
pH	**0.42**	**1.00**	-0.17	**0.26**	**-0.20**	**-0.20**	0.03	-0.11	-0.06	-0.17	-0.07	-0.02	0.04	-0.05	**-0.22**	-0.19	-0.10	0.15
DO	**1.00**	**0.42**	**-0.50**	**-0.39**	**-0.28**	**-0.41**	-0.07	**-0.21**	0.11	**-0.40**	**-0.40**	**-0.42**	**-0.32**	0.05	**-0.29**	**-0.25**	0.08	**-0.30**

Table G. 12: Pearson Correlation Matrix for Bottom – 3 Data Set

Variables	DO	pH	Conductivity	Temperature	S-SP	S-STP	PAR	Water Depth	Secchi	Alkalinity	PO_4-P	Total-P	NO_3	NO_2	NH_3	TKN	TSS	Chl-a
Chl-a	**-0.29**	-0.09	0.15	**0.59**	0.04	0.06	-0.01	**0.17**	0.03	**0.22**	**0.40**	**0.43**	**0.47**	0.00	**0.22**	0.10	0.07	**1.00**
TSS	0.12	0.07	-0.07	-0.13	0.07	0.09	-0.05	-0.07	-0.08	-0.04	0.01	-0.02	-0.05	**0.16**	0.14	-0.03	**1.00**	0.07
TKN	**-0.19**	**-0.23**	0.12	**0.20**	0.14	0.13	0.03	0.15	-0.14	0.11	**0.27**	**0.27**	**0.18**	-0.05	**0.18**	**1.00**	-0.03	0.10
NH_3	**-0.36**	**-0.54**	-0.11	**0.32**	**0.26**	**0.39**	-0.06	**0.46**	**0.16**	**0.32**	**0.68**	**0.66**	**0.31**	**0.41**	**1.00**	**0.18**	0.14	**0.22**
NO_2	-0.15	-0.11	**-0.17**	-0.01	**0.17**	0.14	0.06	0.09	0.09	0.15	**0.32**	**0.26**	0.09	**1.00**	**0.41**	-0.05	**0.16**	0.00
NO_3	**-0.33**	-0.15	0.12	**0.68**	**0.22**	**0.16**	-0.05	**0.23**	0.08	**0.41**	**0.63**	**0.61**	**1.00**	0.09	**0.31**	**0.18**	-0.05	**0.47**
Total-P	**-0.46**	**-0.56**	-0.05	**0.59**	**0.27**	**0.42**	0.09	**0.64**	**0.23**	**0.42**	**0.96**	**1.00**	**0.61**	**0.26**	**0.66**	**0.27**	-0.02	**0.43**
PO_4-P	**-0.44**	**-0.50**	-0.02	**0.53**	**0.31**	**0.46**	0.05	**0.60**	0.14	**0.48**	**1.00**	**0.96**	**0.63**	**0.32**	**0.68**	**0.27**	0.01	**0.40**
Alkalinity	**-0.37**	**-0.17**	0.14	**0.38**	0.00	**0.20**	0.15	0.07	0.05	**1.00**	**0.48**	**0.42**	**0.41**	0.15	**0.32**	0.11	-0.04	**0.22**
Secchi	-0.14	**-0.36**	**-0.57**	0.02	-0.08	-0.03	-0.09	**0.31**	**1.00**	0.05	0.14	**0.23**	0.08	0.09	**0.16**	-0.14	-0.08	0.03
Water Depth	**-0.28**	**-0.59**	**-0.24**	**0.23**	**0.42**	**0.60**	0.05	**1.00**	**0.31**	0.07	**0.60**	**0.64**	**0.23**	0.09	**0.46**	0.15	-0.07	**0.17**
PAR	-0.07	-0.03	-0.01	0.03	0.05	0.07	**1.00**	0.05	-0.09	0.15	0.05	0.09	-0.05	0.06	-0.06	0.03	-0.05	-0.01
S-STP	**-0.29**	**-0.36**	-0.01	0.15	**0.51**	**1.00**	0.07	**0.60**	-0.03	**0.20**	**0.46**	**0.42**	**0.16**	0.14	**0.39**	0.13	0.09	0.06
S-SP	**-0.32**	-0.13	0.11	**0.22**	**1.00**	**0.51**	0.05	**0.42**	-0.08	0.00	**0.31**	**0.27**	**0.22**	**0.17**	**0.26**	0.14	0.07	0.04
Temperature	**-0.47**	**-0.19**	**0.25**	**1.00**	**0.22**	0.15	0.03	**0.23**	0.02	**0.38**	**0.53**	**0.59**	**0.68**	-0.01	**0.32**	**0.20**	-0.13	**0.59**
Conductivity	**-0.31**	**0.20**	**1.00**	**0.25**	0.11	-0.01	-0.01	**-0.24**	**-0.57**	0.14	-0.02	-0.05	0.12	**-0.17**	-0.11	0.12	-0.07	0.15
pH	**0.40**	**1.00**	**0.20**	**-0.19**	-0.13	**-0.36**	-0.03	**-0.59**	**-0.36**	**-0.17**	**-0.50**	**-0.56**	-0.15	-0.11	**-0.54**	**-0.23**	0.07	-0.09
DO	**1.00**	**0.40**	**-0.31**	**-0.47**	**-0.32**	**-0.29**	-0.07	**-0.28**	-0.14	**-0.37**	**-0.44**	**-0.46**	**-0.33**	-0.15	**-0.36**	**-0.19**	0.12	**-0.29**