Great Salt Lake, Farmington Bay

Sediment Phosphorus Study

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Abstract

Water quality concerns for Farmington Bay include issues associated with the health and vitality of the wetlands and the open waters.   Some concerns center around the high concentration of nutrients that enter the lake from natural and man-made sources. Nutrients allow and promote microorganism and algae growth in the Bay. This study evaluated the historic loading of phosphorus to Farmington Bay and the interaction of phosphorus between the sediment and the liquid phases under mixing conditions. Sediment cores were used to evaluate the historic phosphorus loading to the Bay. From the cores it appears that historic loadings are similar to the current loadings. In addition to the sediment phosphorus evaluation, the study tested to see what happens when water and sediment interact under mixing conditions.   The average depth of Farmington Bay is currently about one meter.   At this depth, the shallow areas of the Bay and the sheet flow environments exhibit complete mixing with the sediments during wind events.   Experiments were conducted using lake sediment and various waters with varying phosphorus concentrations which enter the Bay to determine what occurs when mixing takes place. It appears that the sediment has the ability to either absorb or release phosphorus depending on the initial water phosphorus concentration and the oxygen state of the sediment Once the effect of sediment - liquid P interaction was identified, sorption isotherms were constructed to graphically depict the effect of P as it transfers between the liquid and sediment phases.

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Great Salt Lake, Farmington Bay
Phosphorus Study

Introduction

Often times the Great Salt Lake (GSL) is a study in contrast.   "Water, water everywhere, and not a drop to drink,"   is a conflict we all understand very well.   A beautiful lake whose blue waters are not fit for drinking by man or animal.   When people recreate at the GSL they quickly find a playground they must share with brine flies, gnats and lake stink. Birds find the GSL and its surrounding wetlands an inviting habitat for nesting or for resting during migration.   According to the Utah Department of Wildlife Resources, water bird survey, during an average year there are over 87,000,000 bird use days at the GSL (a bird use day is one bird for one day).   The lake is visited by over 450,000 ducks each year.   Between 600,000 and 1.5 million Eared Grebes stay about 90 days at the GSL during the fall staging period.   During 2001, Wilson Phalaropes peaked at the lake at about 566,000.   This represents 30% of the U.S. Wilson Phalaropes population.   50% of the North American Avocet population are also at the lake at the same time.   With such significance, as part of the Western Hemisphere Shorebird Reserve, keeping the lake inviting to birds is of great importance.

Recently some individuals and organizations have expressed concern for the GSL and for man-made pollutants that enter the lake in increasing quantities.   The State of Utah, Division of Water Quality has heard these concerns and has established a program to evaluate whether pollutants of concern need to be controlled more stringently than in the past. Water quality concerns for Farmington Bay include issues associated with the health and vitality of the wetlands and the open waters.   Some concerns center around the high concentration of nutrients that enter the lake from natural and man-made sources.   Nutrients allow and promote microorganism and algae

growth in the Bay. Studies done by Wayne Wurtsbaugh of Utah State University indicate that Farmington Bay is highly eutrophic. During periods of high water inflows to the Bay, salinity can range from one-half to three percent salt.   At salt concentrations of less than 6% cyanobacter is usually abundant because of the sufficient concentration of phosphorus(P) in the bay.   Standard approaches to reducing cyanobacter in a lake would be to reduce the availability of P.   Recent estimates from Wurtsbaugh, et. al. suggest that about half the amount of P reaching Farmington Bay are from anthropogenic sources.   While this was a rather superficial estimate, there is a lot of P that comes from wastewater treatment plant that enters the Bay. As such, there is a need to research P inputs and the fate and effect of it in the Bay.   Wurtsbaugh is currently conducting synoptic studies of the Bay to determine the impact of the high concentrations of cyanobacter on the lake.   Additional studies are proposed to determine more accurately the sources of P to the Bay.

The proposed studies by CDSD will evaluate the historic loading of phosphorus to Farmington Bay and the interaction of P between the sediment and the liquid phases under mixing conditions.   Sediment cores will be used to evaluate the historic P loading to the Bay.   Two studies by USGS indicate that a sediment deposition of about 0.4 cm/year exists in Farmington Bay(Naftz).   Based on this information, the study will evaluate two feet deep sediment cores to determine historic sediment P concentrations. Total P values will be determined for each two inch segment of the core.   The assumption in this analysis is that sediment P values are primarily influenced by current sediment deposition.   Further, EPA land treatment design manuals biosolids land application testing conducted by the District assume that P does not migrate through the sediment column, but usually binds with the surface sediments. These assumptions seem to be correct based on District Biosolids application field studies, although this assumption requires further validation. In these studies (annual CDSD Biosolids Report to EPA) excess P application remains in the top 0-12-inch sample even when significant surface water percolates through the site.   While nitrates can be seen migrating downward, lower soil samples for P remain unchanged.   In addition, there does not

appear to be significant hydraulic transport through the sediment to drive soluble P lower in the sediment.   These assumptions deserve further investigation at a later time.

In addition to the sediment P evaluation, CDSD will also test to see what happens when water and sediment interact under mixing conditions.   The average depth of Farmington Bay is currently about one meter.   At this depth, the shallow areas of the Bay and the sheet flow environments exhibit complete mixing with the sediments during wind events.   The mixing may allow P to become soluble again.   This sediment supply of P is well documented in the literature and can be a major source of P to the lake environment.   Experiments will be conducted using lake sediment and various sources of water inflow to the Bay to determine what occurs when mixing takes place. Some of the treated effluent sources of water will contain significant P while some of the stream sources of water will be low in P.   Ortho-P will be tested for in this evaluation using a Hach colormetric method. Since most of the water sources to the Bay enter through wetlands and sheet flow environments, this appears to be a fair representation of the water P values reaching the lake. The release or deposition of P to the sediment will be evaluated over time.   Liquid samples will be centrifuged to eliminate most particulate P from the testing.   Once the effect of sediment - liquid P interaction had been identified, sorption isotherms will be constructed to graphically depict the effect of P as it transfers between the liquid and sediment phases.

This research will begin to assess the sediment P impact on Farmington Bay. The ability to control P inputs to the lake through treatment or containment and the ability to control sediment P release is critical to understand whether P control can be used to reduce the quantities of cyanobacter that occur in the Bay.   Further studies will be needed to determine if cyanobacter in Farmington Bay is an impairment.

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Chapter 2

Literature Review

Sediment and water phosphorus (P) interaction has been evaluated in many water bodies around the world. Many technical articles have published which report on this body of research. A review of this information was conducted to determine areas where research emphasis should be placed. This section reports on the available research reviewed. Since the Great Salt Lake Farmington Bay sediment-water interface is assumed to be complex, review of other research may help in evaluation of this specific water body.

Generally accepted sediment-water interaction findings state that under aerobic conditions aerobic sediments usually have the potential to bind P from the water, while anaerobic sediments tend to release P to the overlying water (Appan and Wang, 2000; Garcia and De Iorio, 2003; Kelton et al, 2004; de Montigny and Prairie, 1993). Generally this release mechanism is thought to be a chemical reaction although in some research the driving mechanism for the release to occur appeared to be of bacterial origin. In saline systems and salt marsh sediments, P is usually available. Only in low salinity areas has P limitations been reported (Stribling and Cornwall, 2001). Stribling showed that P increased in the later part of the summer due to temperature increases and rising sediment anoxia. This study further showed that during senescence maximum porewater P was observed. The impact of plant originated P has also been shown to be a significant P source in water bodies with more than half the P in a system coming from such humic substances(Qlu and McComb, 2000). Qlu also evaluated the fractionation of P with loosely bound P associated with Fe and Al and tightly bound P associated with Ca. The root zones of submerged macrophytes has also been shown to be a P-sink with P release occurring at the end of the growing season when reductive conditions exist (Hupfer and Dollan, 2003). Sediment P has also been shown to correlate well with macrophyte growth rates, much better than water P. A sediment P

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concentration above 400 ppm was shown to be needed to produce maximum plant tissue P (Carr and Chambers, 1998).   When P reduction is evaluated for a water body, experimentation showed that the a phytoplankton dominated lake lost two to three times more P under anoxic conditions to the water than under oxic conditions.   In a macrophyte dominated lake the P lost under varying oxygen conditions was about the same.   P losses in the macrophyte dominated lake was about equal to the anoxic state in the phytoplankton dominated lake ((Kisand and Noges, 2003).

The sorption of P by a sediment has been shown to occur quickly, usually within 11 - 14 minutes after mixing (Appan and Wang, 2000).   At fish farms where P is added to the overlying water, 90% of the Ortho-P is absorbed into the sediment within 4 days (Bhakta and Jana, 2002).

The microbial community has also been evaluated as factor in P interaction between sediment and the overlying water.   In an evaluation below a point source discharge of P, research was conducted to determine the effect of organic P mineralization.   The research evaluated the effect of the microbial community on the release rate of P compared to the "classical" view that the release is based on redox. In the redox theory, when the redox potentials drop below +120 mV (-80 mV ag-agcl) Fe^{+3} is reduced to Fe^{+2} and phosphate is released from the sediment.   This research evaluated the additional P released from mineralization of organic phosphorus (OP). The study originated because P in the water remained quite high even though there has been a tremendous reduction in influent P.   Soluble Ortho-P release rates correlated with the overlying water P.   Some of the sample sites supported substantial waterfowl populations and this was identified as a P enrichment source. The conclusion was that the microbial community acts as a large source or sink for P (Kelton et al, 2004). Research in a Potomic river estuary also reported the same benthic regeneration of P. This regeneration can supply a large fraction of the total P need.   Regeneration is controlled by physical, biological and chemical factors.   In situ flux chambers were used to evaluate P - H2O interaction.   In situ benthic fluxes were generally 5 - 10 times

higher than calculated diffusive fluxes.   It was noted that tidal river sediments (oxic) retained 80-90% of their phosphorus while seasonally anoxic estuary sediments retained only 10% of their sediment P input.   The paper also reported on several studies where the benthic flux of phosphate provided between 50% and 330% of all the needed P.   In this study all the needed P was supplied in some locations The impact of benthic P was greater in the transition and saline environments than in the fresh water segments. "Sensitivity analysis, whereby the parameters describing water column regeneration are evaluated, suggests that diffusive benthic fluxes of phosphate are nearly as important as water column dissolved phosphorus concentration in the transition zone between freshwater and brackish water.   In situ fluxes, which are enhanced relative to diffusive fluxes by the effects of bioturbation could support a large proportion of these water-column concentrations of dissolved phosphorus." (Callendar, 1982)   A final study reviewed showed that microorganisms may release or bind P through various metabolic reactions, extra-cellular release and cell lysis. Microorganisms may also alter the chemical or physical conditions which would stimulate chemical and biological processes which enhance P cycling.   The lake being researched is highly eutrophic even though over 90% of the P inputs were reduced in 1970.   The surface sediment has a high organic content and total P in the sediment averages about 1600 mg/kg.   Large concentrations of loosely bound P are in the sediment.   Cyanobacteria Microcystis was noted in abundance in the sediment.   There appears to be a relationship between the biomass of Microcystis and chemical parameters in the sediment.   The data strongly indicates that microbial processes play an important roll in the release of P from the sediment.   It is postulated that the presence of Microcystis in the sediment stimulates mineralization by either the decaying of the cells which serve as a substrate for the bacteria or that they excrete products that create a favorable environment.   In this lake it may be that the highly P saturated sediments cause P to recycle frequently between sediment and water.   The net effect has been a significant delay in P reduction.

The research appears to be conflicted over the more important release

mechanism for P between sediment and water.   The difference could be because of the differences in sediment organic concentrations and the salinity of the overlying water system.   One such study for the Wadden Sea concluded that the primary source for bio-available P was from the metal associated P pool, while the next highest source was the organic P pool.   The study also found that the bio-available P was generally higher in fine grained sediments than from coarse grained sediments.   Pore water was shown to have a higher P concentration than the overlying water.   Experiments found that anoxic conditions led to a rather rapid increase in water P.   Availability of P from sediments was four times greater for anoxic vs. oxic conditions (de Jonge et al, 1993).

Mixing of the sediment with the water is important in the release or absorption of P.   Wind has been observed as a major driver of such mixing (Strebling and Cornwall, 2001). Shallow water bodies have an increased tendency to resuspend sediments. In a shallow Florida day, sediment P behaved like a buffer for the water system P (Zhang, 2002). Other forms of mixing have also been observed to drive P from the sediment to the water column.   In a Danish Fjord increased water column P and attendant increased eutrophication occurred when mussel dredging took place.   Anaerobic conditions contributed to high organic matter oxidation which increased sulfate reduction which sulfate competed with P for iron binding sites (Holmer et al, 2003).

Natural runoff and agricultural sources have been shown to be a significant source of P to water systems. Evaluation of sediment cores for an Australian river indicated that P deposition has not changed much for over the past 200 years (Olley and Caitcheon, 2000).   Agricultural losses also occur when excess soil P is available (Tunny et al, 2000). One question that becomes apparent about Farmington Bay is does surface run-off carry excess P from home and open space fertilizer to the Bay during storm events?

The ability and time for a water body to recover from a eutrophic state may depend on the ability of the lake to move the P "down stream" once inputs have been

reduced.   In some water bodies this has been approximated to take years while in others it may take centuries.   One such paper reported that shallow lakes are more resistant to recovery that deep lakes.   The P concentration in a sea being studied fluctuated annually due to changes in the internal P release.   The study indicated that the P release from the sea's sediments was strongly associated with microbial activity. Climactic, hydrologic, and hydro-chemical factors are all factors that have to be evaluated to identify why the "vast difference" in P release occurs. After reduction of input P, the recycling of P from and then back to the sediment is still significant.   Time delays in reducing sediment P could be greater than 66 years (KleeBerg and Kozerski, 1997). A second paper reviewed confirmed this finding on the resistance of shallow lakes to recovery. Further, this research indicated that Without grazing fish, bioturbation can increased due to larger numbers of organisms present.   The highest sediment P release occurred when the total Fe:P ration was the highest.   P release varied throughout the season and from site to site. After twelve years, summer P levels were high and still driven by internal recycle of P (Ramm and Scheps, 1997).

Finally some literature supports the position that P control cannot be effective in salt water systems.   One such study study discussed the difference in fresh and salt water P release under oxic conditions.   In discussing P immobilization, a comparison was drawn between the amount of organic P expected to be released and the amount of the actual release.   Where P released actual is less than the expected organic P release, the difference is assumed to be immobilized in the sediment.   P release in salt water systems is significantly greater than P release in fresh water.   The relative P release in salt water systems has been significantly greater than in fresh water systems. The reason given for this difference is that there is greater P immobilization in the fresh water systems. In oxic, fresh water lake sediments are thought to be sediment traps, while in salt water systems the demonstrated net absorption is much lower.   This abundance of P is probably why P control is not implemented as an effective nutrient control mechanism in salt waters (Caraco, et al, 1990).

The literature reviewed suggests many more areas of study for Farmington Bay than are being proposed for investigation at this time.   All of the possible impacts may need to be investigated over time to insure that a thorough understanding of the Great Salt Lake is developed so that effective, justifiable, protective standards can be developed.

GSL Sediment Cores and Surface Sampling

This section reports on the sampling methods and results for sediment samples taken from Farmington Bay in the Great Salt Lake.   Samples were taken in 2004 and 2005 and results were evaluated and compared.   All samples were tested for total P and percent solids and some samples were also tested for mercury and total volatile solids.   A map showing sampling locations is shown in Appendix 4. One sample underwent a detailed organic and inorganic analysis by the U. S. Geological Survey Laboratory in Denver, Co.

SAMPLING METHODS

Samples were collected from Farmington Bay by District Staff in PVC or polyethylene containers.   Deep samples were collected in 2-inch diameter tubes in the field and then split into 2-inch segments in the District laboratory.   Sample locations were identified by latitude and longitude from a hand-held GPS unit. Samples were labeled and then sent to a commercial, NELAP certified laboratory for analysis.   All samples were refrigerated at 4°C between sampling and transport to the laboratory. Total solids were evaluated in the laboratory using EPA method 160.3 and total volatile solids, when tested, was done using EPA method 160.4.   Total phosphorus concentrations in the samples was evaluated by ICP method EPA 6010A.   Mercury, when tested, was identified using EPA method 7471A.   Methods used by the USGS are not reported here but can be seen in the tabular results of the testing complied by them. All containers were prepared by thorough rinsing with de-ionized water.   Sample handling methods were deemed to be appropriate based on the levels of P anticipated in the samples.

RESULTS AND DISCUSSION

deep samples were evaluated for P in 2-inch increments.   Sample increment

values were graphed with the X-axis being sediment P concentration on a dry basis and the Y-axis being the depth of the sample from the surface.   Sample graphs fell into two general patterns. Figure 1 shows the first general pattern for sample results.

Deep Soil Sample GSL 3 for Phosphorus
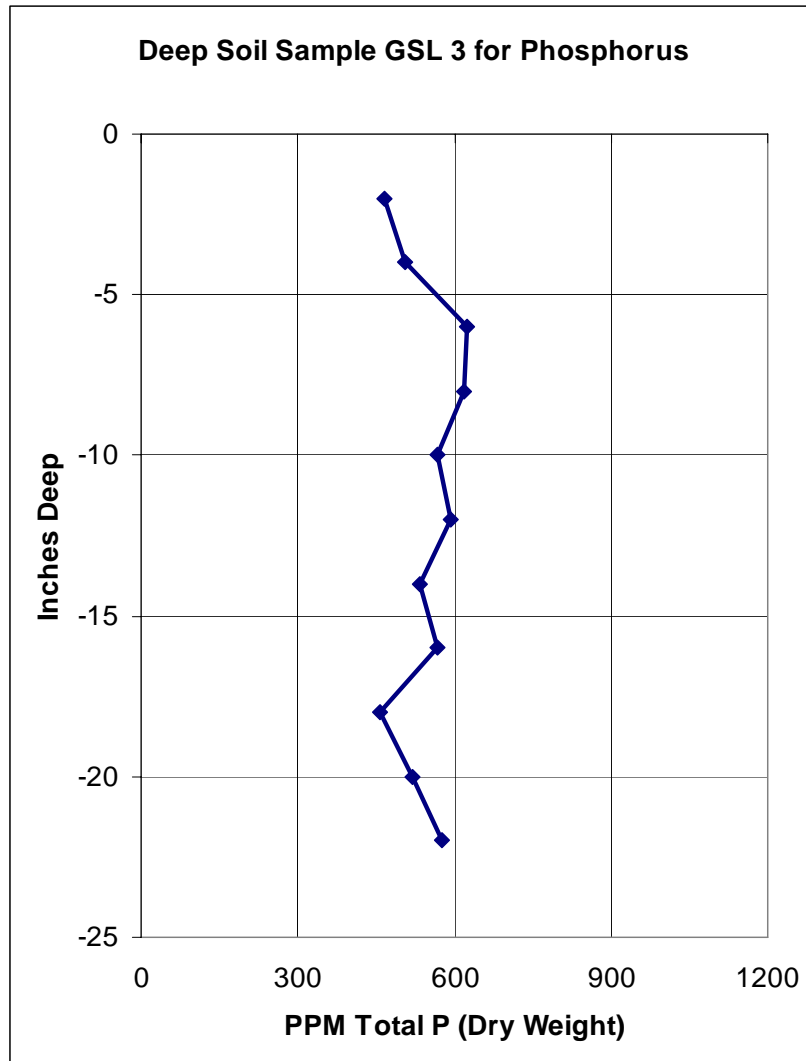

Figure 1 - Farmington Bay Sample GSL-03

In general, Figure 1 demonstrates a P concentration that is consistent throughout the entire sample. While there are concentration variations between sample depths, the overall trend for the sample is a constant value.   This would indicate that the P deposition rate has not changed over the deposition time period.   Evaluations by USGS

of the soil cores indicates a sediment deposition rate of about 0.4 cm per year. Assuming this deposition rate is uniform throughout the core, a 24-inch sample length would be about a 150 year sediment history. Thus, the bottom of the sediment core would be about the time the pioneers entered the Salt Lake Valley.

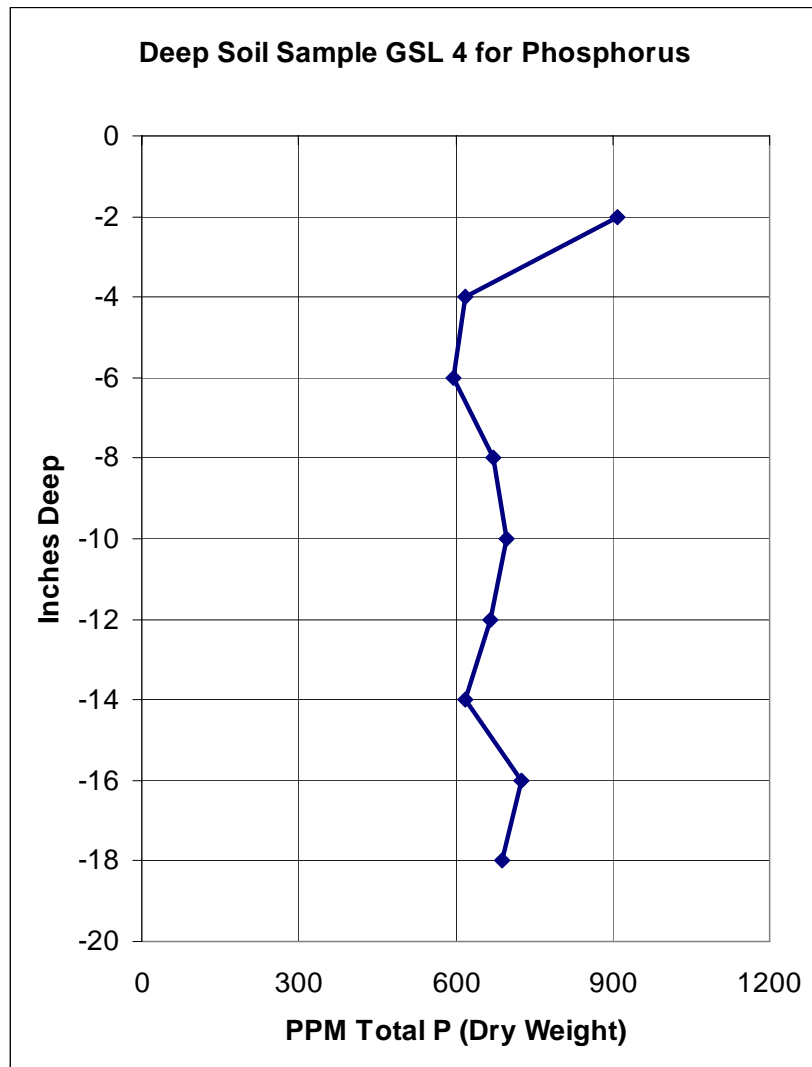The second general pattern for sample results is illustrated by Figure 2.

Deep Soil Sample GSL 4 for Phosphorus

Figure 2 Farmington Bay Sample GSL-04

In Figure 2, the P concentration appears uniform in all but the top sample of the

core. The top most sample has a increasing spike in concentration.   A review of the sampling locations for those samples which display the surface spike shows all these samples were taken from areas where rooted macrophytes were present.   The spike in concentration appears to parallel the literature information which indicates that organic P pools exist around the wetland areas.   Thus the samples appear consistent with other researcher findings.   An alternative conclusion that these areas have a greater anthropogenic impact to the surface could be drawn, however the lack of a spike in the other samples makes this theory seem less acceptable.

Assuming that the explanation of the surface spike values is accurate, all deep samples would indicate that the deposition rate of P in the sediment is relatively constant.   Variation of sample P could be explained by the impact and deposition of organic sediment resulting from varying lake surface levels.   As the lake surface elevation rises and falls, the wetland surrounding the lake may move back and forth. Thus, areas where organic matter deposits may also move.   This is one theory of how varying P concentrations could occur, however, additional testing for organic content of the sediment would be needed to verify or nullify the assumption.   Table 1, below is a summary of the deep sampling results.

In addition to the deep soil profiles, a synoptic sampling of the surface sediment, 0 - 2-inch intervals, was also conducted.   Samples were obtained over a several week period and were analyzed in the same manner as the deep samples.   The synoptic samples were taken to see if P variation occurred across Farmington Bay.   The samples were plotted on a lake map to see if any trends could be observed. Figure 3 is the map with the plotted values displayed.

Depth Inches	GSL USGS	GSL 01	GSL 02	GSL 03	GSL 04	GSL 05
2	1600	452	657	465	908	960
4	1100	486	696	506	619	677
6	N/A	551	592	624	596	719
8	980	541	617	618	672	659
10	1000	547	644	566	698	652
12	1100	566	668	592	667	697
14	N/A	589	654	533	618	656
16	1100	642	656	567	726	607
18	N/A	554	718	457	689	638
20	N/A	556	791	519		628
22	1200	577	703	576		611
24						646
26						628
28						686

Depth Inches	GSL 07	GSL 08	GSL 09	GSL 40	GSL 41
2	571	1030	289	613	889
4	308	546	261	607	534
6	299	574	218	680	471
8	481	701	238	635	634
10	446	603	231	571	664
12	551	600	208	579	629
14	640	740	208	703	512
16	638	689	257	682	302
18	679	720	230	683	346
20	545	581	280	641	1067
22	780	615	400	902	881
24	638	399		963	
26		330		644	
28				720	

Note: All values are Total P on a dry weight basis in ppm or mg/Kg

Table 1 - Deep Soil Sampling Results

A review of the information presented on the map shows that a P gradient exists with higher values near the shore and lowest values next to Antelope Island. Along the shore, the surface sediment P values ranged from about 900 to 1,800 mg/Kg. Further out in the lake bed, generally beyond the wetland zone, the sediment P decreases to a range of 400 to 800 mg/Kg. Along the East shore of Antelope Island the P sediment concentration ranges from about 200 to 400 mg/Kg. The variation of sediment P
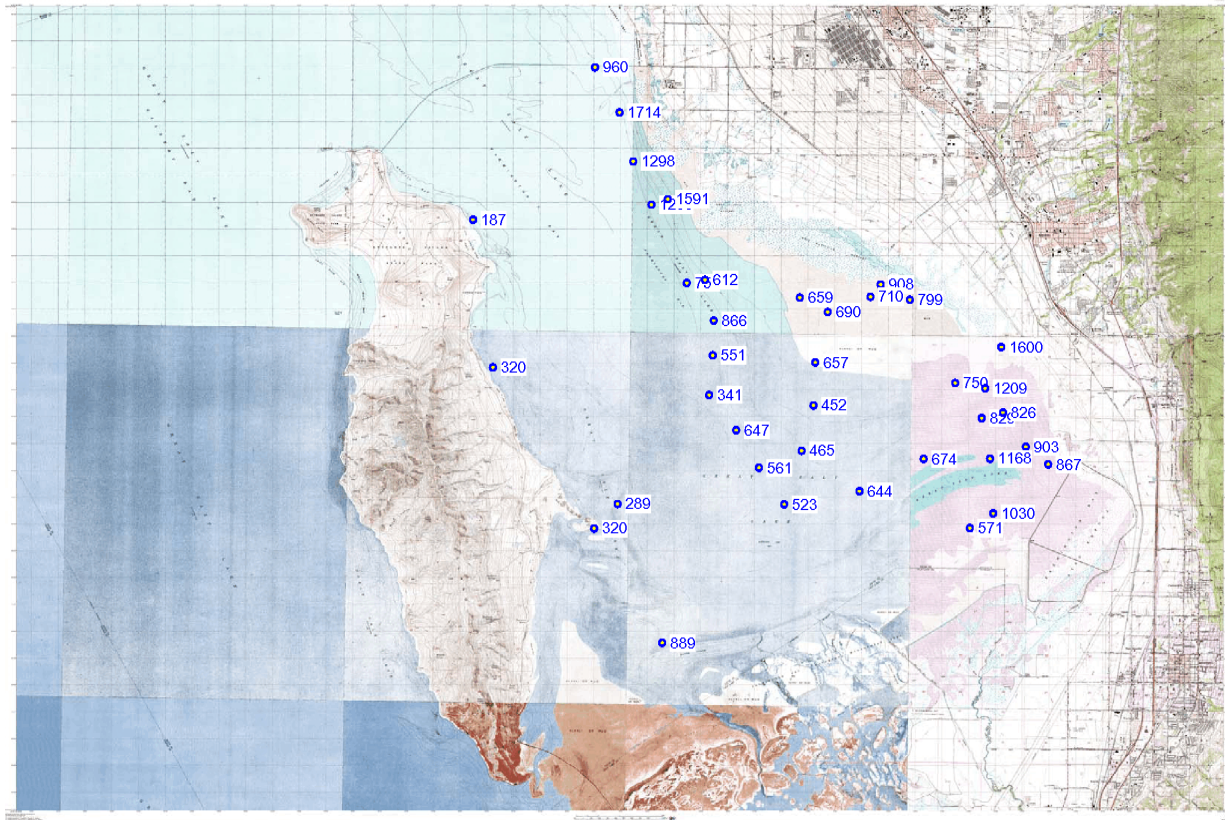

Figure 3 - Synoptic Sampling Results - Surface Samples

'Test Lake2.IT3'; Scale: 1" = 1.348Mi 2,169Mt 7,115Ft, 1 Mi = 0.742" , 1 cm = 854Mt

decreasing from the eastern shore westward could be the results of the impact of wetlands on the sediment with the presence of surface organic P pools. However, the gradient could also be the result of reducing sediment deposition as lake inflows expand across the lake bottom. Finally the reducing P concentrations could be a product of the deposition of anthropogenic generated P attaching to the surface Fe and Al as it flows

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out into the lake.   Additional research will be needed to identify the most likely causes of the surface sediment P gradient.

CONCLUSIONS

Sediment sampling has shown that P deposition may have been constant for over 150 years.   Sediment P deposition may be impacted by organic matter deposits in the wetland areas. Finally, sediment P concentrations display a gradient from the eastern shore westward.   Additional P sediment research should be conducted to determine the specific fate and disposition of the P as it interacts with the sediment. Fe, Al or Ca binding should be quantified as should the amount of organic P in the sediment.   The anoxic or oxic state of the sediment should be evaluated and release mechanisms identified.   The effect of sediment biota on the release of P should also be quantified.   Finally, the potential reasons for the sediment P gradient should be evaluated, and science developed to answer which causes are most likely.   The literature review also poses additional questions which should be addressed on a priority basis.

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Chapter 4

Sediment-Water Interface Effect Testing

This section discusses the impact to water phosphorus concentration as Great Salt Lake Farmington Bay sediment and fresh water sources are mixed. Farmington Bay and the associated wetlands are very shallow and subject to mixing when wind events occur.   The impact sediment conditions have on the water P concentration needs to be identified.   In this section only the ortho-phosphorus concentration was measured in the water samples as this is the portion that is bio-available.   This research has limited the evaluation to the mixing of water and sediment and changes to P over time and has not looked at other potentially significant variable physical conditions which may be changing also.

SAMPLING METHODS

District Staff collected surface sediment from Farmington Bay in plastic containers. Sample containers were prepared by thorough rinsing with laboratory water. A clean, small hand shovel was used to collect a three-inch deep by three-inch diameter soil sample. Sample locations were identified by latitude and longitude from a hand -held GPS unit. Samples were labeled at the sample site, transported to the District laboratory, and refrigerated until testing.

Sediment samples were mixed and quartered until a representative sample was obtained. A small amount of the quartered sediment sample was then placed into centrifuge tubes. Generally, the ratio of water to sediment was about four parts water to one part sediment. Between twenty-four and thirty tubes were used to ensure an adequate amount of water sample was available for ortho-P testing. The tubes were separated into two groups; one group was mixed with water having a relatively low ortho-P concentration while the other was mixed with water having a higher ortho-P concentration. Tubes were then shaken until soil and liquid was mixed. The tubes were left in the laboratory at the room ambient conditions for the remainder of the study. Tubes were mixed at

various times throughout the study period. After a final mixing, two to three tubes were removed from the larger group and centrifuged. The water was removed from the centrifuge tubes and tested for orthophosphates as specified in the HACH DR-4000 spectrophotometer Handbook, Method 8048, pp. 579-585.

RESULTS AND DISCUSSION

The sediment –water mixing was used to simulate the sediment and overlying water mixing in Farmington Bay during wind events. The change in ortho-P caused by mixing as a function of time was looked at. Two general conditions existed after mixing sediment with various source waters.   Each appears to be a result of the condition of the sediment and the initial ortho-P concentration in the water.   The two different results are discussed below.

Aerobic Sediment Interaction

Sediment samples, which appeared to be aerobic based on the lack of any sediment H_2S odors observed during collection usually, responded as shown in Figure 4.
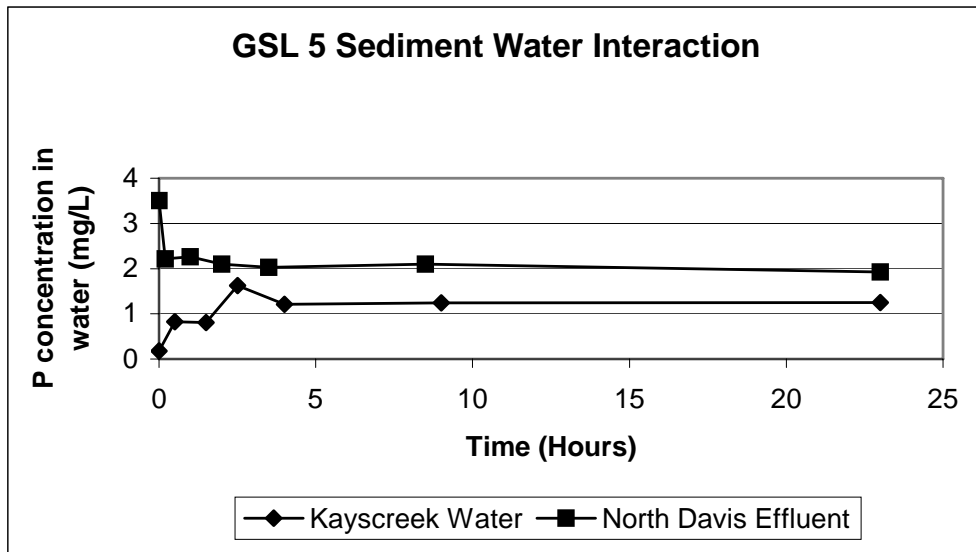

Figure 4 – Aerobic Sediment Sample

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As can be seen, the sediment responded to a low and high ortho-P concentration in the water differently.   When mixed with Kays Creek water that had an initial water concentration of about 0.2 mg/L ortho-P, the sediment released soil ortho-P to the water after mixing.   The release appeared to occur within the first hour and then gradually increased as time continued.   The second water source was North Davis Sewer District effluent.   When the sediment was mixed with this water at an ortho-P concentration of about 3.5 mg/L, the soil rapidly absorbed water column ortho-P. The absorption was rapid initially with only minor changes after about two hours.   While the final values for the low and high initial P waters tended to approach each other after equilibrium was reached, there still was a noticeable difference in the final concentrations.

Some aerobic sediment samples exhibited a different response when mixed with a water source containing low ortho-P concentrations.   Sample GSL 16 demonstrates this alternative response as shown in Figure 5.
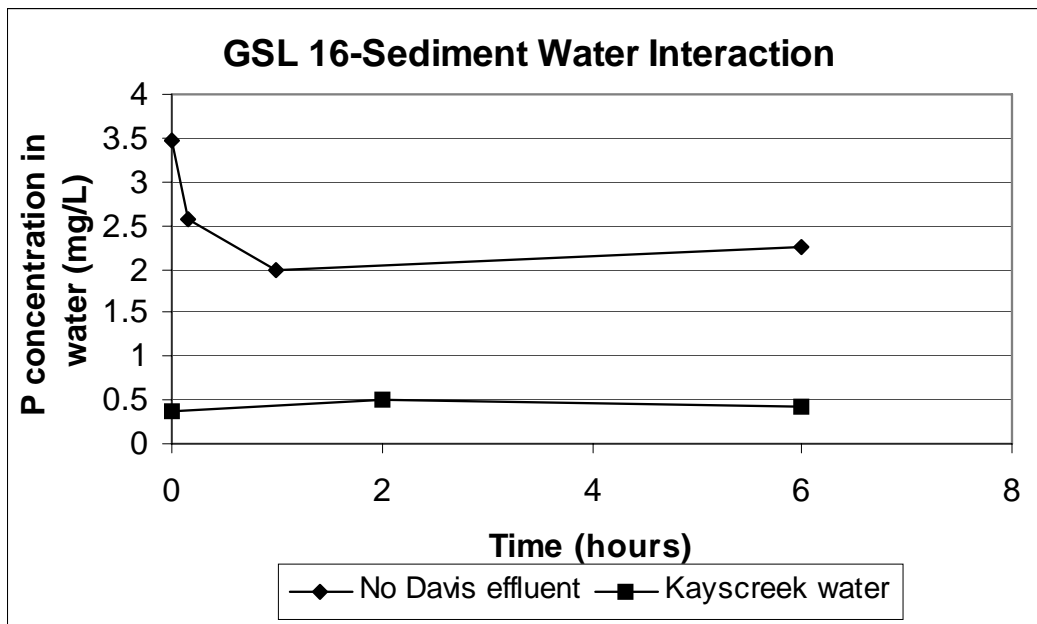

Figure 5 - Aerobic Sediment Sample Alternative

Water taken from Kays Creek had an ortho-P concentration of 0.4 mg/L, which stayed constant with little change after mixing with this sediment. The water taken from the effluent of the North Davis Sewer plant had an ortho-P concentration of 3.5mg/L and, similar to other tests, the water column ortho-P was absorbed into the sediment. This drop of 1.5 mg/L ortho-P in the water column occurred within the first hour and then appeared to taper off over the next six hours.

Anaerobic Sediment Interaction

Sediment samples, which appeared to be anaerobic based on the presence of significant H_2S odors observed during collection and in the laboratory usually, responded as shown in Figure 6.
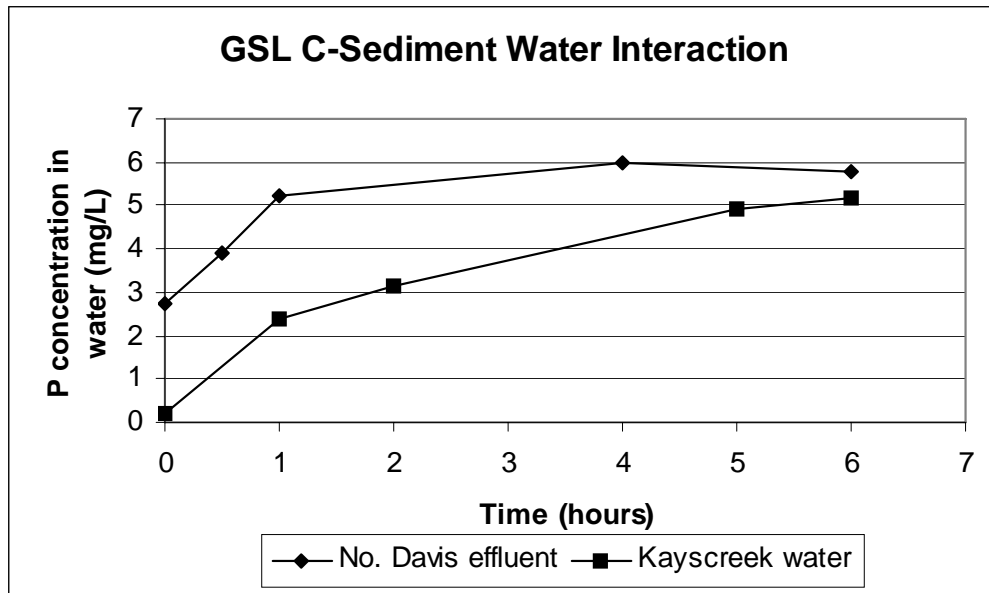

Figure 6 – Anaerobic Sediment Sample

Keys Creek water started with 0.2 mg/L ortho-P.   After mixing with the sediment, ortho-P was released into the water column. Although the most rapid release of ortho-P occurred in the first two hours, the release continued for the

duration of the test, six hours. Similar results were obtained with the water from Central Davis effluent that started off with 2.4 mg/L ortho-P. The sediment released ortho-P rapidly in the first hour and then more slowly for the next few hours slightly dropping at the last test which was 6 hours after initial mixing. It appears as though the two waters approach the same end point.   The release of ortho-P from anaerobic sediment is consistent with the literature which suggests that P associated with iron or aluminum may be released as sulfur compounds tend be absorbed on the surface of iron and aluminum minerals.

CONCLUSION

Several conclusions can be drawn from the experiments mixing water and Bay sediment.   First, it is certain that the sediment has an impact on the overlying water ortho-P concentration.   As mixing occurs, the sediment may uptake or release ortho-P into the water column.   This would mean that the sediment is probably a sink for P.   Secondly, depending on the sediment oxidative state it can either accept or release P. This interaction is a function of the soil condition and the water ortho-P concentration. While it is possible that some of the P changes in the water may be due to either high or low porewater concentrations, this factor would only explain a part of the change. In many of the soil samples there was no free water in the soil and in all samples the volume of water to soil was about 4:1 which would require a very high porewater P value to affect the final water concentration. This study served to illustrate the potential for significant impact of sediment P. More studies are needed to determine soil characteristic such as DO and pH to validate assumptions on aerobic and anaerobic sediment interactions. The interaction between the water and soil needs to be studied in more depth, the use of a flow through cell with varying levels of agitation to mimic flow and wave actions that occur in Farmington Bay would be beneficial.   Finally, many other physical parameters should be also be monitored to be certain that any other mitigating factors have been identified.

Chapter 5

Sorption Isotherms

After having determined that Great Salt Lake sediment may acts as a sink for ortho-P, the development of a relationship, at constant temperature, concerning the transfer of ortho-P between sediment and water was undertaken. A series of dilutions of wastewater treatment effluent with DI water was prepared. These dilutions were measured for ortho-P and then mixed with a predetermined amount of sediment.   Sediment samples were gathered using the same procedures as was done for the sediment water interaction testing. Water samples were mixed with sediment and after mixing were allowed to sit in the lab for at least eight hours. The water was then centrifuged and/or filtered and then re-measured for water concentration ortho=P.   The results of all the sorption isotherms were charted with the water concentration on the X-axis in mg/L and the amount absorbed or released from the sediment was calculated.   This value was plotted on the Y-axis in mg/Kg. Figure 7 is a graph of the collective curves. The results suggest that a correlation between the initial P concentration and the final P in the water can be drawn.   As such, the value of the initial water P concentration in mg/L was plotted on the X-axis with the final P concentration, in mg/L, plotted on the Y-axis for several of the sorption isotherms.   This relationship exhibited two types of graphs.   Figures 8 and 9 show the relationship between initial and final water concentration when the sediment readily absorbs ortho-P. This graph is for GSL 11.
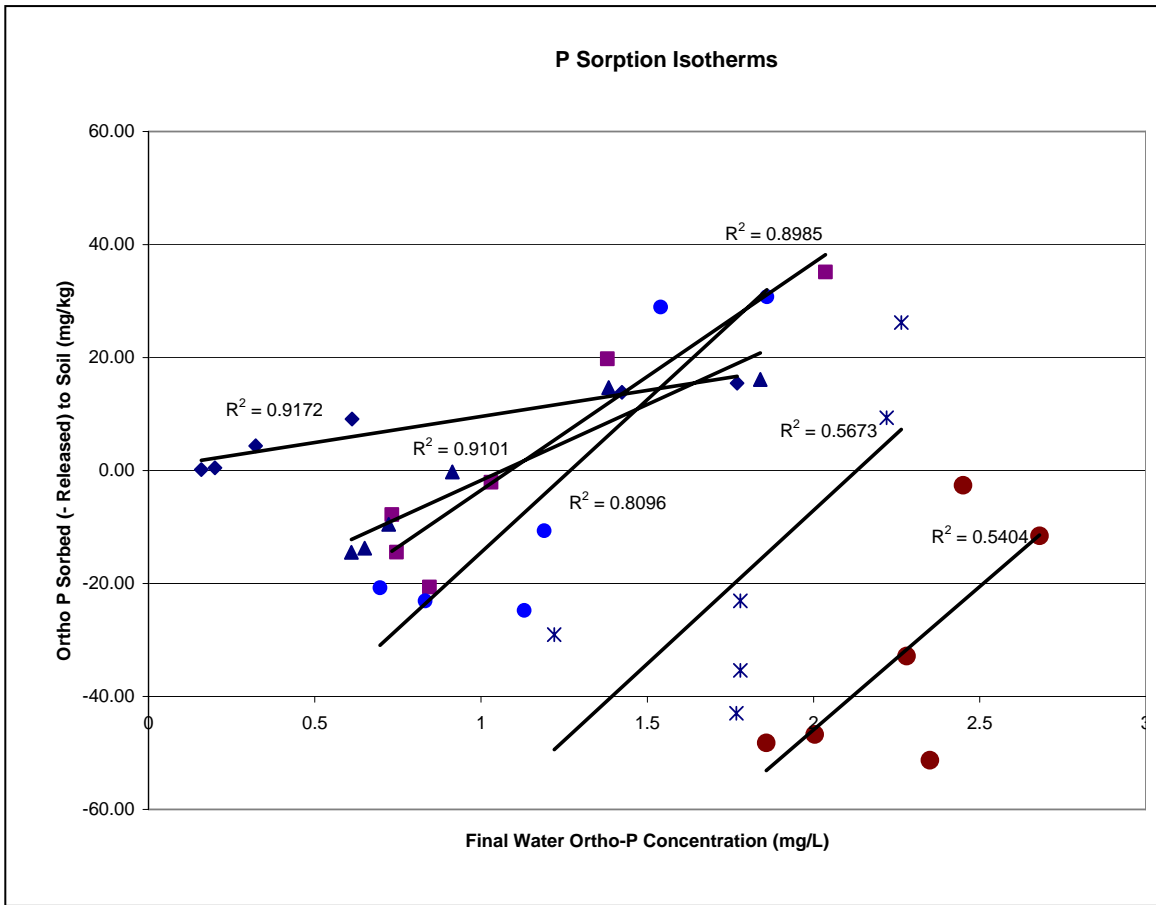
Figure 7 Ortho-P Sorption Isotherms Graph

GSL 11 Sediment Sorption Evaluation
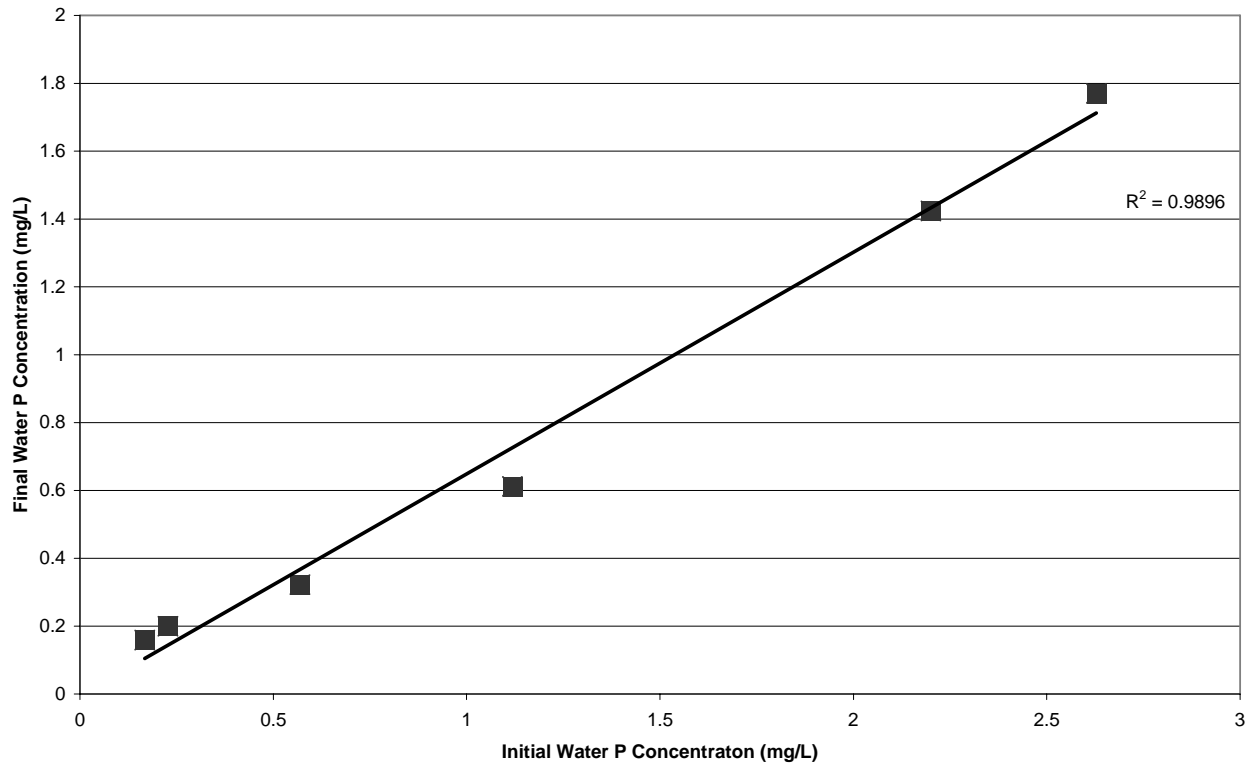
Figure 8 – Initial vs. Final Ortho-P concentration GSL 11

As can be seen, the sediment acted as a sink for P from the water. As the water concentration increased, the amount of P transferred per unit of sediment increased. The correlation coefficient of 0.99 is extremely good, indicating the graph can be used to project the final concentration from the initial water concentration for this sediment at the same physical conditions that existed in this experiment.   Below is a bar chart showing the rate of sediment transfer rate in mg/Kg for each water concentration, starting with the low ortho-P water. Obviously the amount of P available for transfer increases as the concentration increases thus acting as a partial driver for the process.

GSL 11 Ortho-P Absorbed Into Soil
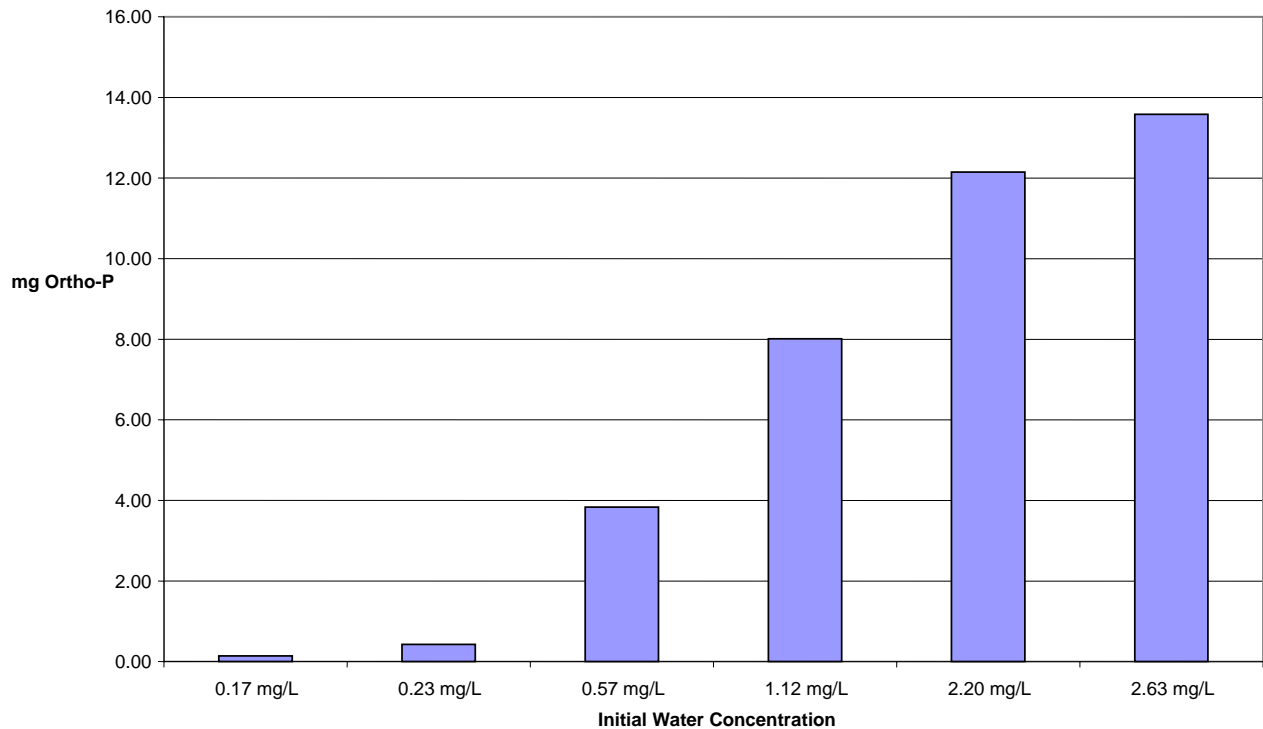
Figure 9 – Sediment ortho-P transfer in mg/Kg GSL 11

The first bar indicates that at an initial water ortho-P concentration of about 0.17 mg/L only a very little amount of P is transferred to the sediment. The fourth bar is for an initial water concentration of about 1.12 mg/L. At this concentration in the water, the sediment accepts about 8.1 mg/Kg. At a water concentration of about 2.63 mg/L, the last bar, almost 14 mg/Kg of ortho-P is partitioned to the sediment.

Another sample, GSL 22 demonstrated the condition when the sediment both donated and then accepted water ortho-P. In this scenario the sediment responded differently when mixed with a varying ortho-P concentration in the water. The results are shown in Figure 10.

GSL 22 Sediment Sorption Evaluation

Figure showing Final Water Concentration in mg/L (y-axis, 0.00 to 2.00) vs Initial Water Concentration in mg/L (x-axis, 0.00 to 3.00), with $R^2 = 0.9259$
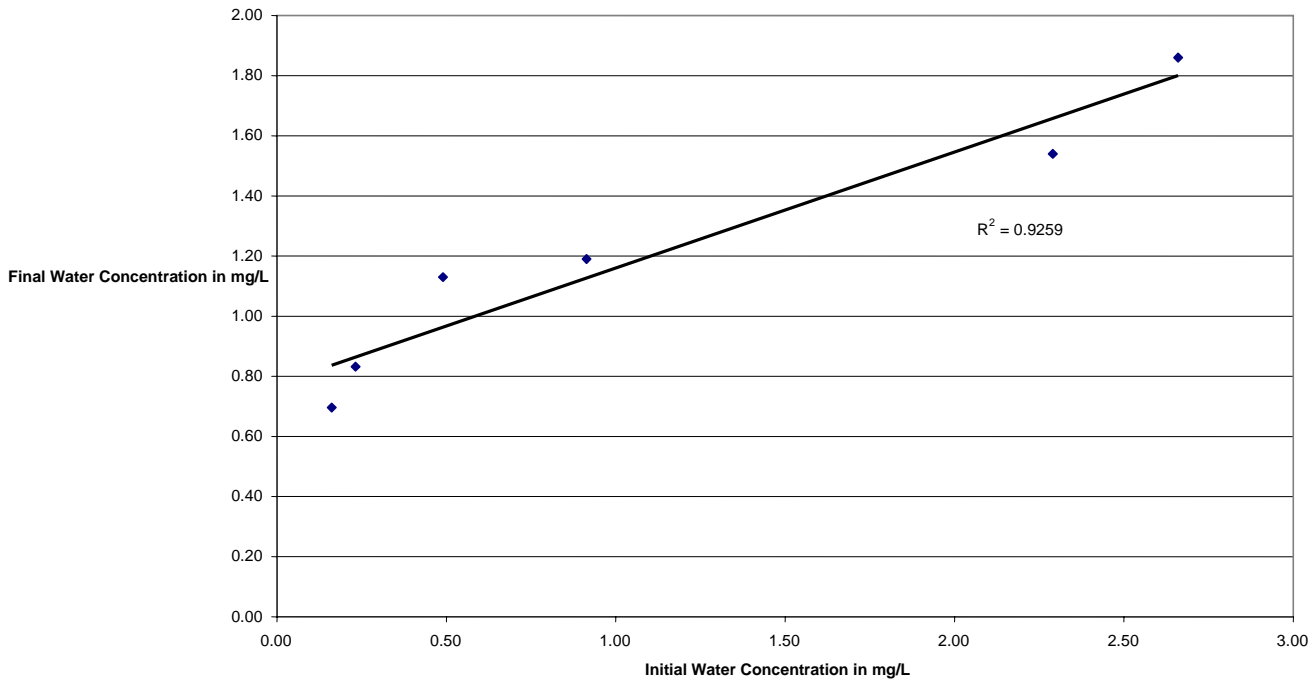
Figure 10 – Initial vs. Final ortho-P Concentration GSL 22

Up to a concentration of about 1.3 mg/L in the water ortho-P is transferred from the sediment to the water. Above 1.3 mg/L, the sediment accepts P from the water. Figure 11 shows the net amount transferred to or from the sediment as the water ortho-P increases. Reiterating the effect of varying ortho-P water concentrations when mixed with sediment, if the water is low in P the sediment releases Ortho-P to the water. When water with high P is mixed with the same sediment, ortho-P is transferred from the water to the sediment.

GSL 22 Ortho-P Absorbed To or (-) Released From Soil
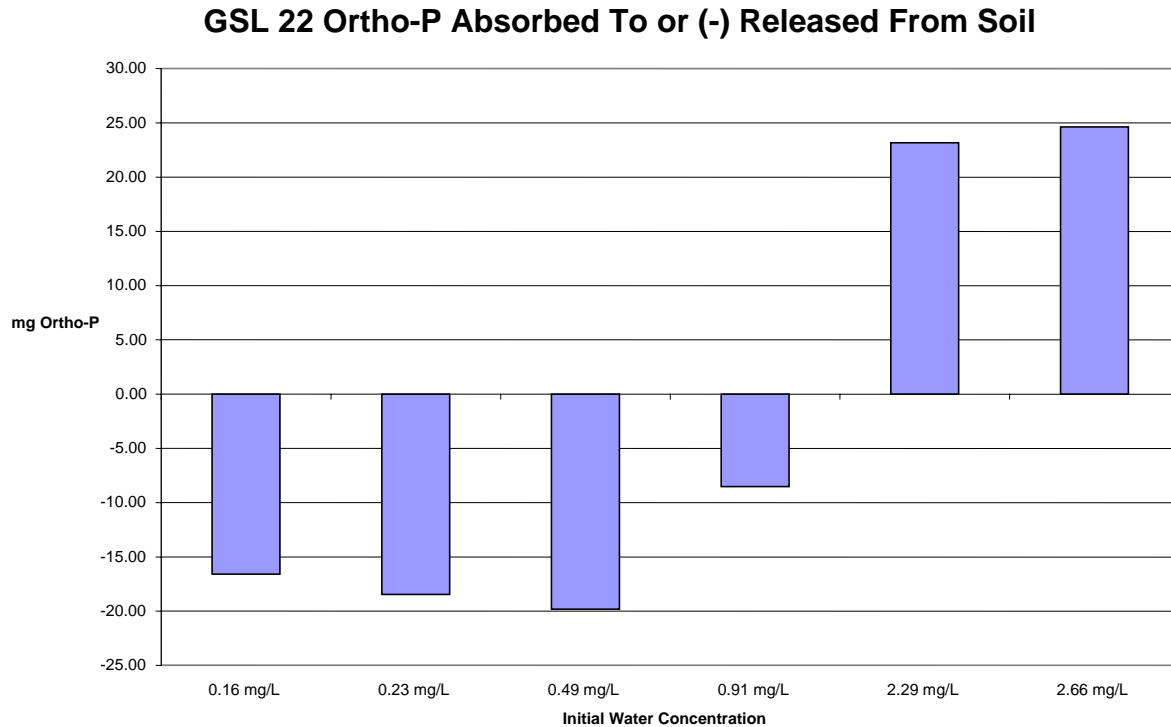
Figure 11 – Sediment ortho-P transfer in mg/Kg GSL 22

GSL 22, when mixed with water at an initial concentration of about 0.16 mg/L, releases P so that the final water ortho-P ends up at about 0.7 mg/L.   At the other end of the spectrum, when an initial water concentration of about 2.7 is mixed with the same sediment, the sediment accepts ortho-P and the final water ortho-P concentration is only about 1.9 mg/L.

CONCLUSION

An apparent correlation exists between the initial and the final concentration of ortho-P in water when mixed with Great Salt Lake Farmington Bay sediment.   The response of the sediment to the water varies depending on the condition of the sediment, although the exact relationship has not been determined as too few physical parameters were measured during the experiment.   Sediment can act as a sink for excess P in the water as well as a source of P when water has low initial ortho-P concentrations.   The actual cycling mechanisms between water and sediment should be investigated further.

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General Conclusions

Each section of this report contains specific conclusions based on the type of testing being conducted. Each section also contains recommendations for additional study. In general the testing and evaluation to date had demonstrated the interrelationship of phosphorus between the Farmington Bay waters and sediments. Too few physical parameters, such as pH were measured for the results to be conclusive. The oxic or anoxic condition of the sediment plays an important role in the release or uptake of phosphorus to the overlying water.   In order for sediment interaction to take place, a mixing event must occur.   A phosphorus balance to Farmington Bay is needed for further determine if phosphorus control to the Bay is viable.   Even if phosphorus control can reduce sufficiently the amount of incoming phosphorus, the reduction of water column P may take a long time to be seen.   Either encapsulation of the exiting sediment must occur from new deposits, or a washout of the existing sediment must take place.   Significant additional research must take place to determine if the concentration of phosphorus is, or contributes to an impairment of Farmington Bay and if such an impairment exists, can any control mechanisms on anthropogenic sources sufficiently reduce phosphorus to achieve an improvement.

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Appendix 1

Sediment Sampling Results

CDSD Deep Sediment Sample
GSL- 2004-1 9/17/2004

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.44	520	-2	1182
4	0.44	480	-4	1091
6	0.6	740	-6	1233
8	0.77	840	-8	1091
10	0.78	700	-10	897
12	0.77	710	-12	922

Deep Soil Sample for P GSL 2004-1

Inches Deep

PPM Total P (Dry Weight)
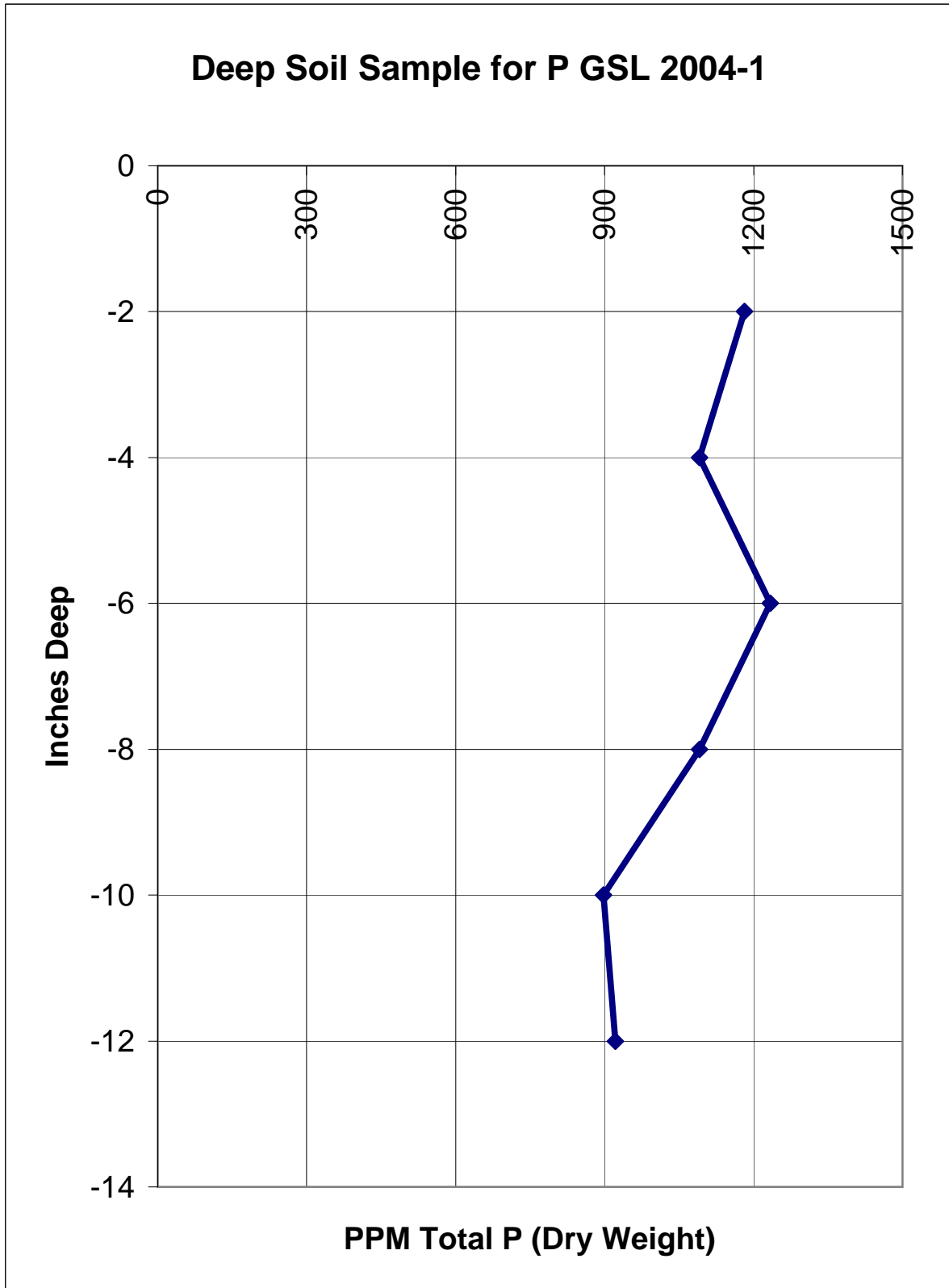
CDSD Deep Sediment Sample
GSL- 2004-2 9/17/2004

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.61	510	-2	836
4	0.56	560	-4	1000
6	0.69	490	-6	710
8	0.7	530	-8	757
10	0.77	470	-10	610
12	0.79	460	-12	582

Deep Soil Sample for P GSL 2004-2
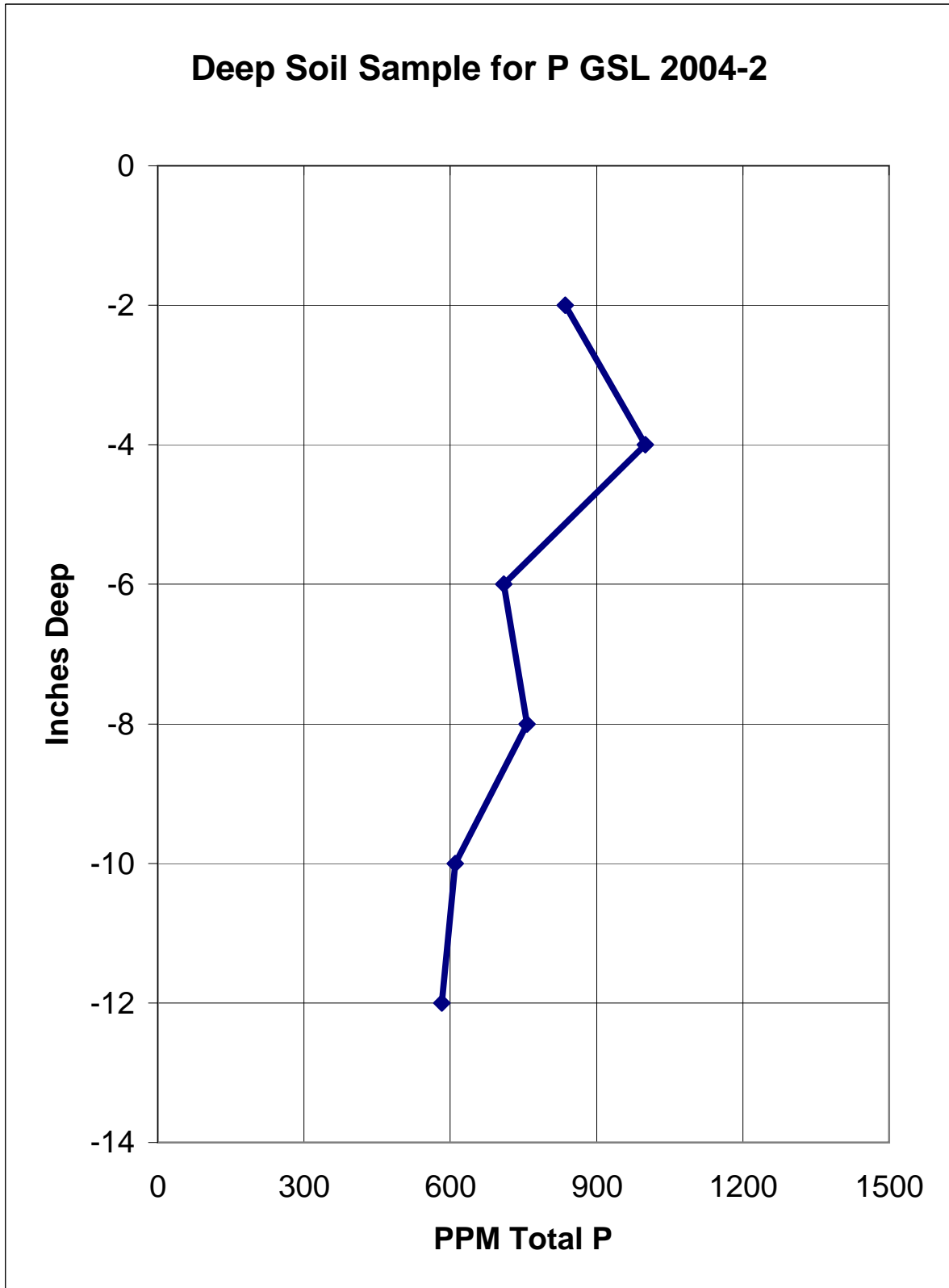
CDSD Deep Sediment Sample
GSL- 2004-3 9/17/2004

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.6	630	-2	1050
4	0.64	520	-4	813
6	0.66	500	-6	758
8	0.66	490	-8	742
10	0.7	560	-10	800
12	0.68	570	-12	838

CDCSD Deep Sediment Sample
GSL - 2004-03

Deep Soil Sample for P GSL 2004-3

Y-axis: Inches Deep
X-axis: PPM Total P (Dry Weight)
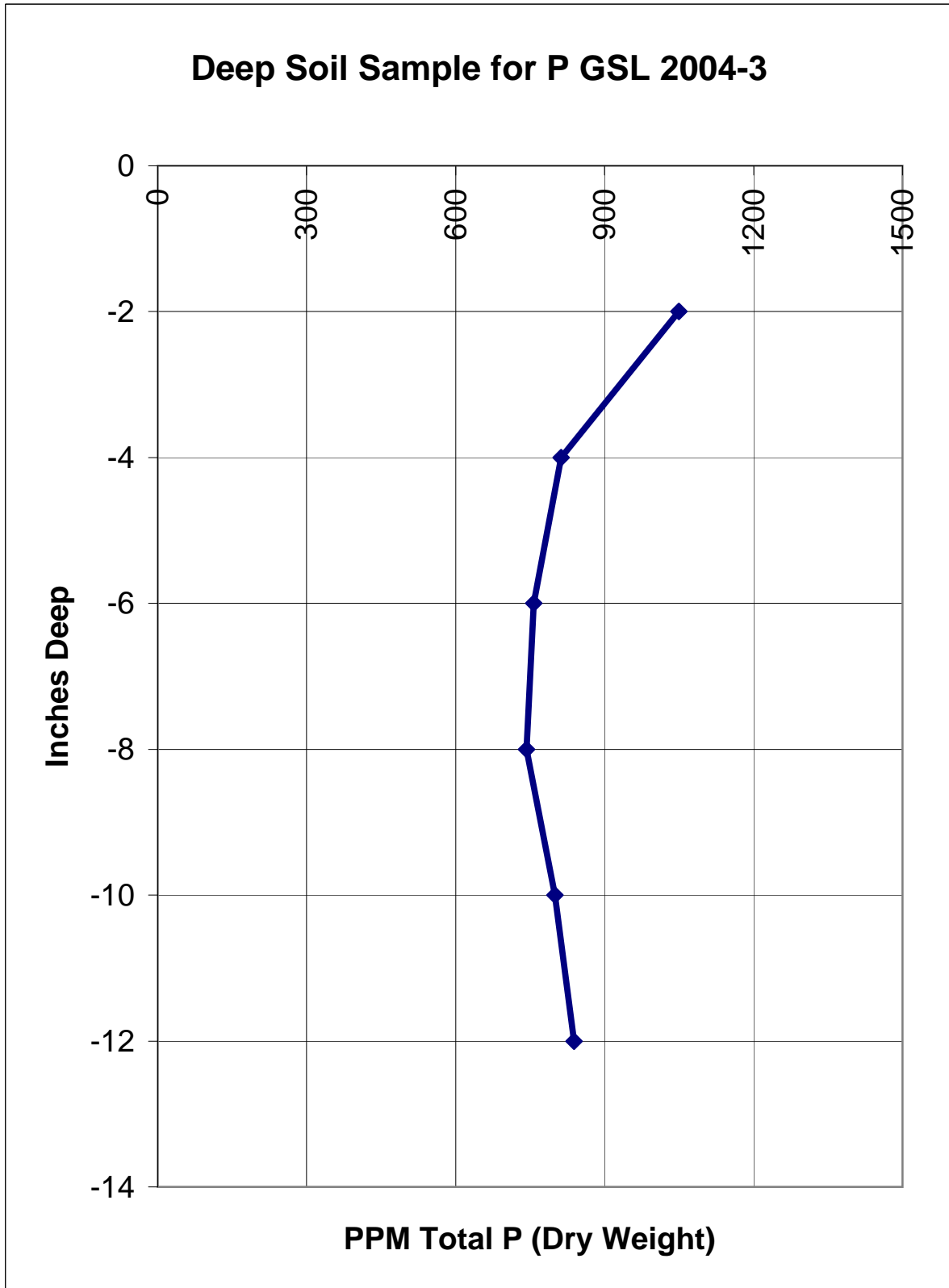
CDSD Deep Sediment Sample
GSL- 2004-4 9/17/2004

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.6	580	-2	967
4	0.63	410	-4	651
6	0.63	430	-6	683
8	0.63	440	-8	698
10	0.62	420	-10	677
12	0.61	420	-12	689

CDCSD Deep Sediment Sample
GSL - 2004-04

Deep Soil Sample for P GSL 2004-4

Y-axis: **Inches Deep** (0, -2, -4, -6, -8, -10, -12, -14)

X-axis (top): 0, 300, 600, 900, 1200, 1500

X-axis label: **PPM Total P (Dry Weight)**
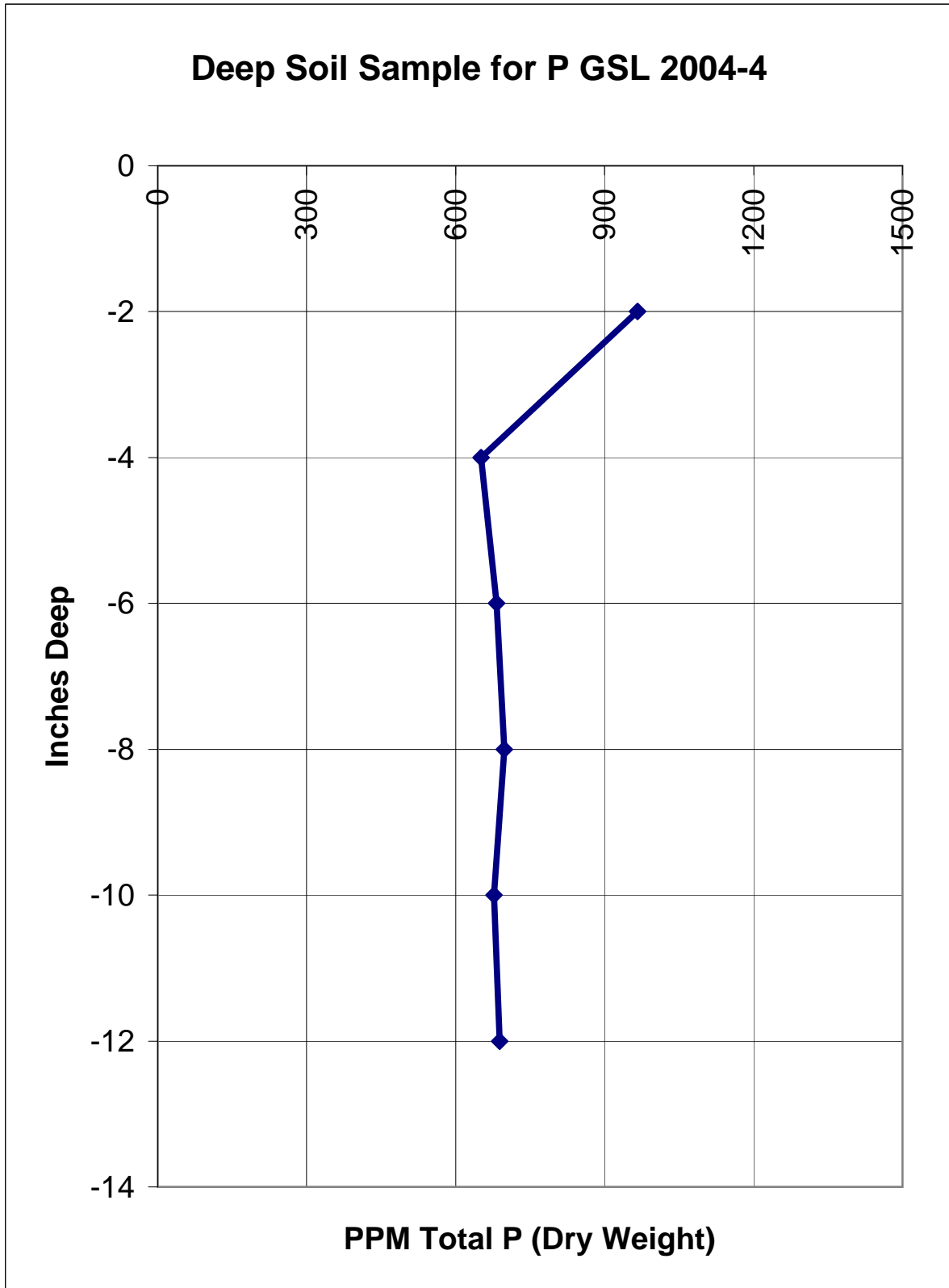
CDSD Deep Sediment Sample
GSL- 2004-5 9/17/2004

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.69	370	-2	536
4	0.7	350	-4	500
6	0.73	350	-6	479
8	0.74	420	-8	568
10	0.8	410	-10	513
12	0.7	410	-12	586

Deep Soil Sample for P in GSL 2004-5

Y-axis: **Inches Deep** (0, -2, -4, -6, -8, -10, -12, -14)

X-axis (top): 0, 300, 600, 900, 1200, 1500

X-axis label: **PPM Total P (Dry Weight)**
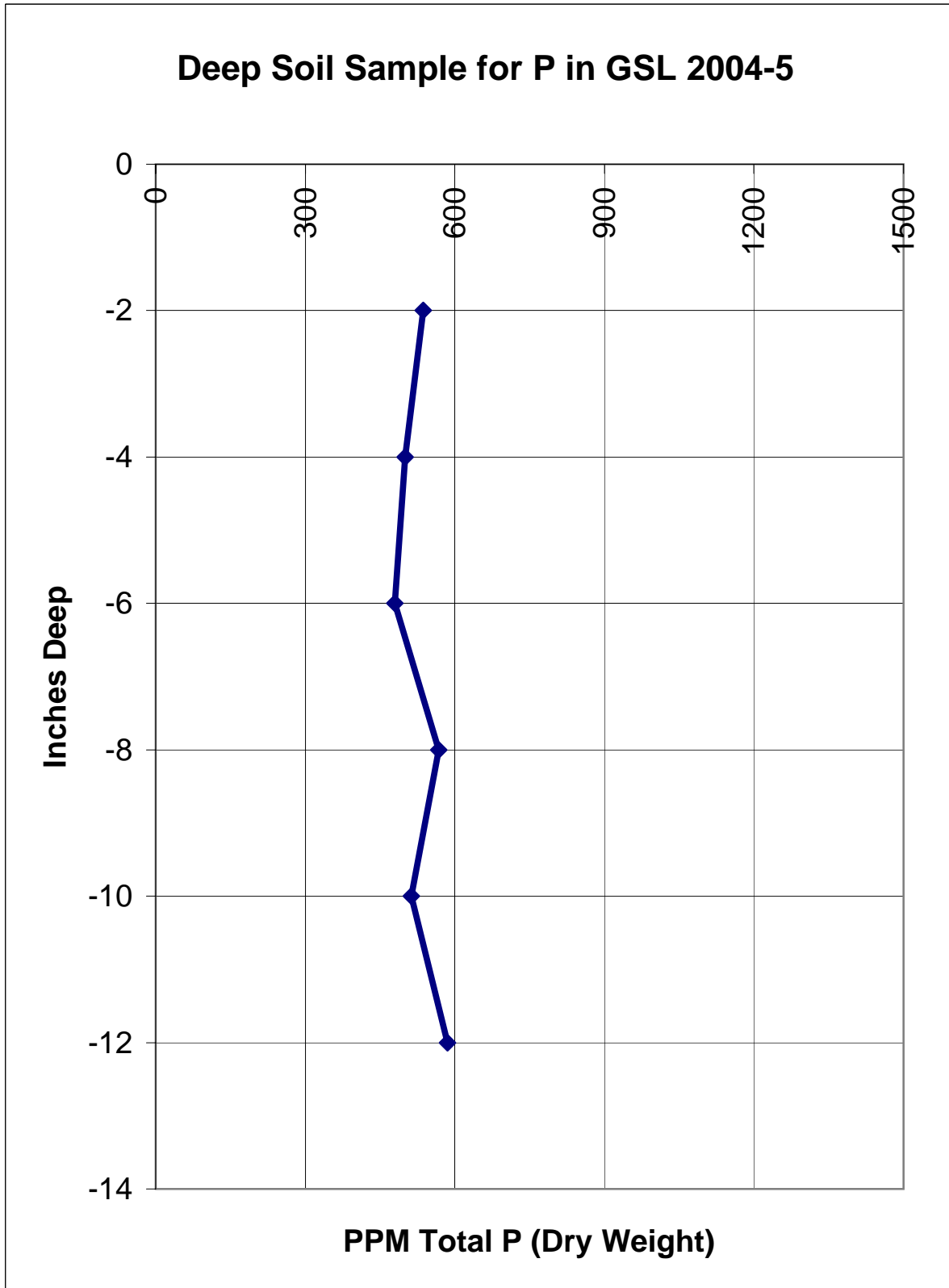
CDSD Deep Sediment Sample
GSL- 2004 USGS 9/29/2004

Depth Feet	Hg ppm - Dry		P ppm Dry		
0.00	0.250	0.00		1600	0.00
0.26	0.720	-0.26		1100	-0.26
0.52	0.16	-0.52		980	-0.52
0.78	0.06	-0.78		1000	-0.78
1.00	0.06	-1.00		1100	-1.00
1.30	0.02	-1.30		1100	-1.30
1.80	0.02	-1.80		1200	-1.80

CDSD Deep Sediment Sample
GSL - 2004 USGS

Deep Soil Sample for P GSL USGS

(Y-axis: Feet Deep, ranging from 0.00 to -2.00)

(X-axis: PPM Total P (Dry Weight), ranging from 0 to 1800)
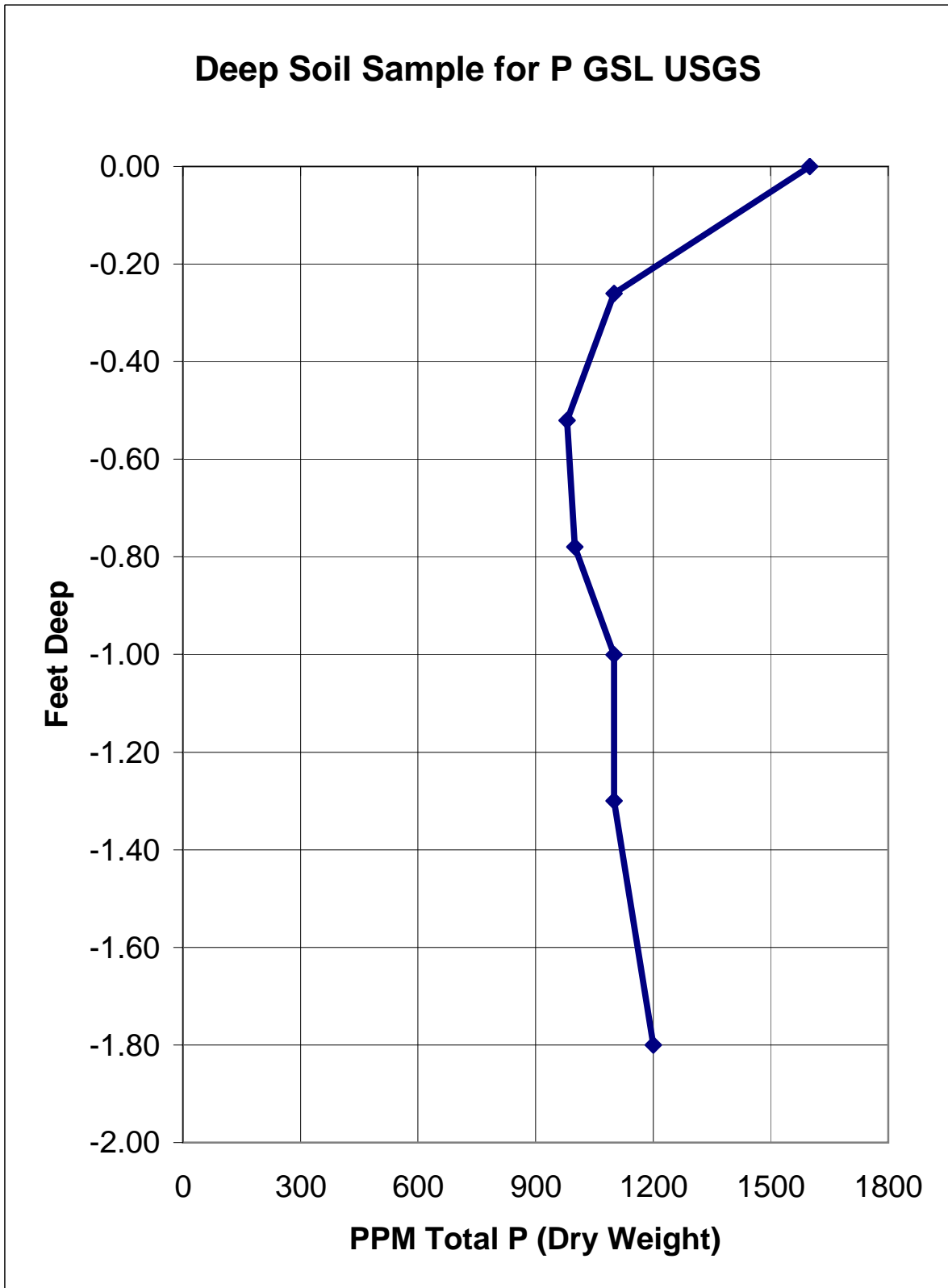
CDSD Deep Sediment Sample
GSL- 01 5/25/2005

Depth Inches	% Solids	Hg ppm	P ppm	Hg ppm - Dry		P ppm Dry
2	0.73	0.25	330	0.342	-2	452
4	0.74	0.05	360	0.068	-4	486
6	0.69	0.034	380	0.034	-6	551
8	0.74	0.037	400	0.037	-8	541
10	0.75	0.037	410	0.037	-10	547
12	0.76	0.038	430	0.038	-12	566
14	0.73	0.036	430	0.036	-14	589
16	0.67	0.033	430	0.033	-16	642
18	0.74	0.037	410	0.037	-18	554
20	0.72	0.036	400	0.036	-20	556
22	0.71	0.036	410	0.036	-22	577
24	0.69	0.034	420	0.034	-24	609

Deep Soil Sample for P GSL 1

C:\Data Files\Great Salt Lake Info\Sediment Sampling Study\P Graph Chart 1
11/29/2005
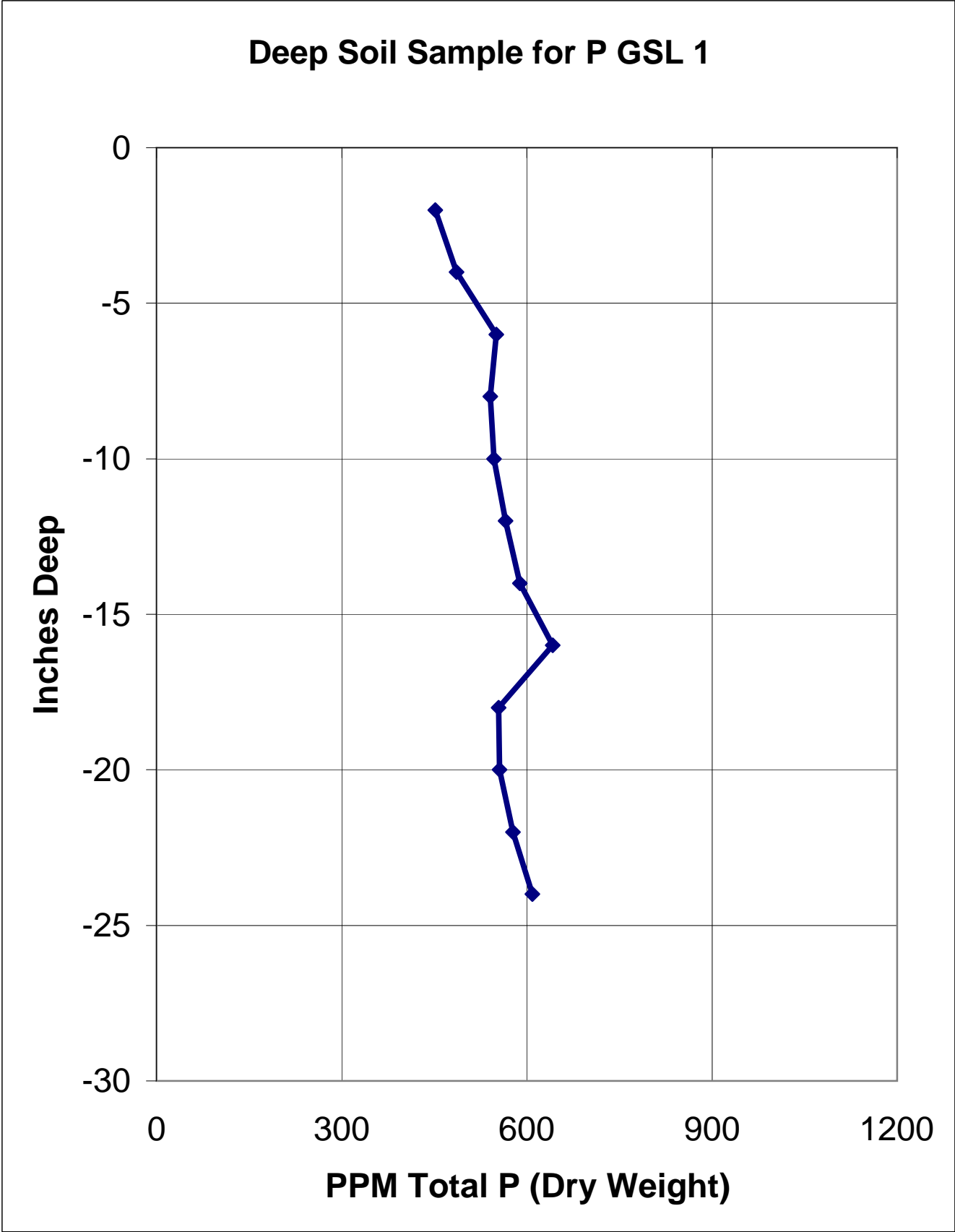
CDSD Deep Sediment Sample
GSL- 02 6/15/2005

Depth Inches	% Solids	% VS	Hg ppm	P ppm	Hg ppm - Dry		P ppm Dry
2	0.769	9.89	0.211	505	0.274	-2	657
4	0.757	10.6	0.096	527	0.127	-4	696
6	0.706	9.27	0.0358	418	0.0358	-6	592
8	0.744	10.3	0.0925	459	0.0925	-8	617
10	0.769	8.06	0.192	495	0.192	-10	644
12	0.733	9.31		490		-12	668
14	0.735	8.3		481		-14	654
16	0.709	10.6		465		-16	656
18	0.756	8.79		543		-18	718
20	0.719	10.5		569		-20	791
22	0.72	6.49		506		-22	703

Deep Soil Sample for P GSL 2
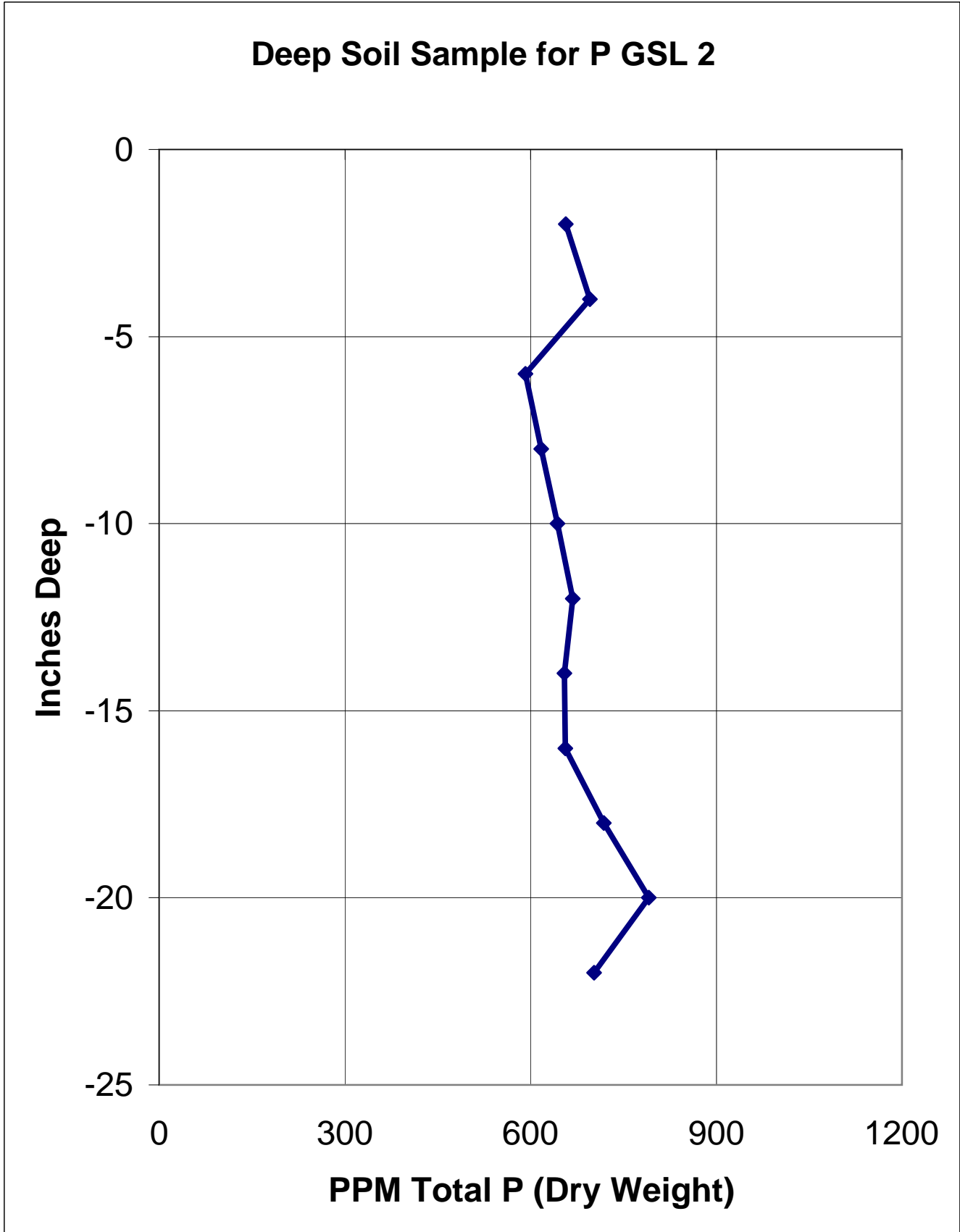
CDSD Deep Sediment Sample
GSL- 03 6/15/2005

Depth Inches	% Solids	% VS	Hg ppm	P ppm	Hg ppm - Dry		P ppm Dry
2	0.725	8.14	0.0358	337	0.049	-2	465
4	0.712	15.5	0.0358	360	0.050	-4	506
6	0.623	18.4	0.0358	389	0.0358	-6	624
8	0.685	15	0.0516	423	0.0516	-8	618
10	0.68	13.3	0.0516	385	0.0516	-10	566
12	0.682	0.134		404		-12	592
14	0.724	10.6		386		-14	533
16	0.704	13.2		399		-16	567
18	0.669	0.16		306		-18	457
20	0.699	0.149		363		-20	519
22	0.682	0.147		393		-22	576

Deep Soil Sample for P GSL 3
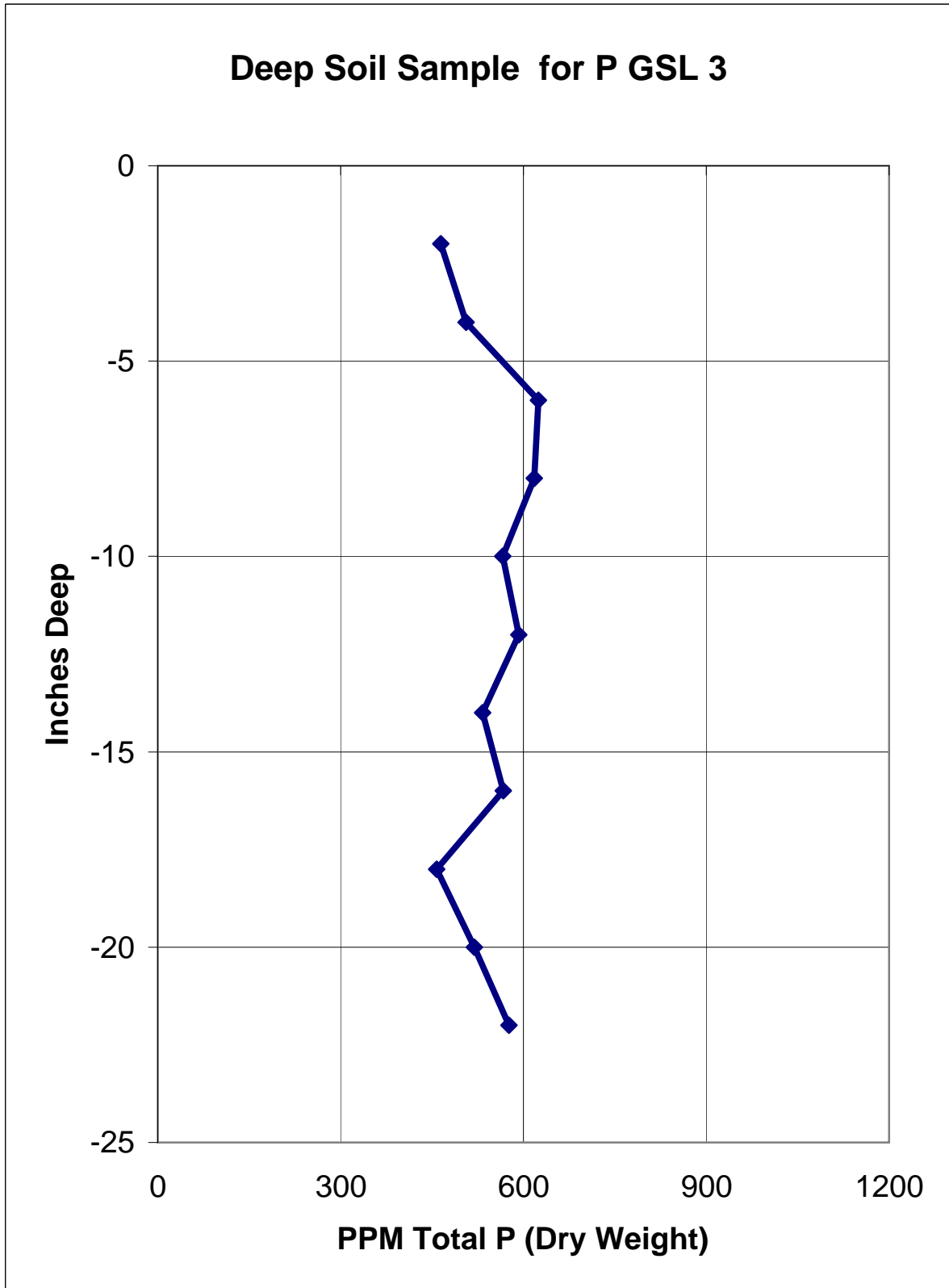
CDSD Deep Sediment Sample
GSL- 04 6/24/2005

Depth Inches	% Solids	% VS	Hg ppm	P ppm	Hg ppm - Dry		P ppm Dry
2	0.721	12.4	0.079	655	0.110	-2	908
4	0.691		0.09	428	0.130	-4	619
6	0.695		0.04	414	0.04	-6	596
8	0.698		0.04	469	0.04	-8	672
10	0.682		0.04	476	0.04	-10	698
12	0.693			462		-12	667
14	0.683			422		-14	618
16	0.664			482		-16	726
18	0.711			490		-18	689

Deep Soil Sample for P GSL 4

Inches Deep

PPM Total P (Dry Weight)
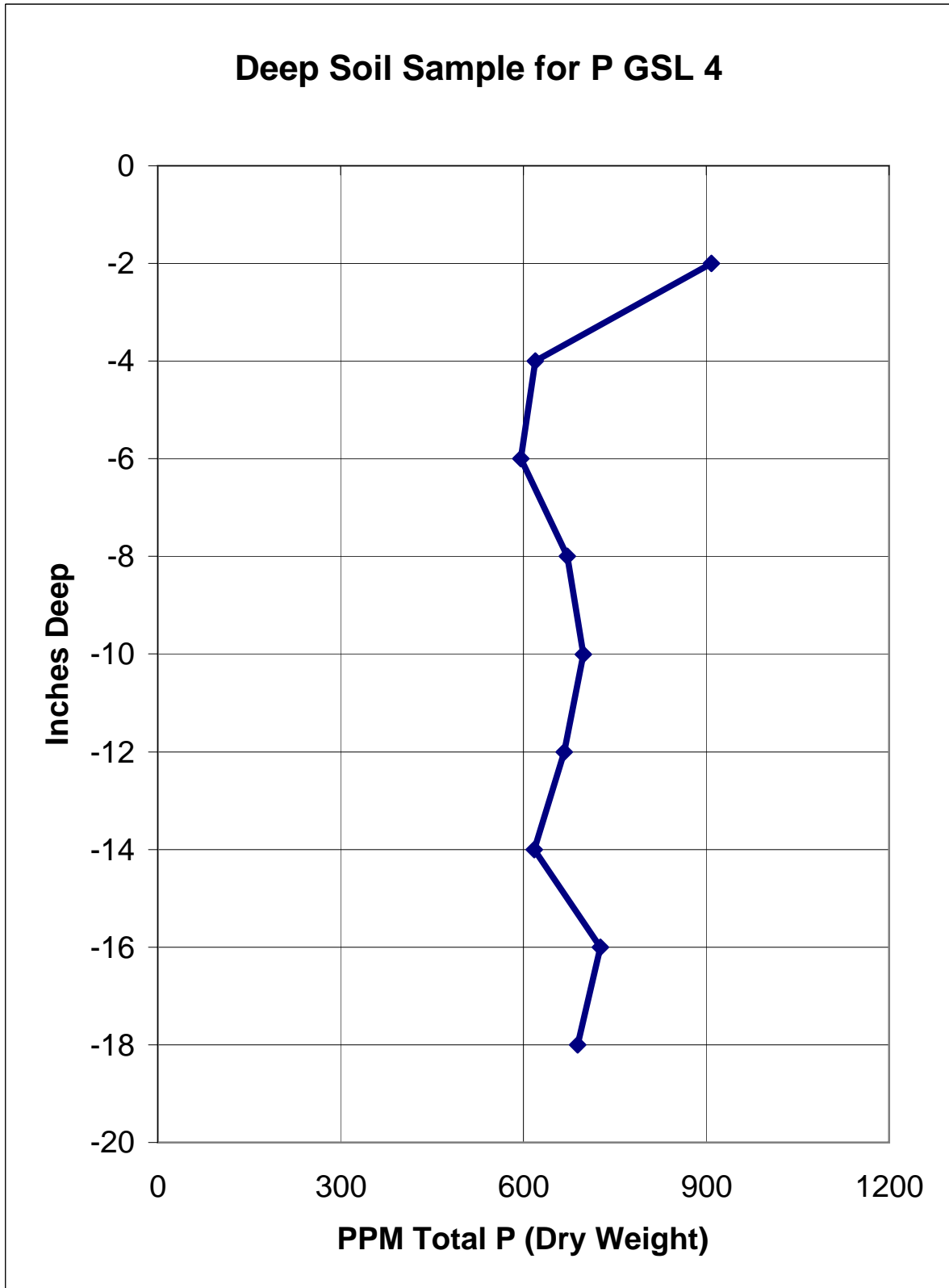
CDSD Deep Sediment Sample
GSL- 05 7/7/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.75	720	-2	960
4	0.731	495	-4	677
6	0.73	525	-6	719
8	0.786	518	-8	659
10	0.772	503	-10	652
12	0.792	552	-12	697
14	0.778	510	-14	656
16	0.791	480	-16	607
18	0.777	496	-18	638
20	0.74	465	-20	628
22	0.75	458	-22	611
24	0.756	495	-24	655

Deep Soil Sample for P GSL 5

Inches Deep

PPM Total P
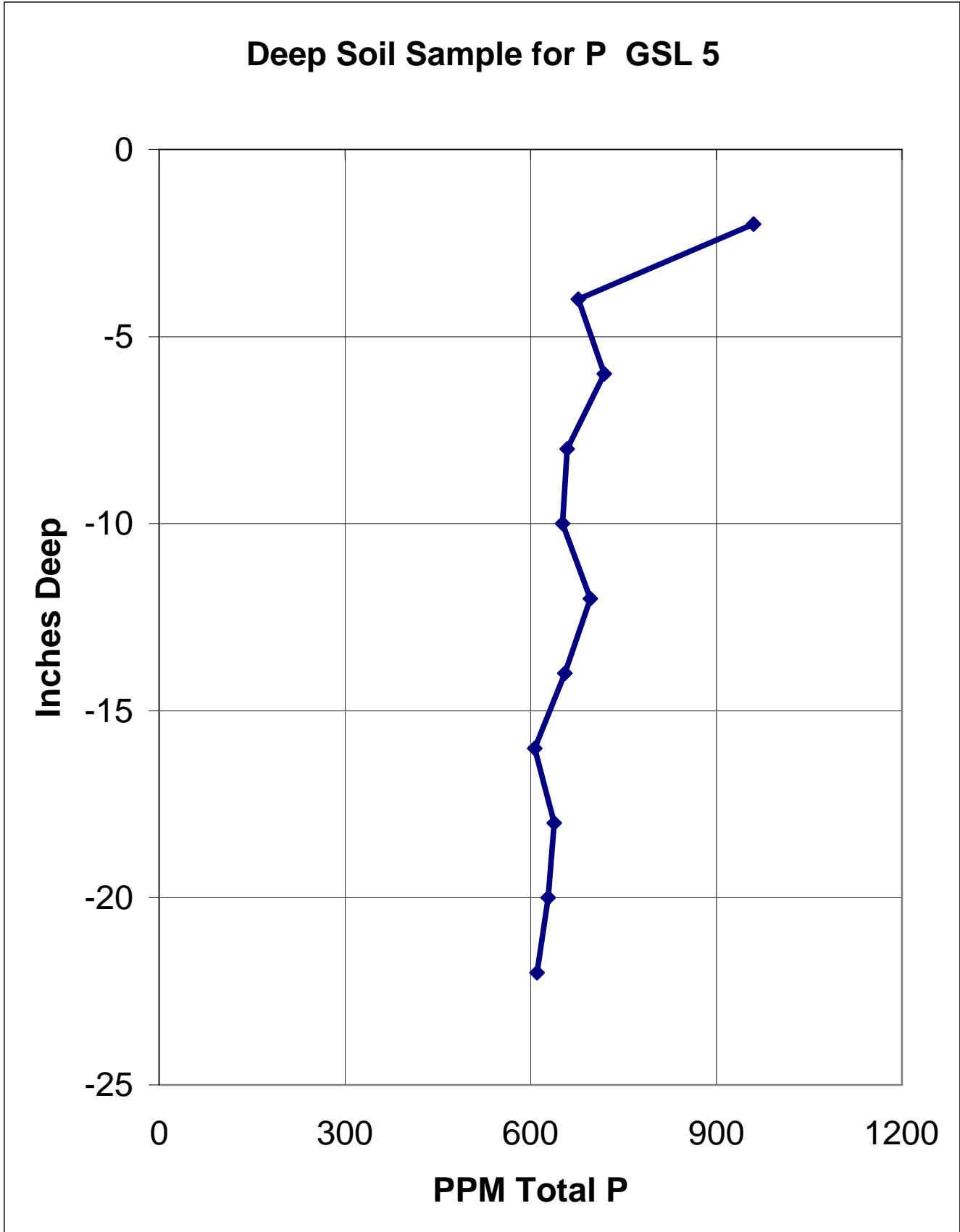
CDSD Deep Sediment Sample
GSL- 07 7/18/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.85	485	-2	571
4	0.813	250	-4	308
6	0.936	280	-6	299
8	0.81	390	-8	481
10	0.897	400	-10	446
12	0.69	380	-12	551
14	0.617	395	-14	640
16	0.596	380	-16	638
18	0.67	455	-18	679
20	0.716	390	-20	545
22	0.641	500	-22	780
24	0.805	520	-24	646
26	0.733	460	-26	628
28	0.743	510	-28	686

Deep Soil Sample for P GSL 7

Inches Deep

PPM Total P
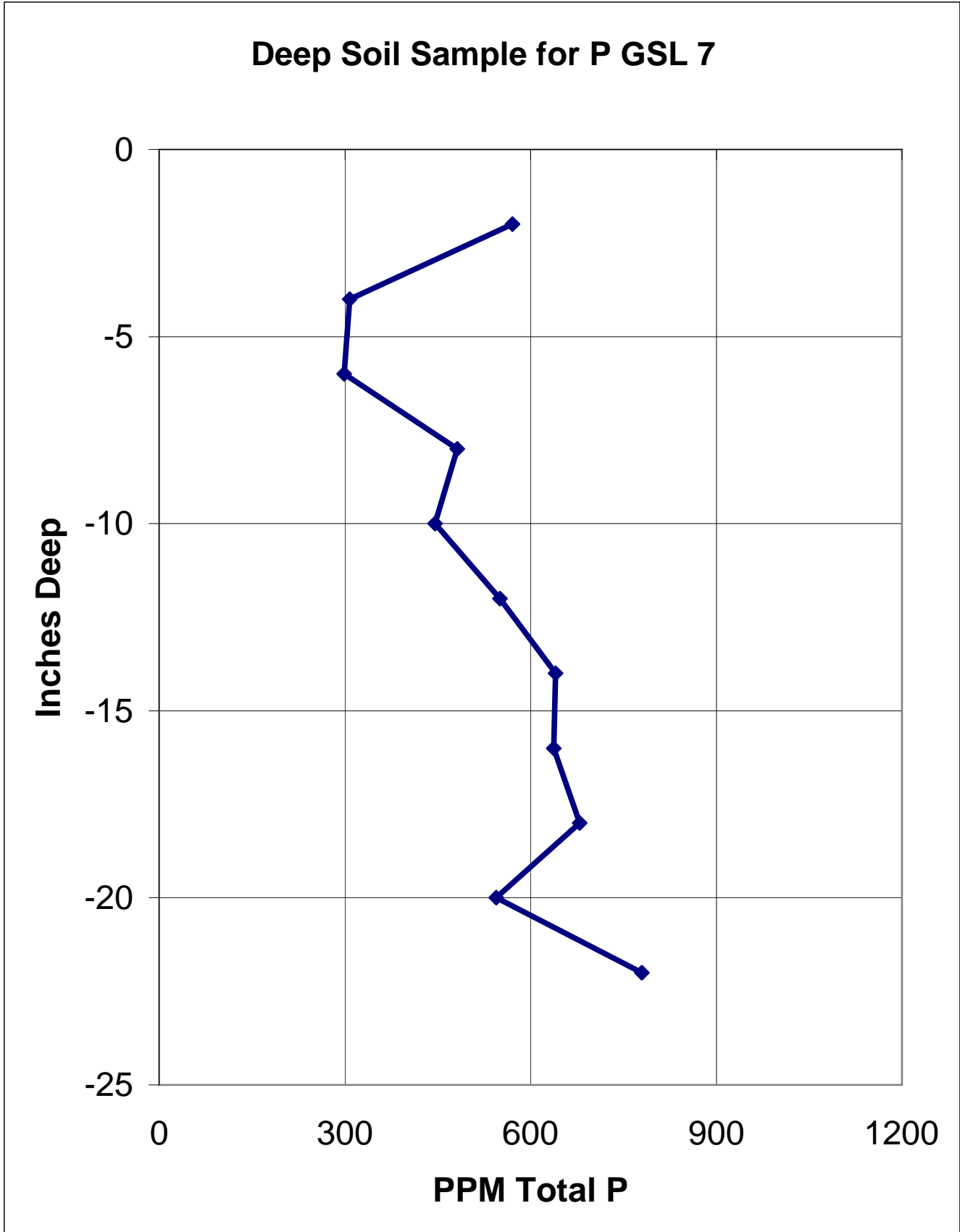
CDSD Deep Sediment Sample
GSL- 08 7/18/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.6	618	-2	1030
4	0.625	341	-4	546
6	0.606	348	-6	574
8	0.599	420	-8	701
10	0.688	415	-10	603
12	0.71	426	-12	600
14	0.67	496	-14	740
16	0.66	455	-16	689
18	0.66	475	-18	720
20	0.709	412	-20	581
22	0.715	440	-22	615
24	0.712	454	-24	638

CDSD Deep Soil Sample
GSL - 08

Deep Soil Sample for P GSL 8

Inches Deep

PPM Total P (Dry Weight)
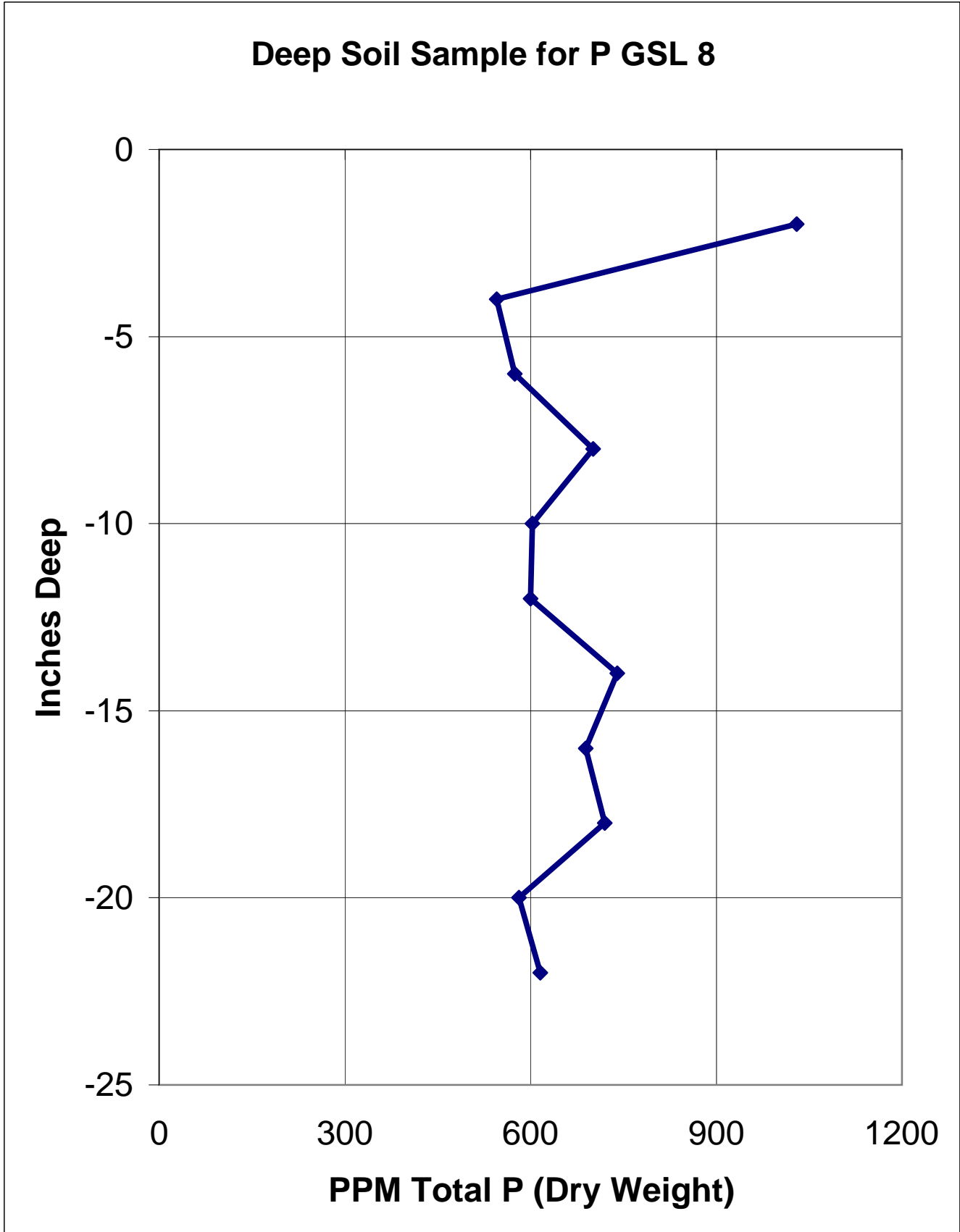
CDSD Deep Sediment Sample
GSL- 09 8/2/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.864	250	-2	289
4	0.846	221	-4	261
6	0.84	183	-6	218
8	0.826	197	-8	238
10	0.817	189	-10	231
12	0.825	172	-12	208
14	0.825	172	-14	208
16	0.799	205	-16	257
18	0.791	182	-18	230
20	0.778	218	-20	280
22	0.79	316	-22	400
24	0.772	308	-24	399
26	0.751	248	-26	330

CDSD Deep Soil Sample
GSL - 09

Deep Soil Sample for P GSL 9

Inches Deep

PPM Total P

C:\Data Files\Great Salt Lake Info\Sediment Sampling Study\Deep P Sample GSL-9 8-2P Graph Chart 1
11/29/2005
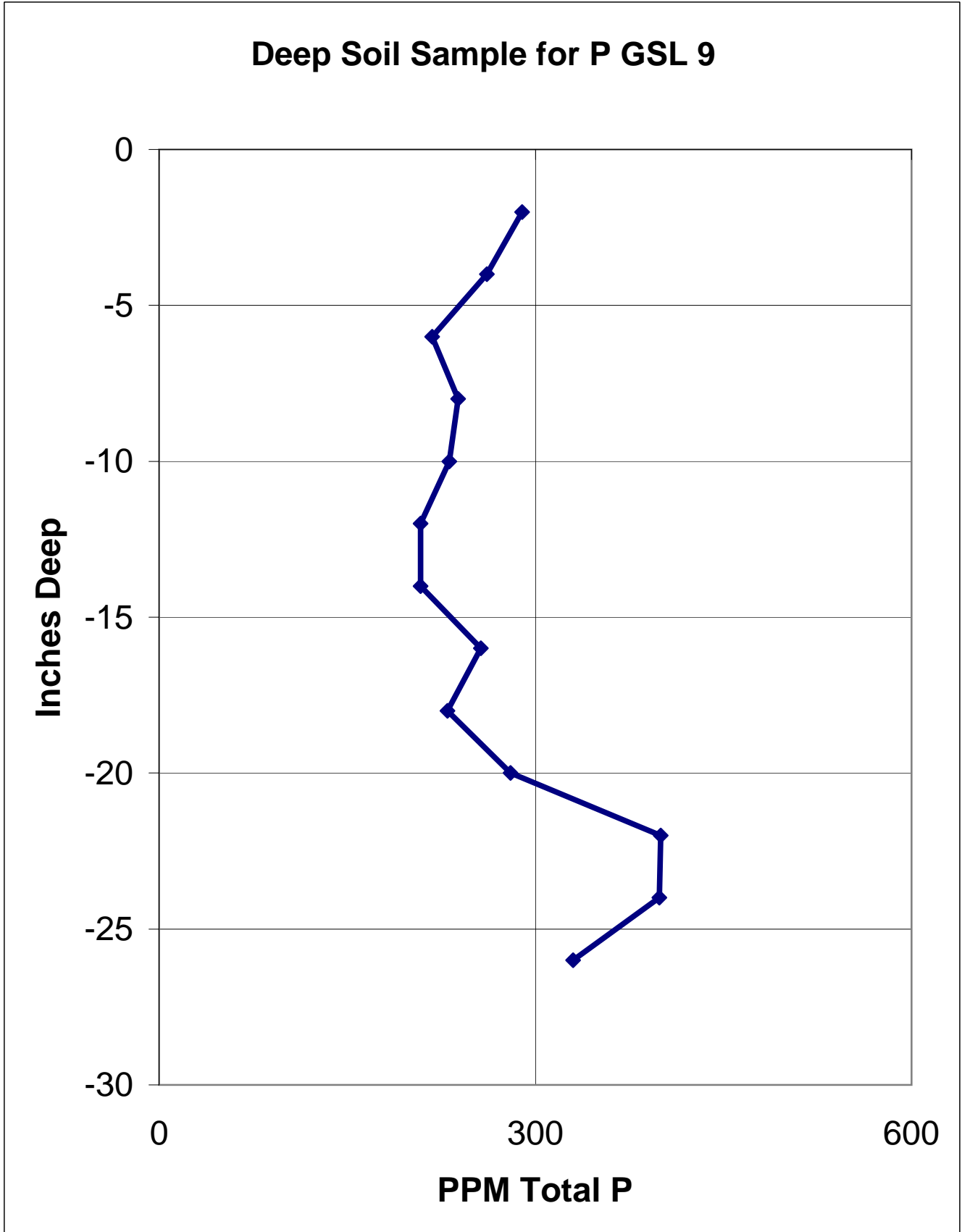
CDSD Deep Sediment Sample
GSL- 40 8/17/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.739	453	-2	613
4	0.694	421	-4	607
6	0.71	483	-6	680
8	0.764	485	-8	635
10	0.788	450	-10	571
12	0.751	435	-12	579
14	0.627	441	-14	703
16	0.677	462	-16	682
18	0.687	469	-18	683
20	0.779	499	-20	641
22	0.778	702	-22	902

CDSD Deep Soil Sample
GSL - 40

Deep Soil Sample for P GSL 40

Inches Deep

PPM Total P (Dry Weight)

C:\Data Files\Great Salt Lake Info\Sediment Sampling Study\Deep P Sample GSL-40 8-17P Graph Chart 1
11/29/2005
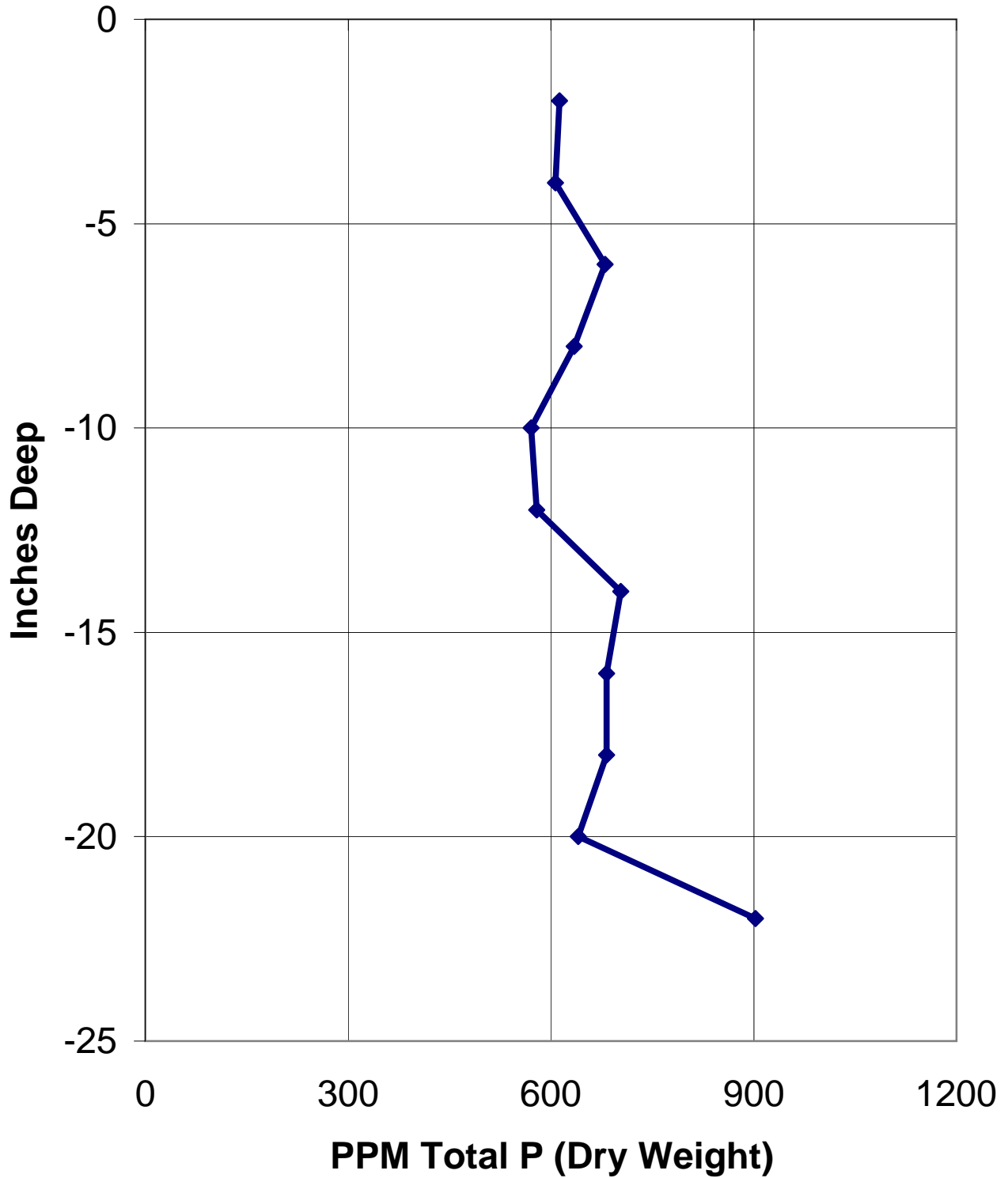
CDSD Deep Sediment Sample
GSL- 41 9/1/2005

Depth Inches	% Solids	P ppm		P ppm Dry
2	0.751	668	-2	889
4	0.745	398	-4	534
6	0.758	357	-6	471
8	0.625	396	-8	634
10	0.717	476	-10	664
12	0.571	359	-12	629
14	0.607	311	-14	512
16	0.567	171	-16	302
18	0.523	181	-18	346
20	0.421	449	-20	1067
22	0.565	498	-22	881
24	0.615	592	-24	963
26	0.547	352	-26	644
28	0.542	390	-28	720

Deep Soil Sample for P GSL 41

C:\Data Files\Great Salt Lake Info\Sediment Sampling Study\Deep P Sample GSL-41 9-1P Graph Chart 1
11/29/2005
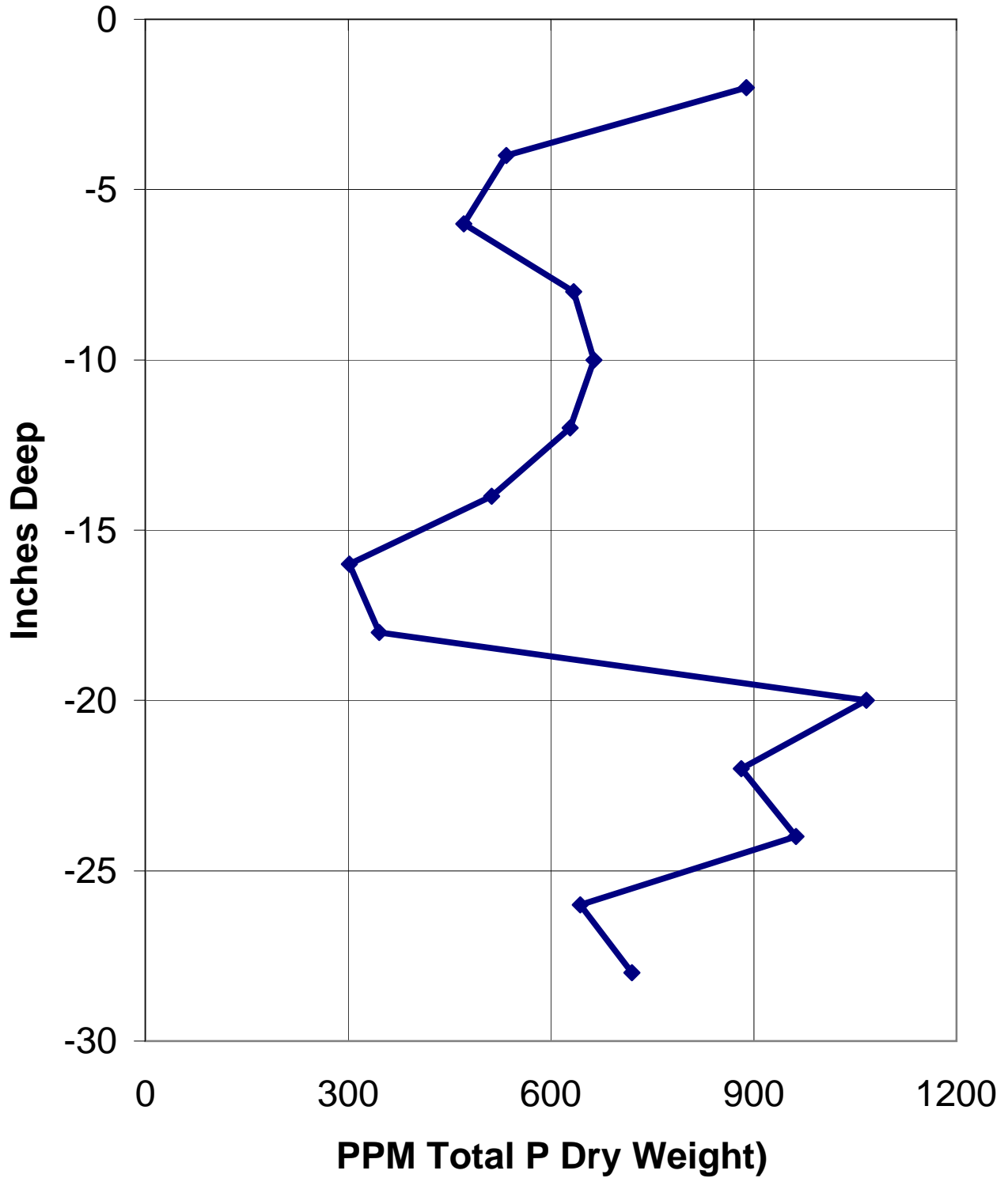
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Appendix 2

Sediment Water Interface Testing Results

Note: All values reported in this appendix as P are ortho-phosphorus (reactive phosphorus).

CDSD Sediment Water Interaction

GSL A

6/22/2005 40°58'32"N 111°58'10"W

w/ Deionized water				w/ Central Davis Effluent			
Date	Time	Hours	P (mg/L)	Date	Time	Hours	P (mg/L)
6/22/2005		0	0.03	6/21/2005	10:30am	0	4.03
	8:00am	0.1	0.62		11:30	1	1.92
	9:00am	1	0.87		12:30	2	1.64
	10:00	2	0.86		1:30	3	1.79
	11:00	3	0.78		2:30	4	1.72
	12:00	4	0.86		4:00	5.5	1.86
	4:00	8	0.86	6/22/2005	7:00am	21	1.84
6/23/2005	8:00am	24	1.05		12:00	25.5	1.91

CDSD Sediment Water Interaction

GSL A Sediment Water Interaction
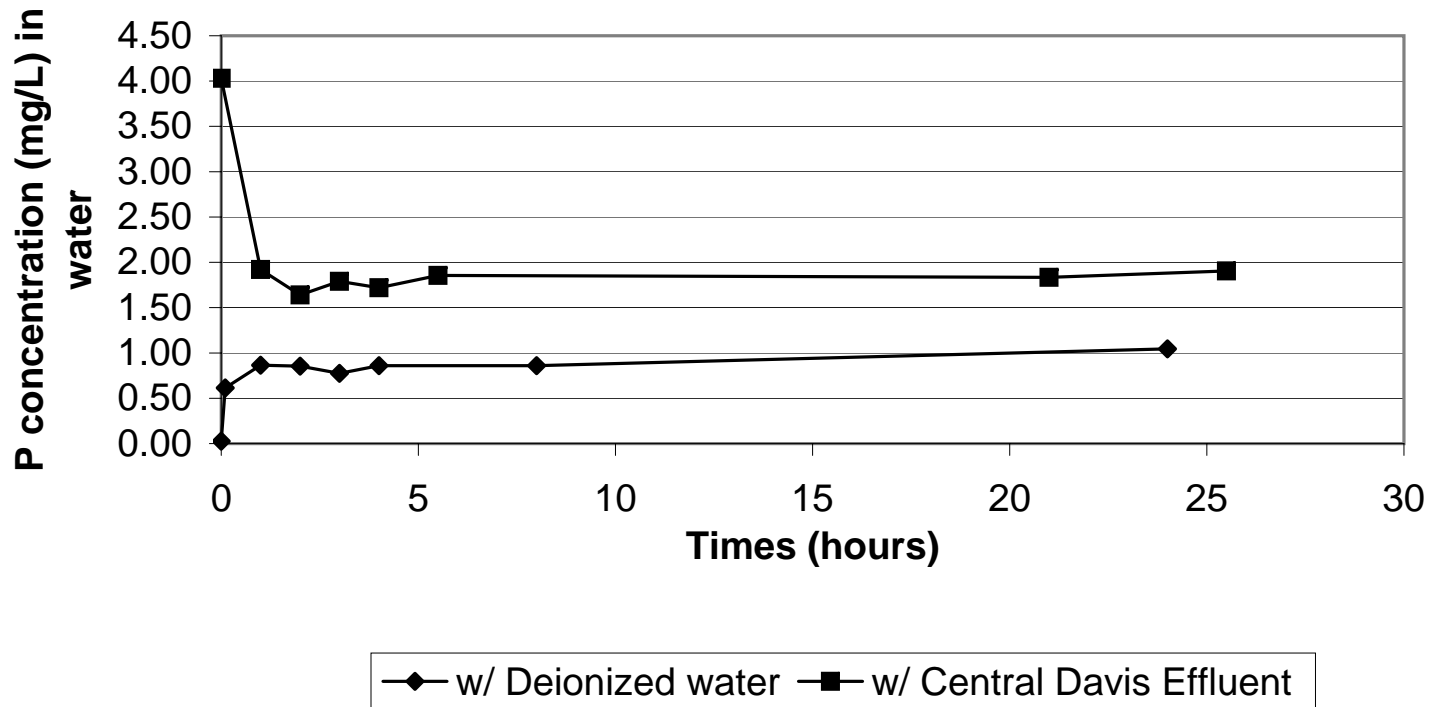
CDSD Sediment Water Interaction

GSL B

6/22/2005 40°56'53"N 111°57'56"W

w/ Deionized water				w/ Central Davis Effluent			
Date	Time	Hours	P (mg/L)	Date	Time	Hours	P (mg/L)
6/22/2005	9:50	0	0.03	6/22/2005	12:50	0	1.98
	10	0.2	2.24		1:00	0.1	2.30
	11:00	1	2.63		2:00	1	3.34
	12:00	2	3.31		3:00	2	3.78
	1:00	3	2.46		4:00	3	3.09
	4:00	6	3.10	6/23/2005	8:00am	19	4.25
6/23/2005	8:00am	22	4.42		12:00	23	3.63
	12:00	26	4.01		4:00	27	3.05

CDSD Sediment Water Interaction

GSL B Sediment Water Interaction
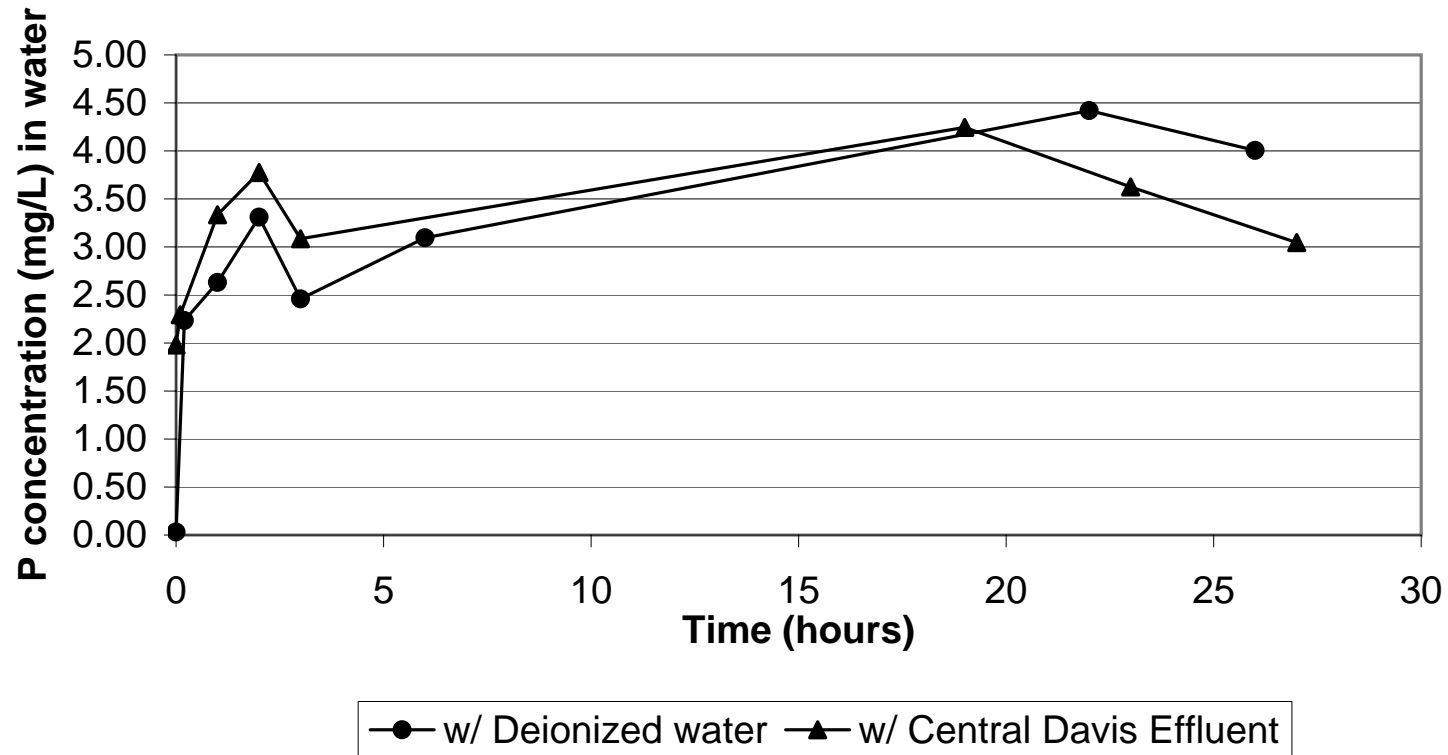
CDSD Sediment Water Interaction

GSL 04

41°01'01"N 112°00'51"W

w/KaysCreek water					w/ Central Davis Sewer Effluent			
Date	**Time**	**Hours**	**P (mg/L)**		**Date**	**Time**	**Hours**	**P (mg/L)**
6/28/2005	7:00	0	0.13					
	7:10	0.2	0.61		6/28/2005	9:50	0	2.44
	8:10	1	0.52			10:00	0.2	1.32
	9:10	2	0.48			10:55	1	1.37
	10:10	3	0.54			11:55	2	1.04
	11:05	4	0.61			1:00	3	1.03
	12:05	5	0.61			2:05	4	0.94
6/29/2005	6:20	23	0.83		6/29/2005	6:30	21	2.00
	11:30	28.3	0.58			11:45	26	0.89
6/30/2005	6:30	47.5	0.60		6/30/2005	6:40	45	0.84

reportdata-1 data
11/30/2005 7:52 PM

GSL 04 Sediment Water Interaction

CDSD Sediment Water Interaction

GSL 5

$41^o5'19"N$ $112o8'32"W$

w/North Davis Sewer Effluent				w/Kayscreek Water			
Date	Time	Hours	P (mg/L)	Date	Time	Hours	P (mg/L)
7/12/2005	7:40am	0	3.50	7/12/2005	7:25am	0	0.18
	7:55	0.2	2.21		7:50	0.5	0.83
	8:50	1	2.26		8:50	1.5	0.81
	10:00	2	2.10		10:00	2.5	1.62
	11:30	3.5	2.03		11:30	4	1.21
	4:30	8.5	2.10		4:20	9	1.24
7/13/2005	6:30 AM	23	1.93	7/13/2005	6:30	23	1.25

GSL 5 Sediment Water Interaction

P concentration (mg/L) in water

Time (Hours)

Kayscreek Water — North Davis Effluent
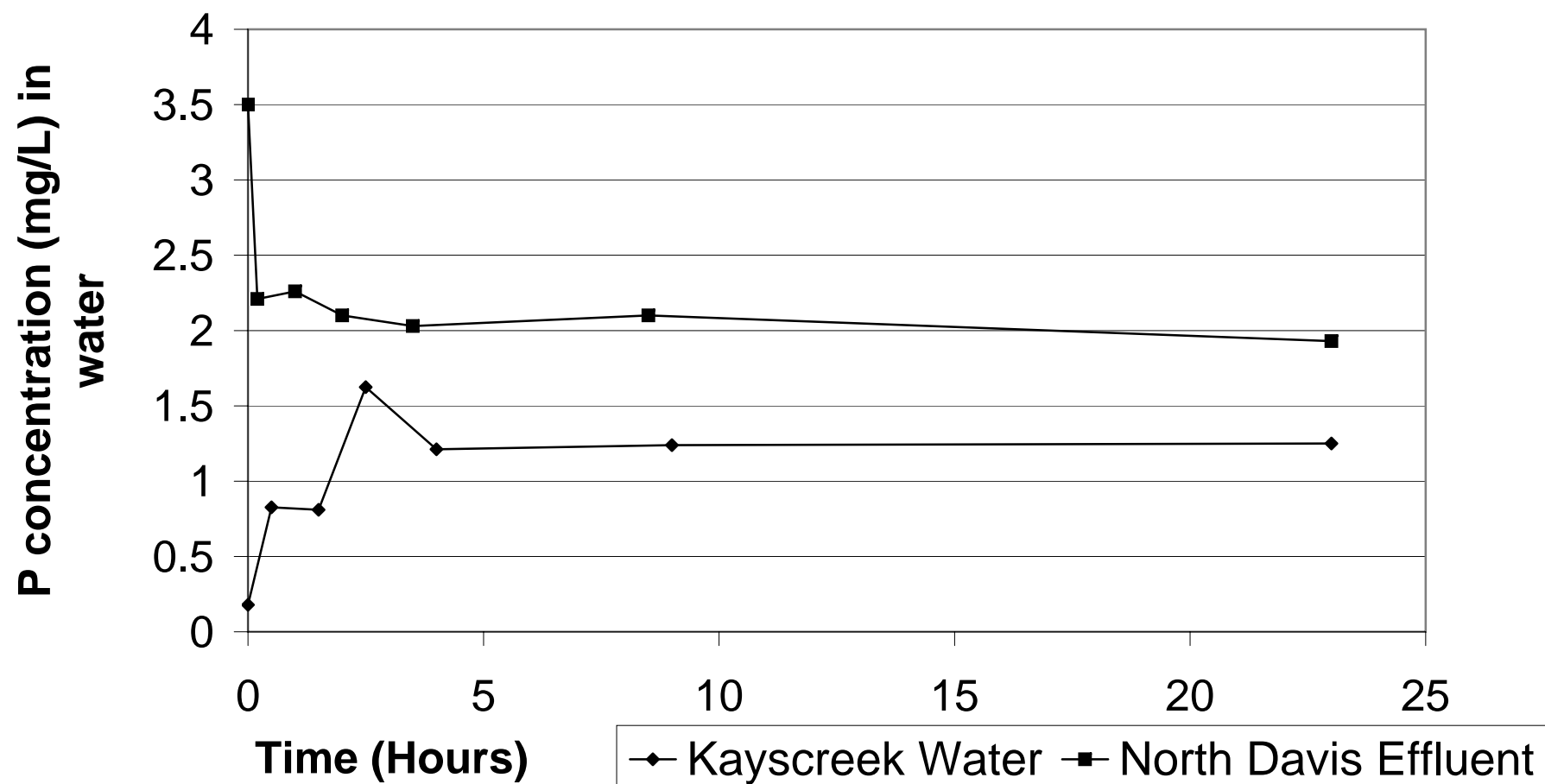
CDSD Sediment Water Interaction

GSL 7

7/18/2005   9:40 AM 40°56'08"N 111°58'24"W

w/Tap Water				w/Central Davis Sewer Effleunt			
	Time	**Hours**	**P (mg/L)**		**Time**	**Hours**	**P (mg/L)**
initial water	11:30	0	0.05	initail water	11:30	0	3.12
	11:55	0.5	0.16		11:50	0.25	2.76
	12:25	1	0.21		12:20	1	2.32
	2:40	3	0.24		2:30	3	2.09
7/19/2005	7:25 AM	20	0.21	7/19/2005	7:20 AM	20	1.69

GSL 7 Sediment Water Interaction
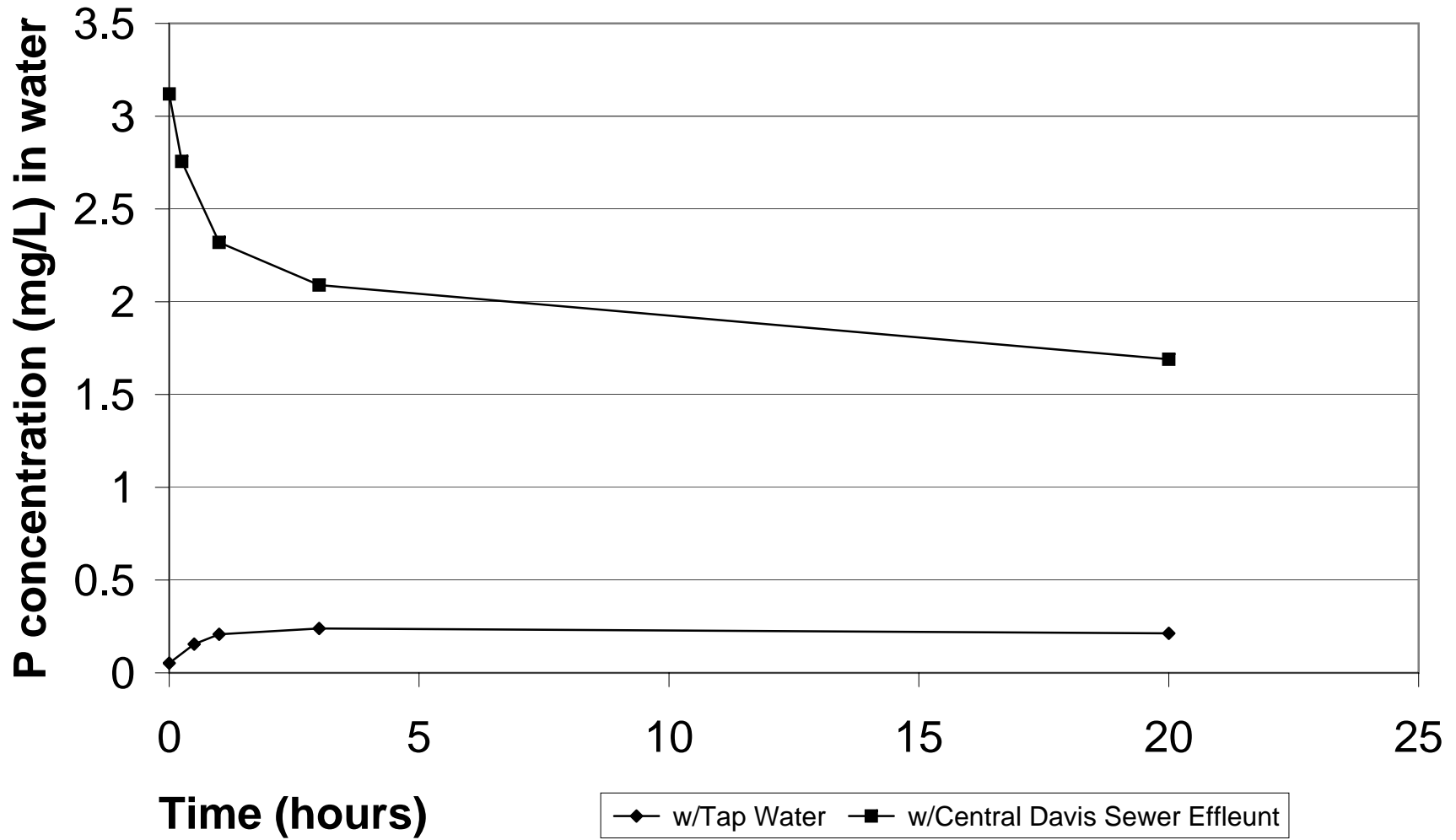
CDSD Sediment Water Interaction

GSL 8

7/18/2005   9:30 AM 40°56'26"N 111°57'47"W

w/ Tap Water

	Time	Hours	P (mg/L)
initial water	11:30	0	0.05
	11:45	0.25	0.55
	12:10	0.45	0.57
	2:25	3	0.73
7/19/2005	7:10 AM	20	1.46

w/Central Davis Sewer Effluent

	Time	Hours	P (mg/L)
initial water	11:30	0	3.12
	11:40	0.25	2.42
	12:00	0.5	2.22
	2:15	3	2.34
7/19/2005	7:00 AM	19.5	2.20

GSL 8 Sediment Water Interaction
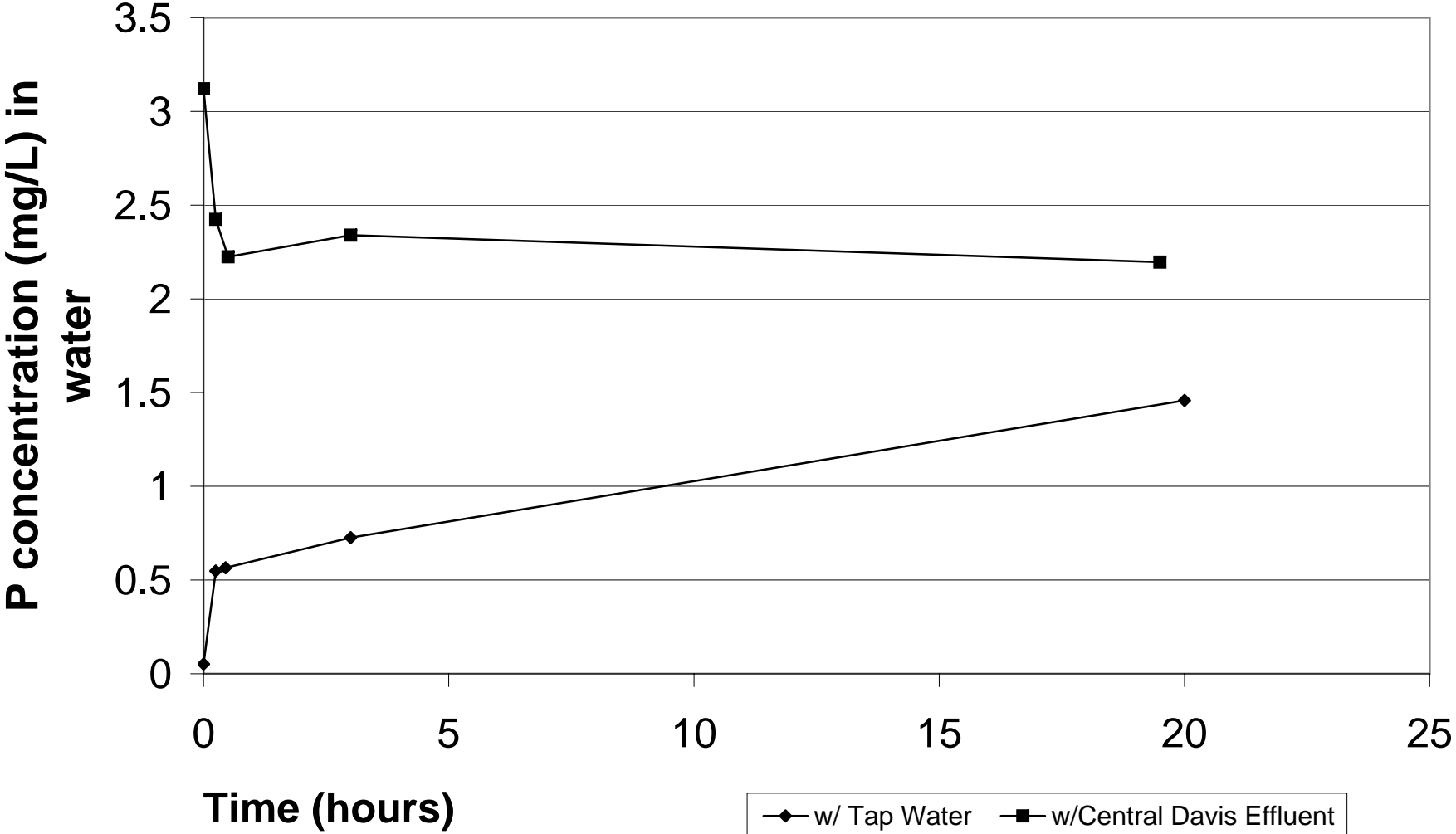
CDSD Sediment Water Interaction

GSL D

7/19/2005   12:01 PM 41°02'13"N 112°11'46"W

w/North Davis Sewer effluent

	Time	Hours	P (mg/L)
initial water	8:35	0	3.48
	8:45	0.15	2.95
	9:45	1	2.80
	2:40	6	2.74

w/ Kayscreek water

	Time	Hours	P (mg/L)
initial water	8:10	0	0.23
	8:30	0.15	0.70
	9:00	1	0.99
	10:00	2	1.16
	2:30	6	0.78

GSL D Sediment Water Interaction

Y-axis: P concentration (mg/L) in water

X-axis: Time (hours)

Legend: —◆— No Davis effluent —■— Kayscreek water
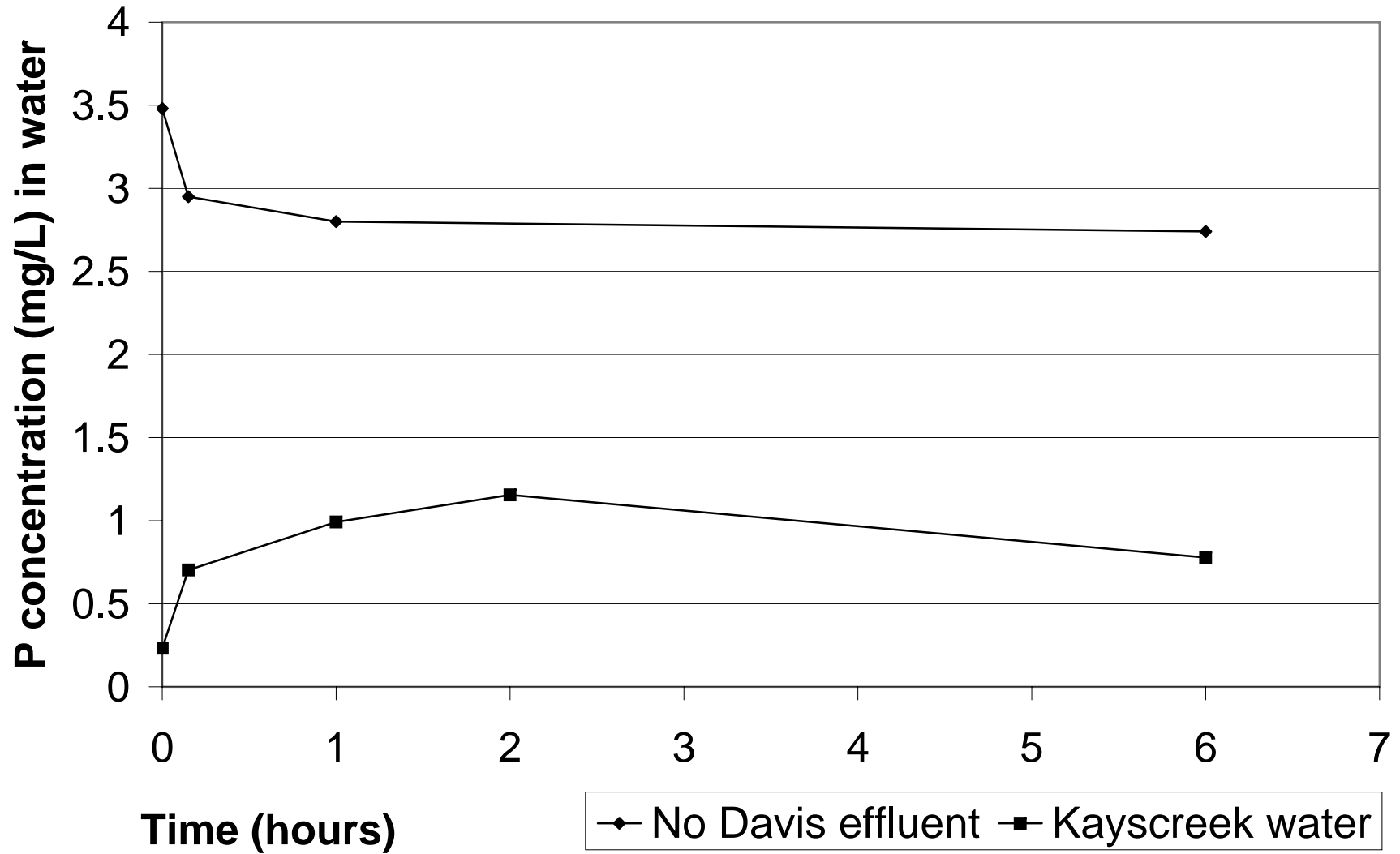
CDSD Sediment Water Interaction

GSL16

7/19/2005   12:12 PM 40°59'15"N 112°11'09"W

w/ North Davis Sewer effluent					w/ Kayscreek water			
	Time	**Hours**	**P (mg/L)**			**Time**	**Hours**	**P (mg/L)**
initial water	8:35	0	3.48		initial water	8:15	0	0.36
	8:45	0.15	2.58			10:00	2	0.49
	9:45	1	1.99			2:30	6	0.43
	2:45	6	2.24					

CDSD Sediment Water Interaction

GSL 16 Sediment Water Interaction

Legend: With North Davis Water ◆ — With Kayscreek water ■

X-axis: Hours
Y-axis: P concentration (mg/L) in water
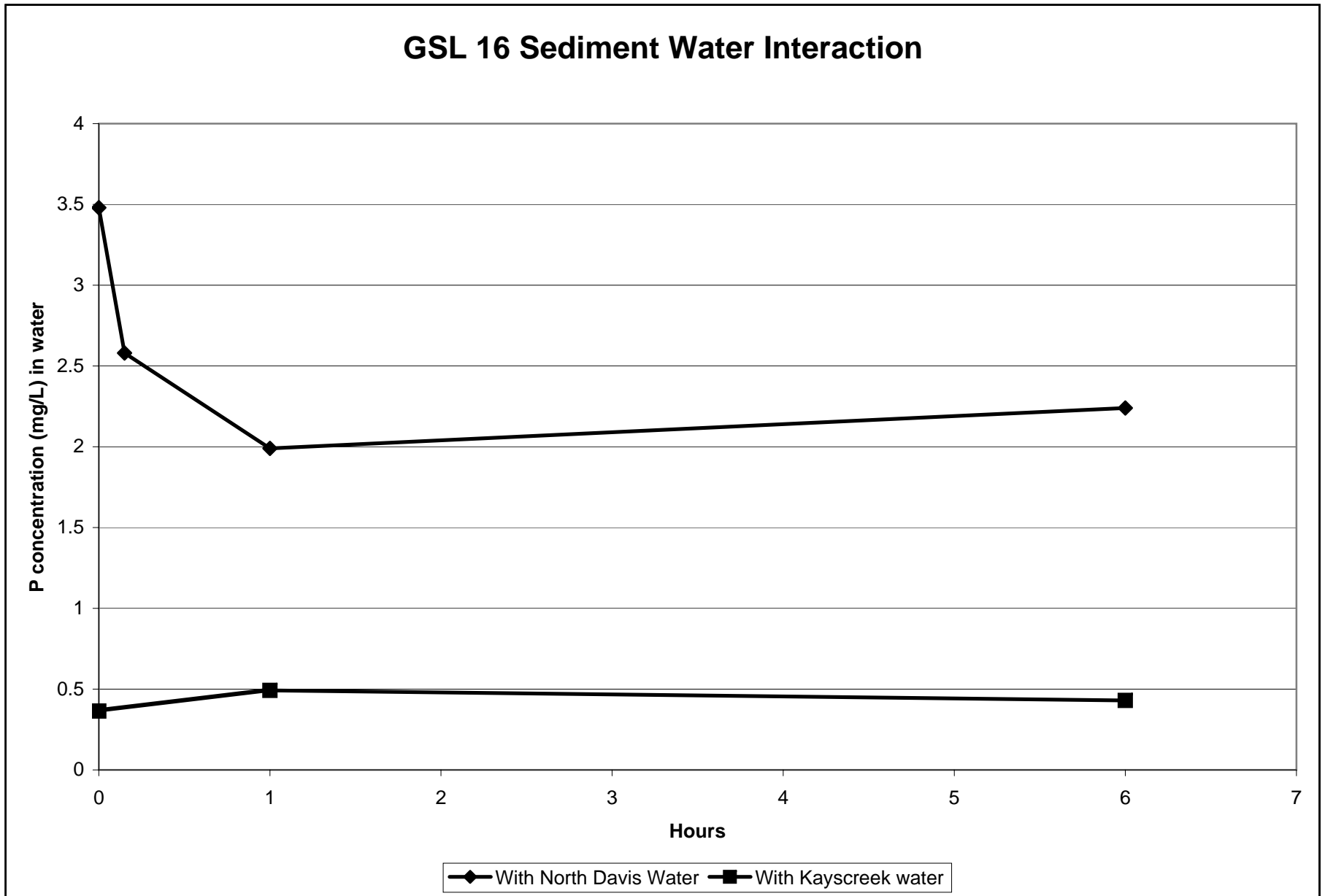
CDSD Sediment Water Interaction

GSL17

7/19/2005   12:30 PM 40°56'02"N 112°08'24"W

w/ North Davis Sewer effluent

	Time	Hours	P (mg/L)
initial water	10:30	0	2.74
	10:55	0.5	1.88
	11:55	1.5	1.52
	3:35	5	1.14

w/ Kayscreek water

	Time	Hours	P (mg/L)
initial water	10:40	0	0.22
	11:20	0.75	0.24
	12:30	2	0.18
	3:45	5	0.12

GSL 17- Sediment Water Interaction
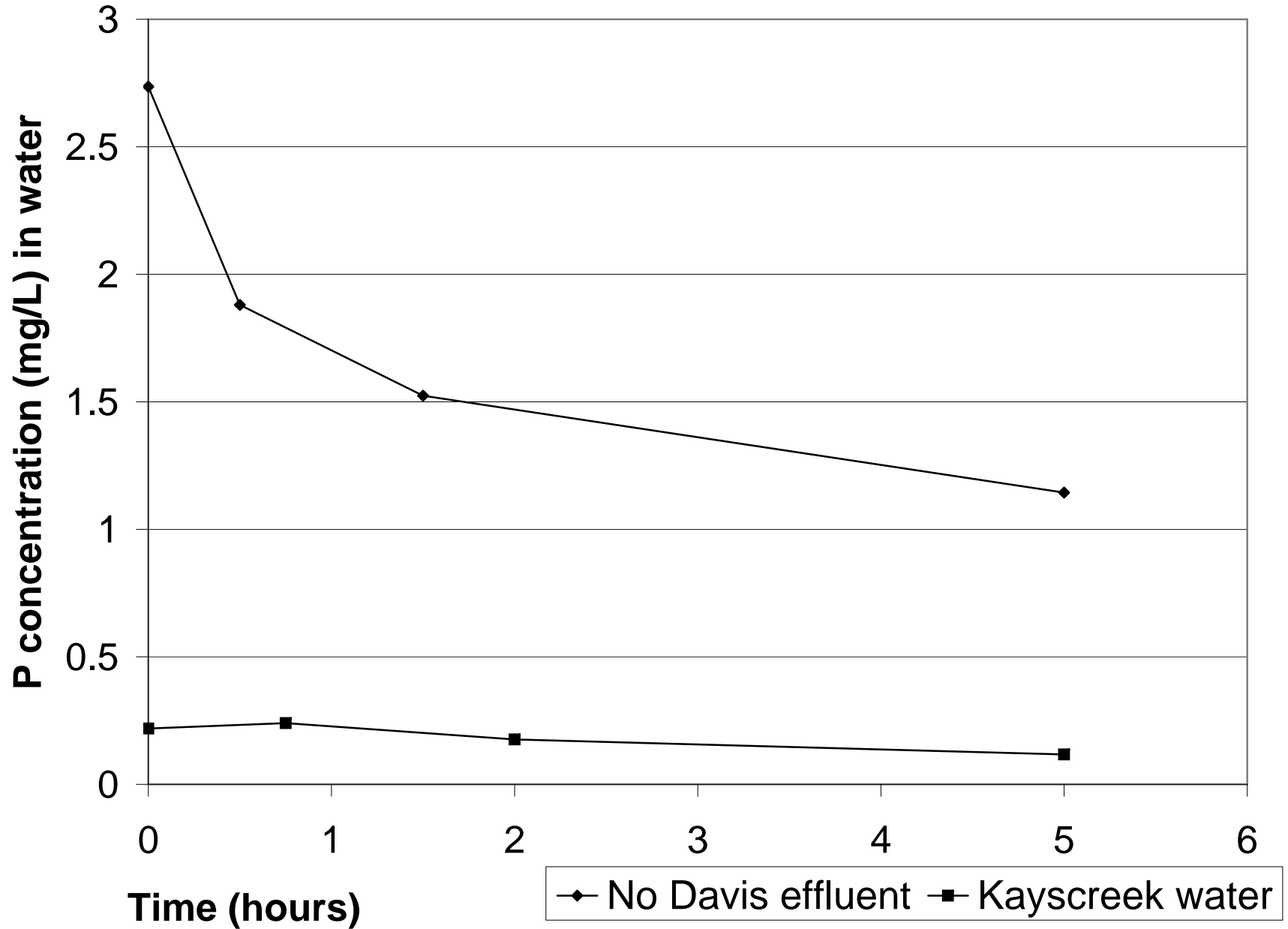
CDSD Sediment Water Interaction

GSL C

7/19/2005   12:57 PM 41°04'25"N 112°07'52"W

w/ North Davis Sewer effluent

	Time	Hours	P (mg/L)
initial water	10:30	0	2.74
	11:10	0.5	3.92
	11:40	1	5.24
	2:45	4	6.01
	4:55	6	5.78

w/ Kayscreek water

	Time	Hours	P (mg/L)
initial water	10:40	0	0.22
	11:30	1	2.39
	12:35	2	3.12
	3:50	5	4.90
	4:50	6	5.19

CDSD Sediment Water Interaction

GSL C-Sediment Water Interaction

Legend: No. Davis effluent — Kayscreek water

X-axis: Time (hours)

Y-axis: P concentration (mg/L) in water
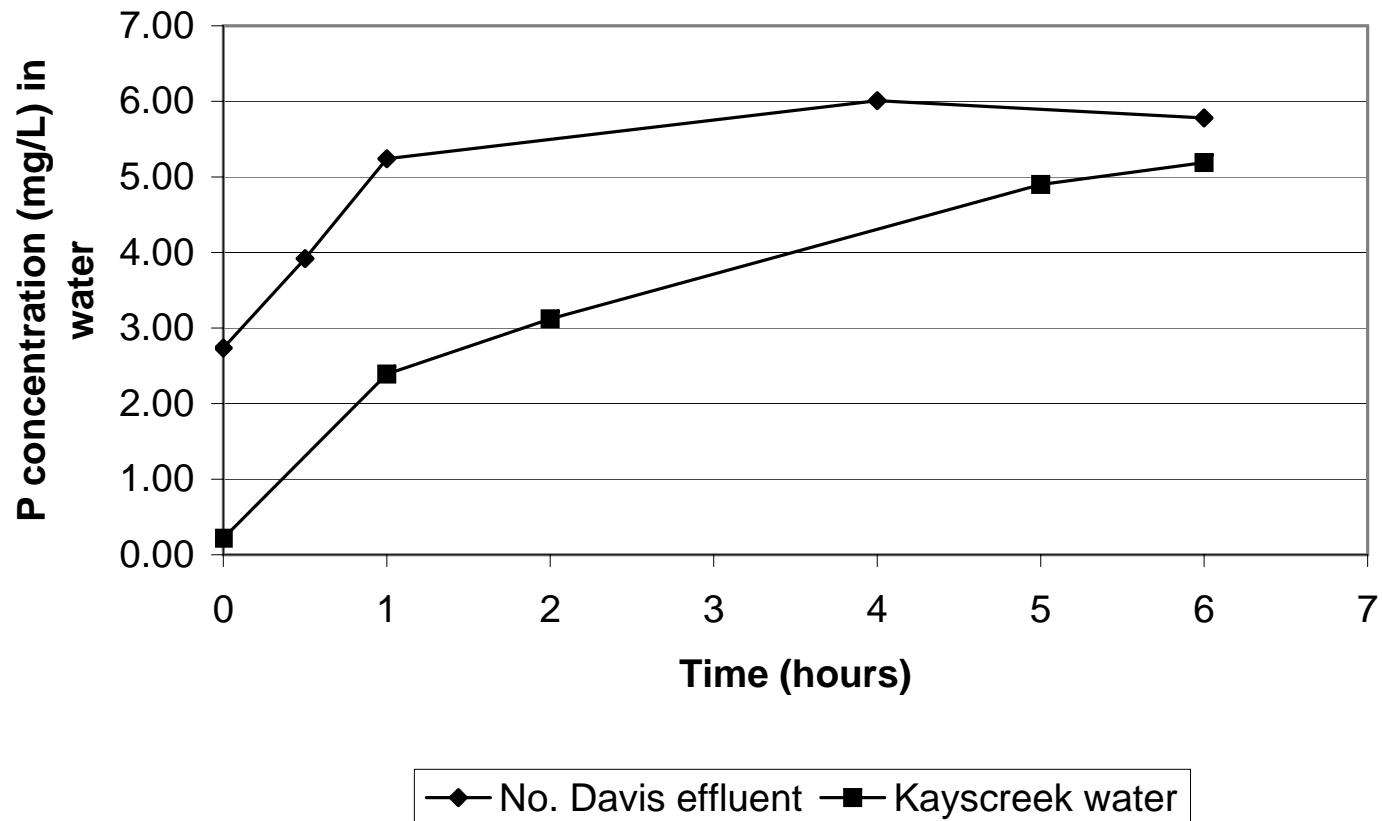
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Appendix 3

Sorption Isotherm Results

Note: All values reported in this appendix as P are ortho-phosphorus (reactive phosphorus).

CDSD Sediment - Water Ortho-P Sorption Isotherms

P Sorption Isotherms

Legend:
- ◆ GSL11
- ■ GSL20
- ● GSL22
- ✳ GSL21
- ▲ GSL25
- ● GSL41

Y-axis: Ortho P Sorbed (- Released) to Soil (mg/kg)

X-axis: Final Water Ortho-P Concentration (mg/L)

$R^2 = 0.8985$
$R^2 = 0.9172$
$R^2 = 0.9101$
$R^2 = 0.8096$
$R^2 = 0.5673$
$R^2 = 0.5404$
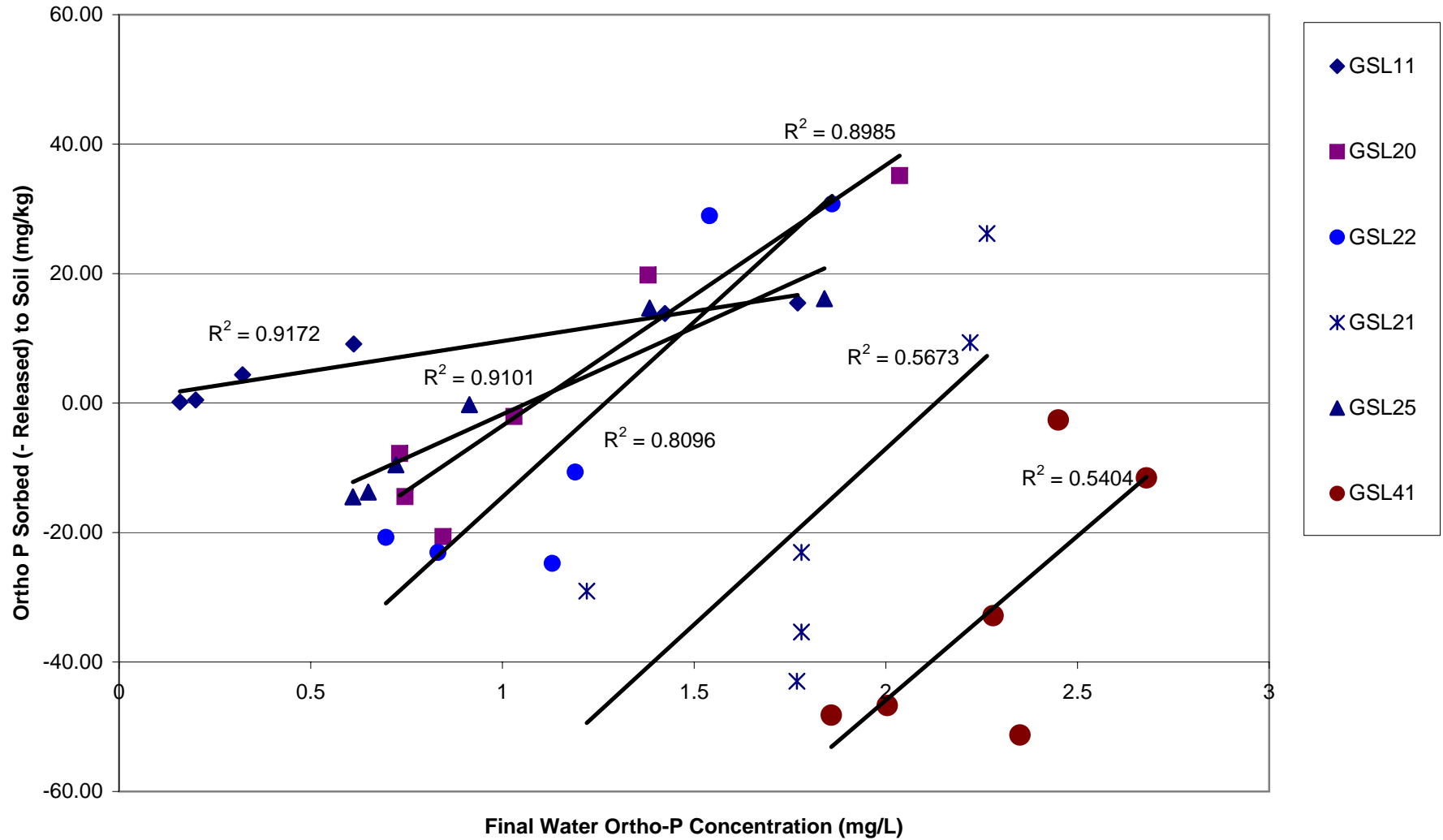
CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 11

10-Aug-05
Added Central Davis effluent to soil 1:00pm
Tested water August 11, 2005 6:30am

P (mg/L) liquid	P (mg) soil	P (mg/L) liquid w/soil	P sorbed (mg/kg)
0.17	115.97	0.159	0.162
0.23	157.38	0.200	0.486
0.57	392.77	0.322	4.367
1.12	771.73	0.612	9.124
2.20	1518.61	1.424	13.835
2.63	1814.05	1.770	15.471

CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 20

6-Sep-05
Added Central Davis effluent to soil 2:00pm
Tested water 9-7-05 11:00am

P (mg/L) liquid	P (mg) soil	P (mg/L) liquid w/soil	P sorbed (mg/kg)
0.151	7.019	0.845	-20.616
0.269	6.889	0.746	-14.438
0.47	7.017	0.732	-7.785
0.964	6.633	1.030	-2.075
2.064	7.211	1.380	19.778
3.252	7.213	2.036	35.148

CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 21

6-Sep-05
Added Central Davis effluent to soil 3:15pm
Tested water 9-8-05 2:00pm

P (mg/L) liquid	P (mg) soil	P (mg/L) liquid w/soil	P sorbed (mg/kg)
0.115	8.259	1.220	-29.043
0.184	8.002	1.768	-42.972
0.394	8.505	1.780	-35.375
0.888	8.396	1.780	-23.062
2.572	8.171	2.220	9.351
3.252	8.186	2.264	26.201

CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 25

16-Sep-05
Added Central Davis effluent 9-15-05 7:15 am
Tested on 9-16-05

P (mg/L) liquid	P (mg) soil	P (mg/L) liquid w/soil	P sorbed (mg/kg)
0.111	0.610	P (mg/L) liquid w/so	P sorbed (mg/kg)
0.203	0.650	2.857	-14.485
0.441	0.722	2.696	-13.749
0.906	0.914	2.447	-9.522
1.856	1.384	2.753	-0.241
2.352	1.840	2.664	14.691
		2.632	16.130

CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 22

10-Aug-05
August 11, 2005 added Central Davis effluent 8:00am
Tested water 4:00pm

P (mg/L) liquid	P (mg) soil	P (mg/L) liquid w/soil	P sorbed (mg/kg)
0.162	0.696	3.007	-20.737
0.232	0.832	3.036	-23.075
0.490	1.130	3.019	-24.757
0.914	1.190	3.024	-10.656
2.290	1.540	3.024	28.956
2.660	1.860	3.036	30.767

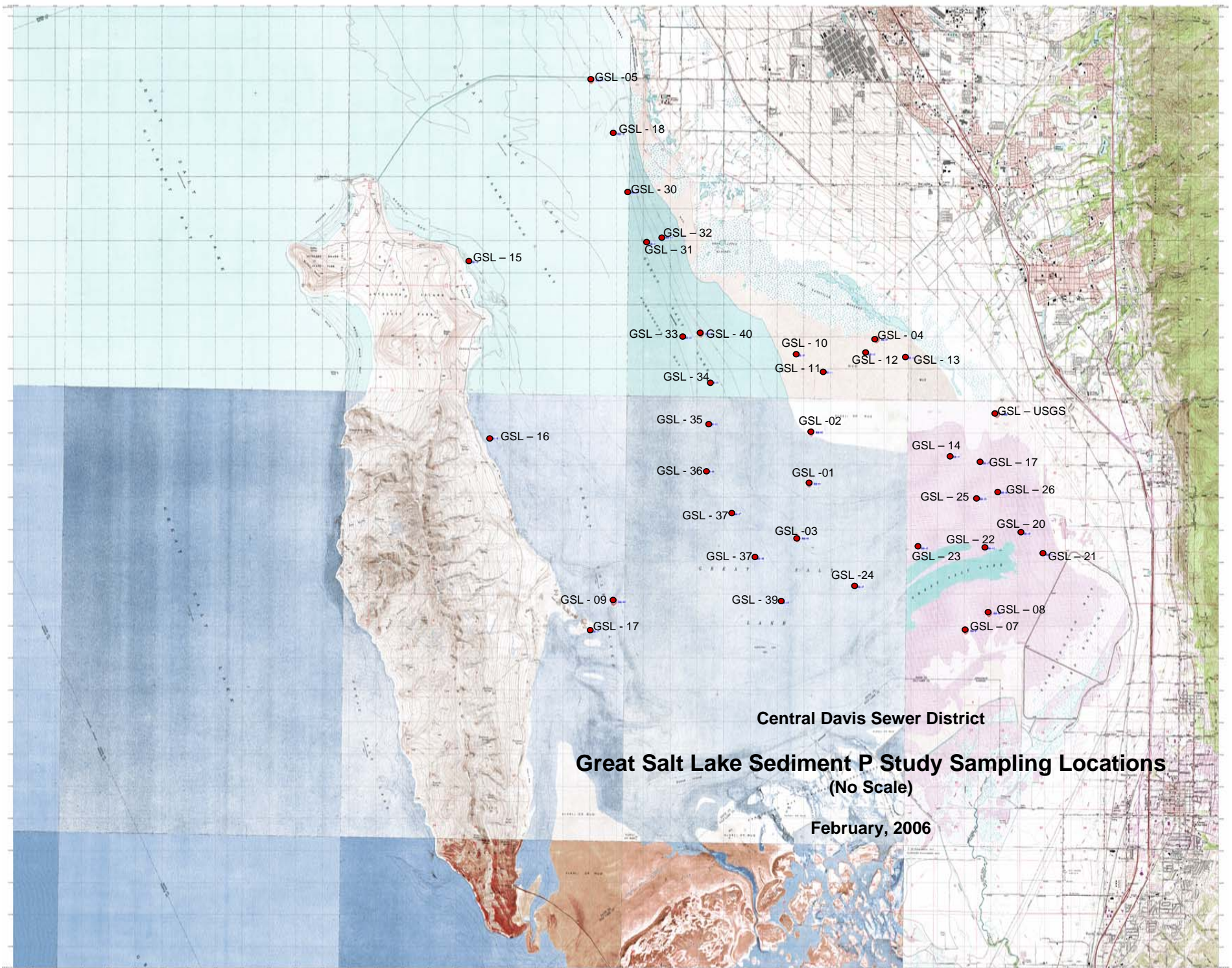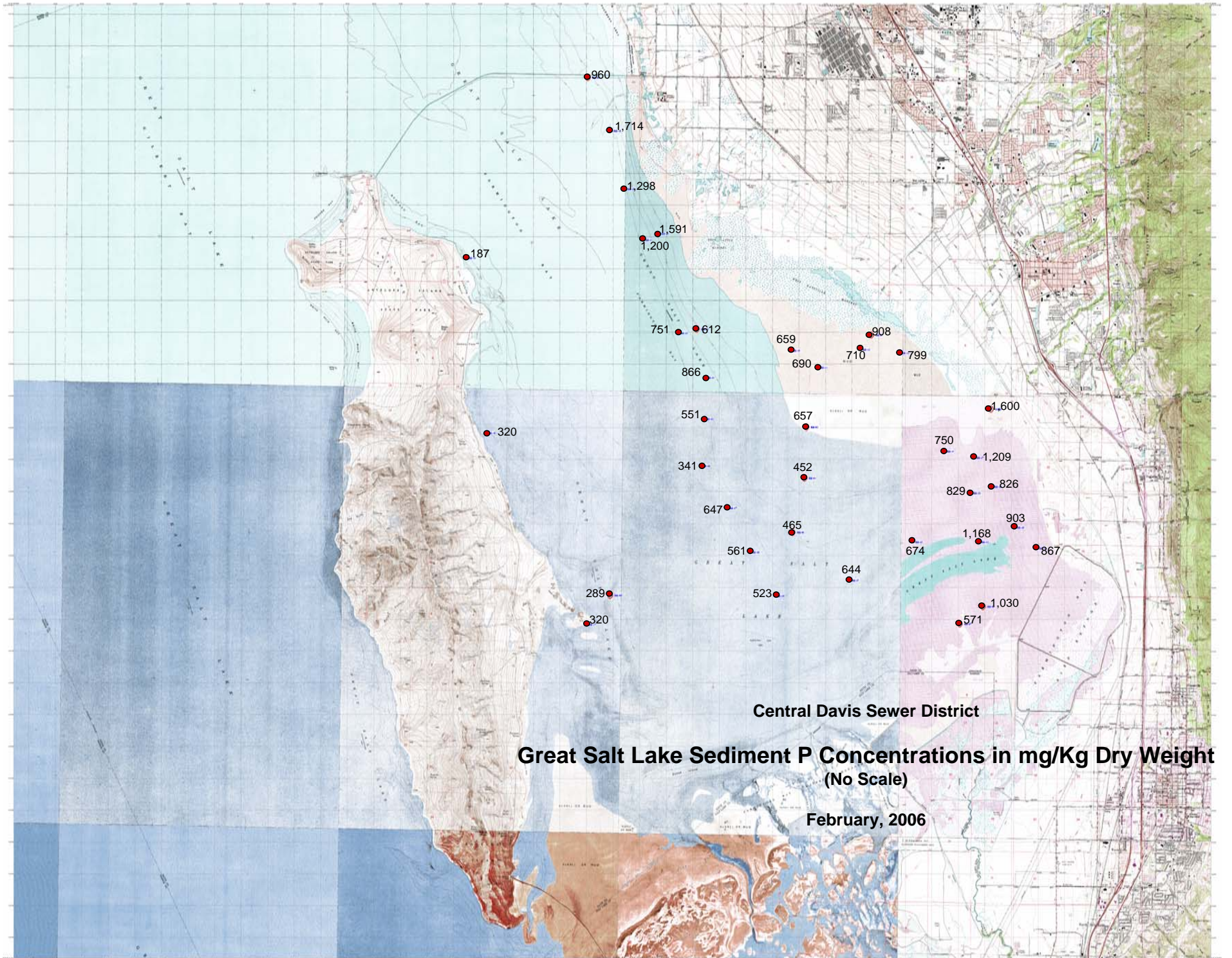# CDSD Sediment - Water Ortho-P Sorption Isotherm

GSL 41

15-Sep-05
Added Central Davis Effluent 9/15/2005 @ 7:15 am
Tested on 9/16/2005 at 8:00 am

initial reading m	final reading (mg/l	initial mg P in soil	Psorbed (mg/kg)
0.114	1.858	5.706	-48.199
0.194	2.004	6.109	-46.726
0.462	2.350	5.807	-51.273
1.082	2.280	5.754	-32.837
2.244	2.680	5.947	-11.561
2.352	2.450	5.935	-2.604

Appendix 4

Sampling Location Map

GSL -05
GSL - 18
GSL - 30
GSL – 32
GSL – 31
GSL – 15
GSL – 33   GSL - 40
GSL - 10   GSL - 04
GSL - 12   GSL - 13
GSL - 11
GSL - 34
GSL – USGS
GSL - 35   GSL -02
GSL – 16
GSL – 14
GSL – 17
GSL - 36   GSL -01
GSL – 25   GSL – 26
GSL - 37
GSL – 20
GSL -03
GSL – 37   GSL – 22
GSL – 23   GSL – 21
GSL -24
GSL - 09   GSL – 08
GSL - 39   GSL – 07
GSL - 17

Central Davis Sewer District

Great Salt Lake Sediment P Study Sampling Locations
(No Scale)

February, 2006

Central Davis Sewer District

Great Salt Lake Sediment P Concentrations in mg/Kg Dry Weight
(No Scale)

February, 2006