Baseline Study of the Hellman Ranch Deed Restriction Property Soil Composition
Los Cerritos Wetland, Seal Beach, CA
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Abstract

Coastal wetlands are a vital habitat that links the terrestrial and marine environments. The chemical and physical composition of the soil is an important factor in classifying a wetland environment. This study evaluated the heavy metal concentrations, total carbon content, salinity, pH, and grain size of soil samples collected in the Hellman Ranch Deed Restriction property of Los Cerritos Wetland complex to determine soil quality. When compared to functioning wetlands, the Hellman property showed low carbon content and salinity, while elevated levels of pH and the heavy metals selenium and zinc were observed. We attribute these results to the high sand fraction percentages and severely muted tidal influence within the property. Observations of vegetation present on the property show that non-native species are out-competing native species due to habitat degradation. Based on our findings, without extensive remediation, it is difficult to classify the Hellman property as a functioning wetland.

Introduction

Wetlands are among the most productive ecological systems on Earth. In California it is estimated that approximately 90% of historic wetland habitat area has been lost to filling and development (Zedler, 1996). Preservation of wetland habitat is of the utmost importance because the areas provide beneficial uses for humans, such as reducing soil erosion, recharging groundwater, and aesthetic beauty (EPA 2001). Wetlands are also involved in many biological and chemical processes which transform nutrients, sequester heavy metals and organic compounds (EPA 2001).

Viable coastal wetlands usually have soil composed of small grain size and anaerobic conditions (Zedler, 2001). Within this type of soil there is a relatively high concentration of organic matter and low decomposition rates by anaerobic microorganisms. This slow decomposition provides a reliable supply of organic nutrients for wetland plant species, and along with salinity, determines the composition and diversity of plant species found in the marsh, transition, and upland zones of a wetland (Hausman, 2007). Pollutants, such as heavy metals, pose a threat by means of bioaccumulation from lower trophic organisms, such as invertebrates and plants, through higher trophic-level organisms, including humans (Xiangyang et al, 2007). In addition, restored wetlands are susceptible to bioaccumulation of heavy metals during extended periods of inundation (Speelmans et al., 2007). Laboratory and field experiments have also yielded results showing that increased salinities, such as those found in tidal salt marshes, can increase heavy metal mobilization and uptake (Hatje et al., 2003). Tidal salt marshes also feature small grain size, with most containing 20-75% clay (Ward et al., 2003). This is a real concern because a previous study found a negative correlation between grain size and heavy metal concentrations within the soil of Los Cerritos Wetlands (LCW) (Conterno et. al., Unpublished Data).

This is extremely important in Southern California, as coastal wetlands are exposed to the tidal influence of water that may be contaminated by surface runoff. Excess nutrients and pollutants are filtered by the wetlands and along with sediment deposition my affect the biodiversity of microbial, plant, and animal species (EPA, 2008). The Clean Water Act (CWA) Section 402 specifically requires permits for any toxic discharges from a point source (EPA, 2006), such as the oil drilling operations taking place within the LCW. Further details on the requirements imposed upon oil drilling operations to prevent point source pollution are described in Sections 311 and 112. In addition, section 303 of the CWA states that California must determine a total maximum daily load (TMDL) of pollutants being discharged into a water body that has beneficial uses, which includes protection of wildlife. Part of LCW, Steam Shovel Slough, is navigable, supports hydrophilic vegetation, and qualifies as a wetland under CWA section 404. This distinction gives it an ecological beneficial use and therefore water quality protection under the jurisdiction of Section 303. This section also requires the state to include a plan for controlling pollution from non-point sources, which is not yet enforceable but gives a guideline for future containment of pollutants entering the wetland. Locally the City of Long Beach has conducted a survey to update the Southeast Area Development and Improvement Plan (SEADIP) to ensure that the public is aware of the wetlands significance to the area. It incorporates laws established by the California Coastal Commission regarding restrictions for development on any areas considered wetlands. Therefore studies of the whole LCW are vital in determining what areas are indeed wetlands to protect them from further development.

Proper soil composition is important in the development and restoration of a degraded coastal wetland. This project will attempt to analyze the soil content of the Hellman Ranch Deed Restriction property within the LCW to determine composition and pollution concentrations. The Hellman property consists of 100 acres within the south-west section of the LCW. The property was part of a mitigation settlement and is held in trust for purchase by an agency with goals of restoring the land back to wetland habitat. Within the property there are no active drilling sites, however, oil drilling is occurring on the other side of the northern property line. The property also contains approximately 12 inactive sump pumps once used during oil production, a filled former landfill, and an area used to bury waste material from oil derricks (Moffatt and Nichol, 2007). The property has a muted tidal influence, through one inlet, from the San Gabriel River channel. A small channel runs through the center of the property from west to east. The greatest tidal influence occurs on the western side of the property. Our study will focus on this location as a priority area for restoration. The 2008 Chemistry/Hydrology Team will be analyzing grain size, salinity, pH, total carbon content and heavy metal concentrations to determine if the Hellman property can be restored to a viable wetland. The analyses will be done in conjunction with research conducted by past and present Environmental Science and Policy 400 students.

Previous years' studies have mainly focused on Steam Shovel Slough, which is considered a functional, tidally-influenced wetland. The 2007 study conducted many of the same analytical methods in this year's project, but in Steam Shovel Slough. This includes salinity, organic carbon content, heavy metal content, and grain size. Their data was useful in comparing with the data that was collected and analyzed from the Hellman property to determine any differences in soil content and composition. This will aid in determining the quantity and types of restoration required.

The project will integrate information collected on transition zone soil composition with information collected about vegetation by the 2008 Biology Team. They are looking at the importance of transition zones as buffer areas around wetland habitat for native plant and animal species (Bjorkquist et. al., Unpublished Data). Soil salinity and pH will be used to determine ideal transition zone soil and what non-native species are able to tolerate these conditions. The Team will also attempt to assist in the valuation process for mitigation and clean-up of the pollution found on the Hellman property. Understanding the soil can provide future scientists with the knowledge needed to determine if restoration of the Hellman property is economically feasible.

Methods

Sample Collection

Five sites representative of wetland habitat types, as well as points of restoration interest, were selected within the Hellman Ranch Deed Restriction property (Figure 1). The sites included the inlet for the muted tidal influence channel, a degraded marsh zone, a marsh transition zone, an upland marsh habitat, and a muted tidal marsh area that is in close proximity to one of the properties twelve oil sumps (Moffatt and Nichol, 2007).

As the first student based soil survey of the Hellman Deed Restriction property, our focus was on the inclusion of greater coring depth rather than sheer site number. As indicated by the sites history (former landfill, dredge filling, and oil production), the interest in coring to greater depths (approximately 45cm) was hypothesized to give us a more comprehensive view of soil content within the five slated coring locations.

We hypothesized that the five sample sites chosen would be representative of the western half of the Hellman property. The core collected from the inlet was hypothesized to show tidal influence based on sediment accumulation, as well as elevated concentrations of priority pollutants that could be draining from the property. The degraded marsh zone was expected to show organic carbon content and salinity levels which are comparable to Steam Shovel Slough, our representative of a "pristine" wetland habitat, due to inundation during high tides. Correlation between grain size and heavy metals were also likely to show that the degraded marsh zone is similar to habitat found at other locations within LCW. We anticipated that cores from the upland and transition zones would show evidence of landfill and waste dumping from oil drilling operations within Hellman Property. A core within close proximity to a sump, muted tidal marsh, was included to help show soil conditions for the purpose of restoration considerations within these locations on the property.

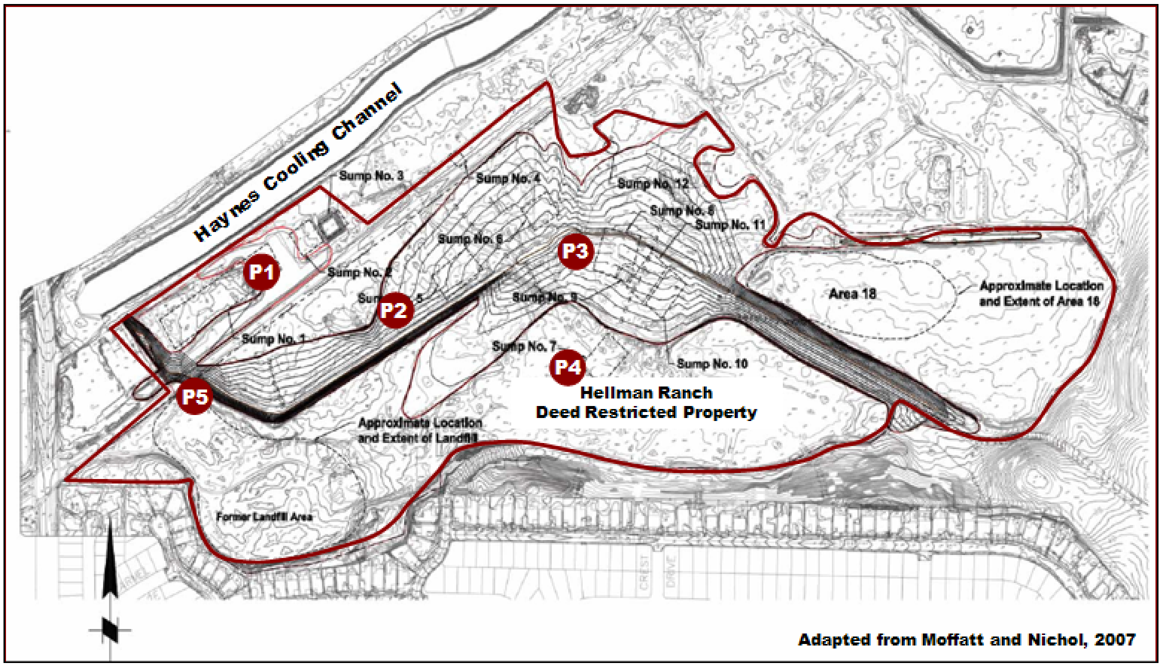

Figure 1 The five locations within the Hellman Ranch property from which soil cores were collected. Latitude and longitude, as well as description of the site, are given in Table 1.

Table 1 Latitude and Longitude for sample sites within the Hellman property measured using a Garmin GPSMAP 60CSx unit.

Location	Latitude	Longitude
P1: Degraded Marsh	N 33°45.099	W 118°06.152
P2: Transition Zone	N 33°45.091	W 118°06.034
P3: Muted Tidal Zone	N 33°45.132	W 118°05.907
P4: Upland Zone	N 33°45.064	W 118°05.900
P5: Inlet	N 33°45.037	W 118°06.232

Soil cores, totaling 45cm in length, were collected with an AMS® slide hammer soil corer with a 1.5 inch diameter barrel with the exception of the inlet which used a Livingston square rod piston corer. Sample locations were recorded via GPS measurement and cores were collected, extruded, and stored in oriented protective plastic sleeves until laboratory analysis. Cores were bisected into two equal halves and further divided into 9cm sections in the laboratory. One half of the bisected sample was dried and used for carbon content, heavy metal and grain size analysis while the other half was bagged and stored in a refrigerator for pH and salinity testing. Heavy metal analysis and organic carbon content tests were performed in cooperation with the Institute for Integrated Research in Materials, Environment, and Society (IIRMES), CSULB.

Grain Size

Grain size analysis followed standard sieve and pipette protocol methods outlined by Lewis and McConchie, and as performed by past Chem/Hydro teams. Approximately 20 grams of homogenized sample was wet sieved through a 0.0625 mm sieve to remove finer sand fractions and then funneled to obtain the coarse sand fraction. Flow-through was then diluted to 1-L with nano-pure water for pipette analysis purposes. 20-ml pipette samples were then extracted at specified time intervals (20 seconds after column agitation and 2 hours after the first sample was pulled) and specified water depths, depending on temperature. For analysis; extractions corresponding to 20 seconds after agitation and 2 hours after first sample pipette represent 4φ and 8φ grain sizes respectfully. The obtained 20-ml samples were oven dried for desiccation purposes, and then weighed and adjusted for 1000mL content. Cumulative weights were analyzed to calculate median grain size, percent sand, mud, and silt using standard equations as referenced by Boggs, 2000.

Salinity and pH

Salinity and pH analysis followed procedures outlined by David R. Parker, Professor in the Department of Environmental Science at the University of California Riverside. Approximately equal volumes of sample and nano-pure water were prepared by mixing in a 1:1 ration in 50mL beakers. After the samples and nano-pure water were mixed, they were allowed to “settle” and a combination pH/TDS electrode was submerged into the supernatant, at which point readings were recorded.

Total Carbon Content

Carbon content for each of the samples was measured using the CM5014 CO^2 Coulometer located in the IIRMES laboratory. After sample homogenization, 10-21mg of sample was weighed in a ceramic or platinum boat, and inserted into a glass cradling spatula. Following several blank runs to calibrate the coulometer, samples within the glass spatula were slid via magnet into a CM5300 Total Carbon Apparatus and combusted at a temperature of 950° C. Sample combustion time ranged from 9-15mins, upon which readings were printed out and recorded. To ensure proper coulometer operation, standards of $CaCO_3$ were combusted following every 8th sample, and values were also recorded.

Heavy Metal Concentration

Heavy metal analysis and preparation was executed per protocol outlined in EPA Method 3052. 500mg samples were prepared and weighed before the addition of nitric and hydrochloric acid; the addition of these acids causes the sample to be stripped of loosely held heavy metals. Following successful sample digestion, dilutions were prepared and measurements were taken with the Perkin-Elmer 6100 ICP-MS. The heavy metals tested for were arsenic, cobalt, copper, chromium, lead, nickel, selenium, and zinc.

Statistical Analysis

Statistical data analysis software, Statistica, was used to determine Pearson Product Moment Correlations between all dependent variables; p-values < 0.05.

Results:

Grain Size

Based on the dry weights from the desiccated sand, 4φ, and 8φ grain size fractions the cumulative weights of sand, silt, and clay was calculated using the cumulative % of mud range formula:

$$\% \text{ Mud} = 100 - \frac{((50 \text{ X Weight of Pipette Sample}) - 1)}{S + F}$$

S = Weight of Sand Fraction
F = Weight of Mud

The results of which are given in the Appendix. For each sample location, an average percent of sand, silt, and clay was taken of each of the nine centimeter sections tested (Fig. 2). All locations had a higher percentage of sand than is found in functioning wetlands. The highest percentage of sand was found in the transition zone, ~76%. Little clay was found at each location with the highest found at the inlet and muted tidal zone. This is consistent with the proximity of the locations to the Hellman channel. Soil classifications of the samples show that the majority of our samples fall within the sandy loam/loamy sand texture (Fig. 3). This contrasts the 2007 Chem/Hydro Teams results which found the majority of the soil textures to be higher in silt and clay.

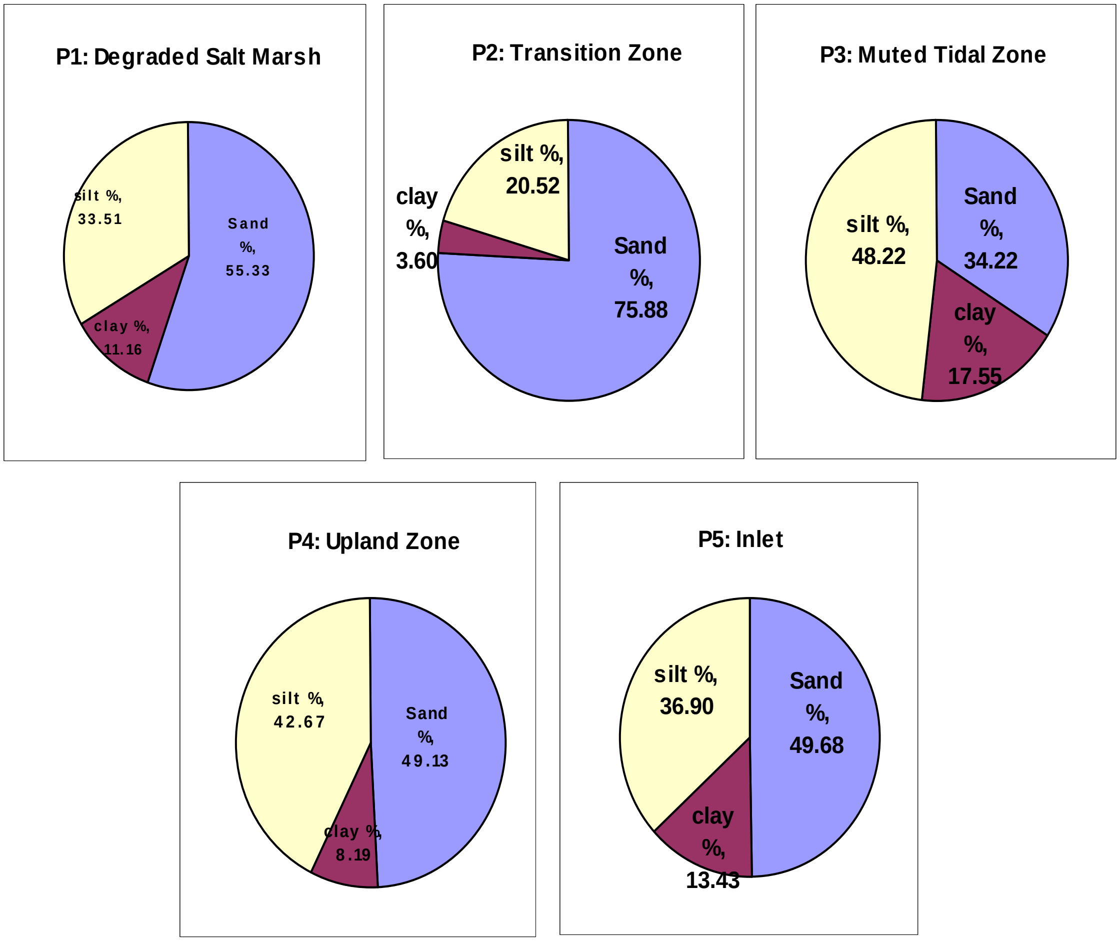

Figure 2 Average Percent of sand, silt, and clay from each of the Hellman sampling locations calculated from the cumulative percent of mud range.

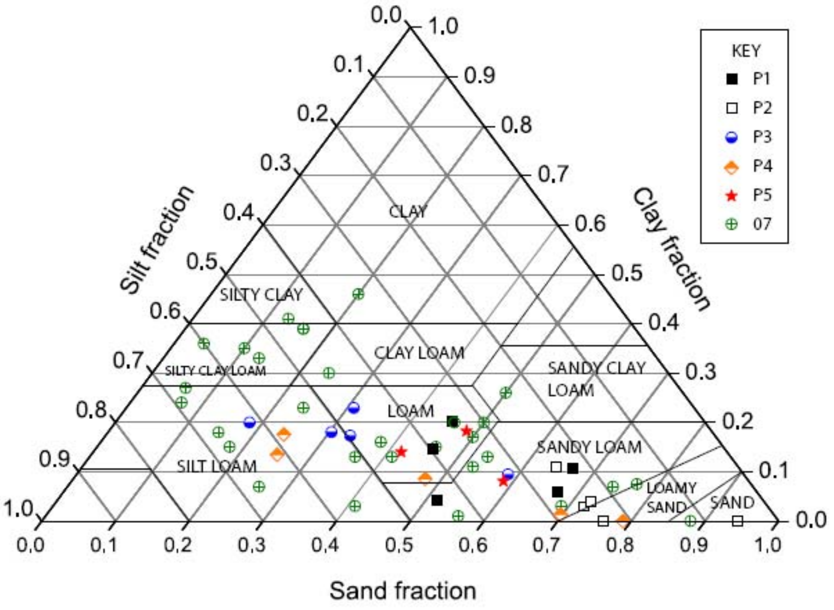

Figure 3 Ternary plot showing average grain size results of the 2007 and 2008 Chem/Hydro Teams. Points are based on cumulative percent clay, silt, and sand fractions.

Salinity and pH

On average, pH is consistently alkaline with a range of values from 8.013 to 8.240 (Table 2). There was little deviation between and among the depths at each site, with no standard deviation greater than 0.31. Average salinity values varied more than pH with a range of 1.272 to 3.982 ppt. Salinity levels were associated with location and the distance of the plot from the channel connected to the San Gabriel River. Raw data is given in the Appendix.

Table 2 Average pH and Salinity measurements at each location with observed dominant vegetation and the degree of tidal influence.

Site	Average pH	Average Salinity (ppt)	Dominant Vegetation	Tidal Influence
P1: Degraded Salt Marsh	8.204±0.12	3.982±0.77	No Vegetation	Periodically Tide-Flooded
P2: Transition Zone	8.198±0.31	1.272±0.42	Non-Native	Far from Hellman Channel
P3: Muted Tidal Zone	8.240±0.14	3.724±0.95	Native	Close To Hellman Channel
P4: Upland Zone	8.128±0.19	2.784±0.87	Non-Native	Higher altitude and far from Channel
P5: Inlet	8.013±0.24	3.66±0.69	No Vegetation	Inlet of Channel

Total Carbon Content

The percent of carbon present in our sample was negligible with few positive results (Table 3). The highest value was found in the top layer of the Degraded Marsh Area (P1). The location with consistent carbon values was the Transition Zone (P2) with a median value of 1.18. All other locations did not test positive for carbon in greater than two sample depths.

Table 3 Results of the Total Carbon Content analysis conducted using the CM5014 CO^2 Coulometer operated by IIRMES.

Total Carbon Content (%)					
Depth (cm)	**P1**	**P2**	**P3**	**P4**	**P5**
0-9	4.83	1.40	1.60	0	0
9-18	0	0.90	0	0	1.20
18-27	0	0.95	0	0	0
27-36	0	0	0	0	-
36-45	0	2.31	1.10	0	-

Heavy metals

Of the heavy metals tested selenium and zinc are the only ones that violate Article 5 of the Soil and Groundwater Pollution Remediation Act (Fig. 4). Zinc breached the standard at two depth segment tested and selenium levels were all excessively higher than the standard given. All other concentrations were well within the standards specified. There was a statistically significant negative correlation found between the metals cobalt, copper, chromium, nickel, and zinc, and the sand fraction percentage. This is consistant with observations of the 2007 Chem/Hydro teams' which found that heavy metal concentrations decreased with increasing grain size (Conterno et. al., Unpublished Data) The selenium levels were also compared to the data collected by the 2007 team (Fig. 6) to further demonstrate the large difference in the concentrations obtained from the Hellman property. Figure 5 displays the average concentrations among the various metals observed at each site sampled within the property. This figure shows that P5 had on average the highest concentrations of heavy metal present, with the highest concentration in six of the eight metals tested.

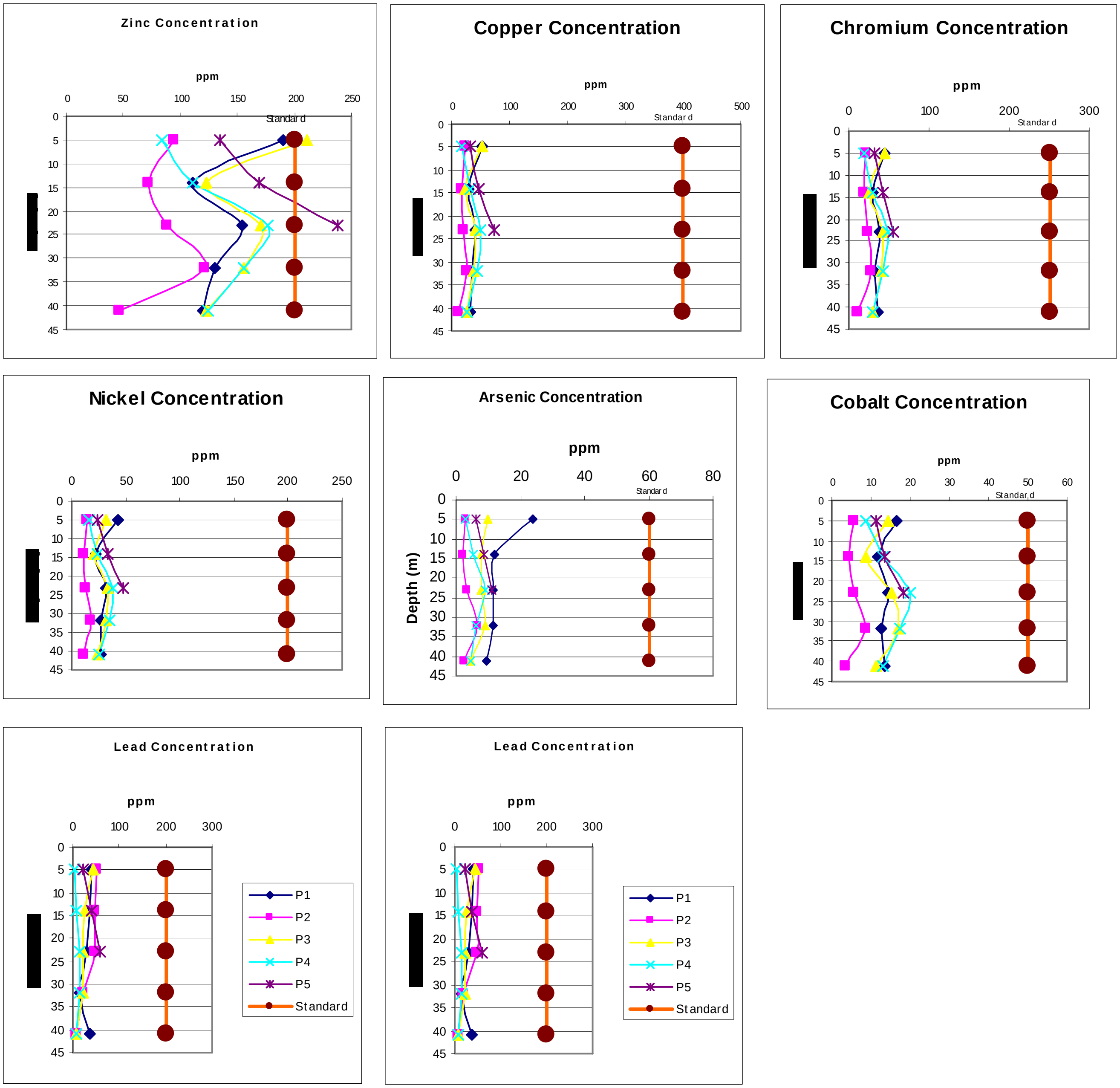

Figure 4 Changes in heavy metal concentration with depth between the sample locations in the Hellman property.

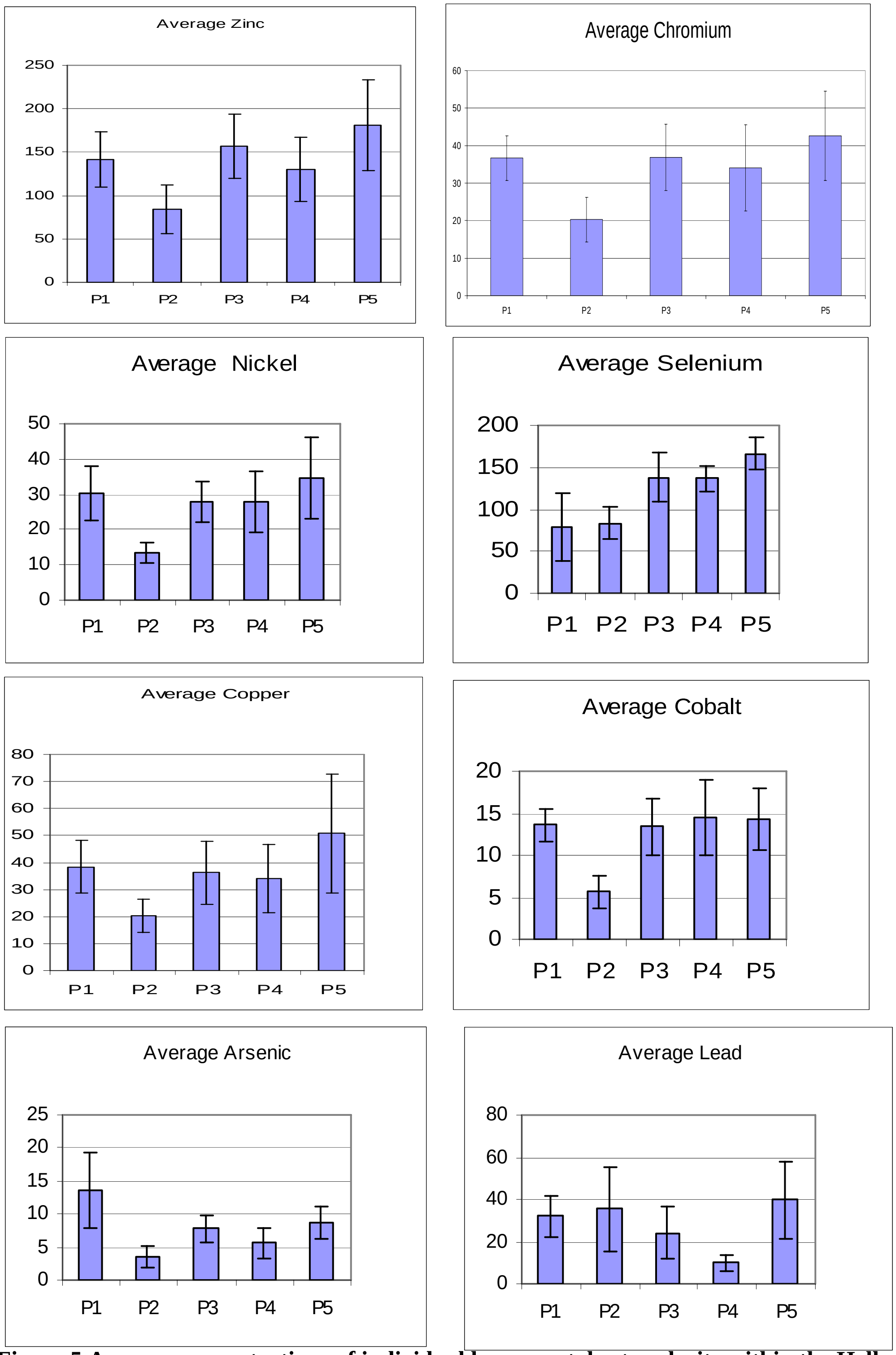

Figure 5 Average concentrations of individual heavy metals at each site within the Hellman property.

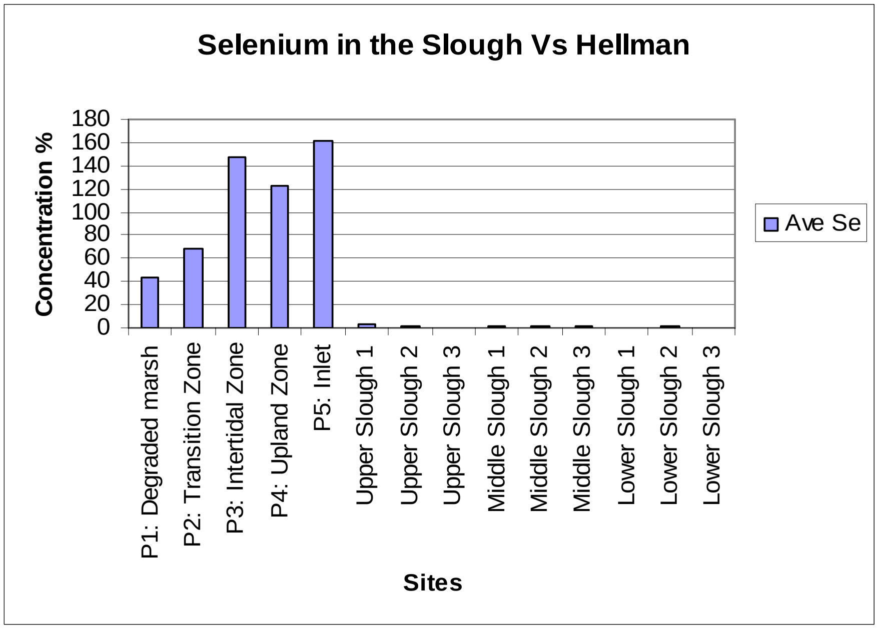

Figure 6 Comparison of the average concentrations of selenium found at each sample location in the Hellman property with the concentrations found in the soil of Steam Shovel Slough by the 2007 Chem/Hydro Team.

Discussion

Grain Size:

Figure 3 shows a dominant proportion of sand in the grain size composition of the Hellman property soil. These grain size composition percentages do not adhere to the standard percentages of 20-75% observed in well-functioning wetland habitats (Ward et al., 2003). The observed high percentages of sand are likely due to the past dredging operations in the San Gabriel River channel which took place during the construction of flood control levees in 1967-68 (Moffat and Nichol, 2007). Our has highest percentages of clay at 17.55 % still fell below the 20% average minimum clay percentages indicative of normal functioning wetlands.

The highest percent composition of sand was observed in the transition zone (P2) where sand constitutes 75.88% of the sample (Fig. 2). Total clay percentage in the transition zone, 3.60 %, is the lowest of our values within the Hellman complex. Vegetation transects from the 2008 Biology team indicate that the transition zone within the Hellman Property is dominated by an abundance of non-native vegetation (Bjorkquist et. al., Unpublished Data). A specialized combination of small grain size and distinct soil chemistry are required to support many of the native transition zone plant species such as pickleweed, *Salicornia virginica*. Due to the high sand percentage, it is likely that non-native species have been able to out-compete native wetland plants within this area.

The degraded salt marsh showed a similar trend of high percent sand composition and low clay and silt percentages. Proximity to one of the Hellman Property oil sumps may indicate that these high levels of sand could be due to dredging activities in the San Gabriel River, or platform build up above oil sump locations. The low values of clay and silt show a general trend of degradation within this marsh zone as well as an observed lack of vegetation (native or non-native). Oil operations on the property likely require servicing equipment to access sump locations, and disturbance from these activities could point to the lack of vegetation observed in these zones.

The upland zone showed comparable grain size composition results as the degraded marsh; however, there was also a greater amount of non-native vegetation observed. The lack of tidal influence as well as the distance from oil sumps may be the general cause of non-native vegetation dominance in this location. Grain size results do show that soil composition in this area is indicative of salt marsh upland habitat, and restoration efforts could be concentrated on non-native vegetation removal rather than soil remediation.

The inlet zone showed the second highest values of clay and silt within our Hellman property samples, while sand percentages remained high. The inlet zone lacks proximity to an oil sump, but is subjected to the highest amount of tidal influence through the culvert connecting the property to the San Gabriel River. Its soil composition could indicate the influence of sediment deposition from the San Gabriel River. As relative grain size decreases, it was hypothesized that heavy metal content would generally increase. Sample cores prepared for heavy metal analysis in IIRMES from the inlet showed our highest values for heavy metal content, and confirmed our hypothesis (Fig. 5; See appendix). High levels of selenium found at this location would probably require some form of soil remediation if a restoration is considered.

The muted tidal zone showed the highest percentages of clay and the lowest percent sand composition of our samples. Though these are the composition percentages that are the closest to a salt marsh, they still fall below values indicative of a truly healthy salt marsh habitat. The muted tidal zone is close to the Hellman Channel, and may be described as the healthiest site with respect to grain size composition within the complex. This location also confirmed our hypothesis that locations with smaller grain sizes would show increased amounts of heavy metals, and a Pearson Product Moment Correlation statistical analysis confirmed this association (See appendix).

Core samples collected by the 2007 Chem/Hydro Team showed higher percentages of clay and silt, particularly within the Slough, than cores collected from the Hellman property (Figure 3). This shows that grain size is an important difference between a functioning wetland habitat and a severely degraded one.

Salinity and pH

Soil salinity in wetlands can vary from approximately 5 ppt, brackish water, to greater than 100 ppt in salt pan areas (Macdonald, 1977). The salinity measured in the samples taken from the Hellman property is extremely low. The low salinity is due to the nature of the fill and low tidal influence. The fill was deposited from dredging to line the San Gabriel River. The sediments would have been deposited from upriver and are completely different from wetland soil. This low salinity would be responsible for the dominance of non-native plant species observed by the 2008 Biology Team in the transition and upland zones. Based on our results salinity levels at P3 (3.724±0.95) appeared to support a higher percentage of native species.

The pH levels were consistent at each site (Table 2). The soil was slightly basic which is inconsistent with normal values, of neutral or slightly acidic, found in wetlands (Callaway, 2001). The change in pH would be result of muted tidal influence and aerobic conditions found on the property. Since the soil was found to be comprised of a large percentage of sand, there would be higher rates of decomposition of organic matter. This would change the chemistry and microorganism community structure of the soil. In both cases greater and consistent tidal influence should correct the discrepancy between the salinity and pH measurements in the Hellman property and those normally found in functioning wetlands.

Total Carbon Content

Typical carbon content within wetland soils ranges from 12 to 18% depending on the percentage of clay present (MDEQ 2001). Grain size and carbon content are inversely proportional (Barko and Smart 1986). This means soils with high clay content (~60%) contain higher percents of carbon due to the negative correlation between grain size and organic carbon content. Our obtained results show no comparison to any of these values, as the highest measured carbon percentage was 4.83% (core depth 0-9cm) at our degraded salt marsh site (Table 1). Our next highest value of 2.3% at the transition zone marked our two highest carbon content locations while the remaining positive results were recorded at levels below 2%. Fifteen of our samples recorded zero percent carbon content giving us skewed results to analyze.

Restored marshes have the greatest accumulation of organic carbon within the top 10 cm of the soil (Craft 2000). Three of our sampling sites recorded values at this depth. While sampling the inlet, we attempted to use the slide hammer corer but were unsuccessful due to the saturated soils. This caused some contamination, due to slumping, of the top layer into the second depth sample, which recorded 1.2% carbon content. Therefore, the data we obtained supports the findings of Craft that most of the carbon can be found within the top layer of soil.

Heavy Metals

Most heavy metal concentrations observed were well below the standards set in accordance with Article 5 from the Soil and Groundwater Pollution Remediation Act, with the exception of zinc and selenium (Figure 4). Selenium especially showed alarmingly high values that exceeded the appropriate standards. These concentrations were more than one hundred times those reported in the Slough in 2007 (Figure 6).

Zinc is a major byproduct from oil drilling operations, which in the past were conducted on the property and are currently being conducted to the north (Carls et al. 2004). Pollutants for the oil sumps could drain into the Hellman channel. This would explain the high concentrations observed along the channel at the neighboring inlet and muted tidal site, P3 and P1 (Fig. 5). Furthermore, the California Coastal Act and CWA can be applied to the oil drilling activities as pollutants draining from the oil sumps and oil derricks may violate TMDL's.

While zinc was exceeded only at two samples, all five sites within the property exceeded the selenium standard levels. The highest levels of selenium were observed in the inlet zone, followed by the muted tidal zone. Both of these sites are exposed to the Hellman Channel, which drains out any discharges from the oil operation sites, but also brings in tide-influenced water from the San Gabriel River. While atmospheric deposition of selenium from coal burning is a major source of selenium contamination in the U.S. (USDHHS, 2003), this possible source is ruled out since the Slough showed very small concentrations of selenium. Next, the Slough is not exposed to the San Gabriel River water which may be contaminated by selenium from the two adjacent power plants' discharges, as selenium is a common by-product discharged by electricity-generating power plant (USDHHS, 2003). Agricultural runoff and sewage effluent are also known sources of selenium contamination in water, but there is little evidence to conclude that these are the cause of the high levels. Future studies should examine selenium concentration in the San Gabriel River as well as the discharge sites of the AES and DWP power plants upstream of the culvert links to the property.

The alarmingly high values of selenium are of great concern because of the negative effects of selenium has on bird reproduction. Selenium is known to pose health hazards in both bird and plant species through bioaccumulation. Birth defects have been observed in certain bird species that have been exposed to excessive concentrations of selenium (Roberts, 1996). While sampling on the Hellman property, both the Biology and Chem/Hydro teams observed the Belding's Savannah Sparrow, an endangered species of bird. Another species of special concern is the California Least Tern. The Least Tern nests in sandy habitats and the Savannah Sparrow nests in native vegetation, especially pickelweed. With the detrimental effects of selenium on bird reproduction and the presence of an endangered species, the Endangered Species Act now has jurisdiction on the remediation of the property. Restoration of transition, upland and sand dune habitats could not be done using the present soil. Grading and removal of the contaminate soil would have to be done to ensure the protection of endangered species that may colonize the restored wetland.

Remediation Recommendatios

Due to the high levels of selenium and zinc contamination, as well as the high sand percentage, establishing a wetland habitat with the existent conditions would be impossible. However, restoration efforts are not inexpensive with a 2012 remediation proposal ranging from 2.3 to 2.9 million dollars (Moffatt and Nichol 2007). This includes site removal clean up which would be required to remove the high level of selenium as well as the top layer of soil that has been found to be too sandy for wetland habitat. Other efforts such as topping the soil with concrete could be more cost effective but would not yield the desired result of a functioning wetland. The import of clean fill to cover the concrete to an appreciable depth would raise the elevation of the wetland and inhibit natural tidal flow. Creating a pumping station to flood the wetlands with sea water would have a greater operating expenditure in the long run.

Clean up of the oil operation sites is imperative for the long-term heath of the Hellman property. Not only do they pose a threat of contamination but they also include heavy traffic and disturbance from trucks and operating equipment. The human impact on the area is clearly evident, grading for drainage, traffic, oil derricks and sumps, and any restoration efforts need to include a reduction of the impact from human activity.

If heavy metal contamination is proven to originate from the San Gabriel River, then a new source of tidal influence should be considered such as the Haynes Cooling Channel used by the AES power plant. The water necessary to flood the Hellman property would be negligible compared to the water pulled into the power plant for cooling. The plant does not run continuously and, to prevent contamination, drainage could continue to flow into the San Gabriel River. Sharing the water could be a requirement for thermal and air pollution expelled. More testing of the soils and water should be conducted to determine the extent and sources of the contamination. We focused on the western half of the Hellman property because it had the greatest tidal influence and was less contaminated than the eastern half of the property. Area 18 is the name given to the section of the property where the residue found at the bottom of oil derricks and sumps was buried. This area is possibly the highest sources of pollution and studies should be done on the extent of contamination and pollutant leakage that drains from this area. For any restoration to be complete and successful containment of the pollutants in this area must be done.

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Appendix

Salinity and pH raw data

Sample #	pH	Salinity (ppt)
P1 0-9	8	4.85
P1 9-18	8.27	3.06
P1 18-27	8.26	3.3
P1 27-36	8.23	4.5
P1 36-45	8.26	4.2
P2 0-9	7.85	1.59
P2 9-18	8.03	1.66
P2 18-27	8.37	1.22
P2 27-36	8.09	1.28
P2 36-45	8.65	0.61
P3 0-9	8.13	3.64
P3 9-18	8.11	3.05
P3 18-27	8.2	5.25
P3 27-36	8.32	3.87
P3 36-45	8.44	2.81
P4 0-9	7.96	2.01
P4 9-18	8.46	1.73
P4 18-27	8.07	3.74
P4 27-36	8.07	3.17
P4 36-45	8.08	3.27
P5 0-9	7.76	4.41
P5 9-18	8.04	3.53
P5 18-27	8.24	3.04

Grain Size raw data

Sample #	Sand %	fine % (silt + clay)	clay %	silt %
P1 0-9	45.6071	54.3929	20.2551	34.13781
P1 9-18	45.72364	54.27636	14.64051	39.63585
P1 18-27	51.5593	48.4407	4.248302	44.1924
P1 27-36	67.0566	32.9434	5.996914	26.94649
P1 36-45	66.71886	33.28114	10.64253	22.63861
P2 0-9	64.29936	35.70064	11.01535	24.68529
P2 9-18	76.13161	23.86839	0	23.86839
P2 18-27	71.99803	28.00197	2.947576	25.0544
P2 27-36	72.51648	27.48352	4.027993	23.45552
P2 36-45	94.44756	5.552442	0	5.552442
P3 0-9	33.21651	66.78349	17.30511	49.47838
P3 9-18	58.54633	41.45367	9.477426	31.97624
P3 18-27	30.85308	69.14692	22.94227	46.20466
P3 27-36	30.29389	69.70611	18.05844	51.64767
P3 36-45	18.20422	81.79578	19.98329	61.81249
P4 0-9	78.86962	21.13038	0	21.13038
P4 9-18	69.7464	30.2536	1.341682	28.91192
P4 18-27	25.24468	74.75532	13.45225	61.30307
P4 27-36	24.08321	75.91679	17.55756	58.35923
P4 36-45	47.73087	52.26913	8.601583	43.66755
P5 0-9	58.6506	41.3494	8.060313	33.28909
P5 9-18	48.56163	51.43837	18.21061	33.22776
P5 18-27	41.81323	58.18677	14.00597	44.1808

Pearson Product Moment Correlations

	Zn	Cu	Cr	Co	Ni	As	Se	Pb
Zn	1.0000							
	p= ---							
Cu	.9634	1.0000						
	p=.000	p= ---						
Cr	.9614	.9574	1.0000					
	p=.000	p=.000	p= ---					
Co	.8541	.8488	.9351	1.0000				
	p=.000	p=.000	p=.000	p= ---				
Ni	.9300	.9486	.9663	.9424	1.0000			
	p=.000	p=.000	p=.000	p=.000	p= ---			
As	.6436	.6565	.6459	.6059	.7197	1.0000		
	p=.001	p=.001	p=.001	p=.002	p=.000	p= ---		
Se	.4350	.3584	.3900	.4081	.3295	-.2613	1.0000	
	p=.038	p=.093	p=.066	p=.053	p=.125	p=.228	p= ---	
Pb	.2836	.3506	.2372	-.0632	.1406	.2543	-.2360	1.0000

Heavy Metal raw data

Sample #	Zn	Cu	Cr	Co	Ni	As	Se	Pb
P1 0-9	190.5561	53.94795	45.64415	16.54969	42.45184	23.74275	9.832531	39.69504
P1 9-18	110.9659	28.90707	30.44493	11.5247	22.62054	11.9234	76.69241	36.41958
P1 18-27	153.5525	40.4961	39.09142	14.35902	32.28772	11.6426	87.49006	30.72977
P1 27-36	130.5541	35.68678	32.77469	12.5302	26.46767	11.59883	110.8511	15.77653
P1 36-45	120.2802	32.83152	35.62491	13.28085	27.56576	9.293247	109.5741	37.5291
P2 0-9	94.16851	22.38634	22.31504	5.613	13.48254	2.909022	74.67957	52.58869
P2 9-18	71.30198	19.04285	19.28778	4.532235	11.33542	2.239743	62.53304	48.61231
P2 18-27	87.97564	21.38276	22.40318	5.799059	13.42377	3.195083	71.30635	48.26145
P2 27-36	121.2342	27.4148	26.65428	8.806479	18.00999	6.441722	108.3256	20.13579
P2 36-45	45.9209	11.12352	10.69059	3.680648	10.82241	2.628843	100.7466	8.511177
P3 0-9	211.6855	52.63151	45.59533	14.48616	31.66612	9.696496	179.9664	42.6335
P3 9-18	123.4296	22.66021	24.60347	8.71377	19.83813	7.80975	115.1117	24.63218
P3 18-27	169.9678	40.16012	43.28456	15.35094	32.47577	7.65146	157.7461	22.36147
P3 27-36	155.4566	38.19506	40.07995	17.07849	31.12835	9.183395	127.7999	23.60949
P3 36-45	123.2897	27.60559	30.79896	11.30801	23.41634	4.43349	111.29	7.650426
P4 0-9	83.39252	17.91514	19.20766	8.677771	16.52496	2.892508	121.0717	4.81527
P4 9-18	111.5179	31.35487	29.35291	13.05106	24.18458	5.238733	124.3344	9.112559
P4 18-27	177.1182	50.05028	48.09192	20.13581	37.58249	9.194841	135.4141	14.51756
P4 27-36	156.2642	43.23278	42.94249	17.41769	35.12611	6.283746	153.6423	13.35575
P4 36-45	123.842	27.85985	30.85005	13.0404	25.21691	4.412441	151.3217	7.456008
P5 0-9	134.7002	31.62989	30.97863	11.11043	24.4109	6.11301	177.0443	22.18278
P5 9-18	169.6966	45.9988	41.92333	13.6336	32.79462	8.638968	144.2338	38.80544
P5 18-27	237.724	74.57583	54.84857	18.32879	47.0909	11.06765	178.2107	58.61078