SECTION 3
SUMMARY OF 1998 MONITORING DATA

This section summarizes both ambient and point source monitoring data for 1998. A total of 32 ambient stations and 29 point source stations were sampled in 1998. Also included is a summary of 1998 precipitation data as pollutants, particularly fecal coliform bacteria, are introduced into intertidal and offshore waters following rainstorms. All data for stations monitored are presented in Appendices A through E. Station locator maps are provided in Section 2.

A summary of the results obtained for specific parameters (e.g., salinity, temperature, bacteria) and matrices (e.g., water, sediment, shellfish) are provided in this section. The results for ambient and point source samples are combined in order to facilitate the interpretation of results in this section.

1998 PRECIPITATION DATA

The monthly total precipitation for Seattle in 1998 is shown in Figure 3-1. For comparative purposes, precipitation totals do not include snow or ice pellet accumulations as the 30-year average does not include these data. The numbers were obtained from the National Climatic Data Center at the Sea-Tac International Airport station (NOAA, 1998). The total precipitation in 1998 was 44.1 inches (in.), which was 1 in. more than the 5-year average, 7 in. more than the 30-year average, and 1 in. more than the 1997 total. A record-setting wet November (11.6 in.) and December (9.0 in.) were the months with the highest rainfall, which accounted for 47% of the total rainfall for 1998. Four months received less than one inch of rainfall (April, July, August, and September), with only 5.6 inches of rain falling in the six month period of April through September.

This rainfall pattern is consistent with the recent El Nino (1997-98) / La Nina (1998-99) events, with a drier winter in early '98 and a wetter winter than average in late '98.

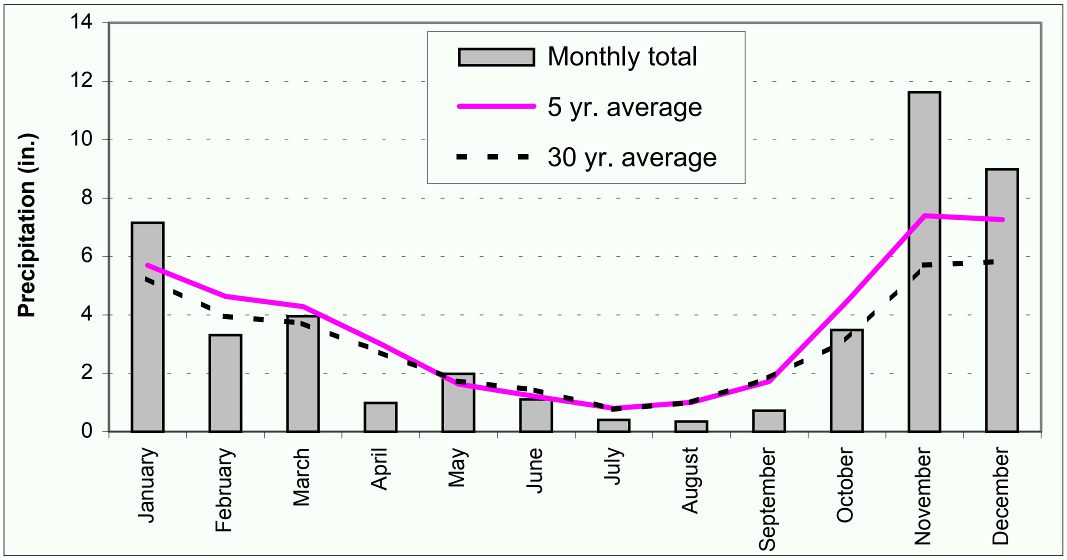

Figure 3-1. Monthly Precipitation for 1998

WATER COLUMN DATA RESULTS

Water column sampling is an important component of King County's water quality monitoring program and includes both offshore and intertidal sampling sites (see Figures 2-1 and 2-2). The monitoring program is structured to detect natural seasonal changes in the water column as well as identify anthropogenic inputs and influences.

Water quality parameters, including temperature, salinity, dissolved oxygen, Secchi disk transparency, nutrients, and chlorophyll-*a*, were measured at ten subtidal stations. Bacteria were measured at ten subtidal and twenty-two intertidal stations. (Station KSRU02 located near the Ballard Locks in the Lake Washington Ship Canal was only monitored for salinity, surface water temperature, and bacteria.)

Bacteria in Water Column

Fecal coliform and enterococcus bacteria were monitored at 10 subtidal water column stations (5 ambient and 5 point source), and 21 intertidal water stations. Two freshwater stations (KTHA01 and KSRU02) are monitored and compared to freshwater bacteria standards. All other stations are compared to saltwater standards. Washington State marine water Class AA fecal coliform standards for surface waters state that organism counts shall not exceed a geometric mean value of 14 colonies/100 ml and not more than 10 percent of the samples used for calculating the geometric mean value may exceed 43 colonies/100 ml. Freshwater Class AA fecal coliform standards state that organism counts shall not exceed a geometric mean value of 50 colonies/100 ml and not more than 10 percent of the samples used for calculating the geometric mean value may exceed 100 colonies/100 ml (WAC 173-201, 1991). King County uses results from the 30 most recent samples (surface samples only) to obtain a geometric mean value as per the guidelines in the National Shellfish Sanitation Program (NSSP, 1995). Surface samples are used as these tend to be the highest values and represent the water level where most contact occurs with people and intertidal organisms.

Enterococcus bacteria standards do not currently exist in Washington State. It is possible that this organism will be used as an indicator of the presence of pathogenic bacteria in the future, therefore, King County will continue to monitor the levels of this organism. There was no correlation between the amount of fecal coliform and the amount of enterococcus bacteria detected, which has also been the case with past sampling. enterococcus data are presented in Appendix A but will not be discussed further.

All the water column stations met Class AA marine water standards for fecal coliform bacteria with the exception of the two stations located in inner Elliott Bay: LTBC41 and LTED04 (Tables 3-1 and 3-2). Levels at these stations met the geometric mean standard of 14 colony forming units (cfu)/100 ml but were above the peak standard. It should be noted that for station LTBC41 located near the Denny Way CSO, as well as several others, the geometric mean was calculated using less than 30 samples. For station LTBC41, 5 of the last 20 samples exceeded 43 cfu/100 ml and for station LTED04, 4 of the last 30 samples exceeded 43 cfu/100 ml. All but two of the over 43 cfu/100 ml values occurred between November and January for both stations. The other two over 43 cfu/100 ml values occurred in May when over an inch of rain fell in the three days prior to sampling. These two stations in inner Elliott Bay receive higher freshwater input than other subtidal stations due to their proximity to the Duwamish River. The freshwater station in the Lake Washington Ship Canal met Class AA freshwater fecal coliform standards.

Table 3-1. 1998 Ambient Monitoring--Fecal Coliform Bacteria

Station	Meets Class AA Marine Water Standards: Geometric mean (14 colonies/100 ml)	Peak [a] (43 colonies/100 ml)	Comments
Intertidal			
Stations north of Ship Canal			
JSWX01	Yes	Yes	Station is south of fuel docks at Richmond Beach.
JSVW04	No	No	8 of the last 30 samples are > 43 colonies/100 ml.
KSLU03	No	No	9 of the last 30 samples are > 43 colonies/100 ml.
KSQU01	No	No	13 of last 30 samples are > 43 col./100 ml. Near Ship Canal.
KRJY01	Yes	Yes	Only sampled from May to September.
Stations between Ship Canal and Alki Point			
KSYV02	No	No	9 of the last 30 samples are > 43 colonies/100 ml.
LTAB01	No	No	6 of the last 30 samples are > 43 colonies/100 ml.
LTEH02	No	No	15 of last 30 samples are > 43 col./100 ml. Inner Elliott Bay stn.
LSGY01	Yes	Yes	Geometric mean was calculated using less than 30 samples.
LSFX01	Yes	Yes	Geometric mean was calculated using less than 30 samples.
LSHV01	Yes	Yes	Located north of Alki Point near Alki Drive.
Stations south of Alki Point			
LSVW01	No	No	18 of last 30 samples are >= 100 col./100 ml. In Fauntleroy Cove.
LSTU01	Yes	No	7 of the last 30 samples are > 43 colonies/100 ml.
MTEC01	Yes	No	8 of last 30 samples are > 43 col./100 ml. Sampled May-Sep.
MSSM05	No	No	15 of last 30 samples are > 43 col./100 ml. Sampled May-Sep.
MTLD03	--	--	Only sampled in Aug.Not enough data to compare to standards.
Offshore			
Point Jefferson			
KSBP01	Yes	Yes	Station is between Carkeek Park and Jefferson Head.
Ship Canal			
KSRU02[b]	Yes	Yes	Station is located in the Lake Washington Ship Canal.
Point Wells			
JSTU01	Yes	Yes	Station is just offshore from Point Wells.
Elliott Bay			
LTED04	Yes	No	Station is lcoated in inner Elliott Bay. Geometric mean was calculated using 20 samples.
Dolphin Point			
LSNT01	Yes	Yes	Station is between the north tip of Vashon Island and Fauntleroy Cove.

[a] -- Not more than 10 percent of the 30 most recent samples may exceed this value.

[b] -- Station results are compared with Class AA freshwater standards which state the geometric mean value not exceed 50 colonies/100ml and not more than 10 percent of the most 30 recent samples may exceed 100 colonies/100

Table 3-2. 1998 Point Source Monitoring--Fecal Coliform Bacteria

Station	Meets Class AA Marine Water Standards: Geometric mean (14 colonies/100 ml)	Peak[a] (43 colonies/100 ml)	Comments
Intertidal			
Carkeek Park			
KSHZ03	No	No	11 of last 30 samples are > 43 col./100 ml. Near mouth of Piper's Creek.
KTHA01[b]	No	No	24 of last 30 samples are >100 col./100 ml. Freshwater station in Piper's Creek.
West Point			
KSSN04	Yes	Yes	Located north of the West Point lighthouse.
KSSN05	Yes	No	6 of last 30 samples are > 43 colonies/100 ml.
Alki Point			
LSKR01	No	No	14 of last 30 samples are > 43 colonies/100 ml.
LSKS01	No	No	23 of last 30 samples are > 43 colonies/100 ml.
Offshore			
Carkeek Park			
KSIW02	Yes	Yes	Geometric mean was calculated using less than 30 samples.
West Point			
KSSK02	Yes	Yes	Geometric mean was calculated using less than 30 samples.
Denny Way			
LTBC41	Yes	No	5 of last 20 samples >43 col./100 ml. Geomean calculated using < 30 samples.
Alki Point			
LSKQ06	Yes	Yes	Station is just off the Alki TP outfall.
Renton outfall			
LSEP01	Yes	Yes	Geometric mean was calculated using less than 30 samples.

[a] -- Not more than 10 percent of the 30 most recent samples may exceed this value.
[b] -- Station results are compared with Class AA freshwater standards which state the geometric mean value may not exceed 50 colonies/100ml and not more than 10 percent of the most 30 recent samples may exceed 100 colonies/100 ml.

Fecal coliform bacteria in the water column near King County's treatment plant discharges were found at low levels if detected at all. The majority of subtidal stations had higher levels in December at all depths when almost three inches of rain fell during the three days prior to sampling. For the subtidal stations, the highest bacteria levels are usually seen at the surface samples.

Fecal coliform levels in water samples taken from intertidal beaches are influenced by freshwater runoff from the surrounding watersheds that drain into the Sound. As a result, the number of stations exceeding the Class AA marine standards increased in the high rainfall months and at stations closer to streams and other sources of freshwater runoff (Figure 3-2). Also, restricted bays and areas removed from the strong tidal mixing of the open Sound tend to retain

Figure 3-2. Fecal Coliform Results: Comparison With Standards freshwater inputs for a longer period of time. Therefore, stations located near these geographic areas, such as station MSSM05 near the Tramp Harbor fishing pier and LSVW01 in Fauntleroy Cove, had higher bacteria levels.

The intertidal beaches with the lowest fecal coliform levels were those near Seacrest Park, Duwamish Head, and the station located between Duwamish Head and Alki Point. Bacteria levels at these three stations were below Class AA marine water standards. The exposed Bainbridge Island beach station at Fay Bainbridge State Park and the northern station at Richmond Beach also met Class AA marine water standards. The results in 1998 for these stations are similar to those obtained in past years.

Three beaches met the geometric mean standard but failed the peak standard; these included the southern West Point station, Lincoln Park, and Seahurst Park.

Beaches that exceeded both the geometric mean and peak standards were in the Carkeek Park area, southern Richmond Beach, south side of Alki Point, Shilshole Bay, Magnolia, inner Elliott Bay, Fauntleroy Cove, and Tramp Harbor (see Figure 3-2). These stations have consistently failed Class AA standards over the past several years. These stations are either located near a freshwater source or in areas with poor circulation where fecal coliform levels are elevated. Counts at these stations increased following periods of rainfall, particularly for the two stations located in inner Elliott Bay: LTAB01 and LTEH02. Most intertidal stations exceeding both standards had higher counts in the summer even though rainfall was low. Waterfowl and dogs tended to congregate at beaches such as Carkeek Park and Golden Gardens during the summer months in 1998, but this is no longer true for dogs as regulations prohibiting dogs on the beach are currently being enforced.

Figure 3-3 shows fecal coliform results throughout the year for all stations. The values, as depicted by the size of the marker, are not geometric mean values, but single point values for that particular month. This figures shows consistently low values detected at offshore stations. Table 3-3 shows which stations have regularly passed or failed standards over the last four years. Again, it is the offshore stations which consistently pass standards while stations near a freshwater source or embayment regularly failed standards over the last four years.

Figure 3-3. Fecal Coliform Concentrations

Table 3-3. Station Results for Fecal Coliform Bacteria Over Four Years

Passed both geometric mean and peak standards between 1995 and 1998	Exceeded both geometric mean and peak standards between 1995 and 1998	Variable from 1995-1998
Offshore		
KSBP01 LSNT01 LSKQ06 LSEP01 * KSSK02 * KSIW02 *	KSQU01	
Intertidal		
JSWX01 KRJY01 LSHV01	KSHZ03 KTHA01 KSLU03 KSYV02 LTAB01 LSKR01 LSKS01 LSVW01 MSSM05	JSVW04 KSSN04 KSSN05 LSTU01 MTEC01

* Indicates station only sampled in 1997 and 1998

Water Temperature

Depending upon the water depth at the station, temperatures were monitored at one to seven depths. Depths ranged from just below the surface down to 200 m (656 ft). Temperatures ranged from 8.2 to 16.2 (mean = 11.2) ^{o}C for all stations. Values for six stations, located off Point Jefferson, the West Point Treatment Plant (TP) outfall, the Renton TP outfall, inner Elliott Bay, the Alki TP outfall, and off Dolphin Point, are shown in Figure 3-4 and are representative of the patterns shown at other stations sampled. Temperature variations during the winter and early spring months were slight, particularly at greater depths. Surface water temperatures varied more than samples taken at deeper depths due to various weather influences, such as air temperature, cloud cover, and wind. The water column started to exhibit seasonal thermal stratification in May. The figures indicate a well-mixed water column throughout most of the year with no development of a thermocline (characterized by a rapid decrease in temperature with increased depth). There

Figure 3-4. Water Temperature at Six Stations (^oC)

is, however, a noted rise in surface water temperatures during the summer months which corresponds to a rise in air temperature and an increase in solar radiation. The warmest temperatures were measured between July and September for all stations.

Salinity

Salinity was measured at seven depths ranging from 1 to 200 meters, depending upon the water depth of the station. Salinities ranged from 21.43 to 30.78 (mean = 29.35) practical salinity units (psu) for all stations except KSRU02. Station KSRU02 is located in the Lake Washington Ship Canal and the salinity at this station is tidally influenced and ranged between 8.44 and 23.56 psu.

Salinities varied due to seasonal influences as depicted in the salinity profiles for six stations (Figure 3-5). Lower salinities were detected in surface waters during winter months when freshwater input is highest. The inner Elliott Bay stations (LTED04 and LTBC41) had lower salinities at the surface throughout the year which is attributed to the freshwater influence of the Duwamish River. The station located at the end of the West Point TP outfall also had lower surface salinities during months with high rainfall, but were not as low as the stations in inner Elliott Bay. Unlike surface waters, salinities measured at depths of 15, 25, 35, 55, 100, and 200 m showed little variation with depth. Values ranged from 28.39 to 30.78 (mean of 29.50) which indicates a well-mixed water column with no development of a strong halocline (characterized by a rapid increase in salinity with increased depth). Salinities were highest from August through November which may be attributed to an increased input of saltier deep oceanic water due to off-coast upwelling during late summer and a decrease in freshwater input from rivers and precipitation.

Density affects vertical mixing processes in the water column. Both temperature and salinity affect water density, which generally increases with colder water or higher salinity. Density is an important measurement as the water column may stratify and trap nutrients and/or contaminants in differing density layers. Figure 3-6 shows density profiles for six stations. Throughout the year for most stations, the figures indicate a non-stratified water column. Station LTED04, which is influenced by freshwater input, had lower density values at the surface throughout the year. For depths 15 m and greater, however, the water column is non-stratified. Station KSSK02 had slightly

Figure 3-5. Salinity at Six Stations (PSU)

Figure 3-6. Density at Six Stations (kg/m^3)

lower densities at the surface for the first part of the year but was non-stratified through the later months. This may be due to a slight freshwater influence from water moving around West Point from Elliott Bay and southward from the Ship Canal or from the freshwater surfacing of the effluent plume.

Dissolved Oxygen

Depending upon the depth of the station, dissolved oxygen was measured at three to seven depths. Depths ranged from just below the surface down to 200 m. Dissolved oxygen concentrations ranged from 4.5 to 14.1 (mean = 7.8) mg/L for all stations sampled in 1998. Concentrations decreased with depth as input from the atmosphere across the air-sea interface and photosynthetic activity yield most of the dissolved oxygen in estuaries (Kennish, 1994). Figure 3-7 shows dissolved oxygen profiles for six stations sampled in 1998. Dissolved oxygen values were below 7.0 mg/L from September to November at most depths and stations. Dissolved oxygen concentrations below 7.0 mg/L occur naturally during late summer and fall due to the input of deep oceanic water which contains low amounts of oxygen. During the summer months, surface water oxygen concentrations are greater than 7.0 mg/L, however, concentrations decrease with increasing depth. This is due to warmer water temperatures which contain less oxygen and no photosynthesis from phytoplankton at these depths.

Washington State marine surface water quality standards for dissolved oxygen vary depending upon the intended water use and classification of a specific body of water. Ecology uses a dissolved oxygen value of 5.0 mg/L as a guideline to indicate where potential problems could occur (DOE, 1998). Concentrations for all stations were above this guideline with one exception. Station KSSK02 had a value of 4.5 mg/L at 55 m, the deepest depth sampled at this station, in November. The other depths sampled for this station ranged between 6.5 and 6.8 mg/L. This station also had one value under 5.0 mg/L in 1997; however, the concentration (4.7 mg/L) was detected at 15 m and not at the deepest depth.

Figure 3-7. Dissolved Oxygen Concentrations (mg/L) at Six Stations

Transparency

Secchi disk depth (transparency) values ranged from 2.5 to 14.5 m for all stations. The lowest values were observed during months when freshwater runoff was high (January) and months when phytoplankton blooms occurred (April and July). For all stations, transparencies were higher in the fall and winter months, particularly for October.

Nutrients

Nitrogen Compounds. Several forms of inorganic nitrogen are commonly found in the marine environment. These compounds include ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-), with nitrate being the primary form of inorganic nitrogen in seawater. The analytical method the King County Environmental Laboratory uses to measure nitrate concentrations does not distinguish between nitrate and nitrite, therefore, these two forms are reported as one value expressed as nitrate+nitrite. Nitrite amounts in the water column are naturally very low and the contribution of nitrite to the total value is usually minimal. Values for total ammonium and total nitrate+nitrite are reported below.

> *Ammonium.* Values ranged from less than the method detection limit (0.02 mg/L) up to 0.21 mg/L for all stations monitored. The mean concentration for all stations and months was 0.02 mg/L. Most ammonium concentrations monitored at all depths were at or below the method detection limit except from May through August--which is similar to the pattern observed in previous years. Higher concentrations during the summer months are expected as ammonium is generated from the decay of organic nitrogen (both natural and from zooplankton grazing of phytoplankton) and peaks about the time of senescence (decay) in the producer growth cycle (Valiela, 1984). Generally, the highest concentration occurred in May, the month following the April phytoplankton bloom. Figure 3-8 shows ammonium concentrations at six stations and a frequency plot of the values obtained for all stations is shown in Figure 3-9. Ammonium concentrations measured in 1998 were similar to those measured in previous years. The two stations which had the highest concentrations in 1997, LSEP01 and KSSK02, also had the

Figure 3-8. Ammonium Concentrations at Six Stations (mg/L)

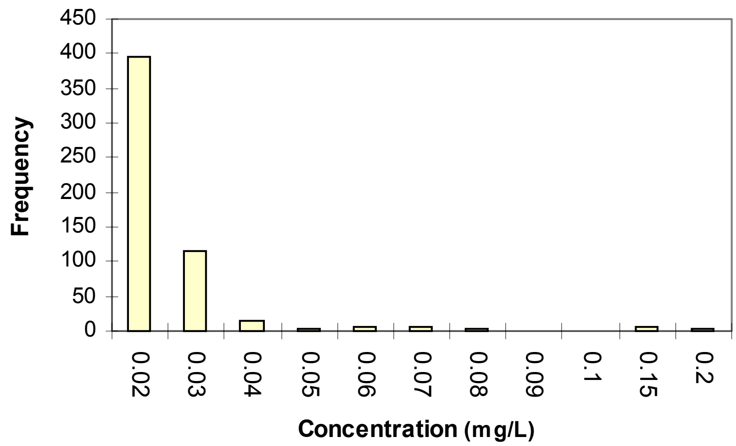

Figure 3-9. Ammonium Frequency Plot for All Stations Sampled in 1998

highest concentrations in 1998. Station LSEP01 which is located at the Renton outfall had a concentration of 0.11 mg/L at 150 m and KSSK02 located at the West Point outfall had a concentration of 0.21 mg/L at 55 m. These ammonium concentrations suggest that the effluent plume from the treatment plants were evident at these depths. At both of these sites, only the deepest depths monitored had higher concentrations than other depths.

Nitrate+Nitrite. As stated above, nitrate is usually the primary form of inorganic nitrogen in seawater and was most abundant in the winter when it was not taken up by phytoplankton and when freshwater runoff was highest. Phytoplankton uptake is restricted to the euphotic zone (the zone where enough light penetrates for photosynthesis to occur) which is why nitrate+nitrite concentrations tend to increase at depth during the summer months. Overall, nitrate+nitrite concentrations ranged from less than the detection limit (0.05) to 0.47 mg/L for all stations monitored. Nitrate+nitrite concentrations for six stations are shown in Figure 3-10. The highest concentration was detected near the surface at station LTBC41 (located in the vicinity of Denny Way in inner Elliott Bay) in January. The higher concentration at the surface is likely due to freshwater runoff. Values below the detection limit occurred only near the surface during the spring and summer months when phytoplankton

Figure 3-10. Nitrate+Nitrite Concentrations for Six Stations (mg/L) blooms were evident. Concentrations were similar for all stations, including the inner Elliott Bay stations, and nitrate+nitrite values measured in 1998 were similar to values from previous years.

Phosphorus

Phosphorus in seawater is found as dissolved inorganic, dissolved organic, and particulate phosphorus. Generally, particulate phosphorus is the most abundant form. Several forms of inorganic phosphorus are found in the marine environment. The most abundant forms of phosphorus are the orthophosphate ions, with HPO_4^{2-} being the major ion in seawater (Valiela, 1984). Total phosphorus (which includes all forms of inorganic and organic phosphorus) was measured at ten stations. Values ranged from 0.02 to 0.13 mg/L with a mean of 0.07 mg/L. Concentrations did not show a clear trend with depth. However, phosphorus did show a clear seasonal trend with levels decreasing at the surface depths during the late spring and summer months which is due to phytoplankton and bacteria uptake. Concentrations were the highest in January and February at all stations. Results obtained in 1998 were similar to concentrations measured in previous years.

Silica

Silica was measured at all stations and depths. Concentrations ranged from 0.67 to 6.8 mg/L with a mean of 2.7 mg/L. Values at the surface were lower than other depths measured from April to July as diatoms (microscopic photosynthetic plants) use silica for skeletal growth and are usually concentrated near the surface. For all depths, concentrations were lower during the summer months than for the rest of the year. Further evidence that silica concentrations are biologically related was seen in winter. Winter months (November through February) had higher mean and maximum concentrations when phytoplankton abundance is low and silica uptake is at a minimum. Also, there was little variation between surface and deeper depths during the winter months. The two stations in inner Elliott Bay, LTBC41 and LTED04, had higher silica concentrations at the surface, which may be attributed to the input of particulates from the Duwamish River. Station LTBC41 had the highest concentration measured (6.8 mg/L) at the surface in 1998. Figure 3-11 shows

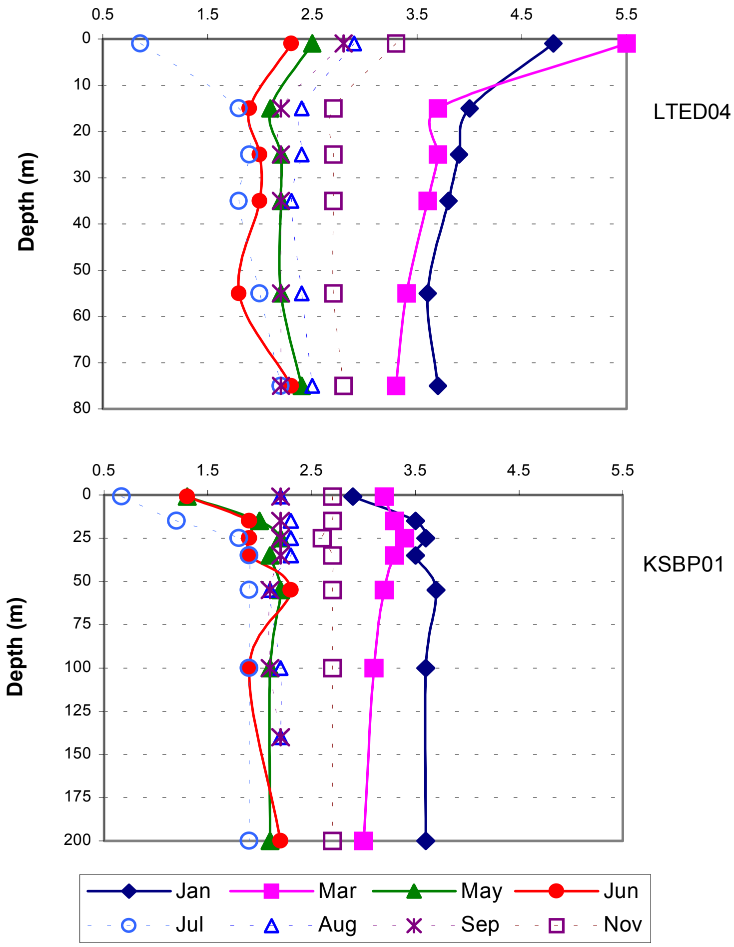

Figure 3-11. Silica Concentrations at Stations LTED04 and KSBP01 (mg/L)

the increase in surface silica at station LTED04 and the typical pattern seen at other stations. Silica concentrations in 1998 were similar to concentrations found in previous years.

Chlorophyll-*a* and Phaeophytin

Chlorophyll-*a* and phaeophytin were measured at ten stations at four depths (1, 15, 25, and 35 m). Chlorophyll-*a* values ranged from 0.11 to 31.5 µg/L (mean concentration was 2.4 µg/L) and phaeophytin levels ranged from <0.01 to 3.3

µg/L (mean concentration was 0.47 µg/L). Chlorophyll-*a* concentrations for six stations are shown in Figure 3-12. Chlorophyll-*a* and phaeophytin levels were low in the winter and decreased with depth for all months. This corresponds to the decreased light availability for plant growth at deeper depths. High chlorophyll-*a* levels at the surface in April and July indicated a bloom occurred. Station KSBP01 had the highest chlorophyll-*a* concentrations for both the April and the July bloom. This station also had high levels at the surface in May, whereas the other stations sampled had low concentrations in May. In 1997, chlorophyll-*a* levels indicated a bloom occurred in September but in both 1996 and 1998, elevated levels were not seen past July. Although maximum concentrations vary from year to year, phytoplankton blooms exhibit seasonal trends with blooms usually occurring in April or May and July. The El Nino event in 1997 likely caused the late bloom and it appears that in 1998, the typical pattern seen in the Central Basin returned.

Several factors influence chlorophyll concentrations, including availability of light and nutrients, air temperature, and zooplankton grazing. As stated in the previous chapter, phaeopigments such as phaeophytin are degradation products of chlorophyll produced when zooplankton graze on phytoplankton cells. Generally, phaeophytin values tended to be higher at 15 m than at the surface and also when chlorophyll concentrations were high. Overall, phaeophytin concentrations at the two inner Elliott Bay stations were not higher than other stations as this parameter is affected more by zooplankton abundance than by water column mixing.

Total Suspended Solids

Total suspended solids values ranged throughout the year from 0.7 to 17.3 (mean = 3.3) mg/L. Generally, values tended to be higher at the lowest depth measured for those stations deeper than 55 m due to resuspension of bottom sediments. This was not the case, however, for stations 55 m or less. Surface values at these stations tended to be higher than other depths. During the months when chlorophyll-*a* levels were elevated, suspended solids values were higher at the surface. This is due to the influence of phytoplankton particles. Suspended solids are measured by filtering a well-mixed water sample through a glass-fiber filter and trapping suspended particles on the filter. Large phytoplankton particles are also trapped on the filter and can cause higher total suspended solid values when phytoplankton are abundant.

Figure 3-12. Chlorophyll-*a* Concentrations at Six Stations (µg/L)

There was no difference in mean values observed from station to station, even for the two stations located in inner Elliott Bay, LTBC41 and LTED04. Also, there was no difference between mean values obtained for the two stations located at the outfalls for the Renton and West Point treatment facilities and other stations sampled. Although the mean for the Renton TP outfall station was similar to other stations, the highest TSS value was found at the 55 m depth for this station.

SEDIMENT CHEMISTRY DATA RESULTS

Offshore and intertidal sediments were sampled as a part of the ambient and point source monitoring programs (see Figures 2-2 and 2-3). Sediments were sampled for conventional parameters (total solids, total volatile solids, total sulfide, nitrogen, oil and grease, total organic carbon, grain size distribution), metals, and organic compounds. Metals and ionizable organics data are presented on a dry weight basis and non-ionizable organics data are presented on both a dry weight and organic carbon normalized basis where appropriate. All sediment data are provided in Appendix B. A total of 29 offshore sediment sites (19 point source and 10 ambient) were sampled for sediment conventionals, metals, and organic compounds. Six intertidal stations (three point source and three ambient) were sampled for conventionals, metals, and organic compounds.

Conventionals

Total sulfides were measured at all 29 offshore stations but were not analyzed for the intertidal stations. Total sulfides are monitored as they may be toxic to benthic organisms, create unaesthetic conditions, and affect the toxicity of certain metals. No sulfides were detected above the detection limit of 10 mg/kg in any of the samples. Total sulfides have been detected in previous years at the stations located in inner Elliott Bay as sulfides tend to be higher in areas with greater amounts of freshwater input. However, the analytical method changed in 1998 which may account for the difference compared to previous years results.

Total oil and grease includes compounds such as hydrocarbons, animal fats, vegetable oils, soaps, and greases. This analysis was conducted on both offshore sediments collected at West Point and for all intertidal sediments. Total oil and grease values ranged from less than the detection limit (100 mg/kg) to 180 mg/kg. Only four stations at West Point had detectable levels of oil and grease and these compounds were not detected for any of the intertidal samples.

Ammonium nitrogen was measured for all subtidal samples. Values ranged from 0.3 to 10.4 mg/kg, with the highest value occurring at station LSML01 in the Central Basin. Concentrations were not higher at the end of the West point and Carkeek outfalls compared to other stations and stations with the lowest nitrogen values also had the lowest total organic carbon values.

Total organic carbon (TOC) was measured for all sediment samples. Values ranged from 596 to 17,200 mg/kg wet weight for offshore sediments and 511 to 3,920 mg/kg wet weight for intertidal sediments. Intertidal sediments are composed mainly of sand and gravel and sandy sediments have lower TOC values than sediments containing a high proportion of silt and clay. For subtidal stations, samples containing a high percentage of sand and gravel had low TOC values as is the case for both the West Point and Carkeek samples. Inner Elliott Bay stations had the highest TOC values; although two inner Elliott Bay stations had higher TOC values than expected, which may be due to organic enrichment. TOC concentrations were not higher at the end of the Carkeek CSO outfall compared to other stations in the area but the station at the end of the West Point outfall had slightly higher values than other stations near the outfall. This may be due to settling of fine particles in the immediate vicinity of the outfall.

Figure 3-13 shows the relationship of TOC to percent sand and gravel. As stated above, the amount of organic carbon contained in sediments is directly related to the physical processes that regulate grain size. Higher concentrations of organic carbon and total solids occur with fine-grained sediments in depositional areas, whereas lower organic carbon content and solids occur where coarse-grained sediments are found and organic-rich fines do not accumulate.

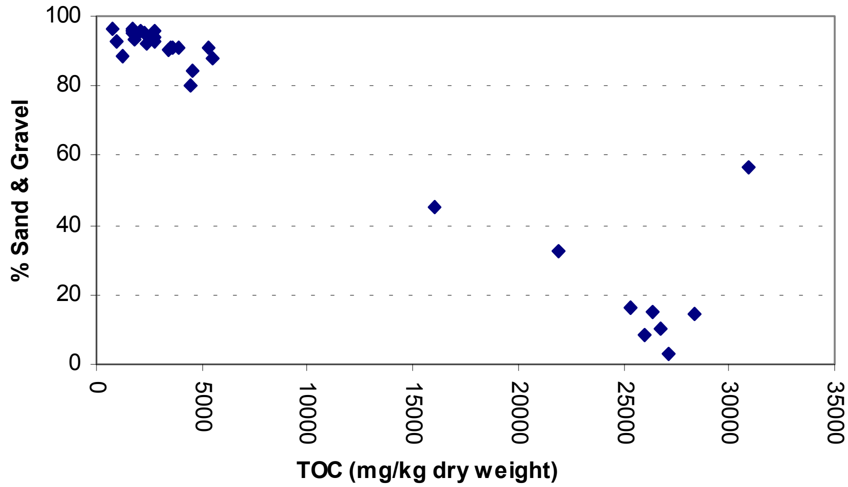

Figure 3-13. Organic Carbon Vs. Grain Size for All Stations

Metals

Sixteen metals were analyzed at 29 offshore stations (19 point source and 10 ambient) and thirteen metals were analyzed at 6 intertidal stations (3 point source and 3 ambient). A summary of the metals detected in offshore sediments is given in Table 3-4. All results are presented on a dry weight basis.

Two metals, selenium and thallium, were not detected in any samples. Antimony and silver were seldom detected and were at levels just slightly above the detection limits. Although a Washington State Sediment Quality Standard (SQS) does not exist for antimony, the silver values were well below the SQS for this metal. Cadmium and beryllium were detected in 10 and 27 of the 29 offshore samples, respectively, but at levels just above the detection limit. These two metals were not detected in the intertidal samples. Arsenic and mercury were detected in 20 of the 29 offshore samples. Mercury was not detected in any of the intertidal samples and arsenic was detected in two intertidal samples. Arsenic values ranged from less than the detection limit to 13.6 mg/kg, with the highest values found in inner Elliott Bay. Arsenic concentrations were well below the SQS of 57 mg/kg for this metal. All the Elliott Bay stations had higher mercury concentrations than samples collected near the wastewater treatment plants and other sites outside of Elliott Bay; concentrations in these areas were all 0.06 mg/kg or less. The highest mercury

Table 3-4. Metals Summary for Sediments

	Range (mg/kg dry weight)		Detection Frequency		Station with Highest Value	
	Offshore	Intertidal	Offshore	Intertidal	Offshore	Intertidal
Aluminum	5,603 - 23,371	na	29/29	na	LTED04	na
Antimony	<1.9 - 3.3	<1.6 - <2.0	5/29	0/6	LSCK01	---
Arsenic	<3.0 - 13.6	<3.0 - 3.5	20/29	2/6	LSEZ01	JSVW04
Beryllium	<0.1 - 0.4	<0.1	27/29	0/6	2 stations	---
Cadmium	<0.2 - 0.5	<0.2	10/29	0/6	LSEZ01	---
Chromium	14.9 - 45.1	15.4 - 23.3	29/29	6/6	LCSI01	JSVW04
Copper	4.4 - 54.9	4.7 - 23.3	29/29	6/6	LTED04	JSVW04
Iron	8,315 - 30,286	na	29/29	na	LTED04	na
Lead	2.1 - 61.4	2.4 - 14.9	29/29	6/6	LTDF01	JSVW04
Manganese	178 - 1020	na	29/29	na	WPD215N	na
Mercury	<0.02 - 0.44	<0.02 - <0.03	20/29	0/6	LTDF01	---
Nickel	13.0 - 37.1	15.0 - 29.5	29/29	6/6	LCSI01	JSVW04
Selenium	<2.7 - <5.2	<2.6 - <3.3	0/29	0/6	---	---
Silver	<0.2 - 0.9	<0.2 - <0.3	4/29	0/6	LTDF01	---
Thallium	<12.0 - <21.2	<10.6 - <13.1	0/29	0/6	---	---
Zinc	19.5 - 100.6	22.2 - 32.5	29/29	6/6	LSEZ01	JSVW04

na = not analyzed

concentration was 0.44 mg/kg detected at station LTDF01 located along the waterfront in inner Elliott Bay. This value exceeded the SQS of 0.41 mg/kg. This station also exceeded the SQS for mercury in 1996. Mercury can enter the marine environment from boat paints, plastics, smelting operations, and creosote and there is a known historical source of mercury along the waterfront.

Chromium, copper, lead, and zinc were detected in all samples; however, concentrations were well below the SQSs for these metals. Nickel was also detected in all samples ranging from 13.0 to 37.1 mg/kg but there is no SQS for this metal. Concentrations detected in 1998 were similar to those detected in previous years for all metals.

Organics

Twenty-nine offshore sediment stations (19 point source and 10 ambient) were monitored for organic compounds. In addition, 6 intertidal stations (3 point source and 3 ambient) were also monitored. Semivolatile organics (including PAHs), pesticides, and PCBs were measured in all samples. Organotins were analyzed only for the offshore samples. Dry weight and organic carbon normalized values are presented in Appendix B.

Results discussed below are compared to both SQSs and apparent effects thresholds (AETs) where appropriate. This is due to the low organic carbon content at most stations; thus it is not appropriate to use organic carbon normalized values to assess compliance with regulatory standards that are organic carbon based. For stations containing less than 0.5% organic carbon, dry weight values are more appropriate for comparison with the regulatory standards that are based upon AETs. For stations with organic carbon content greater than 0.5% (two West Point stations and all the Elliott Bay stations), results will be compared to the organic carbon based SQSs.

Of the 98 organic compounds analyzed, 24 were detected in offshore samples and 6 were detected in intertidal samples. Table 3-5 shows the organic compounds detected and the frequency detected. Most of these compounds were PAHs, particularly the high molecular weight PAHs. PAHs are present in petroleum products and coal-tar related manufacturing products and are byproducts of combustion. PAHs are also found in creosote, a compound used on pilings as a wood preservative. The composition of creosote is approximately 85% PAHs (Arvin and Flyvbjerg, 1992).

Stations with the highest PAH concentrations were located along the Seattle waterfront and at one station located near the West Point TP outfall. High PAH values have typically been detected at stations in inner Elliott Bay relative to other stations sampled over the past several years. This is particularly true for station LTDF01, which is located along the Seattle waterfront just south of the Bell Street Pier. Although concentrations are elevated, PAHs did not exceed SQSs for this station or any other station located in Elliott Bay. High PAH concentrations were also found at station WP430N, located 430 ft north of the West Point TP outfall, but concentrations did not exceed AETs.

Table 3-5. Organic Compounds Detected in Sediments

Compound	Range (µg/kg) dry weight	Detection Frequency	Station with Highest Value
Offshore			
1,4-Dichlorobenzene	<0.9 - 1.4	4/12	WP230P
Acenaphthene	<13.8 - 166.2	3/29	WP430N
Acenaphthylene	<20.1 - 64	4/29	LTDF01
Anthracene	<20.1 - 334	9/29	LTDF01
Benzo(*a*)anthracene	<20.8 - 542	26/29	LTDF01
Benzo(*a*)pyrene	<34.1 - 750	18/29	LTDF01
Benzo(*b*)fluoranthene	<54.0 - 1038	15/29	LTDF01
Benzo(*g,h,i*)perylene	<33.9 - 451.0	19/29	WP430N
Benzo(*k*)fluoranthene	<54.0 - 350	6/29	LTDF01
bis(2-Ethylhexyl)phthalate	<20.1 - 237.0	16/29	LTBC41
Chrysene	<20.2 - 869	21/29	LTDF01
di-*n* -Butyl phthalate	<33.9 - 44.9	1/29	WP230P
Dibenzo(*a,h*)anthracene	<54.0 - 110	2/29	LTDF01
Fluoranthene	<20.8 - 1133.5	27/29	WP430N
Fluorene	<20.1 - 94.7	2/29	WP430N
Indeno(1,2,3-*cd*)pyrene	<33.9 - 408.7	16/29	WP430N
Naphthalene	<54.0 - 99	1/29	LTDF01
Phenanthrene	<20.2 - 1010.9	20/29	WP430N
Pyrene	<20.8 - 1158.0	28/29	WP430N
4,4'-DDD	<1.6 - 5.2	1/29	LTDF01
Aroclor 1248	<16.3 - 48.7	1/29	LTDF01
Aroclor 1254	<16.3 - 59.2	2/29	LTDF01
Aroclor 1260	<16.3 - 188.5	2/29	LTDF01
Tributyltin	<0.3 - 228	16/29	LTBC41
Intertidal			
Benzo(*a*)anthracene	<16.9 - 36	2/6	KSSN04
Benzo(*a*)pyrene	<28.6 - 40	1/6	KSSN04
Chrysene	<16.9 - 32	1/6	KSSN04
Fluoranthene	<16.9 -71	2/6	KSSN04
Phenanthrene	<16.9 - 31	2/6	KSSN04
Pyrene	<16.9 - 89	2/6	KSSN04

Twelve stations were sampled for organic compounds in two transect lines around the West Point TP outfall in 1998--one transect along the end of the diffuser pipe and one at the mid-diffuser point. The stations placed along the mid-diffuser transect had few organic compounds detected, with the exception of station WPD430S. Although this station had less than 0.5 % organic carbon, it had the highest carbon content among the stations along this transect which is a contributing factor to the greater amount of PAHs detected. The stations along the end of the pipe transect had several PAHs detected, but did not follow a consistent gradient with respect to distance away from the pipe, although the stations north of the discharge tended to have higher concentrations. Station WP230P, located at the end of the pipe, had two PAHs that exceeded SQSs: benzo(*g,h,i*)perylene and indeno(1,2,3-*c,d*)pyrene. Concentrations did not exceed the Cleanup Screening Levels (CSLs). Based upon PAH results for stations WP230P and WP430N, three sediment toxicity tests were conducted on sediments from these two stations and will be discussed in a separate section below. As a result of time and weather constraints during the initial sample collection, enough sediment was not collected to run the bioassays; therefore, additional samples for these two stations were collected in March 1999 to run toxicity tests and additional chemical testing. The chemistry results for the samples collected in March are also provided in Appendix B. One sample, WP230P, had poor quality control results and was re-analyzed.

PAHs were the only organic compounds detected in intertidal sediments and were at concentrations all well below AETs. These stations are composed mainly of sand and have low carbon content, one of the reasons intertidal stations consistently have few organic compounds detected. One compound, 1,4-dichlorobenzene, was found at four of the West Point TP offshore stations with the highest concentration detected at the station at the end of the outfall. This compound is contained in some garbage and restroom deodorants as well moth control products. This compound was not detected in West Point sediments collected in 1996. Although not detected in 1998, 1,4-dichlorobenzene was detected at three of the inner Elliott Bay stations in 1996.

The only pesticide detected was 4,4'-DDD and was only detected at station LTDF01. This pesticide is a breakdown product of DDT but was also used as an insecticide for moths and other insects until the early 1970's. Both DDT and DDD were banned from general use in 1972 but these compounds adsorb strongly to sediments. There is no SQS for DDD, however, the concentration detected was just above the MDL. Three PCBs (Aroclor 1248, Aroclor 1254, and Aroclor 1260) were detected at two stations in Elliott Bay. Aroclors 1254 and 1260 were found at stations LTDF01 and LTED04 and Aroclor 1248 was only found at LTDF01. PCBs were also detected at LTDF01 in 1996. Although PCBs are now banned, these compounds are persistent in sediments. All detected concentrations were below the SQS for total PCBs.

Although hexachlorobutadiene and N-nitrosodiphenylamine were not detected in any samples, the method detection limits exceeded the AETs for these compounds. Also not detected was 2,4-dimethylphenol, however, the detection limit exceeded the SQS. It is very difficult to obtain low detection limits for these compounds. Benzyl alcohol was not detected in any samples but the method detection limits exceeded the SQS for most the Elliott Bay stations. These stations had percent solids content less than 42% and when detection limits were dry weight converted, they exceed the SQS.

Organotins were analyzed in all 29 offshore samples--they were not measured in intertidal samples. Organotins, particularly tributyltin (TBT), have been used extensively as anti-fouling agents in boat paints. Organotins are highly effective against marine organisms attaching to boat bottoms, such as barnacles and algae, however, they are also toxic to nontarget marine organisms. Organotins are neurotoxins, disrupt ATP synthesis, impair DNA/RNA production, and have been found to be endocrine disrupters in fish. The use of organotins on leisure craft was banned in 1998, but they may still be used on commercial vessels. The International Maritime Organization is planning to ban the use of organotins in anti-fouling paints by 2003 and ban their presence on vessels by 2008.

The Carkeek and majority of West Point stations were all less than detection limits for organotins. In contrast, these compounds were detected in all the Elliott Bay stations, with the highest TBT value (228 µg/kg dry weight) detected at LTBC41, the station located just south of the Elliott Bay Marina and grain terminal. The next two highest values were found at the easternmost stations in inner Elliott Bay closest to the Seattle waterfront. Station LTBC41 also had the highest TBT value in 1997, which was 311.7 µg/kg dry weight. The values at this station are likely due to the proximity to the marina and ship traffic to the grain terminal.

Sediment Toxicity Results

As discussed above, only two stations had toxicity tests conducted due to the initial chemistry results, specifically PAHs. The two stations were WP230P and WP430N located near the West Point outfall. The KCEL conducted a 10-day acute toxicity test using the amphipod *Rhepoxynius abronius* and a 96-hour acute toxicity echinoderm embryo (*Strongylocentrotus purpuratus*) test. A 20-day chronic toxicity test using the juvenile polychaete, *Neanthes arenaceodentata*, was conducted by a subcontract laboratory. A summary of the test results are provided below and a more thorough discussion regarding toxicity results is presented in Section 4.

The results of the amphipod toxicity test for both stations passed both the Biological and Severe Biological Effects Criteria (i.e., showed no toxicity).

Results from the *Neanthes* test indicate a statistically significant reduction between station WP230P and the reference station with respect to individual and total dry weight and individual growth rate. There was no reduction with regard to percent mortality between the reference station and either of the West Point stations.

Echinoderm embryo test results show significant differences between the reference station and both the West Point stations with respect to mortality and abnormal echinoderm embryo development. Station WP430N exceeded the Biological Effect Criterion for mean effective mortality and station WP230P exceeded the Severe Biological Effect Criterion for mean effective mortality.

Benthic Community Results

Marine benthic communities are useful indicators of sediment quality because they spend most of their lives in direct contact with the sediment. Pollutants contained in sediments and interstitial water could be consumed or absorbed by benthos, resulting in unhealthy animals, stressed communities, and the potential for pollutants to pass through the food web to other marine organisms.

Benthic communities may be analyzed and characterized in several different ways. One of the most common methods is looking at community diversity. Diversity is a measure of the complexity of the community structure and is increased or decreased by physical, chemical, and/or biological factors. High diversity is generally considered good as it indicates a balanced and stable community. Low diversity occurs in an area where the community is dominated by a few species, such as in a stressed environment. Diversity indices are commonly used due to their ease of calculation but are criticized due to their lack of detecting community changes due to a specific environmental factor, such as a particular pollutant or physical factor. This also leads to difficulty in interpreting diversity results as the reason why a particular community structure often cannot be determined.

Additional methods for characterizing benthic communities are used in conjunction with diversity indices to try and establish a clearer picture of why a particular community structure is seen. One of these methods is calculating abundances of pollution tolerant and pollution sensitive species. *Capitella capitata* is a polychaete commonly used as an indicator of polluted, anoxic, or organically enriched sediments (Pearson and Rosenberg, 1978). Ophiurids (brittle stars) have been used as indicators of clean undisturbed sediments (Comiskey et al., 1984).

In 1998, benthic community monitoring was conducted as part of the County's NPDES permit for the West Point treatment plant. The monitoring goals were to determine if discharges from the outfall are impacting (either positively or negatively) the surrounding benthic communities. Communities were examined by calculating several diversity indices, calculating abundances, and looking at species composition. Physical and chemical factors potentially affecting community structure were also explored.

Diversity indices. The Shannon-Wiener index is one of the most widely used diversity indices due to its ease of calculation and its relative independence of sample size. This index uses the total number of species in a sample as well as the abundance of single species to determine diversity. High diversity values are seen in areas with many different species and low environmental stress, while low values are seen in areas with few species and high environmental stress. Shannon-Wiener diversity values were calculated using the following equation:

$$H' = \sum_{i=1}^{S} P_i \log_2 P_i$$

Where H’ = Shannon-Wiener index
P_i = Number of individuals in the i^{th} species
S = Total number of species

Average Shannon-Wiener diversity values for the West Point samples ranged from 3.20 (station WP430N) to 5.79 (WPD215S). The two stations located south of the discharge and the reference station located 1500 feet north of the discharge had higher diversity values than the station at the discharge and the station located 430 feet north of the outfall.

Evenness is another measure of diversity that is commonly used in conjunction with the Shannon-Wiener index. Evenness was calculated with the following equation:

$$J = H' / \log_2 S$$

Where J = Evenness
H’ = Shannon-Wiener index
S = Total number of species

Evenness values close to 1.0 represent a sample composed of several different species while low evenness values indicate a sample composed of only a few dominant species. Average evenness values ranged from 0.75 (WPD430S) to 0.88 (WP1500N). The values tend to be higher at the northernmost stations and decrease as the stations go further south. Evenness values did not follow the same pattern as the Shannon-Wiener values.

Swartz's index is another diversity index which measures the minimum number of species whose abundance makes up 75% of the total sample abundance. Low values indicate a sample with little diversity while high values indicate a sample composed of many species. Swartz's index values ranged from 7.00 (WPD430N) to 36.00 (WPD215S). The same pattern for the Shannon-Wiener index was also seen for Swartz's index, with the two stations located south of the discharge and the reference station having higher diversity values than the station at the discharge and the station located 430 feet north of the outfall.

As all the stations had similar grain size distributions, correlations between diversity index values and grain size were not seen. Generally, greater diversity values are seen with coarser grain sizes, however, grain size was not a determining factor of diversity values for these samples.

Species Abundance. The average total abundance (the total number of organisms) varied from 32 (WPD430N) to 1,386 (WPD430S). The trend in total abundance was the same as seen with the Shannon-Wiener and Swartz's index, in that stations WPD430N and WP230D has the lowest values. Total abundances did not show a correlation with grain size as sediment type controls the type of inhabitant, but does not influence how many individuals are present. The average total number of species ranged from 14 (WPD430N) to 175 (WPD430S) and again followed the same pattern as total abundance.

The percent of total organisms in each major taxa group is shown in Figure 3-14. All the stations have fairly similar assemblages with only slight differences. Table 3-6 gives a summary of benthic community indices.

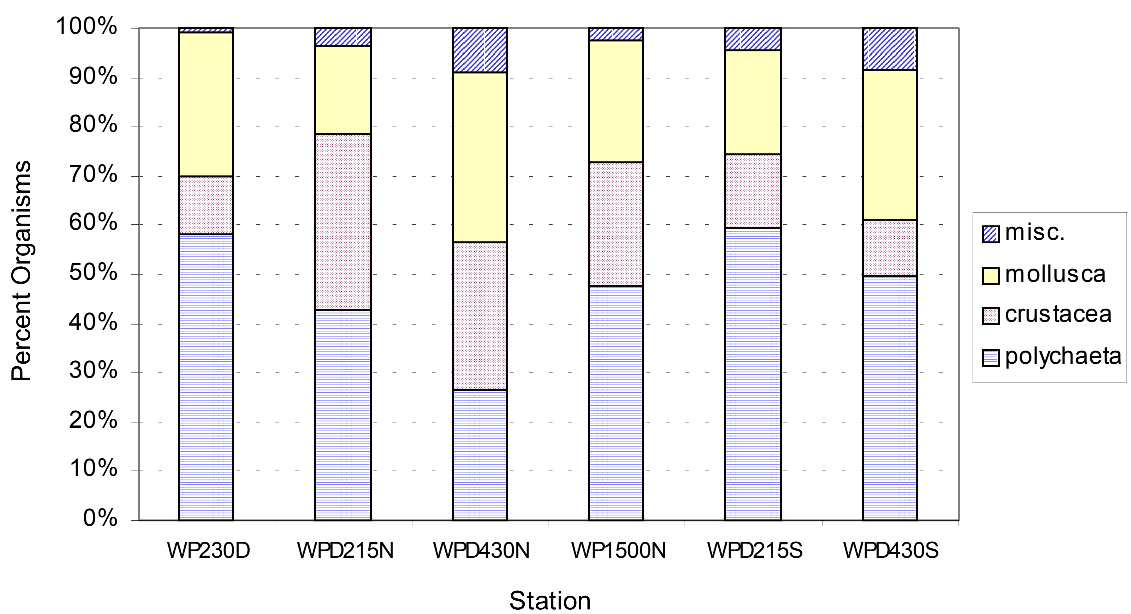

Figure 3-14. Major Taxa Groups

Table 3-6. Benthic Indices Summary

	Station					
Index	**WP230D**	**WPD215N**	**WPD430N**	**WP1500N**	**WPD215S**	**WPD430S**
Avg. # of Individuals	65.7	191.7	32.0	218.3	1020.7	1386.3
std. dev.	52.9	48.6	11.5	21.4	227.8	399.5
Avg. # of Species	24.3	61.3	14.0	74.3	157.3	175.3
std. dev.	12.9	23.8	5.3	11.8	11.7	3.2
Avg. Shannon-Wiener	3.6	5.1	3.2	5.5	5.8	5.6
std. dev.	0.3	0.6	0.7	0.4	0.2	0.3
Avg. Evenness	0.8	0.9	0.8	0.9	0.8	0.7
std. dev.	0.1	0.0	0.1	0.0	0.0	0.0
Avg. Swartz's Index	9.3	25.3	7.0	30.0	36.0	33.7
std. dev.	1.5	12.1	3.0	7.2	4.6	7.0
Avg. Mollusk Evenness	4.0	7.7	2.7	16.7	19.7	28.7
std. dev.	2.0	6.5	2.1	2.5	1.2	1.5
% clay	1.3	3.4	0.6	3.3	4.0	4.3
% silt	5.5	3.5	2.6	1.5	4.2	4.7
% sand	92.7	91.8	96.4	95.2	86.7	86.0
% gravel	0.0	1.6	0.1	0.4	5.2	5.2

Table 3-7 shows the dominant species found at each of the six stations. Many of the dominant species were found at several stations, with *Olivella baetica*, being the most dominant species at three stations. The benthic community results for 1996 sampling at station WP215N show the same dominant species assemblage as stations WPD215N and WPD215S in 1998. The abundance of certain species, such as the polychaete *Capitella capitata* which is known to be tolerant of polluted and organically enriched sediment, provides useful information. *Capitella capitata* was found in one of the three replicate samples for stations WPD215S and WP1500N but not at any of the other stations. *Eteone longo* and *Prionospio steenstrupi*, also considered pollution tolerant polychaetes, were found at all stations with the exception of station WPD430N. Other pollution tolerant species, such as *Paraprionspio pinnata, Leitoscoplos pugettensis*, and *Mya arenaria* were seldom, if at all, seen at any stations. Ophiurids are considered pollution sensitive organisms and were found at stations WPD215S, WPD430S, and WP1500N.

Table 3-7. Dominant Species at Each Station

Station	Dominant Species	Taxonomic Group	Average Number of Individuals	Percent of Total Abundance
WPD215N	*Olivella baetica*	Crustacea	14	7.3
	Neosabellaria cementarium	Polychaeta	12	6.2
	Byblis millsi	Crustacea	10	5.2
	Tritella pilimana	Crustacea	9	4.7
	Hiatella arctica	Mollusca	8	4.2
WPD215S	*Hiatella arctica*	Mollusca	120	11.8
	Dipolydora akaina	Polychaeta	86	8.4
	Neosabellaria cementarium	Polychaeta	80	7.8
	Pholoides asperus	Polychaeta	53	5.2
	Polycirrus sp.	Polychaeta	43	4.2
WPD430N	*Olivella baetica*	Crustacea	10	30.3
	Mandibulaphoxus mayi	Crustacea	5	15.6
	Polycirrus sp.	Polychaeta	3	10.3
	Polycirrus sp. II	Polychaeta	2	5.3
	Eogammarus confervicolus	Crustacea	1	3.1
WPD430S	*Hiatella arctica*	Mollusca	219	15.8
	Pholoides asperus	Polychaeta	148	10.6
	Nemocardium centifilosum	Mollusca	132	9.5
	Neosabellaria cementarium	Polychaeta	100	7.2
	Dipolydora akaina	Polychaeta	80	5.7
WP230D	*Olivella baetica*	Crustacea	16	24.8
	Cirratulus sp. juv.	Polychaeta	12	18.7
	Polycirrus sp.	Polychaeta	4	5.6
	Hippomedon sp.	Crustacea	3	4.1
	Dipolydora akaina	Polychaeta	3	4.1
WP1500N	*Rhepoxynius abronius*	Crustacea	22	10.1
	Nemocardium centifilosum	Mollusca	11	4.8
	Olivella baetica	Crustacea	10	4.7
	Prionospio steenstrupi	Polychaeta	10	4.4
	Macoma yoldiformis	Mollusca	9	4.0

SHELLFISH DATA RESULTS

Shellfish samples were collected from intertidal beaches as a part of the ambient and point source monitoring programs and consisted entirely of butter clam, *Saxidomus giganteus,* whole tissues. This is a change from previous years when samples consisted of several different species. The change to butter clams was initiated in order to facilitate comparisons between stations and to assist in temporal trends for future monitoring. Different feeding strategies can affect results, and mixing species that are surface deposit feeders (*Macoma* sp.) with clams which are filter feeders (butter, littleneck, manila, and horse clams) does not allow for direct comparisons between results. Also, the various species contain different amounts of lipids which may also affect results. Therefore, only general comparisons between previous years results can be made but more specific comparisons between stations for 1998 is possible.

Two point source samples were analyzed for semivolatile organics, pesticides, PCBs, metals, fecal coliform and enterococcus bacteria. One additional point source sample was analyzed for bacteria only. Two ambient samples were analyzed for semivolatile organics, pesticides, PCBs, metals, fecal coliform and enterococcus bacteria. Four additional ambient samples were analyzed for bacteria only. All results are presented on a wet weight basis unless otherwise noted and are provided in Appendix C. Dry weight values for metals are also provided in Appendix C.

Metals

Thirteen metals were analyzed in shellfish tissues at station KSSN04 (West Point), LSKR01 (Alki Point), JSVW04 (Richmond Beach), and MTLD03 (Normandy Park). Antimony, beryllium, and thallium not detected in any samples. These metals were also not detected in previous years' monitoring. Cadmium, chromium, lead, mercury, nickel, selenium, and zinc concentrations varied only slightly between samples and were similar to values detected from previous studies (NOAA, 1981). Station JSVW04 had the highest concentration detected for most of the metals listed above. Arsenic was detected in all samples and concentrations ranged from 15.7 to 20.7 mg/kg dry weight, with the highest concentration found at the West Point station. Arsenic concentrations were similar to values detected previously. Copper was also detected at all stations ranging from 8.1 to 12.9 mg/kg dry weight, with the highest value detected at station JSVW04. Concentrations differed slightly between the same stations monitored in 1997, most likely due to differences in species composition. Silver values ranged from 5.05 to 7.23 mg/kg dry weight and the highest value was found at West Point. Silver concentrations for the other three stations varied only slightly and ranged between 5.05 and 5.86 mg/kg dry weight.

State and federal criteria do not exist for acceptable levels of metals in shellfish tissues. However, the U.S. Food and Drug Administration (FDA) has established guidance values termed Levels of Concern for mollusks for five metals: arsenic, cadmium, chromium, lead, and nickel. These guidance values are risk-based and differ for children and adults. For comparative purposes, the lowest of the two values was chosen. Results from 1998 monitoring were below wet weight Levels of Concern for arsenic (55 mg/kg), cadmium (3 mg/kg), chromium (11 mg/kg), lead (0.8 mg/kg), and nickel (80 mg/kg) (FDA 1993a,b,c,d,e).

The FDA has established an Action Level in fish and shellfish tissues of 1.0 mg/kg for mercury (FDA, 1995). When this value is exceeded, the food product cannot be commercially traded which is how an Action Level differs from a Level of Concern. Mercury concentrations were well below this Action Level.

Organics

The same four stations that were monitored for metals were also monitored for organics, which included semivolatile organics, pesticides and PCBs. Of all the compounds analyzed, only one compound was detected: benzoic acid. Benzoic acid was detected in all samples at concentrations ranging from 661 to 1,670 mg/kg. Benzoic acid is used as a food preservative and an anti-fungal agent; however, it is also a degradation product produced by metabolic processes and has always been detected in shellfish samples in the past. No pesticides or PCBs were detected in any of the samples.

Fecal Coliform Bacteria in Shellfish

Fecal coliform and enterococcus bacteria were monitored at six ambient stations and three point source stations. All but three stations were sampled from May to September. Two stations were sampled in August only, MTLD03 and LSKR01. Station KSSN04 was sampled in August and October. The results can be found in Appendix C.

Fecal coliform concentrations varied from station to station and from month to month. Generally, stations near Seahurst Park (MTEC01) and Carkeek Park (KSHZ03) had the lowest values from May to September. During this five month period, values ranged from <20 to 3,500 MPN/100g with the highest concentration detected at Alki Point (LSKR01) in August. Fecal coliform counts were generally the lowest in September (Figure 3-15). Two samples at

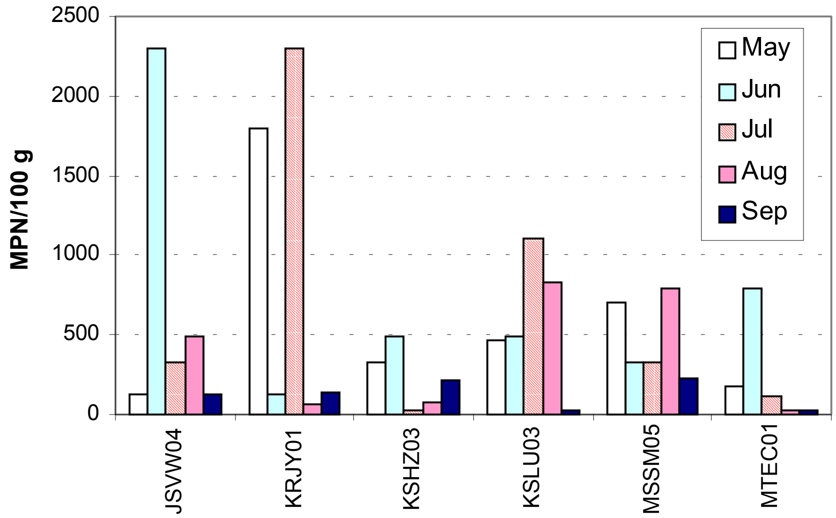

Figure 3-15. Fecal Coliform Concentrations in Shellfish

stations KRJY01 and KSSN04 were collected in October. Counts were 3,300 and 4,900 MPN/100g, respectively, for these two stations. Since samples were not collected in October at other stations, it is not possible to determine if concentrations were elevated at all stations; however, over an inch of rain fell a few days prior to sampling which likely contributed to the high counts. Station KSLU03, located just north of the Lake Washington Ship Canal at Golden Gardens, and MSSM05 located in Tramp Harbor did not have the highest fecal coliform values detected but had consistent concentrations from May to August. Stations such as MTEC01 and KRJY01 had concentrations that fluctuated throughout the year, unlike KSLU03 and MSSM05. Station KSLU03 is influenced by freshwater from a nearby creek and the Lake Washington Ship Canal and station MSSM05 is located in an area with poor mixing. The two stations located near West Point and Alki Point were only sampled in July, therefore, comparisons between stations and months cannot be made for these sites.

Enterococcus bacteria counts were not correlated with fecal coliform counts and the highest concentrations were not found in any particular month. Concentrations ranged from less than 20 to 7,900 MPN/100 ml.

There does not appear to be a consistent relationship between fecal coliform concentrations measured in shellfish and concentrations detected in water however, there was a correlation for some stations and months (Figure 3-16) that was not seen in previous years. For 1997, fecal coliform concentrations in shellfish and water did not show a relationship. Although several other studies have also found that a constant association between fecal coliform concentrations in shellfish and overlying water does not exist, shellfish from waters meeting water quality criteria are unlikely to be involved in the spread of Disease, which is the reason that shellfish beds are classified based upon bacteria concentrations in the water, not in the shellfish themselves (NSSP, 1995).

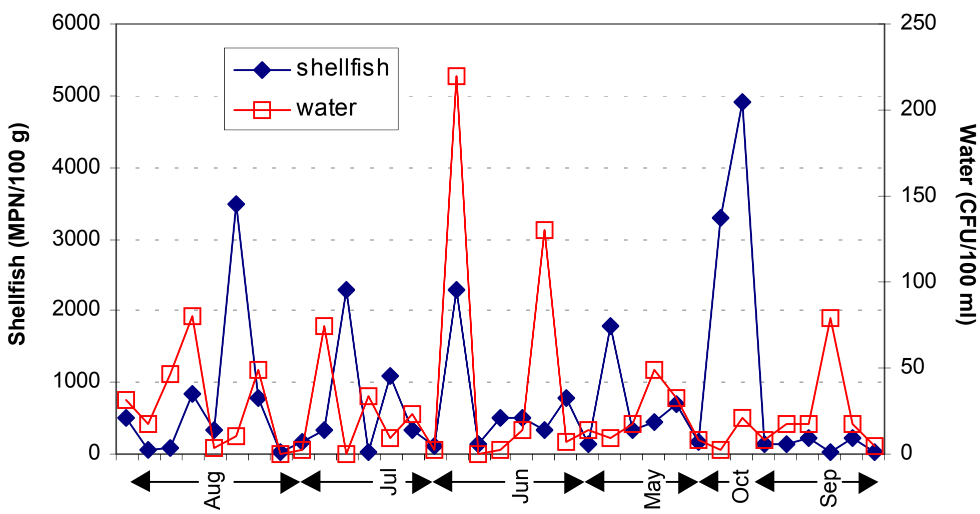

Figure 3-16. Fecal Coliform Concentrations in Shellfish & Water for All Stations

MACROALGAE DATA RESULTS

Macroalgae (algae) samples were collected from seven beaches and consisted entirely of the most prevalent edible algae, *Ulva fenestrata* (known as sea lettuce). Samples were analyzed for metals only. All macroalgae data are presented on a dry weight basis and can be found in Appendix D.

Algae from three point source and four ambient sites were sampled for 13 metals. The point source stations were KSSN04 and KSSN05 located on the north and south side of West Point, respectively, and LSKR01 at Alki Point. One ambient station was located near Richmond Beach and three were located between the southern end of West Point to just north of the Elliott Bay Marina (see Figure 2-1). All seven stations were sampled in August.

Macroalgae samples were monitored for thirteen metals. Five metals, antimony, beryllium, selenium, silver, and thallium were either below or at the MDLs for all samples. Mercury was detected in two samples; one right at the detection limit (0.02 mg/kg) and the other at a concentration of 0.024 mg/kg (station JSVW04). Lead was detected in three samples ranging from 2.05 to 2.74 mg/kg, with the highest concentration detected at KSSN04. Arsenic, cadmium, chromium, copper, nickel, and zinc were detected in all samples. A summary of metal concentrations detected in algae samples from four stations in 1997 and 1998 is given in Table 3-8. In the past few years, certain metals such as chromium, nickel, and zinc have been higher in algae from the stations at West Point than other stations sampled. In 1999, dissolved metals were also monitored in the water column from these beaches at the same time algae was collected. Those results will be discussed in the 1999 marine water quality report.

To determine if the pattern of higher metals near West Point is a continuing event, macroalgae will be sampled at additional stations in 1999. These stations will be located on both the west and east side of the central basin as well as north and south of West Point. In addition, total and dissolved metals will be measured in the water column at several stations, including the West Point stations.

Table 3-8. Metal Concentrations in Macroalgae (mg/kg dry weight)

	KSSN04		KSSN05		KSUR01		LSKR01	
	1998	1997	1998	1997	1998	1997	1998	1997
Arsenic	2.68	6.18	4.04	4.36	3.21	5.9	4.25	6.69
Cadmium	0.35	0.3	0.13	<0.15	<0.12	0.36	0.55	0.7
Chromium	8.39	5.9	8.57	10.2	2.51	0.42	1.16	0.96
Copper	7.00	13.65	6.07	16.23	5.69	13.07	2.49	5.6
Lead	2.74	<1.69	<1.1	1.72	<1.22	2.89	<1.66	<2.21
Nickel	30.22	7.42	10.66	12.16	4.55	4.52	2.38	2.65
Zinc	193.69	15.51	19.49	19.51	10.93	17.23	9.06	5.87