3. RESULTS AND DISCUSSION

This section provides a description and discussion of the overall findings of the four study elements of the Sediment Toxicity Study for Pago Pago Harbor. The information is presented in four main subject areas: seabed characteristics; sediment types and distribution; COC concentrations, distributions, and significance; and evaluation of the source, fate, and transport of identified principal COCs.

3.1 Seabed Characteristics

For discussion and planning purposes, the Harbor was segregated into three sections as shown on Figure 1-1: Inner Harbor, Middle Harbor, and Outer Harbor. Study Element 2, Seabed Characterization and Mapping, developed data and maps on the shape and form of the seafloor including the water depth, seabed features, and sediment thickness throughout the Harbor. These data also provide an indication of where recent sediments can be expected to have accumulated. Study Elements 1 and 3 provided detail on the textural and chemical characteristics of the bottom sediments throughout the Harbor (discussed in more detail in Section 3.2). Collectively this information was used to characterize the geomorphology of the seabed including the horizontal and vertical distribution of sediments throughout the Harbor.

3.1.1 Inner Harbor

The area defined as the Inner Harbor extends from the westernmost end of Pago Pago Harbor to Nuututoi Pt. (present location of Rainmaker Hotel). This region is approximately 1,500 feet wide (North-South orientation) and 8000 feet long (East-West orientation). The water depth of the Inner Harbor ranges from 2 to 165 feet (see Figure 2-1). The westernmost end of the Inner Harbor is a relatively flat shelf with water depths less than 40 feet. Located on this shelf are small shoal areas produced by coral and bedrock knobs. Some of these coral and bedrock outcroppings trap and hold sediment creating large ponds of fine grained material, an example of a sediment pond is shown in Figure 3-1. East of this shelf the water depth increases from 40 feet to 100 feet over a distance of 1000 feet. This area also contains some bedrock knobs. Beyond this point the depth gradually increases to 150 feet over the next 3600 feet.

Inner Harbor sediment characteristics vary along the reach of the Inner Harbor and are significantly finer, with more organic and clay appearance, in the shallow end near the head of the Harbor. Inner Harbor samples are visually and texturally distinct from the Middle and Outer Harbor samples. Of particular interest is the congregation of sediment ponds near the head of the Harbor (Harbor Head Sediment Pool; HHSP). The HHSP traps natural and anthropogenic sediments containing COCs from the surrounding watershed.

3.1.2 Middle Harbor

The Middle Harbor is defined as being between Nuututoi Pt. and the northeastern shoreline of Pago Pago Harbor and includes the area offshore of the Aua Village (Figure 1-1). This area is approximately 2,000 feet in width (Northeast-Southwest orientation) and 5,000 feet in length (Southeast-Northwest orientation). The Middle Harbor is predominantly a deep, flat bottom basin ranging in depth from 150 to 170 feet. The basin is enclosed by steep slopes

along the southern boundary, relatively gentle slopes along the northern boundary and a broad coral shelf on the western boundary (Figure 2-1). The sediment in the Middle Harbor ranges in thickness from 35 to 75 feet and is underlain by what is believed to be the top of the volcanic material of the ancient caldera. The fine-grained, uniform nature of this material, with no evidence of internal stratigraphy, suggests that sediments are deep-water marine deposits.

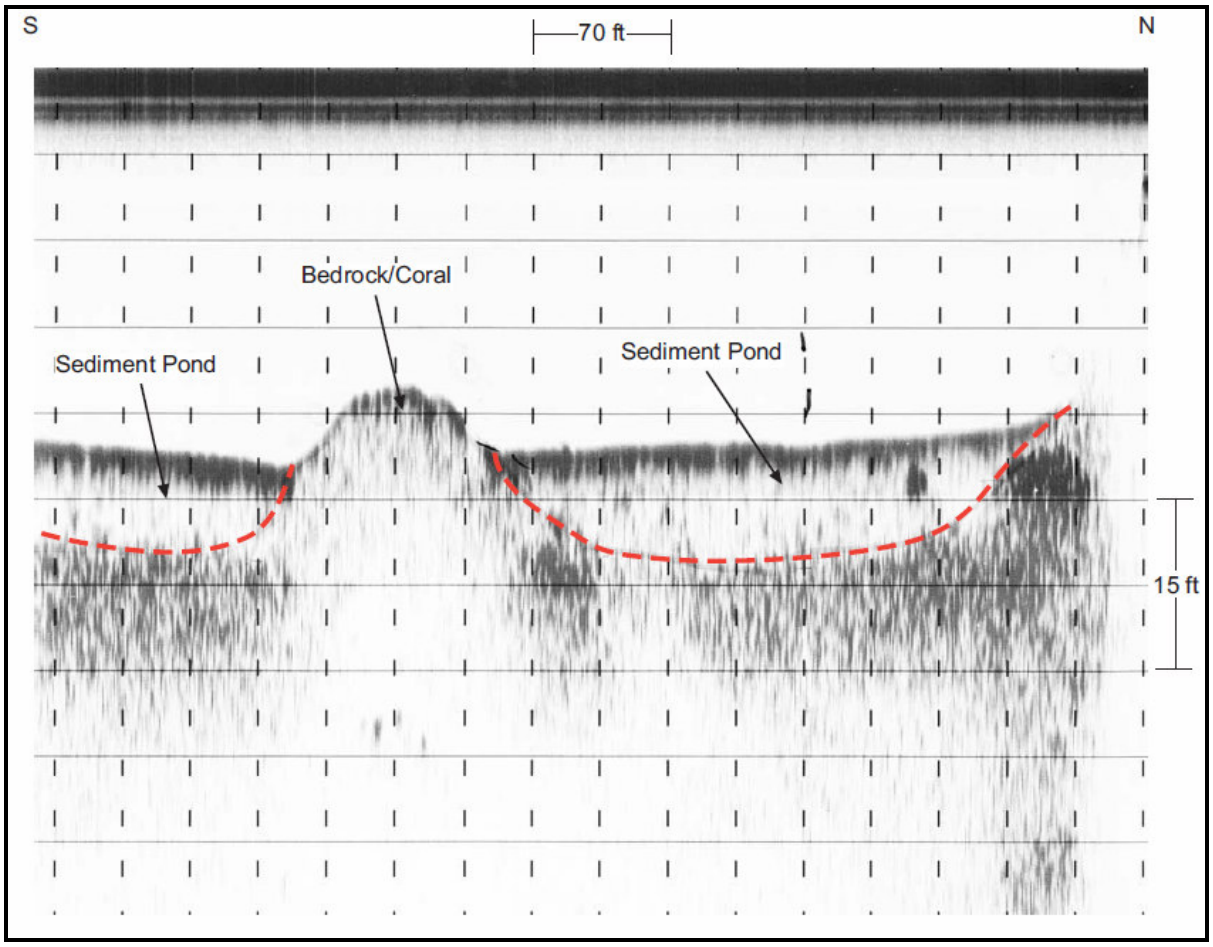

Figure 3-1. Sub-bottom Profile over Coral and Sediment Ponds in the Inner Harbor

The Middle Harbor geomorphology indicates three distinct sub-regions: the main deeper portion of the Middle Harbor, the margins of the Middle Harbor, and the "elbow" near the Village of Aua. Bottom sediments from near Aua were different than most of the sediments from the Middle Harbor with somewhat coarser material. The sediments from the deeper portions of the Middle Harbor were similar in texture and other characteristics compared to those from along the margins of the reef slopes. In general, the Middle Harbor sediments show more sand and less clay than in the Inner Harbor sediments.

3.1.3 Outer Harbor

The Outer Harbor extends southward from Nuututoi Pt. to the opening of Pago Pago Harbor at Breakers Pt. This region is approximately 5,000 feet in width (East-West orientation) and 6,000 feet in length (North-South orientation). The eastern and western boundaries of this

region are nearly vertical reef slopes on the seaward edge of the coral reef flats (Figure 2-1). Between the reef slopes is a relatively flat bottom basin that ranges in depth from 180 to 210 feet. The seafloor of the Outer Harbor is almost featureless except near the center of the basin and along the eastern edge where several areas of extreme shoaling are produced by volcanic pinnacles (Whale Rock, Amuula Rock, and Toasa Rock).

Outer Harbor geomorphology suggests three sub-regions: the main deep portion of the Outer Harbor, the margins of the Outer Harbor along the base of the reef slopes, and Faga'alu Bay. The samples from Faga'alu Bay were different than most of the Outer Harbor samples, with coarser material and a noticeable odor. The samples from the deeper portions of the Outer Harbor were similar in texture and other characteristics compared to those from along the margins of the reef slopes. Outer Harbor sediments are similar to the Middle Harbor sediments and typically more uniform (fine sand and silt) except for the somewhat coarser material from Faga'alu Bay. The uniform thickness of these deposits and the manner in which they drape over the lower slope is indicative of deposition in a deep-water marine environment.

3.2 General Sediment Characteristics

In addition to the overall sediment textural characteristics described in Section 3.1 above, a number of general descriptive parameters were analyzed for all samples that were analyzed for any of the potential COCs throughout the Harbor. The following parameters provide evidence of a transitioning trend from terrigenous (watershed derived) sediment in the Inner Harbor to biogenous (marine calcareous) sediments in the middle and outer Harbor:

- Calcium concentration was measured since it is an indicator of the relative contribution of marine versus watershed derived sediments.

- Percent total solids provide information concerning the depositional history and type of sediment.

- Total organic carbon (TOC), total volatile solids (TVS), and sulfide characterize the origins of the sediment and the chemical and biological environment within the sediment deposits.

These parameters vary along the longitudinal (central) axis of the harbor and reflect the origins of the sediments. In addition, detailed grain size analysis was conducted for each of the samples analyzed for any of the COCs, and these data are provided in the reports for each of the study elements.

Figure 3-2 shows the variation of calcium along the longitudinal axis of the Harbor for the surfical grab samples collected for Study Element 1. Points labeled centerline are in the middle fifty percent of the Harbor width and those labeled southwest and northeast are along the margins (within 25 percent of the Harbor width from the shorelines). Marine derived sediments in the Harbor, from coral reefs and the shells of marine organisms, are largely calcium carbonate. Therefore, the calcium concentration is a good indicator of sediment source. The trend shown in Figure 3-2 indicates that in the Outer Harbor, starting at about 7500 feet from

the head of the harbor, the sediments are essentially all marine derived with little terrigenous input. Through the Middle Harbor and Inner Harbor, the amount of calcium drops steadily towards the head of the Harbor (distance of 0 feet in Figure 3-2) indicating an increasing influence of watershed derived (mineral and organic) sediments.

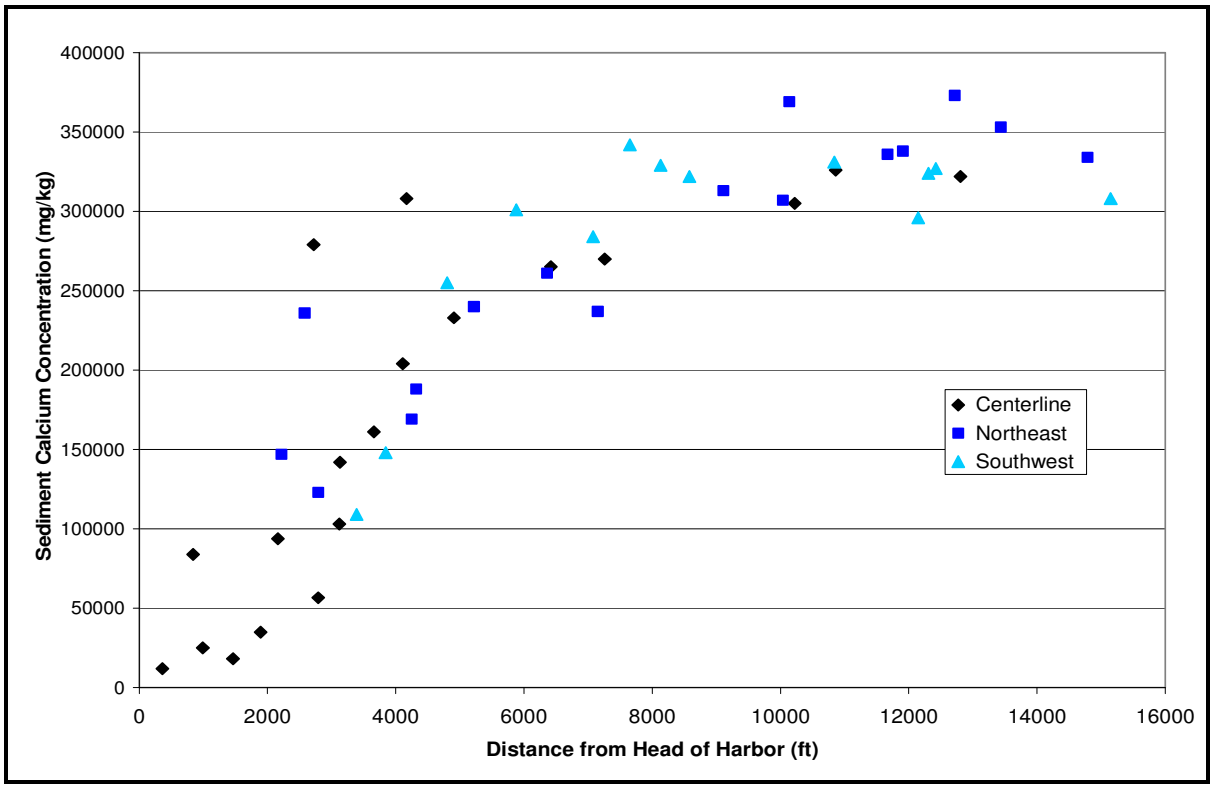

Figure 3-2. Longitudinal Variation of Sediment Calcium Concentrations

Variations of calcium with depth in sediment cores were also observed. The longest core from Station STC 2 (STC-2vc, samples designated as STC-20# - See Figure 2-1) is of particular interest because this core is from the sediment basin at head of the Inner Harbor (HHSP). The sediment basins in the Inner Harbor act as natural sediment traps and provide a record of watershed derived sediments and anthropogenic influence. The calcium concentration with depth in the core is shown in Figure 3-3. There is a rapid change of calcium concentration in the upper 60 cm of the core, increasing with depth in the sediments. It is noted that a distinct horizon was visible in the core at approximately 50 cm to 70 cm from the top of the core. This is reasonably interpreted as a delineation of the initiation of significant and substantial disturbance in the watershed. The calcium concentration at the bottom of this core likely represents an undisturbed watershed. Although the calcium concentration at depth in the core is not as high as in Outer Harbor samples, it would not be expected to be marine dominated near the head of the Harbor, even without anthropogenic influences.

Review of the percent solids, TOC, TVS, and sulfide concentrations indicate that all are consistent with the interpretation of the calcium data. Of this group of parameters, TOC is likely of most interest since it is clearly indicative of recent watershed inputs to the sediments. The variation of TOCalong the Harbor axis is shown in Figure 3-4. TVS and sulfide concentra-

tions show the same trend. Total solids show, as expected, an inverse trend (see Study Element 1).

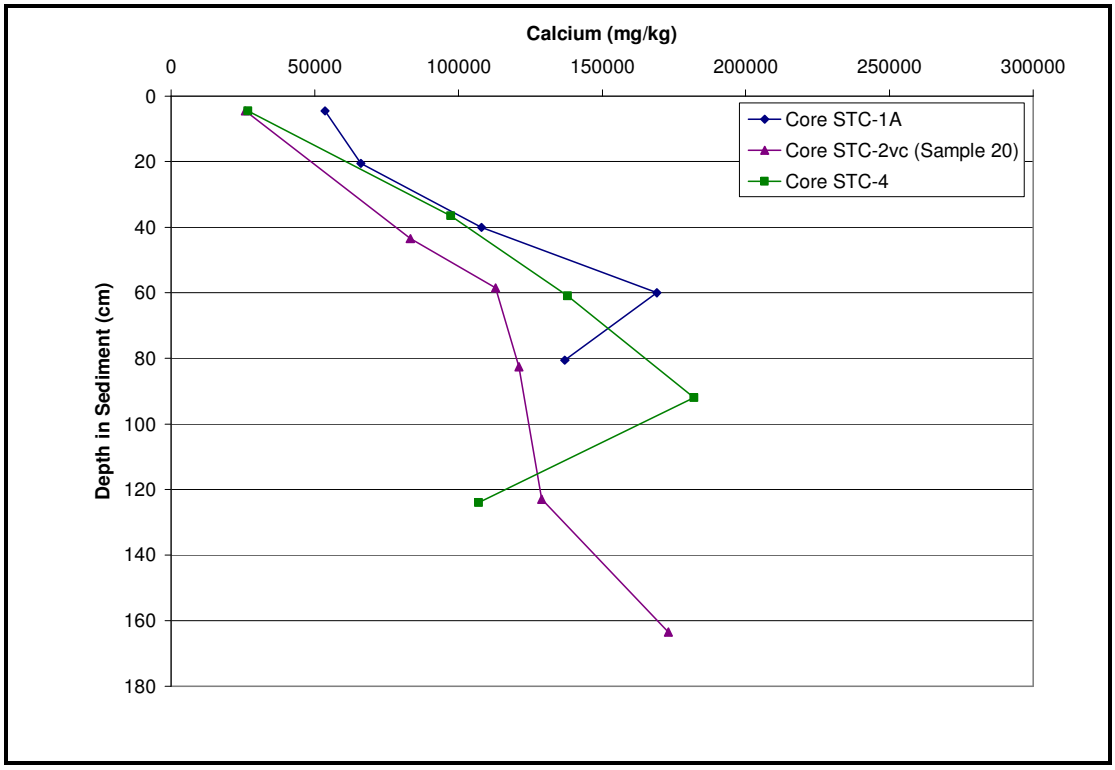

Figure 3-3. Calcium Concentrations in Inner Harbor Cores

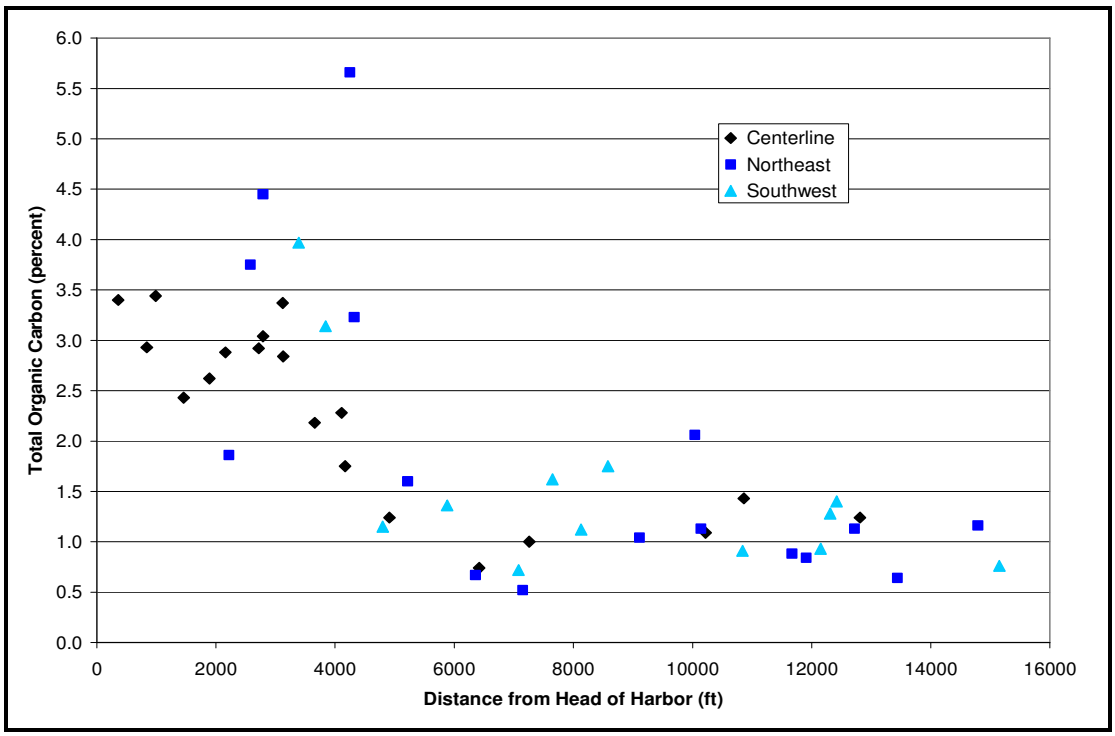

Figure 3-4. Longitudinal Variation of Total Organic Carbon

3.3 COC Concentrations and Observed Distributions

Sediment samples at selected stations throughout the Harbor were analyzed for nutrients, metals, pesticides, polychlorinated biphenyls (PCBs), semi-volatile compounds, volatile compounds, and other COCs (cyanide, organotins, and dioxins). The following sections summarize the results and the relevant findings. Refer to Figure 2-1 for station locations. More detailed descriptions and data are provided in the reports for each of the study elements.

3.3.1 Nutrients

Under Study Element 1 total nitrogen (nitrate+nitrite and TKN) and total phosphorous were analyzed in 22 surfical gab samples, 11 of which were from the Inner Harbor. Concentrations of these parameters are distinctly elevated in the Inner Harbor compared to other areas of the Harbor, as shown in Table 3-1. This is consistent with the general sediment characteristics and inferred sediment sources discussed above. It is noted that prior to 1990 the tuna canneries discharged wastewater into the Inner Harbor in the vicinity of Stations 29 and 30 (refer to Figure 2-1) where the highest nitrogen concentrations were reported (1830 and 4130 mg/kg, respectively). After that time, "high strength" waste was segregated and disposed of at sea under a Special Ocean Disposal Permit, and the remaining waste stream is currently diverted to a new outfall in the Outer Harbor. The distribution of excess nutrient concentrations in the Inner Harbor sediments may reflect effects of this past discharge, but as described below, the stream sediments are also a source of nutrients. The phosphorus concentrations are also observed to increase substantially in the Inner Harbor compared to locations in the Middle and Outer Harbor, but tend to increase even more near the head of the Inner Harbor.

Table 3-1.
Summary of Pago Pago Harbor Sediment Nutrient Data

Location	Number of Samples Analyzed	TKN (mg/Kg)		Total Phosphorus (mg/Kg)	
		Average	Range	Average	Range
Outer Harbor	8	540	(284 - 977)	2.3	(1.4 - 3.1)
Middle Harbor	3	856	(548 - 1030)	2.6	(1.8 - 3.3)
Inner Harbor	11	1668	(1070 - 4130)	164	(1.7 - 672)

Nitrate+nitrite not detected in any sample.

Core samples collected for Study Element 3 near the head of the Harbor, in the HHSP, (Stations STC-2 and STC 4) indicated TKN (Figure 3-5) and total phosphorous (Figure 3-6) levels at depth in the sediment are equivalent to levels observed in the Middle and Outer Harbor from surficial and core samples.

Nitrogen and phosphorous were analyzed in five stream samples. TKN concentrations ranged from 208 mg/Kg to 3470 mg/Kg and total phosphorous ranged from 307mg/Kg to 2460 mg/Kg. The TKN concentrations from the stream samples are consistent with those typically measured in Inner Harbor surficial sediments. Total phosphorus concentrations are similar to, although somewhat higher, than those found in the Inner Harbor surficial sediments.

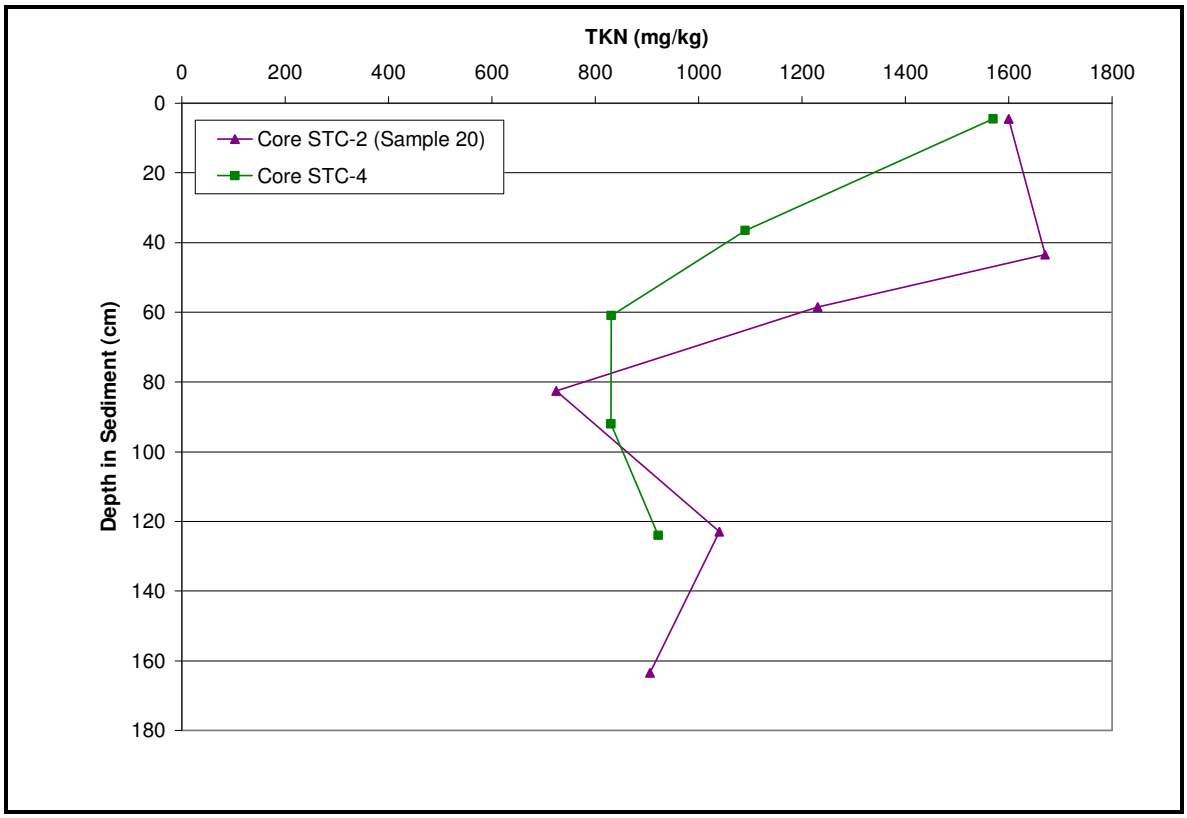

Figure 3-5. Nitrogen (TKN) Concentrations at HHSP Stations

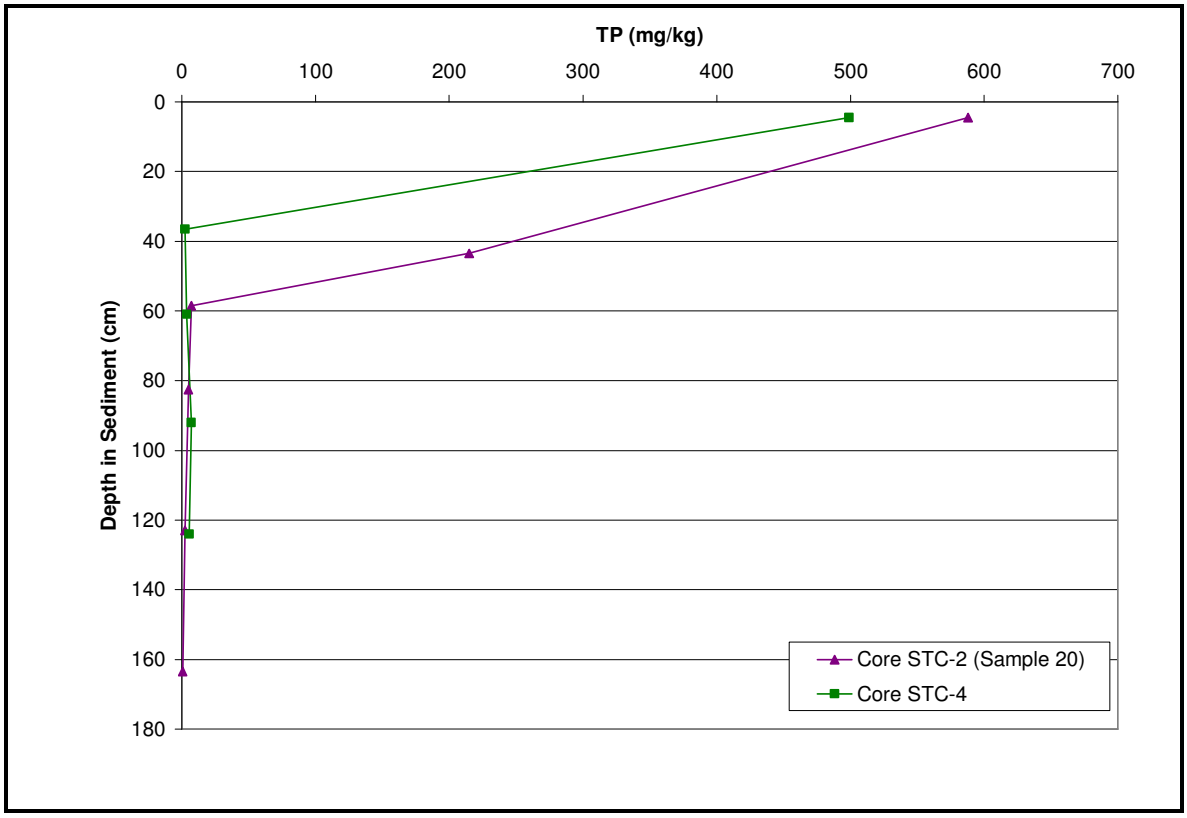

Figure 3-6. Phosphorous (TP) Concentrations at HHSP Stations

3.3.2 Metals

A suite of metals of particular concern was analyzed in samples from 10 stations in the Outer and Middle Harbor and from 11 stations in the Inner Harbor during the Sediment Screening Study (Study Element 1). These data are summarized in Table 3-2. These metals included arsenic, chromium, copper, lead, nickel, zinc, and mercury. Of particular interest were arsenic, lead, and mercury because these were detected during studies of fish tissue concentrations from the Inner Harbor. In all cases there is a distinct trend in concentration from lower to higher in samples going from the Outer Harbor to the Inner Harbor, with maximum concentrations for some metals (zinc and copper in particular) in the vicinity of the old, no longer used, cannery outfalls. However, as discussed in Section 3.4 below, the concentrations measured are not of significant concern in terms of biological or human health.

Table 3-2
Pago Pago Harbor Sediment Metals Data– Sediment Screening Study

	Arsenic (mg/Kg)	Chromium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Mercury (mg/Kg)	Nickel (mg/Kg)	Zinc (mg/Kg)
Outer Harbor (8 samples)							
Minimum	2.3	6.49	2.85	2.28	0.017	8.66	31.7
Maximum	9.1	21.4	9.67	12.7	0.032	15.0	376
Average	5.5	14.4	5.27	6.48	0.025	11.6	108.3
Std Dev	2.2	4.58	2.36	3.78	0.011	2.05	118.5
Middle Harbor (2 samples)							
Minimum	7.2	13.8	15.0	15.5	0.084	13.1	87.3
Maximum	8.8	29.4	40.0	17.2	0.084	21.2	365
Average	8.0	21.6	27.5	16.4	0.084	17.2	226
Inner Harbor (1 samples)							
Minimum	4.4	27.5	39.3	28.4	0.036	23.3	238
Maximum	32.4	98.9	490	305	0.189	59.5	2410
Average	13.4	50.6	142	105.1	0.129	40.6	568
Std Dev	7.7	24.2	152	87.6	0.071	13.3	655

A total of 28 core samples from 8 stations, primarily from the Inner Harbor, collected under Study Element 3, were analyzed for metals. Examination of metals concentrations indicates that the higher values tend to be near the sediment surface or just below the sediment surface; this is particularly striking in the samples from the Station STC-2 in the HHSP. This could possibly indicate improving conditions in the sediments, although the variations are not always large. Metals of particular concern are arsenic, mercury, and lead, based on fish tissue studies. The data for these constituents are shown graphically in Figures 3-7, 3-8, and 3-9, respectively, for the samples from the HHSP.

The metals concentrations in the stream samples collected under Study Element 4 were similar to the concentrations found in the previous study elements (Table 3-3). Stream Station S1-2 (discharging to Faga'alu Bay) had considerably lower concentrations of all metals than the other stream monitoring stations. This watershed is considerably less developed than those drained by the other streams. Harbor samples from Study Element 4 were similar to those from Study Element 1 and metals in pore water samples were consistently below water quality criteria.

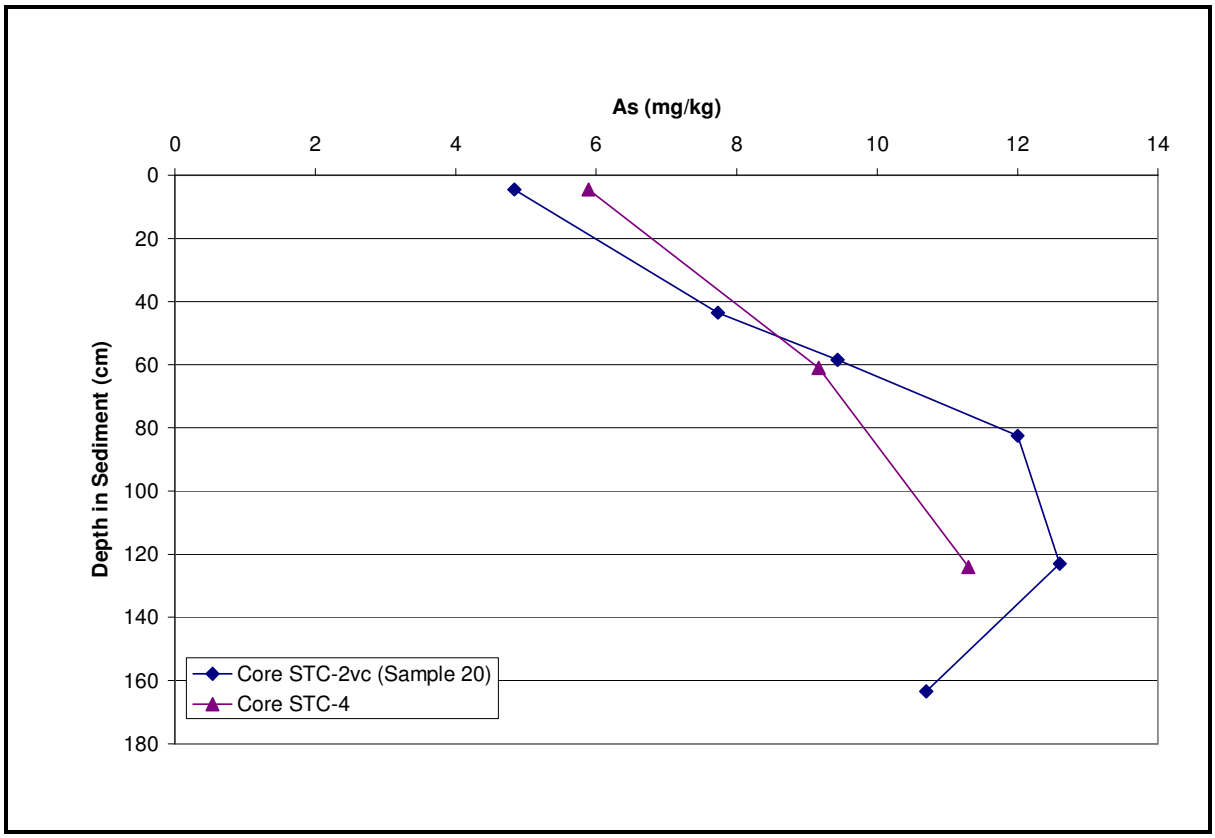

Figure 3-7. Arsenic Concentrations in Two Cores from the HHSP

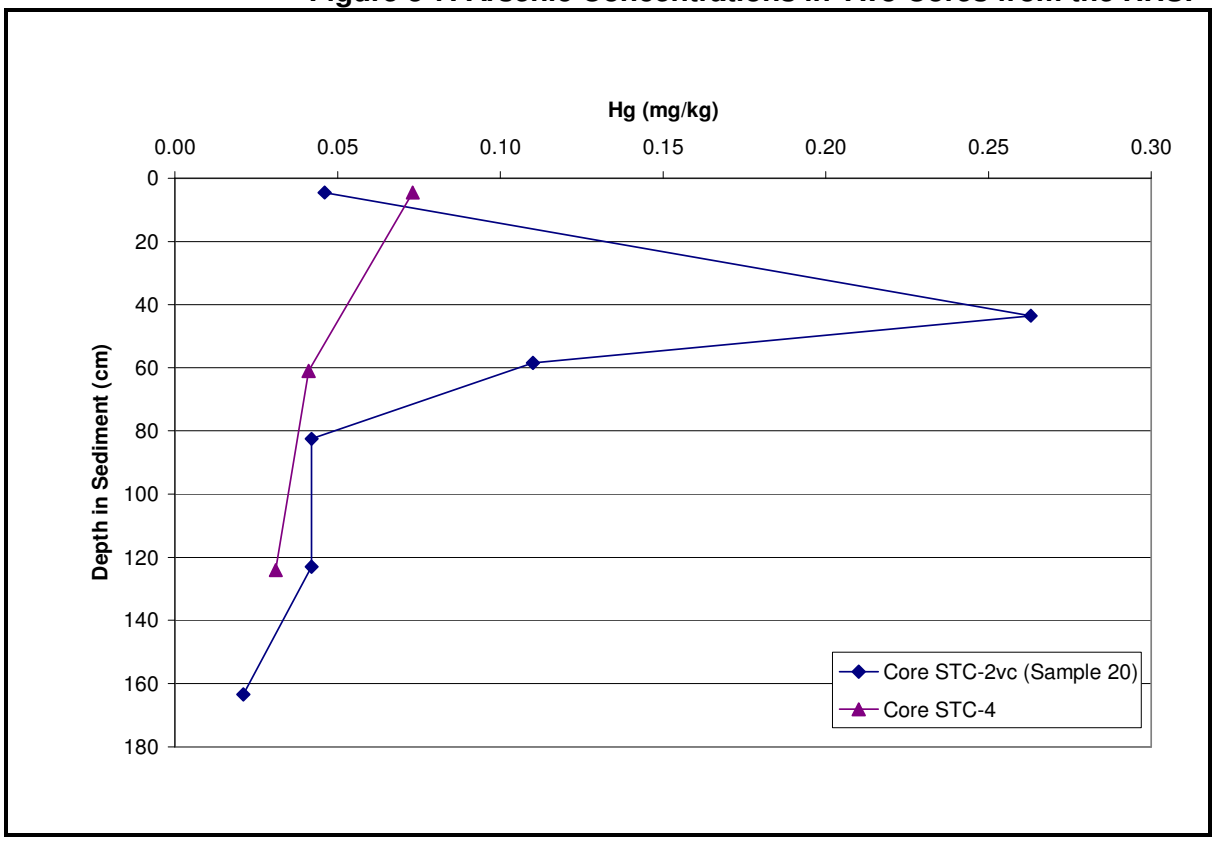

Figure 3-8. Mercury Concentrations in Two Cores from the HHSP

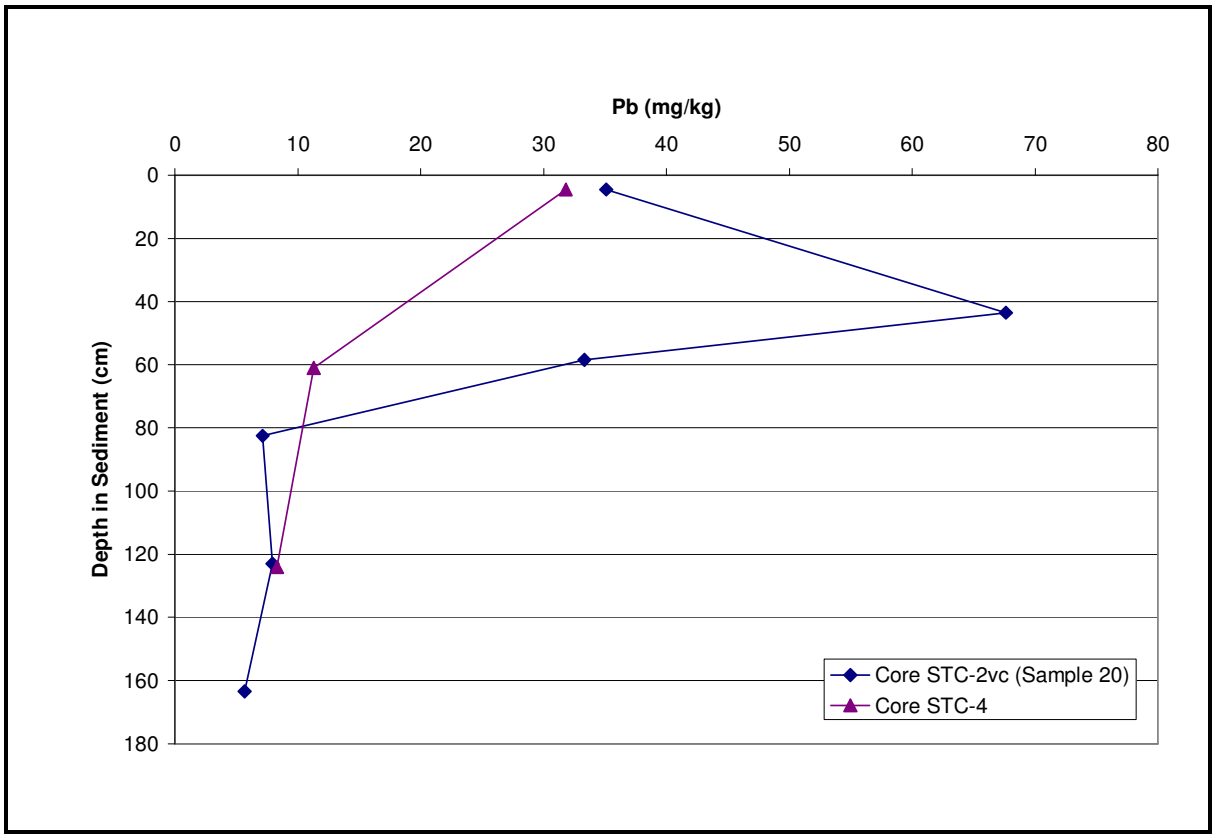

Figure 3-9. Lead Concentrations in Two Cores from the HHSP

Table 3-3
Stream Sediment Metals Data

	Arsenic (mg/Kg)	Chromium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Mercury (mg/Kg)	Nickel (mg/Kg)	Zinc (mg/Kg)
Min.	0.65	1.29	2.79	4.17	0.02	1.83	134.00
Avg.	2.09	61.70	40.38	67.31	0.06	75.63	310.20
Max.	4.35	159.00	83.20	149.00	0.10	139.00	645.00
StDev.	1.52	63.36	30.61	60.72	0.04	60.93	210.05

3.3.3 Pesticides

The priority pollutant pesticides listed in Table 3-4 were analyzed in surficial grab samples from four stations in the Outer Harbor and six stations in the Inner Harbor. A total of six priority pollutant pesticides were detected in the Outer Harbor and eight in the Inner Harbor (Table 3-5).

In the Outer Harbor DDT was detected at three stations and DDD (a decay product of DDT) was detected at two of those stations. DDE, another decay product of DDT, was detected at one station. All three of these parameters were detected at Station 3 in Faga'alu Bay, and may reflect runoff from the stream that drains into this feature. The other station where two

of these parameters were detected, Station STS-9, is in the vicinity of the Utulei WWTP outfall. Three other pesticides were detected, at low levels, at Station STS-3.

In the Inner Harbor, DDT was detected at all six stations with a clear trend in increasing concentrations towards the head of the Harbor. This probably reflects runoff from the stream entering the Harbor at this point. DDD and DDE were detected at five of the six stations (see Table 3-5). Three other pesticides were detected at one to four stations at low levels.

Table 3-4
Organochlorine Pesticides Analyzed in Pago Pago Harbor Sediments

alpha-BHC	Heptachlor Epoxide	Endrin	Endrin Ketone
beta-BHC	gamma-Chlordane	Endosulfan II	Methoxychlor
gamma-BHC (Lindane)	Endosulfan I	4,4'-DDD	Toxaphene
delta-BHC	alpha-Chlordane	Endrin Aldehyde	
Heptachlor	Dieldrin	Endosulfan Sulfate	
Aldrin	4,4'-DDE	4,4'-DDT	

Table 3-5
Pago Pago Harbor Sediment Organochlorine Pesticide Data – Sediment Screening Study

Outer Harbor				
Pesticide (µg/Kg)	**STS-3**	**STS-5**	**STS-9**	**STS-11**
alpha-BHC	**0.25 J,P**	0.13 U	0.28 U	0.13 U
alpha-Chlordane	**0.17 J**	0.096 U	0.095 U	0.093 U
4,4'-DDE	**0.61 J**	0.12 U	0.12 U	0.12 U
4,4'-DDD	**1.4 =**	0.15 U	**0.16 J**	0.14 U
4,4'-DDT	**3.2 =**	**0.71 J**	**3.8 =**	0.26 U
Endrin Ketone	**0.54 J,P**	0.092 U	0.090 U	0.089 U

Inner Harbor						
Pesticide (µg/Kg)	**STS-25**	**STS-29**	**STS-34**	**STS-42**	**STS-44A**	**STS-48**
beta-BHC	**1.8 P**	0.55 U	0.58 U	1.9 U,i	0.59 U	1.0 U,i
Heptachlor Epoxide	**0.72 J**	**1.6 =**	**0.61 J**	0.49 U,i	**0.97 J**	1.0 U,i
gamma-Chlordane	0.38 U, i	**2.7 =**	0.87 U,i	0.75 U,i	**1.5 =**	1.6 U,i
4,4'-DDE	**0.45 J,P**	1.0 U, i	**0.60 J,P**	**0.51 J**	**0.86 J,P**	**1.8 =**
4,4'-DDD	0.18 U	**0.27 J,P**	**0.40 J**	**0.52 J**	**0.47 J**	**1.4 P**
Endrin Aldehyde	0.31 U	0.40 U	0.50 U,i	0.44 U	**0.91 J,P**	0.37 U
Endosulfan Sulfate	0.40 U	0.52 U	0.55 U	0.57 U	0.56 U	**0.91 J**
4,4'-DDT	**4.2 =**	**12 =**	**4.5 =**	**4.5 =**	**5.9 =**	**10 =**

Entries in **bold font** indicate the parameter was detected.
J = The result is an estimated concentration that is less than the MRL but greater or equal to the MDL. The MDL is reported.
P = The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 25% between the two analytical results.
U = The compound was analyzed for, but was not detected at or above the MRL/MDL. The MDL is reported.
i = The MRL/MDL has been elevated due to chromatographic interference.

The priority pollutant pesticides were analyzed in six samples from three sediment cores (three stations) in the Inner Harbor. The parameters that were detected are presented in Table (Table 3-6). The results from the core samples near the sediment surface are comparable to the concentrations found during the Sediment Screening Study. The concentrations appear to drop off dramatically with depth in the sediment layer.

Table 3-6
Organochlorine Pesticide Data from Inner Harbor Core Samples

Sample	STC-1C*	STC-4A	STC-4C	STC-11A
Depth in Core	**56-64 cm**	**0-9 cm**	**56-64 cm**	**0-16 cm**
gamma-Chlordane (µg/Kg)		0.84 J	0.51 JP	2.9
4,4'-DDE (µg/Kg)		1.9 P		
Endosulfan II (µg/Kg)		0.38 J		
4,4'-DDD (µg/Kg)		1.8	0.13 J	
4,4'-DDT (µg/Kg)	0.19 JP	11	1.0	5.2 P

J: The result is an estimated concentration that is less than the MRL but greater or equal to the MDL.
P: The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 25% between the two analytical results.
See Table 2-3 for Station Locations. Samples with all parameters not detected are not listed.

Only three of the 21 possible pesticides were detected in the pore water of the Harbor sediments analyzed under Study Element 4: DDT, endosulfan II, and gamma-chlordane (Table 3-7). Except for DDT the detections were low and inconclusive. The detected levels of DDT in the pore water were substantially lower than levels detected in the stream sediments (discussed below) and Harbor sediment concentrations reported in Study Elements 1 and 3.

Table 3-7
Detected Pesticides in Pago Pago Harbor Sediment Pore Water

Station	ST4-44	ST4-43	ST4-30	ST4-5
4,4'-DDT (µg/l)	0.13 =	ND	ND	0.03 =
Endosulfan II (µg/l)	0.02 =, P	ND	ND	ND
gamma-Chlordane (µg/l)	0.04 =, P	ND	ND	ND

"=" value detected
"i" the MRL/MDL has been elevated due to matrix interference.
"P" The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 40% between the two analytical results (25% for CLP pesticides).

The priority pollutant pesticides were analyzed in the stream samples as shown in Table 3-8. Six separate parameters were identified in the stream samples, most notably DDT, and its decay products DDE and DDD. Endrin ketone, gamma-chlordane, and heptachlor epoxide were each detected in one sample, but the detections were estimated values and at low levels. DDT and its decay products (DDE and DDD) were found in stream sediments at considerably higher levels than in Harbor sediments. The results imply a continuing source of DDT from the watershed to the Harbor from ongoing contamination or the residual from previous use of DDT in the watershed. It is also possible that historic quantities of DDT are buried in the watershed uplands.

3.3.4 Polychlorinated Biphenyls (PCBs)

PCBs were analyzed in surficial grab samples from four stations in the Inner Harbor and two stations in the Outer Harbor. Sample were analyzed for Aroclors and 35 PCB congeners. It is the total Aroclors that are of primary interest and will be discussed here. Additional in-

formation can be found in the report for Study Element 1. Aroclor 1260 was detected in all Inner Harbor samples (Table 3-9). This compound was detected a very low and unquantifiable levels at Station 5 in the Outer Harbor. Aroclor 1260 was formerly used in electrical transformers, hydraulic fluids, and certain other applications. The production and sale was discontinued in late 1977, but it was still present in many transformers and capacitors for many years. It is highly likely that transformers, capacitors, or other electrical equipment that contains PCB oil are still in use by the American Samoa Power Authority. It is also highly probable that discarded equipment is buried at unknown sites across the American Samoan islands (personal communication, Peter Peshut, Technical Services Head, ASEPA).

Table 3-8
Detected Pesticides in Stream Sediments

Station	S1-2	S2-2	S3-1	S4-1	S5-1
4,4'-DDD (µg/Kg)	ND	23.0 =	11.0 =	ND	ND
4,4'-DDE (µg/Kg)	ND	21.0 =	12.0 =	1.50 =, J	ND
4,4'-DDT (µg/Kg)	ND	340 =, D	73.0 =	ND	ND
Endrin Ketone (µg/Kg)	ND	1.80 =, JP	ND	ND	ND
gamma-Chlordane (µg/Kg)	1.30 =, J	ND i	ND i	ND	ND
Heptachlor Epoxide (µg/Kg)	ND	2.10 =, J	ND	ND	ND

"ND" the parameter was not detected at the MDL
"=" value detected
"D" The reported result is from a dilution
"J" The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL
"P" The GC or HPLC confirmation criteria was exceeded.

Table 3-9
Pago Pago Harbor Sediment PCB Data – Sediment Screening Study

PCBs (µg/Kg)	Outer Harbor Stations		Inner Harbor Stations			
	STS-5	STS-11	STS-25	STS-34	STS-42	STS-44A
Aroclor 1016	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1221	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1232	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1242	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1248	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1254	2.8 U	2.7 U	3.4 U	4.7 U	4.9 U	4.8 U
Aroclor 1260	**3.1 J**	2.7 U	**44 =**	**48 =**	**39 =**	**85 =**

J = Estimated concentration that is less than the MRL but greater or equal to the MDL. The MDL is reported.
U = The compound was analyzed for, but was not detected at or above the MRL/MDL. The MDL is reported.

PCBs were also analyzed in samples from three cores (a total of ten samples). Results for detected PCBs are shown in Table 3-10 for samples from Station STC-2 (samples STC-20#) in the HHSP and Stations STC-8 offshore of the power generating station and Station STC-9 further offshore of the power station (refer to Figure 2-1 for station locations). Aroclor 1260 and 1248 were detected in the upper portion of the core from Station 2. This is consistent with the Screening Level Study results with similar concentrations. The same compounds were detected at Stations STC-8 and STC-9, also consistent with the results of the Screening Level Study. In the upper sample from Station STC-8 (STC-8A) substantially higher values were reported compared to those from past studies. There appears to be a limited area of high concentrations in a location where past spills may have occurred.

PCBs were not detected in the sediment samples from the streams and only low levels were detected in pore water samples from two stations near the Satala Power Plant. PCBs are essentially insoluble in water, so they are expected to adhere to sediment particles, and not appear in sediment pore water to any significant extent. The analytical data are presented in the reports for the respective study elements.

Table 3-10
PCB Data from Pago Pago Harbor Sediment Core Samples

Station	Harbor Head Sediment Pool							
	STC-20A		STC-20B*		STC-20C		STC-20E	
Depth in Core	0-9		55-62		80-85		160-167	
Aroclor 1248 (µg/Kg)	17	=	12	=	2.6	ND	2.2	ND
Aroclor 1260 (µg/Kg)	30	=	38	=	7.7	=, J	2.2	ND

Station	Inner Harbor Stations near Power Plant											
	STC-8A		STC-8C		STC-8E		STC-9A		STC-9B		STC-9C	
Depth in Core (cm)	3-16		43-57		87-100		0-20		58-72		93-118	
Aroclor 1248 (µg/Kg)	130	=, P	2.5	ND	2.5	ND	9.9	=, J	2.4	ND	2.3	ND
Aroclor 1260 (µg/Kg)	650	=	18	=	2.5	ND	34	=	2.4	ND	2.3	ND

J: The result is an estimated concentration that is less than the MRL but greater or equal to the MDL. The MDL is reported.
ND: The compound was analyzed for, but was not detected at or above the MRL/MDL. The MDL is reported.
P: The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 25% between the two analytical results.

3.3.5 Semi-volatile Compounds

Semi-volatile compounds were analyzed in samples from five Outer Harbor stations and six Inner Harbor stations in the surficial sediment samples under Study Element 1. In general more compounds were detected and at higher concentrations in the Inner Harbor than in the Outer Harbor. The number of compounds detected and the respective concentrations tend to increase toward the head of the Harbor. The majority of the compounds detected are PAH's. Semi-volatile compounds were analyzed in eight samples from three cores (the same samples analyzed for pesticides discussed above). Most of the compounds detected were PAHs and the results are similar to those from the Sediment Screening Study. There were no parameters of this class detected that are of concern. The data are provided in the respected reports for each study element.

3.3.6 Volatile Compounds

Volatile compounds were analyzed in the same Study Element 1 surfical grab samples as the semi-volatiles. Only acetone and methylene chloride were detected, and these substances were detected at low levels in every sample analyzed, Acetone may be an analytical artifact. Methylene chloride is a commonly used paint stripper, and its presence may indicate improper disposal in the watershed uplands. There were no core samples analyzed for these parameters.

3.3.7 Other COCs

In addition to the parameters described in the sections above, cyanide, organotins, and dioxins were analyzed in selected samples. Cyanide was analyzed in two surficial grab samples: a reference station in the Outer Harbor (STS-5) and a representative station in the Inner Harbor (STS-52). Cyanide was not detected at either station.

Butyltin was analyzed in grab samples from one station in the Outer Harbor and seven stations in the Inner Harbor. Tri-butyltin and Di-butytin were detected in all Inner Harbor samples analyzed (Table 3-11). Maximum concentrations were centered on Stations 43 and 43A which are close to the ship repair facility. Butyltin was also analyzed in samples from two cores taken near the ship repair facility. Tri-butyltin was detected in all samples from the core at Station STC-8 and from the topmost sample from Station STC-9 as shown in Table 3-12. The values detected were not as high as many of the concentrations reported for the surficial samples collected during the Sediment Screening Study.

Table 3-11
Pago Pago Harbor Sediment Butyltin Data – Sediment Screening Study

Parameter (µg/Kg)	Outer Harbor	Inner Harbor						
	STS-5	STS-34	STS-41	STS-42	STS-43	STS-43A	STS-44A	STS-48
Tetra-n-butyltin	0.19 U	3 =	0.6 J	0.39 J	100 =	64 =	1.1 J	0.28 U
Tri-n-butyltin	0.62 J	64 =	19 =	17 =	2400 D	1300 D	28 =	12 =
Di-n-butyltin	0.75 J	14 =	7.2 =	9.9 =	430 D	230 D	18 =	13 =
n-Butyltin	0.22 J	2.1 J	1.9 J	5.1 =	130 =	66 =	5.2 =	2.7 =

J= The result is an estimated concentration that is less than the MRL, but greater than or equal to the MDL
D= Reported amount is from a dilution of 100:1
U= The compound was analyzed for, but was not detected at or above the MRL or MDL

Table 3-12
Tri-butyltin Data from Inner Harbor Core Samples

Station	STC-8A	STC-8C	STC-8E	STC-9A	STC-9B	STC-9C
Depth in Core (cm)	3-16	43-57	87-100	0-20	58-72	93-118
Tri-butyltin (µg/Kg)	56 =	1.2 =, J	0.57 =, J	3.5 =	**0.10** ND	**0.099** ND

"=": The parameter was detected at the concentration shown
J: The result is an estimated concentration that is less than the MRL but greater or equal to the MDL. The MDL is reported.
U: The compound was analyzed for, but was not detected at or above the MRL/MDL. The MDL is reported.

Dioxins were analyzed in a surficial grab sample from the Inner Harbor (STS-44) and in two core samples in the Inner Harbor at Station STC-4, near the sediment surface (STC-4A) and 125 cm below the surface (STC-4E). Results are shown in Table 3-13. The results for the topmost core sample were similar to those from the surficial grab sample analyzed during the Sediment Screening Study from the same general location. The specific dioxins and furans detected have relatively low toxicity compared to TCDD, and are typically associated with incinerated plastics.

3.4 Assessment of Significance of COCs

The data collected during the various elements of the Sediment Toxicity Study for Pago Pago Harbor clearly indicate the influence of anthropogenic activity in both the general sediment characteristics and the levels and type of contaminants present. The sediment texture, organic content, and calcium concentrations indicate that the Outer Harbor sediments are essentially marine sediments with a much lower level of contamination than the Inner Harbor sediments. Fine sediments with associated contaminants are not introduced into the Outer Harbor, or are flushed from the Outer Harbor prior to settling on the seabed, or a combination of both. The vertical distribution of these parameters also indicates the association of contaminants with recent Inner Harbor sedimentation. Sediments buried more than about 100 to 150 centimeters appear to exhibit natural background levels of COCs.

Table 3-13
Pago Pago Harbor Sediment Dioxin Data

Parameter	Concentration (ng/Kg)		
	STS-44 Feb 2004	STC-4A Mar 2005	STC-4E Mar 2005
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	0.322 U	0.059 U	0.032 U
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDD)	0.453 U	0.542 JK	0.049 U
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	0.414 U	0.895 JK	0.056 U
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	0.366 U	4.721 =	0.051 U
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (HxCDD)	0.391 U	4.027 JK	0.052 U
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (HpCDD)	7.155 =	138.595 B	0.817 BJ
Octachlorodibenzo-p-dioxin (OCDD)	55.352 B	1155.010 B	5.893 BJ
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	0.268 U	1.355 J	0.112 U
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	0.346 U	0.577 JK	0.026 U
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	0.338 U	0.545 JK	0.025 U
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	0.353 U	1.655 JK	0.027 U
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	0.351 U	1.131 JK	0.027 U
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	0.465 U	0.230 JK	0.032 U
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)	0.392 U	0.573 JK	0.029 U
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	1.107 J	14.728 =	0.349 J
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)	0.969 U	1.673 JK	0.055 U
Octachlorodibenzofuran (OCDF)	1.729 U	35.525 =	0.463 JK
Tetrachlorodibenzo-p-dioxins (TCDD), Total	0.322 U	1.284 =	0.032 U
Pentachlorodibenzo-p-dioxin (PeCDD), Total	0.453 U	9.294 =	0.049 U
Hexachlorodibenzo-p-dioxins (HxCDD), Total	2.237 =	64.495 =	0.282 =
Heptachlorodibenzo-p-dioxins (HpCDD), Total	19.108 =	347.032 =	1.955 =
Tetrachlorodibenzofurans (TCDF), Total	0.268 U	6.398 =	0.112 U
Pentachlorodibenzofurans (PeCDF), Total	0.338 U	9.168 =	0.025 U
Hexachlorodibenzofurans (HxCDF), Total	0.351 U	17.580 =	0.027 U
Heptachlorodibenzofurans (HpCDF), Total	3.008 =	66.494 =	0.349 =

B= Analyte found in blank as well as the sample
K= Estimated maximum possible concentration for the associated compound
J= Estimated value, concentration is below the method reporting limit and above the detection limit
U= Compound was analyzed but not detected

The concentrations of all COCs analyzed are reflected in the apparent sediment sources, with higher values consistently in the upper layers of Inner Harbor sediments, and are apparently derived from activities on land within the watershed. There are no regulatory criteria or water quality standards applicable to marine sediments that are similar to water quality criteria. Metals, PCBs, and DDT were the only COCs that indicate levels that might be of potential concern compared to various guidance criteria such as the National Atmospheric and Oceanic

Administration's (NOAA) apparent effects threshold (AET). These possibly elevated levels of COCs were all found in the upper layers of sediment in the Inner Harbor region. The vertical extent of elevated concentrations of COCs is relatively thin.

Table 3-14 provides a comparison of concentrations reported in sediment samples and screening guidelines developed by NOAA. The screening quick reference tables (SQuiRTs) developed by NOAA do not represent official NOAA policy and are not intended for regulatory purposes. The SQuiRTs are intended for preliminary screening to identify potential concerns for additional consideration. Listed in Table 3-14 are the following concentrations:

- Threshold Effects Level (TEL): the level below which adverse effects are not expected
- Probable Effects Level (PEL): the level above which adverse effects are frequently expected
- Apparent Effects Threshold (AET): the level above which biological effects are always expected (however, note that the lowest AET is listed and represents affects on only the most sensitive organisms)
- Effects Range-Low (ERL): the lowest 10th percentile concentration of the availed toxicity data that indicates toxic effects (the level at which effects might be expected to appear for the most sensitive species)
- Effects Range-Median (ERM): the median concentration of available toxicity data that indicates toxic effects (screened to remove those samples not displaying toxicity)

A review of the data in Table 3-14 indicates concentrations of the COCs in Harbor and stream sediments that generally exhibit relatively low or no effects of toxicity based on available data. The notable exceptions are as follows:

- Sporadic and isolated samples with concentrations of chromium in the Harbor and stream sediments above the AET, but below the PEL
- Sporadic and isolated Harbor surface sediment samples with concentrations of copper above the AET and PEL
- Sporadic and isolated samples with concentrations of lead above the above the PEL but below the AET in Harbor surface sediments and stream sediments.
- Sporadic and isolated samples with concentrations of nickel above the above the PEL but below the AET for Harbor sediments and above the AET and PEL for stream sediments.
- Concentrations of selenium, but with very limited data, at about the AET (within the analytical variability)
- Sporadic and isolated samples of zinc with concentrations of zinc above the AET and PEL in Harbor and stream sediments.

- Concentrations of PCBs isolated in a small area of the Inner Harbor with concentrations from one sample exceeding the AEL and PEL.
- Concentrations of DDT in stream sediments from two streams exceed the AET and PEL

Table 3-14
Comparison of Selected Parameters with Screening Level Criteria

Parameter	Guidance Criterion					Surficial Samples		Core Samples			
	TEL	ERL	PEL	ERM	AET	Inner Harbor Maximum	Inner Harbor Average	Maximum	Station	Depth In Core (cm)	Average
Metals (ppm)											
Arsenic	7.2	8.2	41.6	70	35	32.4	13.4	14.3	STC-8C	3-16	10.3
Cadmium	0.676	1.2	4.21	9.6	3	0.3					
Chromium	52.3	81	160.4	370	62	98.9	50.6	53.7	STC-20B	40-47	36.3
Copper	18.7	34	108.2	270	390	490	142	61.2	STC-8A	3-16	21.6
Lead	30.42	46.7	112.18	218	400	305	105.1	67.6	STC-20B	40-47	23.4
Mercury	0.13	0.15	0.696	0.71	0.41	0.189	0.129	0.368	STC-8A	3-16	0.104
Nickel	15.9	20.9	42.8	51.6	110	59.5	40.6	40.1	STD-5D[+]	57-62	31.3
Selenium						1.4		1.4	STC-20A	0-9	0.78
Silver	0.73	1	1.77	3.7	3.1	0.25					
Tin (as TBT)					>3.4	2.4	0.55	0.056	STC-8A	3-16	0.001
Zinc	124	150	271	410	410	2410*	384**	252	STC-8A	3-16	115.1
Organic Compounds (ppb)											
PCBs[++]	21.55	22.7	180	188.79	130	114	81	794	STC-8A	3-16	109
DDT	3.89	1.58	46.1	51.7	11	12	6.9	5.2	STC-11A	0-16	1.8

* Identified as potential outlier
** Average calculated without potential outlier
[+] Next highest value is 38.8 ppm at STC-20B
[++] Expressed as the sum of all Alochlors listed, using MDL concentration when not detected.

3.5 Source, Fate, and Transport of COCs

There appear to be predominately two major origins of Pago Pago Harbor sediments: terrigenous sediments from the watershed are derived from relatively recent volcanic soils, and the biogenous calcium carbonate fraction, mostly derived from the fringing coral reefs. Most of the contaminants are derived from past and current watershed activities and legacy point sources (municipal, industrial, and commercial sources) adjacent to the Harbor and correlate well with the non-calcium carbonate sediment fraction. As described in the Sediment Screening Study, the dominance of marine derived biogenous sediments increases moving from the head to the mouth of the Harbor. Visual observations of the sediments clearly indicate a nearly "pure" marine source in the Outer Harbor. This appears to be confirmed by the vertical distribution of calcium as well. Sediments in the Inner Harbor exhibit a significant

increase in calcium concentration with depth, indicating recent increases in the fraction of terrigenous sediments from the watershed consistent with anthropogenic disturbance.

The following observations can be supported concerning the sources, sinks, and transport paths of the COCs:

- Metals are derived in part from natural sources in the watershed but have apparently been elevated by anthropogenic activities throughout the watershed and from specific point sources. The point sources appear to be related to the Satala Power Plant, the South West Marine Shipyard, and potentially the abandoned cannery outfalls (for copper and zinc). There is also potential past contamination from the period in late 19th and early 20th centuries when a U.S. Navy coaling station was operated in the Harbor. The implied transport path, based on general concentration gradients, from west to east, however, masks any definitive conclusion concerning relative contributions based on the available data. Streams are also a source of heavy metals. In general, metals appear to be concentrated in the Inner Harbor with little subsequent transport once deposited on the seabed. The exception to this may be in the vicinity of the areas with large vessel operation (cannery docks, shipyard) which can disturb sediments in shallow water. The disturbed sediments are then transported to deeper water where they are generally not further disturbed.

- DDT appears to be watershed derived and the data collected indicate the Vialoa and Fagotogo watersheds are actively contributing DDT contaminated sediments at relatively high concentrations. The limited data that shows increasing concentrations with depth in the sediment may indicate that the contaminated sediments delivered in the past are being buried by more recent sediments. Except in areas with ship operations, which are typically not near stream mouths, the DDT contaminated sediments are not expected to disperse after settling to the seabed.

- The origin of the PCBs appears to be linked to the Satala Power Plant, with maximum concentrations just offshore. The extent of contamination appears to be very limited in area; however, ship operations may be responsible for remobilizing contaminated sediments and making them available for transport.

All COCs are elevated in the Inner Harbor, with little contamination in the Outer Harbor. This reflects the overall sources of the COCs and indicates little subsequent transport following sedimentation. This is consistent with the weak tidal and wind driven currents in the Harbor which are not sufficient to mobilize sediments. Most of the Harbor is too deep for wave action to mobilize sediments except on the reef flats. Except for limited areas of ship operations in shallow water, there is little further transport of contaminated sediments, once they are deposited in deep water. The data appears to indicate that the rate of introduction of contaminants is decreasing and in many cases the maximum COC concentrations are below the sediment surface, indicating natural burial.