A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Sediment Quality on the West Side of Inner Fidalgo Bay

Abstract

Potentially toxic metals and organic compounds were analyzed in five sediment samples collected along the west side of inner Fidalgo Bay in October 1999. This work was done in connection with the Washington State Department of Natural Resources plans to purchase and protect the inner bay. Results showed no significant contamination. The property has since been purchased.

Summary

The Washington State Department of Ecology (Ecology) Environmental Assessment Program (EAP) conducted a series of chemical analyses on intertidal sediment samples collected from five sites along the west shoreline of inner Fidalgo Bay on October 22, 1999. This work was done for the Washington State Department of Natural Resources (DNR) Aquatic Lands Division and the Ecology Spills Prevention, Preparedness, and Response Program. DNR was negotiating purchase of 450 acres of inner Fidalgo Bay for protection and needed to determine if there was widespread sediment contamination that posed a threat to Fidalgo Bay resources. A previous EAP survey had analyzed sediment quality in other parts of Fidalgo Bay.

Chemicals analyzed included priority pollutant metals, semivolatiles, polyaromatic hydrocarbons (PAH, NOAA list), polychlorinated biphenyls (PCBs), and total petroleum hydrocarbons (TPH). Samples from the head of the bay were analyzed for chlorinated pesticides and screened for the presence of organophosphorus- and nitrogen-containing pesticides. Grain size, total organic carbon, and percent solids were also determined on all samples.

The sediments at all five sites appeared generally similar, both physically and chemically. Metals concentrations were comparable to those in other parts of Fidalgo Bay and Padilla Bay. Twenty-one organic compounds were detected in the semivolatiles analysis. Most of these have been detected elsewhere in Fidalgo Bay and are routinely reported in Puget Sound sediments. Concentrations were generally less than 100 ug/Kg (parts per billion). Sixteen of these were

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PAH; the distribution pattern suggested combustion sources rather than petroleum. Results from the more extensive analysis for NOAA PAH were in good agreement with PAH data obtained through the semivolatiles analysis.

No PCBs or pesticides were detected in any of the sediment samples. There was no petroleum detected in the TPH analysis.

All chemical concentrations detected in Fidalgo Bay samples were well within Ecology's Sediment Management Standards (WAC 173-204). In most instances, concentrations were one-to-two orders of magnitude below the Sediment Quality Standard (SQS) chemical criteria, levels at which adverse effects on biological resources are not expected to occur.

Most of the chemicals detected in inner Fidalgo Bay were at concentrations similar to or only slightly higher than those in reference sediments from Samish Bay, nine miles to the north. Samish Bay is an established sediment reference area known to have a low level of sediment contamination with no significant toxicity.

These results show no evidence of significant chemical contamination in sediments on the west side of inner Fidalgo Bay.

Project Description

The Washington State Department of Ecology (Ecology) Environmental Assessment Program (EAP) conducted a series of chemical analyses on intertidal sediment samples collected from five sites along the west shoreline of inner Fidalgo Bay on October 22, 1999 (Figure 1). This work was done for the Washington State Department of Natural Resources (DNR) Aquatic Lands Division and the Ecology Spills Prevention, Preparedness, and Response Program (SPPR). DNR was negotiating purchase of 450 acres of inner Fidalgo Bay for protection and needed to determine if there was widespread sediment contamination that posed a threat to Fidalgo Bay resources. The purchase of this property has since been completed. A previous survey by EAP (Johnson et al., 1997) had analyzed sediment quality in the central and eastern portions of the bay, also shown in Figure 1.

Chemicals analyzed included priority pollutant metals, semivolatiles, polyaromatic hydrocarbons (PAH, NOAA list), polychlorinated biphenyls (PCBs), and total petroleum hydrocarbons. Samples from sites #4 and #5 at the head of the bay were analyzed for chlorinated pesticides and screened for the presence of organophosphorus- and nitrogen-containing pesticides. Grain size, total organic carbon, and percent solids were also determined on all samples.

Methods

Sampling methods followed PSEP (1996) protocols and SMS requirements (Ecology, 1995a,b). Sampling site coordinates were recorded using a hand-held GPS. Sediments were collected by hand with stainless steels scoops and consisted of the top 10 cm surface layer. The samples were collected in a 2-meter wide "star" pattern used by the SPPR for intertidal sediment sampling (Davis, 1999).

The sediments were homogenized by stirring in stainless steel bowls. Subsamples of the homogenate were placed in glass jars with teflon lid liners, cleaned to EPA QA/QC specifications (EPA, 1990), or Whirl-Pak bags for grain size.

Stainless steel scoops and buckets used to manipulate the sediments were cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, deionized water, and pesticide-grade acetone. The equipment was then air-dried and wrapped in aluminum foil.

The samples were put in individual polyethylene bags and placed on ice immediately after collection. They were transported to the Ecology Manchester Environmental Laboratory (MEL) within two days of collection. Chain-of-custody was maintained.

Sample analysis was conducted by MEL, except for grain size which was done at Rosa Environmental & Geotechnical Laboratory, Seattle. The analytical methods used are shown in Table 1.

Quality of the Data

Appendix A has complete results from the sediment analyses, along with QA reviews of the data prepared by MEL staff. The reviews include an assessment of sample condition on receipt at the laboratory, compliance with holding times, and results for instrument calibration, procedural blanks, laboratory control samples, standard reference materials, surrogates, matrix spikes, and matrix spike duplicates.

Overall, the quality of the data is good. A few problems were encountered, as noted below. None of these shortcomings materially affects conclusions about the presence or absence of significant chemical contamination in the study area.

- Antimony results were qualified as estimates due to low recoveries in a laboratory control sample and in matrix spikes.

- In the semivolatiles analysis, phthalate levels were elevated in both method blanks and samples. Based on the EPA five-times rule, the phthalates detected in samples were judged to be due to contamination.

- Several semivolatiles, including analine, 4-chloroaniline, hexachlorocyclopentadiene, 3-nitroaniline, and 4-nitroaniline, had low matrix spike recoveries. The data for these compounds were rejected in the native sample (site #5, sample #428034).

- Surrogate recoveries of benzo(b)fluoranthene, indeno(1,2,3,c,d)pyrene, and dibenzoanthracene in the NOAA PAH analysis were greater than the 150% acceptance window and the results qualified as estimates (J flag).

- The method blank for the total petroleum hydrocarbon (TPH) analysis was contaminated with oil, traced to poorly cleaned Soxhlet thimbles used in the extractions. This resulted in a raising of the practical quantitation limit (PQL).

- Matrix spike recoveries for the chlorinated pesticides heptachlor and endrin aldehyde were low and the results qualified as estimates. The precision between matrix spike duplicates for heptachlor was also poor.

Results

Chemicals Detected

Table 2 summarizes results of the chemical analyses. The complete data are in Appendix A. Because of the large number of semivolatile compounds analyzed, only data for detected compounds are shown. The extensive NOAA PAH data are reported separately in Table 3.

The sediments at all five sites appeared generally similar, both physically and chemically.

Metals concentrations agreed closely among the five sampling sites. The higher concentrations tended to occur in samples from the head of the bay. The concentrations and relative abundance of the metals analyzed is similar to sediments in other parts of Fidalgo Bay and Padilla Bay (Johnson et al., 1997; Johnson, 1999; USFWS, 1994).

Twenty-one organic compounds were detected in the semivolatiles analysis. Most of these have been detected at similar levels in other parts of inner Fidalgo Bay (Johnson et al., 1997) and are routinely reported in North Puget Sound sediments (Long et al., 1999). All concentrations were less than 100 ug/Kg (parts per billion), except for coprostanol at 160 - 338 ug/Kg. With few exceptions, the same compounds were detectable and at similar concentrations at all five sampling sites.

Sixteen of the 21 semivolatiles were PAH compounds. PAH are present in petroleum and formed during combustion of fossil fuels. Petroleum sources have a higher percentage of alkyl-substituted low molecular weight PAH (LPAH) relative to the parent compound (e.g., methylnaphthalenes vs. naphthalene) compared to combustion sources (Lake et al., 1979). The PAH pattern observed in the Fidalgo Bay samples suggests combustion sources, rather than petroleum. Results from the more extensive analysis for NOAA PAH (Table 3) were in good agreement with the semivolatiles analysis.

Five additional semivolatile compounds were detected. 4-Methylphenol and dibenzofuran are associated with coal tars and petroleum. In Puget Sound, 4-methylphenol is often found elevated in areas with wood waste. Benzyl alcohol has a variety of uses including but not limited to dyes, solvents, perfumes, and inks. Coprostanol is an environmentally persistent steroid formed in the digestive tract of mammals. The last compound, diphenylhydrazine, is used in chemical synthesis of dyes and other products. As demonstrated below, the concentrations detected for these compounds are low.

No petroleum was detectable in the TPH analysis at or below 40 - 85 mg/Kg (parts per million).

PCBs were not detectable at or below 4.4 - 4.9 ug/Kg.

The pesticide analysis was limited to sites #4 and #5 at the head of the bay. No chlorinated pesticides were detected. Reporting limits for chlorinated pesticides were less than 1 ug/Kg (Appendix A). Nothing was found in screening these samples for organophosphorus- and nitrogen-containing pesticides. Reporting limits for these compounds were variable, but generally at or below 25 and 50 ug/Kg, respectively (Appendix A).

Comparison to Standards

Table 4 compares results of this survey to the chemical criteria in Ecology's Sediment Management Standards (SMS; WAC 173-204). Chemicals meeting Sediment Quality Standards (SQS) are not expected to cause adverse effects on biological resources. The Cleanup Screening Level (CSL) is the upper limit of allowable minor adverse effects on biological resources.

For comparison to the standards, concentrations of non-ionizable organic compounds (e.g., PAH and PCBs) are normalized to the organic carbon content of the sample in question (dry weight concentration divided by the decimal fraction representing percent TOC). For a given chemical concentration, sediment toxicity typically varies inversely with TOC. As directed in the standards, only detected concentrations were used to calculate total LPAH and total HPAH, and methylnaphthalenes were not included. For individual undetected compounds, the detection limit is used in normalizing. The PAH data in Table 4 are from the semivolatiles analysis.

Twenty-six of the 47 sediment standard parameters were quantified in the Fidalgo Bay samples. In addition to metals, these included PAH compounds, dibenzofuran, 4-methylphenol, and benzyl alcohol. SMS chemicals not detected were silver, benzo(a)anthracene, dibenzo(a,h)anthracene, dichlorobenzenes, hexachlorobenzene, phthalates, hexachlorobutadiene, N-nitrosodiphenylamine, PCBs, phenol, 2-methylphenol, 2,4-dimethylphenol, pentachlorophenol, and benzoic acid.

As shown in Table 4, all chemical concentrations detected in the Fidalgo Bay samples were well within standards. In most instances, concentrations were one-to-two orders of magnitude below the SQS.

Comparison to Reference Area

Table 5 compares the Fidalgo Bay data to concentrations of the same chemicals analyzed in sediments from Samish Bay, an established sediment reference area (PTI, 1991). Samish Bay is located about nine miles north of inner Fidalgo Bay and removed from local sources of contamination. Sediments at this site are known to have a low level of chemical contamination with no significant toxicity. The Samish Bay data in Table 5 are from a composite sample analyzed by EAP in 1998 (Johnson, 1999). These data did not include an analysis for NOAA PAH.

As can be seen in Table 5, most of the chemicals detected in inner Fidalgo Bay were at concentrations similar to or only slightly higher than those in reference area sediments.

Conclusion

Results of this survey show no evidence of significant chemical contamination in the sediments on the west side of inner Fidalgo Bay.

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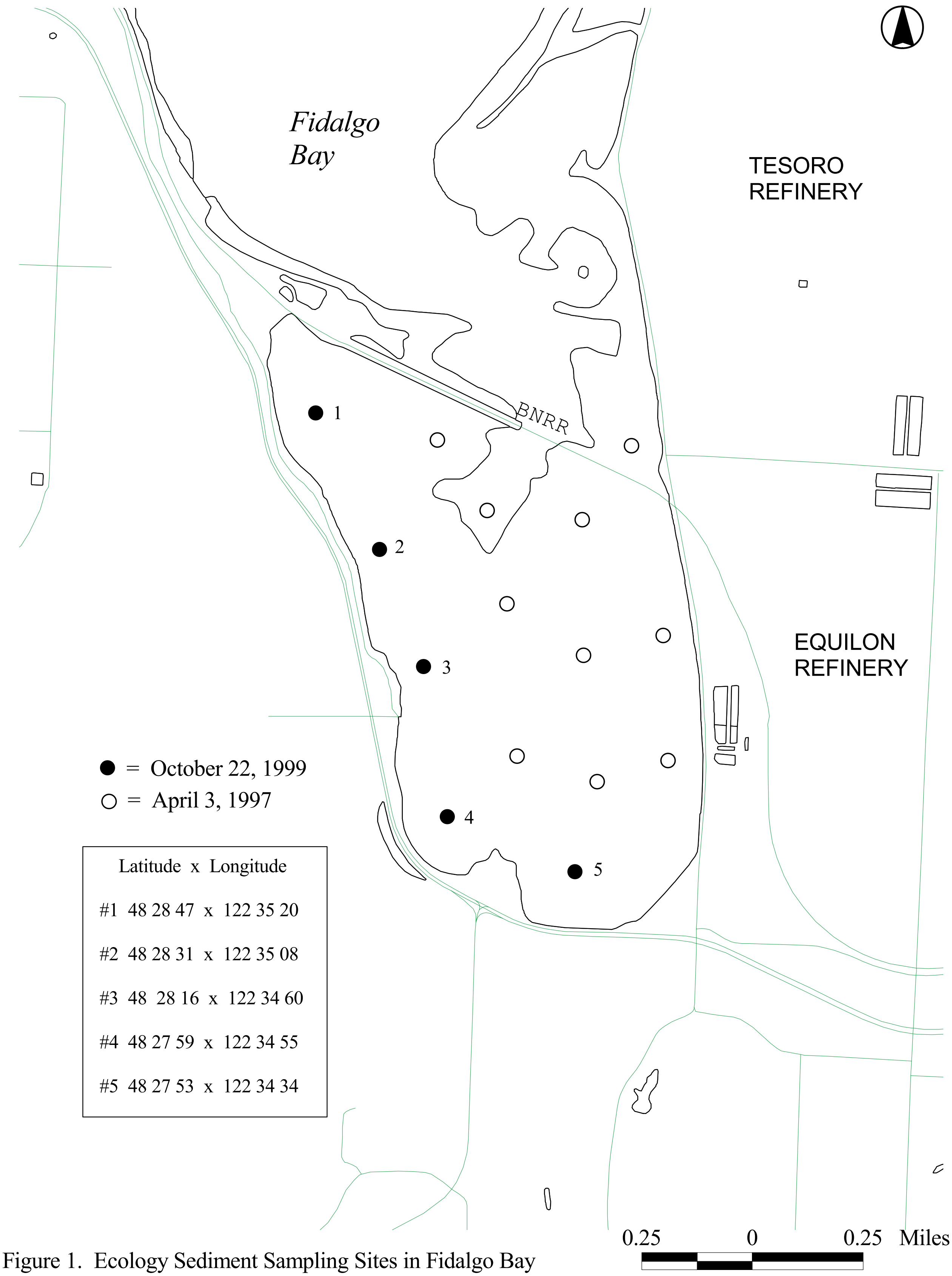

Figure 1. Ecology Sediment Sampling Sites in Fidalgo Bay

Table 1. Analytical Methods for October 1999 Fidalgo Bay Sediment Samples

Analysis	Method	EPA Method No.
Be,Cd,Cr,Cu,Ni,Pb,Sb,Zn	ICP	6010
Arsenic	GFAA	7060
Lead	GFAA	7421
Selenium	GFAA	7740
Thallium	GFAA	7841
Mercury	CVAA	245.5
Semivolatiles	GC/MS	8270
PAH (NOAA List)	GC/MS SIM	8270*
Total Petroleum Hydrocarbons	GC/FID	NWTPH-Dx**
PCBs	GC/ECD	8082
Chlorinated Pesticides	GC/ECD	8081
Phosphorus & Nitrogen Pesticides	GC/AED	8085
Grain Size	Sieve & Pipet	PSEP
Total Organic Carbon	PSEP Methods	PSEP
Percent Solids	Gravimetric	PSEP

*with isotopic dilution
**Manchester Laboratory method
PSEP = Puget Sound Estuary Program

Table 2. Summary of Data on Fidalgo Bay Sediment Samples Collected October 22, 1999
[only detected semivolatile compounds shown]

Site Number:	1	2	3	4	5
Sample Number:	428030	428031	428032	428033	428034
Ancillary Parameters (%)					
Gravel	**0.3**	**1.5**	**1.0**	**28.7**	**26.6**
Sand	**32.8**	**39.2**	**9.8**	**4.6**	**6.6**
Silt	**53.3**	**45.5**	**70.1**	**49.3**	**52.1**
Clay	**13.6**	**13.8**	**19.1**	**17.4**	**14.7**
Total Organic Carbon	**1.3**	**0.9**	**1.4**	**2.1**	**2.1**
Solids	**61**	**60**	**54**	**53**	**52**
Priority Pollutant Metals (mg/Kg, dry weight)					
Zinc	**46**	**41**	**56**	**63**	**51**
Chromium	**29**	**26**	**33**	**38**	**33**
Nickel	**24**	**18**	**23**	**25**	**23**
Copper	**12**	**11**	**17**	**18**	**14**
Lead	**6.1**	**5.3**	**7.8**	**8.4**	**7.2**
Arsenic	**4.1**	**4.8**	**5.8**	**6.9**	**6.2**
Beryllium	**1.4**	**1.2**	**1.6**	**1.8**	**1.6**
Cadmium	**1.3**	**1.4**	**1.6**	**1.8**	**2.2**
Selenium	**0.38**	**0.37**	0.30 U	0.30 U	**0.40**
Mercury	**0.038**	**0.035**	**0.048**	**0.048**	**0.036**
Antimony	5 UJ	5 UJ	5 UJ	5 UJ	5 UJ
Silver	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Thallium	0.80 U	0.80 U	0.80 U	0.80 U	0.80 U
Semivolatiles (ug/Kg, dry weight)					
Low Molecular Weight PAH					
Naphthalene	**25**	**27**	**36**	**37**	**23**
1-Methylnaphthalene	**11**	**12**	**14**	**19**	**13**
2-Methylnaphthalene	**15**	**15**	**20**	**25**	**18**
Acenaphthylene	**6.0** J	**6.4** J	**10**	**8.5** J	**5.6** J
Acenaphthene	**5.6** J	**6.4** J	**8.2** J	9.2 U	**5.9** J
Fluorene	**9.4**	**11**	**15**	**15**	**13**
Phenanthrene	**41**	**42**	**58**	**66**	**46**
Anthracene	**12**	**14**	**16**	**18**	**14**
Total LPAH[a]	**125**	**134**	**177**	**189**	**139**

Table 2 (continued).

	Site Number: 1 Sample Number: 428030	2 428031	3 428032	4 428033	5 428034
<u>High Molecular Weight PAH</u>					
Fluoranthene	**64**	**63**	**85**	**89**	**62**
Pyrene	**55**	**52**	**74**	**80**	**56**
Chrysene	**24**	**22**	**27**	**37**	**25**
Benzo(b)fluoranthene	**30**	**30**	**37**	**44**	**34**
Benzo(k)fluoranthene	**14**	**14**	**15**	**25**	**15**
Benzo[a]pyrene	**42**	**29**	**31**	**36**	**32**
Indeno[1,2,3-c,d]pyrene	**21**	**21**	**25**	**28**	**23**
Benzo[g,h,i]perylene	**22**	**21**	**29**	**33**	9.0 U
Total HPAH[b]	**272**	**252**	**323**	**372**	**247**
<u>Miscellaneous Compounds</u>					
4-Methylphenol	**23**	**32**	**46**	**25**	**23**
Dibenzofuran	**12**	**12**	**14**	**16**	**12**
Benzyl alcohol	**17**	9.0 U	8.9 U	9.2 U	**23**
3B-Coprostanol	**225**	**300**	**338**	**160**	36 U
1,2-Diphenylhydrazine	**41** N	**27** N	**54** N	9.2 U	**25** N
NOAA PAH (see Table 3)	*	*	*	*	*
TPH (mg/Kg, dry weight)	85 U	40 U	55 U	50 U	85 U
PCBs (ug/Kg, dry weight)	4.4 U	4.8 U	4.8 U	4.7 U	4.9 U
Chlorinated Pesticides	NA	NA	NA	ND	ND
Phosphorus Pesticides	NA	NA	NA	ND	ND
Nitrogen Pesticides	NA	NA	NA	ND	ND

U = not detected at or above reported value
UJ = not detected at or above reported estimated value
ND = not detected (reporting limits provided in Appendix A)
J = estimated value
N = evidence the analyte is present
NA = not analyzed

[a]naphthalene+acenaphthylene+acenaphthene+fluorene+phenanthrene+anthracene

[b]fluoranthene+pyrene+benzo[a]anthracene+chrysene+total benzofluoranthenes+benzo[a]pyrene indeno[1,2,3-c,d]pyrene+dibenzo[a,h]anthracene+benzo[g,h,i]perylene

Table 3. Concentrations of NOAA PAH in Fidalgo Bay Sediment Samples Collected October 22, 1999 [ug/Kg, dry weight]

Site Number:	1	2	3	4	5
Sample Number:	428030	428031	42803 2	428033	428034
Naphthalene	**23**	**23**	**36**	**32**	**29**
1-Methylnaphthalene	**7.2**	**7.2**	**9.9**	**14**	**18**
2-Methylnaphthalene	**11**	**12**	**16**	**21**	**18**
2,6-Dimethylnaphthalene	**8.1**	**12**	**16**	**34**	**43**
1,6,7-Trimethylnaphthalene	**5.2**	**5.2**	**7.7**	**9.1**	**8.3**
2-Chloronaphthalene	0.54 U	0.59 U	0.60 U	0.62 U	0.60 U
1,1'-Biphenyl	**4.1**	**4.2**	**5.5**	**6.2**	**5.8**
Acenaphthylene	**4.0**	**3.8**	**6.5**	**6.0**	**5.0**
Acenaphthene	**3.0**	**3.1**	**4.5**	**4.8**	**4.1**
Dibenzofuran	**8.2**	**8.2**	**12**	**13**	**12**
Fluorene	**6.8**	**6.9**	**10**	**11**	**9.4**
9H-Fluorene, 1-methyl	**4.0**	**6.2**	**8.8**	**9.4**	**7.7**
Dibenzothiophene	**2.8**	**2.8**	**4.3**	**5.1**	**5.1**
4,6-Dimethyldibenzothiophene	**0.89**	**0.63**	**0.98**	**0.84**	**0.82**
Phenanthrene	**33**	**34**	**49**	**59**	**49**
1-Methylphenanthrene	**6.1**	**6.1**	**7.8**	**8.7**	**8.0**
2-Methylphenanthrene	**9.5**	**9.6**	**14**	**14**	**13**
3,6-Dimethylphenanthrene	**3.7**	**3.8**	**4.8**	**4.7**	**4.3**
Anthracene	**7.9**	**8.4**	**11**	**12**	**10**
Carbazole	**1.1**	**1.1**	**1.2**	**5.2**	**6.6**
Fluoranthene	**59**	**48**	**69**	**67**	**58**
2-Methylfluoranthene	**6.6**	**6.5**	**8.9**	**11**	**8.0**
Retene	**16**	**15**	**21**	**23**	**18**
Benzo(a)anthracene	**12**	**11**	**15**	**18**	**13**
Chrysene	**20**	**18**	**21**	**34**	**24**
5-Methylchrysene	**6.6**	**3.2**	**3.9**	**4.2**	**3.8**
Benzo(b)fluoranthene	**14**	**14**	**18**	**22**	**17**
Benzo(k)fluoranthene	**21**	**15**	**21**	**20**	**17**
Benzo[e]pyrene	**12**	**11**	**15**	**18**	**13**
Benzo(a)pyrene	**14**	**12**	**18**	**21**	**16**
Perylene	**26**	**25**	**33**	**40**	**33**
Indeno(1,2,3-cd)pyrene	**9.2** J	**9.9** J	**17** J	**17** J	**14** J
Dibenzo(a,h)anthracene	**2.6** J	**3.5** J	**3.9** J	**4.1** J	**3.4** J
Benzo(ghi)perylene	**14**	**13**	**19**	**23**	**19**

Table 3 (continued).

Site Number:	1	2	3	4	5
Sample Number:	428030	428031	42803 2	428033	428034
C1-Naphthalenes	**13** NJ	**22** NJ	**29** NJ	**36** NJ	**35** NJ
C2-Naphthalenes	**23** NJ	**33** NJ	**39** NJ	**70** NJ	**74** NJ
C3-Naphthalenes	**25** NJ	**31** NJ	**34** NJ	**46** NJ	**43** NJ
C4-Naphthalenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U
C1-Fluorenes	**11** NJ	**12** NJ	**18** NJ	**24** NJ	**16** NJ
C2-Fluorenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U
C3-Fluorenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U
C1-Dibenzothiophenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U
C2-Dibenzothiophenes	**2.7** NJ	**2.2** NJ	**3.8** NJ	**2.9** NJ	**3.0** NJ
C3-Dibenzothiophenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U
C1-Phenanthrenes/Anthracenes	**36** NJ	**31** NJ	**44** NJ	**58** NJ	**45** NJ
C2-Phenanthrenes/Anthracenes	**25** NJ	**25** NJ	**34** NJ	**38** NJ	**27** NJ
C3-Phenanthrenes/Anthracenes	**14** NJ	**6.3** NJ	**18** NJ	**24** NJ	**19** NJ
C4-Phenanthrenes/Anthracenes	**16** NJ	**15** NJ	**20** NJ	**23** NJ	**18** NJ
C1-Fluoranthene/Pyrene	**53** NJ	**49** NJ	**72** NJ	**97** NJ	**51** NJ
C1-Chrysenes	**18** NJ	**15** NJ	**26** NJ	**30** NJ	**28** NJ
C2-Chrysenes	**2.2** NJ	2.4 U	2.4 U	2.5 U	2.4 U
C3-Chrysenes	**2.2** NJ	2.4 U	2.4 U	2.5 U	2.4 U
C4-Chrysenes	2.2 U	2.4 U	2.4 U	2.5 U	2.4 U

U = not detected at or above reported value
J = estimated value
UJ = not detected at or above reported estimated value
NJ = evidence the anaylte is present; associated numerical results is an estimate

Table 4. Fidalgo Bay Data Compared to Sediment Management Standards

Chemical Parameter	Site Number #1	#2	#3	#4	#5	SQS	CSL
Metals (mg/Kg, dry weight; ppm)							
Arsenic	**4.1**	**4.8**	**5.8**	**6.9**	**6.2**	57	93
Cadmium	**1.3**	**1.4**	**1.6**	**1.8**	**2.3**	5.1	6.7
Chromium	**29**	**26**	**33**	**38**	**33**	260	270
Copper	**12**	**11**	**17**	**18**	**14**	390	390
Lead	**6.1**	**5.3**	**7.8**	**8.4**	**7.2**	450	530
Mercury	**0.038**	**0.035**	**0.048**	**0.048**	**0.037**	0.41	0.59
Silver	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	6.1	6.1
Zinc	**46**	**41**	**56**	**63**	**51**	410	960
Nonionizable Organic Compounds (mg/Kg TOC; ppm)							
Polyaromatic Hydrocarbons							
Total LPAH[a]	**7.6**	**11**	**10**	**6.9**	**5.1**	370	780
Naphthalene	**1.9**	**2.8**	**2.6**	**1.8**	**1.1**	99	170
Acenaphthylene	**0.5** J	**0.7** J	**0.7**	**0.4** J	**0.3** J	66	66
Acenaphthene	**0.4** J	**0.7** J	**0.6** J	0.4 U	**0.3** J	16	57
Fluorene	**0.7**	**1.2**	**1.1**	**0.7**	**0.6**	23	79
Phenanthrene	**3.2**	**4.4**	**4.1**	**3.1**	**2.2**	100	480
Anthracene	**0.9**	**1.5**	**1.1**	**0.9**	**0.7**	220	1200
2-Methylnaphthalene	**1.2**	**1.6**	**1.4**	**1.2**	**0.9**	38	64
Total HPAH[b]	**21**	**27**	**23**	**18**	**12**	960	5300
Fluoranthene	**4.9**	**6.6**	**6.1**	**4.2**	**3.0**	160	1200
Pyrene	**4.2**	**5.5**	**5.3**	**3.8**	**2.7**	1,000	1400
Benzo[a]anthracene	1.6 U	2.0 U	1.9 U	1.4 U	1.0 U	110	270
Chrysene	**1.8**	**2.3**	**1.9**	**1.8**	**1.2**	110	460
Tot. Benzofluoranthenes	**3.4**	**4.6**	**3.7**	**3.3**	**2.3**	230	450
Benzo[a]pyrene	**3.2**	**3.1**	**2.2**	**1.7**	**1.5**	99	210
Indeno[1,2,3-c,d]pyrene	**1.6**	**2.2**	**1.8**	**1.3**	**1.1**	34	88
Dibenzo[a,h]anthracene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	12	33
Benzo[g,h,i]perylene	**1.7**	**2.2**	**2.1**	**1.6**	0.4 U	31	78
Chlorinated Benzenes							
1,2-Dichlorobenzene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	2.3	2.3
1,4-Dichlorobenzene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	3.1	9
1,2,4-Dichlorobenzene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	0.81	1.8
Hexachlorobenzene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	0.38	2.3

[a]naphthalene+acenaphthylene+acenaphthene+fluorene+phenanthrene+anthracene

[b]fluoranthene+pyrene+benzo[a]anthracene+chrysene+total benzofluoranthenes+benzo[a]pyrene indeno[1,2,3-c,d]pyrene+dibenzo[a,h]anthracene+benzo[g,h,i]perylene

Table 4 (continued).

Chemical Parameter	Site Number #1	#2	#3	#4	#5	SQS	CSL
Nonionizable Organic Compounds (mg/Kg TOC; ppm)							
Phthalate Esters							
Dimethyl phthalate	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	53	53
Diethyl phthalate	5.8 U	8.8 U	4.9 U	1.2 U	2.8 U	61	110
Di-N-butyl phthalate	92 U	208 U	45 U	25 U	28 U	220	1700
Butylbenzyl phthalate	1.5 U	2.6 U	1.5 U	0.4 U	1.2 U	4.9	64
Bis(2-ethylhexyl)phthalate	5.2 U	16 U	4.9 U	1.9 U	4.8 U	47	78
Di-N-octyl phthalate	0.6 U	0.9 U	3.6 U	0.4 U	1.0 U	58	4500
Miscellaneous							
Dibenzofuran	**0.9**	**1.3**	**1.0**	**0.8**	**0.6**	15	58
Hexachlorobutadiene	0.6 U	0.9 U	0.6 U	0.4 U	0.4 UJ	3.9	6.2
N-Nitrosodiphenylamine	0.6 U	0.9 U	0.6 U	0.4 U	0.4 U	11	11
Total PCBs	0.3 U	0.5 U	0.3 U	0.2 U	0.2 U	12	65
Ionizable Organic Compounds (ug/Kg, dry weight; ppb)							
Phenol	69 U	104 U	107 U	50 U	47 U	420	1200
2-Methylphenol	8.2 U	9.0 U	8.9 U	9.2 U	9.0 U	63	63
4-Methylphenol	**23**	**32**	**46**	**25**	**23**	670	670
2,4-Dimethylphenol	8.2 U	9.0 U	8.9 U	9.2 U	9.0 U	29	29
Pentachlorophenol	8.2 U	9.0 U	8.9 U	9.2 U	9.0 U	360	690
Benzyl alcohol	**17**	9.0 U	8.9 U	9.2 U	**23**	57	73
Benzoic acid	230 U	267 U	267 U	289 U	340 U	650	650

SQS = sediment quality standard
CSL = cleanup screening level
LPAH = low molecular weight PAH
HPAH = high molecular weight PAH
J = estimated value
U = not detected at or above reported value

Table 5. Fidalgo Bay Data Compared to Sediments from Samish Bay Reference Area

Chemical Parameter	West Side Fidalgo Bay - 1999 median	minimum	maximum	Samish Bay*
Priority Pollutant Metals (mg/Kg, dry weight)				
Zinc	**51**	**41**	**63**	**42**
Chromium	**33**	**26**	**38**	**22**
Nickel	**23**	**18**	**25**	**26**
Copper	**14**	**11**	**18**	**12**
Lead	**7.2**	**5.3**	**8.4**	**5.8**
Arsenic	**5.8**	**4.1**	**6.9**	**4.8**
Beryllium	**1.6**	**1.2**	**1.8**	**0.25**
Cadmium	**1.6**	**1.3**	**2.2**	0.4 U
Selenium	**0.37**	0.30 U	**0.40**	0.3 U
Mercury	0.038	**0.035**	**0.048**	**0.048**
Antimony	5 UJ	5 UJ	5 UJ	3 UJ
Silver	2.0 U	2.0 U	2.0 U	0.4 U
Thallium	0.8 U	0.8 U	0.8 U	0.3 UJ
Semivolatiles (ug/Kg, dry weight)				
Total LPAH[a]	**107**	**99**	**145**	**160** J
Total HPAH[b]	**272**	**247**	**372**	**441**
4-Methylphenol	**25**	**23**	**46**	**5.9** J
Dibenzofuran	**12**	**12**	**16**	**6.4** J
Benzyl alcohol	9.2 U	8.9 U	**23**	35 U
3B-Coprostanol	**225**	36 U	**338**	**188** J
1,2-Diphenylhydrazine	**27** N	9.2 U	**54** N	35 U
TPH (mg/Kg, dry weight)	55 U	40 U	85 U	77 U
PCBs (ug/Kg, dry weight)	4.8 U	4.4 U	4.9 U	1.1 U

*data from Johnson (1999)

U = not detected at or above reported value

J = estimated value

UJ = not detected at or above reported estimated value

N = evidence the analyte is present

[a]naphthalene+acenaphthylene+acenaphthene+fluorene+phenanthrene+anthracene

[b]fluoranthene+pyrene+benzo[a]anthracene+chrysene+total benzofluoranthenes+benzo[a]pyrene indeno[1,2,3-c,d]pyrene+dibenzo[a,h]anthracene+benzo[g,h,i]perylene

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Appendix A, Laboratory Data, is not available in electronic format.

For Appendix A, order a printed copy of the report (see page 17).