Health Consultation

Fidalgo Bay
Anacortes, Skagit County, Washington

February 25, 2010

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Washington State Department of Health

DOH 334-223 February 2010

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

HEALTH CONSULTATION

FIDALGO BAY

ANACORTES, WASHINGTON

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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so that DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding DOH or the contents of this health consultation, please call the health advisor who prepared this document:

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For persons with disabilities this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (voice) or 1-800-833-6388 (TTY/TDD).

For more information about ATSDR, contact the ATSDR Information Center at 1-888-422-8737 or visit the agency's Web site: www.atsdr.cdc.gov/.

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Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues that is responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Cancer Risk	A theoretical risk for developing cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.
Cancer Risk Evaluation Guide (CREG)	The concentration of a chemical in air, soil or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF).
Cancer Slope Factor	A number assigned to a cancer-causing chemical that is used to estimate its ability to cause cancer in humans.
Carcinogen	Any substance that causes cancer.
Comparison value	Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dermal Contact	Contact with (touching) the skin (see route of exposure).
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Environmental Media Evaluation Guide (EMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on ATSDR's *minimal risk level* (MRL).

Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate (IR)	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Lowest Observed Adverse Effect Level (LOAEL)	The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
Maximum Contaminant Level (MCL)	A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards.
Media	Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

Minimal Risk Level (MRL)	An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **oral reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
No Observed Adverse Effect Level (NOAEL)	The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.
Organic	Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water.
Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Plume	A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.
Reference Dose Media Evaluation Guide (RMEG)	A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The RMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].
Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Time Weighted Approach (TWA)	The exposure concentration of a contaminant during a given period.

Volatile organic compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Summary and Statement of Issues

Introduction:
In the Fidalgo Bay community, Washington State Department of Health's (DOH) top priority is to ensure that the community has the best information possible to safeguard its health. Washington State Department of Ecology (Ecology) asked DOH to conduct this health consultation. The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in sediments, clams, and bottom fish tissue at Fidalgo Bay in Anacortes, Skagit County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Overview:
DOH reached three important conclusions about Fidalgo Bay in Anacortes, Skagit County, Washington.

Conclusion 1:
DOH concludes that eating seafood at tribal scenario rates is expected to harm children and adults' health. The Swinomish, Samish, Lummi and the Upper Skagit are tribes or nations that fish in this area or it is in their usual and accustomed fishing rights areas. If any of the tribes or nations are using Fidalgo Bay for harvesting and eating seafood at tribal scenario rates, this would represent a "public health hazard".

Basis for conclusion:
Based on tribal scenario consumption rates, exposures are above levels known to result in non-cancer and cancer harmful health effects.

Conclusion 2:
DOH concludes that eating bottom fish or shellfish from Fidalgo Bay is not expected to harm the **general** population's (children or adults) health.

Basis for conclusion:
Based on **general** population consumption rates, the exposure scenario is below levels known to result in non-cancer harmful health effects. In addition, the exposure scenario does not present an elevated cancer risk.

Conclusion 3:
DOH concludes that touching, breathing or accidentally eating sediment one-day-per-week or 52 days per year from Fidalgo Bay is not expected to harm people's health.

Basis for conclusion:
The maximum level of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in this exposure scenario is below levels known to result in non-cancer harmful health effects. In addition, the exposure scenario does not present an elevated cancer risk.

For More Information:
Please feel free to contact Lenford O'Garro at (360) 236-3376 or 1-877-485-7316 if you have any questions about this health consultation.

Background

The Fidalgo Bay site is located in western Skagit County, Washington, and is bordered by the City of Anacortes to the west and March Point to the east (Figures 1, 2). Fidalgo Bay has supported wood product industries, recreational marinas, oil refining, and boat building. Several sites are listed on Ecology's Confirmed and Suspected Contaminated Sites List as contributing contaminants into Fidalgo Bay. Therefore, Fidalgo Bay has been identified by Ecology, under the Toxics Cleanup Program's (TCP) Puget Sound Initiative, for focused sediment cleanup and source control.

Fidalgo Bay is a generally shallow embayment with extensive tide flats and eelgrass. The tide flats area supports spawning and rearing of forage fish (e.g., Pacific herring, surf smelt, and sand lance), juvenile salmonids, clams, crabs, and an abundance of other marine life. Many species of birds use the area including bald eagles, peregrine falcons, migratory waterfowl, and wading birds.

Past and current industries along the west shoreline of Fidalgo Bay include Cap Sante Marine, Dakota Creek Industries, Custom Plywood, Former Shell Oil Tank Farm, and Former Scott Paper Mill. Across the bay from Anacortes along March Point to the east, there are two oil refineries that produce gasoline, diesel, and propane. There have been a number of accidental releases from these sites [1]. Custom Plywood, Cap Sante Marine, Former Shell Oil Tank Farm, and Dakota Creek Industries are under an Ecology agreed order to conduct a site remedial investigation and a feasibility study (RI/FS) to guide the selection of a cleanup remedy. Across the southern part of the bay runs the old causeway railroad trestle (Tommy Thompson Trail causeway) that was built with creosote pilings. The southern end of Fidalgo Bay has been proposed as an Aquatic Reserve to be managed by the Washington State Department of Natural Resources [2, 3].

Between August and October 2007, sediment and tissue samples (clams, crabs, and fish (skin-off fillets composites)) were collected (Figure 3). Sediment profile imaging was performed on sediments at 126 locations, surface sediment chemistry analysis on sediments from 58 locations, and toxicity testing on sediments from 24 locations [4, 5].

Native American Tribes and Nations in the Puget Sound have reserved the right to take fish at their usual and accustomed grounds and stations. These include marine and fresh water areas in and around Puget Sound. The Swinomish Indian Tribal Community and Samish Indian Nation are nearest to Fidalgo Bay. The Swinomish Indian Tribal Community stated that Fidalgo Bay is an important historic harvest site that has been impacted by contamination and has therefore not been used for harvest in recent years [6]. However, other Native American Tribes and Nations harvest seafood from the Fidalgo Bay area.

Existing Fish Consumption Advisories

In October 2006, DOH issued a Puget Sound Recreational Marine Area 7 Fish Consumption Advisory and a Puget Sound crab consumption advisory that recommends the following:

1. Eat no more than one meal per week for rockfish and Chinook salmon, and no more than one meal per month for resident (blackmouth) Chinook salmon.

2. Eat Dungeness and Red Rock crab from non-urban areas and do not eat the "crab butter" (viscera). More information regarding these advisories is available at http://www.doh.wa.gov/ehp/oehas/fish/rma7.htm or by calling toll-free 1-877-485-7316.

Discussion

Contaminants of Concern

Contaminants of concern (COC) in sediment were determined by employing a screening process. Maximum sediment contaminant levels were screened against health-based soil comparison values. Several types of health-based comparison or screening values were used during this process [see the glossary for descriptions of "comparison value," "cancer risk evaluation guide (CREG)," "environmental media evaluation guide (EMEG)," and "reference dose media evaluation guide (RMEG)"]. Comparison values such as the CREG and EMEG offer a high degree of protection and assurance that people are unlikely to be harmed by contaminants in the environment. For chemicals that cause cancer, the comparison values represent levels that are calculated to increase the risk of cancer by about one in a million. These types of comparison values often form the basis for cleanup. In general, if a contaminant's maximum concentration is greater than its comparison value, then the contaminant is evaluated further.

Comparisons may also be made with legal standards such as the cleanup levels specified in the Washington State toxic waste cleanup law, the Model Toxics Control Act (MTCA). Legal standards may be strictly health-based or they may incorporate non-health considerations such as the cost, the practicality of attainment, or natural background levels.

Tables 1, 2, and 3 show the maximum concentrations of contaminants detected in analyzed sediment and tissue samples from Fidalgo Bay. The contaminant ranges are similar to maximum values detected or the sample size was small.

Table 1. Maximum concentrations of contaminants detected in sediment within Fidalgo Bay in Anacortes, Washington.

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern (COC)
Arsenic	6.06	20	A	EMEG	No
Cadmium	1.16	10	B1	EMEG	No
Chromium	29.8	200[††]	A	RMEG	No
Copper	26.9 J	2,000	D	IM EMEG	No
Lead	12.8	250	B2	MTCA	No
Mercury	0.086	1	D	MTCA	No
Silver	0.159	300	D	RMEG	No
Zinc	59.9	20,000	D	EMEG	No
2-Methylnaphthalene	0.007 J	200		RMEG	No
Acenaphthene	0.003 J	3000		RMEG	No
Acenaphthylene	0.0088 J	2000*	D		No
Anthracene	0.029	20000	D	RMEG	No
Benzo(a)anthracene	0.066	0.62	B2	Region 9	cPAH
Benzo(a)pyrene	0.073	0.1	B2	CREG	cPAH
Benzo (b)fluoranthene	0.1	0.62	B2	Region 9	cPAH
Benzo (k)fluoranthene	0.033	0.62	B2	Region 9	cPAH
Benzo(ghi)perylene	0.033	2000*	D		No
Chrysene	0.11	62	B2	Region 9	cPAH
Dibenz(a,h)anthracene	0.0079 J	0.1**		CREG	cPAH
Dibenzofuran	0.005 J	290	D	Region 9	No
Fluoranthene	0.24	2000	D	RMEG	No
Fluorene	0.0095 J	2000	D	RMEG	No
Indeno(1,2,3-cd)pyrene	0.044	0.62	B2	Region 9	cPAH
Naphthalene	0.019	30000	C	IM EMEG	No
Phenanthrene	0.082	2000*	D		No
Pyrene	0.16	2000	D	RMEG	No
Hexachlorobenzene	0.0011	0.4	B2	CREG	No
2,4-DDT	0.00025 J	30***	B2	IM EMEG	No
4,4-DDD	0.00081 JP	30***	B2	IM EMEG	No
4,4-DDE	0.00043 JP	30***	B2	IM EMEG	No
4,4-DDT	0.0007 JP	30	B2	IM EMEG	No
Alpha-BHC	0.0014 P	0.1	B2	CREG	No
Endosulfan I	0.0028	100		EMEG	No
Endosulfan Sulfate	0.00023 J	100****		EMEG	No

Endrin aldehyde	0.017	20*****	D	EMEG	No
4-Methylphenol	1.0	310		Region 9	No
Benzyl alcohol	0.0077 J	18000		Region 9	No
Bis(2-ethylhexyl)phthalate	0.026 J	3000	B2	EMEG	No
Butyl benzyl phthalate	0.0084 J	10000	C	RMEG	No
Di-n-butyl phthalate	0.011 J	5000	D	RMEG	No
Diethyl phthalate	0.0034 J	300000	D	IM EMEG	No
Dimethyl phthalate	0.0031 J	100000	D	Region 9	No
Phenol	0.61	20000	D	RMEG	No
Total Aroclors	0.035†	1******		EMEG	No
Total cPAH TEQ	**0.102**	0.1	B2	CREG	**Yes**
Total Dioxin TEQ	0.00000891†	0.00005	B2		No

CREG - ATSDR's Cancer Risk Evaluation Guide (child)
RMEG - ATSDR's Reference Dose Media Evaluation Guide (child)
EMEG - ATSDR's Environmental Media Evaluation Guide (child)
IM EMEG - ATSDR's Intermediate Environmental Media Evaluation Guide (child)
J - data qualifier: The associated numerical result is an estimate
JP - data qualifier: The associated numerical result is an estimate, confirmation criteria was exceeded
P - data qualifier: The confirmation criteria was exceeded
A - EPA: human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
C - EPA: Possible human carcinogen (no human, limited animal studies)
D - EPA: Not classifiable as to health carcinogenicity
Region 9 – EPA: Preliminary Remediation Goals
† Maximum surface sediment
†† Assume hexavalent chromium
* Fluoranthene RMEG value was used as a surrogate
* * Benzo(a)pyrene CREG value was used as a surrogate
* * * 4,4-DDT IM EMEG value was used as a surrogate
* * ** Endosulfan I EMEG value was used as a surrogate
* * *** Endrin EMEG value was used as a surrogate
* * **** Arocolor 1254 EMEG value was used as a surrogate
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
Total cPAH TEQ – sum of all carcinogenic polycyclic aromatic hydrocarbons (cPAH) toxic equivalent (TEQ); all cPAHs in COC are added using the TEQ approach to obtain Total cPAH TEQ.
PPM – parts per million
BOLD values exceed comparison values

Table 2. Maximum concentration of contaminants detected in fish and shellfish sampled at Fidalgo Bay in Anacortes, Washington.

Chemicals	Contaminant maximum concentration (ppm)						Comparison Value[a] (ppm)	EPA Cancer Class
	Horse Clams	Manila Clams	Bent nose Clams	Macoma Clams	Starry Flounder	English Sole		
Arsenic total	**2.82**	**3.14**	**3.84**	n/a	**1.35**	**3.1**	0.003	A
Cadmium	0.15	0.32	0.31	n/a	0.091	0.12	0.5	B1 inhalation
Chromium	**2.23**	**5.94**	**5.91**	n/a	0.43	0.59	1.47	D
Copper	5.20	6.33	**86.34**	n/a	2.65	1.84	19.7	D
Lead	**1.26**	**2.13**	**6.71**	n/a	**1.27**	**1.63**	n/a	B2
Mercury	0.009	0.03	0.02	n/a	**0.071**	0.0077	0.049	D
Nickel	1.76	3.28	3.15	n/a	0.47	0.35	9.8	
Silver	0.15	0.35	0.16	n/a	0.0028	0.0037	2.46	D
Zinc	19.58	13.10	42.54	n/a	11.16	9.85	147.5	D
Total Dioxin TEQ	**7.0E-8**	**1.2E-7**	**7.6E-7**	**6.9E-7**	**1.75E-7**	**1.68E-7**	3.15E-8	

A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
a = Comparison values for contaminants in fish were obtained from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers) [14]
n/a – not available
PPM – parts per million
BOLD values exceed comparison values

Table 3. Maximum concentration of contaminants detected in Red Rock and Dungeness crab sampled at Fidalgo Bay in Anacortes, Washington.

Chemicals	Contaminant maximum concentration (ppm)						Comparison Value[a] (ppm)	EPA Cancer Class
	Red Rock Crab			Dungeness Crab				
	Tissue	Other*	Hepato - pancreas	Tissue	Other*	Hepato - pancreas		
Arsenic total	**5.95**	**4.69**	**7.31**	**10.47**	**6.81**	**6.54**	0.003	A
Cadmium	**1.36**	**6.47**	**33.13**	0.13	0.23	0.37	0.5	B1 inhalation
Chromium	0.11	0.69	0.24	0.095	0.84	0.062	1.47	D
Copper	10.17	**26.43**	**68.52**	11.83	**31.12**	**34.20**	19.7	D
Lead	**1.19**	**1.59**	**1.73**	**1.28**	**1.45**	**1.25**	n/a	B2
Mercury	**0.058**	0.026	**0.060**	**0.088**	**0.051**	0.049	0.049	D
Nickel	0.25	0.62	1.35	0.60	0.54	0.30	9.8	
Silver	0.15	0.23	0.50	0.23	0.31	0.46	2.46	D
Zinc	56.55	35.69	80.57	45.79	24.39	20.09	147.5	D
Total Dioxin TEQ	**1.8E-7**	**1.53E-6**	**6.57E-6**	**1.44E-7**	**5.82E-6**	**1.05E-5**	3.15E-8	

A - EPA: Human carcinogen
B1 - EPA: Probable human carcinogen (limited human, sufficient animal studies)
B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
D - EPA: Not classifiable as to health carcinogenicity
* Other soft tissue (viscera)
Total Dioxin TEQ – sum of dioxin/furans toxic equivalent (TEQ)
a = Comparison values for contaminants in fish were obtained from EPA Guidance for Assessing Chemical Contaminant Data (subsistence fishers) [14]
n/a – not available
PPM – parts per million
BOLD values exceed comparison values

Exposure Pathways

In order for any contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm and there must be a completed route of exposure to people.

Human use patterns and site-specific conditions were considered in the evaluation of exposure to lead and arsenic. Exposure to contaminants in sediment can occur through the following pathways and routes:

Ingestion exposure (swallowing)

Most people inadvertently swallow small amounts of sediments, soil, and dust (and any contaminants they might contain). Young children often put hands, toys, pacifiers, and other things in their mouths that may have dirt or dust on them and may be swallowed. Adults may ingest sediments, soil, and dust through activities such as gardening, mowing, construction work, dusting, and in this case, recreational activities.

Pica behavior is a persistent eating of non-food substances (such as dirt or paper). In a small percentage of children, pica behavior has been found to result in the ingestion of relatively large amounts of soil (one or more grams per day). Compared to typical children, those who swallow large amounts of contaminated soil may have added risks from short-term exposure. Some adults may also exhibit pica behavior.

Inhalation exposure (breathing)

Although people can inhale suspended sediment, soil or dust, airborne sediment usually consists of relatively large particles that are trapped in the nose, mouth, and throat and are then swallowed rather than breathed into the lungs.

Skin exposure (dermal)

Dirt particles that can adhere to the skin may cause additional exposure to contaminants through dermal absorption. Although human skin is an effective barrier for many environmental contaminants, some chemicals can move easily through the skin.

The following discussion addresses possible community behavior and site-specific conditions that are considered in the evaluation of exposure to carcinogenic polycyclic aromatic hydrocarbons (cPAHs) as a contaminant of concern in site sediments through the following pathways and routes:

- Inadvertent sediment ingestion, dust particle inhalation, and dermal absorption of contaminants in sediment during beach play.

Beach Play Scenario

Although contact with sediments at beaches may be an infrequent or seasonal exposure pathway, there is concern because areas along Fidalgo Bay have elevated levels of contaminants (see Table 1). Exposure to contaminants in sediment can occur by swallowing (ingestion exposure), breathing (inhalation exposure), or getting it on skin (dermal exposure). During recreational activities at beaches, people are likely to be exposed to any sediment contaminants. In order for a contaminant to be a health concern, the contaminant must be present at a high enough concentration to cause potential harm, and there must be a completed route of exposure to people. cPAHs are evaluated in this document since they exceed their health comparison values in sediments. See Appendix A for the evaluation of sediments.

Fish and Shellfish Ingestion Scenario

Fidalgo Bay falls under the Puget Sound Recreational Marine Area 7 Fish Consumption Advisory, which states no more than one meal per week for rockfish and Chinook salmon, and no more than one meal per month for resident (blackmouth) Chinook salmon. This area also falls under the Puget Sound Crab Advisory. DOH recommends only Dungeness and Red Rock crab from non-urban areas be consumed and do not eat the “crab butter” (hepatopancreas) and viscera.

Comparison values for contaminants in fish were obtained from EPA’s Guidance for Assessing Chemical Contaminant Data (subsistence fishers) [8]. Bottom fish (English sole and Starry Flounder), shellfish (Bent Nose, Horse, Macoma, and Manila clams), and crabs (Dungeness and Red Rock) were collected and tissue was analyzed for contaminants in these samples (see Tables 2 and 3).

As mentioned above, in order for a contaminant to be a health concern, it must be present at a high enough concentration to cause potential harm and there must be a completed route of exposure to people. People may at times disregard these advisories, and consume more fish and crab from Fidalgo Bay. In the event of this scenario, DOH evaluated bottom fish, clams, and crab contaminant exposure for the general population and for the Swinomish Tribe and Samish Indian Nation. Aspects of EPA’s Tribal Fish and Shellfish consumption framework were used to set rates (See Appendix C) [9]. Horse and Manila clams are targeted shellfish species for human consumption. Bent Nose and Macoma clams are not usually targeted shellfish species for human consumption.

Appendix B details the methodology and assumptions used by DOH to estimate exposure from eating seafood from Fidalgo Bay. For the general adult population, average ingestion rates of 17.5 g/day represent the 90^{th} percentile per capita ingestion rates for people of age 18 or older in the United States, including people that do and do not consume fish [10]. Since there was only data for bottom fish, it was assumed that bottom fish was consumed similarly to the tribal rate of about four percent of the total intake of seafood. For the general adult population, an average shellfish consumption rate of 1.7 g/day was used to calculate exposure doses. For the general child population, an average fish consumption rate of 0.28 g/day based on bottom fish data only was used. The average shellfish consumption rate of 0.57 g/day was used to calculate exposure doses (See Appendix B, Table B1).

The tribal consumer scenario was based on the EPA Tribal framework for fish and shellfish consumption rates for risk-based decisions (See Appendix C) [15]. The percent of their consumption rate was represented by the category of seafood for both the Tulalip and the Suquamish Tribes [9, 11, 12].

Benefits of Fish Consumption

It is important to consider the benefits of eating fish. Fish are an excellent source of protein and are associated with reduced risk of coronary heart disease. The health benefits of eating fish have also been associated with low levels of saturated versus unsaturated fats. Saturated fats are linked with increased cholesterol levels and risk of heart disease while unsaturated fats (e.g., omega-3 polyunsaturated fatty acid) are an essential nutrient. Fish also provide a good source of some vitamins and minerals [13, 14]. The American Heart Association recommends two servings of fish per week as part of a healthy diet [15].

The health benefits of eating fish deserve particular consideration when one is dealing with subsistence consuming populations. Removal of fish from the diet of subsistence consumers can have serious health, social, and economic consequences that must be considered in issuing fish advisories. Consumption advisories for subsistence consumers could therefore, significantly impact diet. Any advice given to fish consumers to reduce the amount of fish they eat based on chemical contamination should attempt to balance the health benefits with the health risks.
In general, people should eat fish low in contaminants and high in omega-3 fatty acid. Fish consumption advice should also take into account that eating alternative sources of protein also has risks. For instance, increasing the consumption rate of beef or pork at the expense of eating fish can increase the risk of heart disease. In addition, some contaminants that are common in fish, such as dioxin, might also be present in other meats.

The level of contaminant exposure from fish consumption varies with the species of fish, whole fish or fillet, consumption rate, and preparation and cooking process. Exposure to contaminants in fish can be significantly reduced through simple preparation measures. Simply removing the skin of the fish can reduce PCB exposure [16]. Cooking fish using fillets instead of whole fish can reduce PCB levels by more than 20%. In some cases, PCBs were removed up to 50% through cooking [17, 18].

Chemical Specific Toxicity

The following sections are general summaries of COC health effects. The public health implications of exposure to these COCs from sediments and tissues are discussed later. Copper will not be evaluated, since Bent Nose clams are not usually targeted shellfish species for human consumption. In addition, DOH recommends only Dungeness and Red Rock crab from non-urban areas be consumed and do not eat the “crab butter” (hepatopancreas) and viscera.

Arsenic

Arsenic is a naturally occurring element in the earth's soil. In Washington, normal soil background concentrations rarely exceed 20 ppm [19]. However, the widespread use of arsenic-containing pesticides and the emissions from smelters has resulted in significantly higher levels of arsenic on many properties in the state. There are two forms of arsenic - organic and inorganic. The EPA-established reference dose (RfD) for arsenic is 0.0003 mg/kg/day based on skin color changes and excessive growth of tissue (human data) [20]. EPA classifies the inorganic form of arsenic as a human carcinogen. DOH will not be using the slope factor of 1.5 per mg/kg/day due to the arsenic weight of evidence approach. The recent EPA IRIS review draft for the Science Advisory Board presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg/day [21]. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg/day [22]. These slope factors could be higher if the combined risk for all arsenic-associated cancers (bladder, lung, skin, kidney, liver, etc.) were evaluated. For this or any other health consultation, DOH will use a slope factor of 5.7 per mg/kg/day, which appears to reflect EPA's Review DRAFT assessment.

Inorganic arsenic is much more harmful than organic arsenic; therefore, DOH based health evaluations on the levels of inorganic arsenic present in fish samples. Generally, inorganic arsenic in fish and shellfish ranged from about 1-20% of total arsenic [20, 22, 23, 24]. The U.S.

Food and Drug Administration (FDA) proposed 10% of total arsenic estimated as inorganic arsenic [24]. Ecology's evaluation of shellfish in Puget Sound indicated that less than 1% of total arsenic found was in the inorganic form of arsenic [25]. For this health consultation, DOH assumed that 1% of the total arsenic detected was inorganic arsenic. Therefore, 1% of the concentration was used to calculate the estimated dose from exposure to inorganic arsenic in shellfish. Similarly, Ecology's evaluation of English Sole fish in Puget Sound indicated that less than 1% of the total arsenic found was in the inorganic form of arsenic [25]. However, since there was no inorganic arsenic data for Starry Flounder, DOH assumed that 10% of the total arsenic detected in bottom fish was inorganic arsenic (see Uncertainty section).

Consuming seafood from Fidalgo Bay could result in an exposure dose of 1.35×10^{-5} mg/kg/day (see Appendix B, Table B4) for the general public. Similarly, consuming seafood from Fidalgo Bay could result in exposure doses ranging from 3.64×10^{-4} to 6.29×10^{-5} mg/kg/day (see Appendix C, Table C1 and Table C6) for a tribal population. Health effects of skin cancer, changes in the skin, vascular disease, and liver enlargement occurred in humans chronically exposed to 1.4×10^{-2} mg/kg/day of arsenic in drinking water [20]. Therefore, DOH does not expect that exposures to arsenic in fish, shellfish, and crabs will cause harmful non-cancer health effects for the general population. The tribal exposure scenario resulted in doses that are slightly above the RfD. In addition, there is the assumption that all the seafood consumed by the tribal members is from Fidalgo Bay only. However, DOH does not expect that exposures to arsenic in fish, shellfish, and crabs will cause harmful non-cancer health effects for tribal consumption population.

Cadmium

Cadmium is a naturally occurring element in the earth's crust. Cadmium is used mainly in batteries, pigments, metal coatings, and metal alloys. Cadmium is found in most foods at low levels with the lowest levels found in fruits and the highest found in leafy vegetables and potatoes. Shellfish have higher cadmium levels (up to 1 ppm) than other types of fish or meat. Cadmium is stored in the liver and kidneys and slowly leaves the body in the urine and feces [26]. However, high levels of cadmium will cause kidney damage and cause bones to become fragile and break easily. Studies of workers exposed to airborne cadmium also suggest a link with prostate cancer. The ability of cadmium to cause cancer via the oral route is disputed by many studies. The RfD for cadmium that is ingested with food is 0.001 mg/kg/day.

Consuming seafood from Fidalgo Bay could result in an exposure dose of 3.94×10^{-5} mg/kg/day (see Appendix B, Table B4) for the general public. Similarly, consuming seafood from Fidalgo Bay could result in exposure doses ranging from 3.0×10^{-3} to 4.80×10^{-4} mg/kg/day (see Appendix C, Table C2 and Table C7) for a tribal population. A NOAEL of 2.1×10^{-3} mg/kg/day was established for exposure to cadmium. Therefore, DOH does not expect that exposures to cadmium in crabs will cause harmful non-cancer health effects for the general population. However, DOH does expect that exposures to cadmium in crabs will cause harmful non-cancer health effects for tribal consumption population.

Chromium

Chromium is a naturally occurring element in the earth's soil. Chromium is found in three main forms: chromium 0 (metal), chromium III (trivalent chromium), and chromium VI (hexavalent chromium). Chromium metal is used for making steel. Chromium III is an essential nutrient required by the body. Chromium VI is more easily absorbed and harmful. Ingesting large amounts of chromium VI can cause stomach ulcers, kidney and liver damage, and even death. However, some ingested chromium VI is converted to chromium III and most will exit the body in feces within a few days and never enter the bloodstream. Only about 2 percent of ingested chromium passes through the walls of the intestine and enters the bloodstream [27, 28, 29]. The EPA established RfD for chromium VI is 0.003 mg/kg/day. The chromium evaluated here represents total chromium as opposed to chromium VI. Dose calculations, however, do not attempt to fractionate the chromium concentrations. DOH is being very conservative in the evaluation of total chromium and considers all chromium to be chromium VI.

Consuming seafood from Fidalgo Bay could result in an exposure dose of 1.51×10^{-4} mg/kg/day (see Appendix B, Table B4) for the general public. Similarly, consuming seafood from Fidalgo Bay could result in exposure doses ranging from 1.16×10^{-2} to 1.84×10^{-3} mg/kg/day (see Appendix C, Table C3 and Table C8) for a tribal population. A NOAEL of 2.5×10^{0} mg/kg/day was established for exposure to chromium (VI). The tribal exposure scenario resulted in doses that exceed the RfD but falls below the actual toxic effect levels. However, since DOH was very conservative in its evaluation and assumed all chromium in the seafood was chromium IV and 100 percent of the chromium was absorbed. In addition, there is the assumption that all the seafood consumed by the tribal members is from Fidalgo Bay only. Therefore, DOH does not expect that exposures to chromium in crabs will cause harmful non-cancer health effects for the general population and tribal consumption population.

Dioxins and furans

Dioxins, Furans and cPAHs TEQ concentrations

Although several dioxin and furan congeners were analyzed in tissue, only a single value called a dioxin toxic equivalent (TEQ) is presented in this health consultation. Each dioxin/furan or dioxin-like PCB congener is multiplied by a Toxic Equivalency Factor (TEF) to produce the dioxin TEQ. The TEQs for each chemical are then summed to give the overall 2,3,7,8-tetrachlorodibenzo-p-dioxin TEQ. The TEQ approach is based on the premise that many dioxins/furans and dioxin-like PCB congeners are structurally and toxicologically similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin. TEFs are used to account for the different potency of dioxins and furans relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin, and are available for ten chlorinated dibenzofurans and seven chlorinated dibenzodioxins using the World Health Organization (WHO) methodology [7]. A similar TEQ approach is developed for each cPAH based on the relative potency to benzo(a)pyrene.

Dioxins and furans (dioxins) consist of about 210 structural variations of dioxin congeners, which differ by the number and location of chlorine atoms on the chemical structure. The primary sources of dioxin releases to the environment are the combustion of fossil fuels and wood; the incineration of municipal, medical and hazardous waste; and certain pulp and paper processes. Dioxins also occur at very low levels from naturally occurring sources and can be found in food, water, air, and cigarette smoke.

The most toxic of the dioxin congeners, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can cause chloracne (a condition of acne like lesions on the face and neck). Exposure to high levels of dioxins can cause liver damage, developmental effects, and impaired immune function [30]. Long-term exposure to dioxins could increase the likelihood of developing cancer. Studies in rats and mice exposed to TCDD resulted in thyroid and liver cancer [31]. EPA considers TCDD to be a probable human carcinogen and developed a cancer slope factor of $1.5x\ 10^{5}$ mg/kg/day [32, 33].

Consuming seafood from Fidalgo Bay could result in an exposure dose of 1.96×10^{-11} mg/kg/day (see Appendix B, Table B4) for the general public. Similarly, consuming seafood from Fidalgo Bay could result in exposure doses ranging from 6.09×10^{-10} to 1.01×10^{-10} mg/kg/day (see Appendix C, Table C4 and Table C9) for a tribal population. Health effects of altered social behavior have been observed in monkeys exposed to 1.2×10^{-7} mg/kg/day of dioxin [30]. The tribal exposure scenario resulted in doses that are below the MRL of $1x\ 10^{9}$ mg/kg/day. Therefore, DOH does not expect that exposures to dioxin in fish, shellfish, and crabs will cause harmful non-cancer health effects for the general population, and tribal consumption population.

Lead – *Occurrence, Health Concerns, and Risks*

Lead is a naturally occurring chemical element that is normally found in soil. In Washington, normal background concentrations rarely exceed 20 ppm [19]. However, the widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and the emissions from certain industrial operations (such as smelters) has resulted in significantly higher levels of lead in many areas of the state.

Elimination of lead in gasoline and solder used in food and beverage cans has greatly reduced exposure to lead. Currently, the main pathways of lead exposure in children are ingestion of paint chips, contaminated soil and house dust, and drinking water in homes with old plumbing.

Children less than seven years old are particularly vulnerable to the effects of lead. Compared to older children and adults, they tend to ingest more dust and soil, absorb significantly more of the lead they swallow, and more of the lead they absorb can enter their developing brain. Pregnant women and women of childbearing age should also be aware of lead in their environment because lead ingested by a mother can affect the unborn fetus.

Health effects

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead rises 3-7 µg/dl for every 1,000 ppm increase in soil or dust concentration [34]. For children, the Centers for Disease Control and Prevention (CDC) has defined an elevated blood lead level (BLL) as greater than or equal to 10 micrograms of lead per deciliter of blood (µg/dl) [35]. However, there is growing evidence that damage to the central nervous system resulting in learning problems can occur at blood lead levels less than 10 µg/dl. About 2.2 percent of children in the U.S. have blood lead levels greater than 10 µg/dl.

Lead poisoning can affect almost every system of the body and often occurs with no obvious or distinctive symptoms. Depending on the amount of exposure a child has, lead can cause behavior and learning problems, central nervous system damage, kidney damage, reduced growth, hearing impairment, and anemia [36].

In adults, lead can cause health problems such as high blood pressure, kidney damage, nerve disorders, memory and concentration problems, difficulties during pregnancy, digestive problems, and pain in the muscles and joints [36]. These have usually been associated with blood lead levels greater than 30 μg/dl.

Because of chemical similarities to calcium, lead can be stored in bone for many years. Even after exposure to environmental lead has been reduced, lead stored in bone can be released back into the blood where it can have harmful effects. Normally this release occurs relatively slowly. However, certain conditions, such as pregnancy, lactation, menopause, and hyperthyroidism can cause more rapid release of the lead, which could lead to a significant rise in blood lead level [37].

EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 μg/dL. Consuming seafood from Fidalgo Bay could result in the estimated BLL for the **general** population, 1.3 to 1.4 percent above 10 μg/dL for a child, and 1.5 to 1.9 percent above 10 μg/dL for an adult with a 95th percentile fetus BLL range of 4.6 to 4.8 μg/dL (see Appendix D, Tables D1 and D6). Consumption of seafood at tribal scenario rates from Fidalgo Bay could result in the estimated BLL, 1.25 to 32.43 percent above 10 μg/dL for a child, and 1.9 to 30.4 percent above 10 μg/dL for an adult with a 95th percentile fetus BLL range of 5.9 to 92.7 μg/dL (see Appendix D, Tables D3, D5, D8 and D10).

Mercury

Mercury exists in the environment in three forms: elemental, inorganic, and organic. Methylmercury is the form of organic mercury related to exposure in fish. Methylmercury is formed from inorganic mercury in the environment by microorganisms in aquatic systems. In the aquatic food chain, methylmercury biomagnifies as it is passed from lower to higher trophic levels through consumption of prey organisms. Fish at the top of the food chain can biomagnify methlymercury, which represents a potential health concern for consumers of fish.

Ingested methlymercury is readily absorbed and complexed with the cysteine amino acid and crosses the blood-brain barrier. In Minamata Bay, Japan, mothers who were exposed to high amounts of mercury but were asymptomatic gave birth to severely affected infants. Other epidemiologic studies have shown developmental effects in both animal and human studies are the primary concern about methylmercury exposure. The EPA established RfD for mercury is 0.0001 mg/kg/day.

Mercury evaluated here represents total mercury as opposed to methylmercury. Dose calculations, however, do not attempt to fractionate the mercury concentrations because almost all of the total mercury found in fish is methylmercury.

Consuming seafood from Fidalgo Bay could result in an exposure dose of 5.59×10^{-6} mg/kg/day (see Appendix B, Table B4) for the general public. Similarly, consuming seafood from Fidalgo

Bay could result in exposure doses ranging from 3.20×10^{-4} to 5.29×10^{-5} mg/kg/day (see Appendix C, Table C5 and Table C10) for a tribal population. ATSDR has derived a NOAEL of 1.3×10^{-3} mg/kg/day for mercury. Therefore, DOH does not expect that exposures to mercury in fish and crabs will cause harmful non-cancer health effects for the general population. The tribal exposure scenario resulted in doses that slightly exceed the RfD but falls below the actual toxic effect levels. In addition, there is the assumption that all the seafood consumed by the tribal members is from Fidalgo Bay only. Therefore, DOH does not expect that exposures to mercury in fish and crabs will cause harmful non-cancer health effects for tribal consumption populations.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are generated by the incomplete combustion of organic matter including oil, wood, and coal. They are found in materials such as creosote, coal, coal tar, and used motor oil. Based on structural similarities, metabolism, and toxicity, PAHs are often grouped together when one is evaluating their potential for adverse health effects. EPA has classified some PAHs – called cPAHs – as probable human carcinogens (Cancer Class B2) as a result of *sufficient* evidence of carcinogenicity in animals and *inadequate* evidence in humans [38].

Benzo(a)pyrene is the only cPAH for which EPA has derived a cancer slope factor. The benzo(a)pyrene cancer slope factor was used as a surrogate to estimate the total cancer risk of cPAHs in sediment. It should be noted, benzo(a)pyrene is considered the most carcinogenic of the cPAHs. The use of its cancer slope factor as a surrogate for total cPAH carcinogenicity may overestimate risk. To address this issue, DOH made an adjustment for each cPAH based on the relative potency to benzo(a)pyrene or TEQ [38].

Dietary sources make up a large percentage of PAH exposure in the U.S. population. Smoked or barbecued meats and fish contain relatively high levels of PAHs. The majority of dietary exposure to PAHs for the average person comes from ingestion of vegetables and grains (cereals) [39].

Sediment ingestion from Fidalgo Bay could result in lifetime non cancer exposure doses of 3.60×10^{-7} mg/kg/day (see Appendix A, Table A2). A LOAEL of 1.0×10^{1} mg/kg/day was established for PAH. Therefore, DOH does not expect that exposures to PAHs in sediment will cause harmful non-cancer health effects.

Evaluating non-cancer hazards

Exposure assumptions for estimating contaminant doses from sediment and tissue exposures are found in Appendices A and B, Tables A1 and B1. In order to evaluate the potential for non-cancer adverse health effects that may result from exposure to contaminated media (i.e., air, water, soil, and sediment), a dose is estimated for each COC. These doses are calculated for situations (scenarios) in which a person might be exposed to the contaminated media. The estimated dose for each contaminant under each scenario is then compared to EPA's oral reference dose (RfD). RfDs are doses below which non-cancer adverse health effects are not expected to occur (considered "safe" doses). They are derived from toxic effect levels obtained from human population and laboratory animal studies. These toxic effect levels can be either the lowest-observed adverse effect level (LOAEL) or a no-observed adverse effect level (NOAEL). In human or animal studies, the LOAEL is the lowest dose at which an adverse health effect is seen, while the NOAEL is the highest dose that does not result in any adverse health effects.

Because of data uncertainty, the toxic effect level is divided by “safety factors” to produce the lower and more protective RfD. If a dose exceeds the RfD, this indicates only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded. If the estimated exposure dose is only slightly above the RfD, then that dose will fall well below the observed toxic effect level. The higher the estimated dose is above the RfD, the closer it will be to the actual observed toxic effect level. This comparison is called a hazard quotient (HQ) and is given by the equation below:

$$HQ = \frac{\text{Estimated Dose (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix A for cPAHs found in sediment. Based on exposure estimates quantified in Appendix A, the general population is not likely to experience adverse non-cancer health effects from exposure to chemical contaminants in Fidalgo Bay since the exposure dose did not exceed the RfD.

Similarly, estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendices B and C for contaminants found in tissue. Based on exposure estimates quantified in Appendix B, the general population is not likely to experience adverse non-cancer health effects from exposure to chemical contaminants in Fidalgo Bay. However, the tribal exposure scenario results in doses that exceed the RfD and in some cases, these exposures fall below the actual toxic effect levels (see Appendix C).

Evaluating Exposure to Lead

The biokinetics of lead are different from most toxicants because it is stored in bones and remains in the body long after it is ingested. Children’s exposure to lead is evaluated through the use of the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) developed by the EPA. The IEUBK predicts blood lead levels in a distribution of exposed children based on the amount of lead that is in environmental media (e.g., fish) [40]. It is important to note that the IEUBK model is not expected to accurately predict the blood lead level of a child (or a small group of children) at a specific point in time. In part, this is because a child (or group of children) may behave differently and therefore have different amounts of exposure to contaminated soil and dust than the average group of children used by the model to calculate blood lead levels. For example, the model does not take into account reductions in exposure that could result from community education programs. Despite this limitation, the IEUBK model is a useful tool to help prevent lead poisoning because of the information it can provide about the hazards of environmental lead exposure. For children who are regularly exposed to lead-contaminated fish, the IEUBK model can estimate the percentage of young children who are likely to have blood lead concentrations that exceed a level that may be associated with health problems (usually 10 μg/dl).

Average fish lead concentrations and estimated blood lead levels

The IEUBK model was used to estimate the percentage of children that could have elevated blood lead levels if they frequently eat lead contaminated fish. Default parameters are used for all model inputs unless stated [40]. Exposure was based on a general population and a tribal scenario for children eating shellfish and bottom fish containing an average concentration of lead (see Appendix D).

The adult lead model was used to estimate the 95^{th} percentile Fetal Blood Lead and the average blood lead levels of women who consume lead contaminated seafood. Exposure was based on a general population and a tribal scenario for adults eating shellfish and bottom fish containing an average concentration of lead (see Appendix D).

Evaluating Cancer Risk

Some chemicals have the ability to cause cancer. Theoretical cancer risk is estimated by calculating a dose similar to that described above and multiplying it by a cancer potency factor, also known as the cancer slope factor. Some cancer potency factors are derived from human population data. Others are derived from laboratory animal studies involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice assumes there is no "safe dose" of a carcinogen. Any dose of a carcinogen will result in some additional cancer risk. Theoretical cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the "no safe dose" assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered to be carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. Recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise [41].

Theoretical Cancer Risk

Theoretical cancer risk estimates do not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

Term		# of Excess Cancers
moderate	is approximately equal to	1 in 1,000
low	is approximately equal to	1 in 10,000
very low	is approximately equal to	1 in 100,000
slight	is approximately equal to	1 in 1,000,000
insignificant	is less than	1 in 1,000,000

This document describes theoretical cancer risk that is attributable to site-related contaminants in qualitative terms like low, very low, slight, and no significant increase in theoretical cancer risk. These terms can be better understood by considering the population size required for such an estimate to result in a single cancer case. For example, a low increase in cancer risk indicates an estimate in the range of one cancer case per ten thousand persons exposed over a lifetime. A very low estimate might result in one cancer case per several tens of thousands exposed over a lifetime and a slight estimate would require an exposed population of several hundreds of thousands to result in a single case. DOH considers theoretical cancer risk insignificant when the estimate results in less than one cancer per one million exposed over a lifetime. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population.

Cancer is a common illness and its occurrence in a population increases with the age of the population. There are many different forms of cancer resulting from a variety of causes; not all are fatal. Approximately 1/4 to 1/3 of people living in the United States will develop cancer at some point in their lives [42].

Theoretical cancer risk estimates for exposure to cPAHs in sediments is considered insignificant (2 cancers estimated per 10,000,000 exposed), (see Appendix A, Table A3). Although exposure to cPAHs may occur, the magnitude is likely to be considerably less than the estimated minimum background exposure from sources in food, water, air, sediment, and soil. Many areas of Fidalgo Bay are already under Ecology Agreed Orders. The Orders require an RI/FS be conducted to guide the selection of a cleanup remedy.

Theoretical cancer risk estimates for exposure to seafood by the general population is very low (2 cancers estimated per 100,000 exposed) (see Appendix B, Tables B5). This estimate is within EPA's acceptable risk for fish consumption. However, this is based on bottom fish and shellfish data only. Theoretical cancer risk estimates for exposure to seafood by Tribal consumers range from low to moderate (4 cancers estimated per 10,000 exposed) and moderate to high (2 cancers estimated per 1,000 exposed) (see Appendix C).

Multiple Chemical Exposures

A person can be exposed to more than one chemical through more than one pathway. Exposure to a chemical through multiple pathways occurs if a contaminant is present in more than one medium (i.e., air, soil, surface water, groundwater, and sediment). For example, the dose of a contaminant received from drinking water might be combined with the dose received from contact with the same contaminant in fish.

For many chemicals, much information is available on how the individual chemical produces effects. However, it is much more difficult to assess exposure to multiple chemicals. Due to the large number of chemicals in the environment, it is impossible to measure all of the possible interactions between these chemicals. The potential exists for these chemicals to interact in the body and increase or decrease the potential for adverse health effects. Individual cancer risk estimates can be added since they are measures of probability. However, when estimating non-cancer risk, similarities must exist between the chemicals if the doses are to be added. Groups of chemicals that have similar toxic effects can be added, such as volatile organic compounds (VOCs) which cause liver toxicity. Polycyclic aromatic hydrocarbons (PAHs) are another group of compounds that can be assessed as one combined dose based on similarities in chemical structure and metabolites.

The ATSDR Interaction Profile for persistent chemicals found in fish evaluates the possibility of interactive effects from exposure to a mixture of contaminants including mercury, PCBs, and dioxins [43].

Uncertainty

Assessment of risks attributable to environmental exposures is filled with many uncertainties. Uncertainty with regard to the health assessment process refers to the lack of knowledge about factors such as chemical toxicity, human variability, human behavior patterns, and chemical concentrations in the environment. Uncertainty can be reduced through further study.

The majority of uncertainty comes from our knowledge of chemical toxicity. For most chemicals, there is little knowledge of the actual health impacts that can occur in humans from environmental exposures unless epidemiological or clinical evidence exists. As a result, toxicological experiments are performed on animals. These animals are exposed to chemicals at much higher levels than found in the environment. The critical doses in animal studies are often extrapolated to "real world" exposures for use in human health risk assessments. In order to be protective of human health, uncertainty factors are used to lower that dose in consideration of variability in sensitivity between animals and humans and the variability within humans. These uncertainty factors can account for a difference of two to three orders of magnitude when calculating risk. Furthermore, there are hundreds of chemicals for which little toxicological information is known in animals or humans. These chemicals may in fact be toxic at some level, but risks to humans cannot be quantified due to uncertainty.

The majority of arsenic found in seafood is organic arsenic. Inorganic arsenic in fish and shellfish ranged from about 1% to 20% of the total arsenic [20, 22, 23, 24]. Ecology's evaluation of shellfish and English sole in the Puget Sound indicated that less than 1% of the total arsenic found was in the inorganic form of arsenic [25]. However, since there was no arsenic speciation data for starry flounder, DOH assumed that 10% of the total arsenic detected in bottom fish was inorganic arsenic. Inorganic arsenic is much more harmful than organic arsenic; therefore, the arsenic evaluation may be overestimated.

The amount of contaminated media (fish, water, air, soil) that people eat, drink, inhale, or absorb through their skin is another source of uncertainty. Although recent work has improved our understanding of these exposure factors, they are still a source of uncertainty. In the case of Fidalgo Bay, uncertainty exists with respect to how much fish people eat from Fidalgo Bay, how often they are eating it, what species they are eating, how often children use public access areas, and how much sediment or soil children may inadvertently eat. Estimates are based on best available information or worst-case scenarios. This evaluation is based on the assumption that 100 percent of the type of seafood (bottom fish and shellfish) harvested and consumed was from Fidalgo Bay.

Another source of uncertainty is how seafood is actually prepared for consumption and laboratory testing (i.e., whole fish with guts versus gutless or fillets, large clams with skin, and gut ball). Bottom fish and clams may contain sediments in their digestive tracts that can affect the concentration of heavy metals during analysis. Horse clams are a large clam and may show similar heavy metal patterns to geoduck clams where the skin and gut ball contain the major portion of heavy metals. Bottom fish species should be analyzed without the gut and large clams should be analyzed without skin and without the gut for human health purposes.

The amount and type of chemical in contaminated media is another source of uncertainty. Environmental samples are very costly; so it is not practical or efficient to analyze an adequate number of samples for every existing chemical. Instead, sampling usually focuses on contaminants that are thought to be present based on historic land use or knowledge of specific chemical spills.

Fish Meal Limits

Several contaminants of concern are present in seafood from Fidalgo Bay. Meal limits were calculated using the RfD/MRL as the target risk value and the exposure parameters provided in Appendix E, Table E1.

Many factors must be considered when one is recommending limits on the consumption of seafood including the health benefits of eating fish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these limits do not consider that multiple species are consumed, a consideration that would require weighting the percent of each species consumed.

Children's Health Concerns

The potential for exposure and subsequent adverse health effects often increases for younger children compared with older children or adults. ATSDR and DOH recognize that children are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. The following factors contribute to this vulnerability:

- Children are more likely to play outdoors in contaminated areas by disregarding signs and wandering onto restricted locations.
- Children often bring food into contaminated areas, resulting in hand-to-mouth activities.
- Children are smaller and receive higher doses of contaminant exposures per body weight.
- Children are shorter than adults; therefore, they have a higher possibility of breathing in dust and soil.
- Fetal and child exposure to contaminants can cause permanent damage during critical growth stages.

These unique vulnerabilities of infants and children demand special attention in communities that have contaminated water, food, soil, or air. Children's health was considered in the writing of this health consultation and the exposure scenarios treated children as the most sensitive population being exposed.

Conclusions

Based on the information provided, DOH concludes the following:

1. DOH concludes that consumption of seafood at tribal scenario rates is expected to harm children and adults health. The Swinomish, Samish, Lummi and the Upper Skagit are tribes or nations that fish in this area or it is in their usual and accustomed fishing rights areas. If any of the tribes or nations are using Fidalgo Bay for harvesting and is consuming at tribal scenario rates, this would represent a "public health hazard". The Swinomish Indian Tribal Community has stated, "Fidalgo Bay, historically an important harvest site, is now impacted by contamination and thus not used for harvest in recent years" [6]. It may also be unlikely that 100% of a subsistence consumer (tribes or nations) would be consuming and harvesting from Fidalgo Bay only.

2. DOH concludes that consuming bottom fish or shellfish from Fidalgo Bay is not expected to harm the **general** population's (children or adults). This area also falls under the Puget Sound Crab Advisory. DOH recommends consuming only Dungeness and Red Rock crab from non-urban areas and that "crab butter" and viscera should not be eaten. Based on contaminants of concern in bottom fish or shellfish, calculated meal limits are 13 clams per month, 14 crabs per month, and 14 bottom fish per month (see Appendix E, Tables E2, E3 and E4). Table E5 shows the adjustment of meal size based on the body weight of the consumer.

3. DOH concludes that touching, breathing or accidentally eating sediment one-day-per-week or 52 days per year from Fidalgo Bay is not expected to harm people's health. The maximum level of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in this exposure scenario is below levels known to result in non-cancer harmful health effects. In addition, the exposure scenario does not present an elevated theoretical cancer risk.

Recommendations

1. DOH recommends Ecology perform the necessary site remedial investigation and feasibility study (RI/FS) as they work through the process of cleaning up Fidalgo Bay. Proceeding with the planned cleanup will contribute to a significant reduction in human health risk.

2. DOH recommends Ecology perform long-term monitoring of Fidalgo Bay. DOH is available to review a monitoring plan and monitoring results.

3. DOH recommends following the Puget Sound Recreational Marine Area 7 Fish Consumption Advisory and the Puget Sound crab consumption advisory that states:

    - Eat no more than one meal per week for rockfish and Chinook salmon, and no more than one meal per month for resident (blackmouth) Chinook salmon.

- Eat Dungeness and Red Rock crab from non-urban areas and do not eat the "crab butter" (viscera). More information regarding these advisories is available at http://www.doh.wa.gov/ehp/oehas/fish/rma7.htm or by calling toll-free 1-877-485-7316.

4. DOH also recommends following the meal limits calculated in Appendix E. Eat no more than 13 or 14, eight-ounce meals per month of clams, crabs, bottom fish (English sole and Starry Flounder), or any combination thereof.

General Advice

DOH encourages all Washingtonians to eat at least two fish meals per week as part of a heart healthy diet in accordance with American Heart Association (AHA) recommendations. People may eat fish more than two times weekly but such frequent consumers should take the following steps to reduce exposure to contaminants in the fish that they eat.

- Eat a variety of fish that are low in contaminants according to guidance provided on our website at http://www.doh.wa.gov/fish.
- Follow fish advisory advice provided by DOH and local health agencies for water bodies where you fish. http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx
- Young children and small adults should eat proportionally smaller meal sizes.
- Grill, bake, or broil fish so that fat drips off while cooking.
- Eat fillets without the skin.
- Mercury and other metals are stored in the fillet of the fish and will not be reduced by preparing fish this way.

Public Health Action Plan

Actions Planned

1. DOH will coordinate with Ecology to provide an educational materials fact sheet.

2. DOH will provide copies of this health consultation to Ecology and concerned parties.

3. DOH will be available at Ecology's planned public meetings in the Fidalgo Bay community.

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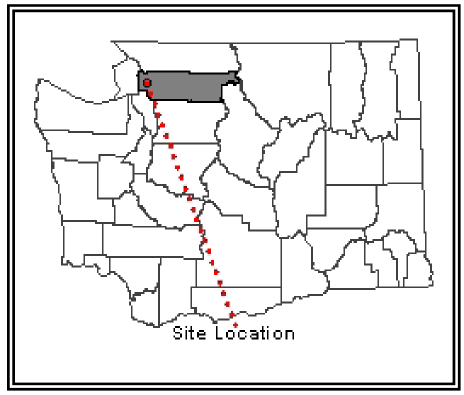
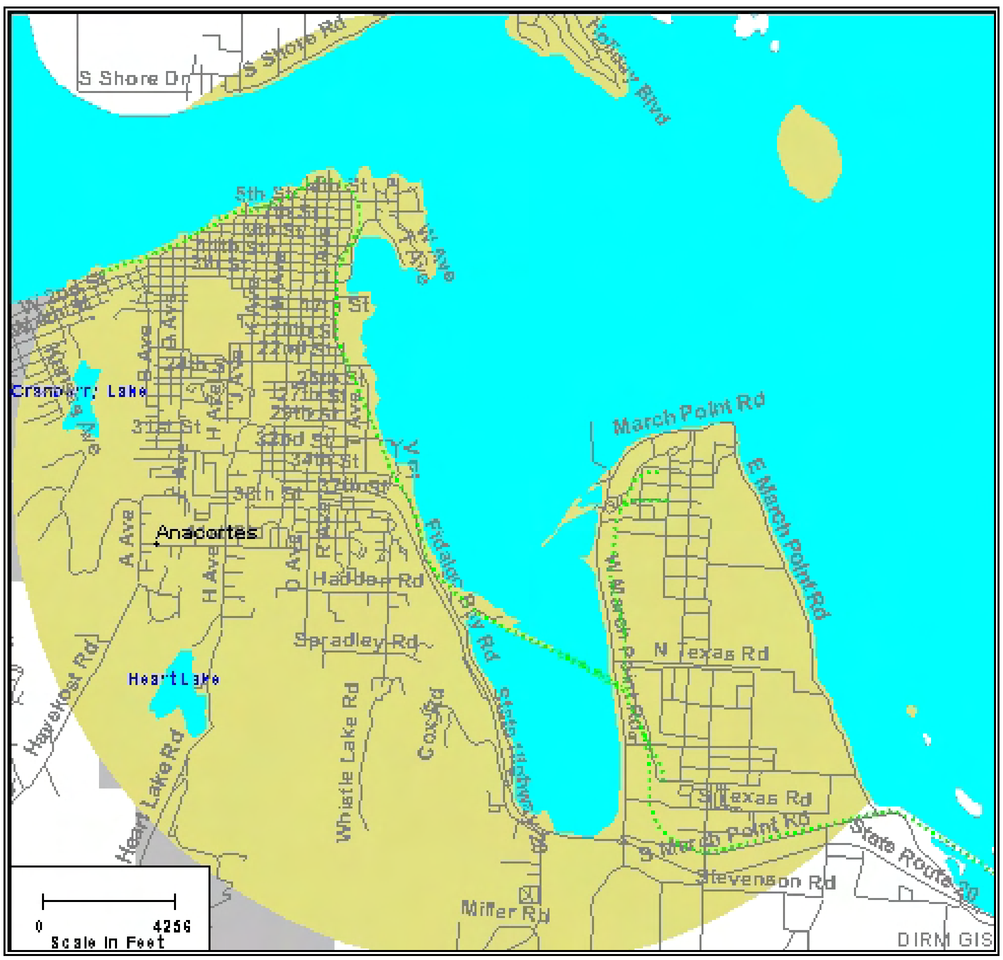
Figure 1. Demographic statistics within three miles of the site* - Fidalgo Bay, Skagit County.

Total Population	**11704**
White	**10818**
Black	**33**
American Indian, Eskimo, Aleut	**143**
Asian or Pacific Islander	**211**
Other Race	**176**
Hispanic Origin	**386**
Children Aged 6 and Younger	**943**
Adults Aged 65 and Older	**2310**
Females Aged 15 - 44	**2088**
Total Aged over 18	**8900**
Total Aged under 18	**2804**
Total Housing Units	**5295**

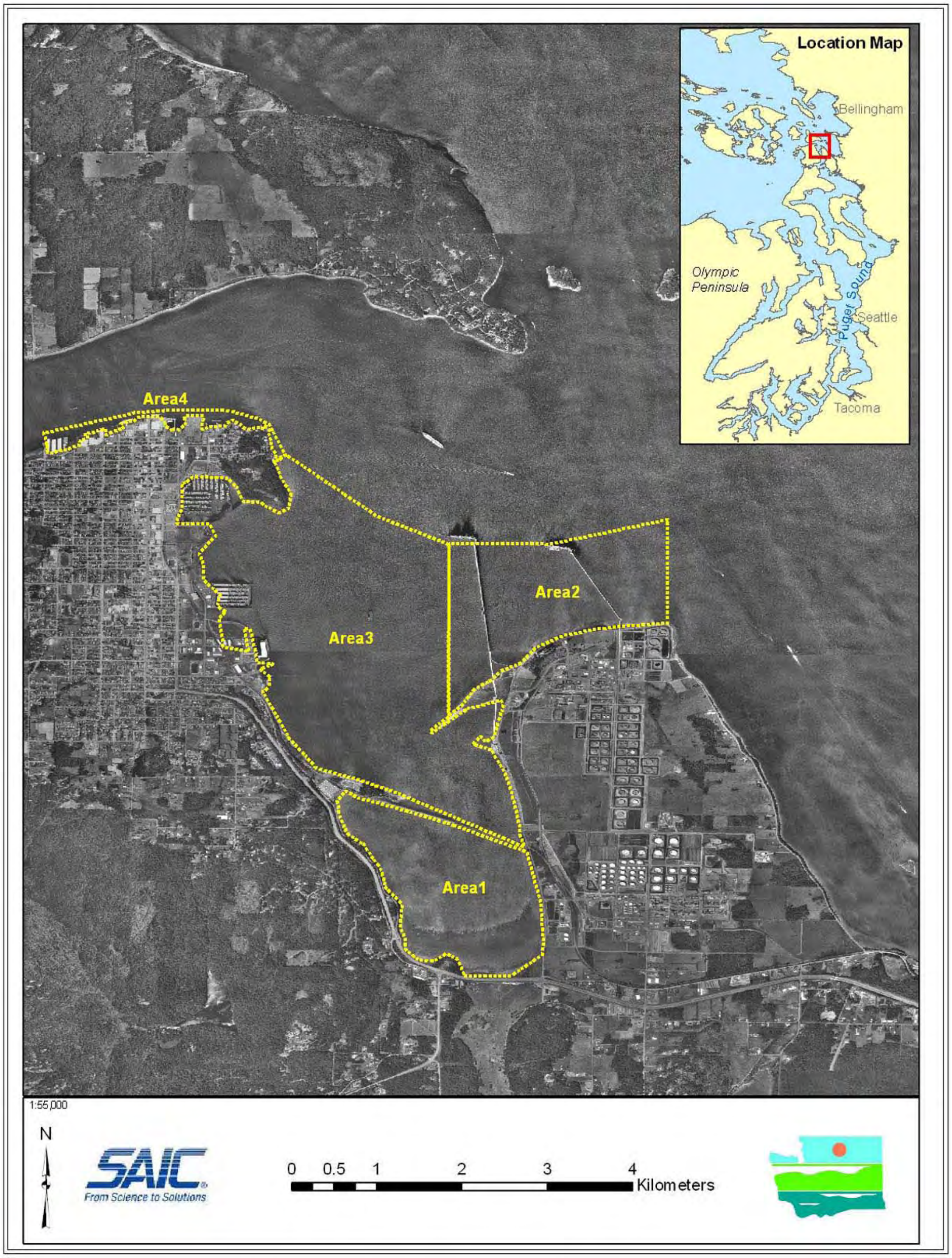




*** Calculated using the area proportion technique. Source: 2000 U.S. CENSUS**

Figure 2. Red box indicates the Fidalgo Bay site location, Skagit County, Washington.

Figure 3. Ecology's sediment and biota sample areas within Fidalgo Bay, Skagit County, Washington.



Appendix A

This section provides calculated exposure doses and assumptions used for exposure to chemicals in sediments at the Fidalgo Bay site. Three different exposure scenarios were developed to model exposures that might occur. These scenarios were devised to represent exposures to a child (0-5 yrs), an older child, and an adult. The following exposure parameters and dose equations were used to estimate exposure doses from direct contact with chemicals in sediments.

Exposure to chemicals in soil via ingestion, inhalation, and dermal absorption.

Total dose $_{\text{(non-cancer)}}$ = Ingested dose + inhaled dose + dermally absorbed dose

Ingestion Route

$$\text{Dose}_{\text{(non-cancer (mg/kg-day)}} = \frac{C \times CF \times IR \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times CF \times IR \times EF \times CPF \times ED}{BW \times AT_{\text{cancer}}}$$

Dermal Route

$$\text{Dermal Transfer (DT)} = \frac{C \times AF \times ABS \times AD \times CF}{ORAF}$$

$$\text{Dose}_{\text{(non-cancer (mg/kg-day)}} = \frac{DT \times SA \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{DT \times SA \times EF \times CPF \times ED}{BW \times AT_{\text{cancer}}}$$

Inhalation Route

$$\text{Dose}_{\text{non-cancer (mg/kg-day)}} = \frac{C \times SMF \times IHR \times EF \times ED \times 1/PEF}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times SMF \times IHR \times EF \times ED \times CPF \times 1/PEF}{BW \times AT_{\text{cancer}}}$$

Table A1. Exposure assumptions used to estimate cPAHs doses from direct contact with sediments in Fidalgo Bay, Anacortes, WA.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	mg/kg	Maximum detected value
Conversion Factor (CF)	0.000001	kg/mg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Ingestion Rate (IR) – adult	100	mg/day	Exposure Factors Handbook [44]
Ingestion Rate (IR) – older child	100		
Ingestion Rate (IR) - child	200		
Exposure Frequency (EF)	52	Days/year	One days a week
Exposure Duration (Ed)	30 (5, 10,15)	years	Number of years at one residence (child, older child, adult yrs)
Body Weight (BW) - adult	72	kg	Adult mean body weight
Body Weight (BW) – older child	41		Older child mean body weight
Body Weight (BW) - child	15		0-5 year-old child average body weight
Surface area (SA) - adult	5700	cm^2	Exposure Factors Handbook
Surface area (SA) – older child	2900		
Surface area (SA) - child	2900		
Averaging $Time_{non-cancer}$ (AT)	1825	days	5 years
Averaging $Time_{cancer}$ (AT)	27375	days	75 years
Cancer Potency Factor (CPF)	7.3	$mg/kg\text{-}day^{-1}$	Source: EPA
24 hr. absorption factor (ABS)	0.13	unitless	Source: EPA (Chemical Specific) PAH
Oral route adjustment factor (ORAF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Adherence duration (AD)	1	days	Source: EPA
Adherence factor (AF)	0.2	mg/cm^2	Child, older child
	0.07		Adult
Inhalation rate (IHR) - adult	15.2	m^3/day	Exposure Factors Handbook [44]
Inhalation rate (IHR) – older child	14		
Inhalation rate (IHR) - child	8.3		
Soil matrix factor (SMF)	1	unitless	Non-cancer (nc) / cancer (c) - default
Particulate emission factor (PEF)	1.45E+7	m^3/kg	Model Parameters

Fidalgo Bay Sediment Exposure Route – Non-cancer

Table A2. Non-cancer hazard calculations resulting from exposure to cPAHs in sediments from Fidalgo Bay, Anacortes, WA.

Contaminant	TEQ Concentration (ppm) (mg/kg)	Scenarios	Estimated Dose (mg/kg/day)			Total Dose	LOAEL (mg/kg/day)	Total Dose/ LOAEL
			Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates			
cPAH	0.102	Child	1.94E-7	7.30E-8	1.34E-11	2.67E-7	1.0E+1	0.00000003
		Older Child	3.54E-8	2.67E-8	8.28E-12	6.22E-8		0.000000006
		Adult	2.02E-8	1.05E-8	5.12E-12	3.07E-8		0.000000003

Fidalgo Bay Sediment Exposure Route – Cancer

Table A3. Cancer hazard calculations resulting from exposure to cPAHs sediments from Fidalgo Bay, Anacortes, WA.

Contaminant	Concentration (ppm)	EPA cancer Group	Cancer Potency Factor (mg/kg-day^{-1})	Scenarios	Increased Cancer Risk			Total Cancer Risk
					Incidental Ingestion of Soil	Dermal Contact with Soil	Inhalation of Particulates	
Total cPAH TEQ	0.102	B2	7.3	Child	9.43E-8	3.55E-8	6.53E-12	1.30E-7
				Older Child	3.45E-8	2.60E-8	8.06E-12	6.05E-8
				Adult	2.95E-8	1.53E-8	7.47E-12	4.48E-8

Lifetime cancer risk: 1.30E-7 + 6.05E-8 + 4.48E-8 = 2.35E-7

Appendix B

This section provides calculated exposure doses and exposure assumptions used for chemicals in bottom fish, shellfish and crab samples taken from Fidalgo Bay. These exposure scenarios were developed to model exposures that might occur and were devised to represent exposures to the general population. The following exposure parameters and dose equations were used to estimate exposure doses from ingestion of contaminants in bottom fish and shellfish.

Ingestion Route

$$\text{Dose}_{(\text{non-cancer (mg/kg-day)})} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times ED}{BW \times AT_{\text{non-cancer}}}$$

$$\text{Cancer Risk} = \frac{C \times CF_1 \times IR \times CF_2 \times EF \times CPF \times ED}{BW \times AT_{\text{cancer}}}$$

Table B1. Exposure assumptions used in exposure evaluation of contaminants in bottom fish, shellfish and crab samples taken from Fidalgo Bay, in Anacortes, Washington.

Parameter	Value	Unit	Comments
Concentration (C)	Variable	ug/kg	Average detected value
Conversion Factor (CF_1)	0.001	mg/kg	Converts contaminant concentration from milligrams (mg) to kilograms (kg)
Conversion Factor (CF_2)	0.001	kg/g	Converts mass of shellfish from grams (g) to kilograms (kg)
Ingestion Rate (IR)	0.57	g/day	Body weight-adjusted shellfish consumption rates to account for children eating nearly 1.6 times as much fish per body weight as do adults (see table B2)
Ingestion Rate (IR)	0.28		Average general population child – bottom fish (see table B3)
Ingestion Rate (IR)	0.81		Body weight-adjusted shellfish consumption rates to account for an older child eating 0.81 times as much fish per body weight as do adults (see table B2)
Ingestion Rate (IR)	0.36		Average general population older child – bottom fish (see table B3)
Ingestion Rate (IR)	1.7		Average general population adult - shellfish
Ingestion Rate (IR)	0.7		Average general population adult – bottom fish (see table B3)
Exposure Frequency (EF)	365	Days/year	Assumes daily exposure
Exposure Duration (ED)	6	years	Number of years at one residence (child)
Exposure Duration (ED)	30		Number of years at one residence (adult)
Body weight (BW)	15	kg	Mean body weight child
Body weight (BW)	70		Mean body weight adult
Averaging Time$_{\text{non-cancer}}$ (AT)	Variable	days	Equal to Exposure Duration
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Cancer Potency Factor (CPF)	Variable	mg/kg-day^{-1}	Source: EPA – Chemical specific

Table B2. Derivation of a child's shellfish consumption rate for the general U.S. population.

Row	Parameter	Adult	Older Child (6-17 yrs)	Child (0-6 yrs)
1	Reported All Fish Consumption Rate-gram fish per kg bodyweight per day (g/kg/day)	0.277	0.225	0.433
2	Ratio to Adult All Fish Consumption Rate	1	0.81	1.6
3	Reported Shellfish Consumption (g/day)	1.70 (average)	Not Reported	Not Reported
4	Average Body Weight (kg)	70	41	15
5	Ratio to Adult BW	1	0.59	0.21
6	Adjusted Shellfish Consumption Rates (g/day) = Row 2 x Row 3 x Row 5	1.70 (average)	0.81 (average)	0.57 (average)

Table B3. Derivation of bottom consumption rate for the general U.S. population based on four percent of total fish intake.

Row	Parameter	Adult	Older Child (6-17 yrs)	Child (0-6 yrs)
1	Reported All Fish Consumption Rate-(g/day)	17.5	9.0	7.0
2	Assume bottom fish intake rate similar to tribal at about 4 percent [15]	0.04	0.04	0.04
3	Adjusted bottom fish rates (g/day) = Row 1 x Row 2	0.70	0.36	0.28

Table B4. Exposure dose and non-cancer risk from ingesting seafood at the average concentrations of contaminants in bottom fish, clams, and crab samples taken from Fidalgo Bay, in Anacortes, Washington.

Species	Contaminant	Average Concentration (ppm)		Estimated Dose (mg/kg/day) General population Average	MRL or RfD (mg/kg/day)	Hazard quotient General population Average
Clams	Arsenic	0.027	Child	1.03E-6	3.00E-4	0.003
			Older child	5.33E-7		0.002
			Adult	6.56E-7		0.002
Crabs		0.071	Child	2.70E-6		0.009
			Older child	1.40E-6		0.005
			Adult	1.72E-6		0.006
Bottom Fish		0.15	Child	2.60E-6		0.009
			Older child	1.32E-6		0.004
			Adult	1.50E-6		0.005
Crabs	Cadmium	0.48	Child	1.82E-5	1.00E-3	0.018
			Older child	9.48E-6		0.009
			Adult	1.17E-5		0.012
Clams	Chromium	1.84	Child	6.99E-5	3.00E-3	0.023
			Older child	3.64E-5		0.012
			Adult	4.47E-5		0.015
Clams	Dioxin	7.99E-8	Child	3.04E-12	1.0E-9	0.003
			Older child	1.58E-12		0.0016
			Adult	1.94E-12		0.0019
Crabs		9.75E-8	Child	3.71E-12		0.0037
			Older child	1.93E-12		0.0019
			Adult	2.37E-12		0.0024
Bottom Fish		1.34E-7	Child	2.50E-12		0.003
			Older child	1.18E-12		0.0012
			Adult	1.34E-12		0.0013
Crabs	Mercury	0.049	Child	1.86E-6	1.00E-4	0.019
			Older child	9.68E-7		0.0097
			Adult	1.19E-6		0.012
Bottom Fish		0.042	Child	7.84E-7		0.008
			Older child	3.69E-7		0.0037
			Adult	4.20E-7		0.0042

PPM – parts per million

Table B5. Cancer risk from ingesting seafood at the average concentrations of contaminants in bottom fish, clams and crab samples taken from Fidalgo Bay, in Anacortes, Washington.

Species	Contaminant	Average Concentration (ppm)	Cancer Potency Factor (mg/kg-day^{-1})		Increased Cancer Risk General population Average	Total Cancer Risk General population Average
Clams	Arsenic	0.027	5.7	Child	5.01E-7	1.53E-5
				Older child	4.34E-7	
				Adult	1.60E-6	
Crabs		0.071		Child	1.32E-6	
				Older child	1.14E-6	
				Adult	4.21E-6	
Bottom Fish		0.15		Child	1.37E-6	
				Older child	1.07E-6	
				Adult	3.66E-6	
Clams	Dioxin	7.99E-8	1.5E+5	Child	3.90E-8	5.82E-7
				Older child	3.38E-8	
				Adult	1.25E-7	
Crabs		9.75E-8		Child	4.76E-8	
				Older child	4.13E-8	
				Adult	1.52E-7	
Bottom Fish		1.34E-7		Child	3.22E-8	
				Older child	2.52E-8	
				Adult	8.61E-8	
Sum of cancer risk						1.59E-5

Appendix C

This section provides calculated exposure doses and assumptions used for exposure to chemicals in seafood at the Fidalgo Bay site using Tulalip Tribe consumption rates. It is based on the EPA Tribal framework for fish and shellfish consumption rates for risk-based decisions.

Intake of contaminant in mg/kg-day (IR_c) = (CF_i x CR_{PS} x $\%_i$ x UCF_1) /BW

[Equation 1]

Where:
IR_c = Intake rate of contaminant by category of fish/shellfish.
CF_i = contaminant concentration (mg/kg) in the tissue of the particular fish or shellfish category.
CR_{PS} = the total consumption rate of fish and shellfish harvested from Puget Sound, 194 grams per day.
$\%_i$ = the percentage of the ingestion rate that consists of the category of fish or shellfish, unitless
BW = body weight, 81.8 kilograms, observed from the Tulalip Tribes' study
UCF_1 = conversion factor 1, 0.001 kilograms per gram

Estimated cancer risk (ECR) = (IR_{total} x ED x EF x CSF) / (AT x UCF_2) [Equation 2]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption
ED = exposure duration, 70 years
EF = exposure frequency, 365 days per year
CSF = oral cancer slope factor for contaminant
AT = averaging time, 70 years for carcinogens
UCF_2 = conversion factor 2, (365 days/year)

Estimated hazard index (EHI) = (IR_{total} x ED x EF x UCF_2) / (RfD x AT) [Equation 3]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption,
ED = exposure duration, 70 years
EF = exposure frequency, 365 days per year
RfD = Oral reference dose for contaminant
AT = averaging time, the same as exposure duration for non-carcinogenic effects
UCF_2 = conversion factor 2, (1 yr/365 days)

Table C1. Fidalgo Bay arsenic intake rate based on the Tulalip Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of arsenic, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic Fish	4.2	0	0
194	Bottom Fish	3.9	0.15	0.0000139
194	Shellfish*	42.2	0.049	0.0000490
Sum, IR_{total}				0.0000629

*Crabs tissues and clams average

Arsenic Estimated hazard index = 0.21

Arsenic Estimated cancer risk = 3.59E-4

Table C2. Fidalgo Bay cadmium intake rate based on the Tulalip Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of cadmium, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic Fish	4.2	0	0
194	Bottom Fish	3.9	0	0
194	Shellfish*	42.2	0.48	0.00048
Sum, IR_{total}				0.00048

*Crabs tissues only average

Cadmium Estimated hazard index = 0.3

Table C3. Fidalgo Bay chromium intake rate based on Tulalip Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of chromium, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic Fish	4.2	0	0
194	Bottom Fish	3.9	0	0
194	Shellfish*	42.2	1.84	0.00184
Sum, IR_{total}				0.00184

*Clams tissues only average

Chromium Estimated hazard index = 0.61

Table C4. Fidalgo Bay dioxin intake rate based on the Tulalip Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of dioxin, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic Fish	4.2	0	0
194	Bottom Fish	3.9	1.34E-7	1.24E-11
194	Shellfish*	42.2	8.87E-8	8.88E-11
Sum, IR_{total}				1.01E-10

*Crabs tissues and clams average

Dioxin Estimated hazard index = 0.10

Dioxin Estimated cancer risk = 1.52E-5

Table C5. Fidalgo Bay mercury intake rate based on the Tulalip Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of mercury, mg/kg in tissue	Category Specific Exposure mg/kg-day
194	Salmon	49.7	0	0
194	Pelagic Fish	4.2	0	0
194	Bottom Fish	3.9	0.042	0.00000388
194	Shellfish*	42.2	0.049	0.000049
Sum, IR_{total}				0.0000529

*Crabs tissues only average

Mercury Estimated hazard index = 0.53

This section provides calculated exposure doses and assumptions used for exposure to chemicals in seafood at Fidalgo Bay using Suquamish Tribe consumption rates. It is based on the EPA Tribal framework for fish and shellfish consumption rates for risk-based decisions.

Intake of contaminant in mg/kg-day (IR_c) = (CF_i x CR_{PS} x $\%_i$ x UCF_1) /BW [Equation 1]

Where:
IR_c = Intake rate of contaminant by category of fish/shellfish.
CF_i = contaminant concentration (mg/kg) in the tissue of the particular fish or shellfish category.
CR_{PS} = the total consumption rate of fish and shellfish harvested from Puget Sound, 766.8 grams per day.
$\%_i$ = the percentage of the ingestion rate that consists of the category of fish or shellfish, unitless
BW = body weight, 79 kilograms, observed from the Suquamish Tribes' study
UCF_1 = conversion factor 1, 0.001 kilograms per gram

Estimated cancer risk (ECR) = (IR_{total} x ED x EF x CSF) / (AT x UCF_2) [Equation 2]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption
ED = exposure duration, 70 years
EF = exposure frequency, 365 days per year
CSF = oral cancer slope factor for contaminant
AT = averaging time, 70 years for carcinogens
UCF_2 = conversion factor 2, (365 days/year)

Estimated hazard index (EHI) = (IR_{total} x ED x EF x UCF_2) / (RfD x AT) [Equation 3]

Where:
IR_{total} = Total intake of contaminant from site-related fish and shellfish consumption
ED = exposure duration, 70 years
EF = exposure frequency, 365 days per year
RfD = Oral reference dose for contaminant
AT = averaging time, the same as exposure duration for non-carcinogenic effects
UCF_2 = conversion factor 2, (1 yr/365 days)

Table C6. Fidalgo Bay arsenic intake rate based on Suquamish Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of arsenic, mg/kg in tissue	Category Specific Exposure mg/kg-day
766.8	Salmon	23.9	0	0
766.8	Pelagic Fish	7.3	0	0
766.8	Bottom Fish	3.8	0.15	0.0000553
766.8	Shellfish*	65	0.049	0.000309
Sum, IR_{total}				0.000364

*Crabs tissues and clams average

Arsenic Estimated hazard index = 1.2

Arsenic Estimated cancer risk = 2.1E-3

Table C7. Fidalgo Bay cadmium intake rate based on Suquamish Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of cadmium, mg/kg in tissue	Category Specific Exposure mg/kg-day
766.8	Salmon	23.9	0	0
766.8	Pelagic Fish	7.3	0	0
766.8	Bottom Fish	3.8	0	0
766.8	Shellfish*	65	0.48	0.003
Sum, IR_{total}				0.003

*Crabs tissues only average

Cadmium Estimated hazard index = 3

Table C8. Fidalgo Bay chromium intake rate based on Suquamish Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of chromium, mg/kg in tissue	Category Specific Exposure mg/kg-day
766.8	Salmon	23.9	0	0
766.8	Pelagic Fish	7.3	0	0
766.8	Bottom Fish	3.8	0	0
766.8	Shellfish*	65	1.84	0.0116
Sum, IR_{total}				0.0116

*Clams tissues only average

Chromium Estimated hazard index = 3.87

Table C9. Fidalgo Bay dioxin intake rate based on Suquamish Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of dioxin, mg/kg in tissue	Category Specific Exposure mg/kg-day
766.8	Salmon	23.9	0	0
766.8	Pelagic Fish	7.3	0	0
766.8	Bottom Fish	3.8	1.34E-7	4.94E-11
766.8	Shellfish*	65	8.87E-8	5.6E-10
Sum, IR_{total}				6.09E-10

*Crabs tissues and clams average

Dioxin Estimated hazard index = 0.61
Dioxin Estimated cancer risk = 9.14E-5

Table C10. Fidalgo Bay mercury intake rate based on Suquamish Tribe seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related concentration of mercury, mg/kg in tissue	Category Specific Exposure mg/kg-day
766.8	Salmon	23.9	0	0
766.8	Pelagic Fish	7.3	0	0
766.8	Bottom Fish	3.8	0.042	0.0000155
766.8	Shellfish*	65	0.049	0.000309
Sum, IR_{total}				0.00032

*Crabs tissues only average

Mercury Estimated hazard index = 3.2

Appendix D

Lead exposure shellfish ingestion scenario used in the IEUBK model

This section provides inputs for the IEUBK model. The following inputs to the model were used to account for the average shellfish ingestion lead exposure from Fidalgo Bay, Anacortes, Washington.

Consumption rates: shellfish, general population child – 0.57 g/day; bottom fish, general population child – 0.28 g/day.

The IEUBK model assumes that a child's total meat intake is 93.5 g/day. EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL. Default assumptions were used unless noted.

Table D1. Blood lead values determined using the IEUBK model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 10 ug/dl Age range 0 - 84 months
Shellfish*	1.21	0.61	1.4
Bottom fish	1.29	0.30	1.3
Average Blood Lead level in percent above 10ug/dl; Age range 0 - 84 months			1.35

PPM – parts per million
*Crabs tissues and clams average

The IEUBK model assumes that a child's total meat intake is 93.5 g/day. EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL. Default assumptions were used unless noted.

Percent of consumption rates represented by category were obtained by using the mean because the 90th percentile did not add up to the total intake of seafood. However, the overall consumption rate was based on the 90th percentile consumers only.

Consumption rates: Tulalip Tribe child – shellfish (5.8 g/day) and bottom fish (0.14 g/day).

Table D2. Fidalgo Bay lead intake rate based on Tulalip Tribe child seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related Consumption Rate, g/day
11.07	Salmon	28.4	0
11.07	Pelagic Fish	18	0
11.07	Bottom Fish	1.3	0.14
11.07	Shellfish*	52.3	5.8

*Crabs tissues and clams average

Table D3. Blood lead values determine using the IEUBK model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 10ug/dl Age range 0 - 84 months
Shellfish*	1.21	6.2	4.26
Bottom fish	1.29	0.15	1.25
Average Blood Lead level in percent above 10ug/dl; Age range 0 - 84 months			2.76

PPM – parts per million
*Crabs tissues and clams average

The IEUBK model assumes that a child's total meat intake is 93.5 g/day. EPA's target cleanup goal is no more than 5 % of the community with BLLs above 10 µg/dL. Default assumptions were used unless noted.

Percent of consumption rates represented by category were obtained by using the mean because the 90th percentile did not add up to the total intake of seafood. However, the overall consumption rate was based on the 90th percentile consumers only.

Consumption rates: Suquamish Tribe child – shellfish 29.26 g/day and bottom fish 1.08 g/day.

Table D4. Fidalgo Bay lead intake rate based on Suquamish Tribe child seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related Consumption Rate, g/day
53.98	Salmon	18.3	0
53.98	Pelagic Fish	9.1	0
53.98	Other	16.2	0
53.98	Bottom Fish	2	1.08
53.98	Shellfish*	54.2	29.26

*Crabs tissues and clams average

Table D5. Blood lead values determine using the IEUBK model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 10ug/dl Age range 0 - 84 months
Shellfish*	1.21	31.29	32.43
Bottom fish	1.29	1.16	1.63
Average Blood Lead level in percent above 10ug/dl Age range 0 - 84 months			17.03

PPM – parts per million
*Crabs tissues and clams average

Lead exposure shellfish ingestion scenario used in the Adult lead model

This section provides inputs for the Adult lead model.
EPA's target cleanup goal is no more than 5% of the community with BLLs above 10 µg/dL.
Default assumptions were used unless noted.

Table D6. Blood lead values determined using the Adult lead model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	Average Concentration (ppm)	Mother's blood lead concentration in ug/dl 95th percentile fetal blood lead in ug/dl	
Shellfish	1.21*	mother	1.9
		fetus	4.8
Bottom fish	1.29	mother	1.5
		fetus	4.6
Average mother's blood lead concentration in ug/dl			1.9
Average 95th percentile fetal blood lead in ug/dl			4.7

PPM – parts per million
*Crabs tissues and clams average

Table D7. Fidalgo Bay lead intake rate based on Tulalip Tribe adult seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related Consumption Rate, g/day
194	Salmon	49.7	0
194	Pelagic Fish	4.2	0
194	Bottom Fish	3.9	7.57
194	Shellfish*	42.2	81.87

*Crabs tissues and clams average

Table D8. Blood lead values determined using the Adult lead model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	**Average Concentration (ppm)**	**Mother's blood lead concentration in ug/dl 95th percentile fetal blood lead in ug/dl**	
Shellfish*	1.21	mother	6.2
		fetus	19.0
Bottom fish	1.29	mother	1.9
		fetus	5.9
Average mother's blood lead concentration in ug/dl			4.1
Average 95th percentile fetal blood lead in ug/dl			12.5

PPM – parts per million
*Crabs tissues and clams average

Table D9. Fidalgo Bay lead intake rate based on the Suquamish Tribe Adult seafood consumption rate Anacortes, Washington.

Overall Fish/Shellfish Consumption Rate, g/day	Category	Percent of Consumption Rate Represented by Category	Site-related Consumption Rate, g/day
766.8	Salmon	23.9	0
766.8	Pelagic Fish	7.3	0
766.8	Bottom Fish	3.8	29.14
766.8	Shellfish*	65	498.42

*Crabs tissues and clams average

Table D10. Blood lead values determined using the Adult lead model for lead in seafood from Fidalgo Bay, Anacortes, Washington.

Seafood	**Average Concentration (ppm)**	**Mother's blood lead concentration in ug/dl** **95^{th} percentile fetal blood lead in ug/dl**	
Shellfish	1.21*	mother	30.4
		fetus	92.7
Bottom fish	1.29	mother	3.3
		fetus	10.0
Average mother's blood lead concentration in ug/dl			16.9
Average 95^{th} percentile fetal blood lead in ug/dl			51.4

PPM – parts per million
*Crabs tissues and clams average

Appendix E

Meal Limit Calculations for contaminants of concern (non-carcinogenic health effects):

Meal limits were calculated for clams, crabs and bottom fish based on contaminants of concern in each species. Additionally, meal limits were calculated based on developmental and immunologic endpoints for dioxin and mercury. Meal limits were calculated using the equation below in conjunction with the MRL or RfD as the target risk value and the exposure parameters provided in the Table E1 below. The developmental and immunologic endpoints are based on the additive effects of dioxin and mercury as recommended in the ATSDR interaction profile for toxic contaminants found in fish. Tables E2, E3 and E4 provides meal limits that would be protective of women and children who eat clams, crabs and bottomfish from Fidalgo Bay based on contaminants of concern in each species.

ML = [(RfD or MRL)*BW* DM]/C * MS
ML = recommended fish meal limit per month (meal/month)
RfD = reference dose (EPA)
MRL = minimal risk level (ATSDR)

Many factors must be considered when one is recommending limits on the consumption of fish, including the health benefits of eating fish, the quality and comprehensiveness of environmental data, and the availability of alternate sources of nutrition. In addition, these limits do not consider that multiple species are consumed, a consideration that would require weighting of the percent of each species consumed. These allowable ingestion rates also do not consider the fact that cooking reduces exposure to some contaminants in fish. Therefore, allowable consumption limits for prepared fish would be greater than those shown in tables E2, E3 and E4.

Table E1. Exposure parameters used to calculate recommended meal limits for clams, crabs and bottom fish from Fidalgo Bay in Anacortes, Washington.

Exposure Parameter	RfD/ MRL	**Endpoint**		**Units**
		Developmental RfD/MRL	Immunological RfD/MRL	
Average Concentration (C)	variable			ug/kg
Arsenic	0.3			ug/kg/day
Cadmium	1			
Chromium	3			
Dioxin	0.000001	0.000001	0.00002	
Mercury	0.1	0.1	0.3	
Days per month (DM)	30.4	30.4	30.4	days/month
Mean Body Weight (BW)	60	60	60	kg
Meal size (MS)	0.227	0.227	0.227	kg

Table E2. Calculated meal limits per month for clams from Fidalgo Bay in Anacortes, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Lowest meals per month (rounded to single digit)
Arsenic	0.027	89.3	
Chromium	1.84	13.1	13
Dioxin	7.99E-8	100.6	

Table E3. Calculated meal limits per month for Crabs from Fidalgo Bay in Anacortes, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded to single digit)
Arsenic	0.071	33.9			
Cadmium	0.48	16.7			14
Dioxin	9.75E-8	82.4	13.7	47.8	
Mercury	0.049	16.4			

Table E4. Calculated meal limits per month for Bottom Fish from Fidalgo Bay in Anacortes, Washington.

Contamination	Concentration (ppm)	Meals based on RfD/ MRL	Meals based on Developmental additive endpoint	Meals based on Immune additive endpoint	Lowest meals per month (rounded to single digit)
Arsenic	0.15	16.1			
Dioxin	1.34E-7	60.0	14.5	54.8	14
Mercury	0.042	19.1			

Applying the Table E2, E3 and E4 meal limits across the general population assumes that meal size will decrease or increase proportionately with body weight. Such an assumption could result in underestimating exposure for consumers who eat proportionately more fish per unit of body weight. Table E5 demonstrates how an eight-ounce meal for a 70-kilogram adult would change to remain proportional with body weight.

Table E5. Adjustment of fish meal size based on the body weight of the consumer.

Body Weight		Meal Size	
Pounds	**Kilograms**	**Ounces**	**Grams**
19	9	1	28
39	18	2	57
58	26	3	85
77	35	4	113
96	44	5	142
116	53	6	170
135	61	7	199
154	70	8	227
173	79	9	255
193	88	10	284
212	96	11	312
231	105	12	340
250	113	13	369
270	123	14	397
289	131	15	425
308	140	16	454

Certification

The Washington State Department of Health prepared this Health Consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

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