Health Consultation

McNeil Island, Chambers and Sequalitchew Creek Study Area
Evaluation of Shellfish and Sediment
Pierce County, Washington

March 12, 2013

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 334-323 March 2013

Foreword

The Washington State Department of Health (DOH) has prepared this health consultation with funds from a cooperative agreement 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 substances. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances.

The purpose of a health consultation is to assess the health threat posed by hazardous substances in the environment and if needed, recommend steps or actions to protect public health. Health consultations are initiated in response to health concerns raised by residents or agencies about exposure to hazardous substances.

This health consultation was prepared in accordance with ATSDR methodologies and guidelines. However, the report has not been reviewed and cleared by ATSDR. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not be relied upon if site conditions or land use changes in the future.

Sediment and shellfish sampling and laboratory analysis have been funded wholly by the United States Environmental Protection Agency under assistance agreement PC-00J283-01 to Department of Health. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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For people with disabilities, this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TTY/TDD call 711).

For more information about ATSDR, contact the CDC Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's Web site: www.atsdr.cdc.gov.

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Summary

Introduction:

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in sediments from the shoreline and geoducks from the Department of Natural Resource geoduck tract # 12800 located to the south of McNeil Island. This area of study was added to an ongoing study of geoduck from tracts near the mainland south of Tacoma from Chambers Creek to Sequalitchew Creek (Chambers Creek Study area), Pierce County, Washington. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

DOH reached three important conclusions about sediment and shellfish from the south McNeil Island geoduck tract # 12800, Pierce County, Washington.

Conclusion 1:
DOH concludes that touching, breathing, or accidentally eating sediment from the shoreline of south McNeil Island is not expected to harm people's health.

Basis for Decision:
Maximum levels of contaminants in sediments are below levels of concern.

Conclusion 2:
DOH concludes that the general population and high-end (subsistence) shellfish consumers are not likely to experience non-cancer health effects from eating geoducks harvested from tract # 12800 south of McNeil Island.

Basis for Decision:
Exposure scenarios used to calculate the potential risks used the maximum detected level of contaminants of concern in geoduck tissues. The results were below levels known to cause harmful non-cancer health effects.

Conclusion 3:
DOH concludes that the general population and high-end (subsistence) shellfish consumers are not likely to experience cancer health effects from eating geoduck harvested from tract # 12800 south of McNeil Island.

Basis for Decision:
Exposure scenarios used to calculate the potential risk used the maximum level of arsenic detected in geoduck tissues. The result is within the Environmental Protection Agency's (EPA) acceptable estimated cancer risk range of 1 additional case of cancer per 10,000 people exposed to 1 additional case of cancer per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$).

Next Steps:
DOH will provide copies of this health consultation to OSWP, the Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), the Nisqually Indian Tribe (NIT), the Squaxin Island Tribe, and Northwest Indian Fisheries Commission.

For More Information:
If you have any questions about this health consultation contact Lenford O'Garro 360-236-3376 or 1-877-485-7316 at Washington State Department of Health. For more information about ATSDR, contact the Center for Disease Control and Prevention (CDC) Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at www.atsdr.cdc.gov.

Purpose and Statement of Issues

The Washington State Department of Health (DOH) has prepared this health consultation at the request of the DOH Office of Shellfish and Water Protection (OSWP). The purpose of this health consultation is to evaluate the potential human health hazard posed by contaminants in geoduck and sediments from the area south McNeil Island, Pierce County, Washington. Department of Natural Resources (DNR) and Department of Fish and Wildlife (WDFW) co-manage the commercial geoduck tracts with the tribes and have identified this harvest area as geoduck tract # 12800. DOH is responsible for classifying recreational shellfish growing areas. DOH prepares health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

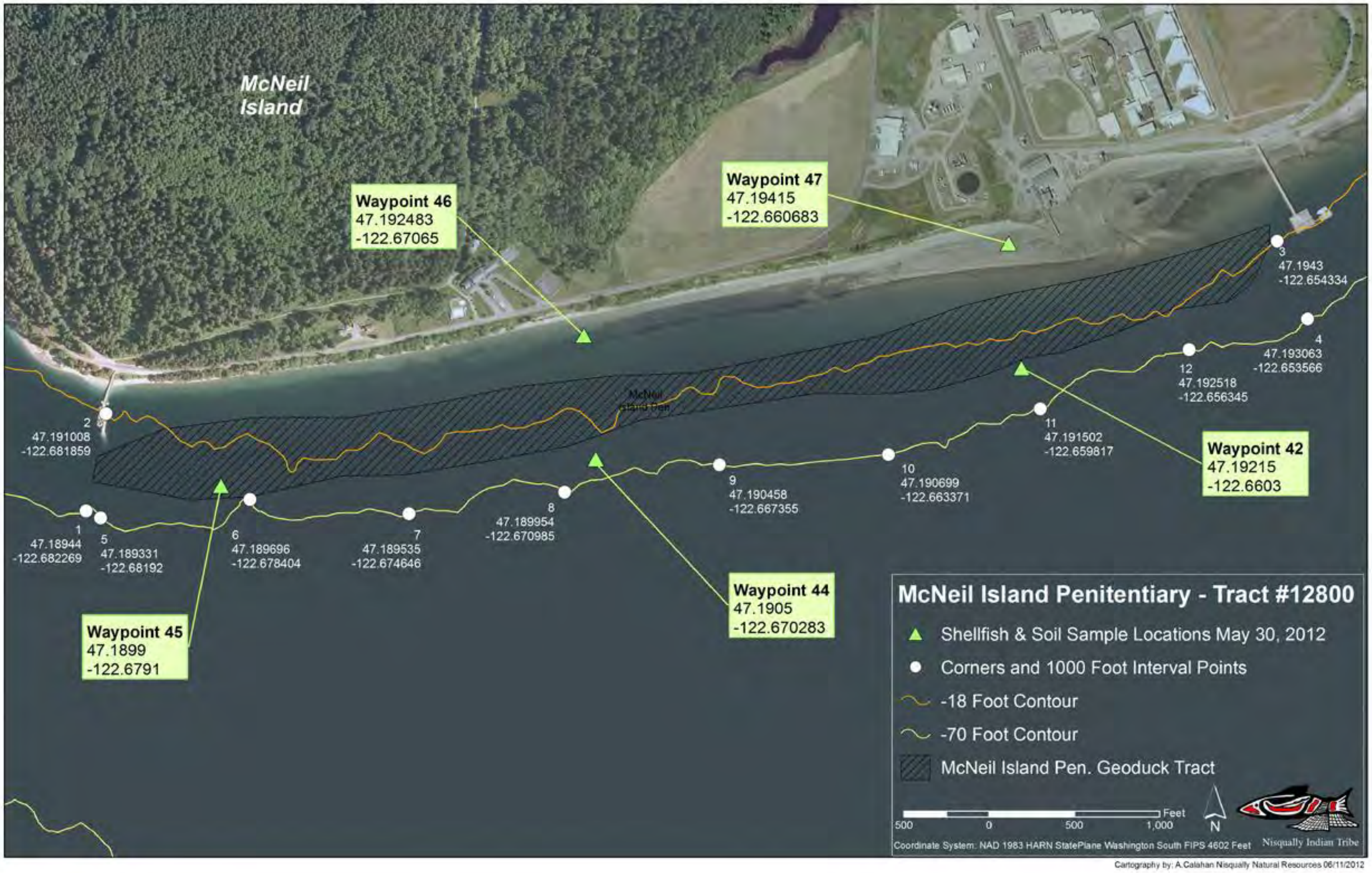
Site Background

The McNeil Island study area is located in Pierce County, Washington (see Figure 1). The federal government deeded the island to Washington State in 1980 to be used as a state prison; The McNeil Island Correction Center, run by the Washington State Department of Corrections (DOC) closed the facility on April 1, 2011. Geoduck tract # 12800 has historically been closed to shellfish harvesting as a result of its proximity to the waste water treatment effluent pipe from McNeil Island Corrections Center (see Figure 2). Therefore, limited assessment of shellfish resources and the status of pollution have occurred.

DOH, OSWP staff reviewed files and interviewed DOC personnel about past and potential current sources of pollution in the study area. OSWP staffs were able to identify a number of potential sources. A sewage outflow is located towards the east end of the geoduck tract. A landfill located at the center of the island has a history of polychlorinated biphenyl (PCB) contamination but is located far from the southern shoreline. Solids obtained from treated wastewater, known as biosolids, have been applied in the center of the island. The Pierce County health department monitors both the landfill and the area of biosolids application. All hazardous waste generated by the corrections center was taken off the island by a hazardous waste contractor via the barge dock. There are no records of any spills. Fueling of trucks was done on the island. Similarly, there are no records of any spills. Farming was done on the north side of the island. Furniture making was the main industry at the prison.

Figure 1: Puget Sound map showing location of McNeil Island in Pierce County, Washington.

Figure 2. South McNeil Island geoduck tract # 12800, sample collection map, Pierce County, Washington.



Sample Collection, Preparation, and Analysis

On May 30, 2012, SCUBA divers from the Nisqually Indian Tribe (NIT) collected 5 geoduck samples at 3 different locations for a total of 15 geoducks. Samples were individually placed in zipper-locked plastic bags, given a unique identifier, placed on ice in coolers, and hand delivered to DOH. DOH staff transported the samples to Ecology's laboratory in Lacey, Washington.

Sample dissection and homogenization followed the DOH standard operating procedure (SOP) for grinding geoduck tissue liquid nitrogen [1]. DOH and NIT staff dissected each geoduck in a manner similar to the way they would be cleaned prior to consumption, as described in the shellfish and sediment sampling plan for south McNeil Island geoduck tract # 12800 [2]. Edible portions of geoduck tissue (neck and mantle) were separated from the shell and gutball. The outer skin of the neck and mantle was removed and discarded. Five geoducks from each location were homogenized in liquid nitrogen and composited into a one sample for each of the three locations along the tract. Three composites of the edible portion and three composites of the gutballs were sent to Test America Laboratories, Inc. then analyzed for metals, PCBs, semi-volatile organics, and percent lipids.

Sediment samples were collected at two locations on the shoreline adjacent to the geoduck tract on May 30, 2012 and delivered to DOH. Sediment samples were collected as described in the sampling plan for south McNeil Island geoduck tract # 12800 [2]. Samples were delivered along with homogenized geoduck tissues to Test America Laboratories, Inc. for analysis. Sediments were analyzed for metals, PCBs, and other semi-volatile organics, percent moisture, and percent solids.

Results

The maximum contaminant concentrations for edible portions (mantle and neck strap) are presented in Tables 1 and 2. The non-edible portions of the geoducks (gutball) had slightly higher levels of contaminants than the edible portions and are presented in Table 3.

The maximum level of contaminants detected in sediments is shown in Table 4. None of the contaminants found in the sediment samples exceeded ATSDR and state residential soil standards for everyday exposure.

Table 1. Screening values and maximum concentration of contaminants detected in geoduck (mantle and neck strap) composite samples collected by the Nisqually Indian Tribe in 2012 south McNeil Island geoduck tract # 12800, Pierce County, Washington.

Chemicals	**Maximum Concentration (ppm)**	**Screening Values (ppm)** [3]		**EPA Cancer Class**	**MRL** (mg/kg/day)	**Non-cancer Contaminant of Concern**
		General Population	**Subsistence Consumer**			
Arsenic total	3.5	n/a	n/a	A	0.0003	n/a
Arsenic, inorganic	0.035	1.2	0.147			No
Cadmium	0.19	4	0.49	B1	0.001*	No
Chromium	0.16	4	0.49	D	0.001	No
Copper	13	160	19.7	D	0.04**	No
Lead	0.035 J	n/a	n/a	B2	n/a	Yes
Selenium	1.2	20	2.46	D	0.005	No
Silver	0.96	20	2.46	D	0.005	No
Zinc	39	1200	147.5	D	0.3	No
Acenaphthene	0.0016 J	240	30	D	0.06***	No
Phenanthrene	0.0015 J	160	19.7	D	0.04****	No
Fluoranthene	0.0015 J	160	19.7	D	0.04***	No
Benzo[a]anthracene	0.0018 J	120	15	B2	0.03*****	No
Chrysene	0.0018 J	120	15	B2	0.03*****	No

ATSDR - Agency for Toxic Substances and Disease Registry
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
J - data qualifier: The associated numerical result is an estimate
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
EPA – Environmental Protection Agency
* EPA oral reference dose for cadmium in food
** EPA oral reference dose for copper based on EPA's health effects assessment summary tables
*** RfD - EPA oral reference dose
**** Fluoranthene RfD value was used as a surrogate
***** Pyrene RfD value was used as a surrogate
n/a – not available
ppm -parts per million
mg/kg/day - milligrams per kilogram body-weight per day

Table 2. Carcinogenic screening values and maximum concentration of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) detected in composited geoduck samples collected by Nisqually Indian Tribe in 2012, south McNeil Island geoduck tract # 12800, Pierce County, Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm) [3]		EPA Cancer Class	Cancer Potency Factor (mg/kg/day^{-1})	Cancer Contaminant of Concern
		General Population	Subsistence Consumer			
Benz(a)anthracene	0.0018 J	cPAH	cPAH	B2	cPAH	cPAH
Chrysene	0.0018 J					
Benzo(a)pyrene	0.0015 U					
Dibenz(a,h)anthracene	0.0015 U					
Indeno(1,2,3-cd)pyrene	0.0015 U					
Benzo(b)fluoranthene	0.0015 U					
Benzo(k)fluoranthene	0.0015 U					
Fluoranthene	0.0015 J					
Benzo(g,h,i)perylene	0.0015 U					
Total cPAH BaP-EQ	9.59E-3	5.5E-3	6.7E-4	B2	7.3	Yes

B2 - EPA: Probable human carcinogen (inadequate human, sufficient animal studies)
U- data qualifier: The analyte was not detected at this level (half the detection limit was used in the evaluation)
ppm -parts per million
cPAH - carcinogenic polycyclic aromatic hydrocarbons
EPA – Environmental Protection Agency
mg/kg/day - milligrams per kilogram body-weight per day
BaP-EQ – Benzo(a)pyrene-equivalent
Total cPAH BaP-EQ –all carcinogenic polycyclic aromatic hydrocarbons (cPAH) are multiplied by their potency factor relative to benzo(a)pyrene to obtain Total cPAH BaP-Eq

Table 3. Maximum concentration of contaminants detected in composited geoduck gutball samples collected by Nisqually Indian Tribe in 2012, south McNeil Island geoduck tract # 12800, Pierce County, Washington.

Chemicals	Maximum Concentration (ppm)	Screening Values (ppm) [3]		EPA Cancer Class	MRL (mg/kg/day)	Non-cancer Contaminant of Concern
		General Population	Subsistence Consumer			
Arsenic total	4.6	n/a	n/a	A	0.0003	n/a
Arsenic, inorganic	0.046	1.2	0.147			No
Cadmium	0.42	4	0.49	B1	0.001*	No
Chromium	0.39	4	0.49	D	0.001	No
Copper	8.6	160	19.7	D	0.04**	No
Lead	0.14	n/a	n/a	B2	n/a	Yes
Nickel	0.19 J	80	9.8		0.02	No
Selenium	2.3	20	2.46	D	0.005	No
Silver	4.8	20	2.46	D	0.005	Yes
Zinc	31	1200	147.5	D	0.3	No
Fluorene	0.0022 J	160	19.7	D	0.04	No

ATSDR - Agency for Toxic Substances and Disease Registry
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
J - data qualifier: The associated numerical result is an estimate
RfD - EPA oral reference dose
MRL- ATSDR's Minimal Risk Level
* EPA oral reference dose for cadmium in food
** EPA oral reference dose for copper based on EPA's health effects assessment summary tables
n/a – not available
EPA – Environmental Protection Agency
ppm -parts per million
mg/kg/day - milligrams per kilogram body-weight per day

Table 4. Maximum concentrations of contaminants detected in sediment within south McNeil Island geoduck tract # 12800 area in Pierce County, Washington collected by Nisqually Indian Tribe and Washington State Department of Health in 2012.

Compounds	Maximum Concentration (ppm)	Comparison Value (ppm)	EPA Cancer Class	Comparison Value Reference	Contaminant of Concern
Antimony	0.20 J	20	D	RMEG	No
Arsenic	2.0	15	A	EMEG	No
Beryllium	0.16 J	100		EMEG	No
Cadmium	0.039 J	5	B1	EMEG	No
Chromium	53	150 *	A	RMEG	No
Copper	13	500	D	IM EMEG	No
Lead	2.4	250	B2	MTCA	No
Mercury	0.0096 J	15**	D	EMEG	No
Nickel	29	1,000		RMEG	No
Silver	0.044 J	250	D	RMEG	No
Zinc	33	15,000	D	EMEG	No

ATSDR - Agency for Toxic Substances and Disease Registry
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)
* Hexavalent chromium
** methylmercury
J - data qualifier: The associated numerical result is an estimate
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
MTCA - Washington State Model Toxics Control Act
EPA – Environmental Protection Agency
ppm -parts per million

Discussion

The main goal of sampling south McNeil Island geoduck tract # 12800 was to determine if geoduck clams are suitable for commercial harvest based on human health criteria. With the exception of mercury, PCBs, and some pesticides, there are no existing regulatory criteria established for screening chemical contaminant levels in shellfish [4, 5]. The following discussion presents how contaminant data for geoduck clam tissue were evaluated with regards to human health.

Screening Potential Shellfish Contaminants of Concern

Contaminants of concern (COC) were determined by employing a screening process. Screening values (SVs) were developed using EPA guidance to focus the evaluation on contaminants that may be present in geoducks at levels that may result in health impacts (Appendix B) [3]. Maximum geoduck composite sample contaminant levels were screened against values for non-cancer and cancer health effects (see Tables 1 - 3). For chemicals that cause cancer, SVs represent levels that are calculated to increase the risk of cancer by about 1 additional cancer in 100,000 people exposed.

As a conservative approach, these SVs used the general population seafood consumption rate (17.5 g/day) and subsistence seafood consumption rate (142.2 g/day) recommended by EPA [3]. With the exception of lead, chemicals detected below non-cancer SVs represent levels that are not expected to cause any health effects. For lead, SVs have been based on the goal of keeping children's blood lead levels (BLL) below 10 micrograms per deciliter (μg/dl). However, the Centers for Disease Control and prevention (CDC) recently updated this reference level to 5 μg/dl [6].

If the maximum concentration of a composite sample is greater than its SV then the contaminant is evaluated further. Contaminants detected at concentrations exceeding their respective SVs, do not necessarily represent a health threat. For this health consultation all contaminants that are possible carcinogens were automatically evaluated further, except cadmium. Cadmium was not considered because it is only known to cause cancer through inhalation, not ingestion. Contaminants that will be evaluated further included:

- Arsenic
- Lead
- Silver
- cPAH

Screening Potential Sediment Contaminants of Concern

COCs in sediments were determined by employing a screening process. Maximum contaminant levels in sediment were screened against health-based residential soil comparison values (CV). Several types of CVs were used during this process [see the glossary (Appendix A) for descriptions of "comparison value," "cancer risk evaluation guide (CREG)," "environmental media evaluation guide (EMEG)," and "reference dose media evaluation guide (RMEG)"]. CVs 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 CVs represent levels that are calculated to increase the estimated risk of cancer by about 1 in a 1,000,000. These types of CVs often form the basis for cleanup. In general, if a contaminant's maximum concentration is greater than its CV, then the contaminant is evaluated further.

Comparisons may also be made with legal standards such as the cleanup levels specified in the Washington State 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.

None of the contaminants detected in the two sediment samples exceeded residential soil CVs and are below the state residential soil standards for everyday exposure. Therefore, exposures through contact with sediments will not be evaluated any further.

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 [a] to people.

In general, people can be exposed through incidental ingestion of soils or sediments that are contaminated, eating foods and drinking water containing contaminants, inhaling airborne contaminants, and skin contact with contaminated media. Human use patterns and site-specific conditions were considered in the evaluation of exposure to the contaminants of concern identified in Tables 1-4. Exposure to contaminants in surface sediment can occur through the following completed pathways and routes:

Ingestion exposure (swallowing)

Most people inadvertently swallow small amounts of sediment, soil, and dust (and any contaminants they might contain). Young children often put hands, toys, pacifiers, and other things in their mouths, and these items may have dirt or dust on them that may be swallowed. Adults may ingest sediments, soil, and dust through activities such as gardening, mowing, construction work, dusting, and recreational activities. Exposure to contaminants in clams and sediment at the McNeil Island site for the general population and a subsistence fish/shellfish consumer would occurs mainly through ingestion.

The following discussion addresses additional human use patterns and site-specific conditions that are considered in the evaluation of exposure to contaminants in surface sediment at the McNeil Island site. Exposure to contaminants in surface sediments can occur through the following pathways and routes:

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

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.

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[a] Route of exposure means the way people come into contact with a substance. There are three routes of exposure, breathing (inhalation), eating or drinking (ingestion), or contact with the skin (dermal contact). A completed exposure pathway exists when there is direct evidence of a strong likelihood that people have in the past or are presently coming in contact with site-related contaminants.

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.

Evaluating Exposure to Contaminants in Geoduck

As mentioned above, there are no established regulatory levels with regard to chemical contaminants in seafood (excluding mercury, PCBs, and some pesticides) [4, 5]. The U.S. Food and Drug Administration (FDA) had previously derived action levels, tolerances, and guidance levels for chemical substances in seafood, but these levels were not intended for enforcement purposes [4, 5]. More recently, these levels were removed from FDA guidance documents to eliminate confusion.

In absence of existing regulatory levels, DOH will assess human health risk using the methodology described below:

- Estimate how much geoduck meat is consumed by potentially exposed consumers, tribal members, and additional high-end geoduck consuming populations.

- Obtain data from analyze geoduck samples for contaminant concentrations in order to estimate levels in tissue (in this case, samples taken from the McNeil Island tract by the NIT).

- Using this information, DOH can establish what people are potentially exposed to (i.e., DOH can calculate the dose of a contaminant that a person would receive from consuming geoduck clams). For the purpose of this health consultation, it will be assumed that all geoduck clams consumed are harvested from geoduck tract # 12800.

- Finally, determine if the calculated exposure dose is considered safe. This is done by comparing the calculated exposure dose to ATSDR’s minimal risk level (MRL) or EPA’s oral reference dose (RfD) specific to each chemical of concern, modeling blood lead levels in children and fetuses, and estimating a consumer’s lifetime increased estimated cancer risk.

Geoduck Consumption Rates

The majority of geoduck harvested in Puget Sound is exported to markets in Asia. The amount of geoduck typically consumed per person in Asia is not known, but geoduck are costly (~ $20.00 per pound), so frequent consumption is not likely and they are probably eaten only on special occasions. Nevertheless, it is important to estimate a reasonable geoduck consumption rate in order to estimate exposure to chemical contaminants.

Table 5 shows shellfish and geoduck consumption rates for the U.S. population, Puget Sound Native American Tribes, and Asian and Pacific Islanders (API) from King County [7, 8, 9, 10]. The Nisqually Indian Tribe has not measured intake of geoduck among its tribe members. As a surrogate, the consumption rate used in this evaluation is based on the 90th percentile Suquamish (consumers only) rate for geoduck (i.e., 0.44 g/kg/day which corresponds to ~ 1.0 eight-oz. meals per week) [8]. This rate represents geoduck as a portion of the total shellfish eaten. The 2000 Suquamish survey presents a range of total seafood ingestion rates that include many species of shellfish, as well as fin fish. Geoduck is a subgroup of all shellfish. Suquamish geoduck consumption rates range from 1 three-ounce (oz.) meal per month (75th percentile Suquamish children) to 2.7 eight-ounce meals per week (95th percentile Suquamish adults). Appendix C, Table C1 shows the exposure assumptions.

Table 5. Consumption rates for adults and children of the general population, Asian Pacific islander, and tribal members eating all shellfish or only geoduck.

Consumption Rate (meals/month)	**Daily rate-** (g/day) [a]		**Grams shellfish consumed per kilogram body weight per day** (g/kg/day) [b]		**Comparable ingestion rates**
	Adults	Children	Adults	Children	
0.25 3 meals per year	1.9	0.7	0.03	0.05	Average U.S. general population marine shellfish consumption rate (1.7 g/day) Suquamish Tribal children median (consumers only) geoduck consumption rate (0.053 g/kg/day) [8]
0.5 6 meals per year	3.7	1.4	0.05	0.09	Squaxin Island Tribal adult median shellfish consumption rate (0.065 g/kg/day) [10] Suquamish Tribal adult median (consumers only) geoduck consumption rate (0.052 g/kg/day) [8]
1	7.5	2.8	0.11	0.19	Tulalip Tribal adult median shellfish consumption rate (0.153 g/kg/day) Suquamish Tribal children 75th percentile (consumers only) geoduck consumption rate (0.23 g/kg/day) [10]
2	15	5.6	0.22	0.37	Suquamish Tribal adults 80th percentile (consumers only) geoduck consumption rate (0.25 g/kg/day) [8]
4	30	11	0.43	0.73	Suquamish Tribal adults 90th percentile (including non-consumers) geoduck consumption rate (0.39 g/kg/day) [8] Suquamish Tribal adults 90th percentile (consumers only) geoduck consumption rate (0.44 g/kg/day) [8] King County Asian and Pacific Islander median all shellfish consumption rate (0.50 g/kg/day) [9] Suquamish Tribal children 95th percentile (including non-consumers) geoduck consumption rate (0.84 g/kg/day) [8]
10	76	28	1.08	1.9	Suquamish Tribal adult 95th percentile geoduck consumption rate consumers only (1.117 g/kg/day) [8]

[a]- assumes eight-ounce meal (227 g) for adults and three-ounce meal (85 g) for children
[b]- assumes a bodyweight of 70 kg for adults and 15 kg for children

Chemical Specific Toxicity

Arsenic

The majority of information concerning the health effects of arsenic exposure in humans comes from studies of populations that were chronically exposed to arsenic in their drinking water and occupational studies in which workers were exposed to arsenic trioxide dust in the workplace.

Several studies have indicated that workers exposed to arsenic trioxide (As2O3) dust in air at smelters have an increased risk of lung cancer [11]. Furthermore, a positive dose response between cumulative exposure to arsenic and lung cancer risk was observed. In other words, the more arsenic workers were exposed, the more likely they were to develop lung cancer. Chronic exposure to arsenic in drinking water has occurred in large populations in Taiwan, Chile, Mexico, Argentina, and Bangladesh [11]. In Bangladesh, where the water concentrations were frequently greater than 0.5 mg/L and as high as 3.8 mg/L, symptoms included dermatological effects (hyperpigmentation, hypopigmentation, keratosis, cracking skin, lesions, and skin cancers), bladder cancer, and black foot disease that ultimately leads to gangrene. Studies in U.S. populations exposed to arsenic in drinking water have not shown increased cancer incidences, but arsenic concentrations in water were generally less than those reported in Taiwan and Bangladesh.

The effects of chronic exposure to arsenic in shellfish have not been studied. Seafood is recognized as one of the main dietary sources of arsenic [12]. However, arsenic in shellfish is considered nontoxic because it is present mainly in its organic form; only the inorganic forms, arsenite and arsenate are considered toxic [13]. Arsenic ingested with shellfish is usually in the relatively nontoxic form of arsenobetaine [14].

Speciation of the various forms of arsenic has been conducted in shellfish [13, 14, 15, 16] Inorganic and organic species present in some shellfish (pacific oysters) include arsenite, arsenate, methylarsonic acid, dimethylarsinic acid, and the nontoxic arsenobetain. Shellfish contains a relatively small amount of inorganic arsenic compared to the total arsenic concentration. The percent of inorganic arsenic to species of total arsenic in oysters ranges approximately from 1% to 2% [14, 15, 16].

On the other hand, other studies revealed that shellfish may contain a relatively large amount of inorganic arsenic (up to 19% of the total arsenic in one homogenate) [13]. The levels of inorganic arsenic compared to total arsenic concentration in most shellfish vary from species to species; therefore, the amount of toxic arsenic species in shellfish (geoduck) is uncertain. Data obtained from the Suquamish Tribe and EPA's Manchester Laboratory revealed that inorganic arsenic levels in edible tissue of geoduck is less than 1% of the total arsenic [17]. For this assessment, DOH assumes that inorganic arsenic represents 1% of the total arsenic detected in edible tissue.

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 evaluating their potential for adverse health effects. EPA has classified some PAHs as probable human carcinogens (B2), called cPAHs as a result of *sufficient* evidence of carcinogenicity in animals and *inadequate* evidence in humans [18].

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) [19].

Non-carcinogenic polycyclic aromatic hydrocarbons (PAHs)

Non-cancer adverse health effects associated with PAH exposure have been observed in animals, but generally not in humans (with the exception of effects to the skin, bone marrow, and lymph node system) [18]. The skin is prone to PAH effects in both humans and animals. However, the observed effect level for carcinogenic endpoints is very much lower than that of the non-cancer endpoints. Therefore, it is routine to focus on the potential cancer effects of PAHs.

Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)

Although several PAHs were analyzed in tissue, only a single value, called a total cPAH was presented in this health consultation. Benzo(a)pyrene (BaP) is the only cPAH for which EPA has derived a cancer slope factor. In a manner similar to deriving the toxic equivalent (TEQ) for dioxin/furan compounds, each cPAH is multiplied by a Relative Potency Factor (RPF) based on BaP (Appendix C, Table C5) [18]. The RFP approach is based on the weight-of-evidence for carcinogenicity and the premise that many cPAHs are structurally and toxicologically similar to BaP. Products of each congener multiplied by its RPF are summed to equal the BaP-relative potency equivalent (BaP-EQ).

Silver

Silver is a naturally-occurring element in the earth's crust. Silver is used in jewelry, silverware, dental fillings, solders, photography, and electronic equipment. Silver is also used in medicines, chewing gum, and as an antibacterial agent. Most people are exposed to very low levels of silver in their diet. Exposure to high levels of silver for prolonged periods may result in a blue-gray discoloration of the skin called arygria [19]. Arygria is considered a cosmetic problem and the most serious effect from exposure to silver. The RfD for silver ingested is 0.005 mg/kg/day based on these cosmetic effects.

Lead – Occurrence, Health Concerns, and Risks

Lead is a naturally occurring chemical that is normally found in soil. In Washington, normal background concentrations rarely exceed 20 ppm [21]. However, widespread use of certain products (such as leaded gasoline, lead-containing pesticides, and lead-based paint) and emissions from certain industrial operations (such as smelters) have resulted in significantly higher levels of lead in many areas of the state, including south McNeil Island.

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, younger children tend to ingest more dust and soil, absorb significantly more of the lead that they swallow, and more of the lead that they absorb can enter their developing brains. 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.

Exposure to lead can be monitored by measuring the level of lead in the blood. In general, blood lead rises 1-5 μg/dl for every 1,000 ppm increase of lead in soil or dust concentration [22]. For children, the CDC defined an elevated blood lead level (BLL) as greater than, or equal to, 10 micrograms of lead per deciliter of blood (μg/dl) [23]. 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. U.S. state childhood lead program's 2006 data showed 1.21% of children tested in the U.S. had blood lead levels greater than 10 μg/dl [24]. Therefore, CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 μg/dl [6].

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 [25].

In adults, high exposure to 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 [25]. These health effects 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 levels [26].

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., shellfish) [27]. 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). However, CDC has recently updated its definition for elevated BLL to greater than, or equal to, 5 μg/dl [6].

Average shellfish 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 shellfish. Default parameters are used for all model inputs unless stated (soil default value removed when evaluating shellfish) [27]. Exposure was based on a tribal scenario for children eating shellfish containing an average concentration of lead (see Appendix D, Tables D1 – D3).

The adult lead model was used to estimate the 95^{th} percentile Fetal Blood Lead and the geometric mean blood lead levels of women who consume lead contaminated seafood. Exposure was based on a general population and tribal scenario for adults eating shellfish containing an average concentration of lead (see Appendix D, Tables D4 – D6).

Consuming shellfish from the McNeil Island tract # 12800 would result in children BLL ranging from 0.007% to 0.015% above the CDC 5 μg/dL target level (see Appendix D, Tables D1 – D3). Similarly, consuming shellfish from the McNeil Island tract # 12800 would result in less than 5% estimated BLL above 5 μg/dL for an adult (see Appendix D, Tables D4 – D6). A pregnant mother consuming geoduck neck and mantle from the McNeil Island tract # 12800 would result in the fetus' BLL ranging from 3.9% to 4.1% above 5 μg/dL and the mother's geometric mean BLL is 1.5 μg/dL. A pregnant mother consuming geoduck gut ball from the McNeil Island tract # 12800 would result in the fetus' BLL ranging from 4.0% to 5.3% above 5 μg/dL and the mother's geometric mean BLL ranging from 1.5 μg/dL to 1.7 μg/dL.

Evaluating Non-cancer Hazards

Estimated doses for average U.S. and Suquamish Tribe shellfish or geoduck consumption were calculated and are shown in Appendix C, Tables C1 – C7. These were intended to represent a reasonable range for exposure to contaminants from geoduck consumption for children and adults. In order to evaluate the potential for *non-cancer* adverse health effects a dose is estimated for each COC. These estimated doses were then compared to either the MRL or EPA's RfD. MRLs are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. In the absence of MRLs, DOH uses the EPA's RfD. RfDs are also doses below which non-cancer adverse health effects are not expected to occur. MRLs and/or RfDs are derived from observed effect levels obtained from human population and laboratory animal studies. These observed 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 uncertainty in these data, the toxic effect level is divided by "uncertainty factors" to produce the lower and more protective MRL or RfD. If a dose exceeds the MRL or RfD, it does not mean that adverse health effects will occur, it just means further toxicological evaluation is needed. Further evaluation includes comparing the site-specific estimated dose to doses from animal and human studies that showed either an effect level or a no effect level. This comparison, combined with other toxicological information, such as sensitive groups and chemical metabolism, is used to determine the risk of specific harmful effects. A MRL or RfD is exceeded whenever the Hazard Quotient (HQ) is greater than one (See Appendix C for the hazard quotient equation).

Estimated exposure doses, exposure assumptions, and hazard quotients are presented in Appendix C for COCs found in shellfish. Based on exposure estimates quantified in Appendix C Table C1, people eating shellfish from the study area are not likely to experience adverse non-cancer health effects. Exposure dose form levels of COCs in shellfish at this site did not exceed the MRL or RfD.

Evaluating Cancer Risk

Some chemicals have the ability to cause cancer. 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. 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 [28].

This document describes estimated cancer risk that is attributable to site-related contaminants in qualitative terms like low, very low, slight, and no significant increase in estimated 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 1 cancer case per 10,000 persons similarly exposed over a lifetime. A very low estimate might result in one cancer case per several tens of thousands similarly exposed persons over a lifetime and a slight estimate would require an similarly exposed population of several hundreds of thousands to result in a single case. DOH considers estimated cancer risk insignificant when the estimate results in less than 1 cancer per 1,000,000 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.

Estimated Cancer Risk

Estimated cancer risk does 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

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 in 3 to 1 in 2 people living in the United States will develop cancer at some point in their lives [29].

Total estimated cancer risk from exposure to maximum contaminants in geoduck (neck and mantle) resulted in 5 estimated excess cancer per 100,000 people exposed (see Appendix C, Table C3). This estimate is within EPA's acceptable risk for fish consumption. The range of cancer risks considered acceptable by EPA is 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$). Similarly, total estimated cancer risk from exposure to maximum contaminants in geoduck (gut ball) resulted in 5 estimated excess cancers per 100,000 people exposed (see Appendix C, Table C4).

Uncertainty

Carcinogenic Potential of Arsenic

Although there is some uncertainty surrounding the magnitude of the carcinogenic potential of arsenic, there is a strong scientific basis for choosing a slope factor that is different from the value (1.5 per mg/kg-day) currently listed in the EPA integrated risk information system (IRIS) database [30]. Several recent reviews of the literature have evaluated bladder and lung cancer endpoints instead of skin cancer (which is the endpoint used for the current IRIS value):

- National Research Council (2001) [31]
- EPA Office of Drinking Water (2001) [32]
- Consumer Product Safety Commission (2003) [33]
- EPA Office of Pesticide Programs (2003) [34]
- California Office of Environmental Health Hazard Assessment (2004) [35]
- EPA IRIS Review Draft for the SAB (2005) [30]

Information provided in these reviews allows the calculation of slope factors for arsenic which range from 0.4 to 23 per mg/kg-day (but mostly greater than 3.7 mg/kg-day). A previous EPA IRIS review draft presented a slope factor for combined lung and bladder cancer of 5.7 per mg/kg-day. The slope factor calculated from the work by the National Research Council is about 21 per mg/kg-day. 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 health consultation, DOH used a slope factor of 5.7 per mg/kg-day.

Child Health Considerations

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. The doses calculated for the COCs are not expected to result in adverse health effects for children.

Conclusions

1. DOH concludes that touching, breathing, or accidentally eating sediment from south McNeil Island geoduck tract # 12800 area is not expected to harm people's health. Maximum levels of contaminants in sediments are below level of contaminants of concern.

2. DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck clams) from south McNeil Island geoduck tract # 12800 area are not likely to experience non-cancer health effects. Exposure scenarios were evaluated using the maximum level of contaminants of concern. The results were below levels known to cause harmful non-cancer health effects.

3. DOH concludes that the general population and high-end (subsistence) consumers of shellfish (geoduck clams) from south McNeil Island geoduck tract # 12800 area are not likely to experience cancer health effects. Exposure scenarios were evaluated using the maximum level of arsenic. The result is within the EPA acceptable estimated cancer risk range of 1 excess cancer risk per 10,000 people exposed to 1 excess cancer risk per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$).

Public Health Action Plan

Actions Planned

DOH will provide copies of this health consultation to OSWP, EPA, Ecology, the Nisqually Indian Tribe (NIT), the Squaxin Island Tribe, and Northwest Indian Fisheries Commission.

Report Preparation

This Health Consultation for the McNeil Island was prepared by the Washington State Department of Health (DOH) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. This report was supported by funds from a cooperative agreement with the Agency for Toxics Substances and Disease Registry, U.S. Department of Health and Human Services. This document has not been reviewed and cleared by ATSDR.

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Appendix A Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, 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 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 (CSF)	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.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
Comparison Value (CV)	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.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect.
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].
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.
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 **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.
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 EMEG 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].

Appendix B Screening Value Calculations

For Non-cancer Health Effects

SV = [(MRL or RfD)*BW]/CR [3]

SV = Screening value (mg/kg or ppm)
MRL = Minimal risk level (mg/kg/day)
RfD = Reference dose (mg/kg/day)
BW = Mean body weight (kg)
CR = Mean daily consumption rate (kg/day)

BW (adult) = 70 kg
General population CR = 17.5 g/day = 0.0175 kg/day
Subsistence Consumer CR = 142.4 g/day = 0.1424 kg/day

If maximum concentration is greater than screening value, further evaluation is required.

For Cancer Health Effects

SV_{cancer} = [(RL / CSF) * BW]/ CR [3]

SV_{cancer} = Cancer screening value (mg/kg or ppm)
RL = Risk level (life time cancer risk)
BW = Mean body weight (kg)
CR = Mean daily consumption rate (kg/day)
CSF = Oral cancer slope factor (mg/kg/day)

BW (adult) = 70 kg
General population CR = 17.5 g/day = 0.0175 kg/day
Subsistence Consumer CR = 142.4 g/day = 0.1424 kg/day
RL = $1x10^{-5}$
CSF = contaminants specific
If maximum concentration is greater than screening value, further evaluation is required.

Appendix C Exposure Assumptions

General population and Tribal exposure scenarios were evaluated for consumption of shellfish from south McNeil Island geoduck tract # 12800 area. Exposure assumptions given in Table C1 below were used with the following equations to estimate contaminant doses associated with shellfish consumption.

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

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

Table C1. Exposure Assumptions

Parameter	Value	Unit	Comments
Concentration (C) – High-end	Variable	ug/kg	Maximum value.
Conversion Factor$_1$ (CF_1)	0.001	mg/ug	Converts contaminant concentration from micrograms (ug) to milligrams (mg)
Ingestion Rate (IR) – median Suquamish children - geoduck [8]	0.05	g/kg/day	~ 3 three-oz. meals per year
Ingestion Rate (IR) – 75th percentile Suquamish children – geoduck [8]	0.23		~ 1 three-oz. meal per month
Ingestion Rate (IR) – 95th percentile Suquamish children (includes non-consumers) – geoduck [8]	0.84		~ 1 three-oz. meal per week
Ingestion Rate (IR) – U.S. average adults - all shellfish	0.03		~ 3 eight-oz. meals per year
Ingestion Rate (IR) – median Tulalip adults - all shellfish [10]	0.11		~ 1 eight-oz. meal per month
Ingestion Rate (IR) – 90th percentile adults Suquamish – geoduck (consumers only) [8]	0.44		~ 1 eight-oz. meal per week
Body Weight (BW) - child	15		0-5 year-old child average body weight
Body Weight (BW) - adult	70		Adult mean body weight
Body Weight (BW) – adult tribal	79		Adult mean body weight (Suquamish)
Conversion Factor$_2$ (CF_2)	0.001	kg/g	Converts mass of fish from grams (g) to kilograms (kg)
Exposure Frequency (EF)	365	days/year	Assumes daily exposure consistent with units of ingestion rate given in g/day
Exposure Duration (ED)	6	years	Number of years eating shellfish (child)
	30		Number of years eating shellfish (adult)
Averaging Time$_{\text{non-cancer}}$ (AT)	2190	days	6 years (child)
	10950		30 years (adult)
Averaging Time$_{\text{cancer}}$ (AT)	25550	days	70 years
Minimal Risk Level (MRL) or Oral Reference Dose (RfD)	Contaminant-specific	mg/kg/day	Source: ATSDR, EPA
Cancer Slope Factor (CSF)	Contaminant-specific	mg/kg-day^{-1}	Source: EPA

Table C2. Non-cancer hazards associated with exposure to contaminants of concern in geoduck gutball sampled from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Chemical	Maximum Concentration (ppm)	RfD (mg/kg/day)	Child Dose			Adult Dose		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish (consumers only)
Silver	4.8	0.005	0.00024	0.0011	0.0052	0.00014	0.00053	0.0021
Hazard Quotient			0.05	0.22	1.0	0.03	0.11	0.42

RfD - EPA's Oral Reference Dose
mg/kg/day - milligrams per kilogram body-weight per day
ppm - parts per million

Hazard Quotient (HQ) formula:

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

Table C3. Estimated cancer risk associated with exposure to maximum contaminants of concern in geoduck (neck and strap) sampled from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Chemical	Maximum Concentration (ppm)	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish (consumers only)
Arsenic (inorganic)	0.035	5.7 [b]	8.6E-7	3.9E-6	1.4E-5	2.6E-6	9.4E-6	3.8E-5
Total cPAH (BaP-EQ)	9.59E-3	7.3	3.0E-7	1.4E-6	5.0E-6	9.0E-7	3.3E-6	1.3E-5
Total Estimated Cancer Risk			1.2E-6	5.3E-6	1.9E-5	3.5E-6	1.3E-5	5.1E-5

[a]- Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b]- See uncertainty section on page 23 for the rationale of using this value.
EPA's Oral Reference Dose
ATSDR Intermediate Minimal Risk Level
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
CSF- cancer slope factor
cPAHs – Carcinogenic Polycyclic Aromatic Hydrocarbons
BaP-EQ – Benzo(a)pyrene Equivalents: sum of individual cPAHs multiplied by the relative potency factor (RPF) describing the carcinogenic potential relative to BaP.

Table C4. Estimated cancer risk associated with exposure to maximum contaminants of concern in geoduck gutball sampled from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Chemical	Maximum Concentration (ppm)	CSF (mg/kg/day)	Child Cancer Risk [a]			Adult Cancer Risk [a]		
			Median Suquamish	75th Suquamish	95th Suquamish (includes non-consumers)	Average U.S	Median Tulalip (All Shellfish)	90th Suquamish (consumers only)
Arsenic (inorganic)	0.046	5.7 [b]	1.1E-6	5.2E-6	1.9E-5	3.4E-6	1.2E-5	4.9E-5
Total Estimated Cancer Risk								

[a]- Cancer risks do not represent cumulative lifetime exposure from childhood to adulthood due to lack of consumption data from 7 to 15 year old children.
[b]- See uncertainty section on page 23 for the rationale of using this value.
EPA's Oral Reference Dose
ATSDR Intermediate Minimal Risk Level
ppm – parts per million
mg/kg/day - milligrams per kilogram body-weight per day
CSF- cancer slope factor

Table C5. Benzo(a)pyrene relative potency equivalent (BaP-EQ) For Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs) [36, 37]

Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)	BaP-EQ
Benzo(a)anthracene	0.2
Chrysene	0.1
Benzo(a)pyrene	1
Dibenz(a,h)anthracene	10
Benzo(g,h,i)perylene	0.009
Indeno(1,2,3-cd)pyrene	0.07
Benzo(b)fluoranthene	0.8
Benzo(k)fluoranthene	0.03
Fluoranthene	0.08

cPAHs – Carcinogenic Polycyclic Aromatic Hydrocarbons
BaP-EQ – Benzo(a)pyrene Equivalents: sum of individual cPAHs multiplied by the relative potency factor (RPF) describing the carcinogenic potential relative to BaP.

Appendix D Lead exposure

Shellfish Ingestion Scenario Used in the IEUBK Model

This section provides the inputs for the Integrated Exposure Uptake Biokinetic Model (IEUBK) estimated blood lead levels (BLLs) in children (0 to 84 months) after eating geoduck from south McNeil Island geoduck tract # 12800, Pierce County, Washington. The IEUBK model (IEUBKwin32 Lead Model Version 1.1 Build 11) utilizes exposure, uptake, biokinetic, and probability distribution modules to estimate BLLs in children exposed to lead contaminated media. The model estimates the risk (i.e, probability) that a child's or population of children's BLL concentration will exceed a certain reference value. Default assumptions were used except for changes to the following four parameters:

- Outdoor soil lead concentration was changed to 0 ppm.
- Alternate dietary shellfish concentrations were based on average concentration of the edible tissues (neck and mantle) (0.016 ppm) and gutball (0.12 ppm) measured in the three composite samples for each.
- Alternate dietary percent of food class (fish) was calculated by dividing the each of the child geoduck consumption rates by the IEUBK assumption that a child's total meat intake is 93.5 g/day. The shellfish (geoduck) consumption rates used were from the Suquamish survey [8]:
    - 0.7 g/day, 50th percentile (median) of Suquamish children;
    - 2.8 g/day, 75th percentile of Suquamish children;
    - 11.0 g/day, 95th percentile Suquamish of children (includes non-consumers);
- The target blood lead cutoff goal was no more than 5% of the community's children with BLLs above 5 µg/dL.

Table D1. Blood lead values determined using the IEUBK model and median Suquamish children geoduck consumption rate for lead in seafood from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 5ug/dl Age range 0 - 84 months
Geoduck (neck and mantle)	0.016	0.8	0.007
Geoduck Gut Ball	0.12		0.007

ppm – parts per million
µg/dL – micrograms per deciliter
The target cleanup goal of having no more than 5 % of the community (0-84 months) with BLLs above 5µg/dL.

Table D2. Blood lead values determined using the IEUBK model and 75th percentile Suquamish children geoduck consumption rate for lead in seafood from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 5ug/dl Age range 0 - 84 months
Geoduck (neck and mantle)	0.016	3.0	0.007
Geoduck Gut Ball	0.12		0.008

ppm – parts per million
μg/dL – micrograms per deciliter
The target cleanup goal of having no more than 5 % of the community (0-84 months) with BLLs above 5μg/dL.

Table D3. Blood lead values determined using the IEUBK model and 95th percentile Suquamish children (includes non-consumers) geoduck consumption rate for lead in seafood from south McNeil Island geoduck tract # 12800 area, Pierce County, Washington.

Seafood	Average Concentration (ppm)	Percent meat intake as shellfish (%)	Blood Lead level in percent above 5ug/dl Age range 0 - 84 months
Geoduck (neck and mantle)	0.016	11.8	0.007
Geoduck Gut Ball	0.12		0.015

ppm – parts per million
μg/dL – micrograms per deciliter
The target cleanup goal of having no more than 5 % of the community (0-84 months) with BLLs above 5μg/dL.

Shellfish Ingestion Scenario Used in the Adult Lead Model

The Adult Lead Mode (ALM), usually used for estimating exposures to lead in soil, was adapted to estimate blood lead levels of adults eating from south McNeil Island geoduck tract # 12800, Pierce County, Washington. The ALM estimates the blood lead (geometric mean) of an adult and the probability that fetal blood lead as a result of the mother's exposure will be greater than a certain reference value. Default assumptions using the National Health and Nutrition Examination Survey (NHANES) III Phase 1 and 2 data were utilized except for changes to the following three parameters:

- Instead of soil lead concentration (PbS), average geoduck concentrations were used including the edible tissues (neck and mantle) (0.016 ppm) and gutball (0.12 ppm).
- Instead of the soil ingestion rate (IRs), adult shellfish and geoduck consumption rates: were used based on the following:
    - 1.9 g/day, U.S. average adults - all shellfish
    - 7.7 g/day, median Tulalip adults - all shellfish
    - 30.8 g/day, 90th percentile adults Suquamish – geoduck (consumers only)
- The target blood lead reference value was adjusted to 5 µg/dL.

Table D4. Adult blood lead values and estimated effect on fetal blood from adults eating shellfish from south McNeil Island geoduck tract # 12800, Pierce County, Washington as determined using the adult lead model and U.S. average shellfish adult consumption rate.

Seafood	Average Concentration (ppm)	Geometric mean of mother Blood Lead concentration in ug/dl Fetus Blood Lead in percent above 5ug/dl	
Geoduck (neck and mantle)	0.016	mother	1.5
		fetus	3.9
Geoduck Gut Ball	0.12	mother	1.5
		fetus	4.0

ppm – parts per million
µg/dL – micrograms per deciliter

Table D5. Adult blood lead values and estimated effect on fetal blood from adults eating shellfish from south McNeil Island geoduck tract # 12800, Pierce County, Washington as determined using the adult lead model and the median Tulalip adult consumption rate.

Seafood	**Average Concentration (ppm)**	**Geometric mean of mother Blood Lead concentration in ug/dl Fetus Blood Lead in percent above 5ug/dl**	
Geoduck (neck and mantle)	0.016	mother	1.5
		fetus	3.9
Geoduck Gut Ball	0.12	mother	1.5
		fetus	4.2

ppm – parts per million
µg/dL – micrograms per deciliter

Table D6. Adult blood lead values and estimated effect on fetal blood from adults eating shellfish from south McNeil Island geoduck tract # 12800, Pierce County, Washington as determined using the adult lead model and the 90th percentile adult Suquamish consumption rate – geoduck (consumers only) consumption rate.

Seafood	**Average Concentration (ppm)**	**Geometric mean of mother Blood Lead concentration in ug/dl Fetus Blood Lead in percent above 5ug/dl**	
Geoduck (neck and mantle)	0.016	mother	1.5
		fetus	4.1
Geoduck Gut Ball	0.12	mother	1.7
		fetus	5.3

ppm – parts per million
µg/dL – micrograms per deciliter