Health Consultation

Site Characterization Evaluation
Landsburg Mine Site
King County, Washington

November 16, 2016

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

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Foreword

The Washington State Department of Health (Health) prepared this health consultation in accordance with the Agency for Toxic Substances and Disease Registry (ATSDR) methodologies and guidelines. Health consultations are initiated in response to health concerns raised by community members or agencies about exposure to hazardous substances released into the environment. The health consultation summarizes our health findings and if needed, provides steps or actions to protect public health.

The findings in this report are relevant to conditions at the site during the time the report was written. It should not be relied upon if site conditions or land use changes in the future.

This report was supported by funds provided through a cooperative agreement with the ATSDR, U.S. Department of Health and Human Services. The findings and conclusions in these reports are those of the author(s) and do not necessarily represent the views of the ATSDR or the U.S. Department of Health and Human Services. This document has not been revised or edited to conform to agency standards.

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Summary

Introduction

The Washington State Department of Health (Health) conducted this health consultation for the Landsburg Mine site at the request of the City of Kent (City). The City asked Health to evaluate whether the site characterization work done to date is adequate to assess the site's potential health threat to the City's Clark Springs' municipal drinking water system and private wells. The Washington State Department of Ecology (Ecology) has been working with the potentially liable parties (PLPs) to characterize the site and develop cleanup plans. Ecology's work is being done under the state's Model Toxics Control Act (MTCA) Cleanup Regulation.[a]

The site is located approximately 1.5 miles northwest of Ravensdale in southeast King County, Washington (Figure 1). It consists of the Rogers seam, one of the three coal seams that is part of the former Landsburg Mine, and land immediately surrounding the seam (Figure 2). Between the late 1960s and late 1970s, a large volume of industrial waste was disposed in subsidence trenches that formed above the mined-out Rogers seam. The waste poses a potential threat to groundwater, which is used as a public and private drinking water source. It also poses a potential threat to surface water.

The City is concerned that the completed site characterization work is inadequate to assess the potential impact on its municipal drinking water system and private wells. Site characterization includes adequately determining the nature and extent of contamination and evaluating the possible risk that contamination poses to human health and the environment. Since site characterization findings are important for selecting a cleanup option, the City is concerned that the proposed option selected for the site may not be protective of human health. Based on this concern, the City asked Health to conduct a separate evaluation of the site characterization work. In addition to health hazards, Health also considered potential physical hazards posed by the site.

Health completed its evaluation and reached three conclusions about the Landsburg Mine site:

Conclusion 1

Health concludes that the site poses a potential chemical health hazard. The extent of the potential hazard is unknown.

Basis for Decision

Only a small amount of industrial waste disposed in the Rogers seam between the late 1960s and late 1970s has been removed from the site. Since it is difficult to characterize the site, we cannot determine how much of the waste or what type of waste remains within the trenches and former mine. However, based on disposal records, observations made during the limited 1991drum removal, and limited sampling, Ecology, the PLPs and Health all assume some industrial waste remains. These wastes could pose a threat to groundwater, which is used as a public and private

[a] In March of 1989, a citizen-mandated toxic waste cleanup law went into effect in Washington, changing the way hazardous waste sites in the state are cleaned up. This law is known as the Model Toxics Control Act. The regulation Ecology adopted to implement this law is known at the Model Toxics Control Act Cleanup Regulation.

drinking water source near the site. The extent of this potential threat is unknown because of the uncertainty about if, when, where, and what type of release could occur. However, there is currently no indication that the wastes have affected groundwater.

Conclusion 2

Health concludes that, except for arsenic, none of the chemicals found in groundwater at the site in May and November 2013 and June 2014 are a public health hazard. Although the maximum level of arsenic found in the groundwater presents some risk of causing long-term health effects, the levels are below state and federal drinking water standards.

Basis for Decision

Although no one is drinking groundwater from the site monitoring wells, data from these wells provide the only available information about chemicals potentially leaving the mined-out Rogers seam. Based on an assessment of the May and November 2013 and June 2014 groundwater data, the only chemical in groundwater that poses a potential health threat at the site is arsenic. The other chemicals were either not detected or were detected below levels of health concern.

Health has not determined the source of the arsenic found at the site; however, naturally occurring arsenic is commonly found in groundwater across the state. Drinking water in Washington generally has less than 3 micrograms per liter (µg/L) of arsenic but has been found in some Washington wells from 10 to 33,000 µg/L. These higher levels are usually associated with groundwater located in rock or soil that has a naturally high content of arsenic.

Arsenic concentrations from the shallower north and south monitoring wells were below the 3 µg/L level generally found in drinking water in Washington. However, to conservatively estimate the potential health threat posed by arsenic at the site, Health used the maximum groundwater concentration (8 µg/L), which was found in the deepest groundwater monitoring well within the mined-out area, for this evaluation. No water system or private wells located at various distances from the north or south ends of the mine are currently drawing water from this depth (Cruz, Jerome. Message to Barbara Trejo, Health. February 4, 2016. E-mail).[b] However, we conservatively assumed that might be possible in the future although it is not expected given the availability of groundwater at shallower depths in the area.

The 8 µg/L arsenic level found in the deepest groundwater monitoring well could pose an increased cancer risk if the water was used for drinking or food preparation. Skin contact with the arsenic in that water could pose a low cancer risk. This level of arsenic could also poses a non-cancer health threat for a child from birth to less than 1 year old. The 8 µg/L level, however, is below the 10 µg/L federal and state drinking water standards for public water systems. When setting drinking water standards, the U.S. Environmental Protection Agency (EPA) considers the health risks as well as the cost and difficulty of removing arsenic down to that amount. When conducting health consultations, Health considers health risks only and has found that arsenic

[b] Ecology has determined that the water systems and private wells at various distances from the north and south ends of the mine are drawing groundwater that is located hundreds of feet higher than the deepest monitoring well at the site.

levels even below 3 µg/L commonly found in Washington drinking water could pose some long-term health risks.

Conclusion 3

Health concludes that the site poses a physical hazard.

Basis for Decision

The predominant physical hazards at the site appear to be the steep, unfenced subsidence trench walls and possible brush-covered openings into the underground mine that might occur over time within the trenches.

Next Steps

Health recommends taking the following steps to address the potential chemical and physical hazards at the site:

1. Ecology should ensure that additional site characterization tasks are completed and that collected data are evaluated. We recommend completing these tasks before placing the soil cap, which is the cleanup remedy selected for the site. Additional tasks include:

   Monitoring Wells

   a. Install and measure water levels in an appropriate number of monitoring wells to help determine where the groundwater divide is located.

   b. Install and sample additional monitoring wells at the north end of the mine to better assess whether contaminants are being released from the mine. After defining the groundwater divide, additional wells may also need to be installed and sampled at the south end of the mine.

   Public Water Systems

   c. Provide information in the final CAP about the City of Kent's Clark Springs' municipal drinking water system, Covington Water District system, and Cedar Valley Sole Source Aquifer (used by the City of Renton) to ensure that there is a common understanding about these systems. Information would include location relative to the site, brief system description, sources of the facility water, wellhead protection areas/capture zones, and number of people served by the system. Also, provide details to the water system owners about the modifications to the draft cleanup action plan (DCAP) that Ecology and the PLP will make to further reduce the chance of contaminants leaving the site and potentially affecting these systems.

   Private Wells

   d. Conduct a well survey to identify private wells installed in the area since the RI well survey work was completed. Since the site will exist in perpetuity, include language in the final cleanup action plan (CAP) requiring additional well surveys in the future to ensure that new wells in the area are not at risk.

e. Test private wells nearest the north and south portals annually for five years for the same chemicals as the monitoring wells. Re-evaluate the need for further private well testing as part of the five-year site review.

f. Test private wells east and west of the waste disposal area annually for five years and re-evaluate the need for further testing at the five-year review unless it can be confirmed the groundwater from the surrounding bedrock discharges into the mine rather than flowing away from the mine.

Sampling

g. Sample and analyze surface and subsurface soils beyond the trench rim for volatile organic compounds (VOCs) if the soils are located in an area where waste might have been released in the past and will not be covered by the proposed future soil cover.

h. Test the surface water at portals #2 and #3. If surface water continues to discharge from the mine, test it as part of the compliance monitoring program.

i. Continue to ensure that future groundwater sampling methods/procedures and testing methods are appropriately conducted to obtain representative samples

Pumping Test

j. Modify the CAP to explain why pumping tests are not feasible and explain what steps will be taken to ensure that the contaminants do not migrate beyond the conditional point of compliance if a plume is found migrating from the former mine in the future.

Fence Maintenance and Warning Signs

k. Maintain the existing fencing around the waste disposal area and add warning signs explaining why the area is fenced.

2. The property owners should take steps to evaluate and address physical hazards posed by the site.

The following actions will be completed to address these recommendations:

1. Ecology will work with the PLPs to complete the following tasks:

Monitoring Wells

a. Modify the Cleanup Action Plan (CAP) to require water level data collection at the existing monitoring wells LMW-2 through LMW-11 and sentinel/performance wells to better define the groundwater divide at the site. LMW-1 and LMW-1A, which are installed in the adjacent sandstone unit, may also be used to define the divide. A decision about using water level data from these two wells will be made after the sentinel wells are installed.

b. Modify the CAP to require that the deeper sentinel well at the north end of the mine be set at a higher elevation to allow better overall vertical groundwater monitoring coverage. If logistically possible, the shallow and deeper northern sentinel wells will be moved within the inclined northern mine shaft location. However, if that is not possible, they will be moved as close as possible. The changes in locations will be addressed in the CAP and engineering design report. The CAP will also be modified to require considering additional monitoring wells in the southern portion of the mine if the groundwater divide is found to be located beneath any portion of the former waste disposal area.

Public Water Systems

c. Modify the CAP to include information about the City of Kent's Clark Springs' municipal drinking water system, Covington Water District system, and Cedar Valley Sole Source Aquifer (used by the City of Renton) to ensure there is a common understanding and context about these systems in relation to the physical site, site conditions, and remedial design objectives. This information would include location relative to the site, brief system description, sources of the facility water, wellhead protection areas/capture zones, and number of people served by the system. Also, the Responsiveness Summary and final CAP will provide details about the modifications that Ecology and the PLPs will be taking to further reduce the chance of contaminants leaving the site and potentially affecting these systems.

Private Wells

d. Modify the CAP to require the PLPs to conduct private well surveys near the site during the periodic site reviews. Under the MTCA Cleanup Regulation periodic reviews occur at least every 5 years after initiation of the cleanup action.

e. Modify the CAP to require the PLPs to test active private wells nearest the north and south portals annually for five years for the same chemicals as the monitoring wells. Ecology and the PLPs will re-evaluate the need for further private well testing during the five year review.

f. Ecology indicates that it does not feel testing active private wells located west and east of the site is needed at this point in the site's history based on its present monitoring network and proposed groundwater restrictions.

Sampling

g. Modify the CAP to require the PLPs test soil just outside of the proposed cap edge for volatiles.

h. Modify the CAP to require the PLPs conduct some limited surface water testing at the north and south portals prior to remedial construction. The CAP will also be modified to require limited surface water sampling at the north and south portals during remedial construction performance monitoring (Exhibit E, Part A Compliance Monitoring Plan, Table A-2).

i. Continue to ensure that future groundwater sampling methods/procedures and testing methods are appropriately conducted to obtain representative samples.

Pumping Test

j. Modify the CAP to explain why pumping tests are not feasible and explain (or highlight) what steps will be taken to ensure that the contaminants do not migrate beyond the conditional point of compliance if a plume is found migrating from the former mine in the future.

Fence Maintenance and Warning Signs

k. Ecology understands that fencing or portions of the fencing around the waste area will need to be put down during implementation of the Cleanup Action Plan. In the interim, Ecology will notify the PLP Group that existing and future fencing around the waste area must be properly maintained and that signage must be posted that warns why it is being fenced.

2. The property owners addressed the physical hazards posed by the site (Zimmerman, Gary, Golder Associates. Message to Barbara Trejo, Health. October 18, 2016. E-mail). The trench backfilling and soil capping called for in the CAP will eliminate the current physical hazards in the northern portion of the subsidence trench. Other site physical hazards have been assessed by the property owners and addressed with King County on September 28, 2005.

3. Health will provide copies of this health consultation report to the City, Ecology, and PLPs. A copy of the report will also be posted on the Department of Health Site Assessment webpage at www.doh.wa.gov/consults.

4. Health will be available to support the evaluation of site data collected in the future that will be used to assess whether additional monitoring or sentinel wells are needed at the south end of the mine. Health will also be available to review future site characterization plans and results and if requested, groundwater results from private and/or monitoring wells to evaluate if the contaminants pose a potential health threat.

For More Information

If you have any questions about this health consultation, contact Barbara Trejo at 360-236-3373 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 (Health) conducted this health consultation for the Landsburg Mine site at the request of the City of Kent (City). The City asked Health to evaluate whether the site characterization work done to date is adequate to assess the site's potential health threat to the City's Clark Springs' municipal drinking water system and private wells (Trejo, Barbara. Message to Tim LaPorte, City of Kent. April 21, 2014. E-mail).

The site is located approximately 1.5 miles northwest of Ravensdale in southeast King County, Washington (Figure 1). It consists of the Rogers seam, one of the three coal seams that is part of the former Landsburg Mine, and land immediately surrounding the seam (Figure 2). Between the late 1960s and late 1970s, a large volume of industrial waste was disposed in subsidence trenches that formed above the mined-out Rogers seam [1, 2]. The waste poses a potential threat to groundwater, which is used as a public and private drinking water source. It also poses a potential threat to surface water. The Washington State Department of Ecology (Ecology) has been working with the potentially liable parties (PLPs) to characterize the site and develop cleanup plans. Ecology's work is being done under the state's Model Toxics Control Act (MTCA) Cleanup Regulation.

Health conducts health consultations under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Site Background

The Landsburg Mine, a former underground coal mine, is located in a rural residential area. The mine includes three north-south striking coal seams: Fraser, Rogers, and Landsburg. The coal seams dip between almost vertical at the northern end and approximately 70 degrees at the southern end [3]. Subsidence has occurred above each of the seams. The Rogers seam subsidence trenches were used from the late 1960s to1983 for disposal of various industrial waste materials, construction materials, land-clearing debris, tires, and miscellaneous household garbage [1].

The mined section of the Rogers Seam is about a mile in length, up to 750 feet deep, and approximately 16 feet wide [2, 4]. Mine access occurred at the north and south mine portals (Portal #2 and Portal #3, respectively). The seam was mined from four different levels between 1959 and 1975 when all mine openings were closed by blasting.

Numerous faults were encountered during mining [3]. The largest fault, located in the northern portion of the Rogers Seam, had a 75 foot offset, which required the construction of a 130 foot long rock tunnel to rejoin the coal seam [2]. This fault reportedly extends from the land surface vertically through the mine and also appears to have been encountered when mining occurred at the Landsburg and Frazier seams to the east and west, respectively [2, 3]. It appears there was a lack of water when mining through this fault [1]. The other faults were reported to have offsets from 2 to 15 feet, polished surfaces, and tightness [3]. It was postulated that the faults were tight because of north-south compressive forces. Interviews conducted with some mine personnel in 1992 indicate that mining through these smaller faults did not increase water flow in the mine [2].

Subsidence has occurred above the coal seam creating discontinuous trenches at the land surface. The dimensions of the trenches vary from about 60 to 100 feet wide, 20 to 60 feet in depth, and cover a distance of about 3/4 mile [5]. A small area located north of portal #2 appears to have been surface mined to approximately 25 feet below ground surface (bgs) and later back filled with gravel [1]. This area reportedly was initially covered by about 13 feet of gravel.

Between the late 1960s and late 1970s, a large volume of industrial waste was disposed in subsidence trenches that formed above the Rogers Seam [1, 2]. The last documented disposal of this waste was made in 1978 [5]. Approximately 4,500 drums of industrial wastes and about 200,000 gallons of oily wastewater and sludge were reportedly disposed into the northern half of the trenches. The wastes included paint wastes, solvents, metal sludge, and oily water and sludge. What is known about the nature of the waste disposed in the Rogers seam subsidence trenches is based on record searches, limited drum removal activities conducted in 1991, limited sampling performed during the site hazard assessment, field reconnaissance, and a geophysical survey[c] conducted during the remedial investigation [1].

The potentially liable parties removed approximately 115 of the estimated 4,500 drums in 1991 [6]. They reported that most were located in one of the northern trenches. However, 13 barrels were removed from a sludge pond[d] and a nearby stump pile. Volatile and semi-volatile compounds, PCBs, metals, and cyanide were found in drum contents, adjacent soils, and ponded surface water within the subsidence trenches during the drum removal.

Ten additional barrels were reportedly found in the stump pile [6]. However, they were not removed at that time because it was outside the project's scope of work. Some additional drums were also noted in the trench where drum removal had occurred. Those drums were reportedly left in place but covered with a liner at the end of the drum removal project.

The condition of the remaining drums (approximately 4,385) disposed in the trench is unknown. However, it has been suggested that some may have already released their contents or that the content of some of the drums was destroyed by fires that occurred in1971 [1].

A number of environmental investigations have been conducted since the 1991 removal work. A remedial investigation/feasibility study (RI/FS) was completed in 1996 [1]. The RI/FS study boundaries are shown in Figure 2. The RI included the installation and testing of seven monitoring wells and testing of the City of Kent's Clark Springs municipal water supply source and some private wells. Two of the seven monitoring wells are located in the Fraser and Landsburg seams to the east and west of the Rogers seam, respectively. The well within the Landsburg seam (LMW-7) appears to be screened in the mine workings of this separate coal seam. The well in the Fraser seam (LMW-6) is screened in coal but appears to be outside the mined-out area. Three additional monitoring wells were installed in the vicinity of the mined-out Rogers seam in April 2004 and another was installed in the mined-out area in August 2005 [7, 8]. Only three of the monitoring wells (LMW-2, LMW-5, and LMW-11) appear to be screened

[c] The purpose of the geophysical survey was to identify ferrous metal objects.
[d] The sludge pond, which was located within the northern trenches, was reported as oily and containing layers of different colors.

within the mined-out area. LMW-9 and LMW-10 may also be located in the mined-out area; however, it is difficult to determine based on examination of the boring logs.

LMW-2 and LMW-10 are located north of portal #2. LMW-2 appears to be screened in the area where surface mining occurred while LMW-10 may be screened where underground mining occurred. The geophysical survey suggests that some ferrous metals objects may have also been disposed in the former surface mined area. It was suggested that this debris was domestic refuse from the general public because of the close proximity to the road and easy access [1]. However, that has not been confirmed.

Two of the borings/wells (LMW-5 and LMW-11), located at the southern end of the mine appear to have been drilled where underground mining occurred. LMW-5 appears to be installed at the south end of the mined-out area and screened from approximately 232 to 242 feet below ground surface (bgs) LMW-11 is screened near the base of the mine from 697 to 707 feet bgs. LMW-9 might also be installed in the mined-out southern portion of the Rogers seam; however, it is not clear-cut.

Groundwater monitoring at the site has occurred intermittently since monitoring wells were installed during the RI; however, it appears no further monitoring of the Clark Springs facility has been conducted by the PLPs since the 1995 RI work. It also appears that only two private wells have been tested since 1995; those two wells were tested in 2014 [9, 10]. Only a few contaminants were detected in those two private wells; however, they were not considered attributable to the site. Groundwater that discharges to the surface at portal #2 also does not appear to have been tested since the 1995 RI work. However, groundwater discharging near portal #3 was tested in 2000 and 2003 [11, 12].

LMW-8 was intended to replace surface water sampling at portal #3 [8]. It was reportedly screened from 8 to 13 feet bgs in loose silty gravels and gravel-sand-silt mixture; however, the LMW-8 boring log seems to suggest that it may be screened in weathered till, while the cross section along the strike of the coal seam appears to suggest the well may be screened in unweathered till [5, 8]. The PLPs report that the soils encountered at LMW-8 appear to represent the collapsed and filled in Portal #3 gangway (Zimmerman, Gary, Golder Associates. Message to Barbara Trejo, Health. October 18, 2016. E-mail). Based upon it position and depth, they believe LMW-8 is screening mine water just prior to surfacing at Portal #3.

Groundwater samples have been analyzed for the typical groups of chemicals associated with contaminated sites including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals, pesticides, PCBs, and petroleum hydrocarbons. The primary reported groundwater contaminants are metals [5]. Health has not made a determination whether those are naturally occurring. A few organic contaminants were also detected but this appeared to occur infrequently and at low levels. None of the detected contaminants found during the PLP's testing or Ecology's recent private well testing were reportedly considered attributable to waste disposed in the trenches [5, 9, 10].

Today, the site and immediate surrounding area has multiple uses: forestry, rural residential (approximately 130 residential dwellings), and open space [5]. A new junior high school is located approximately 0.65 miles northwest of the site. Water and sewer service is reportedly provided to the junior high school from utility lines extending west from Four Corners in Maple Valley [5]. The nearest home is reportedly 800 feet southwest of the site [1]. Homes in the area receive their drinking water through private wells. Approximately 80 wells exist in the vicinity of the RI/FS study area in 2014; some of the private wells are community wells [13]. Fifty-six private wells were identified in the study area during the RI; however only 30 well logs were available [1]. In September, 2014, Health found 25 additional well logs within the RI study area on Ecology's Well Log Reviewer webpage (Table 1). Septic systems are used for domestic sewage disposal. The City of Kent's Clark Spring municipal water system is located about a half mile southwest of the site [14]. The system provides approximately 60 percent of the City's water supply (Trejo, Barbara. Conversation with Tim LaPorte, City of Kent. April 11, 2014.) The City's population is approximately 124,400 [15].

The Washington Department of Ecology (Ecology) has been working with the potentially liable parties (PLPs) since the early 1990s to characterize the site and develop cleanup plans. Ecology released a final draft cleanup action plan (DCAP) for public comment in October 2013 [5]. All this work is being done under the state's MTCA Cleanup Regulation [16].

The City of Kent has expressed opposition to the DCAP [14]. One of the reasons is because they believe the site has not been adequately characterized. Specifically, the City believes the DCAP has been prepared without knowing:

- what hazardous wastes were disposed into the former mine,
- where the hazardous wastes are located within the mine, and
- how and where the hazardous wastes have moved in the past and might move in the future to potentially impact nearby public and private water supplies.

Because site characterization findings are important for selecting a cleanup option, the City is concerned that the proposed options selected for the site may not be protective of human health.

Community Health Concerns

The City of Kent continues to be concerned that the Landsburg Mine site has not been adequately characterized and that it poses a potential threat to its Clark Springs water supply [14]. In the past, the City of Renton and Covington Water District have expressed similar concerns regarding the site and its potential impact on their water supplies [17, 18]. The City of Renton notes that the site is located in the Cedar Valley Sole Source Aquifer, the source of Renton's drinking water [17]. The Covington Water District indicates that the Portal #3 is located within the capture zone of the 222nd wellhead protection area and within the zone of contribution to their Witte Wellhead protection area [18]. Some private well owners in the area are also concerned about their water quality [19].

Discussion

The wastes disposed at the Landsburg Mine site pose a potential threat to public and private drinking water supplies and surface water in the area. To effectively reduce the potential threat, the site needs to be sufficiently characterized so an appropriate remedy can be selected.[e] Health reviewed a number of documents to understand the site characterization work that has been completed at the site over the years. This included evaluating the May and November 2013 and June 2014 groundwater data obtained from the site monitoring well network to determine if the levels of contaminants found in the groundwater pose a possible health threat. These three monitoring events were the most recent sampling events available at the time Health began its evaluation. Groundwater monitoring has been conducted at the site since 1995, and routine groundwater monitoring events continue to be conducted.

Exposure Pathway Evaluation

The site poses both a potential physical and chemical health threat. The predominant physical hazards at the site appear to be the steep, unfenced subsidence trench walls and possible brush-covered openings into the underground mine that might occur over time within the trenches.

The potential chemical health threat is associated with waste remaining in the mined-out Rogers seam. To begin assessing the possible health threat posed by contaminants found in the groundwater, Health conducted an exposure pathway evaluation to determine ways people might come into contact with the contaminants. An exposure pathway is the route a contaminant takes from where it began (source) to where it ends, and how people can come into contact with it. An exposure pathway has five parts:

- **Source of contamination** (such as the waste disposed in the Rogers seam);
- **Environmental media and transport mechanism** (such as a chemical leaching from a source material);
- **Point of exposure** (such as tap water);
- **Route of exposure** (such as ingestion, inhalation, or dermal contact); and
- **Receptor population** (people potentially or actually exposed to a chemical).

When all five parts are present, it is considered a complete exposure pathway. A potential exposure pathway exists if one or more parts are missing.

Properties in the vicinity of the Landsburg Mine site use groundwater for domestic and other purposes. If drinking water wells or systems associated with these properties draw groundwater that contains contaminants from the site, a completed past, current, and potential future exposure pathway exists.

There are many factors that determine if an exposure will cause health effects, including:

- **Dose** (how much),
- **Duration** (how long),
- **Exposure** (how someone comes in contact with the chemicals), and
- **Personal** (a person's age, sex, diet, family traits, lifestyle (such as smoking tobacco), and state of health).

[e] Ecology made a determination that sufficient site characterization information exists to select a remedy [7].

Exposures, if they occurred, would be through ingestion, dermal contact, and/or inhalation. Exposures could occur over a lifetime if groundwater is used daily for drinking, cooking, or showering and bathing. Dermal contact and inhalation of contaminants could also occur if the groundwater or surface water is used for irrigation or other non-potable uses.

Site Characterization Evaluation

A significant amount of site characterization work has been done since 1991. When evaluating that work, Health identified some uncertainties and data gaps:

- Nature and extent of the contamination within the mined-out area is unknown,
- Groundwater divide location is uncertain,
- Preferential flow paths that the contamination might follow if released from the mined-out area are uncertain,
- Potential impact of the site on public and private well systems is uncertain,
- Whether soil contamination exists beyond the subsidence trench rim is unknown, and
- Lack of current surface water data.
- Pumping test data that are unusable.

The following sections summarize our findings.

Nature and Extent of the Contamination within the Mined-out Area

What is known about the nature and extent of the contamination within the mined-out area of the Rogers seam is based on historical records searches, 1991 drum removal work, limited sampling performed during the site hazard assessment, field reconnaissance, and the geophysical survey conducted during the remedial investigation [1].[f] However, waste disposal records, while helpful, may be incomplete given the time period in which waste disposal occurred. Field reconnaissance only provides surficial evidence of disposal. Drum removal work was limited to visible drums. Site hazardous sampling was limited, and the geophysical survey focused on looking for ferrous metal objects, such as barrels, which is only a portion of the way that wastes were disposed at the site.

It was noted in the RI work plan that mobile liquid wastes may have infiltrated all levels of the mine because much of the waste was disposed when the mine was active and dewatered [4]. Other theories about the waste disposal and what has happened to the waste since it was disposed have also been suggested:

- o Waste disposal occurred only in the northern subsidence trenches.
- o Waste has not migrated beyond the reported disposal area.
- o The majority of the waste was consumed during fires in the early 1970s.
- o Waste has already been released from the drums and discharged through the highly

[f] Nine borings/monitoring wells have been installed in the vicinity of the mined-out Rogers seam [5]. However, none of the boring/monitoring wells are located directly in the northern portion of the mined-out area where the wastes were reportedly disposed.

permeable mined-out coal seam.

- Primary pathway for wastes to exit is through the Rogers seam to the north.
- Some of the waste was sorbed onto the coal or soil in the trench and immobilized [1].

Drums discovered at the site in 1991 and the follow-up geophysical survey support the theory that drum disposal occurred in the northern subsidence trenches. However, it appears that some waste disposal, possibly domestic, also occurred in the southern trenches based on visual observations made during the RI [1]. An old clothes dryer and tires with hubs were observed during the geophysical survey. This suggests access to the southern portion of the trench was not limited to foot traffic. The PLPs report that the clothes dryer and tires were the only items observed in the southern portion of the trench (Zimmerman, Gary, Golder Associates. Message to Barbara Trejo, Health. October 18, 2016. E-mail).

It is unknown what waste, if any, was destroyed during early fires, released from the drums, or sorbed onto the coal. It is also unknown whether wastes migrated beyond the general area where they were reportedly disposed. However, if chemicals did migrate within the mined-out area before or after the mine was closed, it would be difficult to predict where they might have moved. For example, dense non-aqueous phase liquids (DNAPLs) could have migrated horizontally, vertically, or in both directions within the vadose or saturated zones.

Given the above described uncertainties, it has to be assumed that waste remains in the trenches as well as in the vadose and saturated zones within the mined-out coal seam. However, installing additional monitoring wells to try to understand the nature and extent of contamination within the mined-out area would be difficult given the conditions within the mine and uncertainty about where the waste migrated. Additionally, installing new monitoring wells within the mine-out area could create new pathways for contaminant migration. This would be of particular concern if monitoring wells were installed in the identified waste disposal area. As such, installing additional monitoring wells within the mined-out portion of the Rogers seam may not lead to a better understanding about the nature and extent of the contamination and could potentially result in release of contaminants if installed in the waste disposal area.

Groundwater Divide

Groundwater from the mine discharges at the north and south portals, which indicates that a groundwater divide exists somewhere within the mined-out Rogers seam. North of the divide, groundwater flows northward toward the Cedar River. South of the divide, groundwater flows south toward Rock Creek. It has been suggested that the divide may be located near the south end of the mined-out Rogers seam [1, 5]. The hydraulic head data collected at the monitoring wells located at the south end of the mine between December 2006 and June 2014 seem to support that finding; however, the differences in hydraulic heads in wells located at the south end of the mine are very small and in some cases, very close to the level of measurement accuracy (0.01 feet) [20-30]. This small difference in hydraulic head in the wells located in the southern end of the mine makes it difficult to determining the exact location of the divide. Because of the uncertainty about the location of the contamination within the mine, knowing where the groundwater divide occurs is particularly important for determining where contaminants located in the Rogers Seam might migrate.

Preferential Flow Paths

Based on water level data collected during the RI, it was found that groundwater in the primary groundwater system flows radially away from the Rogers seam (see RI Figure 3-19) [1]. However, because of the geology of the surrounding area, the dominant groundwater flow direction has been described as flowing toward the north and south ends of the site with most of the flow going northward [5]. This finding seems consistent with available data; however, as noted in the Groundwater Divide section above, there is some uncertainty whether the predominant flow direction is to the north.

Whether the monitoring wells located at the south and north ends of the mine are at locations and depths where contaminated groundwater might be discharging is uncertain. The mined-out area ranges from approximately 450 feet deep in the northern third of the Rogers seam and 750 feet in the southern two-thirds. The water table is approximately 70 to 120 feet bgs. Three monitoring wells have been installed north of the mined-out area to monitor groundwater discharge:

- LMW-2 (10-foot screen installed from approximately 28 to 38 feet bgs),
- LMW-4 (15-foot screen from 195 to 210 feet bgs), and
- LMW-10 (20-foot screen from 267 to 287 feet bgs).

It is likely that some waste remains in the vadose zone at the north end of the mined-out area where rainwater can percolate through it and affect shallow groundwater; however, none of these monitoring wells are located at the top of the water table. There is also a significant vertical distance between the screened intervals of the two deeper monitoring wells so it is possible that contaminants could be discharging from the mined-out area and are being missed by the current monitoring network.

A similar situation occurs at the south end of the Rogers Seam, where groundwater in the mine is approximately 650 feet deep. Three monitoring wells have been installed to monitor groundwater discharging from the mined-out area:

- LMW-3 (15 foot screen installed from approximately 50 to 65 feet bgs);
- LMW-5 (10 foot screen installed from approximately 232 to 242 feet bgs);
- LMW-8 (5 foot screen installed from approximately 8 to 13 feet bgs)

This is 35 feet of well screen to monitor groundwater discharging from only a small portion of the saturated portion of the mined-out area.

Groundwater flow through the bedrock to the east and west of the Rogers seam, which contains faults and fractures, has been described as “negligible” because of the observed tightness of the faults and fractures within the Rogers seam and the near vertical orientation and layering of low-permeability strata [1, 5]. However, groundwater flow through faults and fractures in the adjacent bedrock may be occurring at faster rate.

While two monitoring wells installed in the Fraser (LMW-6) and Landsburg (LMW-7) seams located to the west and east of the site, respectively, help monitor groundwater moving away from the waste disposal area in the Rogers seam, these wells only provide limited groundwater quality information because both wells are only screened across 15 feet of each seam. As a result, it is possible that contaminants could be found at locations beyond the Fraser and Landsburg seams.

Recently, the PLPs have suggested the Rogers seam could be acting as a groundwater sink to the adjacent bedrock groundwater (Cruz, Jerome. Response to E-mail Message from Barbara Trejo, Health, May 18, 2016. E-mail). This is based on groundwater levels they observed when drilling LMW-11 where it appears the hydraulic head in the adjacent bedrock was higher than in the mine workings. However, they have not installed any wells to the east and west of the Rogers seam to confirm that hypothesis.

Potential Impact of the Site on Public and Private Water Supply Systems

The City of Kent's Clark Springs' facility has been identified as a potential receptor of contaminants that could be released from the Rogers seam. However, there is little information provided about the facility (e.g. system description, sources of the facility water, wellhead protection areas, and number of people served by the system) in the RI or DCAP and no information provided about the potential threat to the system if a contaminant release from the site were to occur via surface water at portal #3 or groundwater. The City of Renton and the Covington Water District water systems are also potential receptors but neither system nor the potential threat to those systems if a contaminant release occurred was mentioned in the RI report or DCAP. All three systems have expressed concerns about the site and the risk it might pose to their systems [14, 17, 18]. The Health Department understands that Ecology and the PLP are aware of these concerns and intend to modify steps in the DCAP to further reduce the chance of contaminants leaving the site (personal communication with Jerome Cruz, Ecology, February 10, 2016). Those additional steps will be discussed with the water system owners and summarized in Ecology's upcoming responsiveness summary (personal communication with Jerome Cruz, Ecology, February 19, 2016).

In August 2014 Ecology offered to test nine private wells located near the site (Jerome Cruz. Message to Barbara Trejo, Washington State Department of Health. October 30, 2015. E-mail). These wells were selected because of their proximity to the north and south mine portals. This was important testing given the uncertainty about where contaminants located in the Rogers seam might exit the site. Only two private well owners accepted Ecology's 2014 offer, and neither well was reported to contain contaminants related to the mine [9, 10]. Since completing the RI in 1995, no private well testing has occurred east or west of the site. However, Ecology did offer to test two private wells located east of the waste disposal area in 2014 because of their proximity to the waste but both well owners declined to participate.

Ecology reports they have not offered private well testing to others well owners east or west of the site because subsurface conditions between the private wells and the site suggest that that contamination is unlikely to reach these wells (e.g., adjacent bedrock has very low hydraulic conductivity, Fraser and Landsburg seams are intercepting groundwater moving away from the site and discharging through the former portals, Rogers seam may be acting as a groundwater sink to the surrounding bedrock aquifer) (Cruz, Jerome. Message to Barbara Trejo, Health, May 24, 2016. E-mail) Additionally, Ecology plans to use institutional controls to prevent private wells from being installed between the site and Fraser and Landsburg seams. Such features reduce the chance of contaminants reaching wells to the east and west of the waste disposal area. However, some uncertainty remains about contaminant transport through the bedrock to the east and west because groundwater flow rates through fractures and faults in the surrounding bedrock are not quantified. It is also unknown how much groundwater moving away from the site is being intercepted by the Fraser and Landsburg seams and discharged through the former portals.

Since 1995, a number of new private wells have been installed in the area (Table 1). These newer private wells have not been addressed in subsequent site documents, including the DCAP. Given that the site will remain in perpetuity and uncertainty about contaminant travel times between the mined-out area and the private wells if a release were to occur, it is important that well surveys be conducted periodically to ensure that new wells are identified and assessed for vulnerability. It is also important that private wells located to the north and south of the portals are tested during compliance monitoring.

Potential Soil Contamination beyond the Subsidence Trench Rims

Soil sampling beyond the subsidence trench rims was limited to composite surface soil samples (upper 3-6 inches) and a few shallow backhoe trench samples (0-4 feet) collected during the RI [1]. The backhoe trench samples were only analyzed for metals. The surface soil samples were analyzed for a broad range of contaminants, including VOCs. While only two VOCs were detected at very low levels in the surface samples, these results may not be representative because VOC loss can occur when compositing [31]. Given the limited sampling, it is uncertain whether the soil contamination exists beyond the subsidence trench rims. If the contamination does exist and will not be covered under the proposed cap, it could pose a potential threat to groundwater.

Surface Water

Groundwater that discharges to the surface at portal #2 does not appear to have been tested since the 1995 RI work. Groundwater at this location appears to represent the top of the water table so collecting samples at this location is important since there are no monitoring wells located at the top of the water table on the north end of the Rogers seam. Groundwater discharging near portal #3 was last tested in 2003. However, LMW-8 was installed to replace the sampling done at portal #3 and appears to provide a more representative sample of water discharging from the mine [8].

Pumping Tests

Pumping tests are important for determining basic hydraulic parameters as well as determining whether remedial options like plume containment will be successful. During the RI, slug and pumping tests were conducted at LMW-2 and LMW-4 at the north end of the site and LMW-3 and LMW-5 at the south end during the RI [1]. Well logs for these four monitoring wells suggest that LMW-2 and LMW-5 are installed in the mined out area. While the slug test data appear useable, the data generated during the pumping tests were considered unusable because of the very small drawdowns produced during the tests and the lack of stress induced on the formation.

Despite the problem with the pumping tests, the slug and pumping test results suggest the hydraulic conductivities outside and within the mined-out seam are high.

It was noted in the RI report that "the highly conductive nature of the mined-out Rogers Coal Seam would require a much higher capacity pumping capability or a longer time period in order to obtain usable pump testing data." However, rather than conducting additional pump tests, the PLPs instead used historical mine records and interviews with a few former miners along with water balance calculations to estimate groundwater extraction rates to contain a possible future contaminant plume. While this information may be helpful, it is not conclusive.

An appropriate number of pumping tests conducted to evaluate drawdowns and cones of depression to achieve plume capture could be used to reduce the uncertainty. However, Ecology believes that conducting such tests (especially at a very high rate of pumping) could potentially result in a release from the waste disposal area creating a possible health hazard where none existed before (Cruz, Jerome. Message to Barbara Trejo, Health, June 17, 2016. E-mail). Additionally, the amount of infiltrating water entering groundwater (i.e. the recharge rate) and flow rates below the waste disposal area are expected to reduce once the waste area is capped, so pumping test results collected before the cap is in place would likely be unusable for making decisions in the future if a release were to occur (Morell, Douglas. Comment. August 19, 2016. Ecology, Health, Aspect, and Golder Meeting.)

Because additional pumping tests are not feasible, the PLP's have proposed instead a revised plan for making sure that a contaminant plume(s), if identified in the future, would be contained on the Landsburg Mine site (i.e., the plumes would not travel beyond the conditional point of compliance) (Morell, Douglas and Zimmerman, Gary. Discussion. August 19, 2016. Ecology, Health, Aspect, and Golder Meeting.). The revised plan would include monitoring the sentinel well system to insure that low levels of contaminants are detected early; when triggered at the site wells, installing a groundwater extraction system that would target the depth where the contaminant plume was found; and installing down-gradient observation wells to ensure that complete plume capture is occurring and contaminants are not migrating beyond the conditional point of compliance. This revised plan seems to be a reasonable alternative to conducting further pumping tests, which may be of limited use and could potentially trigger a contaminant release.

Health Evaluation - Groundwater

Three rounds of groundwater results from the site monitoring wells were evaluated during this health consultation: May 2013, November 2013, and June 2014. Samples were analyzed for metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOC), pesticides, polychlorinated biphenyl ethers (PCBs), and petroleum hydrocarbons [20-22]. During these sampling events, groundwater was collected from 10 of the 11 site monitoring wells (LMW-2 to LMW-11) except in June 2014 when only 9 monitoring wells were tested. LMW-7 was not tested during that round because of a pump malfunction [21]. No samples were collected from monitoring well LMW-1, which is located in a sandstone unit located between the northern and southern portions of the mine where waste was disposed.[g] Ecology reportedly made this

[g] It is unclear whether the groundwater levels being recorded for LMW-1 are representative of water levels within the mine because the well is screened in the adjacent sandstone unit.

decision because they only intended to monitor groundwater coming out of the mine (Cruz, Jerome. Response to E-mail Message from Barbara Trejo, Health, May 13, 2015. E-mail).

Overall, it appears groundwater samples were collected appropriately. However, a few issues were identified during our data review that suggests some results might not be representative because of some sampling or analytical issues.

At the time the groundwater samples were logged in at the lab, bubbles were reported to have been observed in some of the VOC samples collected at the monitoring wells during the following sampling events:

- May 2013 – LMW-6, LMW-9, and LMW-11 [20].
- November 2013 –LMW-3, LMW-4, LMW-5, and LMW-9 [22].
- June 2014 – LMW-2, LMW-3, and LMW-EB [21].

The size and quantity of bubbles in the 2013 samples is unknown. The bubbles found in the June 2014 samples were reported as small to pea sized and it was suggested that these were not a problem. Bubbles in VOC samples could result in an underestimation of contaminant concentrations. Whether the VOC results were underestimated during these sample rounds is unknown. Care should be taken during future sampling rounds to ensure that this does not continue to be a problem.

Pesticide, SVOCs and PCB surrogate recoveries for the November 2013 samples were generally low [22]. Low surrogate recoveries suggest that contaminants may not have been detected if present in low concentrations.

Health Screening Evaluation

Although no one is drinking the water from the site monitoring wells, we conservatively compared the May and November 2013 and June 2014 results to health comparison values (CVs) to assess whether groundwater discharging from the former mine poses a possible health threat if someone were to drink that water. Health comparison values are concentrations of contaminants that are unlikely to cause people to get sick. Using these values allows us to identify contaminants that might be of health concern. This is done to protect the most sensitive individuals (i.e., children and older adults). It is also done to account for our lack of certainty regarding the adverse health effects of low levels of contaminants. If a chemical was noted as being less than a reporting limit, Health compared the reporting limit[h] to the health comparison values.

Because groundwater in the vicinity of the Landsburg Mine site is a known drinking water source, Health used ATSDR drinking water health comparison values (e.g., cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEGs)) [32]. The CREG is the concentration of a contaminant in water that is expected to cause no more than one additional cancer in a million persons

[h] Reporting limits are the lowest concentration at which a chemical can be detected in a sample and its concentration can be reported with a reasonable degree of accuracy and precision.

exposed over a lifetime. An EMEG and RMEG are concentrations in water below which adverse non-cancer health effects are not expected to occur. The EMEG was developed using ATSDR minimal risk levels (MRLs) while the RMEG was developed using EPA's reference doses (RfDs). If no ATSDR health comparison values were available, Health used EPA's tap water regional screening levels (RSLs) [33] . In the absence of the EPA RSLs, Health used levels set in the Federal Drinking Water Standards and Health Advisories and Washington State Administrative Code 246-290 for Group A Public Water Supplies.

Tables 2 through 7 summarize the tested chemicals, range of concentrations, and health comparison values. As shown in the tables, metals were the only contaminants detected during the three groundwater sampling rounds. However, the detection limits for some of the metals, petroleum hydrocarbons, VOCs, SVOCs, polychlorinated biphenyls (PCBs), and pesticides exceeded the health comparison values. This was expected because the laboratories often cannot achieve detection limits below the health screening levels for all the analytes. While some of the detection limits exceeded the CVs, we did not consider these contaminants of health concern if an individual contaminant was not detected in any of the groundwater samples.

Six metals were identified as groundwater contaminants of potential concern (COPC): arsenic, calcium, magnesium, manganese, potassium, and sodium (Table 2). Arsenic was detected in six of the ten samples. Sodium was detected above the health comparison value in five of the ten samples. Calcium, magnesium, and potassium were detected in all the samples. Manganese was also detected in all the samples but was only found above the health comparison value in LMW-8, which is located near portal #3.

Health Evaluation Results

All six contaminants of potential health concern (arsenic, calcium, magnesium, manganese, potassium, and sodium) are considered metals and may be found in rock, soil, water, air, food, and dust. Metals like these are often naturally occurring but sometimes can be associated with a chemical release.

Calcium, magnesium, and potassium are essential nutrients. They typically are not harmful in drinking water under most environmental exposure scenarios. As a result, no health based levels have been established for these contaminants in drinking water. However, they could pose a health threat if large amounts are ingested. To determine if they needed to be carried forward for further evaluation, Health calculated intake levels (Table 8) and compared them to National Academies, Institute of Medicine, Food and Nutrition Board's tolerable upper intake levels (ULs) for dietary calcium and supplemental magnesium (Tables 9 and 10). Because a UL was not available for potassium, Health used the National Academies' adequate intake (AI) level (Table 11).

Health calculated intake levels by conservatively multiplying the reasonable maximum exposure ingestion rates for children of various ages and adults by the highest levels of calcium, magnesium, and potassium found in the site monitoring wells. To estimate whether the intake levels might pose a health threat, they were compared to appropriate gender and age range ULs or AIs. As noted in Table 8, the highest concentrations of these elements in groundwater are below the AI or ULs except for magnesium, which is slightly above the UL for supplemental magnesium for a 3 year old child. However, the actual amount of magnesium that a 3 year old child would be exposed to through diet and supplementation would be greater than the level found in site groundwater. As a result, Health does not expect calcium, magnesium, or potassium to pose a health threat.

Sodium is also an essential nutrient and also typically not harmful in drinking water under most environmental exposure scenarios. However, it can pose a health threat for individuals restricted to an intake of 500 mg/day [34]. As noted in Table 8, the estimated intake of sodium if someone was to drink the maximum amount found in groundwater at the site was approximately half of the recommended daily dose for someone on a sodium restricted diet. While the sodium intake for the maximum groundwater concentration is below 500 mg/kg, it may not be the only source of sodium in a diet.

Arsenic and manganese are commonly found in groundwater across Washington. Long-term exposure to low levels of arsenic can increase the risk of developing cancer and may also cause non-cancer health effects [35]. There is no evidence that manganese causes cancer; however, it may cause non-cancer health effects [36]. Information about typical arsenic and manganese levels in groundwater and possible health effects associated with these two metals are included in Appendix B.

To evaluate the possible health effects associated with exposure to arsenic and manganese found in groundwater at the site, doses were calculated for the ingestion and dermal routes of exposure using the maximum concentration found in the monitoring wells during the three sampling rounds. The equations and exposure parameters used to calculate doses for a child, older child, and adult are provided in Appendix C.

<u>Evaluating Non-Cancer Health Effects – Arsenic and Manganese</u>

To evaluate possible non-cancer health effects, arsenic and manganese doses were compared to ATSDR's chronic minimal risk levels (MRLs). When a dose exceeded a MRL, further assessment was conducted by comparing the doses to an oral "no observed adverse effects level" (NOAEL).

Table 12 summarizes the estimated doses and comparisons with the MRLs and NOAELs. As shown in the tables, arsenic was the only metal that exceeded its NOAEL for a child from birth to less than 1 year old. This suggests that the maximum amount of arsenic in groundwater from the site could pose a non-cancer health threat. It is important to note that the maximum amount of arsenic found at the site (8 µg/l) is below the federal and state drinking water standard (10 µg/l) used for public water systems. These standards, however, are not strictly health based. When setting drinking water standards, the EPA considers the health risks, as well as the cost and difficulty of removing arsenic down to that amount. Health considers the health risks only.

Evaluating Cancer Health Effects - Arsenic

Some contaminants have the ability to increase a person's risk of developing cancer. Because current risk assessment practice assumes there is no "safe dose" of a carcinogen, any dose of a carcinogen will result in some additional increased cancer risk. Cancer risk estimates are measures of chance (probability) and are useful in determining the magnitude of a cancer threat.

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. Approximately 1 in 3 to 1 in 2 people living in the United States will develop cancer at some point in their lifetime [37].

Cancer risk attributable to site-related contaminants can be described in quantitative and qualitative terms by considering the population size required for such an estimate to result in a single cancer case. Contaminants are considered to pose an increased cancer risk when the estimated cancer risk is greater than or equal to one additional cancer case per 10,000 persons exposed over a lifetime (≥1E-04). One additional cancer cases per million persons exposed over a lifetime to nine additional cancer cases per 100,000 persons exposed over a lifetime (1E-06 to 9E-05) is considered a low cancer risk. A cancer risk is considered insignificant or indiscernible from background when the cancer risk estimate is less than one additional cancer per one million persons exposed over a lifetime (<1E-06).

Table 13 summarizes the estimated doses and cancer risk levels associated with ingesting and dermal exposure to the maximum amounts of arsenic found in groundwater from the monitoring wells. As shown in the tables, most of the risk is associated with ingesting the water. The estimated total cancer risk (ingestion and dermal) for the maximum amount of arsenic found in groundwater at the site is 9 additional cancers in a population of 10,000 people. This estimated cancer risk for arsenic is greater than or equal to one additional cancer case per 10,000 persons exposed over a lifetime (≥1E-04) and is considered to pose an increased cancer risk.[i]

Children's Health Considerations

Children can be uniquely vulnerable to the hazardous effects of environmental contaminants like those found in drinking water. This is because children are smaller and receive higher doses of contaminant exposure per body weight. Additionally, the fetus is highly sensitive to many contaminants, particularly with respect to potential impacts on childhood development. For these reasons, Health considered the specific impacts that contaminated drinking water might have on children.

Conclusions

1. Health concludes that the site poses a potential chemical health hazard. The extent of the potential hazard is unknown.

[i] Arsenic as low as 1 µg/l also poses an increased cancer risk of 1 additional cancer in a population of 10,000 people.

2. Health concludes that, except for arsenic, none of the chemicals found in groundwater at the site in May and November 2013 and June 2014 are a public health hazard. Although the maximum level of arsenic found in the groundwater presents some risk of causing long-term health effects, the levels are below state and federal drinking water standards.

3. Health concludes that the site poses a physical hazard.

Recommendations

Health recommends taking the following steps to address the potential chemical and physical hazards at the site:

1. Ecology should ensure that additional site characterization tasks are completed and that collected data are evaluated. We recommend completing these tasks before placing the soil cap, which is part of the cleanup remedy selected for the site. Additional tasks include:

   Monitoring Wells

   a. Install and measure water levels in an appropriate number of monitoring wells to help determine where the groundwater divide is located.

   b. Install and sample additional monitoring wells at the north end of the mine to better assess whether contaminants are being released from the mine. After defining the groundwater divide, additional wells may also need to be installed and sampled at the south end of the mine.

   Public Water Systems

   c. Provide information in the final CAP about the City of Kent's Clark Springs' municipal drinking water system, Covington Water District system, and Cedar Valley Sole Source Aquifer (used by the City of Renton) to ensure that there is a common understanding about these systems. Information would include location relative to the site, brief system description, sources of the facility water, wellhead protection areas/capture zones, and number of people served by the system. Also, provide details to the water system owners about the modifications to the draft cleanup action plan (DCAP) that Ecology and the PLP will make to further reduce the chance of contaminants leaving the site and potentially affecting these systems.

   Private Wells

   d. Conduct a well survey to identify private wells installed in the area since the RI well survey work was completed. Since the site will exist in perpetuity, include language in the final cleanup action plan (CAP) requiring additional well surveys in the future to ensure that new wells in the area are not at risk

e. Test private wells nearest the north and south portals annually for five years for the same chemicals as the monitoring wells. Re-evaluate the need for further private well testing as part of the five-year site review.

f. Test private wells east and west of the waste disposal area annually for five years and re-evaluate the need for further testing at the five-year review unless it can be confirmed the groundwater from the surrounding bedrock discharges into the mine rather than flowing away from the mine.

Sampling

g. Sample and analyze surface and subsurface soils beyond the trench rim for volatile organic compounds (VOCs) if the soils are located in an area where waste might have been released in the past and will not be covered by the proposed future soil cover.

h. Test the surface water at portals #2 and #3. If surface water continues to discharge from the mine, test it as part of the compliance monitoring program.

i. Continue to ensure that future groundwater sampling methods/procedures and testing methods are appropriately conducted to obtain representative samples

Pumping Tests

j. Modify the CAP to explain why pumping tests are not feasible and explain what steps will be taken to ensure that the contaminants do not migrate beyond the conditional point of compliance if a plume is found migrating from the former mine in the future.

Fence Maintenance and Warning Signs

k. Maintain the existing fencing around the waste disposal area and add warning signs explaining why the area is fenced.

2. The property owners should take steps to evaluate and address physical hazards posed by the site.

Public Health Actions

The following actions will be completed to address these recommendations:

1. Ecology will work with the PLPs to complete the following tasks:

Monitoring Wells

a. Modify the Cleanup Action Plan (CAP) to require water level data collection at the existing monitoring wells LMW-2 through LMW-11 and sentinel/performance wells to better define the groundwater divide at the site. LMW-1 and LMW-1A, which are installed in the adjacent sandstone unit, may also be used to define the divide. A decision about using water level data from these two wells will be made after the sentinel wells are installed.

b. Modify the CAP to require that the deeper sentinel well at the north end of the mine be set at a higher elevation to allow better overall vertical groundwater monitoring coverage. If logistically possible, the shallow and deeper northern sentinel wells will be moved within the inclined northern mine shaft location. However, if that is not possible, they will be moved as close as possible. The changes in locations will be addressed in the CAP and engineering design report. The CAP will also be modified to require considering additional monitoring wells in the southern portion of the mine if the groundwater divide is found to be located beneath any portion of the former waste disposal area.

Public Water Systems

c. Modify the CAP to include information about the City of Kent's Clark Springs' municipal drinking water system, Covington Water District system, and Cedar Valley Sole Source Aquifer (used by the City of Renton) to ensure there is a common understanding and context about these systems in relation to the physical site, site conditions, and remedial design objectives. This information would include location relative to the site, brief system description, sources of the facility water, wellhead protection areas/capture zones, and number of people served by the system. Also, the Responsiveness Summary and final CAP will provide details about the modifications that Ecology and the PLPs will be taking to further reduce the chance of contaminants leaving the site and potentially affecting these systems.

Private Wells

d. Modify the CAP to require the PLPs to conduct private well surveys near the site during the periodic site reviews. Under the MTCA Cleanup Regulation periodic reviews occur at least every 5 years after initiation of the cleanup action.

e. Modify the CAP to require the PLPs to test active private wells nearest the north and south portals annually for five years for the same chemicals as the monitoring wells. Ecology and the PLPs will re-evaluate the need for further private well testing during the five year review.

f. Ecology indicates that it does not feel testing active private wells located west and east of the site is needed at this point in the site's history based on its present monitoring network and proposed groundwater restrictions.

Sampling

g. Modify the CAP to require the PLPs test soil just outside of the proposed cap edge for volatiles.

h. Modify the CAP to require the PLPs conduct some limited surface water testing at the north and south portals prior to remedial construction. The CAP will also be modified to require limited surface water sampling at the north and south portals during remedial construction performance monitoring (Exhibit E, Part A Compliance Monitoring Plan, Table A-2).

i. Continue to ensure that future groundwater sampling methods/procedures and testing methods are appropriately conducted to obtain representative samples.

Pumping Tests

j. Modify the CAP to explain why pumping tests are not feasible and explain (or highlight) what steps will be taken to ensure that the contaminants do not migrate beyond the conditional point of compliance if a plume is found migrating from the former mine in the future.

Fence Maintenance and Warning Signs

k. Ecology understands that fencing or portions of the fencing around the waste area will need to be put down during implementation of the Cleanup Action Plan. In the interim, Ecology will notify the PLP Group that existing and future fencing around the waste area must be properly maintained and that signage must be posted that warns why it is being fenced.

2. The property owners addressed the physical hazards posed by the site (Zimmerman, Gary, Golder Associates. Message to Barbara Trejo, Health. October 18, 2016. E-mail). The trench backfilling and soil capping called for in the CAP will eliminate the current physical hazards in the northern portion of the subsidence trench. Other site physical hazards have been assessed by the property owners and addressed with King County on September 28, 2005.

3. Health will provide copies of this health consultation report to the City, Ecology, and PLPs. A copy of the report will also be posted on the Department of Health Site Assessment webpage at www.doh.wa.gov/consults.

4. Health will be available to support the evaluation of site data collected in the future that will be used to assess whether additional monitoring or sentinel wells are needed at the south end of the mine. Health will also be available to review future site characterization plans and results and if requested, groundwater results from private and/or monitoring wells to evaluate if the contaminants pose a potential health threat.

Report Preparation

The health consultation for the Landsburg Mine Site was prepared by the Washington State Department of Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry. It is in accordance with 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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Tables

Table 1: Landsburg Mine Site, Additional Well Logs Identified in the Site Vicinity, September 2014

Well Log Number [38]	Well Completion Date	Well Depth (feet)	Well Type	Latitude	Longitude
92807	10/29/1990	86	Water	47.368379	-121.968948
97572	10/12/1991	125	Water	47.371435	-121.974350
390717	10/7/2004	320	Water	47.366176	-121.979263
94149	8/12/1990	138	Water	47.375977	-121.991970
91651	5/6/1993	140	Water	47.363886	-121.993737
93310	8/24/1993	175	Water	47.376957	-121.994333
99936	10/29/1996	180	Water	47.365990	-121.979277
100062	5/9/1997	320	Water	47.366529	-121.010715
100042	5/9/1997	300	Water	47.370026	-121.975281
100427	1/6/1998	172	Water	47.370653	-121.965484
100425	2/9/1998	330	Water	47.361421	-121.974009
304392	8/25/2000	56	Water	47.361421	-121.974009
304391	9/13/2000	206	Water	47.361421	-121.974009
304315	1/25/2001	500	Water	47.367339	-121.979223
325186	12/11/2001	300	Water	47.367222	-121.979218
394458	7/24/2003	370	Water	47.370026	-121.975281
390717	10/7/2004	320	Water	47.366176	-121.979263
422131	10/6/2005	220	Water	47.369047	-121.975314
468737	12/6/2006	350	Water	47.367304	-121.980607
497718	8/14/2007	290	Water	47.370968	-121.984261
530254	3/5/2008	320	Water	47.372933	-121.976123
613457	10/15/2009	395	Water	47.368138	-121.979288
669832	9/10/2010	420	Water	47.371951	-121.982008
866083	5/15/2013	235	Water	47.373092	-121.974647

Table 2: Landsburg Mine Site, Metal Ranges in Groundwater, May and November 2013 and June 2014

Metals (Total)	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV**	CV Reference
Aluminum	µg/l	NA	50U -1,000U	50U -1,000U	50U -1,000U	50U -1,000U	50U -1,000U	50U -1,000U	60 - 1,000U	50U -1,000U	50U -1,000U	50U -1,000U	10,000	ATSDR Child Chronic EMEG
Antimony	µg/l	NA	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	0.2U - 3U	4	ATSDR Child RMEG
Arsenic	µg/l	A	**0.2U - 3U**	**0.6 - 3U**	**0.2U - 3U**	**0.2U - 3U**	**0.2U - 3U**	**2.1 - 3.9**	**2.1 - 3U**	**0.3 - 3U**	**0.2 - 3U**	**5 - 8**	0.023	ATSDR CREG
Barium	µg/l	CN	346 - 500U	76 - 500U	356 - 500U	284 - 500U	112 - 500U	486 - 500U	41 - 500U	304 - 500U	34 - 500U	317 - 500U	2,000	ATSDR Child Chronic EMEG
Beryllium	µg/l	KL	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	1U - 2U	20	ATSDR Child Chronic EMEG
Cadmium	µg/l	B1	**2U**	**2U**	**2U**	**2U**	**2U**	**2U**	**2U**	**2U**	**2U**	**2U**	1	ATSDR Child Chronic EMEG
Calcium	µg/l	NA	**111,000 - 118,000**	**37,400 - 38,200**	**107,000 - 115,000**	**93,000 - 98,200**	**25,700 - 27,600**	**50,400 - 54,200**	**48,500 - 72,300**	**84,400 - 86,100**	**6,490 - 7,080**	**54,800 - 59,100**	NA	NA
Chromium	µg/l	KL	**5U - 1000U**	**5U - 1000U**	**5U - 1000U**	**5U - 1000U**	**5U - 1000U**	**5U - 1000U**	**5U - 1000U**	**5U - 1000UJ**	**5U - 1000UJ**	**5U - 1000U**	9	ATSDR Child Chronic EMEG for CrVI)
Cobalt	µg/l	2B	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	**3U -10U**	6	EPA Child Non-cancer Screening Level
Copper	µg/l	D	2U - 3U	2U - 3U	2U - 3U	2U - 3U	2U - 3U	2 - 3U	2U - 3U	2U - 3U	2U - 3U	2U - 3U	100	ATSDR Child Intermediate EMEG
Iron	µg/l	NA	130 - 230	50U -200U	900 - 12,800	90 -200U	2020 - 2,440	1,220 - 1,610	9,320 - 10,900	1,500 - 1590	50U -200U	1,820 - 1,890	14,000	EPA Child Non-cancer Screening Level
Lead	µg/l	B2	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	0.1U - 10U	15	EPA Drinking Water Action Level
Magnesium	µg/l	NA	**67,400 - 71,400**	**15,600 - 15,700**	**64,200 - 69,100**	**52,100 - 54,400-**	**12,200 - 14,100**	**23,100 - 24,700**	**25,300 - 39,300**	**46,000 - 47,000**	**2,690 - 2,910**	**27,400 -27,700**	NA	NA
Manganese	µg/l	D	210 - 231	49 - 60	160 - 186	237 - 265	30 -34	126 - 162	**420 - 563**	170 - 180	7 - 20U	117 - 152	300	EPA Lifetime Health Advisory
Mercury	µg/l	D	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.02U	0.63	EPA Child Non-cancer Screening Level
Nickel	µg/l	2B	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	100	EPA Lifetime Health Advisory
Potassium	µg/l	NA	**3,530 - 3,760**	**1,690- 1,760**	**3,620 - 3,910**	**2,720 - 2,860**	**640 - 730**	**2,810 - 2,970**	**1,900 - 2,280**	**2,540 - 2,690**	**1,220 - 1,330**	**2,050 - 2,140**	NA	NA
Selenium	µg/l	D	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	0.5U - 5U	50	ATSDR Child Chronic EMEG
Silver	µg/l	D	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	50	ATSDR Child RMEG
Sodium	µg/l	NA	**20,900 - 21,800**	10,300 - 10,500	**27,500 - 29,200**	15,300 - 17,300	6,470 - 7,100	**38,800 - 43,300**	9,160 -13,200	15,600 - 16,600	**77,000 - 82,700**	**25,400 - 34,500**	20000***	EPA
Thallium	µg/l	NA	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	**0.2U - 2 U**	0.2	EPA Child Non-cancer Screening Level
Vanadium	µg/l	2A	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	86	EPA Child Non-cancer Screening Level
Zinc	µg/l	IN	10U - 20U	10U - 20U	10U - 20U	10U - 20U	10U - 20U	60	10U - 20U	10U - 20U	10U - 20U	10U - 20U	2,000	EPA Lifetime Health Advisory

* not sampled during June 2014 sampling event due to pump malfunction

** CVs - ATSDR Drinking Water (August 2016), EPA (May 2016 RSLS for Residential Tap Water) and other EPA values

*** EPA guidance level for sodium in drinking water is 20 mg/L. extrapolated to the entire population. This value was developed for those individuals restricted to an intake of 500 mg/day and should not be extrapolated to the entire population.

µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

NA - not available; A - human carcinogen (EPA, 1986); CN - carcinogenic potential cannot be determined (EPA, 1996);

KL - Known/Likely human carcinogen (EPA, 1996); B1 - probable human carcinogen (limited human, sufficient animal studies)(EPA, 1986);

B2 Probable human carcinogen (inadequate human, sufficient animal studies)(EPA, 1986)

2A - probably carcinogenic to humans (limited human evidence; sufficient evidence in animals)(IARC)

2B - possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals)(IARC); (EPA, 1986)

D - not classified as to human carcinogenicity; IN - Inadequate information to assess carcinogenic potential (EPA, 2005)

[green shading] Concentration or reporting limiit exceeds the CV

Table 3: Landsburg Mine Site, Volatile Organic Compound (VOC) Ranges in Groundwater, May and November 2013 and June 2014

Volatile Organic Compounds	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV**	CV Reference
Acetone	µg/l	DI	5U	5U	5U	5U	5U	2.6J - 5U	5U	5U	5U	5U	9,000	ATSDR Child RMEG
Acrolein	µg/l	DI	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	5	ATSDR Child RMEG
Acrylonitrile	µg/l	B1	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.065	ATSDR CREG
Benzene	µg/l	KL	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.64	ATSDR CREG
Bromobenzene	µg/l	IN	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	60	ATSDR Child RMEG
Bromochloromethane	µg/l	D	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	90	EPA Lifetime Health Advisory
Bromodichloromethane	µg/l	B2	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.56	ATSDR CREG
Bromoform	µg/l	B2	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	4.4	ATSDR CREG
Bromomethane	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	10	EPA Lifetime Health Advisory
2-Butanone	µg/l	DI	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	4,000	EPA Lifetime Health Advisory
n-Butylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1,000	EPA Regional Screening Level
sec-Butylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2,000	EPA Regional Screening Level
tert-Butylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	690	EPA Regional Screening Level
Carbon Disulfide	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1,000	ATSDR Child RMEG
Carbon Tetrachloride	µg/l	LC	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.5	ATSDR CREG
Chlorobenzene	µg/l	D	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	100	EPA Lifetime Health Advisory
Chloroethane	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	21,000	EPA Regional Screening Level
2-Chloroethyl vinyl ether	µg/l	NA	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	1	Florida State Drinking Water Standard
Chloroform	µg/l	LI	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	70	EPA Lifetime Health Advisory
Chloromethane	µg/l	CN	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	190	EPA Regional Screening Level
2-Chlorotoluene	µg/l	NA	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	100	EPA Lifetime Health Advisory
4-Chlorotoluene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	100	EPA Lifetime Health Advisory
Chlorodibromomethane	µg/l	C	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.42	ATSDR CREG
1,2-Dibromo-3-Chloropropane	µg/l	2B	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.2	EPA MCL
1,2-Dibromomethane	µg/l	LI	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.018	ATSDR CREG
Dibromomethane	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.022	Ecology Method B GW Cleanup Level
1,2-Dichlorobenzene	µg/l	D	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	600	EPA Lifetime Health Advisory
1,3-Dichlorobenzene	µg/l	D	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	600	EPA Lifetime Health Advisory
1,4-Dichlorobenzene	µg/l	2B	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	75	EPA Lifetime Health Advisory
trans-1,4-Dichloro-2-butene	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.0013	EPA Regional Screening Level
1,1-Dichloroethane	µg/l	C	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2.7	EPA Regional Screening Level
1,2-Dichloroethane	µg/l	B2	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.38	ATSDR CREG
1,1-Dichloroethene	µg/l	NS	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	7	EPA MCL
cis-1,2-Dichloroethene	µg/l	IN	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	10	EPA Lifetime Health Advisory
trans-1,2-Dichloroethene	µg/l	IN	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	100	EPA Lifetime Health Advisory
1,2-Dichloropropane	µg/l	3	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	5	EPA MCL
1,3-Dichloropropane	µg/l	NA	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	370	EPA Regional Screening Level
2,2-Dichloropropane	µg/l	NA	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	5	EPA MCL
1,1-Dichloropropene	µg/l	NA	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.35	ATSDR CREG
cis-1,3-Dichloropropene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.35	ATSDR CREG
trans-1,3-Dichloropropene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.35	ATSDR CREG
Ethylbenzene	µg/l	D	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	700	EPA MCL
Hexachloro-1,3-butadiene	µg/l	C	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.45	ATSDR CREG
2-Hexanone	µg/l	IN	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	50	ATSDR Child RMEG
Iodomethane	µg/l	NA	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	10	EPA Lifetime Health Advisory

Table 3: Landsburg Mine Site, Volatile Organic Compound (VOC) Ranges in Groundwater, May and November 2013 and June 2014 (continued)

Volatile Organic Compounds	**Units**	**Cancer Class**	**LMW-2**	**LMW-3**	**LMW-4**	**LMW-5**	**LMW-6**	**LMW-7 ***	**LMW-8**	**LMW-9**	**LMW-10**	**LMW-11**	**CV****	**CV Reference**
Isopropylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1,000	ATSDR Child RMEG
4-Isopropyltoluene	µg/l	NA	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	1,000	ATSDR Child RMEG
Methylene Chloride	µg/l	LC	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	5	EPA MCL
4-Methyl-2-Pentanone	µg/l	NA	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	2.5U	1,200	EPA Regional Screening Level
Naphthalene	µg/l	CN	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	100	EPA Lifetime Health Advisory
N-Propylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	660	EPA Regional Screening Level
Styrene	µg/l	2B	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	100	EPA Lifetime Health Advisory
1,2,3-Trichlorobenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	7	EPA Regional Screening Level
1,2,4-Trichlorobenzene	µg/l	D	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	70	EPA Lifetime Health Advisory
1,3,5-Trichlorobenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	40	EPA Lifetime Health Advisory
1,1,1,2-Tetrachloroethane	µg/l	C	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	1	ATSDR CREG
1,1,2,2-Tetrachloroethane	µg/l	LC	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.18	ATSDR CREG
Tetrachloroethene	µg/l	LC	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	17	ATSDR CREG
Toluene	µg/l	IN	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	800	ATSDR Child RMEG
1,1,1-Trichloroethane	µg/l	IN	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	200	EPA MCL
1,1,2-Trichloroethane	µg/l	C	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.61	ATSDR CREG
Trichloroethene	µg/l	CH	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.76	ATSDR CREG
Trichlorofluormethane	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	2,000	EPA Lifetime Health Advisory
1,1,2-Trichloro-1,2,2-trifluoroethane	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	300,000	ATSDR Child RMEG
1,2,3-Trichloropropane	µg/l	LC	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.0012	ATSDR CREG
1,2,4-Trimethylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	15	EPA Regional Screening Level
1,3,5-Trimethylbenzene	µg/l	NA	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	120	EPA Regional Screening Level
Vinyl Acetate	µg/l	2B	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	410	EPA Regional Screening Level
Vinyl Chloride	µg/l	KL	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.025	ATSDR CREG
m and p-Xylenes	µg/l	DI	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	190	EPA Regional Screening Level
o-Xylene	µg/l	DI	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	0.2U	190	EPA Regional Screening Level
Xylenes-Total	µg/l	DI	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	0.4U	2,000	ATSDR Child Chronic EMEG

* not sampled during June 2014 sampling event due to pump malfunction; ** CVs - ATSDR Drinking Water (August 2016), EPA (May 2016 RSLS for Residential Tap Water) and other values

µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

NA - not available;

A - human carcinogen (EPA, 1986); CN - carcinogenic potential cannot be determined (EPA, 1996); KL - Known/Likely human carcinogen (EPA, 1996);

B1 - probable human carcinogen (limited human, sufficient animal studies)(EPA, 1986); B2 - Probable human carcinogen (inadequate human, sufficient animal studies)(EPA, 1986)

DI - Data are inadequate for assessment of human carcinogenic potential (EPA, 1999); KL - Known/Likely human carcinogen (EPA, 1996); IN - Inadequate information to assess carcinogenic potential

D - Not classified as to human carcinogenicity (EPA, 1986); LC - Likely to be carcinogenic to humans; LI - Likely to be carcinogenic to humans (EPA, 2005)

2A - probably carcinogenic to humans (limited human evidence; sufficient evidence in animals)(IARC)

2B - possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals)(IARC);

IN - Inadequate information to assess carcinogenic potential (EPA, 2005); C - Possible human carcinogen (no human, limited animal studies)(EPA, 1986)

NS - Suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential (EPA,1999); 3 - Not classifiable (IARC);

CN - Carcinogenic potential cannot be determined (EPA, 1996); CH Carcinogenic to humans (EPA, 2005)

Surrogates used: 2-chlorotoluene for 4-chlorotoluene; 1,2-dichloropropane for 2,2-dichloropropane; 1,3-dichloropropene for 1,1-dichloropropene;

1,3-dichloropropene for cis- and trans-1,3 dichloropropene; bromomethane for iodomethane; cumene for 4-isopropyltoluene

(green shading) Concentration or reporting limiit exceeds the CV

Table 4: Landsburg Mine Site, Semi-Volatile Organic Compound (SVOC) Ranges in Groundwater, May and November 2013 and June 2014

SVOCs	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV	CV Reference
Acenaphthene	µg/l	3	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	600	ATSDR Child RMEG
Acenaphthylene	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	600	ATSDR Child RMEG
Anthracene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3,000	ATSDR Child RMEG
Benzo(a)anthracene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.034	EPA Regional Screening Level
Benzo (a)pyrene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.0048	ATSDR CREG
Benzo(b)fluoranthene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.034	EPA Regional Screening Level
Benzo(ghi)perylene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	300	ATSDR Child RMEG
Benzo(k)fluoranthene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.34	EPA Regional Screening Level
Benzoic Acid	µg/l	D	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	40,000	ATSDR Child RMEG
Benzyl Alcohol	µg/l	NA	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	2,000	EPA Regional Screening Level
Bis(2-chloroethoxy)methane	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	59	EPA Regional Screening Level
Bis(2-chloroethyl)ether	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.032	ATSDR CREG
Bis(2-ethylhexyl)phthalate	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	5.6	EPA Regional Screening Level
4-Bromophenyl phenyl ether	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	20	ATSDR Child RMEG
Butyl benzyl phthalate	µg/l	C	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2,000	ATSDR Child RMEG
Carbazole	µg/l	2B	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	10	ATSDR Child RMEG
4-Choloroaniline	µg/l	2B	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	40	ATSDR Child RMEG
4-Chloro-3-methylphenol	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	300	EPA Ambient Water Quality Criteria
2-Chloronaphthalene	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	800	ATSDR Child RMEG
2-Chlorophenol	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	40	EPA Lifetime Health Advisory
4-Chlorophenyl phenyl ether	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	20	ATSDR Child RMEG
3&4 Methylphenol(m,p-Cresols)	µg/l	C	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	500	ATSDR Child RMEG
2-Methylphenol (o-Cresol)	µg/l	C	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	500	ATSDR Child RMEG
Chrysene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3.4	ATSDR Regional Screening Level
Di-n-butyl phthalate	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	900	EPA Regional Screening Level
Dibenz(a,h)anthracene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.0034	EPA Regional Screening Level
Dibenzofuran	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	290	EPA Regional Screening Level
1,2-Dichlorobenzene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	600	EPA Lifetime Health Advisory
1,3-Dichlorobenzene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	600	EPA Lifetime Health Advisory
1,4-Dichlorobenzene	µg/l	2B	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	75	EPA Lifetime Health Advisory
3,3'-Dichlorobenzidine	µg/l	B2	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	0.078	ATSDR CREG
2,4-Dichlorophenol	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	20	EPA Lifetime Health Advisory
Diethyl phthalate	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	8,000	ATSDR Child RMEG
2,4-Dimethylphenol	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	200	ATSDR Child RMEG
Dimethyl phthalate	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1,000	ATSDR Child RMEG
4,6-Dinitro-2-methylphenol	µg/l	NA	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	40	ATSDR Child Intermediate EMEG
2,4-Dinitrophenol	µg/l	NA	20U	20U	20U	20U	20U	20U	20U	20U	20U	20U	20	ATSDR Child RMEG
2,4-Dinitrotoluene	µg/l	2B	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	20	ATSDR Child EMEG
2,6-Dinitrotoluene	µg/l	2B	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	40	ATSDR Child Intermediate EMEG

Table 4: Landsburg Mine Site, Semi-Volatile Organic Compound (SVOC) Ranges in Groundwater, May and November 2013 and June 2014 (continued)

SVOCs	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV	CV Reference
N-Nitrosodiphenylamine	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	7.1	ATSDR CREG
Fluoranthene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	400	ATSDR Child RMEG
Fluorene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	400	ATSDR Child RMEG
Hexachlorobenzene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.022	ATSDR CREG
Hexachlorobutadiene	µg/l	C	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	0.45	ATSDR CREG
Hexachlorocyclopentadiene	µg/l	NO	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	60	ATSDR Child RMEG
Hexachlorethane	µg/l	LC	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	0.88	ATSDR CREG
Indeno(1,2,3-cd)pyrene	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.034	EPA Regional Screening Level
Isophorone	µg/l	C	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2,000	ATSDR Child Chronic EMEG
1-Methylnaphthalene	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	700	ATSDR Child Chronic EMEG
2-Methylnaphthalene	µg/l	DI	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	40	ATSDR Child RMEG
4-Methylphenol	µg/l	NA	2U	2U	2U	2U	2U	2U	2U	2U	2U	2U	200	ATSDR Child RMEG
Naphthalene	µg/l	CN	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	100	EPA Lifetime Health Advisory
2-Nitroaniline	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	190	EPA Regional Screening Level
3-Nitroaniline	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	3.8	EPA Regional Screening Level
4-Nitroaniline	µg/l	NA	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	3.8	EPA Regional Screening Level
Nitrobenzene	µg/l	LC	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	20	ATSDR Child RMEG
2-Nitrophenol	µg/l	D	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	60	EPA Lifetime Health Advisory
4-Nitrophenol	µg/l	D	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	60	EPA Lifetime Health Advisory
N-Nitrosodi-n-propylamine	µg/l	B2	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	0.005	ATSDR CREG
2,2'-Oxybis(1-Chloropropane)	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	300	EPA Lifetime Health Advisory
Di-n-octyl phthalate	µg/l	NA	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	4,000	ATSDR Child Intermediate EMEG
Pentachlorophenol	µg/l	LC	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	0.088	ATSDR CREG
Phenanthrene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	3,000	ATSDR Child RMEG
Phenol	µg/l	DI	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2,000	EPA Lifetime Health Advisory
Pyrene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	300	ATSDR Child RMEG
1,2,4-Trichlorobenzene	µg/l	D	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	70	EPA Lifetime Health Advisory
2,4,5-Trichlorophenol	µg/l	NA	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	1,000	ATSDR Child RMEG
2,4,6-Trichlorophenol	µg/l	B2	3U	3U	3U	3U	3U	3U	3U	3U	3U	3U	3.2	ATSDR CREG

* not sampled during June 2014 sampling event due to pump malfunction; µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

NA - not available

3 - Not classifiable (IARC);

B1 - probable human carcinogen (limited human, sufficient animal studies)(EPA, 1986); B2 - Probable human carcinogen (inadequate human, sufficient animal studies)(EPA, 1986)

C - Possible human carcinogen (no human, limited animal studies)(EPA, 1986); D - Not classified as to human carcinogenicity (EPA, 1986);

2B - possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals)(IARC);

NO - Not likely to be carcinogenic to humans (EPA, 1996); LC Likely to be carcinogenic to humans (EPA, 2005)

DI - Data are inadequate for assessment of human carcinogenic potential (EPA, 1999)

CN Carcinogenic potential cannot be determined (EPA, 1996)

4,6-dinitro-2-methylphenol; dimethyl phenol for methyl phenol; 4-notroaniline for 3-nitroaniline; 4-nitrophenol for 2-nitrophenol; bis(2-chloro-1-1methylethyl) ether for 2,2'-oxybis(1-chloropropane); anthrene for phenanthrene.

(green shading) Concentration or reporting limiit exceeds the CV

Table 5: Landsburg Mine Site, Pesticide Ranges in Groundwater, May and November 2013 and June 2014

Pesticides	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV	CV Reference
Aldrin	µg/l	B2	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.0021	ATSDR CREG
alpha-BHC	µg/l	B2	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.0056	ATSDR CREG
beta-BHC	µg/l	C	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.019	ATSDR CREG
delta-BHC	µg/l	NA	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.019	ATSDR CREG
gamma-BHC	µg/l	NA	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.041	EPA Regional Screening Level
cis-Chlordane	µg/l	NA	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.1	ATSDR CREG
trans-Chlordane	µg/l	NA	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.1	ATSDR CREG
4,4'-DDD	µg/l	B2	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.15	ATSDR CREG
4,4'-DDE	µg/l	B2	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.1	ATSDR CREG
4,4'-DDT	µg/l	B2	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.1	ATSDR CREG
Dieldrin	µg/l	B2	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.0022	ATSDR CREG
Endosulfan	µg/l	NA	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	20	ATSDR Child Chronic EMEG
Endosulfan II	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	20	ATSDR Child Chronic EMEG
Endosulfan Sulfate	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	20	ATSDR Child Chronic EMEG
Endrin	µg/l	D	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	2	EPA Lifetime Health Advisory
Endrin aldehyde	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	2	EPA Lifetime Health Advisory
Endrin ketone	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	2	EPA Lifetime Health Advisory
Heptachlor	µg/l	B2	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.0078	ATSDR CREG
Heptachlor epoxide	µg/l	B2	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.05U	0.0038	ATSDR CREG
Methoxychlor	µg/l	D	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	0.5U	40	EPA Lifetime Health Advisory
Toxaphene	µg/l	B2	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	0.032	ATSDR CREG

* not sampled during June 2014 sampling event due to pump malfunction; µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

NA - not available

B2 - Probable human carcinogen (inadequate human, sufficient animal studies)(EPA, 1986)

C - Possible human carcinogen (no human, limited animal studies)(EPA, 1986)

KL - Known/Likely human carcinogen (EPA, 1996)

D - Not classified as to human carcinogenicity (EPA, 1986)

Surrogates used: beta-BHC for delta BHC; chlordane used for cis- and trans-chlorodane; endosulfan used for endosulfan II and endosulfan sulfate; endrin used for endrin aldehyde and endrin ketone

(green shading) Concentration or reporting limiit exceeds the CV

Table 6: Landsburg Mine Site, Polychlorinated Biphenyl Ether (PCB) Ranges in Groundwater, May and November 2013 and June 2014

PCBs	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW 7*	LMW-8	LMW-9	LMW-10	LMW-11	CV	CV Reference
Aroclor 1016	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	1.1	EPA Regional Screening Level
Aroclor 1221	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.0046	EPA Regional Screening Level
Aroclor 1232	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.0046	EPA Regional Screening Level
Aroclor 1242	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.039	EPA Regional Screening Level
Aroclor 1248	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.039	EPA Regional Screening Level
Aroclor 1254	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.039	EPA Regional Screening Level
Aroclor 1260	µg/l	NA	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.01U	0.039	EPA Regional Screening Level

NA - not available; µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

* not sampled during June 2014 sampling event due to pump malfunction ;

(green shading) Concentration or reporting limiit exceeds the CV

Table 7: Landsburg Mine Site, Petroleum Hydrocarbon Ranges in Groundwater, May and November 2013 and June 2014

Petroleum Hydrocarbon	Units	Cancer Class	LMW-2	LMW-3	LMW-4	LMW-5	LMW-6	LMW-7 *	LMW-8	LMW-9	LMW-10	LMW-11	CV	CV Reference
Diesel Range	µg/l	NA	500U	500U	500U	500U	500U	500U	500U	500U	500U	500U	500	Ecology - MTCA Method A GW Cleanup Level
Gas Range	µg/l	NA	250U	250U	250U	250U	250U	250U	250U	250U	250U	250U	800	Ecology - MTCA Method A GW Cleanup Level
Oil Range	µg/l	NA	500U	500U	500U	500U	500U	500U	500U	500U	500U	500U	500	Ecology - MTCA Method A GW Cleanup Level

* not sampled during June 2014 sampling event due to pump malfunction;

µg/l - micrograms per liter; U - the analyte was not detected above the reporting limit

NA - not available

Table 8: Landsburg Mine Site, Calcium, Magnesium, and Potassium Intake Compared to UL or AI

Metal	Units	Maximum Concentration at Monitoring Wells North End of the Mine (LMW-2, LMW-4, and LMW10)	Maximum Concentration at Monitoring Wells at the south end of the mine (LMW-3, LMW-5, LMW-8, LMW-9, LMW-11)
Calcium	µg/l	6,490 - 118, 000	37,400 - 98,200
Magnesium	µg/l	2,690 - 71,400	15,600 - 54,400
Potassium	µg/l	1,220 - 3,910	1,690 - 2,860
Sodium	µg/l	20,900 - 82,700	9,160 - 34,500

	Drinking Water Intake	Maximum Calcium (mg/l)	Calcium Intake (mg/day)*	Maximum Magnesium (mg/l)	Magnesium Intake (mg/day)	Maximum Potassium (mg/l)	Potassium Intake (mg/day)	Maximum Sodium (mg/l)	Sodium Intake (mg/day)
	RME								
Age Groups	l/day								
Child Birth to < 1 yr	1.113	118	131	71.4	79.5	3.9	4.3	82.7	92.0
Child 1 to < 2 yr	0.893	118	105	71.4	63.8	3.9	3.5	82.7	73.9
Child 2 to < 6 yr	0.977	118	115	71.4	69.8	3.9	3.8	82.7	80.8
Child 6 to < 11 yr	1.404	118	166	71.4	100.2	3.9	5.5	82.7	116.1
Child 11 to <16 yr	1.976	118	233	71.4	141.1	3.9	7.7	82.7	163.4
Child 16 to <21 yr	2.444	118	288	71.4	174.5	3.9	9.5	82.7	202.1
Adults ≥ 21 yr	3.092	118	365	71.4	220.8	3.9	12.1	82.7	255.7
			Below guidelines		Slightly above guidelines for 3 yr old child (note: level for children < 1 year has not been established).		Below guidelines		Intake below 500 mg/day for people on a sodium restricted diet.**

* Calcium Intake = Maximum Calcium (mg/l) x Drinking Water Intake (l/day)

mg - milligram; l - liters

** While the sodium intake for the maximum groundwater concentration is below 500 mg/kg, sodium in groundwater is not likely the only source of sodium in the diet.

Table 9: National Academies, Institute of Medicine, Food and Nutrition Board
Tolerable Upper Intake Levels (ULs) for Calcium

Age	Male (mg/day)	Female (mg/day)	Pregnant (mg/day)	Lactating (mg/day)
0-6 months	1,000	1,000	-	-
7-12 months	1,500	1,500	-	-
1-8 years	2,500	2,500	-	-
9-18 years	3,000	3,000	3,000	3,000
19-50 years	2,500	2,500	2,500	2,500
51+ years	2,000	2,000	-	-

mg/day - milligrams per day

Table 10: National Academies, Institute of Medicine, Food and Nutrition Board
Tolerable Upper Intake Levels (ULs) for Supplemental Magnesium*

Age	Males (mg/day)	Females (mg/day)	Pregnant (mg/day)	Lactating (mg/day)
Infants	Undetermined	Undetermined	-	-
1-3	65	65	-	-
4-8	110	110	-	-
9-18	350	350	350	350
19+	350	350	350	350

mg/day - milligrams per day
* ULs for supplemental magnesium does not includes intake from food or water. Therefore, acceptable total intakes would be much higher.

Table 11: National Academies, Institute of Medicine, Food and Nutrition Board Adequate Intake (AI) for Potassium

Life Stage	Age	Males (mg/day)	Females (mg/day)
Infants	0-6 months	400	400
Infants	7-12 months	700	700
Children	1-3 years	3,000	3,000
Children	4-8 years	3,800	3,800
Children	9-13 years	4,500	4,500
Adolescents	14-18 years	4,700	4,700
Adults	19 years and older	4,700	4,700
Pregnancy	14-50 years	-	4,700
Breast-feeding	14-50 years	-	5,100

mg/day – milligrams per day

Table 12: Landsburg Mine Site, Non-Cancer Doses for Maximum Concentration of Chemicals of Potential Concern Compared to Oral MRLs and NOAELs

Contaminant	Maximum Concentration (µg/l)	Age Group (years)	Non-Cancer Dose (mg/kg/day)		Estimated Total Non-Cancer Dose (mg/kg/day)	Chronic Oral MRL (mg/kg/day)	Estimated Dose/ MRL	NOAEL (mg/kg/day)	Doses Exceed NOAEL
			Ingestion	Dermal					
Arsenic	8	Child Birth to < 1	1.1E-03	2.1E-06	1.1E-03	3.0E-04 [39]	**3.7**	8.0E-04 [40]	**Yes**
		Child 1 to < 2	6.3E-04	2.1E-06	6.3E-04		**2.1**		No
		Child 2 to < 6	4.5E-04	2.2E-06	4.5E-04		**1.5**		No
		Child 6 to < 11	3.5E-04	1.9E-06	3.5E-04		**1.2**		No
		Child 11 to <16	2.8E-04	1.5E-06	2.8E-04		0.9		No
		Child 16 to <21	2.7E-04	1.3E-06	2.7E-04		0.9		No
		Adult ≥ 21	3.1E-04	1.2E-06	3.1E-04		**1.0**		No
Manganese	563	Child Birth to < 1	8.0E-02	1.5E-04	8.0E-02	5.0E-02 [39]	**1.6**	1.4E-01 [41]	No
		Child 1 to < 2	4.4E-02	1.5E-04	4.4E-02		0.9		No
		Child 2 to < 6	3.2E-02	1.5E-04	3.2E-02		0.6		No
		Child 6 to < 11	2.5E-02	1.3E-04	2.5E-02		0.5		No
		Child 11 to <16	2.0E-02	1.0E-04	2.0E-02		0.4		No
		Child 16 to <21	1.9E-02	9.2E-05	1.9E-02		0.4		No
		Adult ≥ 21	2.2E-02	8.3E-05	2.2E-02		0.4		No

MRL – ATSDR minimal risk level; NOAEL – no observed adverse effect level
mg/kg/day – milligrams per kilogram/day
µg/l – microgram per liter
< - less than

Table 13: Landsburg Mine Site, Groundwater Cancer Dose and Risk Estimates for Maximum Concentration Chemicals of Potential Concern

Contaminant	Maximum Concentration (µg/l)	Age Group*	Exposure Dose (mg/kg/day)			Cancer Slope Factor (mg/kg/day)	Estimated Cancer Risk		
			Ingestion	Dermal	Ingestion + Dermal (mg/kg/day)		Ingestion	Dermal	Ingestion + Dermal
Arsenic	8	Child Birth to < 1	1.5E-05	2.7E-08	1.5E-05	5.7E+00 [42]	8.3E-05	1.6E-07	8.3E-05
		Child 1 to < 2	8.0E-06	2.7E-08	8.0E-06		4.6E-05	1.6E-07	4.6E-05
		Child 2 to < 6	2.3E-05	1.1E-07	2.3E-05		1.3E-04	6.4E-07	1.3E-04
		Child 6 to < 11	2.3E-05	1.2E-07	2.3E-05		1.3E-04	6.8E-07	1.3E-04
		Child 11 to <16	1.8E-05	9.3E-08	1.8E-05		1.0E-04	5.3E-07	1.0E-04
		Child 16 to <21	1.8E-05	8.3E-08	1.8E-05		1.0E-04	4.8E-07	1.0E-04
		Adult ≥ 21	4.8E-05	1.8E-07	4.8E-05		2.7E-04	1.0E-06	2.7E-04
		Total	1.5E-04	6.4E-07	1.5E-04		8.6E-04	3.65E-06	8.6E-04

mg/kg/day – milligrams per kilogram/day
µg/l – microgram per liter
< - less than

Figures

Figure 1: Vicinity Map

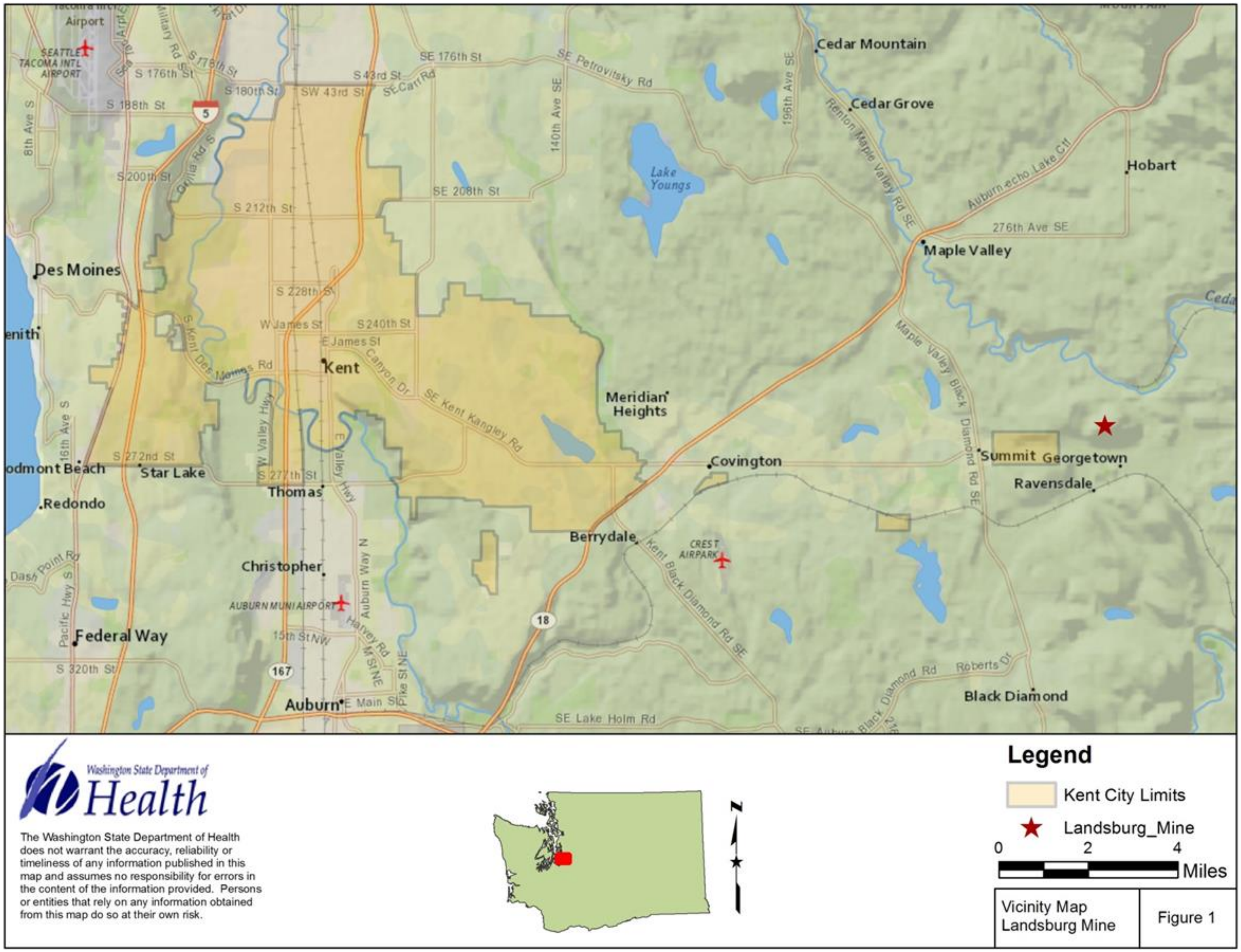
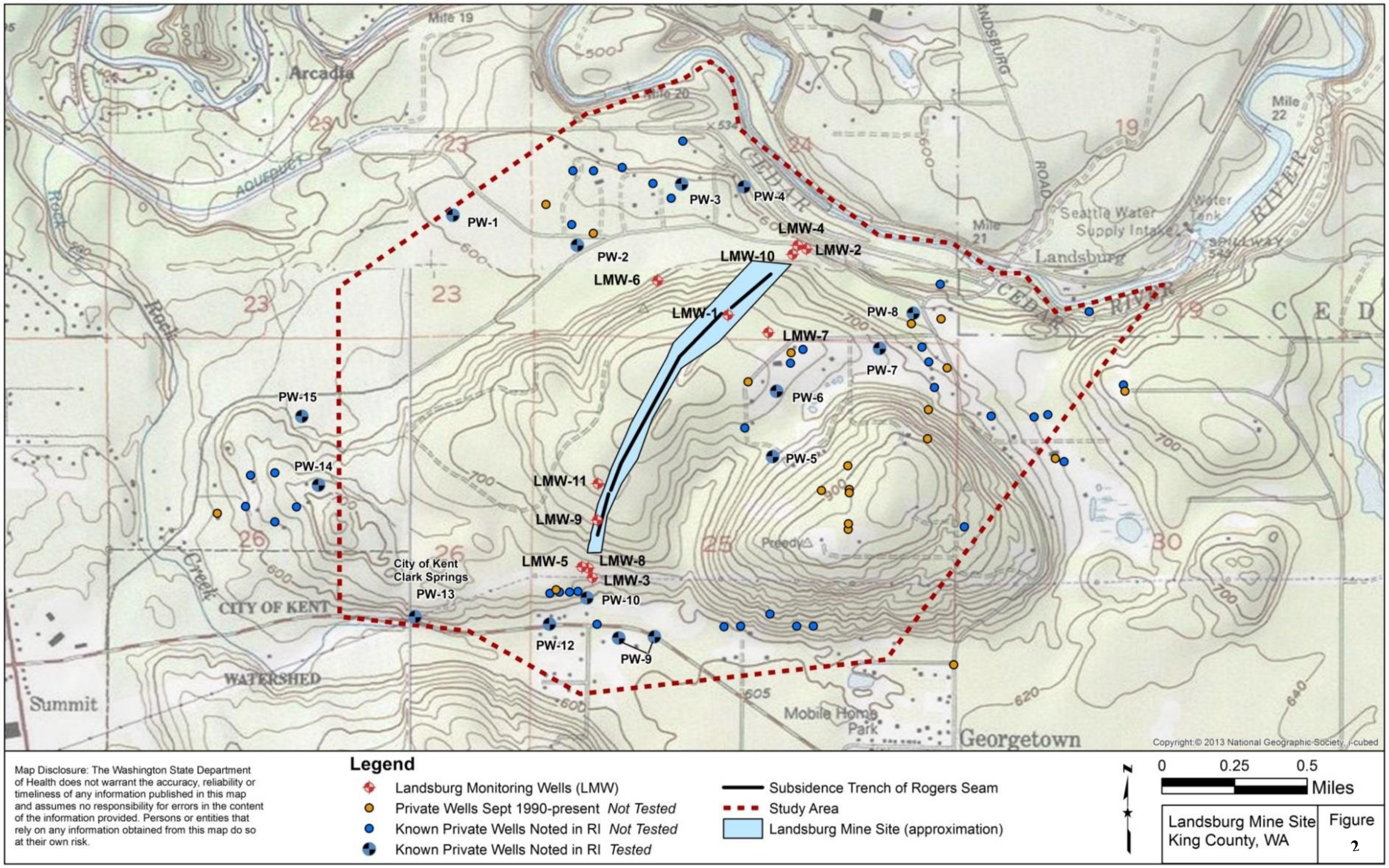


Figure 2: Landsburg Mine Site



Appendices

Appendix A - Glossary

Acute	Occurring over a short time [compare with **chronic**].
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.
Aquifer	An underground formation composed of materials such as sand, soil, or gravel that can store and/or supply groundwater to wells and springs.
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**].
CERCLA	Comprehensive Environmental Response Compensation and Liability Act.
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 [see **acute exposure**], of intermediate duration, or long-term [see **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.
Indeterminate Public Health Hazard	The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.
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 per day (1/day) for water and milligrams per day (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 **reference dose**].
Model Toxics Control Act (MTCA)	The hazardous waste cleanup law for Washington State.
Monitoring Wells	Special wells drilled at locations on or off a hazardous waste site so water can be sampled at selected depths and studied to determine the movement of groundwater and the amount, distribution, and type of contaminant.
No Apparent Public Health Hazard	A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.
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.
No Public Health Hazard	A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.
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 EMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD).
Remedial Investigation (RI)	The CERCLA process of determining the type and extent of hazardous material contamination at a site.
Route of Exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [see **inhalation**], eating or drinking [see **ingestion**], or contact with the skin [see **dermal contact**].
Surface Water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].
Volatile Organic Compound (VOC)	Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Appendix B – Arsenic and Manganese Information

Arsenic

Arsenic can occur in inorganic or organic forms. It is typically found in soils and many types of rock in the inorganic form. In the past, arsenic was used to treat wood and as a pesticide in orchards. It has also been added in small amounts to other metals to form alloys with improved properties [40].

Drinking water in Washington typically contains less than 3 µg/l arsenic but has been found in some Washington wells from 10 to 33,000 µg/L [35]. Those elevated levels are usually associated with water located in rock or soil that has a naturally high amount of arsenic.

EPA has set a maximum contaminant level goal (MCLG) for arsenic in drinking water at zero and a maximum contaminant level at 10 µg/l [34].

The primary way people are exposed to arsenic is by drinking or preparing food with water containing arsenic [40]. Arsenic in water is poorly absorbed through the skin so dermal exposure is not a concern unless levels are very high. Arsenic does not readily evaporate from water so inhalation exposure is also not a concern.

Long-term exposure to small amounts of arsenic can increase the risk of developing cancer of the bladder, lung, skin, liver, kidney, or prostate [35]. Other health effects may include high blood pressure, narrowing of the blood vessels, nerve damage, anemia, diabetes, stomach upset, and skin changes.

Manganese

Manganese does not exist in nature as an elemental form, but is found mainly as oxides, carbonates, and silicates. It exists in both inorganic and organic forms. Inorganic forms of manganese are most often found in the environment and the workplace. Manganese is found in foods and water and can be added to certain foods and nutritional supplements [36].

Groundwater in the United States contains median manganese levels ranging from 5 µg/l to 150 µg/l [36]. The 99th percentile levels for rural and urban areas were reported as 2,900 µg/l and 5,600 µg/l, respectively.

There is currently no EPA MCLG or MCL for manganese. However, EPA has established a 300 µg/l lifetime health advisory for manganese [43]. The lifetime health advisory is estimated to be an intake level for the general population that is not expected to result in adverse health effects.

ATSDR reports in its toxicological profile that exposure to manganese can occur through ingestion, inhalation, and dermal contact [36]. They report that the primary source of manganese intake is through eating food or drinking water that contains manganese. Inhaling air with manganese containing particulate matter is the primary source of excess exposure for the general population in the United States. Only very small amounts of manganese will enter the skin when coming into contact with manganese containing liquids.

ATSDR also reports that there is no evidence that manganese causes cancer in humans or animals [36]. However, they do report non-cancer health effects in humans and animals. Inhaling manganese containing dust or particulate matter can produce significant non-cancer health effects including neurological effects. Fumes from welding activities can also increase the chance of manganese exposure. Increased concentrations of manganese in drinking water also appear to result in adverse neurological effects. The level at which manganese produces neurological effects in humans ingesting water containing manganese has not been established. Children appear to be potentially more sensitive to manganese toxicity than adults. Animals exposed to very high manganese doses in a laboratory experienced nervous system disturbances, reproductive changes, and illnesses involving the kidneys and urinary tract.

Appendix C – Equations and Exposure Parameters

Ingestion Route

$$ID = \frac{Cw \times IR \times EF \times ED}{BW \times AT}$$

		RME
ID = ingested dose (mg/kg/day)		*calculated*
Cw = concentration in water (mg/l)		
IR = ingestion rate (l/day)	*Child Birth to < 1 yr*	1.113
	Child 1 to < 2 yr	0.893
	Child 2 to < 6 yr	0.977
	Child 6 to < 11 yr	1.404
	Child 11 to <16 yr	1.976
	Child 16 to <21 yr	2.444
	Adults ≥ 21 yr	3.092
Default Adults (9 years) -- mean residential occupancy period		3.092
Default Adults (33 years) -- 95% residential occupancy period		3.092
EF = exposure frequency (days/year)		365
ED = exposure duration (years)	*Child Birth to < 1 yr*	1
	Child 1 to < 2 yr	1
	Child 2 to < 6 yr	4
	Child 6 to < 11 yr	5
	Child 11 to <16 yr	5
	Child 16 to <21 yr	5
	Adults ≥ 21 yr	12
Default Adults (9 years) -- mean residential occupancy period		9
Default Adults (33 years) -- 95% residential occupancy period		33
BW = body weight (kg)	*Child Birth to < 1 yr*	7.8
	Child 1 to < 2 yr	11.4
	Child 2 to < 6 yr	17.4
	Child 6 to < 11 yr	31.8
	Child 11 to <16 yr	56.8
	Child 16 to <21 yr	71.6
	Adults ≥ 21 yr	80
AT = averaging time (days) non-cancer	*Child Birth to < 1 yr*	365
	Child 1 to < 2 yr	365
	Child 2 to < 6 yr	1460
	Child 6 to < 11 yr	1825
	Child 11 to <16 yr	1825
	Child 16 to <21 yr	1825
	Adults ≥ 21 yr	4380
Default Adults (9 years) -- mean residential occupancy period		3285
Default Adults (33 years) -- 95% residential occupancy period		12045
AT = averaging time (days) cancer		28470
Oral Cancer Slope Factor	carc	

Dermal Route

$$DAD = \frac{DAev \times EV \times EF \times ED \times SA}{BW \times AT}$$

Inorganics

$$DA_{event} = \frac{Kp \times Cw \times t}{ORAFnc} = 4.0E\text{-}09 \text{ mg/cm2-event}$$

Model Parameters

Kp = skin permeability coef. (cm/hr)	*1.0E-03*	*chemical specific*
tau = lag time (hr)		*chemical specific*
B =		*chemical specific*
t = hours/event	*0.5*	*site specific*
pi =	3.1415927	
ORAFnc = Oral Route Adjustment Factor	1	
ORAFc = Oral Route Adjustment Factor	1	
FA = Fraction absorbed water	*1*	*chemical specific*

Kp (EPA RSL, June 2015)
Arsenic = 0.001
Manganese (non-diet) = 0.001

(see next page for dermal exposure parameters)

		RME	CTE
DAD = dermally absorbed dose (mg/kg/day)		*calculated*	*calculated*
DA_{event} = dermally absorbed dose per event (mg/event)		*calculated*	*calculated*
C_{dw} = concentration in drinking water mg/L		*8.0E-03*	
EV = event frequency (events/day)		1	
EF = exposure frequency (days/year)		365	
ED = exposure duration (years)	*Child Birth to < 1 yr*	1	
	Child 1 to < 2 yr	1	
	Child 2 to < 6 yr	4	
	Child 6 to < 11 yr	5	
	Child 11 to <16 yr	5	
	Child 16 to <21 yr	5	
	Adults ≥ 21 yr	12	
Default Adults (9 years) -- mean residential occupancy period		9	
Default Adults (33 years) -- 95% residential occupancy period		33	
BW = body weight (kg)	*Child Birth to < 1 yr*	7.8	
	Child 1 to < 2 yr	11.4	
	Child 2 to < 6 yr	17.4	
	Child 6 to < 11 yr	31.8	
	Child 11 to <16 yr	56.8	
	Child 16 to <21 yr	71.6	
	Adults ≥ 21 yr	80	
AT = averaging time (days) non-cancer	*Child Birth to < 1 yr*	365	
	Child 1 to < 2 yr	365	
	Child 2 to < 6 yr	1460	
	Child 6 to < 11 yr	1825	
	Child 11 to <16 yr	1825	
	Child 16 to <21 yr	1825	
	Adults ≥ 21 yr	4380	
Default Adults (9 years) -- mean residential occupancy period		3285	
Default Adults (33 years) -- 95% residential occupancy period		12045	
AT = averaging time (days) cancer		28470	
Oral Cancer Slope Factor		5.7	
SA = surface area (cm2)	*Child Birth to < 1 yr*	4175	3625
	Child 1 to < 2 yr	6100	5300
	Child 2 to < 6 yr	9500	7600
	Child 6 to < 11 yr	14800	10800
	Child 11 to <16 yr	20600	15900
	Child 16 to <21 yr	23300	18400
	Adults ≥ 21 yr	23579	19450

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