# Health Consultation

# Evaluation of Contaminants in Private Residential Well Water

**Pavillion, Wyoming**

**Fremont County**


**Prepared by:**

**Agency for Toxic Substances and Disease Registry**



**August 31, 2010**

## PAVILLION GROUNDWATER SUPERFUND SITE ASSESSMENT
## PAVILLION, FREMONT COUNTY, WYOMING

### Statement of Issues

On March 19, 2010 the United States Environmental Protection Agency (EPA) Region 8 requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate potential public health risks from contamination identified in domestic wells located in Pavillion, Fremont County, Wyoming. EPA sampled residential, municipal water supply, and temporary monitoring wells in two phases as a part of a site assessment conducted under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) authority. EPA Region 8's investigation was intended to determine whether constituents of concern were present in the wells, and if possible, to evaluate any potential sources, including the predominant activities in the area – agriculture or gas development. Sources considered included agricultural use of pesticides and fertilizer, household impacts such as nitrates from septic tanks, and natural gas production and extraction activities. Based on EPA's request and the need to prioritize public health concerns, the exposure pathways examined in this health consultation are the ingestion of drinking well water and inhalation of contaminants from vapors while showering. Other potential exposure pathways exist for exposure to water contaminants, including watering livestock and irrigation of crops, which were not addressed in this health consultation. EPA continues to investigate groundwater in the Pavillion area. ATSDR recognizes that a need to reevaluate the findings of this report may emerge as additional data becomes available.

### Background

Pavillion, Wyoming is located in Fremont County, about 20 miles northwest of Riverton and west of Boysen State Park (Appendix A. Area Map). In 2003, the estimated population was 166 residents. Pavillion has approximately 80 domestic wells and approximately 8 public water supply wells. Water wells in Pavillion are used for drinking water, irrigation, and livestock watering. According to state engineering records, these wells are completed at depths from 50 to 800 feet or more. The town of Pavillion is within the Wind River Indian Reservation as described by the Northern Arapaho and Eastern Shoshone Tribes. The focus area of the EPA groundwater investigation (Pavillion area) is located east north east of the town of Pavillion, which covers an area of approximately 8 square miles. Land use is predominantly rural with residential properties located among agricultural fields, as well as oil and gas production facilities.

Some residents living just outside the town of Pavillion use private well water for their source of drinking water. Residents are concerned that there may be a potential impact of gas drilling and exploration on their water supply, since drilling operations have or are occurring in close proximity of their wells. Residents have reported visual changes in their water including a yellow color, increased turbidity, oil sheen, and inclusion of small gas bubbles. In one case, a resident reported a strong hydrocarbon odor emanating from the tap (1). Some residents raised concerns that a loss of sense of taste and mouth numbness was related to past exposures to chemicals detected in their well. Residents are concerned that there may be a risk of cancer from the chemicals in the water.

During March and May of 2009, EPA collected well water samples in the first phase of their investigations in the Pavillion area (1). In early 2009, EPA requested that ATSDR assist in responding to community health concerns. Following an EPA sponsored August 2009 public meeting in Pavillion, ATSDR responded to a citizen's request for an emergency consultation addressing methane and tentatively identified compounds (TICs) in her residential well that was her primary source of drinking water. ATSDR's analysis of the well data collected by EPA concluded that the methane levels were not considered an immediate hazard (2). ATSDR noted, however, that methane levels could fluctuate with changing conditions. To decrease the risk of explosion from the methane gas, ATSDR recommended that: 1) well houses or enclosed areas of the house where water is used (basements and bathrooms) be ventilated; 2) sources of ignition in any enclosed areas be removed; and 3) installation of combustible gas meters, and/or discussion of combustible gas monitoring with the local fire department be considered.

After the first phase of investigations, ATSDR received calls from four Pavillion residents with health concerns about the presence of TICs in their water. Three of the four homeowners were using bottled water supplies for drinking. One homeowner's water was filtered through a reverse osmosis unit connected to the well water line, but the remaining residents used unfiltered well water for bathing. All had used their well water as their primary drinking water supply in the past. In conversations with residents, ATSDR explained that the data regarding TICs provided by EPA was qualitative and that health based, toxicological reference values were not available. ATSDR verbally indicated that prudent public health practice would be to continue using bottled water, until the results of the EPA Expanded Site Investigation (ESI) permitted a more thorough analysis of the water supply (3).

**Potential Sources of Contamination**

**Natural Gas Exploration and Extraction**

Natural gas exploration and extraction is extensive in the Pavillion area and petroleum operations occur in close proximity to domestic wells. Multiple production wells, both active and abandoned, exist in the area of investigation (4). Recent information for the Pavillion area from the Wyoming Oil and Gas Conservation Commission indicates approximately 211 active gas wells, 30 plugged and abandoned wells, and 20 wells identified as "shut-in." 37 pits (which formerly held drilling fluids) have been identified in the area. Some pits have been addressed through the Wyoming Department of Environmental Quality (WDEQ) Voluntary Remediation Program.

The United States Geological Survey (USGS) has reported that contaminants associated with oil and gas production have the potential to affect the water resources of the area. The potential contaminants associated with oil and gas production include petroleum hydrocarbons, brines, and trace metals, and in some cases naturally occurring radioactive material. Sources of these contaminants include overflowing, failing, or unlined pits, leaking tanks, leaking well heads, and interaction between the groundwater and petroleum or brine zones inside well bores (5).

**Agricultural Practices**

Poor drainage resulting in salt accumulation has been a problem in many irrigated areas of the Wind River Indian Reservation. After irrigation began in the 1920's, seepages and salt accumulation became apparent in the Riverton Reclamation Project. An extensive network of drains has been installed throughout the irrigated lands on the Reservation to help mitigate the problem. Most of the drains are constructed in unconsolidated surface materials and are unlined, so that percolation of drain water to the groundwater occurs. No specific study has investigated the relation between ground water quality and irrigation drainage on the Reservation, however studies have looked at surface water quality in the irrigation-drainage system. It has been reported that nutrients, trace metals, and pesticides were detected in water quality samples collected from irrigation drains (6).

**Septic Systems**

In rural areas of Wyoming, people depend upon private septic systems to dispose of domestic wastewater (7). Septic systems can contribute to the contamination of groundwater, which can result in disease outbreaks. Septic systems can be sources of nitrate and bacteriological contamination. EPA has established a level of 10 milligrams per liter (mg/L) for nitrate for public water systems. Nitrate levels in private water also should be below 10 mg/L.

**Hydrology of the Site**

The groundwater in the Pavilion area is defined by EPA as an "underground source of drinking water. As such, the water quality of the groundwater is potentially "suitable for human consumption". Shallow groundwater wells, approximately 50 feet below the ground surface, and deeper drinking water wells, up to 800 feet below the ground surface, are currently being used in the Pavillion area (EPA; Personal communication; 8).

None of the aquifers currently used for drinking water in the Wind River formation in the Pavilion area are completely "confined" or isolated from other aquifers. This characteristic means that that the water in one aquifer can flow to another. Well water quality can be affected by water from two general sources. Shallow groundwater wells receive water from the surface; for instance rain and irrigation water, in addition to waters from groundwater flows. Deeper wells receive water primarily through groundwater flows that are not related to direct infiltration from precipitation or irrigation.

The USGS has indicated that flood irrigation, a practice that is common in the Pavillion area, can provide water to the shallow groundwater (5). A notable site-related characteristic for the Pavillion area is the presence of "pits" which contain organic chemicals that were left from oil and gas production well activities in the area. Sampling results indicate that groundwater contamination has occurred by migration of organic compounds from pit areas into the shallow groundwater. Information about sources of contamination of the deeper wells in the area is limited. However, EPA has recently installed two monitoring wells (up to 1000 feet deep) to better assess contaminant impacts to water quality in deeper aquifers (EPA; Personal communication: 8).

Currently, there is a very limited understanding of the groundwater flow (including horizontal flow directions, vertical flow direction, and the gradient of the flow) in the Pavillion area. The lack of this important information limits the ability to predict the velocity and direction of contaminant movement and creates considerable uncertainty in our understanding of the site characteristics, especially the potential for contamination of the private wells by the contaminated groundwater.

**Environmental Data**

EPA Region 8 has conducted two sampling rounds of municipal, domestic and groundwater monitoring wells. This consultation evaluates the public health implications of ingestion and inhalation of the chemicals identified in residential wells by EPA Region 8 as part of its investigation of groundwater contamination in the Pavillion area.

## Discussion

### Environmental Data

In March 2009, under CERCLA authority, EPA Region 8 conducted a Focused Site Investigation (FSI), which included sampling of 2 municipal and 37 residential water wells (Appendix B-Sampling locations) (4). Samples were analyzed for some or all of the following parameters: Target Compound List (TCL), Volatile Organic Compounds (VOCs), Semi-volatile Organic Compounds (SVOCs), Target Analyte List (TAL) total metals, pesticides, polychlorinated biphenyls (PCBs), microbacteriological parameters, anions, and petroleum hydrocarbons including Volatile Petroleum Hydrocarbons and Extractable Petroleum Hydrocarbons. All 39 samples were analyzed for VOCs, SVOCs, TAL total metals, pesticides, anions, and PCBs by the EPA Contract Laboratory Program (CLP). Samples from 35 locations were analyzed for SVOC Tentatively Identified Compounds (TICs), anions, alkalinity, and dissolved methane by EPA Region 8 Laboratory. Samples from all 39 locations were analyzed for VPH and EPH by a commercial laboratory and samples from 9 locations were analyzed for bacteriological parameters by a commercial laboratory (4). Analytic standards necessary to definitively identify and quantify concentrations of some compounds by mass spectroscopy were not available at the time of the FSI laboratory analysis. As a result many compounds are referred to as "tentatively identified compounds" (TICs). These compounds were tentatively identified based on molecular weights associated with peaks on the gas chromatograms, but could not be quantified. SVOC TICs from the FSI included: adamantanes, tri (2-butoxyethly) phosphate (also referred to as 2-butoxyethanol phosphate), 2,4-bis(1-phenyl)-phenol, bisphenol A, terpineol, 5-hydroxymethyldihydrofuran, and limonene. Iron and sulfur bacteria were detected in some of the wells. (4).

In January 2010, EPA conducted additional water sampling in an Expanded Site Investigation (ESI), which included the sampling of municipal water, private wells, and monitoring wells (1). More sophisticated laboratory analysis used in the ESI permitted a definitive consideration of pertinent TICs noted in the first sampling event. The ESI laboratory analysis confirmed the presence of some of the compounds referred to as TICs in the initial investigation. Of note, adamantanes (naturally occurring compounds found in crude and gas condensate), and tri (2-butoxyethyl) phosphate were detected. The presence of methane, diesel range organics (DRO), and caprolactam in some drinking and stock water supplies was also confirmed.

The analytical results of the FSI and ESI sampling rounds for the monitoring wells and the private wells are included in Appendix D and E. While some of the analytic results had data that were qualified for various reasons, the flagged data were carefully examined by EPA and determined to be valid. Additional information on the data qualifications can be found in EPA's

Analytical Results Report (1). The water samples were analyzed for volatile compounds, pesticides, semi-volatile compounds, petroleum hydrocarbons, bacteria and inorganic ions.

ATSDR compared the levels of compounds to available comparison values (CVs). Health CVs were used to identify contaminants which should be further evaluated for their potential to produce adverse health effects (i.e. if a compound was detected at a level above the CV, it would be considered a compound of concern). The following CVs were utilized and are defined in the Glossary (Appendix C). The data was screened against values for the most sensitive receptor, a child.

- Environmental Media Evaluation Guide (EMEG)
- Reference Media Evaluation Guide (RMEG)
- Cancer Risk Evaluation Guide (CREG)
- Maximum Contaminant Level ( MCL)
- Maximum Contaminant Level Goal (MCLG)
- Lifetime Health Advisory (LTHA)
- Minnesota Total Petroleum Hydrocarbon Value (MN TPH)
- EPA Provisional Peer Reviewed Toxicity Values (EPA PPRTV)
- EPA Secondary Maximum Contaminant Levels (SMCL)

Compounds of concern and compounds which did not have existing CVs were examined in greater detail. This review included an analysis of the specific exposure scenario and a review of available scientific literature to determine whether or not exposure to the contaminant represents a public health issue. Because CVs are based on conservative assumptions, the presence of concentrations greater than a CV does not necessarily indicate that adverse health effects will occur in exposed populations. The data was screened for the most sensitive receptor, a child.

**Monitoring Wells**

EPA sampled 3 shallow groundwater (approximately 10’-15’ in depth) monitoring wells in the area of investigation near 3 oil and gas well pit sites. The monitoring well data was screened against CVs since the groundwater could potentially provide a source of water for private wells. The groundwater from the 3 pit site monitoring wells is highly contaminated. Significant quantities of petroleum hydrocarbons were identified in these wells. Total Petroleum Hydrocarbon (TPH) as diesel range organics (DRO) and gasoline range organics (GRO) were measured in all three wells with maximum values of 62,100 µg/L and 2,720 µg/L, respectively. TPH as Total Extractable Hydrocarbons and Total Purgeable Hydrocarbons were measured in all three wells with maximum values of 42,000 µg/L and 3,790 µg/L.

Individual petroleum constituents identified above levels of concern in monitoring wells included: benzene (390 µg/L maximum), cyclohexane (140 µg/L maximum), and methylcyclohexane (140 µg/L). Methane, propane, and ethane – compounds without CVs – were detected dissolved in water at maximum values of 708, 43.8, and 299 µg/L, respectively. Sodium and sulfates were elevated at approximately 4 times the CVs at maximum values of 1,020,000 and 1,040,000 µg/L, respectively. TICs were identified in the monitoring wells, including adamantane (range 1.78-3.86 µg/L) and 1,3 dimethyl adamantane (0.29-0.64 µg/L).

Arsenic was detected in a range of 3.6-41.8 µg/L in all 3 wells, which exceeded the CV of 3 µg/L (Chronic EMEG). Calcium was detected in a range of 150,000-337,000 µg/L. There was no CV for calcium. Chloride was detected in a range of 3500- 265,000 µg/L. One value exceeded the EPA SMCL for chloride (250,000 µg/L). Iron levels ranged from 1220-10,800 µg/L which exceeded the EPA SMCL (300 µg/L) in all 3 wells. Magnesium was found in a range of 24,700 - 91,800 µg/L. There was no CV for magnesium. Manganese was found in 2 wells (379, 3640µg/L) which exceeded the RMEG (500 µg/L). Potassium was detected in a range of 2930-4150 µg/L in all wells. There is no CV for potassium. Sodium and sulfates were found at levels that exceeded their respective EPA SMCL values of 20,000 µg/L and 250,000 µg/L. Sodium levels ranged from 26,900-1,040,000 µg/L. Sulfate levels ranged from 28,400 -1,040,000 µg/L. Table 1. Includes the compounds in the groundwater which exceed CVs or no CV is available.

**Table 1. Compounds Detected in Groundwater Wells Which Exceed CVs or No CV is Available**

| Compound | Result Range ( Minimum to Maximum) (µg/L) | Comparison Value (CV) (µg/L) | Source | Exceed CV | Monitoring Wells with Contaminant |
|---|---|---|---|---|---|
| 1,1 biphenyl | 0.76-1 | None | | | 3/3 |
| 1,2,4 trimethyl benzene | 14.1 | None | | | 1/3 |
| 1,3,5 trimethyl benzene | 2.6-19.7 | None | | | 3/3 |
| 1,3 dimethyl admantane | 0.29-0.64 | None | | | 3/3 |
| 2,4 dimethyl phenol | 1.6-39 | 200 | Chronic RMEG child | No | 3/3 |
| 4 methyl phenol | 0.39-24 | None | | | 3/3 |
| 3,4 methyl phenol | 12.8 | None | | | 1/3 |
| adamantine | 1.78-3.86 | None | | | 3/3 |
| alkalinity | 438,000-2,750,000 | 30,000-400,000 | | Yes | 3/3 |
| aluminum | 565 | 10,000 | Chronic EMEG child | No | 1/3 |
| arsenic | 3.6-41.8 | 3<br>0.02 | Chronic EMEG child<br>CREG | Yes<br>Yes | 3/3 |
| benzene | 5.3-390 | 5 | Chronic EMEG child | Yes | 3/3 |
| tert butyl benzene | 1.6-9.68 | None | | | 3/3 |
| calcium | 150,000-337,000 | None | | | 2/3 |
| chloride | 3,500-265,000 | 250,000 | EPA | Yes | 3/3 |

| | | | | | |
|---|---|---|---|---|---|
| | | | SMCL | | |
| cyclohexane | 68-140 | 1,000 | Action Level | No | 3/3 |
| diesel range organics | 638-62,100 | 200 | MN TPH Value | Yes | 3/3 |
| ethane | 299 | None | | | 1/3 |
| **Compound** | **Result Range ( Minimum to Maximum) (µg/L)** | Comparison Value (CV) (µg/L) | **Source** | **Exceed CV** | **Monitoring Wells with Contaminant** |
| fluoride | 200-1400 | 4000 | EPA MCL | No | 3/3 |
| gasoline range organics | 1,300-2720 | 200 | | Yes | 3/3 |
| iron | 1,220-10,800 | 300 | EPA SMCL | Yes | 3/3 |
| isopropyl benzene | 8.3-53 | None | | | 3/3 |
| magnesium | 24,700-91,800 | None | | | 3/3 |
| manganese | 379-3640 | 500 | Chronic RMEG child | Yes | 2/3 |
| methane | 361-708 | None | | | 3/3 |
| methyl cyclohexane | 56-140 | 1000 | Action Level | | 3/3 |
| potassium | 2,,930-4,150 | None | | | 3/3 |
| propane | 43.8 | None | | | 1/3 |
| sodium | 26,900-1,020,000 | 20000 | EPA SMCL | Yes | 3/3 |
| sulfate | 28,400-1,040,000 | 250,000 | EPA SMCL | Yes | 3/3 |
| TPH (extractable) | 810-42,000 | 200 | MN TPH Value | Yes | 3/3 |
| TPH (purgeable) | 1,700-3,790 | 200 | MN TPH Value | Yes | 3/3 |
| m, p xylene | 32-150 | none | | | 3/3 |

Levels of hydrocarbons were measured in groundwater. Methane, ethane, and propane were measured dissolved in groundwater. Table 2 list the range of the compounds detected.

**Table 2. Hydrocarbons Dissolved in Groundwater**

| Compound | Min-Max (µg/L) |
|---|---|
| methane | 361-708 |
| ethane | 299 |
| propane | 43.8 |

## Private Well sampling Results

EPA sampled 41 private wells (Table 3) (approximately 50-800 feet in depth) in the area of investigation. The private well sampling results for the FSI and ESI were screened against comparison values and background concentrations for the Wind River Formation. Petrochemicals, formerly identified TICs, methane and other hydrocarbons, sulfates, and sodium as found in the monitoring wells were detected in the private wells. Table 3 identifies the compounds which exceeded their respective comparison values, background concentrations, or compounds which have no health comparison values in private wells.

**Table 3**: **Contaminants Detected in Private Wells: FSI and ESI Sampling Which Exceed CVs or No CV is Available and/or Exceed Background Concentrations.**

| Compound | EPA MCLs µg/L | CV (µg/L)** | Wind River Formation, Fremont County, WY Groundwater[#] Background Concentrations (µg/L) | Pavillion Well Results Range (µg/L) | Number of wells with Detects | Exceed CV | Exceed BKG |
|---|---|---|---|---|---|---|---|
| 1,3 dimethyl adamantane | none | none | | 0.36-1.81 | 4 | | |
| 4-chloro-3-methylphenol | none | none | | 0.19 | 1 | | |
| 1,1,2-trichloro-1,2,2-trifluroethane | | 300,000 Chronic RMEG child | | 0.38 | 1 | no | |
| adamantane | none | none | | 0.21-0.3 | 3 | | |
| arsenic | | 3 Chronic EMEG child | | 0.22-34.0 | 28 | yes | |
| butanes | none | none | | 3.1-12.0 | 4 | | |
| calcium | none | none | 1,700-380,000 | 3,150-486,000 | 41 | | |
| copper | 1,300 TT | 100 Intermediate EMEG child | 2-3 | 2.6-201.0 | 32 | yes | yes |
| diethyl hexyl phalate | none | 60,000 Intermediate EMEG child | | 0.15-9.80 | 15 | yes | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | CREG-3 | | | | | |
| diesel range organics | none | 200 MN TPH Value/ EPA PPRTV | | 16.2-850.0 | 20 | yes | |
| ethane | none | none | | 1.4-52.0 | 4 | | |
| fluoride | 4,000 | 4,000 MCL** | <100-4,900 | 200.0-4,100.0 | 39 | yes | no |
| heptanes | none | none | | 0.5-2.8 | 4 | | |
| | | | | | | | |
| iron | 300 SMCL | 300 SMCL | <10-250 | 18.3-1,880.0 | 16 | yes | yes |
| lead | 15 | 15 MCL | <1 | 0.12-38.3 | 24 | yes | |

| **Compound** | **EPA MCLs µg/L** | **CV (µg/L)**** | **Wind River Formation, Fremont County, WY Groundwater[#] Background Concentrations (µg/L)** | **Pavillion Well Results Range (µg/L)** | **Number of wells with Detects** | **Exceed CV** | **Exceed BKG** |
|---|---|---|---|---|---|---|---|
| magnesium | none | none | 110-99,000 | 4,350-147,000 | 26 | | yes |
| methane (dissolved) | none | none | | 10.6-808.0 | 8 | | |
| nitrates | 10,000 | 2,000 Chronic RMEG Child | <50-100,000 | 500-43,600 | 15 | yes | no |
| pentanes | none | none | | 1.3-11.0 | 5 | | |
| potassium | | none | <100-16,000 | 417.0-8,990.0 | 10 | | |
| propane | none | none | | 5.8 | 1 | | |
| sodium | | 20,000 EPA HBV | 16,000-990,000 | 1,120-1,110,000 | 41 | yes | yes |
| sulfate | 250,000* | 250,000 EPA SMCL | 12,000-3,100,000 | 126,000-3,640,000 | 37 | yes | yes |
| thallium | 2 | 0.5 LTHA | | 0.008-0.76 | 11 | yes | yes |
| TPH (purgeable) | none | 200 MN TPH Value/ EPA PPRTV | | 36-1,300 | 4 | yes | |
| TPH (extractable as gasoline) | none | MN TPH Value/EPA PPRTV | | 22.6-26.3 | 3 | no | |
| vanadium | none | 30 Intermediate EMEG Child | | 0.049-42.2 | 24 | yes | |

# Data from USGS (United States Geological Survey) 1995. Water Resources of Fremont County, Wyoming. Water-Resources Investigations Report 95-4095. Data for Wind River Formation (various sampling events between 1987 and 1992).

** Considered concentrations against new proposed guidance.

Petrochemicals were detected in many wells. DRO was detected in 20 wells with a range of 16.2-850 µg/L . Only one value exceeded the CV of 200 µg/L, which was found in a formerly utilized drinking water well. Two other wells approached the CV of 200 µg/L, at levels of 105 and 154 µg/L. GRO was detected in two wells at the concentration of 22.6 and 31.1µg/L. TPH (extractable) was detected in 1 drinking water well at 1300 ug/L (formerly used drinking water well), which exceeded the CV of 200 µg/L.

The ESI laboratory analysis confirmed the presence of some of the same compounds referred to as TICs in the initial investigation. Of note, adamantanes and tri (2-butoxyethyl) phosphate (also called 2-butoxyethanol phosphate or 2BE-P) were detected. Adamantanes were detected in 3 wells with a concentration range of 0.21-3.86 µg/L. 1,3-dimethyl adamantane was detected in 4 wells at a concentration of 0.36-1.81 µg/L. No CVs were available for the adamantanes, so a surrogate was used to assess the potential health effects (See Public Health Implications Section).

There were eleven domestic wells with detections for 2BE-P. The concentration range in these wells are between 0.55 to 2.1 µg/L. 2BE-P is a common flame retardant and has been detected in surface water by the United States Geological Survey (USGS) in many locations. A nationwide USGS groundwater survey found only one well, out of over 200 wells tested, with a detectable amount of tri 2BE-P (9). The levels of 2BE-P found in the domestic wells did not exceed the CV of 2000 µg/L (ATSDR's intermediate EMEG) (10). Therefore, at this concentration, exposures from drinking the water are not likely to be associated with adverse health effects.

Several inorganics were detected in the wells and exceeded comparison values and background levels. Arsenic was found in one well at 34 µg/L which exceeded a CV (3 µg/L). On the second round of sampling a value of 0.46 µg/L was detected for the same well, which did not exceed the CV. Lead was detected in a formerly utilized water at 38.3 µg/ L, which exceeds the EPA MCL (15 µg/L). Lead concentrations in the remaining wells were below the EPA MCL. Calcium was detected in all wells in a range from 3,330-486,000 µg/L. There was no CV for calcium. Copper was detected in one well at a value of 201 µg/L which exceeded Intermediate EMEG value of 100 µg/L and background concentrations. Fluoride was detected in a range of 200-4,100 µg/L. The highest value exceeded the MCL of 4000 µg/L and the proposed revised value for fluoride in water of 1000 µg/L.

Iron levels ranged from 44.1 -1,880 µg/L and exceeded background concentrations. Some of the iron levels exceeded the EPA SMCL of 300 µg/L. Magnesium was detected in a range of 4,350- 147,000 µg/L and exceeded background concentrations. There was no CV for magnesium. Nitrate levels ranged from 500-43,500 µg/L in wells and exceeded EPA MCL of 10,000 µg/L. Potassium levels range from 2,610-11,400 µg/L. There was no CV for potassium.

Selenium was detected in levels ranging from 0.98-67.3 µg/L. The highest level exceeded the Chronic EMEG of 50 µg/L. Many of the sodium levels detected in the wells exceeded the EPA SMCL of 20,000 µg/L and background concentrations, with a range of 85,000-1,030,000 µg/L. Sulfate ranged from 126,000-3,200,000 µg/L in the wells. Some of the well values for sulfate exceeded the EPA SMCL of 250,000 µg/L and exceeded background concentrations. Thallium levels ranged from 0.23-0.76 µg/L. The highest level of thallium exceeded the LTHA of 0.5 µg/L. Vanadium levels ranged from 0.33-42.4 µg/L. Some of the vanadium levels, ranging from 0.049-42.2 µg/L exceeded the Intermediate EMEG of 30 µg/L.

Methane and ethane were detected in dissolved water. Methane was detected in 8 wells in a range of 10.6-808 µg/L. Ethane was detected in 4 wells at concentrations between 1.4-53.0 µg/L. In order to evaluate the potential for an explosive hazard, EPA measured methane, ethane, propanes, butanes, pentanes, hexanes, heptanes, and octanes (i.e. light gases) in the headspace of the sample jars with water collected from domestic wells. EPA detected methane (6300 parts per million (ppm) maximum value) in eight of the wells. Seven of the samples with methane detections were accompanied by additional light gases. Ethane was detected in a single well with no other detections of light gases. Table 3 presents the detections of light gases measured in the headspace of sample jars after collection.

**Table 4. Gas Hydrocarbon Levels in Water Headspace: Private Wells**

| **Compound** | **Min-Max (ppm)** |
|---|---|
| methane | 5.2-6300 |
| ethane | 1.4-52 |
| propanes | 5.8 |
| butanes | 3.1-12 |
| pentanes | 1.3-11 |
| hexanes | 0.75-4.7 |
| heptanes | ).47-2.8 |
| octanes | 1.9-4.1 |

While measurements of methane and other alkanes were below the lower explosive limit (LEL) for each compound, such a comparison in this case is not a reliable indication of the explosive hazard. Combustible gas measurements, such as LEL, are best taken beneath the well head without disturbing the well water. EPA's sampling methodology required purging the wells, which potentially removed a portion of gases prior to analysis. The properties of the gas mixture may also differ than a single gas constituent. Additional information is necessary to assess the risk of explosion in residential plumbing. The presence of these light gases in drinking water raises concerns that the water supply has been contaminated with petroleum products.

### Bacteriology of Well Water

Bacterial testing was conducted for 5 wells for heterotrophic plate count bacteria (HPC), iron reducing bacteria, and sulfate reducing bacteria (Table 5) (1). HPC is a nonspecific classification term for growth of viable, naturally occurring bacteria in water. HPC bacteria are often found in water supplies and measured as Most Probable Number (MPN) of bacterial colonies per milliliter. Plate counts revealed bacteria between 2 and 130 MPN/mL. There are no EPA regulations or recommendations for the counts of HPC in water. In most studies, there have been no correlations between disease and high counts of HPC bacteria in water in healthy individuals.

Iron bacteria combine dissolved iron or manganese with oxygen and use it to form rust colored deposits. Of the 5 wells tested, 2 contained iron-reducing bacteria. Iron bacteria in wells do not cause health problems, but may cause odors, corrode plumbing, reduce well yields by clogging screens, and increase sulfur bacterial infestations.

The presence of sulfur reducing bacteria indicates that there is a potential for generation of hydrogen sulfide, since these bacteria chemically change natural sulfates in water to hydrogen sulfide. Of the five wells tested, one well contained sulfate reducing bacteria. Hydrogen sulfide gas produces an offensive rotten egg odor which can affect the taste and odor of the water.

**Table 5. Microbacteriological Sample Results**

| Analyte | Unit | Min-Max detects | Number of wells/ number of wells with detects |
|---|---|---|---|
| Bacteria, HPC | MPN/ml | ND-130 | 3/6 |
| Bacteria, Iron Related | CFU/ml | ND-present | 3/6 |
| Bacteria, Sulfate Reducing | CFU/ml | ND-present | 1/6 |

**Municipal Water Results**

EPA sampled 2 of the 8 wells used to supply the Pavillion municipal water plant, located approximately five miles southwest of the study area. EPA's site assessment was a groundwater investigation. As such, the finished water from the plant was not sampled. The 2 public water supply wells were identified to best represent the depths of the domestic wells. These wells were sampled at the well head prior to any treatment to best represent the aquifer. The quality of the finished water may differ significantly, depending on the level of treatment at the plant and the mix from different wells. The groundwater met primary water treatment standards. Sulfate was detected at 300 and 847 ppm, values in excess of the secondary MCL. Diesel Range Organic (DRO) was detected in one well at 23.1 µg/L, a value less than the CV for DRO. Potential sources for this detection have not been examined.

**Indoor Air Quality Analysis: Showering**

Residents have expressed concerns about exposure to compounds when showering with their water. Volatile organic chemicals (VOCs) pose the greatest risk for exposure through inhalation. For VOCs, the rate of transfer from the aqueous phase to the gas phase increases with temperature and agitation.

Hence, showering presents an exposure scenario that requires evaluation. ATSDR used a model (11) to predict the maximum potential daily exposure concentrations of VOCs in bathroom air without ventilation, assuming an individual is exposed to the air for 30 minutes during a daily shower. The following formula was used to calculate the air concentration in bathroom air:

$$C_{air} = \frac{C_w \text{ x } f \text{ x } F_w \text{ x } t}{V_a}$$

$C_{air}$ bathroom air concentration (mg/m$^3$)

$C_w$ tap water concentration (mg/L): maximum detected concentration

f fractional volatilization rate (unitless): default value of 0.9

$F_w$ shower water flow rate in liters per minute (L/min): default value of 8 L/min

t exposure time in minutes (min): assumed 10 shower duration

$V_a$ bathroom volume in cubic meters (m$^3$): default value of 10 m$^3$

To estimate the time-weighted daily exposure concentration, the estimated air concentration was multiplied by the fraction of the day spent exposed to that concentration (30 minutes per day; 0.5 hr / 24 hr = 0.02). The time-weighted concentrations and the corresponding chronic comparison values are shown in Table 6.

The following compounds were modeled with the maximum values from the Pavillion data set: 1,1,2-trichloro-1,2,2-trifluorethane (also called CFC 113), benzene, chloroform, chloromethane, methylene chloride, styrene, and toluene. Although 1,3-dimethyladamantane was detected in residential wells, it will have an insignificant presence in the vapor phase due to its low volatility and insolubility in water. Therefore, the adamantane compounds were not evaluated in the showering scenario.

**Table 6. Evaluation of Inhalation of Volatile Organic Compound Concentrations in the Showering Scenario**

| Compound | Concentration in Domestic Wells (µg/L) | Maximum modeled time-weighted exposure concentration in air from showering (µg/m$^3$) | Comparison Value (µg/m$^3$) | Basis |
|---|---|---|---|---|
| 1,1,2-trichloro-1,2,2-trifluoethane | 0.38 | 0.06 | 31,000 | EPA-RSL |
| benzene | 0.54 | 0.08 | 10 | ATSDR Chronic Inhalation MRL |

| | | | | |
|---|---|---|---|---|
| chloroform | 0.24 | 0.04 | 100 | ATSDR Chronic Inhalation MRL |
| chloromethane | 0.27 | 0.04 | 100 | ATSDR Chronic Inhalation MRL |
| methylene chloride | 0.33 | 0.05 | 1,000 | ATSDR Chronic Inhalation MRL |
| styrene | 0.14 | 0.02 | 900 | ATSDR Chronic Inhalation MRL |
| toluene | 0.51 | 0.08 | 300 | ATSDR Chronic Inhalation MRL |

The modeled concentrations of these compounds did not exceed comparison values for chronic inhalation exposure (Table 6).

In addition to exposure to chemicals through inhalation during showering, there is also the potential for exposure from the absorption through the skin. The EPA Dermal Guidance document provides a screening criterion to select chemicals where dermal absorption during showering could make a significant contribution to exposure compared to the ingestion of drinking water. None of the organic or inorganic compounds listed in Table 1 as being present above their comparison value or without comparison values indicate physical-chemical properties that indicate that dermal absorption would make a significant contribution to the overall exposure dose (12).

Volatilization of methane, ethane, propane, butane, pentanes, and hexane in a confined space such as unvented bathroom could result in an explosive hazard. While measurements of methane and other alkanes were below the lower explosive limit (LEL) for each compound (based on measures taken in the headspace of the sample jars), such a comparison is not a reliable indication of the explosive hazard. Combustible gas measurements, such as the LEL, are best taken in the confined space. There is a possibility that these compounds could accumulate in a confined space and pose an explosive hazard. To ensure safety, residents should ventilate their bathroom during showering.

### Odor Concerns

Some residents have raised concerns about the odor of water in their domestic wells. Given the presence of petroleum hydrocarbons, sulfate, and bacteria indicated in the EPA sampling, odor issues are plausible. EPA has established odor as a secondary MCL. The Threshold Odor Number (TON) is a test for odors. The secondary MCL is a 3 TON. While the Safe Water Drinking ACT MCLs are directly applicable to municipal water supplies, they nevertheless provide a basis of comparison for domestic wells. The TON has not been measured in the Pavillion domestic wells.

### Public Health Implications of Exposure to Contaminants of Concern in Private Wells

Environmental contamination cannot affect a person's health unless there is a completed exposure pathway. A completed exposure pathway exists when all of the following five elements are present 1) a source of contamination 2) transport through an environmental medium 3) a point of exposure 4) a route of human exposure and 5) an exposed population. Pavillion residents are exposed to contaminants through ingestion of drinking water and inhalation of volatile compounds while showering. Based on the available data, inhalation exposures to the volatile compounds detected in the well water did not exceed health comparison values for showering exposures. However, there is concern that methane and other hydrocarbons could build in a confined space, such as a shower, and create an explosive hazard. The issues related to explosive hazards while showering were addressed in the previous section. Information will be provided in this section to address exposure to contaminants from drinking the well water.

A number of substances were found in the Pavillion drinking water wells at levels that exceeded comparison values for ingestion. These were labeled “chemicals of concern” (COC) and were investigated further. In addition, certain substances that were found did not have comparison values. These were also labeled COCs and were investigated further. In cases where there no CV was found for a COC, attempts were made to consider alternate sources of information that could provide some toxicological prospective for the COC.

For some of the naturally occurring substances (for example sulfate and calcium), information regarding the substance as a nutrient was employed to evaluate possible harmful effects associated with the substances. These evaluations typically considered the substance found in drinking water as nutrients, and focused the assessments around estimated dietary intakes. These assessments specifically utilized “adequate intake” levels (AI) and the tolerable upper intake levels (UL), that have been described by the National Academies (13). To add additional perspective for our assessment of these substances, previously reported data describing well water samples from the area, taken from a report by the USGS, (14) are also mentioned.

For other substances such as 4-chloro-3-methylphenol, “surrogate” compounds were used to aid in the toxicity assessments. When surrogates were used, a deliberate attempt was made to choose a surrogate that was considered to be, at a minimum, similar in toxicity or likely more toxic than the COC under consideration.

For exposure estimates, a daily intake of 2 liters of water/day and a 70 kg body weight was used for adults. For a child, daily intake was assumed to be 1 liter of water/day and 10 kg body weight was used. The discussion of potential health effects are presented below.

**Adamantanes (Adamantane and 1,3-dimethyl adamantane)**

Adamantanes have been recognized as a petroleum component since the early 1930s. Adamantane was detected in 3 wells and 1,3-dimethyl adamantane was detected in 4 wells. Adamantanes are considered to be relatively stable cyclic hydrocarbons, however specific toxicity information on adamantanes was not found. Because of the lack of chemical-specific health based screening information, the evaluation described here considers adamantane, and the 2- and 1,3- methylated adamantanes as generic “adamantanes”, and uses an adamantane derivative that is used as a pharmaceutical for a surrogate in the toxicity evaluation.

1-aminoadamantane, a derivative of adamantane, has been used as a pharmaceutical to treat flu for more than 20 years. More recently, it has been used to reduce symptoms related to Parkinson’s disease. In these pharmaceutical applications, the daily dose is typically 100 – 200 mg/day, with lower doses used in patients with a history of seizures or psychiatric symptoms. Side effects associated with use of 1-aminoadamantane include nervousness, anxiety and insomnia (15).

When considering a typically used dose, the daily intake for an adult is 200 mg. If used at a 10 fold lower dose, the daily intake is 20 mg/day. The daily intake, based on the highest level of adamantane in the Pavillion area well water is approximately 0.004 mg/day for adults and approximately 0.002 mg/day for small children. There is at least a 2000 fold difference in the level of adamantanes found in the Pavilion-area wells versus the lower pharmacologic dose of the surrogate adamantane (1-aminoadamantane) used for this evaluation. Based on the difference in the levels found in the well water versus the daily intakes used for therapeutic purposes, health effects associated with drinking the "adamantanes" in the Pavillion area are not likely to be associated with adverse health effects.

**Arsenic**

Arsenic can be found as a naturally occurring substance in water. In the Wind River formation, arsenic levels in well water have been reported as < 1-2 µg/L (14). One drinking water well currently in use contained 34 µg/L arsenic (FSI sampling). This value exceeded the Chronic EMEG for the child and adult, 3 ppb and 10 ppb respectively, the CREG of 0.02 ppb, and the EPA MCL of 10 ppb (16). In the subsequent ESI sampling, the same well measured 0.46 µg/L, a value which exceeded the CREG of 0.02 ppb. A drinking water concentration of 34µg/L would result in an exposure dose for an adult of 0.000971 mg/kg/day and for a child that exposure dose is 0.0034 mg/kg/day.

The non-cancer no-observed–adverse-effect-level (NOAEL) for chronic oral exposures for inorganic arsenic is approximately 0.0005 mg/kg/day based on gastrointestinal irritation (17). At the higher arsenic water concentration, the estimated exposures exceed the NOAEL and could be associated with gastrointestional irritation. The initial effects associated with cancer are observed at arsenic doses of approximately 0.02 to 0.05 mg/kg/day (17). The estimated exposure doses of arsenic are below these values for both well samples, therefore the arsenic in the drinking water wells is not likely to result in adverse health effects associated with cancer. The variability in the arsenic levels found in the two samples indicates that the arsenic levels in this well should be re-evaluated following additional testing.

**Calcium**

Calcium is a natural constituent in water and has been found in the Wind River formation at levels of 3 -150 mg/L (14). Calcium is a required nutrient with an AI of 1,000 mg/day for adults and 1,200 mg/day for those over 50 years of age. The UL for children from 1-13 years of age, as well as for adults is, 1,250 mg/day (13).

Calcium was detected in 41 wells. The highest level of calcium found in a Pavillion-area well was 486,000 µg/L. The estimated exposure intake for an adult drinking the area well water, at a concentration of 486,000 µg/L, is 972 mg/day. For a small child the estimated exposure intake is 486 mg/day. The estimated daily intake for both adults and small children is below the UL for calcium. Therefore, ingesting the calcium in the Pavillion-area well water is not likely to result in adverse health effects.

It is worth noting that elevated calcium intakes, such as involved with therapy use to treat osteoporosis, can result in a total calcium intake of 2400 mg/day (13). Some researchers suggest that daily intakes of 5 mg/day are commonly provided in dietary supplements and that a level of approximately 5 mg/day represents a LOAEL for total calcium intake. Pavillion area residents drinking well water containing elevated levels of calcium, and also taking calcium supplements, should discuss their calcium intakes with their physicians.

**4-chloro-3-methylphenol**

4-chloro-3-methylphenol was historically used as a biocide and germicide. 4- chloro-3-methylphenol was detected in 3 wells. Given the absence of a Chronic MRL for 4-chloro-3-methylphenol, for this evaluation, the intermediate oral MRL for 2,4-chlorophenol of 0.003 mg/kg/day is used as a surrogate for evaluating the toxicity of 4-chloro-3-methylphenol (18).

The highest level of 4-chloro-3-methylphenol in Pavillion area well water was 0.19 µg/L. Given this concentration in drinking water, the estimated exposure dose for adults is 0.0000054 mg/kg/day; and for a small child is 0.000019 mg/kg/day. The difference between the MRL for the surrogate and the highest estimated exposure dose is a factor of at least 100. This factor of 100 between the exposure dose and the dose described by the reference value indicates that the concentration of 4-chloro-3-methylphenol in drinking water is not likely to be associated with adverse health effects.

**Copper**

Copper can be found naturally occurring in water. Copper concentrations in the area are described as 2-3 µg/L (19). A median copper concentration of of 8.3 µg/L has been reported in treated water from public supply systems (14). However, waters impacted by acid mine drainage can have levels that exceed 100 µg/L (19). Copper was detected in 32 wells.

Copper is a required nutrient and recommended copper intake is 900 µg/day for both men and women. The tolerable upper intake level (UL) is 10 mg/day (20). Only one drinking water well contained copper at levels that exceeded the drinking water CV of 100 µg/L (EMEG). That well contained copper levels of 201 µg/L. The daily intake for adults consuming drinking water with copper at 201 µg/L is 402 µg/day. The daily intake for small children consuming drinking water with copper at 201 µg/L is 201 µg/day. Both of these intake rates are well below the UL of 10 mg/day and are not likely to be associated with adverse health effects.

**Di(2-ethylhexyl)phthalate (DEHP)**

Di (2-ethylhexyl) phthalate are plasticizers used to make PVC pipes more flexible.
DEHP was detected in 15 wells. The highest level of DEHP was found in a Pavillion area water well at 9.8 µg/L. This level did not exceed the chronic health comparison values for non cancer health effects. The value did, however, exceed the drinking water CV of 3µg/L (ATSDR Cancer Risk Evaluation Guide (CREG)). A drinking water concentration of 9.8 µg/L would result in an

exposure dose for an adult of 0.00028 mg/kg/day, and for a child that exposure dose is 0.00098 mg/kg/day. The cancer risk associated with drinking the water containing DEHP at 9.8 µg/L – based on a 70 year lifetime exposure – was calculated to be 3.9 x 10-6. It is unlikely that excess cancers would be expected from this exposure.

**Fluoride**

Fluoride in natural waters is typically present at less than 1 mg/L, however concentrations of up to 50 mg/L have been reported (19). Fluoride was detected in 39 wells. Fluoride has been added as an agent to prevent tooth decay to the drinking water provided by numerous public supply systems. Recently, the level of fluoride added to publically supplied water has come under scrutiny due to research findings of an association of high levels of fluoride with increased risks of skeletal fluorosis and associated bone fractures. The current MCL for fluoride in drinking water is 4 mg/L. However, some scientists argue that this level should be lowered to 1 mg/L (21). For the evaluation presented in this report, a conservative reference value of 1 mg/L is used to assess the level of fluoride in the Pavillion area well water.

The highest level of fluoride in the Pavillion area wells was 4.1 mg/L. This level of fluoride in drinking water exceeds the conservative reference value of 1 mg/L. While there is considerable uncertainty regarding the possibility of adverse health effects from drinking water containing such a concentration of fluoride, it is noted that some scientists contend that drinking water containing fluoride at more than 1 mg/L has been associated with an increased risks for bone fractures.

**Iron**

Iron is a required nutrient, and levels in well water are typically in the range of 10-250 ug/L (14). The recommended AIs are: 8 mg/day for men and post-menopausal women, 18 mg/day for pre-menopausal women, 10 mg/day for adolescents, and 27 mg/day for pregnant women. The UL is 45 mg/day. (20)

Iron was detected in 16 wells. The highest level was 1880 µg/L, which exceeded the CV of 1000 µg/L (MVC). Drinking water from the well with the highest level of iron would add approximately 4 mg of iron to an adult's diet and add approximately 2 mg of iron to a child's diet. These increased intakes of iron are not likely to result in adverse health effects in healthy residents. It should be noted that a disease called hemochromatosis is associated with iron overload in a small percentage of persons. If there are any Pavillion area residents on reduced-iron diets to treat this condition, these individuals should consult their health professionals.

**Lead**

Natural surface waters typically contain between about 1 and 10 µg/L lead (19), and lead levels in the water from the Wind River formation are typically less than 1 µg/L (14). Concentrations in the Western U.S. are more commonly below 1 µg/L lead. Lead was detected in 24 wells. One former drinking water well contained lead at 38.3 µg/L which exceeded the EPA MCL of 15 µg/L. Consumption of water from this well could have elevated the blood lead levels of residents consuming the water. Lead exposure is a particular concern if young children are exposed. Young children are particularly vulnerable to the effects of lead since it may affect the developing nervous system. High levels of lead exposure in adults can cause weakness in fingers, wrists, or ankles, small decreases in blood pressure, and anemia.

**Magnesium**

Magnesium in the ground water of the Wind River formation is typically between 110 and 99,000 ug/L (14). Magnesium is an essential nutrient with a Recommended Daily Allowance (RDA) for young children of 80 mg/day; for adult males of 420 mg/day; and for adult female of 320 mg/day. The UL for magnesium, as a supplement in addition to magnesium in food, is 350 mg/day for adults and 65 mg/day for young children (13).

Magnesium was detected in 26 wells. The highest level of magnesium in the Pavillion-area wells was 147,000 µg/L. At this concentration the estimated daily intake for adults is approximately 300 mg of additional magnesium per day. The estimated daily intake of magnesium due to drinking the Pavillion area water is below the daily intake of magnesium associated with gastrointestinal discomfort in adults, therefore the magnesium in the drinking water wells is not likely to result in adverse health effects in adults. However, some children who consume a liter of water containing 147 mg/L will exceed the UL of 65 mg/day and may experience gastrointestinal discomfort.

**Methane and Other Volatile Alkanes**

Methane is a naturally occurring, flammable gas that forms explosive mixtures with air. Methane is odorless and tasteless. EPA detected methane (6,300 ppm maximum value) and other volatile alkanes (ethane 52 ppm, propane 5.8 ppm, and butane 12 ppm maximum value) in the headspace of jars containing water samples**.** Methane and other volatile alkanes were detected in the head space of jars collected from 9 wells. EPA's sampling methodology required purging the wells, which potentially removed a portion of the gases prior to analysis. The lower explosive limit (LEL) is 5% and the upper explosive limit (UEL) is 15%. Methane levels below 5% by volume in air and above 15% by volume in air are not explosive. While measurements of methane and other alkanes were below the lower explosive limit (LEL) for each compound, the sampling methodology in this case does not permit an evaluation of the explosive hazard inherent with such gas-phase hydrocarbon present in the water. Additionally, the properties of the gas mixture may be different than a single gas constituent.

Methane is a simple asphyxiant (at around 87% by volume). Asphyxiants displace oxygen from air primarily in enclosed spaces. This can result in insufficient oxygen in the blood. Methane exposure can also produce symptoms of central nervous depression including nausea, headache, dizziness, confusion, fatique, and weakness. It is unlikely these effects would be seen in Pavillion based on the current measures, as methane has practically no clinical effects at concentrations less than the Upper Explosive Limit.

**Nitrate**

Nitrate levels in water are influenced by human activities. Drainage from barnyards and septic systems can greatly influence nitrate levels in nearby waters. Most residents in rural Wyoming are on septic tanks (7). Nitrate was detected in 19 wells. Nitrate is commonly found in the water from the Wind River formation at concentrations of <50 to 100,000 µg/L (14).

Levels of nitrate at approximately 50 mg/L have been associated with a condition known as methaemoglobinemia, a decreased ability to carry oxygen in the blood. Nitrates in water are of particular significance for infants, because they may be exclusively fed with formula that is reconstituted with water from a single source.

The highest level of nitrate in the Pavillion area wells was 43.5 mg/L. This level of nitrate is essentially equal to the NOAEL derived by the EPA (22). The EPA has established an MCL for nitrate of 10 mg/L. The level of nitrate found in the Pavillion area is at the NOAEL, and therefore health effects associated with drinking that water are not expected. However, because the nitrate level in the well is approaching an effect level, limiting consumption of that water to minimize exposures to nitrate would be a prudent public health practice. This advice is particularly warranted when considering the feeding of infants with formula reconstituted with water containing elevated levels of nitrate.

**Potassium**

Potassium is an essential nutrient and adults in the U.S. typically consume 2.8 – 3.3 g of potassium/day. The AI for adults is 4.7 g/day. There is no UL for potassium because there is no evidence that food can supply an excessive level of potassium. Initial gastrointestinal discomfort with potassium supplements is seen with intake rates of 1.6 to 2.3 g/day. One study added 5.6 g/day to diets of adults without altering normal-range producing plasma sodium concentrations (23). Potassium is generally found in Pavillion area groundwater at concentration of 100 to 16,000 ug/L (14), and was detected in 10 of the wells sampled in this investigation.

The highest level of potassium in the Pavillion wells in these investigations was 8,990 µg/L. At this concentration, the estimated daily intake for adults is approximately 18 mg. This level of supplemental potassium obtained in the Pavilion area drinking water is well below the typical daily intake for adults in the U.S., and is not likely to be associated with adverse health effects.

**Sodium**

The water from the Wind River formation is considered to be a sodium sulfate dominant water type and sodium concentrations range from 4.5 to 1,500 mg/L. (14). Sodium levels in surface and ground waters can also be affected by human activities. These activities include salting of highways, reusing irrigation water, pumping ground water, and the "…disposal of brine pumped or flowing from oil wells…" (14). The extent to which any of these activities may affect the groundwater quality in the area of the Pavillion site is unknown. Sodium was detected in all wells.

Sodium is an essential nutrient. It is needed for proper muscle and nerve function, and it is involved in the control of blood pressure. It is estimated that approximately 75% of adults in the U.S. exceed the recommended daily sodium intake (23). Excessive sodium intake is associated with high blood pressure. The UL for sodium in adults is 2.3 g/day.

Sodium was detected in 41 wells. Most of the sodium levels found in the drinking water wells of this study are at approximately 100-200 mg sodium/L with only a few wells approaching, or at approximately 1,000 mg/L. If Pavillion area adults have a daily intake of water with a sodium concentration of approximately 100 to 1,000 mg/L, those residents would consume approximately 200 to 2000 mg of sodium in addition to the sodium contained in food. If residents use water softeners, the sodium level consumed by drinking water could be even higher. Thus, the drinking well water with elevated sodium levels will increase sodium intake in the users. Pavillion area residents who may be on a sodium-restricted diet should consult their health professionals and discuss the effect that the increased sodium intake may have on their health.

**Sulfate**

Sulfate is found in natural water. Sulfate in water is detectable by smell and taste at concentrations of about 250 mg/L (23). Most public water supplies (approximately 95%) provide water with sulfate concentrations below 500 mg/L (23). Sulfate was detected in 37 wells in the Pavillion area. Previous work has found area groundwater concentrations of sulfate range from 175,000 to 3,640,000 µg/L (14).

Sulfate is a dietary requirement, but this requirement is met with an adequate intake of amino acids in the form of protein. The average adult in the U.S. has a dietary intake of sulfate of 4.4 g/day (23). There is no UL for sulfate.

The MCL for sulfate that has been established by Health Canada is 500 mg/L. The WHO has established an MCL of 400 mg/L. The EPA SMCL for sulfate is 250,000 µg/L. The EPA has recommended (but not finalized) an MCL for sulfate of 500 mg/L. This value is recommended with the intention of preventing acute onset diarrhea. One study found a “laxative effect” with drinking water that contained 1 g sulfate/L, while a second, using drinking water containing 1.2 g/L, found no “laxative effect”( 23).

The highest level of sulfate found in a Pavillion area well was 3,640,000 µg/L. Drinking this water would result in an estimated daily intake for an adult of 7.3 g/day. The estimated daily intake for a small child would be 3.6 g/day. Both of these daily intake rates would exceed established MCL guidance for sulfate consumption. These intake rates also exceed the intake rate associated with the gastrointestinal discomfort (intake rate of 2 g/day). Given these comparisons versus the available reference values, some persons drinking water containing 3-7 g/L of sulfate could experience adverse health effects related to gastrointestinal discomfort.

**Thallium**

Thallium is a metal found in natural deposits as ores containing other elements. Thallium was detected in 11 wells. One well contained 0.76 µg/L of thallium which exceeded the CV of 0.5 µg/L. A drinking water concentration of 0.76 µg/L would result in an exposure dose for an adult of 0.0000217 mg/kg/day and for a child that exposure dose is 0.000076 mg/kg/day. ATSDR’s Toxicological Profile for thallium indicates that the NOAEL for various endpoints for oral intermediate doses in test animals is ~0.1 mg/kg/day (24). Exposure dose estimates are well below a thallium dose (in animals) that is associated with adverse health effects, and is unlikely to produce health effects in humans.

**Total Petroleum Hydrocarbons (TPH, DRO, GRO)**

Petroleum constituents are not common contaminants in groundwater used as a drinking water supply (9). Twenty wells in the Pavillion area contained petroleum products (either TPH, DRO, or GRO). One formerly utilized drinking water well had petroleum products at concentrations (850 µg/L DRO and 1300 µg/L TPH) greater than the health comparison value (200 µg/L) used to assess the contamination of area wells.

Because monitoring each of the several hundred hydrocarbon chemicals in petroleum is particularly difficult, a more efficient means of monitoring petroleum in the environment has been developed. This method measures the total of the petroleum products. The method quantifies what is described as "total petroleum hydrocarbons" (TPH). It provides a general measure of the petroleum hydrocarbon content of an environmental media. Specifically, TPH measures the concentration of an aggregate of chemicals that constitute the range of petroleum hydrocarbons. Fractional ranges of TPH can be reported as gasoline range organics (GRO) (i.e., $C_6$ to $C_{10-12}$) and diesel range organics (DRO) (i.e., $C_{8-12}$ to $C_{24-26}$). Under EPA analytical method 8015 Modified, GRO and DRO most closely align with purgeable and extractable hydrocarbons, respectively.

The state of Wyoming has established cleanup levels for TPH GRO and TPH DRO based on protection of groundwater for non-cancer effects. The clean up levels are: 1,100 µg/L TPH DRO and 7,300 µg/L GRO. The Wyoming TPH clean-up levels are based on an RfD of 0.2 mg/kg/day for GRO $C_5$- $C_8$ petroleum hydrocarbons and an RfD of 0.03 mg/kg/day for DRO $C_9$-$C_{34}$ petroleum hydrocarbons. The state may require additional sampling requirements and clean up levels based on site-specific conditions.

The State of Minnesota, following the rationale first developed by the State of Massachusetts, uses pyrene as a surrogate to assess the toxicity of TPH and has developed a health based value of 200 µg/L for TPH. Similarly, the state of Kansas Bureau of Environmental Remediation has established 0.500 mg/L for GRO and DRO clean up levels, based on n-hexane and pyrene as surrogates.

No federally established regulatory limits (e.g. MCLs) or comparison values (CVs) for TPH exist. However, in 2002, EPA recommended "provisional peer reviewed toxicity" values for total petroleum hydrocarbons for aliphatic and aromatic fractions of specific carbon lengths ( 25). For the aromatic medium weight fraction of equivalent carbons (EC) of EC>9-EC16, the recommendation was to use the lowest IRIS RfD in this group, 0.02 mg/kg-day for naphthalene to represent this group. For a 10 kg child consuming 1 liter of water per day, this RfD corresponds to 200 µg/L. Because a full characterization of the individual constituents of TPH at the site is not available, the value of 200 µg/L was selected by ATSDR for the comparison value for assessment of TPH. The selection of this value is supported by that the following rationale: this fraction includes overlap with both GRO and DRO fractions, the surrogate has both cancer and non-cancer health endpoints of toxicity, and the evidence that drinking the Pavillion area well water would result in exposures to total petroleum hydrocarbons. The lack of a characterization of the specific petroleum constituents in the Pavillion area wells is a major data gap. This data gap severely limits our ability to ascertain non-cancer or cancer risks posed by petroleum hydrocarbons. Constituent analysis is needed to aid the assessment of health risks associated with the Pavillion area well water.

### Vanadium

Vanadium is a widely distributed naturally occurring element that is found in more than 50 different minerals and in association with fossil fuels (27). While areas impacted by acid water may have vanadium concentrations of a few hundred µg/L, most surface waters contain less than 10 µg/L. Vanadium in US public water supplies can contain vanadium as high as 70µg/L, however median levels are reported as < 4.3 µg/L (19).

Vanadium was found in most of the Pavillion area wells with the highest level at 42.2 µg/L. Drinking water with vanadium at this level would result in an estimated exposure dose for adults of 0.00121 mg/kg/day; and for a small child the estimated exposure dose is 0.00422 mg/kd/day. The intermediate oral MRL for vanadium is 0.01 mg/kg/day (26). The exposure dose estimates are below the MRL for vanadium, therefore consumption of the vanadium in the Pavilion area well water is not likely to be associated with adverse health effects.

### Overall Water Quality in Pavillion

Drinking water is a solution containing water with small concentrations of other compounds. Pure water is tasteless and odorless. Impurities in drinking water provide the taste and odor. All drinking water contains impurities. Under the Safe Water Drinking Act, the EPA regulates the maximum contaminant level, or MCL, for public water supplies for about 90 specific contaminants. The levels are set based on concerns for either an acute effect (such as bacteria count) or for concerns based on a lifetime of exposure. Exceeding the MCL for a constituent does not necessarily mean there will be a health effect. EPA also has secondary drinking water guidelines regarding cosmetic and esthetic effects, including taste, odor, and color.

In this health consultation, ATSDR evaluated the potential public health risks from the constituents identified in the domestic drinking water wells in Pavillion. ATSDR reviewed the sampling data for each compound, whether or not the compound was regulated by the EPA, and compared the data to health-based comparison values or available toxicological data. ATSDR identified several individual constituents (in Public Health Implications Section) present at concentrations that can cause more immediate health effects, especially to sensitive populations such as children and individuals with some health conditions. All but one well had at least one contaminant of concern and most wells had two or three contaminants of concern which could result in a health effect from ingesting the well water (Table 7).

**Table 7. Number of Contaminants of Concern Per Well**

| Contaminants of Concern | Number of Wells | Contaminants of Concern |
|---|---|---|
| Zero | 1/41 | |

| | | |
|---|---|---|
| One | 4/41 | *One of the following:* Sodium, Fluoride |
| Two | 17/41 | Sodium, Sulfate |
| Three | 16/41 | *Three of the following:* Sodium, Sulfate, Magnesium, Fluoride, Iron |
| Four | 2/41 | *Four of the following:* Sodium, Sulfate, Nitrate, Magnesium, Fluoride, Selenium |
| Five | 1/41 | Sodium, Sulfate, TPH, DRO, Lead |

There were twenty private wells that contained petroleum products. Between five and eleven wells contained other man-made organic compounds that were either present below health based screening levels, or where there were no screening levels were available. In either situation, the presence of these compounds in drinking water is not desirable, and concern for continued exposure from drinking water contaminated with these constituents remains high. Sodium, in many of the drinking water wells, is of concern for individuals that must control their salt intake. Sulfate was present in concentrations that could alter the taste and odor of the water. Combustible gases were found dissolved in water. It is not known if these levels indicate an explosive hazard based on the current measures.

For the reasons cited above, taken as a whole, ATSDR considers the drinking water quality of many of the private domestic wells tested in the Pavillion area to be not acceptable. The prudent public health practice for individual private well owners would be to use an alternative water supply or to use treatment technology demonstrated to be effective in reducing or eliminating constituents of concern.

## Conclusions

### Conclusions Related to General Site Conditions

- Agricultural operations and oil and gas production facilities are predominant land uses in the Pavillion area.
- Agricultural operations, primarily irrigation, may have increased the salt content of the water. No pesticides were detected above comparison values in the monitoring wells or private wells.
- There are an estimated 211 active gas wells, 30 plugged and abandoned wells, 20 wells identified as “shut in” and 37 former pits associated with the natural gas exploration. Petrochemical products were identified in the private wells.
- The hydrology of the site has not been adequately characterized. The relationships between groundwater contamination and the private wells and how the well water could be impacted in the future are not well understood.
- The data utilized in this evaluation represents “a snap shot” in time of the current contaminants found in the drinking water wells. It is not possible to determine if these data are suggestive of past or future contaminant levels in well water.

- Even though some of the analytical data were qualified or flagged, EPA carefully examined the data and determined it to be valid.
- Odor concerns expressed by citizens have not been addressed.

**Conclusions Related to Well Water Contaminants Based on Current Sampling**

Analysis of current well data indicates that exposure to some of the contaminants found in the well water could result in health effects. Specifically, ATSDR concluded that:

- Groundwater monitoring wells and a formerly utilized drinking water well are contaminated with petroleum hydrocarbons (Total Petroleum Hydrocarbons-TPH) at levels which exceed comparison values.
- Nineteen residential wells used for drinking water contained TPH (TPH, DRO, or GRO) below the MN TPH Values or EPA PPRTV.
- TPH at a level below the MN TPH or EPA PPRTV has been detected in a well which supplied “raw” water to the Pavillion municipal water plant.
- The available data describing the TPH components in the Pavillion area well water are not adequate to assess the potential health effects that could be associated with exposures to the individual components.
- Methane and other light gases associated with petroleum contaminants were detected in well water and monitoring wells. Actual levels of the gases may be higher than reported, given the loss of these compounds during purging. The potential for an explosive hazard associated with these gases has not been well characterized.
- In the formerly utilized drinking water well, lead levels exceeded the EPA MCL. Consumption of the well water could have resulted in increases in blood lead levels for residents consuming the water.
- Magnesium levels in some of the wells could result in gastrointestinal upset for children consuming the water.
- Sodium in many of the drinking wells is at levels that may be of concern for individuals that must control their salt intake.
- Iron levels in some of the wells could be associated with gastrointestinal stress for persons who are currently taking iron supplements.
- Consumption of arsenic detected in a well during one sampling round could lead to gastrointestinal irritation. The arsenic level in the same well, when sampled at a later date, was below a level of concern.
- Nitrates exist at levels in some wells where prudent public health practice would suggest limiting usage as a drinking water source for infants and children.
- Sulfate occurs at levels that could generate objectionable odors and gastrointestinal stress
- Hetertrophic, iron-reducing, and sulfur reducing bacteria were detected in some wells. Levels of HPC bacteria are not known to be associated with illness in humans. The presence of iron and sulfur bacteria may be associated with odor and foul taste of the water.
- Based on available data, inhalation of VOCs from showering does not appear to pose a health hazard.

- There is a lack of toxicological information on several compounds identified in drinking water, specifically adamantane and 1,3-dimethyl adamantane.
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## RECOMMENDATIONS

Given the limited understanding of the interconnection of private wells with highly contaminated groundwater, the limited monitoring data on the private drinking water wells, the presence of petrochemical constituents and TICs in the well water, the potential for explosive hazards, and the elevated salt levels in the well water, ATSDR recommends:

- Pavillion residents should use alternate or treated water supplies (that have been demonstrated to be clean post-treatment) as their source of drinking water.
- Until long term solutions are found for mitigating water quality issues, a monitoring program for the domestic wells should be established.
- All private wells in the area should be identified and sampled.
- Sampling of the finished water at the Pavillion municipal wells should be conducted.
- The groundwater and connectivity to private wells needs to be better characterized.
- The constituents of the TPH should be characterized to improve ATSDR's ability to assess health risks from consumption of the water.
- A direct measurement of gas phase hydrocarbon accumulation in drinking water wells should be conducted to assess the risk of an explosive hazard.
- Until the potential explosive hazard is characterized, residents should ventilate their bathrooms when they shower.
- A Threshold Odor Number (TON) test should be conducted to provide an objective benchmark for evaluation of resident concerns about odor.
- Toxicity data should be developed for TICs including adamantane and 1,3-dimethyl adamantane.

## BEST PUBLIC HEALTH PRACTICES

ATSDR has identified the following best public health practice for residents:

- Residents who are currently drinking bottled water should continue to do so, until alternative water supplies are provided.
- Filtration systems have the potential to significantly reduce compounds of concerns in well water. Whole-house systems are preferred to point of use systems. Testing of the treated water should be conducted to verify the absence of contamination.
- While bathing or showering, ventilate the bathroom. Ventilation can be achieved with ventilation fans, opening a door during colder months, and opening a window during warmer months.
- Residents should vent wells at the well head to prevent the accumulation of methane in plumbing which would reduce the risks of an explosive hazard.
- Sources of ignition in any enclosed areas should be avoided.

- Installation of combustible gas meters should be considered.
- Combustible gas monitoring should be discussed with the local fire department.

**Public Health Action Plan**

ATSDR will continue to support the Pavillion community, by:

**1)** Working with the Pavillion community, the local water district, and local and state health offices to provide health information about groundwater and private well water quality, as needed.

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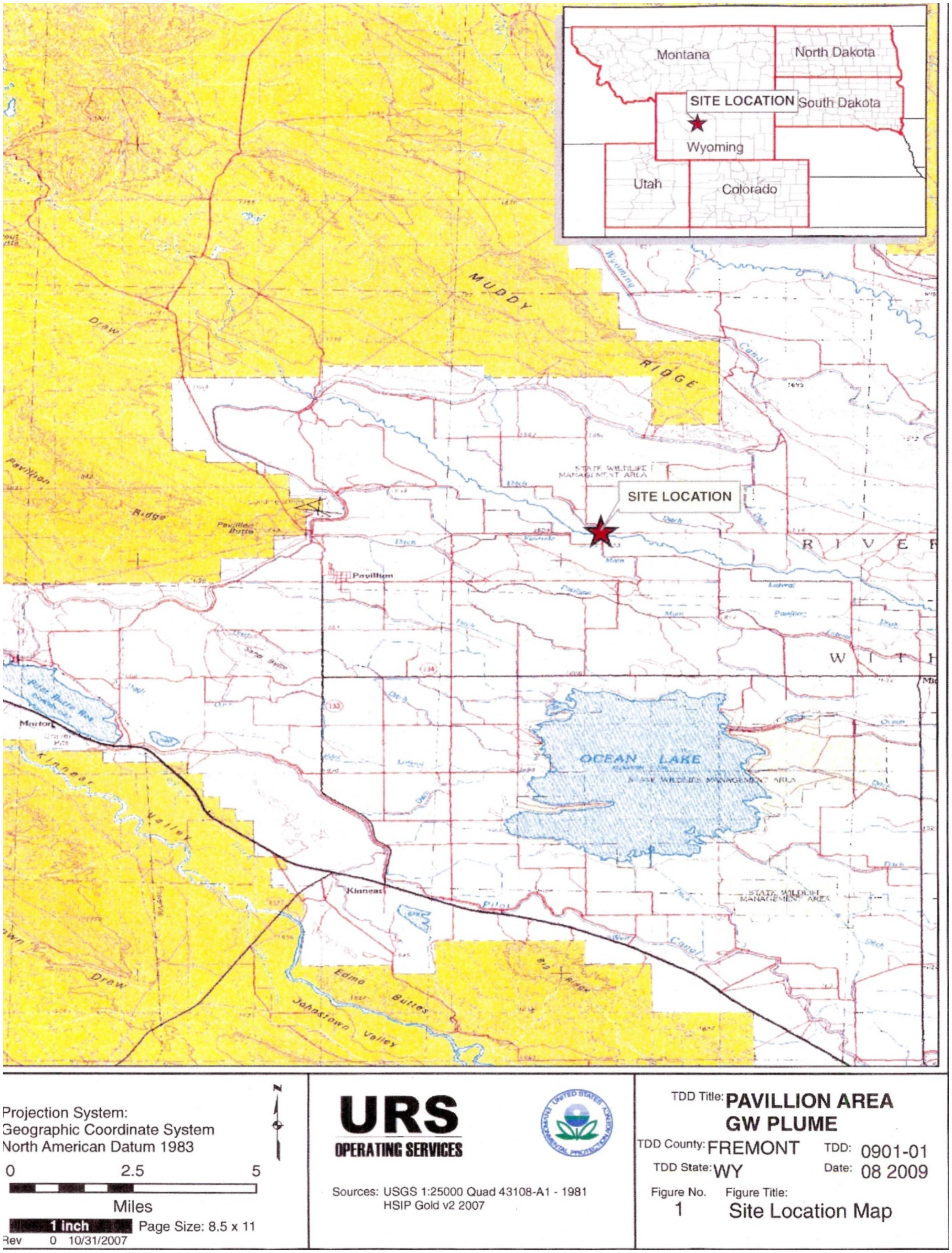
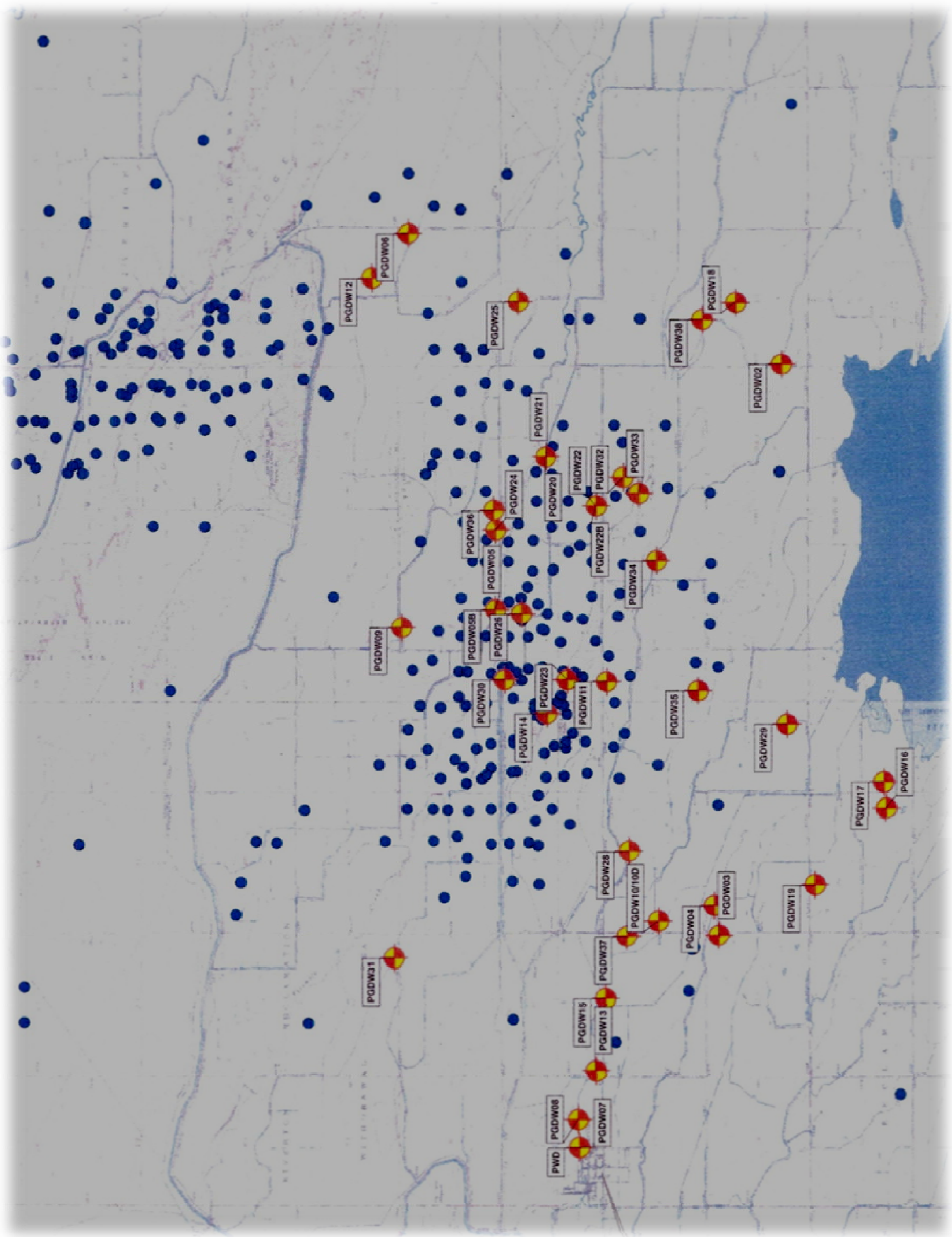
## APPENDIX A: AREA MAP



## APPENDIX B: MAP OF EPA ESI SAMPLE LOCATIONS



## APPENDIX C: GLOSSARY

**Adequate Intake (AI) –** The recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate—used when an RDA cannot be determined.

**Cancer Risk Guide- CREG-** CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million persons exposed during a lifetime (70 years). CREGs are calculated on EPA's cancer slope factors for oral exposures or for unit risk on inhalation exposures.

**Colony Forming Units**- CFUs-Unit of measurement for viable bacteria numbers.

**Comparison values-CVs-** Environmental contaminant concentrations utilized to screen environmental data.

**Environmental Media Evaluation Guideline-EMEG-** EMEGs are estimated contaminant concentrations that are not expected to result on adverse health effects based on ATSDR evaluation. EMEGs are based on ATSDR's Minimal Risk Levels ( MRLs) and conservative assumptions about exposure, such as intake rate, exposure frequency, duration and body weight.

**EPA Health Based Value-EPA HBV- -** The concentration of a groundwater contaminant that can be consumed daily with little or no risk to health. HBVs have not been promulgated as rules and have not undergone peer review.

**EPA Provisional Peer Reviewed Toxicity Value-PPRTV-** A toxicity value derived for use in Superfund Program when such a value is not available in EPA's Integrated Risk Information System (IRIS).

**EPA Secondary Maximum Contaminant Level- SMCL**- A non- enforceable guideline regulating contaminants that may cause cosmetic effects or aesthetic effects (taste, color, odor).

**Expanded Site Investigation (ESI)–** A site investigation that occurs if the Focused Site Investigation indicates that a threat exists but is not immediate.

**Focused Site Investigation (FSI) –** A site investigation conducted by EPA.

**Lifetime Health Advisory –LTHA-** The concentration of a chemical in drinking water, that is not expected to cause any adverse non-carcinogenic effects for a life time of exposure and is based on a 70 kilogram adult consuming one liter of water per day.

**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.

**Lower Explosive Limit (LEL) –** The concentration above which an explosion of a combustible gas can take place.

**Maximum Contaminant Level- EPA's MCL** is the highest level of a contaminant that is allowed in drinking water.

**Maximum Contaminant Level Goal- EPA's MCLG** is the level of a contaminant in drinking water below which there is no expected risk to health.

**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.

**Microgram per cubic meter (µg/m3) –** A measure of the concentration of a chemical in a known volume (a cubic meter) of air.

**Milliliter (mL) –** One thousandth of a liter.

**Minnesota Total Petroleum Hydrocarbon Value (MN TPH) –** The Total Petroleum Hydrocarbon value derived by the state of Minnesota, above which health effects may occur.

**Microgram per cubic meter- µg/m3**

**Micrograms per liter- µg/L** or parts per billion.

**Minnesota Total Petroleum Hydrocarbon Value (MN TPH)-** Minnesota health screening value for TPH in water -200 µg/L.

**Recommened Daily Allowance ( RDA)–** The average daily dietary nutrient intake level sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life stage and gender group.

**Reference Media Evaluation Guide-RMEG-** ATSDR derives RMEGs from EPA's oral reference doses. RMEG represent the concentration of a contaminant in water or soil at which daily health exposures is unlikely to result in adverse noncancer health effects.

**Tolerable Upper Intake Level (UL)–** The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects may increase.

**Treatment Technique-TT-** A required process intended to reduce the level of a contaminant.

**Upper Explosive Limit (UEL)–** The concentration below which an explosion of a combustible gas can take place.

## APPENDIX D. Compounds Detected in Shallow Groundwater Monitoring Wells

| Compound | Result Range (Minimum to Maximum) (µg/L) | Comparison Value (CV) (µg/L) | Source | Exceed CV | Monitoring Wells with Contaminant |
|---|---|---|---|---|---|
| 1,1 biphenyl | 0.76-1 | none | | | 3/3 |
| 1,2,4 trimethyl benzene | 14.1 | none | | | 1/3 |
| 1,3,5 trimethyl benzene | 2.6-19.7 | none | | | 3/3 |
| 1,3 dimethyl admantane | 0.29-0.64 | none | | | 3/3 |
| 2,4 dimethyl phenol | 1.6-39 | 200 | Chronic RMEG child | no | 3/3 |
| 4 methyl phenol | 0.39-24 | none | | | 3/3 |
| 3,4 methyl phenol | 12.8 | none | | | 1/3 |
| 2-methylnaphthalene | 2.4-74 | 400 | Chronic EMEG child | no | 3/3 |
| adamantine | 1.78-3.86 | none | | | 3/3 |
| alkalinity | 438,000-2,750,000 | 30,000-400,000 | | yes | 3/3 |
| aluminum | 565 | 10,000 | Chronic EMEG child | no | 1/3 |
| antimony | 0.34-0.43 | 4 | Chronic RMEG child | no | 2/3 |
| arsenic | 3.6-41.8 | 3 | Chronic EMEG child | yes | 3/3 |
| barium | 139-707 | 2000 | Chronic EMEG child | no | 3/3 |
| benzene | 5.3-390 | 5 | Chronic EMEG child | yes | 3/3 |
| tert butyl benzene | 1.6-9.68 | none | | | 3/3 |
| calcium | 150,000-337,000 | none | | | 2/3 |
| carbon disulfide | 1.6-8.2 | 1000 | Chronic RMEG child | no | 3/3 |
| chloride | 3,500-265,000 | 250,000 | EPA SMCL | yes | 3/3 |
| cobalt | 0.64-1.9 | 100 | Intermediate EMEG child | no | 2/3 |
| copper | 2-5.3 | 100 | Intermediate EMEG child | no | 1/3 |
| cyclohexane | 68-140 | 1000 | Action Level | no | 3/3 |
| dieldrin | 0.002 | 0.5 | Chronic EMEG child | no | 1/3 |
| diesel range organics | 638-62,100 | 200 | mn TPH value | yes | 3/3 |
| ethane | 299 | none | | | 1/3 |
| ethyl benzene | 15-93 | 5000 | Intermediate EMEG child | no | 3/3 |
| fluoride | 200-1400 | 4000 | EPA MCL | no | 3/3 |
| gasoline range organics | 1,300-2720 | 200 | | yes | 3/3 |
| iron | 1,220-10,800 | 300 | EPA SMCL | yes | 3/3 |
| isopropyl benzene | 8.3-53 | none | | | 3/3 |
| lead | 0.22-0.58 | 15 | | no | 2/3 |
| magnesium | 24,700-91,800 | none | | | 3/3 |
| manganese | 379-3640 | 500 | Chronic RMEG child | yes | 2/3 |
| methane | 361-708 | none | | | 3/3 |

| Compound | Result Range (Minimum to Maximum) (μg/L) | Comparison Value (CV) (μg/L) | Source | Exceed CV | Monitoring Wells with Contaminant |
|---|---|---|---|---|---|
| methyl cyclohexane | 56-140 | 1000 | Action Level | no | 3/3 |
| naphthalene | 2.2-179 | 6000 | Intermediate child EMEG | no | 3/3 |
| naphthalene | 2.2-179 | 6000 | Intermediate child EMEG | no | 3/3 |
| nickel | 1.9-2.4 | 200 | Chronic RMEG child | no | 3/3 |
| phenol | 2.3-41 | 3000 | Chronic RMEG child | no | 3/3 |
| potassium | 2,,930-4,150 | none | | | 3/3 |
| propane | 43.8 | none | | | 1/3 |
| selenium | 1.8 | 50 | Chronic EMEG child | no | 1/3 |
| sodium | 26,900-1,020,000 | 20000 | EPA SMCL | yes | 3/3 |
| sulfate | 28,400-1,040,000 | 250,000 | EPA SMCL | yes | 3/3 |
| toluene | 0.16-0.61 | 200 | Intermediate EMEG child | no | 2/3 |
| TPH (extractable) | 810-42,000 | 200 | MN TPH Value/EPA PPRTV | yes | 3/3 |
| TPH (purgeable) | 1,700-3,790 | 200 | MN TPH Value/ EPA PPRTV | yes | 3/3 |
| m, p xylene | 32-150 | none | | | 3/3 |
| o-xylene | 0.62-2.2 | 1000 | Action Level | no | 3/3 |
| vanadium | 8.7 | 100 | Intermediate EMEG child | no | 1/3 |
| zinc | 1.4-2.3 | 3000 | Chronic EMEG child | no | 3/3 |

**Appendix E**. Contaminants Detected in Private Wells: ESI Sampling and Background Inorganic Concentrations in Wind River Formation, Fremont County, Wyoming Groundwater (USGS 1995).

| Compound | EPA MCL/SMCL* (µg/L) | CV (µg/L)** | Wind River Formation, Fremont County, WY Groundwater# (µg/L) | Wells Result Range (µg/L) Phase 1 | No. of Detects in wells Phase 1 (35 wells) | Exceed CV Phase 1 | Exceed BKG |
|---|---|---|---|---|---|---|---|
| aluminum | 50-200* SMCL | 10,000 Chronic EMEG child | <10-10 | 27.6-890 | 16 | no | yes |
| arsenic | | 3 Chronic EMEG child | | 0.22-34 | 20 | yes | |
| barium | 2,000 | 2,000 Chronic EMEG child | 8-16 | 4.6-48.5 | 27 | no | yes |
| beryllium | 4 | 20 Chronic EMEG child | | 0.072-0.47 | 2 | no | |
| cadmium | 5 | 2 Chronic EMEG child | 40-380 | 0.26-0.9 | 6 | no | no |
| calcium | none | none | 1,700-380,000 | 3,600-416,000 | 30 | | yes |
| caprolactam | none | 5,000 RMEG child | | 0.22-1.4 | 2 | no | |
| chloride | 250,000 SMCL* | 250,000 EPA SMCL | 3,000-150,000 | 3,700-34,300 | 31 | no | no |
| chromium (total) | 100 | 100 EPA MCLl | <1 | 0.43-1.8 | 4 | no | yes |
| cobalt | none | 100 Intermediate EMEG child | | 0.024-4.2 | 15 | no | |
| copper | 1,300 tt* | 100 Intermediate EMEG child | 2-3 | 3.9-139 | 32 | no | yes |
| cyanide | | 200 Intermediate EMEG Child | | 1.2-3.1 | 7 | no | no |
| di (2-ethylhexyl) phthalate | 6 | 600 Chronic EMEG | | 0.59-6.4 | 5 | no | |
| diesel range organics | none | 200 MNTPH Value/EPA PPRTV | | 16.2-105.0 | 10 | no | |
| diethyl hexyl phthalate | none | 60,000 Intermediate EMEG | | 0.59-9.80 | 15 | no | |
| fluoride | 4,000 | 4,000 EPA MCL | <100-4,900 | 200-4100 | 33 | yes | no |

| **Compound** | **EPA MCL/SMCL* (µg/L)** | **CV (µg/L)**** | **Wind River Formation, Fremont County, WY Groundwater# (µg/L)** | **Wells Result Range (µg/L) Phase 1** | **No. of Detects in wells Phase 1 (35 wells)** | **Exceed CV Phase 1** | **Exceed BKG** |
|---|---|---|---|---|---|---|---|
| iron | 300 SMCL | 300 EPA SMCL | <10-250 | 18.3-1100 | 9 | yes | yes |
| lead | 15 | 15 EPA MCL | <1 | 0.12-4.2 | 19/36 | no | yes |
| magnesium | none | none | 110-99,000 | 5,320-147,000 | 18 | | yes |
| manganese | 50* | 500 Chronic RMEG child | <1-120 | 0.38-302 | 27 | no | yes |
| mercury | | 20 Intermediate EMEG Child | | 0.091-1.8 | 2 | no | |
| methane (dissolved) | none | none | | 10.6-588 | 8 | | |
| nickel | none | 200 Chronic RMEG child | | 0.87-7.3 | 14 | no | |
| nitrate + nitrite | 10,000 | 2,000 Chronic RMEG child | <50-100,000 | 500-43,600 | 15 | no | |
| pentachlorophenol | 1 | 10 Chronic EMEG child | | 0.905 | 1 | | |
| potassium | | none | <100-16,000 | 417-8,990 | 7 | | no |
| selenium | 50 | 50 Chronic EMEG child | <1-58 | 3-38 | 13 | | no |
| sodium | | 20,000 EPA HBV | 16,000-990,000 | 1,120-938,000 | 36 | yes | yes |
| sulfate | 250,000 SMCL | 250,000 EPA SMCL | 12,000-3,100,000 | 187,000-2,720,000 | 36 | yes | yes |
| thallium | 2 | 0.5 LTHA | | 0.008-0.12 | 9 | no | |
| TPH (extractable) | none | 200 MN TPH Value/ EPA PPRTV | | 25-26 | 2 | no | |
| vanadium | none | 30 Intermediate EMEG child | | 0.049-42.2 | 23 | | |
| zinc | 5,000 SMCL | 3000 Chronic EMEG child | <3-20 | 5.1-102 | 18 | no | |

# Data from USGS (United States Geological Survey) 1995. Water Resources of Fremont County, Wyoming. Water-Resources Investigations Report 95-4095. Data for Wind River Formation (various sampling events between 1987 and 1992).

**Appendix F**. Contaminants Detected in Private Wells: FSI Sampling and Background Inorganic Concentrations in Wind River Formation, Fremont County, Wyoming Groundwater (USGS 1995).

| Compound | EPA MCL/S MCL (µg/L) | CV (µg/L)** | Wind River Formation Fremont County, WY Ground-water# (µg/L) | Wells Result Range (µg/L) Phase2 | No. of Detects in Wells Phase 2 (17 wells) | Exceed CV Phase 2 | Exceed BKG |
|---|---|---|---|---|---|---|---|
| 1,3 dimethyl adamantane | none | none | | 0.36-1.81 | 4 | | |
| 2,4,5 trichlorophenol | none | 1,000 RMEG child | | 0.19 | 1 | no | |
| 1,1,2-trichloro-1,2,2-trifluroethane | none | 300,000 Chronic RMEG child | | 0.38 | | | |
| 2,6-dinitrotoluene | none | 40 Intermediate EMEG child | | 0.12 | 1 | no | |
| 2-butoxyethanol phosphate | none | | | 0.55-2.10 | 9 | | |
| 4-chloro-3-methylphenol | none | none | | 0.19 | 1 | | |
| adamantane | none | none | | 0.21-0.3 | 3 | | |
| aluminum | 50-200 SMCL | 10,000 Chronic EMEG child | <10-10 | 741 | 1 | | yes |
| antimony | 6 | 4 Chronic RMEG child | | 0.33-2.1 | 4 | no | |
| arsenic | | 3 Chronic EMEG child | | 0.32-0.894 | 13 | no | |
| barium | 2,000 | 2,000 Chronic EMEG child | 8-16 | 6.0-75.1 | 17 | no | yes |
| benzene | | 0.6 CREG | | 0.54J | | no | |
| butanes | none | none | | 3.1-12.0 | 4 | | |
| butyl benzyl phthalate | none | 2,000 RMEG child | | 0.14-0.23 | 6 | no | |
| calcium | none | none | 1,700-380,000 | 3,150-486,000 | 17 | | yes |
| caprolactam | none | 5,000 RMEG child | | 0.22-0.98 | 8 | no | |

| Compound | EPA MCL/S MCL | CV (µg/L)** | Wind River Formation | Wells Result Range | No. of Detects in | Exceed CV Phase 2 | Exceed BKG |
|---|---|---|---|---|---|---|---|

| | (µg/L) | | Fremont County, WY Ground-water# (µg/L) | (µg/L) Phase2 | Wells Phase 2 (17 wells) | | |
|---|---|---|---|---|---|---|---|
| chloride | 250,00 SMCL | 250,000 EPA SMCL | 3,000-150,000 | 7,500-74,000 | 17 | no | no |
| chloroform | | 100 Chronic EMEGChild | | 0.245 | 1 | | |
| chloromethane | none | 30 EPA LTHA | | 0.27 | 1 | no | |
| chromium (total) | 100 | 100 EPA MCL | <1 | 0.45-1.7 | 2 | no | yes |
| cobalt | none | 100 Intermediate EMEG child | | 0.33-0.57 | 4 | no | |
| copper | 1,300 tt* | 100 Intermediate EMEG child | 2-3 | 2.6-201.0 | 17 | yes | yes |
| cyanide | | 200 ppb Intermediate EMEG Child | | 1.2-3.1 | 7/36 | no | |
| di (2-ethylhexyl) phthalate | 6 | 600 Chronic EMEG child | | 0.59-3.1 | 11 | no | |
| diesel range organics | none | 200 MN TPH Value/EPA PP | | 21.6-850 | 12 | | |
| diethyl hexyl phthalate | none | 60,000 Intermediate EMEG child | | 0.15-0.36 | 4 | no | |
| di-n-butyl phthalate | none | 1000 RMEG child | | 0.12-0.18 | 9 | no | |
| di-n-octyl nophthalate | none | 4,000 Intermediate EMEG child | | 0.14-6 | 5 | no | |
| endosulfan | none | 20 Chronic EMEG | | 0.0015 | 1 | no | |
| ethane | none | none | | 1.4-52.0 | 4 | | |
| fluoride | 4,000 | 4,000 EPA MCL | <100-4,900 | 300-2,400 | 15 | no | no |
| gamma-chlorodane | | 6 Chronic EMEG child | | 0.0016 | 1 | no | |
| heptanes | none | none | | 0.5-2.8 | 4 | | |
| hexane | | | | 0.75-4.7 | 4 | | |
| iron | 300 SMCL | 300 EPA SMCL | <10-250 | 44.1-1880 | 10 | yes | yes |
| lead | 15 | 15 EPA MCL | <1 | 0.21-38.2 | 5 | yes | yes |

| Compound | EPA MCL/SMCL (µg/L) | CV (µg/L)** | Wind River Formation Fremont County, WY Ground-water# (µg/L) | Wells Result Range (µg/L) Phase2 | No. of Detects in Wells Phase 2 (17 wells) | Exceed CV Phase 2 | Exceed BKG |
|---|---|---|---|---|---|---|---|
| magnesium | none | none | 110-99,000 | 4,350-147,000 | 8 | | yes |
| manganese | 50 SMCL | 500 Chronic RMEG child | <1-120 | 1.6-222.0 | 17 | no | yes |
| methane (dissolved) | none | none | | 5.44-808.0 | 7 | | |
| napthalene | | 6000 Intermediate EMEG child | | 0.3J** | 1 | no | |
| nickel | none | 200 Chronic RMEG child | | 0.21-1.9 | 17 | no | |
| nitrate + nitrite | 10,000 | 2,000 Chronic RMEG child | <50-100,000 | | | | |
| octanes | none | none | | 1.9-4.1 | 4 | | |
| pentanes | none | none | | 1.3-11.0 | 5 | | |
| phenol | | 3000 Chronic RMEG child | | 0.17 | 1 | | |
| potassium | | none | <100-16,000 | 1810.0-5830.0 | 4 | | no |
| selenium | 50 | 50 Chronic EMEG child | <1-58 | 0.98-3.9 | 7 | no | no |
| silver | | 50 Chronic RMEG child | | 0.3 | 1 | | |
| sodium | | 20,000 EPA HBV | 16,000-990,000 | 91,100-1,110,000 | 17 | yes | yes |
| styrene | 100 | 2000 RMEG child | | 0.14j | 1 | no | |
| sulfate | 250,000 SMCL | 250,000 EPA SMCL | 12,000-3,100,000 | 126,000-3,640,000 | 17 | yes | yes |
| thallium | 2 | 0.5 LTHA | | 0.23-0.76 | 2 | yes | |
| TPH (extractable) | none | 200 MN TPH Value/ EPA PPRTV | | 22.6-31.1 | 3 | no | |
| TPH (purgeable) | none | 200 MN TPH Value/ EPA PPRTV | | 36.0-1300.0 | 3 | yes | |
| zinc | 5,000 SMCL | 3000 Chronic | <3-20 | 1.1-32.7 | 16 | no | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | EMEG Child | | | | | |

# Data from USGS (United States Geological Survey) 1995. Water Resources of Fremont County, Wyoming. Water-Resources Investigations Report 95-4095. Data for Wind River Formation (various sampling events between 1987 and 1992).

*TT-Treatment Technique- A required process intended to reduce the level of contaminant.

**J –The identification of the analyte is acceptable, but quality assurance criteria indicate that the quantitative values may be outside the normal expected range of precision, i.e, the quantitative value is considered estimated.