Health Consultation

ARSENIC EXPOSURE IN CULINARY DRINKING WATER

MILLARD COUNTY, UTAH

Prepared by the
Utah Department of Health

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Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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Environmental Epidemiology Program
With assistance from the Utah Public Health Laboratory,
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TABLE OF CONTENTS

SUMMARY 2
PURPOSE 2
BACKGROUND 2
METHODS 4
UPHL samples 4
DISCUSSION 6
Source of Exposure 6
Exposure Pathway Evaluation 7
Exposure Quantification 7
Exposure Analysis 8
Non-Cancer Health Effects 8
CHILD HEALTH CONSIDERATIONS 17
Acute Duration Health Effects 17
CONCLUSIONS 18
RECOMMENDATIONS 18
PUBLIC HEALTH ACTION PLAN 20
REFERENCES 22
AUTHOR 25
CERTIFICATION 26
APPENDICES 27

SUMMARY

The Utah Department of Health (UDOH), Environmental Epidemiology Program (EEP) collaborated with the Utah Public Health Laboratories (UPHL) to quantify health effects to residents of Millard County from drinking arsenic contaminated water supplied from private wells. Results confirmed that many of the private wells in the Delta Conservation Districts (Tiers V and VI) had arsenic concentrations high enough to be considered an urgent public health hazard. Water supplied from these wells should not be used as potable water until mitigation or reduction strategies have been installed to ensure the water is safe for culinary purposes.

Private wells identified in Tiers II, III and IV, although not an urgent public health threat, still contain arsenic above screening values and recommended health guidelines, especially for children; therefore, it is recommended that these homes reduce the levels of arsenic in their wells. One recommendation is to install a treatment system on all household fixtures used most frequently to supply water for both cooking and drinking purposes. Reverse osmosis systems have been shown to provide a cost effective way to reduce arsenic exposure in drinking water.

Due to the high levels of arsenic found in this report, EEP will work with the Utah Department of Environmental Quality (UDEQ) and Utah Department of Agriculture and Food (UDAF) to ensure all efforts are being taken to reduce exposure to affected communities in Millard County. In addition, EEP will provide this health consultation to affected residents, as well as pertinent and targeted health education aimed at reducing or eliminating exposure. EEP will also perform a follow-up cancer study to examine the long-term effects of chronic arsenic exposure in this community

PURPOSE

The Utah Public Health Laboratories (UPHL), UDOH, as part of the Rocky Mountain Biomonitoring Consortium (RMBC), collected samples of drinking water from private wells and community water systems in the Delta area of Millard County, Utah, in 2007 and 2008. Urine samples were also collected from adult residents of homes where water samples were collected. The UDAF Ground Water Program (GWP), in cooperation with the Utah Conservation Districts (CDs), has collected private well samples statewide since 1996. Community members and local officials requested information regarding the arsenic levels detected in their well water and urine samples. The UDOH EEP has a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) to address environmental health issues related to exposure from hazardous waste sites and other facilities in Utah. The objective of this public health consultation is to evaluate the UPHL and GWP sample data to determine the potential for adverse health effects from exposure to arsenic in drinking water sources in Millard County.

BACKGROUND

Millard County, Utah, is a predominately rural community in west central Utah. Delta, in the northeast area of the county, is approximately 135 miles southwest of Salt Lake City. A map of Millard County can be found in Appendix D of this report. Millard County is located in Congressional District 03. According to the US Census Bureau, Millard County has a total area of 6,828 square miles; 6,589 square miles is land and 239 square miles (3.5%) is water. The population of Millard County is approximately 12,405, with a population density of 1.817 per square mile (Census 2000). Most Millard County towns and cities are in the eastern third of the county. The two largest cities are Delta (population 3,209) and Fillmore (population 2,253).

There are two Conservation Districts (CDs) in Millard County - "Delta" and "Millard." The Delta CD covers an area approximately 1,440 square miles, and the Millard CD covers the remaining 5,388 square miles. (See map of Millard County CDs in Appendix D.) The Delta CD includes Delta, Hinckley, Abraham, Deseret, Oasis, Sutherland, Woodrow, and Sugarville. The Millard CD region covers the remainder of the county. The ZIP codes areas of the Delta CD, 84624 and 84635, also cover several small towns in the Millard CD (Oak City, Leamington, and Lynndyl). The population of the Delta CD is approximately 5,609 (Census 2000), with 1,971 single family housing units and a housing density of 1.37 units per square mile. The population of the Millard CD region is approximately 6,796, with 2,551 single family housing units and housing density of approximately 0.47 units per square mile.

There are 15 community water systems (CWSs) in Millard County that provide drinking water primarily to residents who live within municipal boundaries. Five CWSs in the Delta area supply water to 4,734 residents, and 10 CWSs in the Millard CD supply water to 5,020 residents. The remaining 2,650 residents (21.4%) of Millard County rely on private wells for drinking water. National drinking water standards do not apply to private wells, and no water monitoring or treatment is required for arsenic for private wells.

Arsenic levels have historically been elevated in Millard County, particularly in private wells and in CWSs in the Delta region. In Millard County, weathering of volcanic rocks is the major sources of arsenic in groundwater (Lewis 1998, Welch 1988). Studies by the U.S. Environmental Protection Agency ([EPA] Southwick 1982, Lewis 1999) and the U.S. Geologic Survey (USGS 2007) have found high arsenic concentrations in the drinking water of the Delta region of Millard County. The historic Maximum Contaminant Level (MCL) for arsenic in drinking water supplied by CWSs was lowered from 50 µg/L to 10 µg/L effective January 2006. The five CWSs in the Delta area were granted exemptions for meeting the revised MCL to allow additional time to develop engineering remedies to reduce arsenic levels. By 2009, remedies approved by the Utah Department of Environmental Quality (UDEQ), including new tanks, new wells, and/or point-of-use (POU) treatment systems, were in place in 4 of the 5 Delta area CWS. The fifth CWS, which serves a population of 160, was granted a 2-year extension in 2009 to meet the arsenic standards.

Table 1. Millard County Demographics (Source: 2000 Census).

Characteristic	Millard County	% Millard	% U.S.
Total Population	12405		
Male	6351	51.2	49.1
Female	6054	48.8	50.9
Age			
< 5 years old	1003	8.1	6.8
>18	7779	62.7	74.3
>65	1529	12.3	12.4
Race			
White	11653	93.9	75.1
Black	13	0.1	12.3
American Indian	163	1.3	0.9
Asian	59	0.5	3.6
Hispanic (of any race)	891	7.2	12.5
Owner-Occupied Housing	3062	79.7	66.2
Disability Status	1879	16.7	19.3

The RMBC was formed through a grant award by the Centers for Disease Control and Prevention (CDC) in 2002 to integrate biomonitoring programs in Utah, Montana, Wyoming, Colorado, Arizona, and New Mexico. One of the RMBC projects was a study on whether a difference in urine arsenic levels and arsenic speciation ratios could be detected in individuals exposed to various levels of arsenic in drinking water (CDC, http://www.cdc.gov/biomonitoring/state_grants.htm). The UPHL, with the assistance of the Central Utah Health District, collected samples of drinking water and urine from individuals in the Delta area of Millard County due to the area's historically elevated arsenic in drinking water (Lamm et al. 2004; Lewis et al. 1999; Lewis et al. 1998; Southwick et al. 1981). Due to the high levels of arsenic found in many of the samples, the UPHL shared the laboratory analyses with EEP staff for use to assess the risk to health in a health consultation document. This health consultation, a collaboration between UPHL and EEP, allows the distribution of health education in the community to warn of the risks associated with chronic exposure to arsenic through drinking water sources.

From 1996 to 2008, the GWP, in cooperation with the 38 Utah CDs, collected an annual average of 349 water samples statewide from private well owners who volunteered for the testing. The number of samples varies each year by region. The GWP provides the testing results to each well owner. Specific well locations and names of property owners are kept confidential, however sample results and general information on well locations for 1999-2008 are available on-line in annual GWP reports (http://ag.utah.gov/divisions/conservation/groundwater.html). The private

wells sampled by the GWP include those used for culinary purposes (primary drinking water source), as well as those used for livestock and irrigation. Test results are reported by well usage, as MCLs vary by well function. The GWP data included in this analysis is sample data from 2007 and 2008 for private wells used for culinary purposes[1]. Although samples exist for this area from 1999-2008, only 2007-2008 sample data is reported in this report due to the robust sample sizes collected and analyzed in these years compared to previous years. The concentrations of arsenic in samples were consistent across time periods.

METHODS

The method employed for selecting a chemical for further toxicological evaluation is that if a chemical is detected in excess of ATSDR chronic exposure comparison values (CVs) for children. The CVs for children were used because they represent the most protective value and were the values used in a similar PHC using Arizona data collected under the Rocky Mountain Biomonitoring Consortium (ADHS 2007). Concentrations of chemicals less than the corresponding CVs are unlikely to cause adverse health effects.

UPHL samples
During 2007-2008, 21 adult (≥18 years old) Delta area residents answered a questionnaire, submitted urine samples, and had their drinking water (private well and community water system) tested. (See Appendices A-C.) Samples from 11 private wells and 10 homes served by a CWS were tested for 14 different chemicals. Metals selected for detection were: arsenic (As), antimony (Sb), barium (Ba), beryllium (Be), cadmium (Cd), cesium (Cs), cobalt (Co), lead (Pb), manganese (Mn), molybdenum (Mo), platinum (Pt), selenium (Se), thallium (Tl), tungsten (W), and uranium (U). The UPHL, located in Salt Lake City, Utah, analyzed the samples using Inductive Coupling Plasma and Mass Spectrometry (ICP-MS) and following the validated EPA Method 200.8 and CDC analytical protocols for heavy metal analysis. Arsenic in drinking water ranged from below detection (< 1.65 µg/L) to 495.5 µg/L. Because this area of Utah has historically been exposed to high arsenic concentrations through groundwater, the biomonitoring project provided a means for collaboration to assess arsenic exposure and provide health education activities to mitigate risk in the community.

Total arsenic in urine ranged from 5.12 to 337.7 µg/L. Delta residents in the UPHL/RMBC study were asked to refrain from eating seafood for three days prior to the testing, as arsenic levels in urine can be elevated from organic forms of arsenic in seafood which are generally considered to be much less toxic than inorganic forms and metabolites of arsenic that predominate in drinking water. Urine samples with arsenic levels higher than 50 µg/L had additional testing to determine the proportions of arsenic in the samples that were organic and inorganic. The 95th percentile of total arsenic in urine of subjects tested in 2003-2004 as part of the National Health and Nutrition Examination Survey (NHANES) was 65.4 µg/L.

GWP samples
During 2007, the GWP collected 457 samples statewide, 1 in the Delta region and 33 in the Millard region. During 2008, the GWP collected 322 samples statewide, 25 in the Delta region

[1] The conclusions and recommendations expressed in this health consultation are those of the UDOH and ATSDR and do not necessary reflect those of the UDAF.

and 55 in the Millard region. In the Delta region, 25 of the 26 samples were culinary (1 in 2007 and 24 in 2008), and in the Millard region, 40 of the 88 samples were culinary (7 in 2007 and 33 in 2008). GWP tests of culinary wells included nine of the 15 metals tested for the UPHL/RMBC study: As, Ba, Be, Cd, Co, Mn, Mo, Pb, and Se. Metals in the GWP water samples were analyzed by ICP-MS at the UDAF laboratory. The UDAF also tested culinary wells for aluminum, chromium, chlorine, copper, fluorine, iron, mercury, silicon, silver, sodium, nickel, nitrate, perchlorate, sulfate, zinc, total dissolved solids (TDS), *E Coli*, Coliform, pH, and hardness. These sample results can be found on the GWP website: http://ag.utah.gov/divisions/conservation/groundwater.html.

It should be noted that only one sample was collected at each residence. Because of potential seasonal variation in arsenic levels, ATSDR recommends that private well samples be collected at different times of the year for more accurate assessment of arsenic levels (ATSDR 2007a). Arsenic levels may also vary somewhat in CWSs, particularly those that use a combination of water sources in areas with varying levels of seasonal water demand.

SUMMARY OF RESULTS

The pH of water in private wells in the GWP Delta CD samples was significantly higher (more basic) than in the Millard CD ($p < 0.001$). In a few of the Millard CD culinary wells, levels of nitrates (#7435, 8109, 8111), sulfates (#8071, 8111), and total dissolved solids (#7435, 8071, 8111) were higher than the MCL allowed for CWSs.

A summary of water and urine analytical results can be found in Appendix C of this report. Although both water and urine samples have been collected and analyzed in the Millard County area, due to the complexity of the data, the results of this consultation will focus solely on the water data. The concentrations of arsenic and other analytes in urine, including follow-up speciation results, will be discussed in a separate health consultation. This will ensure that a solid public health message is sent to the community on hazards related to their drinking water.

Arsenic

Of the 36 culinary wells sampled in the Delta region, 36 (100%) contained arsenic at levels exceeding the Environmental Media Evaluation Guides (EMEG) for children (3 µg/L), and 28 (78%) exceeded the EPA MCL (10 µg/L). Of the 10 CWS tap water samples in the Delta region, 10 (100%) contained arsenic at levels exceeding the EMEG for children, and 9 (90%) exceeded the EPA MCL. Of the 40 culinary wells sampled in the Millard region, only 8 (20%) contained arsenic at levels exceeding the EMEG for children, and none of the wells (0%) exceeded the EPA MCL. Table 2 summarizes the arsenic sample results of community water system samples (UPHL), private culinary well samples (UPHL and GWP) in the Delta CD region, and private culinary well samples in the Millard CD region (GWP). (See Appendix B for sample results for the other analytes tested in the UPHL and GWP studies.)

Table 2. Arsenic Levels in Samples Collected in 2007 and 2008 for UPHL/RMBC and GWP studies.

Arsenic Samples Source	# of Samples	Mean (µg/L)	Median (µg/L)	Range (µg/L)	# of samples below detection	EPA MCL (µg/L)	# > MCL	% > MCL	EMEG Child (µg/L)	# > EMEG	% > EMEG
Community Water Systems in Delta area - UPHL	10	**16.78***	**11.55**	ND to **54.5**	1	10	9	90%	3	10	100%
Private Wells in Delta Area- UPHL	11	**101.54**	**36.8**	ND to **495.5**	2	10	9	82%	3	11	100%
Private Wells in the Delta Area - GWP	25	**34.828**	**15.9**	6.2 to **117**	0	10	19	76%	3	25	100%
Private Wells in Delta Area - UPHL and GWP combined	36	**56.3**	**28.85**	ND to **495.5**	2	10	28	78%	3	36	100%
Private Wells in Millard Area - GWP	40	1.986	2.1	ND to 6.2	15	10	0	0%	3	8	20%

- *Red-highlighted values exceed the EPA MCL of 10 µg/L.*

Boron

The concentrations of boron were higher than the World Health Organization (WHO) drinking water quality guideline of 500 µg/l (or ppb) in three culinary private wells in the Millard CD (#7435, 8015, 8075) and in one culinary private well in the Delta CD (#8164). Although the concentrations detected were above WHO levels, they did not exceed ATSDR's intermediate EMEG value for children of 2,000 ppb. EPA also has a 10-day health advisory standard for children of 900 µg/l (or ppb). Only two of the four wells referenced above (#8015 in the Millard CD and #8164 in the Delta CD) also exceeded the EPA 10-day health standard. The exposure doses calculated from the concentrations of boron found in these wells did not, however, exceed the MRL of 0.2 mg/kg/day for acute and intermediate health effects.

DISCUSSION

Source of Exposure

Studies by the USGS and EPA have identified the source of arsenic contamination in privately owned water supplies as coming from the natural geology of this region, including previous volcanic activity (Welch 1988). Besides water, arsenic intake can come from many other sources, including seafood, dietary supplements, home remedies, vitamins, hobbies, and industrial exposure. This report will only focus on the impact of arsenic in drinking water.

Exposure Pathway Evaluation
The EEP identified exposure pathways to determine if, and how residents might be exposed to chemicals in the water. There are five components to consider in evaluating exposure pathways:

A source of contamination
Transport through an environmental medium
A point of exposure
Route of exposure
A receptor population

Exposure pathways are classified as completed, potential, or eliminated. Completed pathways exist when the five conditions (above) are present and indicate that exposure to a contaminant has occurred in the past and/or is occurring now. Potential pathways are those that may occur in the past, present, or future. An eliminated pathway is one where at least one of the five elements is missing, and will never be present. Completed and potential pathways, however, may be eliminated when they are unlikely to be significant.

Completed and potential exposure pathways may result from people using the water for domestic purposes. Typical domestic water exposures to metals include dermal exposures from bathing and showering and ingestion exposures from drinking and using water for cooking. Table 3 shows the completed and potential exposure pathway elements.

Table 3. Complete and Potential Exposure Pathways**.**

Exposure Pathway Elements					**Time**	**Type of Exposure Pathway**
Source	**Media**	**Point of Exposure**	**Route of Exposure**	**Estimated Exposed Population**		
Naturally Occurring Arsenic (As) in Rocks & Soil	Aquifer: Water-Saturated Soils	Residential Tap Water	Ingestion	Approximately 5600 residents*	Past	Completed
					Current	Completed
					Future	Potential

**Estimate based on the fact that arsenic levels in the Delta CD area in private wells and in community water systems have historically been above the current EPA MCL.*

Exposure Quantification
To quantify exposures, EEP made several assumptions regarding intake of arsenic, including: children (ages 0 to 6) drink 1 liter of water per day from this water source; adults drink 2 liters of water per day from this water source. Also, children are assumed to ingest 0.6 ml of water daily from brushing their teeth twice a day (Barnhart et al.1974). Bathing was not considered to contribute to arsenic exposure, as studies have shown that dermal contact with arsenic, at doses observed in this study, does not significantly contribute to the body's burden of this contaminant (ATSDR 2007b). The dose calculations assume a child's bodyweight of 15 kg and assume an adult bodyweight of 70 kg. The exposure variables and equations used to determine exposure can be found in Appendix E.

Exposure Analysis
To evaluate the health effects of exposure to contaminants in specific environmental media, which include water, soil, and air, ATSDR has developed Minimal Risk Level (MRL) for common chemical contaminants. The MRL is an estimate of daily human exposure to a contaminant below which non-cancerous, adverse health effects are unlikely to occur. MRLs are developed for acute (less than 14 days), intermediate (14 to 365 days), and chronic (greater than 365 days) exposures. Health guidance values, such as MRLs, do not represent a level above which toxic effects are likely to happen. While Comparison Values (CV) are established for screening purposes to determine whether further evaluation of the contaminant is necessary, MRLs are based on studies used to develop health guidelines. When exposure estimates exceed MRLs, evaluation of the contaminant through dose calculations is necessary to determine the magnitude of the health hazard.

The *No Observed Adverse Effect Level* (NOAEL) is the highest exposure dose at which no effect was observed on the animal or human population in a study. The *Lowest Observed Effect Level* (LOAEL) for a chemical is the lowest exposure dose at which a measurable adverse health effect is observed in a human or animal study population. Whenever possible, NOAELs and LOAELs from studies involving human cases are reviewed. If, however, no human studies exist, studies on laboratory animals are reviewed. Also, the health assessor might include safety factors to address human differences when evaluating whether health effects from animal studies are fully applicable. Appendix A contains a discussion of potential health effects from chronic, oral, arsenic exposure, and Appendix G provides additional information on the risk assessment process.

Toxicological Considerations

Arsenic is a naturally occurring element widely distributed in the earth's crust. Arsenic can be released to water by natural weathering of soil and rocks, and can also be leached from soil and minerals into groundwater. Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Ingestion of arsenic can increase the risk for skin cancer and internal cancers: liver, lung, bladder, and kidney (ATSDR 2007b).

Non-Cancer Health Effects
Non-cancer health effects are classified below in 6 tiers. (See Table 4 for summary of tiers by water source, and Appendix D for maps showing private well sample locations by tier.)

Tier I samples (Table 4) are less than the EPA MCL (10 µg/L), and corresponding exposure doses do not exceed the ATSDR chronic oral MRL (0.0003 mg/kg/day), the chronic NOAEL (0.0008 mg/kg/day), the ATSDR acute oral MRL (0.005 mg/kg/day), nor the chronic LOAEL (0.014 mg/kg/day).

Tier II samples (Table 5) do not exceed the EPA MCL, but the corresponding exposure doses exceed the **ATSDR chronic oral MRL in children.** Exposure doses did not exceed the chronic NOAEL, the ATSDR acute oral MRL, or the chronic LOAEL.

Tier III samples (Table 6) exceed the **EPA MCL** and the corresponding exposure doses exceed the **ATSDR chronic oral MRL**, but do not exceed the NOAEL, the ATSDR acute oral MRL, nor the chronic LOAEL.

Tier IV samples (Table 7) exceed the **EPA MCL**, and the corresponding exposure doses exceed the **ATSDR chronic oral MRL**, and the chronic **NOAEL**, but do not exceed the ATSDR acute oral MRL nor the chronic LOAEL.

- Children: Thirty-four (34) of the 36 private culinary wells in the Delta area (94%), 9 of the 10 CWS tap water samples in the Delta area (90%), and 4 of the 40 Millard area wells (10%) of the wells sampled contained arsenic levels that correspond to doses exceeding the ATSDR chronic oral exposure MRL for children.
- Adults: Twenty-seven (27) of the 36 culinary wells in the Delta area (75%), 5 of the 10 CWS tap water samples in the Delta area (50%), and 0 of the 40 Millard area wells contained arsenic levels that correspond to doses exceeding the ATSDR chronic oral exposure MRL for adults.

Tier V samples (Table 8) exceed the **EPA MCL**, and corresponding exposure doses exceed the **ATSDR chronic oral MRL**, the chronic **NOAEL** and the **ATSDR acute oral MRL**, but not the chronic LOAEL.

- Children: Six (6) of the 36 private culinary wells in the Delta area (17%) correspond to doses that exceed the acute oral exposure MRL for children.
- Adults: Two (2) of the 36 private culinary wells in the Delta area (6%) (and 0 of the 10 CWS samples) correspond to doses that exceed the acute oral exposure MRL for adults.

Tier VI (Table 8) samples exceed the **EPA MCL**, and corresponding exposure doses exceed the **ATSDR chronic oral MRL**, the chronic **NOAEL**, the **ATSDR acute oral MRL**, and the chronic **LOAEL**.

Tier I. In the Delta CD area, 1 of the 10 CWS samples (10%) (#54) and 2 of the 11 UPHL private culinary well samples (18%) (#55 and #67) are in Tier I and do not exceed screening values (Table 5). These arsenic levels are not expected to harm people's health. In the Millard Region, 36 of the 40 GWP culinary well samples (90%) are in Tier I and do not exceed screening values. These arsenic levels are not expected to harm people's health**.**

Table 4. Tier I CWS Samples & Private Culinary Wells.

UPHL - CWS #	As µg/L	> EPA MCL 10 µg/L	Child Dose (mg/kg/day)	Adult Dose (mg/kg/day)	>Chronic Oral MRL 0.0003 mg/kg/day	>NOAEL 0.0008 mg/kg/day	> Acute Oral MRL 0.005 mg/kg/day	>Chronic LOAEL 0.014 mg/kg/day
Tier I - Delta Area (Less than MCL, MRL, NOAEL, LOAEL)								
54	<1.625	No	0.00010	0.00004	No	No	No	No
UPHL wells								
55	<1.625	No	0.00010	0.00004	No	No	No	No
67	<1.625	No	0.00010	0.00004	No	No	No	No
Tier I - Millard Area (GWP) (Less than MCL, MRL, NOAEL, LOAEL)								
7148	2.5	No	0.00016	0.00007	No	No	No	No
7150	ND*	No	0.00000	0.00000	No	No	No	No
7151	ND	No	0.00000	0.00000	No	No	No	No
7217	4.2	No	0.00027	0.00012	No	No	No	No
7222	2.7	No	0.00017	0.00007	No	No	No	No
7231	2	No	0.00013	0.00005	No	No	No	No
8015	ND	No	0.00000	0.00000	No	No	No	No
8016	ND	No	0.00000	0.00000	No	No	No	No
8017	2.4	No	0.00015	0.00007	No	No	No	No
8070	2.2	No	0.00014	0.00006	No	No	No	No
8071	4.5	No	0.00029	0.00012	No	No	No	No
8074	0.05	No	0.00000	0.00000	No	No	No	No
8076	2.9	No	0.00019	0.00008	No	No	No	No
8078	2.6	No	0.00017	0.00007	No	No	No	No
8079	ND	No	0.00000	0.00000	No	No	No	No
8109	ND	No	0.00000	0.00000	No	No	No	No
8110	ND	No	0.00000	0.00000	No	No	No	No
8111	1.9	No	0.00012	0.00005	No	No	No	No
8112	2.2	No	0.00014	0.00006	No	No	No	No
8113	ND	No	0.00000	0.00000	No	No	No	No
8114	ND	No	0.00000	0.00000	No	No	No	No
8115	2	No	0.00013	0.00005	No	No	No	No
8116	ND	No	0.00000	0.00000	No	No	No	No
8118	ND	No	0.00000	0.00000	No	No	No	No
8119	ND	No	0.00000	0.00000	No	No	No	No
8122	2.3	No	0.00015	0.00006	No	No	No	No
8123	2.5	No	0.00016	0.00007	No	No	No	No
8124	ND	No	0.00000	0.00000	No	No	No	No
8125	2.3	No	0.00015	0.00006	No	No	No	No
8126	ND	No	0.00000	0.00000	No	No	No	No
8127	1.9	No	0.00012	0.00005	No	No	No	No
8128	2.1	No	0.00013	0.00006	No	No	No	No
8129	2.5	No	0.00016	0.00007	No	No	No	No
8130	3.7	No	0.00024	0.00010	No	No	No	No
8131	2.9	No	0.00019	0.00008	No	No	No	No
8150	3.7	No	0.00024	0.00010	No	No	No	No

** ND = below detection level*

Tier II. Six (6) of the 25 GWP Delta CD area samples (24%) (#8080, 8082, 8083, 8084, 8087, and 8089) and 4 of the 40 GWP Millard CD area culinary well samples (10%) (#7435, 8014, 8075, and 8077) contained arsenic at a level that exceeds the chronic oral MRL when compared to estimated exposure doses for children (Table 6).

However, these arsenic levels do not exceed the EPA MCL and the child doses do not exceed the NOAEL for chronic exposure (0.0008 mg/kg-day). **Exposures lower than this level would not be expected to result in adverse health effects in exposed persons. This water is not expected to harm people's health.**

Table 5. Tier II CWS Samples & Private Culinary Wells.

GWP Well #	As µg/L	> EPA MCL 10 µg/L	Child Dose (mg/kg/day)	Adult Dose (mg/kg/day)	>Chronic Oral MRL 0.0003 mg/kg/day	>NOAEL 0.0008 mg/kg/day	> Acute Oral MRL 0.005 mg/kg/day	>Chronic LOAEL 0.014 mg/kg/day
Tier II - Delta Area (Exceeds Chronic MRL; Less than MCL, NOAEL, LOAEL)								
8080	6.2	No	**0.00040**	0.00017	**Yes**	No	No	No
8082	8.8	No	**0.00056**	0.00024	**Yes**	No	No	No
8083	6.8	No	**0.00043**	0.00019	**Yes**	No	No	No
8084	8.2	No	**0.00052**	0.00022	**Yes**	No	No	No
8087	7.2	No	**0.00046**	0.00020	**Yes**	No	No	No
8089	9.1	No	**0.00058**	0.00025	**Yes**	No	No	No
Tier II - Millard Area (GWP) (Exceeds Chronic MRL in children; Less than MCL, NOAEL, LOAEL)								
7435	5.9	No	**0.00038**	0.00016	**Yes**	No	No	No
8014	5.2	No	**0.00033**	0.00014	**Yes**	No	No	No
8075	5.4	No	**0.00035**	0.00015	**Yes**	No	No	No
8077	6.2	No	**0.00040**	0.00017	**Yes**	No	No	No

Tier III. Five (5) of the 10 UPHL CWS samples (50%) (#52, 58, 60, 61, and 64), and 2 of the 25 GWP Delta CD area private culinary well samples (8%) (#8086 and 8090) are in Tier III and levels exceed the MCL of 10 ug/l (Table 7). Exposure doses for children in all of these wells and doses for adults in two wells exceed the ATSDR chronic MRL. The doses for children are also close to the chronic NOAEL of 0.0008 mg/kg/day and less than 20 times the chronic LOAEL. Arsenic levels in Tier III wells are approaching levels in studies that may harm people's health, especially children if the water is consumed daily for a long period of time. **As a public health precaution, the levels of arsenic in this tier should be reduced, especially if children are drinking the water. This water can still be used for bathing, cleaning and sanitation purposes. It should be noted, however, that additional improvements to reduce arsenic levels below 10 µg/L have been implemented in most of the CWSs in Millard County since the UPHL samples were collected.**

None of the water samples in the Millard CD region had arsenic levels that were Tier III or higher.

Table 6. Tier III CWS Samples & Private Culinary Wells.

	Tier III - Delta Area (Exceeds Chronic MRL and EPA MCL; Less than NOAEL, Acute MRL, & LOAEL)							
UPHL - CWS # 52	As µg/L 10.8	> EPA MCL 10 µg/L Yes	Child Dose (mg/kg/day) 0.00069	Adult Dose (mg/kg/day) 0.00030	>Chronic MRL 0.0003 mg/kg/day Yes	>NOAEL 0.0008 mg/kg/day No	> Acute MRL 0.005 mg/kg/day No	>Chronic LOAEL 0.014 mg/kg/day No
58	12.1	Yes	0.00077	0.00033	Yes	No	No	No
60	10.5	Yes	0.00067	0.00029	Yes	No	No	No
61	10.6	Yes	0.00068	0.00029	Yes	No	No	No
64	11	Yes	0.00070	0.00030	Yes	No	No	No
GWP Delta area Well # 8086	As µg/L 11	> EPA MCL? 10 µg/L Yes	Child (mg/kg/day) 0.00070	Adult Dose 0.00030	>Chronic MRL? 0.0003 mg/kg/day Yes	>NOAEL? 0.0008 mg/kg/day No	> Acute MRL? 0.005 mg/kg/day No	>LOAEL? 0.014 mg/kg/day No
8090	11.2	Yes	0.00072	0.00031	Yes	No	No	No

Tier IV. Four (4) of the 10 UPHL CWS samples (40%) (#42, 44, 62, and 77); 5 of the 11 UPHL private well samples (45%) (# 43, 53, 56, 59, and 75); and 15 of the 25 GWP Delta CD area private culinary well samples (60%) (#7212, 8081, 8085, 8088, 8151, 8152, 8153, 8155, 8156, 8157, 8158, 8159, 8160, 8161 and 8162) are in Tier IV and exceed the EPA MCL (Table 8). The estimated exposure doses for children and adults exceed the ATSDR chronic oral MRL and come close or exceed the ATSDR NOAEL of 0.0008 mg As/kg/day. The highest doses in this tier also come close to the ATSDR acute MRL of 0.005 mg/kg/day. In addition, the child doses are only 3.5 – 14 times less than the chronic LOAEL of 0.014 mg/kg/day. Arsenic levels in Tier IV wells are approaching levels in studies that may harm people's health, especially children, if the water is consumed daily for a long period of time. The health effects observed at the chronic LOAEL of 0.014 mg/kg-day (23 µg/L) include reports of fatigue, headache, dizziness and numbness (ATSDR 2000). **Untreated water from wells in this tier should not be used for drinking, but can still be used for bathing, cleaning and sanitation purposes. It should be noted, however, that additional improvements to reduce arsenic levels below 10 µg/L have been implemented in most of the CWSs in Millard County since the UPHL samples were collected.**

Table 7. Tier IV CWS Samples & Private Culinary Wells.

	Tier IV - Delta Area (Exceeds Chronic MRL, EPA MCL & NOAEL; Less than Acute MRL, & LOAEL)							
UPHL - CWS # 42	As µg/L 54.5	> EPA MCL 10 µg/L Yes	Child Dose mg/kg/day 0.00348	Adult Dose mg/kg/day 0.00149	>Chronic MRL 0.0003 mg/kg/day Yes	>NOAEL 0.0008 mg/kg/day Yes	> Acute MRL 0.005 mg/kg/day No	>Chronic LOAEL 0.014 mg/kg/day No
44	26.2	Yes	0.00167	0.00072	Yes	Yes	No	No
62	13.8	Yes	0.00088	0.00038	Yes	Yes	No	No
77	16.7	Yes	0.00107	0.00046	Yes	Yes	No	No
UPHL-wells # 43	As µg/L 17.1	> EPA MCL? 10 µg/L Yes	Child Dose mg/kg/day 0.00109	Adult Dose mg/kg/day 0.00047	>Chronic MRL? 0.0003 mg/kg/day Yes	>NOAEL? 0.0008 mg/kg/day Yes	> Acute MRL? 0.005 mg/kg/day No	>LOAEL? 0.014 mg/kg/day No
53	36.8	Yes	0.00235	0.00101	Yes	Yes	No	No
56	30.6	Yes	0.00196	0.00084	Yes	Yes	No	No
59	30.3	Yes	0.00194	0.00083	Yes	Yes	No	No
75	49.9	Yes	0.00319	0.00137	Yes	Yes	No	No
GWP Delta area Well # 7212	As µg/L 58.7	> EPA MCL? 10 µg/L Yes	Child Dose mg/kg/day 0.00375	Adult Dose mg/kg/day 0.00161	>Chronic MRL? 0.0003 mg/kg/day Yes	>NOAEL? 0.0008 mg/kg/day Yes	> Acute MRL? 0.005 mg/kg/day No	>LOAEL? 0.014 mg/kg/day No
8081	14.2	Yes	0.00091	0.00039	Yes	Yes	No	No
8085	14.4	Yes	0.00092	0.00039	Yes	Yes	No	No
8088	13.3	Yes	0.00085	0.00036	Yes	Yes	No	No
8151	24.5	Yes	0.00157	0.00067	Yes	Yes	No	No
8152	71.5	Yes	0.00457	0.00196	Yes	Yes	No	No
8153	59.5	Yes	0.00380	0.00163	Yes	Yes	No	No
8155	15.9	Yes	0.00102	0.00044	Yes	Yes	No	No
8156	27.4	Yes	0.00175	0.00075	Yes	Yes	No	No
8157	14.9	Yes	0.00095	0.00041	Yes	Yes	No	No
8158	39.8	Yes	0.00254	0.00109	Yes	Yes	No	No
8159	67.4	Yes	0.00431	0.00185	Yes	Yes	No	No
8160	64.1	Yes	0.00410	0.00176	Yes	Yes	No	No
8161	59.1	Yes	0.00378	0.00162	Yes	Yes	No	No
8162	43.3	Yes	0.00277	0.00119	Yes	Yes	No	No

Tiers V and VI. Four (4) of the 11 (36%) private wells sampled by UPHL (#49, 50, 63, and 65) and 2 of the 25 (8%) Delta (GWP) private culinary well samples (#8154 and 8164) represent poor quality water and pose a health risk, particularly for children. Arsenic levels exceed the EPA MCL, and corresponding exposure doses exceed the ATSDR chronic oral MRL, the chronic NOAEL for both children and adults, and the ATSDR acute oral MRL for children. Wells 49 and 50 exceed the ATSDR acute oral MRL for both children and adults. Well #49 also exceeded the chronic LOAEL of 0.014 mg As/kg/day (for children). **All of these wells pose a risk for children (and wells 49 and 50 pose risk for adults) for an acute health effect which could result in serious gastrointestinal, neurological, and/or cardiovascular illness with an onset of less than two weeks. Untreated water from these wells should not be used for drinking water.**

Due to the fact that many residents have been consuming water from private wells for many years, chronic health effects were also considered. Long-term exposure to arsenic via drinking-water causes cancer of the skin, lungs, urinary bladder, and kidney, as well as other skin changes such as pigmentation changes and thickening (hyperkeratosis). An increased risk of lung and bladder cancer and of arsenic-associated skin lesions have been observed at drinking-water arsenic concentrations of more than 0.05 ug/L (ATSDR 2007b).

Following long-term exposure, the first changes are usually observed in the skin: pigmentation changes, and then hyperkeratosis. Cancer is a late phenomenon, and usually takes more than 10 years to develop. The relationship between arsenic exposure and other health effects is not clear-cut. For example, some studies have reported hypertensive and cardiovascular disease, diabetes and reproductive effects (Navas-Acien et al. 2008; 2005; Pant et al. 2001).

Due to the high concentrations of arsenic detected in these private wells exceeding the ATSDR acute oral MRL, waters from these sources are considered an urgent public health hazard. None of these wells would harm people's health **IF** water is used only for bathing, washing dishes, tooth brushing and general sanitary purposes; however, these wells should not be used for potable water sources.

Other private wells in the area were not tested. Wells in Millard County that were tested by the UPHL and the UDAF were also not randomly selected. In the GWP study, private well owners responded to newspaper advertisements offering free well testing and/or were referred or were members of the Utah CDs. For the UPHL/RMBC study in Millard County, the local public health office staff provided the UPHL with names and phone numbers of residents who they thought might be interested in participating in the study.

Arsenic levels were significantly higher ($p < 0.001$) in the Delta CD area culinary wells than in the Millard CD culinary wells.

Table 8. Tier V and Tier VI Private Culinary Wells.

Tier V - Delta Area (Exceeds Chronic MRL, EPA MCL, NOAEL & Acute MRL; Less than LOAEL)								
UPHL wells #	As µg/L	> EPA MCL 10 µg/L	Child Dose mg/kg/day	Adult Dose mg/kg/day	>Chronic MRL 0.0003 mg/kg/day	>NOAEL 0.0008 mg/kg/day	> Acute MRL 0.005 mg/kg/day	>Chronic LOAEL 0.014 mg/kg/day
50	207.5	Yes	0.01326	0.00568	Yes	Yes	Yes	No
63	85.5	Yes	0.00547	0.00234	Yes	Yes	Yes	No
65	160.5	Yes	0.01026	0.00440	Yes	Yes	Yes	No
GWP Delta area Well #	As µg/L	> EPA MCL? 10 µg/L	Child Dose mg/kg/day	Adult Dose mg/kg/day	>Chronic MRL? 0.0003 mg/kg/day	>NOAEL? 0.0008 mg/kg/day	> Acute MRL? 0.005 mg/kg/day	>LOAEL? 0.014 mg/kg/day
8154	97.2	Yes	0.00621	0.00266	Yes	Yes	Yes	No
8164	117	Yes	0.00748	0.00321	Yes	Yes	Yes	No
Tier VI - Delta Area (Exceeds Chronic MRL, EPA MCL,NOAEL & Acute MRL, & LOAEL)								
UPHL wells #	As µg/L	> EPA MCL? 10 µg/L	Child Dose mg/kg/day	Adult Dose mg/kg/day	>Chronic MRL? 0.0003 mg/kg/day	>NOAEL? 0.0008 mg/kg/day	> Acute MRL? 0.005 mg/kg/day	>LOAEL? 0.014 mg/kg/day
49	495.5	Yes	0.03168	0.01358	Yes	Yes	Yes	Yes

Cancer Health Effects

The excess theoretical lifetime cancer risks due to ingesting dissolved arsenic in water were based on the cancer slope factor of arsenic developed by the EPA. The "acceptable cancer risk" is calculated on a lifetime exposure, and would not exceed 1 excess case in a population of 10,000 people. It is important that these numbers be kept in perspective. Over the course of a 70-year life span it is estimated that one in three people will develop cancer. Below (Table 10) are the calculated cancer risks for only those water systems that exceeded the 1:10,000 rate.

Table 9. Millard County Private Wells and Community Water Systems (Excess Cancer Risk 87.3 to 1 Case(s)/10,000 Population).

UPHL - Private CulinaryWells

#	As µg/L	Adult CDI mg/kg/day	Ca Risk
49	495.5	0.00582	8.73E-03
50	207.5	0.00244	3.65E-03
65	160.5	0.00188	2.83E-03
63	85.5	0.00100	1.51E-03
75	49.9	0.00059	8.79E-04
53	35.75	0.00042	6.30E-04
56	30.6	0.00036	5.39E-04
59	30.3	0.00036	5.34E-04
43	17.1	0.00020	3.01E-04

UPHL- CWS

#	As µg/L	Adult CDI mg/kg/day	Ca Risk
42	54.5	0.00064	9.60E-04
44	26.2	0.00031	4.61E-04
77	16.7	0.00020	2.94E-04
62	13.8	0.00016	2.43E-04
58	12.1	0.00014	2.13E-04
64	11	0.00013	1.94E-04
52	10.8	0.00013	1.90E-04
61	10.6	0.00012	1.87E-04
60	10.5	0.00012	1.85E-04

GWP- Delta CD Region

#	As µg/L	Adult CDI mg/kg/day	Ca Risk
8164	117	0.00137	2.06E-03
8154	97.2	0.00114	1.71E-03
8152	71.5	0.00084	1.26E-03
8159	67.4	0.00079	1.19E-03
8160	64.1	0.00075	1.19E-03
8153	59.5	0.00070	1.05E-03
8161	59.1	0.00069	1.04E-03
7212	58.7	0.00069	1.03E-03
8162	43.3	0.00051	7.63E-04
8155	15.9	0.00019	2.80E-04
8157	14.9	0.00017	2.62E-04
8085	14.4	0.00017	2.54E-04
8081	14.2	0.00017	2.50E-04
8088	13.3	0.00016	2.34E-04
8090	11.2	0.00013	1.97E-04
8086	11	0.00013	1.94E-04
8089	9.1	0.00011	1.60E-04
8082	8.8	0.00010	1.55E-04
8084	8.2	0.00010	1.44E-04
8087	7.2	0.00008	1.27E-04
8083	6.8	0.00008	1.20E-04
8080	6.2	0.00007	1.09E-04

GWP - Millard CD

#	As µg/L	Adult CDI mg/kg/day	Ca Risk
8077	6.2	0.00007	1.09E-04
7435	5.9	0.00007	1.04E-04

Example: The chronic daily intake (CDI) of arsenic for well #7435 is 0.0001 mg/kg/day. When multiplied by the EPA's Cancer Slope Factor for As, the theoretical lifetime cancer risk is one (1) additional case in a population of 10,000 people, over a lifetime. This is the EPAs upper-bound threshold for acceptable risk. The 3 UPHL samples (2 wells and 1 CWS) and 38

Millard Region GWP samples with a lower cancer risk (below 1:10,000) were not included in Table 10.

An April 1991 memo from Assistant Administrator Donald Clay, of the EPA Office of Solid Waste and Emergency Response, states that in certain cases the agency, "may consider risk estimates slightly greater than 10,000 to be protective" (EPA 1991). The EPA MCL for arsenic of 10 µg/L, for example, is associated with a theoretical excess lifetime cancer risk of 0.00018 (i.e., 1.8 cases per 10,000 persons). In addition, the cancer slope factor of arsenic, based in part on a study in Taiwan used to determine the NOAEL and LOAEL for precancerous skin lesions (Tseng 1968), may be overestimated due to the uncertainty related to the model assumptions and differences in the health and nutrition between Taiwanese and American populations (ATSDR 2007b). As a result, the ability of arsenic to cause cancer may be less than estimated. Based on the EPA MCL as well as the potential uncertainty associated with these calculations, the estimated, theoretical excess lifetime cancer risks (i.e.,0.0001 through 0.00007) from 6 wells in the Delta CD area (#8089, 8082, 8084, 8087, 8083, and 8080) and two wells in the Millard CD area (#7435 and 8077) are considered by the UDOH Health Hazard Assessment program to be within the range of "acceptable risk."

There is clear evidence from studies in humans that exposure to inorganic arsenic by oral routes increases the risk of cancer. Seventy-eight percent (78%) of the wells sampled in the Delta CD area exceeded the level of "Acceptable Risk" for cancer (>1.8 additional cases/10,000 people). The greatest risk is for skin cancer. The most common tumors seen are squamous cell carcinomas, which may develop from hyperkeratotic warts or corns (ATSDR 2007b). Arsenic has been linked to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate (EPA 2006, Smith 1992).

Twenty-eight (28) of the private culinary wells **(**56%**)** and 2 CWSs (#42 and 44) in the Delta CD area had cancer risk rates ranging from 87.3 to 1.94 excess cases per 10,000 population; again this is based on a lifetime exposure. The identifiers for these wells are: #49, 50, 53, 56, 59, 63, 65, 75, 8164, 8154, 8152, 8159, 8160, 8153, 8161, 7212, 8162, 8158, 8156, 8151, 8155, 8157, 8085, 8081, 8088, 8090, and 8086. After a review of available exposure and health effect data, EEP has determined that the arsenic content in these wells cause a moderate to high increased theoretical risk of cancer, and are harmful to human health.

CHILD HEALTH CONSIDERATIONS

ATSDR recognizes the unique vulnerabilities of infants and children and places special emphasis on this sensitive population in making toxicological determinations. A child's developing body can sustain permanent damage if toxic exposures occur during critical growth stages. Children ingest a larger amount of water, relative to body weight, resulting in higher burden of contaminants. Therefore, with the exception of determining cancer risk (based on lifetime exposure), all exposure dose estimates gave consideration to children.

Acute Duration Health Effects

Water from six drinking water systems in this study exceeded the provisional, acute-duration (<14 days) Minimal Risk Level (MRL) for children. The two wells with the highest arsenic readings (in Tiers V & VI) also presented an acute-duration health risk for adults. There was a

documented, human poisoning outbreak (Mizuta et al. 1956) in Japan involving soy sauce. Victims were dosed with approximately 0.05 mg As/kg/day of arsenic. Symptoms included edema of the face, gastrointestinal disease (nausea, diarrhea, vomiting), upper respiratory symptoms, skin lesions and neuropathy. The gastrointestinal effects were serious enough to apply an uncertainty factor of 10 to the Lowest Observed Adverse Effect Level (LOAEL) of this outbreak, thus setting the provisional, acute-duration MRL at 0.005 mg/kg/day (ATSDR 2007b). Children drinking well water with high levels of arsenic, as seen in tiers V& VI, could experience harmful health effects such as gastrointestinal disturbances, upper respiratory symptoms, skin problems, nervous system problems, and increased theoretical risk of cancer.

CONCLUSIONS

In the rural community comprising Millard County, UDOH's purpose is to serve the public by using the best science, taking responsive public health actions and providing trusted health information to the public to prevent people residing in close proximity to hazards from coming into contact with harmful toxic substances.

UDOH concludes that the concentrations of arsenic in water in the Delta CD area of Utah, particularly those west and southwest of the city of Delta, could harm the health of most of the residents using private water systems. Private wells are unregulated, and homeowners have a personal responsibility to protect household members from the significant health effects associated with drinking this chemically unsafe water.

The private wells: #49, 50, 65, 63, 8164, 8154, 8152, 8159, 8160, 8153, 8161, 7212, 75, 53, 56, 59, 8162, 8158, 8156, 815, 8155, 8157, 8085, 8081, 8088, 8090, and 8086 contain arsenic at levels that could harm people's health if they drink the water every day for a short period of time (i.e., less than 2 weeks – one year); this is identified as an urgent public health hazard.

Samples #42 and 44 from community water systems also pose risks for chronic health effects; however, steps are being taken by the water systems, under the oversight of the UDEQ to reduce arsenic to levels below the EPA MCL.

The concentrations of arsenic in water samples from wells in the Millard CD (which comprises most of the county area) are not expected to harm people's health.

Boron concentrations in private culinary wells # 8015 in the Millard CD and private culinary well #8146 in the Delta CD were found to exceed EPA's 10-day health advisory (900 ppb) for children. Well #8146 was also found to contain high arsenic concentrations and water should not be consumed from this well for drinking water purposes. Due to adverse effects associated with boron exposure, well #8015 should not be used as potable drinking water until levels are reduced.

RECOMMENDATIONS

In order to protect public health from exposure to arsenic through contaminated groundwater, action items to reduce exposure are listed below.

- Residents in homes whose drinking water is supplied from wells identified as having the highest and most urgent level of risk (Tiers V and VI), should immediately stop consuming water from these sources. In addition, a long-term mitigation plan should be created for providing permanent and safe drinking water for impacted residents. There are two main options:

    1) Finding an alternative safe source of drinking water- this includes the installation of deep tube wells since deeper aquifers seem to have much lower levels of arsenic contamination. Another option is to construct shallow dug wells for individual residents; however, there is an increased risk of bacterial contamination of the well. A more realistic option may be to use surface water sources equipped with a household water treatment system built in to reduce the risk of microbial contamination as potable water.

    2) Removing arsenic from the water- Many new treatment technologies are being tested for their effectiveness at removing arsenic from contaminated water. These techniques include co-precipitation, ion exchange, activated alumina filtration and slow-sand filtration. Systems like these have been developed for community or household level arsenic removal. One potential problem with these systems is that, upon removal, the arsenic is left in a more concentrated and toxic form which must be appropriately disposed (Howard 2003)..

- Because the levels of arsenic pose a significant health risk to residents using this water as a drinking water source, UDEQ will be consulted to determine if removal actions are required. Mitigation/reduction techniques will need to be discussed and weighed by many organizations and agencies, including UDAF, UDEQ, UDOH, Millard County water system, Millard County government, residents and the Central Utah Public Health Department.

- In the interim, in order to protect public health and reduce risk associated with the consumption of arsenic and boron contaminated groundwater, UDOH recommends that residents with high arsenic and/or boron levels in their drinking water (Tiers V and VI) be temporarily supplied with bottled water until more permanent remediation techniques can be employed.

- Residents of homes whose drinking water is supplied from wells identified in Tiers II, III and IV of this report should install a treatment system on the household fixture used most to supply drinking and cooking water. Another alternative is to use bottled water. (See figures 1-3.) Not all types of water filter systems remove or reduce arsenic; before installing a water treatment system, residents should make sure that the system is designed to remove or reduce arsenic levels. Reverse osmosis systems until recently cost thousands of dollars but are now available for less than $200 (plus the cost of filters – annual maintenance approximately $129).

- All residents in the Delta area whose drinking water source is a private well and who do not know the arsenic level in their well or have not tested their well within the last five

years should have their well water tested for arsenic. If high arsenic levels are found through individual urine or well water testing, residents are recommended to make an appointment with their primary care physician to discuss the results in conjunction with this report and determine a plan of action to reduce future exposure.

Figure 1. Under the counter; **Figure 2.** Under the counter ANSI/NSF Certified POU Adsorptive Media Unit; **Figure 3.** Bottled Water Dispenser.

If you have additional concerns about your health, as it relates to arsenic in drinking water, you should contact your health care provider or the Utah Department of Health, Environmental Epidemiology Program at (801) 538-6191. You can also call ATSDR at 1-800-CDC-INFO and ask for information on the Millard County Arsenic in Culinary Drinking Water Health Consultation.

PUBLIC HEALTH ACTION PLAN

Community water systems in the Delta area are working with the UDEQ to reduce arsenic levels in drinking water to meet EPA MCL requirements.

Residents who participated in the UPHL/RMBC and GWP studies received individual testing results by mail.

- UPHL. Individuals in the UPHL/RMBC study received individual testing results and information on drinking water treatment options to reduce arsenic levels in private wells. Urine samples with arsenic levels of 50 µg/L or higher had additional testing to identify whether the arsenic was inorganic or the less toxic organic species. UPHL staff contacted individuals in the RMBC study by phone who had high drinking water arsenic levels (greater than 200 ug/L) to discuss sampling results, respond to questions and concerns, and to offer to collect additional samples of drinking water and urine samples of other family members who had not been tested.
- GWP. Individuals who participated in the GWP received individual testing results that indicated whether any of the water constituents tested did not meet drinking water

primary standards, drinking water secondary standards, irrigation standards, and/or livestock standards.

EEP will organize a public meeting in the Delta area to raise awareness of well water quality, potential health effects, and methods to reduce exposure to arsenic in drinking water. UDOH staff will respond to follow-up questions and concerns from individuals. The UDEQ Division of Drinking Water, representatives from CWSs, UDAF, and the Central Utah Health District will be invited to participate in the public meeting and community outreach.

EEP will develop and distribute a brochure on "Well Water and Your Health" and a flyer that provides a summary of the results of the drinking water testing conducted by UPHL and the GWP. The flyer will include information on water treatment and private well testing options in Millard County and will be included in the mailing of results to those residents who have had water tested.

EEP will post the brochure, the flyer, and the health consultation on the EEP website. The finalized health consultation will be mailed to the Delta and Millard Conservation Districts, the Delta Library, the Millard Health District (main office and Delta satellite office), and the UDAF.

Due to the fact that adverse health effects can occur from chronic exposure to arsenic through drinking water sources, a health study will be conducted by UDOH to determine if there are any elevations in cancers specifically related to the contaminants of interest in this study. Cancers of interest would include those which have been correlated in the literature to arsenic in drinking waters and include cancers of the skin, lung, bladder and kidney as well as vascular diseases (WHO 2009).

Information on potential health risks from exposure to contaminants in drinking water from private wells, water treatment systems, and well testing options should be provided to residents of the Delta CD area, particularly to residents who live in rural areas west and south of the City of Delta where arsenic levels have been found to be highly elevated in private wells. Additionally, if future samples are collected and further sampling data becomes available to EEP, UDPH will evaluate the results and update conclusions in this health consultation as necessary.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (2007a). Arsenic in Private Drinking-Water Wells, Department of Health and Human Services, http://www.atsdr.cdc.gov/arsenic/arsenic.pdf, Accessed June 8, 2009.

Agency for Toxic Substances and Disease Registry (ATSDR) (2007b). Toxicological Profile for Arsenic. ATSDR (Update), Department of Health and Human Services, http://www.atsdr.cdc.gov/.

Arizona Department of Health Services (ADHS) 2007. Arsenic Exposure from Private Drinking Water Wells, New River, Maricopa County, Arizona. Agency for Toxic Substances and Disease Registry.

Barnhart, WE et al. 1974. "Dentifrice Usage and Ingestion Among Four Age Groups". Journal of Dental Research. 53:1317-25.

Centers for Disease Control and Prevention (CDC), National Biomonitoring Program, http://www.cdc.gov/biomonitoring/state_grants.htm, Accessed June 9, 2009.

Environmental Protection Agency (2006). Drinking Water Standards and Health Advisories. http://www.epa.gov/watersience/criteria/drinking/dwstandards.pdf, accessed 5/20/2009.

Environmental Protection Agency (2006). Arsenic in Drinking Water, http://www.epa.gov/safewater/arsenic/index.html.

Howard, G (2003). "Arsenic, Drinking Water and Health Risk Substitution in Arsenic Mitigation: A Discussion Paper". World Health Organization, Geneva.

Lamm, SH et al. 2004. "Arsenic in Drinking Water and Bladder Cancer Mortality in the United States: An Analysis Based on 133 U.S. Counties and 30 years of Observation." Journal of Occupational and Environmental Medicine. **46**(3): 298-306.

Lewis, DR, et al. 1999. "Drinking Water Arsenic in Utah: a Cohort Mortality Study." Environmental Health Perspectives. 107(5):359-365.

Lewis, D.R., "The Feasibility of Epidemiologic Studies of Waterborne Arsenic: A Mortality Study in Millard County, Utah." Journal of Environmental Health 1998. **60**(9): p. 14.

National Research Council. 2001. Arsenic in Drinking Water: 2001 Update. National Academy Press, Washington, D.C.

Navas-Acien, A et al. 2008. "Arsenic Exposure and Prevalence of Type 2 Diabetes in US Adults." Journal of the American Medical Association (JAMA) **300**(7): 814-822.

Navas-Acien, A et al. 2005. "Arsenic Exposure and Cardiovascular Disease: A Systematic Review of the Epidemiologic Evidence." American Journal of Epidemiology **162**(11): 1037-1049.

Pant, N. 2001. "Male Reproductive Effect of Arsenic in Mice." Biometals **14**(2): 113-117.

Smith A.H. et al. 1992. "Cancer Risks from Arsenic in Drinking Water." Environmental Health Perspectives. July; 97:259-267.

Southwick, JW, et al. 1982. Community Health Associated with Arsenic in Drinking Water in Millard County, Utah. EPA-600/S1-81-064. Health Effects Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH. EPA Final Report 1 Nov 1976- 31 Jan 1980.

Tseng, W.P, Chu HM, How SW, et al. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. Journal of the National Cancer Institute. 40:453-463.

Utah Cancer Registry (UCR). (2006). *Utah Cancer Registry Data for 1973 to 2004, in Microsoft Access Database Format*. Available from URL: http://ucr.utah.edu/. Accessed July 14, 2009.

U.S. Census Bureau Website, American FactFinder, http://factfinder.census.gov accessed 5/20/2009.

U.S. Environmental Protection Agency (EPA). 1991. Risk Assessment Guidance for Superfund (RAGS), Supplemental Guidance Standard Default Exposure Factors (OSWER Directive, 9285.6-03), March 25, 1991.

U.S. Environmental Protection Agency (EPA), 2006. Arsenic in Drinking Water, http://www.epa.gov/safewater/arsenic/index.html.

U.S. Geologic Survey (USGS). Bartholomay Roy C., et al. *Scientific Investigations Report 2007-5213: Summary of Selected U.S. Geological Survey Data on Domestic Well Water Quality for the Centers for Disease Control's National Environmental Public Health Tracking Program.* [cited June 9, 2009]; Available from: http://pubs.usgs.gov/sir/2007/5213/downloads/pdfLinks/UTstatesum.pdf.

Utah Department of Agriculture and Food (UDAF), State Ground-Water Program Reports, http://ag.utah.gov/divisions/conservation/groundwater.html, 1999-2008. http://ag.utah.gov/divisions/conservation/documents/2008UtahGroundWaterProgramReport.pdf

Utah Department of Environmental Quality (UDEQ) Division of Drinking Water. http://www.drinkingwater.utah.gov/

Utah Geographic Information System Portal (UGIS). (2008). http://gis.utah.gov. Accessed June 18, 2009.

Utah Indicator-Based Information System for Public Health (IBIS). Cancer Registry Query Module Configuration Selection. (2008). http://ibis.health.utah.gov/query/selection/ucr/UCRSelection.html. Accessed June 9, 2009.

Welch, A.H., M.S. Lico, and J.L. Hughes. 1988. "Arsenic in Ground Water of the Western United States". Ground Water. **26**(3): p. 333-347.

World Health Organization (WHO). 2009. Arsenic in Drinking Water. http://www.who.int/mediacentre/factsheets/fs210/en/. Accessed September 2, 2009.

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CERTIFICATION

This Health Consultation, **Arsenic Exposure from Culinary Drinking Water Sources, Millard County, Utah**, was prepared by the Utah Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the public health assessment was begun. Editorial review was completed by the Cooperative Agreement partner.

Jennifer Freed
Technical Project Officer, DHAC, ATSDR

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

Alan Yarbrough
Cooperative Agreement Team Leader, DHAC, ATSDR

APPENDICES

Appendix A - Health Effects from Chronic Arsenic Ingestion

One of the most common effects of both acute and long-term arsenic ingestion is a pattern of skin changes, including changes in skin pigmentation (hyperpigmentation, interspersed with small areas of hypopigmentation of the face, neck, and back), generalized hyperkeratosis, or thickening of the skin, and formation of hyperkeratotic warts on the palms and soles. These effects are most often reported at chronic dose levels ranging from about 0.01 to 0.1 mg/kg/day. Human studies document gastrointestinal irritation from chronic oral exposure to arsenic at dose levels of about 0.01 mg/kg/day and above. Symptoms include nausea, diarrhea, and vomiting.

Damage to the liver and elevated levels of hepatic enzymes are reported at dose levels of 0.01 to 0.01 mg/kg/day. Hematological effects, including anemia and, have been documented at chronic oral exposures of 0.05 mg/kg/day and above. Neurological effects are reported at chronic oral doses of 0.03-0.1 mg/kg/day, including peripheral neuropathy and numbness in hands and feet, possibly developing into a painful “pins and needles” sensation. Cardiovascular effects include cardiac arrhythmia and myocardial depolarization. A serious vascular condition called Blackfoot disease is endemic in an area of Taiwan where residents are exposed to arsenic in drinking water from about 0.014-0.065 mg/kg/day. Studies in Chile report indicate that consumption of drinking water doses of 0.02-0.06 mg/kg/day increases in the incidence of Raynaud’s disease and cyanosis of the fingers and toes (ATSDR 2007b).

Arsenic has been classified as a human carcinogen by the U.S. Environmental Protection Agency (EPA), the National Toxicology Program (NTP), and the International Agency for Research on Cancer (IARC). Reports indicate that arsenic in drinking water increases the risk of skin, liver, bladder, kidney, lung, and prostate cancers. Numerous studies have shown that cancer effects may occur following long-term exposure to drinking arsenic-contaminated water (ATSDR 2007b).

Appendix B – Sampling Results for Metals in Samples Collected by the UPHL and the GWP in 2007 and 2008

Community Water System Samples – Delta Region (UPHL); n = 10

Chemical	Mean (µg/L)	Range (µg/L)	EPA MCL[1] (µg/L)	# > MCL	% > MCL	EMEG[2] Child (µg/L)	# > EMEG	% > EMEG
Antimony	0.1295	ND[3] to 0.16	6	0	0	4	0	0
Arsenic	**16.78**	**ND to 54.5**	10	**9**	**90%**	3	**10**	**100%**
Barium	23.913	ND to 30	2000	0	0	6000	0	0
Beryllium	ND	ND	4	0	0	20	0	0
Cadmium	ND	ND	5	0	0	2	0	0
Cesium	ND	ND	NS	NS	NS	4	0	0
Cobalt	0.059	ND to 0.28	NS	NS	NS	100	0	0
Lead	0.583	ND to 1.89	15	0	0	NS	NS	NS
Molybdenum	1.03	ND to 1.8	NS	NS	NS	50	0	0
Platinum	ND	ND	NS	NS	NS	NS	NS	NS
Selenium	0.83	ND to 1.8	50	0	0	50	0	0
Thallium	ND	ND	2	0	0	NS	NS	NS
Tungsten	0.338	ND to 0.7	NS	NS	NS	NS	NS	NS
Uranium	2.417	1.47 to 2.85	30	0	0	NS	NS	NS

Private Culinary Water Samples – Delta Region (UPHL); n = 11

Chem	Mean (µg/L)	Range (µg/L)	MCL (µg/L)	# > MCL	% > MCL	EMEG Child (µg/L)	# > EMEG	% > EMEG
Antimony	0.0695	ND to 0.225	6	0	0	4	0	0
Arsenic	**101.54**	**ND to 495.5**	10	**9**	**82%**	**3**	**11**	**100%**
Barium	53.727	ND to 120	2000	0	0	6000	0	0
Beryllium	ND	ND	4	0	0	20	0	0
Cadmium	ND	ND	5	0	0	2	0	0
Cesium	ND	ND	NS	NS	NS	NS	NS	NS
Cobalt	0.058	ND to 0.19	NS	NS	NS	100	0	0
Lead	0.161	ND to 0.21	15	0	0	NS	NS	NS
Molybdenum	3.945	ND to 6.79	NS	NS	NS	50	0	0
Platinum	ND	ND	NS	NS	NS	NS	NS	NS
Selenium	0.583	ND to 1.45	50	0	0	50	0	0
Thallium	ND	ND	2	0	0	NS	NS	NS
Tungsten	1.107	0.1 to 2.47	NS	NS	NS	NS	NS	NS
Uranium	1.398	0.2 to 4.05	30	0	0	NS	NS	NS

Private Culinary Water Samples – Delta Region (GWP); n = 25

Chem	Mean (µg/L)	Range (µg/L)	MCL (µg/L)	#> MCL	% > MCL	EMEG Child (µg/L)	#> EMEG	% > EMEG
Arsenic	**34.828**	**6.2 to 117**	**10**	**19**	**76%**	**3**	**25**	**100%**
Barium	62.672	12.5 to 139.4	2000	0	0	6000	0	0
Beryllium	ND	ND	4	0	0	20	0	0
Boron	190.268	61.1 to 1,105	-	-	-	2000	0	0
Cadmium	ND	ND	5	0	0	NS	NS	NS
Cobalt	ND	ND	NS	NS	NS	100	0	0
Lead	0.234	ND to 1.3	15	0	0	NS	NS	NS
Molybdenum	2.81	0.6 to 7.3	NS	NS	NS	50	0	0
Selenium	ND	ND	50	0	0	50	0	0

Private Culinary Water Samples – Millard Region (GWP); n = 40

Chem	Mean (µg/L)	Range (µg/L)	MCL (µg/L)	# > MCL	% > MCL	EMEG Child (µg/L)	#> EMEG	% > EMEG
Arsenic	**1.986**	**ND to 6.2**	**10**	**0**	**0%**	**3**	**8**	**20%**
Barium	113.57	8.2 to 349.5	2000	0	0	6000	0	0
Beryllium	ND	ND	4	0	0	20	0	0
Boron	822.5	500.9 to 1,074	-	-	-	2000	0	0
Cadmium	ND	ND	5	0	0	NS	NS	NS
Cobalt	0.185	ND to 1	NS	NS	NS	100	0	0
Lead	0.41	ND to 2.9	15	0	0	NS	NS	NS
Molybdenum	1.566	ND to 19.3	NS	NS	NS	50	0	0
Selenium	1.78	ND to 48.2	50	0	0	50	0	0

[1] MCL: Maximum Contaminant Level

2 EMEG- Environmental Media Evaluation Guide for children exposure

3 ND: Non-detected (i.e. chemical concentrations in water samples were below the laboratory instrument reporting level) *Sample results that were below detection level were assigned a value of one-half of the detection level reported for each analyte (for determining average/mean level). Detection levels were not reported in the UDAF Groundwater reports. Because some of the sample results reported were lower than the detection levels in the RMBC reports, sample results that were below detection level were assigned a value of one half of the lowest sampling result reported.*

Appendix C - Correlation between Chemicals in Drinking Water and Urine (UPHL/RMBC 2007-2008), Millard County, Utah

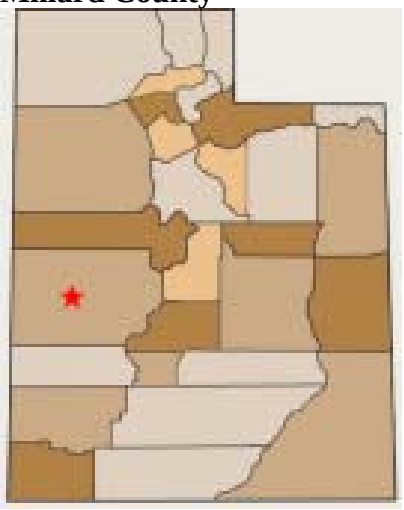
Water Chem	n = 21 Mean (µg/L)	Range (µg/L)	EPA MCL (µg/L)	# > MCL	EMEG Child (µg/L)	# > EMEG
Sb	0.098	ND* to 0.225	6	0	4	0
As	61.18	ND to 495.5	10	18	3	21
Ba	39.53	ND to 120	2000	0	6000	0
Be	ND	ND	4	0	20	0
Cd	ND	ND	5	0	2	0
Cs	ND	ND	NS**	NS	4	0
Co	0.058	ND to 0.28	NS	NS	100	0
Pb	0.361	ND to 1.89	15	0	NS	NS
Mo	2.947	ND to 6.79	NS	NS	50	0
Pt	ND	ND	NS	NS	NS	NS
Se	0.645	ND to 1.8	50	0	50	0
Tl	ND	ND	2	0	NS	NS
W	0.741	ND to 2.47	NS	NS	NS	NS
U	1.883	0.2 to 4.1	30	0	NS	NS

Urine	n = 27 Mean (ppb)	Range (ppb	Ref (ppb)	# > Ref
Sb	0.056	ND to 0.121	0.42	0
As	73.347	3.91 to 337.7	65.4	9
Ba	3.331	0.52 to 7.92	6.8	1
Be	ND	ND	<0.05	0
Cd	0.501	0.115 to 1.44	1.2	1
Cs	6.633	1.715 to 13.279	11.4	3
Co	0.466	ND to 2.349	1.32	3
Pb	0.794	0.121 to 2.41	2.9	0
Mo	78.306	12.53 to 211.01	178	1
Pt	ND	ND	<0.03	0
Se	67.018	14.45 to 183.75	140	2
Tl	0.203	ND to 0.435	0.45	0
W	0.382	ND to 1.545	0.5	7
U	0.024	ND to 0.068	0.046	4

** ND = below the level of detection*
***NS = No MCL or EMEG has been established*

Appendix D - Maps

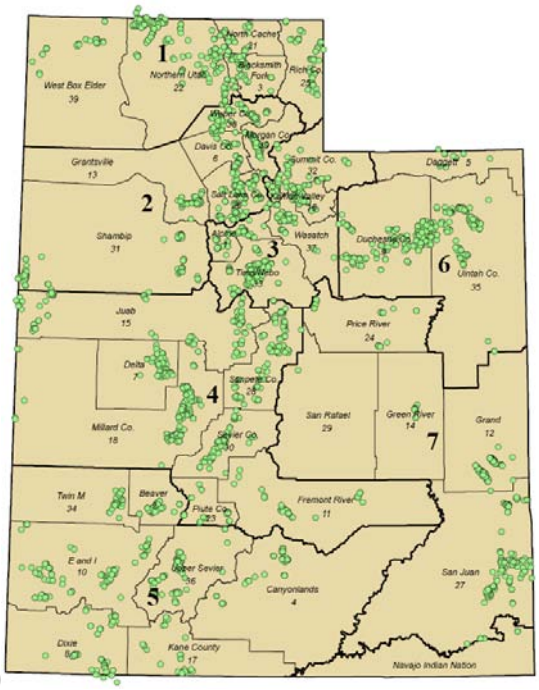
Millard County



dream.lib.utah.edu/digital/unews/mcc.html

Utah Department of Agriculture and Foods (UDAF) Groundwater Program (GWP) maps of Delta and Millard Conservation District (CD) regions

Historic Ground Water Sample Locations 1996 - 2008

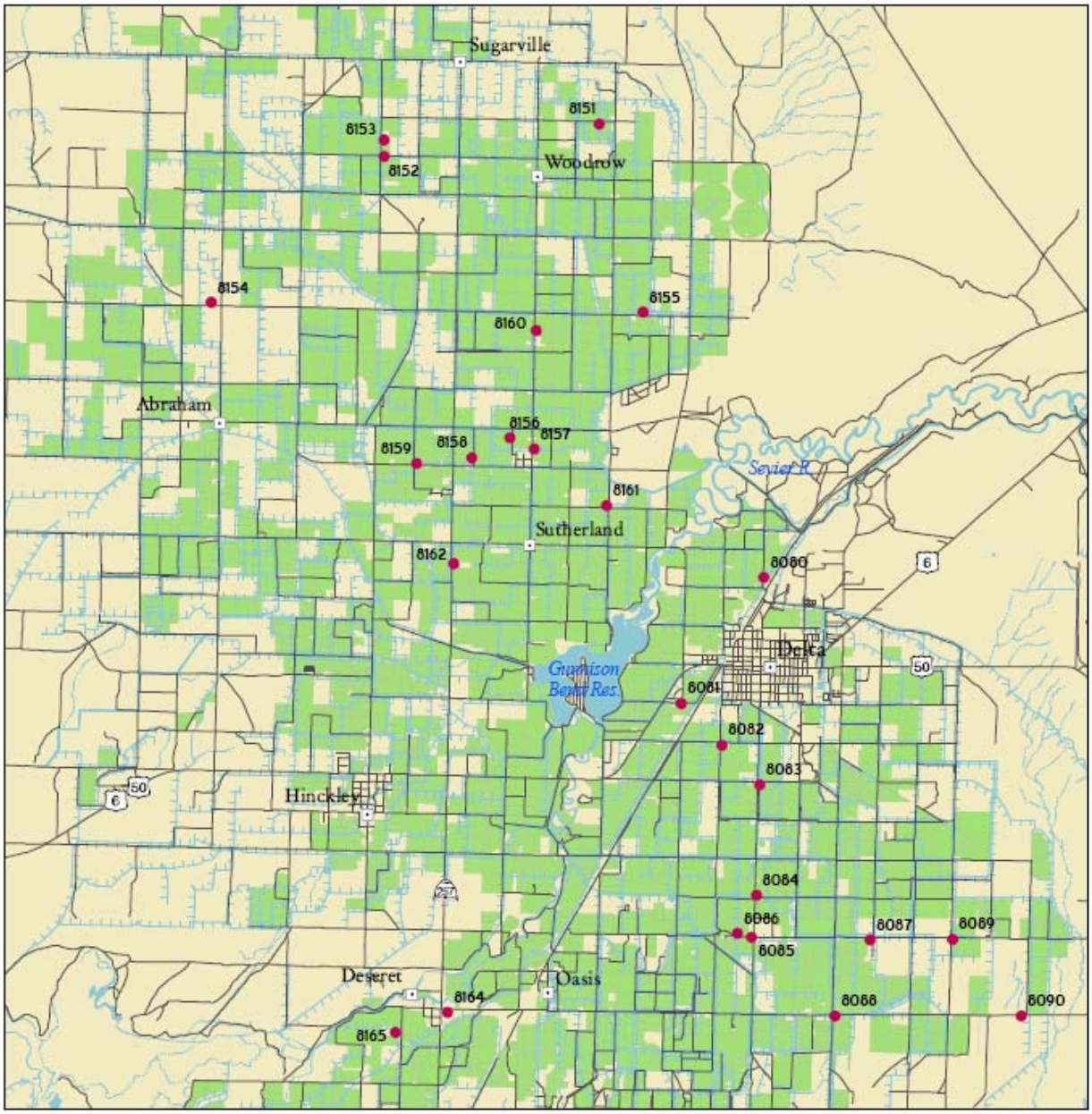


District Location

District Location

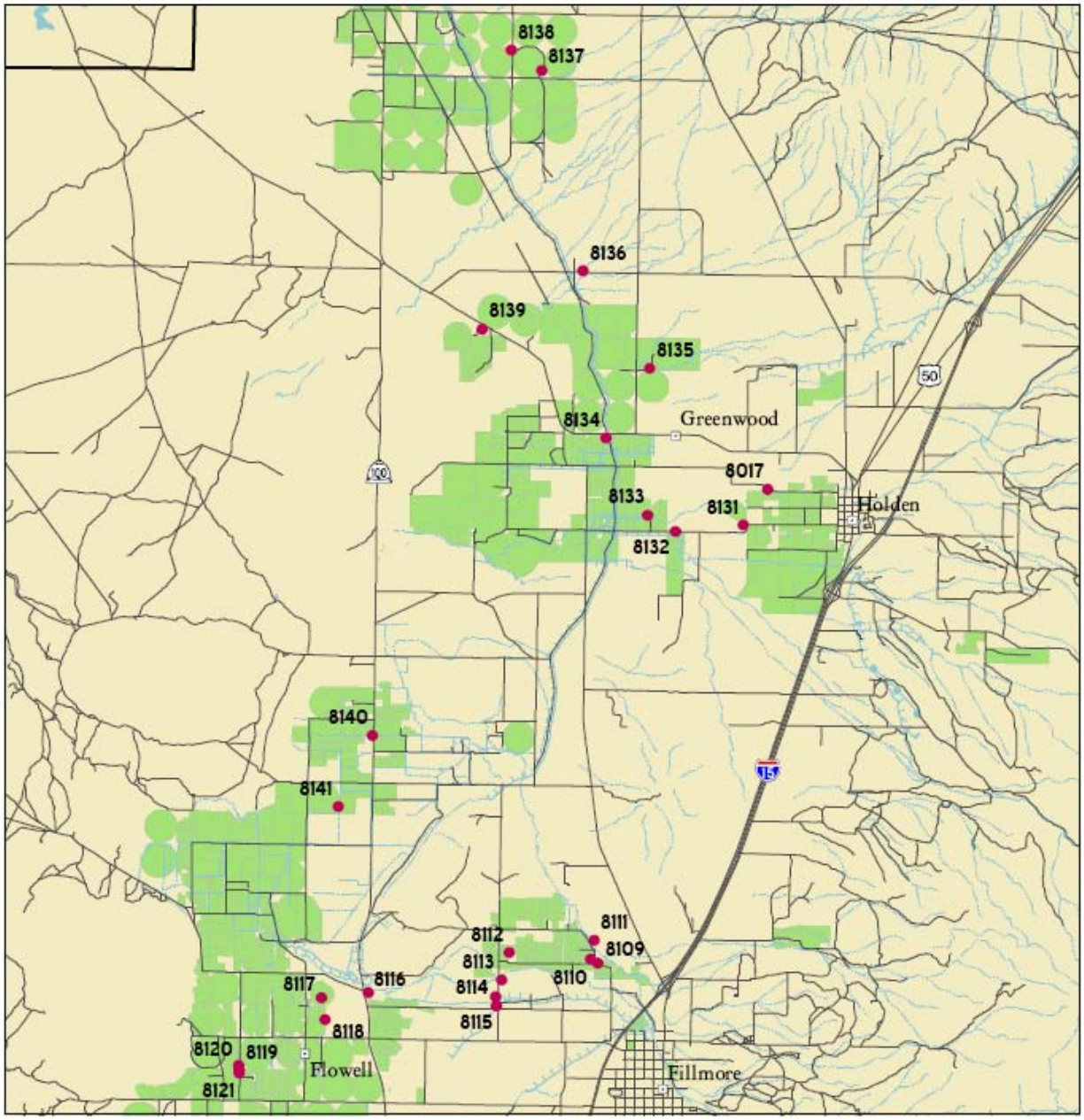
(GWP)

Delta CD Area 2008 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2008).



Map Scale 1:126,720 (1 inch = 2 miles)

Millard CD – Fillmore Area 2008 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2008).



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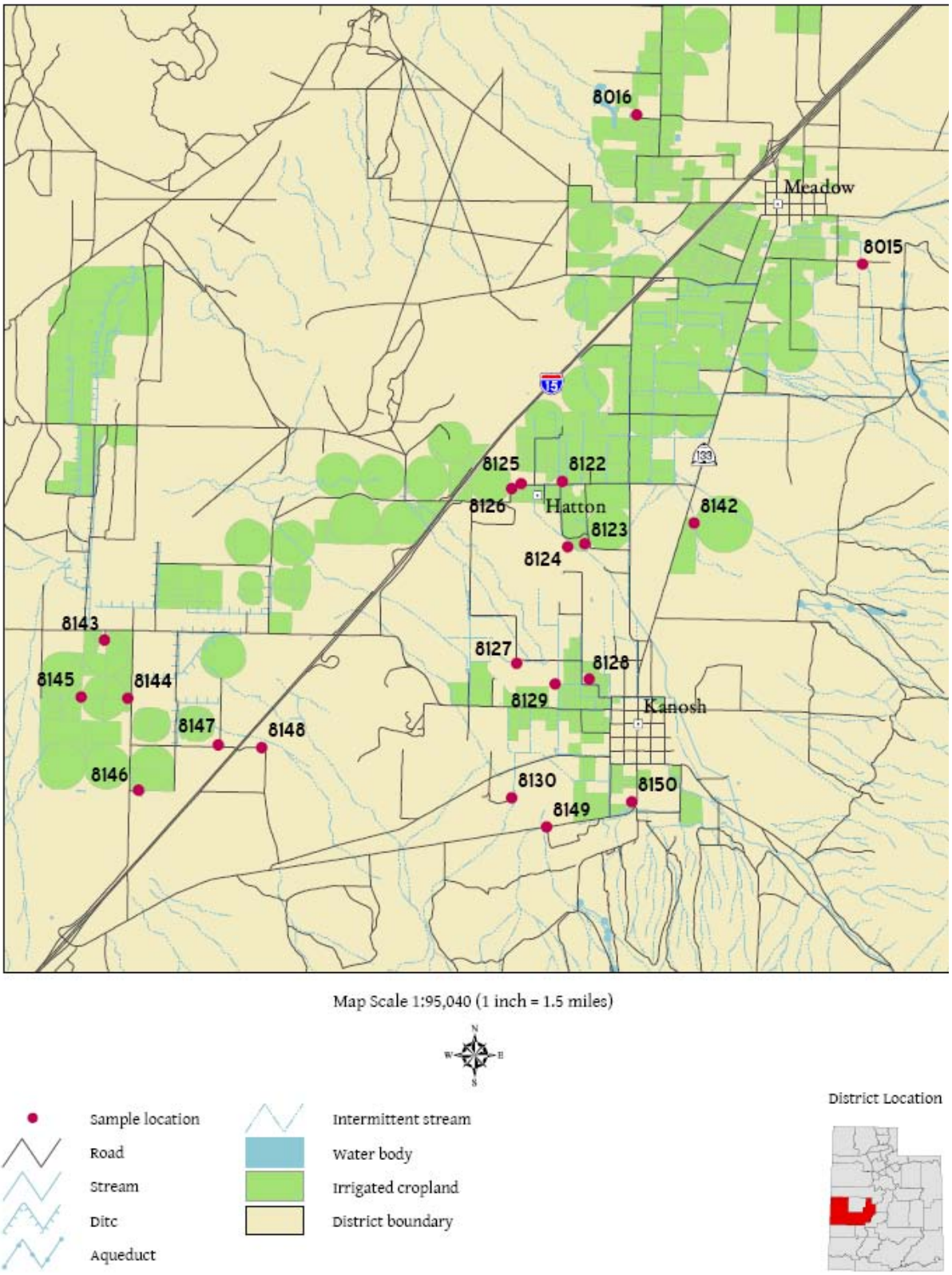
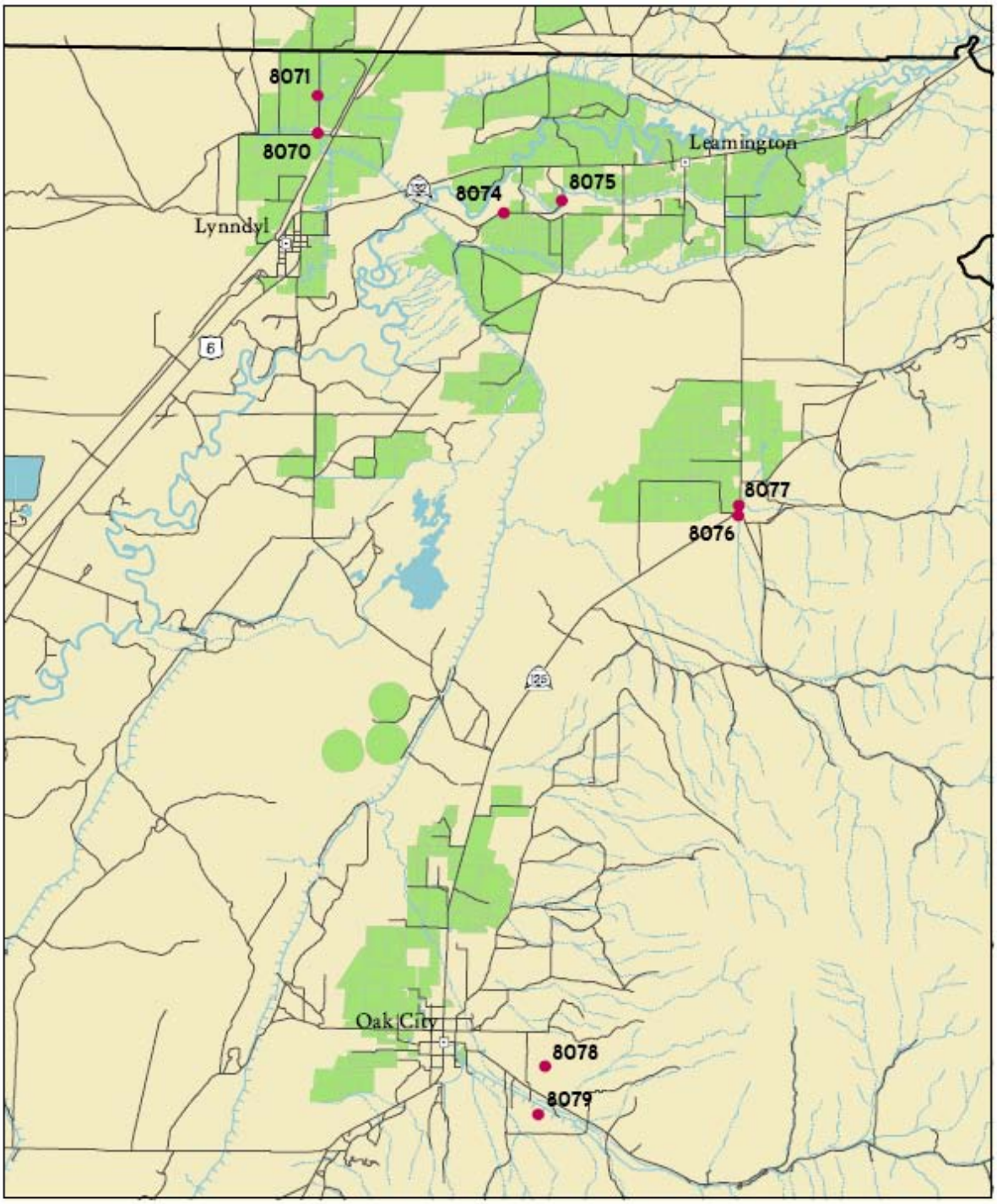
Millard CD Kanosh Area 2008 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2008).

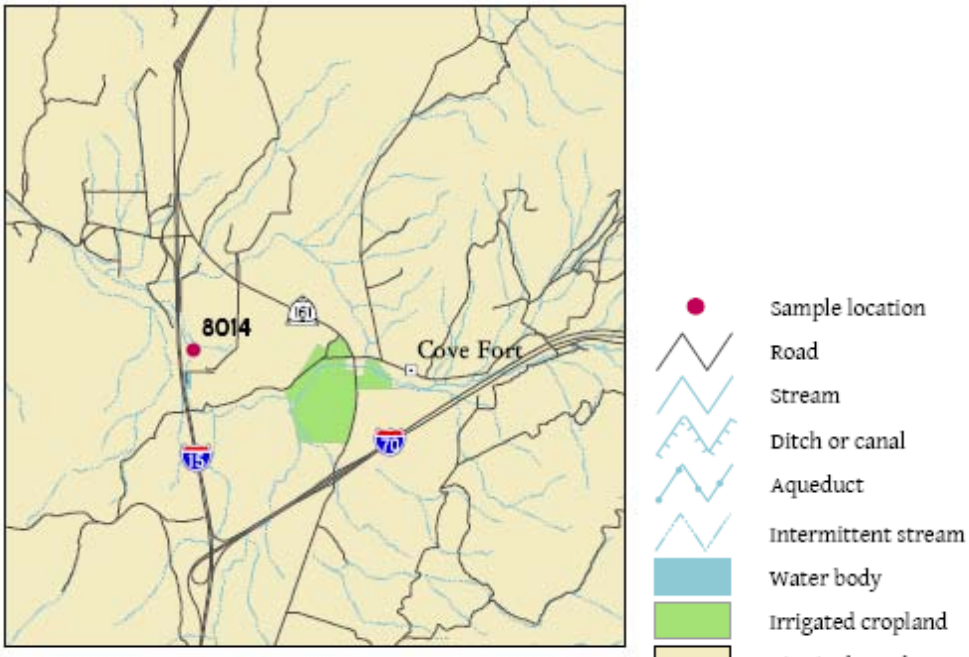


Millard CD – Oak City area 2008 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2008).



Map Scale 1:126,720 (1 inch = 2 miles)

Millard CD – Cove Fort and Eskdale Area 2008 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2008).



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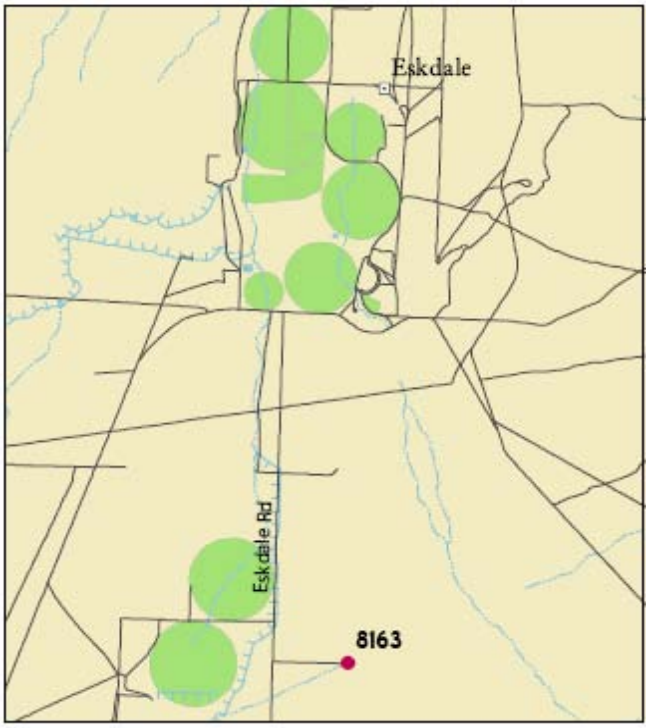
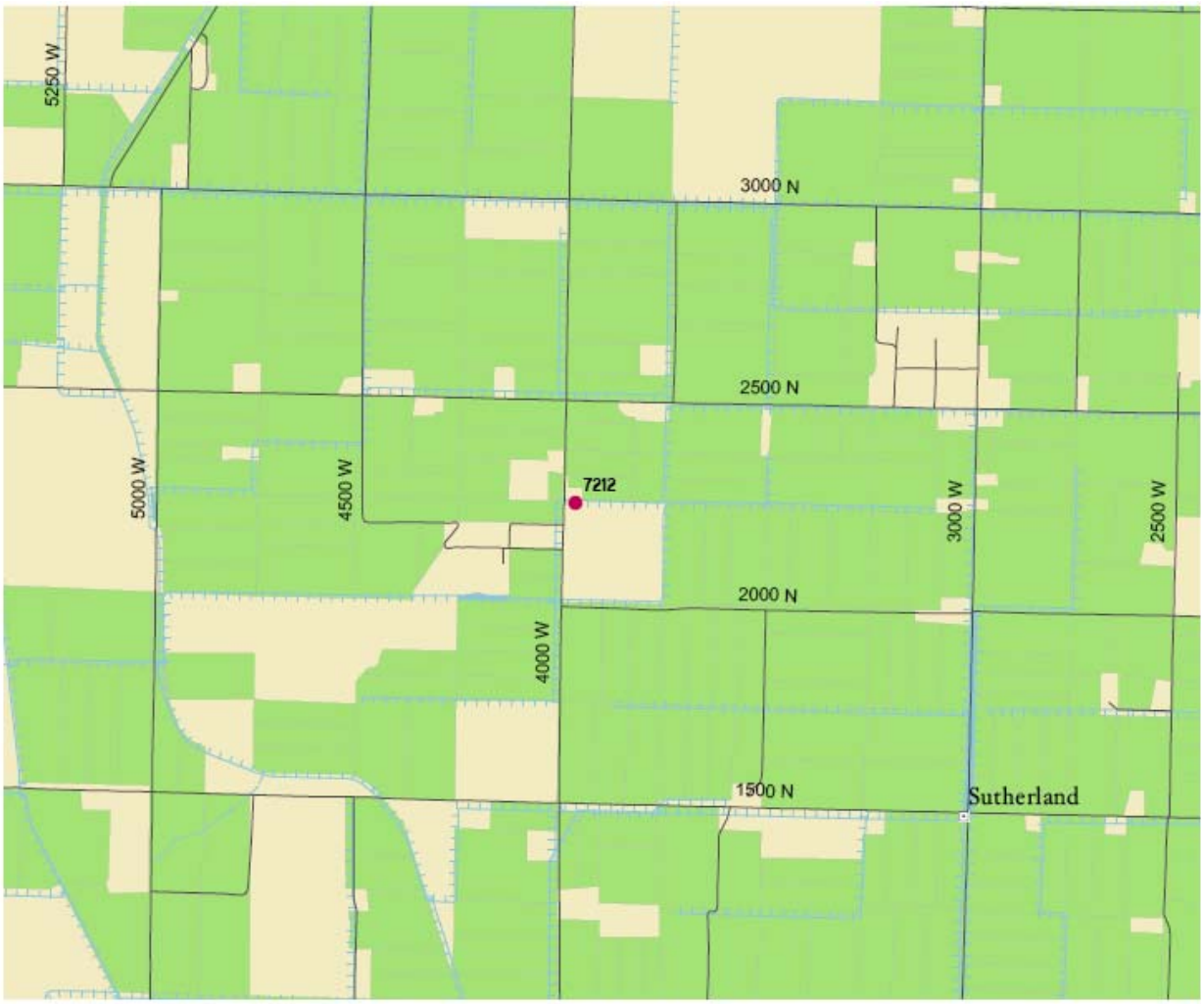


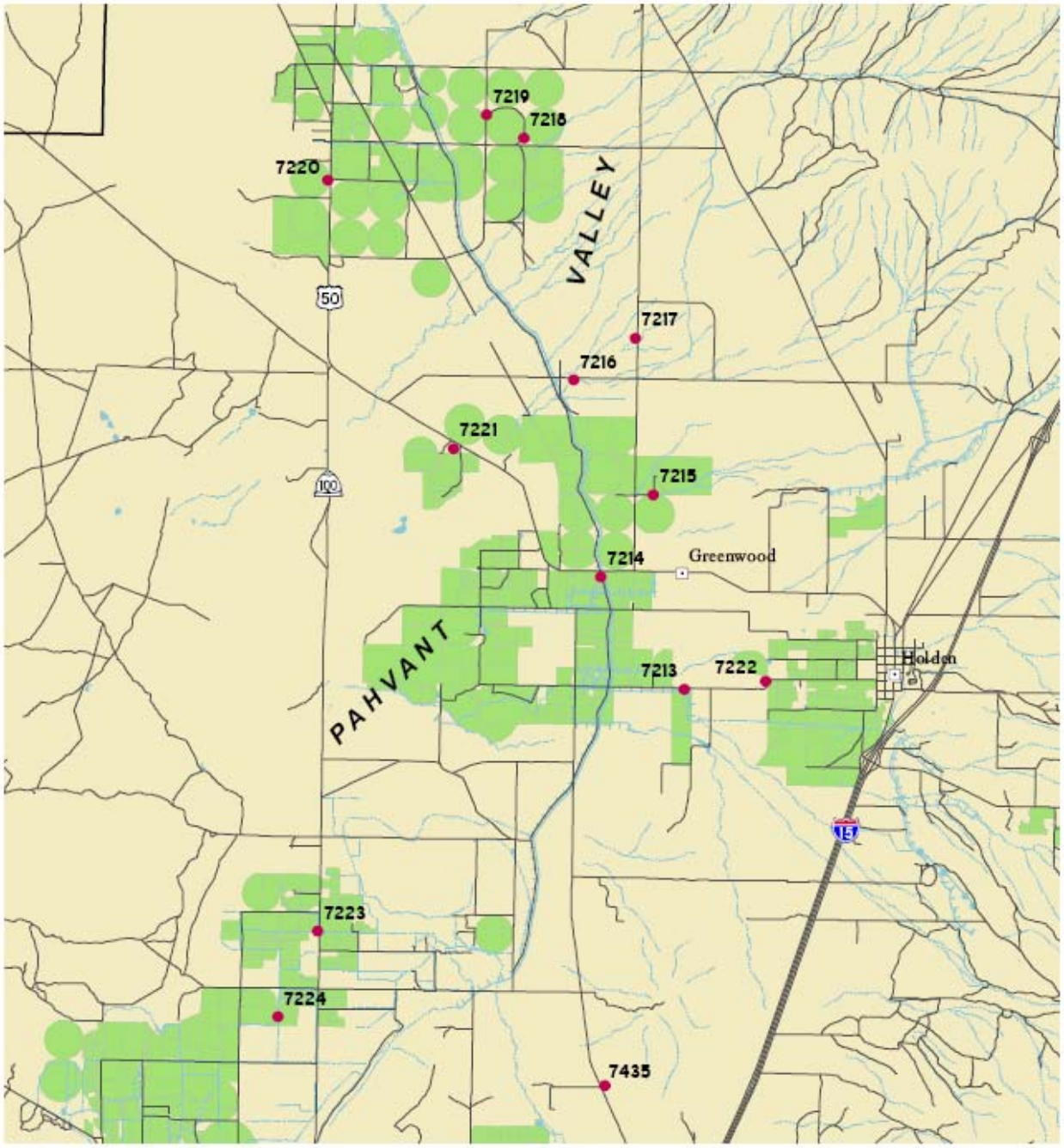
Map Scale 1:79,200 (1 inch = 1.25 miles)

Delta CD Area – 2007 sample (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2007).



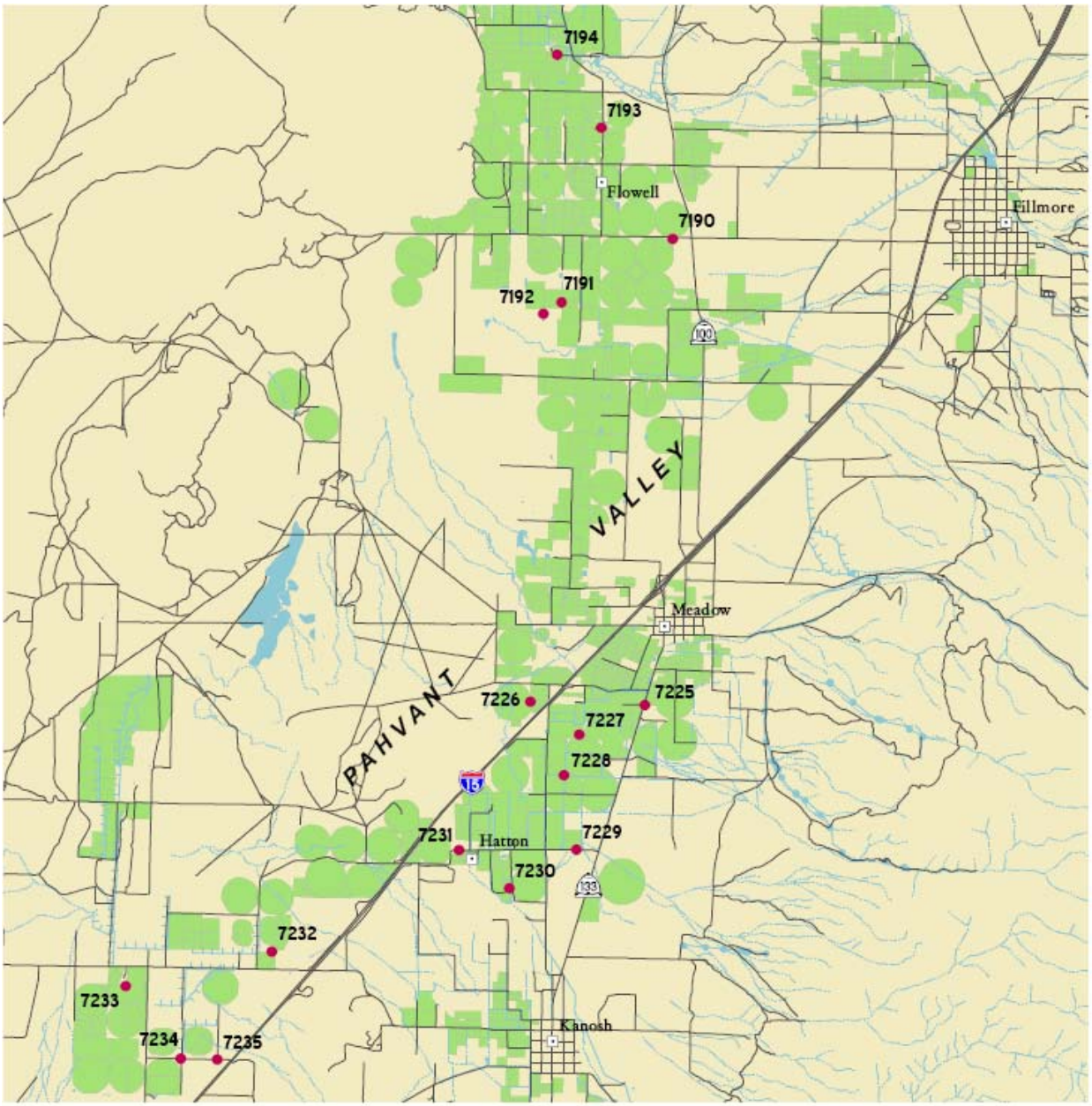
Map Scale 1:24,000 (1 inch = 0.38 miles)

Millard CD Area – Pahvant Valley North – 2007 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2007).



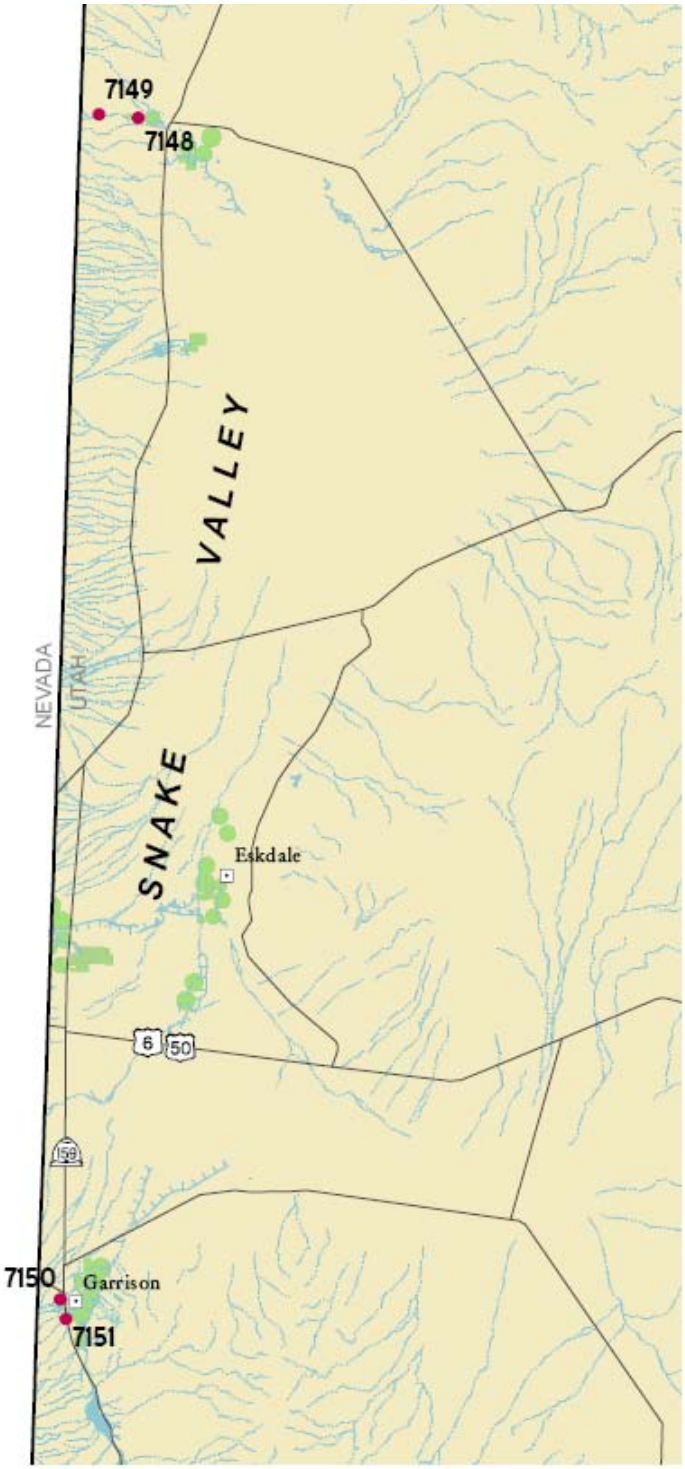
Map Scale 1:126,720 (1 inch = 2 miles)

Millard CD – Pahvant Valley South – 2007 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2007).



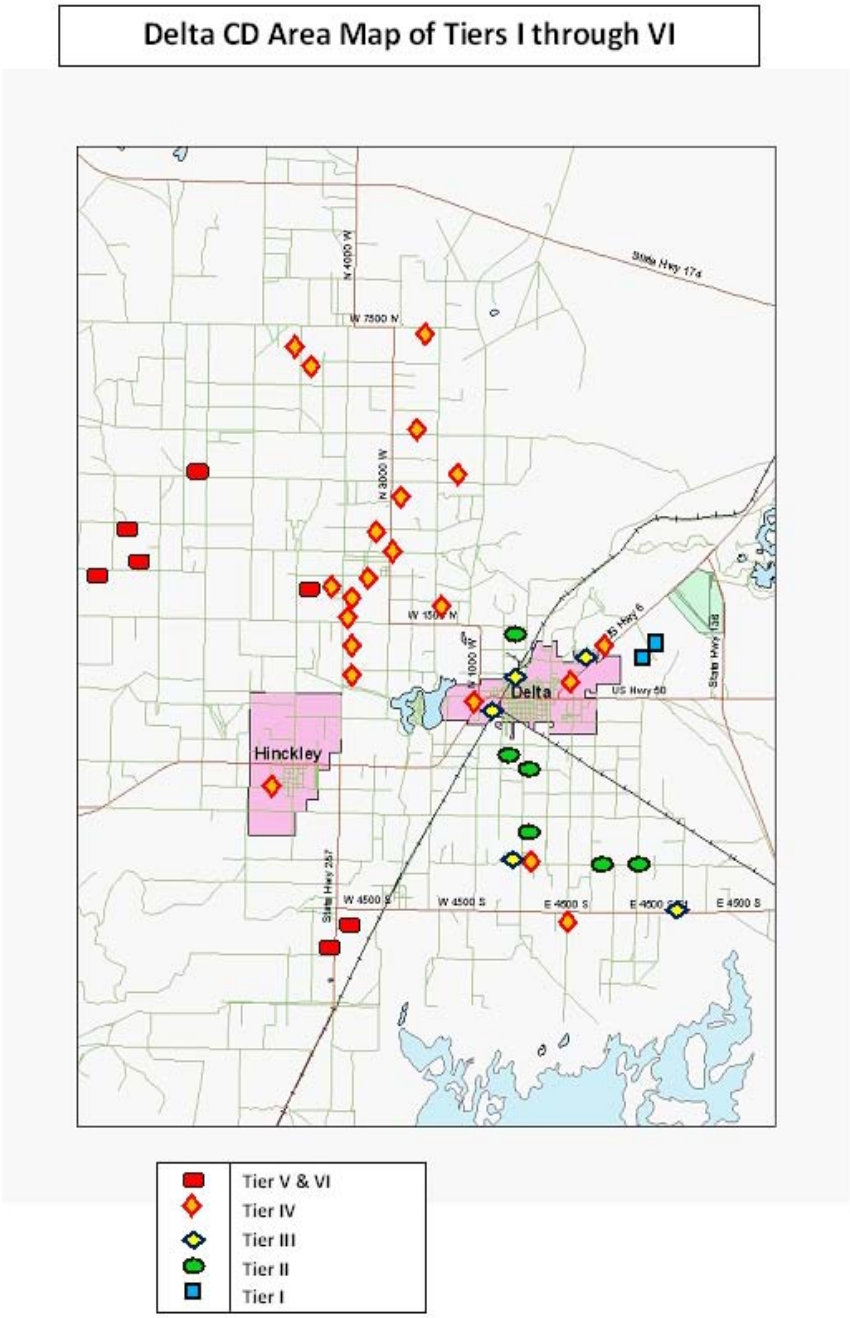
Map Scale 1:126,720 (1 inch = 2 miles)

Millard CD – Snake Valley Area – 2007 samples (GWP) (Utah Department of Agriculture and food State Ground-Water Program Report 2007).

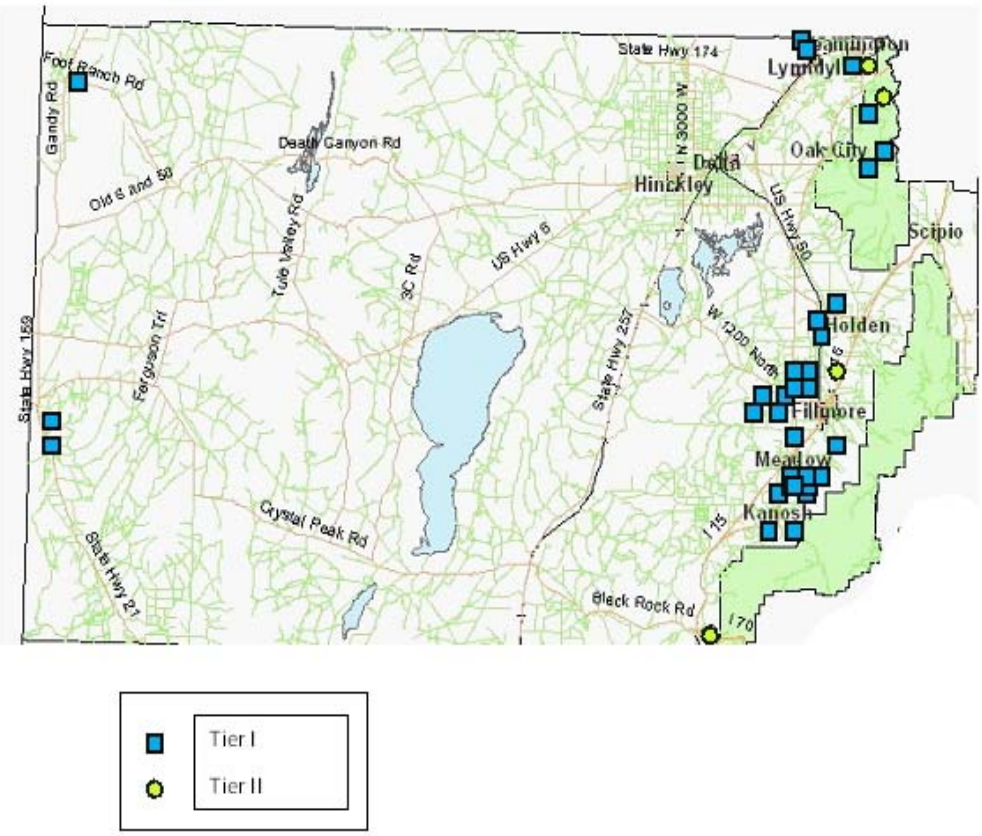


Map Scale 1:332,640 (1 inch = 5.25 miles)

Delta CD Area Map of Tiers I through VI
UPHL and GWP Sample Collection Sites



Millard CD Area Map of Tiers I through VI*
UPHL and GWP Sample Collection Sites



- ***There were no private wells in the Millard CD area that were above the Tier II arsenic values.***

Appendix E
Calculations:

Exposure Dose Equations
UDOH used the ATSDR exposure assessment documents to calculate an exposure dose for persons living in Millard County (Delta and Millard Conservation Districts). The doses were calculated using the following equations:

Ingestion of chemicals in water:

$$CDI = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

CDI: chronic daily intake (mg/kg/day)
CW: concentration in water (mg/L)
IR: intake rate (L/day)
EF: exposure frequency (days/yr)
ED: exposure duration (yrs)
BW: body weight (kg)
AT: Averaging time (days)

Variable Assumptions	Adults	Children
IR (ingestion, liters):	2	1
EF (days/yr.):	350	350
ED (years):	30	6
BW (Kg):	70	15
AT (days) Non-Cancer:	10950	2190
AT (days) Cancer:	25550	25550

Appendix F - ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR serves the public by using the best science to take responsive public health actions and provides trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway**.

Comparison Value: **(CVs)** Concentrations of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

EMEG: See **Environmental Media Evaluation Guides**.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than the **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

Environmental Media Evaluation Guides (EMEG): Estimated contaminant concentrations in a media where non-carcinogenic health effects are unlikely. The EMEG is derived from the ATSDR minimal risk level (MRL).

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical. ATSDR defines an exposure pathway as having 5 parts:
1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). Some examples include: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:
– Urgent Public Health Hazard
– Public Health Hazard
– Indeterminate Public Health Hazard
– No Apparent Public Health Hazard
– No Public Health Hazard

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:

- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

Sample Size: The number of people that are needed for a health study.

Sample: A small number of people chosen from a larger population (See **Population**).

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix G - Summary of the Health Evaluation Process

Screening Process
In evaluating data, ATSDR uses comparison values (CVs) to determine which chemicals to examine more closely. CVs are the contaminant concentrations found in a specific media (soil or water). CVs incorporate assumptions of daily exposure to the chemical and a standard amount of air, water, and soil that someone may inhale or ingest each day. As health-based thresholds, CVs are set at a concentration below which no known or anticipated adverse human health effects are expected to occur. Different CVs are developed for cancer and non-cancer health effects. Non-cancer levels are based on valid toxicological studies for a chemical, with appropriate safety factors included, and the assumption that small children (22 pounds) and adults are exposed every day. Cancer levels are the media concentrations at which there could be a one in a million excess cancer risk for an adult eating contaminated soil or drinking contaminated water every day for 70 years. For chemicals for which both cancer and non-cancer numbers exist, the lower level is used to be protective. Exceeding a CV does not mean that health effects will occur, just that more evaluation is needed.

CV sources used in this document are listed below:

Environmental Media Evaluation Guides (EMEGs) are estimated contaminant concentrations in a media where non-carcinogenic health effects are unlikely. The EMEG is derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL).

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in one million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors (CSFs).

Evaluation of Public Health Implications

Estimation of Exposure Dose
The next step is to take those contaminants that are above the CVs and further identify which chemicals and exposure situations are likely to be a health hazard. Child and adult exposure doses are calculated for the site-specific exposure scenario, using our assumptions of who accesses the site and how often they contact the site contaminants. The exposure dose is the amount of a contaminant that gets into a person's body.

Non-cancer Health Effects
The calculated exposure doses are then compared to an appropriate health guideline for that chemical. Health guideline values are considered safe doses; that is, health effects are unlikely below this level. The health guideline value is based on valid toxicological studies for a chemical, with appropriate safety factors built in to account for human variation, animal-to-human differences, and/or the use of the lowest adverse effect level.

For non-cancer health effects, the following health guideline values are used:

- *Minimal Risk Level (MRLs)* - developed by ATSDR. An estimate of daily human exposure – by a specified route and length of time – to a dose of chemical that is likely to

be without a measurable risk of adverse, non-cancerous effects. An MRL should not be used as a predictor of adverse health effects. A list of MRLs can be found at http://www.atsdr.cdc.gov/mrls.html.

– *Reference Dose (RfD)* - developed by EPA. An estimate, with safety factors built in, of the daily, lifetime exposure of human populations to a possible hazard that is not likely to cause non-cancerous health effects. The RfDs can be found at http://www.epa.gov/iris/.

If the estimated exposure dose for a chemical is less than the health guideline value, then the exposure is unlikely to cause a non-carcinogenic health affect in that specific situation. If the exposure dose for a chemical is greater than the health guideline, then the exposure dose is compared to known toxicological values for that chemical. These toxicological values are doses derived from human and animal studies which are summarized in the ATSDR Toxicological Profiles. A direct comparison of site-specific exposure and doses to study-derived exposures and doses found to cause adverse health effects is the basis for deciding whether health effects are likely or not.

Risk of Carcinogenic Effects

The estimated risk of developing cancer from exposure to the contaminants was calculated by multiplying the site-specific adult exposure dose by EPA's corresponding Cancer Slope Factor (which can be found at http://www.epa.gov/iris/). The results estimate the maximum increase in risk of developing cancer after 70 years of exposure to the contaminant.

The actual risk of cancer is probably lower than the calculated number. The method used to calculate EPA's Cancer Slope Factor assumes that high-dose animal data can be used to estimate the risk for low dose exposures in humans. The method also assumes that there is no safe level for exposure. Little experimental evidence exists to confirm or refute those two assumptions. Lastly, the method computes the 95% upper bound for the risk, rather than the average risk, suggesting that the cancer risk is actually lower, perhaps by several orders of magnitude.

Because of uncertainties involved in estimating carcinogenic risk, ATSDR employs a weight-of-evidence approach in evaluating all relevant data. Therefore, the carcinogenic risk is described in words (qualitatively) rather than giving a numerical risk estimate only. The numerical risk estimate must be considered in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions. The actual parameters of environmental exposures must be given careful consideration in evaluating the assumptions and variables relating to both toxicity and exposure.